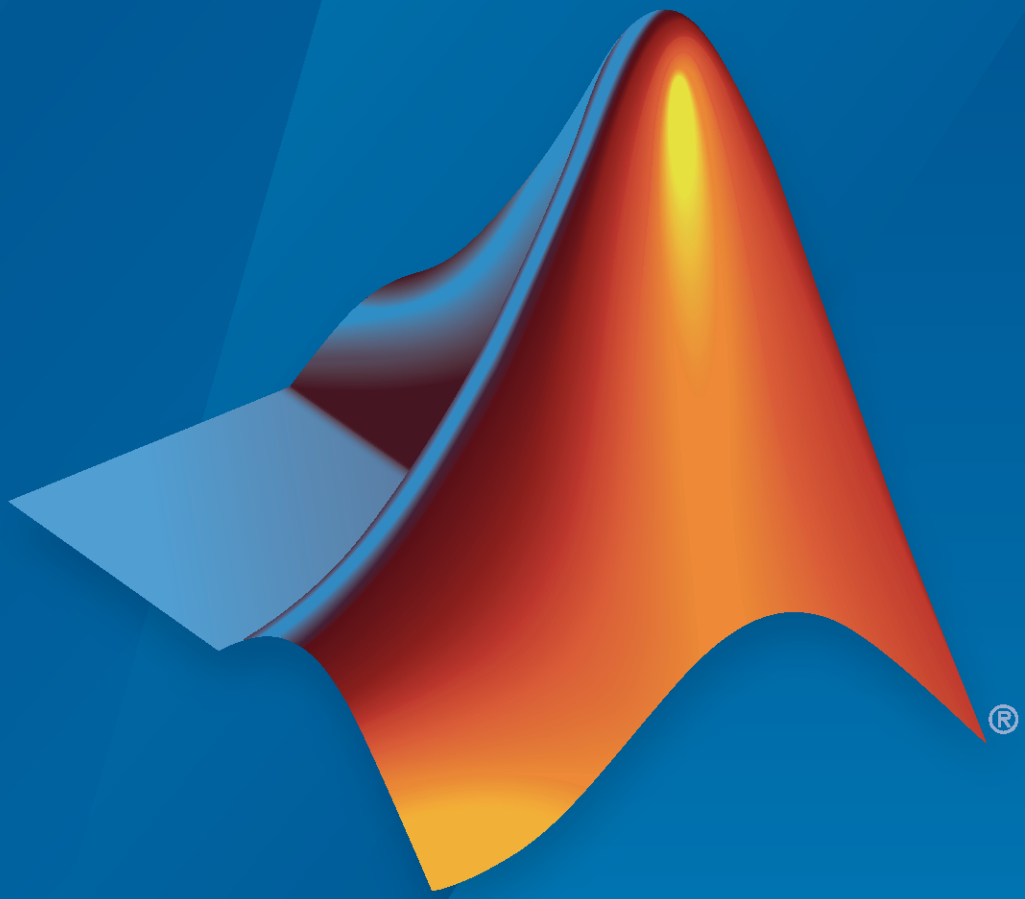
# RF PCB Toolbox™

Reference



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R2023a

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*RF PCB Toolbox™ Reference*



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#### Revision History

| | | |
|---|---|---|
| September 2021 | Online only | New for Version 1.0 (R2021b) |
| March 2022 | Online only | Revised for Version 1.1 (R2022a) |
| September 2022 | Online only | Revised for Version 1.2 (R2022b) |
| March 2023 | Online only | Revised for Version 1.3 (R2023a) |

# Contents

# Objects

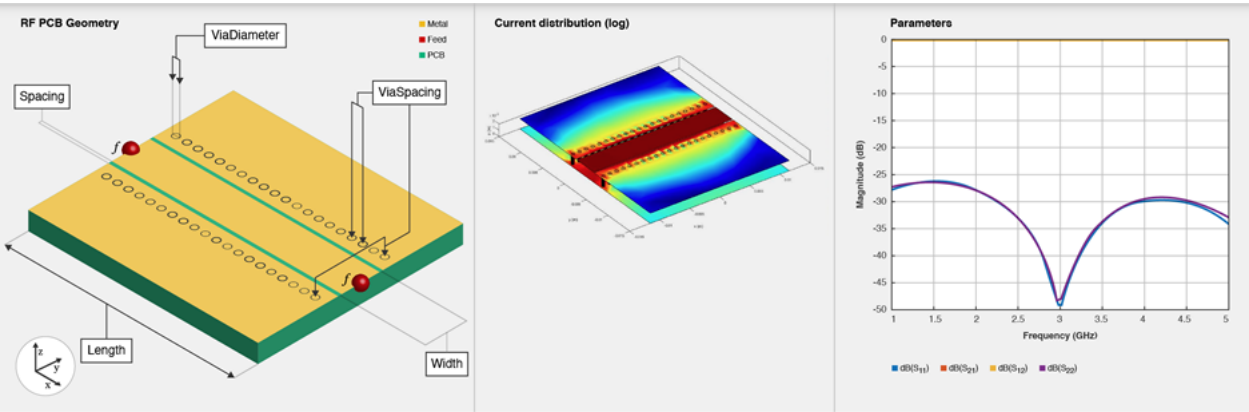
# coplanarWaveguide

Create coplanar waveguide transmission line

## Description

Use the `coplanarWaveguide` object to create a coplanar waveguide transmission line. A Coplanar waveguide is a common type of transmission line used in any PCB implementation of RF and microwave components. A coplanar waveguide transmission line has a center conductor strip and two ground planes. One ground plane is the layer that acts as the conductor strip and the other ground plane is the bottom layer.

**Note** This PCB object supports behavioral modeling. For more information, see “Behavioral Models”. To analyze the behavioral model for a coplanar waveguide, set the `Behavioral` property in the `sparameters` function to `true or 1`




## Creation

### Syntax

```
cpgw = coplanarWaveguide
cpgw = coplanarWaveguide(Name=Value)
```

#### Description

`cpgw = coplanarWaveguide` creates a default coplanar waveguide transmission line with a Teflon substrate and default property values for a 50 ohm transmission line.

`cpgw = coplanarWaveguide(Name=Value)` sets “Properties” on page 1-3 using one or more name-value arguments. For example, `coplanarWaveguide(Width=0.0047)` creates a coplanar waveguide transmission line of width 0.0047 meters. Properties not specified retain their default values.

## Properties

### `Length` — Length of coplanar waveguide transmission line

`0.0231` (default) | positive scalar

Length of the coplanar waveguide transmission line in meters, specified as a positive scalar.

Example: `cpgw = coplanarWaveguide(Length=0.0300)`

Data Types: `double`

### `Width` — Width of coplanar waveguide transmission line

`0.0039` (default) | positive scalar

Width of the coplanar waveguide transmission line in meters, specified as a positive scalar.

Example: `cpgw = coplanarWaveguide(Width=0.0047)`

Data Types: `double`

### `Spacing` — Distance between transmission line and adjacent ground plane

`2.0000e-04` (default) | positive scalar

Distance between the transmission line and the adjacent top layer metal of the ground plane, specified as a positive scalar in meters.

Example: `cpgw = coplanarWaveguide(Spacing=3.0000e-04)`

Data Types: `double`

### `ViaSpacing` — Distance between vias

`[0.0011 0.0070]` (default) | two-element vector

Distance between the vias in meters, specified as a two-element vector of positive elements.

Example: `cpgw = coplanarWaveguide(ViaSpacing=[0.0021 0.0060])`

Data Types: `double`

### `ViaDiameter` — Diameter of via

`5.0000e-04` (default) | positive scalar

Diameter of the via in meters, specified as a positive scalar.

Example: `cpgw = coplanarWaveguide(ViaDiameter=7.0000e-04)`

Data Types: `double`

### `Height` — Height of coplanar waveguide transmission line

`0.0016` (default) | positive scalar

Height of the coplanar waveguide transmission line from the ground plane, specified as a positive scalar in meters.

Example: `cpgw = coplanarWaveguide(Height=0.0020)`

Data Types: `double`

### `GroundPlaneWidth` — Width of ground plane

`0.0300` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `cpgw = coplanarWaveguide(GroundPlaneWidth=0.0350)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `coplanarWaveguide` object with default properties is Teflon.

Example: `d = dielectric("FR4"); cpgw = coplanarWaveguide(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `coplanarWaveguide` object with default properties is PEC.

Example: `m = metal("Copper"); cpgw =coplanarWaveguide(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design coplanar waveguide transmission line around particular frequency |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Create Default Coplanar Waveguide

Create a coplanar waveguide transmission line.

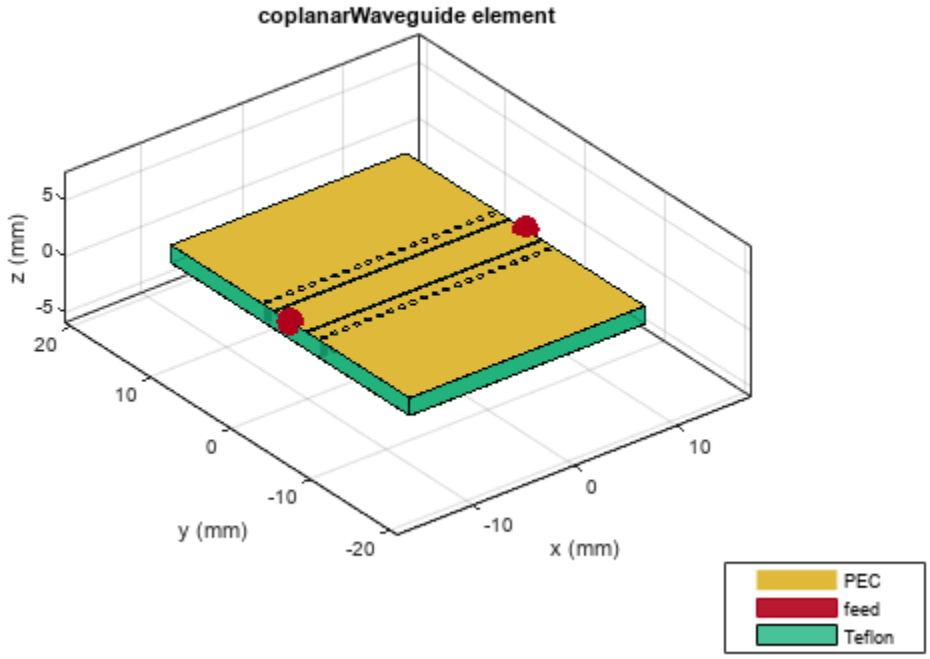
```
waveguide = coplanarWaveguide
```

```
waveguide =
  coplanarWaveguide with properties:

              Length: 0.0231
               Width: 0.0039
             Spacing: 2.0000e-04
          ViaSpacing: [0.0011 0.0070]
         ViaDiameter: 5.0000e-04
              Height: 0.0016
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
```

```
            Conductor: [1x1 metal]
```

View the coplanar waveguide transmission line.

```
show(waveguide)
```



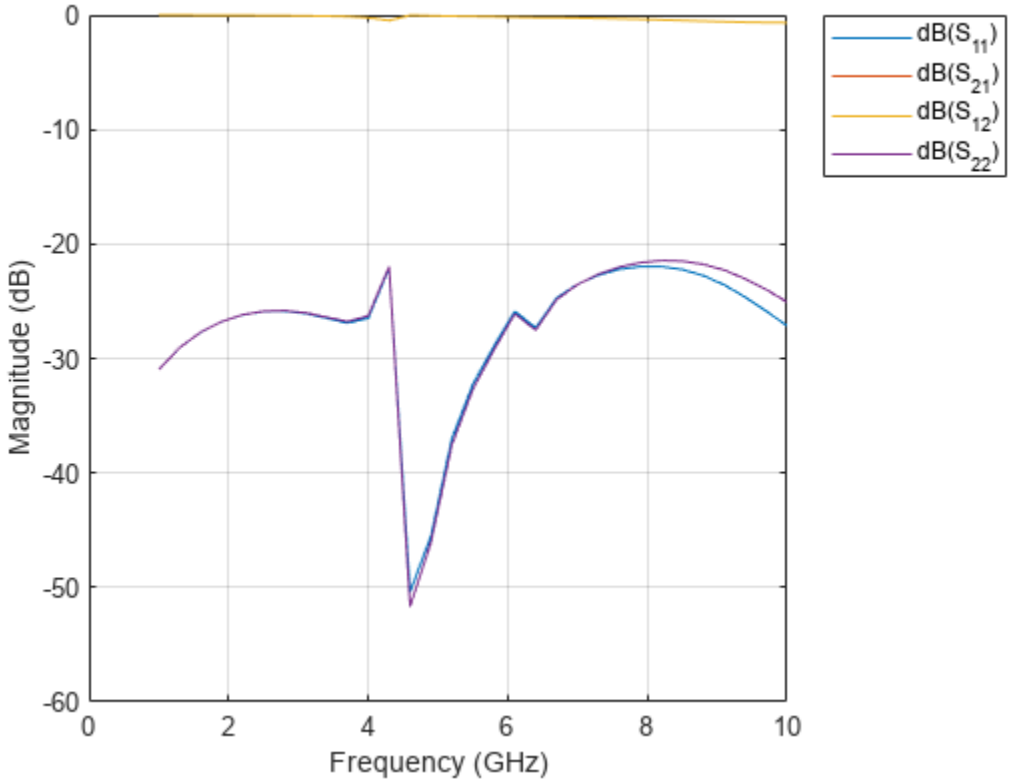

Calculate the S-parameters of the waveguide from 1-10 GHz.

```
sparam = sparameters(waveguide,1e9:0.3e9:10e9)
```

```
sparam =
  sparameters: S-parameters object

       NumPorts: 2
    Frequencies: [31x1 double]
     Parameters: [2x2x31 double]
      Impedance: 50

  rfparam(obj,i,j) returns S-parameter Sij
```

Plot the S-parameters.

```
rfplot(sparam)
```



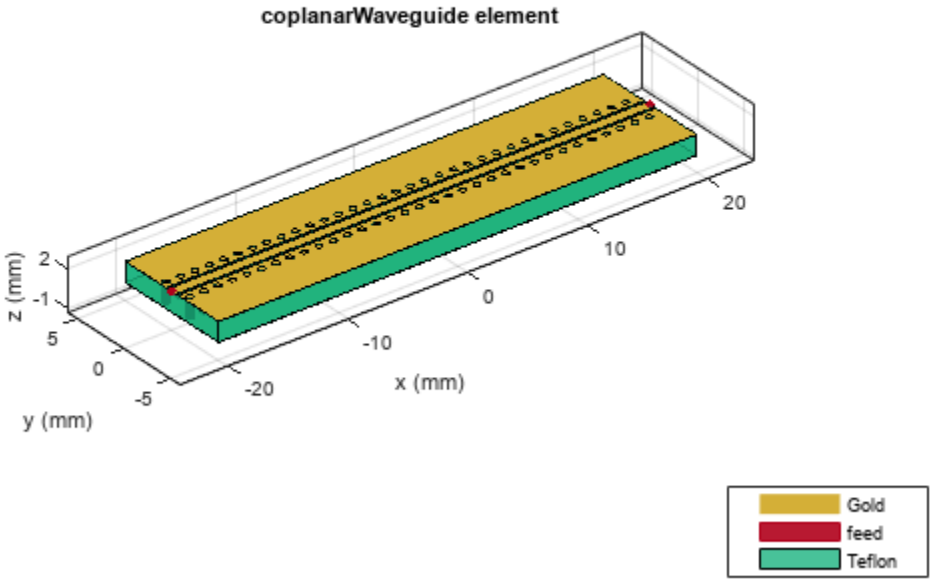

**Behavioral S-parameters of Coplanar Waveguide Transmission Line**

Create a coplanar waveguide transmission line using a gold substrate as the dielectric.

```
txem = coplanarWaveguide;
txem.Conductor = metal("Gold");
```

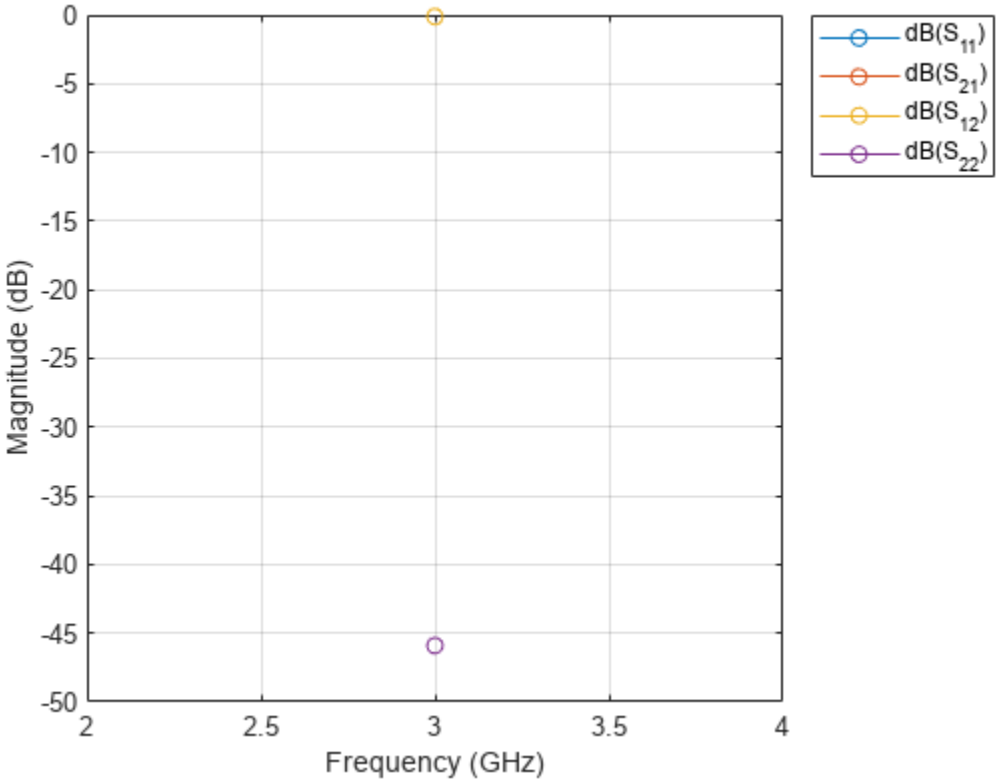
Design the coplanar waveguide at a frequency of 3 GHz, line length of 0.5 meters, and impedence of 75 ohms.

```
txem = design(txem,3e9,LineLength=0.5,Z0=75);
show(txem)
```




Compute and plot the behavioral S-parameters of the waveguide.

```
spar = sparameters(txem,3e9,Behavioral=true);
rfplot(spar)
```




## Version History

**Introduced in R2021b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`microstripLine` | `coupledMicrostripLine`

# microstripLine

Create transmission line in microstrip form

## Description

Use the `microstripLine` object to create a microstrip transmission line. A microstrip line is a transmission line that is a basic building block for most RF planar microwave devices. You can use this transmission line to connect two PCB components or to create components such as filters, couplers, and feeding elements of various types of antennas.

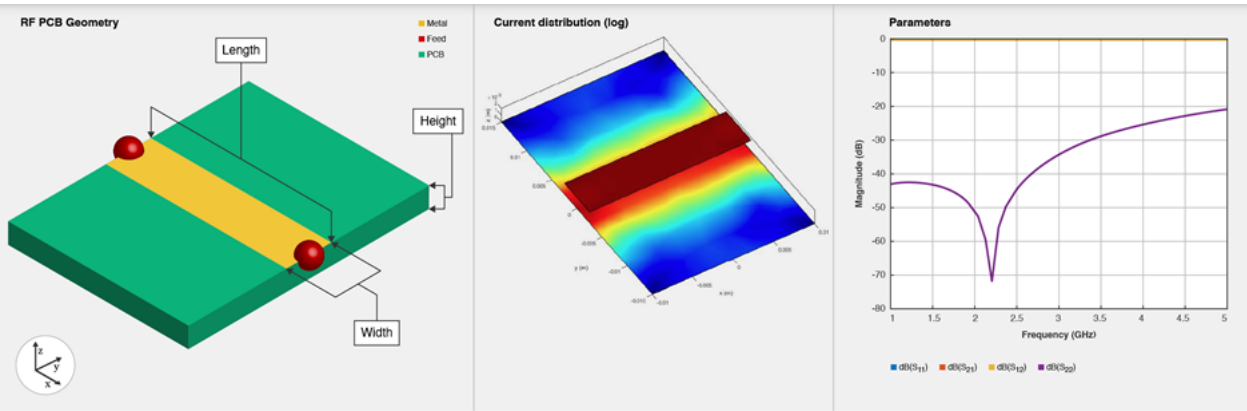
---

**Note** This PCB object supports behavioral modeling. For more information, see “Behavioral Models”. To analyze the behavioral model for a microstrip transmission line, set the `Behavioral` property in the `sparameters` function to `true or 1`

---

A few applications of microstrip transmission lines are:

- Creating matching feed and coupling networks
- Transmitting power from one component to another
- Feeding planar antennas and coupling structures
- Creating varying inductances or capacitances using open- or short ended- transmission lines




## Creation

### Syntax

```
microstrip = microstripLine
microstrip = microstripLine(Name=Value)
microstrip = microstripLine(txlineobj)
```

### Description

`microstrip = microstripLine` creates a default microstrip transmission line using a Teflon substrate.

`microstrip = microstripLine(Name=Value)` sets properties using one or more name value pair arguments. For example, `microstrip = microstripLine(Length=0.0300)` creates a microstrip line of length 0.0300 meters. Properties not specified retain their default values.

`microstrip = microstripLine(txlineobj)` creates a microstrip transmission line from the behavioral model of a `txlineMicrostrip` object in RF Toolbox™.

## Properties

**`Length` — Length of microstrip line**
`0.0200` (default) | positive scalar

Length of the microstrip line in meters, specified as a positive scalar.

Example: `microstrip = microstripLine(Length=0.0300)`

Data Types: `double`

**`Width` — Width of microstrip line**
`0.0050` (default) | positive scalar

Width of the microstrip line in meters, specified as a positive scalar.

Example: `microstrip = microstripLine(Width=0.00630)`

Data Types: `double`

**`Height` — Height of microstrip line**
`0.0016` (default) | positive scalar

Height of the microstrip line from the ground plane in meters, specified as a positive scalar.

In the case of a multilayer substrate, you can use the height property to create a microstrip line at the interface of the two dielectrics.

Example: `microstrip = microstripLine(Height=0.0015)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0300` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `microstrip = microstripLine(GroundPlaneWidth=0.0400)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. For more information, see `dielectric`. The dielectric material in a `microstripLine` object with default

properties is Teflon. The thickness of the default dielectric material Teflon is `0.0016` m or the same as the height property.

Example: `d = dielectric('FR4'); microstrip = microstripLine(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in conducting layers, specified as a `metal` object. For more information see `metal`. The type of metal in a `microstripLine` object with default properties is PEC.

Example: `m = metal('Copper'); microstrip = microstripLine(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design microstrip transmission line around specified frequency |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

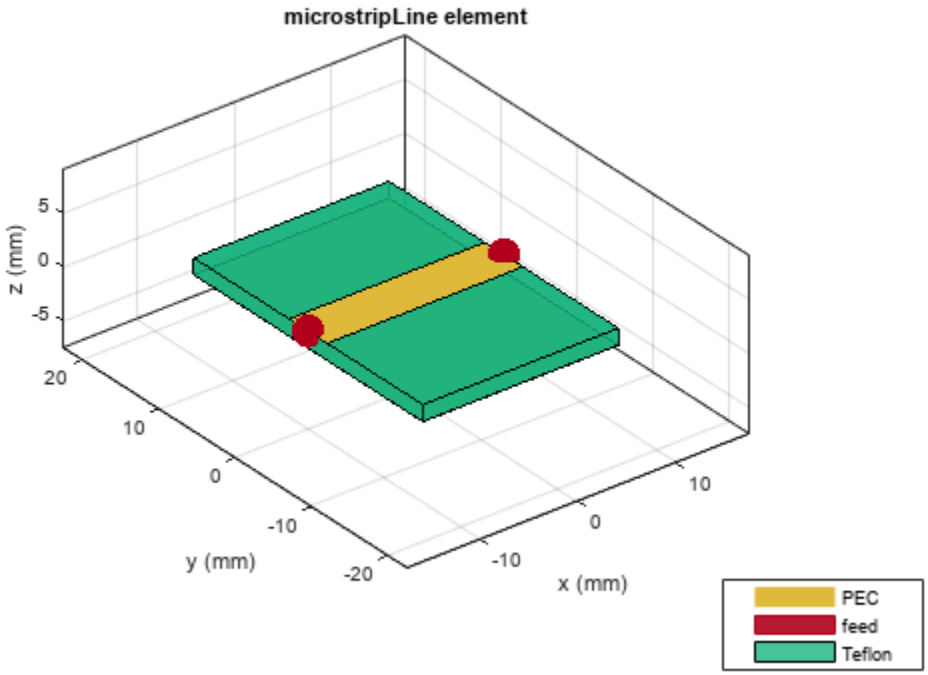
### Default Microstrip Line

Create and view a default microstrip transmission line.

```
microstrip = microstripLine
```

```
microstrip =
  microstripLine with properties:

              Length: 0.0200
               Width: 0.0050
              Height: 0.0016
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

```
show(microstrip)
```




### Microstrip Transmission Line at 3 GHz

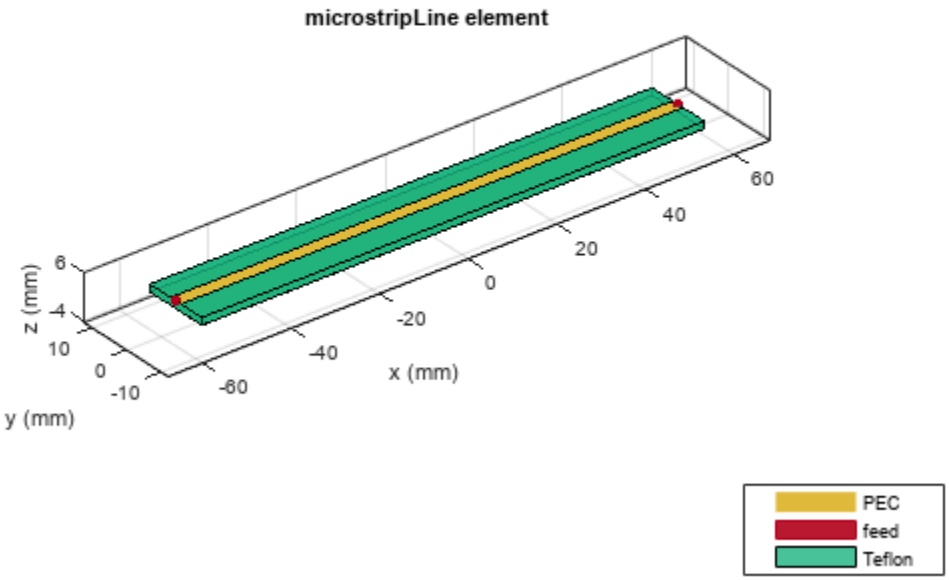
Design a microstrip transmission line at 3 GHz, with a characteristic impedance of 70 ohms and a line length 1.5 times the wavelength.

```
microstrip = design(microstripLine,3e9,'Z0',70,'LineLength',1.5)
```

```
microstrip =
  microstripLine with properties:

             Length: 0.1132
              Width: 0.0030
             Height: 0.0016
    GroundPlaneWidth: 0.0150
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the microstrip transmission line.

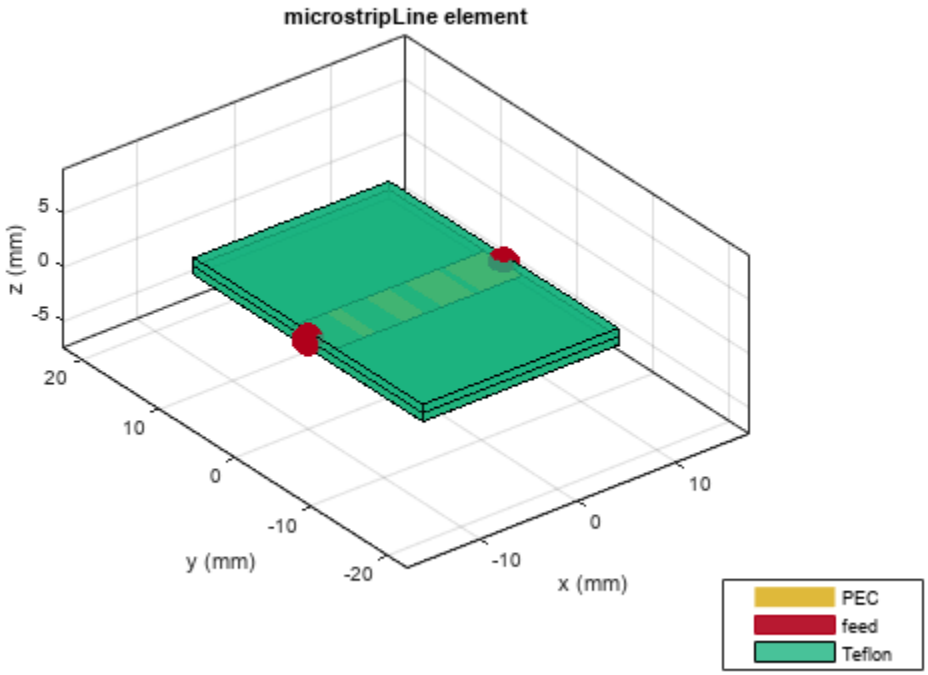
```
show(microstrip)
```




### Multilayer Dielectric Microstrip Transmission Line

Create and view a multilayer dielectric microstrip transmission line.

```
microstrip = microstripLine;
microstrip.Substrate = dielectric('Name',{'Teflon','Teflon'},'EpsilonR', ...
    [2.1 2.1],'LossTangent',[0 0],'Thickness',[0.8e-3 0.8e-3]);
    microstrip.Height = 0.8e-3;
show(microstrip);
```




### Use Behavioral Model to Calculate S-Parameters of Microstrip Cross

Design a microstrip transmission line at 3 GHz using FR4 substrate.

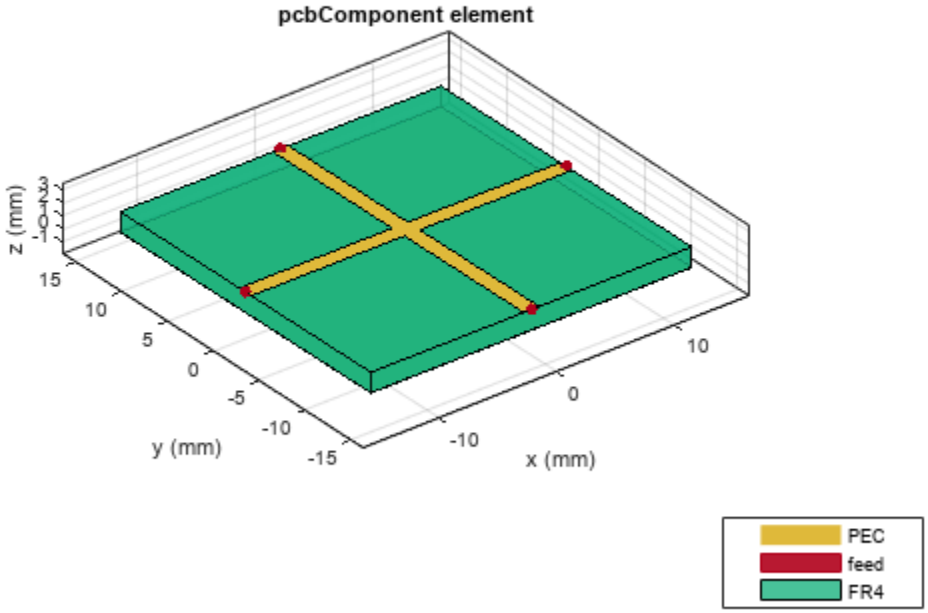
```
d = dielectric('FR4');
d.LossTangent = 0;
m = design(microstripLine('Substrate',d),3e9,'Z0',75,...
    'LineLength',0.5);
```

Create a microstrip cross.

```
layer2d = traceCross('Length',[m.Length m.Length], ...
    'Width',[m.Width m.Width]);
```

Convert the cross trace to a PCB component.

```
robj = pcbComponent(layer2d);
robj.BoardThickness = m.Substrate.Thickness;
robj.Layers{2} = m.Substrate;
show(robj)
```




Define frequency points to calculate the s-parameters.

```
freq = (1:3:40)*100e6;
```

Calculate the s-parameters of the cross trace using the behavioral model.

```
Sckt = sparameters(robj,freq,'Behavioral',true);
```

```
Warning: Behavioral model is valid only when EpsilonR is 9.9.
```

Calculate the s-parameters of the cross trace using the electromagnetic solver.

```
Sem = sparameters(robj,freq);
```

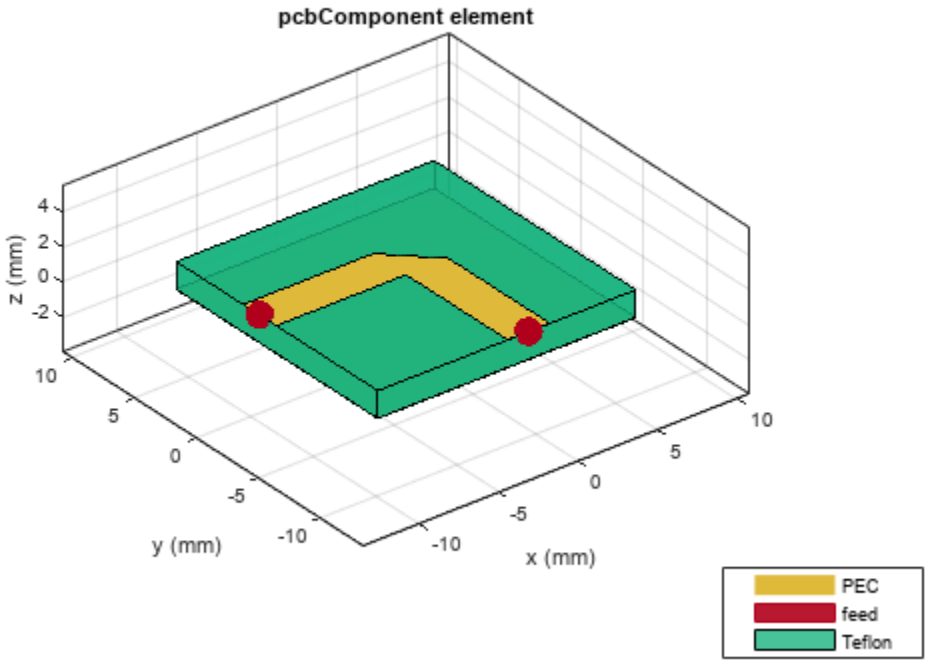
References:


1. Ramesh Garg & I. J. Bahl (1978) Microstrip discontinuities, International Journal of Electronics, 45:1, 81-87, DOI: 10.1080/00207217808900883
2. Wadell, Brian C. *Transmission Line Design Handbook*. The Artech House Microwave Library. Boston: Artech House, 1991.


### Use Behavioral Model to Calculate S-Parameters of Mitered Bend Microstrip

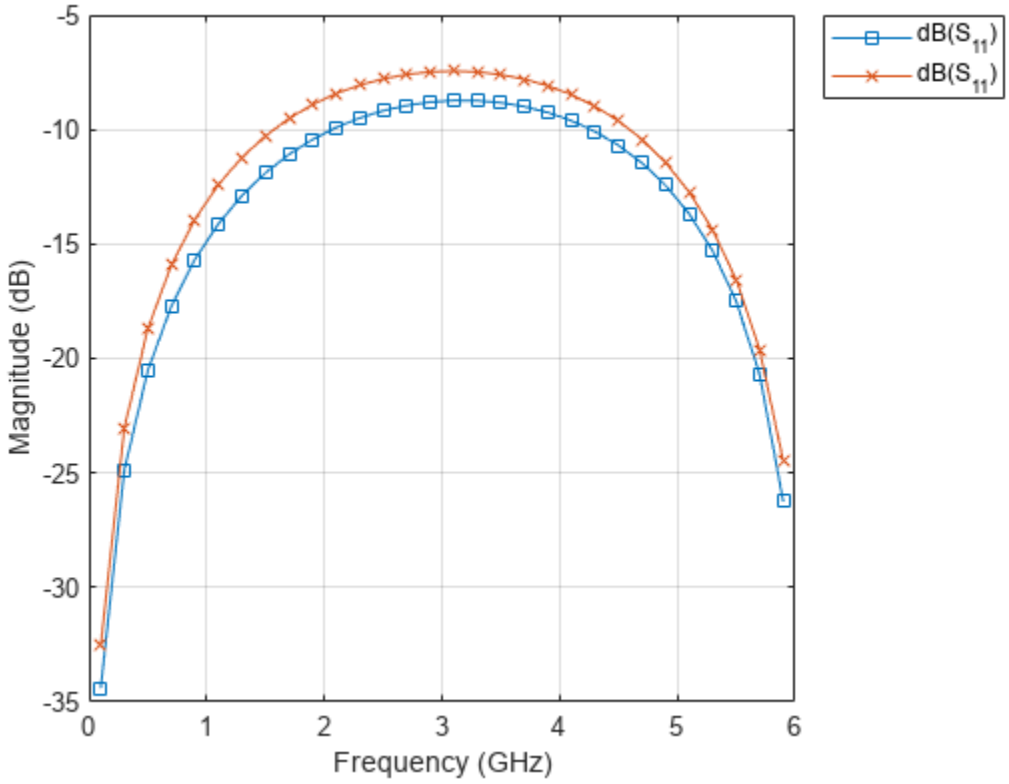
Create mitered bend microstrip.

```
m = design(microstripLine,6e9,"Z0",75);
layer2d = bendMitered('Length',[m.Length/2 m.Length/2],...
"Width",[m.Width m.Width],'MiterDiagonal',sqrt(2)*m.Width);
robj = pcbComponent(layer2d);
robj.BoardThickness = m.Substrate.Thickness;
robj.Layers{2} = m.Substrate;
show(robj)
```




Compute and plot s-parameters.

```
freq = (1:2:60)*100e6;
Sckt = sparameters(robj,freq,'Behavioral',true);
Sem = sparameters(robj,freq);
rfplot(Sckt,1,1,'db','-s')
hold on
rfplot(Sem,1,1,'db','-x')
```




Reference:

M. Kirschning, R. H. Jansen and N. H. L. Koster, "Measurement and Computer-Aided Modeling of Microstrip Discontinuities by an Improved Resonator Method," 1983 IEEE MTT-S International Microwave Symposium Digest, Boston, MA, USA, 1983, pp. 495-497, doi: 10.1109/MWSYM.1983.1130959.

# Version History

**Introduced in R2021b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`coplanarWaveguide` | `coupledMicrostripLine`

# spiralInductor

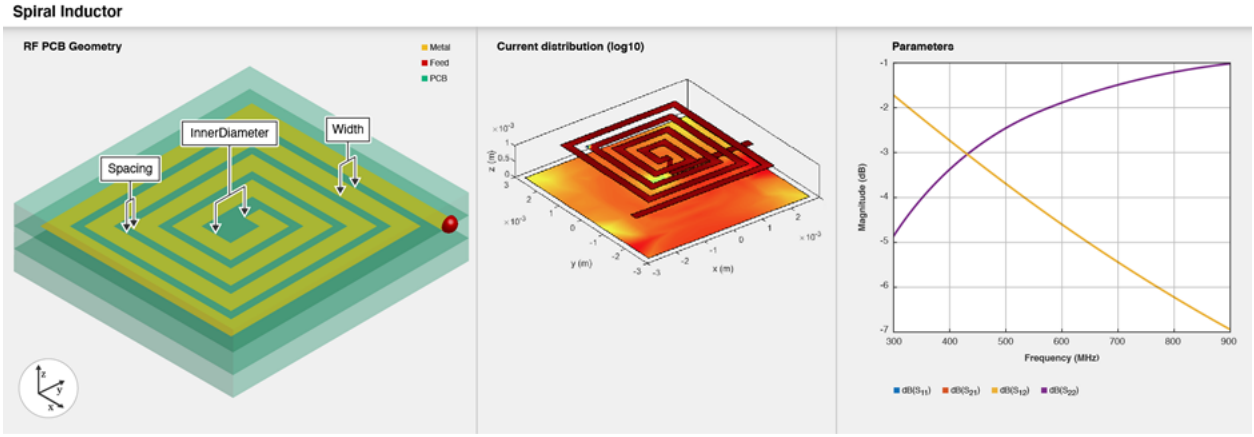
Create spiral inductor in four different shapes

## Description

Use the `spiralInductor` object to create a spiral inductor in one of four different shapes: square, circle, hexagon, or octagon. The spiral inductor is a two-port planar inductor with a single or multiple dielectric layers. A turn in a spiral inductor is the length of a complete 360-degree revolution. Spiral inductor filaments have uniform spacing and width throughout the structure. Spiral inductors are an integral part of many radio-frequency and microwave circuits, acting as resonant elements or chokes. The inductor feed can be configured in one of the following two ways:

**Note** This PCB object supports behavioral modeling. For more information, see “Behavioral Models”. To analyze the behavioral model for a spiral inductor, set the `Behavioral` property in the `sparameters` function to `true or 1`

- The input and output ports are punched through at the same layer.
- The input port is routed out from the layer below the inductor by a via hole. The output port is extended to the end of the dielectric in the same layer.




## Creation

### Syntax

```
inductor = spiralInductor
inductor = spiralInductor(Name=Value)
```

#### Description

`inductor = spiralInductor` creates a square spiral planar inductor with default properties for a resonant frequency of 600 MHz.

`inductor = spiralInductor(Name=Value)` sets “Properties” on page 1-19 using one or more name-value arguments. For example, `spiralInductor(SpiralShape="Octagon")` creates an octagonal spiral inductor. Properties not specified retain their default values.

## Properties

### `SpiralShape` — Shape of spiral inductor

`"Square"` (default) | `"Circle"` | `"Hexagon"` | `"Octagon"`

Shape of the spiral inductor, specified as either `"Square"`, `"Circle"`, `"Hexagon"`, or `"Octagon"`.

Example: `inductor = spiralInductor(SpiralShape="Circle")`

Data Types: `string` | `char`

### `InnerDiameter` — Inner diameter of polygon along edge

`5.0000e-04` (default) | positive scalar

Inner diameter of the polygon along the edge in meters, specified as a positive scalar.

Example: `inductor = spiralInductor(InnerDiameter=8.0000e-04)`

Data Types: `double`

### `Width` — Strip width

`2.5000e-04` (default) | positive scalar

Strip width in meters, specified as a positive scalar.

Example: `inductor = spiralInductor(Width=3.8000e-04)`

Data Types: `double`

### `Spacing` — Distance between strips

`2.5000e-04` (default) | positive scalar

Distance between the strips in meters, specified as a positive scalar.

Example: `inductor = spiralInductor(Spacing=3.8000e-04)`

Data Types: `double`

### `NumTurns` — Number of turns in spiral inductor

`4` (default) | positive scalar

Number of turns in the spiral inductor, specified as a positive scalar. You can specify a minimum of 1 turn and a maximum of 12 turns. One turn length is the length of a complete 360-degree revolution.

Example: `inductor = spiralInductor(NumTurns=6)`

Data Types: `double`

### `Height` — Height from ground plane to inductor

`0.0010` (default) | positive scalar

Height from the ground plane to the inductor in meters, specified as a positive scalar.

Example: `inductor = spiralInductor(Height=0.0056)`

Data Types: `double`

**`GroundPlaneLength` — Length of ground plane**
`0.0056` (default) | positive scalar

Length of the ground plane in meters, specified as a positive scalar. This object does not support infinite ground plane length.

Example: `inductor = spiralInductor(GroundPlaneLength=0.046)`

Example: double

**`GroundPlaneWidth` — Width of ground plane**
`0.0056` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar. This object does not support infinite ground plane width.

Example: `inductor = spiralInductor(GroundPlaneWidth=0.046)`

Example: double

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `spiralInductor` object with default properties have the following properties:

- `Name—{'RTDuroid','RTDuroid','RTDuroid'}`
- `EpsilonR—[3.66,3.66,3.66]`
- `LossTangent—[0.0013,0.0013,0.0013]`
- `Thickness—[0.508e-3,0.508e-3,0.508e-3]`

Example: `d = dielectric("FR4"); inductor = spiralInductor(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `spiralInductor` object with default properties is Copper

Example: `m = metal("PEC"); inductor = spiralInductor(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| inductance | Calculate inductance |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |

sparameters  Calculate S-parameters for RF PCB objects

## Examples

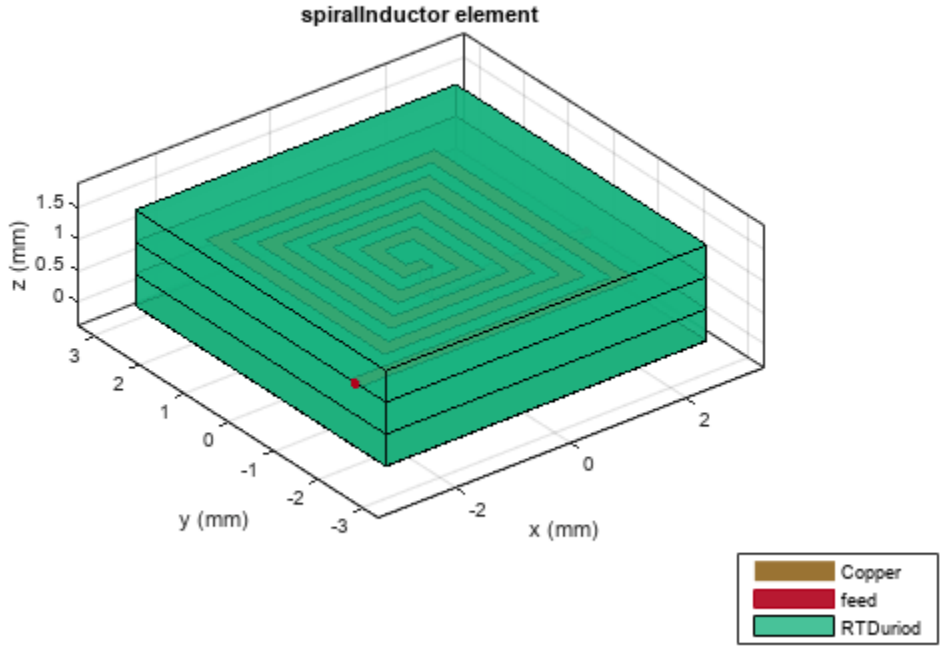
### Create Default Spiral Inductor

Create and view a default spiral inductor.

```
inductor = spiralInductor
```

```
inductor =
  spiralInductor with properties:

          SpiralShape: 'Square'
        InnerDiameter: 5.0000e-04
                Width: 2.5000e-04
              Spacing: 2.5000e-04
             NumTurns: 4
               Height: 0.0010
    GroundPlaneLength: 0.0056
     GroundPlaneWidth: 0.0056
            Substrate: [1x1 dielectric]
            Conductor: [1x1 metal]
```

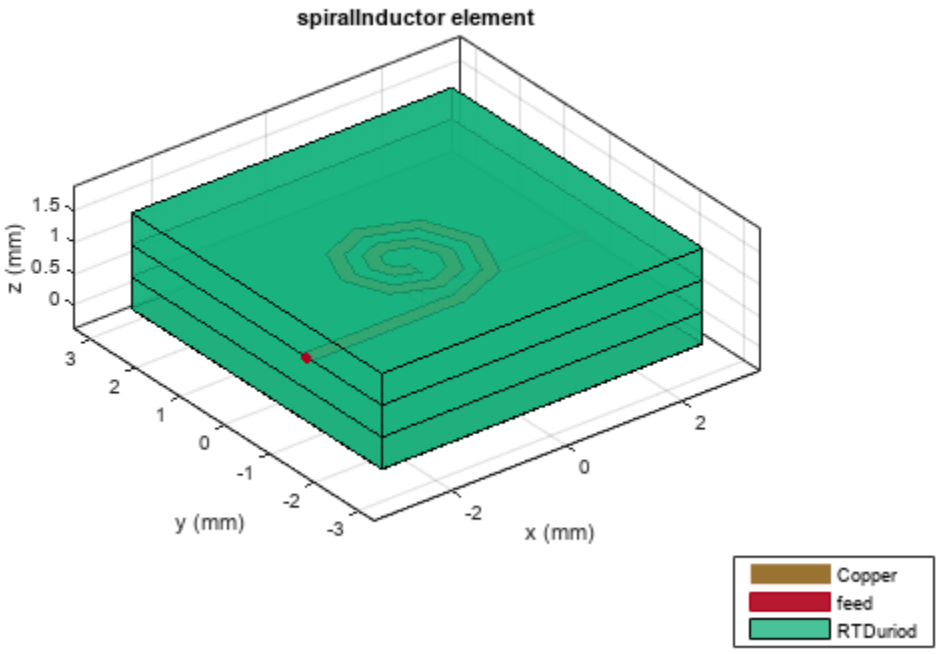
```
show(inductor)
```



### Octagonal Spiral Inductor

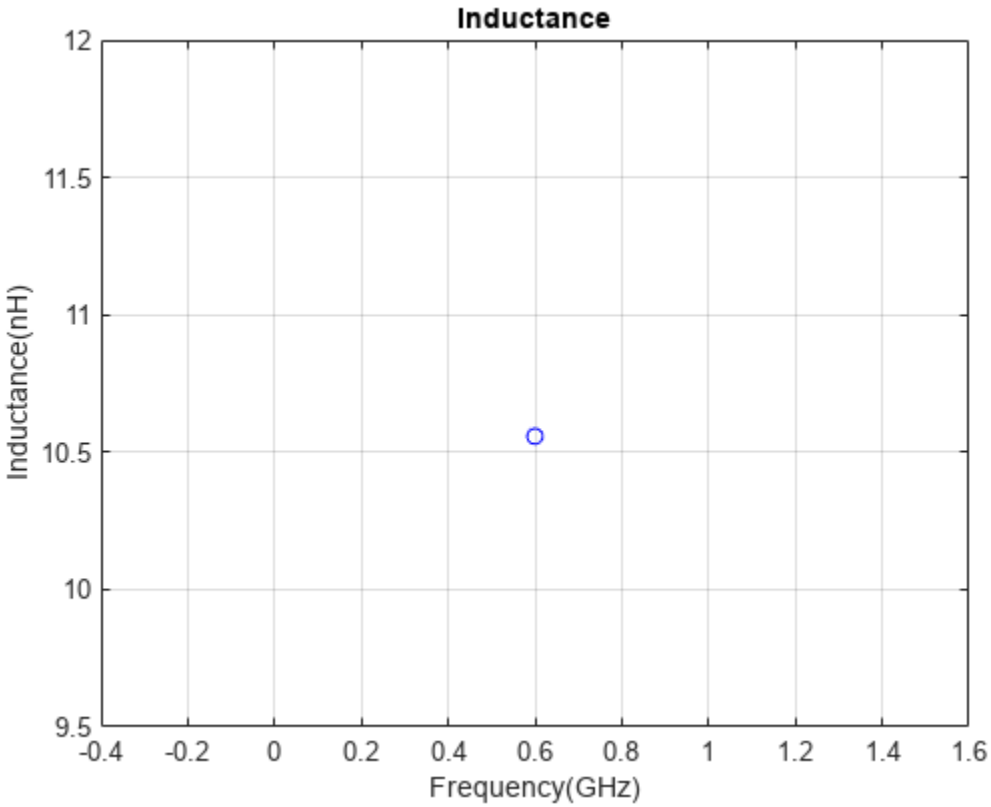
Create and view a two-turn octagonal spiral inductor.

```
inductor = spiralInductor(SpiralShape="Octagon",NumTurns=2);
show(inductor)
```




Measure the inductance of the inductor.

```
figure
inductance(inductor,600e6)
```



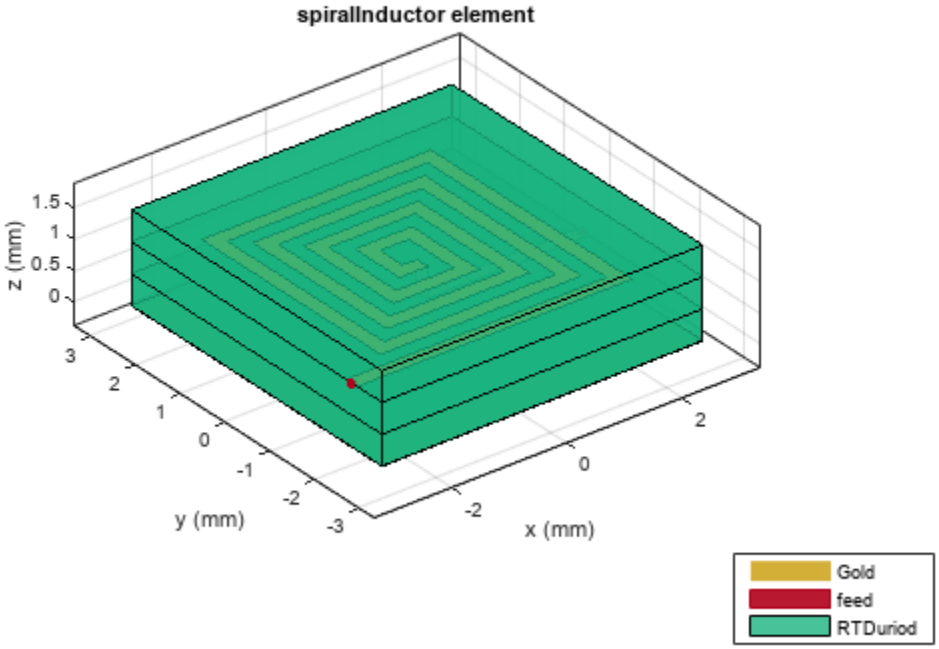

```
ind = inductance(inductor,600e6)
```

```
ind = 1.0558e-08
```

### Analyze Spiral Inductor Using Behavioral S-parameters

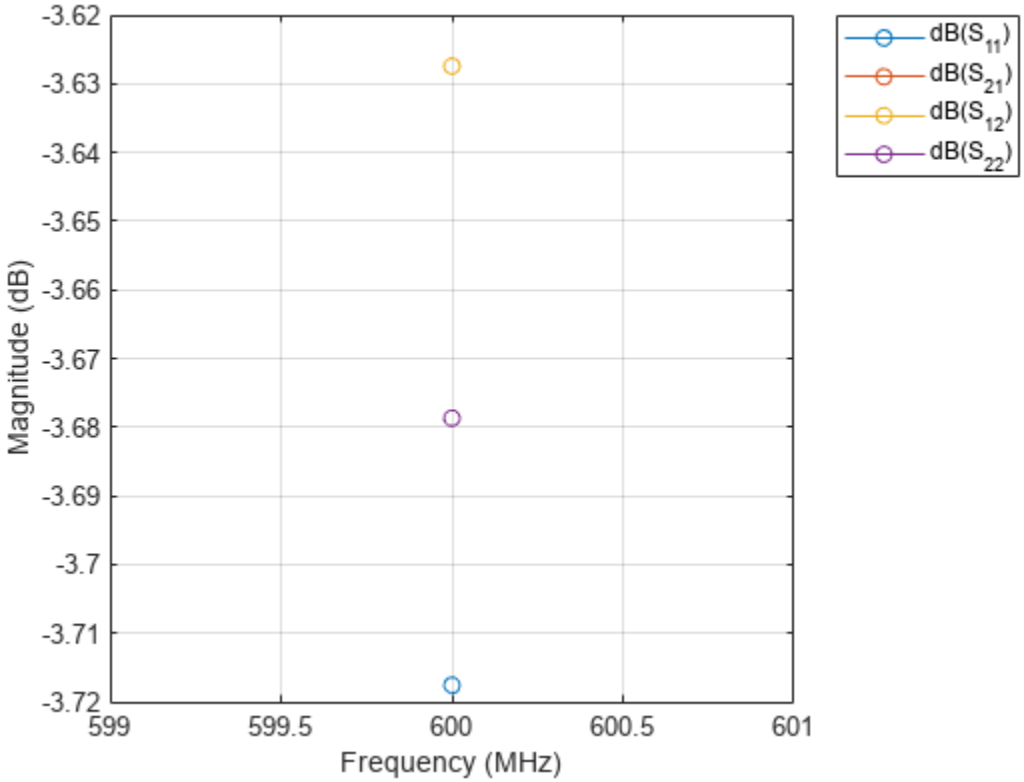
Create a spiral inductor using gold as the conductor.

```
inductor = spiralInductor;
inductor.Conductor = metal("Gold");
show(inductor)
```




Compute and plot the behavioral S-parameters of the inductor at 600 MHz.

```
spar = sparameters(inductor,600e6,Behavioral=true);
rfplot(spar)
```




## More About

### Parametric Analysis Guidelines

- The inductance of a spiral inductor is directly proportional to the physical parameters such as NumTurns, Spacing, and Width.
- The decrease in the width reduces the capacitance between the turns of the inductor.

### Inductor Length and Area

Inductor length equation:

$$inductorlength = NumTurns * Davg * N * \tan\left(\frac{\pi}{N}\right)$$

where,

- $N$ = Number of sides of the polygon
- $D_{avg} = \frac{(d_{out} - d_{in})}{(d_{out} + d_{in})}$

  where when `obj = spiralInductor`,

  $d_{in} = obj.InnerDiameter$

  $d_{out} = obj.InnerDiameter + 2((obj.NumTurns * obj.Width) + (obj.NumTurns - 1) * obj.Spacing)$

# Version History

**Introduced in R2021b**

## References

[1] Beeresha, R.S., A.M. Khan, and H.V. Manjunatha Reddy. “The Design and EM-Simulation of Square Spiral Inductor Using Simple Equations.” *Materials Today: Proceedings* 5, no. 4 (2018): 10875–82. https://doi.org/10.1016/j.matpr.2018.05.074.

[2] Mohan, S.S., M. del Mar Hershenson, S.P. Boyd, and T.H. Lee. “Simple Accurate Expressions for Planar Spiral Inductances.” *IEEE Journal of Solid-State Circuits* 34, no. 10 (October 1999): 1419–24. https://doi.org/10.1109/4.792620.

## See Also

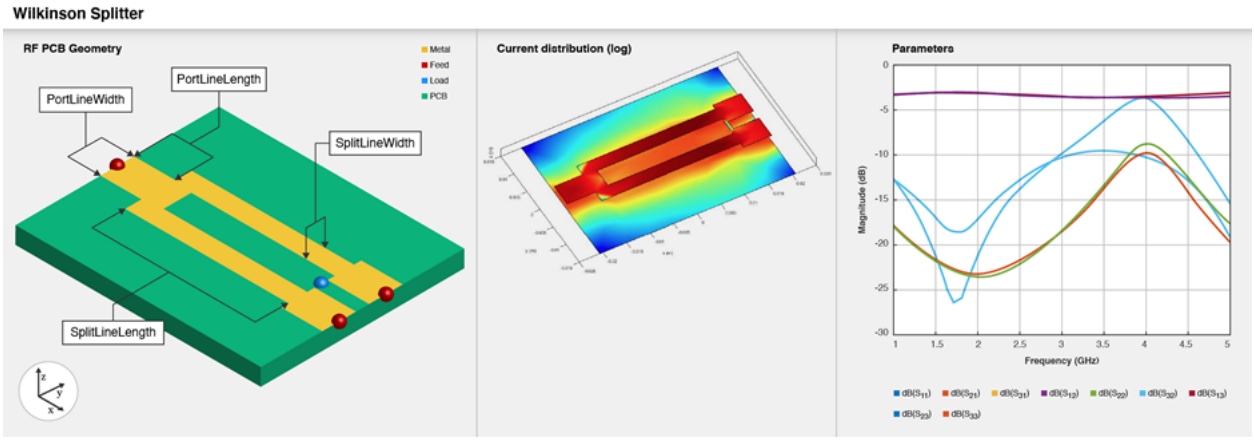
`interdigitalCapacitor`

# wilkinsonSplitter

Create Wilkinson splitter in microstrip form on X-Y plane

## Description

Use the `wilkinsonSplitter` object to create a Wilkinson power splitter in microstrip form on the X-Y plane. The Wilkinson power splitter is the most common type of power divider. It is a lossless power divider and provides matching at all ports. The isolation between the output ports is achieved using a `2*Z0` resistor connected between the output ports. The Wilkinson splitter is used in transmitters, receivers, power combining applications, and in devices measuring the power of a test signal.




To analyze the behavioral model for the Wilkinson power splitter, set the `Behavioral` property in the `sparameters` to `true` or 1.

## Creation

### Syntax

```
splitter = wilkinsonSplitter
splitter = wilkinsonSplitter(Name=Value)
```

#### Description

`splitter = wilkinsonSplitter` creates a Wilkinson splitter with default property values for an operating frequency of 1.8 GHz.

`splitter = wilkinsonSplitter(Name=Value)` sets “Properties” on page 1-28 using one or more name-value arguments. For example, `wilkinsonSplitter(PortLineLength=0.0300)` creates a Wilkinson splitter with an input and output line length of 0.0300 meters. Properties not specified retain their default values.

## Properties

**Shape — Shape of Wilkinson splitter**
`"Rectangular"` (default) | `"Circular"`

Shape of the Wilkinson splitter, specified as `"Rectangular"` or `"Circular"`.

Example: `splitter = wilkinsonSplitter(Shape="Circular")`

Data Types: `char` | `string`

**`PortLineLength` — Length of input and output line**
`0.0060` (default) | positive scalar

Length of the input and the output line in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitter(PortLineLength=0.0070)`

Data Types: `double`

**`PortLineWidth` — Width of input and output line**
`0.0049` (default) | positive scalar

Width of the input and the output line in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitter(PortLineWidth=0.0070)`

Data Types: `double`

**`SplitLineLength` — Length of 70-ohm line**
`0.0300` (default) | positive scalar

Length of the 70-ohm line in meters, specified as a positive scalar. The typical length of a Wilkinson splitter is $\lambda/4$.

Example: `splitter = wilkinsonSplitter(SplitLineLength=0.0570)`

Data Types: `double`

**`SplitLineWidth` — Width of 70-ohm line**
`0.0028` (default) | positive scalar

Width of the 70-ohm line in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitter(SplitLineWidth=0.00780)`

Data Types: `double`

**`ResistorLength` — Length of resistor**
`0.0020` (default) | positive scalar

Length of the resistor in meters, specified as a positive scalar. The resistor length determines the distance between the output ports.

Example: `splitter = wilkinsonSplitter(ResistorLength=0.0050)`

Data Types: `double`

**`Resistance` — Resistance value**
`100` (default) | positive scalar

Resistance value in ohms, specified as a positive scalar. The default value is for an equal-split Wilkinson splitter.

Example: `splitter = wilkinsonSplitter(Resistance=50)`

Data Types: `double`

**`Height` — Height of Wilkinson splitter from ground plane**
`0.0016` (default) | positive scalar

Height of the Wilkinson splitter from the ground plane in meters, specified as a positive scalar. In the case of a multilayer substrate, you can use the `Height` property to create a Wilkinson splitter where the two dielectrics interface.

Example: `splitter = wilkinsonSplitter(Height=0.0076)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane in meters**
`0.0300` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitter(GroundPlaneWidth=0.046)`

Example: double

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `wilkinsonSplitter` object with default properties is Teflon. The thickness of the default dielectric material Teflon is `0.0016` m or the same value as the `Height` property.

Example: `d = dielectric("FR4"); splitter = wilkinsonSplitter(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `wilkinsonSplitter` object with default properties is Copper.

Example: `m = metal("PEC"); splitter = wilkinsonSplitter(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design Wilkinson splitter around specified frequency |
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |

sparameters Calculate S-parameters for RF PCB objects

## Examples

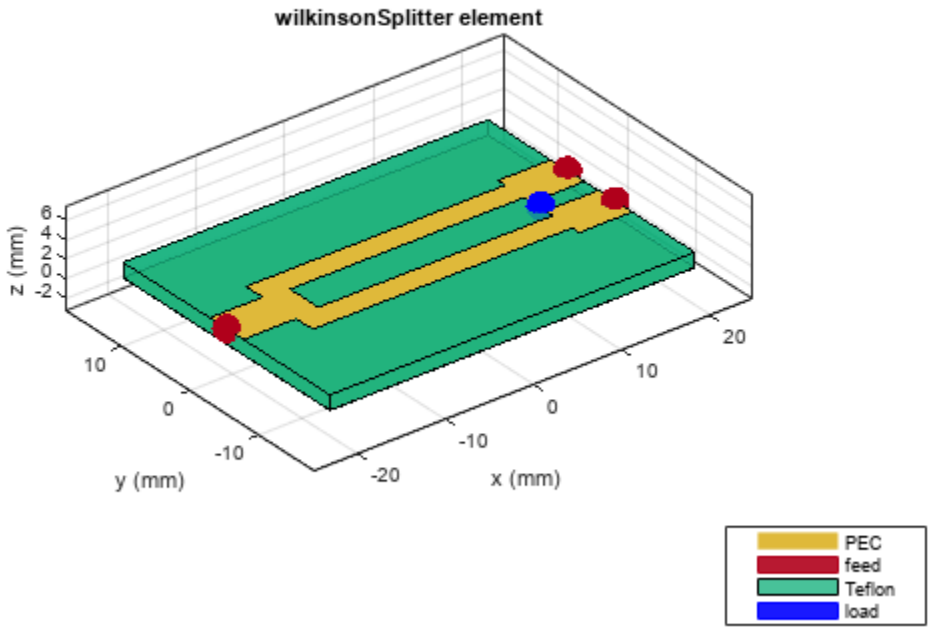
### Create Default Wilkinson Splitter

Create and view a default Wilkinson splitter on the X-Y plane.

```
splitter = wilkinsonSplitter
```

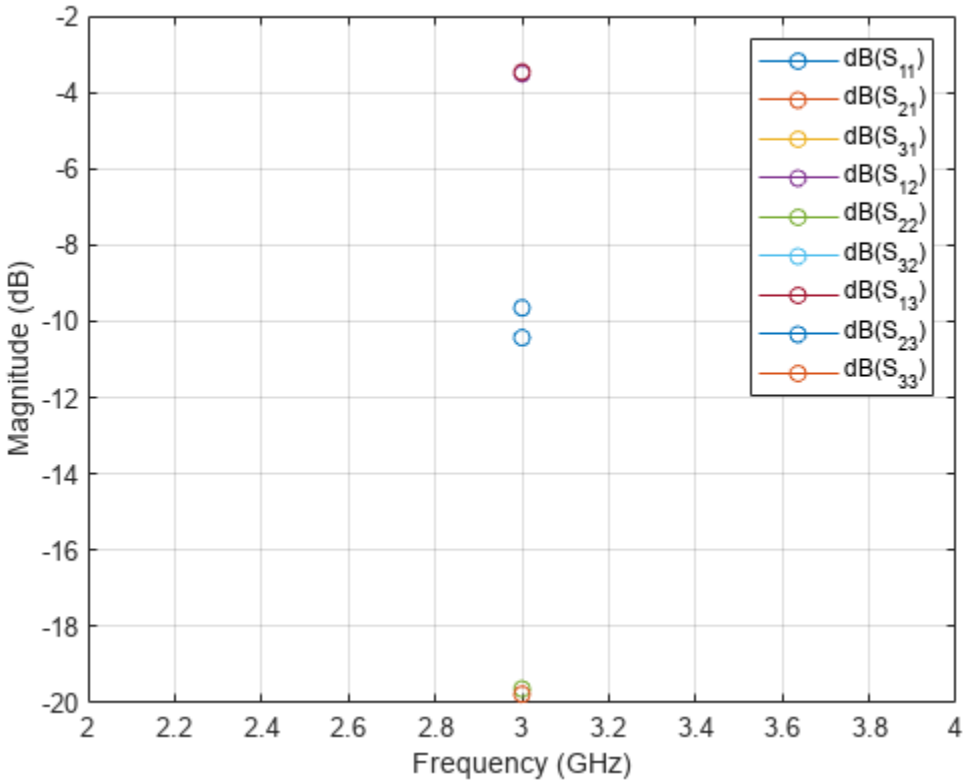
```
splitter =
  wilkinsonSplitter with properties:

              Shape: 'Rectangular'
     PortLineLength: 0.0060
      PortLineWidth: 0.0049
    SplitLineLength: 0.0300
     SplitLineWidth: 0.0028
     ResistorLength: 0.0020
         Resistance: 100
             Height: 0.0016
   GroundPlaneWidth: 0.0300
          Substrate: [1x1 dielectric]
          Conductor: [1x1 metal]
```

```
show(splitter)
```



Calculate and plot the S-parameters of the splitter at 3 GHz.

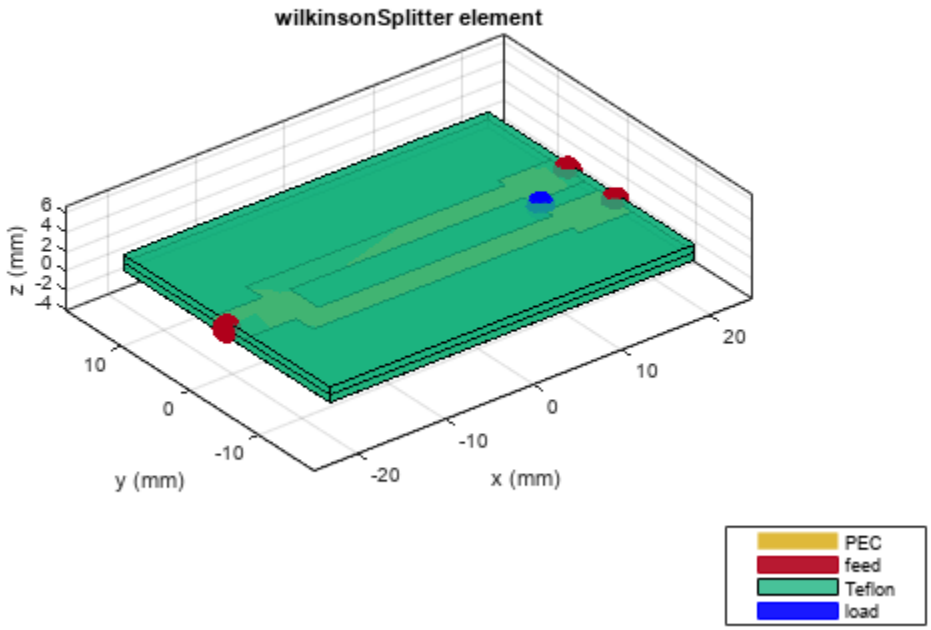
```
spar=sparameters(splitter,3e9);
figure
rfplot(spar);
```




### Create Multilayer Wilkinson Splitter

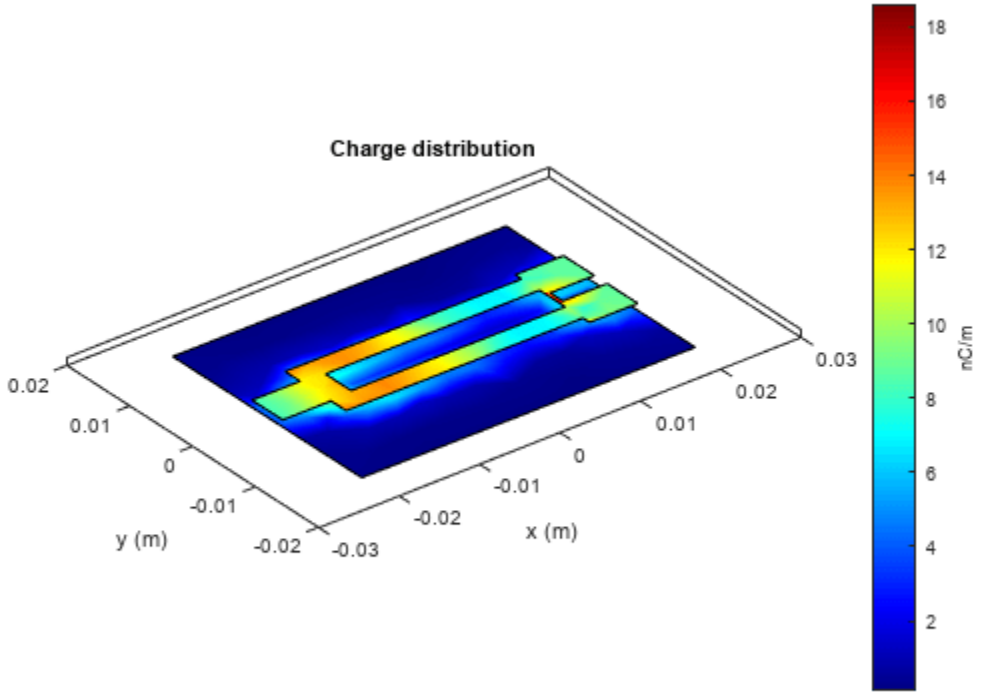
Create and view a multilayer Wilkinson splitter.

```
sub =  dielectric(Name=["Teflon","Teflon"],EpsilonR=[2.1 2.1], ...
    LossTangent=[0 0],Thickness=[0.8e-3 0.8e-3]);
splitter = wilkinsonSplitter(Height=0.8e-3,Substrate=sub);
show(splitter)
```

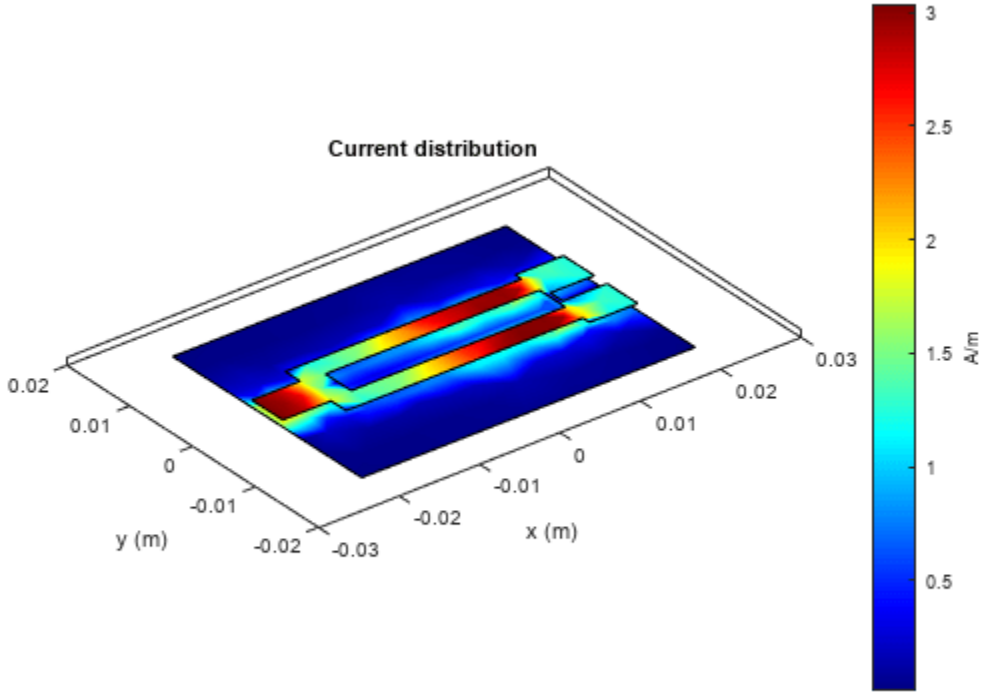



Plot the charge and current on this splitter at 3 GHz.

```
figure
charge(splitter,3e9)
```




```
figure
current(splitter,3e9)
```




# Version History

**Introduced in R2021b**

### R2022b: Behavioral Analysis for Wilkinson Power Splitter

Use the `sparameters` function and the `pcbElement` object to perform the behavioral analysis of a Wilkinson power splitter.

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`wilkinsonSplitterUnequal`

**Topics**

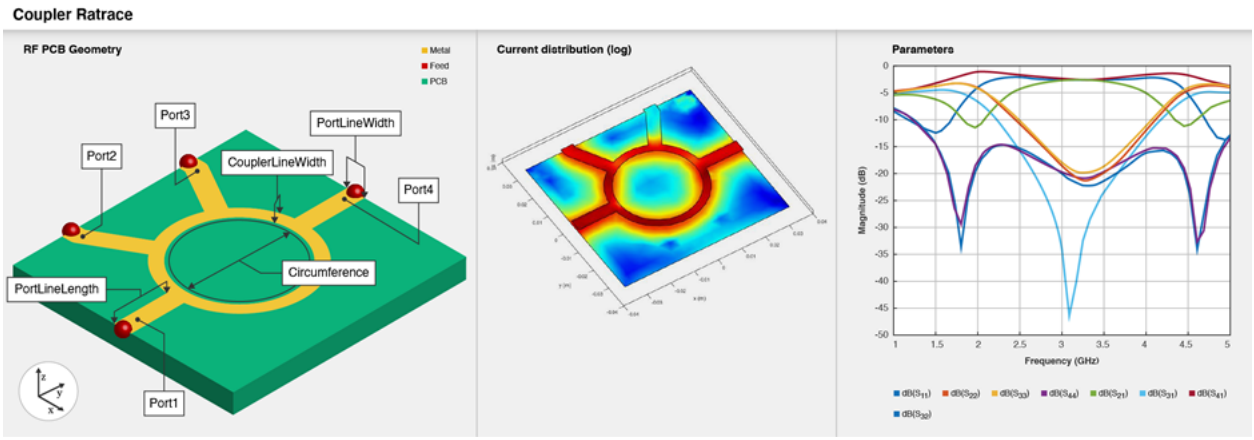
“Behavioral Models”

# couplerRatrace

Create equal-split rat-race coupler or 180-degree-ring hybrid

## Description

Use the `couplerRatrace` object to create an equal-split rat-race coupler or a 180-degree-ring hybrid.




The rat-race coupler is used as a splitter with a phase shift. When given two inputs, the coupler can create sum and difference ports for added and subtracted power. It also acts as an interface between transmitters and receivers for integrating with an antenna and in building circuits with complex functionality like a comparator with sum and difference ports.

There are four ports and the circumference is 1.5 λ. The phase shift between the output ports is 180 degrees. When you apply an input at port 1, port 2 and port 4 are coupled ports, where the output has a phase difference of 180 degrees, and port 3 is the isolated port. When you apply an input at port 3, the output is split equally with same phase at port 2 and port 4.

To analyze the behavioral model for the rat-race coupler, set the `Behavioral` property in the `sparameters` to `true` or 1.

## Creation

### Syntax

```
coupler = couplerRatrace
coupler = couplerRatrace(Name=Value)
```

#### Description

`coupler = couplerRatrace` creates a rat-race coupler with default property values for a frequency of 3 GHz.

`coupler = couplerRatrace(Name=Value)` sets "Properties" on page 1-36 using one or more name-value arguments. For example, `couplerRatrace(PortLineLength=0.0286)` creates a rat-race coupler with a port line length of 0.0286 meters. Properties not specified retain their default values.

## Properties

### `PortLineLength` — Length of input and output line

`0.0186` (default) | positive scalar

Length of the input and the output line in meters, specified as a positive scalar.

Example: `coupler = couplerRatrace(PortLineLength=0.0286)`

Data Types: `double`

### `PortLineWidth` — Width of input and output line

`0.0050` (default) | positive scalar

Width of the input and the output line in meters, specified as a positive scalar.

Example: `coupler = couplerRatrace(PortLineWidth=0.0070)`

Data Types: `double`

### `CouplerLineWidth` — Width of coupler line

`0.0030` (default) | positive scalar

Width of the coupler line in meters, specified as a positive scalar. The default value is for a λ/4 line with an impedance of `Zo/sqrt(2)` ohms.

Example: `coupler = couplerRatrace(CouplerLineWidth=0.0070)`

Data Types: `double`

### `Circumference` — Length of coupler line

`0.1110` (default) | positive scalar

Length of the coupler line in meters, specified as a positive scalar. The default value is for a 1.5 λ line with an impedance of `Zo/sqrt(2)` ohms.

Example: `coupler = couplerRatrace(Circumference=0.2303)`

Data Types: `double`

### `Height` — Height of rat-race coupler from ground plane

`0.0016` (default) | positive scalar

Height of the rat-race coupler from the ground plane in meters, specified as a positive scalar.

In the case of a multilayer substrate, you can use the `Height` property to create a rat-race coupler where the two dielectrics interface.

Example: `coupler = couplerRatrace(Height=0.0015)`

Data Types: `double`

### `Substrate` — Type of dielectric material

`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `couplerRatrace` object with default properties is Teflon. The thickness of the default dielectric material Teflon is `0.0016` m or the same as the `Height` property.

Example: `d = dielectric("FR4"); coupler = couplerRatrace(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `couplerRatrace` object with default properties is Copper.

Example: `m = metal("PEC"); coupler = couplerRatrace(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| coupling | Calculate coupling factor of coupler |
| current | Calculate and plot current distribution |
| design | Design rat-race coupler around specified frequency |
| directivity | Calculate directivity of coupler |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| isolation | Calculate isolation of coupler |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

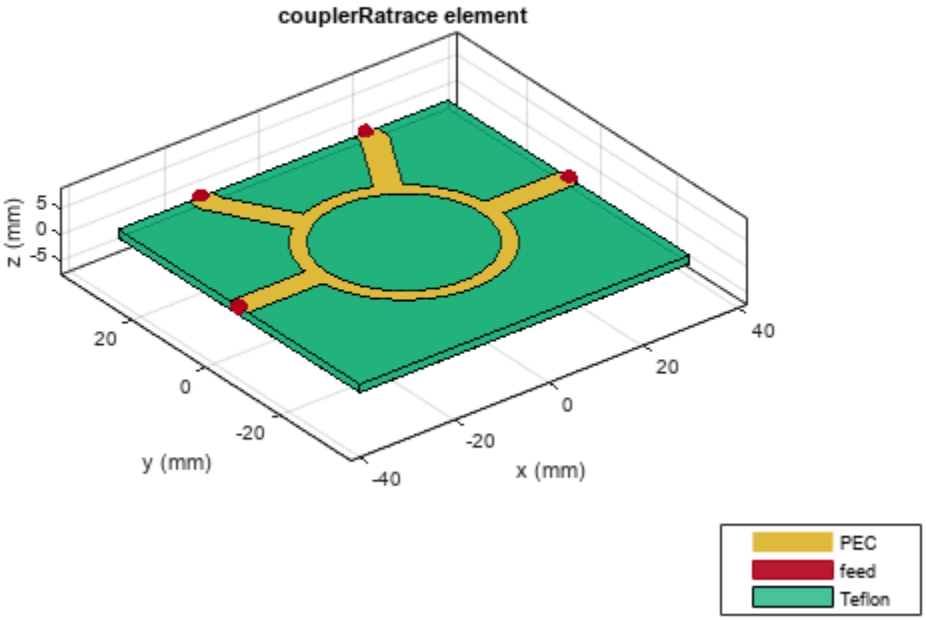
### Create Default Rat-Race Coupler

Create and view a default rat-race coupler.

```
ratrace = couplerRatrace
```

```
ratrace =
  couplerRatrace with properties:

      PortLineLength: 0.0186
       PortLineWidth: 0.0050
    CouplerLineWidth: 0.0030
       Circumference: 0.1110
              Height: 0.0016
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

```
show(ratrace)
```




### Calculate Current Distribution on Rat-Race Coupler

Create a rat-race coupler with default properties.

```
coupler = couplerRatrace;
```

Set the excitation voltage and the phase angle at the ports of the coupler.

```
v = voltagePort(4)
```

```
v =
  voltagePort with properties:

         NumPorts: 4
      FeedVoltage: [1 0 0 0]
        FeedPhase: [0 0 0 0]
    PortImpedance: 50
```

```
v.FeedVoltage = [1 0 1 0]
```

```
v =
  voltagePort with properties:

         NumPorts: 4
```

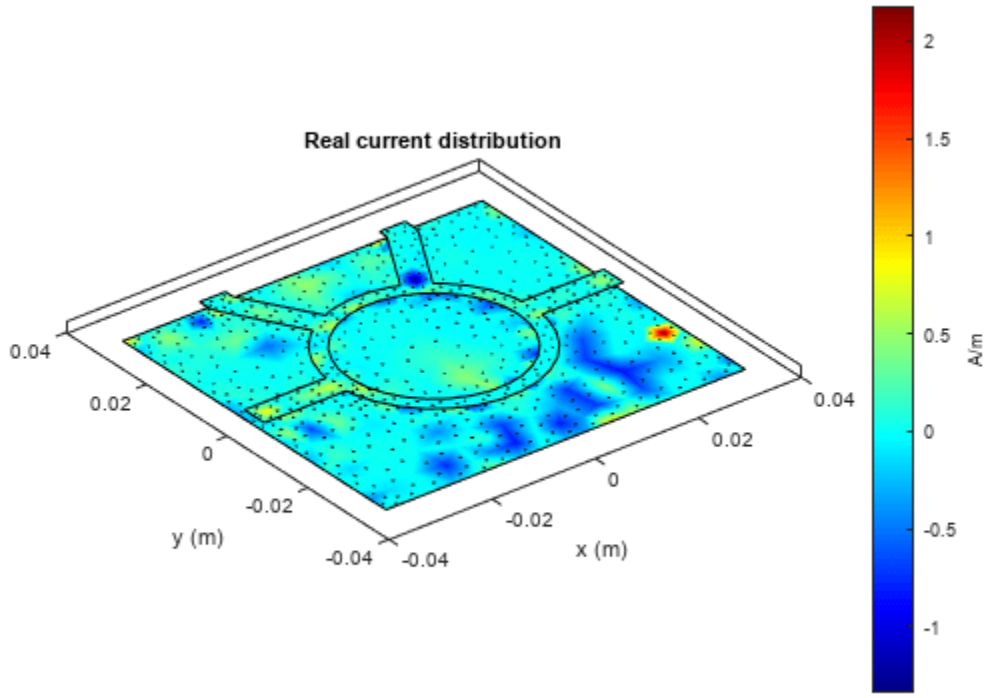
```
      FeedVoltage: [1 0 1 0]
        FeedPhase: [0 0 0 0]
    PortImpedance: 50
```

```
v.FeedPhase = [90 0 270 0]
```

```
v =
  voltagePort with properties:

         NumPorts: 4
      FeedVoltage: [1 0 1 0]
        FeedPhase: [90 0 270 0]
    PortImpedance: 50
```

Calculate and plot the current on the coupler at 3 GHz.

```
figure
current(coupler,3e9,Excitation=v,Type='real',Direction='on')
```




# Version History

**Introduced in R2021b**

**R2022b: Behavioral Analysis for Rat-Race Coupler**

Use the `sparameters` function and the `pcbElement` object to perform the behavioral analysis of a rat-race coupler.

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`couplerBranchline`

**Topics**

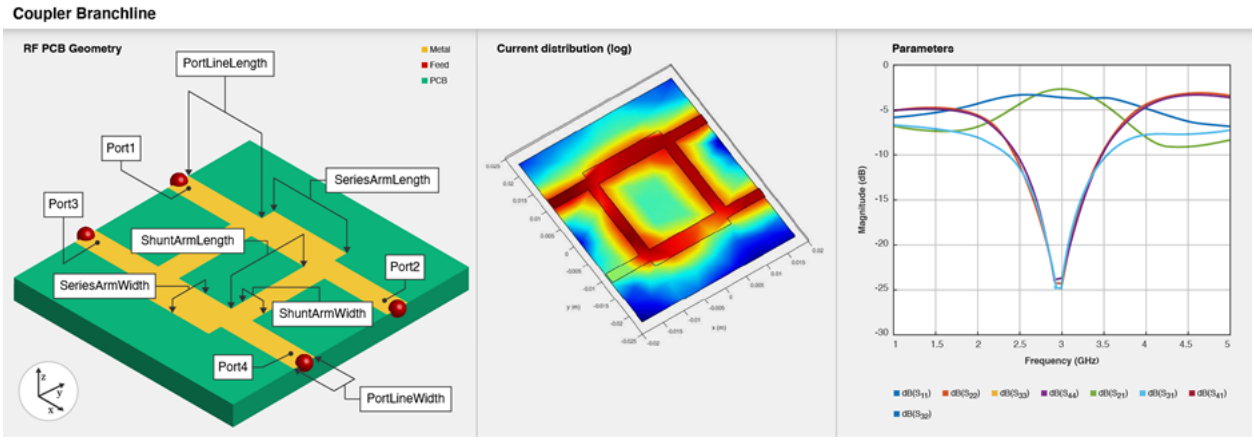
“Behavioral Models”

# couplerBranchline

Create branch line coupler or quadrature hybrid

## Description

Use the `couplerBranchline` object to create a branch line coupler or a quadrature hybrid. A branch line coupler or a quadrature hybrid divides the power between two ports with a phase difference of 90 degrees. This PCB component has four ports. By default, port 1 is the input port, port 2 is the through port, port 4 is the coupled port, and port 3 is the isolated port.




To analyze the behavioral model for the branchline coupler, set the `Behavioral` property in the `sparameters` to `true` or 1.

## Creation

### Syntax

```
coupler = couplerBranchline
coupler = couplerBranchline(Name=Value)
```

#### Description

`coupler = couplerBranchline` creates a branch line coupler with default property values for a frequency of 3 GHz.

`coupler = couplerBranchline(Name=Value)` sets “Properties” on page 1-42 using one or more name-value arguments. For example, `couplerBranchline(PortLineLength=0.0286)` creates a branch line coupler of length 0.0286 meters. Properties not specified retain their default values.

## Properties

**`PortLineLength` — Length of input and output line**
`0.0186` (default) | positive scalar

Length of the input and the output line in meters, specified as a positive scalar.

Example: `coupler = couplerBranchline(PortLineLength=0.0286)`

Data Types: `double`

**`PortLineWidth` — Width of input and output line**
`0.0051` (default) | positive scalar

Width of the input and the output line in meters, specified as a positive scalar.

Example: `coupler = couplerBranchline(PortLineWidth=0.0070)`

Data Types: `double`

**`SeriesArmLength` — Length of series arm**
`0.0184` (default) | positive scalar

Length of the series arm in meters, specified as a positive scalar.

Example: `coupler = couplerBranchline(SeriesArmLength=0.0286)`

Data Types: `double`

**`SeriesArmWidth` — Width of series arm**
`0.0083` (default) | positive scalar

Width of the series arm in meters, specified as a positive scalar.

Example: `coupler = couplerBranchline(SeriesArmWidth=0.0096)`

Data Types: `double`

**`ShuntArmLength` — Length of shunt arm**
`0.0186` (default) | positive scalar

Length of the shunt arm in meters, specified as a positive scalar.

Example: `coupler = couplerBranchline(ShuntArmLength=0.0286)`

Data Types: `double`

**`ShuntArmWidth` — Width of shunt arm**
`0.0051` (default) | positive scalar

Width of the shunt arm in meters, specified as a positive scalar.

Example: `coupler = couplerBranchline(ShuntArmWidth=0.0096)`

Data Types: `double`

**`Height` — Height of branch line coupler from ground plane**
`0.0016` (default) | positive scalar

Height of the branch line coupler from the ground plane in meters, specified as a positive scalar.

In the case of a multilayer substrate, you can use the `Height` property to create a branch line coupler line where the two dielectrics interface.

Example: `coupler = couplerBranchline(Height=0.0076)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0600` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `coupler = couplerBranchline(GroundPlaneWidth=0.046)`

Example: double

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `couplerBranchline` object with default properties is RTDuroid

Example: `d = dielectric("FR4"); coupler = couplerBranchline(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `couplerBranchline` object with default properties is Copper.

Example: `m = metal("PEC"); coupler = couplerBranchline(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

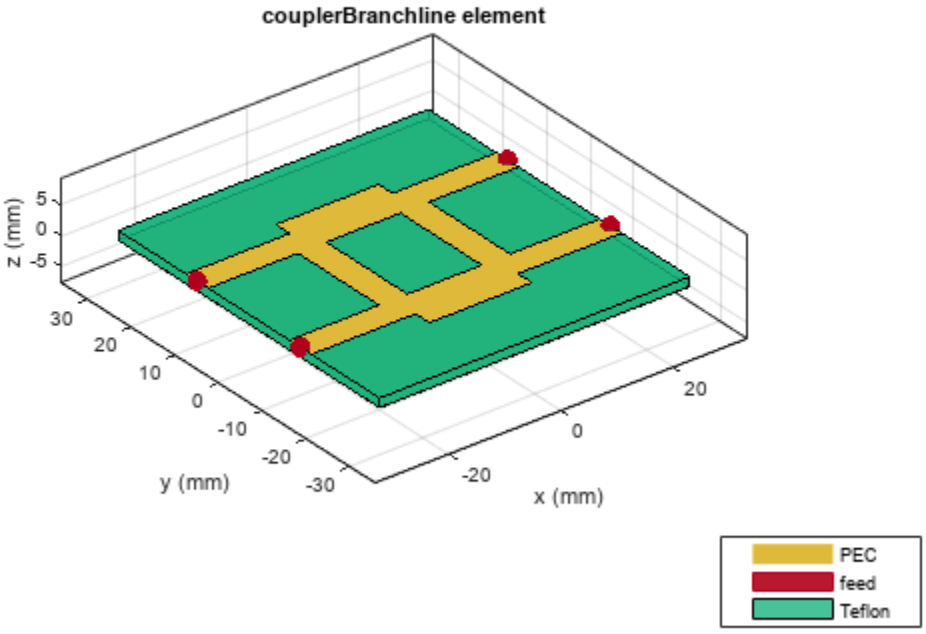
| | |
|---|---|
| charge | Calculate and plot charge distribution |
| coupling | Calculate coupling factor of coupler |
| current | Calculate and plot current distribution |
| design | Design branchline coupler around particular frequency |
| directivity | Calculate directivity of coupler |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| isolation | Calculate isolation of coupler |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Create Default Branchline Coupler

Create and view a default branchline coupler.

```
coupler = couplerBranchline

coupler =
  couplerBranchline with properties:

      PortLineLength: 0.0186
       PortLineWidth: 0.0051
     SeriesArmLength: 0.0184
      SeriesArmWidth: 0.0083
      ShuntArmLength: 0.0186
       ShuntArmWidth: 0.0051
              Height: 0.0016
    GroundPlaneWidth: 0.0600
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]


show(coupler)
```




# Version History

**Introduced in R2021b**

**R2022b: Behavioral Analysis for Branchline Coupler**

Use the `sparameters` function and the `pcbElement` object to perform the behavioral analysis of a branchline coupler.

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`couplerRatrace`

**Topics**

“Behavioral Models”

# interdigitalCapacitor

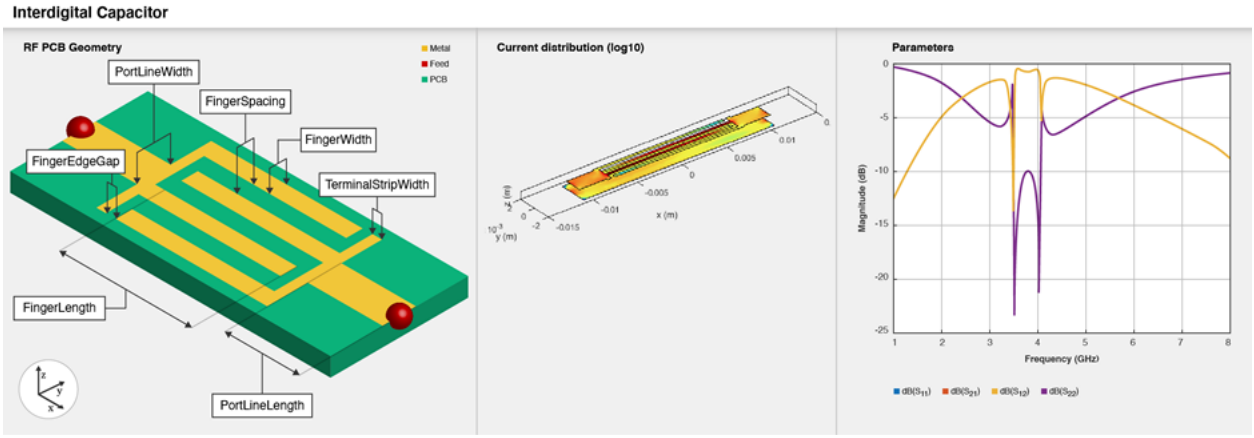
Create basic interdigital capacitor

## Description

Use the `interdigitalCapacitor` object to create an interdigital planar capacitor (IDC). IDCs are used in high frequency applications such as:

- Receiver circuits where antenna radiators are connected to RF
- Wireless data communications with RFID
- Humidity and solution concentration measurements
- Lab-on-chip devices (LOCs)

**Note** This PCB object supports behavioral modeling. For more information, see “Behavioral Models”. To analyze the behavioral model for a interdigital capacitor, set the `Behavioral` property in the `sparameters` function to `true or 1`




A two-port series IDC with microstrip form feeder lines supports single and multiple dielectrics. It is a coplanar structure consisting of multiple comb electrodes or intersecting fingers with spaces between the fingers. An IDC can have identical port line lengths and widths on either sides.

## Creation

### Syntax

```
capacitor = interdigitalCapacitor
capacitor = interdigitalCapacitor(Name=Value)
```

### Description

`capacitor = interdigitalCapacitor` creates a basic interdigital capacitor with default property values for an operating bandwidth of 3.6-4 GHz.

`capacitor = interdigitalCapacitor(Name=Value)` sets "Properties" on page 1-47 using one or more name-value arguments. For example, `interdigitalCapacitor(NumFingers=10)` creates an interdigital capacitor with 10 fingers. Properties not specified retain their default values.

## Properties

**`NumFingers` — Number of fingers on capacitor**
`4` (default) | positive scalar

Number of fingers on the capacitor, specified as a positive scalar.

Example: `capacitor = interdigitalCapacitor(NumFingers=10)`

Data Types: `double`

**`FingerLength` — Length of overlapping fingers**
`0.0137` (default) | positive scalar

Length of the overlapping fingers in meters, specified as a positive scalar.

Example: `capacitor = interdigitalCapacitor(FingerLength=0.0217)`

Data Types: `double`

**`FingerWidth` — Width of overlapping fingers**
`3.1600e-04` (default) | positive scalar

Width of the overlapping fingers in meters, specified as a positive scalar.

Example: `capacitor = interdigitalCapacitor(FingerWidth=4.8000e-04)`

Data Types: `double`

**`FingerSpacing` — Distance between fingers**
`3.0000e-04` (default) | positive scalar

Distance between the fingers in meters, specified as a positive scalar.

Example: `capacitor = interdigitalCapacitor(FingerSpacing=2.9000e-04)`

Data Types: `double`

**`FingerEdgeGap` — Gap between edges of fingers**
`3.4100e-04` (default) | positive scalar

Gap between the edges of the fingers in meters, specified as a positive scalar.

Example: `capacitor = interdigitalCapacitor(FingerEdgeGap=2.05000e-04)`

Data Types: `double`

**`TerminalStripWidth` — Width of terminals**
`5.0000e-04` (default) | positive scalar

Width of the terminals in meters, specified as a positive scalar.

Example: `capacitor = interdigitalCapacitor(TerminalStripWidth=4.9000e-04)`

Data Types: `double`

**`PortLineWidth` — Width of ports**
`0.0019` (default) | positive scalar

Width of the ports in meters, specified as a positive scalar.

Example: `capacitor = interdigitalCapacitor(PortLineWidth=0.0020)`

Data Types: `double`

**`PortLineLength` — Length of ports**
`0.0030` (default) | positive scalar

Length of the ports in meters, specified as a positive scalar.

Example: `capacitor = interdigitalCapacitor(PortLineLength=0.0040)`

Data Types: `double`

**`Height` — Height from ground plane to capacitor**
`7.8700e-04` (default) | positive scalar

Height from the capacitor to the ground plane in meters, specified as a positive scalar.

Example: `capacitor = interdigitalCapacitor(Height=6.9000e-04)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0030` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `capacitor = interdigitalCapacitor(GroundPlaneWidth=0.0040)`

Example: double

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `interdigitalCapacitor` with default properties have the following properties:

- `Name—{'Roger'}`
- `EpsilonR—3.2`
- `LossTangent—0.0002`
- `Thickness—0.000787`

Example: `d = dielectric("FR4"); capacitor = interdigitalCapacitor(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. he type of metal in a `couplerBranchlineWideband` object with default properties is Copper.

Example: `m = metal("PEC"); capacitor =interdigitalCapacitor(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| capacitance | Calculate capacitance |
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

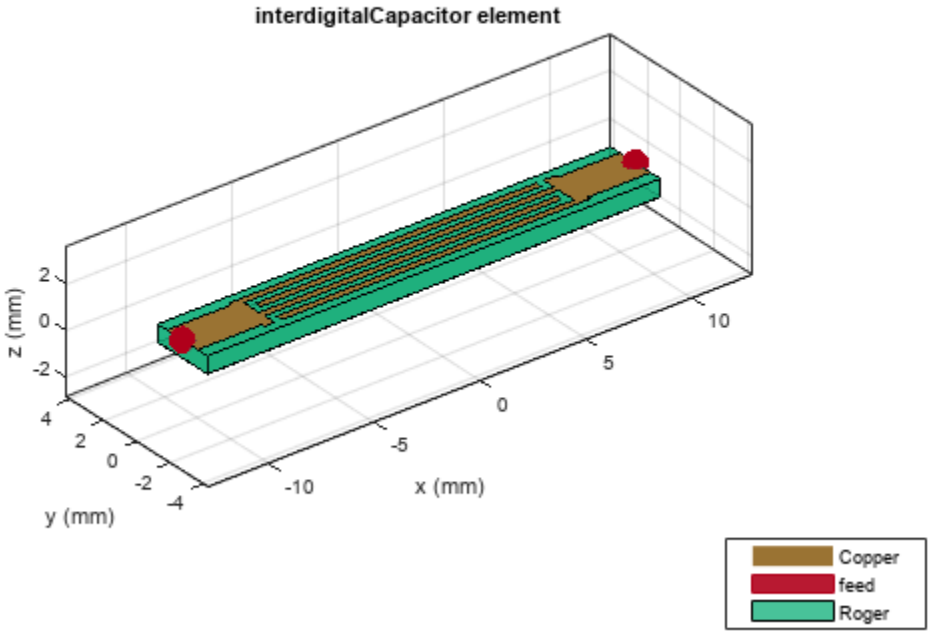
### Create Default Interdigital Capacitor

Create and view a default interdigital capacitor.

```
idcapacitor = interdigitalCapacitor
```

```
idcapacitor =
  interdigitalCapacitor with properties:

           NumFingers: 4
         FingerLength: 0.0137
          FingerWidth: 3.1600e-04
        FingerSpacing: 3.0000e-04
        FingerEdgeGap: 3.4100e-04
    TerminalStripWidth: 5.0000e-04
         PortLineWidth: 0.0019
        PortLineLength: 0.0030
                Height: 7.8700e-04
      GroundPlaneWidth: 0.0030
             Substrate: [1x1 dielectric]
             Conductor: [1x1 metal]
```

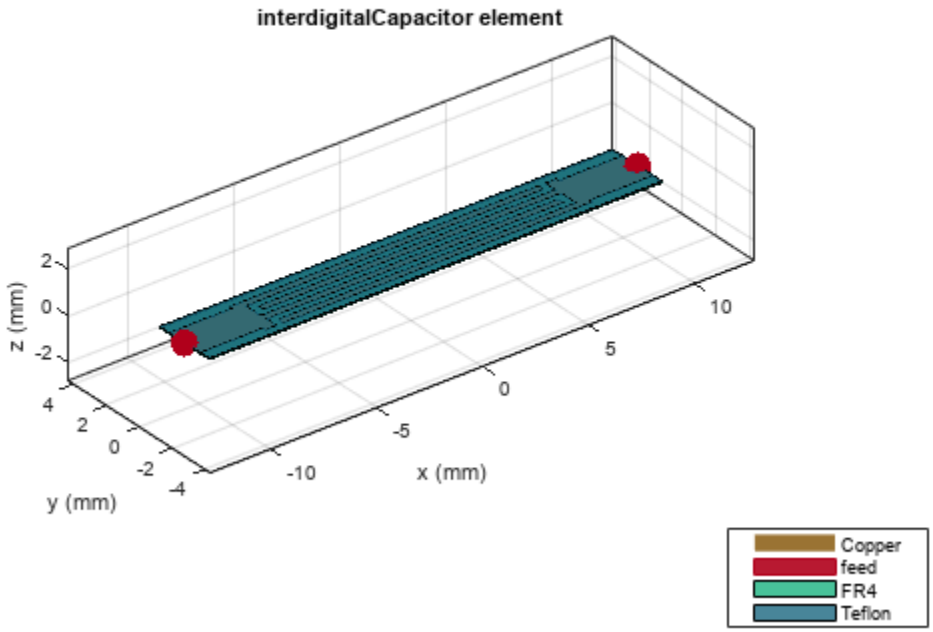
```
show(idcapacitor)
```




### Multilayer Interdigital Capacitor

Create and view a multilayer interdigital capacitor with two different dielectrics.

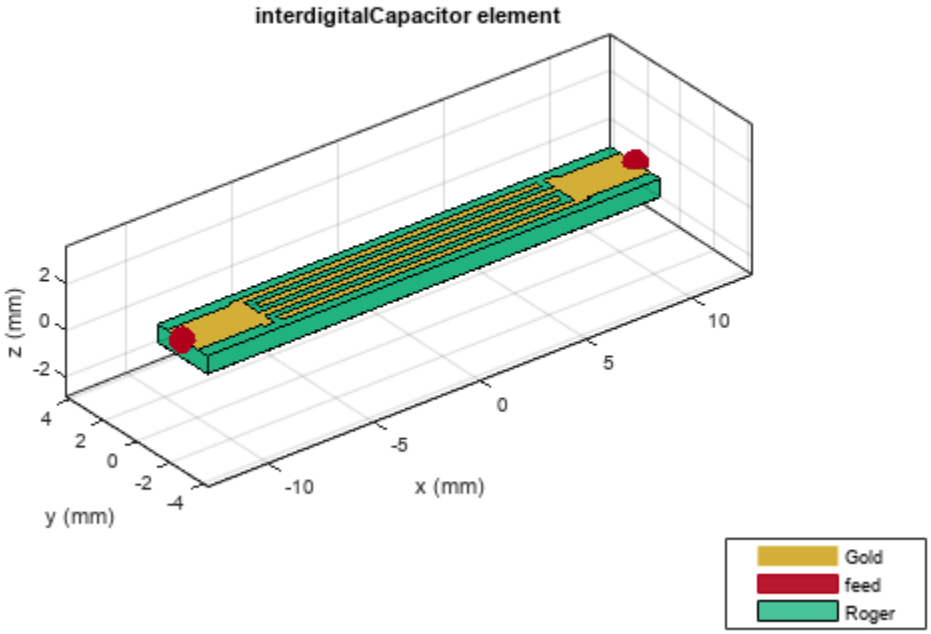
```
idcapacitor = interdigitalCapacitor;
sub = dielectric("FR4","Teflon");
sub.Thickness =[0.00003 0.00003];
idcapacitor.Substrate = sub;
idcapacitor.Height = 0.00003;
show(idcapacitor);
```




### Analyze Interdigital Capacitor Using Behavioral S-parameters

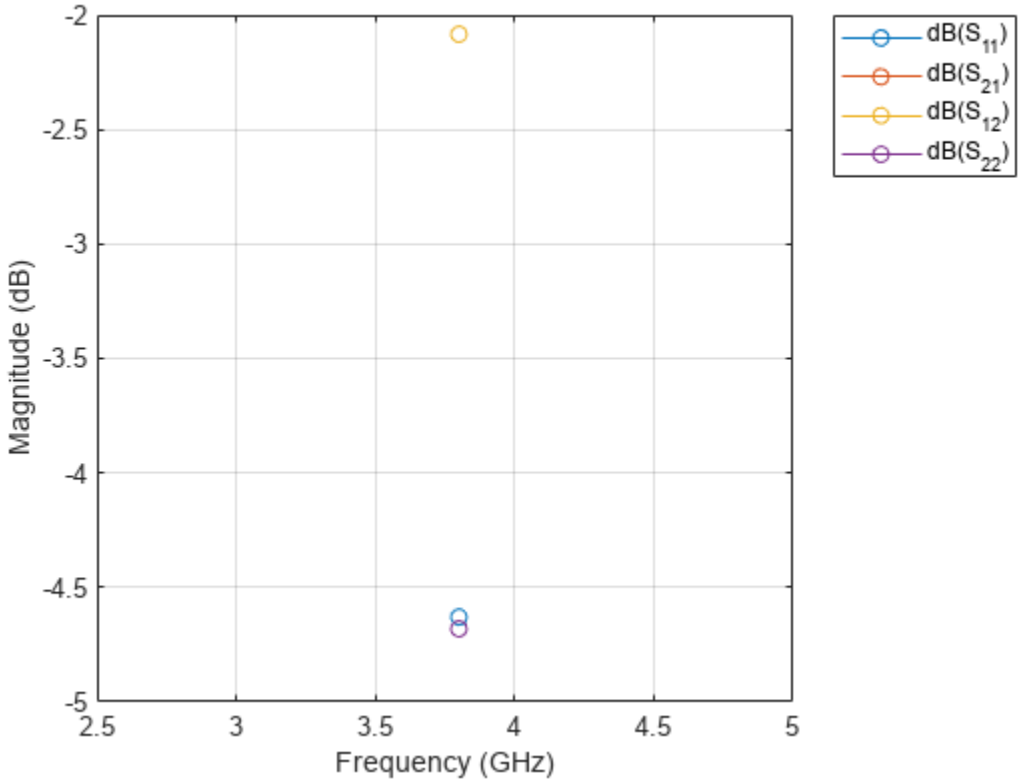
Create an interdigital capacitor using gold as the conductor.

```
capacitor = interdigitalCapacitor;
capacitor.Conductor = metal("Gold");
show(capacitor)
```




Compute and plot the behavioral S-parameters of the capacitor at 3.8 GHz.

```
spar = sparameters(capacitor,3.8e9,Behavioral=true);
rfplot(spar)
```




## More About

### Parametric Analysis Guidelines

- The capacitance of an interdigital capacitor is directly proportional to its physical parameters such as NumFingers, FingerLength, FingerWidth, and FingerSpacing.
- Increasing the height of the dielectric decreases the parasitic capacitance.

To design the capacitor at high frequency consider the following assumptions:

- Increasing the number of fingers creates a periodic and smooth structure.
- Capacitor dimensions should be much smaller than the quarter wavelength.

# Version History

**Introduced in R2021b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

[2] Jungreuthmayer, Christian, Gerald M. Birnbaumer, Peter Ertl, and Jürgen Zanghellini. “Improving the Measurement Sensitivity of Interdigital Dielectric Capacitors (IDC) by Optimizing the

Dielectric Property of the Homogeneous Passivation Layer." *Sensors and Actuators B: Chemical* 162, no. 1 (February 2012): 418–24. https://doi.org/10.1016/j.snb.2011.12.009.

[3] Ruppin, R. "Surface Polaritons of a Left-Handed Material Slab." *Journal of Physics: Condensed Matter* 13, no. 9 (March 5, 2001): 1811–18. https://doi.org/10.1088/0953-8984/13/9/304.

[4] Caloz, Christophe, and Tatsuo Itoh. *Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications: The Engineering Approach*. Hoboken, NJ, USA: John Wiley & Sons, Inc., 2005. https://doi.org/10.1002/0471754323.

## See Also

`spiralInductor`

# bendCurved

Create curved bend shape on X-Y plane

## Description

Use the `bendCurved` object to create a curved bend shape on the X-Y plane.

**Note** This shape object supports behavioral modeling. For more information, see “Behavioral Models”.

## Creation

### Syntax

```
bend = bendCurved
bend = bendCurved(Name=Value)
```

#### Description

`bend = bendCurved` creates a curved bend shape on the X-Y plane.

`bend = bendCurved(Name=Value)` sets “Properties” on page 1-55 using one or more name-value arguments. For example, `bendCurved(ReferencePoint=[1 1])` creates a curved bend shape with the reference point at `[1 1]`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of curved bend shape

`'myCurvedbend'` (default) | character vector | string scalar

Name of the curved bend shape, specified as a character vector or a string scalar.

Example: `bend = bendCurved(Name="bendcurve1")`

Data Types: `char`

#### `ReferencePoint` — Reference point

`[0 0]` (default) | two-element vector

Reference point for the curved bend shape in Cartesian coordinates, specified as a two-element vector.

Example: `bend = bendCurved(ReferencePoint=[1 1])`

Data Types: `double`

#### `Length` — Length of curved bend shape

`[0.0100 0.01000]` (default) | two-element vector

Length of the curved bend shape in meters, specified as a two-element vector.

Example: `bend = bendCurved(Length=[0.0500 0.0500])`

Data Types: `double`

**`Width` — Width of curved bend shape**
`[0.0500 0.0500]` (default) | two-element vector

Width of the curved bend shape in meters, specified as a two-element vector.

Example: `bend = bendCurved(Width=[0.0100 0.0100])`

Data Types: `double`

**`CurveRadius` — Radius of corner**
`0.0035` (default) | positive scalar

Radius of the corner in meters, specified as a positive scalar.

Example: `bend = bendCurved(CurveRadius=2)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Curved Bend Shape

Create a curved bend shape with default properties.

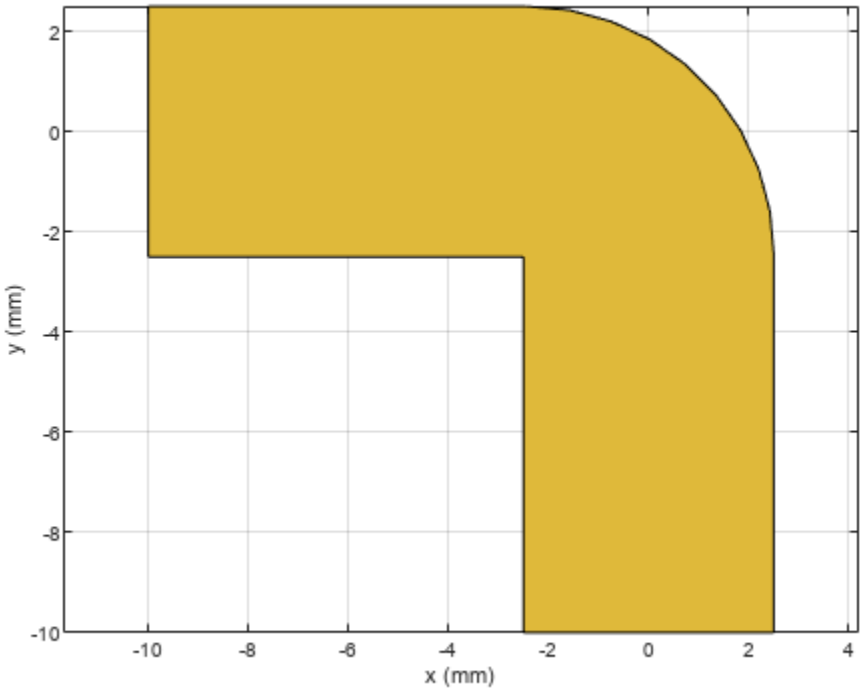
```
bend = bendCurved
```

```
bend =
  bendCurved with properties:

              Name: 'myCurvedbend'
    ReferencePoint: [0 0]
            Length: [0.0100 0.0100]
```

```
            Width: [0.0050 0.0050]
      CurveRadius: 0.0035
```

View the shape.

```
show(bend)
```



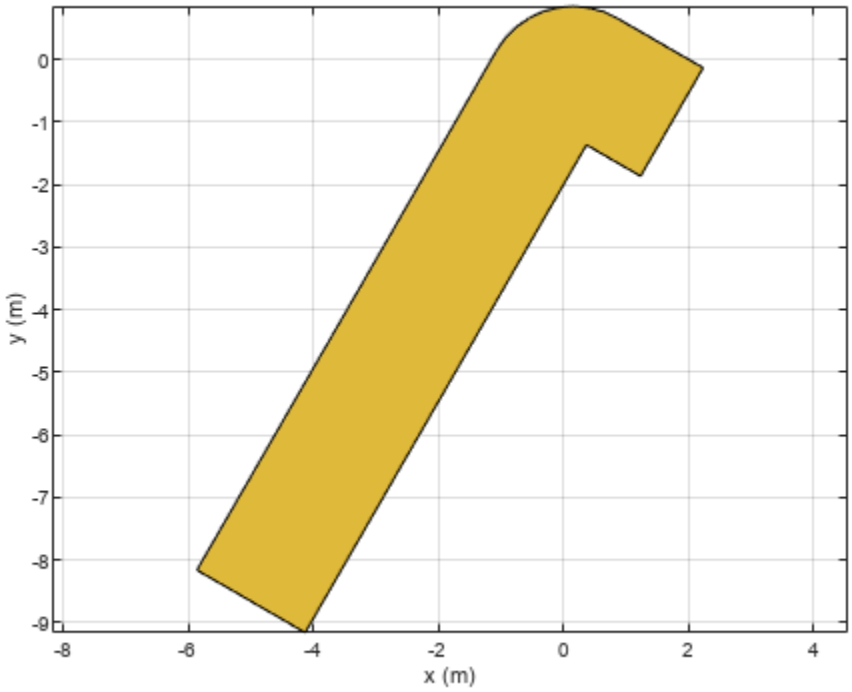

### Mesh Rotated Curved Bend Shape

Create a curved bend shape of lengths of 10 m and 2 m, width of 2 m, and rotate it about the Z-axis by 60 degrees.

```
bend = bendCurved(Length=[10 2],Width=[2 2],CurveRadius=1)
```

```
bend =
  bendCurved with properties:

             Name: 'myCurvedbend'
   ReferencePoint: [0 0]
           Length: [10 2]
            Width: [2 2]
      CurveRadius: 1
```

```
bend = rotateZ(bend,60);
show(bend)
```

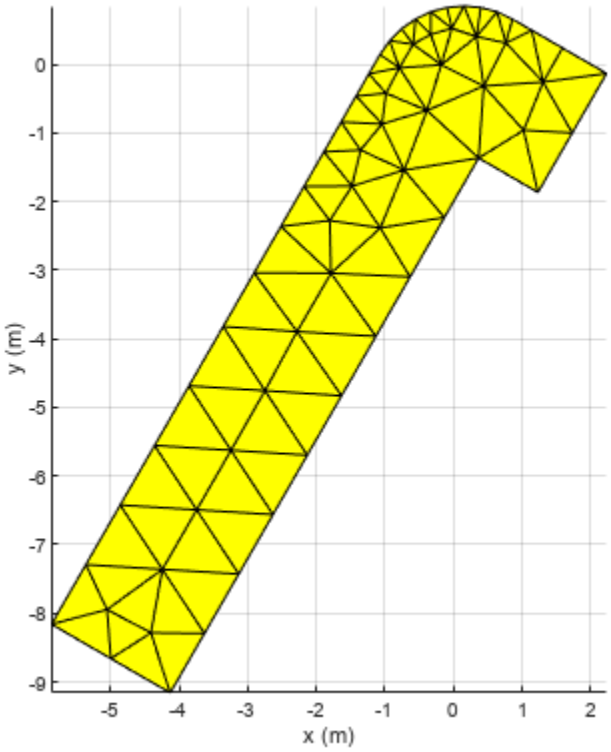



Mesh the curved bend shape at a maximum edge length of 1 m.

```
meshconfig(bend,"manual")
```

```
ans = struct with fields:
     NumTriangles: 0
    NumTetrahedra: 0
         NumBasis: []
    MaxEdgeLength: []
    MinEdgeLength: []
       GrowthRate: []
         MeshMode: 'manual'
```

```
mesh(bend,MaxEdgeLength=1)
```




## Version History

**Introduced in R2021b**

## See Also

`bendRightAngle` | `bendMitered`

# bendMitered

Create mitered bend shape on X-Y plane

## Description

Use the `bendMitered` object to create a mitered bend shape on the X-Y plane.

**Note** This shape object supports behavioral modeling. For more information, see "Behavioral Models".

## Creation

### Syntax

```
bend = bendMitered
bend = bendMitered(Name=Value)
```

#### Description

`bend = bendMitered` creates a mitered bend shape on the X-Y plane.

`bend = bendMitered(Name=Value)` sets "Properties" on page 1-60 using one or more name-value arguments. For example, `bendMitered(ReferencePoint=[1 1])` creates a mitered bend shape with the reference point at `[1 1]`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of mitered bend shape

`'myMiteredbend'` (default) | character vector | string scalar

Name of the mitered bend shape, specified as a character vector or a string scalar.

Example: `bend = bendMitered(Name="bendmitered1")`

Data Types: `char`

#### `ReferencePoint` — Reference point

`[0 0]` (default) | two-element vector

Reference point for the mitered bend shape in Cartesian coordinates, specified as a two-element vector.

Example: `bend = bendMitered(ReferencePoint=[1 2])`

Data Types: `double`

#### `Length` — Length of mitered bend shape

`[0.0100 0.0100]` (default) | two-element vector

Length of the mitered bend shape in meters, specified as a two-element vector.

Example: `bend = bendMitered(Length=[0.005 0.005])`

Data Types: `double`

**`Width` — Width of mitered bend shape**
`[0.0050 0.0500]` (default) | two-element vector

Width of the mitered bend shape in meters, specified as a two-element vector.

Example: `bend = bendMitered(Width=[1 1])`

Data Types: `double`

**`MiterDiagonal` — Length of miter diagonal**
`0.0035` (default) | positive scalar

Length of the miter diagonal in meters, specified as a positive scalar.

Example: `bend = bendMitered(MiterDiagonal=2)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Mitered Bend

Create a mitered bend with default properties.

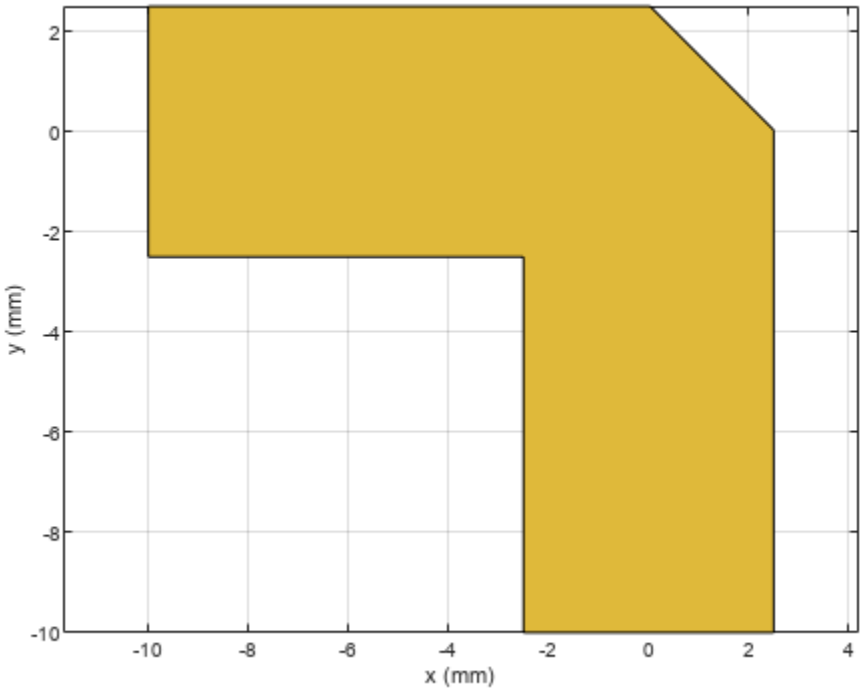
```
bend = bendMitered
```

```
bend =
  bendMitered with properties:

              Name: 'myMiteredbend'
    ReferencePoint: [0 0]
            Length: [0.0100 0.0100]
```

```
          Width: [0.0050 0.0050]
    MiterDiagonal: 0.0035
```

View the shape.

```
show(bend)
```



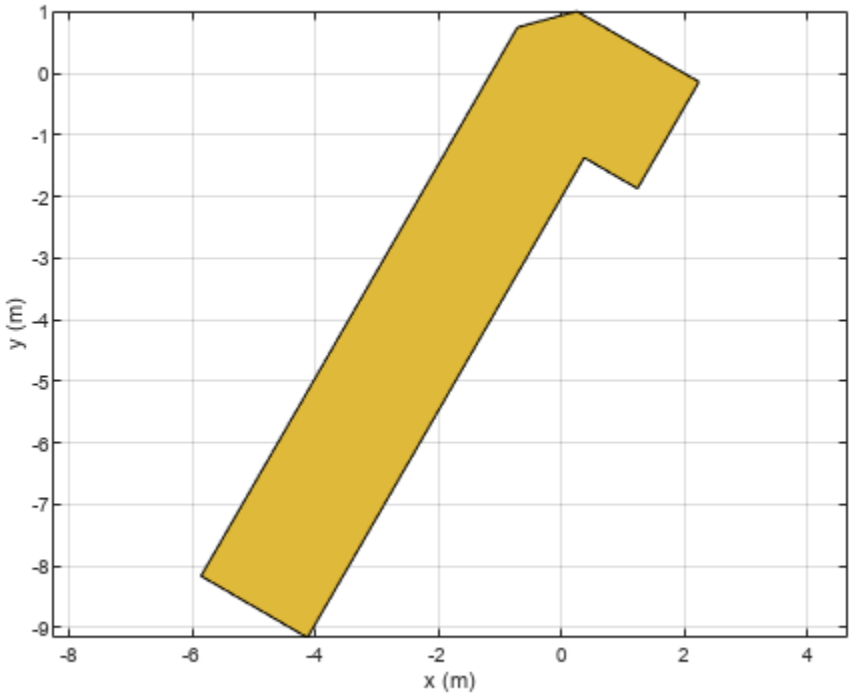

### Mesh Rotated Mitered Bend Shape

Create a mitered bend shape of lengths of 10 m and 2 m, width of 2 m, and rotate it about the Z-axis by 60 degrees.

```
bend = bendMitered(Length=[10 2],Width=[2 2],MiterDiagonal=1);
bend = rotateZ(bend,60)
```

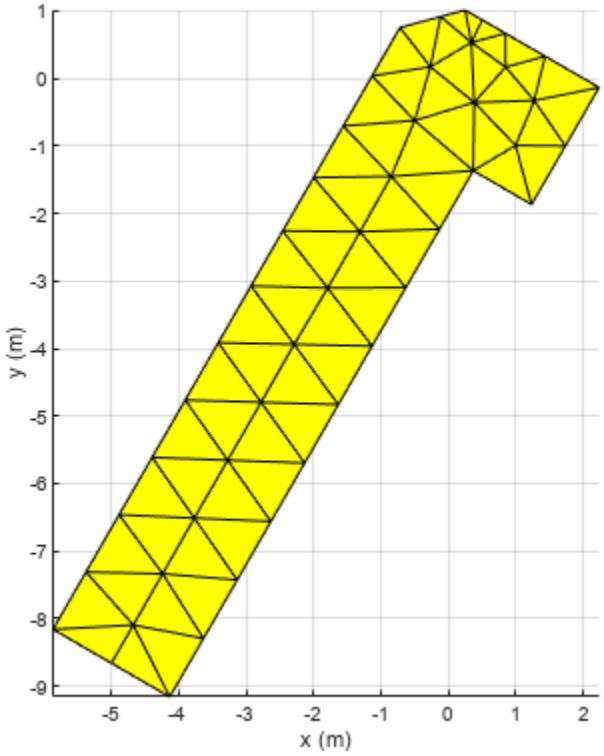
```
bend =
  bendMitered with properties:

             Name: 'myMiteredbend'
    ReferencePoint: [0 0]
           Length: [10 2]
            Width: [2 2]
     MiterDiagonal: 1
```

```
show(bend)
```




Mesh the mitered bend shape at a maximum edge length of 1 m.

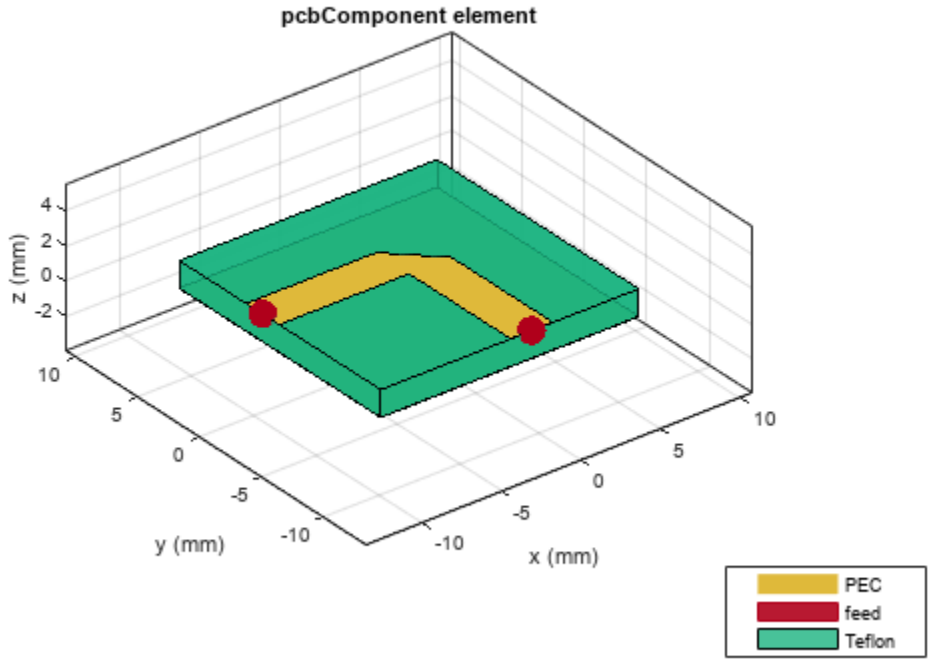
```
mesh(bend,MaxEdgeLength=1)
```




### Use Behavioral Model to Calculate S-Parameters of Mitered Bend Microstrip

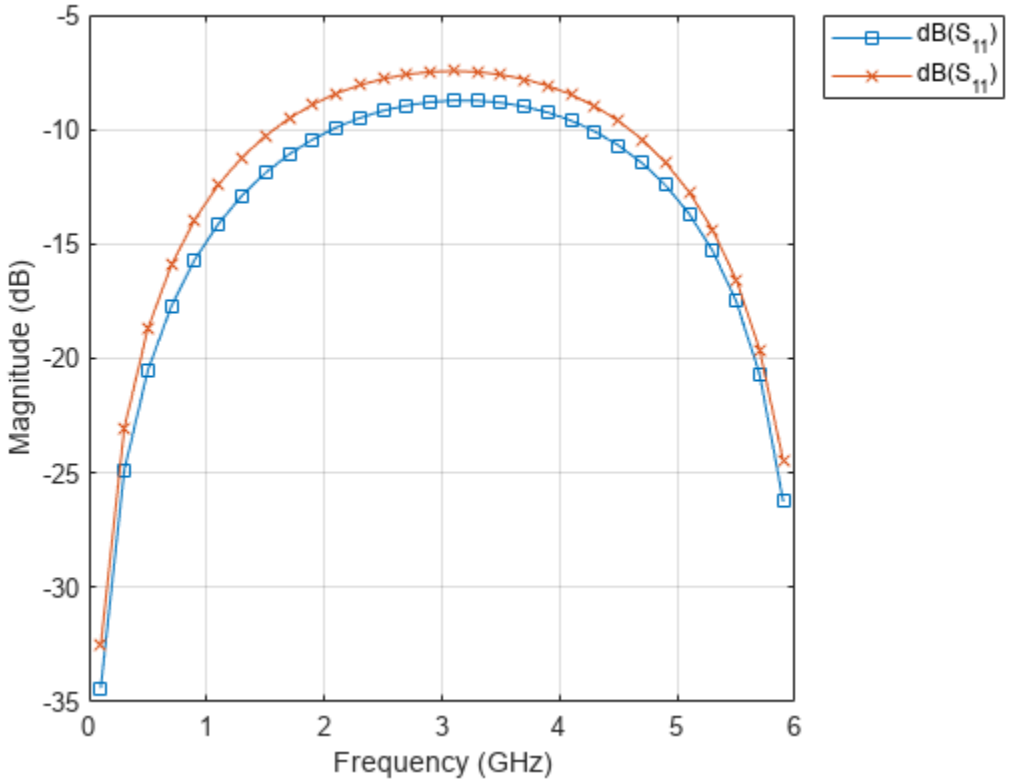
Create mitered bend microstrip.

```
m = design(microstripLine,6e9,"Z0",75);
layer2d = bendMitered('Length',[m.Length/2 m.Length/2],...
"Width",[m.Width m.Width],'MiterDiagonal',sqrt(2)*m.Width);
robj = pcbComponent(layer2d);
robj.BoardThickness = m.Substrate.Thickness;
robj.Layers{2} = m.Substrate;
show(robj)
```




Compute and plot s-parameters.

```
freq = (1:2:60)*100e6;
Sckt = sparameters(robj,freq,'Behavioral',true);
Sem = sparameters(robj,freq);
rfplot(Sckt,1,1,'db','-s')
hold on
rfplot(Sem,1,1,'db','-x')
```




Reference:

M. Kirschning, R. H. Jansen and N. H. L. Koster, "Measurement and Computer-Aided Modeling of Microstrip Discontinuities by an Improved Resonator Method," 1983 IEEE MTT-S International Microwave Symposium Digest, Boston, MA, USA, 1983, pp. 495-497, doi: 10.1109/MWSYM.1983.1130959.

## Version History

**Introduced in R2021b**

## See Also

`bendRightAngle` | `bendCurved`

# bendRightAngle

Create right-angle bend shape on X-Y plane

## Description

Use the `bendRightAngle` object to create a right-angle bend shape on the X-Y plane.

**Note** This shape object supports behavioral modeling. For more information, see “Behavioral Models”.

## Creation

### Syntax

```
bend = bendRightAngle
bend = bendRightAngle(Name=Value)
```

#### Description

`bend = bendRightAngle` creates a right-angle bend shape on the X-Y plane.

`bend = bendRightAngle(Name=Value)` sets “Properties” on page 1-67 using one or more name-value arguments. For example, `bendRightAngle(ReferencePoint=[1 1])` creates a right-angle bend shape with the reference point at `[1 1]`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of right-angle bend shape

`'myRightAnglebend'` (default) | character vector | string scalar

Name of the right-angle bend shape, specified as a character vector or a string scalar.

Example: `bend = bendRightAngle(Name="bendrightangle1")`

Data Types: `char`

#### `ReferencePoint` — Reference point

`[0 0]` (default) | two-element vector

Reference point for the right-angle bend shape in Cartesian coordinates, specified as a two-element vector.

Example: `bend = bendRightAngle(ReferencePoint=[1 2])`

Data Types: `double`

#### `Length` — Length of right-angle bend shape

`[0.0100 0.0100]` (default) | two-element vector

Length of the right-angle bend shape in meters, specified as a two-element vector.

Example: `bend = bendRightAngle(Length=[0.0500 0.0500])`

Data Types: `double`

**`Width` — Width of right-angle bend shape**
`[0.0050 0.0050]` (default) | two-element vector

Width of the right-angle bend shape in meters, specified as a two-element vector.

Example: `bend = bendRightAngle(Width=[0.0200 0.0200])`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Right-Angle Bend

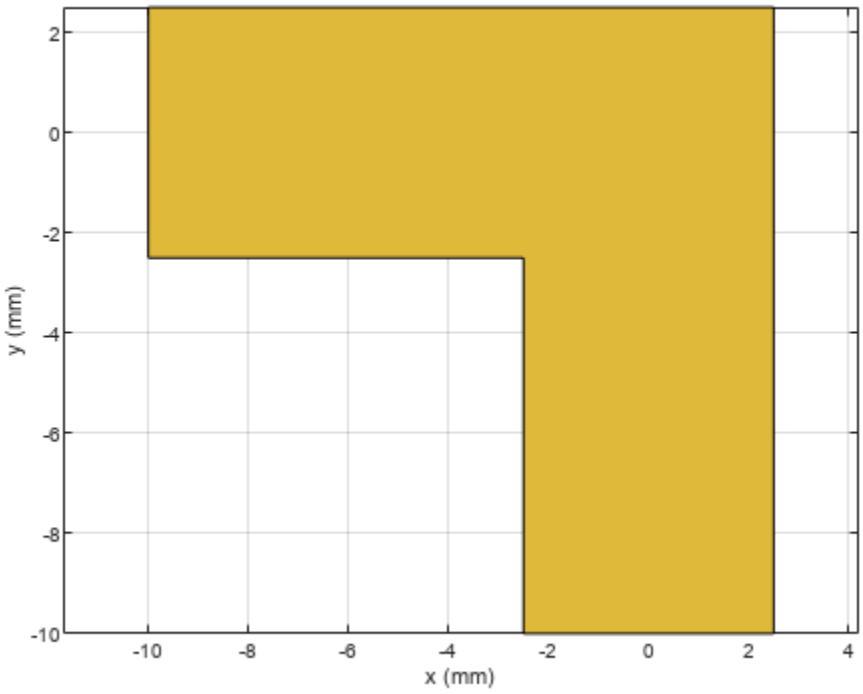
Create a right-angle bend with default properties.

```
bend = bendRightAngle
```

```
bend =
  bendRightAngle with properties:

              Name: 'myRightAnglebend'
    ReferencePoint: [0 0]
            Length: [0.0100 0.0100]
             Width: [0.0050 0.0050]
```

View the shape.

```
show(bend)
```



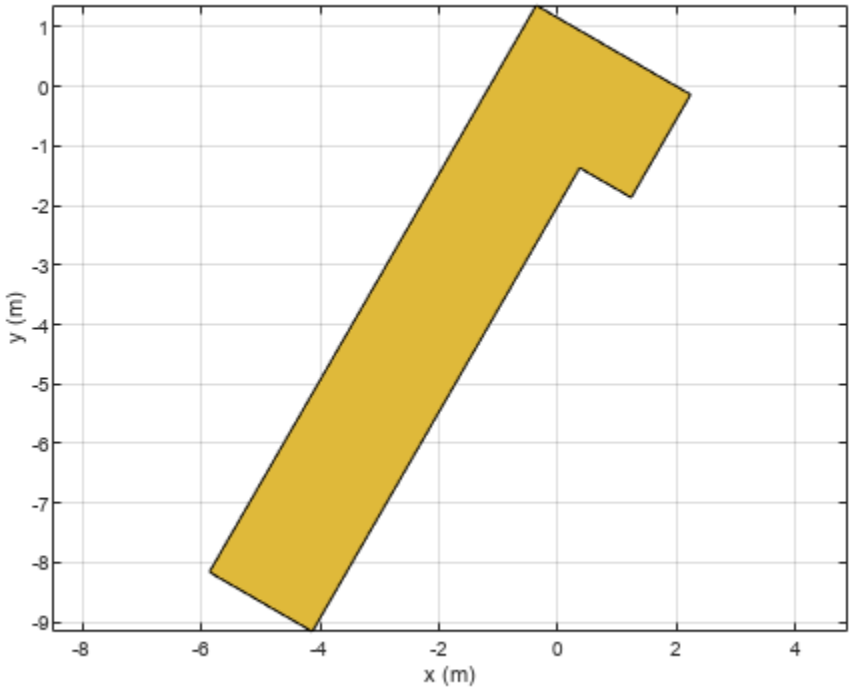

### Mesh Rotated Right-Angle Bend Shape

Create a right-angle bend shape of lengths of 10 m and 2 m, width of 2m, and rotate it about the Z-axis by 60 degrees.

```
bend = bendRightAngle(Length=[10 2],Width=[2 2]);
bend = rotateZ(bend,60)
```

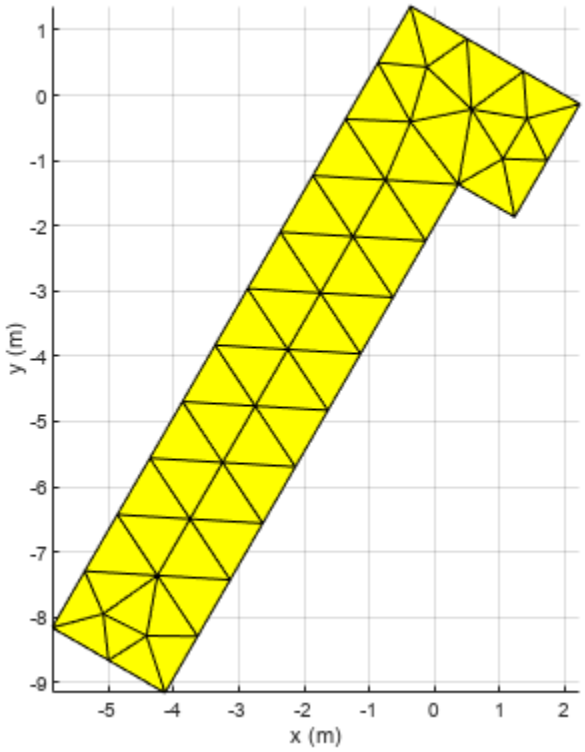
```
bend =
  bendRightAngle with properties:

              Name: 'myRightAnglebend'
    ReferencePoint: [0 0]
            Length: [10 2]
             Width: [2 2]
```

```
show(bend)
```




Mesh the right-angle bend shape at a maximum edge length of 1 m.

```
mesh(bend,MaxEdgeLength=1)
```




## Version History

**Introduced in R2021b**

## See Also

`bendMitered` | `bendCurved`

# curve

Create curved shape on X-Y plane

# Description

Use the `curve` object to create a curved shape centered on the X-Y plane.

# Creation

## Syntax

```
curvedshape = curve
curvedshape = curve(Name=Value)
```

### Description

`curvedshape = curve` creates a curved shape centered on the X-Y plane.

`curvedshape = curve(Name=Value)` sets "Properties" on page 1-72 using one or more name-value arguments. For example, `curve(ReferencePoint=[1 1])` creates a curved shape at the reference point `[1 1]`. Properties not specified retain their default values.

## Properties

**`Name` — Name of curved shape**
`'myCurve'` (default) | character vector | string scalar

Name of the curved shape, specified as a character vector or string scalar.

Example: `curvedshape = curve(Name='curvedshape1')`

Data Types: `char` | `string`

**`ReferencePoint` — Reference point**
`[0 0]` (default) | two-element vector

Reference point of the curved shape in Cartesian coordinates, specified as a two-element vector.

Example: `curvedshape = curve(ReferencePoint=[1 1])`

Data Types: `double`

**`Radius` — Radius of curved shape**
`0.0100` (default) | positive scalar

Radius of the curved shape, specified as a positive scalar in meters.

Example: `curvedshape = curve(Radius=0.0300)`

Data Types: `double`

### `Width` — Width of curved shape

`0.0020` (default) | positive scalar

Width of the curved shape, specified as a positive scalar in meters.

Example: `curvedshape = curve(Width=0.0030)`

Data Types: `double`

### `ArcAngle` — Start angle and stop angle

`[0 180]` (default) | two-element vector

Start angle and stop angle in degrees, specified as a two-element vector.

Example: `curvedshape = curve(ArcAngle=[90 140)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Curved Shape

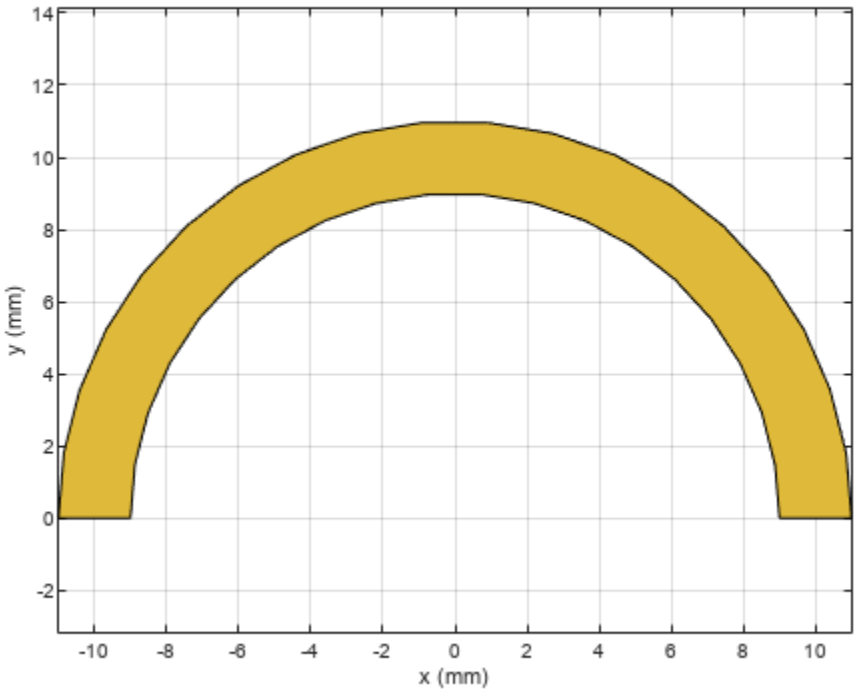
Create a curved shape with default properties.

```
curved = curve
```

```
curved =
  curve with properties:

              Name: 'myCurve'
    ReferencePoint: [0 0]
            Radius: 0.0100
             Width: 0.0020
          ArcAngle: [0 180]
```

View the curved shape.

```
show(curved)
```




### Mesh Rotated Curved Shape

Create a curved shape with the of 8 m and width of 2 m.

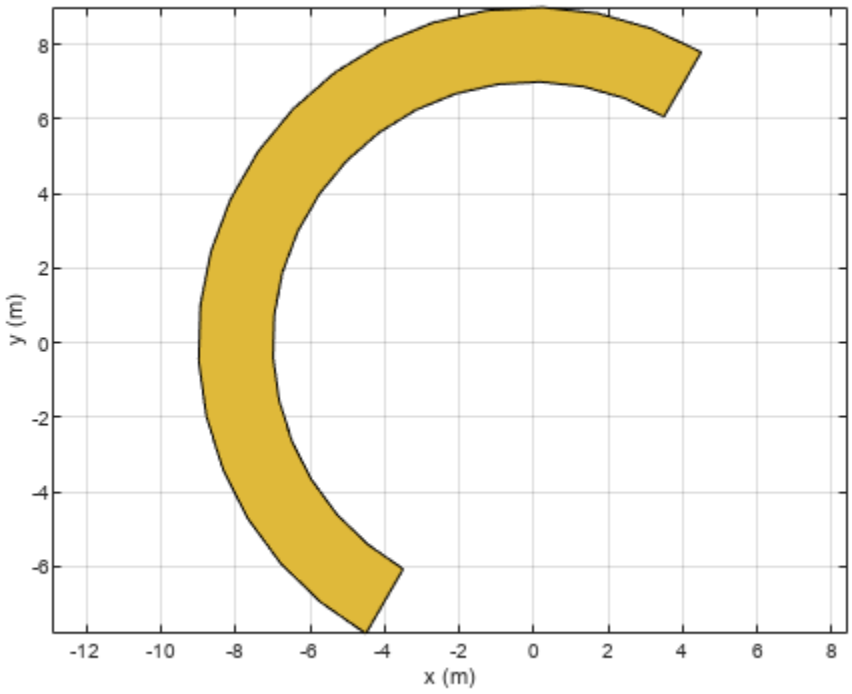
```
curved = curve(Radius=8,Width=2);
```

Rotate the shape by 60 degrees.

```
curved = rotateZ(curved,60)
```

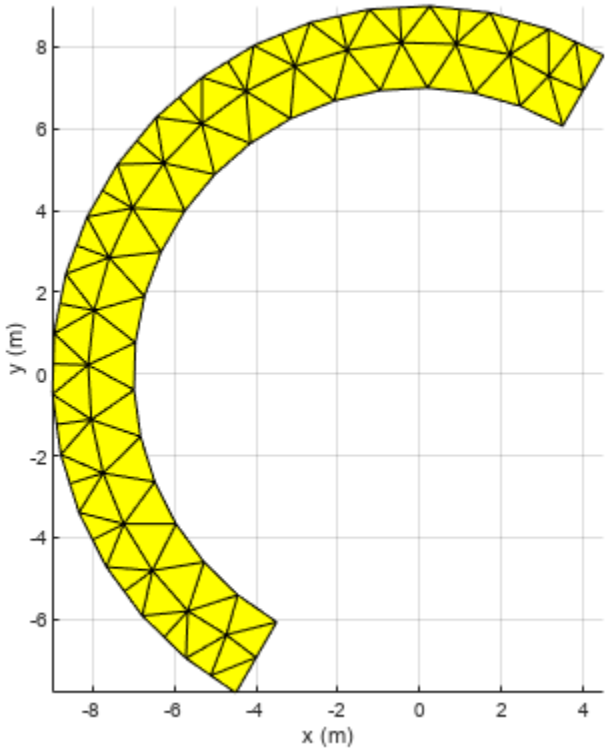
```
curved =
  curve with properties:

              Name: 'myCurve'
    ReferencePoint: [0 0]
            Radius: 8
             Width: 2
          ArcAngle: [0 180]
```

```
show(curved)
```




Mesh the curved shape at a maximum edge length of 1 m.

```
mesh(curved,MaxEdgeLength=1)
```




## Version History

**Introduced in R2021b**

## See Also

`ringAnnular` | `ringSquare` | `radial` | `delta`

# ringAnnular

Create annular ring on X-Y plane

## Description

Use the `ringAnnular` object to create an annular ring on the X-Y plane.

## Creation

### Syntax

```
ring = ringAnnular
ring = ringAnnular(Name=Value)
```

#### Description

`ring = ringAnnular` creates an annular ring on the X-Y plane.

`ring = ringAnnular(Name=Value)` sets "Properties" on page 1-77 using one or more name-value arguments. For example, `ringAnnular(Center=[1 1])` creates an annular ring shape centered at `[1 1]`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of annular ring

`'myringAnnular'` (default) | character vector | string scalar

Name of the annular ring, specified as a character vector or string scalar.

Example: `ring = ringAnnular(Name='ringannular1')`

Data Types: `char` | `string`

#### `Center` — Center of annular ring

`[0 0]` (default) | two-element vector

Center of the annular ring in Cartesian coordinates, specified as a two-element vector.

Example: `ring = ringAnnular(Center=[1 1])`

Data Types: `double`

#### `InnerRadius` — Inner radius of annular ring

`0.0050` (default) | positive scalar

Inner radius of the annular ring, specified as a positive scalar in meters.

Example: `ring = ringAnnular(InnerRadius=0.006)`

Data Types: `double`

**`Width` — Width of annular ring**
`0.0020` (default) | positive scalar

Width of the annular ring, specified as a positive scalar in meters.

Example: `ring = ringAnnular(Width=3)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Annular Ring Shape

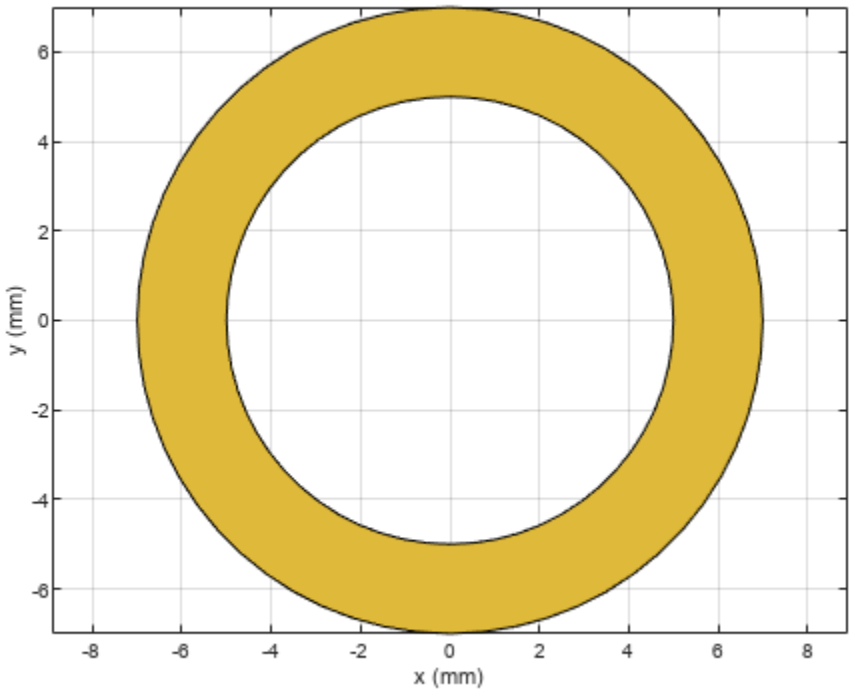
Create an annular ring shape with default properties.

```
ring = ringAnnular
```

```
ring =
  ringAnnular with properties:

           Name: 'myringAnnular'
         Center: [0 0]
          Width: 0.0020
    InnerRadius: 0.0050
```

View the shape.

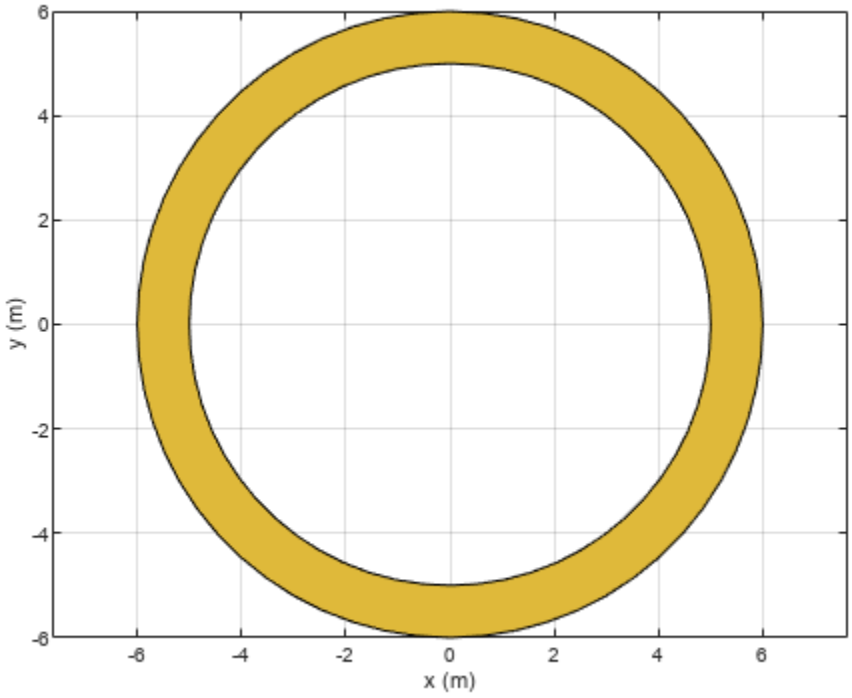
```
show(ring)
```




### Mesh Annular Ring Shape

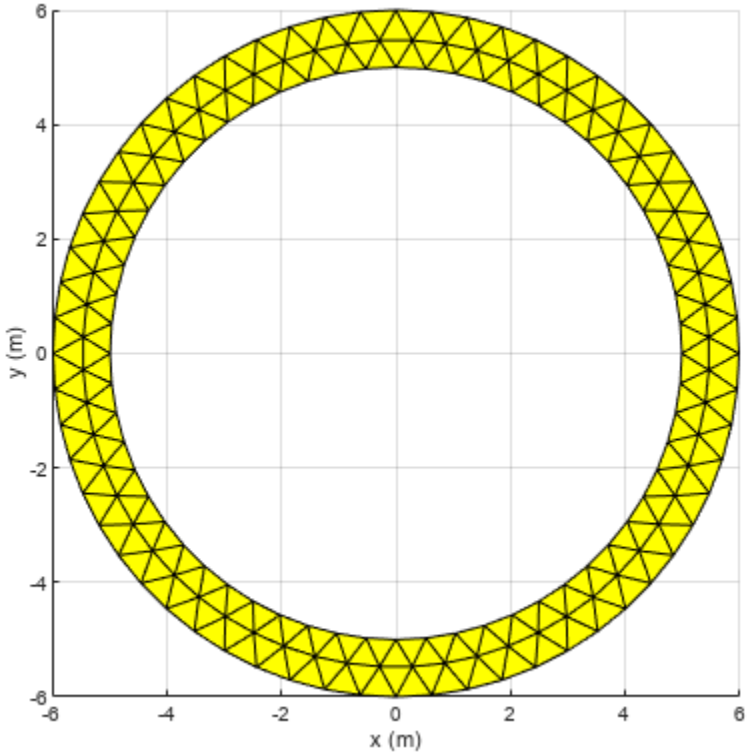
Create an annular ring shape of inner radius 5 m and width 1 m.

```
ring = ringAnnular(InnerRadius=5,Width=1);
show(ring)
```




Mesh the ring at a maximum edge length of 1 m.

```
mesh(ring,MaxEdgeLength=1)
```




## Version History

**Introduced in R2021b**

## See Also

`ringSquare`

# ringSquare

Create square ring on X-Y plane

## Description

Use the `ringSquare` object to create a square ring on the X-Y plane.

## Creation

### Syntax

```
ring = ringSquare
ring = ringSquare(Name=Value)
```

#### Description

`ring = ringSquare` creates a square ring on the X-Y plane.

`ring = ringSquare(Name=Value)` sets "Properties" on page 1-82 using one or more name-value arguments. For example, `ringSquare(Center=[1 1])` creates an square ring shape centered at `[1 1]`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of square ring

`'myringSquare'` (default) | character vector | string scalar

Name of square ring, specified as a character vector or string scalar.

Example: `ring = ringSquare(Name='ringsquare1')`

Data Types: `char` | `string`

#### `Center` — Center of square ring

`[0 0]` (default) | two-element vector

Center of the square ring in Cartesian coordinates, specified as a two-element vector.

Example: `ring = ringAnnular(Center=[1 1])`

Data Types: `double`

#### `InnerSide` — Length of inner side

`0.0050` (default) | positive scalar

Length of the inner side, specified as a positive scalar in meters.

Example: `ring = ringSquare(InnerSide=0.0060)`

Data Types: `double`

**`Width` — Width of square ring**
`0.0020` (default) | positive scalar

Width of the square ring, specified as a positive scalar in meters.

Example: `ring = ringSquare(Width=0.0030)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Square Ring Shape

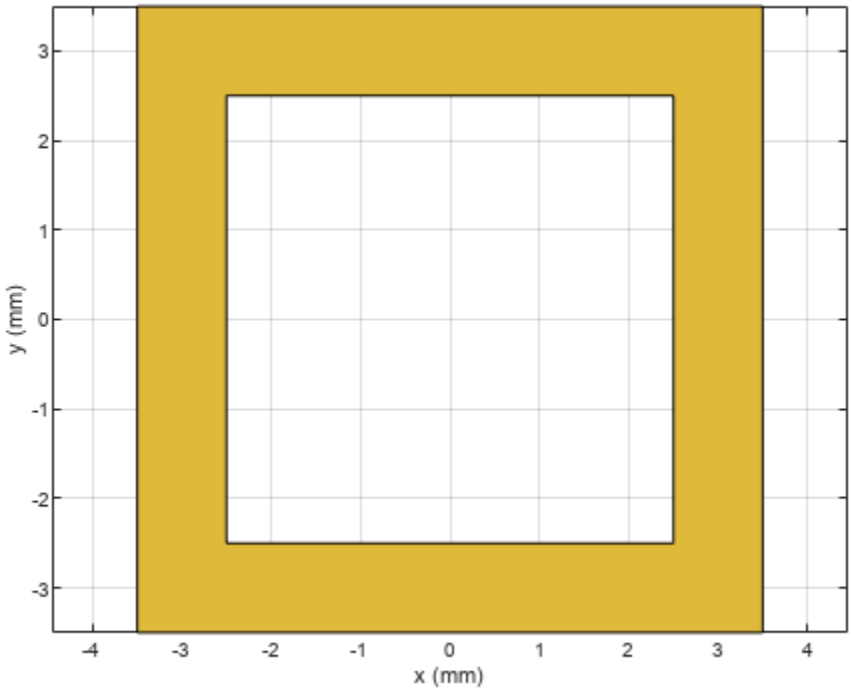
Create a square ring with default properties.

```
ring = ringSquare
```

```
ring =
  ringSquare with properties:

         Name: 'myringSquare'
       Center: [0 0]
        Width: 0.0020
    InnerSide: 0.0050
```

View the shape.

```
show(ring)
```



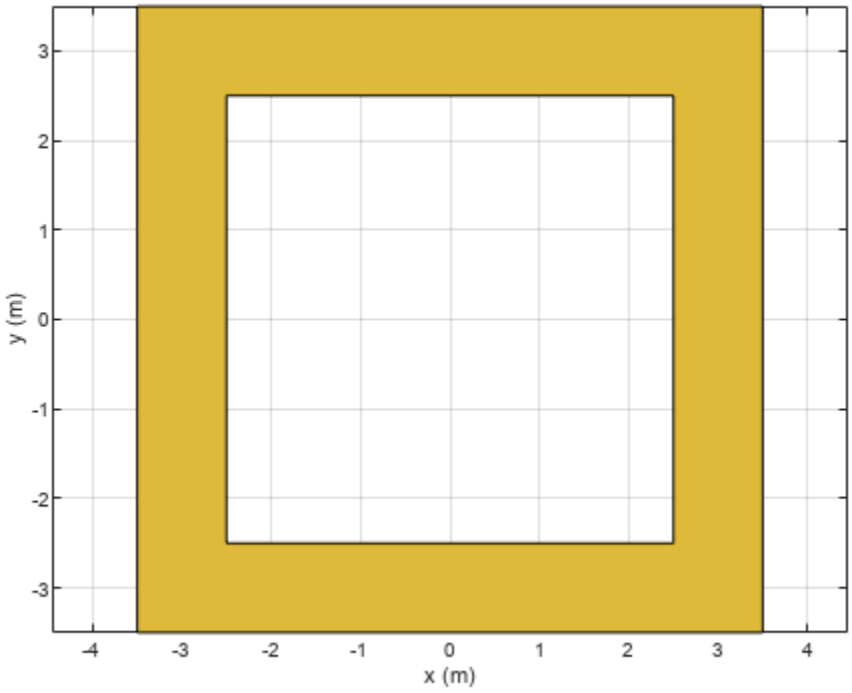

### Mesh Square Ring Shape

Create a square ring with with the inner side length of 5 m and a width of 2 m.

```
ring = ringSquare(InnerSide=5,Width=2)
```

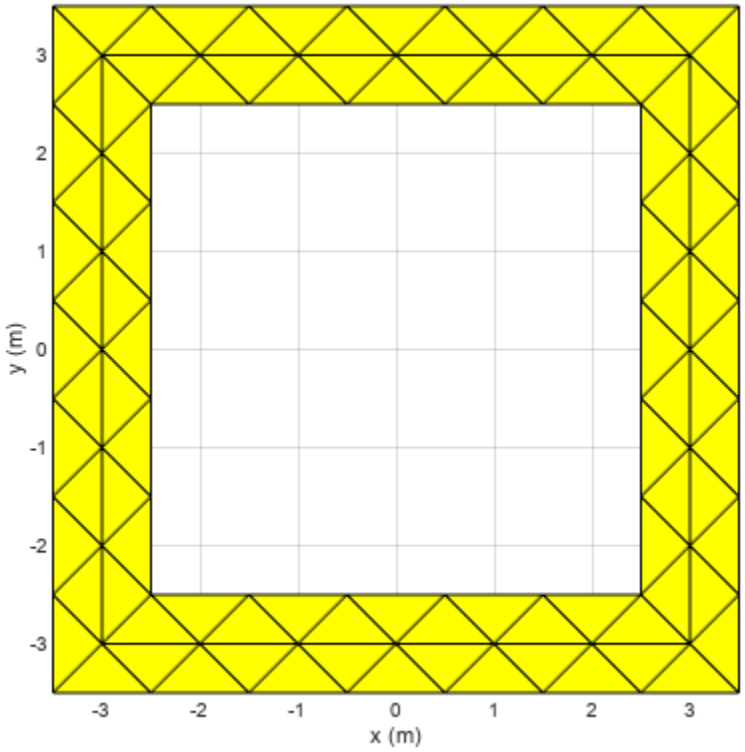
```
ring =
  ringSquare with properties:

         Name: 'myringSquare'
       Center: [0 0]
        Width: 2
    InnerSide: 5
```

```
show(ring)
```




Mesh the square ring at a maximum edge length of 1 m.

```
mesh(ring,MaxEdgeLength=1)
```




## Version History

**Introduced in R2021b**

## See Also

`ringAnnular`

# ubendCurved

Create U-bend with curved edges on X-Y plane

## Description

Use the `ubendCurved` object to create a U-bend with curved edges on the X-Y plane.

## Creation

### Syntax

```
bend = ubendCurved
bend = ubendCurved(Name=Value)
```

#### Description

`bend = ubendCurved` creates a U-bend with curved edges on the X-Y plane.

`bend = ubendCurved(Name=Value)` sets "Properties" on page 1-87 using one or more name-value arguments. For example, `ubendCurved(ReferencePoint=[1 1])` creates a U-bend with curved edges at the reference point `[1 1]`. Properties not specified retain their default values.

### Properties

**`Name` — Name of curved U-bend**
`'myCurvedubend'` (default) | character vector | string scalar

Name of the curved U-bend, specified as a character vector or a string scalar.

Example: `bend = ubendCurved(Name="ubendcurve1")`

Data Types: `char` | `string`

**`ReferencePoint` — Reference point of curved U-bend**
`[0 0]` (default) | two-element vector

Reference point of the curved U-bend in Cartesian coordinates, specified as a two-element vector.

Example: `bend = ubendCurved(ReferencePoint=[1 2])`

Data Types: `double`

**`Length` — Length of curved U-bend**
`[0.0150 0.0050 0.0150]` (default) | three-element vector

Length of the curved U-bend in meters, specified as a three-element vector of positive elements.

Example: `bend = ubendCurved(Length=[0.0050 0.0020 0.0050])`

Data Types: `double`

### `Width` — Width of curved U-bend

`[0.0050 0.0050 0.0050]` (default) | three-element vector

Width of the curved U-bend in meters, specified as a three-element vector of positive elements.

Example: `bend = ubendCurved(Width=[0.0040 0.0040 0.0040])`

Data Types: `double`

### `CurveRadius` — Radius of corner

`0.0035` (default) | positive scalar

Radius of the corner in meters, specified as a positive scalar.

Example: `bend = ubendCurved(CurveRadius=0.0025)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Curved U-Bend

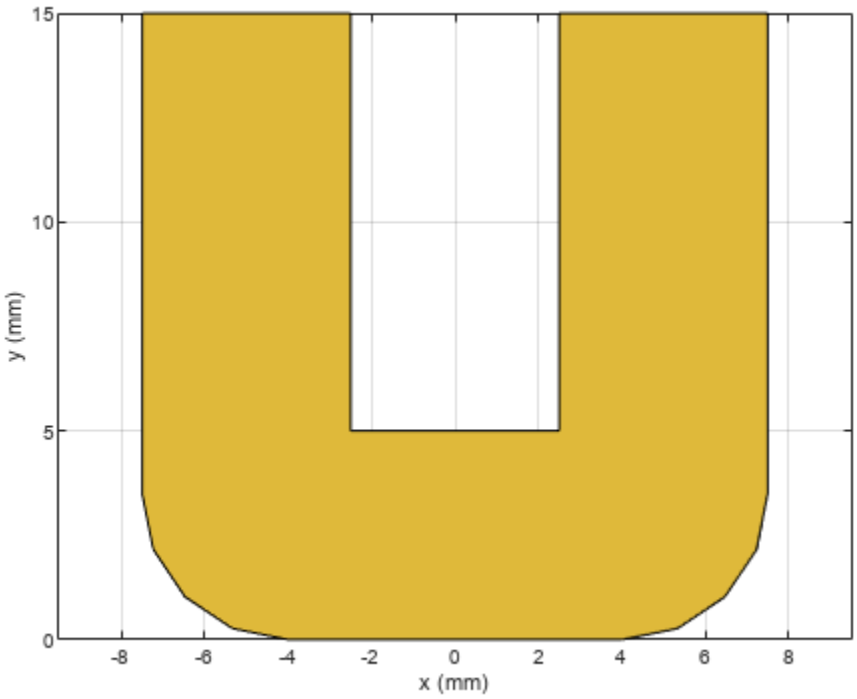
Create a curved U-bend with default properties.

```
curvedubend = ubendCurved
```

```
curvedubend =
  ubendCurved with properties:

              Name: 'myCurvedubend'
    ReferencePoint: [0 0]
            Length: [0.0150 0.0050 0.0150]
             Width: [0.0050 0.0050 0.0050]
       CurveRadius: 0.0035
```

View the shape.

```
show(curvedubend)
```




## Version History

**Introduced in R2021b**

## See Also

`ubendMitered` | `ubendRightAngle`

# ubendMitered

Create U-bend with mitered edges on X-Y plane

## Description

Use the `ubendMitered` object to create a U-bend with mitered edges on the X-Y plane.

## Creation

### Syntax

```
bend = ubendMitered
bend = ubendMitered(Name=Value)
```

#### Description

`bend = ubendMitered` creates a U-bend with mitered edges on the X-Y plane.

`bend = ubendMitered(Name=Value)` sets "Properties" on page 1-90 using one or more name-value arguments. For example, `ubendMitered(ReferencePoint=[1 1])` creates a mitered U-bend at the reference point `[1 1]`. Properties not specified retain their default values.

### Properties

**`Name` — Name of mitered U-bend**
`'myMiteredubend'` (default) | character vector | string scalar

Name of the mitered U-bend, specified as a character vector or a string scalar.

Example: `bend = ubendMitered(Name="ubendmitered1")`

Data Types: `char` | `string`

**`ReferencePoint` — Reference point of mitered U-bend**
`[0 0]` (default) | two-element vector

Reference point of the mitered U-bend in Cartesian coordinates, specified as a two-element vector.

Example: `bend = ubendMitered(ReferencePoint=[1 2])`

Data Types: `double`

**`Length` — Length of mitered U-bend**
`[0.0150 0.0050 0.0150]` (default) | three-element vector

Length of the mitered U-bend in meters, specified as a three-element vector of positive elements.

Example: `bend = ubendMitered(Length=[0.0250 0.0030 0.0250])`

Data Types: `double`

### `Width` — Width of mitered U-bend

`[0.0050 0.0050 0.0050]` (default) | three-element vector

Width of the mitered U-bend in meters, specified as a three-element vector of positive elements.

Example: `bend = ubendMitered(Width=[0.0060 0.0060 0.0060])`

Data Types: `double`

### `MiterDiagonal` — Length of miter diagonal

`0.0035` (default) | positive scalar

Length of the miter diagonal in meters, specified as a positive scalar.

Example: `bend = ubendMitered(MiterDiagonal=0.0060)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Mitered U-Bend

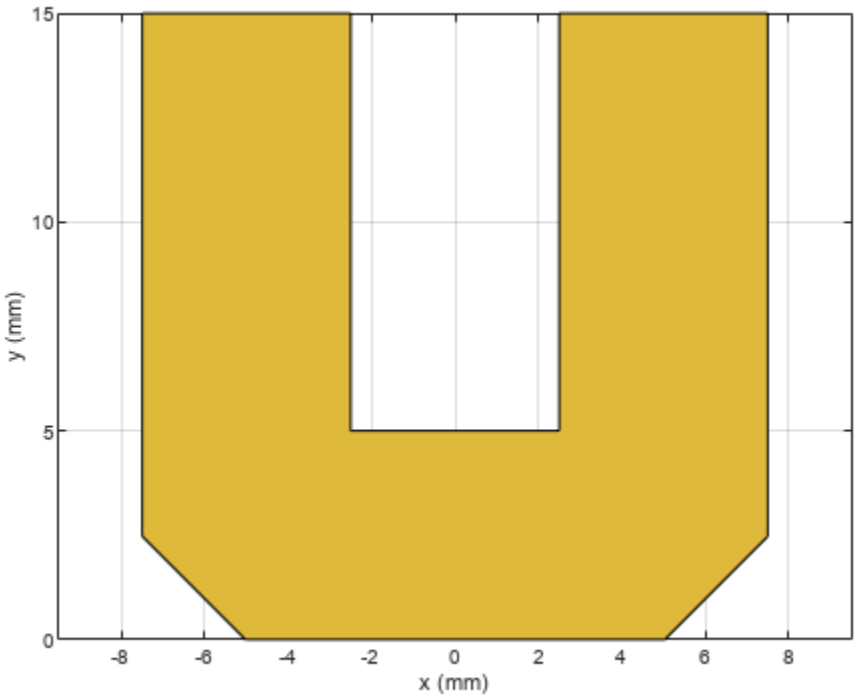
Create a mitered U-bend with default properties.

```
bend = ubendMitered
```

```
bend =
  ubendMitered with properties:

              Name: 'myMiteredubend'
    ReferencePoint: [0 0]
            Length: [0.0150 0.0050 0.0150]
             Width: [0.0050 0.0050 0.0050]
     MiterDiagonal: 0.0035
```

View the shape.

```
show(bend)
```




## Version History

**Introduced in R2021b**

## See Also

`ubendCurved` | `ubendRightAngle`

# ubendRightAngle

Create right-angle U-bend shape on X-Y plane

## Description

Use the `ubendRightAngle` object to create a right-angle U-bend shape on the X-Y plane.

## Creation

### Syntax

```
bend = ubendRightAngle
bend = ubendRightAngle(Name=Value)
```

#### Description

`bend = ubendRightAngle` creates a right-angle U-bend shape on the X-Y plane.

`bend = ubendRightAngle(Name=Value)` sets "Properties" on page 1-93 using one or more name-value arguments. For example, `ubendRightAngle(ReferencePoint=[1 1])` creates a right-angle U-bend at the reference point `[1 1]`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of right-angle U-bend

`'myRightAngleubend'` (default) | character vector | string scalar

Name of the right-angle U-bend, specified as a character vector or a string scalar.

Example: `bend = ubendRightAngle(Name="ubendrightangle1")`

Data Types: `char` | `string`

#### `ReferencePoint` — Reference point of right-angle U-bend

`[0 0]` (default) | two-element vector

Reference point of the right-angle U-bend in Cartesian coordinates, specified as a two-element vector.

Example: `bend = ubendRightAngle(ReferencePoint=[1 2])`

Data Types: `double`

#### `Length` — Length of right-angle U-bend

`[0.0150 0.0050 0.0150]` (default) | three-element vector

Length of the right-angled U-bend in meters, specified as a three-element vector of positive elements.

Example: `bend = ubendRightAngle(Length=[0.0250 0.0150 0.0250])`

Data Types: `double`

### `Width` — Width of right-angle U-bend

`[0.0050 0.0050 0.0050]` (default) | three-element vector

Width of the right-angle U-bend in meters, specified as a three-element vector of positive values.

Example: `bend = ubendRightAngle(Width=[0.0150 0.0150 0.0010])`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Right-Angle U-Bend

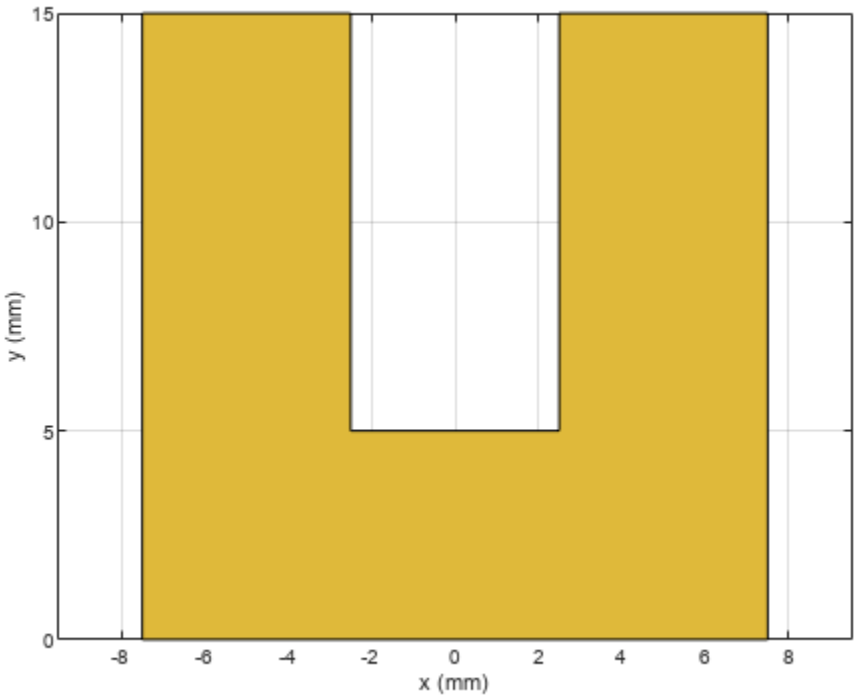
Create a right-angle U-bend with default properties.

```
bend = ubendRightAngle
```

```
bend =
  ubendRightAngle with properties:

              Name: 'myRightAngleubend'
    ReferencePoint: [0 0]
            Length: [0.0150 0.0050 0.0150]
             Width: [0.0050 0.0050 0.0050]
```

View the shape.

```
show(bend)
```




## Version History

**Introduced in R2021b**

## See Also

`ubendCurved` | `ubendMitered`

# tracePoint

Create custom line trace based on specified X and Y coordinates

## Description

Use the `tracePoint` object to create a custom line trace by tracing a line along the specified X and Y coordinates.

## Creation

### Syntax

```
trace = tracePoint
trace = tracePoint(Name=Value)
```

#### Description

`trace = tracePoint` creates a line trace using default properties.

`trace = tracePoint(Name=Value)` sets "Properties" on page 1-96 using one or more name-value arguments. For example, `tracePoint(Width=0.0050)` creates a line trace with the width of `0.0050`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of custom line trace

`'tracePoint'` (default) | character vector | string scalar

Name of the custom line trace, specified as a character vector or string scalar.

Example: `trace = tracePoint(Name='tracepoint1')`

Data Types: `char` | `string`

#### `TracePoints` — Coordinates of custom line trace

`10-by-2`array (default) | *n*-by-2-array

Coordinates of custom line trace, specified as a *n*-by-2-array of X and Y coordinates.

Example: `trace = tracePoint(TracePoints=[0 0;0 -10;6 -10;6 0]])`

Data Types: `double`

#### `Width` — Width of line trace

`0.002` (default) | positive scalar

Width of the line trace, specified as a positive scalar in meters. This value is applied to all line segments in the custom trace.

Example: `trace = tracePoint(Width=0.005)`

Data Types: `double`

**`Corner` — Corner where two line segments interface**
`"Sharp"` (default) | `"Miter"` | `"Smooth"`

Corner where two line segments interface, specified as either `"Sharp"`, `"Miter"`, or `"Smooth"`. To apply the same value to all corners, specify a string scalar. For a different value for all corners, specify a (*n*-2)-by-1 vector of strings.

Example: `trace = tracePoint(Corner="Miter")`

Data Types: `string`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| intersect | Boolean intersection operation on two RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| minus | Shape1 - Shape2 for RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| translate | Move RF PCB shape to new location |
| scale | Change size of RF PCB shape by fixed amount |

## Examples

### Create Default Custom Line

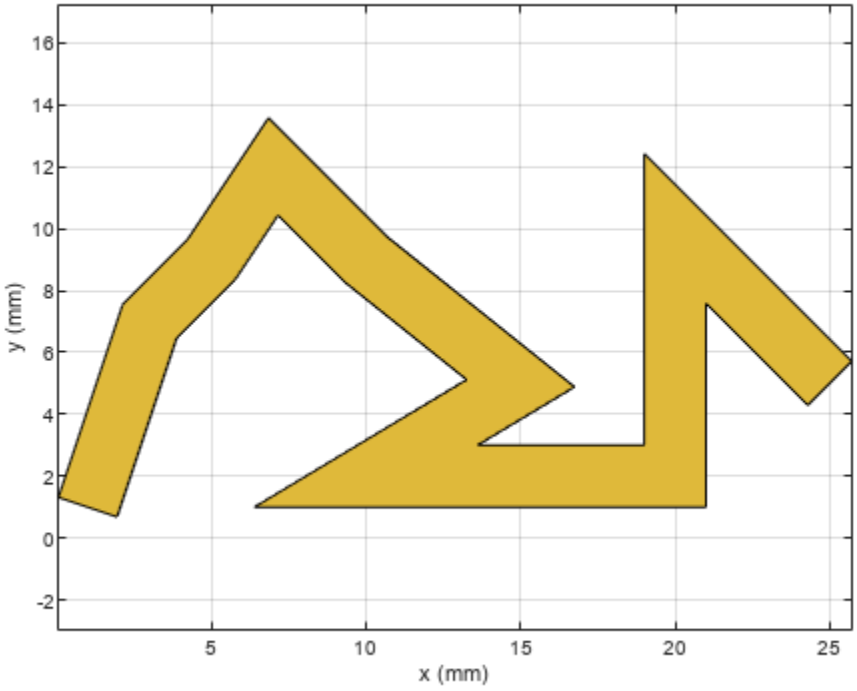
Create a custom line using default properties.

```
customLine = tracePoint
```

```
customLine =
  tracePoint with properties:

           Name: 'mytracePoint'
    TracePoints: [10x2 double]
          Width: 0.0020
         Corner: "Sharp"
```

View the trace.

```
show(customLine)
```




### Rotate and Mesh Custom Line

Create a custom line trace using default properties.

```
customLine = tracePoint;
```

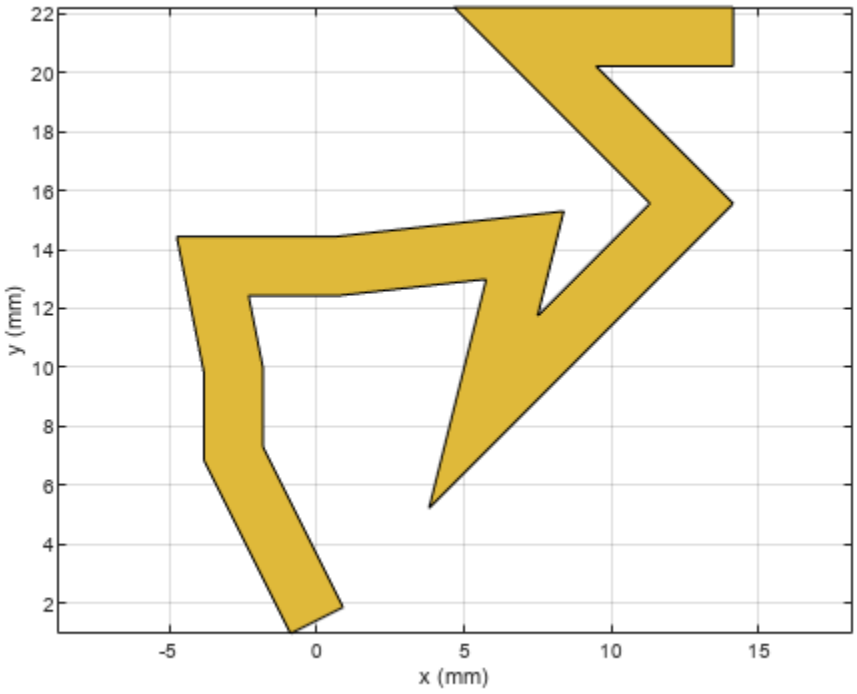
Rotate the trace by 45 degrees along the Z-axis.

```
customLine = rotateZ(customLine,45)
```

```
customLine =
  tracePoint with properties:

           Name: 'mytracePoint'
    TracePoints: [10x2 double]
          Width: 0.0020
         Corner: "Sharp"
```

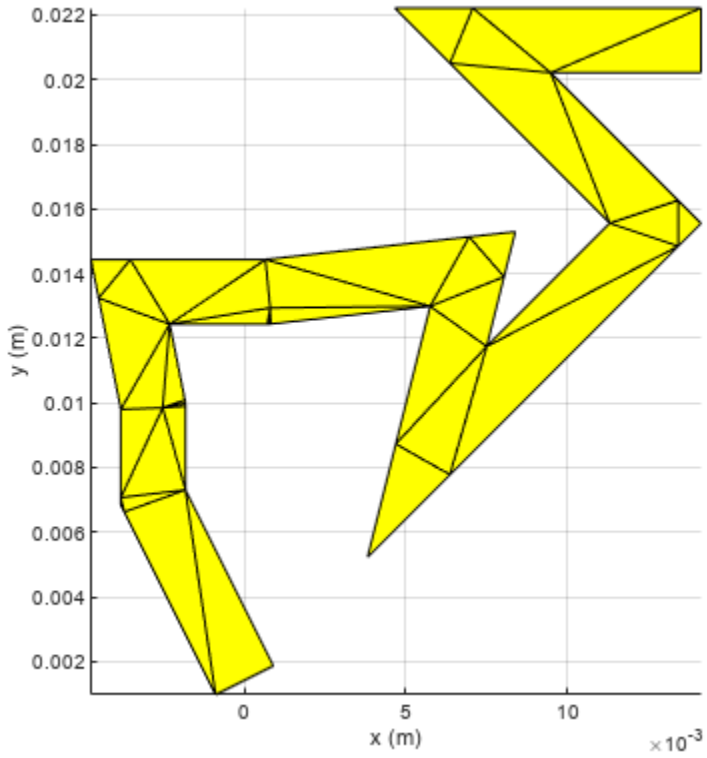
View the trace.

```
show(customLine)
```




Mesh the custom line trace at a maximum edge length of 1 m.

```
mesh(customLine,MaxEdgeLength=1)
```



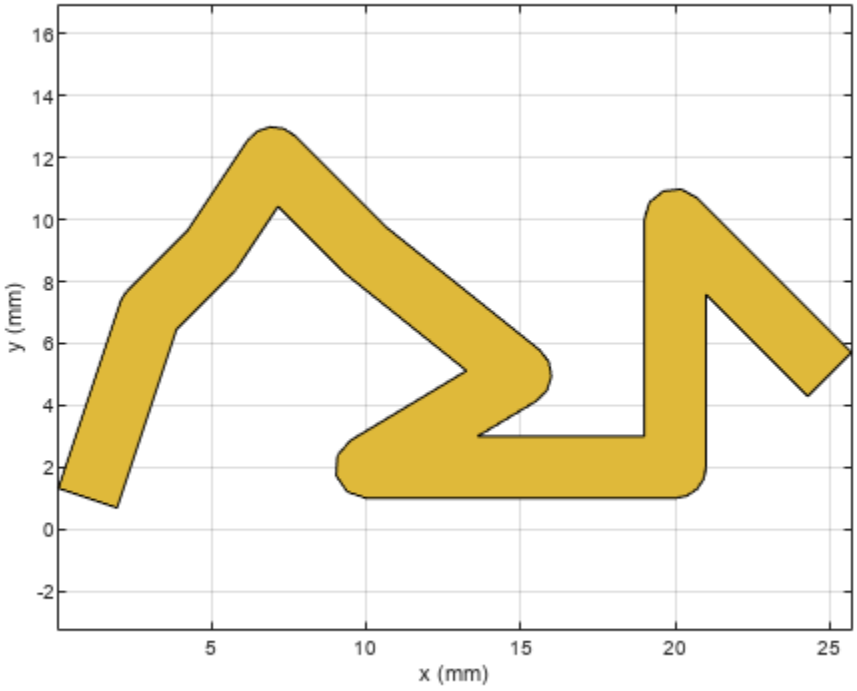

### Create Custom Trace with Smooth Corners

Create a custom trace line with smooth corners.

```
customLine = tracePoint(Name='tracepoint',Corner="Smooth")
```

```
customLine =
  tracePoint with properties:

          Name: 'tracepoint'
    TracePoints: [10x2 double]
         Width: 0.0020
        Corner: "Smooth"
```

```
show(customLine)
```




## Version History

**Introduced in R2021b**

## See Also

`traceLine` | `traceCross` | `traceTee` | `traceRectangular` | `traceSpiral`

# traceLine

Create line trace

# Description

Use the `traceLine` object to create a line trace. You can use this object to create lines of different lengths and different angles

# Creation

## Syntax

```
trace = traceLine
trace = traceLine(Name=Value)
```

### Description

`trace = traceLine` creates a line trace using default properties.

`trace = traceLine(Name=Value)` sets properties using one or more name-value arguments. For example, `traceLine('StartPoint',[1 1])` creates a line trace shape with the starting point of `[1 1]`. Properties not specified retain their default values.

## Properties

### `Name` — Name of line trace

`'traceLine'` (default) | character vector | string scalar

Name of the line trace, specified as a character vector or string scalar.

Example: `customtrace = traceLine(Name=traceline1)`

Data Types: `char` | `string`

### `StartPoint` — Start point of line trace

`[0 0]` (default) | two-element vector

Start point of the line trace in Cartesian coordinates, specified as a two-element vector.

Example: `customtrace = traceLine(StartPoint=[1 1])`

Data Types: `double`

### `Length` — Length of line trace

`[0.0200 0.0200 0.0200 0.0150]` (default) | *n*-by-1 vector

Length of line trace, specified as an *n*-by-1 vector in meters. Each element represents the length of a line segment.

Example: `customtrace = traceLine(Length=[0.0100 0.0100 0.0100 0.0500])`

Data Types: `double`

**`Width` — Width of line trace**
`0.0050` (default) | *n*-by-1 vector

Width of the line trace, specified as a scalar or an *n*-by-1 vector in meters. Each element represents the length of a line segment

Example: `customtrace = traceLine(Width=[0.0040 0.0040 0.0040 0.0050])`

Data Types: `double`

**`Angle` — Angle of line trace**
`[90 0 -90 45]` (default) | *n*-by-1 vector

Angle of the line trace, specified as an *n*-by-1 vector in degrees. Each element represents an angle of a line segment.

Example: `customtrace = traceLine(Angle=[40 10 -40 35)`

Data Types: `double`

**`Corner` — Corner where two line segments interface**
`"Sharp"` (default) | `"Miter"` | `"Smooth"`

Corner where two line segments interface, specified as either `"Sharp"`, `"Miter"`, or `"Smooth"`. To apply the same value to all corners, specify a string scalar. For a different value for all corners, specify a (*n*-2)-by-1 vector of strings.

Example: `trace = traceLine(Corner="Miter")`

Data Types: `string`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Custom Line Trace

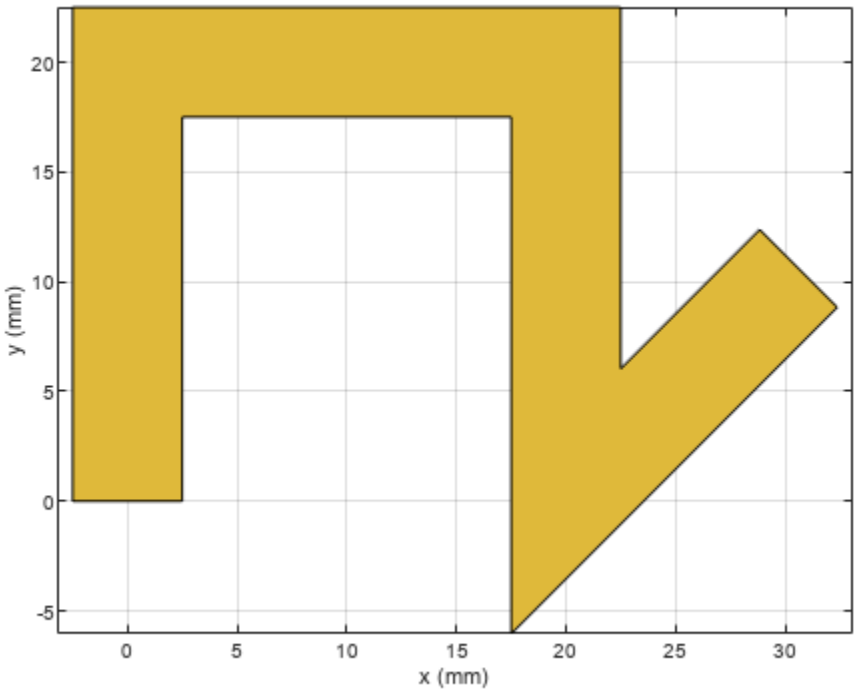
Create a custom line trace with default properties.

```
customLine = traceLine
```

```
customLine =
  traceLine with properties:

          Name: 'mytraceLine'
    StartPoint: [0 0]
        Length: [0.0200 0.0200 0.0200 0.0150]
         Width: 0.0050
         Angle: [90 0 -90 45]
        Corner: "Sharp"
```

View the trace.

```
show(customLine)
```




### Rotate and Mesh Line Trace

Create a line trace.

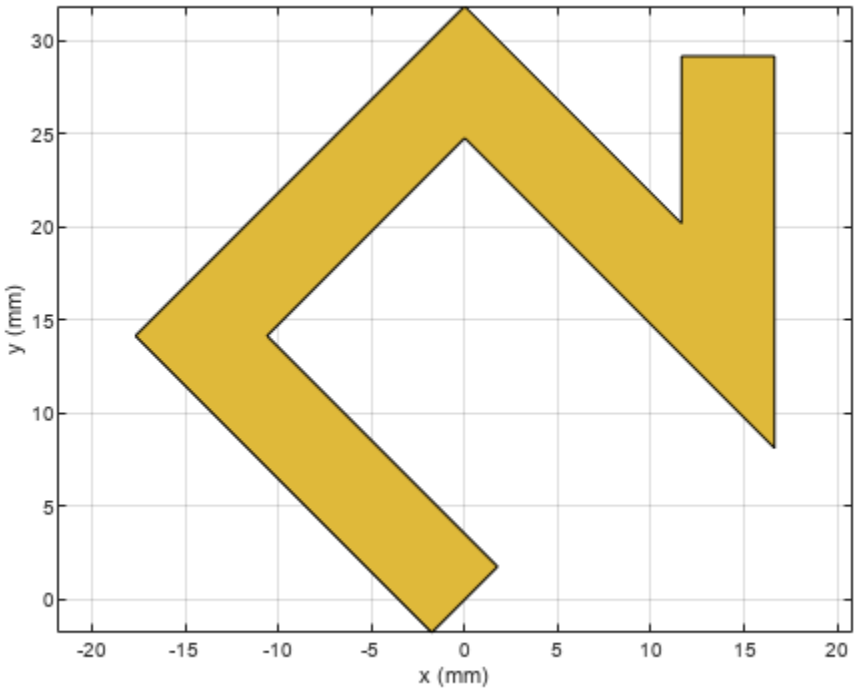
```
customLine = traceLine;
```

Rotate the trace by 45 degrees along the Z-axis.

```
customLine = rotateZ(customLine,45)
```

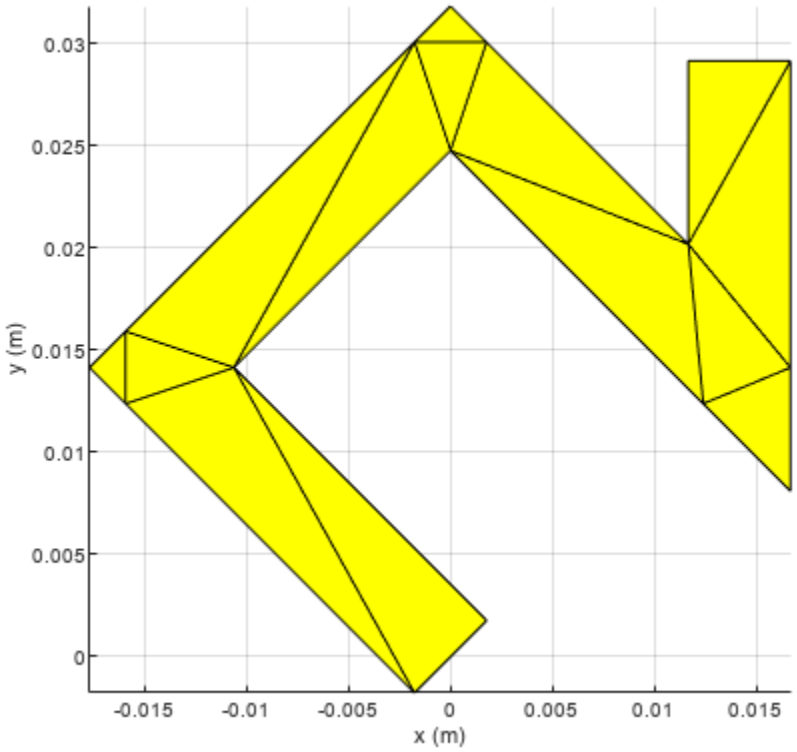
```
customLine =
  traceLine with properties:

          Name: 'mytraceLine'
    StartPoint: [0 0]
        Length: [0.0200 0.0200 0.0200 0.0150]
         Width: 0.0050
         Angle: [90 0 -90 45]
        Corner: "Sharp"
```

```
show(customLine)
```




Mesh the line trace at a maximum edge length of 1 m.

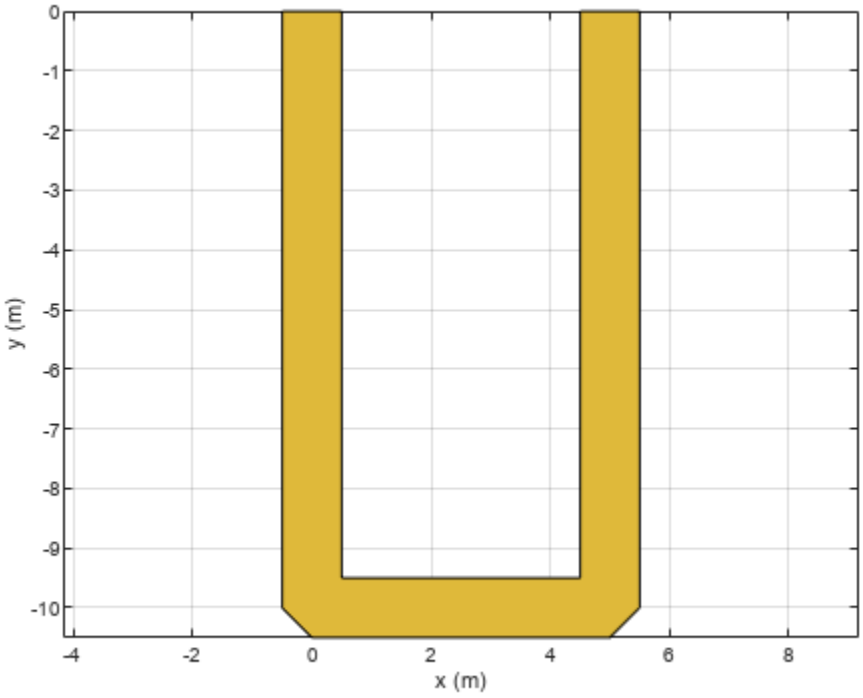
```
mesh(customLine,MaxEdgeLength=1)
```




### U-Shaped Line Trace

Create and view a U-shaped line trace with mitered bends and a width of 1 m.

```
Ushapeline = traceLine;
Ushapeline.Length = [10 5 10];
Ushapeline.Angle  = [-90 0 90];
Ushapeline.Width  = 1;
Ushapeline.Corner = 2;
show(Ushapeline);
```




## Version History

**Introduced in R2021b**

## See Also

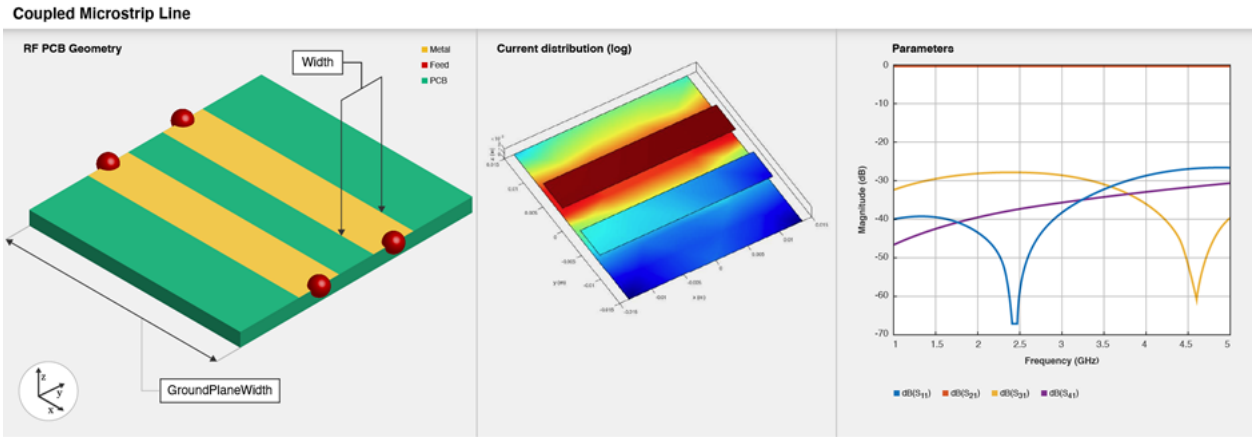
`traceCross` | `traceTee` | `traceRectangular` | `traceSpiral` | `tracePoint`

# coupledMicrostripLine

Create coupled microstrip transmission line

## Description

Use the `coupledMicrostripLine` object to create a coupled microstrip transmission line. Coupled microstrip transmission lines are used to design directional couplers and filters. The combination of even and odd mode impedances determines the coupling ratio between the direct arm and the coupled arm.




## Creation

### Syntax

```
coupledmicrostrip = coupledMicrostripLine
coupledmicrostrip = coupledMicrostripLine(Name=Value)
```

#### Description

`coupledmicrostrip = coupledMicrostripLine` creates a default coupled microstrip transmission line with a Teflon substrate and default properties for a resonating frequency of 1.5 GHz.

`coupledmicrostrip = coupledMicrostripLine(Name=Value)` sets “Properties” on page 1-108 using one or more name-value arguments. For example, `coupledMicrostripLine(Length=0.0300)` creates a coupled microstrip transmission line of length 0.0300 meters.

### Properties

**Length — Length of coupled microstrip line**
`0.0271` (default) | positive scalar

Length of the coupled microstrip line in meters, specified as a positive scalar.

Example: `coupledmicrostrip = coupledMicrostripLine(Length=0.0300)`

Data Types: `double`

**`Width` — Width of coupled microstrip line**
`0.0051` (default) | positive scalar

Width of the coupled microstrip line in meters, specified as a positive scalar.

Example: `coupledmicrostrip = coupledMicrostripLine(Width=0.0041)`

Data Types: `double`

**`Spacing` — Distance between the direct arm and the coupled arm**
`0.0046` (default) | positive scalar

Distance between the direct arm and the coupled arm of the coupled microstrip transmission line, specified as a positive scalar in meters.

Example: `coupledmicrostrip = coupledMicrostripLine(Spacing=0.00300)`

Data Types: `double`

**`Height` — Height of coupled microstrip line**
`0.0016` (default) | positive scalar

Height of the coupled microstrip line from the ground plane, specified as a positive scalar in meters. In the case of a multilayer substrate, use the `Height` property to create a coupled microstrip line at the interface of the two dielectrics.

Example: `coupledmicrostrip = coupledMicrostripLine(Height=0.0023)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0300` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `coupledmicrostrip = coupledMicrostripLine(GroundPlaneWidth=0.0400)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of the dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `coupledMicrostripLine` object with default properties is Teflon. The thickness of the default dielectric material Teflon is `0.0016` m or the same as the `Height` property.

Example: `d = dielectric("FR4"); coupledmicrostrip = coupledMicrostripLine(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `coupledMicrostripLine` object with default properties is PEC.

Example: `m = metal("PEC"); coupledmicrostrip =coupledMicrostripLine(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design coupled microstrip transmission line around particular frequency |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Coupled Microstrip Line

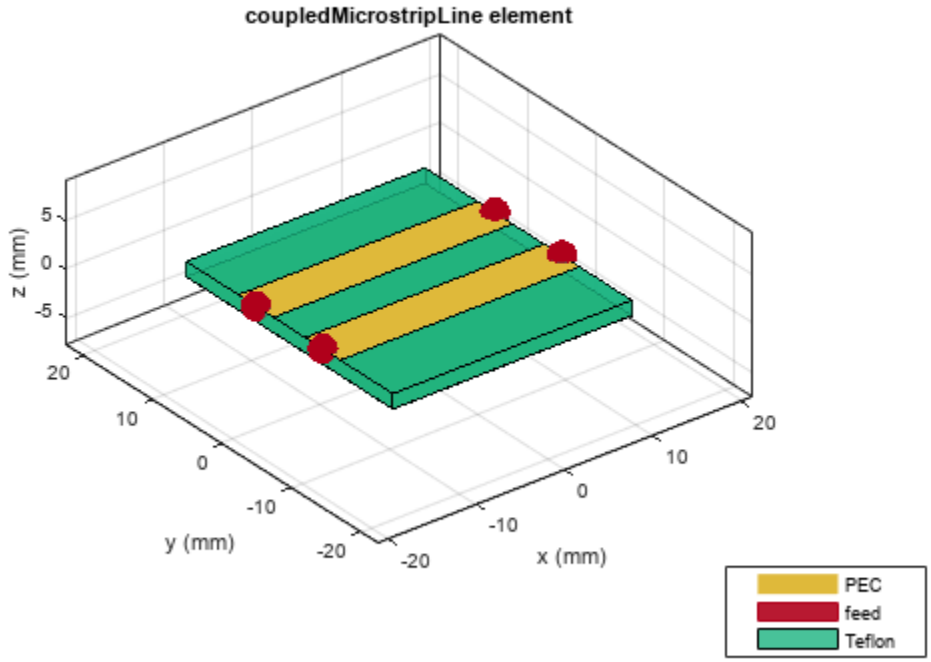
Create a default coupled microstrip line.

```
cml = coupledMicrostripLine
```

```
cml =
  coupledMicrostripLine with properties:

              Length: 0.0271
               Width: 0.0051
             Spacing: 0.0046
              Height: 0.0016
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the coupled microstrip line.

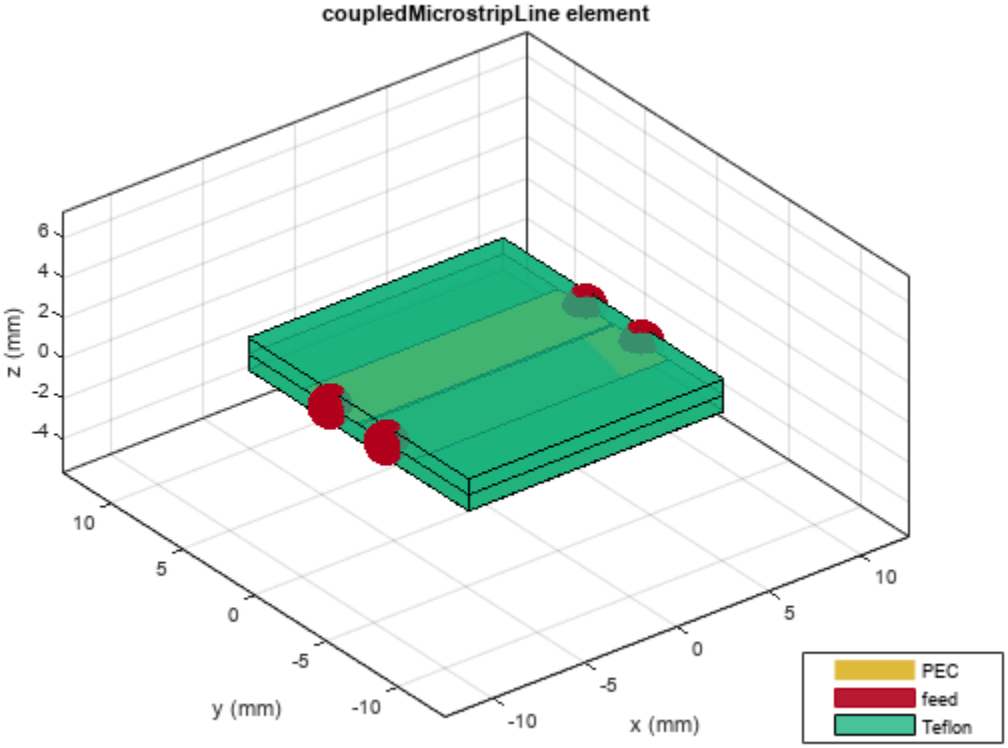
```
show(cml)
```




### Multilayer Coupled Microstrip Line

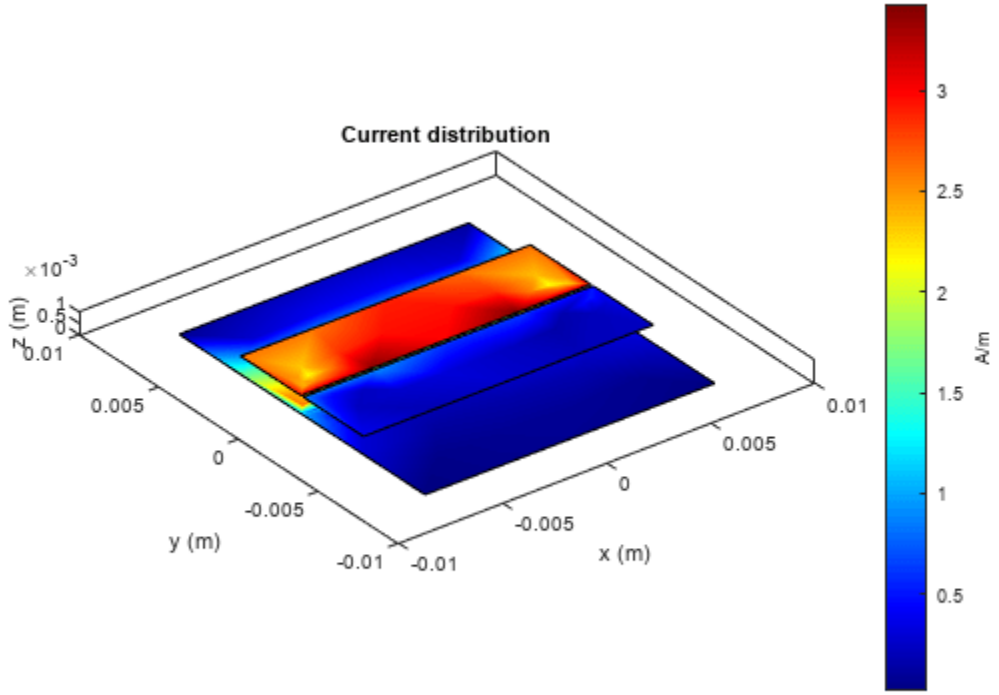
Design and view a coupled microstrip line at the interface of a multilayer dielectric.

```
cml = design(coupledMicrostripLine,4e9,Z0e=75,Z0o=36);
cml.Substrate = dielectric(Name=["Teflon","Teflon"],EpsilonR=[2.1 2.1], ...
    LossTangent=[0 0],Thickness=[0.8e-3 0.8e-3]);
cml.Height = 0.8e-3;
show(cml)
```

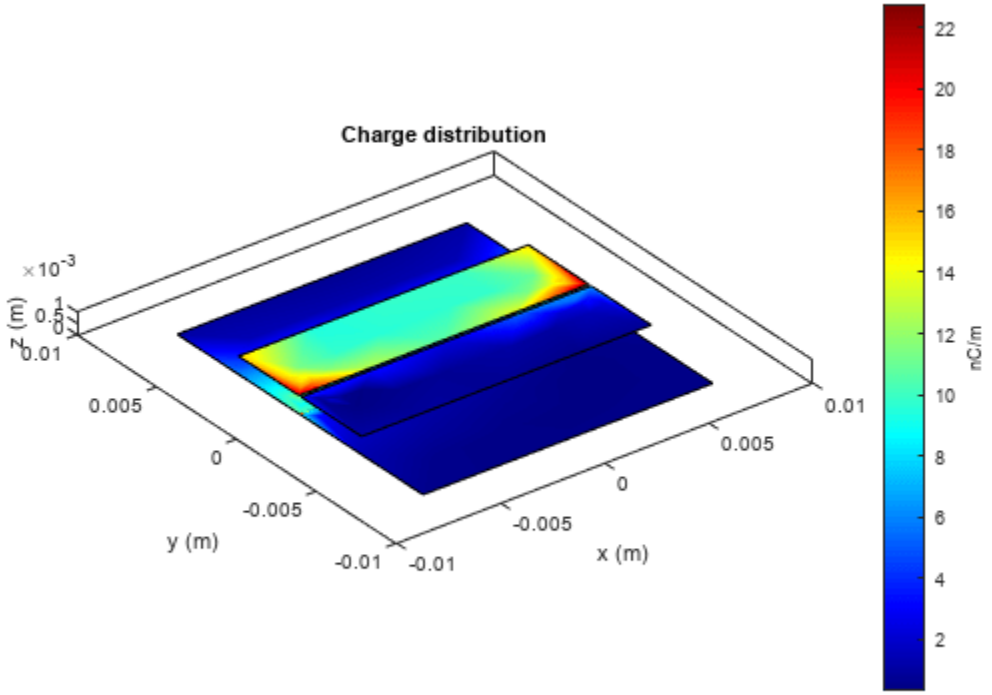



Plot the current and charge distribution on the transmission line.

```
current(cml,4e9)
```




```
figure
charge(cml,4e9)
```




## More About

### Parametric Analysis

Use the `design` function to change the even impedance ($Z_{oe}$) and the odd impedance ($Z_{oo}$) of the coupled microstrip line.

- Increasing the difference between the even impedance ($Z_{oe}$) and the odd impedance ($Z_{oo}$) decreases the distance between the lines.
- Increasing the difference between $Z_{oe}$ and $Z_{oo}$ increases the power at the coupled ports.
- The impedance of the coupled lines $Z_o$ is the geometric mean of $Z_{oe}$ and $Z_{oo}$. If the even and odd impedance values do not satisfy this condition, then calculate the S-parameters using $Z_o$ to get a proper match.

# Version History

**Introduced in R2021b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

[2] “Microwaves101 | Coupled Line Couplers.” Accessed July 7, 2021. https://www.microwaves101.com/encyclopedias/coupled-line-couplers.

## See Also

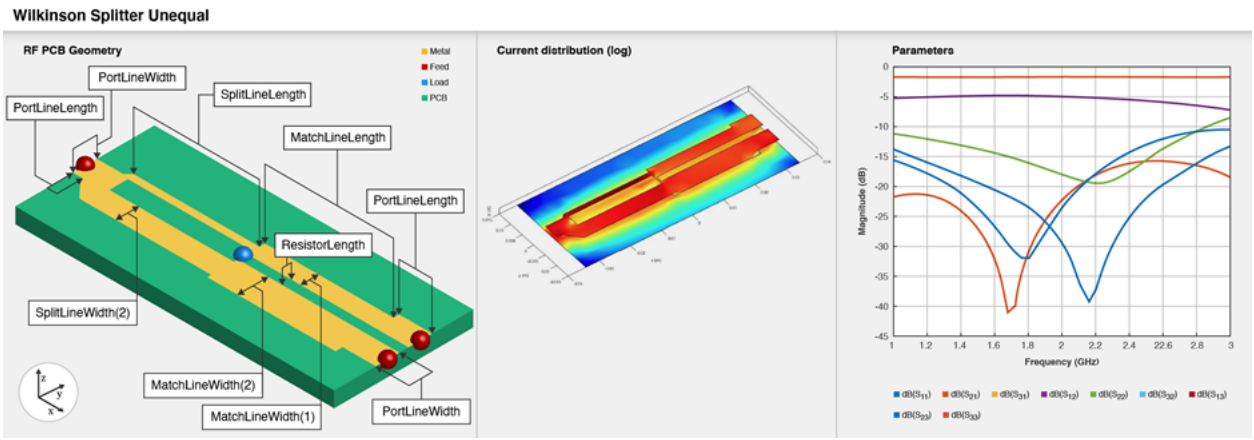
`coplanarWaveguide` | `microstripLine`

# wilkinsonSplitterUnequal

Create unequal Wilkinson splitter

## Description

Use the `wilkinsonSplitterUnequal` object to create an unequal Wilkinson power splitter. You can use the unequal Wilkinson splitter to divide power unequally between two output ports. Unequal splitters are also used to feed power to antenna arrays for beam shaping.




To analyze the behavioral model for the unequal Wilkinson power splitter, set the `Behavioral` property in the `sparameters` to `true` or 1.

## Creation

### Syntax

```
splitter = wilkinsonSplitterUnequal
splitter = wilkinsonSplitterUnequal(Name=Value)
```

#### Description

`splitter = wilkinsonSplitterUnequal` creates an unequal Wilkinson splitter with default properties for a resonating frequency of 1 GHz.

`splitter = wilkinsonSplitterUnequal(Name=Value)` sets “Properties” on page 1-117 using one or more name-value arguments. For example, `wilkinsonSplitterUnequal(PortLineLength=0.0300)` creates a Wilkinson splitter with an input and output line length of 0.0300 meters. Properties not specified retain their default values.

## Properties

**`PortLineLength` — Length of input and output line**
`0.0070` (default) | positive scalar

Length of the input and the output line in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitterUnequal(PortLineLength=0.0070)`

Data Types: `double`

**`PortLineWidth` — Width of input and output line**
`0.0051` (default) | positive scalar

Width of the input and the output line in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitterUnequal(PortLineWidth=0.0070)`

Data Types: `double`

**`SplitLineLength` — Length of 70-ohm line**
`0.0279` (default) | positive scalar

Length of the 70-ohm line in meters, specified as a positive scalar. The typical length of a Wilkinson splitter is λ/4.

Example: `splitter = wilkinsonSplitterUnequal(SplitLineLength=0.0570)`

Data Types: `double`

**`SplitLineWidth` — Width of 70-ohm line**
`[0.0014 0.0049]` (default) | two-element vector

Width of the 70-ohm line in meters, specified as a two-element vector of positive elements.

Example: `splitter = wilkinsonSplitterUnequal(SplitLineWidth=[0.00780 0.00890])`

Data Types: `double`

**`MatchLineLength` — Length of output matching line**
`0.0277` (default) | positive scalar

Length of the output matching line in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitterUnequal(MatchLineLength=0.0780)`

Data Types: `double`

**`MatchLineWidth` — Width of output matching line**
`[0.0039 0.0066]` (default) | two-element vector

Width of the output matching line in meters, specified as a two-element vector of positive elements.

Example: `splitter = wilkinsonSplitterUnequal(MatchLineWidth=[0.0049 0.0076])`

Data Types: `double`

**`ResistorLength` — Length of resistor in meters**
`0.0020` (default) | positive scalar

Length of the resistor in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitterUnequal(ResistorSLength=0.0050)`

Data Types: `double`

**`Resistance` — Resistance value**
`106` (default) | positive scalar

Resistance value in ohms, specified as a positive scalar.

Example: `splitter = wilkinsonSplitterUnequal(Resistance=50)`

Data Types: `double`

**`Height` — Height of Wilkinson splitter from ground plane**
`0.0016` (default) | positive scalar

Height of the Wilkinson splitter from the ground plane in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitterUnequal(Height=0.0076)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane in meters**
`0.0300` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitterUnequal(GroundPlaneWidth=0.046)`

Example: double

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `wilkinsonSplitterUnequal` object with default properties is Teflon. The thickness of the default dielectric material Teflon is `0.0016` m or the same value as the `Height` property.

Example: `d = dielectric("FR4"); splitter = wilkinsonSplitterUnequal(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `wilkinsonSplitterUnequal` object with default properties is Copper.

Example: `m = metal("PEC"); splitter = wilkinsonSplitterUnequal(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design unequal Wilkinson splitter around specified frequency |
| feedCurrent | Calculate current at feed port |

| | |
|---|---|
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

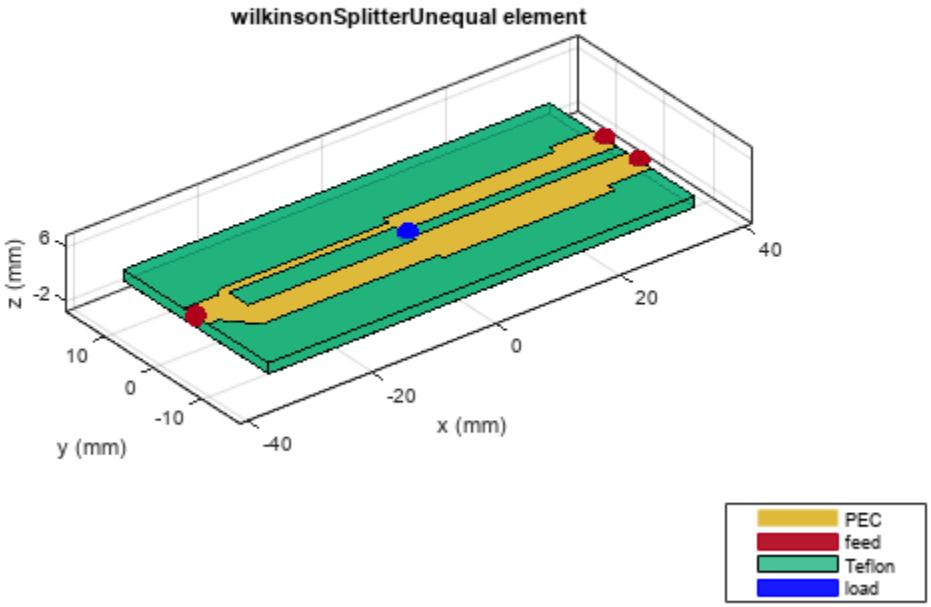
### Create Default Unequal Wilkinson Splitter

Create and view a default unequal Wilkinson splitter.

```
splitter = wilkinsonSplitterUnequal
```

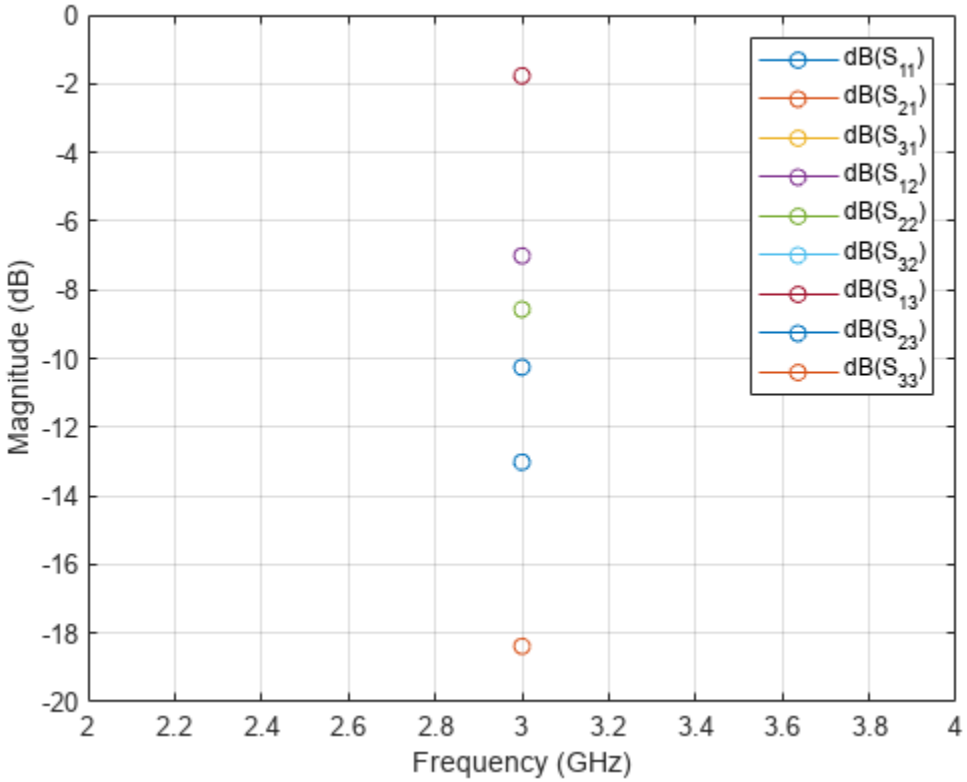
```
splitter =
  wilkinsonSplitterUnequal with properties:

      PortLineLength: 0.0070
       PortLineWidth: 0.0051
     SplitLineLength: 0.0279
      SplitLineWidth: [0.0014 0.0049]
     MatchLineLength: 0.0277
      MatchLineWidth: [0.0039 0.0066]
      ResistorLength: 0.0020
          Resistance: 106
              Height: 0.0016
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

```
show(splitter)
```




Calculate and plot the S-parameters of the splitter at 3 GHz.

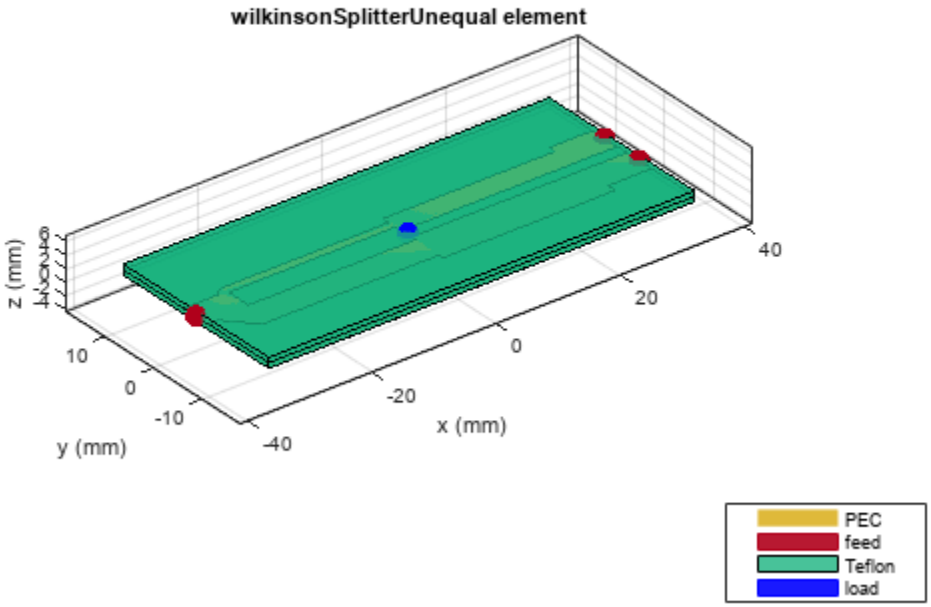
```
spar=sparameters(splitter,3e9);
figure
rfplot(spar);
```




### Create Multilayer Unequal Wilkinson Splitter

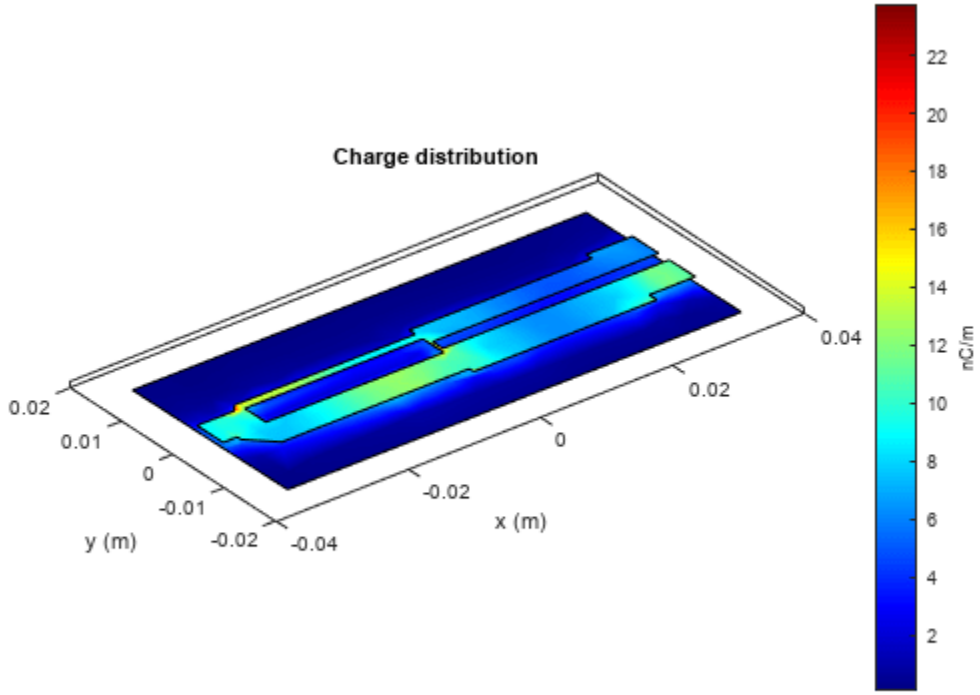
Create and view a multilayer unequal Wilkinson splitter.

```
sub =  dielectric(Name=["Teflon","Teflon"],EpsilonR=[2.1 2.1], ...
    LossTangent=[0 0],Thickness=[0.8e-3 0.8e-3]);
unsplitter = wilkinsonSplitterUnequal(Height=0.8e-3,Substrate=sub);
show(unsplitter)
```

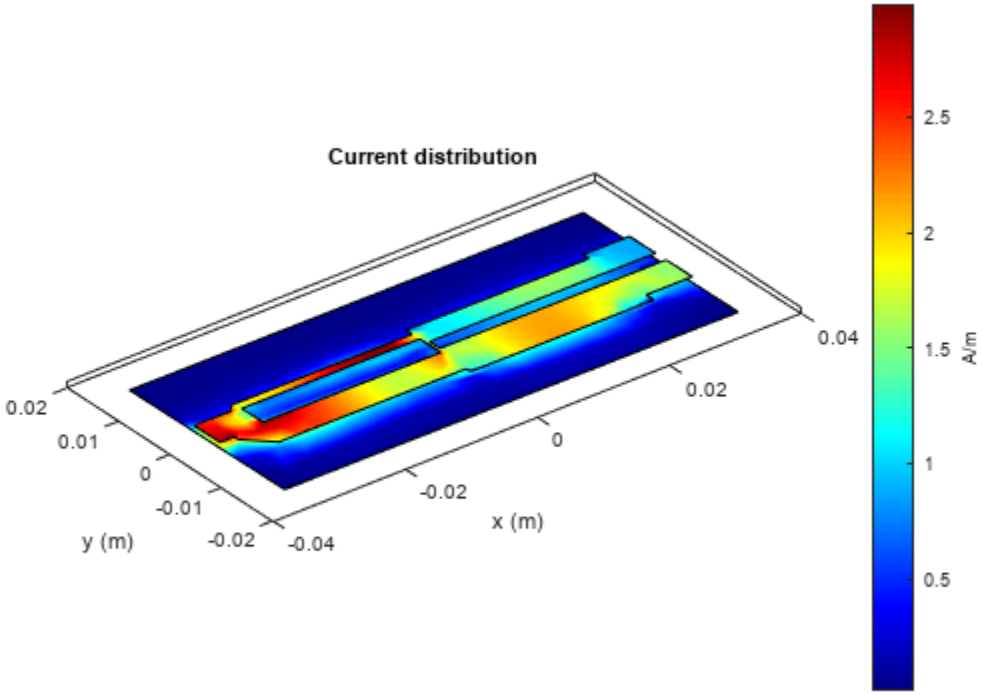



Plot the charge and current on this splitter at 3 GHz.

```
figure
charge(unsplitter,3e9)
```




```
figure
current(unsplitter,3e9)
```




# Version History

**Introduced in R2021b**

### R2022b: Behavioral Analysis for Unequal Wilkinson Power Splitter

Use the `sparameters` function and the `pcbElement` object to perform the behavioral analysis of a unequal Wilkinson power splitter.

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`wilkinsonSplitter`

**Topics**

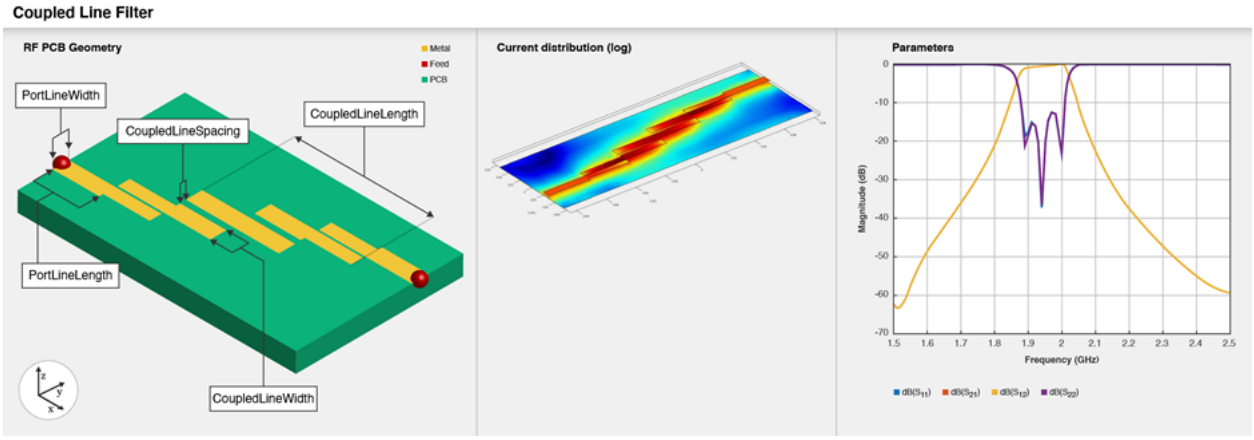
“Behavioral Models”

# filterCoupledLine

Create coupled line filter in microstrip form

## Description

Use the `filterCoupledLine` object to create a coupled line filter in microstrip form. The filter structure consists of open-circuited coupled microstrip lines. You can control the bandwidth of the filter by varying the filter order, width, and distance between the coupled lines.




## Creation

### Syntax

```
filter = filterCoupledLine
filter = filterCoupledLine(Name=Value)
```

#### Description

`filter = filterCoupledLine` creates a default coupled line filter with default passband of the filter centered around 2 GHz.

`filter = filterCoupledLine(Name=Value)` sets “Properties” on page 1-125 using one or more name-value arguments. For example, `filterCoupledLine(FilterOrder=5)` creates a fifth-order coupled line filter. Properties not specified retain their default values.

### Properties

#### `FilterOrder` — Filter order

3 (default) | positive scalar

Filter order, specified as a positive scalar.

Example: `filter = filterCoupledLine(FilterOrder=5)`

Data Types: `double`

**`PortLineLength` — Length of input and output lines**
`0.0279` (default) | positive scalar

Length of the input and output lines in meters, specified as a positive scalar.

Example: `filter = filterCoupledLine(PortLineLength=0.0553)`

Data Types: `double`

**`PortLineWidth` — Width of input and output lines**
`0.0051` (default) | positive scalar

Width of the input and output lines in meters, specified as a positive scalar.

Example: `filter = filterCoupledLine(PortLineWidth=0.0087)`

Data Types: `double`

**`CoupledLineLength` — Lengths of coupled lines**
`[0.0279 0.0279 0.0279 0.0279]` (default) | vector

Lengths of the coupled lines in meters, specified as a vector of positive elements.

Example: `filter = filterCoupledLine(CoupledLineLength=[0.0553 0.0553 0.0553 0.0553])`

Data Types: `double`

**`CoupledLineWidth` — Widths of coupled lines**
`[0.0036 0.0049 0.0049 0.0036]` (default) | vector

Widths of the coupled lines in meters, specified as a vector of positive elements.

Example: `filter = filterCoupledLine(CoupledLineWidth=[0.0046 0.0059 0.0059 0.0046])`

Data Types: `double`

**`CoupledLineSpacing` — Distance between coupled lines**
`[1.8270e-04 0.0019 0.0019 1.8270e-04]` (default) | vector

Distance between the coupled lines in meters, specified as a vector of positive elements.

Example: `filter = filterCoupledLine(CoupledLineSpacing=[2.8270e-04 0.0020 0.0020 2.8270e-04])`

Data Types: `double`

**`Height` — Height of coupled line filter from ground plane**
`0.0016` (default) | positive scalar

Height of the coupled line filter from the ground plane in meters, specified as a positive scalar. For multilayer dielectrics, use the `Height` property to create the filter between the two dielectric layers.

Example: `filter = filterCoupledLine(Height=0.0028)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0551` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `filter = filterCoupledLine(GroundPlaneWidth=0.0048)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `filterCoupledLine` object with default properties is Teflon. The thickness of the default dielectric material Teflon is `0.0016` m.

Example: `d = dielectric("FR4"); filter = filterCoupledLine(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `filterCoupledLine` object with default properties is PEC.

Example: `m = metal("Copper"); filter = filterCoupledLine(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design coupled line filter around specified frequency |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Create Default Coupled Line Filter

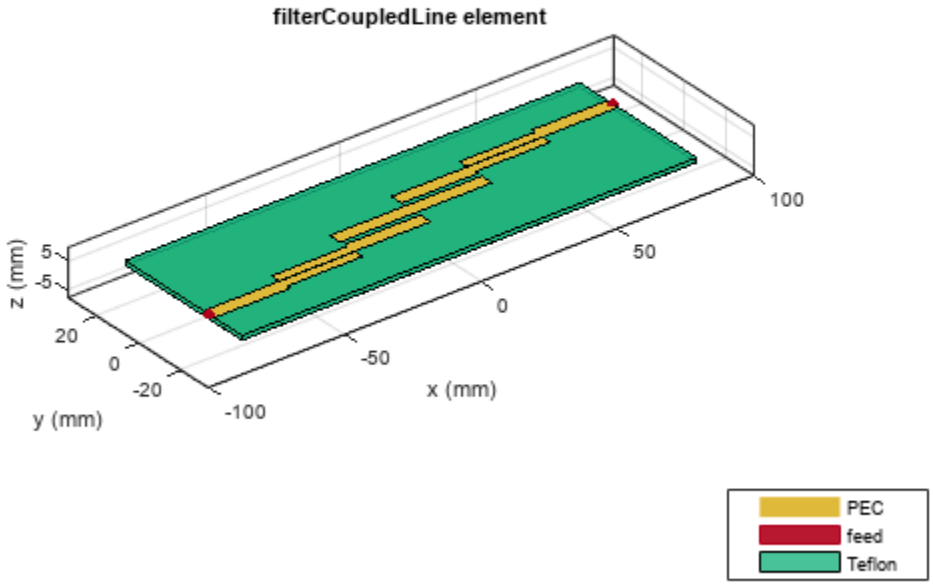
Create and view a default coupled line filter.

```
coupledfilter = filterCoupledLine
```

```
coupledfilter =
  filterCoupledLine with properties:

           FilterOrder: 3
        PortLineLength: 0.0279
```

```
        PortLineWidth: 0.0051
    CoupledLineLength: [0.0279 0.0279 0.0279 0.0279]
     CoupledLineWidth: [0.0036 0.0049 0.0049 0.0036]
   CoupledLineSpacing: [1.8270e-04 0.0019 0.0019 1.8270e-04]
               Height: 0.0016
     GroundPlaneWidth: 0.0551
            Substrate: [1x1 dielectric]
            Conductor: [1x1 metal]
```

```
show(coupledfilter)
```




### Coupled Line Filter at Specified Frequency

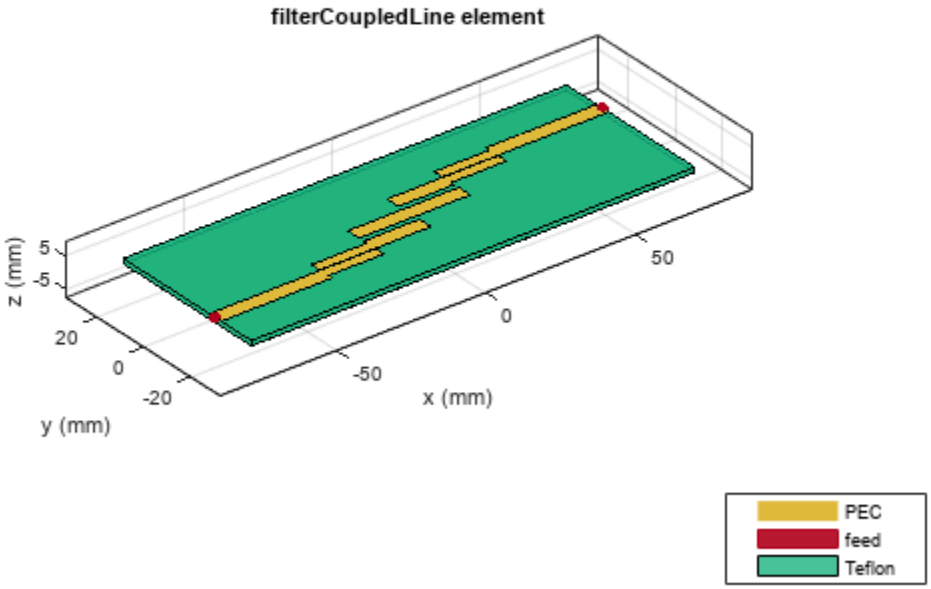
Create and view a coupled line filter at 3 GHz.

```
coupledfilter = design(filterCoupledLine,3e9)
```

```
coupledfilter =
  filterCoupledLine with properties:

           FilterOrder: 3
        PortLineLength: 0.0372
         PortLineWidth: 0.0051
     CoupledLineLength: [0.0186 0.0186 0.0186 0.0186]
```

```
      CoupledLineWidth: [0.0036 0.0049 0.0049 0.0036]
    CoupledLineSpacing: [1.8270e-04 0.0019 0.0019 1.8270e-04]
                Height: 0.0016
      GroundPlaneWidth: 0.0551
             Substrate: [1x1 dielectric]
             Conductor: [1x1 metal]
```

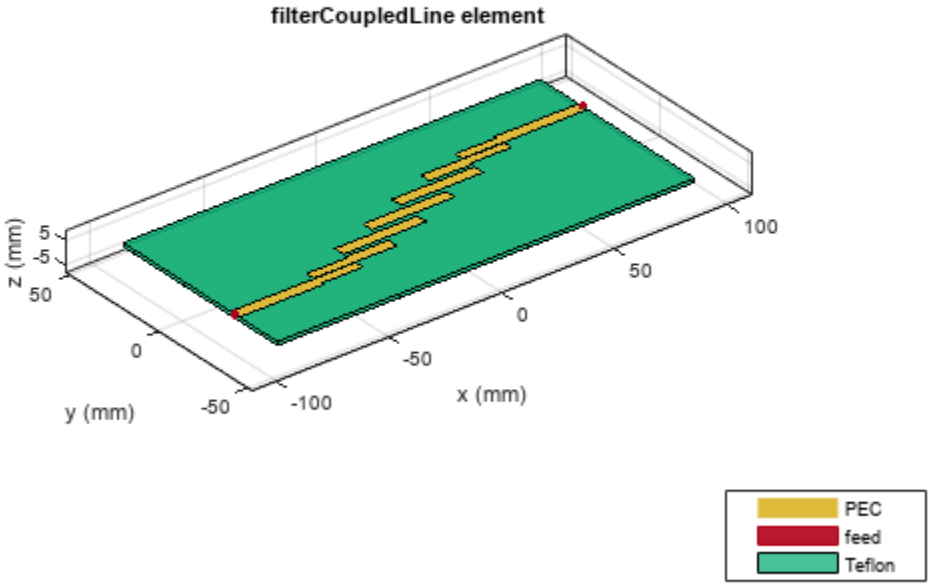
```
show(coupledfilter)
```




### Fifth-Order Coupled Line Chebyshev Filter

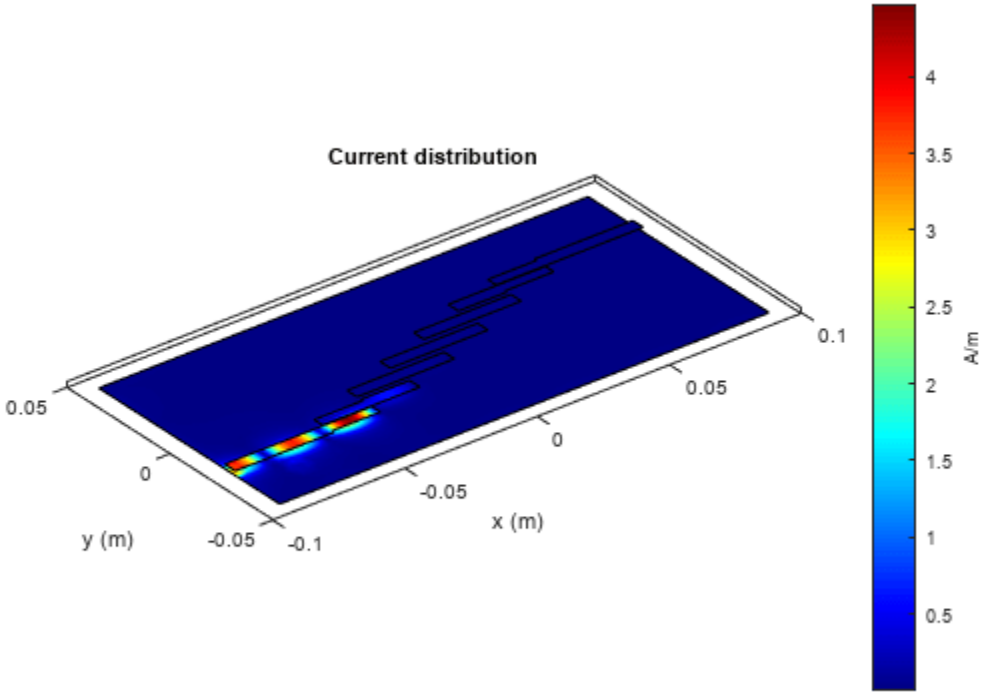
Design and view a fifth-order coupled-line Chebyshev filter at 3 GHz with a ripple factor of 0.5 dB.

```
coupledfilter = filterCoupledLine(FilterOrder=5);
coupledfilter = design(coupledfilter,3e9,FilterType="Chebyshev",RippleFactor=0.5);
show(coupledfilter)
```

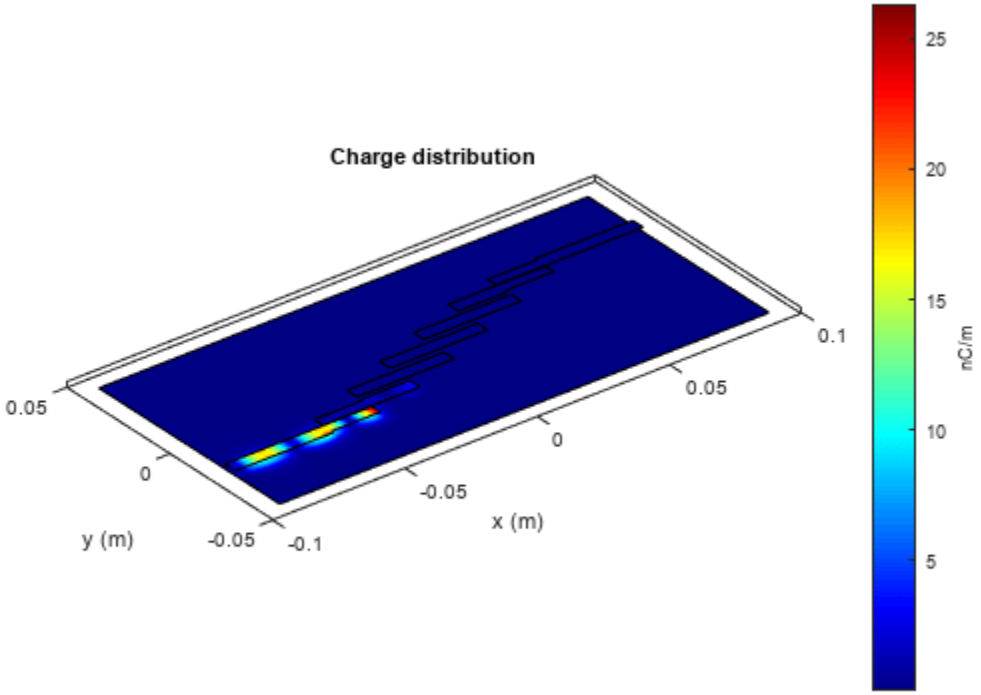



Plot the current and charge distribution of this filter at 5 GHz.

```
figure
current(coupledfilter,5e9)
```




```
figure
charge(coupledfilter,5e9)
```




## Version History

**Introduced in R2021b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

[2] Ragani, Taoufik, N. Amar Touhami, and M. Agoutane. “Designing a Microstrip Coupled Line Bandpass Filter.” *International Journal of Engineering & Technology* 2, no. 4 (September 6, 2013): 266. https://doi.org/10.14419/ijet.v2i4.1173.

## See Also

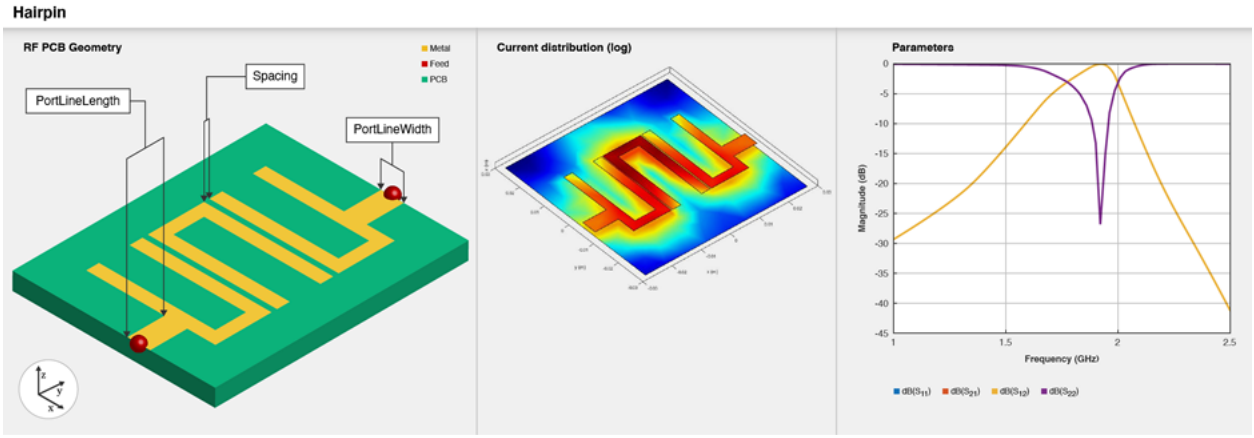
`filterHairpin` | `filterStepImpedanceLowPass`

# filterHairpin

Create hairpin filter in microstrip form

## Description

Use the `filterHairpin` object to create a hairpin filter in microstrip form.




Hairpin filters are easy to fabricate. Design these filters at different frequencies by changing the roll-offs and the ripple factors. You can control the bandwidth of the filter by varying the filter order, width, and the distance between the coupled lines. There are two types of hairpin filters based on the feed: tapped-line input hairpin filters and coupled-line input hairpin filters.

## Creation

### Syntax

```
filter = filterHairpin
filter = filterHairpin(Name=Value)
```

#### Description

`filter = filterHairpin` creates a default hairpin filter with default passband of the filter at 2 GHz.

`filter = filterHairpin(Name=Value)` sets “Properties” on page 1-134 using one or more name-value arguments. For example, `filterHairpin(Resonator=ubendMitered)` creates a hairpin filter with a mitered u-bend element as the resonator. Properties not specified retain their default values

## Properties

**`Resonator` — Shape of hairpin element**
`uBendRightAngle` (default) | `ubendMitered` | `ubendCurved`

Shape of the hairpin element, specified as either `uBendRightAngle`, `ubendMitered`, or `ubendCurved`.

Example: `filter = filterHairpin(Resonator=ubendCurved)`

Data Types: `char` | `string`

**`FilterOrder` — Filter order**
`3` (default) | positive scalar

Filter order, specified as a positive scalar.

Example: `filter = filterHairpin(FilterOrder=5)`

Data Types: `double`

**`ResonatorOffset` — Y-offset of each resonator**
`[0 0 0]` (default) | vector

Y-offset of each resonator in meters, specified as a vector.

Example: `filter = filterHairpin(ResonatorOffset=[0.02 0.02 0.02])`

Data Types: `double`

**`Spacing` — Distance between hairpin bends**
`[4.0000e-04 4.0000e-04]` (default) | vector

Distance between the hairpin bends in meters, specified as a vector of positive elements.

Example: `filter = filterHairpin(Spacing=[0.02 0.02 0.02])`

Data Types: `double`

**`PortLineLength` — Length of input and output lines**
`0.0080` (default) | positive scalar

Length of the input and output lines in meters, specified as a positive scalar.

Example: `filter = filterHairpin(PortLineLength=0.0553)`

Data Types: `double`

**`PortLineWidth` — Width of input and output lines**
`0.0050` (default) | positive scalar

Width of the input and output lines in meters, specified as a positive scalar.

Example: `filter = filterHairpin(PortLineWidth=0.0087)`

Data Types: `double`

**`FeedOffset` — Y-offset for input and output lines**
`[-0.0055 -0.0055]` (default) | vector

Y-offset for the input and the output lines, specified as a vector.

Example: `filter = filterHairpin(FeedOffset=[-0.002 -0.002])`

Data Types: `double`

**`FeedType` — Type of feed at input and output ports**
`"Tapped"` (default) | `"Coupled"`

Type of feed at the input and output ports, specified as either `"Tapped"` or `"Coupled"`.

Example: `filter = filterHairpin(FeedType="Coupled")`

Data Types: `char` | `string`

**`CoupledLineLength` — Length of coupled feed lines**
`[0.0279 0.0279 0.0279 0.0279]` (default) | vector

Length of the coupled feed lines in meters, specified as a vector of positive elements.

Example: `filter = filterHairpin(CoupledLineLength=[0.0553 0.0553 0.0553 0.0553])`

**Dependencies**

To enable `CoupledLineLength`, set the `FeedType` property to `"Coupled"`.

Data Types: `double`

**`CoupledLineWidth` — Width of coupled feed lines**
`[0.0036 0.0049 0.0049 0.0036]` (default) | vector

Width of the coupled feed lines in meters, specified as a vector of positive elements.

Example: `filter = filterHairpin(CoupledLineWidth=[0.0046 0.0059 0.0059 0.0046])`

**Dependencies**

To enable `CoupledLineLength`, set the `FeedType` property to `"Coupled"`.

Data Types: `double`

**`CoupledLineSpacing` — Distance between feed line and hairpin**
`[1.8270e-04 0.0019 0.0019 1.8270e-04]` (default) | vector

Distance between the feed line and the hairpin in meters, specified as a vector.

Example: `filter = filterHairpin(CoupledLineSpacing=[2.8270e-04 0.0020 0.0020 2.8270e-04])`

**Dependencies**

To enable `CoupledLineLength`, set the `FeedType` property to `"Coupled"`.

Data Types: `double`

**`Height` — Height of hairpin filter from ground plane**
`0.0016` (default) | positive scalar

Height of the hairpin filter from the ground plane in meters, specified as a positive scalar. In the case of a multilayer substrate, you can use the `Height` property to create a hairpin filter where the two dielectrics interface.

Example: `filter = filterHairpin(Height=0.020)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0567` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `filter = filterHairpin(GroundPlaneWidth=[0.0679)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `filterHairpin` object with default properties is Teflon.

Example: `d = dielectric("FR4"); filter = filterHairpin(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `filterHairpin` object with default properties is PEC.

Example: `m = metal("Copper"); filter = filterHairpin(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design hairpin filter around specified frequency |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Create Default Hairpin Filter

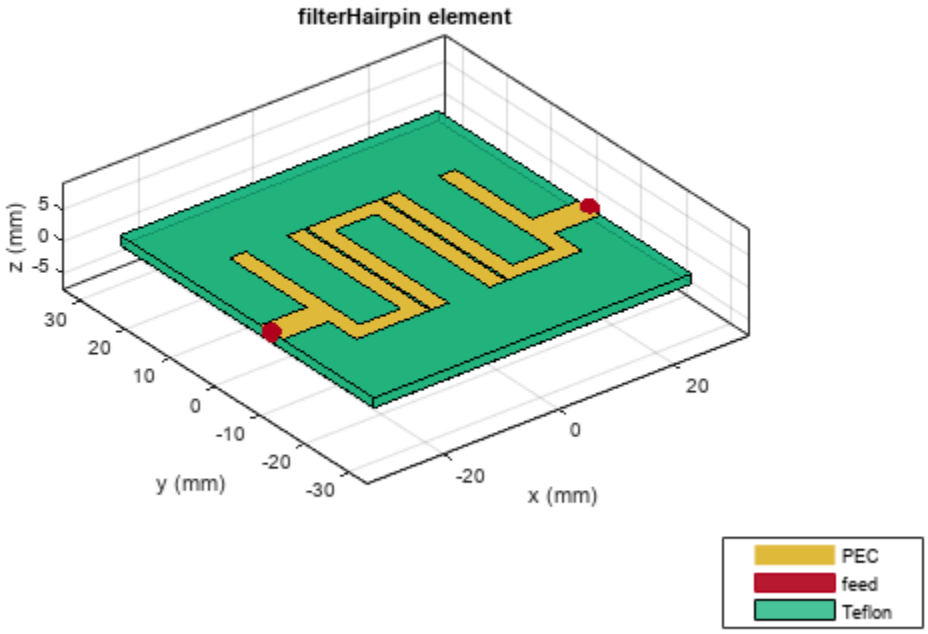
Create and view a default hairpin filter.

```
hairpinfilter = filterHairpin
```

```
hairpinfilter =
  filterHairpin with properties:
```

```
          Resonator: [1x1 ubendRightAngle]
        FilterOrder: 3
     ResonatorOffset: [0 0 0]
            Spacing: [4.0000e-04 4.0000e-04]
      PortLineLength: 0.0080
       PortLineWidth: 0.0050
          FeedOffset: [-0.0055 -0.0055]
            FeedType: 'Tapped'
              Height: 0.0016
    GroundPlaneWidth: 0.0567
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

```
show(hairpinfilter)
```




### Fifth-Order Coupled Hairpin Filter

Create and view a fifth-order coupled hairpin filter.

```
hairpinfilter = filterHairpin(FeedType="Coupled")
```

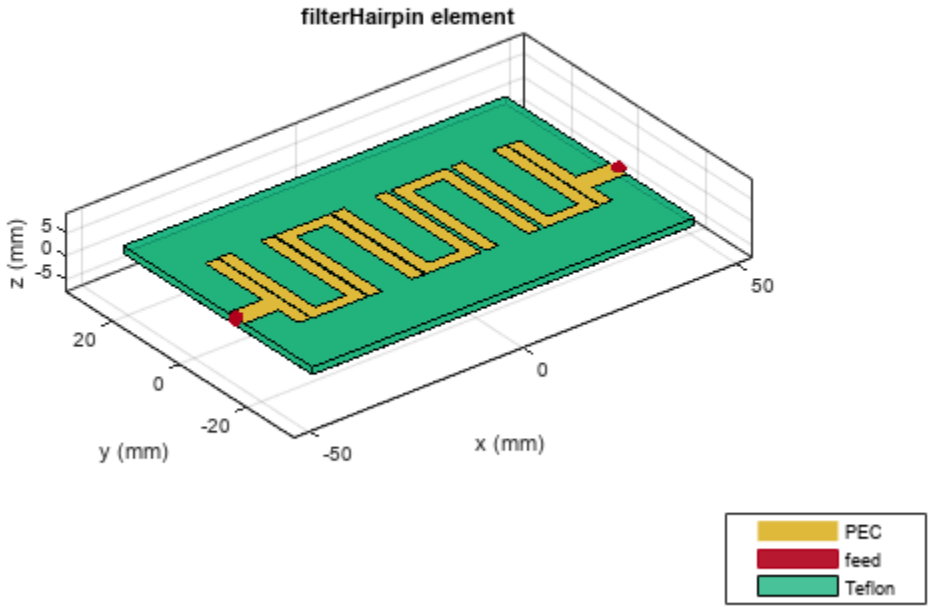
```
hairpinfilter =
  filterHairpin with properties:
```

```
              Resonator: [1x1 ubendRightAngle]
            FilterOrder: 3
       ResonatorOffset: [0 0 0]
               Spacing: [4.0000e-04 4.0000e-04]
            FeedOffset: [-0.0055 -0.0055]
        PortLineLength: 0.0080
         PortLineWidth: 0.0050
              FeedType: 'Coupled'
     CoupledLineLength: 0.0279
      CoupledLineWidth: 0.0029
    CoupledLineSpacing: [1.8270e-04 1.8270e-04]
                Height: 0.0016
      GroundPlaneWidth: 0.0567
             Substrate: [1x1 dielectric]
             Conductor: [1x1 metal]
```

```
hairpinfilter.FilterOrder = 5
```

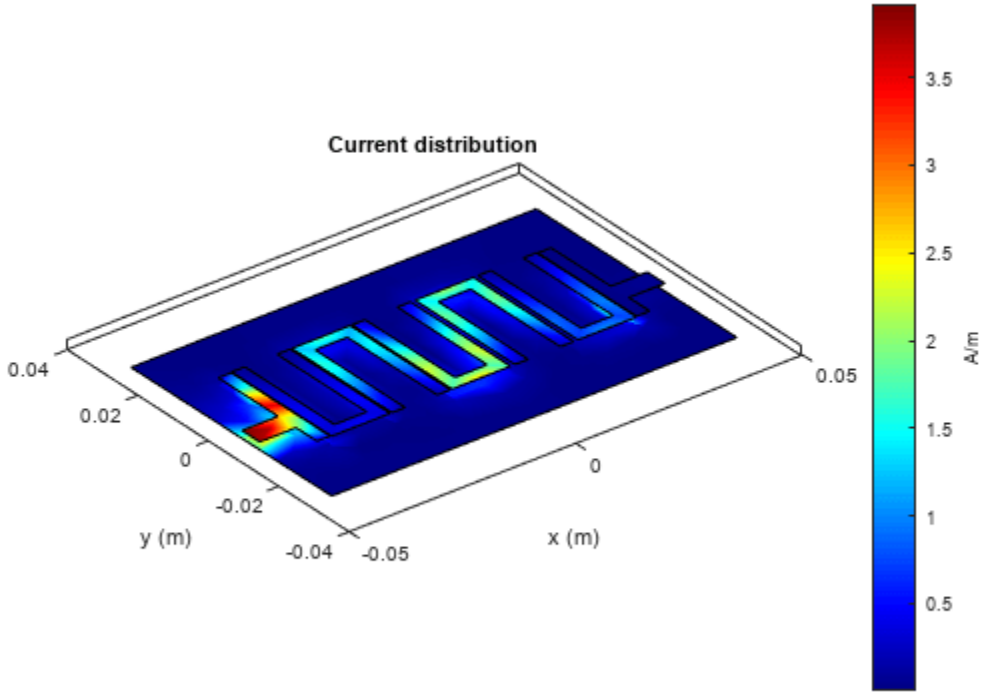
```
hairpinfilter =
  filterHairpin with properties:

              Resonator: [1x1 ubendRightAngle]
            FilterOrder: 5
       ResonatorOffset: [0 0 0 0 0]
               Spacing: [4.0000e-04 4.0000e-04 1.0000e-03 1.0000e-03]
            FeedOffset: [-0.0055 -0.0055]
        PortLineLength: 0.0080
         PortLineWidth: 0.0050
              FeedType: 'Coupled'
     CoupledLineLength: 0.0279
      CoupledLineWidth: 0.0029
    CoupledLineSpacing: [1.8270e-04 1.8270e-04]
                Height: 0.0016
      GroundPlaneWidth: 0.0567
             Substrate: [1x1 dielectric]
             Conductor: [1x1 metal]
```

```
show(hairpinfilter)
```

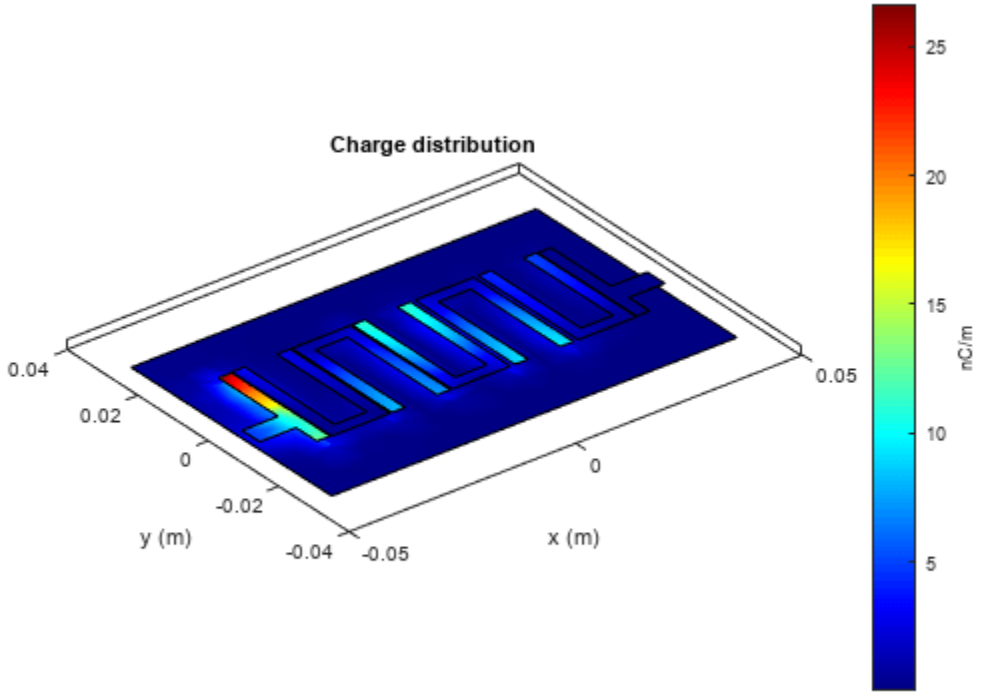



Plot the current and charge distribution of the filter at 2 GHZ.

```
figure
current(hairpinfilter,2e9)
```




```
figure
charge(hairpinfilter,2e9)
```




# Version History

**Introduced in R2021b**

## References

[1] Bankey, Kavita, and Abhinav Bhargava. “Design of Compact Microstrip Hairpin Multi Bandpass Filter.” *International Journal of Scientific Progress and Research* 34, no. 96 (2017): 66–69.

[2] Parikh, Nikunj, Pragya Katare, Ketan Kathal, Nandini Patel, and Gaurav Chaitanya. “Design and Analysis of Hairpin Micro-Strip Line Band Pass Filter.” *International Journal of Innovative Research in Electrical, Electronics, Instrumentation, and Control Engineering* 3 (April 2015). https://doi.org/10.17148/IJIREEICE.2015.3512.

## See Also

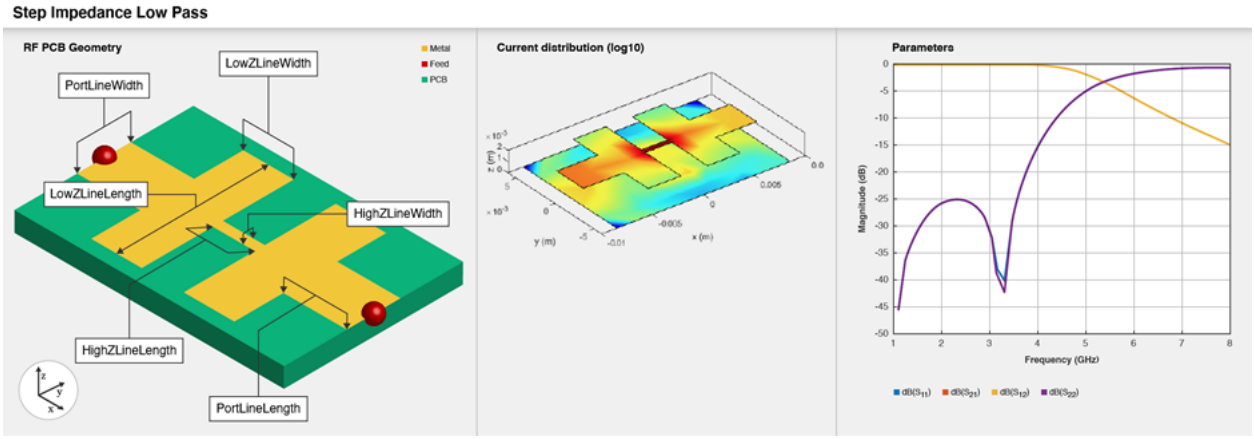
`filterCoupledLine` | `filterStepImpedanceLowPass`

# filterStepImpedanceLowPass

Create stepped impedance lowpass filter in microstrip form

## Description

Use the `filterStepImpedanceLowPass` object to create a stepped impedance lowpass filter in microstrip form.




The stepped impedance lowpass microstrip filters have a cascaded structure of alternating high- and low-impedance transmission lines. These lines are considerably shorter in length than the design wavelength and act as semi-lumped elements. The high-impedance lines act as series inductors, and the low-impedance lines act as shunt capacitors. This filter structure realizes a Pi LC ladder type of a lowpass filter. You can control the impedance by adjusting the width of the strip. This filter is used in radar, satellite, and terrestrial communications and in electronic counter-measure applications.

## Creation

### Syntax

```
filter = filterStepImpedanceLowPass
filter = filterStepImpedanceLowPass(Name=Value)
```

#### Description

`filter = filterStepImpedanceLowPass` creates a default stepped impedance lowpass filter with default property values for a cutoff frequency 5 GHz.

`filter = filterStepImpedanceLowPass(Name=Value)` sets “Properties” on page 1-143 using one or more name-value arguments. For example, `filterStepImpedanceLowPass(FilterOrder=10)` creates a tenth-order stepped impedance lowpass filter. Properties not specified retain their default values

## Properties

### `FilterOrder` — Filter order

3 (default) | positive scalar in the range [3,11]

Filter order, specified as a positive scalar. The minimum filter order you can specify is 3 and the maximum order is 11.

Example: `filter = filterStepImpedanceLowPass(FilterOrder=5)`

Data Types: `double`

### `PortLineLength` — Length of input and output lines

`0.0034` (default) | positive scalar

Length of the input and output lines in meters, specified as a positive scalar.

Example: `filter = filterStepImpedanceLowPass(PortLineLength=0.0553)`

Data Types: `double`

### `PortLineWidth` — Width of input and output lines

`0.0040` (default) | positive scalar

Width of the input and output lines in meters, specified as a positive scalar.

Example: `filter = filterStepImpedanceLowPass(PortLineWidth=0.0087)`

Data Types: `double`

### `LowZLineWidth` — Width of low-impedance line

`0.0096` (default) | positive scalar

Width of the low-impedance line in meters, specified as a positive scalar.

Example: `filter = filterStepImpedanceLowPass(LowZLineWidth=0.0553)`

Data Types: `double`

### `HighZLineWidth` — Width of high-impedance line

`5.0000e-04` (default) | positive scalar

Width of the high-impedance line in meters, specified as a positive scalar.

Example: `filter = filterStepImpedanceLowPass(HighZLineWidth=0.0553)`

Data Types: `double`

### `LowZLineLength` — Length of low-impedance line

`0.0032` (default) | positive scalar

Length of the low-impedance line in meters, specified as a positive scalar.

Example: `filter = filterStepImpedanceLowPass(LowZLineLength=0.0553)`

Data Types: `double`

### `HighZLineLength` — Length of high-impedance line

`0.0026` (default) | positive scalar

Length of the high-impedance line in meters, specified as a positive scalar.

Example: `filter = filterStepImpedanceLowPass(HighZLineWidth=0.0553)`

Data Types: `double`

**`Height` — Height of filter from ground plane**
`0.0016` (default) | positive scalar

Height of the filter from the ground plane in meters, specified as a positive scalar.

Example: `filter = filterStepImpedanceLowPass(Height=0.020)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.012` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `filter = filterStepImpedanceLowPass(GroundPlaneWidth=0.013)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `filterStepImpedanceLowPass` object with default properties have the following properties:

- `Name—{'CustomDielectric'}`
- `EpsilonR—3.7`
- `LossTangent—0.001`
- `Thickness—1.6e-3`

Example: `d = dielectric("FR4"); filter = filterStepImpedanceLowPass(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `filterStepImpedanceLowPass` object with default properties is PEC.

Example: `m = metal("Copper"); filter = filterStepImpedanceLowPass(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design stepped impedance low pass filter around desired cut-off frequency |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |

| | |
|---|---|
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

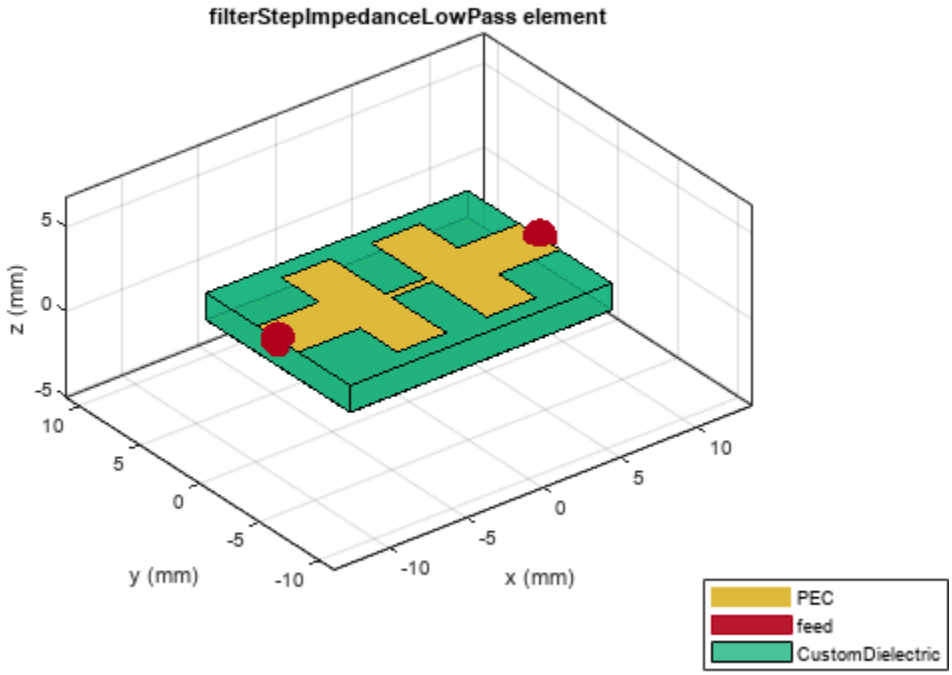
### Default Stepped Impedance Lowpass Filter

Create and view a default stepped impedance lowpass filter.

```
steppedfilter = filterStepImpedanceLowPass
```

```
steppedfilter =
  filterStepImpedanceLowPass with properties:

         FilterOrder: 3
       PortLineWidth: 0.0034
      PortLineLength: 0.0040
      HighZLineWidth: 5.0000e-04
       LowZLineWidth: 0.0096
     HighZLineLength: 0.0026
      LowZLineLength: 0.0032
              Height: 0.0016
    GroundPlaneWidth: 0.0120
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

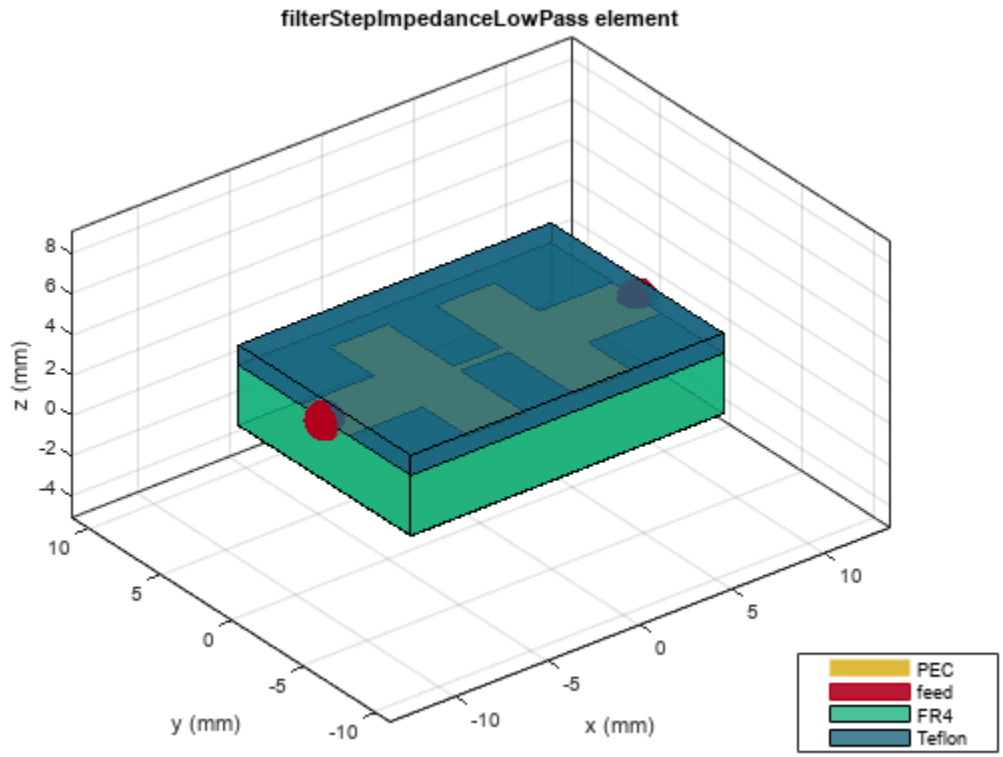
```
show(steppedfilter)
```




### Create Stepped Impedance Lowpass Filter with Multilayer Dielectric Substrate

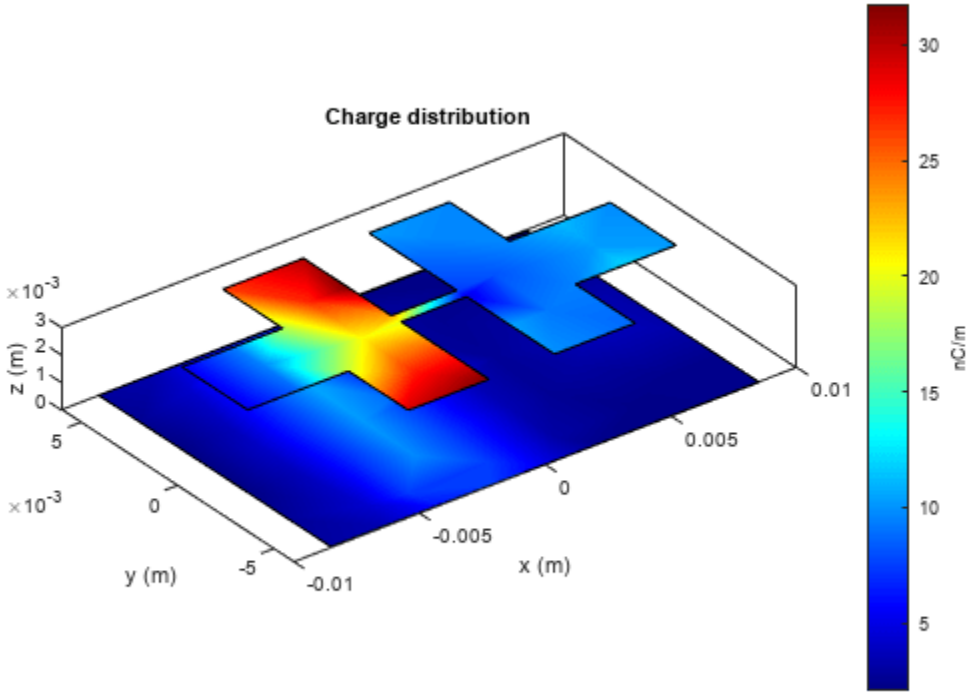
Create and view a stepped impedance lowpass filter with a multilayer dielectric substrate.

```
sub = dielectric("FR4","Teflon");
sub.Thickness =[0.003 0.001];
steppedfilter = filterStepImpedanceLowPass;
steppedfilter.Height = 0.003;
steppedfilter.Substrate = sub;
figure
show(steppedfilter)
```

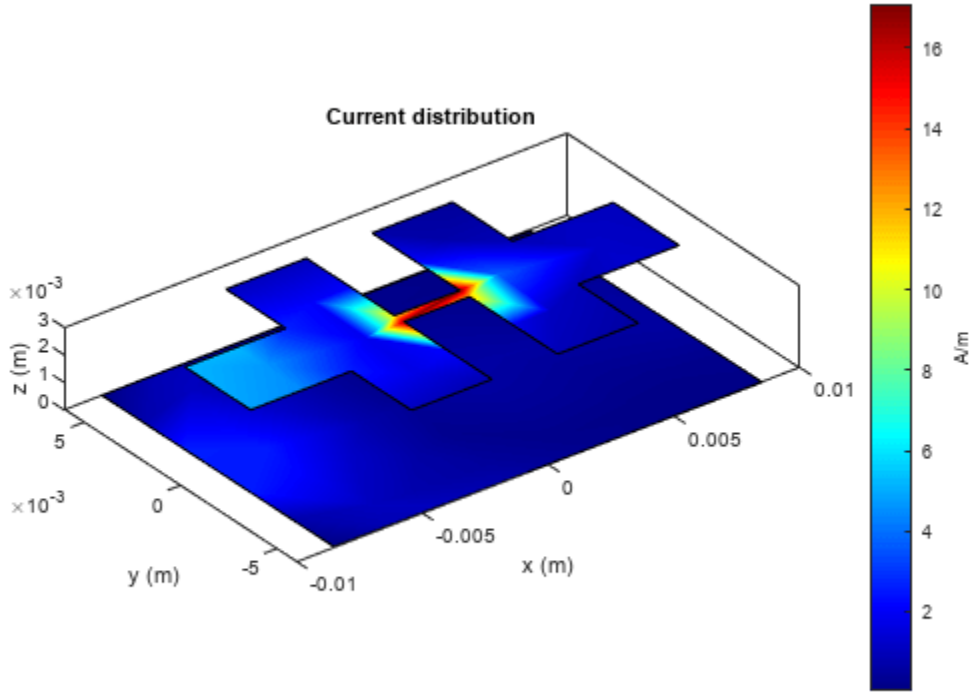



Plot the charge and current on the filter at 5 GHz.

```
figure
charge(steppedfilter,5e9)
```




```
figure
current(steppedfilter,5e9)
```




```
info(steppedfilter)
```

```
ans = struct with fields:
          IsSolved: "true"
          IsMeshed: "true"
       MeshingMode: "auto"
      HasSubstrate: "true"
           HasLoad: "false"
     PortFrequency: []
    MemoryEstimate: "790 MB"
```

# Version History

**Introduced in R2021b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

[2] Garvansh, Abhay, Singh Kushwaha, Navita Singh, and Arun Kumar. “Implementation of Stepped Impedance Low Pass Microstrip Line Filter for Wireless Communication.” *International Journal of Advanced Research in Computer and Communication Engineering* 3, no. 7 (July 2014): 7608–10.

[3] Maity, Budhadeb. “Stepped Impedance Low Pass Filter Using Microstrip Line for C-Band Wireless Communication.” In *2016 International Conference on Computer Communication and Informatics (ICCCI)*, 1–4. Coimbatore, India: IEEE, 2016. https://doi.org/10.1109/ICCCI.2016.7480008.

## See Also

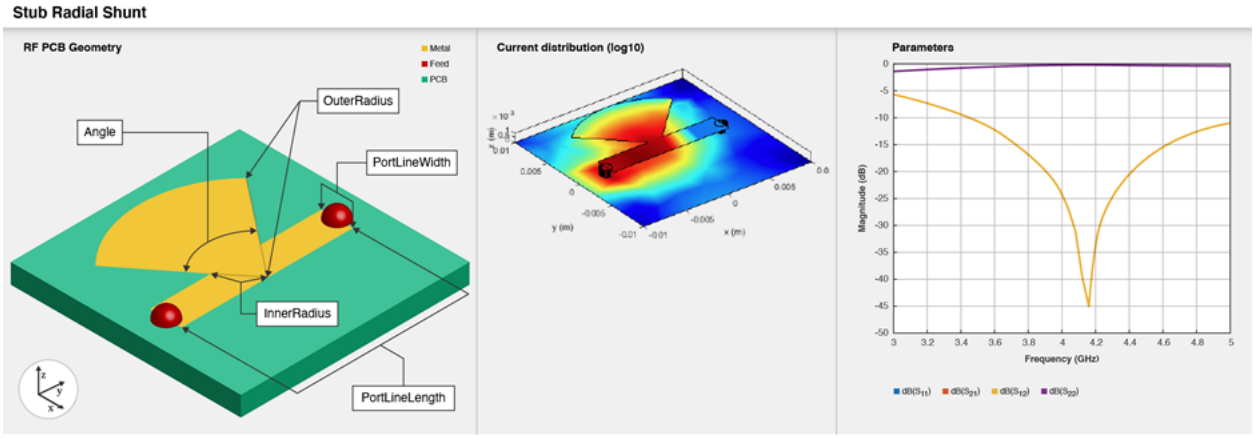
`filterCoupledLine` | `filterHairpin`

# stubRadialShunt

Create single- and double-radial stub shunt on X-Y plane

## Description

Use the `stubRadialShunt` object to create a single- or double-radial stub shunt on the X-Y plane.




Radial stubs provide broadly resonant RF short circuits by introducing the short at a concentrated point. When cascaded with high-impedance quarter-wavelength transmission lines, radial stubs provide an effectively decoupled network for microwave amplifiers and other active components.

## Creation

### Syntax

```
stub = stubRadialShunt
stub = stubRadialShunt(Name=Value)
```

#### Description

`stub = stubRadialShunt` creates a single-radial stub shunt in the X-Y plane. The stub dimensions are for the frequency range of 3-5 GHz with a resonant frequency of 4.2 GHz on the X-Y plane.

`stub = stubRadialShunt(Name=Value)` sets “Properties” on page 1-151 using one or more name-value arguments. For example, `stubRadialStub(OuterRadius=0.0070)` creates a radial stub shunt with an outer radius of `0.0070` meters. Properties not specified retain their default values.

### Properties

**StubType — Type of radial stub**
`"Single"` (default) | `"Double"`

Type of radial stub, specified as `"Single"` or `"Double"`.

Example: `stub = stubRadialShunt(StubType="Double")`

Data Types: `string` | `char`

**`OuterRadius` — Outer radius of radial stub**
`0.0085` (default) | positive scalar | two-element vector

Outer radius of the radial stub in meters, specified as a positive scalar or a two-element vector of positive elements. Specify a two-element vector for a double-radial stub.

Example: `stub = stubRadialShunt(OuterRadius=0.0070)`

Data Types: `double`

**`InnerRadius` — Inner radius of radial stub**
`0.0012` (default) | positive scalar | two-element vector

Inner radius of the radial stub in meters, specified as a positive scalar or a two-element vector of positive elements. Specify a two-element vector for a double-radial stub.

Example: `stub = stubRadialShunt(InnerRadius=0.0023)`

Data Types: `double`

**`Angle` — Angle of stub**
`90` (default) | positive scalar in the range [5, 175] | two-element vector in the range [5, 175]

Angle of the stub in degrees, specified as a positive scalar or a two-element vector of positive elements. Specify a two-element vector for a double-radial stub. The stub angles must be greater than or equal to 5 degrees and less than or equal to 175 degrees.

Example: `stub = stubRadialShunt(Angle=60)`

Data Types: `double`

**`PortLineWidth` — Width of microstrip line**
`0.0025` (default) | positive scalar

Width of the microstrip line in meters, specified as a positive scalar.

Example: `stub = stubRadialShunt(PortLineWidth=0.0035)`

Data Types: `double`

**`PortLineLength` — Length of microstrip line**
`0.0137` (default) | positive scalar

Length of the microstrip line in meters, specified as a positive scalar.

Example: `stub = stubRadialShunt(PortLineLength=0.0237)`

Data Types: `double`

**`Height` — Height of radial stub from ground plane**
`0.0016` (default) | positive scalar

Height of the radial stub from the ground plane, specified as a positive scalar.

Example: `stub = stubRadialShunt(Height=0.0015)`

Data Types: `double`

**`GroundPlaneLength` — Length of ground plane**
`0.0200` (default) | positive scalar

Length of the ground plane in meters, specified as a positive scalar.

Example: `stub = stubRadialShunt(GroundPlaneLength=0.046)`

Example: double

**`GroundPlaneWidth` — Width of ground plane**
`0.0200` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `stub = stubRadialShunt(GroundPlaneWidth=0.046)`

Example: double

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `stubRadialShunt` object with default properties is Teflon. The thickness of the default dielectric material Teflon is `0.8` mm or the same as the `Height` property.

Example: `d = dielectric("FR4"); stub = stubRadialShunt(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `stubRadialShunt` object with default properties is PEC.

Example: `m = metal("PEC"); stub = stubRadialShunt(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Create Default Radial Stub Shunt

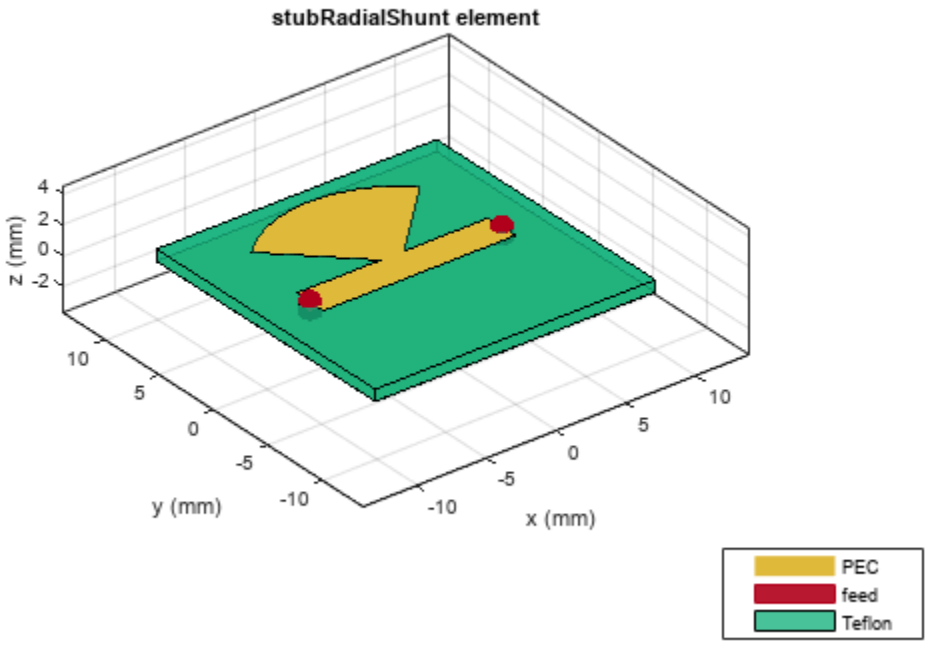
Create a default radial stub shunt.

```
stub = stubRadialShunt
```

```
stub =
  stubRadialShunt with properties:

            StubType: 'Single'
         OuterRadius: 0.0085
         InnerRadius: 0.0012
               Angle: 90
      PortLineLength: 0.0137
       PortLineWidth: 0.0025
              Height: 8.0000e-04
   GroundPlaneLength: 0.0200
    GroundPlaneWidth: 0.0200
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the radial stub shunt.

```
show(stub)
```



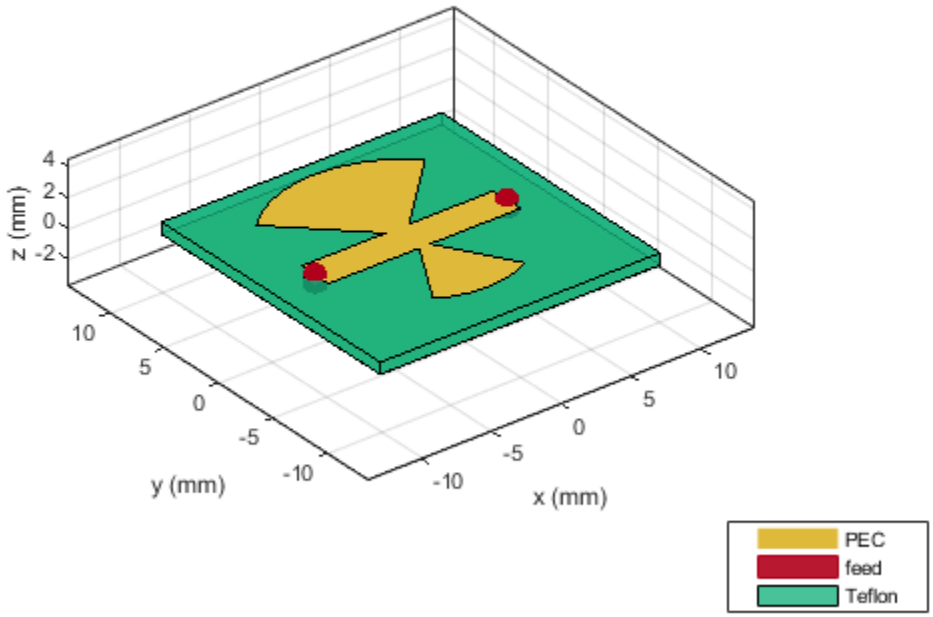
### Create Double Shunt Radial Stub

Create shunt radial stub of type double.

```
stub = stubRadialShunt(StubType='double');
stub.OuterRadius = [0.0085 0.0065];
stub.InnerRadius = [0.0012 0.0008];
stub.Angle       = [90 60];
```

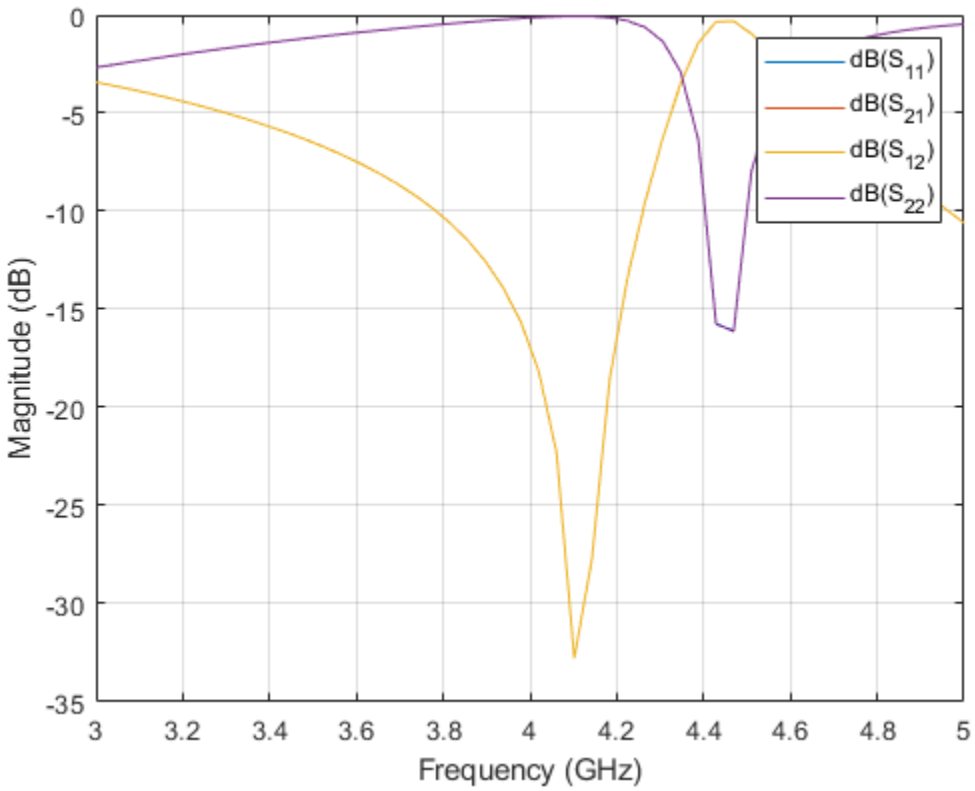
View shunt radial stub.

```
show(stub)
```




Plot s-parameters.

```
spar = sparameters(stub,linspace(3e9,5e9,50));
rfplot(spar)
```




## More About

### Parametric Analysis Guidelines

- Increase the Angle to shift the resonance of the stub to a lower frequency.
- Increase the OuterRadius to shift the resonance of the stub to a lower frequency.
- Adjust the OuterRadius and increase the Angle to design a radial stub at a desired frequency, line length, low insertion loss, and wide bandwidth.

# Version History

**Introduced in R2021b**

## References

[1] Wang , Zhebin, and Chan-Wang Park. “Novel Wideband GaN HEMT Power Amplifier Using Microstrip Radial Stub to Suppress Harmonics.” In *2012 IEEE/MTT-S International Microwave Symposium Digest*, 1–3. Montreal, QC, Canada: IEEE, 2012. https://doi.org/10.1109/MWSYM.2012.6259464.

[2] Singh, Prashant, and Tiwary Anjini. “Novel Compact Dual Bandstop Filter Using Radial Stub.” *Microwave Review* 21 (September 1, 2015): 17–22.

## See Also

`microstripLine`

# traceSpiral

Create even-sided polygon trace in spiral form

## Description

Use the `traceSpiral` object to create an even-sided polygon trace such as a square, hexagon, octagon, decagon, or a circle in a spiral form.

## Creation

### Syntax

```
trace = traceSpiral
trace = traceSpiral(Name=Value)
```

#### Description

`trace = traceSpiral` creates a square spiral trace. The spiral trace is centered at the origin on the X-Y plane.

`trace = traceSpiral(Name=Value)` sets "Properties" on page 1-158 using one or more name-value arguments. For example, `traceSpiral(ReferencePoint=[1 1])` creates a spiral trace with the reference point `[1 1]`. Properties not specified retain their default values.

### Properties

#### Name — Name of spiral trace

`'myspiral'` (default) | character vector | string scalar

Name of the spiral trace, specified as a character vector or a string scalar.

Example: `trace = traceSpiral(Name="spiraltrace1")`

Data Types: `char` | `string`

#### ReferencePoint — Point of reference of spiral trace

`[0 0]` (default) | two-element vector

Point of reference of the spiral trace in Cartesian coordinates, specified as a two-element vector. Use the reference point to modify the shape from its initial position.

Example: `trace = traceSpiral(ReferencePoint=[1 1])`

Data Types: `double`

#### InnerDiameter — Inner diameter of spiral trace

`0.0040` (default) | positive scalar

Inner diameter of the spiral trace in meters, specified as a positive scalar. If the polygon is a square, the inner diameter is the distance between the innermost vertex and the midpoint of the opposite side

of the inner square. For all other shapes, the value is the distance between the innermost vertex and the opposite vertex of the inner turn.

Example: `trace = traceSpiral(InnerDiameter=0.0015)`

Data Types: `double`

**`TraceWidth` — Width of spiral trace**
`0.0020` (default) | positive scalar

Width of the spiral trace in meters, specified as a positive scalar.

Example: `trace = traceSpiral(TraceWidth=0.0050)`

Data Types: `double`

**`Spacing` — Distance between traces of spiral**
`5.0000e-04` (default) | positive scalar

Distance between the traces of the spiral in meters, specified as a positive scalar. For a square spiral trace, the spacing is the gap between the flat edges of adjacent turns. For all other shapes, the spacing is the gap between vertices of adjacent turns.

Example: `trace = traceSpiral(Spacing=6.0000e-04)`

Data Types: `double`

**`NumTurns` — Number of turns in spiral**
4 (default) | positive scalar

Number of turns in the spiral, specified as a positive scalar.

Example: `trace = traceSpiral(NumTurns=6)`

Data Types: `double`

**`NumSides` — Number of sides in each turn**
4 (default) | positive, even scalar

Number of sides in each turn of the spiral based on the polygon, specified as a positive, even scalar. The minimum number of sides is `4` and the maximum number is `10`. If the number exceeds `10`, then the shape is a circle.

Example: `trace = traceSpiral(NumSides=6)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |

| | |
|---|---|
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Spiral Trace

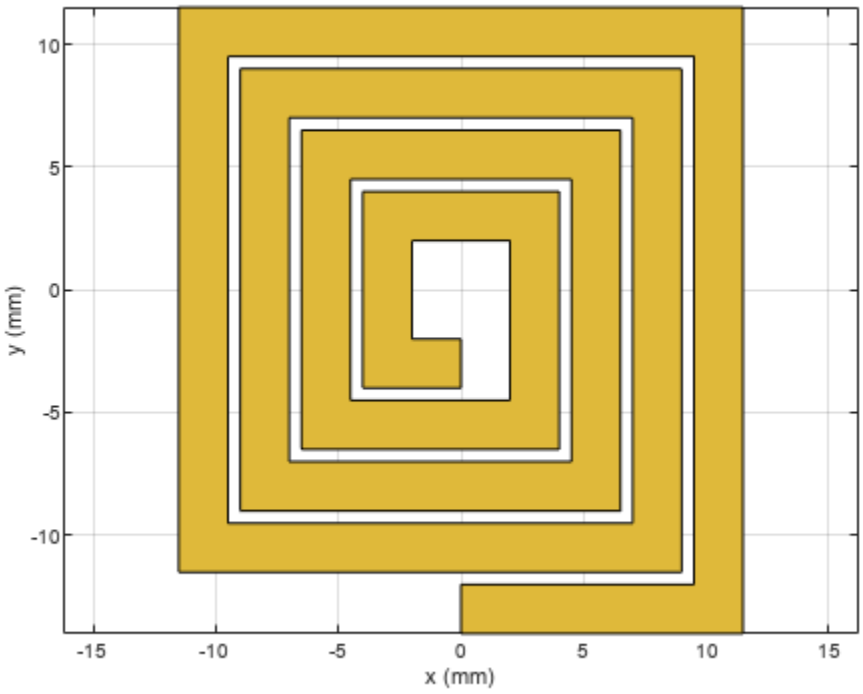
Create a spiral trace with default properties.

```
trace = traceSpiral
```

```
trace =
  traceSpiral with properties:

              Name: 'myspiral'
    ReferencePoint: [0 0]
     InnerDiameter: 0.0040
        TraceWidth: 0.0020
           Spacing: 5.0000e-04
          NumTurns: 4
          NumSides: 4
```

View the trace.

```
show(trace)
```




## Version History

**Introduced in R2021b**

## See Also

`traceLine` | `traceCross` | `traceTee` | `tracePoint` | `traceRectangular`

# traceRectangular

Create rectangular trace

## Description

Use the `traceRectangular` object to create a rectangular trace centered at the origin on the X-Y plane.

## Creation

### Syntax

```
trace = traceRectangular
trace = traceRectangular(Name=Value)
```

#### Description

`trace = traceRectangular` creates a rectangular trace centered at the origin and on the X-Y plane.

`trace = traceRectangular(Name=Value)` sets "Properties" on page 1-162 using one or more name-value arguments. For example, `traceRectangular(Center=[1 1])` creates a rectangular trace centered at `[1 1]`. Properties not specified retain their default values.

### Properties

**`Name` — Name of rectangular trace**
`'mytraceRectangular'` (default) | character vector | string scalar

Name of the rectangular trace, specified as a character vector or a string scalar.

Example: `trace = traceRectangular(Name="rectangletrace1")`

Data Types: `char` | `string`

**`Center` — Center of rectangular trace**
`[0 0]` (default) | two-element vector

Center of the rectangular trace in Cartesian coordinates, specified as a two-element vector.

Example: `trace = traceRectangular(Center=[1 1])`

Data Types: `double`

**`Length` — Length of rectangle**
`0.0200` (default) | positive scalar

Length of the rectangle in meters, specified as a positive scalar.

Example: `trace = traceRectangular(Length=0.0500)`

Data Types: `double`

**`Width` — Width of rectangle**
`0.0050` (default) | positive scalar

Width of the rectangle in meters, specified as a positive scalar.

Example: `trace = traceRectangular(Width=0.015)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Rectangular Trace

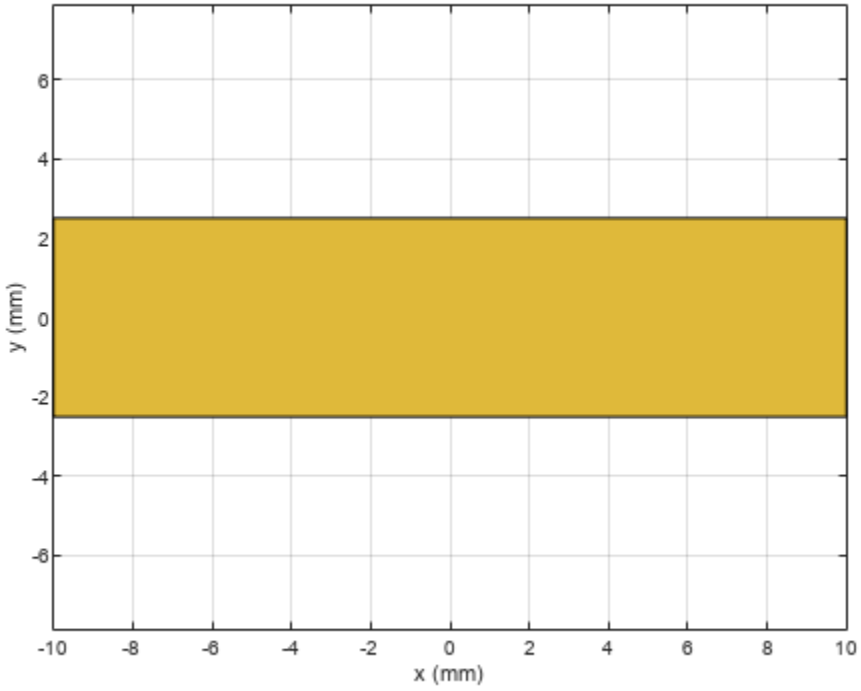
Create a rectangular trace with default properties.

```
trace = traceRectangular
```

```
trace =
  traceRectangular with properties:

      Name: 'mytraceRectangular'
    Center: [0 0]
    Length: 0.0200
     Width: 0.0050
```

View the trace.

```
show(trace)
```




### Mesh Rectangular Trace

Create a 2 cm-by-2 cm rectangular trace.

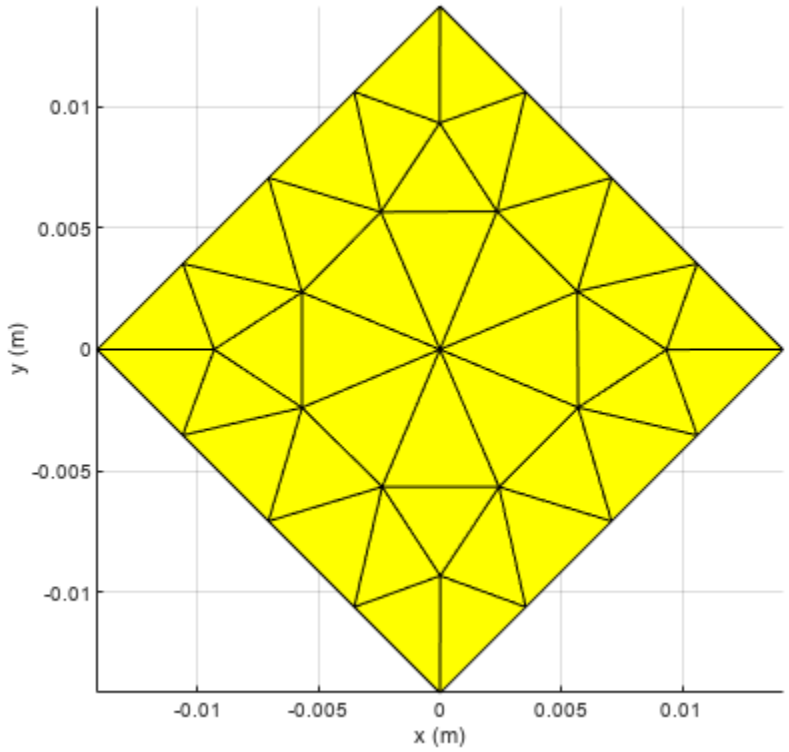
```
trace = traceRectangular(Length=0.02,Width=0.02);
```

Rotate the trace by 45 degrees about the z-axis.

```
trace = rotateZ(trace,45);
```

Mesh the trace at a maximum edge length of 5 mm.

```
mesh(trace,MaxEdgeLength=5e-3)
```




## Version History

**Introduced in R2021b**

## See Also

`traceLine` | `traceCross` | `traceTee` | `tracePoint` | `traceSpiral`

# traceTee

Create tee trace

# Description

Use the `traceTee` object to create a tee trace on the X-Y plane.

**Note** This shape object supports behavioral modeling. For more information, see "Behavioral Models".

# Creation

## Syntax

```
trace = traceTee
trace = traceTee(Name=Value)
```

### Description

`trace = traceTee` creates a tee trace with default properties on the X-Y plane.

`trace = traceTee(Name=Value)` sets "Properties" on page 1-166 using one or more name-value arguments. For example, `traceTee(ReferencePoint=[1 1])` creates a tee trace with the reference point `[1 1]`. Properties not specified retain their default values.

## Properties

### Name — Name of tee trace

`'mytraceTeeShape'` (default) | character vector | string scalar

Name of the tee trace, specified as a character vector or a string scalar.

Example: `trace = traceTee(Name="traceTeeShape")`

Data Types: `char` | `string`

### ReferencePoint — Reference point of tee trace

`[0 0]` (default) | two-element vector

Reference point of the tee trace in meters, specified as a two-element vector of nonnegative elements.

Example: `trace = traceTee(ReferencePoint=[1 1])`

Data Types: `double`

### Length — Length of horizontal and vertical lines

`[0.0200 0.0100]` (default) | two-element vector

Length of the horizontal and vertical lines in meters, specified as a two-element vector of positive elements.

Example: `trace = traceTee(Length=[0.0300 0.0200])`

Data Types: `double`

### `Width` — Width of horizontal and vertical lines

`[0.0050 0.0050]` (default) | two-element vector

Width of the horizontal and vertical lines in meters, specified as a two-element vector of positive elements.

Example: `trace = traceTee(Width=[0.0060 0.0060])`

Data Types: `double`

### `Offset` — Offset along X-axis

`0` (default) | nonnegative scalar

Offset along the X-axis in meters, specified as a nonnegative scalar.

Example: `trace = traceTee(Offset=0.0005)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| intersect | Boolean intersection operation on two RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| minus | Shape1 - Shape2 for RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| translate | Move RF PCB shape to new location |
| scale | Change size of RF PCB shape by fixed amount |

## Examples

### Create Default Tee Trace

Create a tee trace with default properties.

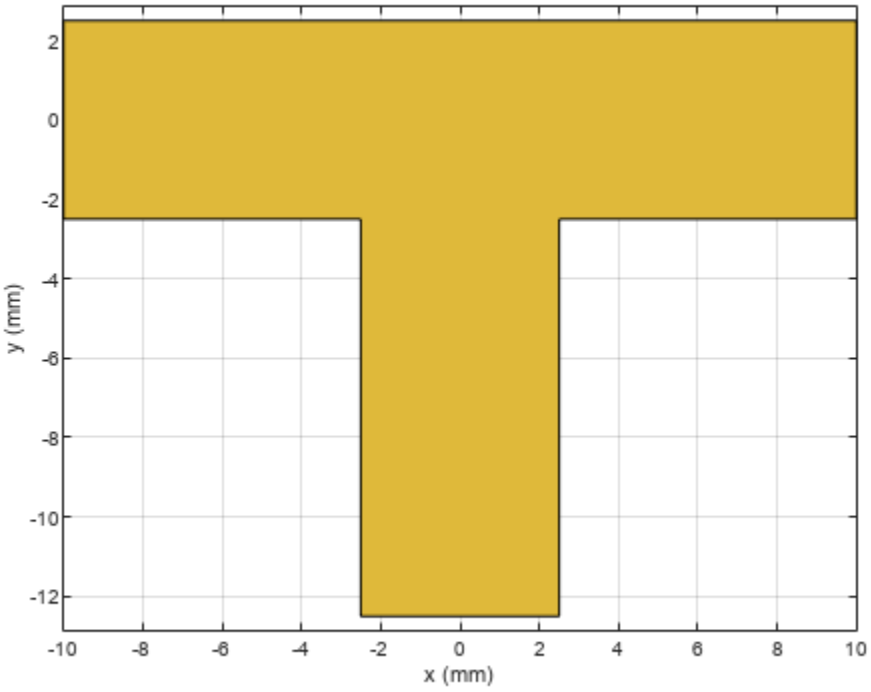
```
trace = traceTee
```

```
trace =
  traceTee with properties:

              Name: 'mytraceTeeShape'
    ReferencePoint: [0 0]
            Length: [0.0200 0.0100]
```

```
    Width: [0.0050 0.0050]
   Offset: 0
```

View the trace.

```
show(trace)
```




### Use Behavioral Model to Calculate S-Parameters of Microstrip T-Junction

Design a microstrip transmission line at 3 GHz for FR4 substrate.

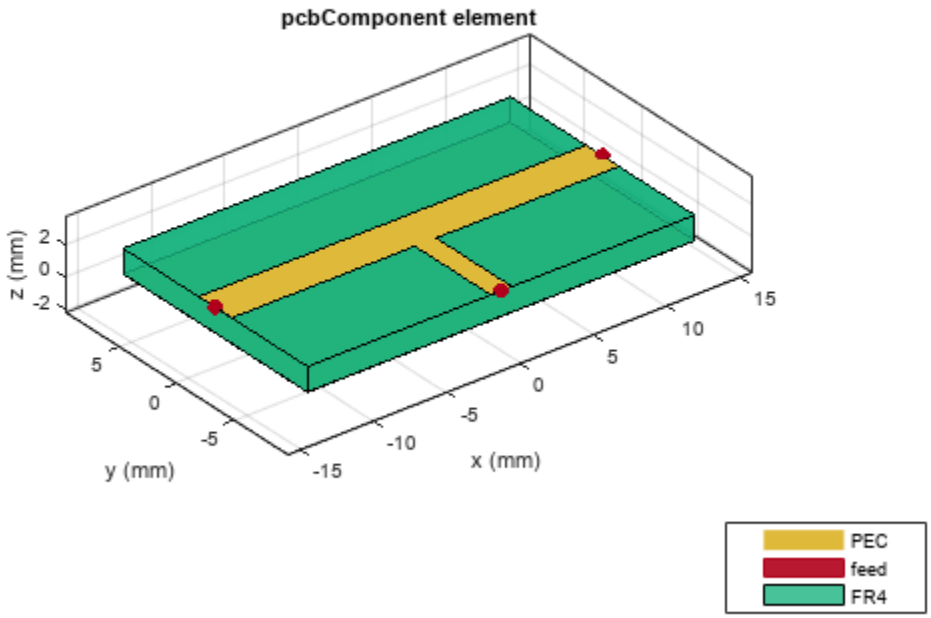
```
m = design(microstripLine('Substrate',dielectric('FR4')),3e9);
```

Create a microstrip T-junction.

```
layer2d = traceTee('Length',[m.Length m.Length/4],...
"Width",[m.Width m.Width/2]);
```

Convert the T-junction trace to a 3-D component.

```
robj = pcbComponent(layer2d);
robj.BoardThickness = m.Substrate.Thickness;
robj.Layers{2} = m.Substrate;
show(robj)
```




Define frequency points to calculate the s-parameters.

```
freq = (1:40)*100e6;
```

Calculate the s-parameters of the T-junction trace using the behavioral model.

```
Sckt = sparameters(robj,freq,75,'Behavioral',true);
```

```
Warning: Behavioral model is valid only when Z0 of main line is 50 ohms and for EpsilonR of 9.9.
```

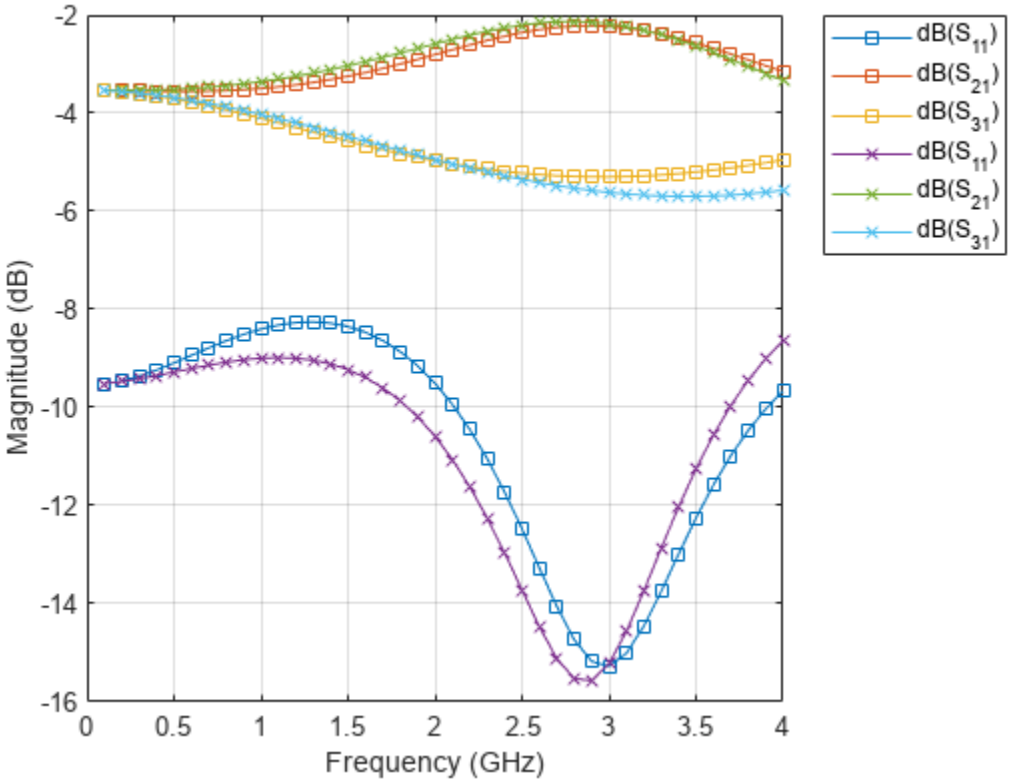
Calculate the s-parameters of the T-junction trace using the electromagnetic solver.

```
Sem = sparameters(robj,freq,75)
```

```
Sem =
  sparameters: S-parameters object

       NumPorts: 3
    Frequencies: [40x1 double]
     Parameters: [3x3x40 double]
      Impedance: 75

  rfparam(obj,i,j) returns S-parameter Sij
```

Plot the s-parameter data using the `rfplot` function.

```
rfplot(Sckt,1:3,1,'db','-s')
hold on
rfplot(Sem,1:3,1,'db','-x')
```




References:


1 Ramesh Garg & I. J. Bahl (1978) Microstrip discontinuities, International Journal of Electronics, 45:1, 81-87, DOI: 10.1080/00207217808900883

2 Wadell, Brian C. *Transmission Line Design Handbook*. The Artech House Microwave Library. Boston: Artech House, 1991.


## Version History

**Introduced in R2021b**

## See Also

`traceLine` | `traceCross` | `traceRectangular` | `tracePoint` | `traceSpiral`

# traceCross

Create cross-shaped trace

## Description

Use the `traceCross` object to create a cross-shaped trace on the X-Y plane.

**Note** This shape object supports behavioral modeling. For more information, see “Behavioral Models”.

## Creation

### Syntax

```
trace = traceCross
trace = traceCross(Name=Value)
```

#### Description

`trace = traceCross` creates a cross-shaped trace with default properties on the X-Y plane.

`trace = traceCross(Name=Value)` sets “Properties” on page 1-171 using one or more name-value arguments. For example, `traceCross(ReferencePoint=[1 1])` creates a cross-shaped trace at the reference point `[1 1]`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of cross-shaped trace

`'mytraceCross'` (default) | character vector | string scalar

Name of the cross-shaped trace, specified as a character vector or a string scalar.

Example: `trace = traceCross(Name="traceCrossShape")`

Data Types: `char` | `string`

#### `ReferencePoint` — Reference point for cross-shaped trace

`[0 0]` (default) | two-element vector

Reference point for the cross-shaped trace in Cartesian coordinates, specified as a two-element vector.

Example: `trace = traceCross(ReferencePoint=[1 1])`

Data Types: `double`

#### `Length` — Length of cross-shaped trace

`[0.0100 0.0100]` (default) | two-element vector

Length of the cross-shaped trace in meters, specified as a two-element vector of positive elements.

Example: `trace = traceCross(Length=[0.0800 0.0400])`

Data Types: `double`

### `Width` — Width of cross-shaped trace

`[0.0020 0.0020]` (default) | two-element vector

Width of the cross-shaped trace in meters, specified as a two-element vector of positive elements.

Example: `trace = traceCross(Width=[0.005 0.005])`

Data Types: `double`

### `Offset` — Offset along X and Y direction

`[0 0]` (default) | two-element vector

Offset along the X and Y direction in meters, specified as a two-element vector.

Example: `trace = traceCross(Offset=[1 1])`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Cross Trace

Create a cross-shaped trace with default properties.

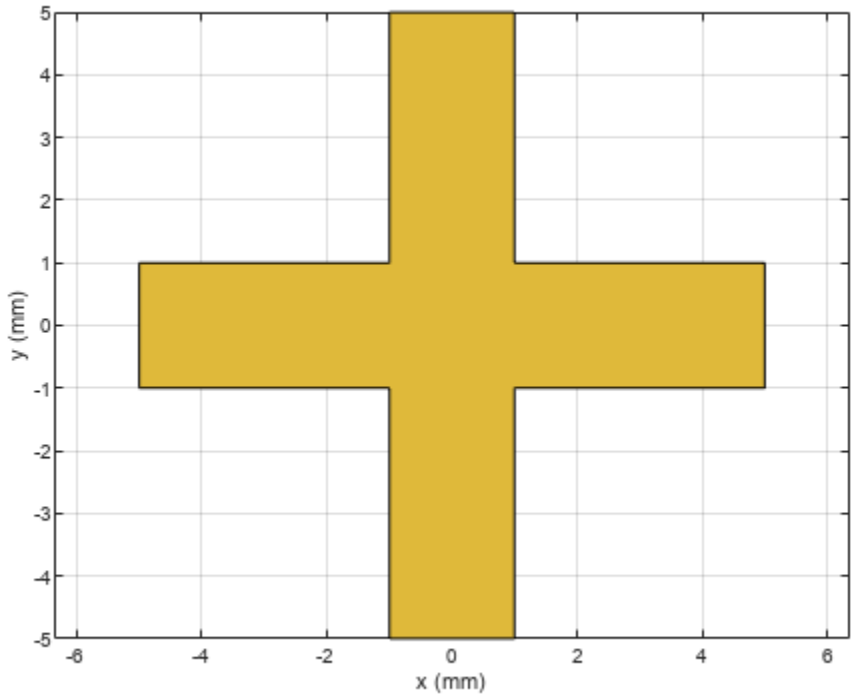
```
trace = traceCross
```

```
trace =
  traceCross with properties:

              Name: 'mytraceCross'
    ReferencePoint: [0 0]
            Length: [0.0100 0.0100]
```

```
    Width: [0.0020 0.0020]
   Offset: [0 0]
```

View the trace.

```
show(trace)
```




### Use Behavioral Model to Calculate S-Parameters of Microstrip Cross

Design a microstrip transmission line at 3 GHz using FR4 substrate.

```
d = dielectric('FR4');
d.LossTangent = 0;
m = design(microstripLine('Substrate',d),3e9,'Z0',75,...
    'LineLength',0.5);
```

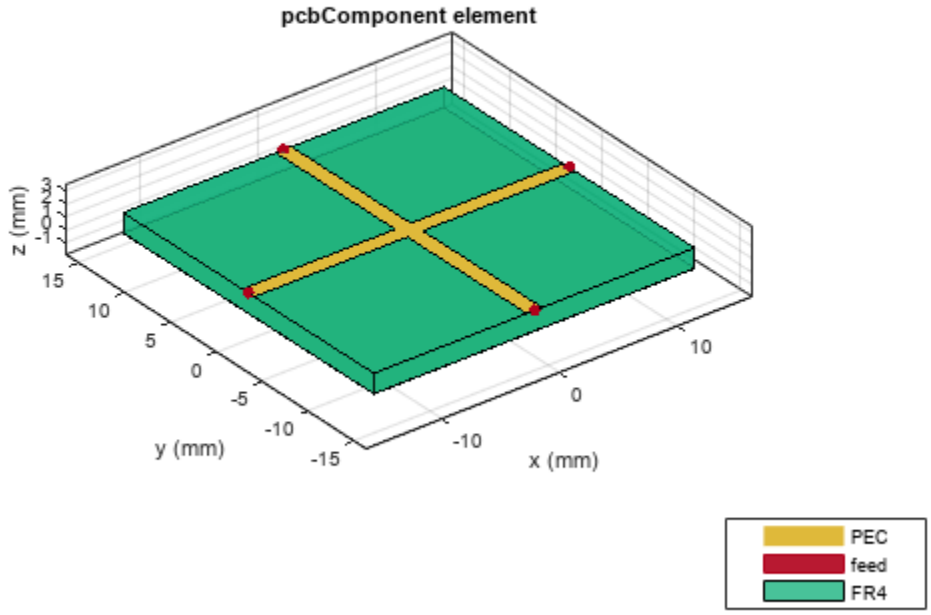
Create a microstrip cross.

```
layer2d = traceCross('Length',[m.Length m.Length], ...
    'Width',[m.Width m.Width]);
```

Convert the cross trace to a PCB component.

```
robj = pcbComponent(layer2d);
robj.BoardThickness = m.Substrate.Thickness;
```

```
robj.Layers{2} = m.Substrate;
show(robj)
```




Define frequency points to calculate the s-parameters.

```
freq = (1:3:40)*100e6;
```

Calculate the s-parameters of the cross trace using the behavioral model.

```
Sckt = sparameters(robj,freq,'Behavioral',true);
```

```
Warning: Behavioral model is valid only when EpsilonR is 9.9.
```

Calculate the s-parameters of the cross trace using the electromagnetic solver.

```
Sem = sparameters(robj,freq);
```

References:

1 Ramesh Garg & I. J. Bahl (1978) Microstrip discontinuities, International Journal of Electronics, 45:1, 81-87, DOI: 10.1080/00207217808900883

2 Wadell, Brian C. *Transmission Line Design Handbook*. The Artech House Microwave Library. Boston: Artech House, 1991.

## Version History

**Introduced in R2021b**

## See Also

`traceTee` | `traceRectangular` | `traceSpiral` | `tracePoint` | `traceLine`

# delta

Create delta shape

## Description

Use `delta` object to create a delta shape on the X-Y plane.

## Creation

### Syntax

```
deltashape = delta
deltashape = delta(Name=Value)
```

#### Description

`deltashape = delta` creates a delta shape on the X-Y plane.

`deltashape = delta(Name=Value)` sets "Properties" on page 1-176 using one or more name-value arguments. For example, `delta(ReferencePoint=[1 1])` creates a delta shape with the reference point at `[1 1]`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of delta shape

`'mydelta'` (default) | character vector | string scalar

Name of the delta shape, specified as a character vector or string scalar.

Example: `deltashape = delta(Name='deltaShape')`

Data Types: `char`

#### `ReferencePoint` — Reference point of delta shape

`[0 0]` (default) | two-element vector

Reference point of delta shape in Cartesian coordinates, specified as a two-element vector of nonnegative elements. Use the reference point to modify the shape relative to its initial position.

Example: `deltashape = delta(ReferencePoint=[1 1])`

Data Types: `double`

#### `OuterRadius` — Outer radius of delta

`0.0016` (default) | positive scalar

Outer radius of the delta, specified as a positive scalar in meters.

Example: `shape = delta(OuterRadius=0.0024)`

Data Types: `double`

#### `InnerRadius` — Inner radius of delta

`0` (default) | nonnegative scalar

Inner radius of the delta, specified as a nonnegative scalar in meters. This value truncates the delta from the tip.

Example: `shape = delta(InnerRadius=0.3)`

Data Types: `double`

#### `Angle` — Angel of delta

`90` (default) | positive scalar

Angel of the delta shape, specified as a positive scalar in degrees. The value of the angle must be greater than 0 degrees and lesser than 180 degrees.

Example: `shape = delta(Angle=50)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Delta Shape

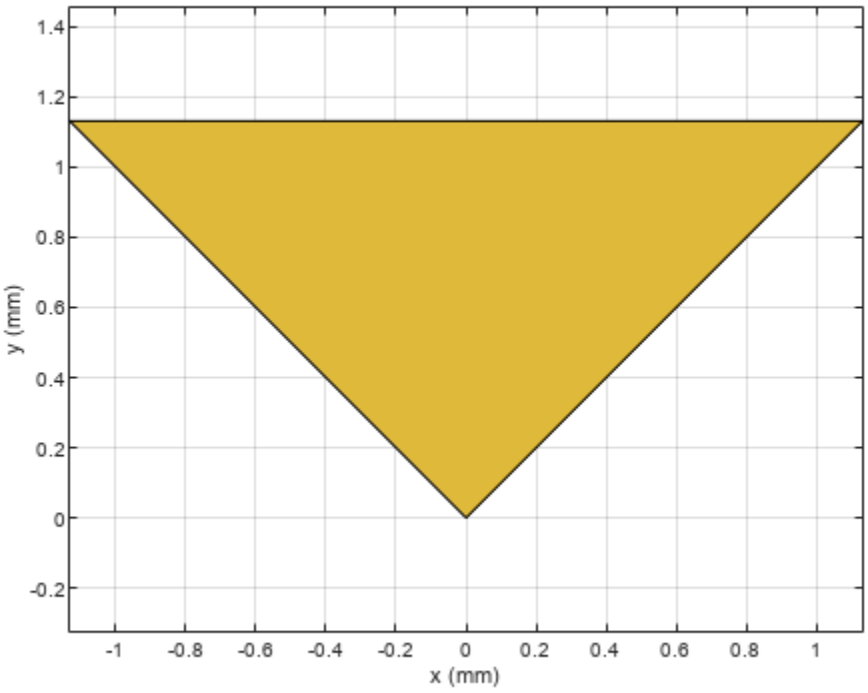
Create a delta shape with default properties.

```
deltashape = delta
```

```
deltashape =
  delta with properties:

              Name: 'mydelta'
    ReferencePoint: [0 0]
       OuterRadius: 0.0016
       InnerRadius: 0
             Angle: 90
```

View the shape.

```
show(deltashape)
```




## Version History

**Introduced in R2021b**

## See Also

`radial`

# radial

Create radial shape

## Description

Use the `radial` object to create a radial shape on the X-Y plane.

## Creation

### Syntax

```
radialshape = radial
radialshape = radial(Name=Value)
```

#### Description

`radialshape = radial` creates a radial shape on the X-Y plane.

`radialshape = radial(Name=Value)` sets "Properties" on page 1-179 using one or more name-value arguments. For example, `radial(ReferencePoint=[1 1])` creates a radial shape with the reference point at `[1 1]`. Properties not specified retain their default values.

### Properties

**`Name` — Name of radial shape**
`'myradial'` (default) | character vector | string scalar

Name of the radial shape, specified as a character vector or string scalar.

Example: `radialshape = radial(Name='radialShape')`

Data Types: `char` | `string`

**`ReferencePoint` — Reference point of radial shape**
`[0 0]` (default) | two-element vector

Reference point of radial shape, specified as a two-element vector of nonnegative elements in Cartesian coordinates. Use the reference point to modify the shape relative to its initial position.

Example: `radialshape = radial(ReferencePoint=[1 1])`

Data Types: `double`

**`OuterRadius` — Outer radius of radial**
`0.0016` (default) | positive scalar

Outer radius of the radial shape, specified as a positive scalar in meters.

Example: `radialshape = radial(OuterRadius=0.0024)`

Data Types: `double`

#### `InnerRadius` — Inner radius of radial

`0` (default) | positive scalar

Inner radius of the radial shape, specified as a positive scalar in meters. This value truncates the radial from the tip.

Example: `radialshape = radial(InnerRadius=0.4)`

Data Types: `double`

#### `Angle` — Angel of radial

`90` (default) | positive scalar

Angel of the radial shape, specified as a positive scalar in degrees. The value of the angle must be greater than 0 degrees and lesser than 180 degrees.

Example: `radialshape = radial(Angle=50)`

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Create Default Radial Shape

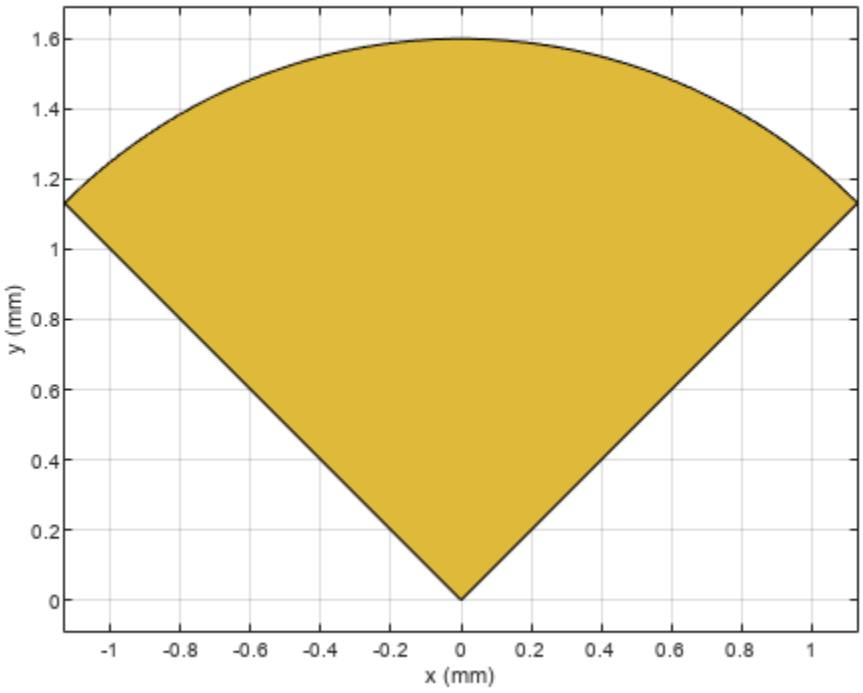
Create a radial shape with default properties.

```
radialshape = radial
```

```
radialshape =
  radial with properties:

              Name: 'myradial'
    ReferencePoint: [0 0]
       OuterRadius: 0.0016
       InnerRadius: 0
             Angle: 90
```

View the shape.

```
show(radialshape)
```




## Version History

**Introduced in R2021b**

## See Also

`delta`

# PCBConnectors

RF connector at RF PCB feedpoint

# Description

Use `PCBConnectors` object to specify RF connectors used for RF printed circuit board (PCB) feed points. The result is generally a set of modifications to the PCB design files. The changes to the PCB include new copper landing pads and traces, and changes to solder mask, silk screen, and solder paste files.

# Creation

## Syntax

```
c = PCBConnectors.connectorType
```

### Description

`c = PCBConnectors.connectorType` creates Gerber files based on the type of connector to use at the PCB feedpoint specified in `connectorType`.

### Input Arguments

#### `connectorType` — Type of connector from PCB connector package

character vector

Type of connector from PCB connector package, specified as one of the following:

- Coax Connectors - Coax RG11, RG174, RG58, and RG59 connectors directly soldered to PCB pads.
- IPX Connectors - LightHorse IPX SMT jack or plug surface mount RF connector.
- MMCX Connectors - MMCX Cinch or Samtec surface mount RF connectors.
- SMA Connectors - Generic 5-pad SMA surface mount RF connectors, with four corner rectangular pads, one round center pin. Cinch and Multicomp SMA RF connectors.
- SMAEdge Connectors- Generic SMA edge-launch surface mount RF connector. Cinch and Samtec SMA edge-launch RF connectors.
- SMB Connectors - Johnson/Emerson and Pasternack SMB surface mount RF connectors.
- SMC Connectors - Pasternack SMC and SMC edge-launch surface mount RF connectors.
- Coaxial Cable Connectors - Semi-rigid `0.020 inch`, `0.034 inch`, `0.047 inch`, and `0.118 inch` coaxial cable soldered to PCB pads.

For list of connectors, see “PCB Connectors List” on page 1-189.

Example: `c = PCBConnectors.Semi_020` creates Gerber files configured to use semi-rigid `0.020 inch` coaxial cables.

## Properties

**Common Properties for All Connectors**

### Type — Type of connector
character vector

This property is read-only.

Type of connector, specified as a character vector.

Example: `'Coax_RG11'`

Data Types: `char` | `string`

### Mfg — Name of component manufacturer
character vector

This property is read-only.

Name of component manufacturer, specified as a character vector.

Example: `'Belden'`

Data Types: `char` | `string`

### Part — Manufacturer part number
character vector | string

This property is read-only.

Manufacturer part number, specified as a character vector or string.

Example: `'RG11'`

Data Types: `char` | `string`

### Annotation — Text added to PCB to identify component
character vector

This property is read-only.

Text added to PCB to identify component, specified as a character vector.

Example: `'RG59U'`

Data Types: `char` | `string`

### Impedance — Connector impedance
`50` | positive scalar

This property is read-only.

Connector impedance, specified as a positive scalar in ohms.

Example: `c = PCBConnectors.MMCX_Cinch; c.Impedance = 70;`

Data Types: `double`

**`Datasheet` — URL for component specifications**
character vector

This property is read-only.

URL for component specifications, specified as a character vector. Data sheets are typically PDF files.

Data Types: `char` | `string`

**`Purchase` — URL for purchasing connector**
character vector

This property is read-only.

URL for purchasing connector, specified as a character vector.

Data Types: `char` | `string`

**Common Properties for All Coax Connectors**

**`PinDiameter` — Circular pad diameter**
positive scalar

Circular pad diameter connecting the signal wire of the coax to the feedpoint, specified as a positive scalar in meters. The pin diameter is greater than the diameter of the signal wire.

Example: `c = PCBConnectors.Coax_RG59; c.PinDiameter = 1.0000e-03;`

Data Types: `double`

**`DielectricDiameter` — Dielectric diameter**
positive scalar

Dielectric diameter (white material around signal wire), specified as a positive scalar in meters. Dielectric diameter specifies the size of the non-conductive isolation ring on the PCB between the signal wire and the ground plane.

Example: `c = PCBConnectors.Coax_RG59; c.DielectricDiameter = 0.0073;`

Data Types: `double`

**`ShieldDiameter` — Ground ring diameter**
positive scalar

Ground ring diameters used to solder coax shield, specified as a positive scalar in meters.

Example: `c = PCBConnectors.Coax_RG59; c.ShieldDiameter = 0.0085;`

Data Types: `double`

**`AddThermals` — Thermal relief**
`1` | `0`

Thermal relief around coaxial shield connection, specified as `0` or `1`. Thermal relief reduces the heat needed to solder the coax shield to the ground.

Example: `c = PCBConnectors.Coax_RG59; c.AddThermals = 0;`

Data Types: `logical`

**`ThermalsDiameter` — Arc-shaped gaps outer diameter**
positive scalar

Arc-shaped gaps outer diameter in the ground plane, specified as a positive scalar in meters.

Example: `c = PCBConnectors.Coax_RG59; c.ThermalsDiameter = 0.0100;`

Data Types: `double`

**`ThermalsBridgeWidth` — Width of four conductive bridges**
positive scalar

Width of four conductive bridges created across thermal gap, specified as a positive scalar in meters. The bridges are established during electrical grounding.

Example: `c = PCBConnectors.Coax_RG59; c.ThermalBridgeWidth = 0.0015;`

Data Types: `double`

**Common Properties for All 5-Pad Symmetric Surface Mount Connectors**

**`TotalSize` — Total length of each side of rectangular connector footprint**
two-element vector

Total length of each side of rectangular connector footprint, specified as a two-element vector with each element unit in meters.

Example: `c = PCBConnectors.SMA_Multicomp; c.TotalSize = [0.0063 0.0063];`

Data Types: `double`

**`GroundPadSize` — Length of each side of ground pad**
two-element vector

Length of each side of ground pad, specified as a two-element vector with each element unit in meters. The pads are located in each of the four corners of the connector footprint.

Example: `c = PCBConnectors.SMA_Multicomp; c.GroundPadSize = [0.0016 0.0016];`

Data Types: `double`

**`SignalPadDiameter` — Circular pad diameter**
positive scalar

Circular pad diameter connecting the signal pin of the coax connector, specified as a positive scalar in meters. The pad is at the center of the connector footprint.

Example: `c = PCBConnectors.SMA_Multicomp; c.SignalPadDiameter = 0.0012;`

Data Types: `double`

**`PinHoleDiameter` — Via pin diameter**
positive scalar

Via pin diameter, specified as a positive scalar in meters.

Example: `c = PCBConnectors.SMA_Multicomp; c.ViaPinDiameter = 0.0012;`

Data Types: `double`

**`IsolationRing` — Diameter of isolation ring that removes semicircle of copper from inner corner of ground pads**
scalar

Diameter of isolation ring that removes semicircle of copper from inner corner of ground pads, specified as a scalar in meters.

Example: `c = PCBConnectors.SMA_Multicomp; c.IsoltationRing = 0.0012;`

Data Types:

**`VerticalGroundStrips` — Vertical ground strips between upper and lower ground pads**
scalar

Vertical ground strips between upper and lower ground pads, specified as a scalar.

Example: `c = PCBConnectors.SMA_Multicomp; c.VerticalGroundStrips = 1;`

Data Types: `double`

**Common Properties for All Edge-Launch Surface Mount Connectors**

**`GroundPadSize` — Ground pad size**
two-element vector

Ground pad size, specified as a two-element vector with each element unit in meters.

Example: `c = PCBConnectors.SMAEdge; c.GroundPadSize = [0.0014 0.0042];`

Data Types: `double`

**`GroundSeparation` — Space between ground pads**
positive scalar

Space between ground pads on the ground side of the board, specified as a positive scalar in meters.

Example: `c = PCBConnectors.SMAEdge; c.GroundSeparation = 0.0043;`

Data Types: `double`

**`GroundPadIsolation` — Width of copper removed around top layer ground pads**
positive scalar

Width of copper removed around top layer ground pads, specified as a positive scalar in meters. This property isolates the ground pads from any signal traces or structures.

Example: `c = PCBConnectors.SMAEdge; c.GroundPadIsolation = 2.5000e-04;`

Data Types: `double`

**`SignalPadSize` — Signal pad size**
two-element vector

Signal pad size, specified as a two-element vector with each element unit in meters.

Example: `c = PCBConnectors.SMAEdge; c.SignalPadSize = [0.0013 0.0036];`

Data Types: `double`

**`SignalGap` — Gap between PCB edge and start of signal pad copper**
positive scalar

Gap between PCB edge and start of signal pad copper, specified as a positive scalar in meters.

Example: `c = PCBConnectors.SMAEdge; c.SignalGap = 1.0000e-04;`

Data Types: `double`

**`SignalLineWidth` — Width of signal trace**
positive scalar

Width of signal trace extending from the signal pad to the feedpoint location, specified as a positive scalar in meters.

Example: `c = PCBConnectors.SMAEdge; c.SignalLineWidth = 8.0000e-04;`

Data Types: `double`

**`EdgeLocation` — PCB side that receives edge connector**
`'north'` | `'south'` | `'east'` | `'west'`

PCB side that receives edge connector, specified as `'north'`, `'south'`, `'east'`, `'west'`.

Example: `c = PCBConnectors.SMAEdge; c.EdgeLocation = 'south';`

Data Types: `char`

**`EdgeBoardProfile` — Extend PCB to add connector beyond design area**
`0` | `1`

Extend PCB to add connector beyond design area, specified as `0` or `1`

Example: `c = PCBConnectors.SMAEdge; c.EdgeBoardProfile = 1;`

Data Types: `logical`

**`FillGroundSide` — Fill connector region on ground side of board with copper**
`0` | `1`

Fill connector region on ground side of the board with copper, specified as `0` or `1`

Example: `c = PCBConnectors.SMAEdge; c.FillGroundSide = 1;`

Data Types: `logical`

**Common Properties for All Staggered Surface Mount Connectors**

**`GroundPadSize` — Ground pad size**
two-element vector

Ground pad size, specified as a two-element vector with each element unit in meters.

Example: `c = PCBConnectors.IPX_Plug_Lighthorse; c.GroundPadSize = [0.0010 0.0022];`

Data Types: `double`

**`GroundPadXSeparation` — Distance between pair of ground pads along X-axis**
positive scalar

Distance between pair of ground pads along X-axis, specified as a positive scalar in meters.

Example: `c = PCBConnectors.IPX_Plug_Lighthorse; c.GroundPadXSeparation = 0.0019;`

Data Types: `double`

**`GroundPadYOffset` — Y-offset from signal pad to signal pad center line**
positive scalar

Y-offset from signal pad to signal pad center line, specified as a positive scalar in meters.

Example: `c = PCBConnectors.IPX_Plug_Lighthorse; c.GroundPadYOffset = 0.0015;`

Data Types: `double`

**`SignalPadSize` — Signal pad size**
2-element vector

Signal pad size, specified as a 2-element vector with each element unit in meters.

Example: `c = PCBConnectors.IPX_Plug_Lighthorse; c.SignalPadSize = [1.0000e-03 1.0000e-03];`

Data Types: `double`

**`SignalMinYSeparation` — Minimum separation from ground at bottom or top for signal pad**
positive scalar

Minimum separation from ground at bottom or top for signal pad, specified as a positive scalar in meters.

Example: `c = PCBConnectors.IPX_Plug_Lighthorse; c.SignalMinYSeparation = 1.0000e-03;`

Data Types: `double`

## Examples

### Authoring Custom RF Connector

This example shows how to define custom RF connector class.

```
classdef SMA_Jack_Cinch < PCBConnectors.BaseSMT5PadSymmetric
    % Cinch SMA surface mount RF connector.

    properties (Constant) % Abstract
        Type       = 'SMA'
        Mfg        = 'Cinch'
        Part       = '142-0701-631'
        Annotation = 'SMA'
        Impedance  = 50
        Datasheet  = 'http://www.farnell.com/datasheets/1720451.pdf?_ga=2.164811836.2075200750.14
        Purchase   = 'http://www.newark.com/johnson/142-0701-631/rf-coaxial-sma-jack-straight-50/
    end

    methods
        function RFC = SMA_Jack_Cinch
            RFC.TotalSize           = [0.5 0.5]*25.4e-3;
            RFC.GroundPadSize       = [0.102 0.102]*25.4e-3;
            RFC.SignalPadDiameter   = 0.1*25.4e-3;
            RFC.PinHoleDiameter     = 1.27e-3;
```

```
            RFC.IsolationRing       = 0.22*25.4e-3;
            RFC.VerticalGroundStrips = false;
        end
    end
end
```

### Generate Gerber Format Files for PCB Component

Create a PCB component with default values.

```
p = pcbComponent;
```

Use 2 Cinch SMA connectors and the Mayhew Labs PCB viewer.

```
W = PCBServices.MayhewWriter;
C1 = PCBConnectors.SMA_Cinch;
C2 = PCBConnectors.SMA_Cinch;
```

Generate the Gerber-format files.

```
[A,g] = gerberWrite(p,W,{C1,C2})
```

```
A =
  PCBWriter with properties:

                      Design: [1x1 struct]
                      Writer: [1x1 PCBServices.MayhewWriter]
                   Connector: {[1x1 PCBConnectors.SMA_Cinch]  [1x1 PCBConnectors.SMA_Cinch]}
           UseDefaultConnector: 0
    ComponentBoundaryLineWidth: 8
         ComponentNameFontSize: []
            DesignInfoFontSize: []
                        Font: 'Arial'
                   PCBMargin: 5.0000e-04
                  Soldermask: 'both'
                 Solderpaste: 1

   See info for details

g =
'C:\TEMP\Bdoc23a_2213998_3568\ib570499\29\tpee34cbcd\rfpcb-ex06685827\untitled'
```

## More About

### PCB Connectors List

| PCB Connectors | Descriptions |
|---|---|
| PCBConnectors.Coax_RG11 | RG11 coaxial cable direct soldered to PCB pads. |
| PCBConnectors.Coax_RG58 | RG58 coaxial cable direct soldered to PCB pads. |
| PCBConnectors.Coax_RG59 | RG59 coaxial cable direct soldered to PCB pads. |
| PCBConnectors.Coax_RG174 | RG174 coaxial cable direct soldered to PCB pads. |

| PCB Connectors | Descriptions |
|---|---|
| PCBConnectors.SMA | Generic 5-pad SMA surface mount RF connector, with four corner rectangular ground pads, one round. |
| PCBConnectors.SMAEdge | Generic SMA edge-launch surface mount RF connector. |
| PCBConnectors.SMACinch | Cinch SMA surface mount RF connector |
| PCBConnectors.SMAEdge_Cinch | Cinch SMA edge-launch surface mount RF connector |
| PCBConnectors.SMAEdge_Samtec | Samtec SMA edge-launch surface mount RF connector |
| PCBConnectors.SMAEdge_Amphenol | Amphenol SMA edge-launch surface mount RF connector |
| PCBConnectors.SMAEdge_Linx | Linx SMA edge-launch surface mount RF connector |
| PCBConnectors.SMA_Multicomp | Multicomp SMA surface mount RF connector |
| PCBConnectors.SMB_Johnson | Johnson/Emerson SMB surface mount RF connector |
| PCBConnectors.SMB_Pasternack | Pasternack SMB surface mount RF connector |
| PCBConnectors.SMC_Pasternack | Pasternack SMC surface mount RF connector |
| PCBConnectors.SMCEdge_Pasternack | Pasternack SMC edge-launch surface mount RF connector |
| PCBConnectors.MMCX_Cinch | Cinch MMCX surface mount RF connector |
| PCBConnectors.MMCX_Samtec | Samtec MMCX surface mount RF connector |
| PCBConnectors.IPX_Jack_LightHorse | LightHorse IPX SMT jack surface mount RF connector |
| PCBConnectors.IPX_Plug_LightHorse | LightHorse IPX SMT plug surface mount RF connector |
| PCBConnectors.UFL_Hirose | Hirose u.fl surface mount RF connector |
| PCBConnectors.Semi_020 | Pasternack semi-rigid 0.020" coaxial cable soldered to PCB pads |
| PCBConnectors.Semi_034 | Pasternack semi-rigid 0.020" coaxial cable soldered to PCB pads |
| PCBConnectors.Semi_047 | Pasternack semi-rigid 0.047" coaxial cable soldered to PCB pads |
| PCBConnectors.Semi_118 | Pasternack semi-rigid 0.118" coaxial cable soldered to PCB pads |

## Version History

**Introduced in R2021b**

## See Also

`PCBWriter` | `PCBServices` | `gerberWrite`

# PCBReader

Import and update Gerber files

## Description

Use the `PCBReader` object to create a printed circuit board (PCB) reader to import Gerber files and to facilitate the creation of a PCB model. A Gerber file is a set of manufacturing files used to describe a PCB. A Gerber file uses an ASCII vector format to describe 2-D binary images.

## Creation

You can create a `PCBReader` object using the following methods:

- `gerberRead` — Create a `PCBReader` object with the specified Gerber and drill files.
- The `PCBReader` function described here.

### Syntax

```
B = PCBReader(S)
B = PCBReader(Name=Value)
```

#### Description

`B = PCBReader(S)` creates a `PCBReader` object that imports multilayer PCB design files described in `S`.

**Note**

- To translate the center of an imported symmetrical or asymmetrical polygon to `[0,0]`, please use one of the following MATLAB® functions: `boundingbox` and `centroid`. See examples, “Translate Center of Imported Symmetrical Polygon to [0,0]” on page 1-194 and “Translate Center of Imported Asymmetrical Polygon to [0,0]” on page 1-196.
- The `PCBReader` object reads RS-274X Gerber files. It does not support RS-274D Gerber files.

`B = PCBReader(Name=Value)` sets “Properties” on page 1-193 using name-value arguments. `Name` is the property name and `Value` is the corresponding value. You can specify several name-value pair arguments in any order as Name1,Value1,...,NameN,ValueN. Properties not specified retain their default values. For example, `B = PCBReader('StackUp',S,'Drillfile','ant.txt')` imports the layer and drill files into the `PCBReader`.

#### Input Arguments

**S — PCB stackup definition**
`stackUp` object

PCB stackup definition, specified as a `stackUp` object.

Example: `S = stackUp; B = PCBReader(S)`

Example: `B = PCBReader('StackUp',S)`

## Properties

### `StackUp` — PCB stackup definition

`stackUp` object

PCB stackup definition, specified as a `stackUp` object.

Example: `S = stackUp; B.StackUp = S;`

Example: `B = PCBReader('StackUp',S)`

### `DrillFile` — Name of Excellon drill file

[ ] (default) | character vector | string scalar

Name of Excellon drill file, specified as a character vector or string scalar. You can specify either a DRL or a TXT file.

Example: `B.DrillFile = 'ant.drl'`

### `NumPointsOnCurves` — Discretization points on curved segments

`50` (default) | positive scalar

Discretization points on curved segments, specified as a positive scalar.

Example: `B.NumPointsOnCurves = 80`

## Examples

### Import Gerber Files Using Stackup Definition

Create a PCB stack up definition object using default properties.

```
S = stackUp;
```

Set the thickness of the dielectric Air in layer 1 to 0.1 mm.

```
S.Layer1.Thickness = 0.1e-3;
```

Import a top layer Gerber file to layer 2.

```
S.Layer2 = 'interdigital_Capacitor.gtl';
```

Create a `PCBReader` object using the `stackUp` object, `S`.

```
p = PCBReader('StackUp',S);
```

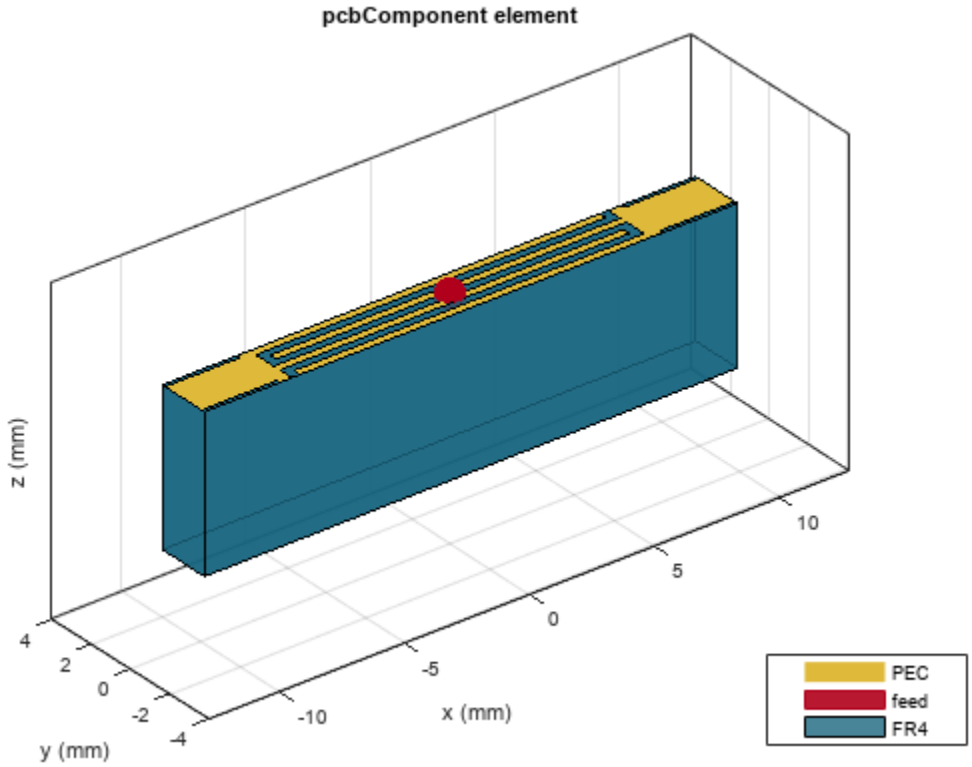
To update the Gerber file, convert the `PCBReader` object to a `pcbComponent` object.

```
pcbcapacitor = pcbComponent(p);
pcbcapacitor.FeedDiameter = 0.001
```

```
pcbcapacitor =
  pcbComponent with properties:

             Name: 'interdigital_Capacitor'
         Revision: 'v1.0'
       BoardShape: [1x1 antenna.Rectangle]
    BoardThickness: 0.0061
           Layers: {[1x1 dielectric]  [1x1 antenna.Polygon]  [1x1 dielectric]  [1x1 dielectric]}
     FeedLocations: [0 0 2]
      FeedDiameter: 1.0000e-03
      ViaLocations: []
       ViaDiameter: []
      FeedViaModel: 'square'
         Conductor: [1x1 metal]
              Tilt: 0
          TiltAxis: [0 0 1]
              Load: [1x1 lumpedElement]
```

View the PCB component in the Gerber file.

```
show(pcbcapacitor)
```



### Translate Center of Imported Symmetrical Polygon to [0,0]

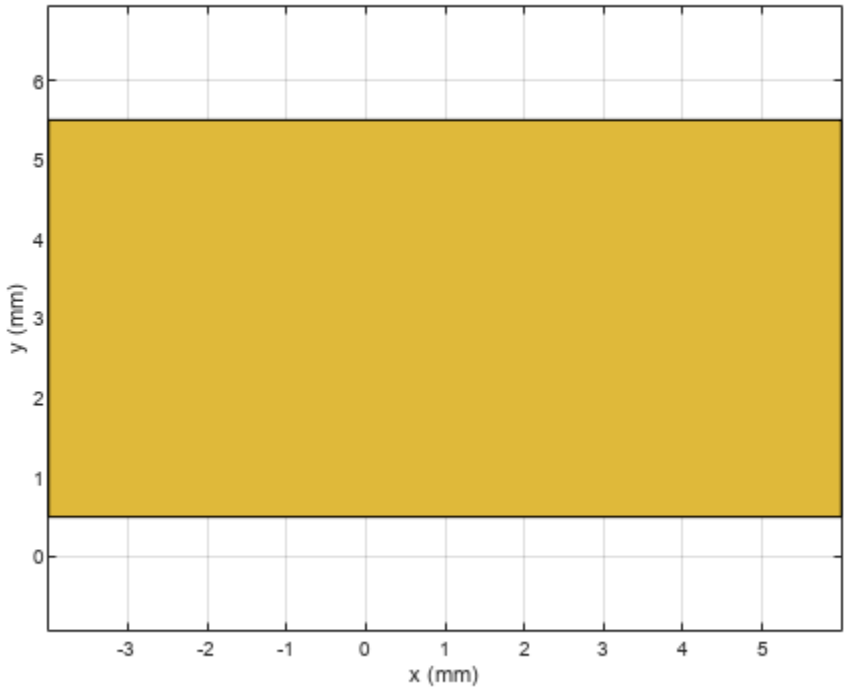
This example will show how to translate the symmetrical polygon imported from the Gerber file to the respective co-ordinates.

Create a PCB stackup and import rectangular patch on it.

```
S = stackUp;
S.Layer2 = 'PatchRectangular.gtl';
S.Layer3 = dielectric('Teflon');
```

Use a PCB Reader to read the polygon shape from the stackup.

```
p1 = PCBReader ('StackUp',S);
figure; show(p1.shapes);
```

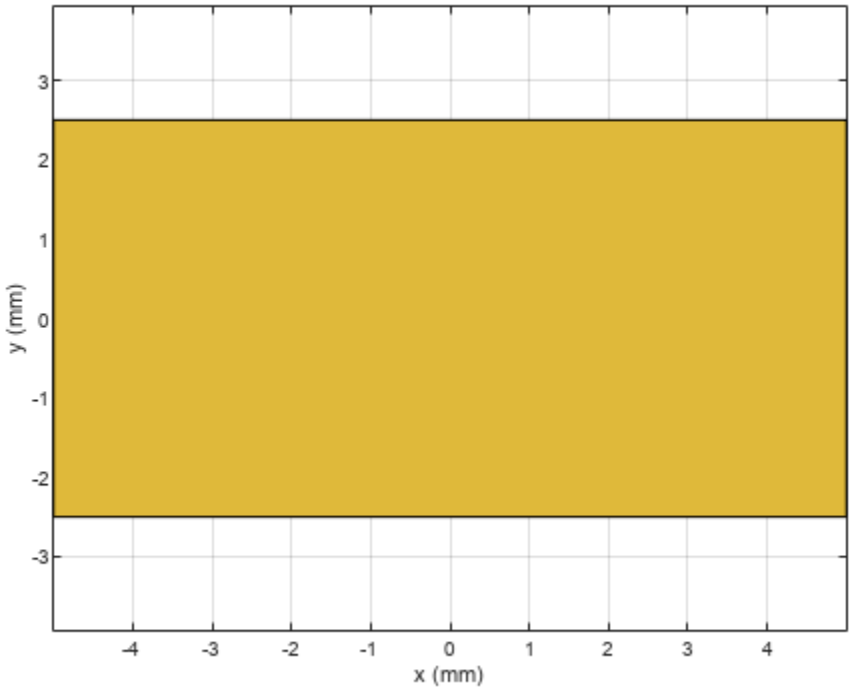



Translate the shape with center (0,0) using the `centriod` function from MATLAB.

```
s = p1.shapes
```

```
s =
  Polygon with properties:

        Name: 'mypolygon'
    Vertices: [4x3 double]
```

```
polygon = s;
[x,y] = centroid(polygon);
translate(polygon,[-x, -y, 0]);
```




### Translate Center of Imported Asymmetrical Polygon to [0,0]

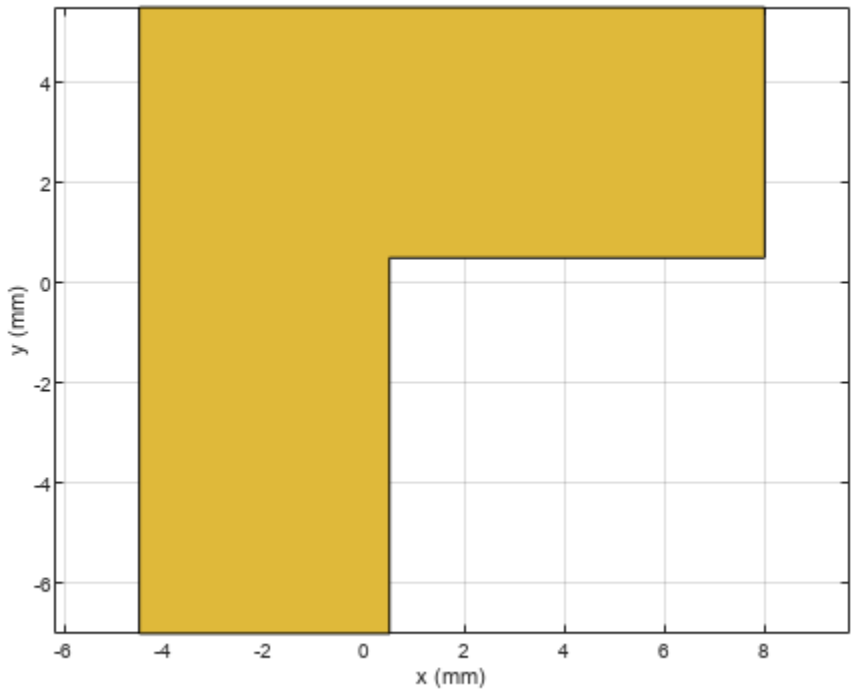
This example shows how to translate the asymmetrical polygon imported from the Gerber file to the respective co-ordinates.

Create a PCB stackup and import rectangular patch on it.

```
S = stackUp;
S.Layer2 = 'RightAngleBend.gtl';
S.Layer3 = dielectric('Teflon');
```

Use a PCB Reader to read the polygon shape from the stackup.

```
p1 = PCBReader ('StackUp',S);
figure; show(p1.shapes);
```

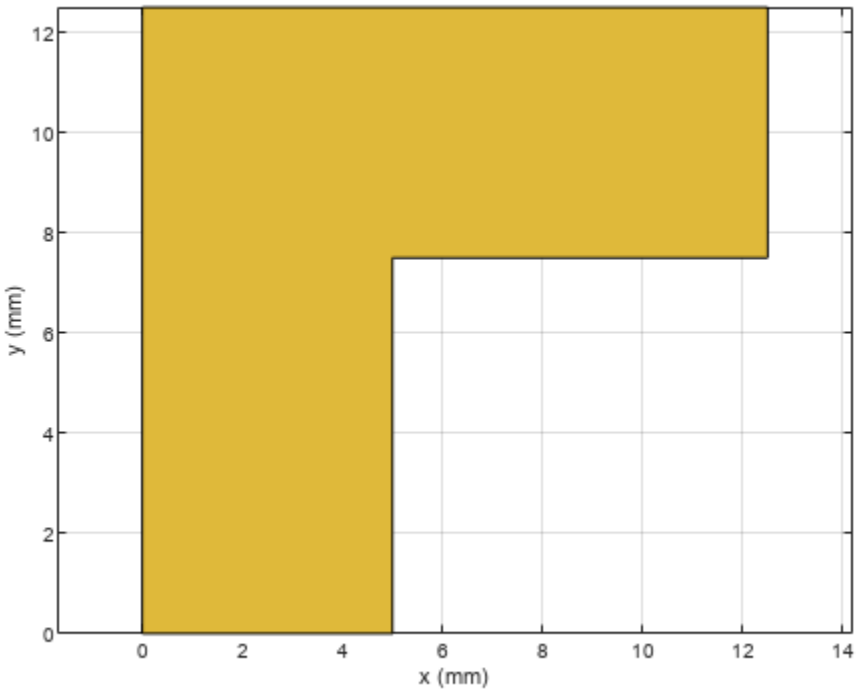



Translate the shape's bottom left corner to (0,0). Use the boundingbox function from MATLAB to convert the shape to polyshape and find the upper and lower bounds of the shape.

```
s = p1.shapes
```

```
s =
  Polygon with properties:

        Name: 'mypolygon'
    Vertices: [6x3 double]
```

```
ver = s.Vertices(:,1:2);
polygon = polyshape(ver);
[xlim, ylim] = boundingbox(polygon);
translate(s,[-xlim(1), -ylim(1), 0]);
```




## Version History

**Introduced in R2021b**

## See Also

`PCBWriter` | `PCBServices` | `PCBConnectors` | `stackUp` | `gerberRead`

# PCBServices

Customize PCB file generation for PCB manufacturing service

# Description

Use the `PCBServices` object to customize printed circuit board (PCB) file generation for a PCB manufacturing service.

# Creation

## Syntax

```
w = PCBServices.serviceType
```

### Description

`w = PCBServices.serviceType` creates a Gerber file based on the type of service specified in `serviceType`.

### Input Arguments

**`serviceType` — Type of service from PCB services package**
character vector

Type of service from PCB services package, specified as one of the following:

- AdvancedCircuitsWriter – Configure Gerber file generation for Advanced Circuits manufacturing.
- CircuitPeopleWriter – Configure Gerber file generation for CircuitPeople online viewer.
- DirtyPCBsWriter – Configure Gerber file generation for Dirty PCBs manufacturing.
- EuroCircuitsWriter – Configure Gerber file generation for EuroCircuits online viewer.
- GerberLookWriter – Configure Gerber file generation for GerbLook online viewer.
- GerberViewerWriter – Configure Gerber file generation for GerberViewer online viewer.
- MayhewWriter – Configure Gerber file generation for Mayhew Labs online 3-D viewer.
- OSHParkWriter – Configure Gerber file generation for OSH Park PCB manufacturing.
- PCBWayWriter – Configure Gerber file generation for PCBWay PCB manufacturing.
- ParagonWriter – Configure Gerber file generation for Paragon Robotics online viewer.
- SeeedWriter – Configure Gerber file generation for Seeed Fusion PCB manufacturing.
- SunstoneWriter – Configure Gerber file generation for Sunstone PCB manufacturing.
- ZofzWriter – Configure Gerber file generation for Zofz 3-D viewer.

Example: `w = PCBServices.SunstoneWriter` creates Gerber files configured to use Sunstone PCB manufacturing service.

### Output Arguments

**`w` — PCB manufacturing service**
object

PCB manufacturing service, returned as an object.

## Properties

**`BoardProfileFile` — File type for board profile**
`'legend'` | `'profile'`

File type for board profile, specified as `'legend'` or `'profile'`.

Example: `w = PCBServices.SunstoneWriter; w.BoardProfileFile = 'profile'.`

Data Types: `char` | `string`

**`BoardProfileLineWidth` — Width of line**
`1` | positive scalar

Width of line, specified as a positive scalar in mils.

PCB manufacturers vary on board profile. The most common line width is zero of a fraction width in the chosen unit, for example, 0.1 mil.

Example: `w = PCBServices.SunstoneWriter; w.BoardProfileLineWidth = 0.1`

Data Types: `double`

**`CoordPrecision` — Precision of X and Y coordinates written to file**
`[2 6]` | 1-by-2 vector

Precision of X and Y coordinates written to file, specified as a 1-by2 vector [*I F*], where,

- *I* – Number of digits in the integer part, 0<=*I*<=6.
- *F* – Number of digits in the fractional part, 4<=*F*<=6.

Example: `w = PCBServices.SunstoneWriter; w.CoordPrecision = [1 3]`

Data Types: `double`

**`CoordUnits` — Units of X and Y coordinate**
`'in'` | `'mm'`

Units of X and Y coordinates, specified as inches or millimeters.

Example: `w = PCBServices.SunstoneWriter; w.CoordUnits = 'mm'`

Data Types: `char` | `string`

**`CreateArchiveFile` — Creates single archive file with all Gerber files**
`1` (default) | `0`

Creates single archive file with all Gerber files, specified as `1` or `0`.

Example: `w = PCBServices.SunstoneWriter; w.CreateArchiveFile = 0`

Data Types: `logical`

**`DefaultViaDiameter` — Via drill diameter**
`3.0000e-04` | positive scalar

Via drill diameter, specified as a positive scalar in meters. PCB manufacturers also call it minimum drilling hole diameter.

Example: `w = PCBServices.SunstoneWriter; w.DefaultViaDiameter = 0.1`

Data Types: `double`

**`DrawArcsUsingLines` — Force arcs to be drawn using lines**
`0` | `1`

Force arcs to be drawn using lines, specified as `1` or `0`.

Example: `w = PCBServices.SunstoneWriter; w.DrawArcsUsingLines = 0`

Data Types: `logical`

**`ExtensionLevel` — Feature content for Gerber file format**
`1` (default) | `2`

Feature content for Gerber file format, specified as:

- `1` - Extension 1 is the most compatible setting for downstream PCB manufacturing tools.
- `2` - Extension 2 adds file attributes `%TF.<attr>*%"` to the header and footer of Gerber files.

Example: `w = PCBServices.SunstoneWriter; w.ExtensionLevel = 2`

Data Types: `double`

**`Filename` — Name of all files containing Gerber design**
`'untitled'` (default) | character vector

Name of all files containing Gerber design, specified as a character vector.

Example: `w = PCBServices.SunstoneWriter; w.Filename = 'pcb_design'.`

Data Types: `char` | `string`

**`Files` — Define stack of PCB files**
character vector

Define stack of PCB files, specified as a character vector. This definition includes:

- Multiples files describing one PCB.
- A "file" as a memory object containing buffers that describe or hold the file content before the file is written.
- Cell vector of `Gerber.FileFunction` objects, one per file.

Data Types: `cell` | `char` | `string`

**`IncludeRootFolderInZip` — Include top-level folder in zip archive**
`1` | `0`

Include top-level folder in zip archive, specified as `1` or `0`.

Example: `w = PCBServices.SunstoneWriter; w.IncludeRootFolderInZip = 0`

Data Types: `logical`

**`PostWriteFcn` — Function to invoke after a successful write operation**
function handle (default)

Function to invoke after a successful write operation, specified as a function handle. In this case, it is the `sendTo` function. This property makes sure that the location of the Gerber files and the website of the manufacturing service is open after a successful write function.

Example: `w = PCBServices.SunstoneWriter; w.PostWriteFcn = @(obj)sendTo(obj)`

Data Types: `function_handle`

**`SameExtensionForGerberFiles` — Use `.gbr` to be file extension for all Gerber files**
`0 | 1`

Use `.gbr` to be file extension for all Gerber files, specified as `0` or `1`.

Example: `w = PCBServices.SunstoneWriter; w.SameExtensionForGerberFiles = 1`

Data Types: `logical`

**`UseExcellon` — Generate Excellon drill files**
`1 | 0`

Generate Excellon drill files, specified as `0` or `1`.

Example: `w = PCBServices.SunstoneWriter; w.UseExcellon = 1`, generates Gerber format drill files with `'x2'` extension.

Data Types: `logical`

## Examples

### Generate Gerber Format Files for PCB Component

Create a PCB component with default values.

```
p = pcbComponent;
```

Use 2 Cinch SMA connectors and the Mayhew Labs PCB viewer.

```
W = PCBServices.MayhewWriter;
C1 = PCBConnectors.SMA_Cinch;
C2 = PCBConnectors.SMA_Cinch;
```

Generate the Gerber-format files.

```
[A,g] = gerberWrite(p,W,{C1,C2})
```

```
A =
  PCBWriter with properties:

                      Design: [1x1 struct]
                      Writer: [1x1 PCBServices.MayhewWriter]
                   Connector: {[1x1 PCBConnectors.SMA_Cinch]  [1x1 PCBConnectors.SMA_Cinch]}
          UseDefaultConnector: 0
    ComponentBoundaryLineWidth: 8
```

```
         ComponentNameFontSize: []
            DesignInfoFontSize: []
                          Font: 'Arial'
                     PCBMargin: 5.0000e-04
                    Soldermask: 'both'
                   Solderpaste: 1

   See info for details

g =
'C:\TEMP\Bdoc23a_2213998_3568\ib570499\29\tpee34cbcd\rfpcb-ex06685827\untitled'
```

# Version History

**Introduced in R2021b**

## See Also

PCBWriter | PCBConnectors | gerberWrite

# PCBWriter

Create PCB board definitions from 2-D PCB designs

# Description

Use the `PCBWriter` object to create a printed circuit board (PCB) design files based on multilayer 2-D PCB design. A set of manufacturing files known as Gerber files describes a PCB. A Gerber file uses an ASCII vector format for 2-D binary images.

# Creation

## Syntax

```
b = PCBWriter(pcbcomponentObject)
b = PCBWriter(pcbcomponentObject,rfConnector)
b = PCBWriter(pcbcomponentObject,writer)
b = PCBWriter(pcbcomponentObject,rfConnector,writer)
```

### Description

`b = PCBWriter(pcbcomponentObject)` creates a `PCBWriter` object that generates Gerber-format PCB design files based on a 2-D PCB design geometry using PCB stack.

`b = PCBWriter(pcbcomponentObject,rfConnector)` creates a customized PCB file using specified `rfConnector` type.

`b = PCBWriter(pcbcomponentObject,writer)` creates a customized PCB file using a specified PCB service, `writer`.

`b = PCBWriter(pcbcomponentObject,rfConnector,writer)` creates customised PCB file using specified PCB service and PCB connector type.

### Input Arguments

**`pcbcomponentObject` — Single feed PCB**
`pcbComponent` object

Single feed PCB, specified as a `pcbComponent` object.

Example: `p1 = pcbComponent` creates a PCB component object, `p1` . `a = PCBWriter(p1)` uses `p1` to create a `PCBWriter` object `a`.

**`writer` — PCB service to view PCB design**
`PCBServices` object

PCB service to view PCB design, specified as a `PCBServices` object.

Example: `s = PCBServices.MayhewWriter; a = PCBWriter(p1,s)` uses Mayhew Labs PCB service to view the PCB design.

**`rfConnector` — RF connector type**
`PCBConnectors` object

RF connector type for PCB feedpoint, specified as a `PCBConnectors` object.

Example: `c = PCBConnectors.SMA_Cinch; a = PCBWriter(p1,c)` uses SMA_Cinch RF connector at feedpoint.

## Properties

**`UseDefaultConnector` — Use default connector**
`1` (default) | `0`

Use default connector, specified as `0` or `1`.

Example: `a.UseDefaultConnector = 1`, where `a` is a `PCBWriter` object.

Data Types: `logical`

**`ComponentBoundaryLineWidth` — Line widths drawn around components on silk screens**
`8` (default) | positive scalar

Line widths drawn around components on silk screens, specified as a positive scalar in mils.

Example: `a.ComponentBoundaryLineWidth = 10`, where `a` is a `PCBWriter` object.

Data Types: `double`

**`ComponentNameFontSize` — Font size to label components on silk screen**
positive scalar

Font size to label components on silk screen, specified as a positive scalar in points.

Example: `a.ComponentNameFontSize = 12`, where `a` is a `PCBWriter` object.

Data Types: `double`

**`DesignInfoFontSize` — Font size for design informzation added outside board profile**
positive scalar

Design information text font size added outside board profile, specified as a positive scalar.

Example: `a.DesignInfoFontSize = 12`, where `a` is a `PCBWriter` object.

Data Types: `double`

**`Font` — Font used for component name and design info**
`'Arial'` (default) | character vector

Font used for component name and design info, specified as a character vector.

Example: `a.Font = 'TimesNewRoman'`, where `a` is a `PCBWriter` object.

Data Types: `char` | `string`

**`PCBMargin` — Copper free margin around board**
`0.5e-3` (default) | positive scalar

Copper free margin around board, specified as a positive scalar in meters.

Example: `a.PCBMargin = 0.7e-3`, where `a` is a `PCBWriter` object.

Data Types: `double`

**`SolderMask` — Add solder mask to top and bottom of PCB**
`'both'` (default) | `'top'` | `'bottom'` | `'none'`

Add solder mask to top and bottom of PCB, specified as `'both'`, `'top'`, `'bottom'` or `'none'`.

Example: `a.SolderMask = 'top'`, where `a` is a `PCBWriter` object.

Data Types: `char` | `string`

**`SolderPaste` — Generate solder paste files**
`1` (default) | `0`

Generate solder paste files as a part of PCB stack, specified as `1` or `0`.

Example: `a.SolderPaste = 0`, where `a` is a `PCBWriter` object.

Data Types: `logical`

## Object Functions

gerberWrite Generate Gerber files

## Examples

### Create PCB Component Design File Using Mayhew Manufacturing Services

Create a coplanar waveguide.

```
cpw = coplanarWaveguide
```

```
cpw =
  coplanarWaveguide with properties:

              Length: 0.0231
               Width: 0.0039
             Spacing: 2.0000e-04
          ViaSpacing: [0.0011 0.0070]
         ViaDiameter: 5.0000e-04
              Height: 0.0016
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

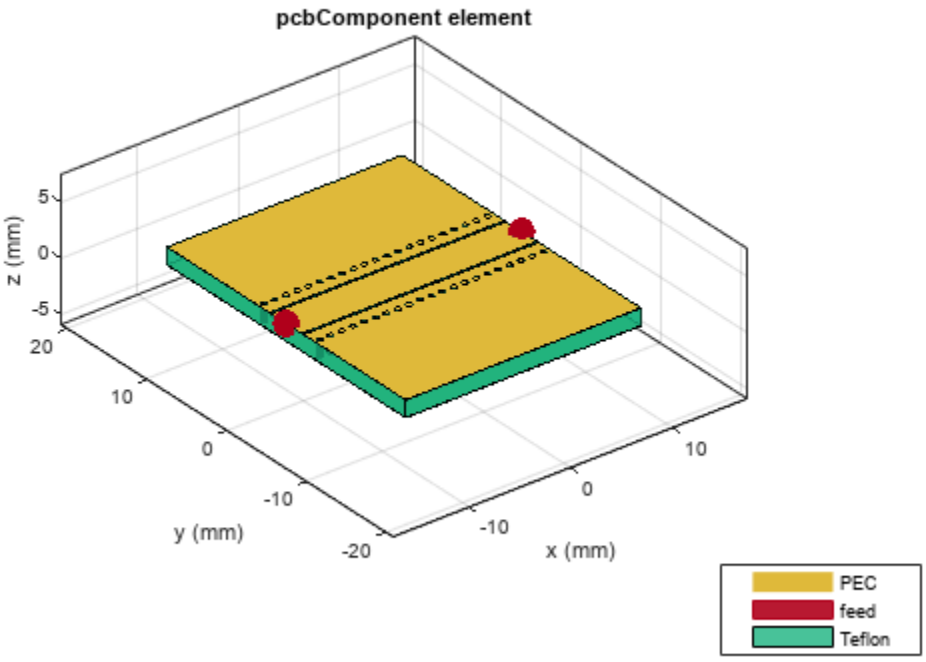
Use this waveguide to create a `pcbComponent` object.

```
p = pcbComponent(cpw);
p.Name = 'Coplanar Waveguide'
```

```
p =
  pcbComponent with properties:

              Name: 'Coplanar Waveguide'
          Revision: 'v1.0'
```

```
        BoardShape: [1x1 antenna.Rectangle]
    BoardThickness: 0.0016
            Layers: {[1x1 antenna.Polygon]  [1x1 dielectric]  [1x1 antenna.Rectangle]}
     FeedLocations: [2x4 double]
      FeedDiameter: 0.0019
      ViaLocations: [42x4 double]
       ViaDiameter: 5.0000e-04
      FeedViaModel: 'strip'
         Conductor: [1x1 metal]
              Tilt: 0
          TiltAxis: [0 0 1]
              Load: [1x1 lumpedElement]
```

```
show(p)
```




Use an SMA_Cinch as an RF connector and Mayhew Writer as a 3-D viewer.

```
c = PCBConnectors.SMA_Cinch
```

```
c =
  SMA_Cinch with properties:

                  Type: 'SMA'
                   Mfg: 'Cinch'
                  Part: '142-0711-202'
            Annotation: 'SMA'
             Impedance: 50
```

```
               Datasheet: 'https://belfuse.com/resources/Johnson/drawings/dr-142-0711-202.pdf'
                Purchase: 'https://www.digikey.com/product-detail/en/cinch-connectivity-solutions
               TotalSize: [0.0071 0.0071]
           GroundPadSize: [0.0024 0.0024]
       SignalPadDiameter: 0.0017
         PinHoleDiameter: 0.0013
           IsolationRing: 0.0041
    VerticalGroundStrips: 1

   Cinch 142-0711-202 (Example Purchase)
```

```
s = PCBServices.MayhewWriter
```

```
s =
  MayhewWriter with properties:

               BoardProfileFile: 'legend'
         BoardProfileLineWidth: 1
                CoordPrecision: [2 6]
                    CoordUnits: 'in'
              CreateArchiveFile: 0
                 DefaultViaDiam: 3.0000e-04
             DrawArcsUsingLines: 1
                 ExtensionLevel: 1
                       Filename: 'untitled'
                          Files: {}
        IncludeRootFolderInZip: 0
                   PostWriteFcn: @(obj)sendTo(obj)
    SameExtensionForGerberFiles: 0
                   UseExcellon: 1
```

Create a PCB component design file.

```
PW = PCBWriter(p,s,c)
```

```
PW =
  PCBWriter with properties:

                       Design: [1x1 struct]
                       Writer: [1x1 PCBServices.MayhewWriter]
                    Connector: {[1x1 PCBConnectors.SMA_Cinch]  [1x1 PCBConnectors.SMA_Cinch]}
          UseDefaultConnector: 0
    ComponentBoundaryLineWidth: 8
         ComponentNameFontSize: []
            DesignInfoFontSize: []
                          Font: 'Arial'
                     PCBMargin: 5.0000e-04
                    Soldermask: 'both'
                   Solderpaste: 1

   See info for details
```

# Version History

**Introduced in R2021b**

## See Also

`PCBServices` | `PCBConnectors`

# stackUp

Create PCB stackup definition

# Description

Use the `stackUp` object to create a printed circuit board (PCB) stackup definition to import Gerber files. A Gerber file is a set of manufacturing files used to describe a PCB. A Gerber file uses an ASCII vector format for 2-D binary images.

# Creation

## Syntax

```
s = stackUp
```

### Description

`s = stackUp` creates a default PCB stackup object with five layers. Specify Gerber files as inputs to the second and fourth layers. Specify dielectric material objects as inputs to layers one, three, and five.

## Properties

**`NumLayers` — Number of layers in stackup**
5 (default) | positive scalar

This property is read-only.

Number of layers in the stackup, returned as a positive scalar.

**`Layer1` — First layer in stackup**
`'Air'` (default) | `dielectric` object

First layer in the stackup definition object, specified as a `dielectric` object.

Example: `s = stackUp; d = dielectric('RO4725JXR'); s.Layer1 = d;`

**`Layer2` — Second layer in stackup**
character vector | string scalar

Second layer in the stackup definition object, specified as a character vector or string. The file should be saved as a GTL, GBL, or GBR file.

Example: `s = stackUp; s.Layer2 = 'antenna_design_file.gtl';`

**Note** The Gerber file must be imported to the MATLAB workspace before setting this property.

### Layer3 — Third layer in stackup

`'FR4'` (default) | `dielectric` object

Third layer in the stackup definition object, specified as a `dielectric` object.

Example: `s = stackUp; d = dielectric('RO4725JXR'); s.Layer3 = d;`

### Layer4 — Fourth layer in stackup

character vector | string scalar

Fourth layer in the stackup definition object, specified as a character vector or string. The file should be saved as a GTL, GBL, or GBR file.

Example: `s = stackUp; s.Layer4 = 'antenna_design_file.gbl';`

**Note** The Gerber file must be imported to the MATLAB workspace before setting this property.

### Layer5 — Fifth layer in stackup

`'Air'` (default) | `dielectric` object

Fifth layer in the stackup definition object, specified as a `dielectric` object.

Example: `s = stackUp; d = dielectric('RO4725JXR'); s.Layer5 = d;`

## Examples

### Import Gerber Files Using Stackup Definition

Create a PCB stack up definition object using default properties.

```
S = stackUp;
```

Set the thickness of the dielectric Air in layer 1 to 0.1 mm.

```
S.Layer1.Thickness = 0.1e-3;
```

Import a top layer Gerber file to layer 2.

```
S.Layer2 = 'interdigital_Capacitor.gtl';
```

Create a `PCBReader` object using the `stackUp` object, `S`.

```
p = PCBReader('StackUp',S);
```

To update the Gerber file, convert the `PCBReader` object to a `pcbComponent` object.

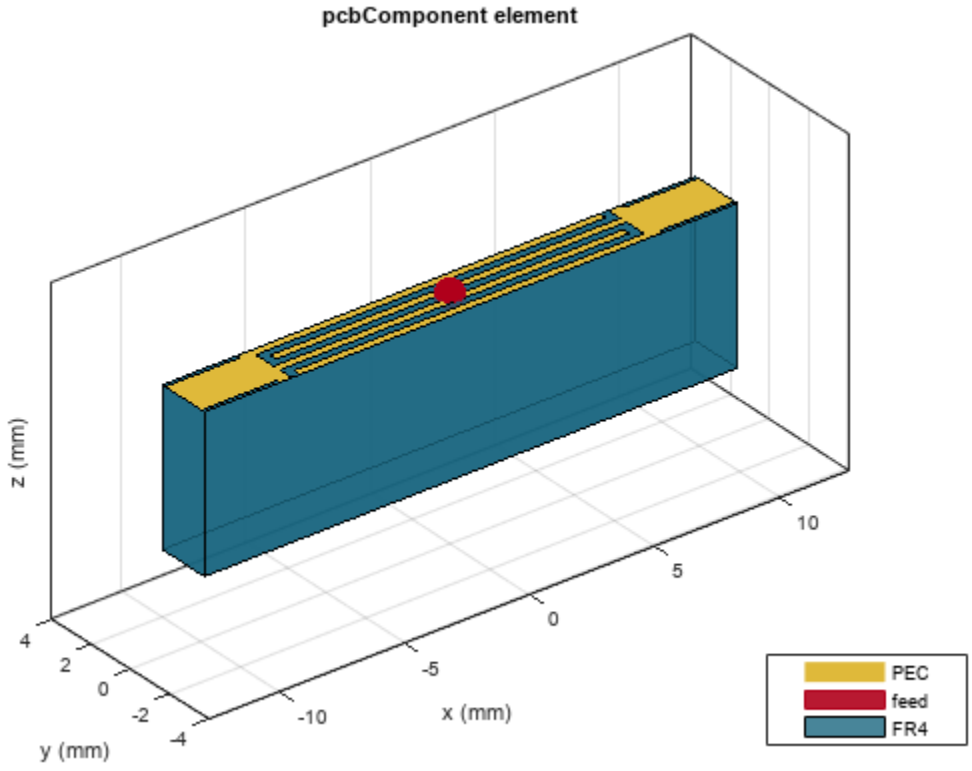
```
pcbcapacitor = pcbComponent(p);
pcbcapacitor.FeedDiameter = 0.001
```

```
pcbcapacitor =
  pcbComponent with properties:

              Name: 'interdigital_Capacitor'
          Revision: 'v1.0'
        BoardShape: [1x1 antenna.Rectangle]
```

```
BoardThickness: 0.0061
        Layers: {[1x1 dielectric]  [1x1 antenna.Polygon]  [1x1 dielectric]  [1x1 dielectric]}
 FeedLocations: [0 0 2]
  FeedDiameter: 1.0000e-03
  ViaLocations: []
   ViaDiameter: []
  FeedViaModel: 'square'
     Conductor: [1x1 metal]
          Tilt: 0
      TiltAxis: [0 0 1]
          Load: [1x1 lumpedElement]
```

View the PCB component in the Gerber file.

```
show(pcbcapacitor)
```




# Version History

**Introduced in R2021b**

## See Also

`PCBReader` | `gerberRead` | `DielectricCatalog` | `dielectric`

# pcbComponent

Create single or multifeed PCB component

## Description

Use the `pcbComponent` object to create a multiport PCB component consisting of metal and dielectric layers.

## Creation

### Syntax

```
pcb = pcbComponent
pcb = pcbComponent(Name=Value)
```

#### Description

`pcb = pcbComponent` creates a two-port PCB component.

`pcb = pcbComponent(Name=Value)` sets "Properties" on page 1-213 using one or more name-value arguments. For example, `pcb = pcbComponent(Name=PCBWilkinson)` creates a PCB component named `'PCBWilkinson'` Properties not specified retain their default values.

### Properties

#### `Name` — Name of PCB component

`'MyPCB'` (default) | character vector | string scalar

Name of the PCB component, specified a character vector or string scalar.

Example: `component = pcbComponent(Name='PCBsplitter')`

Data Types: `char` | `string`

#### `Revision` — Revision details

`'v1.0'` (default) | character vector | string scalar

Design revision details of the PCB component, specified as a character vector or string scalar.

Example: `component = pcbComponent(Revision='v2.0')`

Data Types: `char` | `string`

#### `BoardShape` — Shape of PCB

`traceRectangular` (default) | object

Shape of the PC board, specified as a shape object. You can specify any one of the shapes from "Custom Geometry and PCB Fabrication".

Example: `trace = tracerectangular; component = pcbComponent(BoardShape=trace)` creates a rectangle shaped trace on a PCB.

Data Types: `char` | `string`

**`BoardThickness` — Height of PCB component**
`0.0016` (default) | positive scalar

Height of the PCB component, specified as a positive scalar in meters. To understand more about `BoardThickness`, see "Board Thickness versus Dielectric Thickness in PCB".

Example: `component = pcbComponent(BoardThickness=0.0026)`

Data Types: `double`

**`Layers` — Metal and dielectric layers**
`{[1×1 traceRectangular] [1×1 dielectric] [1×1 traceRectangular]}` (default) | cell array of metal and dielectric layers

Metal and dielectric layers, specified a cell array of metal and dielectric layers. You can specify one metal shape or one dielectric substrate per layer starting with the top layer and proceeding downward.

Data Types: `cell`

**`FeedLocations` — Feed locations on PCB component**
`[2×4 double]` (default) | *N*-by-3 array | *N*-by-4 array

Feed locations on the PCB component in Cartesian coordinates, specified as either an *N*-by-3 or *N*-by-4 array with *N* representing the number for ports on the PCB component. You can place the feed inside the board or at the edge of the board. The arrays translate into the following:

- *N*-by-3 – [*x*, *y*, *Layer*]
- *N*-by-4 – [*x*, *y*, *SigLayer*, *GndLayer*]

Example: `component = pcbComponent(FeedLocations=[-0.0187 0 1 2])`

Data Types: `double`

**`FeedDiameter` — Diameter of center pin of feed connector**
`0.0025` (default) | positive scalar

Diameter of center pin of the feed connector, specified as a positive scalar in meters.

Example: `component = pcbComponent(FeedDiameter=2.000e-04)`

Data Types: `double`

**`ViaLocations` — Electrical short locations on PCB component**
real vector of size *M*-by-4 array

Electrical short locations on the PCB component in Cartesian coordinates, specified as a real vector of size *M*-by-4 array. The array translates into the following:

- *M*-by-4 – [*x*, *y*, *SigLayer*, *GndLayer*]

Example: `component = pcbComponent(ViaLocations=[0 -0.025 1 2])`

Data Types: `double`

**`ViaDiameter` — Diameter of electrical shorting pin used between metal layers**
positive scalar | positive vector

Diameter of electrical shorting pin used between metal layers, specified as a positive scalar in meters for a single pin or a positive vector in meters for multiple pins. Number of values specified in this property must match the number of pins.

Example: `component = pcbComponent(ViaDiameter=1.0e-3)`

Data Types: `double`

**`FeedViaModel` — Model for approximating feed and via**
`'strip'` (default) | `'square'` | `'hexagon'` | `'octagon'`

Model for approximating the feed and via, specified as one of the following:

- `'strip'` – A rectangular strip approximation to the feed and via cylinder. This approximation is the simplest and results in a small mesh.
- `'square'` – A four-sided polyhedron approximation to the feed and via cylinder.
- `'hexagon'` – A six-sided polyhedron approximation to the feed and via cylinder.
- `'octagon'` – A eight-sided polyhedron approximation to the feed and via cylinder.

Example: `component = pcbComponent(FeedViaModel='octagon')`

Data Types: `char` | `string`

**`Conductor` — Type of metal material**
`'PEC'` (default) | `metal` object

Type of the metal used as a conductor, specified as a `metal` object. You can choose any metal from the `MetalCatalog` or specify a metal of your choice. For more information, see `metal`. For more information on metal conductor meshing, see “Method of Moments Solver for Metal and Dielectric Structures”.

Example: `m = metal('Copper'); component = pcbComponent(Conductor=m)`

**`Load` — Lumped elements**
[1x1 LumpedElement] (default) | lumped element object handle

Lumped elements added to the PCB component feed, specified as a lumped element object handle. For more information, see `lumpedElement` Antenna Toolbox™.

Example: `Load = lumpedelement`. `lumpedelement` is the object handle for the load created using `lumpedElement`.

**`Tilt` — Tilt angle of PCB component along Z-axis**
`0` (default) | scalar

Tilt angle of the PCB component along Z-axis, specified as a scalar or vector with each element unit in degrees.

Example: `Tilt=90`

Example: `pcb.Tilt = 90`

Data Types: `double`

#### `TiltAxis` — Tilt axis of PCB component

`[0 0 1]` (default) | `'Z'`

Tilt axis of the PCB component, specified as `[0 0 1]` or `'Z'`.

Example: `pcb.TiltAxis = 'Z'`

Data Types: `double`

## Object Functions

| | |
|---|---|
| current | Calculate and plot current distribution |
| charge | Calculate and plot charge distribution |
| feedCurrent | Calculate current at feed port |
| gerberWrite | Generate Gerber files |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| meshconfig | Change mesh mode of PCB component or shape structure |
| sparameters | Calculate S-parameters for RF PCB objects |
| show | Display PCB component structure or PCB shape |

## Examples

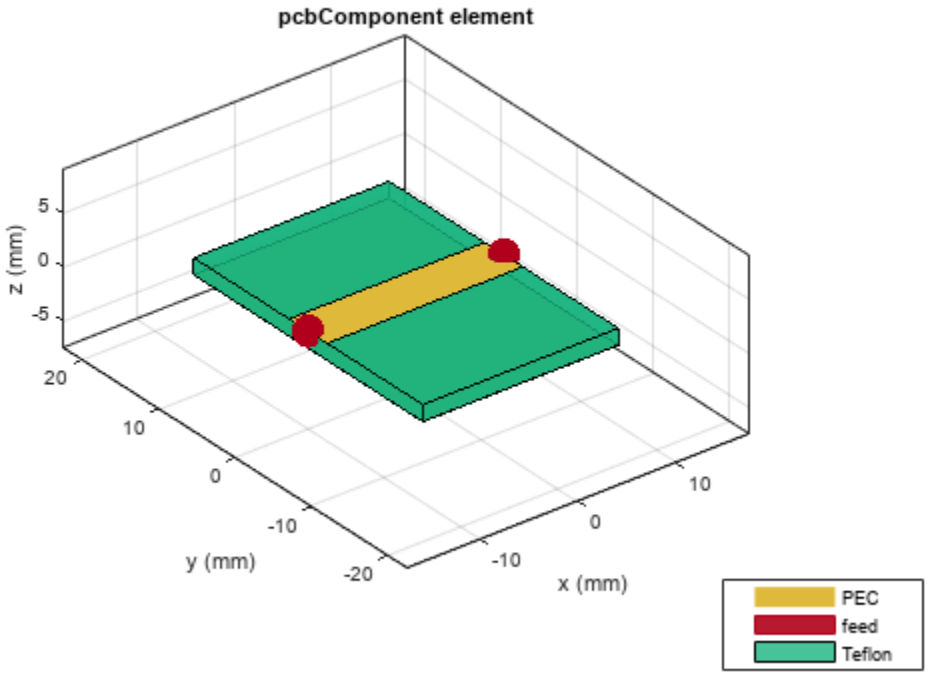
### Create Default PCB Component and Plot S-Parameters

Create a PCB component using default properties.

```
pcb = pcbComponent;
```

View the PCB component.

```
show(pcb)
```

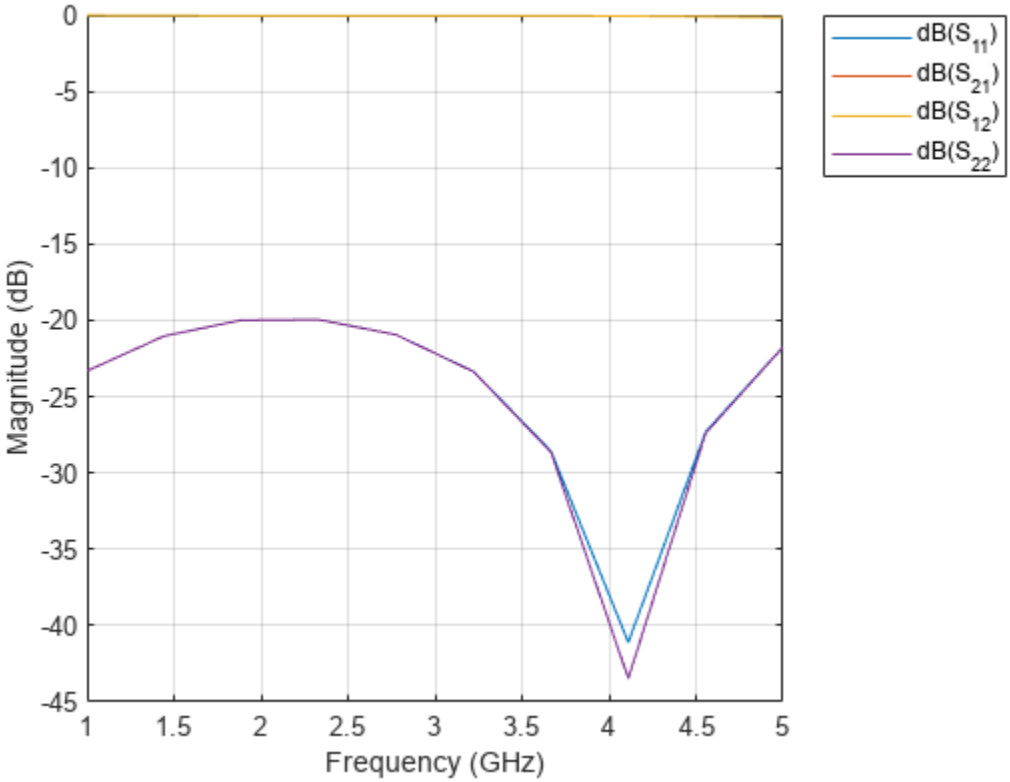



Calculate S-parameters over 10 frequencies from 1-5 GHz.

```
s=sparameters(pcb,linspace(1e9,5e9,10));
```

Plot the S-parameters.

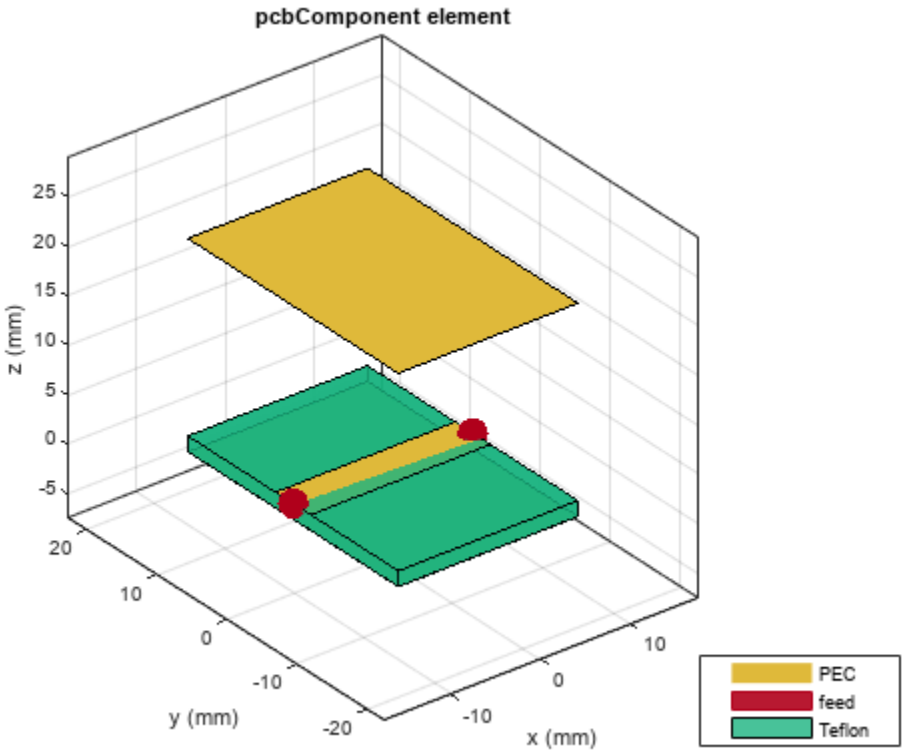
```
rfplot(s)
```




### Create PCB Component with Lid on Top

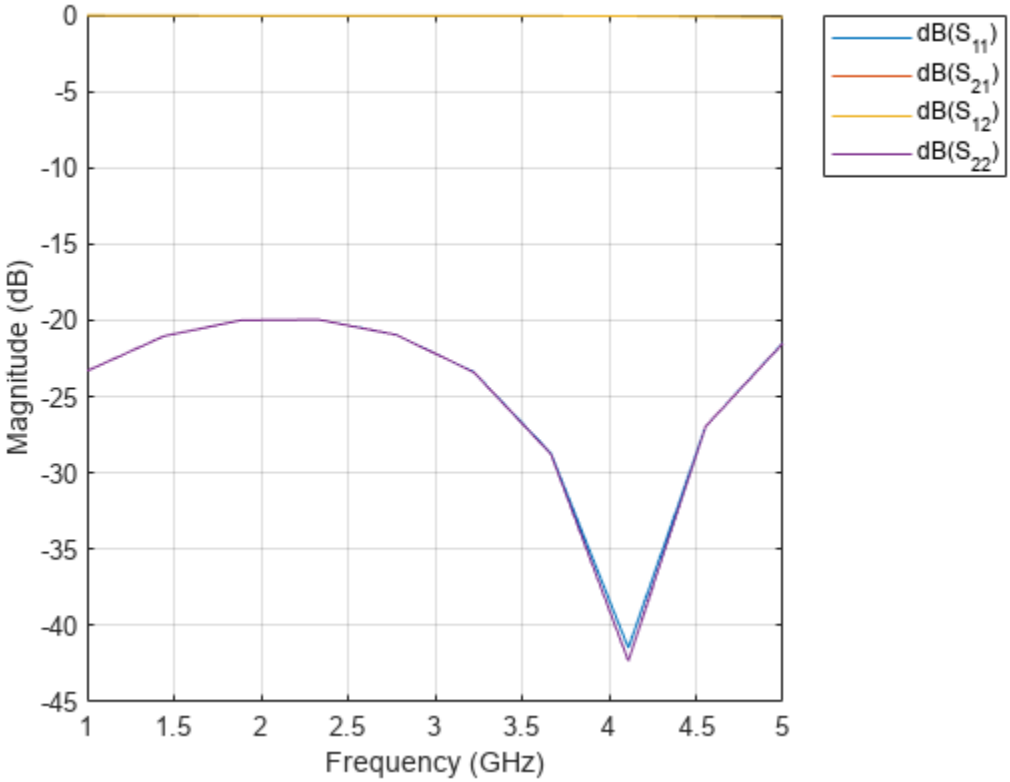
Create a PCB component with a lid at a distance of 2 cm above the component.

```
p = pcbComponent;
pcblid = traceRectangular(Length=p.Layers{1}.Length,Width=p.Layers{3}.Width);
dAir = dielectric('Air');
dAir.Thickness = 2e-2;
p.BoardThickness = p.BoardThickness + dAir.Thickness;
p.Layers = {pcblid,dAir,p.Layers{1},p.Layers{2},p.Layers{3}};
p.FeedLocations(:,3:4) = [3 5;3 5];
show(p)
```




Calculate the S-parameters over the 10 frequencies from 1-5 GHz.

```
s = sparameters(p,linspace(1e9,5e9,10));
rfplot(s)
```




## Version History

**Introduced in R2021b**

## See Also

`gerberRead` | `gerberWrite` | `PCBReader` | `PCBWriter` | `PCBServices`

# pcbElement

Create RF Toolbox circuit element

## Description

Use the `pcbElement` object to create an RF Toolbox circuit element.

## Creation

### Syntax

```
circuit_element = pcbElement(rfpcbobject)
circuit_element = pcbElement(rfpcbobject,Name=Value)
```

#### Description

`circuit_element = pcbElement(rfpcbobject)` creates a PCB element object from a PCB component. You can use this element in an RF Toolbox circuit.

`circuit_element = pcbElement(rfpcbobject,Name=Value)` sets properties using one or more name-value arguments.

#### Input Arguments

**`rfpcbobject` — PCB component object**
RF PCB object

PCB component object, specified as an RF PCB object. For a complete list of the PCB components, see “PCB Components Catalog”.

### Properties

**`Behavioral` — Computes S-parameters using behavioral model**
`'true'` (default) | `'false'`

Compute S-parameters of the PCB element using the behavioral model, specified as a logical true or false. When you specify true, the object calculates the S-parameters using the behavioral model. When you specify false, the object calculates the S-parameters using the full-wave solver. For components and shapes that support the behavioral model, see “Behavioral Models” and `sparameters`.

Data Types: `logical`

### Examples

### Calculate S-Parameters of Two Capacitors in Circuit

Create a circuit using default properties.

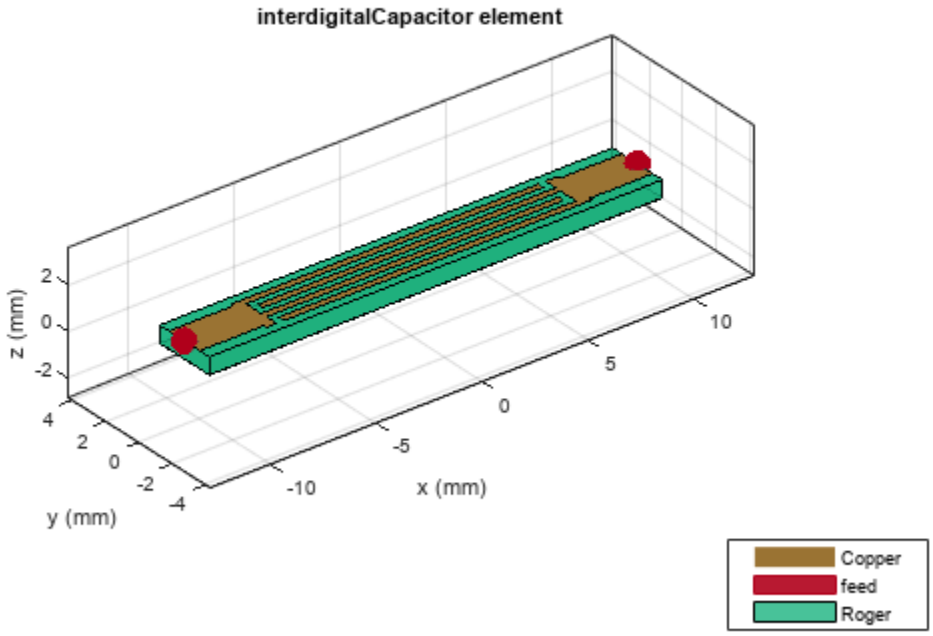
```
ckt = circuit;
```

Create two interdigital capacitors, one using default properties and one with three fingers.

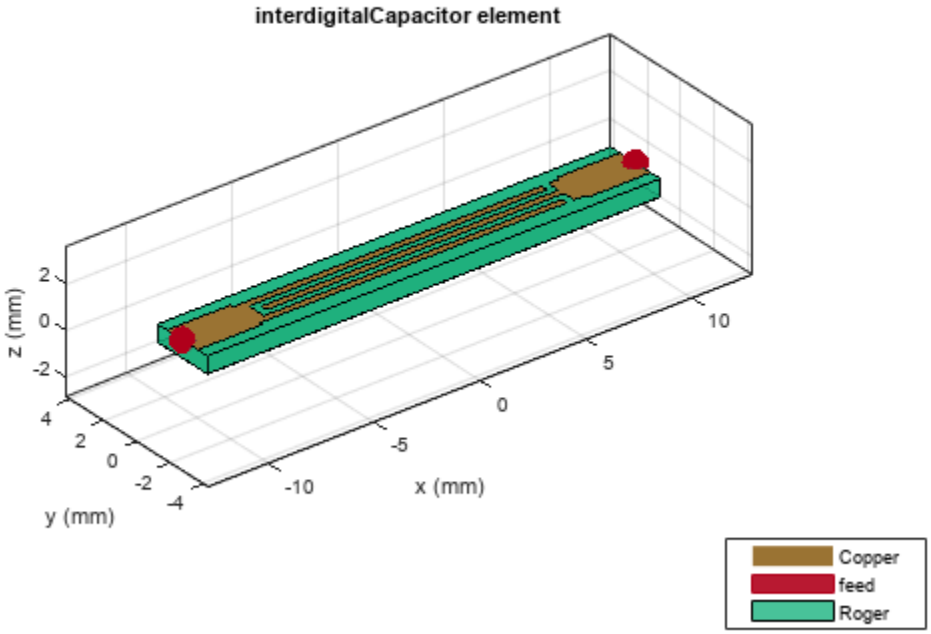
```
c1 = interdigitalCapacitor;
c2 = interdigitalCapacitor('NumFingers',3);
```

View both `c1` and `c2`.

```
show(c1)
```




```
figure;
show(c2)
```




Convert `c2` to a PCB element with the `Behavioral` property set to false.

```
p = pcbElement(c2,'Behavioral',false);
```

Add both capacitors to the circuit object.

```
add(ckt,[1 2 0 0],c1) % default pcbElement created automatically
add(ckt,[2 3 0 0],p)
setports(ckt,[1 0],[3 0])
```

Calculate the S-parameters.

```
S = sparameters(ckt,8e9)
```

```
S =
  sparameters: S-parameters object

       NumPorts: 2
    Frequencies: 8.0000e+09
     Parameters: [2x2 double]
      Impedance: 50

  rfparam(obj,i,j) returns S-parameter Sij
```

## Version History

**Introduced in R2021b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`sparameters`

**Topics**

“Behavioral Models”

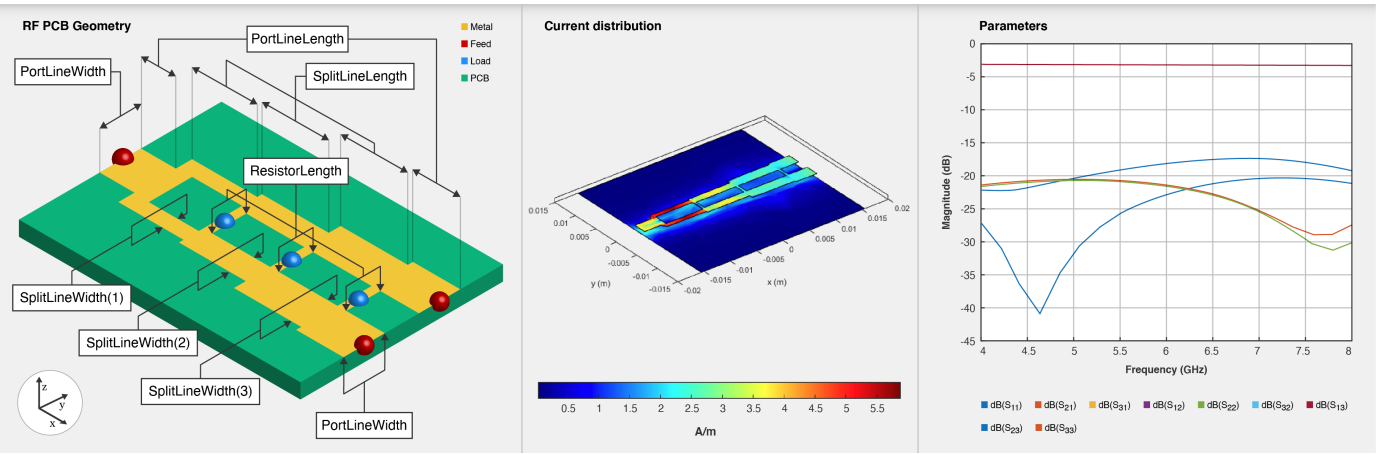
# wilkinsonSplitterWideband

Create wideband Wilkinson power divider

## Description

Use the `wilkinsonSplitterWideband` object to create a wideband Wilkinson power divider. The wide bandwidth is achieved through the multiple sections that are used in the construction of the divider. It is a lossless power divider and provides matching at all ports. The isolation between the output ports is achieved using a resistor connected in between the output ports.

**Wideband Wilkinson Splitter**




## Creation

### Syntax

```
splitter = wilkinsonSplitterWideband
splitter = wilkinsonSplitterWideband(Name=Value)
```

#### Description

`splitter = wilkinsonSplitterWideband` creates a wideband Wilkinson splitter with default properties for a resonating frequency of 6 GHz.

`splitter = wilkinsonSplitterWideband(Name=Value)` sets “Properties” on page 1-117 using one or more name-value arguments. For example, `wilkinsonSplitterWideband(PortLineLength=0.0300)` creates a wideband Wilkinson splitter with an input and output line length of 0.0300 meters. Properties not specified retain their default values.

## Properties

**Shape — Shape of sections**
`"Rectangular"` (default) | `"Circular"`

Shape of the sections, specified as `"Rectangular"` or `"Circular"`.

Example: `splitter = wilkinsonSplitterWideband(Shape="Circular")`

Data Types: `char` | `string`

**NumSections — Number of sections**
3 (default) | positive scalar

Number of sections, specified as a positive scalar. The minimum value is 2 and the maximum value is 7.

Example: `splitter = wilkinsonSplitterWideband(NumSections=4)`

Data Types: `double`

**PortLineLength — Length of input and output line**
`0.0040` (default) | positive scalar

Length of the input and the output line in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitterWideband(PortLineLength=0.0070)`

Data Types: `double`

**PortLineWidth — Width of input and output line**
`0.0024` (default) | positive scalar

Width of the input and the output line in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitterWideband(PortLineWidth=0.0034)`

Data Types: `double`

**SplitLineLength — Length of quarter wave transformer**
`0.0080` (default) | positive scalar

Length of the quarter wave transformer in meters, specified as a positive scalar. The typical length of a Wilkinson splitter is λ/4.

Example: `splitter = wilkinsonSplitterWideband(SplitLineLength=0.0570)`

Data Types: `double`

**SplitLineWidth — Width of quarter wave transformer**
`[8.5495e-04 0.0014 0.0021]` (default) | two-element vector

Width of the quarter wave transformer in meters, specified as a two-element vector of positive elements.

Example: `splitter = wilkinsonSplitterWideband(SplitLineWidth=[0.00780 0.00890])`

Data Types: `double`

**ResistorLength — Length of resistor**
`0.0020` (default) | positive scalar

Length of the resistor in meters, specified as a positive scalar. The resistor length decided the spacing between the output ports.

Example: `splitter = wilkinsonSplitterWideband(ResistorLength=0.0050)`

Data Types: `double`

**`Resistance` — Resistance value**
`[100 183.4008 141.4214]` (default) | three-element vector

Resistance value in ohms, specified as a three-element vector of positive elements. The default value is for an equal-split wideband Wilkinson splitter.

Example: `splitter = wilkinsonSplitterWideband(Resistance=[90 173.4008 166.4214])`

Data Types: `double`

**`Height` — Height of splitter from ground plane**
`7.6200e-04` (default) | positive scalar

Height of the splitter from the ground plane in meters, specified as a positive scalar. If your substrate has multiple layers, you can use the `Height` property to create a wideband Wilkinson splitter where the two dielectrics interface.

Example: `splitter = wilkinsonSplitterWideband(Height=0.0076)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0300` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `splitter = wilkinsonSplitterWideband(GroundPlaneWidth=0.046)`

Example: double

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `wilkinsonSplitterWideband` object with default properties is Teflon. The thickness of the default dielectric material Teflon is `0.0016` m or the same value as the `Height` property.

Example: `d = dielectric("FR4"); splitter = wilkinsonSplitterWideband(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `wilkinsonSplitterWideband` object with default properties is PEC.

Example: `m = metal("Copper"); splitter = wilkinsonSplitterWideband(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design wideband Wilkinson splitter around specified frequency |
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Wideband Wilkinson Splitter

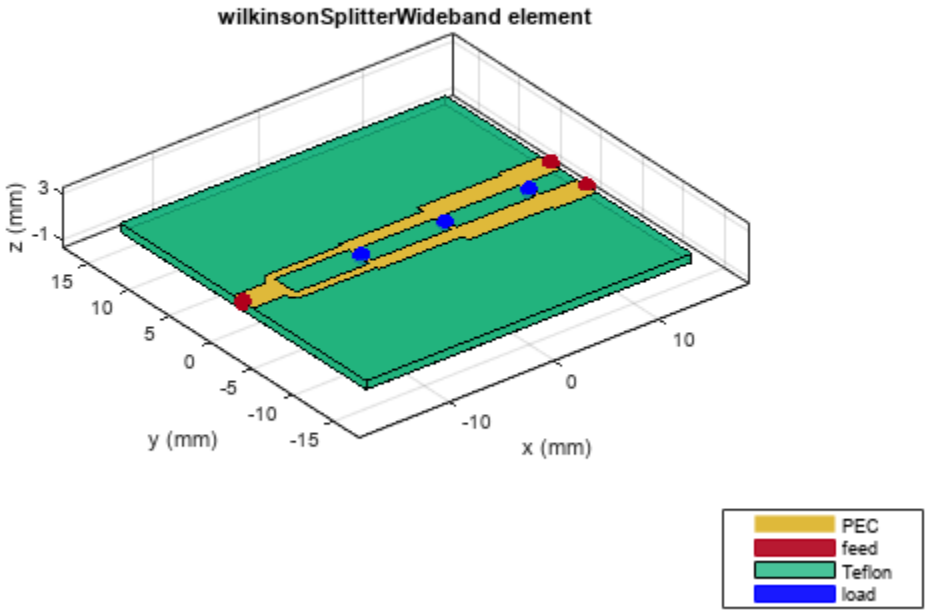
Create a wideband Wilkinson splitter with default properties.

```
splitter = wilkinsonSplitterWideband
```

```
splitter =
  wilkinsonSplitterWideband with properties:

               Shape: 'Rectangular'
        NumSections: 3
      PortLineLength: 0.0040
       PortLineWidth: 0.0024
     SplitLineLength: 0.0080
      SplitLineWidth: [8.5495e-04 0.0014 0.0021]
      ResistorLength: 0.0020
          Resistance: [100 183.4008 141.4214]
              Height: 7.6200e-04
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

Visualize the splitter.

```
show(splitter);
```



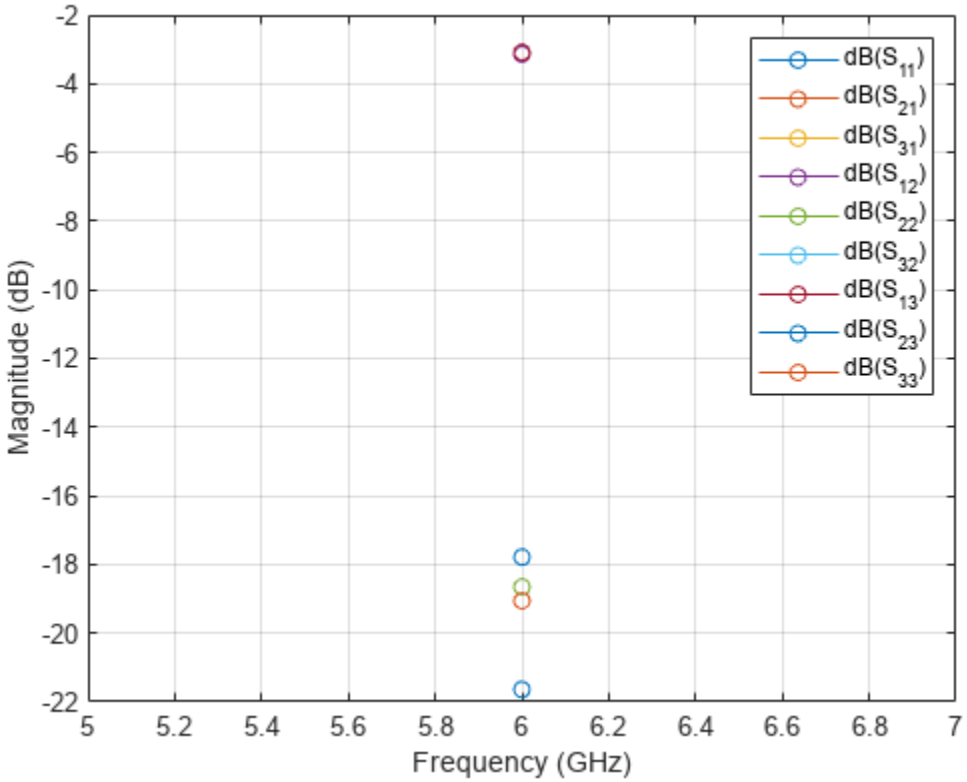

### S-Parameters of Wideband Wilkinson

Create a wideband Wilkinson splitter with default properties.

```
splitter = wilkinsonSplitterWideband;
```

Calculate the s-parameters of this splitter at 6 GHz.

```
spar = sparameters(splitter,6e9);
figure;
rfplot(spar);
```




**Wideband Wilkinson with Multi-Layered Dielectric**

Create a wideband Wilkinson splitter with the default properties.

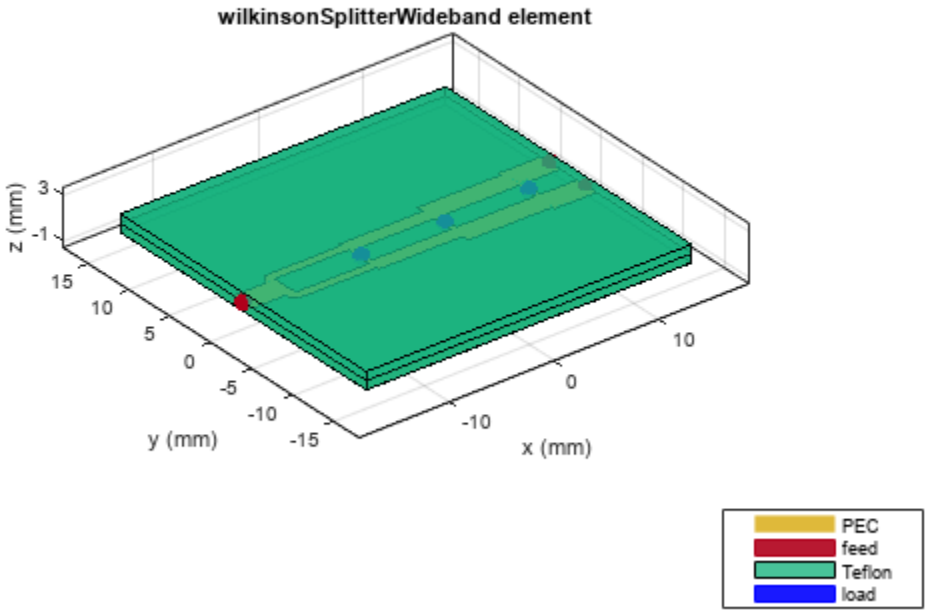
```
splitter = wilkinsonSplitterWideband;
```

Change the substrate to a multilayered substrate. Change the height of the splitter.

```
splitter.Substrate = dielectric('Name',{'Teflon','Teflon'},'EpsilonR', ...
    [2.1 2.1],'LossTangent',[0 0],'Thickness',[0.8e-3 0.8e-3]);
splitter.Height = 0.8e-3;
```

Visualize the splitter.

```
show(splitter);
```




# Version History

**Introduced in R2022a**

## References

[1] Mishra, B, A.Rahman, S.Shaw, M.Mohammed, S.Mondal, P.P.Shankar. "Design of an ultra-wideband Wilkinson power divider." *Automation, Control, Energy, and Systems (IEEE 2014)*

[2] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`wilkinsonSplitter` | `wilkinsonSplitterUnequal`

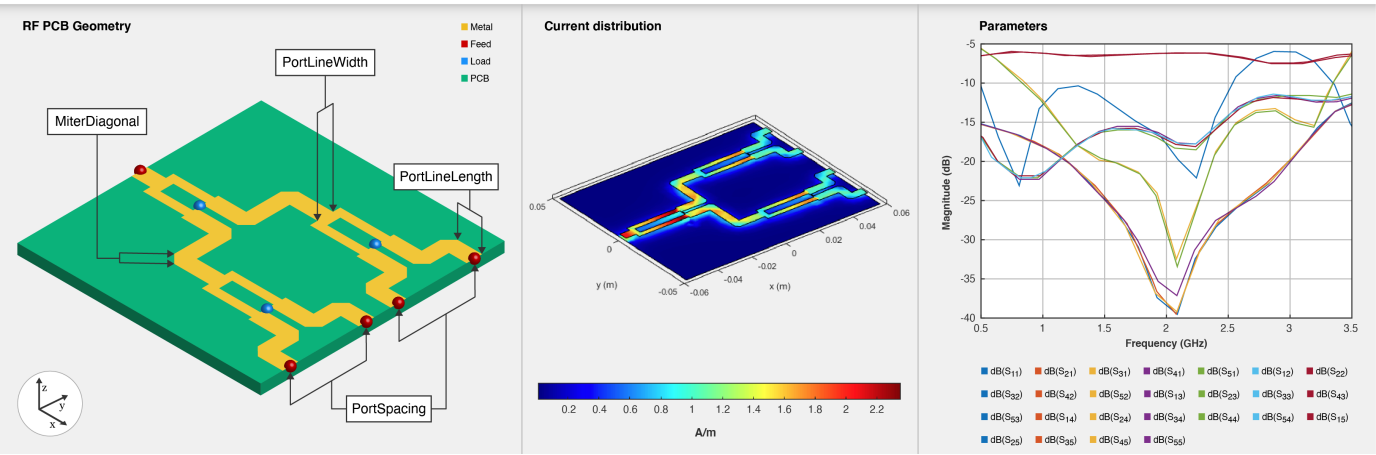
# powerDividerCorporate

Create corporate power divider

## Description

Use the `powerDividerCorporate` object to create a corporate power divider to divide power equally or unequally from a single port to multiple ports.

Corporate Power Divider




## Creation

### Syntax

```
divider = powerDividerCorporate
divider = powerDividerCorporate(Name=Value)
```

#### Description

`divider = powerDividerCorporate` creates a corporate power divider with default properties for an operating frequency of 1.6 GHz.

`divider = powerDividerCorporate(Name=Value)` sets "Properties" on page 1-117 using one or more name-value arguments. For example, `powerDividerCorporate(PortLineLength=0.0300)` creates a corporate power divider with an input and output line length of 0.0300 meters. Properties not specified retain their default values.

### Properties

**`NumOutputPorts` — Number of output ports**
4 (default) | 2 | 8 | 16 | 32 | positive scalar

Number of output ports, specified as a positive scalar.

Example: `divider = powerDividerCorporate(NumOutputPorts=8)`

Data Types: `double`

**`SplitterElement` — Basic divider element**
`"wilkinsonSplitter"` (default) | `"wilkinsonSplitterUnequal"` | `"wilkinsonSplitterWideband"`

Basic divider element, specified as `wilkinsonSplitter`, `wilkinsonSplitterUnequal`, or `wilkinsonSplitterWideband` object.

Example: `divider = powerDividerCorporate(SplitterElement="wilkinsonSplitterWideband")`

Data Types: `char` | `string`

**`Corner` — Shape of corner at each bend**
`'Mitered'` (default) | `'Curved'`

Shape of corner at each bend specified as `'Mitered'` or `'Curved'`. If you set `Corner` to `'Mitered'`, specify the miter diagonal by setting the `MiterDiagonal` property. If you set `Corner` to `'Curved'`, specify the radius of the curve by setting the `CurveRadius` property.

Example: `divider = powerDividerCorporate(SplitterElement='Curved')`

Data Types: `char` | `string`

**`MiterDiagonal` — Length of miter diagonal**
`0.0025` (default) | positive scalar

Length of the miter diagonal in meters, specified as a positive scalar. This property applies only when you set the `Corner` property to `'Mitered'`.

Example: `divider = powerDividerCorporate(MiterDiagonal=0.0046)`

**`CurveRadius` — Radius of curve**
`0.0025` (default) | positive scalar

Radius of the curve at the bends in meters, specified as a positive scalar. This property applies only when you set the `Corner` property to `'Curved'`.

Example: `divider = powerDividerCorporate(CurveRadius=0.0046)`

Data Types: `double`

**`PortLineLength` — Length of input and output line**
`0.0080` (default) | positive scalar

Length of the input and the output line in meters, specified as a positive scalar.

Example: `divider =powerDividerCorporate(PortLineLength=0.0070)`

Data Types: `double`

**`PortLineWidth` — Width of input and output line**
`0.0049` (default) | positive scalar

Width of the input and the output line in meters, specified as a positive scalar.

Example: `divider =powerDividerCorporate(PortLineWidth=0.0034)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0960` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `divider =powerDividerCorporate(GroundPlaneWidth=0.046)`

Example: double

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design corporate power divider around specified frequency |
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Corporate Power Divider

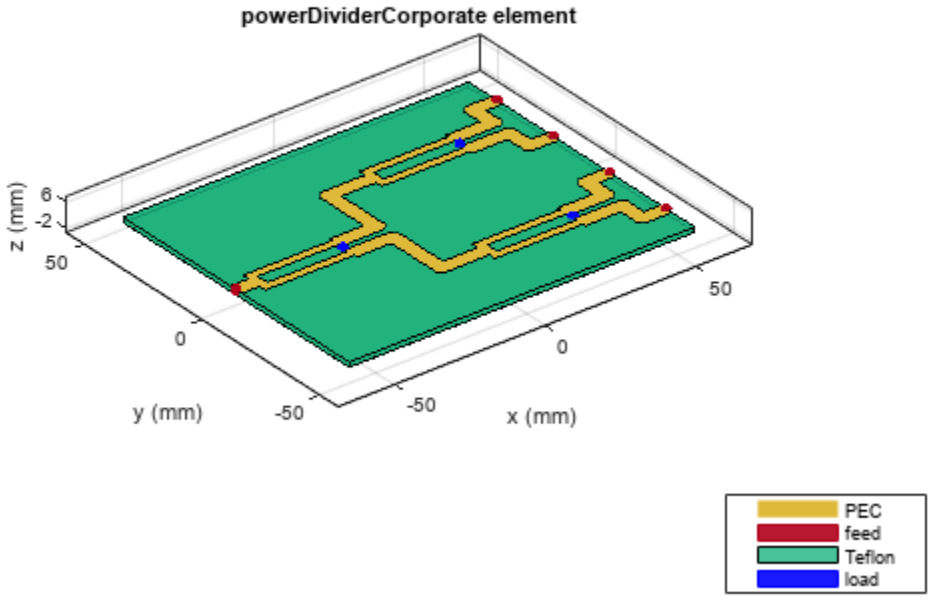
Create a corporate power divider with default values.

```
divider = powerDividerCorporate
```

```
divider =
  powerDividerCorporate with properties:

      NumOutputPorts: 4
     SplitterElement: [1x1 wilkinsonSplitter]
              Corner: 'Mitered'
       MiterDiagonal: 0.0025
         PortSpacing: 0.0240
      PortLineLength: 0.0080
       PortLineWidth: 0.0049
    GroundPlaneWidth: 0.0960
```

Visualize the power divider.

```
show(divider)
```




### Corporate Power Divider with Multi-Layered Dielectric

Create a corporate power divider with default values.

```
divider = powerDividerCorporate;
```

Change the substrate of the splitter element to a multi-layered substrate.

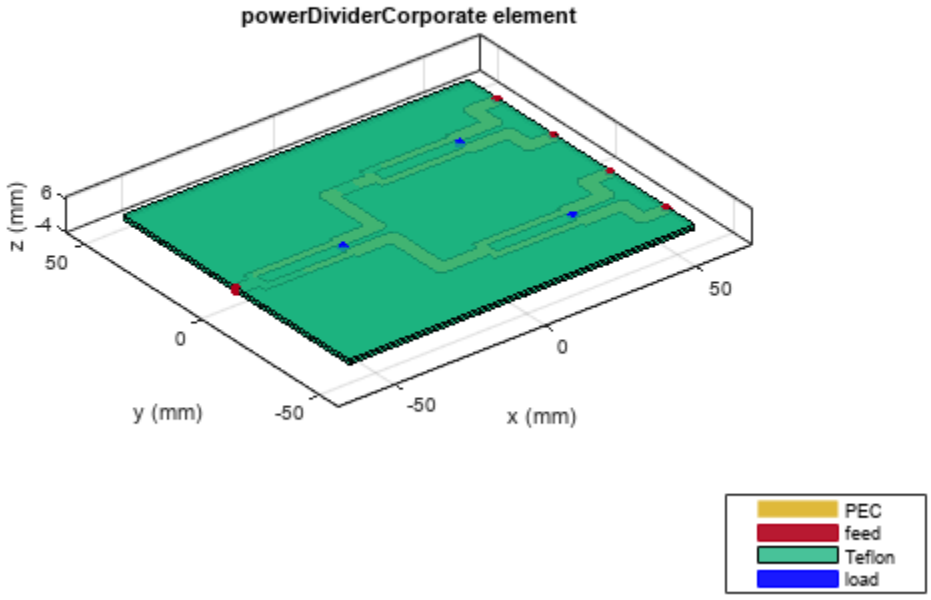
```
divider.SplitterElement.Substrate = dielectric('Name',{'Teflon','Teflon'},'EpsilonR', ...
    [2.1 2.1],'LossTangent',[0 0],'Thickness',[0.8e-3 0.8e-3]);
```

Change the height of the splitter element.

```
divider.SplitterElement.Height = 0.8e-3;
```

Visualize the power divider

```
show(divider)
```




## Version History

**Introduced in R2022a**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`wilkinsonSplitter` | `wilkinsonSplitterUnequal` | `wilkinsonSplitterWideband`

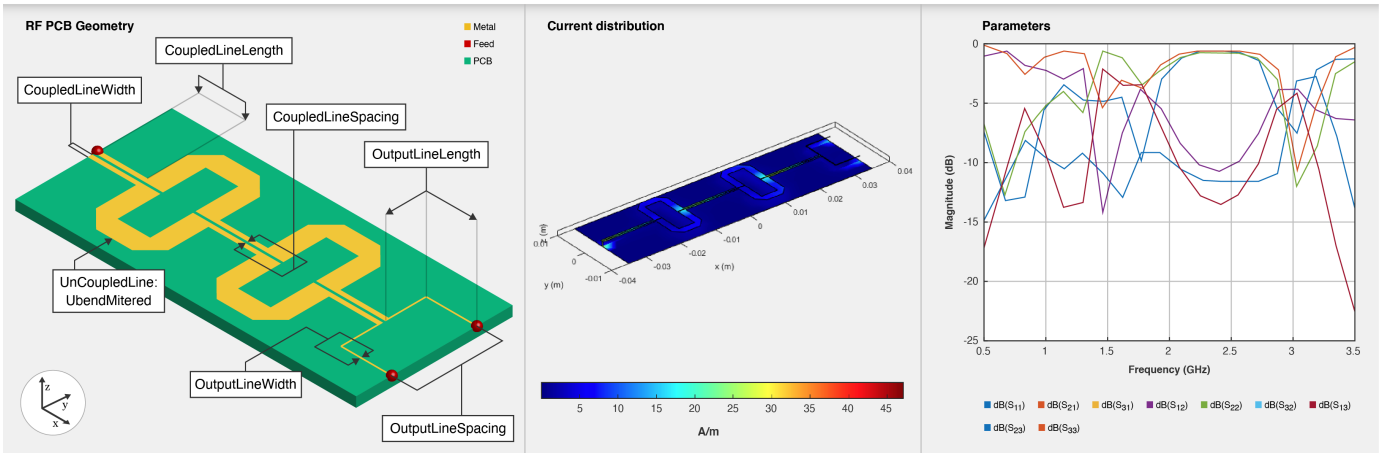
# balunCoupledLine

Create multisection coupled-line balun on X-Y plane

## Description

Use the `balunCoupledLine` object to create a multisection coupled-line balun with an unbalanced input and a balanced output. The output signal has a phase difference of 180 degrees.

**Coupled Line Balun**




## Creation

### Syntax

```
balun = balunCoupledLine
balun = balunCoupledLine(Name=Value)
```

#### Description

`balun = balunCoupledLine` creates a coupled-line balun in the microstrip form with default properties for a resonant frequency of 2.96 GHz.

`balun = balunCoupledLine(Name=Value)` sets “Properties” on page 1-237 using one or more name-value arguments. For example, `balunCoupledLine(OutputLineLength=0.0286)` creates a coupled-line balun with an output line length of 0.0286 meters. Properties not specified retain their default values.

### Properties

**`NumCoupledLineSection` — Number of coupled-line sections**
3 (default) | positive scalar

Number of coupled-line sections, specified as a positive scalar. The minimum number of sections you can specify is two and the maximum number is five.

Example: `balun = balunCoupledLine(NumCoupledLine=4)`

Data Types: `double`

**`CoupledLineLength` — Length of coupled line**
`0.01526` (default) | positive scalar

Length of the coupled line in meters, specified as a positive scalar.

Example: `balun = balunCoupledLine(CoupledLineLength=0.0254)`

Data Types: `double`

**`CoupledLineWidth` — Width of coupled line**
`0.0004` (default) | positive scalar

Width of the coupled line in meters, specified as a positive scalar.

Example: `balun = balunCoupledLine(CoupledLineWidth=0.0005)`

Data Types: `double`

**`CoupledLineSpacing` — Distance between coupled lines**
`0.00014` (default) | positive scalar

Spacing between the coupled lines in meters, specified as a positive scalar.

Example: `balun = balunCoupledLine(CoupledLineSpacing=0.00015)`

Data Types: `double`

**`UncoupledLineShape` — Shape of uncoupled-line section**
`ubendMitered` (default) | shape object

Shape of the uncoupled-line section, specified as a shape object. The default shape of the uncoupled-line section is the `ubendMitered` shape. The default dimensions of the `ubendMitered` shape are: length of `[0.0082 0.00453 0.0082]`, width of `[0.002 0.002 0.002]`, and a miter diagonal of `0.002828`.

Example: `balun = balunCoupledLine(UncoupledLineShape=ubendMitered)`

Data Types: `char` | `string`

**`OutputLineLength` — Length of quarter wave transformer**
`0.0124` (default) | positive scalar

Length of the quarter wave transformer used to extend the ports in meters, specified as a positive scalar.

Example: `balun = balunCoupledLine(OutputLineLength=0.0224)`

Data Types: `double`

**`OuputLineWidth` — Width of output line**
`0.000153` (default) | positive scalar

Width of the output line in meters, specified as a positive scalar.

Example: `balun = balunCoupledLine(OutputLineWidth=0.000253)`

Data Types: `double`

**`OutputLineSpacing` — Distance between output ports**
`0.011` (default) | positive scalar

Spacing between the output ports in meters, specified as a positive scalar.

Example: `balun = balunCoupledLine(OutputLineSpacing=0.022)`

Data Types: `double`

**`Height` — Height of coupled-line balun from ground plane**
`0.0013` (default) | positive scalar

Height of the coupled-line balun from the ground plane in meters, specified as a positive scalar.

Example: `balun = balunCoupledLine(Height=0.022)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0200` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `balun = balunCoupledLine(GroundPlaneWidth=0.032)`

Example: double

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The default height of the substrate is `0.0013` meters. The dielectric material in a `balunCoupledLine` object with default properties is FR4.

Example: `d = dielectric("RTDuriod"); balun = balunCoupledLine(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `balunCoupledLine` object with default properties is PEC.

Example: `m = metal("Copper"); balun = balunCoupledLine(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| designCoupledLine | Calculate dimensions of coupled-line section for specified frequency |
| designUncoupledLine | Calculate dimensions of uncoupled-line section for specified frequency |
| designOutputLine | Calculate dimensions of output line section for specified frequency |

| | |
|---|---|
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Coupled-Line Balun

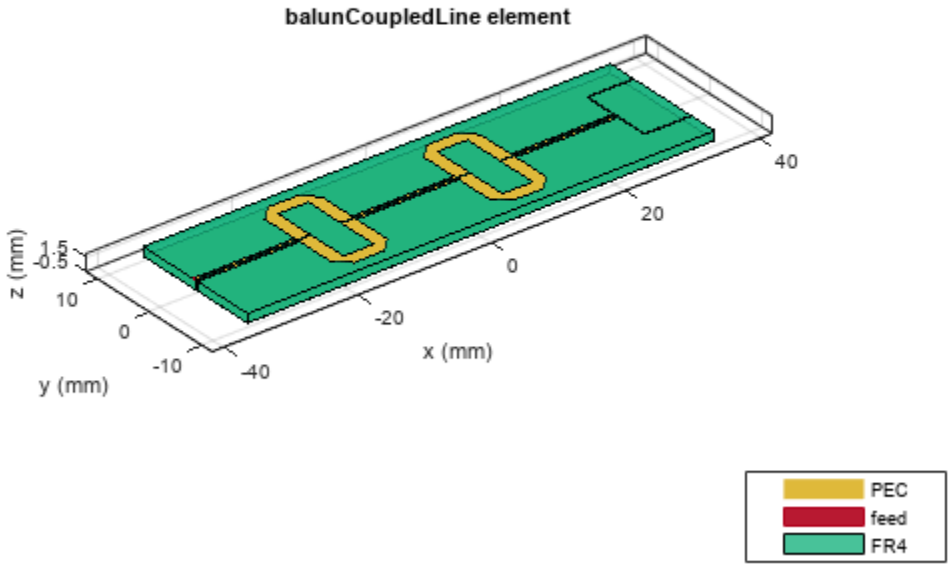
Create a coupled-line balun using default properties.

```
balun = balunCoupledLine
```

```
balun =
  balunCoupledLine with properties:

    NumCoupledLineSection: 3
        CoupledLineLength: 0.0153
         CoupledLineWidth: 4.0000e-04
       CoupledLineSpacing: 1.4000e-04
       UncoupledLineShape: [1x1 ubendMitered]
         OutputLineLength: 0.0124
          OutputLineWidth: 1.5300e-04
        OutputLineSpacing: 0.0110
                   Height: 0.0013
         GroundPlaneWidth: 0.0200
                Substrate: [1x1 dielectric]
                Conductor: [1x1 metal]
```

Visualize the coupled-line balun.

```
show(balun)
```




### Coupled-Line Balun with Multiple Dielectric Layers

Create a coupled-line balun using default properties.

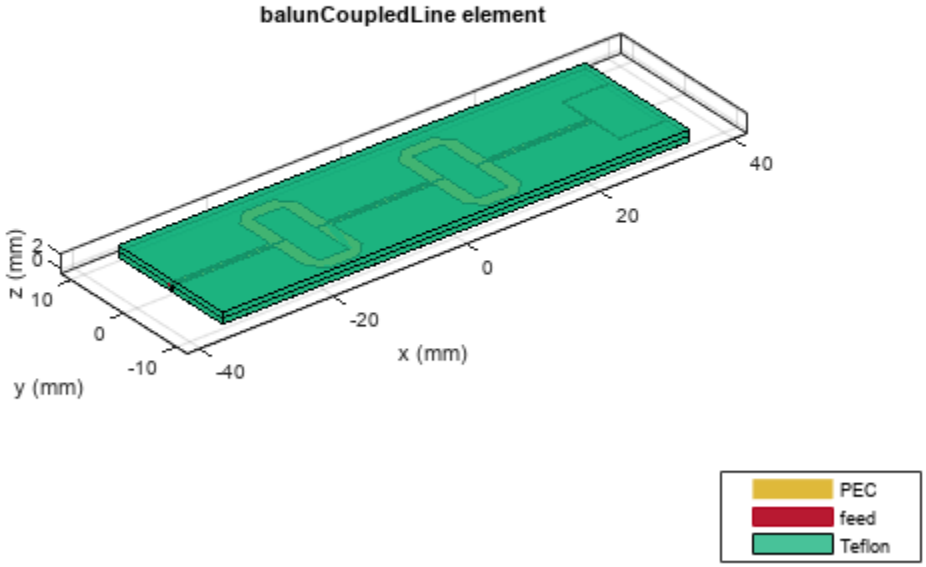
```
balun = balunCoupledLine;
```

Change the substrate and the dielectric of the balun.

```
balun.Substrate = dielectric('Name',{'Teflon','Teflon'},'EpsilonR', ...
    [2.1 2.1],'LossTangent',[0 0],'Thickness',[0.8e-3 0.8e-3]);
balun.Height = 0.8e-3;
```

Visualize the balun.

```
show(balun)
```



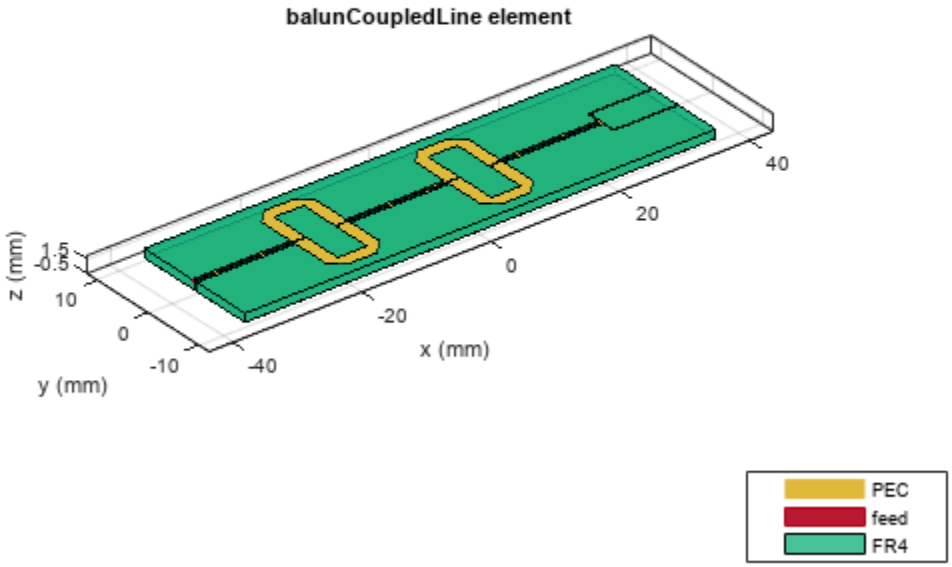

### Customize Coupled-Line Balun

Create a coupled-line balun with an `OutputLineSpacing` of 5 mm.

```
balun = balunCoupledLine('OutputLineSpacing',0.005);
```

Visualize the balun.

```
show(balun);
```




### Design Coupled Line Balun at 4 GHz

Define the frequency at 4 GHz.

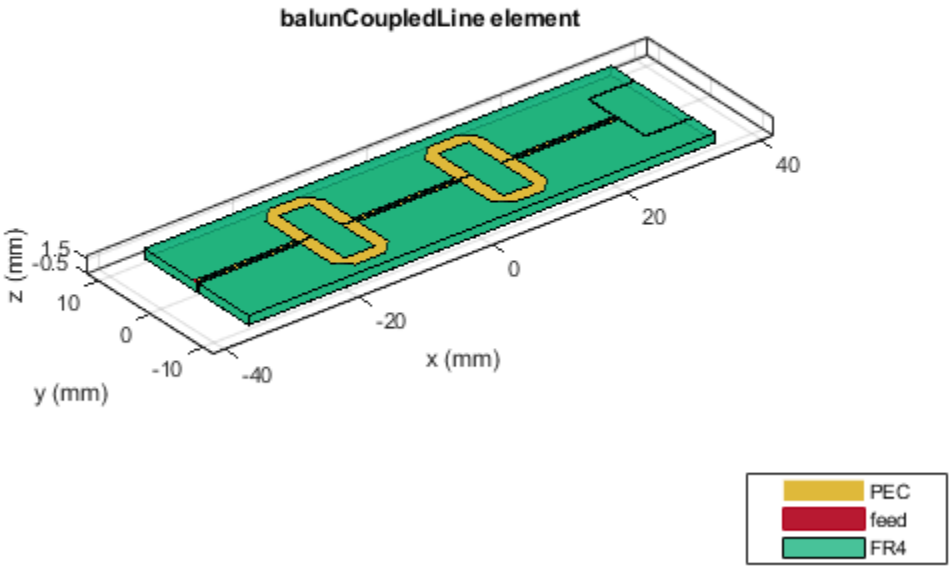
```
f = 4e9;
```

Create a coupled line balun object.

```
balun = balunCoupledLine
```

```
balun =
  balunCoupledLine with properties:

    NumCoupledLineSection: 3
        CoupledLineLength: 0.0153
         CoupledLineWidth: 4.0000e-04
       CoupledLineSpacing: 1.4000e-04
       UncoupledLineShape: [1×1 ubendMitered]
         OutputLineLength: 0.0124
          OutputLineWidth: 1.5300e-04
        OutputLineSpacing: 0.0110
                   Height: 0.0013
         GroundPlaneWidth: 0.0200
                Substrate: [1×1 dielectric]
                Conductor: [1×1 metal]
```

```
show(balun)
```




### Step 1: Design coupled line section

Design the coupled line section of the balun with an even mode impedance of 159 ohms and an odd mode impedance of 51 ohms. Use the helper function **designCoupledLine**.

```
[ClineL,ClineW,ClineS] = designCoupledLine(balun,f,'Z0e',159,'Z0o',51)
```

```
ClineL = 0.0107
```

```
ClineW = 4.2682e-04
```

```
ClineS = 1.4374e-04
```

### Step 2: Design uncoupled line section

Design the uncoupled line section of the balun with the even and odd mode impedance of 59 ohms. Use the helper function **designUncoupledLine**.

```
[unclineL,unclineW] = designUncoupledLine(balun,f,'Z0',59,'LineLength',0.25)
```

```
unclineL = 0.0103
```

```
unclineW = 0.0018
```

### Step 3: Design output line section

Design the output line section of the balun at the same frequency to extend the port 2 and port3. Use the helper function **designOutputLine**.

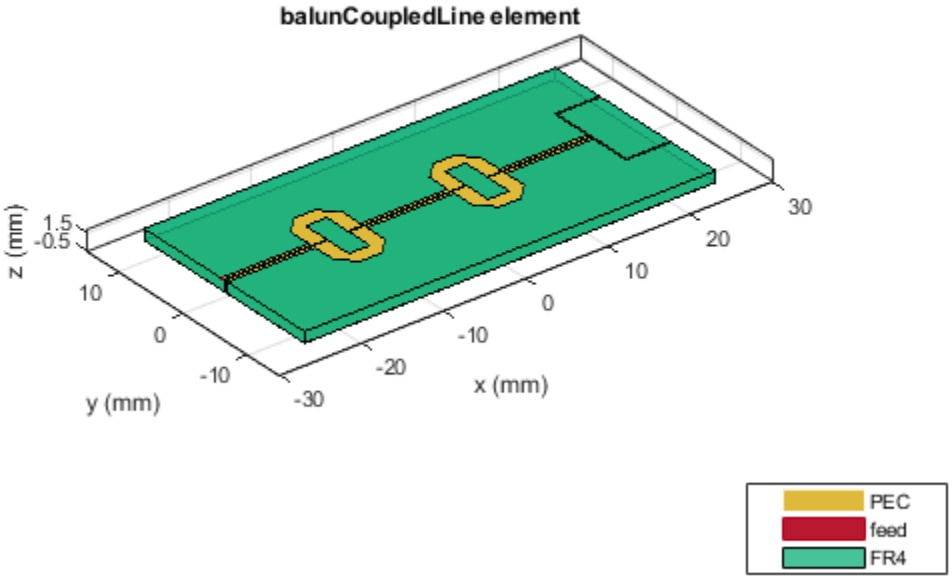
```
[OutL,OutW] = designOutputLine(balun,f,'Z0e',159,'Z0o',51,'Z0',59,'Zref',50)
```

```
OutL = 0.0109
```

```
OutW = 1.6115e-04
```

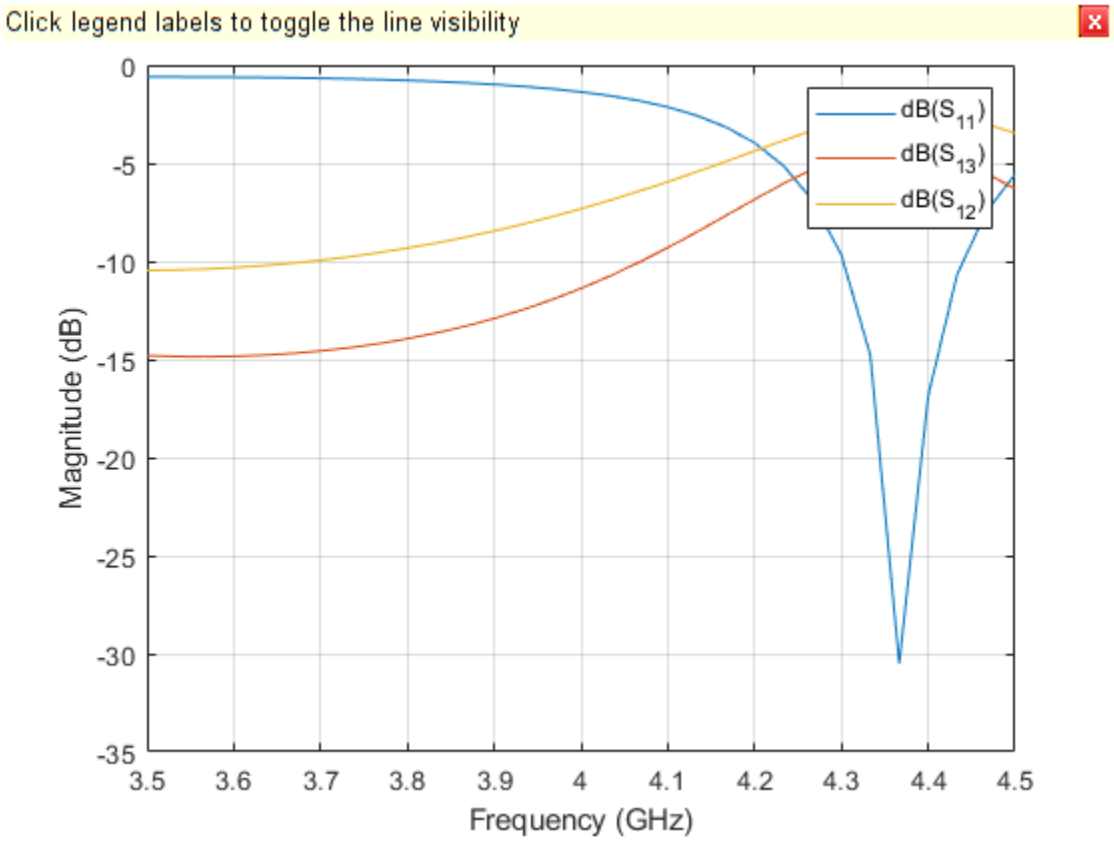
Set all the design dimensions to the coupled balun object.

```
balun.CoupledLineLength  = ClineL;
balun.CoupledLineWidth  = ClineW;
balun.CoupledLineSpacing  = ClineS;
UnCoupledLine = ubendMitered;
UnCoupledLine.Length  = [unclineL/2,unclineL/4,unclineL/2];
UnCoupledLine.Width   = [unclineW,unclineW,unclineW];
balun.UncoupledLineShape = UnCoupledLine;
balun.OutputLineLength = OutL;
balun.OutputLineWidth = OutW;
balun.OutputLineSpacing = OutL+ClineS;
gndW = 25e-3;
balun.GroundPlaneWidth = gndW;
show(balun)
```




Analyze and plot the S-paramters of this balun.

```
s11 = sparameters(balun,linspace(3.5e9,4.5e9,31));

figure; rfplot(s11,1,1);
hold on; rfplot(s11,1,3)
hold on; rfplot(s11,1,2)
```




## Version History

**Introduced in R2022a**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`couplerRatrace`

# traceStep

Create step trace in XY plane

## Description

Use the `traceStep` object to create a step trace in the *XY* plane.

## Creation

### Syntax

```
trace = traceStep
trace = traceStep(Name=Value)
```

#### Description

`trace = traceStep` creates a step trace in the *XY* plane.

`trace = traceStep(Name=Value)` sets "Properties" on page 1-166 using one or more name-value arguments. For example, `traceStep(ReferencePoint=[1 1])` creates a step trace with the reference point `[1 1]`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of step trace

`'mytraceStep'` (default) | character vector | string scalar

Name of the step trace, specified as a character vector or a string scalar.

Example: `trace = traceStep(Name="traceStep")`

Data Types: `char` | `string`

#### `ReferencePoint` — X and Y coordinate of step trace

`[0 0]` (default) | two-element vector

X and Y coordinate of the step trace in meters, specified as a two-element vector of real elements.

Example: `trace = traceStep(ReferencePoint=[1 1])`

Data Types: `double`

#### `Length` — Length of each section of step trace

`[0.0050 0.0280 0.0260]` (default) | vector

Length of each section of the step trace in meters, specified as a vector of positive elements.

Example: `trace = traceStep(Length=[0.0300 0.0200 0.0230])`

Data Types: `double`

### `Width` — Width of each section of step trace

`[0.0020 0.0050 0.0090]` (default) | vector

Width of each section of the step trace in meters, specified as a vector of positive elements.

Example: `trace = traceStep(Width=[0.0060 0.0060 0.0080])`

Data Types: `double`

### `Symmetry` — Symmetry of step trace along X-axis

`1` (default) | `0`

Symmetry of the step trace along the X-axis, specified as `1` or `0`. If set to `1`, symmetry is enabled. Set the property to 1 to create a symmetric step trace and to 0 to create a nonsymmetric step trace.

Example: `trace = traceStep(Symmetry=0)`

Data Types: `logical`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| intersect | Boolean intersection operation on two RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| minus | Shape1 - Shape2 for RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| translate | Move RF PCB shape to new location |
| scale | Change size of RF PCB shape by fixed amount |

## Examples

### Default Step Trace

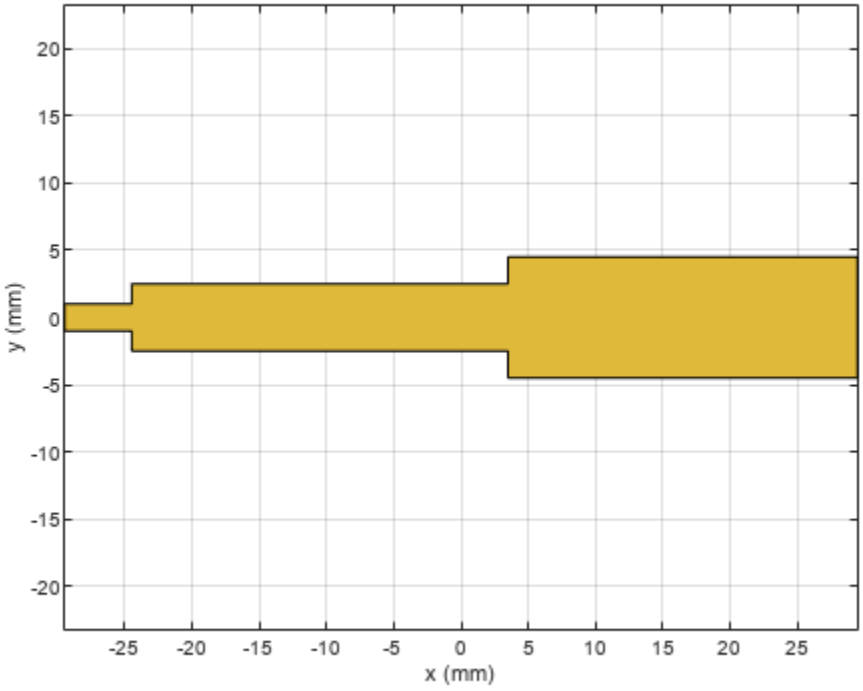
Create a step trace with default values.

```
trace = traceStep
```

```
trace =
  traceStep with properties:

              Name: 'mytraceStep'
    ReferencePoint: [0 0]
            Length: [0.0050 0.0280 0.0260]
             Width: [0.0020 0.0050 0.0090]
          Symmetry: 1
```

Visualize the step trace.

```
show(trace)
```




### Nonsymmetrical Step Trace

Create a nonsymmetrical stepped trace.

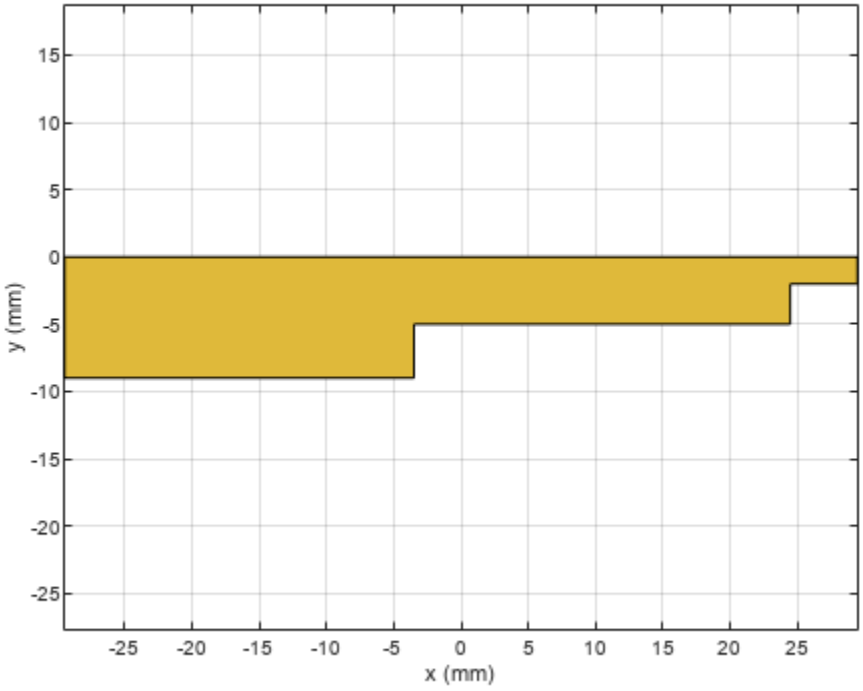
```
trace = traceStep;
trace.Symmetry = 0;
```

Rotate the step trace by 180 degrees about the Z-axis.

```
trace = rotateZ(trace,180);
```

Visualize the step trace.

```
show(trace)
```




## Version History

**Introduced in R2022a**

## See Also

`traceLine` | `traceCross` | `traceRectangular` | `tracePoint` | `traceSpiral`

# traceTapered

Create tapered trace in X-Y plane

## Description

Use the `traceTapered` object to create a tapered trace in the X-Y plane.

## Creation

### Syntax

```
trace = traceTapered
trace = traceTapered(Name=Value)
```

#### Description

`trace = traceTapered` creates a tapered trace in the X-Y plane.

`trace = traceTapered(Name=Value)` sets "Properties" on page 1-166 using one or more name-value arguments. For example, `traceTapered(ReferencePoint=[1 1])` creates a tapered trace with the reference point `[1 1]`. Properties not specified retain their default values.

### Properties

**`Name` — Name of tapered trace**
`'mytraceTapered'` (default) | character vector | string scalar

Name of the tapered trace, specified as a character vector or a string scalar.

Example: `trace = traceTapered(Name="traceTapered")`

Data Types: `char` | `string`

**`ReferencePoint` — X and Y coordinate of tapered trace**
`[0 0]` (default) | two-element vector

X and Y coordinate of the tapered trace in meters, specified as a two-element vector of real elements.

Example: `trace = traceTapered(ReferencePoint=[1 1])`

Data Types: `double`

**`CurvatureRate` — Curvature rate of tapered trace**
`50` (default) | real scalar

Curvature rate of the tapered trace in meters, specified as a real scalar. Set the property to 0 to create a linear trace.

Example: `trace = traceStep(CurvatureRate=20)`

Data Types: `double`

**`InputWidth` — Width of tapered trace at input end**
`0.0050` (default) | positive scalar

Width of the tapered trace at the input end in meters, specified as a positive scalar

Example: `trace = traceTrapered(Width=0.0060)`

Data Types: `double`

**`OutputWidth` — Width of tapered trace at output end**
`0.02` (default) | positive scalar

Width of the output side of the taper trace in meters, specified as a positive scalar

Example: `trace = traceTrapered(Width=0.070)`

Data Types: `double`

**`Length` — Length of tapered trace**
`0.03` (default) | positive scalar

Length of the tapered trace in meters, specified as a positive scalar.

Example: `trace = traceTrapered(Length=0.040)`

Data Types: `double`

**`Symmetry` — Symmetry of tapered trace along X-axis**
`1` (default) | `0`

Symmetry of tapered trace along X-axis, specified as `1` or `0`. If set to `1`, symmetry is enabled.

Example: `trace = traceTapered(Symmetry=0)`

Data Types: `logical`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| intersect | Boolean intersection operation on two RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| minus | Shape1 - Shape2 for RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| translate | Move RF PCB shape to new location |
| scale | Change size of RF PCB shape by fixed amount |

## Examples

### Default Tapered Trace

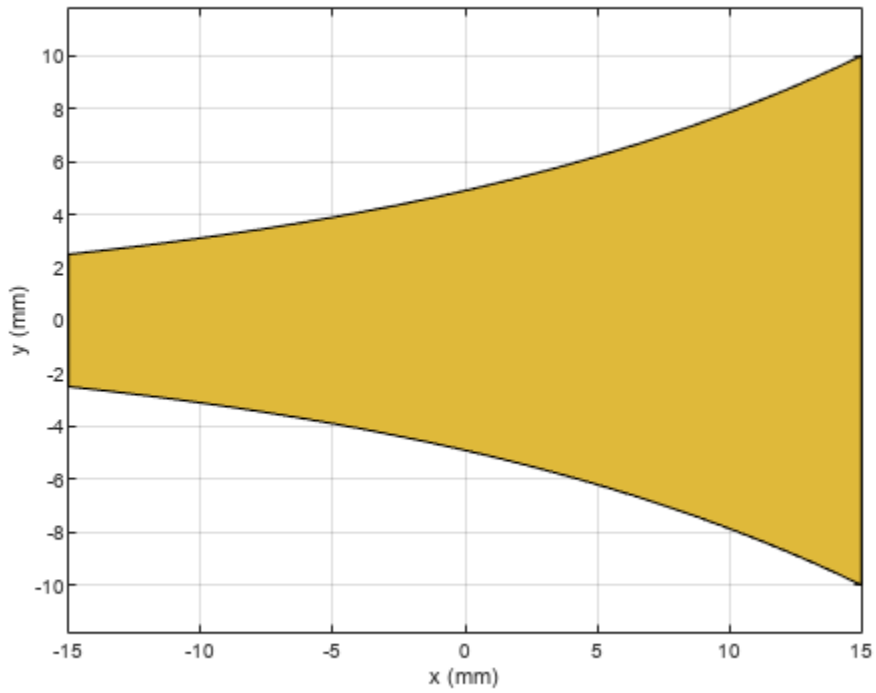
Create a tapered trace with default values.

```
trace = traceTapered
```

```
trace =
  traceTapered with properties:

              Name: 'mytraceTapered'
    ReferencePoint: [0 0]
     CurvatureRate: 50
        InputWidth: 0.0050
       OutputWidth: 0.0200
            Length: 0.0300
          Symmetry: 1
```

Visualize the step trace.

```
show(trace)
```




### Nonsymmetrical Tapered Trace

Create a nonsymmetrical tapered trace.

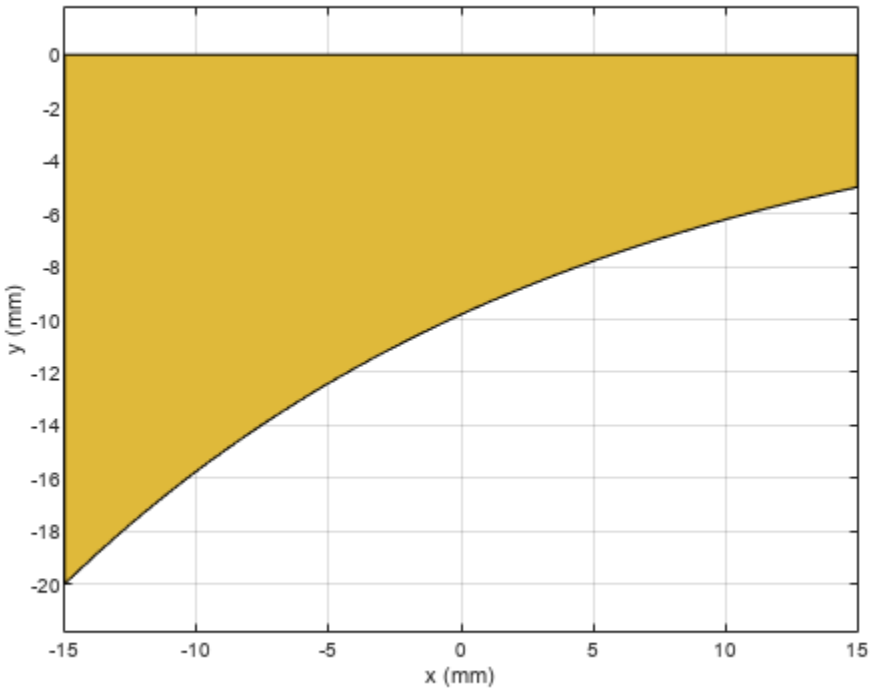
```
trace = traceTapered;
trace.Symmetry = 0;
```

Rotate by 180 degrees about the Z-axis.

```
trace = rotateZ(trace,180);
```

Visualize the step trace.

```
show(trace)
```




# Version History

**Introduced in R2022a**

## See Also

`traceLine` | `traceCross` | `traceRectangular` | `tracePoint` | `traceSpiral` | `traceStep`

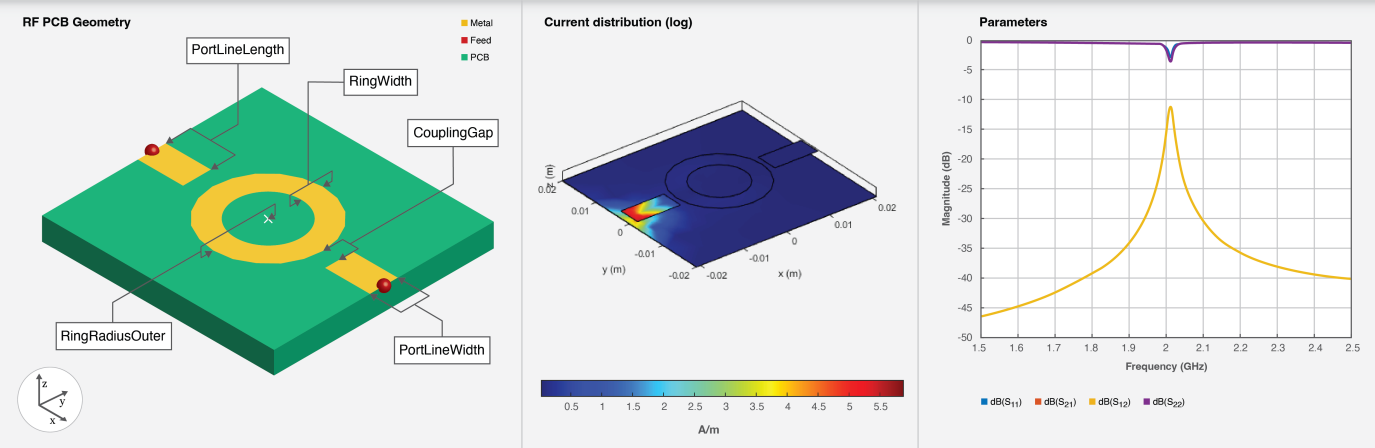
# resonatorRing

Create gap-coupled ring resonator in microstrip form

## Description

Use the `resonatorRing` object to create a gap-coupled ring resonator in the microstrip form. Resonant structures such as rectangular, circular, and ring resonators are used in oscillators and filters.

Resonator Ring




## Creation

### Syntax

```
resonator = resonatorRing
resonator = resonatorRing(Name=Value)
```

#### Description

`resonator = resonatorRing` creates a default gap-coupled ring resonator. The default properties of the ring resonator are for a design frequency of 1 GHz.

`resonator = resonatorRing(Name=Value)` sets "Properties" on page 1-255 using one or more name-value arguments. For example, `resonatorRing(RingWidth=0.045)` creates a ring resonator with a ring width of `0.045` meters. Properties not specified retain their default values

### Properties

#### `PortLineLength` — Length of port line

`0.0100` (default) | positive scalar

Length of the port line in meters, specified as a positive scalar.

Example: `resonator = resonatorRing(PortLineLength=0.045)`

Data Types: `double`

**`PortLineWidth` — Width of port line**
`0.0050` (default) | positive scalar

Width of the port line in meters, specified as a positive scalar.

Example: `resonator = resonatorRing(PortLineWidth=0.0061)`

Data Types: `double`

**`CouplingGap` — Gap between port lines and ring**
`0.001` (default) | positive scalar

Gap between the port lines and the ring in meters, specified as a positive scalar.

Example: `resonator = resonatorRing(CouplingGap=0.002)`

Data Types: `double`

**`RingRadiusOuter` — Outer radius of ring**
`0.0100` (default) | positive scalar

Outer radius of the ring in meters, specified as a positive scalar.

Example: `resonator = resonatorRing(RingRadiusOuter=0.0481)`

Data Types: `double`

**`RingWidth` — Width of ring**
`0.0051` (default) | positive scalar

Width of the ring in meters, specified as a positive scalar.

Example: `resonator = resonatorRing(RingWidth=0.0061)`

Data Types: `double`

**`Height` — Height of resonator from ground plane**
`0.0016` (default) | positive scalar

Height of the resonator from the ground plane in meters, specified as a positive scalar. In the case of a multilayer substrate, you can use the `Height` property to create a resonator where the two dielectrics interface.

Example: `resonator = resonatorRing(Height=0.020)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0400` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `resonator = resonatorRing(GroundPlaneWidth=0.2241)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric("Teflon")` (default) | `dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The thickness of the default dielectric material Teflon is `0.0016` m or the same value as the `Height` property.

Example: `d = dielectric("FR4"); resonator = resonatorRing(Substrate=d)`

**`Conductor` — Type of metal used in conducting layers**
`metal("PEC")` (default) | `metal` object

Type of metal used in the conducting layers, specified as a `metal` object.

Example: `m = metal("Copper"); resonator = resonatorRing(Conductor=m)`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design ring resonator around specified frequency |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Ring Resonator

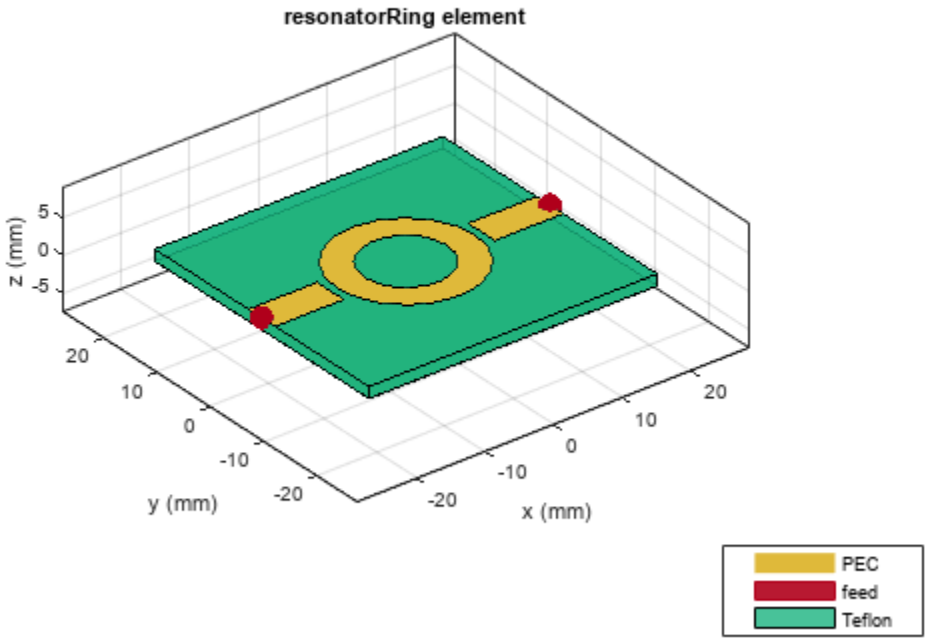
Create a default ring resonator.

```
resonator = resonatorRing
```

```
resonator =
  resonatorRing with properties:

      PortLineLength: 0.0100
       PortLineWidth: 0.0050
         CouplingGap: 1.0000e-03
     RingRadiusOuter: 0.0100
           RingWidth: 0.0040
              Height: 0.0016
    GroundPlaneWidth: 0.0400
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

Visualize the resonator.

```
show(resonator)
```



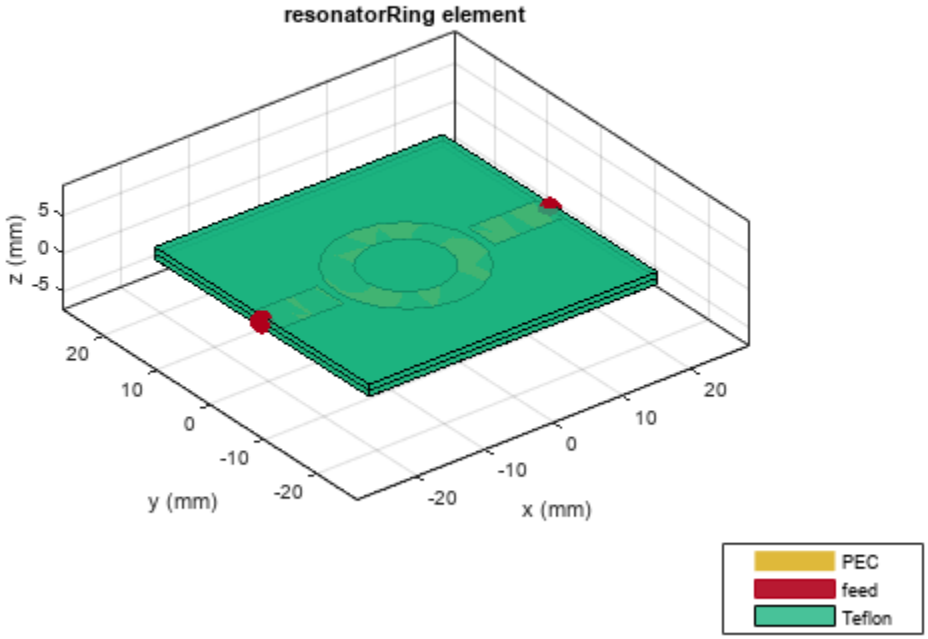

### Multilayer Dielectric Ring Resonator

Create a ring resonator at the interface of a multilayer dielectric.

```
resonator = resonatorRing;
resonator.Substrate = dielectric(Name={'Teflon','Teflon'},EpsilonR=[2.1 2.1],...
    LossTangent=[0 0],Thickness=[0.8e-3 0.8e-3]);
resonator.Height = 0.8e-3;
```

Visualize the ring resonator.

```
show(resonator)
```




# Version History

**Introduced in R2022b**

## References

[1] Pozar, David.M. *Microwave Engineering* Singapore; JohnWiley and Sons. Inc, 2012.

[2] Bogner, Andreas, Carsten Steiner, Stefanie Walter, Jaroslaw Kita, Gunter Hagen, and Ralf Moos. *Planar Microstrip ring resonators for Microwave-Based Gas Sensing: Design Aspects and Initial Transducers for Humidity and Ammonia Sensing*.

[3] Bernard, P.A., and J.M. Gautray. “Measurement of Dielectric Constant Using a Microstrip Ring Resonator.” *IEEE Transactions on Microwave Theory and Techniques* 39, no. 3 (March 1991): 592–95.

## See Also

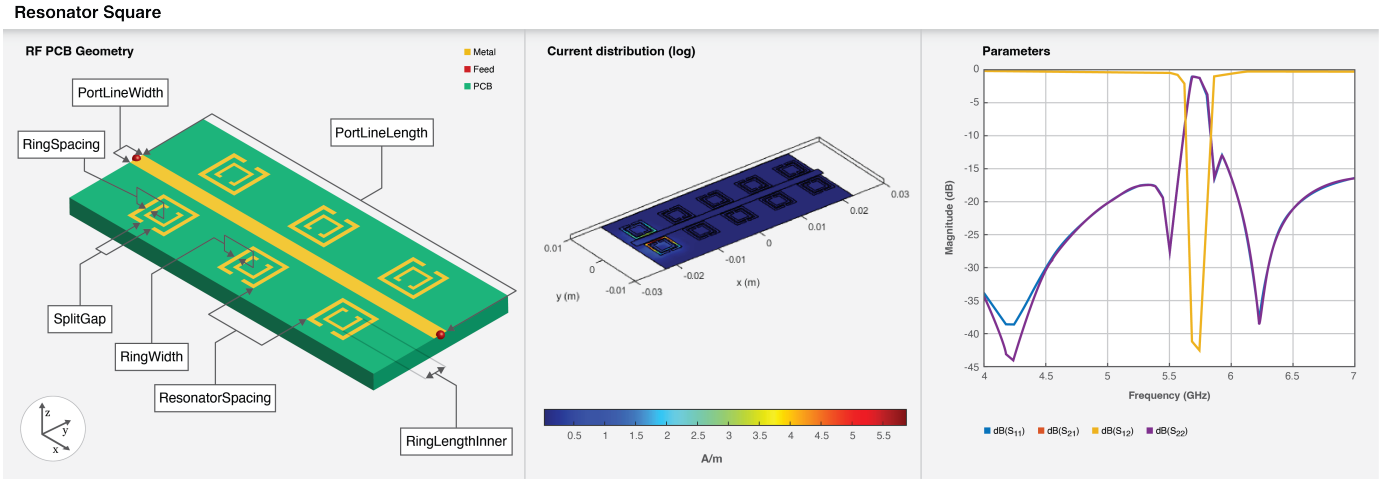
`resonatorSplitRingSquare`

# resonatorSplitRingSquare

Create microstrip line loaded with square split-ring resonator

## Description

Use the `resonatorSplitRingSquare` object to create a microstrip line loaded with a square split-ring resonator.




## Creation

### Syntax

```
resonator = resonatorSplitRingSquare
resonator = resonatorSplitRingSquare(Name=Value)
```

#### Description

`resonator = resonatorSplitRingSquare` creates a microstrip line loaded with a square split-ring resonator on the *X*-*Y* plane. The default proprieties are for a design frequency of 5.7 GHz.

`resonator = resonatorSplitRingSquare(Name=Value)` sets "Properties" on page 1-260 using one or more name-value arguments. For example, `resonatorSplitRingSquare(RingWidth=0.045)` creates a square split-ring resonator with a ring width of `0.045` meters. Properties not specified retain their default values

### Properties

#### `RingLengthInner` — Length of inner ring

`0.0036` (default) | positive scalar

Length of the inner ring of the ring resonator in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingSquare(RingLengthInner=0.045)`

Data Types: `double`

**`RingWidth` — Width of square ring**
`5.0000e-04` (default) | positive scalar

Width of the square ring in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingSquare(RingWidth=0.0009)`

Data Types: `double`

**`RingSpacing` — Spacing between inner and outer square ring**
`3.0000e-04` (default) | positive scalar

Spacing between the inner and outer square ring in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingSquare(RingSpacing=0.0008)`

Data Types: `double`

**`SplitGap` — Split gap on square ring**
`5.0000e-04` (default) | positive scalar

Split gap on the square ring in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingSquare(SplitGap=0.0008)`

Data Types: `double`

**`CouplingGap` — Gap between resonator and microstrip line**
`2.50000e-04` (default) | positive scalar

Gap between the resonator and the microstrip line in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingSquare(CouplingGap=0.00082)`

Data Types: `double`

**`NumResonator` — Number of resonators on one side of transmission line**
`5` (default) | positive scalar in the range [1,7]

Number of resonators on one side of the transmission line, specified as a positive scalar in the range [1,7]. The object supports a minimum of one resonator and a maximum of seven resonators.

Example: `resonator = resonatorSplitRingSquare(NumResonator=4)`

Data Types: `double`

**`ResonatorSpacing` — Spacing between resonators**
`0.004` (default) | positive scalar

Spacing between the resonators when number of resonators is more than one in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingSquare(NumResonator=4)`

Data Types: `double`

**`PortLineLength` — Length of microstrip line**
`0.0450` (default) | positive scalar

Length of the microstrip line in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingSquare(PortLineLength=0.055)`

Data Types: `double`

**`PortLineWidth` — Width of microstrip line**
`0.0019` (default) | positive scalar

Width of the microstrip line in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingSquare(PortLineWidth=0.0061)`

Data Types: `double`

**`Height` — Height of resonator from ground plane**
`8.1300e-04` (default) | positive scalar

Height of the resonator from the ground plane in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingSquare(Height=0.020)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0200` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingSquare(GroundPlaneWidth=0.2241)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric("FR4")` (default) | `dielectric` object

Type of dielectric material to use as a substrate, specified as a `dielectric` object. The thickness of the default dielectric material has the following parameters: `(Name={'FR4'},EpsilonR=3.38,LossTangent=0.0002,Thickness=0.813e-3)`.

Example: `d = dielectric("FR4"); resonator = resonatorSplitRingSquare(Substrate=d)`

**`Conductor` — Type of metal in conducting layers**
`metal("Copper")` (default) | `metal` object

Type of metal to use in the conducting layers, specified as a `metal` object.

Example: `m = metal("PEC"); resonator = resonatorSplitRingSquare(Conductor=m)`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design hairpin filter around specified frequency |
| feedCurrent | Calculate current at feed port |

| | |
|---|---|
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Square Split-Ring Resonator

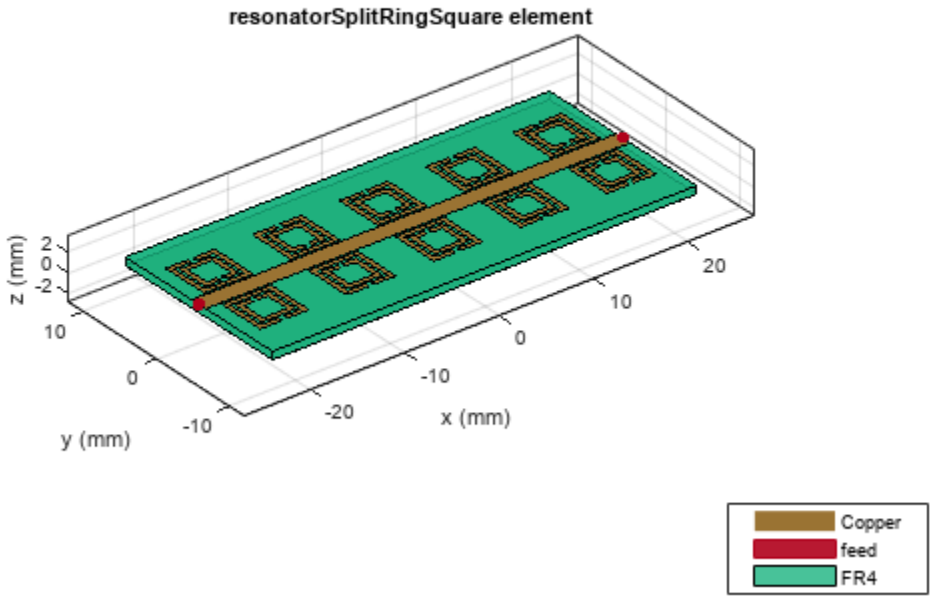
Create a default square split-ring resonator.

```
resonator = resonatorSplitRingSquare
```

```
resonator =
  resonatorSplitRingSquare with properties:

     RingLengthInner: 0.0036
           RingWidth: 5.0000e-04
         RingSpacing: 3.0000e-04
            SplitGap: 5.0000e-04
         CouplingGap: 2.5000e-04
        NumResonator: 5
    ResonatorSpacing: 0.0040
      PortLineLength: 0.0450
       PortLineWidth: 0.0019
              Height: 8.1300e-04
    GroundPlaneWidth: 0.0200
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the resonator.

```
show(resonator)
```




### Square Split-Ring Resonator with Different Dielectrics

Create a split-ring square with one resonator.

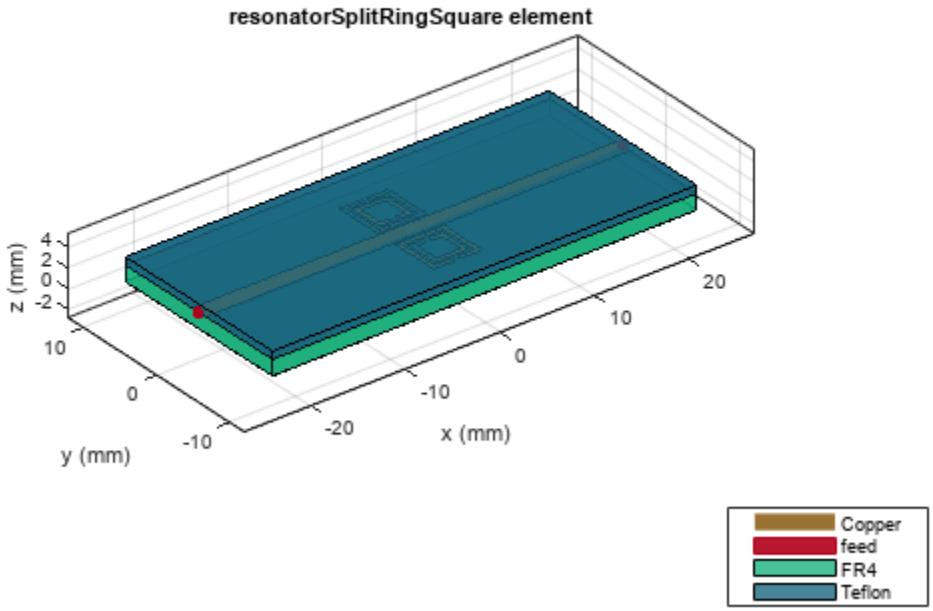
```
resonator = resonatorSplitRingSquare(NumResonator=1);
resonator.Height =  0.0016;
```

Create a dielectric object with two dielectrics. Use this substrate in the resonator.

```
sub = dielectric('FR4','Teflon');
sub.Thickness =[0.0016 0.0008];
resonator.Substrate = sub;
```

View the resonator.

```
figure;
show(resonator);
```




# Version History

**Introduced in R2022b**

## References

[1] Pozar, David.M. *Microwave Engineering* Singapore; JohnWiley and Sons. Inc, 2012.

[2] Mahyuddin, Muzlifah and Nur Farah Syazwani Ab. Kadir. *Design of a 5.8 GHz Bandstop Filter Using Split Ring Resonator Array*

[3] Mahyuddin, Muzlifah and Nur Farah Syazwani Ab. Kadir. "A 10 GHz Low Phase Noise Split-Ring Resonator Oscillator." *International Journal of Information and Electronics Engineering*, 2013.

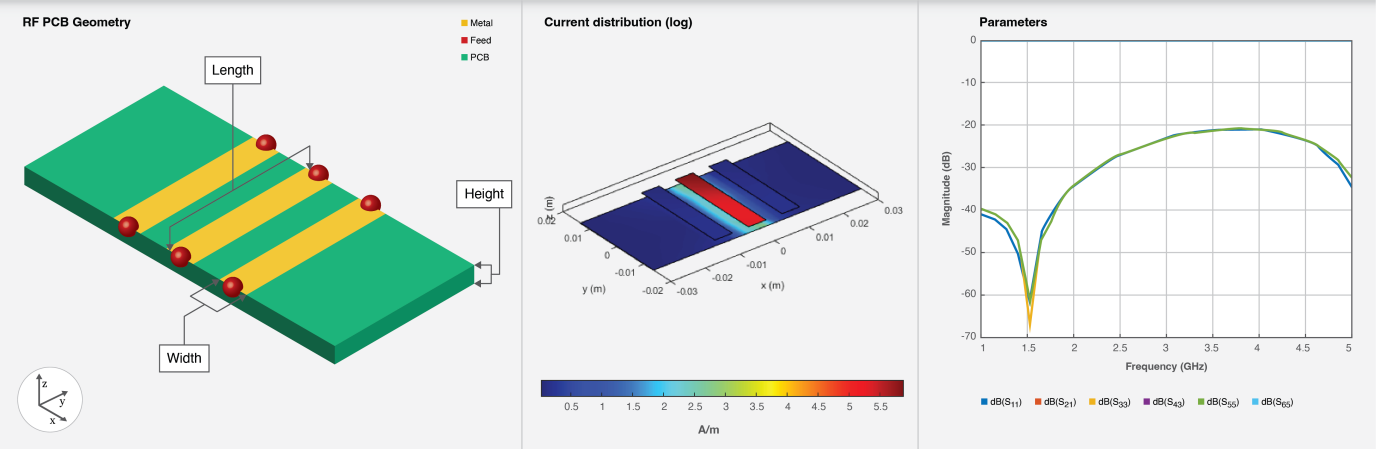
# microstripLineCustom

Create coupled form of single or differential microstrip transmission line

## Description

Use the `microstripLineCustom` object to create a coupled form of single or differential microstrip transmission line. A microstrip line is a transmission line that is a basic building block for most RF planar microwave devices. You can use this transmission line to connect two PCB components or to create components such as filters, couplers, and feeding elements of several types of antennas.

Micro Strip Line Custom




A few applications of microstrip transmission lines are:

- Creating matching feed and coupling networks
- Transmitting power from one component to another
- Feeding planar antennas and coupling structures
- Creating varying inductances or capacitances using open- or short ended- transmission lines

## Creation

### Syntax

```
microstrip = microstripLineCustom
microstrip = microstripLineCustom(Name=Value)
```

#### Description

`microstrip = microstripLineCustom` creates a coupled form of single or differential microstrip transmission line. The default properties are for a design frequency of 2.5 GHz.

`microstrip = microstripLineCustom(Name=Value)` sets properties using one or more name value pair arguments. For example, `microstrip =`

`microstripLineCustom(TraceSpacing=0.0300)` creates a custom differential microstrip transmission line with a trace spacing of 0.0300 meters. Properties not specified retain their default values.

## Properties

### `TraceType` — Types of traces

`'Single'` (default) | `'Differential'`

Types of traces, specified as `'Single'` or `'Differential'`.

Example: `microstrip = microstripLineCustom(TraceType='Differential')`

Data Types: `string` | `char`

### `TraceLength` — Length of trace

`0.0271` (default) | positive scalar

Length of the trace in meters, specified as a positive scalar.

Example: `microstrip = microstripLineCustom(TraceLength=0.0371)`

Data Types: `double`

### `TraceWidth` — Width of trace

`0.0051` (default) | positive scalar

Width of the trace in meters, specified as a positive scalar.

Example: `microstrip = microstripLineCustom(TraceWidth=0.0041)`

Data Types: `double`

### `TraceSpacing` — Spacing between two traces of differential pair

`0.0046` (default) | positive scalar

Spacing between the two traces of a differential pair in meters, specified as a positive scalar. Set the `TraceType` property to `'Differential'` to enable this property.

Example: `microstrip = microstripLineCustom(TraceSpacing=0.0041)`

Data Types: `double`

### `TraceOffsetX` — Position to offset reference trace along X-axis

`0` (default) | scalar

Position to offset reference trace along the X-axis, specified as a positive scalar.

Example: `microstrip = microstripLineCustom(TraceOffsetX=0.5)`

Data Types: `double`

### `Height` — Height from custom microstrip line to ground plane

`0.0016` (default) | positive scalar

Height from the custom microstrip line to the ground plane in meters, specified as a positive scalar.

In the case of a multilayer substrate, you can use the height property to create a microstrip line at the interface of the two dielectrics.

Example: `microstrip = microstripLineCustom(Height=0.0026)`

Data Types: `double`

**`GroundPlaneLength` — Length of ground plane**
`0.0600` (default) | positive scalar

Length of the ground plane in meters, specified as a positive scalar.

Example: `microstrip = microstripLineCustom(GroundPlaneLength=0.0500)`

Data Types: `double`

**`LeftCoupledTraceGap` — Gap between left coupled traces**
`0.0046` (default) | scalar | vector

Gap between the left coupled traces in meters, specified as a scalar or vector. Set this property to `0`, if there are no left coupled traces.

Example: `microstrip = microstripLineCustom(LeftCoupledTraceGap=0)`

Data Types: `double`

**`RightCoupledTraceGap` — Gap between right coupled traces**
`0.0046` (default) | scalar | vector

Gap between the right coupled traces in meters, specified as a scalar or vector. Set this property to `0`, if there are no right coupled traces.

Example: `microstrip = microstripLineCustom(RightCoupledTraceGap=0)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `microstriplineCustom` with default properties is Teflon. The thickness of the default dielectric material Teflon is `0.0016` m or the same as the height property.

Example: `d = dielectric('FR4'); microstrip = microstripLineCustom(Substrate=d)`

**`Conductor` — Type of metal used in conducting layers**
`metal("PEC")` (default) | `metal` object

Type of metal used in conducting layers, specified as a `metal` object. The type of metal in a `microstriplineCustom` object with default properties is PEC.

Example: `m = metal('PEC'); microstrip = microstripLineCustom(Conductor=m)`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design microstrip transmission line around specified frequency |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |

| | |
|---|---|
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

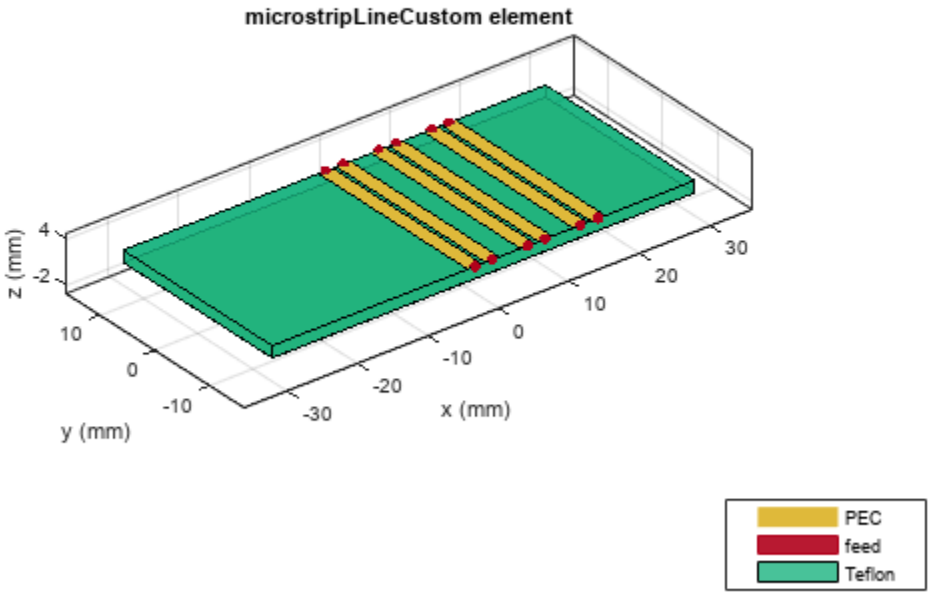
### Differential Right Coupled Microstrip Line

Create a coupled form of differential microstrip line with two pairs of right coupled lines.

```
microstrip = microstripLineCustom(TraceType='Differential',TraceWidth=...
    0.002,TraceSpacing=0.0005,RightCoupledTraceGap=[0.003,0.003],...
    LeftCoupledTraceGap=0);
```

View the custom transmission line.

```
show(microstrip)
```



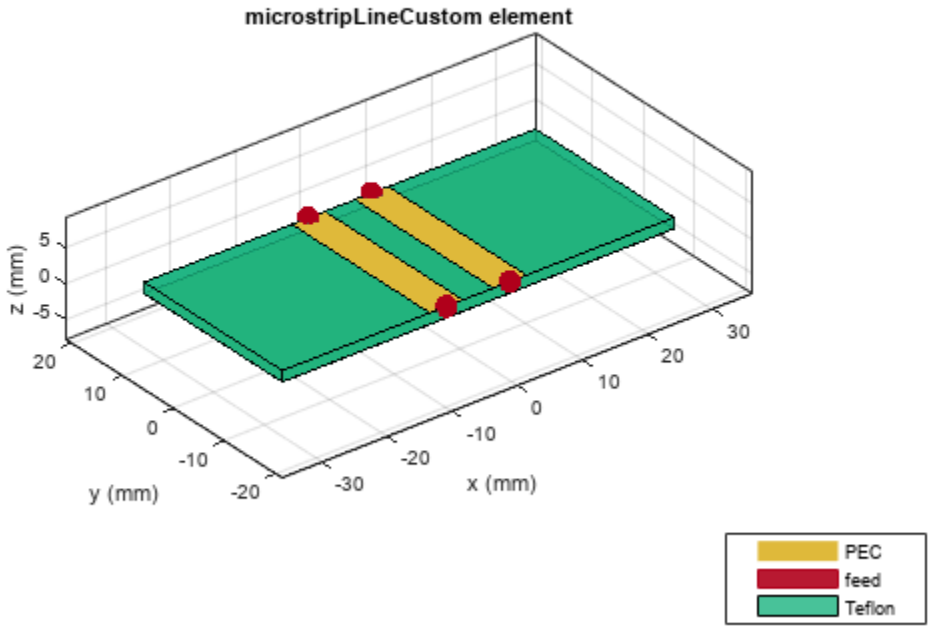

### Differential Microstrip Line with No Left or Right Traces

Create a differential microstrip transmission line with no left or right traces

```
microstrip = microstripLineCustom(TraceType='Differential',TraceSpacing=...
    0.0046,LeftCoupledTraceGap=0,RightCoupledTraceGap=0);
```

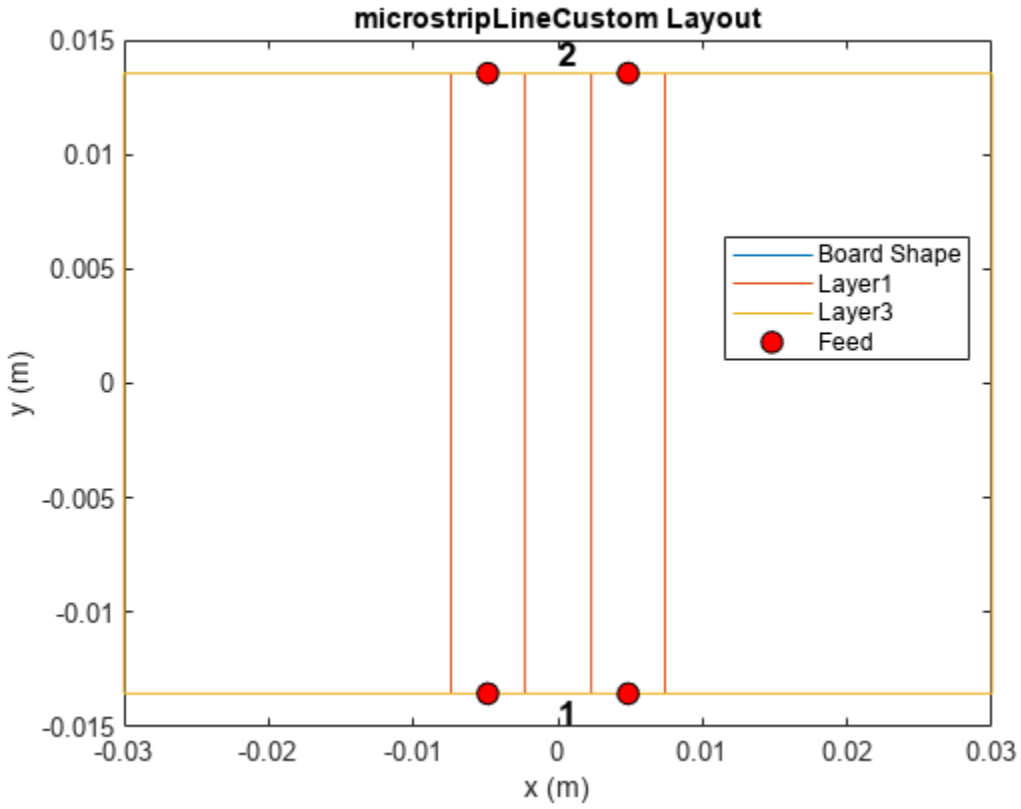
View the transmission line.

```
show(microstrip)
```



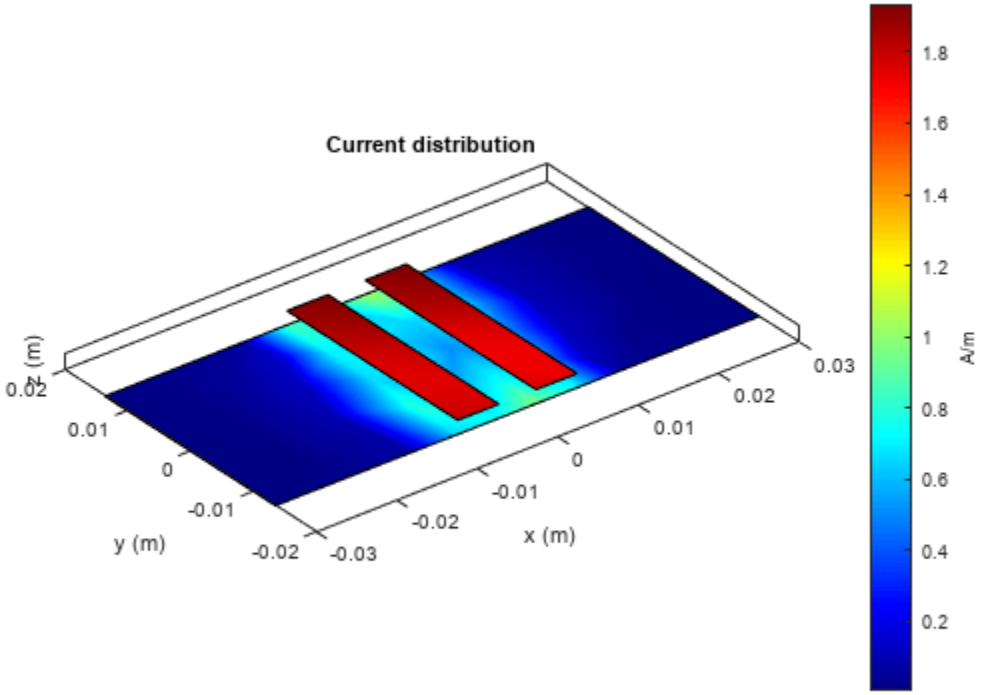

Set the voltage on the transmission line ports. View the layout.

```
v = voltagePort(4);
v.FeedVoltage = [1 0 1 0];
v.FeedPhase = [0 0 180 0];
figure;
layout(microstrip)
```




Analyze the current at 2.5 GHz.

```
figure;
current(microstrip,2.5e9,Excitation=v)
```




## Version History

**Introduced in R2022b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`coplanarWaveguide` | `coupledMicrostripLine`

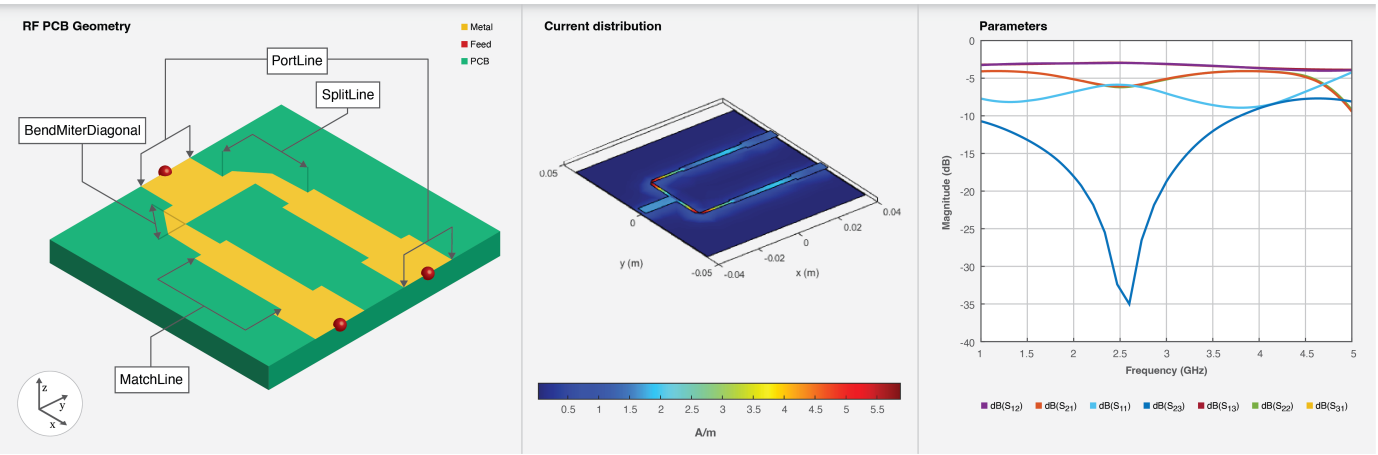
# splitterTee

Create T-junction power splitter

## Description

Use the `splitterTee` object to create a T-junction power splitter. The T-junction is a lossless and reciprocal three-port divider which divides the input equally between the two output ports.

Splitter Tee




To analyze the behavioral model for the T-junction power splitter, set the `Behavioral` property in `sparameters` to `true` or `1`.

## Creation

### Syntax

```
splitter = splitterTee
splitter = splitterTee(Name=Value)
```

#### Description

`splitter = splitterTee` creates a T-junction power splitter with default properties for a design frequency of 1.8 GHz.

`splitter = splitterTee(Name=Value)` sets “Properties” on page 1-274 using one or more name-value arguments. For example, `splitterTee(PortLineLength=0.0155)` creates a T-junction splitter with a port line length of 0.0155 meters. Properties not specified retain their default values.

## Properties

**Shape — Shape of T-junction splitter**
`'RectangularMitered'` (default) | `'RectangularCurved'` | `'Circular'`

Shape of the T-junction splitter, specified as `'RectangularMitered'`, `'RectangularCurved'`, or `'Circular'`.

Example: `splitter = splitterTee(Shape='Circular')`

Data Types: `char`

**PortLineLength — Length of port line**
`0.0155` (default) | positive scalar

Length of the port line in meters, specified as a positive scalar.

Example: `splitter = splitterTee(PortLineLength=0.0144)`

Data Types: `double`

**PortLineWidth — Width of port line**
`0.0051` (default) | positive scalar

Width of the port line in meters, specified as a positive scalar.

Example: `splitter = splitterTee(PortLineWidth=0.0041)`

Data Types: `double`

**SplitLineLength — Length of split line**
`0.0320` (default) | positive scalar

Length of the split line in meters, specified as a positive scalar. Generally the length is λ/4 for a Tee splitter.

Example: `splitter = splitterTee(SplitLineLength=0.0420)`

Data Types: `double`

**SplitLineWidth — Width of split line**
`0.0015` (default) | positive scalar

Width of the split line in meters, specified as a positive scalar.

Example: `splitter = splitterTee(SplitLineWidth=0.0025)`

Data Types: `double`

**BendMiterDiagonal — Length of miter diagonal at bend**
`0.0035` (default) | positive scalar

Length of the miter diagonal at the bend in meters, specified as a positive scalar.

Example: `splitter = splitterTee(BendMiterDiagonal=0.0045)`

Data Types: `double`

**BendCurveRadius — Radius of curve at bend**
`0.0020` (default) | positive scalar

Radius of the curve at the bend in meters, specified as a positive scalar.

Example: `splitter = splitterTee(BendCurveRadius=0.0030)`

**Dependencies**

To enable this property, set the `Shape` property to `'RectangularCurved'`.

Data Types: `double`

### `MatchLineLength` — Length of match line

`0.0315` (default) | positive scalar

Length of the match line in meters, specified as a positive scalar.

Example: `splitter = splitterTee(MatchLineLength=0.0415)`

Data Types: `double`

### `MatchLineWidth` — Width of match line

`0.0029` (default) | positive scalar

Width of the match line in meters, specified as a positive scalar.

Example: `splitter = splitterTee(MatchLineWidth=0.0039)`

Data Types: `double`

### `PortSpacing` — Spacing between output ports

`0.0320` (default) | positive scalar

Spacing between the output ports in meters, specified as a positive scalar.

Example: `splitter = splitterTee(PortSpacing=0.0420)`

Data Types: `double`

### `Height` — Height of T-junction power splitter from ground plane

`0.0016` (default) | positive scalar

Height of the T-junction power splitter from the ground plane in meters, specified as a positive scalar.

In the case of a multilayer substrate, you can use the `Height` property to create a T-junction power splitter where the two dielectrics interface.

Example: `splitter = splitterTee(Height=0.0076)`

Data Types: `double`

### `GroundPlaneWidth` — Width of ground plane

`0.0847` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `splitter = splitterTee(GroundPlaneWidth=0.098)`

Example: double

### `Substrate` — Type of dielectric material

`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `splitterTee` object with default properties in Teflon.

Example: `d = dielectric("FR4"); splitter = splitterTee(Substrate=d)`

Data Types: `string` | `char`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The metal in a `splitterTee` object with default properties in PEC.

Example: `m = metal("Copper"); splitter = splitterTee(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design T-junction power splitter around specified frequency |
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Splitter Tee

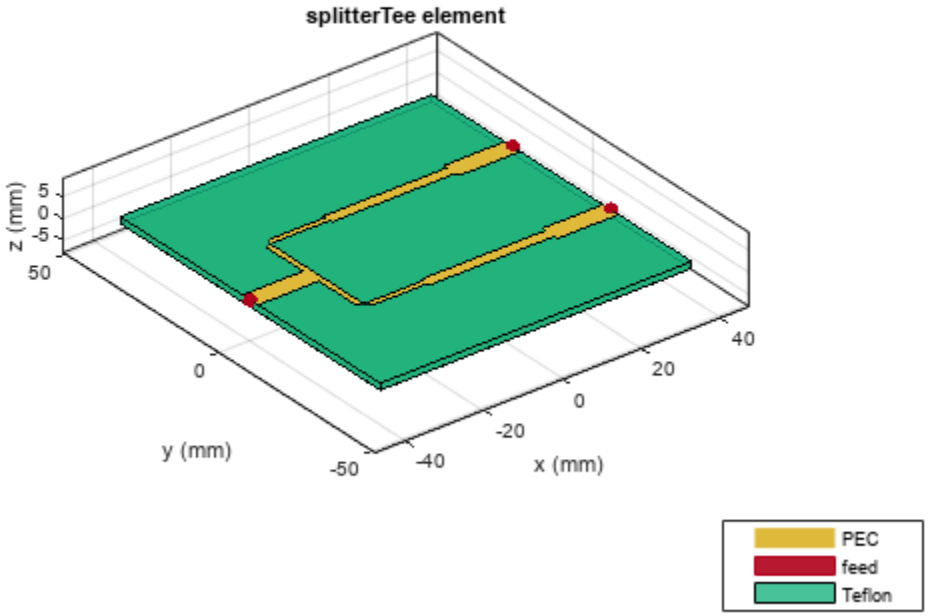
Create a default splitter tee.

```
splitter = splitterTee
```

```
splitter =
  splitterTee with properties:

                Shape: 'RectangularMitered'
       PortLineLength: 0.0155
        PortLineWidth: 0.0051
      SplitLineLength: 0.0320
       SplitLineWidth: 0.0015
    BendMiterDiagonal: 0.0035
      MatchLineLength: 0.0315
       MatchLineWidth: 0.0029
          PortSpacing: 0.0320
               Height: 0.0016
     GroundPlaneWidth: 0.0847
            Substrate: [1x1 dielectric]
            Conductor: [1x1 metal]
```

Visualize the splitter tee.

```
show(splitter)
```




### S-Parameters of Curved Rectangular Splitter Tee

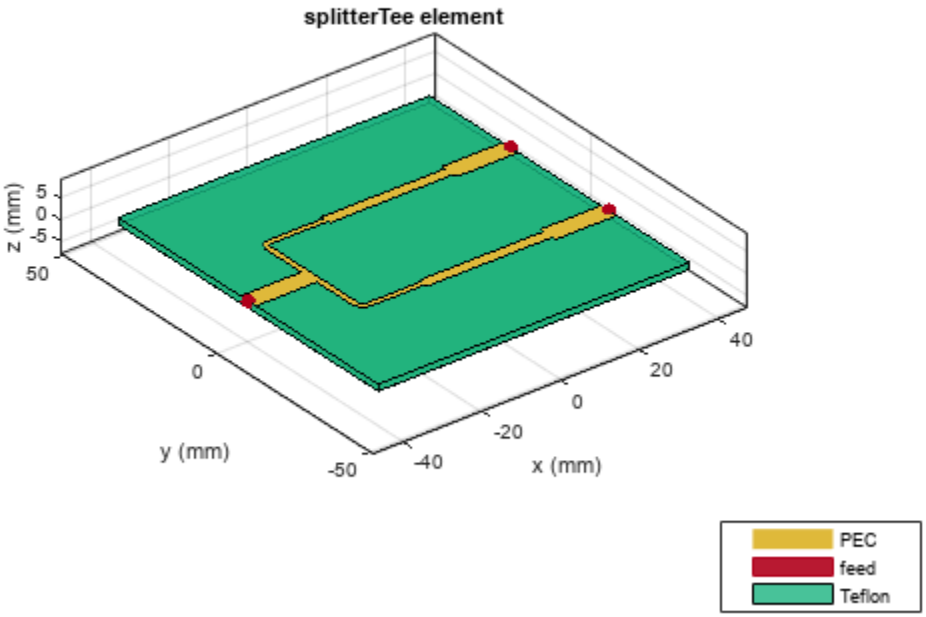
Create a curved rectangular splitter tee.

```
splitter = splitterTee(Shape='RectangularCurved')
```

```
splitter =
  splitterTee with properties:

              Shape: 'RectangularCurved'
     PortLineLength: 0.0155
      PortLineWidth: 0.0051
    SplitLineLength: 0.0320
     SplitLineWidth: 0.0015
    BendCurveRadius: 0.0020
    MatchLineLength: 0.0315
     MatchLineWidth: 0.0029
        PortSpacing: 0.0320
             Height: 0.0016
   GroundPlaneWidth: 0.0847
          Substrate: [1x1 dielectric]
          Conductor: [1x1 metal]
```

Visualize the splitter tee.

```
show(splitter)
```

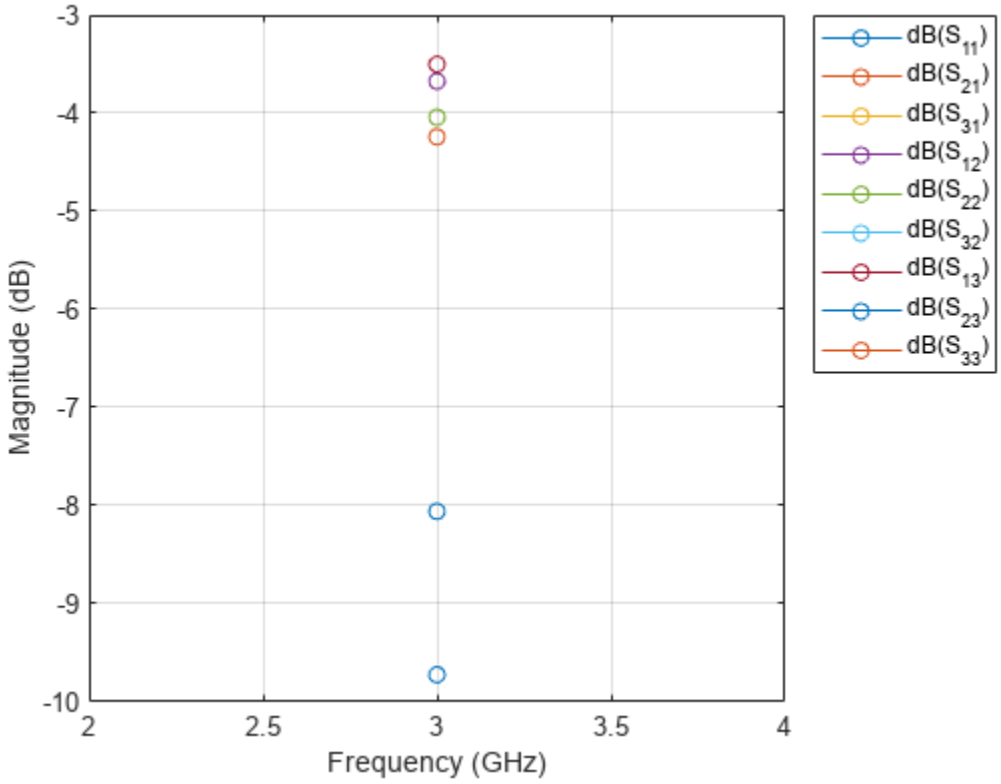



Calculate and plot the s-parameters of the tee at 3 GHz.

```
spar = sparameters(splitter,3e9)
```

```
spar =
  sparameters: S-parameters object

       NumPorts: 3
    Frequencies: 3.0000e+09
     Parameters: [3x3 double]
      Impedance: 50

  rfparam(obj,i,j) returns S-parameter Sij
```

```
rfplot(spar)
```



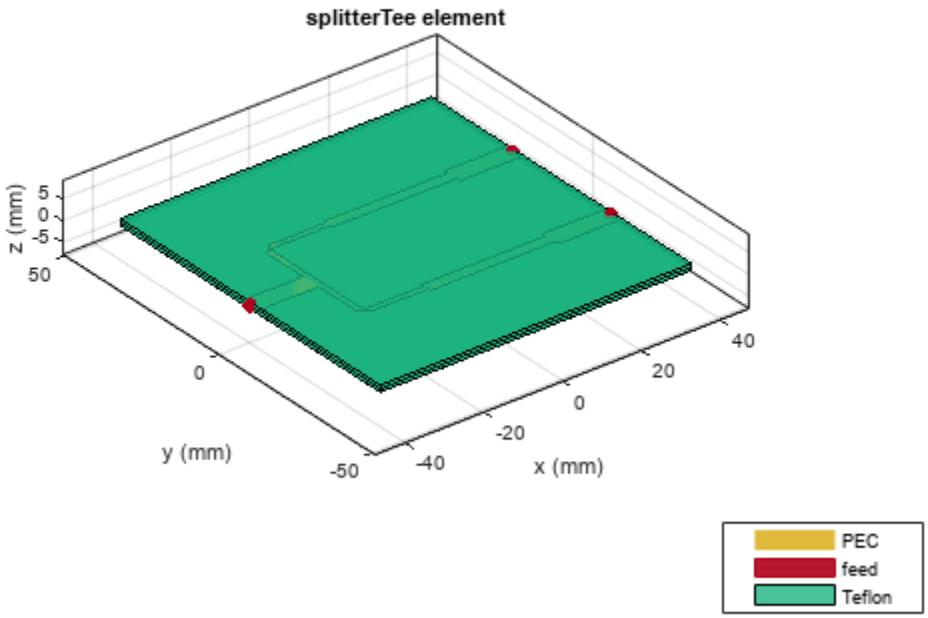

### Multilayer Dielectric Splitter Tee

Create a splitter tee at the interface of a multilayer dielectric.

```
splitter = splitterTee;
splitter.Substrate = dielectric(Name={'Teflon','Teflon'},EpsilonR=[2.1 2.1], ...
    LossTangent=[0 0],Thickness=[0.8e-3 0.8e-3]);
splitter.Height = 0.8e-3;
```

Visualize the splitter tee.

```
show(splitter);
```




# Version History

**Introduced in R2022b**

### R2022b: Behavioral Analysis for T-Junction Power Splitter

Use the `sparameters` function and the `pcbElement` object to perform the behavioral analysis of a T-junction power splitter.

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

[2] Kumari, Chanchala, and Neela Chattoraj. “Design of an Elementary Microstrip Power Splitter for Antenna Array.” In 2021 National Conference on Communications (NCC), 1–5. Kanpur, India: IEEE, 2021. https://doi.org/10.1109/NCC52529.2021.9530097.

## See Also

`wilkinsonSplitter` | `wilkinsonSplitterUnequal` | `wilkinsonSplitterWideband`

**Topics**

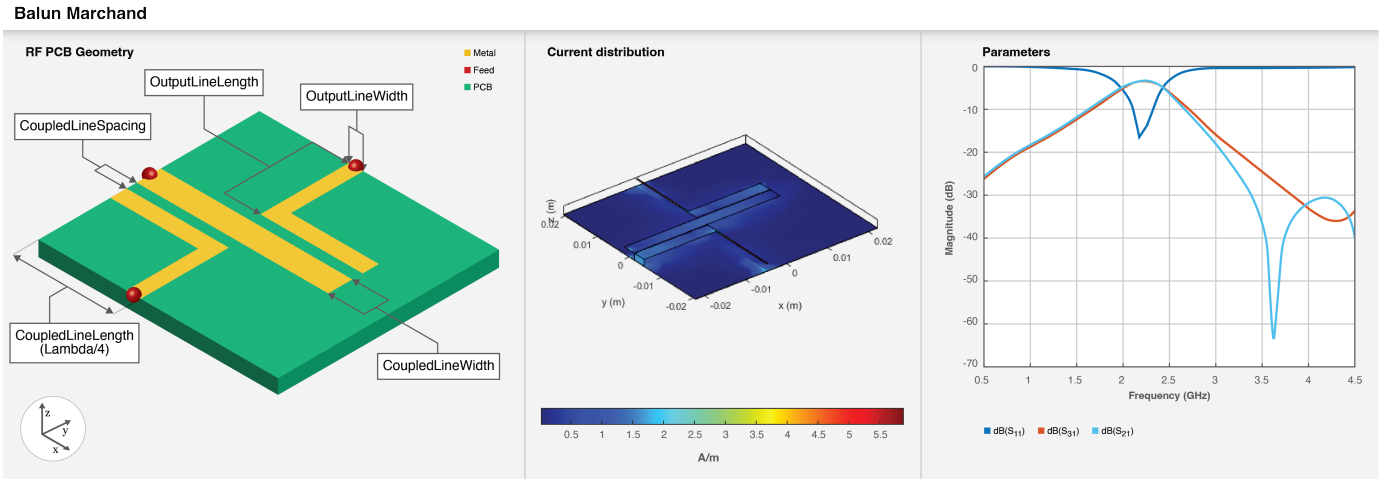
“Behavioral Models”

# balunMarchand

Create Marchand balun in microstrip form

## Description

Use the `balunMarchund` object to create a Marchand balun in the microstrip form with an unbalanced and balanced output. There is a 180 degrees phase difference between the input and the output ports.




Baluns are used to connect an unbalanced source line to a balanced load or vice-versa enabling you to create a matching transition between balanced and unbalanced transmission lines. A Marchand balun has a pair of quarter-wavelength coupled lines of quarter wavelength for dividing and combining signals with the same amplitude and opposite phase.

## Creation

### Syntax

```
balun = balunMarchand
balun = balunMarchand(Name=Value)
```

#### Description

`balun = balunMarchand` creates a Marchand balun in the microstrip form with default properties for a resonant frequency of 2.2 GHz.

`balun = balunMarchand(Name=Value)` sets “Properties” on page 1-42 using one or more name-value arguments. For example, `balunMarchand(OutputLineLength=0.016)` creates a Marchand balun with an output line length of `0.016` meters. Properties not specified retain their default values.

## Properties

**`CoupledLineLength` — Length of coupled line**
`0.0178` (default) | positive scalar

Length of the coupled line in meters, specified as a positive scalar.

Example: `balun = balunMarchand(CoupledLineLength=0.0254)`

Data Types: `double`

**`CoupledLineWidth` — Width of coupled line**
`0.0003` (default) | positive scalar

Width of the coupled line in meters, specified as a positive scalar.

Example: `balun = balunMarchand(CoupledLineWidth=0.0005)`

Data Types: `double`

**`CoupledLineSpacing` — Spacing between coupled lines**
`1.5e-04` (default) | positive scalar

Spacing between the coupled lines in meters, specified as a positive scalar.

Example: `balun = balunMarchand(CoupledLineSpacing=0.00014)`

Data Types: `double`

**`OutputLineLength` — Length of output line**
`0.016` (default) | positive scalar

Length of the output line in meters, specified as a positive scalar.

Example: `balun = balunMarchand(OutputLineLength=0.0224)`

Data Types: `double`

**`OuputLineWidth` — Width of output line**
`2.9e-04` (default) | positive scalar

Width of the output line in meters, specified as a positive scalar.

Example: `balun = balunMarchand(OutputLineWidth=0.000253)`

Data Types: `double`

**`Height` — Height of Marchand balun from ground plane**
`0.0016` (default) | positive scalar

Height of the Marchand balun from the ground plane in meters, specified as a positive scalar.

In the case of a multilayer substrate, you can use the `Height` property to create a Marchand balun where the two dielectrics interface.

Example: `balun = balunMarchand(Height=0.022)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The default height of the substrate is `0.0013` meters. The dielectric material in a `balunMarchand` object with default properties is FR4.

Example: `d = dielectric("RTDuriod"); balun =balunMarchand(Substrate=d)`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `balunMarchand` object with default properties is PEC.

Example: `m = metal("Copper"); balun =balunMarchand(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| designCoupledLine | Calculate dimensions of coupled-line section for specified frequency |
| designUncoupledLine | Calculate dimensions of uncoupled-line section for specified frequency |
| designOutputLine | Calculate dimensions of output line section for specified frequency |
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Marchand Balun

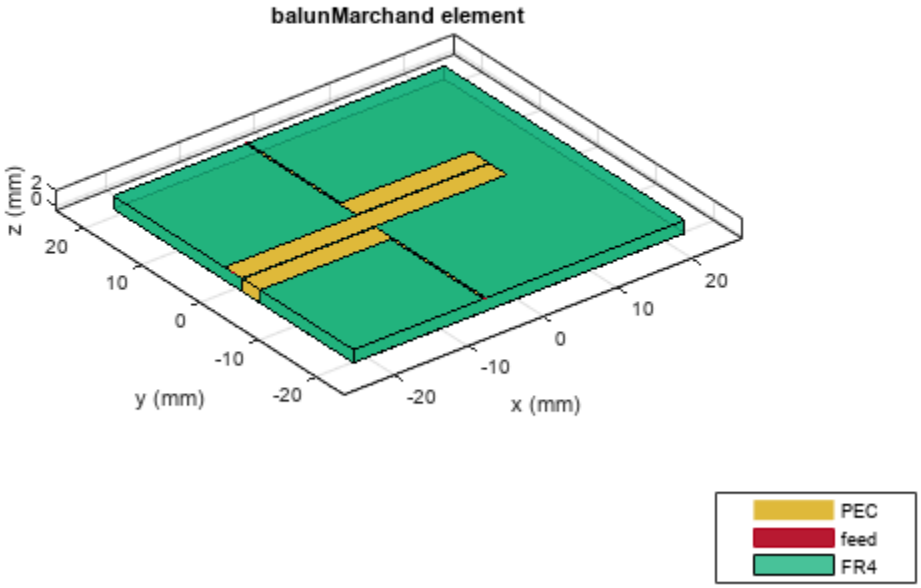
Create a default Marchand balun.

```
balun = balunMarchand
```

```
balun =
  balunMarchand with properties:

     CoupledLineLength: 0.0178
      CoupledLineWidth: 0.0030
    CoupledLineSpacing: 1.5000e-04
      OutputLineLength: 0.0160
       OutputLineWidth: 2.9000e-04
                Height: 0.0016
             Substrate: [1x1 dielectric]
             Conductor: [1x1 metal]
```

View the balun.

```
show(balun)
```




### Multilayer Dielectric Marchand Balun

Create a Marchand balun.

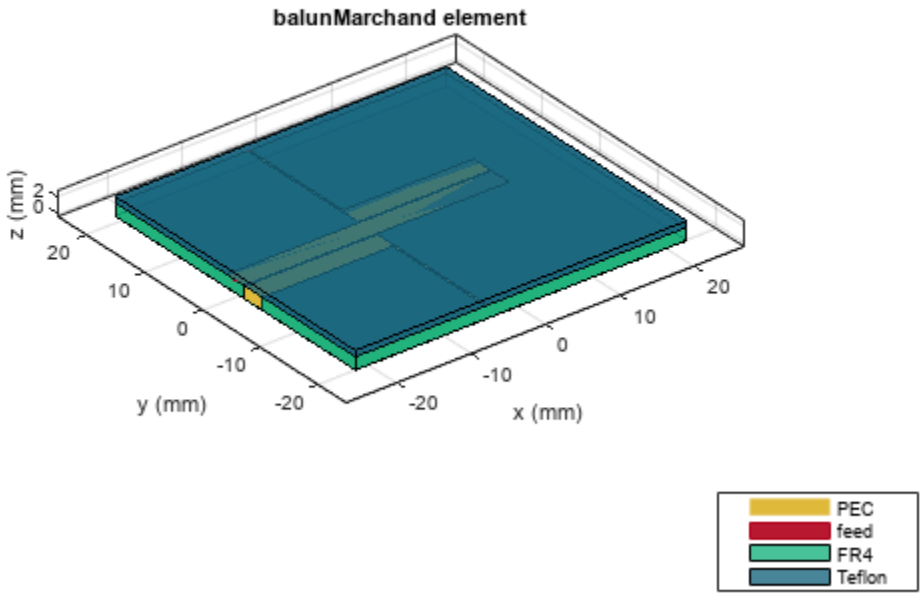
```
balun = balunMarchand;
balun.Height =  0.0016;
```

Create a multilayer dielectric of FR4 and Teflon.

```
sub = dielectric('FR4','Teflon');
sub.Thickness =[0.0016 0.0008];
balun.Substrate = sub;
figure;
```

View the balun.

```
show(balun);
```




## Version History

**Introduced in R2022b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

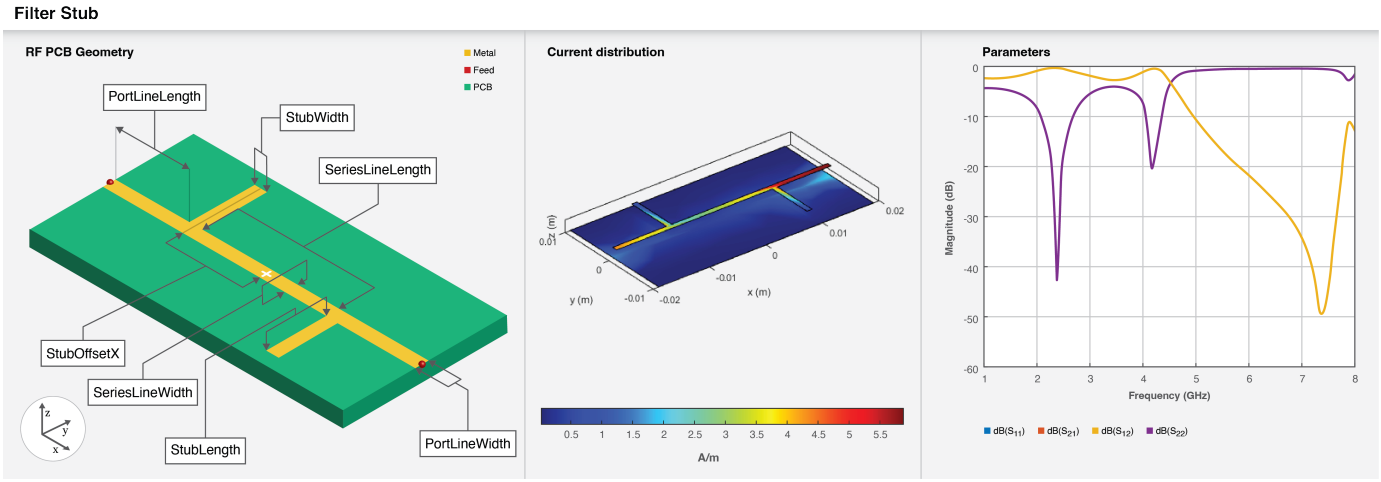
`balunCoupledLine`

# filterStub

Create stub filter in microstrip form

## Description

Use the `filterStub` object to create a stub filter in the microstrip form.




## Creation

### Syntax

```
filter = filterStub
filter = filterStub(Name=Value)
```

#### Description

`filter = filterStub` creates a default stub with default property values for a passband frequency centered around 2 GHz.

`filter = filterStub(Name=Value)` sets “Properties” on page 1-286 using one or more name-value arguments. For example, `filterStub(PortLineLength=9e-4)` creates a stub filter with a port line length of `9e-4` meters. Properties not specified retain their original values.

### Properties

#### `PortLineLength` — Length of input and output lines

`0.0150` (default) | positive scalar

Length of the input and output lines in meters, specified as a positive scalar.

Example: `filter = filterStub(PortLineLength=0.0014)`

Data Types: `double`

**`PortLineWidth` — Width of input and output lines**
`9e-4` (default) | positive scalar

Width of the input and output lines in meters, specified as a positive scalar.

Example: `filter = filterStub(PortLineWidth=8e-4)`

Data Types: `double`

**`SeriesLineLength` — Length of series line**
`0.0080` (default) | positive scalar | two-element vector

Length of the series line in meters, specified as a positive scalar or a two-element vector.

Example: `filter = filterStub(SeriesLineLength=0.0070)`

Data Types: `double`

**`SeriesLineWidth` — Width of series line**
`9e-4` (default) | positive scalar | two-element vector

Width of the series line in meters, specified as a positive scalar or a two-element vector.

Example: `filter = filterStub(SeriesLineWidth=8e-4)`

Data Types: `double`

**`StubLength` — Length of stubs**
`[0.0083 0.0083]` (default) | positive scalar | two-element vector

Length of the stubs in meters, specified as a positive scalar or a two-element vector.

Example: `filter = filterStub(StubLength=[0.0078 0.0078])`

Data Types: `double`

**`StubWidth` — Width of stubs**
`[9e-04 9e-04]` (default) | positive scalar | two-element vector

Width of the stubs in meters, specified as a positive scalar or a two-element vector.

Example: `filter = filterStub(StubWidth=[0.0078 0.0078])`

Data Types: `double`

**`StubFeedOffsetX` — X-offset from origin**
`[-0.0090 0.0090]` (default) | positive scalar | two-element vector

X-offset from the origin in meters, specified as a positive scalar or a two-element vector.

Example: `filter = filterStub(StubFeedOffsetX=0.0087)`

Data Types: `double`

**`StubDirection` — Direction of stubs**
`[1 0]` (default) | `1` | `0`

Direction of the stubs, specified as a two-element vector of:

- `1` — Indicates that the stub points to the top.
- `0` — Indicates that the stub points to the bottom.

Example: `filter = filterStub(StubDirection=[0 1])`

Data Types: `double`

**`StubShort` — Flag to indicate short-circuited stubs**
`[0 0]` (default) | `1` | `0`

Flag to indicate short-circuited stubs, specified as a two-element vector of:

- `1` — Indicates stub is short-circuited.
- `0` — Indicates stub is open-circuited.

Example: `filter = filterStub(StubShort=[1 1])`

Data Types: `double`

**`Height` — Height of stub filter from ground plane**
`0.0016` (default) | positive scalar

Height of the stub filter from the ground plane in meters, specified as a positive scalar. For multilayer dielectrics, use the `Height` property to create the filter between the two dielectric layers.

Example: `filter = filterStub(Height=0.0028)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0200` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `filter = filterStub(GroundPlaneWidth=0.0048)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `filterStub` object with default properties is Teflon.

Example: `d = dielectric("FR4"); filter = filterStub(Substrate=d)`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `filterStub` object with default properties is PEC.

Example: `m = metal("Copper"); filter = filterStub(Conductor=m)`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |

| | |
|---|---|
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Short-Circuited Stub Filter

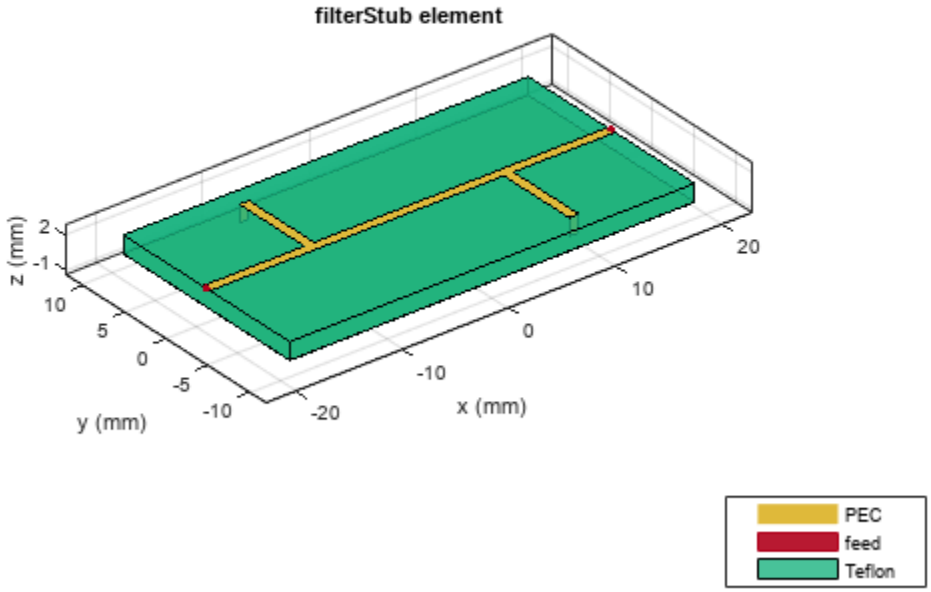
Create a short-circuited stub filter.

```
filter = filterStub(StubShort=[1 1])
```

```
filter =
  filterStub with properties:

      PortLineLength: 0.0150
       PortLineWidth: 9.0000e-04
    SeriesLineLength: 0.0080
     SeriesLineWidth: 9.0000e-04
          StubLength: [0.0083 0.0083]
           StubWidth: [9.0000e-04 9.0000e-04]
         StubOffsetX: [-0.0090 0.0090]
       StubDirection: [1 0]
           StubShort: [1 1]
              Height: 0.0016
    GroundPlaneWidth: 0.0200
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

Visualize the filter.

```
show(filter)
```



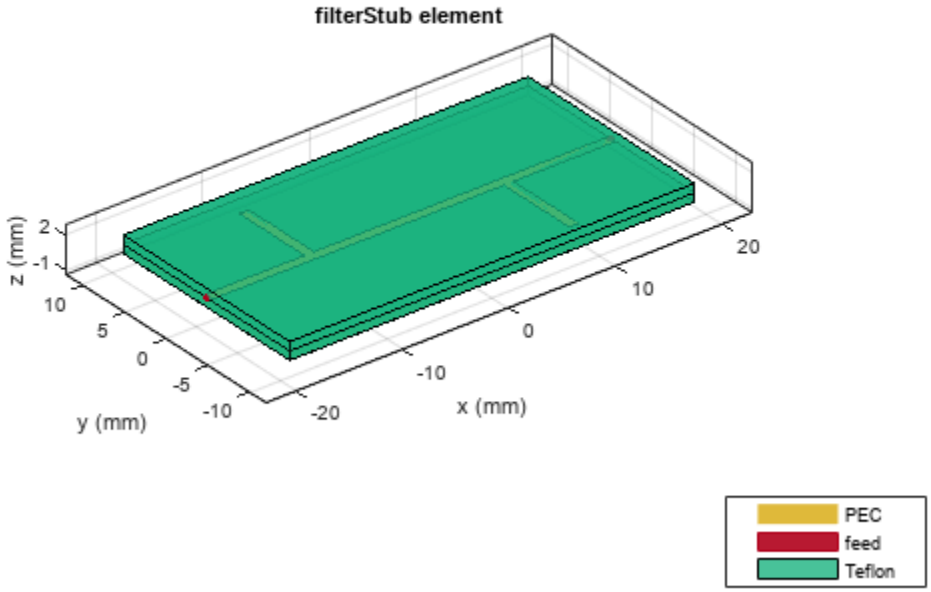

### Multilayered Stub Filter

Create a multilayered dielectric stub filter.

```
filter = filterStub;
filter.Substrate = dielectric(Name={'Teflon','Teflon'},EpsilonR=[2.1 2.1], ...
    LossTangent=[0 0],Thickness=[0.8e-3 0.8e-3]);
filter.Height = 0.8e-3;
```

Visualize the filter.

```
show(filter);
```




# Version History

**Introduced in R2022b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

[2] Wen-Hua Tu and Kai Chang. “Compact Microstrip Bandstop Filter Using Open Stub and Spurline.” *IEEE Microwave and Wireless Components Letters 15*, no. 4 (April 2005): 268–70. https://doi.org/10.1109/LMWC.2005.845739.

## See Also

`filterHairpin` | `filterStepImpedanceLowPass`

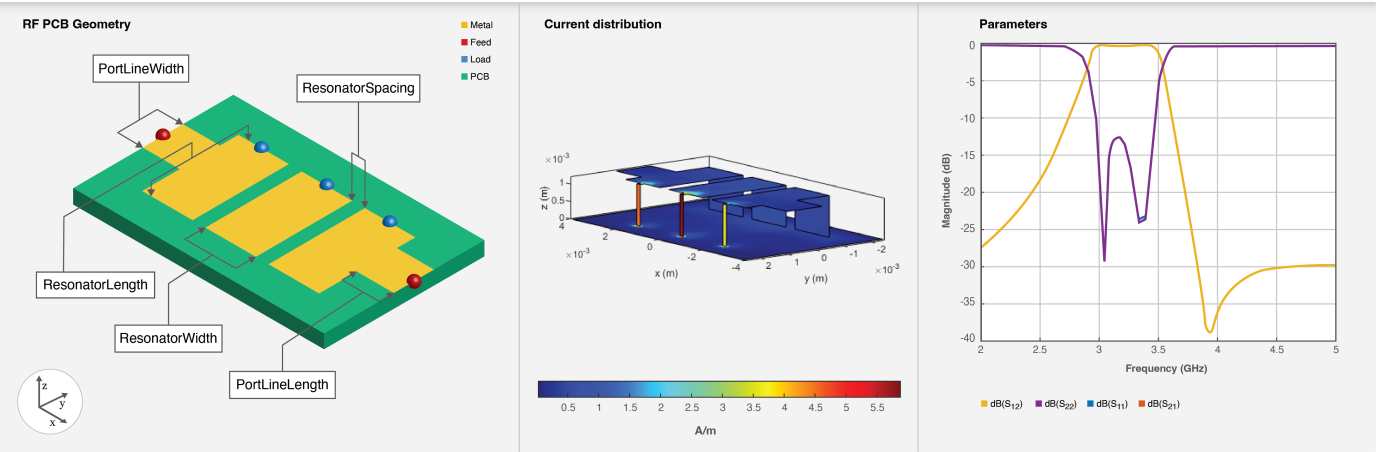
# filterCombline

Create combline filter in microstrip form

## Description

Use the `filterCombline` object to create a combline filter in the microstrip form.

**Filter Combline**




## Creation

### Syntax

```
filter = filterCombline
filter = filterCombline(Name=Value)
```

#### Description

`filter = filterCombline` creates a default combline line filter using an Alumina substrate with the passband of the filter centered around 3.1 GHz.

`filter = filterCombline(Name=Value)` sets “Properties” on page 1-292 using one or more name-value arguments. For example, `filterCombline(ResonatorWidth=0.0016)` creates a combline filter with a resonator width of `0.0016` meters. Properties not specified retain their original values.

### Properties

**`FilterOrder` — Order of filter**
3 (default) | positive scalar

Order of the filter, specified as a positive scalar.

Example: `filter = filterCombline(FilterOrder=4)`

Data Types: `double`

**`ResonatorLength` — Length of resonator**
`0.0030` (default) | positive scalar | vector

Length of the resonator in meters, specified as a positive scalar or a vector of positive elements equal in size to `FilterOrder`.

Example: `filter = filterCombline(ResonatorLength=0.007)`

Data Types: `double`

**`ResonatorWidth` — Width of resonator**
`0.0016` (default) | positive scalar

Width of the resonator in meters, specified as a positive scalar.

Example: `filter = filterCombline(ResonatorWidth=0.0017)`

Data Types: `double`

**`ResonatorSpacing` — Spacing between resonators**
`4e-04` (default) | positive scalar | vector

Spacing between the resonators in meters, specified as a positive scalar or a vector of positive elements equal in size to (`FilterOrder`-1).

Example: `filter = filterCombline(ResonatorSpacing=0.0008)`

Data Types: `double`

**`ResonatorOffset` — Y-offset of each resonator**
`0` (default) | positive scalar | vector

Y-offset for each resonator in meters, specified as a positive scalar or a vector of positive elements equal in size to `FilterOrder`. If the value is a scalar, all the resonators have the same offset along the *Y*-axis.

Example: `filter = filterCombline(ResonatorOffset=(0 0.1 0.2))`

Data Types: `double`

**`PortLineLength` — Length of input and output lines**
`0.0011` (default) | positive scalar

Length of the input and output lines in meters, specified as a positive scalar.

Example: `filter = filterCombline(PortLineLength=0.0014)`

Data Types: `double`

**`PortLineWidth` — Width of input and output lines**
`0.0013` (default) | positive scalar

Width of the input and output lines in meters, specified as a positive scalar.

Example: `filter = filterCombline(PortLineWidth=0.0087)`

Data Types: `double`

**FeedOffset — Y-offset for input and output lines**
3e-04 (default) | positive scalar

Y-offset for the input and output lines in meters, specified as a positive scalar.

Example: filter = filterCombline(FeedOffset=0.0087)

Data Types: double

**Capacitor — Capacitor value**
1e-12 (default) | positive scalar

Capacitor value in farad, specified as a positive scalar.

Example: filter = filterCombline(Capacitor=2e-12)

Data Types: double

**Height — Height of combline filter from ground plane**
0.0012 (default) | positive scalar

Height of the combline filter from the ground plane in meters, specified as a positive scalar. For multilayer dielectrics, use the Height property to create the filter between the two dielectric layers.

Example: filter = filterCombline(Height=0.0028)

Data Types: double

**GroundPlaneWidth — Width of ground plane**
0.0050 (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: filter = filterCombline(GroundPlaneWidth=0.0048)

Data Types: double

**Substrate — Type of dielectric material**
dielectric object

Type of dielectric material used as a substrate, specified as a dielectric object. The dielectric material in a filterCombline object with default properties is Alumina.

Example: d = dielectric("FR4"); filter = filterCombline(Substrate=d)

**Conductor — Type of metal used in conducting layers**
metal object

Type of metal used in the conducting layers, specified as a metal object. The type of metal in a filterCombline object with default properties is PEC.

Example: m = metal("Copper"); filter = filterCombline(Conductor=m)

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| design | Design coupled line filter around specified frequency |
| feedCurrent | Calculate current at feed port |

| | |
|---|---|
| getZ0 | Calculate characteristic impedance of transmission line |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Combline Filter

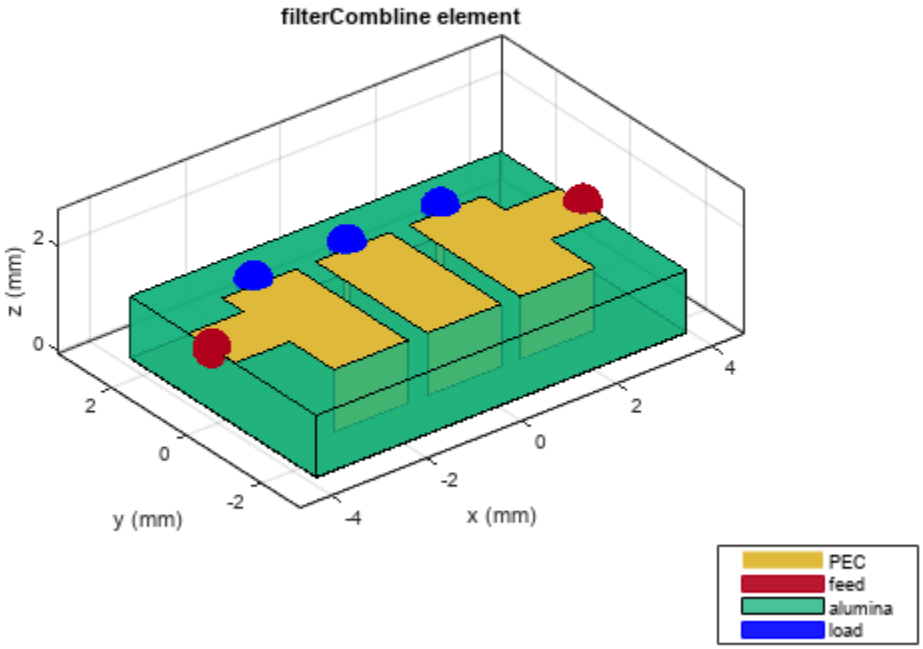
Create a default combline filter.

```
filter = filterCombline
```

```
filter =
  filterCombline with properties:

         FilterOrder: 3
     ResonatorLength: 0.0030
      ResonatorWidth: 0.0016
    ResonatorSpacing: 4.0000e-04
     ResonatorOffset: 0
      PortLineLength: 0.0011
       PortLineWidth: 0.0013
          FeedOffset: 3.0000e-04
           Capacitor: 1.0000e-12
              Height: 0.0012
    GroundPlaneWidth: 0.0050
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the filter.

```
show(filter)
```



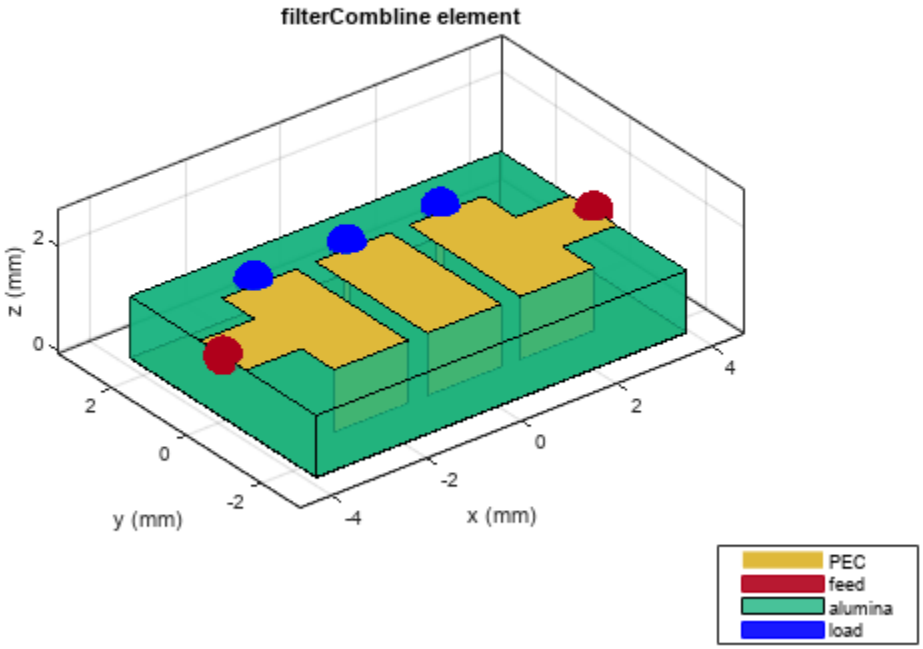

### Zero-Offset Feed Combline Filter

Create a combline filter with the feed offset equal to zero.

```
filter = filterCombline('FeedOffset',0);
```

Visualize the filter.

```
show(filter);
```



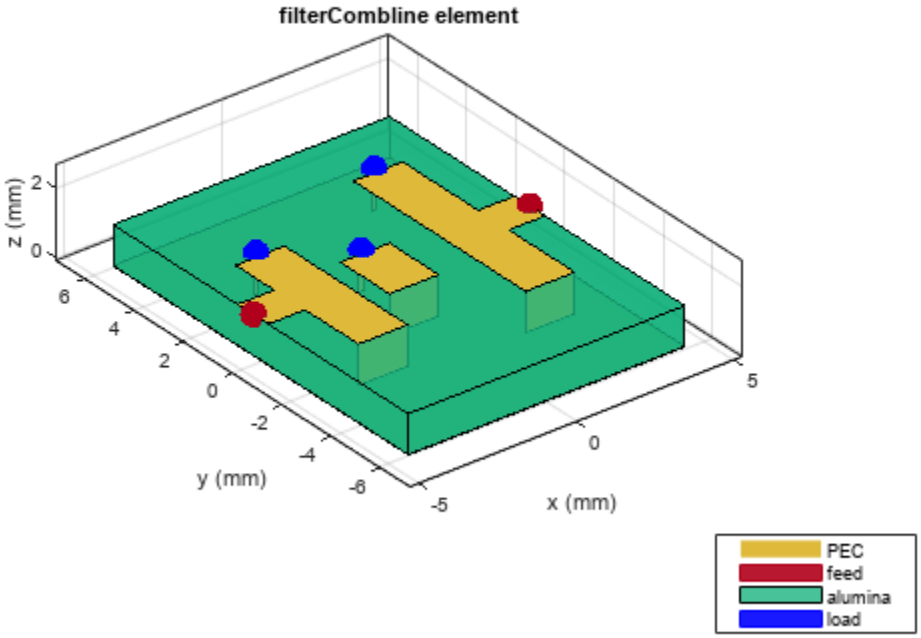

### Third-Order Combline Filter with Resonator Offset

Create a third-order combline filter with a different resonator offset.

```
filter = filterCombline(FilterOrder=3,ResonatorLength=[0.005,0.002,0.007],...
    ResonatorSpacing=[0.6e-3,1.2e-3],ResonatorOffset=[0.001e-3,0,0.5e-3], ...
    GroundPlaneWidth=12e-3);
```

Visualize the filter.

```
show(filter);
```




## Version History

**Introduced in R2022b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

[2] Al-Yasir, Y., R.A. Abd-Alhameed, J.M. Noras, A.M. Abdulkhaleq, and N.O. Parchin. “Design of Very Compact Combline Band-Pass Filter for 5G Applications.” In *Loughborough Antennas & Propagation Conference* 2018 (LAPC 2018), 61 (4 pp.)-61 (4 pp.). Loughborough, UK: Institution of Engineering and Technology, 2018

[3] Hong, Jia-Sheng. "Microstrip Filters for RF/Microwave Applications". 2nd ed. Wiley Series in *Microwave and Optical Engineering*. Hoboken, N.J: Wiley, 2011.

## See Also

`filterHairpin` | `filterStepImpedanceLowPass`

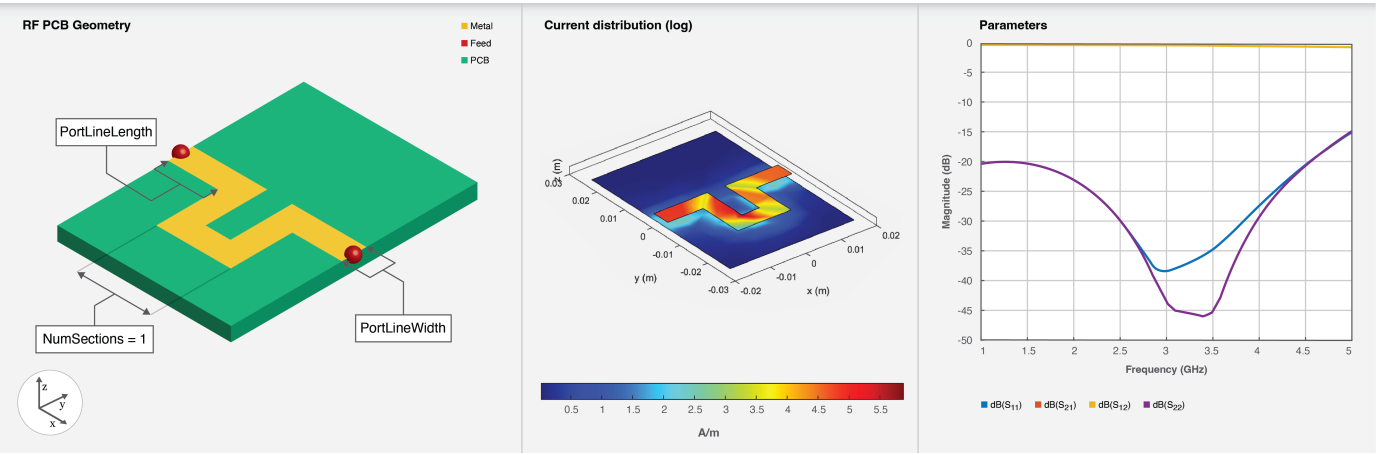
# phaseShifter

Create phase shifter in microstrip form

## Description

Use the `phaseShifter` object to create a phase shifter in the microstrip form. Phase shifters change the phase of a signal using proper matching at the input and output ports and minimum insertion loss.

**Phase Shifter**




## Creation

### Syntax

```
ps = phaseShifter
ps = phaseShifter(Name=Value)
```

#### Description

`ps = phaseShifter` creates a phase shifter using Teflon as the default substrate.

`ps = phaseShifter(Name=Value)` sets "Properties" on page 1-299 using one or more name-value arguments. For example, `phaseShifter(NumSections=3)` creates a phase shifter with 3 U-sections. Properties not specified retain their default values.

### Properties

#### `NumSections` — Number of U-sections

1 (default) | positive scalar

Number of U-sections, specified as a positive scalar.

Example: `ps = phaseShifter(NumSections=3)`

Data Types: `double`

**`SectionShape` — Shape of U-sections**
`ubendRightAngle` (default) | `ubendMitered` | `ubendCurved`

Shape of the U-sections, specified as a `ubendRightAngle`, `ubendMitered`, or `ubendCurved` object.

Example: `shape = ubendMitered; ps = phaseShifter(SectionShape=shape)`

Data Types: `double`

**`PortLineLength` — Length of port line**
`0.0200` (default) | positive scalar

Length of the port line in meters, specified as a positive scalar.

Example: `ps = phaseShifter(PortLineLength=0.0400)`

Data Types: `double`

**`PortLineWidth` — Width of port line**
`0.0050` (default) | positive scalar

Width of the port line in meters, specified as a positive scalar.

Example: `ps = phaseShifter(PortLineWidth=0.0800)`

Data Types: `double`

**`Height` — Height of phase shifter from ground plane**
`0.0016` (default) | positive scalar

Height of the phase shifter from the ground plane in meters, specified as a positive scalar. For multilayer dielectrics, use the `Height` property to create the filter between the two dielectric layers.

Example: `ps = phaseShifter(Height=0.0019)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0300` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `ps = phaseShifter(GroundPlaneWidth=0.0500)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `phaseShifter` object with default properties is Teflon.

Example: `d = dielectric("FR4"); ps = phaseShifter(Substrate=d)`

Data Types: `string` | `char`

#### `Conductor` — Type of metal used in conducting layers

`'PEC'` (default) | `metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `phaseShifter` object with default properties is PEC.

Example: `m = metal("Copper"); ps = phaseShifter(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| current | Calculate and plot current distribution |
| charge | Calculate and plot charge distribution |
| design | Design phase shifter around specified frequency |
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Phase Shifter

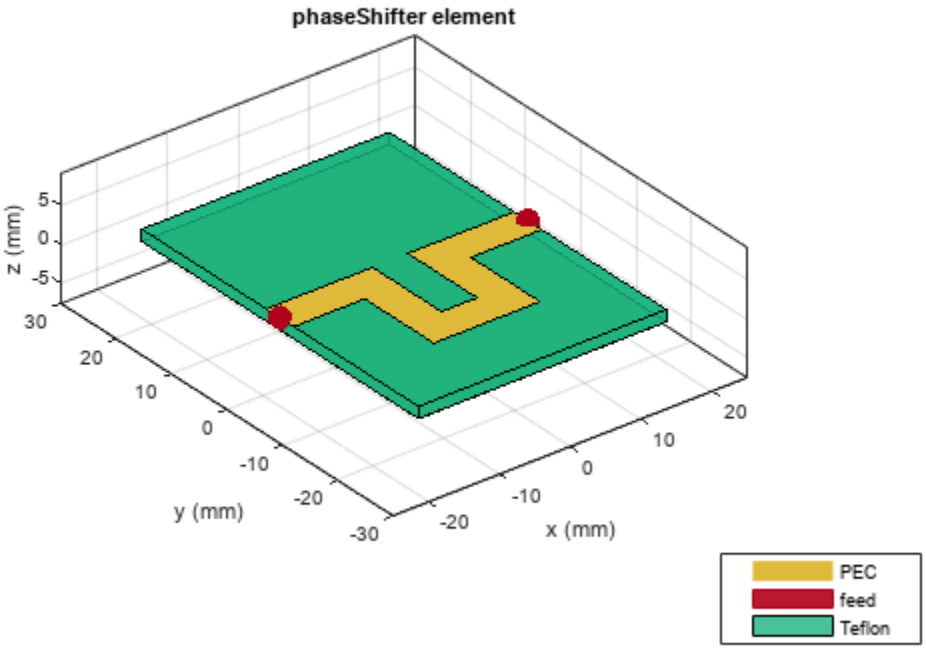
Create a phase shifter with default values.

```
ps = phaseShifter
```

```
ps =
  phaseShifter with properties:

         NumSections: 1
        SectionShape: [1x1 ubendRightAngle]
      PortLineLength: 0.0100
       PortLineWidth: 0.0050
              Height: 0.0016
    GroundPlaneWidth: 0.0500
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

Visualize the phase shifter.

```
show(ps)
```



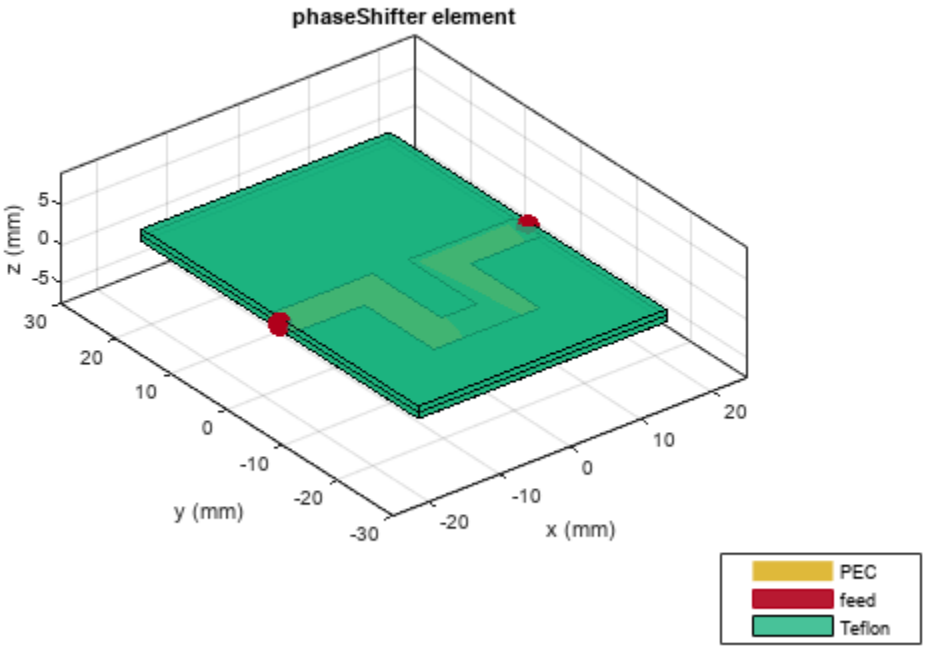

### Multilayer Dielectric Phase Shifter

Create a phase shifter at the interface of a multilayered dielectric.

```
ps = phaseShifter;
ps.Substrate = dielectric(Name={'Teflon','Teflon'},EpsilonR=[2.1 2.1], ...
    LossTangent=[0 0],Thickness=[0.8e-3 0.8e-3]);
ps.Height = 0.8e-3;
```

Visualize the phase shifter.

```
show(ps)
```




## Version History

**Introduced in R2022b**

## See Also

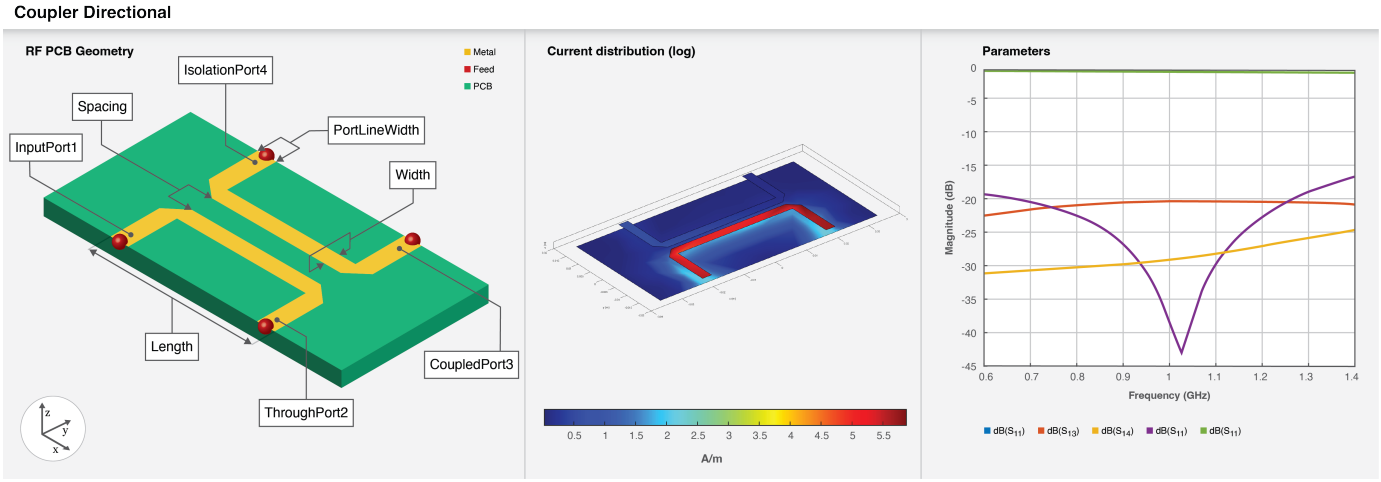
`microstripLine` | `wilkinsonSplitter`

# couplerDirectional

Create single section or multi-section directional coupler in microstrip form

## Description

Use the `couplerDirectional` object to create a single section or a multi-section coupler in the microstrip form.




## Creation

### Syntax

```
coupler = couplerDirectional
coupler = couplerDirectional(Name=Value)
```

#### Description

`coupler = couplerDirectional` creates a single section coupler in the microstrip form with default property values for a resonating frequency of 1 GHz for a 21 dB coupling.

`coupler = couplerDirectional(Name=Value)` sets "Properties" on page 1-304 using one or more name-value arguments. For example, `couplerDirectional(PortLineWidth=0.0286)` creates a directional coupler with a port line width of 0.0286 meters. Properties not specified retain their default values.

### Properties

#### `Length` — Length of coupled line in each section

`0.0397` (default) | positive scalar

Length of the coupled line in each section, specified as a positive scalar.

Example: `coupler = couplerDirectional(Length=0.0096)`

Data Types: `double`

**`Width` — Width of coupled line in each section**
`0.0028` (default) | positive scalar | vector

Width of the coupled line in each section, specified as a positive scalar or vector.

Example: `coupler = couplerDirectional(Width=0.0036)`

Data Types: `double`

**`Spacing` — Spacing between coupled lines in each section**
`0.0013` (default) | positive scalar | vector

Spacing between the coupled lines in each section, specified as a positive scalar or vector.

Example: `coupler = couplerDirectional(Spacing=0.0016)`

Data Types: `double`

**`NumSections` — Number of coupled line sections**
`1` (default) | positive scalar

Number of coupled line sections, specified as a positive scalar. To create a multi-section directional coupler, the number of sections must be greater than one.

Example: `coupler = couplerDirectional(NumSections=2)`

Data Types: `double`

**`Corner` — Bend type at corners of coupler**
`'Mitered'` (default) | `'Curved'` | `'RightAngle'`

Bend type at the corners of the coupler for extending the ports, specified as `'Mitered'`, `'Curved'`, or `'RightAngle'`.

Example: `coupler = couplerDirectional(Corner='Curved')`

Data Types: `char`

**`Height` — Height of directional coupler from ground plane**
`0.0016` (default) | positive scalar

Height of the directional coupler from the ground plane in meters, specified as a positive scalar.

In the case of a multilayer substrate, you can use the `Height` property to create a branch line coupler line where the two dielectrics interface.

Example: `coupler = couplerDirectional(Height=0.0026)`

Data Types: `double`

**`PortLineWidth` — Width of port line**
`0.0029` (default) | positive scalar

Width of the port line in meters, specified as a positive scalar.

Example: `coupler = couplerDirectional(PortLineWidth=0.0070)`

Data Types: `double`

**`GroundPlaneLength` — Length of ground plane**
`0.0697` (default) | positive scalar

Length of the ground plane in meters, specified as a positive scalar.

Example: `coupler = couplerDirectional(GroundPlaneLength=0.046)`

Example: double

**`GroundPlaneWidth` — Width of ground plane**
`0.0345` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `coupler = couplerDirectional(GroundPlaneWidth=0.046)`

Example: double

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object.

Example: `d = dielectric("FR4"); coupler = couplerDirectional(Substrate=d)`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The type of metal in a `couplerBranchline` object with default properties is Copper.

Example: `m = metal("PEC"); coupler = couplerDirectional(Conductor=m)`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| coupling | Calculate coupling factor of coupler |
| current | Calculate and plot current distribution |
| directivity | Calculate directivity of coupler |
| feedCurrent | Calculate current at feed port |
| getZ0 | Calculate characteristic impedance of transmission line |
| isolation | Calculate isolation of coupler |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Coupler Directional

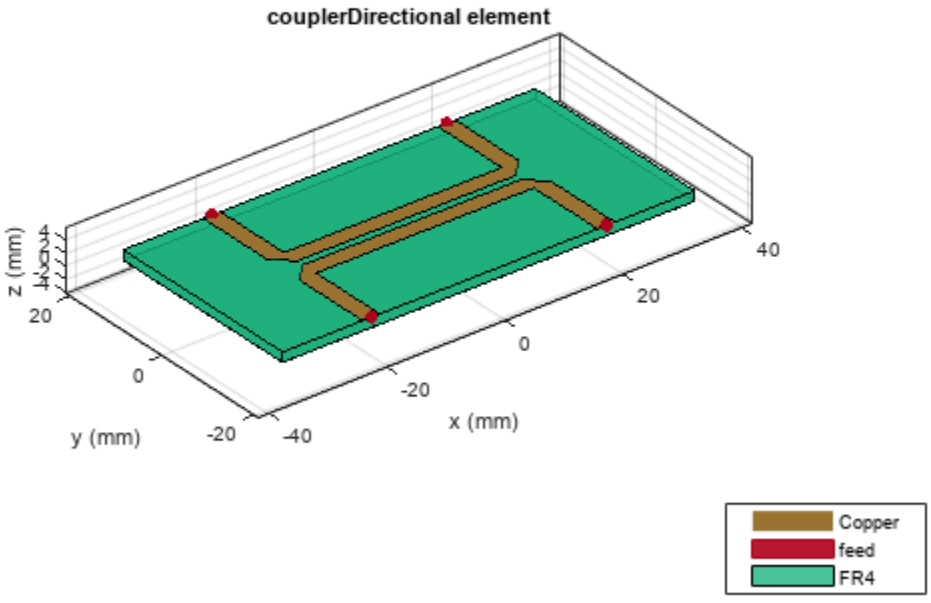
Create a default directional coupler.

```
coupler = couplerDirectional
```

```
coupler =
  couplerDirectional with properties:

              Length: 0.0397
               Width: 0.0028
             Spacing: 0.0013
          NumSections: 1
              Corner: 'Mitered'
              Height: 0.0016
       PortLineWidth: 0.0029
    GroundPlaneLength: 0.0697
     GroundPlaneWidth: 0.0345
            Substrate: [1x1 dielectric]
            Conductor: [1x1 metal]
```

View the coupler.

```
show(coupler)
```




### Three-Section Symmetrical Directional Coupler

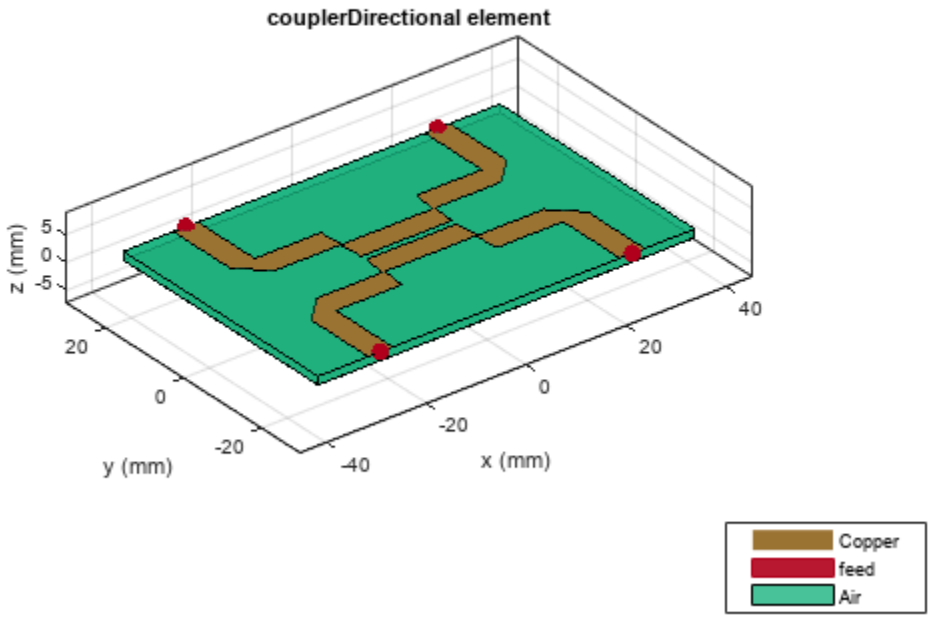
Create a three-section symmetrical directional coupler on a Teflon substrate.

```
coupler = couplerDirectional(Length=18.15e-3, Width=[4.942e-3,...
   4.813e-3,4.942e-3],Spacing=[10.95e-3,1.295e-3,10.95e-3],...
   NumSections=3 ,Substrate=dielectric(EpsilonR=2.2,LossTangent=0.005,...
   Thickness=0.0016),PortLineWidth=4.942e-3,...
   GroundPlaneLength=75.5e-3,GroundPlaneWidth=50e-3 )
```

```
coupler =
  couplerDirectional with properties:

              Length: 0.0181
               Width: [0.0049 0.0048 0.0049]
             Spacing: [0.0109 0.0013 0.0109]
         NumSections: 3
              Corner: 'Mitered'
              Height: 0.0016
       PortLineWidth: 0.0049
   GroundPlaneLength: 0.0755
    GroundPlaneWidth: 0.0500
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the coupler.

```
show(coupler)
```



# Version History

**Introduced in R2022b**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

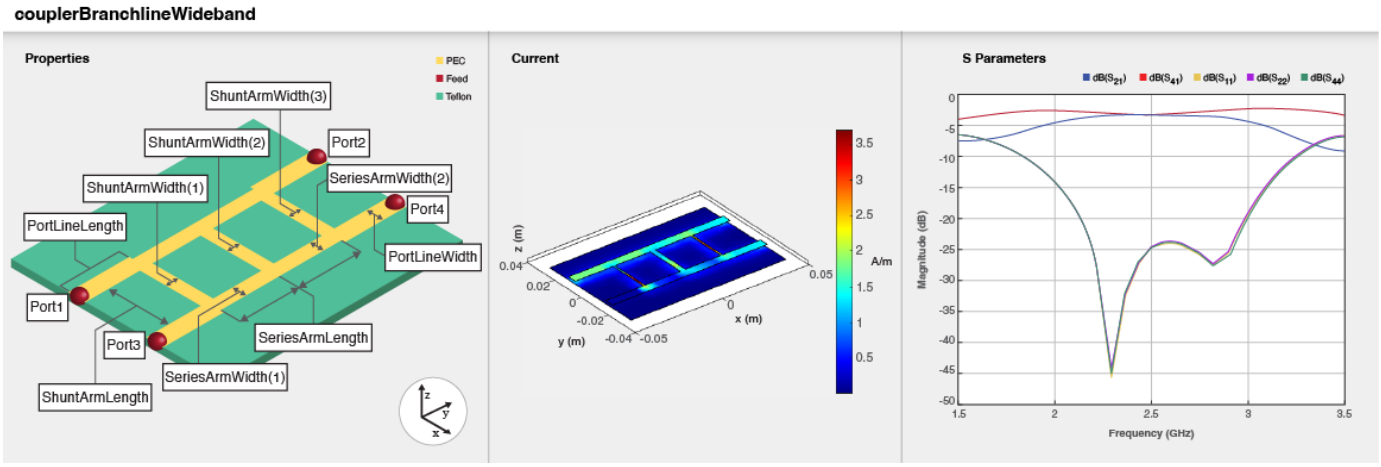
`couplerRatrace`

# couplerBranchlineWideband

Create equal split multisection branchline coupler or quadrature hybrid

## Description

Use the `couplerBranchlineWideband` object to create an equal split multi-section branchline coupler or quadrature hybrid.




To analyze the behavioral model for the branchline coupler, set the `Behavioral` property in the `sparameters` function to `true` or `1`.

## Creation

### Syntax

```
coupler = couplerBranchlineWideband
coupler = couplerBranchlineWideband(Name=Value)
```

#### Description

`coupler = couplerBranchlineWideband` creates a equal split multisection branchline coupler with properties for a frequency of 2.5 GHz.

`coupler = couplerBranchlineWideband(Name=Value)` sets “Properties” on page 1-311 using one or more name-value arguments. For example, `couplerBranchlineWideband(NumSections=4)` creates a branch line coupler with four sections. Properties not specified retain their default values.

## Properties

### `NumSections` — Number of sections

`2` (default) | positive scalar

Number of sections, specified as a positive scalar. The minimum number of sections you can specify is two and the maximum is six.

Example: `coupler = couplerBranchlineWideband(NumSections=4)`

Data Types: `double`

### `PortLineLength` — Length of input and output line

`0.0223` (default) | positive scalar

Length of the input and the output line in meters, specified as a positive scalar.

Example: `coupler = couplerBranchlineWideband(PortLineLength=0.0286)`

Data Types: `double`

### `PortLineWidth` — Width of input and output line

`0.0051` (default) | positive scalar

Width of the input and the output line in meters, specified as a positive scalar.

Example: `coupler = couplerBranchlineWideband(PortLineWidth=0.0070)`

Data Types: `double`

### `SeriesArmLength` — Length of series arm

`0.0223` (default) | positive scalar

Length of the series arm in meters, specified as a positive scalar.

Example: `coupler = couplerBranchlineWideband(SeriesArmLength=0.0286)`

Data Types: `double`

### `SeriesArmWidth` — Width of series arm

`0.0051` (default) | positive scalar | vector

Width of the series arm in meters, specified as a positive scalar or a vector.

Example: `coupler = couplerBranchlineWideband(SeriesArmWidth=0.0096)`

Data Types: `double`

### `ShuntArmLength` — Length of shunt arm

`0.0223` (default) | positive scalar

Length of the shunt arm in meters, specified as a positive scalar.

Example: `coupler = couplerBranchlineWideband(ShuntArmLength=0.0286)`

Data Types: `double`

### `ShuntArmWidth` — Width of shunt arm

`[0.00096,0.0029,0.00096]` (default) | positive scalar | vector

Width of the shunt arm in meters, specified as a positive scalar or a vector.

Example: `coupler = couplerBranchlineWideband(ShuntArmWidth=0.0096)`

Data Types: `double`

**`Height` — Height of branchline coupler from ground plane**
`0.0016` (default) | positive scalar

Height of the branchline coupler from the ground plane in meters, specified as a positive scalar.

In a multilayer substrate, you can use the `Height` property to create a branchline coupler where the two dielectrics interface.

Example: `coupler = couplerBranchlineWideband(Height=0.0076)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0600` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `coupler = couplerBranchlineWideband(GroundPlaneWidth=0.046)`

Example: double

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The default height of the substrate is `0.0016` meters. The dielectric material in a `couplerBranchlineWideband` object with default properties is Teflon.

Example: `d = dielectric("FR4"); coupler = couplerBranchlineWideband(Substrate=d)`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The metal used in the conducting layers of a `couplerBranchlineWideband` object with default properties is PEC.

Example: `m = metal("Copper"); coupler = couplerBranchlineWideband(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| coupling | Calculate coupling factor of coupler |
| current | Calculate and plot current distribution |
| dgs | Create defected ground structure of PCB element |
| design | Design wideband branchline coupler around particular frequency |
| directivity | Calculate directivity of coupler |
| feedCurrent | Calculate current at feed port |
| isolation | Calculate isolation of coupler |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |

| | |
|---|---|
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Default Wideband Branchline Coupler

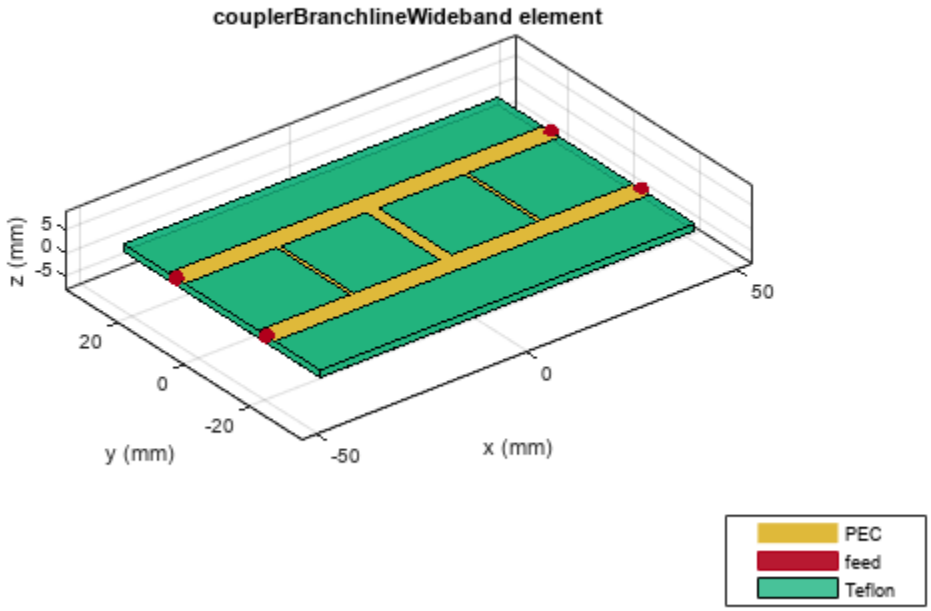
Create a default wideband branchline coupler.

```
coupler = couplerBranchlineWideband
```

```
coupler =
  couplerBranchlineWideband with properties:

         NumSections: 2
      PortLineLength: 0.0223
       PortLineWidth: 0.0051
     SeriesArmLength: 0.0223
      SeriesArmWidth: 0.0051
      ShuntArmLength: 0.0223
       ShuntArmWidth: [9.6000e-04 0.0029 9.6000e-04]
              Height: 0.0016
    GroundPlaneWidth: 0.0600
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the coupler.

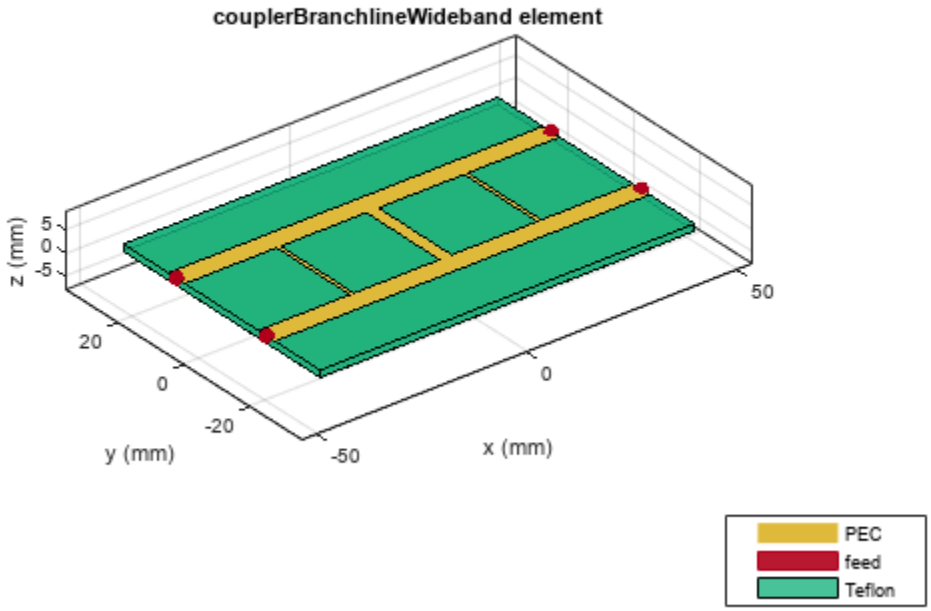
```
show(coupler)
```




### Two-Section Wideband Branchline Coupler

Create a default two-section wideband branchline coupler and visualize it.

```
coupler = couplerBranchlineWideband;
show(coupler);
```




Calculate the coupling at 2.5 GHz.

```
c = coupling(coupler,2.5e9)
```

```
c = -3.1935
```



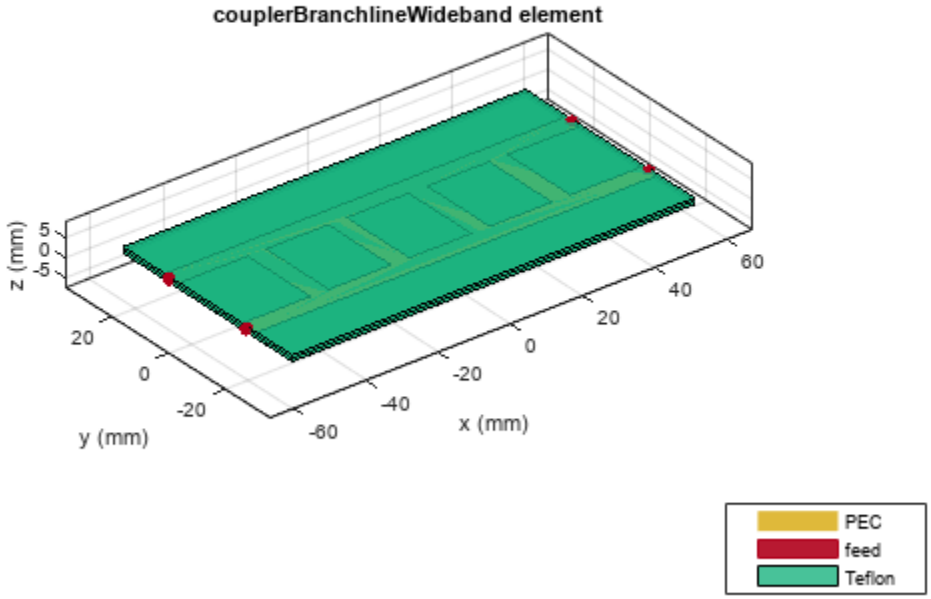
### Three-Section Wideband Branchline Coupler

Create a three-section wideband branchline coupler at the interface of a multi-layer dielectric.

```
coupler = couplerBranchlineWideband(NumSections=3,ShuntArmWidth=0.0051);
coupler.Substrate = dielectric(Name={'Teflon','Teflon'},EpsilonR=[2.1 2.1], ...
    LossTangent=[0 0],Thickness=[0.8e-3 0.8e-3]);
coupler.Height = 0.8e-3;
```

View the coupler.

```
show(coupler)
```




## Version History

**Introduced in R2023a**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`couplerRatrace` | `couplerBranchline`

### Topics

“Behavioral Models”

# dumbbell

Create dumbbell shape on X-Y plane

## Description

Use the `dumbbell` object to create a dumbbell shape centered at the origin and on the *X*-*Y* plane.

## Creation

### Syntax

```
dumbbellshape = dumbbell
dumbbellshape = dumbbell(Name=Value)
```

#### Description

`dumbbellshape = dumbbell` creates a dumbbell shape centered on at the origin and on the *X*-*Y* plane.

`dumbbellshape = dumbbell(Name=Value)` sets "Properties" on page 1-317 using one or more name-value arguments. For example, `dumbbell(ReferencePoint=[1 1])` creates a dumbbell shape at the reference point `[1 1]`. Properties not specified retain their default values.

### Properties

**`Name` — Name of dumbbell shape**
`'mydumbbell'` (default) | character vector | string scalar

Name of the dumbbell shape, specified as a character vector or string scalar.

Example: `dumbbellshape = dumbbell(Name='dumbbellshape1')`

Data Types: `char` | `string`

**`ReferencePoint` — Reference point**
`[0 0]` (default) | two-element vector

Reference point of the dumbbell shape in Cartesian coordinates, specified as a two-element vector.

Example: `dumbbellshape = dumbbell(ReferencePoint=[1 1])`

Data Types: `double`

**`Type` — Type of dumbbell**
`'Polygon'` (default) | `'Circle'`

Type of dumbbell, specified as a `'Polygon'` or a `'Circle'`.

Example: `dumbbellshape = dumbbell(Type='Circle')`

Data Types: `char`

### `NumSides` — Number of sides in polygon

4 (default) | positive scalar

Number of sides in the polygon, specified as a positive scalar in the range [3,8].

Example: `dumbbellshape = dumbbell(Numsides=7)`

#### Dependencies

To enable this property, set `Type` to `'Polygon'`.

Data Types: `double`

### `ArmLength` — Length of dumbbell arm

`0.0200` (default) | positive scalar

Length of the dumbbell arm in meters, specified as a positive scalar.

Example: `dumbbellshape = dumbbell(ArmLength=0.0400)`

Data Types: `double`

### `ArmWidth` — Width of dumbbell arm

`0.00200` (default) | positive scalar

Width of the dumbbell arm in meters, specified as a positive scalar.

Example: `dumbbellshape = dumbbell(ArmWidth=0.00400)`

Data Types: `double`

### `SideLength` — Length of polygon sides

`0.0100` (default) | positive scalar

Length of the polygon sides in meters, specified as a positive scalar.

Example: `dumbbellshape = dumbbell(SideLength=0.0300)`

#### Dependencies

To enable this property, set `Type` to `'Polygon'`.

Data Types: `double`

### `Diameter` — Diameter of circle

`0.0100` (default) | positive scalar

Diameter of the circle in meters, specified as a positive scalar.

Example: `dumbbellshape = dumbbell(Diameter=0.0300)`

#### Dependencies

To enable this property, set `Type` to `'Circle'`.

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |

| | |
|---|---|
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| mirrorX | Mirror shape along X-axis |
| mirrorY | Mirror shape along Y-axis |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| plot | Plot boundary of RF PCB shape |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Dumbbell Shape with Default Shape

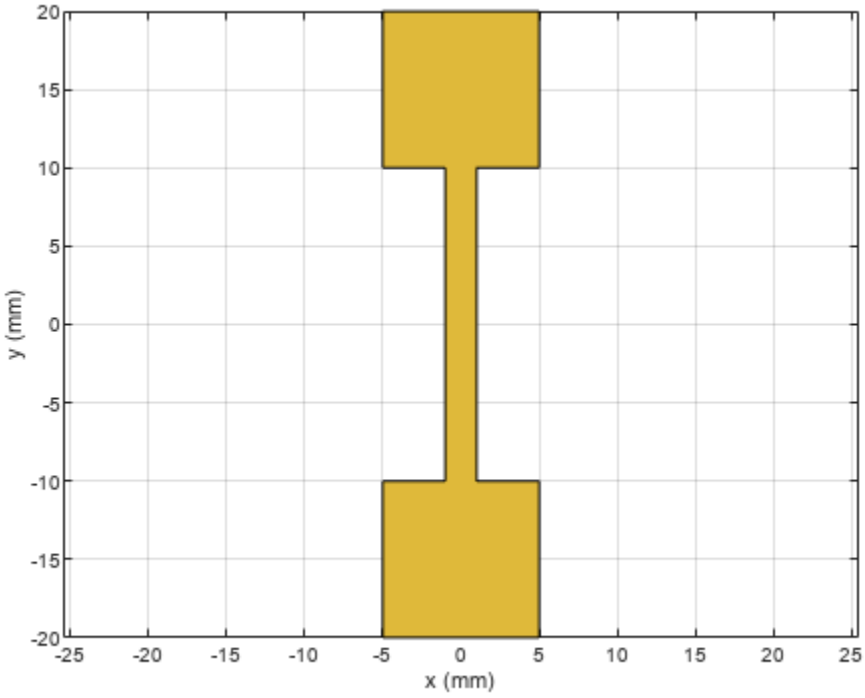
Create a dumbbell shape with default properties.

```
dumbbellshape = dumbbell
```

```
dumbbellshape =
  dumbbell with properties:

              Name: 'mydumbbell'
    ReferencePoint: [0 0]
              Type: 'Polygon'
          NumSides: 4
         ArmLength: 0.0200
          ArmWidth: 0.0020
        SideLength: 0.0100
```

View the dumbbell shape.

```
show(dumbbellshape)
```




### Circular Dumbbell

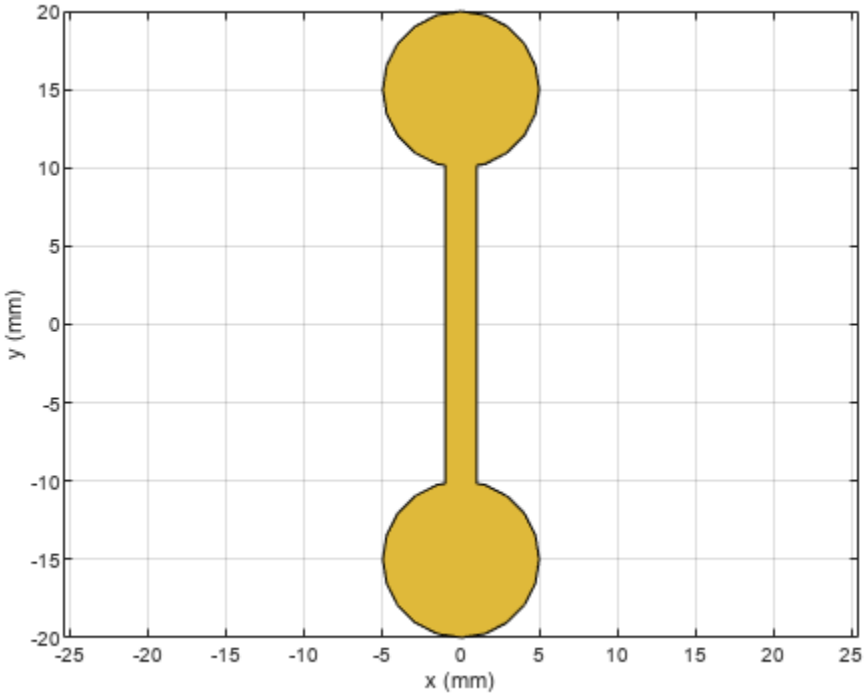
Create a dumbbell with circular heads.

```
dumbbellshape = dumbbell(Type='Circle')
```

```
dumbbellshape =
  dumbbell with properties:

              Name: 'mydumbbell'
    ReferencePoint: [0 0]
              Type: 'Circle'
          Diameter: 0.0100
         ArmLength: 0.0200
          ArmWidth: 0.0020
```

View the dumbbell shape.

```
show(dumbbellshape)
```




## Version History

**Introduced in R2023a**

## See Also

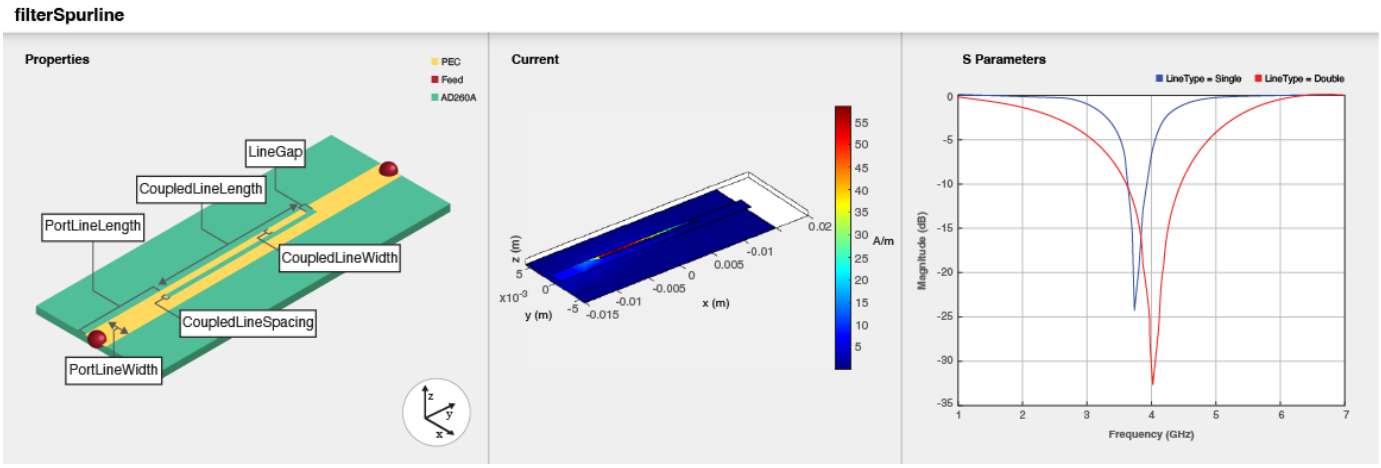
`ringAnnular` | `ringSquare` | `radial` | `delta`

# filterSpurline

Create spurline bandstop filter in microstrip from

## Description

Use the `filterSpurline` object to create a spurline bandstop filter in the microstrip form.




## Creation

### Syntax

```
filter = filterSpurline
filter = filterSpurline(Name=Value)
```

#### Description

`filter = filterSpurline` creates a spurline bandstop filter with default properties for a frequency of 3.743 GHz.

`filter = filterSpurline(Name=Value)` sets “Properties” on page 1-322 using one or more name-value arguments. For example, `filterSpurline(LineType='Double')` creates a spurline bandstop filter with two lines. Properties not specified retain their default values.

### Properties

#### LineType — Type of spurline

`'Single'` (default) | `'Double'`

Type of spurline, specified as `'Single'` or `'Double'`.

Example: `filter = filterSpurline(LineType='Double')`

Data Types: `char`

**`CoupledLineLength` — Length of coupled line**
`0.0146` (default) | positive scalar

Length of the coupled line in meters, specified as a positive scalar.

Example: `filter = filterSpurline(CoupledLineLength = 0.0156)`

Data Types: `double`

**`CoupledLineWidth` — Width of coupled line**
`4.0000e-04` (default) | positive scalar

Width of the coupled line in meters, specified as a positive scalar.

Example: `filter = filterSpurline(CoupledLineWidth = 0.0008)`

Data Types: `double`

**`CoupledLineSpacing` — Spacing between coupled line**
`4.0000e-04` (default) | positive scalar

Spacing between the coupled line in meters, specified as a positive scalar.

Example: `filter = filterSpurline(CoupledLineSpacing = 0.0008)`

Data Types: `double`

**`LineGap` — Gap between coupled line and output line**
`4.0000e-04` (default) | positive scalar

Gap between the coupled line and the output line in meters, specified as a positive scalar.

Example: `filter = filterSpurline(LineGap = 0.0008)`

Data Types: `double`

**`PortLineLength` — Length of input and output line**
`0.0075` (default) | positive scalar

Length of the input and the output line in meters, specified as a positive scalar.

Example: `filter = filterSpurline(PortLineLength = 0.0095)`

Data Types: `double`

**`PortLineWidth` — Width of input and output line**
`0.0021` (default) | positive scalar

Width of the input and the output line in meters, specified as a positive scalar.

Example: `filter = filterSpurline(PortLineWidth = 0.0041)`

Data Types: `double`

**`Height` — Height from ground plane to filter**
`7.6000e-04` (default) | positive scalar

Height from the ground plane to the filter in meters, specified as a positive scalar.

Example: `filter = filterSpurline(Height = 0.00096)`

Data Types: `double`

**`GroundPlaneWidth` — Height from ground plane to filter**
`0.0120` (default) | positive scalar

Height from the ground plane to the filter in meters specified as a positive scalar.

Example: `filter = filterSpurline(GroundPlaneWidth = 0.00096)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `filterSpurline` object has the default properties: `(Name={'AD260A'},EpsilonR=2.6,LossTangent=0.001,Thickness=0.76e-3)`.

.

Example: `d = dielectric("FR4"); coupler = filterSpurline(Substrate=d)`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The metal used in the conducting layers of `filterSpurline` object with default properties is PEC.

Example: `m = metal("Copper"); coupler = filterSpurline(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Spurline Filter with Default Values

Create a spurline filter with default properties.

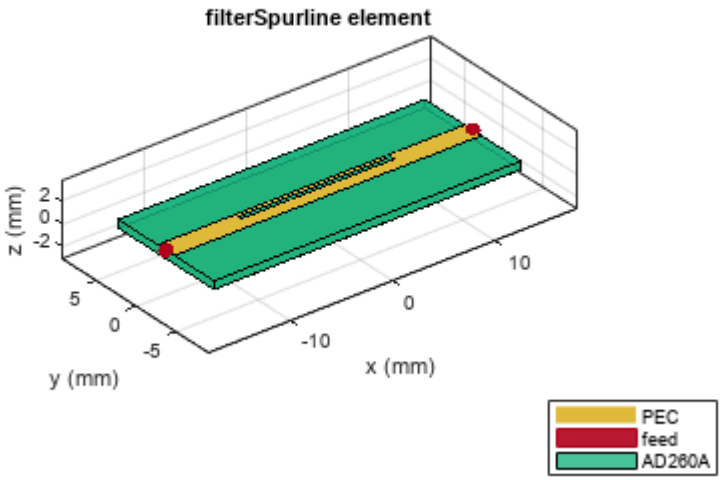
```
filter = filterSpurline
```

```
filter =
  filterSpurline with properties:
```

```
          LineType: 'Single'
 CoupledLineLength: 0.0146
  CoupledLineWidth: 4.0000e-04
CoupledLineSpacing: 4.0000e-04
           LineGap: 4.0000e-04
    PortLineLength: 0.0075
     PortLineWidth: 0.0021
            Height: 7.6000e-04
  GroundPlaneWidth: 0.0120
         Substrate: [1x1 dielectric]
         Conductor: [1x1 metal]
```

Visualize the filter.

```
show(filter)
```



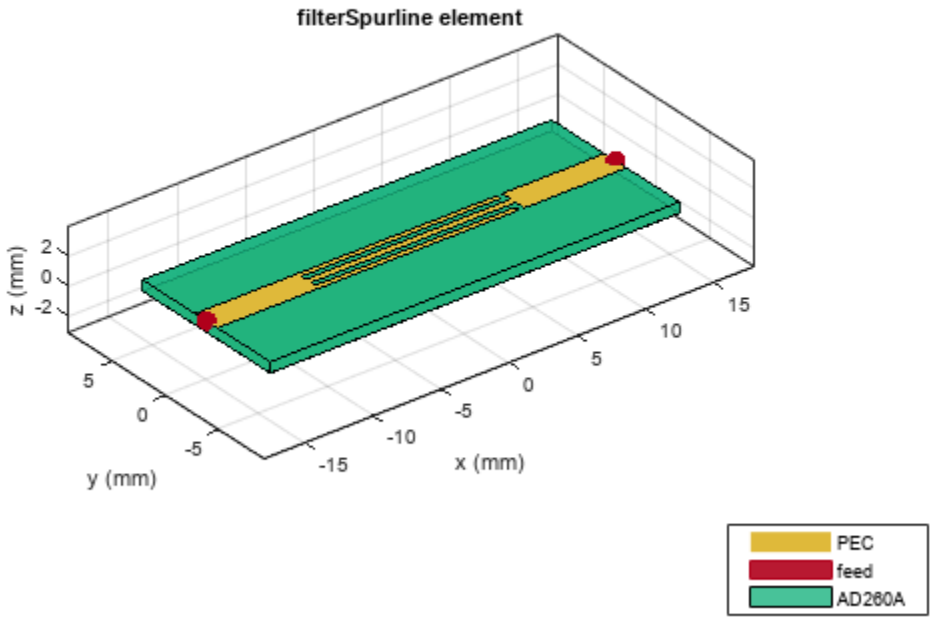

### Spurline Filter with Two Lines

Create a spurline filter with two lines.

```
filter = filterSpurline('LineType','double');
```

Visualize the filter.

```
show(filter);
```




# Version History

**Introduced in R2023a**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

## See Also

`filterCoupledLine` | `filterCombline` | `filterStepImpedanceLowPass` | `filterStub`

**Topics**

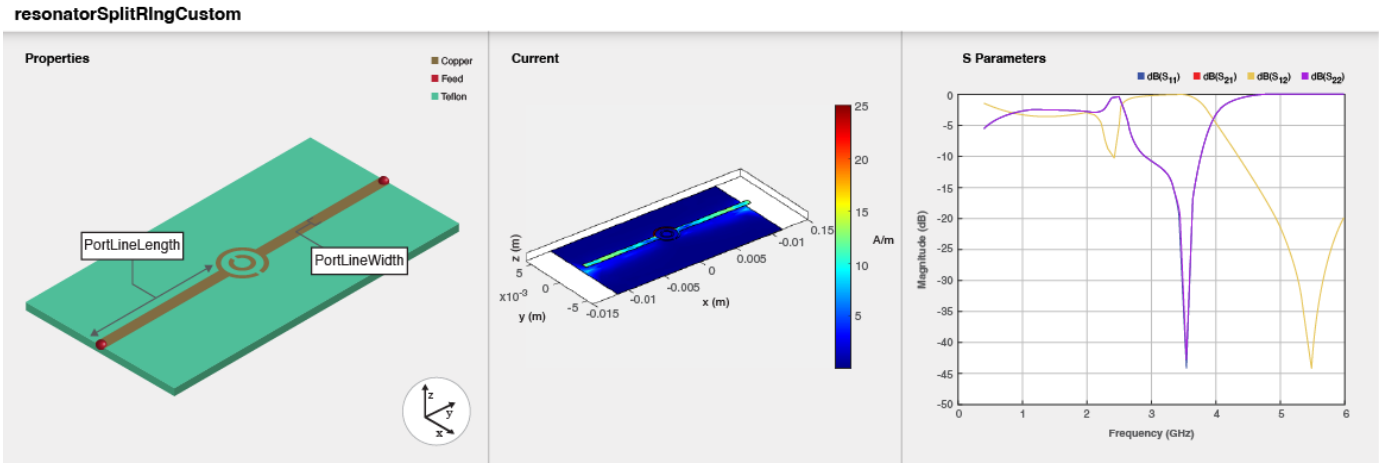
“Behavioral Models”

# resonatorSplitRingCustom

Create custom split-ring resonator in microstrip form

## Description

Use the `resonatorSplitRingCustom` object to create a custom split-ring resonator in the microstrip form.




## Creation

### Syntax

```
resonator = resonatorSplitRingCustom
resonator = resonatorSplitRingCustom(Name=Value)
```

#### Description

`resonator = resonatorSplitRingCustom` creates a custom split-ring resonator with default properties.

`resonator = resonatorSplitRingCustom(Name=Value)` sets "Properties" on page 1-327 using one or more name-value arguments. For example, `resonatorSplitRingCustom(Resonator="Square")` creates a custom split-ring resonator with the split-ring element in the shape of a square. Properties not specified retain their default values

### Properties

**`Resonator` — Shape of split-ring element**
`'splitRing'` shape object (default)

Shape of the split-ring element, specified as a `splitRing` shape object. This property also accepts different types in split ring like square, triangle, hexagon, and octagon.

Example: `resonator = resonatorSplitRingCustom(Resonator=split)`

Data Types: `char` | `string`

**`NumResonator` — Number of resonators in coupled feed**
`2` (default) | positive scalar

Number of resonators in the coupled feed, specified as a positive scalar in the range 1 to11.

Example: `resonator = resonatorSplitRingCustom(NumResonator=2)`

**Dependencies**

To enable this property, set `FeedType` to `'Coupled'`.

Data Types: `double`

**`ResonatorSpacing` — Spacing between resonators**
`4.0325e-3` (default) | positive scalar

Spacing between the resonators in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingCustom(ResonatorSpacing=5.07e-3)`

**Dependencies**

To enable this property, set `FeedType` to `'Coupled'`.

Data Types: `double`

**`PortLineLength` — Length of port line**
`0.0100` (default) | positive scalar

Length of the port line in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingCustom(PortLineLength=0.055)`

Data Types: `double`

**`PortLineWidth` — Width of port line**
`7.5000e-04` (default) | positive scalar

Width of the port line in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingCustom(PortLineWidth=0.0061)`

Data Types: `double`

**`FeedType` — Type of feed**
`'Tapped'` (default) | `'Coupled'`

Type of feed, specified as `'Tapped'` or `'Coupled'`.

Example: `resonator = resonatorSplitRingCustom(FeedType='Coupled')`

Data Types: `char` | `string`

**`CouplingGap` — Gap between resonator and microstrip line**
`1.8270e-04` (default) | positive scalar

Gap between the resonator and the microstrip line in meters for the coupled feed resonator, specified as a positive scalar.

Example: `resonator = resonatorSplitRingCustom(CouplingGap=0.00082)`

**Dependencies**

To enable this property, set `FeedType` to `'Coupled'`.

Data Types: `double`

### `Height` — Height of resonator from ground plane

`0.000813` (default) | positive scalar

Height of the resonator from the ground plane in meters, specified as a positive scalar.

In the case of a multilayer substrate, you can use the `Height` property to create a custom split-ring resonator where the two dielectrics interface.

Example: `resonator = resonatorSplitRingCustom(Height=0.020)`

Data Types: `double`

### `GroundPlaneWidth` — Width of ground plane

`0.0120` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `resonator = resonatorSplitRingCustom(GroundPlaneWidth=0.2241)`

Data Types: `double`

### `Substrate` — Type of dielectric material

`dielectric("Teflon")` (default) | `dielectric` object

Type of dielectric material to use as a substrate, specified as a `dielectric` object. The type of substrate in a `resonatorSplitRingCustom` object with default properties is Teflon.

Example: `d = dielectric("FR4"); resonator = resonatorSplitRingCustom(Substrate=d)`

### `Conductor` — Type of metal in conducting layers

`metal("Copper")` (default) | `metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The metal used in the conducting layers of `resonatorSplitRingCustom` object with default properties is Copper.

Example: `m = metal("Copper"); coupler = resonatorSplitRingCustom(Conductor=m)`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| dgs | Create defected ground structure of PCB element |
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |

| | |
|---|---|
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Custom Split-Ring Resonator with Default Values

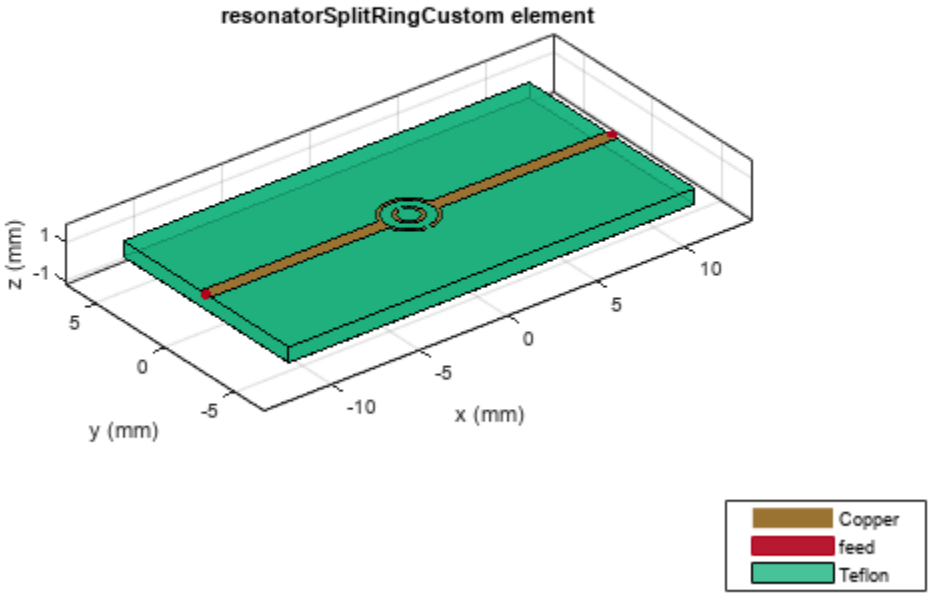
Create a custom split-ring resonator with default properties.

```
resonator = resonatorSplitRingCustom
```

```
resonator =
  resonatorSplitRingCustom with properties:

           Resonator: [1x1 splitRing]
      PortLineLength: 0.0100
       PortLineWidth: 7.5000e-04
            FeedType: 'Tapped'
              Height: 8.1300e-04
    GroundPlaneWidth: 0.0120
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the resonator.

```
show(resonator)
```



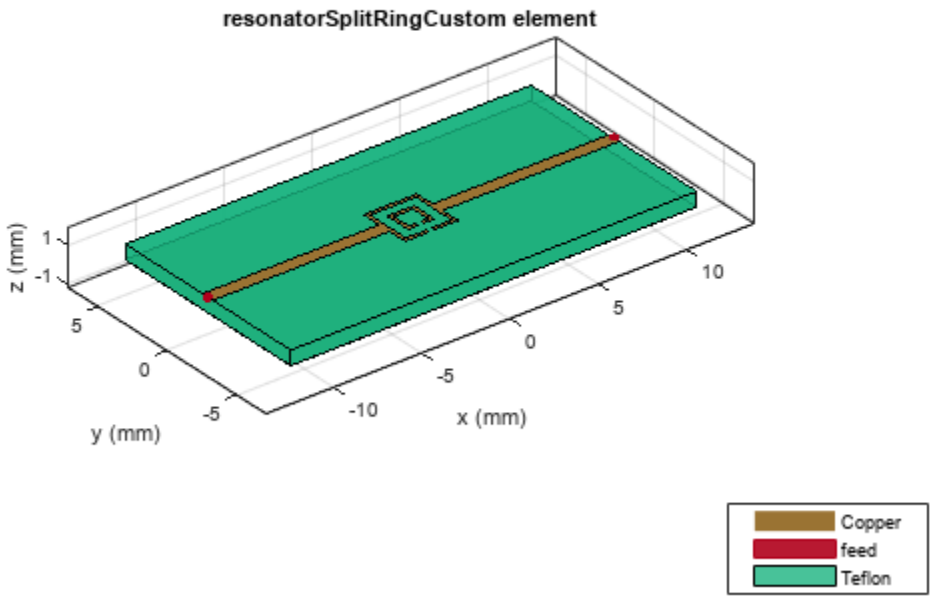
### Square Split-Ring Resonator with Tapped Feed

Create a resonator with a tapped feed and a square split ring.

```
resonator = resonatorSplitRingCustom;
resonator.Resonator.Type='Square';
```

View the resonator.

```
show(resonator);
```



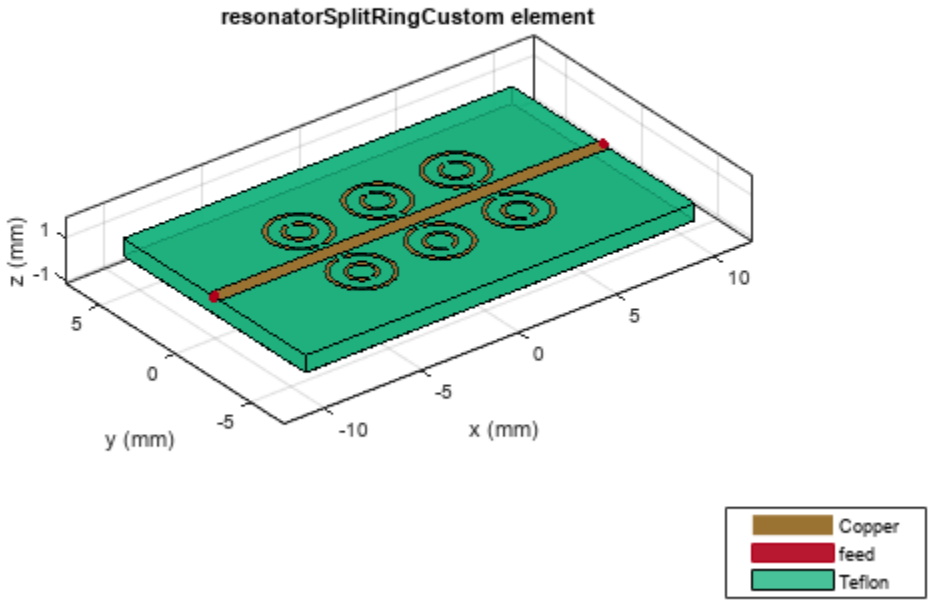

### Split-Ring Resonator with Coupled Feed

Create a split-ring resonator with coupled-feed and three resonators.

```
resonator = resonatorSplitRingCustom('FeedType','Coupled');
resonator.PortLineLength= 20e-3;
resonator.NumResonator = 3;
```

View the resonator.

```
show(resonator);
```




## Version History

**Introduced in R2023a**

## References

[1] Pozar, David.M. *Microwave Engineering* Singapore; JohnWiley and Sons. Inc, 2012.

[2] Mahyuddin, Muzlifah and Nur Farah Syazwani Ab. Kadir. *Design of a 5.8 GHz Bandstop Filter Using Split Ring Resonator Array*

## See Also

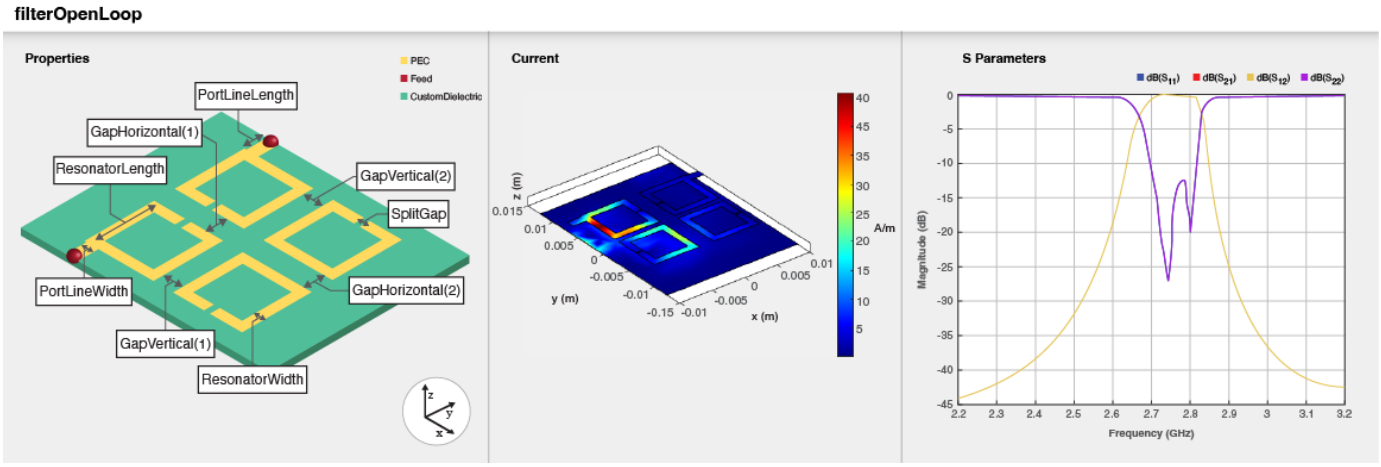
`resonatorRing` | `resonatorSplitRingSquare`

# filterOpenLoop

Create open-loop band pass filter in microstrip form

## Description

Use the `filterOpenLoop` object to create an open-loop bandpass filter in the microstrip form.




## Creation

### Syntax

```
filter = filterOpenLoop
filter = filterOpenLoop(Name=Value)
```

#### Description

`filter = filterOpenLoop` creates an open-loop bandpass filter with default properties for a cutoff frequency of 2.75 GHz.

`filter = filterOpenLoop(Name=Value)` sets “Properties” on page 1-311 using one or more name-value arguments. For example, `filterOpenLoop(ResonatorLength=0.008)` creates an open-loop bandpass filter with resonator length of 8 cm. Properties not specified retain their default values.

### Properties

#### `NumPoles` — Number of poles

4 (default) | 6 | 8

Number of poles in the filter, specified as 4, 6, or 8.

Example: `filter = filterOpenLoop(NumPoles=8)`

Data Types: `double`

**`ResonatorLength` — Resonator length**
`0.007` (default) | scalar

Length of resonator in meters, specified as a scalar.

Example: `filter = filterOpenLoop(ResonatorLength=0.009)`

Data Types: `double`

**`ResonatorWidth` — Resonator width**
`1.0000e-03` (default) | scalar

Width of resonator in meters, specified as a scalar.

Example: `filter = filterOpenLoop(ResonatorWidth=0.002)`

Data Types: `double`

**`SplitGap` — Length of split in resonator**
`1.0000e-04` (default) | scalar

Length of the split in the resonator in meters, specified as a scalar.

Example: `filter = filterOpenLoop(SplitGap=0.0001)`

Data Types: `double`

**`GapHorizontal` — Horizontal gaps between open-loop resonators of quadruplet**
`0.0022` (default) | scalar | vector

Horizontal gaps between the open-loop resonators of a quadruplet in meters, specified as one of these:

- scalar
- two-element vector when `NumPoles` is 2 or 4
- four-element vector when `NumPoles` is 8

Example: `filter = filterOpenLoop(GapHorizontal=[0.0033 0.0044])`

Data Types: `double`

**`GapVertical` — Vertical gaps between open-loop resonators of quadruplet**
`8.0000e-04` (default) | scalar | vector

Vertical gaps between the open-loop resonators of a quadruplet in meters, specified as one of these:

- scalar
- two-element vector when `NumPoles` is 2 or 4
- four-element vector when `NumPoles` is 8

Example: `filter = filterOpenLoop(GapVertical=[0.0009 0.0008])`

Data Types: `double`

**`FeedOffset` — Offset of input and output feed lines**
`0.0066` (default) | scalar | two-element vector

Offset of the input and output feed lines in meters, specified as a scalar or a two-element vector. If you specify a scalar value, then input and output lines are offset by the same value. If you specify a two-element vector, the first element represents the offset for the input line and the second element the offset for the output line.

Example: `filter = filterOpenLoop(FeedOffset=[0.0076 0.0096])`

Data Types: `double`

**`CoupledResonatorGap` — Spacing between quadruplet and input and output resonators**
`0.0022` (default) | scalar | two-element vector

Spacing between the quadruplet and input and output resonators in meters, specified as a scalar or a two-element vector. This property is enabled only when you set `NumPoles` to 6.

Example: `filter = filterOpenLoop(CoupledResonatorGap=[0.0032 0.0042])`

Data Types: `double`

**`QuadrupletGap` — Spacing between two quadruplets**
`0.00175` (default) | scalar

Spacing between the two quadruplets in meters, specified as a scalar. This property is enabled only when you set `NumPoles` to 8.

Example: `filter = filterOpenLoop(QuadrupletGap=0.00275)`

Data Types: `double`

**`QuadrupletOffset` — Offset center of right side quadruplet along Y-axis**
`0` (default) | scalar

Offset the center of right side quadruplet along Y-axis in meters, specified as a scalar. This property is enabled only when you set `NumPoles` to 8

Example: `filter = filterOpenLoop(QuadrupletOffset=0.3)`

Data Types: `double`

**`PortLineLength` — Length of input and output line**
`0.0020` (default) | positive scalar

Length of the input and the output line in meters, specified as a positive scalar.

Example: `filter = filterOpenLoop(PortLineLength = 0.0035)`

Data Types: `double`

**`PortLineWidth` — Width of input and output line**
`0.0011` (default) | positive scalar

Width of the input and the output line in meters, specified as a positive scalar.

Example: `filter = filterOpenLoop(PortLineWidth = 0.001135)`

Data Types: `double`

**`Height` — Height from ground plane to filter**
`0.00013` (default) | positive scalar

Height from the ground plane to the filter in meters, specified as a positive scalar.

Example: `filter = filteropenLoop(Height = 0.00096)`

Data Types: `double`

**`GroundPlaneWidth` — Width of ground plane**
`0.0250` (default) | positive scalar

Width of the ground plane in meters, specified as a positive scalar.

Example: `filter = filteropenLoop(GroundPlaneWidth = 0.00096)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `filterOpenLoop` object has these default properties:
`(Name='CustomDielectric',EpsilonR=10.8,LossTangent=0.0001,Thickness=1.27e-3)`

Example: `d = dielectric("FR4"); coupler = filterOpenLoop(Substrate=d)`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The metal used in the conducting layers of `filterOpenLoop` object with default properties is PEC.

Example: `m = metal("Copper"); coupler = filterOpenLoop(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| dgs | Create defected ground structure of PCB element |
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Open-Loop Filter with Default Values

Create an open-loop filter with default properties.

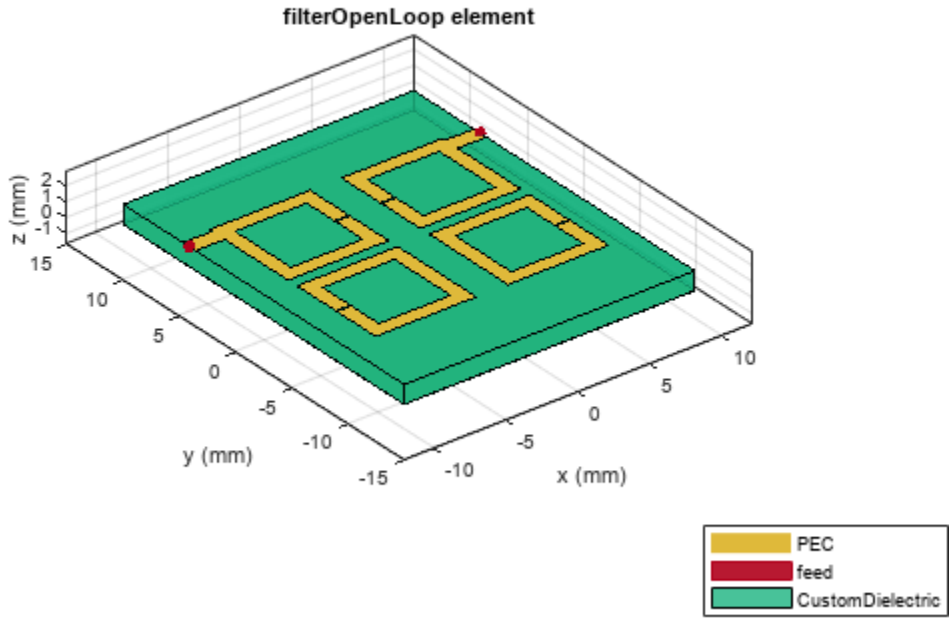
```
filter = filterOpenLoop
```

```
filter =
  filterOpenLoop with properties:

            NumPoles: 4
```

```
     ResonatorLength: 0.0070
      ResonatorWidth: 1.0000e-03
             SplitGap: 1.0000e-04
       GapHorizontal: 0.0022
         GapVertical: 8.0000e-04
          FeedOffset: 0.0066
       PortLineWidth: 0.0011
      PortLineLength: 0.0020
              Height: 0.0013
    GroundPlaneWidth: 0.0250
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the filter.

```
show(filter)
```



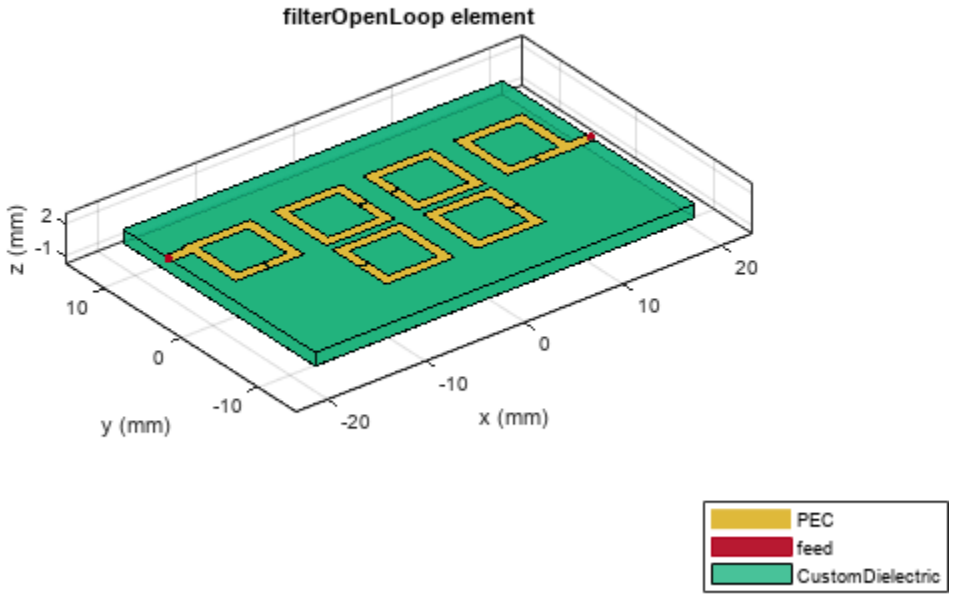

### Open-Loop Filter with Six Poles

Create an open-loop filter with six poles and a different offset for the input and output lines.

```
filter = filterOpenLoop(NumPoles=6,FeedOffset=[0.0066,0.001]);
```

View the filter.

```
show(filter);
```




# Version History

**Introduced in R2023a**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

[2] Hong, Jia-Sheng, and M. J. Lancaster. *Microstrip Filters for RF/Microwave Applications*. Wiley, 2001.

[3] Pal Singh, Inder, Praveen Bhatt, Dinesh Bisht. "Design of Tunable Microstrip Bandpass Cascaded Quadruplet Filter". *Advances in Computer Science and Information Technology (ACIST)*.Vol 2, Number 12, (July -September 2015) pp 11-14.

[4] Hong, Jia-Sheng, Michael J Lancaster. "Couplings of Microstrip Square, Open-Loop Resonators or Cross-Coupled Planar Microwave Filters". *IEEE Transactions on Microwave Theory and Techniques*.Vol 44, Number 12, (December 1996).

## See Also

`filterCoupledLine` | `filterCombline` | `filterStepImpedanceLowPass` | `filterStub`

**Topics**
“Behavioral Models”

# viaSingleEnded

Create single ended via in PCB stack

## Description

Use the `viaSingleEnded` object to create a single-ended via model within a printed circuit board (PCB) stack.

A vertical interconnect access (via) is an essential part of a multilayer PCB. You can use vias to create an electrical connection between the different layers in a PCB. You can construct vias by placing copper pads on each layer of the PCB and drilling a hole through the pads, using a non-conductive material in the inner layer of the via and a conductive plating on the outer layer.

A via consists of:

1. Barrel — Conductive tube filling the drilled hole
2. Pad — Connects each end of the barrel to a component, plane, or trace
3. Antipad — Clearance hole between the barrel and metal layer

In a multilayer PCB, vias reduce the length over which you need to route a trace to complete its connection. Smaller the via, the better the performance of the circuit.

**Note** In this release, `viaSingleEnded` only supports behavioral model analysis of s-parameters. For more information, see “Behavioral Models”.

## Creation

### Syntax

```
via = viaSingleEnded
via = viaSingleEnded(number of dilectric layers)
via = viaSingleEnded(Name=Value)
```

#### Description

`via = viaSingleEnded` creates a single-ended via with default properties. This via has one dielectric layer, two ground layers, one signal via, and one ground return via.

`via = viaSingleEnded(number of dilectric layers)` returns a single-ended via based on the number of dielectric layers.

`via = viaSingleEnded(Name=Value)` sets “Properties” on page 1-134 using one or more name-value arguments. For example, `viaSingleEnded(ViaDiameter=0.0065)` creates a single-ended via with a diameter of `0.0065` meters. Properties not specified retain their default values

## Properties

### `SignalViaDiameter` — Diameter of signal via(s) barrel

`2.5000e-04` (default) | scalar | vector

Diameter of the signal via(s) barrel in meters, specified as a scalar or a vector. if this is a vector, the size is equal to the number of signal vias.

Example: `via = viaSingleEnded(SignalViaDiameter=0.0045)`

Data Types: `double`

### `SignalViaLocations` — Location of signal via(s)

`[0 0 1 3]` (default) | *N*-by-4 matrix

Location of the signal via(s) in Cartesian coordinates, specified as a *N*-by-4 matrix, where *N* is the number of signal vias. The first and the second column corresponds to the *X* and *Y* coordinates of the via in meters, respectively. The third and the fourth columns corresponds to layer where the via starts and stops, respectively.

**Note** All vias start at layer 1. This object only supports through vias.

Example: `via = viaSingleEnded(SignalViaLocations=[0.5 0.25 1 5])`

Data Types: `double`

### `GroundReturnViaDiameter` — Diameter of ground return via(s)

`2.5000e-04` (default) | scalar | vector

Diameter of the ground return via(s) in meters, specified as a scalar or a vector. If this property is a vector, the size of the vector is equal to the number of ground return vias.

Example: `via = viaSingleEnded(GroundReturnViaDiameter=0.0045)`

Data Types: `double`

### `GroundReturnViaLocations` — Location(s) of ground return via(s)

`[1e-3 1e-3 1 3]` (default) | scalar | *M*-by-4 matrix

Location(s) of the ground return via(s) in Cartesian coordinates, specified as an *M*-by-4 matrix, where *M* represents the number of ground return vias in the PCB stack. The first and the second column corresponds to the *X* and *Y* coordinates, respectively, of the via in meters. The third and the fourth columns corresponds to layer where the via starts and stops, respectively.

**Note** All vias start at layer 1. This object only supports through vias.

Example: `via = viaSingleEnded(GroundReturnViaLocations=[1 1 1 5])`

Data Types: `double`

### `GroundLayer` — Position of ground layers in PCB stack

`[1 3]` (default) | positive integer vector

Position of the ground layers in the PCB stack, specified as a positive integer vector. The start and stop layers should be among the ground layers.

Example: `via = viaSingleEnded(GroundLayer=[1 4 6])`

Data Types: `double`

**`SignalViaAntipad` — Shape of signal via antipad**
`antenna.circle` shape object (default)

Shape of the signal via antipad, specified as an antenna shape object. For this release, the shape is limited to circle.

Example:
```
obj = viaSingleEnded('SignalViaLocations',[0 0 1 3;3e-3 -3e-3 1 3]);
obj.SignalViaAntipad = [antenna.Circle('Radius',6e-4)
antenna.Circle('Radius',8e-4)];
```

**`Substrate` — Type of dielectric material**
`'FR4'` (default) | `dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The thickness of the default dielectric material FR4 is `0.000127` m. The object supports a heterogeneous substrate, but if you position the substrate in the region between consecutive conducting planes.

Example: `obj = viaSingleEnded(2);d = dielectric("FR4", "Teflon");d.Thickness = [1e-4 1e-4];obj.Substrate = d;`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| criticalwavelength | Number of wavelengths between signal via and ground return vias |
| gapratedistance | Gap rate distance metric |
| layout | Plot all metal layers and board shape |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Single-Ended Via with Default Properties

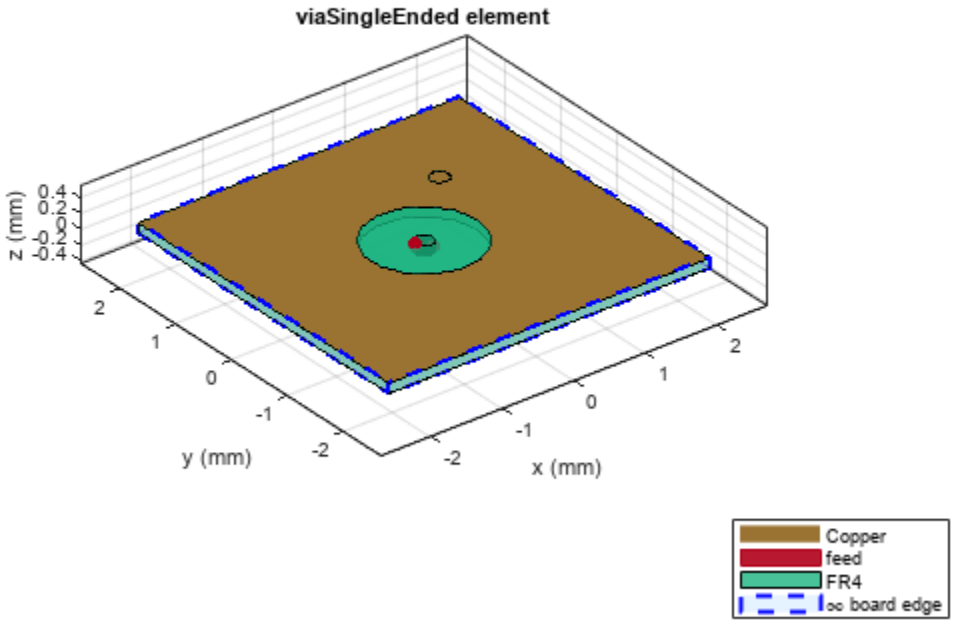
Create a single-ended via with default properties.

```
via = viaSingleEnded
```

```
via =
  viaSingleEnded with properties:

         SignalViaLocations: [0 0 1 3]
          SignalViaDiameter: 2.5000e-04
    GroundReturnViaLocations: [1.0000e-03 1.0000e-03 1 3]
     GroundReturnViaDiameter: 2.5000e-04
                 GroundLayer: [1 3]
           SignalViaAntipad: [1x1 antenna.Circle]
                  Substrate: [1x1 dielectric]
```

View the via.

```
show(via)
```




### Single-Ended Vias with Ground Return Via

Create a single-ended via.

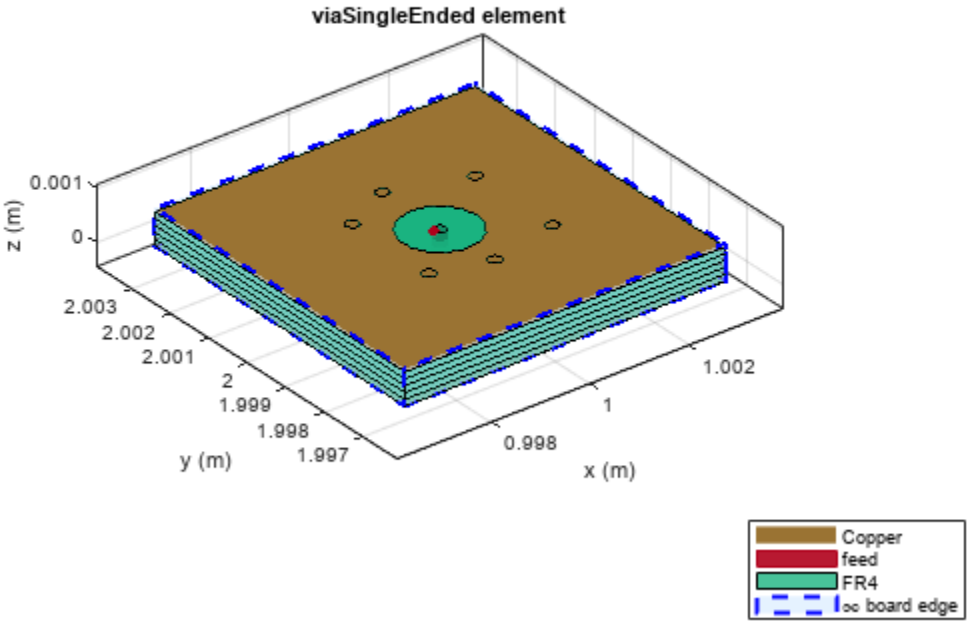
```
via = viaSingleEnded;
```

Create signal via locations and the ground return via locations.

```
via.SignalViaLocations = [1,2,1,7];
via.GroundLayer = [1 7];
via.GroundReturnViaLocations = [1.0015,2.001,1,7;1.0015,1.999,1,7; ...
          0.999,1.999,1,7;1,2.0015,1,7;0.999,2.001,1,7;1.0001,1.9987,1,7];
via.Substrate = dielectric("Name","FR4","EpsilonR",4.8,...
               "LossTangent",0.026,"Thickness",1.27e-4,"Frequency",1e8);
```

View the via.

```
show(via)
```




# Version History

**Introduced in R2023a**

## References

[1] Steinberger, Telian, Tsuk, Iyer and Yanamadala, “Proper Ground Via Placement for 40+ Gbps Signaling”, *DesignCon 2022*, April 2022.

[2] Ramo, Whinnery and Van Duzer, *Fields and Waves in Communications Electronics*, third edition, section 9.3, John Wiley and Sons Inc., copyright 1994

## See Also

### Topics

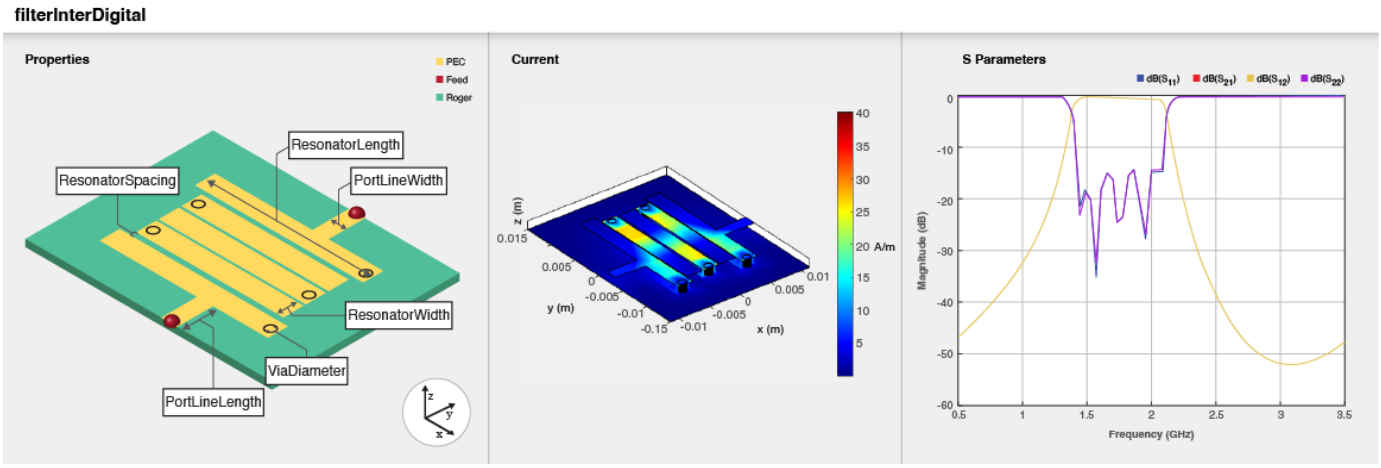
“Analysis of a Single Ended Via for Proper Placement of Ground Return Vias for 40+ Gbps Signaling”
“Eigenmode-Based Solver for PCB Vias”

# filterInterdigital

Create interdigital filter in microstrip from

## Description

Use the `filterInterdigital` object to create an interdigital filter in the microstrip form.




## Creation

### Syntax

```
filter = filterInterdigital
filter = filterInterdigital(Name=Value)
```

#### Description

`filter = filterInterdigital` creates an interdigital filter with default properties for a bandpass frequency of 2 GHz.

`filter = filterInterdigital(Name=Value)` sets “Properties” on page 1-345 using one or more name-value arguments. For example, `filterInterdigital(FilterOrder=3)` creates an interdigital filter with a filter order of three. Properties not specified retain their default values.

### Properties

#### `FilterOrder` — Order of filter

5 (default) | positive scalar

Order of the filter, specified as a positive scalar in the range `[3,9]`.

Example: `filter = filterInterdigital(FilterOrder=6)`

Data Types: `double`

**`ResonatorLength` — Length of resonator**
`[0.0204 0.0179 0.0178 0.0179 0.0204]` (default) | scalar | vector

Length of the resonator in meters, specified as a scalar or a vector equal in length to the order in `FilterOrder`.

Example: `filter = filterInterdigital(ResonatorLength=[0.03045 0.01291 0.01683 0.01691 0.03045])`

Data Types: `double`

**`ResonatorWidth` — Width of resonator**
`0.0024` (default) | scalar | vector

Width of the resonator in meters, specified as a scalar or a vector equal in length to the order in `FilterOrder`.

Example: `filter = filterInterdigital(ResonatorWidth=0.03045)`

Data Types: `double`

**`ResonatorSpacing` — Spacing between resonator**
`[1.3000e-04 3.6000e-04 3.6000e-04 1.3000e-04]` (default) | scalar | vector

Spacing between the resonators in meters, specified as a scalar or vector.

Example: `filter = filterInterdigital(ResonatorSpacing=0.00014)`

Data Types: `double`

**`ResonatorOffset` — *Y*-axis offset of each resonator**
`0` (default) | scalar | vector

*Y*-axis offset of each resonator in meters, specified as a scalar or vector. If the value is a scalar, all the resonators in the filter are offset by the same value along the *Y*-axis.

Example: `filter = filterInterdigital(ResonatorOffset=0.1)`

Data Types: `double`

**`PortLineLength` — Length of input and output line**
`0.0049` (default) | scalar | two-element vector

Length of the input and the output line in meters, specified as a scalar or a two-element vector.

Example: `filter = filterInterdigital(PortLineLength = 0.0095)`

Data Types: `double`

**`PortLineWidth` — Width of input and output line**
`0.0019` (default) | positive scalar

Width of the input and the output line in meters, specified as a positive scalar.

Example: `filter = filterInterdigital(PortLineWidth = 0.0041)`

Data Types: `double`

**`ViaDiameter` — Diameter of via**
`0.0011` (default) | positive scalar | vector

Diameter of the via in meters, specified as a scalar or a vector equal in length to the order in `FilterOrder`.

Example: `filter = filterInterdigital(ViaDiameter = 0.00113)`

Data Types: `double`

**`FeedOffset` — *Y*-axis offset of input and output lines**
`-0.0025` (default) | scalar | two-element vector

*Y*-axis offset of the input and output lines in meters, specified as a scalar or a two-element vector.

Example: `filter = filterInterdigital(FeedOffset=0.1)`

Data Types: `double`

**`Height` — Height from ground plane to filter**
`0.0013` (default) | positive scalar

Height from the ground plane to the filter in meters, specified as a positive scalar. In the case of a multilayer substrate, use the `Height` property to create an interdigital filter at the interface of the two dielectrics.

Example: `filter = filterInterDigital(Height = 0.00096)`

Data Types: `double`

**`GroundPlaneWidth` — Height from ground plane to filter**
`0.0300` (default) | positive scalar

Height from the ground plane to the filter in meters, specified as a positive scalar.

Example: `filter = filterInterdigital(GroundPlaneWidth = 0.040)`

Data Types: `double`

**`Substrate` — Type of dielectric material**
`dielectric` object

Type of dielectric material used as a substrate, specified as a `dielectric` object. The dielectric material in a `filterInterdigital` object has these default properties: `(Name={'Roger'},EpsilonR=6.15,LossTangent=0.002,Thickness=0.00127)`

Example: `d = dielectric("RTDuriod"); coupler = filterInterdigital(Substrate=d)`

**`Conductor` — Type of metal used in conducting layers**
`metal` object

Type of metal used in the conducting layers, specified as a `metal` object. The metal used in the conducting layers of `filterInterDigital` object with default properties is PEC.

Example: `m = metal("Copper"); coupler = filterInterdigital(Conductor=m)`

Data Types: `string` | `char`

## Object Functions

| | |
|---|---|
| charge | Calculate and plot charge distribution |
| current | Calculate and plot current distribution |
| feedCurrent | Calculate current at feed port |
| layout | Plot all metal layers and board shape |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| shapes | Extract all metal layer shapes of PCB component |
| show | Display PCB component structure or PCB shape |
| sparameters | Calculate S-parameters for RF PCB objects |

## Examples

### Interdigital Filter with Default Values

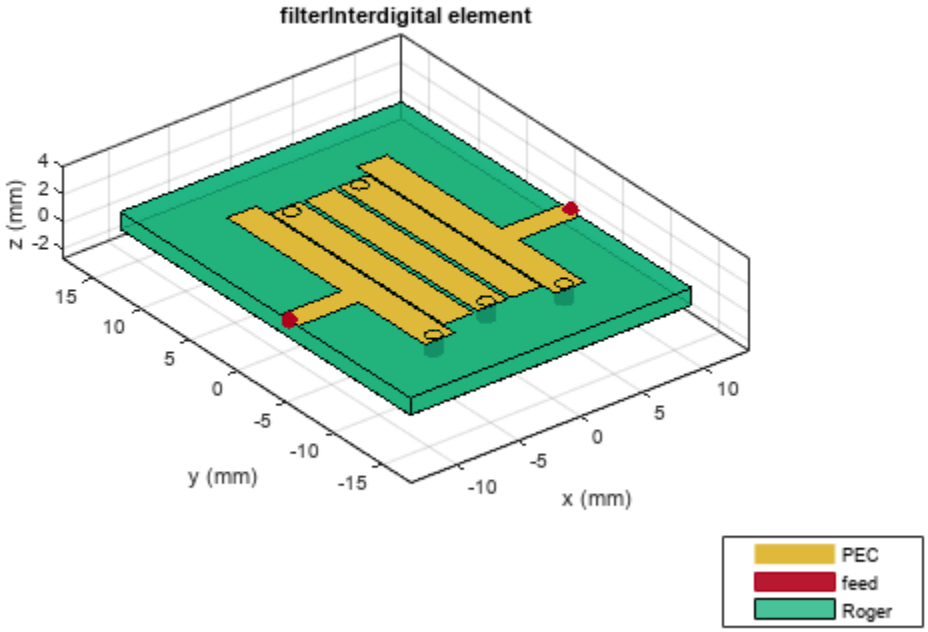
Create an interdigital filter with default properties.

```
filter = filterInterdigital
```

```
filter =
  filterInterdigital with properties:

         FilterOrder: 5
     ResonatorLength: [0.0204 0.0179 0.0178 0.0179 0.0204]
      ResonatorWidth: 0.0024
    ResonatorSpacing: [1.3000e-04 3.6000e-04 3.6000e-04 1.3000e-04]
     ResonatorOffset: 0
      PortLineLength: 0.0049
       PortLineWidth: 0.0019
          FeedOffset: -0.0025
         ViaDiameter: 0.0011
              Height: 0.0013
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the filter.

```
show(filter)
```



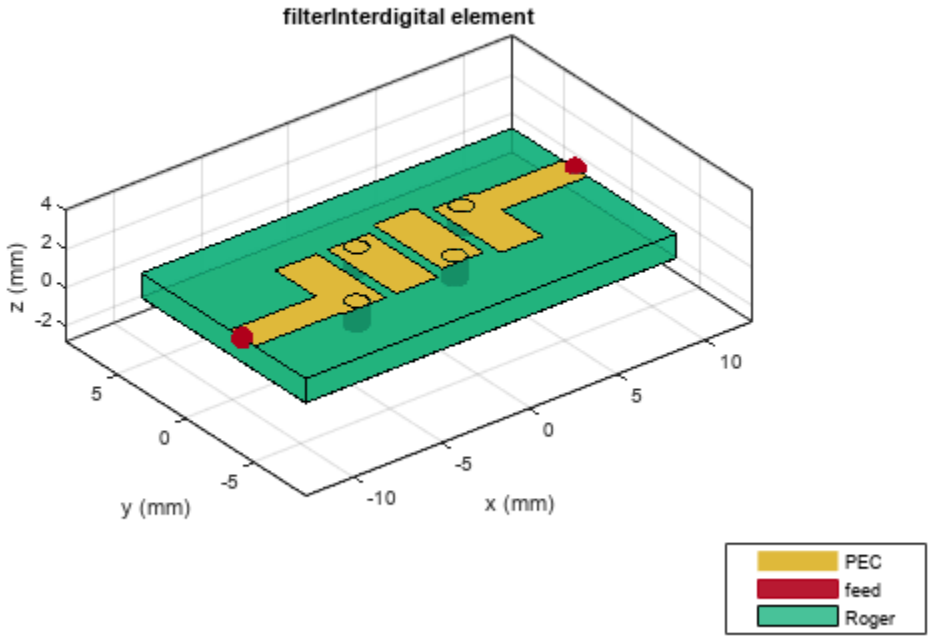

### Fourth-Order Interdigital Filter

Create a fourth-order interdigital filter with a different offset for the four resonators and a different offset for the input and output lines.

```
filter = filterInterdigital(FilterOrder=4,ResonatorLength=0.005, ...
    ResonatorSpacing=0.6e-3,ResonatorOffset=[0.001e-3,0,0.5e-3,0], ...
    FeedOffset=[-0.0014,0.0014],GroundPlaneWidth=12e-3);
```

View the filter.

```
show(filter)
```




## Version History

**Introduced in R2023a**

## References

[1] Pozar, David M. *Microwave Engineering*. 4th ed. Hoboken, NJ: Wiley, 2012.

[2] Hong, Jia-Sheng, and M. J. Lancaster. *Microstrip Filters for RF/Microwave Applications*. Wiley, 2001.

[3] Saleh, Sahar, Widad Ismail, Intan Sorfina, Zainal Abidin. “5G Hairpin and Interdigital Bandpass Filters.” *International Journal of Integrated Engineering*, Vol. 12, No.6, July 2020.

## See Also

`filterCoupledLine` | `filterCombline` | `filterStepImpedanceLowPass` | `filterStub`

**Topics**

“Behavioral Models”

# splitRing

Create split ring shape on X-Y plane

## Description

Use the `splitRing` object to create a split-ring shape centered at the origin on the *X*-*Y* plane.

## Creation

### Syntax

```
splitringshape = splitRing
splitringshape = splitRing(Name=Value)
```

#### Description

`splitringshape = splitRing` creates a split-ring shape centered at the origin and on the *X*-*Y* plane.

`splitringshape = splitRing(Name=Value)` sets "Properties" on page 1-351 using one or more name-value arguments. For example, `splitRing(ReferencePoint=[1 1])` creates a split ring shape at the reference point `[1 1]`. Properties not specified retain their default values.

### Properties

#### `Name` — Name of split-ring shape

`'mysplitring'` (default) | character vector | string scalar

Name of the split-ring shape, specified as a character vector or string scalar.

Example: `splitringshape = splitRing(Name='splitringshape1')`

Data Types: `char` | `string`

#### `Type` — Shape of split ring

`'Circle'` (default) | `'Triangle'` | `'Square'` | `'Hexagon'` | `'Octagon'`

Shape of split ring, specified as: `'Circle'`, `'Triangle'`, `'Square'`, `'Hexagon'`, or `'Octagon'`.

Example: `splitringshape = splitRing(Type='Hexagon')`

Data Types: `char`

#### `ReferencePoint` — Reference point

`[0 0]` (default) | two-element vector

Reference point of the split-ring shape in Cartesian coordinates, specified as a two-element vector.

Example: `splitringshape = splitRing(ReferencePoint=[1 1])`

Data Types: `double`

**`RingDiameterInner` — Diameter of inner ring**
`0.0015` (default) | positive scalar

Diameter of the inner ring in meters, specified as a positive scalar.

Example: `splitringshape = splitRing(RingDiameterInner=0.0025)`

**Dependencies**

To enable this property, set `Type` to `'Circle'`.

Data Types: `double`

**`RingDiameterOuter` — Diameter of outer ring**
`0.0030` (default) | positive scalar

Diameter of the outer ring in meters, specified as a positive scalar.

Example: `splitringshape = splitRing(RingDiameterOuter=0.0040)`

**Dependencies**

To enable this property, set `Type` to `'Circle'`.

Data Types: `double`

**`SideLengthInner` — Side length of inner ring**
`0.0015` (default) | positive scalar

Side length of the inner ring in meters, specified as a positive scalar.

Example: `splitringshape = splitRing(SideLengthInner=0.0025)`

**Dependencies**

To enable this property, set `Type` to `'Triangle'`, `'Hexagon'`, `'Square'`, or `'Octagon'`.

Data Types: `double`

**`SideLengthOuter` — Side length of outer ring**
`0.0030` (default) | positive scalar

Side length of the outer ring in meters, specified as a positive scalar.

Example: `splitringshape = splitRing(SideLengthOuter=0.0030)`

**Dependencies**

To enable this property, set `Type` to `'Triangle'`, `'Hexagon'`, `'Square'`, or `'Octagon'`.

Data Types: `double`

**`TraceWidth` — Width of inner and outer ring**
`2.0000e-04` (default) | positive scalar

Width of the inner and the outer rings in meters, specified as a positive scalar.

Example: `splitringshape = splitRing(TraceWidth=5.0000e-04)`

Data Types: `double`

### `SplitAngle` — Angle of split

`[0 0]` (default) | two-element vector

Angle of the split between the inner and outer ring in degrees, specified as a two-element vector.

Example: `splitringshape = splitRing(SplitAngle=[10 10])`

#### Dependencies

To enable this property, set `Type` to `'Circle'`.

Data Types: `double`

### `SplitSide` — Side of split in polygon

`[1 1]` (default) | two-element vector

Side of the split between the inner and outer ring in meters, specified as a two-element vector.

Example: `splitringshape = splitRing(SplitSide=[2 2])`

#### Dependencies

To enable this property, set `Type` to `'Triangle'`, `'Hexagon'`, `'Square'`, or `'Octagon'`.

Data Types: `double`

### `SplitGap` — Width of split

`3.0000e-04` (default) | positive scalar

Width of split on both inner and outer ring in meters, specified as a positive scalar.

Example: `splitringshape = splitRing(SplitSide=2.0000e-04)`

#### Dependencies

To enable this property, set `Type` to `'Triangle'`, `'Hexagon'`, `'Square'`, or `'Octagon'`.

Data Types: `double`

## Object Functions

| | |
|---|---|
| add | Boolean unite operation on two RF PCB shapes |
| and | Shape1 & Shape2 for RF PCB shapes |
| area | Calculate area of RF PCB shape in square meters |
| intersect | Boolean intersection operation on two RF PCB shapes |
| mesh | Change and view mesh properties of metal or dielectric in PCB component |
| minus | Shape1 - Shape2 for RF PCB shapes |
| plus | Shape1 + Shape2 for RF PCB shapes |
| rotate | Rotate RF PCB shape about defined axis |
| rotateX | Rotate RF PCB shape about x-axis |
| rotateY | Rotate RF PCB shape about y-axis and angle |
| rotateZ | Rotate RF PCB shape about z-axis |
| subtract | Boolean subtraction operation on two RF PCB shapes |
| scale | Change size of RF PCB shape by fixed amount |
| show | Display PCB component structure or PCB shape |
| translate | Move RF PCB shape to new location |

## Examples

### Split-Ring Shape with Default Values

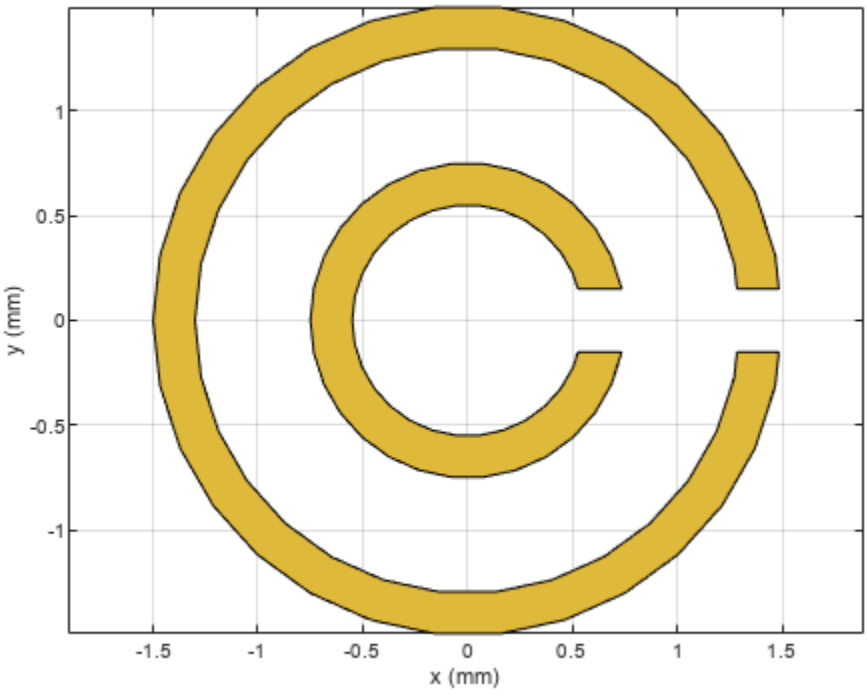
Create a default split-ring shape.

```
splitringshape = splitRing
```

```
splitringshape =
  splitRing with properties:

                Name: 'mysplitring'
                Type: 'Circle'
      ReferencePoint: [0 0]
   RingDiameterInner: 0.0015
   RingDiameterOuter: 0.0030
          TraceWidth: 2.0000e-04
            SplitGap: 3.0000e-04
          SplitAngle: [0 0]
```

View the shape.

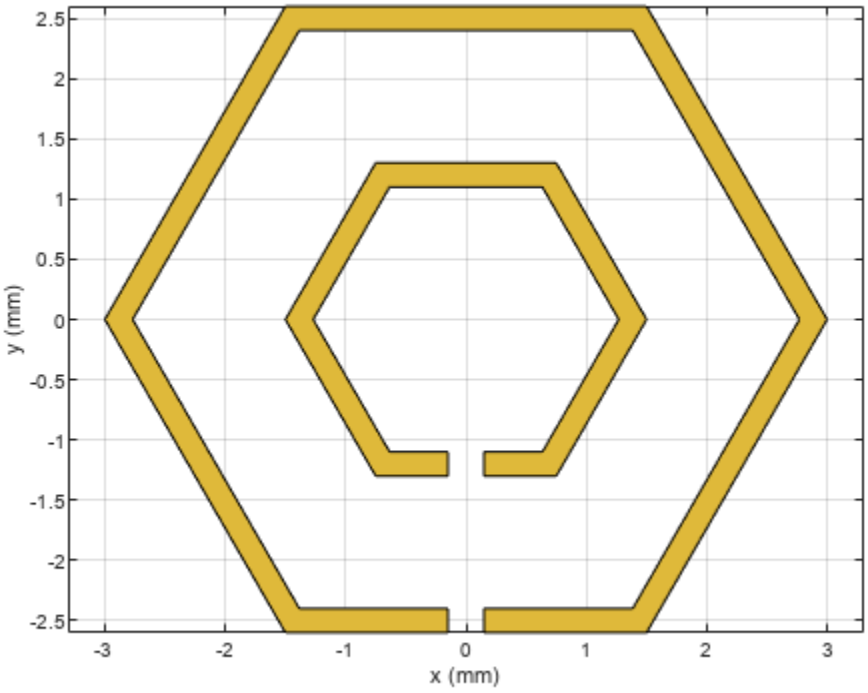
```
show(splitringshape)
```



### Hexagonal Split Ring

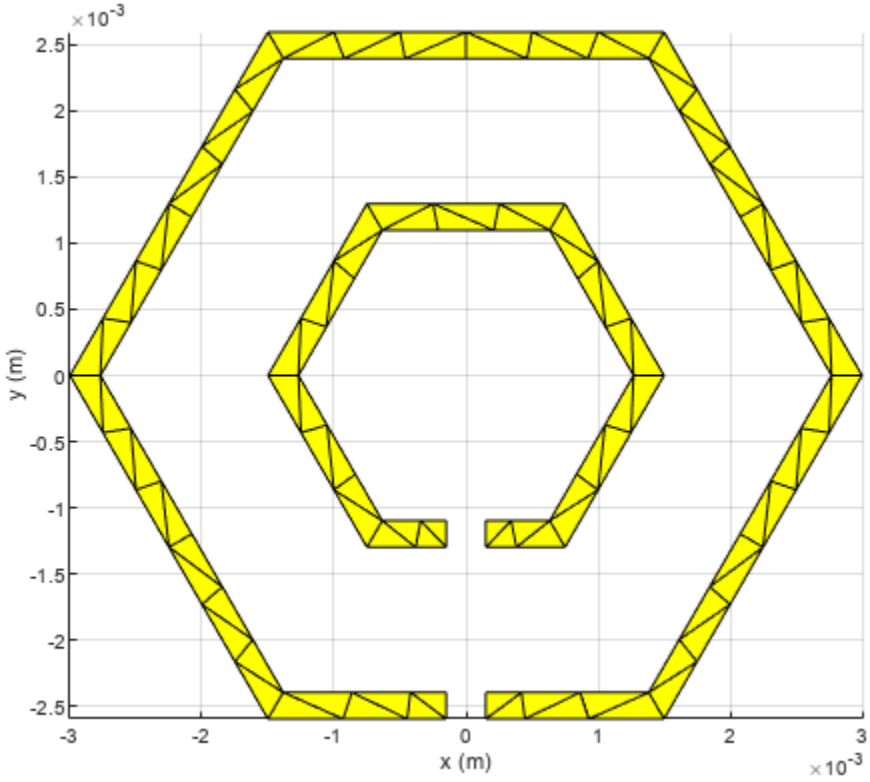
Create a hexagonal split ring.

```
splitringshape = splitRing('Type','Hexagon');
show(splitringshape)
```




Mesh it with maximum edge length of 0.5 mm.

```
figure; mesh(splitringshape,'MaxEdgeLength',0.5e-3);
```




## Version History

**Introduced in R2023a**

## See Also

`ringAnnular` | `ringSquare` | `radial` | `delta`

# Functions

# show

Display PCB component structure or PCB shape

## Syntax

```
show(pcbcomponent)
show(shape)
```

## Description

`show(pcbcomponent)` displays the PCB component structure in the figure window.

`show(shape)` plots the shape as a filled region using patches.

## Examples

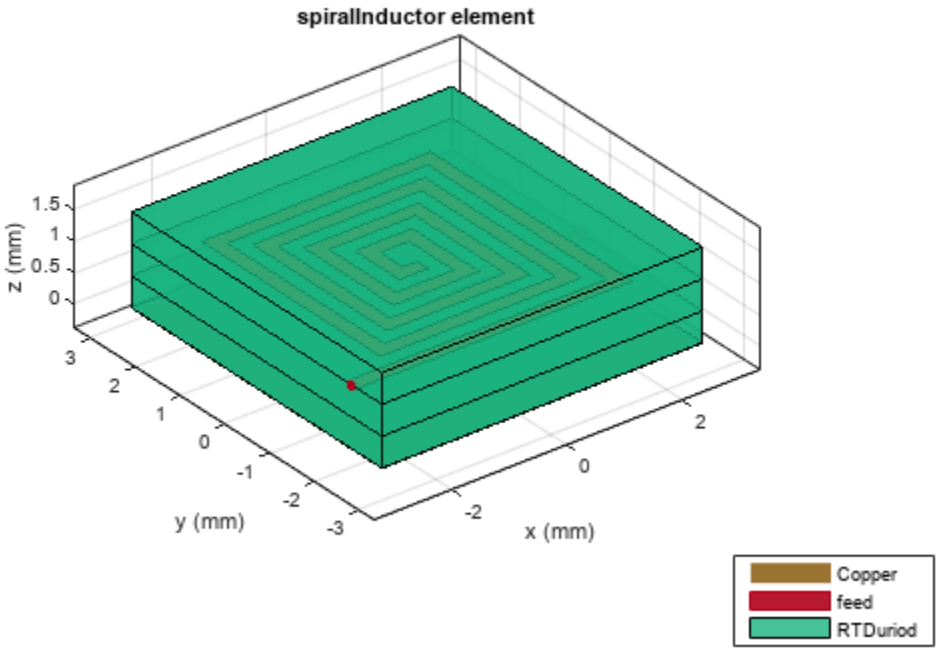
### Create Default Spiral Inductor

Create and view a default spiral inductor.

```
inductor = spiralInductor
```

```
inductor =
  spiralInductor with properties:

          SpiralShape: 'Square'
        InnerDiameter: 5.0000e-04
                Width: 2.5000e-04
              Spacing: 2.5000e-04
             NumTurns: 4
               Height: 0.0010
    GroundPlaneLength: 0.0056
     GroundPlaneWidth: 0.0056
            Substrate: [1x1 dielectric]
            Conductor: [1x1 metal]
```

```
show(inductor)
```




### Create Default Curved U-Bend

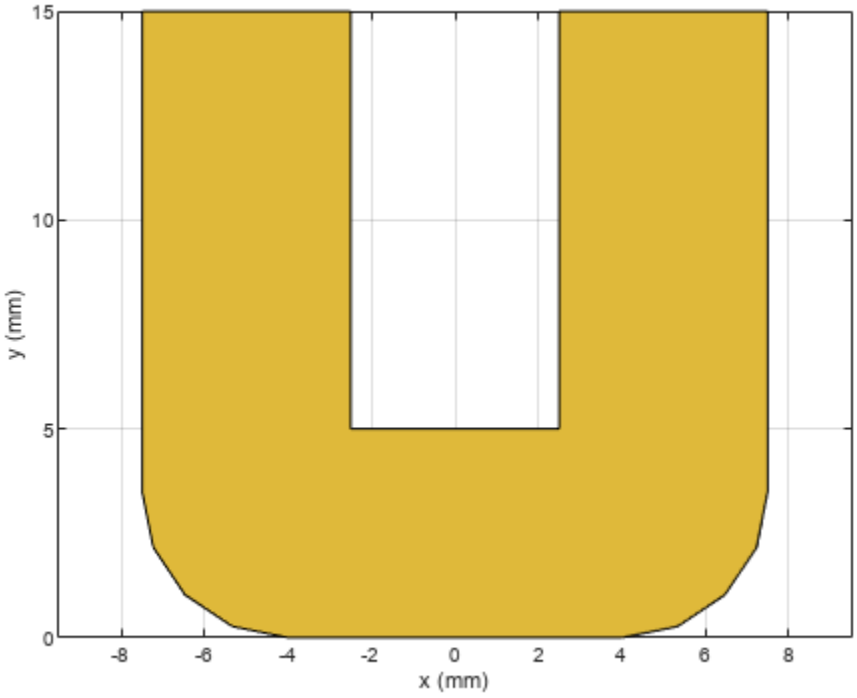
Create a curved U-bend with default properties.

```
curvedubend = ubendCurved
```

```
curvedubend =
  ubendCurved with properties:

              Name: 'myCurvedubend'
    ReferencePoint: [0 0]
            Length: [0.0150 0.0050 0.0150]
             Width: [0.0050 0.0050 0.0050]
       CurveRadius: 0.0035
```

View the shape.

```
show(curvedubend)
```




## Input Arguments

**`pcbcomponent` — PCB component object**
object handle

PCB component object, specified as a object handle.

Example: `microstrip = microstripLine; show(microstrip)`

**shape — Shape created using custom elements and shape objects**
object handle

Shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object handle.

Example: `shape = bendCurved; show(shape)`

# Version History

**Introduced in R2021b**

# current

Calculate and plot current distribution

## Syntax

```
current(rfpcbobject,frequency)

i = current(rfpcbobject,frequency)
[i,p] = current(rfpcbobject,frequency)

current(rfpcbobject,frequency,'dielectric')
i = current(rfpcbobject,frequency,'dielectric')
i = current( ___ ,Name=Value)
```

## Description

`current(rfpcbobject,frequency)` calculates and plots the absolute value of the current on the metal surface of a PCB component at the specified frequency.

`i = current(rfpcbobject,frequency)` calculates the *x, y, z* components of the current on the surface of a PCB component at a specified frequencies.

`[i,p] = current(rfpcbobject,frequency)` returns the current distribution and the points at which the current calculation was performed.

`current(rfpcbobject,frequency,'dielectric')` calculates and plots the absolute value of the current at the specified frequency on the dielectric surface of the PCB component.

`i = current(rfpcbobject,frequency,'dielectric')` calculates the *x, y, z* components of the current on the dielectric surface of a PCB component at the specified frequency.

`i = current( ___ ,Name=Value)` calculates the current on the surface of a PCB component using additional name-value arguments.

## Examples

### Calculate Current Distribution on Rat-Race Coupler

Create a rat-race coupler with default properties.

```
coupler = couplerRatrace;
```

Set the excitation voltage and the phase angle at the ports of the coupler.

```
v = voltagePort(4)
```

```
v =
  voltagePort with properties:

         NumPorts: 4
```

```
      FeedVoltage: [1 0 0 0]
        FeedPhase: [0 0 0 0]
    PortImpedance: 50
```

```
v.FeedVoltage = [1 0 1 0]
```

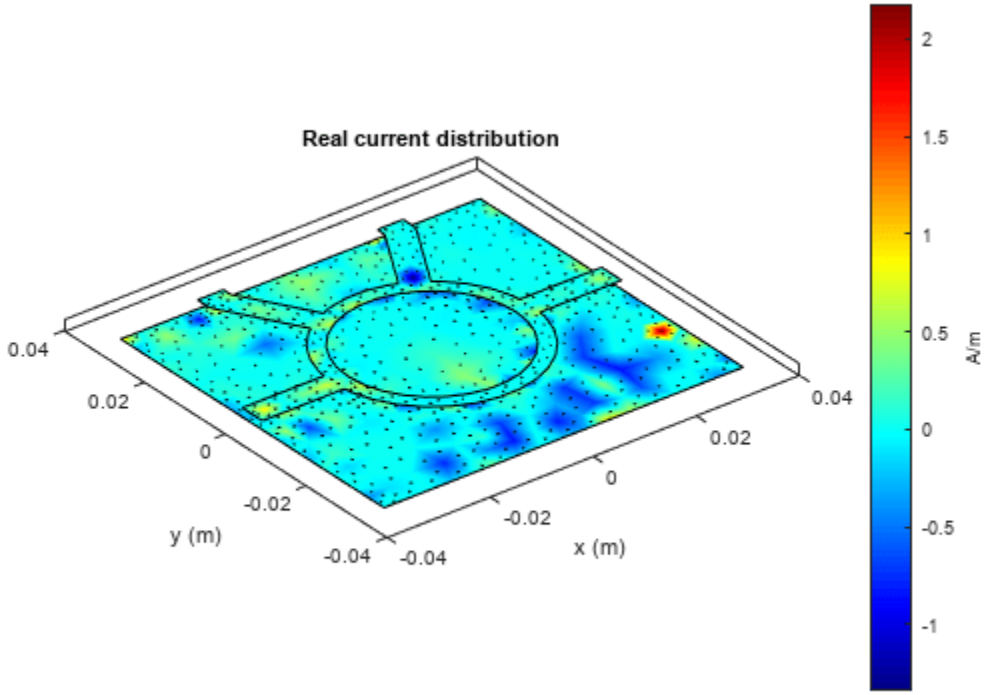
```
v =
  voltagePort with properties:

         NumPorts: 4
      FeedVoltage: [1 0 1 0]
        FeedPhase: [0 0 0 0]
    PortImpedance: 50
```

```
v.FeedPhase = [90 0 270 0]
```

```
v =
  voltagePort with properties:

         NumPorts: 4
      FeedVoltage: [1 0 1 0]
        FeedPhase: [90 0 270 0]
    PortImpedance: 50
```

Calculate and plot the current on the coupler at 3 GHz.

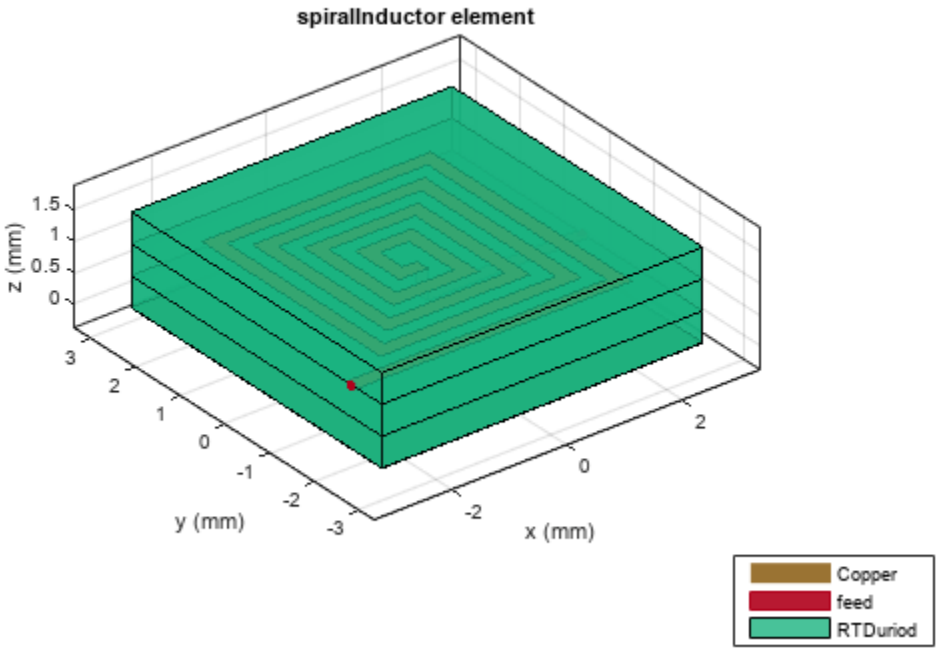
```
figure
current(coupler,3e9,Excitation=v,Type='real',Direction='on')
```




### Calculate Current Distribution on Spiral Inductor

Create a default spiral inductor.

```
inductor = spiralInductor;
show(inductor)
```



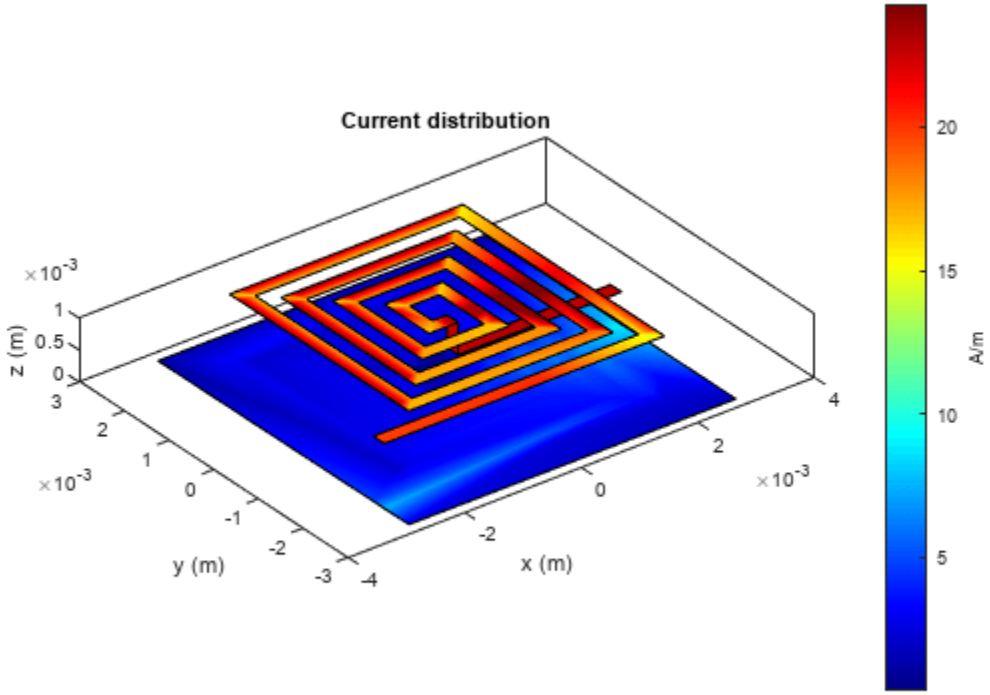

Calculate the current distribution on the inductor at 600 MHz.

```
[i,p] = current(inductor,600e6)
```

```
i = 3×258 complex

  -0.0699 + 0.1423i  11.2295 -19.7501i  -0.0006 + 0.0040i   0.1174 - 0.2520i  -0.8849 + 1.3742i
   0.7425 - 1.2120i   2.9572 - 4.7485i   0.8632 - 1.2992i   0.5293 - 0.5556i  -0.0001 + 0.0018i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i


p = 3×258

    0.0024    0.0025    0.0025    0.0023   -0.0001   -0.0022   -0.0009   -0.0019    0.0021    0.0
   -0.0022   -0.0002    0.0017    0.0007    0.0027    0.0025   -0.0022   -0.0021   -0.0020   -0.0
         0         0         0         0         0         0         0         0         0
```

Plot the current distribution.

```
current(inductor,600e6)
```




## Input Arguments

### `rfpcbobject` — PCB component object

RF PCB object

PCB component object, specified as an RF PCB object. For a complete list of the PCB components, microstrip bends, and traces, see “PCB Components Catalog” and “Custom Geometry and PCB Fabrication”.

### `frequency` — Frequency used to calculate current distribution

scalar

Frequency to calculate the current distribution, specified as a scalar in Hz.

Example: 70e6

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `scale=log10`

**`Scale` — Scale to visualize current distribution**
linear (default) | string scalar | character vector

Scale to visualize the current distribution on the surface of the PCB component, specified as a string or a character vector. The string values are either `'linear'`, `'log'`, or `'log10'` or as a function. You can specify any mathematical function such as `log`, `log10`, `cos`, or `sin`.

Data Types: `char` | `function_handle`

**`Slicer` — Slicer to focus on desired portion of current plot**
`'on'` | `'off'`

Slicer to slice the current plot and focus on the desired portion, specified as `'on'` or `'off'`. Choosing `'on'` adds the slicer panel to the current plot and choosing `'off'` does not change the current plot.

Data Types: `logical`

**`Excitation` — Excitation using voltage source**
function handle

Excitation using as voltage source, specified function handle from the `voltagePort` function.

Data Types: `char` | `function_handle`

**`Type` — Choose component of metal current**
`absolute` (default) | `real` | `imaginary`

Choose the component to display of the metal current, specified as.`absolute`, `real`, or `imaginary`.

Data Types: `char` | `function_handle`

**`Direction` — Visualize direction of vector when plotting metal current**
`off` (default) | `on`

Visualize the direction of the vector when plotting metal current, specified as `off` or `on`.

Data Types: `logical`

## Output Arguments

**`i` — *x*, *y*, *z* components of current distribution**
3-by-*n* complex matrix in A/m

*x*, *y*, *z* components of the current distribution, returned as a 3-by-*n* complex matrix in A/m. The value of the current is calculated on every triangle mesh on the surface of the PCB component.

**`p` — Cartesian coordinates representing center of each triangle in mesh**
3-by-*n* real matrix

Cartesian coordinates representing the center of each triangle in the mesh, returned as a 3-by-*n* real matrix.

# Version History

**Introduced in R2021b**

## See Also

`voltagePort` | `charge`

# charge

Calculate and plot charge distribution

## Syntax

```
charge(rfpcbobject,frequency)

c = charge(rfpcbobject,frequency)
[c,p] = charge(rfpcbobject,frequency)

charge(rfpcbobject,frequency,'dielectric')
c = charge(rfpcbobject,frequency,'dielectric')
c = charge( ___ ,Name=Value)
```

## Description

`charge(rfpcbobject,frequency)` calculates and plots the absolute value of the charge in C/m on the metal surface of a PCB component at the specified frequencies.

`c = charge(rfpcbobject,frequency)` calculates a vector of charges in C/m on the metal surface of a PCB component, at the specified frequencies.

`[c,p] = charge(rfpcbobject,frequency)` returns the point at which the charge calculation was performed.

`charge(rfpcbobject,frequency,'dielectric')` calculates and plots the absolute value of the charge at the specified frequency on the dielectric surface of the PCB component.

`c = charge(rfpcbobject,frequency,'dielectric')` calculates the charge on the dielectric surface of a PCB component at the specified frequency.

`c = charge( ___ ,Name=Value)` calculates the charge on the surface of a PCB component using additional name-value arguments.

## Examples

### Calculate Charge Distribution on Rat-Race Coupler

Create a rat-race coupler with default properties.

```
coupler = couplerRatrace;
```

Set the feed voltage and phase at the coupler ports.

```
v = voltagePort(4)
```

```
v =
  voltagePort with properties:

          NumPorts: 4
```

```
      FeedVoltage: [1 0 0 0]
        FeedPhase: [0 0 0 0]
    PortImpedance: 50
```

```
v.FeedVoltage = [1 0 1 0]
```

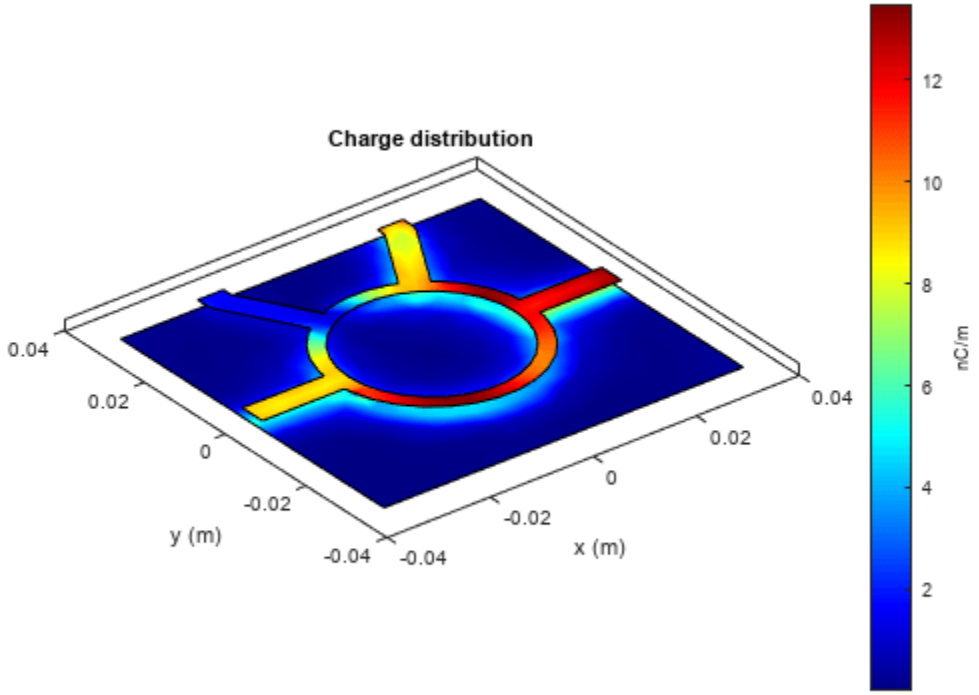
```
v =
  voltagePort with properties:

         NumPorts: 4
      FeedVoltage: [1 0 1 0]
        FeedPhase: [0 0 0 0]
    PortImpedance: 50
```

```
v.FeedPhase = [90 0 270 0]
```

```
v =
  voltagePort with properties:

         NumPorts: 4
      FeedVoltage: [1 0 1 0]
        FeedPhase: [90 0 270 0]
    PortImpedance: 50
```

Calculate and view the charge distribution of the coupler at 3 GHz.

```
figure
charge(coupler,3e9,Excitation=v)
```




## Input Arguments

### `rfpcbobject` — PCB component object

RF PCB object

PCB component object, specified as an RF PCB object. For a complete list of the PCB components and shapes, see “PCB Components Catalog” and “Custom Geometry and PCB Fabrication”.

### `frequency` — Frequency to calculate charge distribution

scalar

Frequency to calculate charge distribution in hertz, specified as a scalar.

Example: 70e6

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `scale='log10'`

**`Scale` — Scale to visualize charge distribution**
string (default) | character vector

Scale to visualize the charge distribution on the surface of the PCB component, specified as a string or a character vector. The string values are either `'linear'`, `'log'`, or `'log10'` or as a function. You can specify any mathematical function such as `log`, `log10`, `cos`, or `sin`.

Data Types: `char` | `function_handle`

**`Excitation` — Excitation using voltage source**
function handle

Excitation using as voltage source of N-ports to excite an N-port RF PCB component, specified a string or a function handle.

Data Types: `string` | `function_handle`

## Output Arguments

**`c` — Complex charges**
1-by-*n* vector in C/m

Complex charges, returned as a 1-by-*n* vector in C/m. This value is calculated on every triangle mesh or every dielectric tetrahedron face on the surface of a PCB component.

**`p` — Cartesian coordinates representing center of each triangle in mesh**
3-by-*n* real matrix

Cartesian coordinates representing the center of each triangle in the mesh, returned as a 3-by-*n* real matrix.

# Version History

**Introduced in R2021b**

## See Also

`current`

# feedCurrent

Calculate current at feed port

## Syntax

```
feedCurrent(rfpcbobject,frequency)
feedCurrent( ___ ,Name=Value)
```

## Description

`feedCurrent(rfpcbobject,frequency)` calculates the current in A/m at the feed port of a PCB component at the specified frequency. The feed current when multiplied by the PCB impedance gives the voltage across the PCB component.

`feedCurrent( ___ ,Name=Value)` calculates the feed current at the feed port of the PCB component using additional name-value arguments.

## Examples

### Calculate Feed Current of Rat-Race Coupler

Create a rat-race coupler with default properties.

```
coupler = couplerRatrace;
```

Set the feed voltage and phase at the ports of the rat-race coupler:

```
v = voltagePort(4);
v.FeedVoltage = [1 0 1 0];
v.FeedPhase = [90 0 270,0];
```

Calculate the feed current at 3 GHz.

```
If = feedCurrent(coupler,3e9)
```

```
If = 1×4 complex

   0.0102 + 0.0004i   0.0032 - 0.0060i  -0.0002 + 0.0002i  -0.0050 + 0.0051i
```

## Input Arguments

### `rfpcbobject` — PCB component object

RF PCB object

PCB component object, specified as an RF PCB object. For a complete list of the PCB components and shapes, see “PCB Components Catalog” and “Custom Geometry and PCB Fabrication”.

**`frequency` — Frequency to calculate feed current**
scalar | vector

Frequency to calculate the feed current, specified as a scalar integer in Hz or as a vector with each element specified in Hz.

**Name-Value Pair Arguments**

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `excitation='2'`

**`excitation` — Excitation using voltage source**
`string` (default) | function handle

Excitation using as voltage source, specified function handle from the `voltagePort` function.

Data Types: `char` | `function_handle`

## Version History

**Introduced in R2021b**

## See Also

`current` | `voltagePort`

# mesh

Change and view mesh properties of metal or dielectric in PCB component

## Syntax

```
mesh(object)
mesh(shape)
mesh( ___ ,Name,Value)
meshdata = mesh( ___ ,Name,Value)
```

## Description

`mesh(object)` plots the mesh used to analyze a PCB component.

`mesh(shape)` plots the mesh for the shapes.

`mesh( ___ ,Name,Value)` changes and plots the mesh structure of a PCB component, using additional options specified by the name-value pairs. You can also determine the number of unknowns from the number of basis functions in the output.

`meshdata = mesh( ___ ,Name,Value)` returns a mesh structure that specifies the properties used to analyze the PCB component.

## Examples

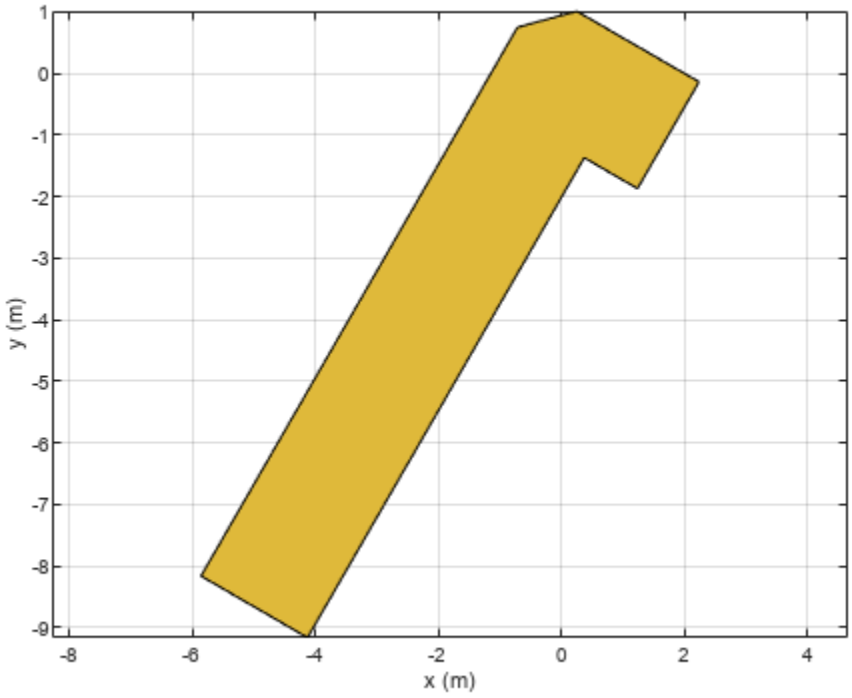
### Mesh Rotated Mitered Bend Shape

Create a mitered bend shape of lengths of 10 m and 2 m, width of 2 m, and rotate it about the Z-axis by 60 degrees.

```
bend = bendMitered(Length=[10 2],Width=[2 2],MiterDiagonal=1);
bend = rotateZ(bend,60)
```

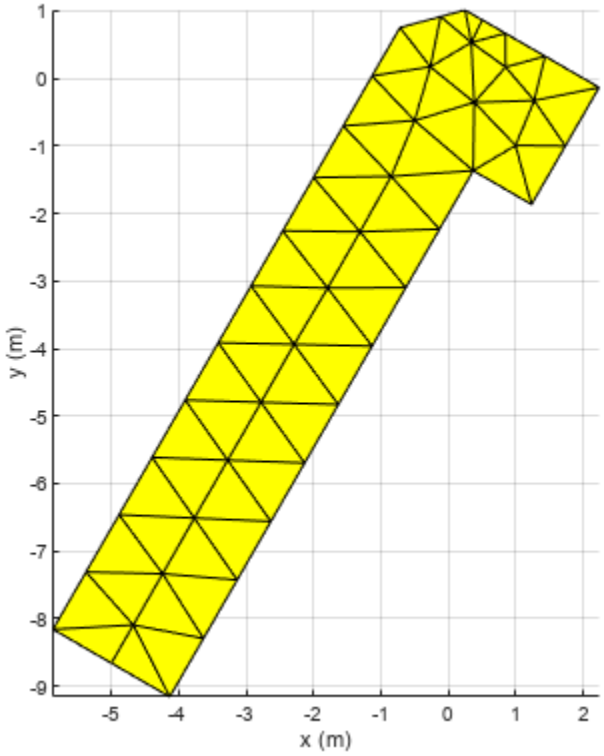
```
bend =
  bendMitered with properties:

              Name: 'myMiteredbend'
    ReferencePoint: [0 0]
            Length: [10 2]
             Width: [2 2]
     MiterDiagonal: 1
```

```
show(bend)
```




Mesh the mitered bend shape at a maximum edge length of 1 m.

```
mesh(bend,MaxEdgeLength=1)
```




## Input Arguments

### `object` — PCB component

object handle

PCB component, specified as an object handle. For complete list of PCB components and shapes, see "PCB Components Catalog"

### `shape` — Shape created using custom elements and shape objects

object handle

Shape created using custom elements and shape objects, specified as an object handle. For a complete list of custom shapes, see "Custom Geometry and PCB Fabrication".

Example: `c = bendCurved; mesh(c)`

### Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` pair arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`''`). You can specify several name and value pair arguments in any order as `Name1, Value1, ..., NameN, ValueN`.

Example: `'MaxEdgeLength', 0.1`

### `MaxEdgeLength` — Maximum edge length of triangles in mesh

scalar

Maximum edge length of triangles in mesh, specified as a positive scalar in meters. All triangles in the mesh have sides less than or equal to the `'MaxEdgeLength'` value.

Data Types: `double`

**`MinEdgeLength` — Smallest edge length of triangles in mesh**
scalar

Smallest edge length of triangles in mesh, specified a positive scalar in meters. All triangles in the mesh have sides greater than or equal to the `'MinEdgeLength'`.

Data Types: `double`

**`GrowthRate` — Mesh growth rate**
`0.7` (default) | scalar

Gradation in the triangle size of the mesh, specified a scalar. The default value of `0.7` states that the growth rate of the mesh is 70 percent. Growth rate values lie between `0` and `1`.

Data Types: `double`

**`View` — Customize mesh view of a PCB component**
`'all'` (default) | `'metal'` | `'dielectric surface'` | `'dielectric volume'`

Customize mesh view of a PCB component, specified as a comma-separated pair consisting of `'View'` and `'all'`, `'metal'`,`'dielectric surface'`, or `'dielectric volume'`.

You choose `'dielectric surface'` to view the boundary triangle mesh of the dielectric. You choose `'dielectric volume'` to view the tetrahedral volume mesh of the dielectric.

Data Types: `char`

**`Slicer` — Option to enable or disable plot interactivity**
`0` (default) | `1` | `'off'` | `'on'`

Option to enable or disable plot interactivity, specified as `'on'` or `'off'`, or as numeric or logical `1(true)` or `0(false)`. Set this argument to `1` or `'on'` to open the plot with the slicer panel, and to slice and view the desired cross section of the plot along the *xy-*, *yz-*, and *xz-* planes. Set this argument to `0` or `'off'` to open the plot without the slicer panel.

Example: `Slicer='on'`

Data Types: `string` | `logical`

# Version History

**Introduced in R2021b**

## See Also

`meshconfig`

# getZ0

Calculate characteristic impedance of transmission line

## Syntax

```
z0 = getZ0(txline)
```

## Description

`z0 = getZ0(txline)` calculates the characteristic impedance `z0` of a transmission line.

## Examples

### Calculate Characteristic Impedance of Microstrip Transmission Line

Create a microstrip transmission line with default properties.

```
mline = microstripLine
```

```
mline =
  microstripLine with properties:

              Length: 0.0200
               Width: 0.0050
              Height: 0.0016
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

Calculate the characteristic impedance of the line.

```
Z0 = getZ0(mline)
```

```
Z0 = 49.7015 + 0.0087i
```

## Input Arguments

### `txline` — Transmission line

transmission line object (default)

Transmission line, specified as one of the following: `coplanarWaveguide`, `coupledMicrostripLine`, and `microstripLine`.

Example: `txline = microstripLine;getZ0(txline)`. Calculates the characteristic impedance of the microstrip transmission line object with handle `txline`.

Data Types: `char` | `string`

## Output Arguments

### `z0` — Characteristic impedance of transmission lines

complex scalar

Characteristic impedance of the transmission line, returned as a complex scalar.

Data Types: `double`

# Version History

**Introduced in R2021b**

## See Also

`sparameters`

# inductance

Calculate inductance

## Syntax

```
inductance(object,frequency)
l = inductance(object,frequency)
```

## Description

`inductance(object,frequency)` calculates and plots the inductance of an inductor over the specified frequency.

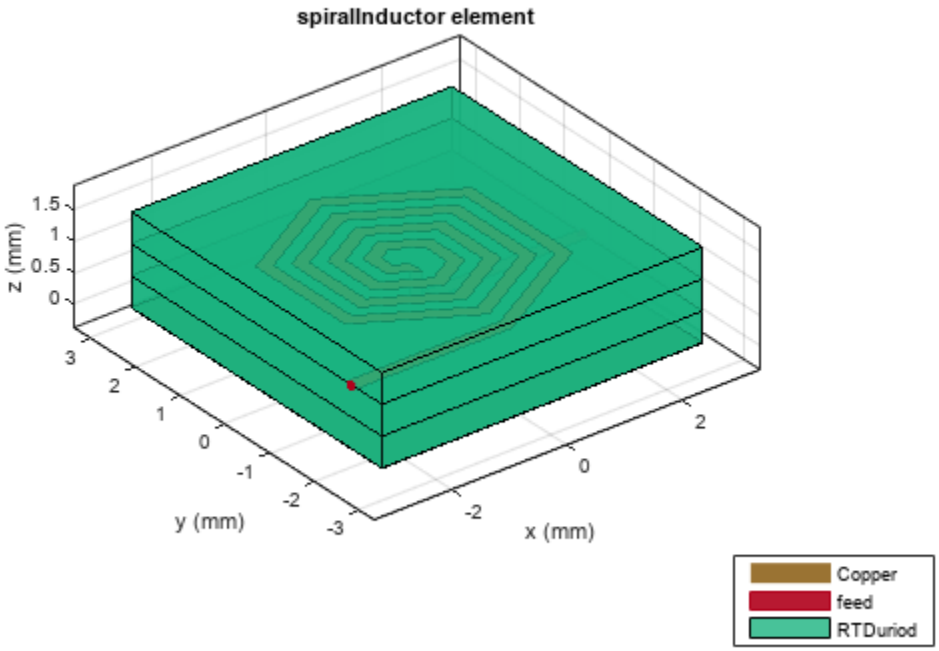
`l = inductance(object,frequency)` calculates the inductance of an inductor over the specified frequency.

## Examples

### Calculate Inductance of Spiral Inductor

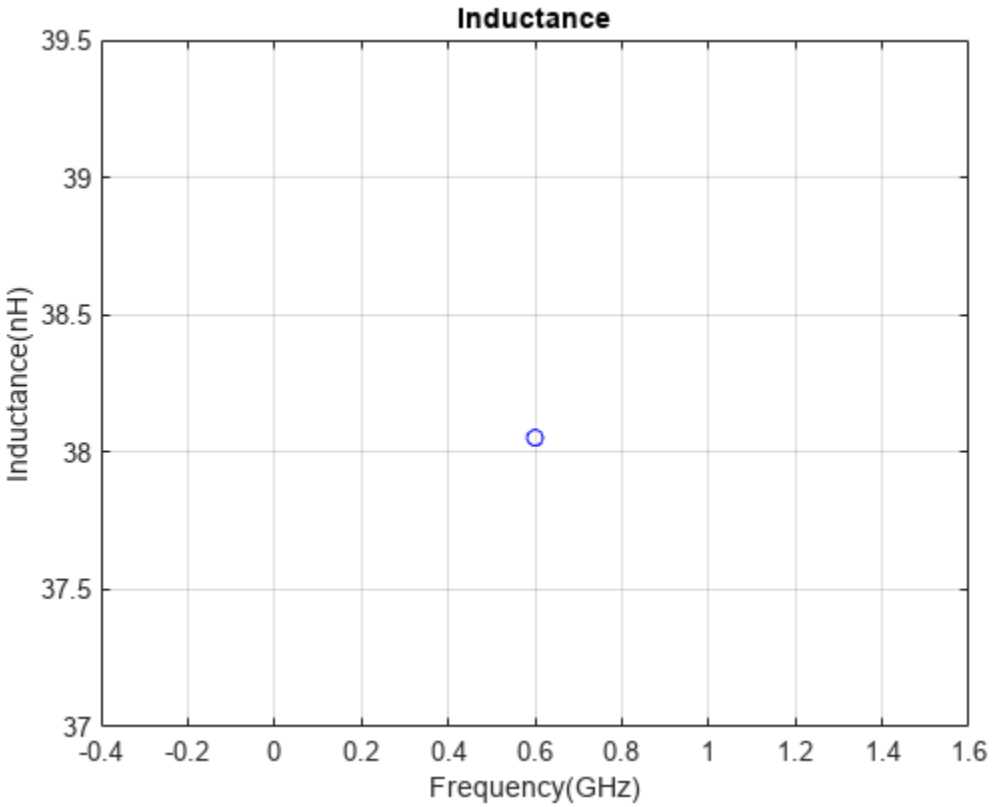
Create a hexagonal spiral inductor with default properties.

```
inductor = spiralInductor(SpiralShape='Hexagon');
show(inductor)
```




Calculate the inductance of the inductor at 600 MHz.

```
inductance(inductor,600e6)
```




```
l = inductance(inductor,600e6)
```

```
l = 3.8052e-08
```

## Input Arguments

### `object` — Spiral inductor

`spiralInductor` object

Spiral inductor, specified as an `spiralInductor` object.

Data Types: `char` | `string`

### `frequency` — Frequency to calculate inductance

nonnegative scalar | nonnegative vector

Frequency to calculate inductance, specified as a nonnegative scalar or vector in hertz.

Data Types: `double`

## Output Arguments

### `l` — Inductance of inductor

scalar | vector

Inductance of the inductor, returned as a scalar or vector in henries.

Data Types: `double`

## Version History

**Introduced in R2021b**

## See Also

`capacitance`

# capacitance

Calculate capacitance

## Syntax

```
capacitance(object,frequency)
c = capacitance(object,frequency)
capacitance( ___ ,Name=Value)
```

## Description

`capacitance(object,frequency)` calculates and plots the capacitance of a capacitor over the specified frequency.

`c = capacitance(object,frequency)` calculates the capacitance of a capacitor over the specified frequency.

`capacitance( ___ ,Name=Value)` calculates the capacitance with additional options specified using name-value arguments.

## Examples

### Calculate Capacitance of Interdigital Capacitor

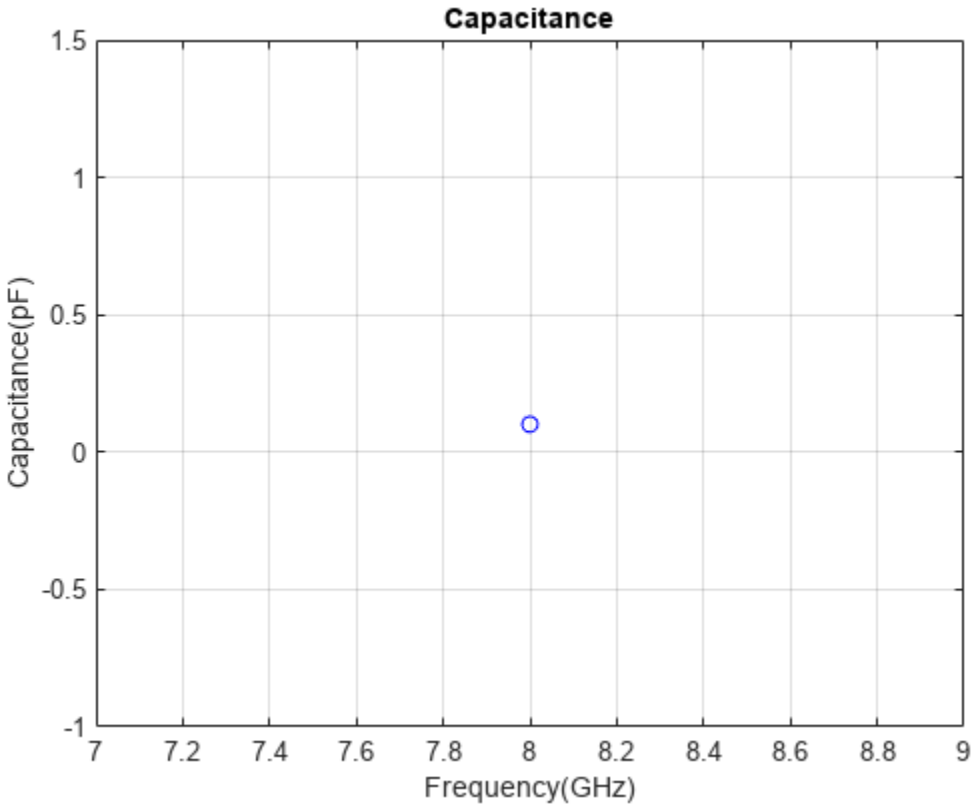
Create an interdigital capacitor using default properties.

```
capacitor = interdigitalCapacitor
```

```
capacitor =
  interdigitalCapacitor with properties:

           NumFingers: 4
         FingerLength: 0.0137
          FingerWidth: 3.1600e-04
        FingerSpacing: 3.0000e-04
        FingerEdgeGap: 3.4100e-04
   TerminalStripWidth: 5.0000e-04
        PortLineWidth: 0.0019
       PortLineLength: 0.0030
               Height: 7.8700e-04
     GroundPlaneWidth: 0.0030
            Substrate: [1x1 dielectric]
            Conductor: [1x1 metal]
```

Calculate the capacitance of the capacitor at 8 GHz.

```
capacitance(capacitor,8e9,DeEmbed=1,IncludeParasitics=1)
```




## Input Arguments

### `object` — Interdigital capacitor

`interdigitalCapacitor` object

Interdigital capacitor, specified as an `interdigitalCapacitor` object.

Data Types: `char` | `string`

### `frequency` — Frequency to calculate capacitance

nonnegative scalar | vector

Frequency to calculate the capacitance in hertz, specified as a nonnegative scalar or vector of nonnegative elements.

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `DeEmbed=1`

**`DeEmbed` — Deembed feeder line**
`1` (default) | `0`

Dembed feeder line, specified as `0` or `1`. When you specify `1`, the function deembeds the feeder line.

**`IncludeParasitics` — Include parasitic effects**
`1` (default) | `0`

Include parasitic effects, specified as `0` or `1`. When you specify `1`, the function includes the parasitic effects.

**`Z0` — Input and output line impedance**
`50` (default) | positive scalar

Input and output line impedance to feed the capacitor, specified as a positive scalar in ohms.

## Output Arguments

**`c` — Capacitance of capacitor**
scalar | vector

Capacitance of the capacitor, returned as a scalar or vector in farads.

Data Types: `double`

# Version History

**Introduced in R2021b**

## See Also

`inductance`

# qualityfactor

Calculates and plots Q-factor of capacitor

## Syntax

```
qualityfactor(objectfrequency)
qf = qualityfactor(objectfrequency)
qualityfactor(object,frequency,Name,Value)
qf = qualityfactor(object,frequency,Name,Value)
```

## Description

`qualityfactor(objectfrequency)` calculates and plots the Q-factor (quality factor) of the capacitor over the specified frequency values in the figure window.

`qf = qualityfactor(objectfrequency)` returns the Q-factor of the capacitor over the specified frequency values.

`qualityfactor(object,frequency,Name,Value)` sets properties using one or more name-value pairs.

`qf = qualityfactor(object,frequency,Name,Value)` sets properties using one or more name-value pairs.

## Examples

## Input Arguments

### `object` — PCB capacitor component

object handle

PCB capacitor component, specified as an object handle.

Example:

Data Types: `char` | `string`

### `frequency` — Frequency to calculate inductance in hertz

nonnegative scalar or vector

Frequency to calculate inductance in hertz, specified as a nonnegative scalar or vector.

Example:

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

*Before R2021a, use commas to separate each name and value, and enclose* `Name` *in quotes.*

Example: `'DeEmbed',1`

**`DeEmbed` — Deembed feeder line**
`1` (default) | `0`

Dembed feeder line when set to 1, specified as `0` or `1`.

**`Z0` — Input and output line impedance in ohms**
`50` (default) | positive scalar

Input and output line impedance to feed the capacitor in ohms, specified as a positive scalar.

## Output Arguments

**`qf` — Quality factor of capacitor**
scalar or vector

Quality factor of the capacitor, returned as a scalar or vector.

Data Types: `double`

# Version History

**Introduced in R2021b**

# qualityfactor

Calculates and plots Q-factor of inductor

## Syntax

```
qualityfactor(objectfrequency)
qf = qualityfactor(objectfrequency)
```

## Description

`qualityfactor(objectfrequency)` calculates and plots the Q-factor (quality factor) of the inductor over the specified frequency values in the figure window.

`qf = qualityfactor(objectfrequency)` returns the Q-factor of the inductor over the specified frequency values.

## Examples

## Input Arguments

### `object` — PCB inductor component

object handle

PCB inductor component, specified as an object handle.

Example:

Data Types: `char` | `string`

### `frequency` — Frequency to calculate inductance in hertz

nonnegative scalar or vector

Frequency to calculate inductance in hertz, specified as a nonnegative scalar or vector.

Example:

Data Types: `double`

## Output Arguments

### `qf` — Quality factor of inductor

scalar or vector

Quality factor of the inductor, returned as a scalar or vector.

Data Types: `double`

# Version History

**Introduced in R2021b**

# metal

Conductor material

## Syntax

```
m = metal(material)
m = metal(Name=Value)
```

## Description

`m = metal(material)` returns the metal used as a conductor in the PCB components. You can specify a material from the `MetalCatalog`. The default value for material is perfect electric conductor (PEC).

`m = metal(Name=Value)` returns the metal based on the properties specified by one or more .name-value pairs.

## Examples

### Microstrip Line with Copper Conductor

Create a microstrip transmission line with copper conductor.

```
mline = microstripLine;
```

Create a copper metal conductor.

```
m = metal('copper')
```

```
m =
  metal with properties:

            Name: 'Copper'
    Conductivity: 59600000
       Thickness: 3.5560e-05

For more materials see catalog
```

Change the microstrip transmission line conductor to copper.

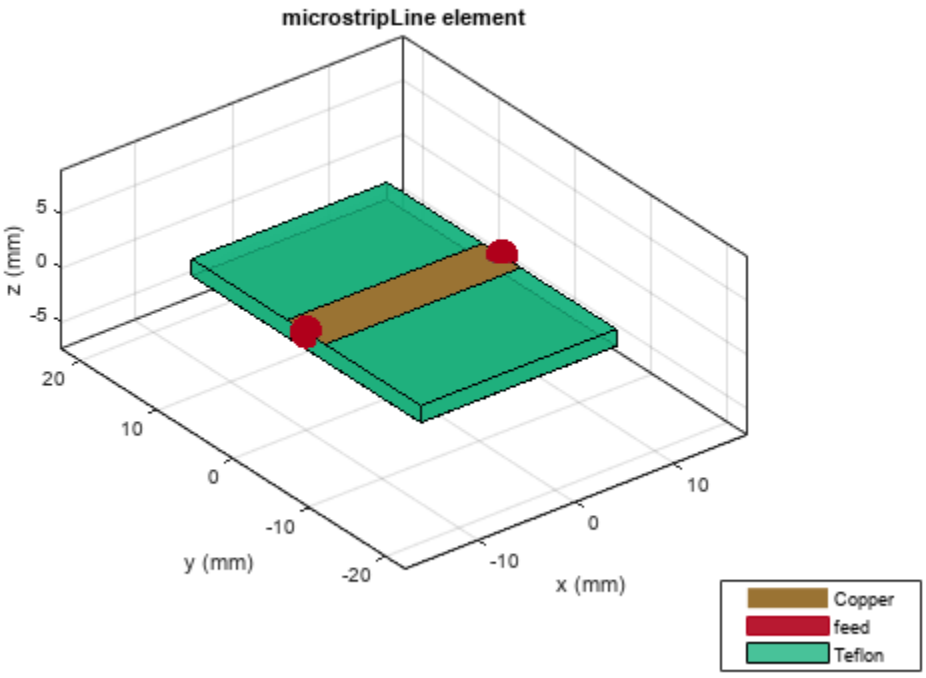
```
mline.Conductor = m
```

```
mline =
  microstripLine with properties:

              Length: 0.0200
               Width: 0.0050
              Height: 0.0016
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
```

```
            Conductor: [1x1 metal]
```

View the microstrip transmission line.

```
show(mline)
```




## Input Arguments

### `material` — Material from metal catalog

`'PEC'` (default) | character vector

Material from the dielectric catalog, specified as a metal from the `MetalCatalog`. The default material is perfect electric conductor (PEC), which has infinite conductivity and zero thickness.

Example: `'Iron'`

Data Types: `char`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Name='Iron'`

**`Name` — Name of metal material**
`'PEC'` (default) | character vector

Name of the metal material you want to use as a conductor, specified as a character vector.

Example: `Name='Iron'`

Data Types: `char`

**`Conductivity` — Conductivity of metal material**
`Inf` (default) | scalar

Conductivity of the metal material, specified as a scalar in Siemens per meter(S/m). If you set `'Conductivity'` to `'Inf'`, you must set `'Thickness'` to `'0'`.

Example: `Conductivity=4.8e06`

Data Types: `double`

**`Thickness` — Thickness of metal**
`0` (default) | scalar

Thickness of the metal material along the default *z*-axis, specified as a scalar in meters.

Example: `Thickness=0.26e-6`

Data Types: `double`

## Output Arguments

**`m` — Conductor metal**
metal object

Conductor metal, returned as a metal object.

# Version History

**Introduced in R2021a**

## See Also

`MetalCatalog`

# MetalCatalog

Catalog of metals

## Syntax

```
mc = MetalCatalog
```

## Description

`mc = MetalCatalog` creates an object handle for the metal catalog.

- To open the metal catalog, use `open(mc)`
- To see the properties of a metal from the metal catalog, use `s = find(mc,name)`.

## Examples

### Use Metal Catalog to Design Coplanar Waveguide

Open the metal catalog.

```
mc = MetalCatalog;
open(mc)
```

| | Name | Conductivity | Thickness | Units | Comments |
|---|---|---|---|---|---|
| 1 | PEC | Inf | 0 | m | |
| 2 | Copper | 59.6000e+006 | 1.4000 | mil | 1 oz |
| 3 | Aluminium | 37.7000e+006 | 30 | mil | |
| 4 | Gold | 41.1000e+006 | 0.2000 | um | |
| 5 | Silver | 63.0000e+006 | 0.2000 | um | |
| 6 | Zinc | 16.9000e+006 | 4 | mil | |
| 7 | Tungsten | 17.9000e+006 | 0.2000 | um | |
| 8 | Lead | 4.5500e+006 | 0.2000 | um | |
| 9 | Iron | 10.0000e+006 | 0.2000 | um | |
| 10 | Steel | 6.9900e+006 | 0.6800 | mm | |

List the properties of the metal material `Aluminium`.

```
s = find(mc,'Aluminium')
```

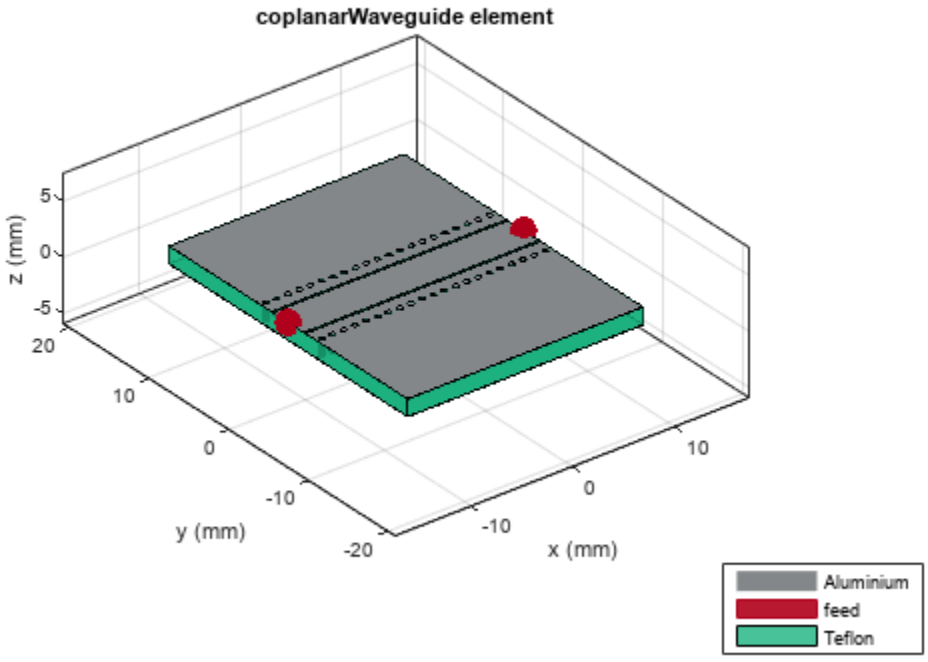
```
s = struct with fields:
            Name: 'Aluminium'
    Conductivity: 37700000
       Thickness: 30
           Units: 'mil'
        Comments: ''
```

Use the above metal in a coplanar waveguide.

```
m = metal('Aluminium');
waveguide = coplanarWaveguide('Conductor',m)

waveguide =
  coplanarWaveguide with properties:

              Length: 0.0231
               Width: 0.0039
             Spacing: 2.0000e-04
          ViaSpacing: [0.0011 0.0070]
         ViaDiameter: 5.0000e-04
              Height: 0.0016
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the waveguide using show function.

```
figure;
show(waveguide)
```




## Input Arguments

### name — Name of metal

`'PEC'` (default) | character vector

Name of the metal from the metal catalog, specified as a character vector.

Example: `'Copper'`

Data Types: `char`

**`mc` — Metal catalog**
`metal` object

Metal catalog, specified as an object.

## Output Arguments

**`mc` — Metal catalog**
object

Metal catalog, returned as an object.

**`s` — Parameters of metal**
structure

Parameters of the specified metal from the metal catalog, returned as a structure.

# Version History

**Introduced in R2021a**

## See Also

`metal`

# dielectric

Dielectric material for use as substrate

## Syntax

```
d = dielectric(material)
d = dielectric(Name=Value)
```

## Description

`d = dielectric(material)` returns dielectric materials for use as a substrate in PCB components.

`d = dielectric(Name=Value)` returns dielectric materials based on the properties specified by one or more `Name,Value` pair arguments.

## Examples

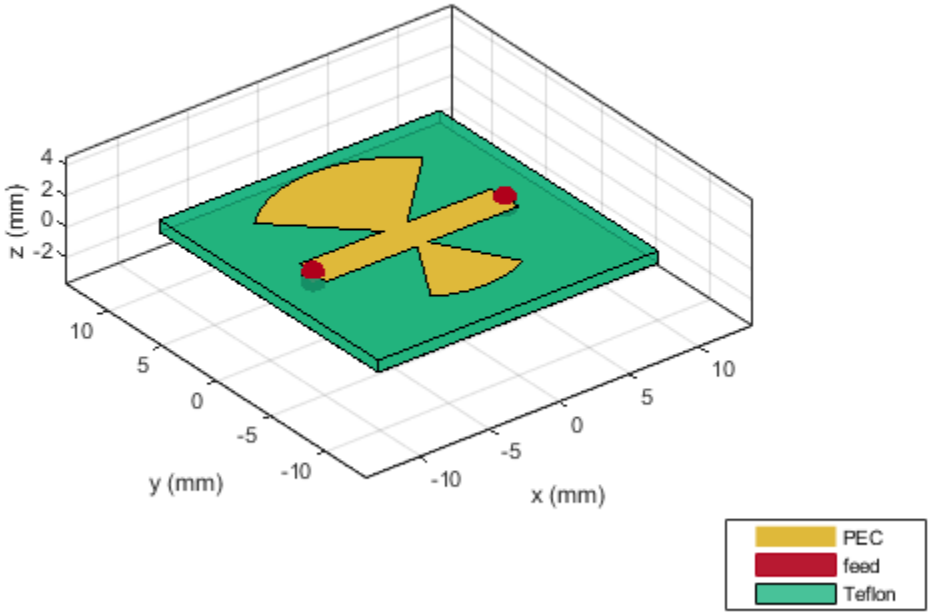
### Create Double Shunt Radial Stub

Create shunt radial stub of type double.

```
stub = stubRadialShunt(StubType='double');
stub.OuterRadius = [0.0085 0.0065];
stub.InnerRadius = [0.0012 0.0008];
stub.Angle       = [90 60];
```

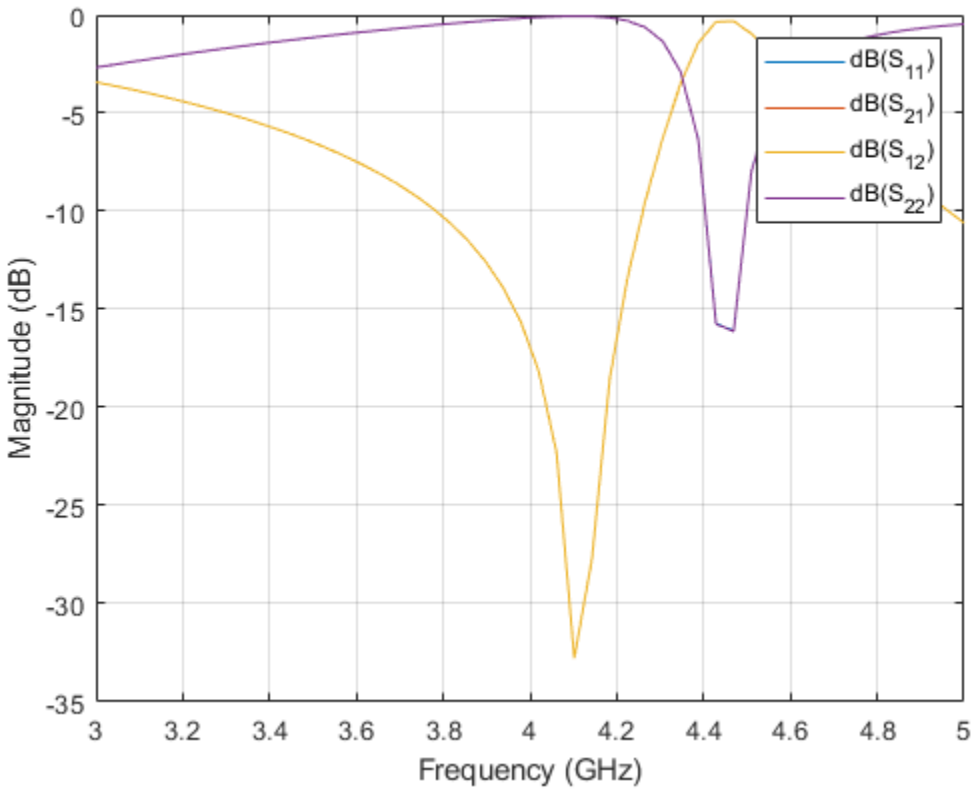
View shunt radial stub.

```
show(stub)
```




Plot s-parameters.

```
spar = sparameters(stub,linspace(3e9,5e9,50));
rfplot(spar)
```




## Input Arguments

### `material` — Material from dielectric catalog

`'Air'` (default) | character

Material from the dielectric catalog, specified as one of the values from the `DielectricCatalog`.

Example: `'FR4'`

Data Types: `char`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Name=Air`

### `Name` — Name of dielectric material

character vector

Name of the dielectric material you want to specify in the output, specified as a character vector.

Example: `Name='Taconic_TLC'`

Data Types: `char`

**EpsilonR — Relative permittivity of dielectric material**
1 | real-valued vector

Relative permittivity of the dielectric material, specified as a real-valued vector.

Example: `EpsilonR=4.8000`

Data Types: `double`

**LossTangent — Loss in dielectric material**
0 (default) | real-valued vector

Loss in the dielectric material, specified as a vector.

Example: `LossTangent=0.0260`

Data Types: `double`

**Thickness — Thickness of dielectric material**
`0.0060` (default) | positive vector

Thickness of the dielectric material in meters along default z-axis, specified as a positive vector. This property applies only when you call the function with no output arguments.

Example: `Thickness=0.05`

Data Types: `double`

## Output Arguments

**d — Dielectric material**
object handle

Dielectric material, returned as an object handle. You can use the dielectric material object handle to add dielectric material as a substrate to any PCB component.

# Version History

**Introduced in R2016a**

## See Also

`DielectricCatalog`

# DielectricCatalog

Catalog of dielectric materials

## Syntax

```
dc = DielectricCatalog
```

## Description

`dc = DielectricCatalog` creates an object handle for the dielectric catalog.

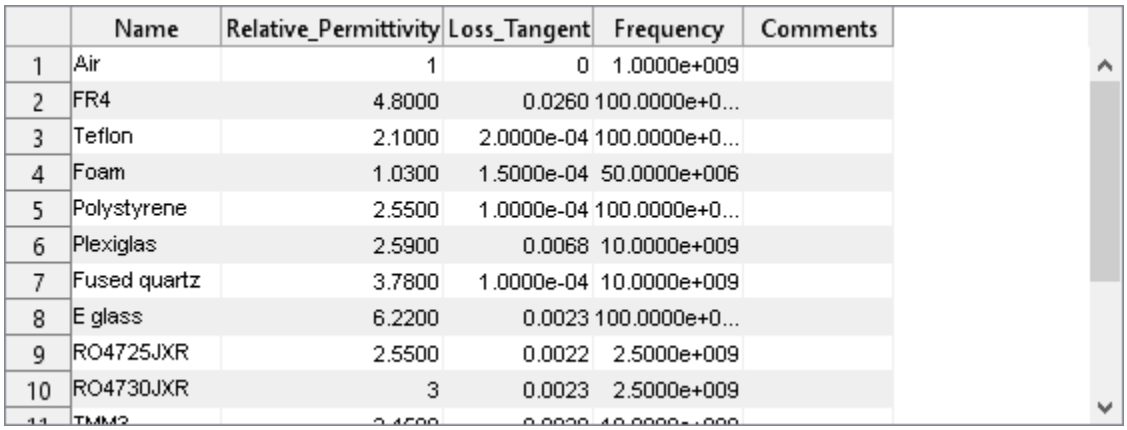
- To open the dielectric catalog, use `open(dc)`
- To see the properties of a dielectric material from the dielectric catalog, use `s = find(dc, name)`.

## Examples

### Use Dielectric Catalog to Design Coplanar Waveguide

Open the dielectric catalog.

```
dc = DielectricCatalog;
open(dc)
```



| | Name | Relative_Permittivity | Loss_Tangent | Frequency | Comments |
|---|---|---|---|---|---|
| 1 | Air | 1 | 0 | 1.0000e+009 | |
| 2 | FR4 | 4.8000 | 0.0260 | 100.0000e+0... | |
| 3 | Teflon | 2.1000 | 2.0000e-04 | 100.0000e+0... | |
| 4 | Foam | 1.0300 | 1.5000e-04 | 50.0000e+006 | |
| 5 | Polystyrene | 2.5500 | 1.0000e-04 | 100.0000e+0... | |
| 6 | Plexiglas | 2.5900 | 0.0068 | 10.0000e+009 | |
| 7 | Fused quartz | 3.7800 | 1.0000e-04 | 10.0000e+009 | |
| 8 | E glass | 6.2200 | 0.0023 | 100.0000e+0... | |
| 9 | RO4725JXR | 2.5500 | 0.0022 | 2.5000e+009 | |
| 10 | RO4730JXR | 3 | 0.0023 | 2.5000e+009 | |
| 11 | TMM3 | 3.4500 | 0.0020 | 10.0000e+009 | |

List the properties of the dielectric substrate `Foam`.

```
s = find(dc,'Foam')
```

```
s = struct with fields:
                     Name: 'Foam'
    Relative_Permittivity: 1.0300
            Loss_Tangent: 1.5000e-04
               Frequency: 50000000
                Comments: ''
```

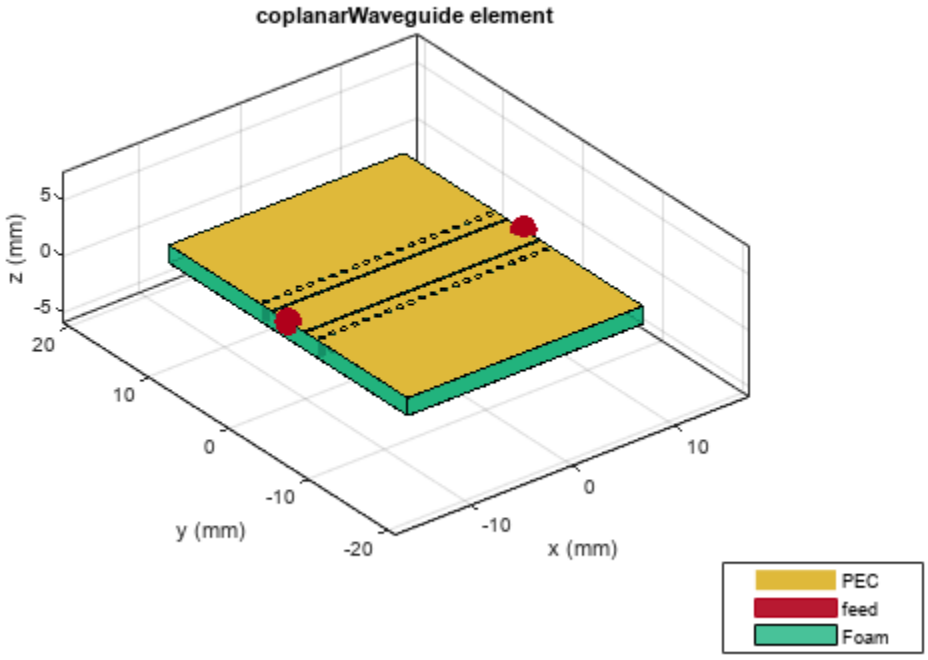
Use the substrate `Foam` in coplanar waveguide.

```
d = dielectric('Foam');
waveguide = coplanarWaveguide('Substrate',d)
```

```
waveguide =
  coplanarWaveguide with properties:

              Length: 0.0231
               Width: 0.0039
             Spacing: 2.0000e-04
          ViaSpacing: [0.0011 0.0070]
         ViaDiameter: 5.0000e-04
              Height: 0.0016
    GroundPlaneWidth: 0.0300
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the waveguide.

```
figure;
show(waveguide)
```



## Input Arguments

### `name` — Name of dielectric material

`'Air'` (default) | character vector

Name of a dielectric material from the dielectric catalog, specified as a character vector.

Example: `'FR4'`

Data Types: `char`

### `dc` — Dielectric catalog

object handle

Dielectric catalog, specified as an object handle.

## Output Arguments

### `dc` — Dielectric catalog

object handle

Dielectric catalog, returned as an object handle.

### `s` — Parameters of dielectric material

structure

Parameters of a dielectric material from the dielectric catalog, returned as a structure.

# Version History

**Introduced in R2016a**

## See Also

`dielectric`

# gerberRead

Create `PCBReader` object with specified Gerber and drill files

## Syntax

```
P = gerberRead(T)
P = gerberRead([],B)
P = gerberRead(T,B)
P = gerberRead(T,B,D)
```

## Description

`P = gerberRead(T)` creates a `PCBReader` object with the top layer Gerber file specified in `T`.

**Note** The `PCBReader` object reads RS-274X Gerber files. It does not support RS-274D Gerber files.

`P = gerberRead([],B)` creates a `PCBReader` object with the bottom layer Gerber file specified in `B`.

`P = gerberRead(T,B)` creates a `PCBReader` object with the specified top and bottom layer Gerber file names.

`P = gerberRead(T,B,D)` creates a `PCBReader` object with the specified top and bottom layer Gerber files and the drill file specified in `D` .

## Examples

### Import and View Top Layer Gerber File

Use the `gerberRead` function to import a top layer Gerber file.

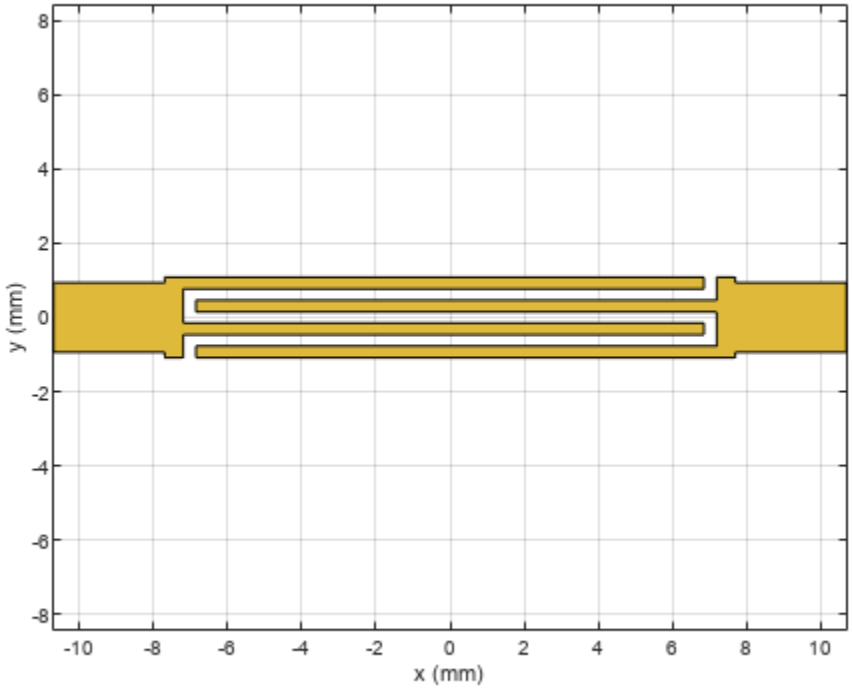
```
P = gerberRead('interdigital_Capacitor.gtl');
```

Extract the metal layer from the file using the `shapes` function.

```
s = shapes(P);
```

View the top metal layer.

```
show(s)
```




## Input Arguments

### `T` — Top layer Gerber file

string scalar | character vector

Top layer Gerber file, specified as a character vector or string scalar. The file must be saved as a GTL file.

Example: `gerberRead('Filetop.gtl');`

### `B` — Bottom layer Gerber file

string scalar | character vector

Bottom layer Gerber file, specified as a character vector or string scalar. The file must be saved as a GBL file.

Example: `gerberRead([],'FileBottom.gbl');`

### `D` — Drill file

string scalar | character vector

Drill file, specified a character vector or string scalar. You can specify either a DRL or a TXT file.

Example: `gerberRead('Filetop.gtl','FileBottom.gbl','FileDrill.txt');`

## Output Arguments

**P — Files read**
`PCBReader` object

Gerber and drill files read, returned as a `PCBReader` object.

## Limitations

Limitations of the `gerberRead` function while reading a gtl or gbl file are:

| Command | Description | Comments |
|---|---|---|
| AM | Aperture Macro | Not supported |
| AB | Aperture Block | Not supported |
| SR | Step and Repeat | Not supported |
| TF | File Attributes | Command is ignored and no error is thrown |
| TA | Aperture Attributes | Command is ignored and no error is thrown |
| TO | Object Attributes | Command is ignored and no error is thrown |
| TD | Delete Attributes | Command is ignored and no error is thrown |

Cut-ins are not supported.

# Version History

**Introduced in R2021b**

## See Also

`PCBReader` | `PCBServices` | `PCBConnectors` | `PCBWriter`

# gerberWrite

Generate Gerber files

## Syntax

```
gerberWrite(designObject)
gerberWrite(designObject,writer)
gerberWrite(designObject,writer,rfConnector)
[a,g] = gerberWrite(designObject,writer,rfConnector)
```

## Description

`gerberWrite(designObject)` creates Gerber-format files based on multilayer 2.5D design from PCB component stack up.

`gerberWrite(designObject,writer)` creates a Gerber-format files based on multilayer 2.5D design from PCB component using specified PCB writer services.

`gerberWrite(designObject,writer,rfConnector)` creates Gerber-format files based on multilayer 2.5D design from PCB component using a writer object and an RF connector object.

`[a,g] = gerberWrite(designObject,writer,rfConnector)` returns the `PCBWriter` object , `a` and the path to the location of the Gerber files.

## Examples

### Generate Gerber Format Files for PCB Component

Create a PCB component with default values.

```
p = pcbComponent;
```

Use 2 Cinch SMA connectors and the Mayhew Labs PCB viewer.

```
W = PCBServices.MayhewWriter;
C1 = PCBConnectors.SMA_Cinch;
C2 = PCBConnectors.SMA_Cinch;
```

Generate the Gerber-format files.

```
[A,g] = gerberWrite(p,W,{C1,C2})
```

```
A =
  PCBWriter with properties:

                      Design: [1x1 struct]
                      Writer: [1x1 PCBServices.MayhewWriter]
                   Connector: {[1x1 PCBConnectors.SMA_Cinch]  [1x1 PCBConnectors.SMA_Cinch]}
          UseDefaultConnector: 0
    ComponentBoundaryLineWidth: 8
         ComponentNameFontSize: []
```

```
            DesignInfoFontSize: []
                          Font: 'Arial'
                     PCBMargin: 5.0000e-04
                    Soldermask: 'both'
                   Solderpaste: 1

   See info for details

g =
'C:\TEMP\Bdoc23a_2213998_3568\ib570499\29\tpee34cbcd\rfpcb-ex06685827\untitled'
```

## Input Arguments

### `designObject` — PCB design geometry file

`PCBWriter` object

PCB design geometry file, specified as a `PCBWriter` object.

Example: `a = PCBWriter(p1)` creates a `PCBWriter` object, `a`. `gerberWrite(a)` creates a Gerber file using `a`.

### `rfConnector` — RF connector type

`PCBConnector` object

RF connector type, specified as a `PCBConnectors` object.

Example: `c = PCBConnectors.SMA_Cinch; gerberWrite(p1,c)` uses SMA_Cinch RF connector at the feedpoint.

### `writer` — PCB service

`PCBServices` object

PCB service, specified as a `PCBServices` object.

Example: `s = PCBServices.MayhewWriter; gerberWrite(p1,s)` uses Mayhew Labs PCB service to create and view the PCB design.

## Output Arguments

### `a` — PCB writer

`PCBWriter` object

PCB writer that generated the Gerber files, returned as a `PCBWriter` object.

### `g` — Path to generated Gerber files folder

character vector

Path to generated Gerber files folder, returned as a character vector.

# Version History

**Introduced in R2021b**

## See Also

`PCBServices` | `PCBConnectors` | `PCBWriter`

# add

Boolean unite operation on two RF PCB shapes

## Syntax

```
c = add(shape1,shape2)
```

## Description

`c = add(shape1,shape2)` unites `shape1` and `shape2` using the add operation. You can also use the + symbol to add the two shapes together.

## Examples

### Add Two RF PCB Shapes

Create a curved bend shape with a length of 5 mm.

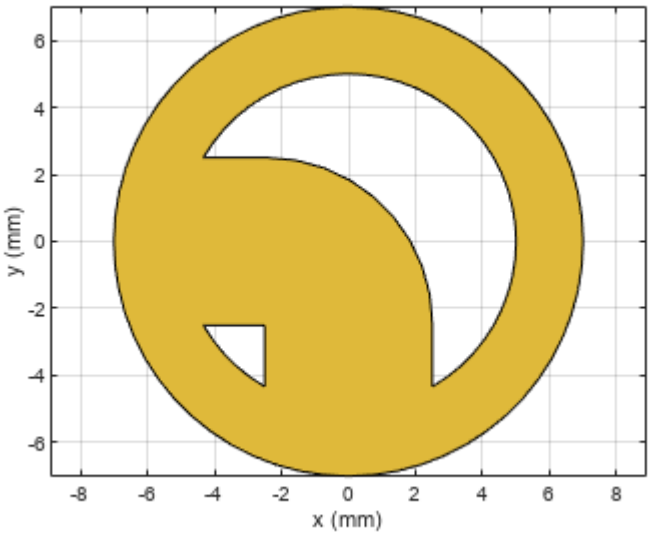
```
bend = bendCurved(Length=[5e-3 5e-3]);
```

Create an annular ring shape with the default inner radius of 5 m.

```
ring = ringAnnular;
```

Add the two shapes and display the result.

```
shapeSum = add(bend,ring);
show(shapeSum)
```



### Add Two RF PCB Shapes Using + Operator

Create the default curve shape.

```
shape1 = curve;
```

Create a right angle U-bend shape with an adjusted size and position to complement the curve shape.

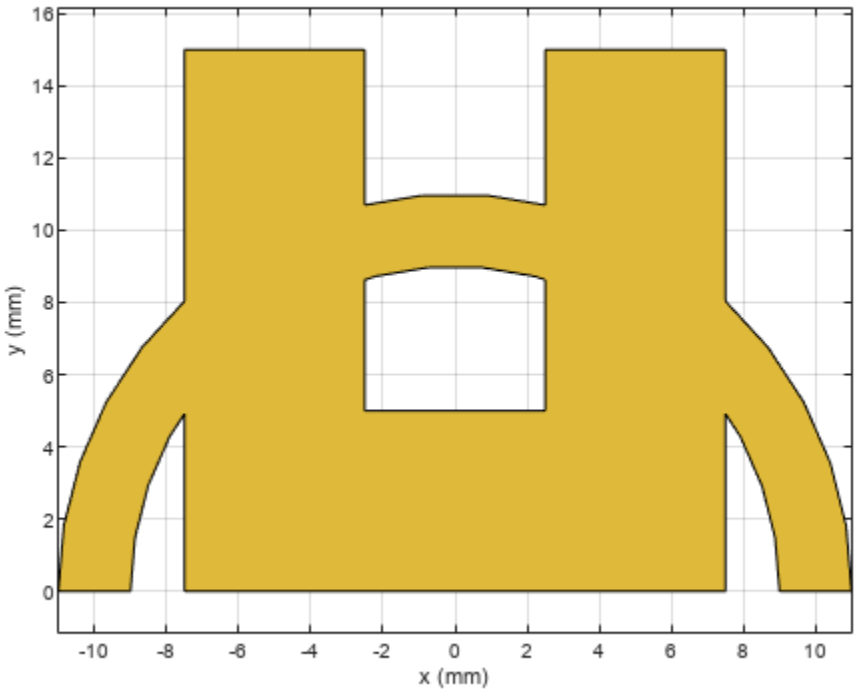
```
shape2 = ubendRightAngle;
```

Add the two shapes using the + operator, and display the resulting `Polygon` object.

```
shapeSum = shape1+shape2
```

```
shapeSum =
  Polygon with properties:

        Name: 'mypolygon'
    Vertices: [43x3 double]
```

```
show(shapeSum)
```



## Input Arguments

### `shape1` — First shape

object

First shape created using custom elements and shape objects of RF PCB Toolbox™, specified as an object.

Example: `shape1 = bendCurved;` specifies the first shape as a `bendCurved` object.

### `shape2` — Second shape

object

Second shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape2 = ringAnnular;` specifies the second shape as a `ringAnnular` object.

# Version History

**Introduced in R2021b**

## See Also

`area` | `intersect` | `subtract` | `rotate` | `rotateX` | `rotateY` | `rotateZ` | `translate` | `show` | `mesh` | `plot` | `scale`

# and

Shape1 & Shape2 for RF PCB shapes

## Syntax

```
c = and(shape1,shape2)
```

## Description

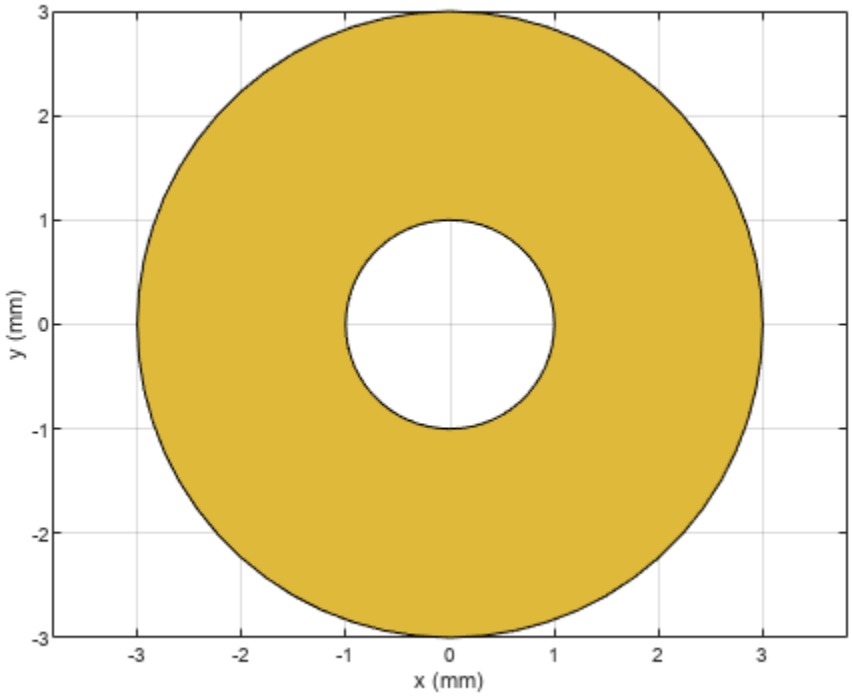
`c = and(shape1,shape2)` calls the syntax `shape1 & shape2` to intersect two shapes.

## Examples

### Intersect Two RF PCB Shapes

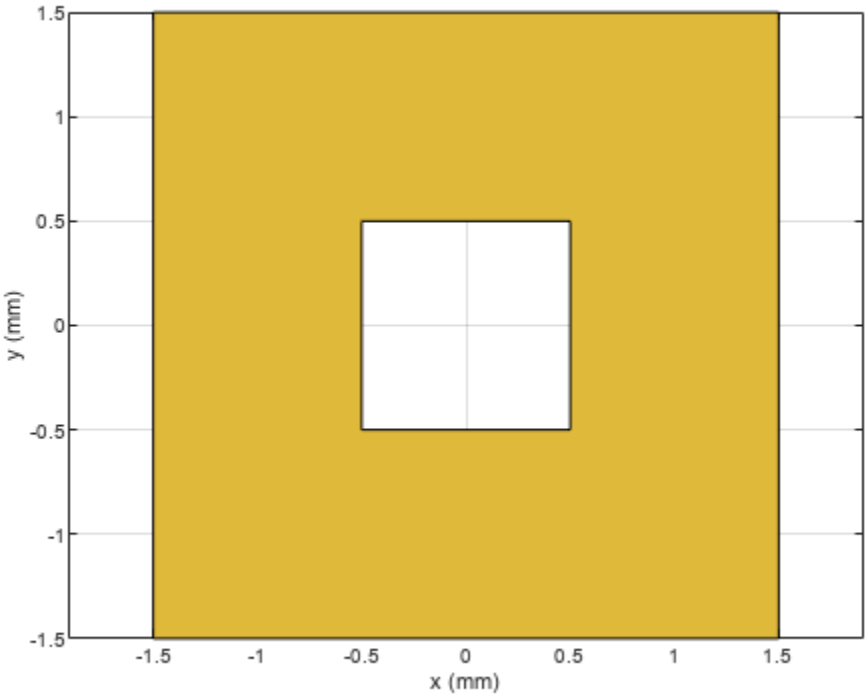
Create and display an annular ring.

```
shape1 = ringAnnular(InnerRadius=1e-3);
show(shape1)
```



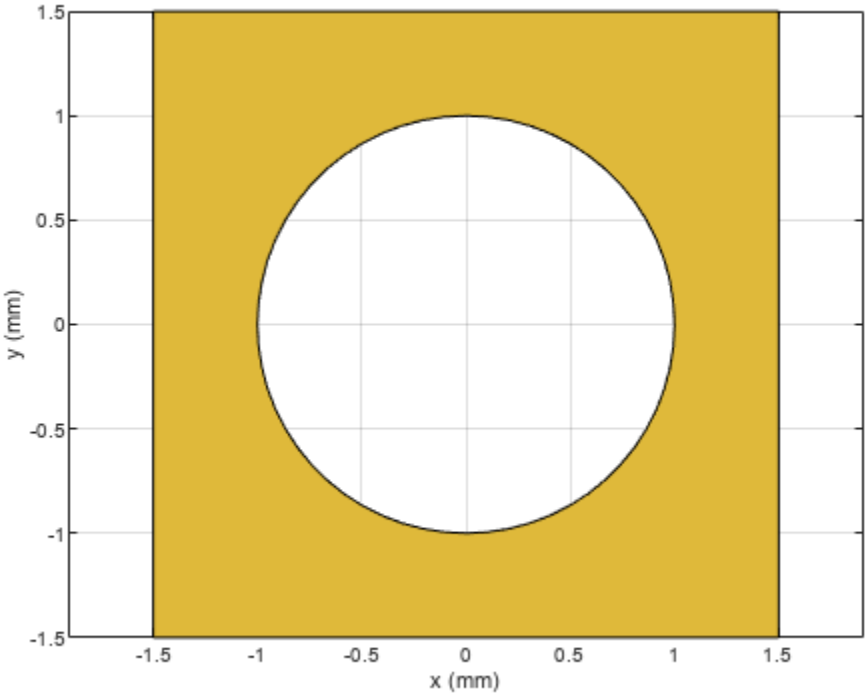

Create and display a square ring.

```
shape2 = ringSquare(InnerSide=1e-3);
show(shape2)
```




Find and display the intersection of the shapes.

```
shapeIntersection = and(shape1,shape2);
show(shapeIntersection)
```




**Intersect Two RF PCB Shapes Using & Operator**

Create and display an annular ring.

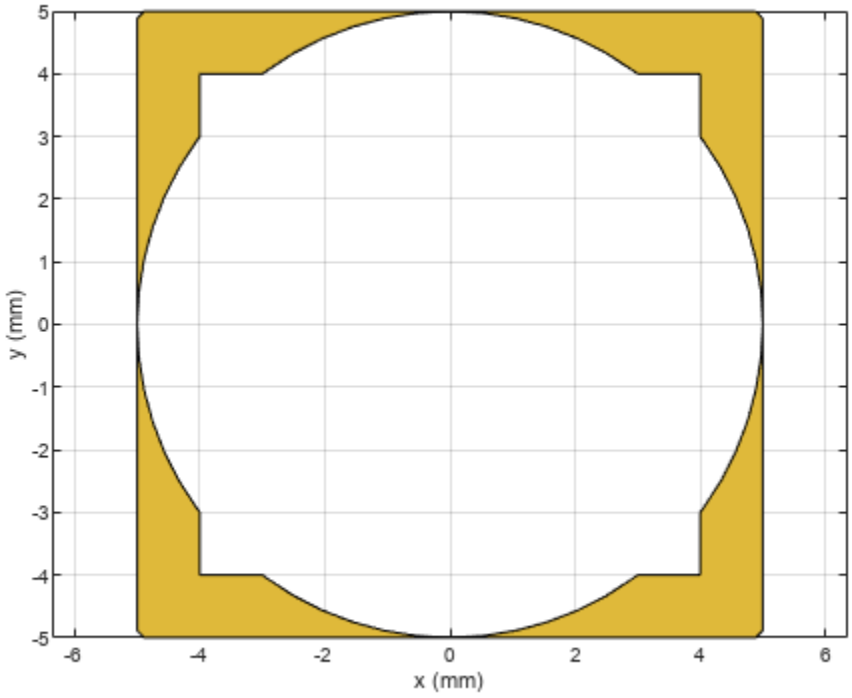
```
shape1 = ringAnnular;
```

Create and display a square ring.

```
shape2 = ringSquare('InnerSide',8e-3);
```

Find and display the intersection of the shapes.

```
shapeIntersection = shape1&shape2;
show(shapeIntersection)
```




## Input Arguments

### shape1 — First shape

object

First shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape1 = bendCurved;` specifies the first shape as a `bendCurved` object.

### shape2 — Second shape

object

Second shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape2 = ringAnnular;` specifies the second shape as a `ringAnnular` object.

# Version History

**Introduced in R2021b**

## See Also

add | subtract | area | intersect | rotate | rotateX | rotateY | rotateZ | translate | show | mesh | plot | scale

# area

Calculate area of RF PCB shape in square meters

## Syntax

```
a = area(shape)
```

## Description

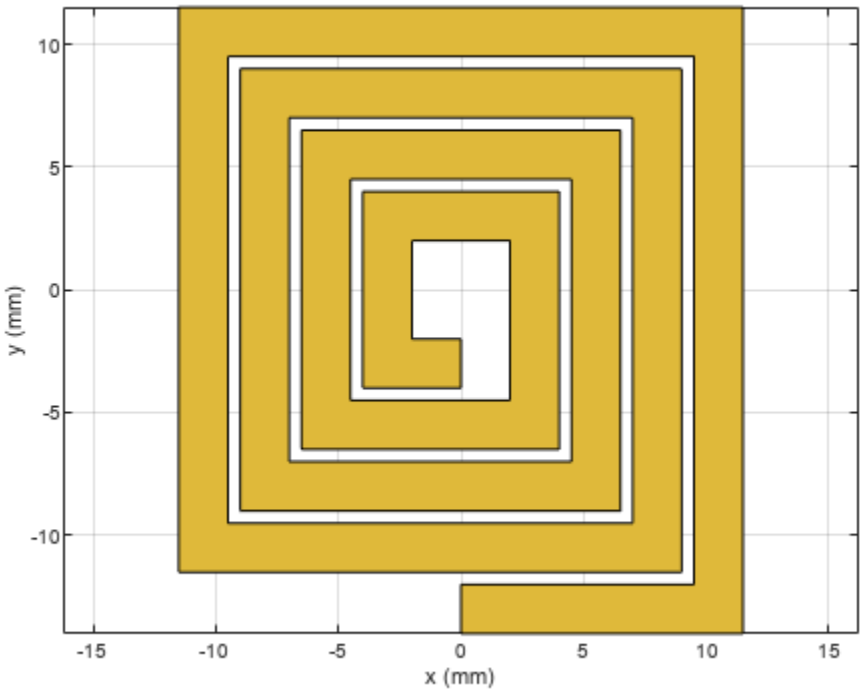
`a = area(shape)` calculates the area of the shape in units of square meters.

## Examples

### Calculate Area of Spiral Trace

Create and view a default spiral trace.

```
trace = traceSpiral;
show(trace)
```




Get the area of the spiral trace.

```
a = area(trace)
```

```
a = 4.5200e-04
```

## Input Arguments

### shape — RF PCB shape

object

RF PCB shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape = bendCurved;` specifies the shape as a `bendCurved` object.

# Version History

**Introduced in R2021b**

## See Also

`add` | `subtract` | `intersect` | `rotate` | `rotateX` | `rotateY` | `rotateZ` | `translate` | `show` | `mesh` | `plot` | `scale`

# intersect

Boolean intersection operation on two RF PCB shapes

## Syntax

```
c = intersect(shape1,shape2)
```

## Description

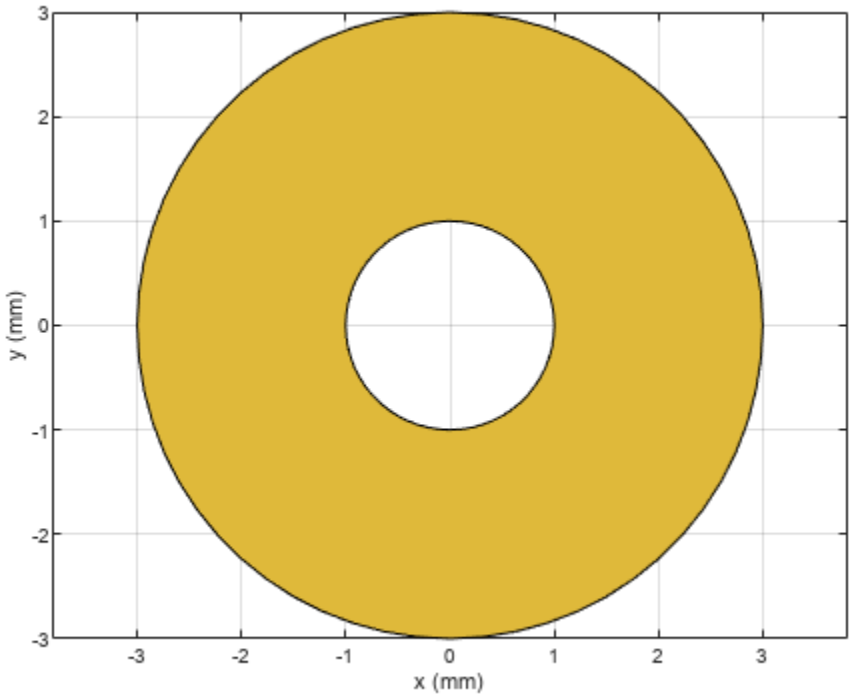
`c = intersect(shape1,shape2)` intersects `shape1` and `shape2` using the intersect operation. You can also use the & to intersect the two shapes.

## Examples

### Boolean Intersection of Two RF PCB Shapes

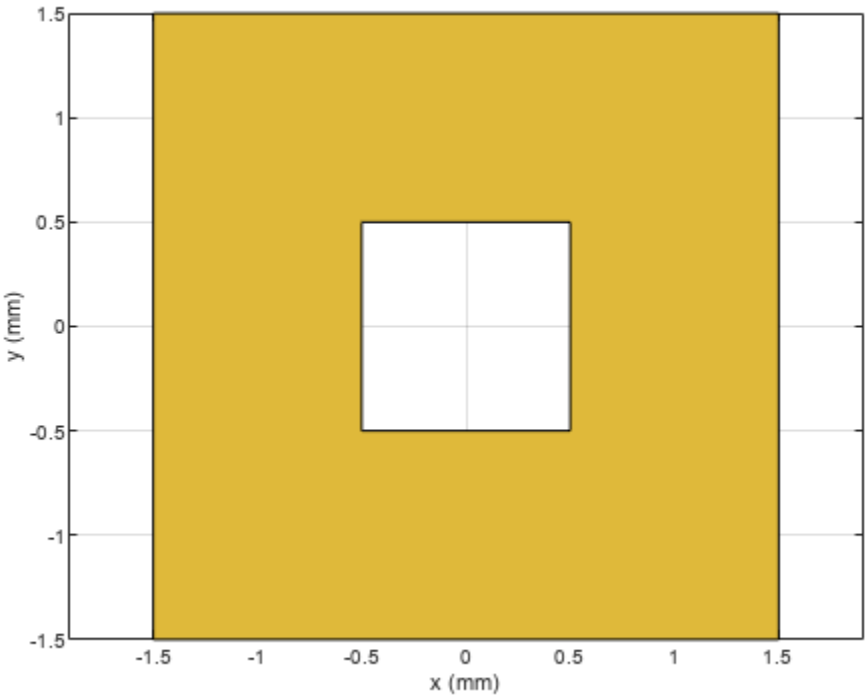
Create and display an annular ring.

```
shape1 = ringAnnular(InnerRadius=1e-3);
show(shape1)
```



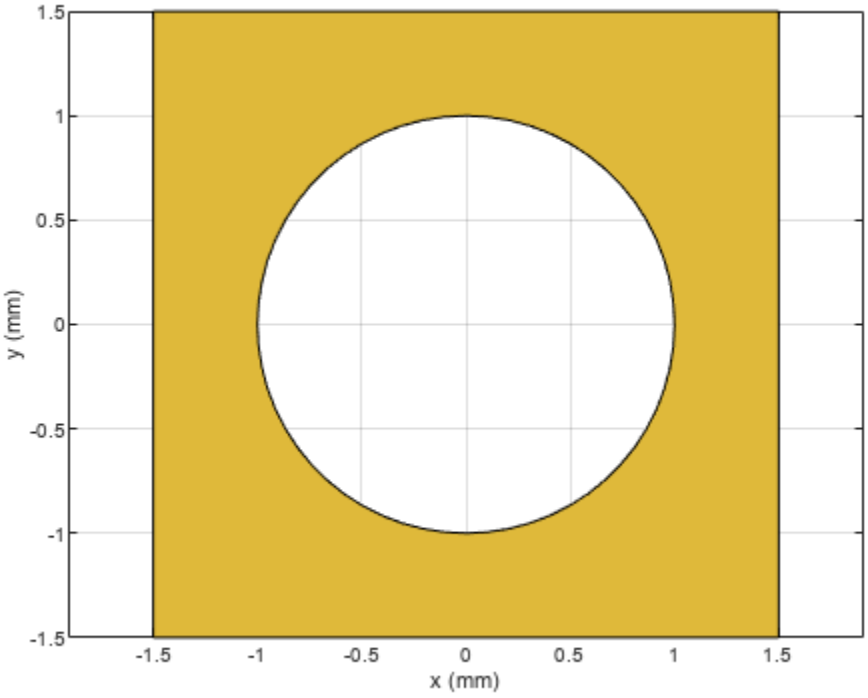
Create and display a square ring.

```
shape2 = ringSquare(InnerSide=1e-3);
show(shape2)
```




Find and display the intersection of the shapes.

```
shapeIntersection = intersect(shape1,shape2);
show(shapeIntersection)
```




### Intersect Two RF PCB Shapes Using & Operator

Create and display an annular ring.

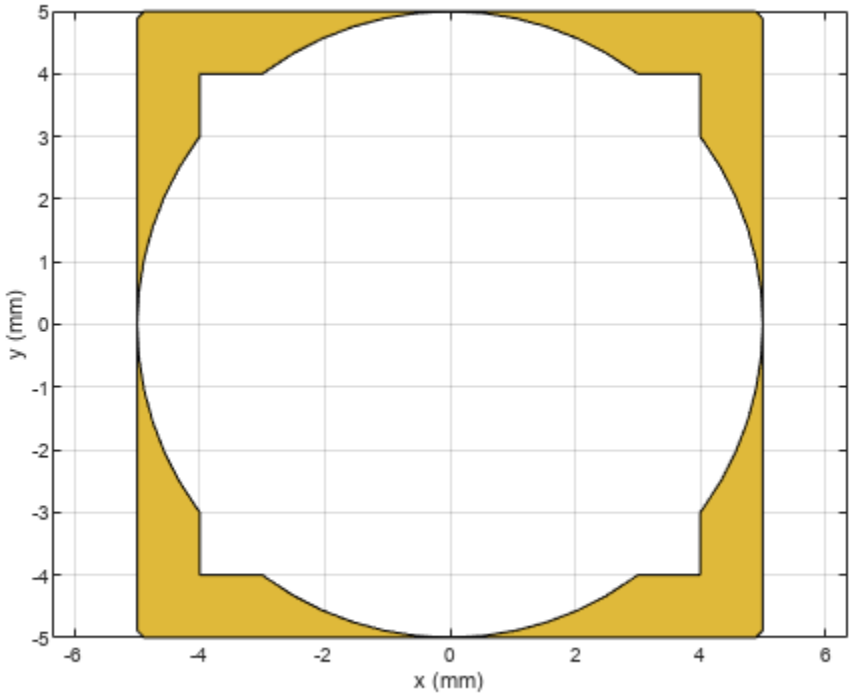
```
shape1 = ringAnnular;
```

Create and display a square ring.

```
shape2 = ringSquare('InnerSide',8e-3);
```

Find and display the intersection of the shapes.

```
shapeIntersection = shape1&shape2;
show(shapeIntersection)
```




## Input Arguments

### shape1 — First shape

object

First shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape1 = bendCurved;` specifies the first shape as a `bendCurved` object.

### shape2 — Second shape

object

Second shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape2 = ringAnnular;` specifies the second shape as a `ringAnnular` object.

# Version History

**Introduced in R2021b**

## See Also

add | subtract | area | rotate | rotateX | rotateY | rotateZ | translate | show | mesh | plot

# minus

Shape1 - Shape2 for RF PCB shapes

## Syntax

```
c = minus(shape1,shape2)
```

## Description

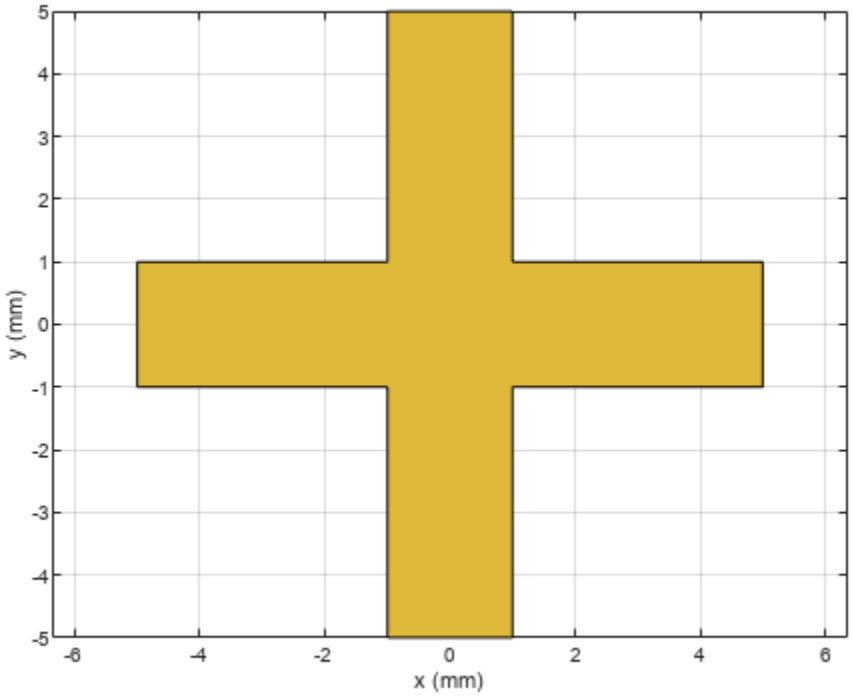
`c = minus(shape1,shape2)` calls the syntax `shape1 - shape2` to subtract two shapes.

## Examples

### Boolean Subtraction of Two RF PCB Shapes

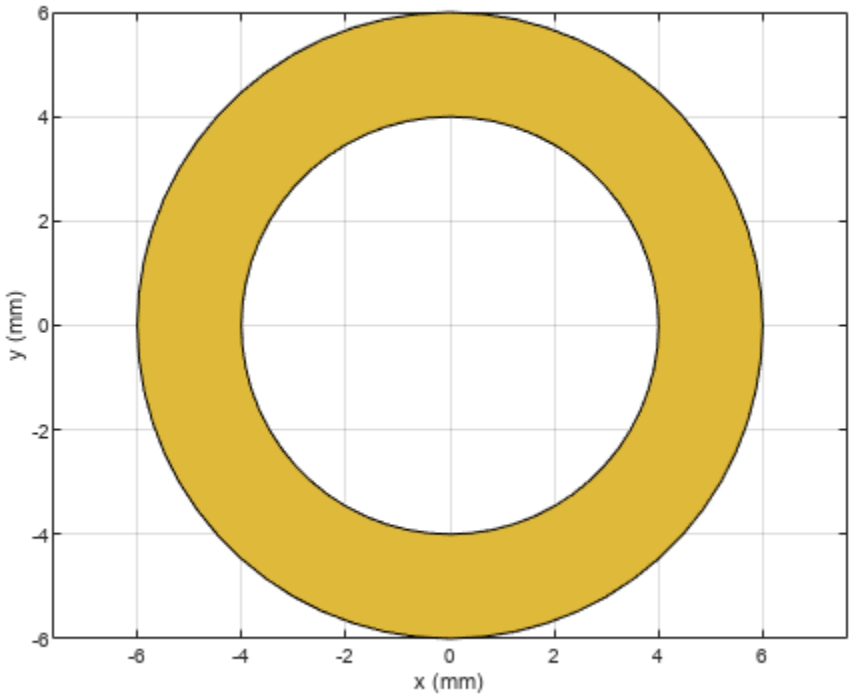
Create and display a cross trace shape.

```
trace = traceCross;
show(trace)
```



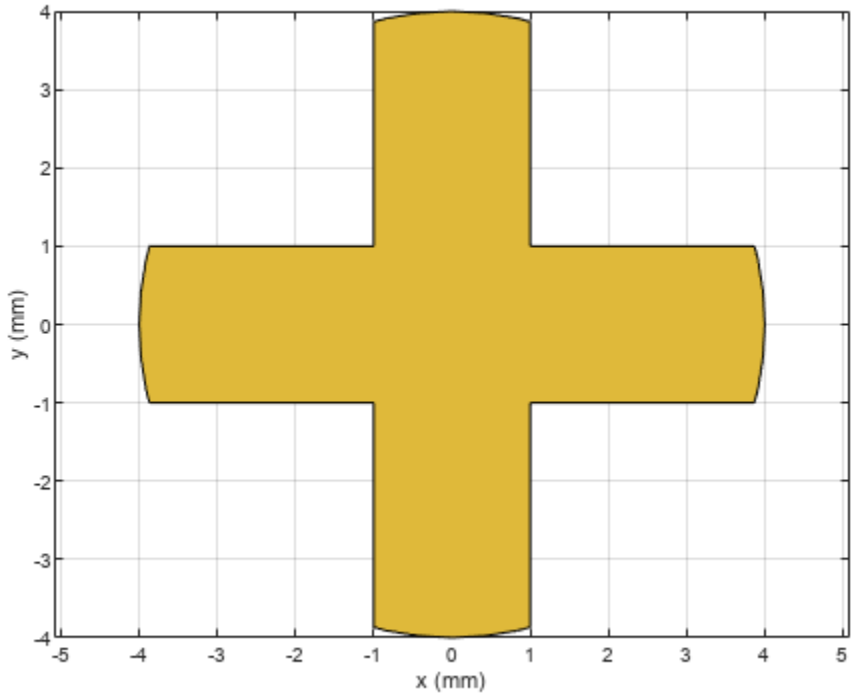

Create and display an annular ring shape with an inner radius of 4 mm.

```
ring = ringAnnular(InnerRadius=4e-3);
show(ring)
```




Subtract the annular ring from the cross trace and display the result.

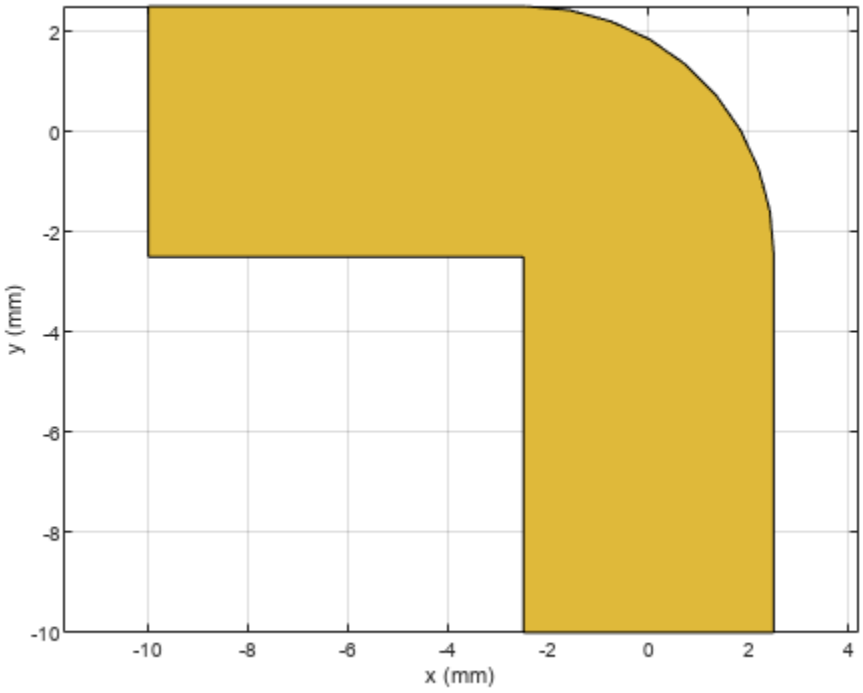
```
shapeDiff = minus(trace,ring);
show(shapeDiff)
```




**Subtract Two RF PCB Shapes Using - Operator**

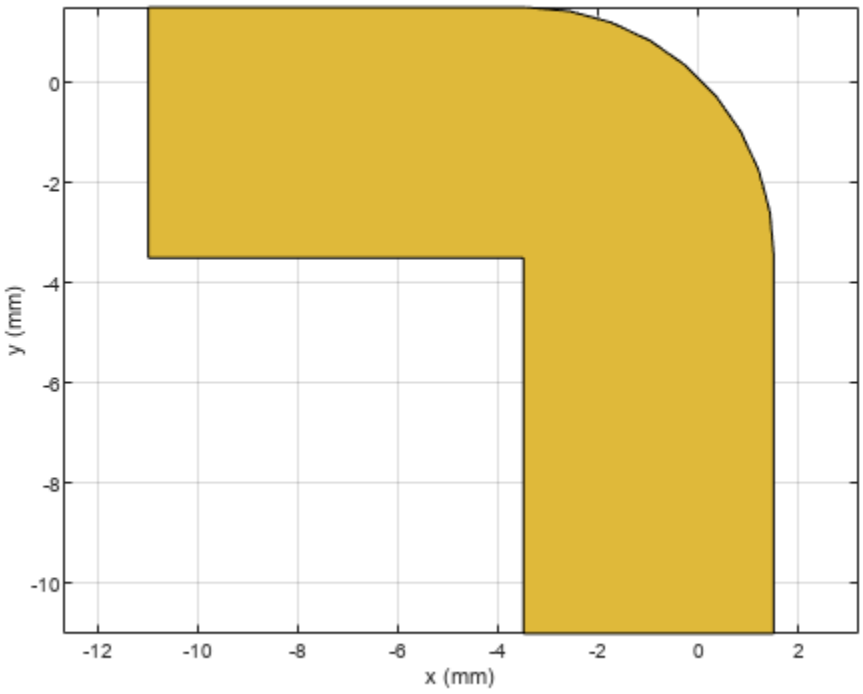
Create and display a curved bend shape.

```
bend1 = bendCurved;
show(bend1)
```



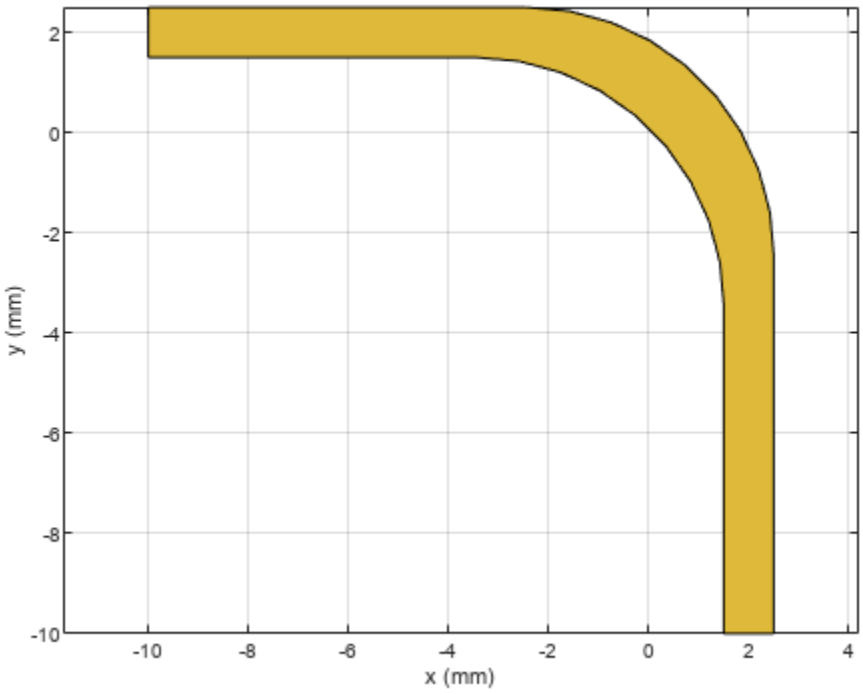

Create and display a curved bend shape with a spatial offset.

```
bend2 = bendCurved(ReferencePoint=[-1e-3 -1e-3]);
show(bend2)
```




Subtract the offset bend from the default bend and display the result.

```
shapeDiff = bend1 - bend2;
show(shapeDiff)
```




## Input Arguments

### shape1 — First shape

object

First shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape1 = bendCurved;` specifies the first shape as a `bendCurved` object.

### shape2 — Second shape

object

Second shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape2 = ringAnnular;` specifies the second shape as a `ringAnnular` object.

# Version History

**Introduced in R2021b**

## See Also

add | subtract | area | intersect | rotate | rotateX | rotateY | rotateZ | translate | show | mesh | plot | scale

# plot

Plot boundary of RF PCB shape

## Syntax

```
plot(shape)
plot(shape,Name,Value)
p = plot( ___ )
```

## Description

`plot(shape)` plots the boundary of the shape.

`plot(shape,Name,Value)` specifies the line properties using one or more name-value arguments.

Example: `plot(shape,Color="r",LineWidth=2)` plots the boundary of the shape as a red line with a width of 2 pixels.

`p = plot( ___ )` returns the line object. Use `p` to modify properties of the line after it is created.

## Examples

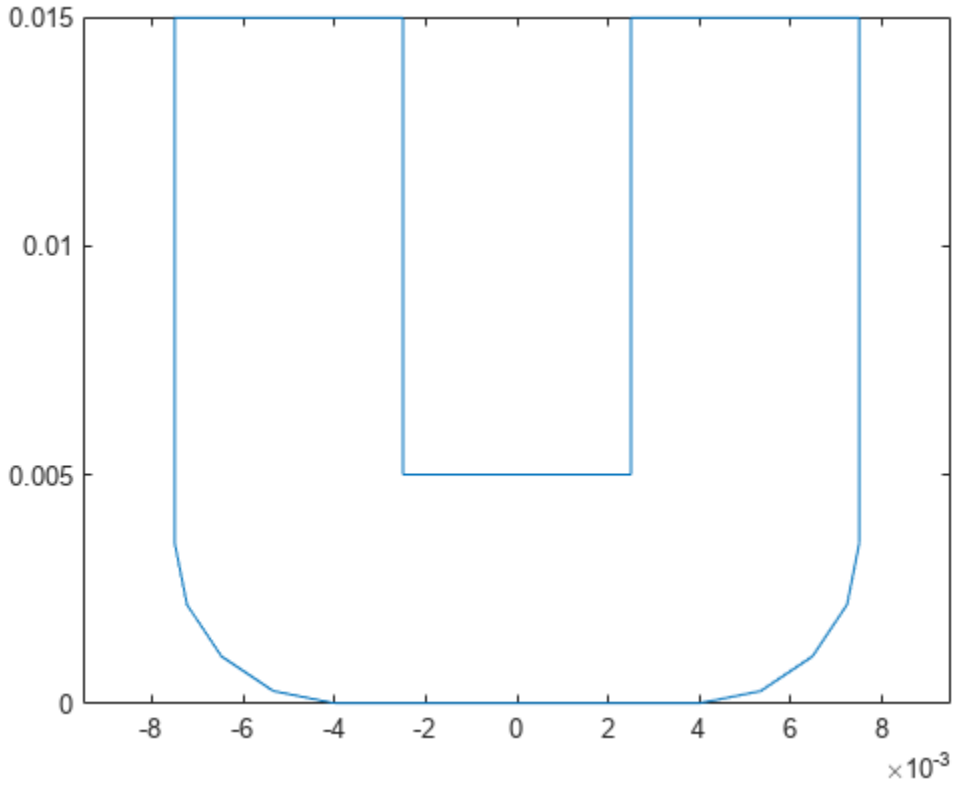
### Plot Curved U-Bend

Create a curved U-bend shape.

```
ubend = ubendCurved;
```

Plot the shape.

```
plot(ubend)
```



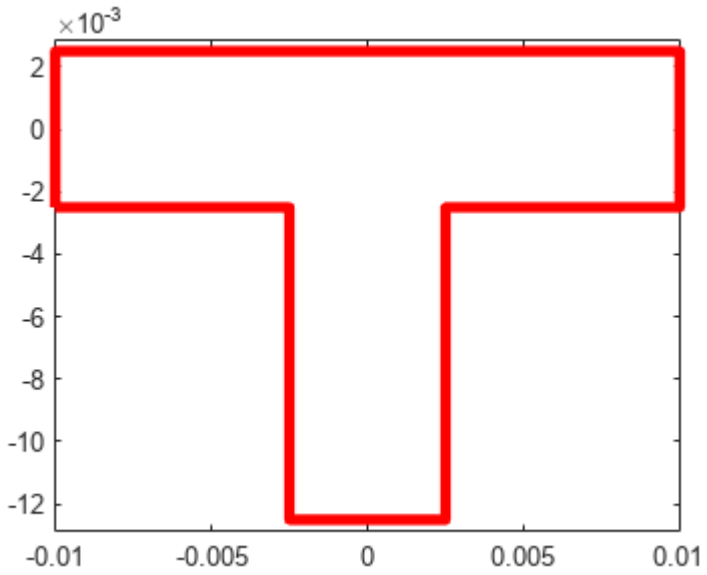

**Plot Shape and Modify Line Properties**

Create a tee trace shape.

```
trace = traceTee;
```

Plot the shape using a red line of width 4 pixels.

```
plot(trace,LineWidth=4,Color="r")
```




## Input Arguments

### shape — RF PCB shape

object

RF PCB shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape = bendCurved;` specifies the shape as a `bendCurved` object.

# Version History

**Introduced in R2021b**

## See Also

`show` | `mesh`

# plus

Shape1 + Shape2 for RF PCB shapes

## Syntax

```
c = plus(shape1,shape2)
```

## Description

`c = plus(shape1,shape2)` calls the syntax `shape1 + shape2` to unite two shapes.

## Examples

### Boolean Unite of Two RF PCB Shapes

Create a curved bend shape with a length of 5 m

```
bend = bendCurved(Length=[5 5]);
```

Create an annular ring shape with the default inner radius of 5 m.

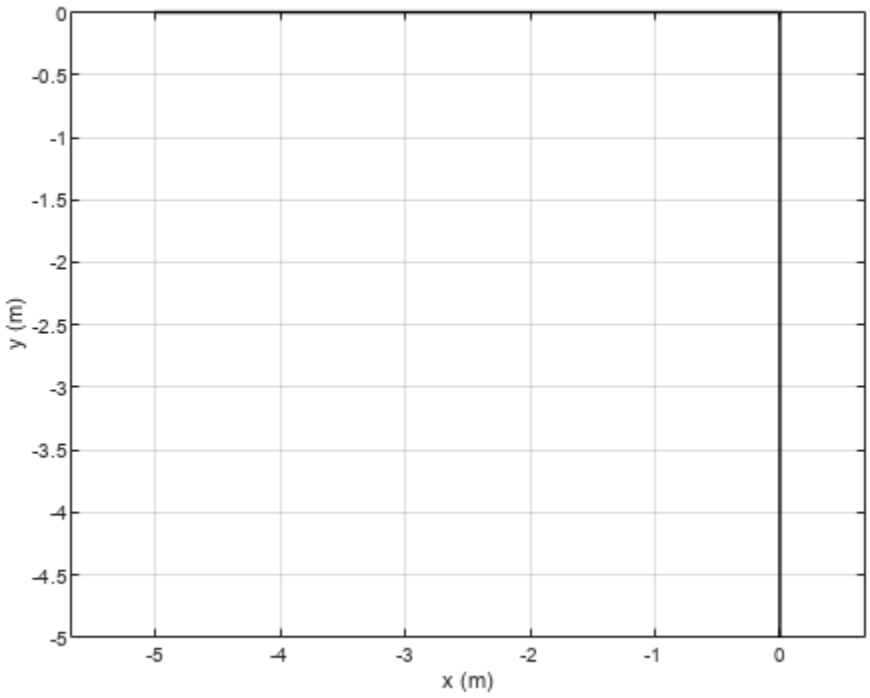
```
ring = ringAnnular;
```

Add the two shapes and display the result.

```
shapeSum = plus(bend,ring)
```

```
shapeSum =
  Polygon with properties:

        Name: 'mypolygon'
    Vertices: [111x3 double]
```

```
show(shapeSum)
```




**Add Two RF PCB Shapes Using + Operator**

Create the default curve shape.

```
shape1 = curve;
```

Create a right angle U-bend shape with an adjusted size and position to complement the curve shape.

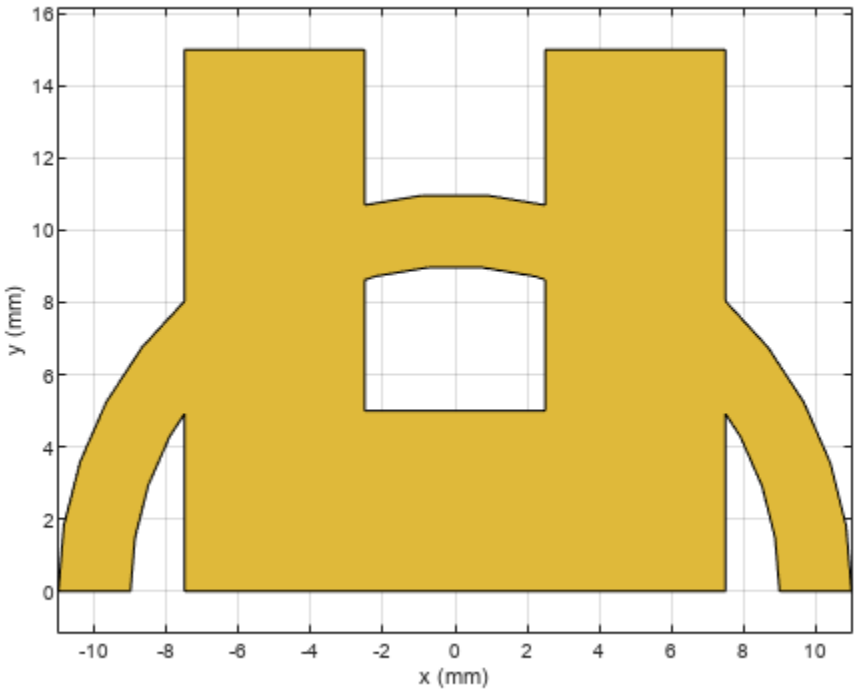
```
shape2 = ubendRightAngle;
```

Add the two shapes using the + operator, and display the resulting `Polygon` object.

```
shapeSum = shape1+shape2
```

```
shapeSum =
  Polygon with properties:

        Name: 'mypolygon'
    Vertices: [43x3 double]
```

```
show(shapeSum)
```




## Input Arguments

### shape1 — First shape

object

First shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape1 = bendCurved;` specifies the first shape as a `bendCurved` object.

### shape2 — Second shape

object

Second shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape2 = ringAnnular;` specifies the second shape as a `ringAnnular` object.

# Version History

**Introduced in R2021b**

## See Also

add | subtract | area | intersect | rotate | rotateX | rotateY | rotateZ | translate | show | mesh | plot | scale

# rotate

Rotate RF PCB shape about defined axis

## Syntax

```
c = rotate(shape,angle,axis1,axis2)
```

## Description

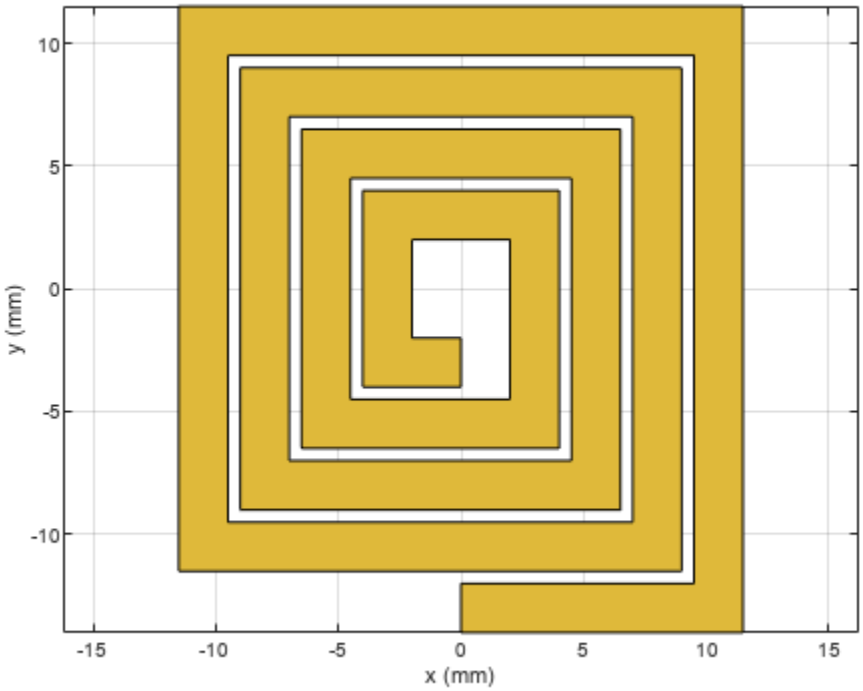
`c = rotate(shape,angle,axis1,axis2)` rotates a shape by a specified angle about an axes defined by two points `axis1` and `axis2`.

## Examples

### Rotate Spiral Trace About Axis

Create and display a spiral trace.

```
trace = traceSpiral;
show(trace)
```



Specify two points that define the axes of rotation.

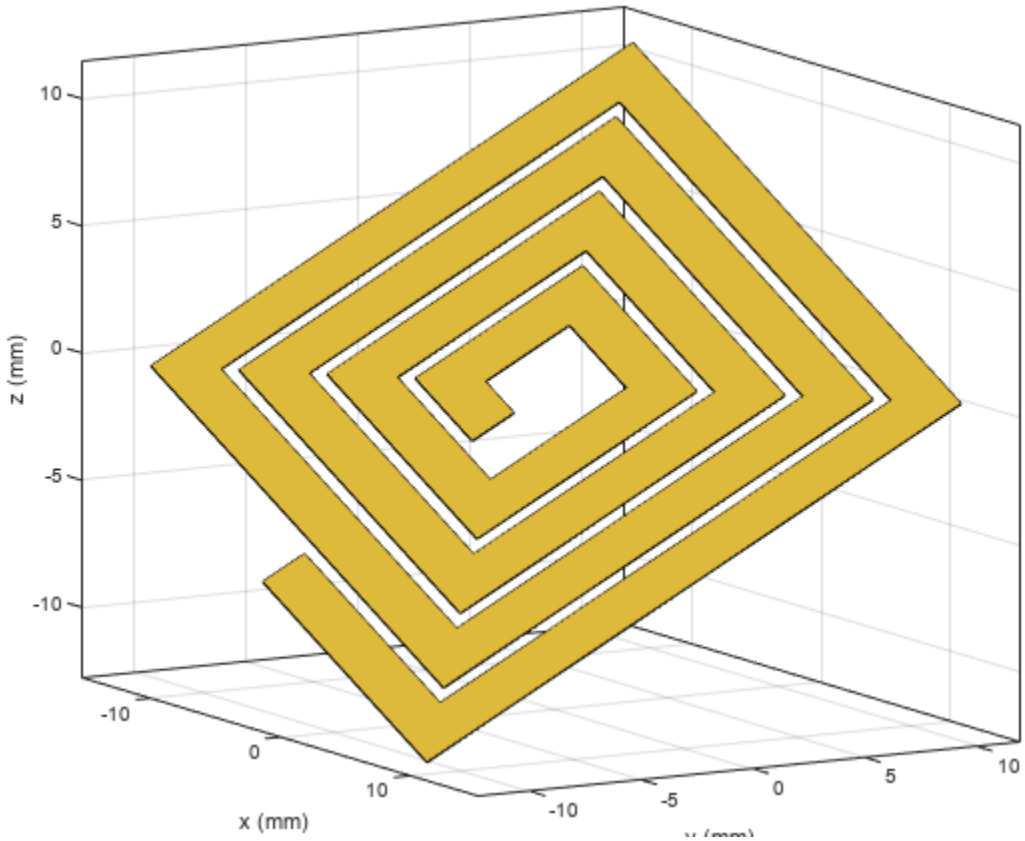
```
pt1 = [0 0 0];
pt2 = [1 1 0];
```

Rotate the spiral trace by 45 degrees about the axis.

```
traceRot = rotate(trace,45,pt1,pt2);
```

Display the rotated shape. Set the camera line of sight to display in 3-D space.

```
show(traceRot)
view(60,10)
```




## Input Arguments

### `shape` — RF PCB shape

object

RF PCB shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape = bendCurved;` specifies the shape as a `bendCurved` object.

### `angle` — Angle of rotation

scalar

Angle of rotation, specified as a scalar in degrees.

Example: 45 rotates the shape around the axis by 45 degrees.

Data Types: `double`

**`axis1` — One point on axis of rotation**
three-element vector

One point on the axis of rotation, specified as a three-element vector of Cartesian coordinates in meters.

Example: `[0 0 0]`

Data Types: `double`

**`axis2` — Second point on axis of rotation**
three-element vector

Second point on the axis of rotation, specified as a three-element vectors of Cartesian coordinates in meters. `axis2` must be different than `axis1`.

Example: `[0 0 1]`

Data Types: `double`

# Version History

**Introduced in R2021b**

## See Also

`add` | `subtract` | `area` | `intersect` | `rotateX` | `rotateY` | `rotateZ` | `translate` | `show` | `mesh` | `plot` | `scale`

# rotateX

Rotate RF PCB shape about *x*-axis

## Syntax

```
c = rotateX(shape,angle)
```

## Description

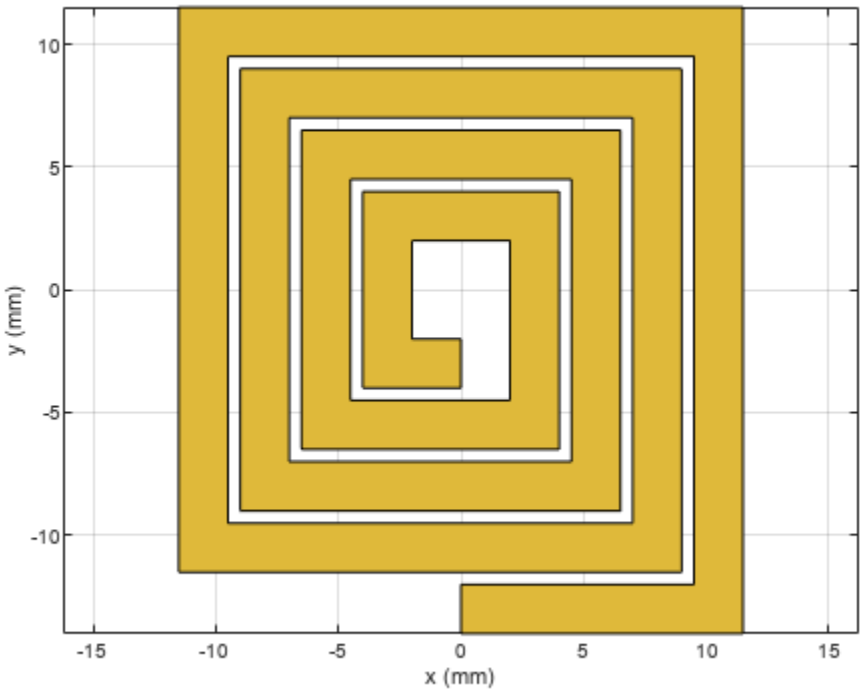
`c = rotateX(shape,angle)` rotates a shape by the specified angle about the *x*-axis.

## Examples

### Rotate Spiral Trace About X-Axis

Create and display a spiral trace.

```
trace = traceSpiral;
show(trace)
```

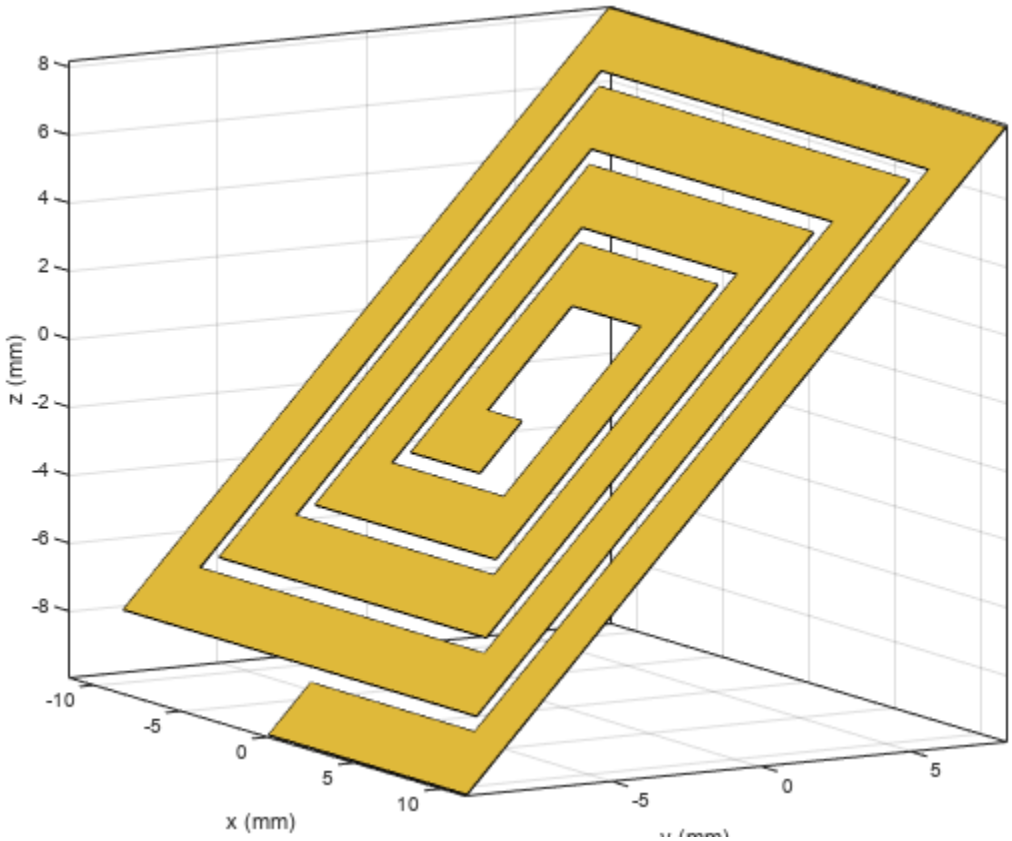



Rotate the spiral trace by 45 degrees about the *x*-axis.

```
traceRotX = rotateX(trace,45);
```

Display the rotated shape. Set the camera line of sight to display in 3-D space.

```
show(traceRotX)
view(60,10)
```




## Input Arguments

### `shape` — RF PCB shape

object

RF PCB shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape = bendCurved;` specifies the shape as a `bendCurved` object.

### `angle` — Angle of rotation

scalar

Angle of rotation, specified as a scalar in degrees.

Example: 45 rotates the shape around the *x*-axis by 45 degrees.

Data Types: `double`

## Version History

**Introduced in R2021b**

## See Also

`add` | `subtract` | `area` | `intersect` | `rotate` | `rotateY` | `rotateZ` | `translate` | `show` | `mesh` | `plot` | `scale`

# rotateY

Rotate RF PCB shape about *y*-axis and angle

## Syntax

```
c = rotateY(shape,angle)
```

## Description

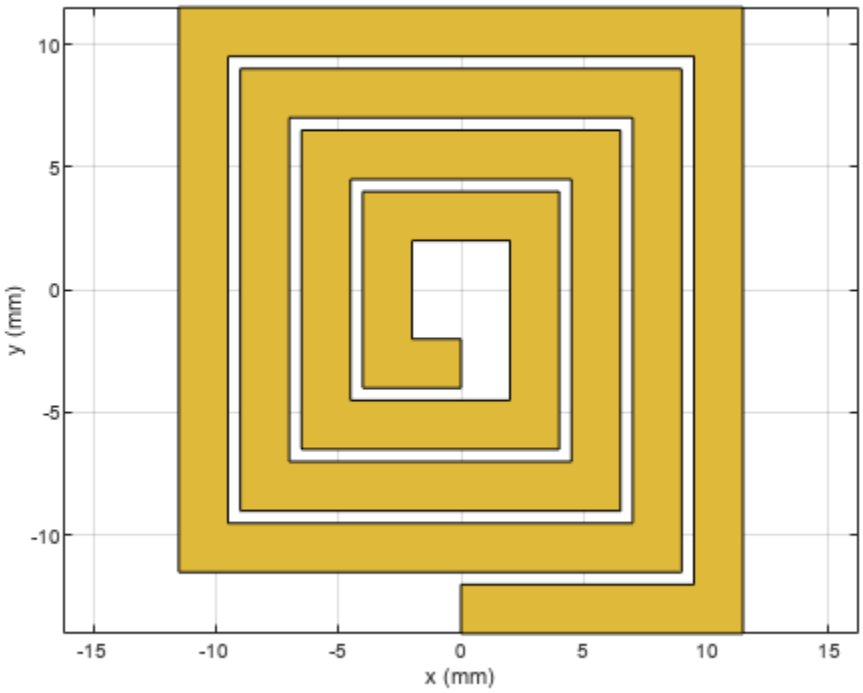
`c = rotateY(shape,angle)` rotates a shape by the specified angle about the *y*-axis.

## Examples

### Rotate Spiral Trace About Y-Axis

Create and display a spiral trace.

```
trace = traceSpiral;
show(trace)
```

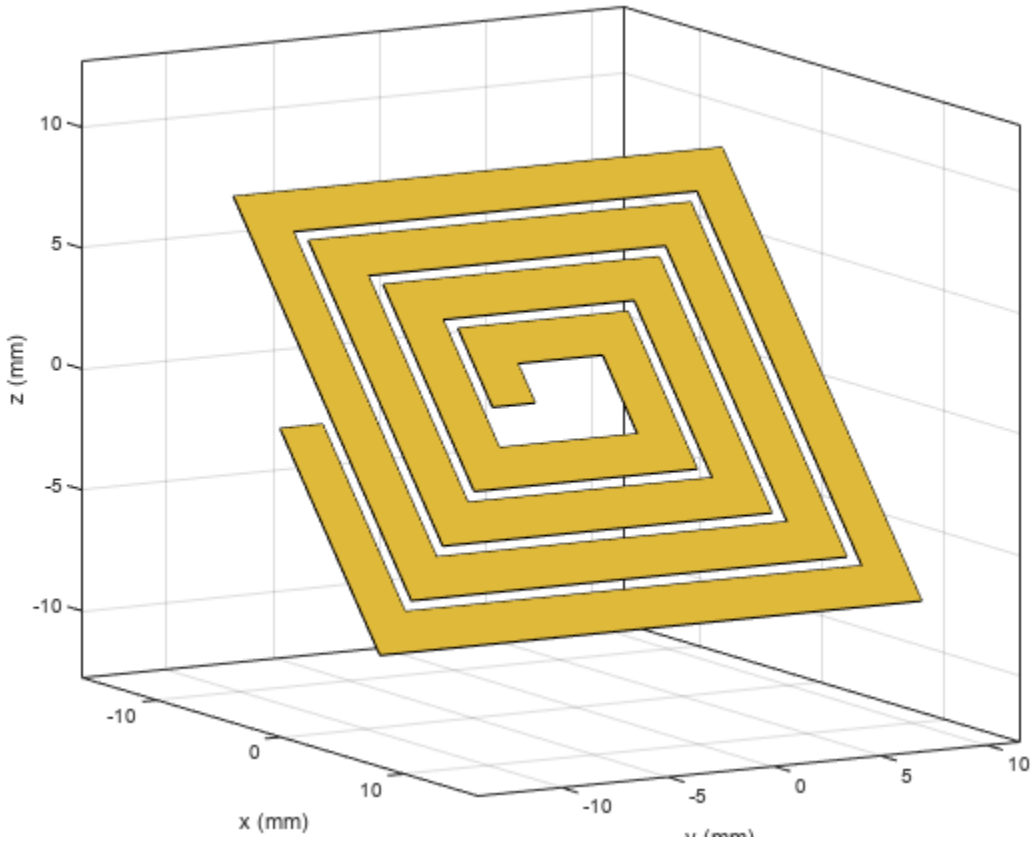



Rotate the spiral trace by 45 degrees about the *y*-axis.

```
traceRotY = rotateY(trace,45);
```

Display the rotated shape. Set the camera line of sight to display in 3-D space.

```
show(traceRotY)
view(60,10)
```




## Input Arguments

### `shape` — RF PCB shape

object

RF PCB shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape = bendCurved;` specifies the shape as a `bendCurved` object.

### `angle` — Angle of rotation

scalar

Angle of rotation, specified as a scalar in degrees.

Example: 45 rotates the shape around the *y*-axis by 45 degrees.

Data Types: `double`

## Version History

**Introduced in R2021b**

## See Also

`add` | `subtract` | `area` | `intersect` | `rotate` | `rotateX` | `rotateZ` | `translate` | `show` | `mesh` | `plot` | `scale`

# rotateZ

Rotate RF PCB shape about *z*-axis

## Syntax

```
c = rotateZ(shape,angle)
```

## Description

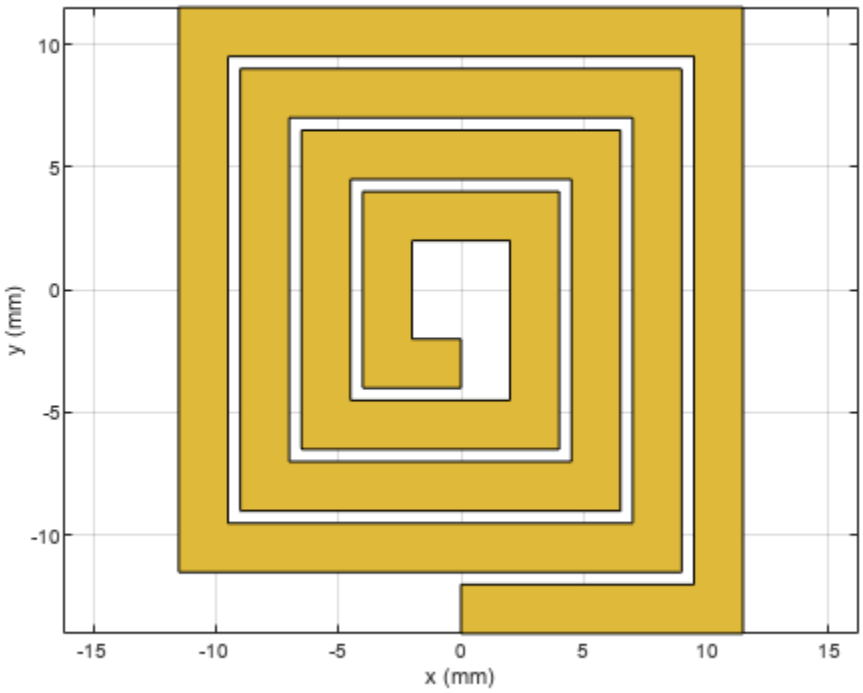
`c = rotateZ(shape,angle)` rotates a shape by the specified angle about the *z*-axis.

## Examples

### Rotate Spiral Trace About Z-Axis

Create and display a spiral trace.

```
trace = traceSpiral;
show(trace)
```

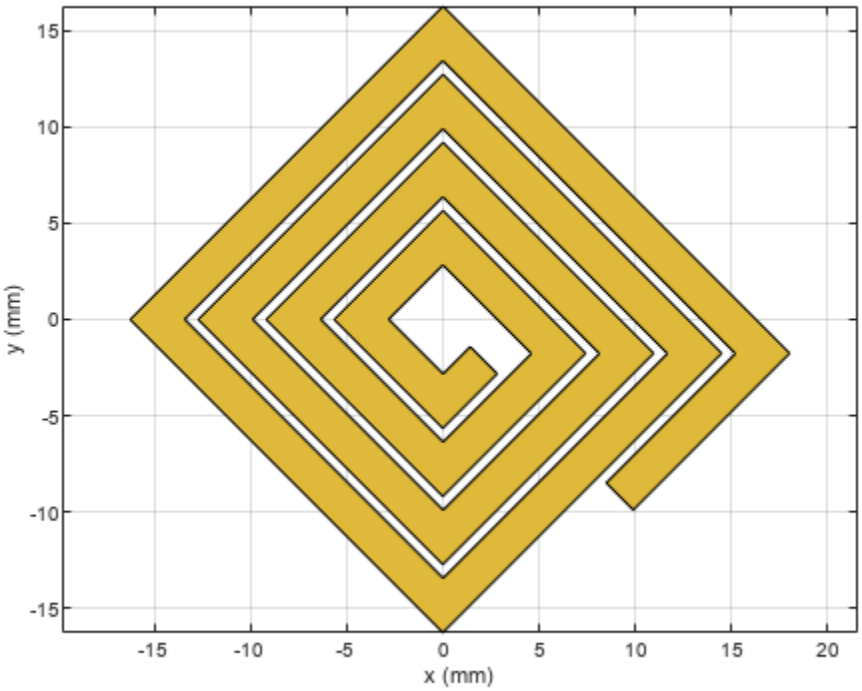



Rotate the spiral trace by 45 degrees about the *z*-axis.

```
traceRotZ = rotateZ(trace,45);
```

Display the rotated shape.

```
show(traceRotZ)
```




## Input Arguments

### `shape` — RF PCB shape

object

RF PCB shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape = bendCurved;` specifies the shape as a `bendCurved` object.

### `angle` — Angle of rotation

scalar

Angle of rotation, specified as a scalar in degrees.

Example: 45 rotates the shape around the *z*-axis by 45 degrees.

Data Types: `double`

## Version History

**Introduced in R2021b**

## See Also

`add` | `subtract` | `area` | `intersect` | `rotate` | `rotateX` | `rotateY` | `translate` | `show` | `mesh` | `plot` | `scale`

# scale

Change size of RF PCB shape by fixed amount

## Syntax

```
c = scale(shape,scaleFactor)
c = scale(shape,scaleFactor,RefPoint)
```

## Description

`c = scale(shape,scaleFactor)` resizes the shape by a scaling factor.

`c = scale(shape,scaleFactor,RefPoint)` scales the shape by a constant factor with respect to the reference point. The reference point is ignored if the shape is symmetrical and scale is performed based on centroid. The reference point is considered if the shape is unsymmetrical and scale is performed based on specified reference point.

## Examples

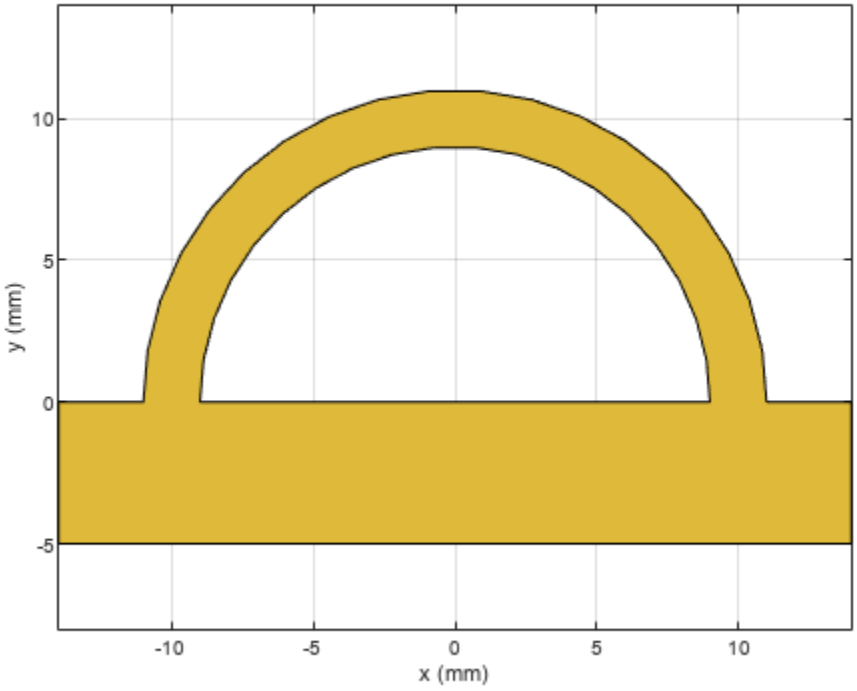
### Resize Shape by Scale Factor

Create a shape consisting of a curve and a right angle U-bend.

```
shape1 = curve;
shape2 = ubendRightAngle(Length=[5 18 5]*1e-3,ReferencePoint=[0 -5]*1e-3);
shapeSum = shape1+shape2;
```

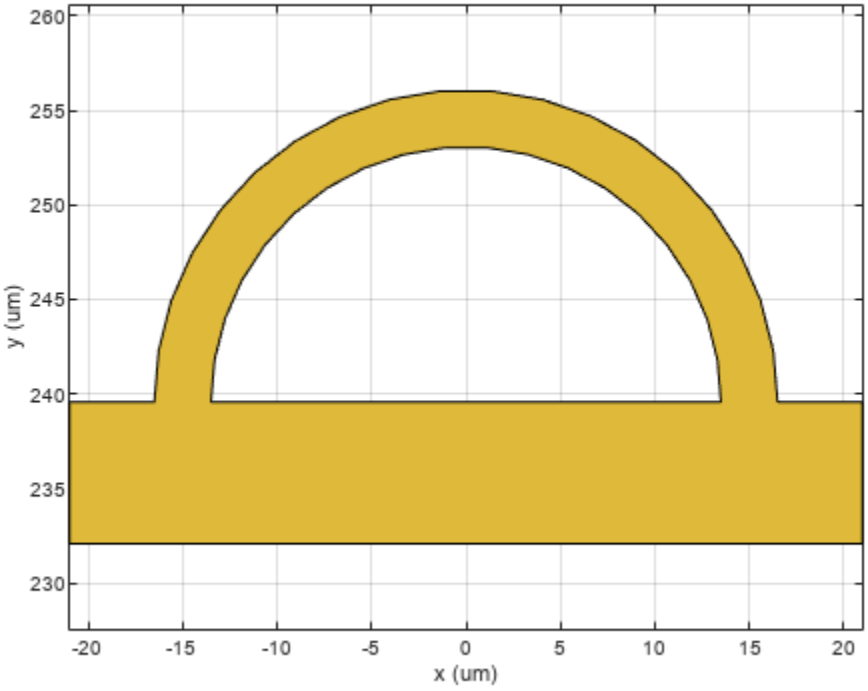
Display the shape.

```
show(shapeSum)
```




Specify a scale factor, then resize the shape. Display the result.

```
s = 1.5e-3;
shapeTrans = scale(shapeSum,s);
show(shapeTrans)
```




## Input Arguments

### `shape` — RF PCB shape

object

RF PCB shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape = bendCurved;` specifies the shape as a `bendCurved` object.

### `scaleFactor` — Scaling factor

scalar

Scaling factor to change shape size, specified as a scalar.

Data Types: `double`

# Version History

**Introduced in R2021b**

## See Also

`add` | `subtract` | `area` | `intersect` | `rotate` | `rotateX` | `rotateY` | `rotateZ` | `show` | `mesh` | `plot`

# subtract

Boolean subtraction operation on two RF PCB shapes

## Syntax

```
c = subtract(shape1,shape2)
```

## Description

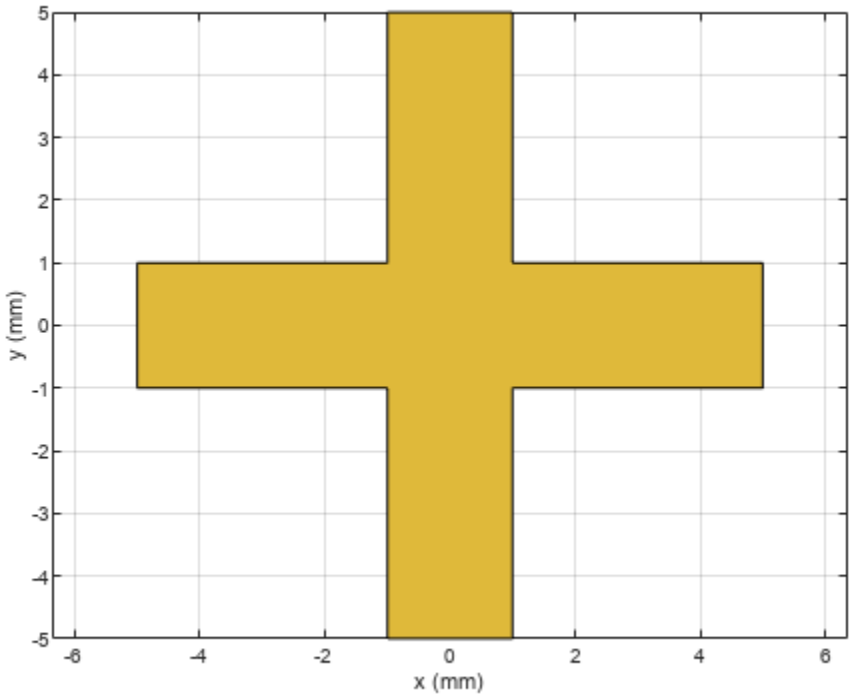
`c = subtract(shape1,shape2)` subtracts `shape1` and `shape2` using the subtract operation. You can also use the `-` symbol to subtract the two shapes.

## Examples

### Subtract Two RF PCB Shapes

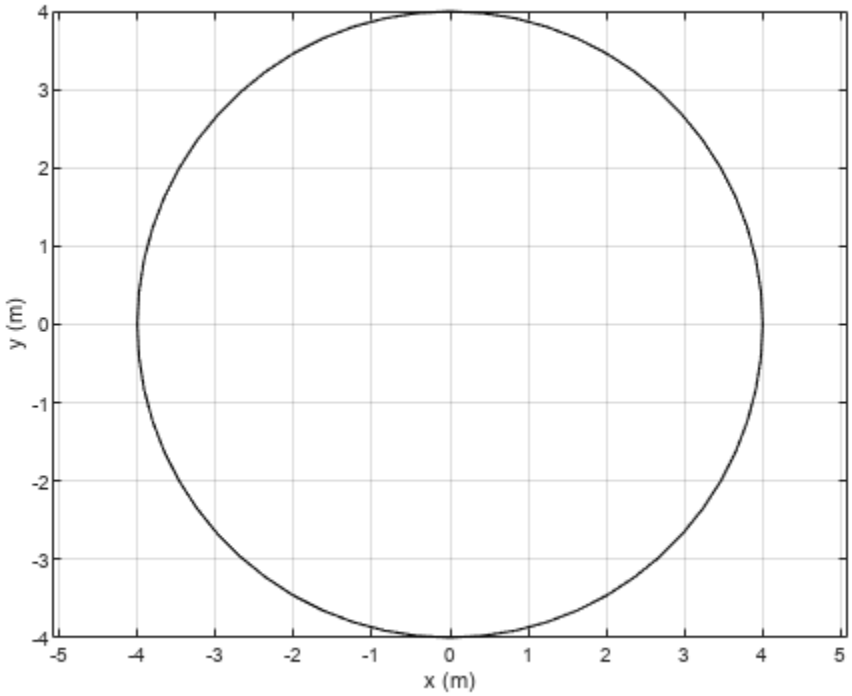
Create and display a cross trace shape.

```
trace = traceCross;
show(trace)
```



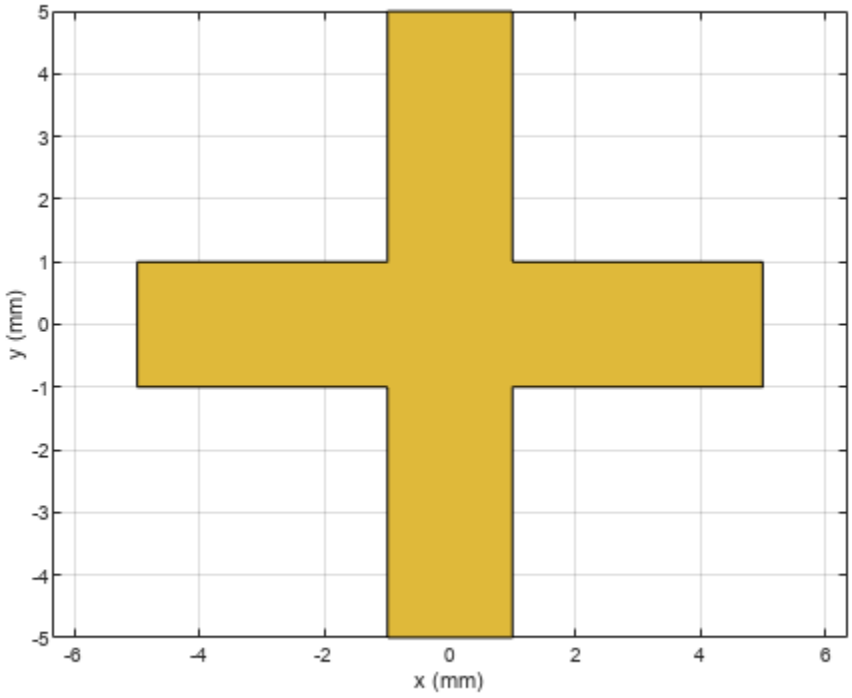
Create and display an annular ring shape with an inner radius of 4 m.

```
ring = ringAnnular(InnerRadius=4);
show(ring)
```




Subtract the annular ring from the cross trace and display the result.

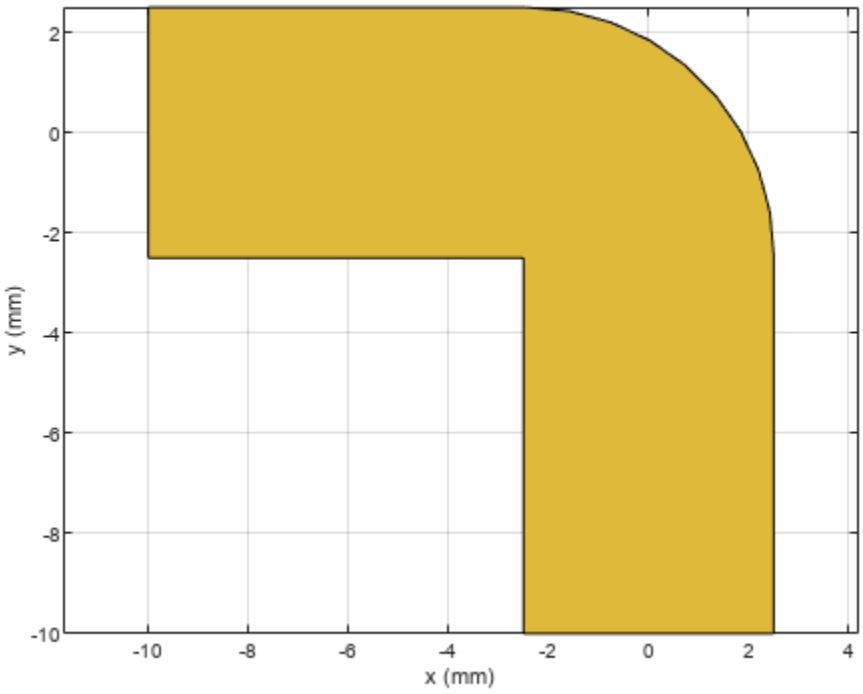
```
shapeDiff = subtract(trace,ring);
show(shapeDiff)
```




### Subtract Two RF PCB Shapes Using - Operator

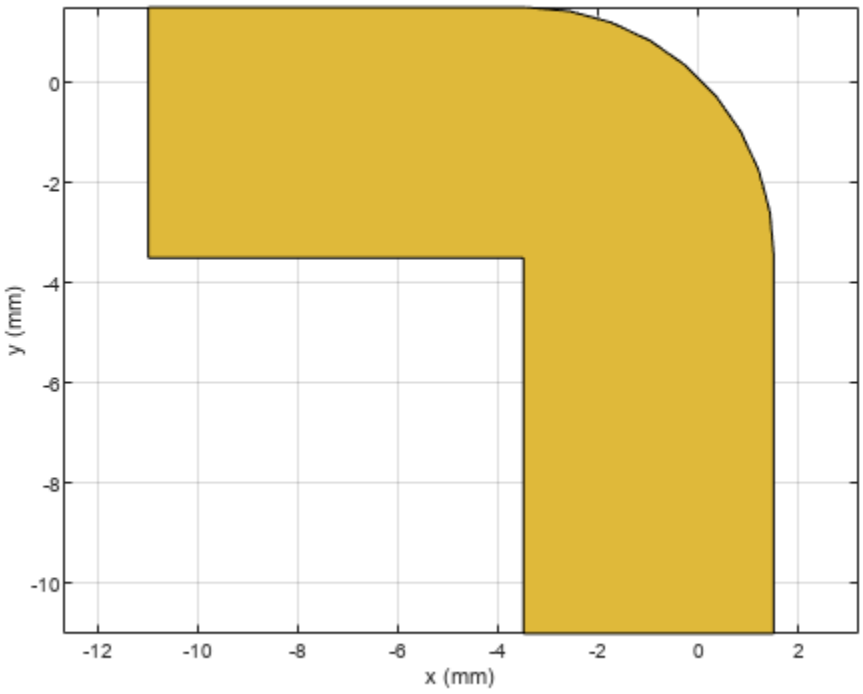
Create and display a curved bend shape.

```
bend1 = bendCurved;
show(bend1)
```



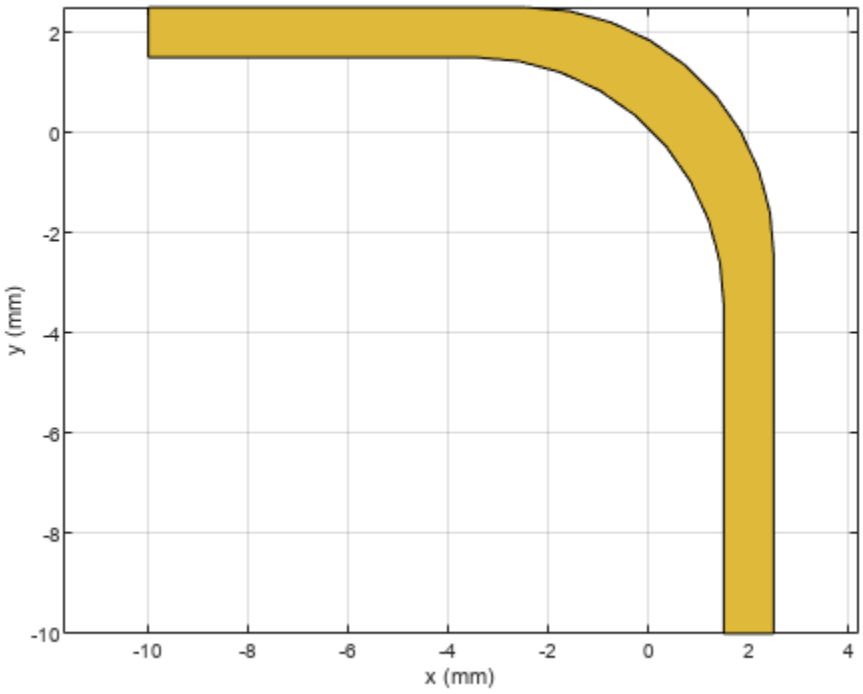

Create and display a curved bend shape with a spatial offset.

```
bend2 = bendCurved(ReferencePoint=[-1e-3 -1e-3]);
show(bend2)
```




Subtract the offset bend from the default bend and display the result.

```
shapeDiff = bend1 - bend2;
show(shapeDiff)
```




## Input Arguments

### shape1 — First shape

object

First shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape1 = bendCurved;` specifies the first shape as a `bendCurved` object.

### shape2 — Second shape

object

Second shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape2 = ringAnnular;` specifies the second shape as a `ringAnnular` object.

# Version History

**Introduced in R2021b**

## See Also

add | area | intersect | rotate | rotateX | rotateY | rotateZ | translate | show | mesh | plot | scale

# translate

Move RF PCB shape to new location

## Syntax

```
c = translate(shape,offset)
```

## Description

`c = translate(shape,offset)` moves the shape to a new specified location using a translation vector.

## Examples

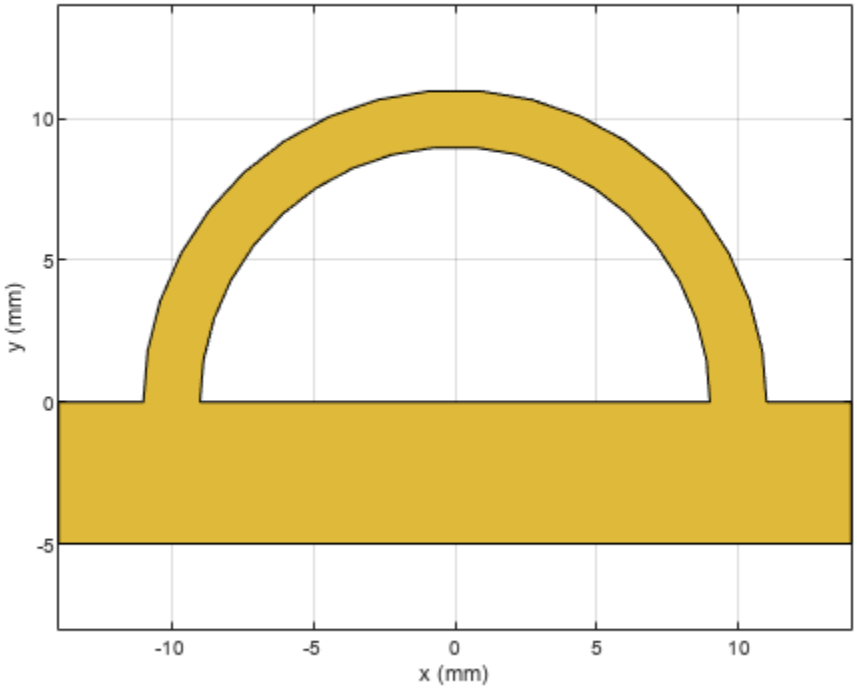
### Translate Shape in XY Plane

Create a shape consisting of a curve and a right angle U-bend.

```
shape1 = curve;
shape2 = ubendRightAngle(Length=[5 18 5]*1e-3,ReferencePoint=[0 -5]*1e-3);
shapeSum = shape1+shape2;
```

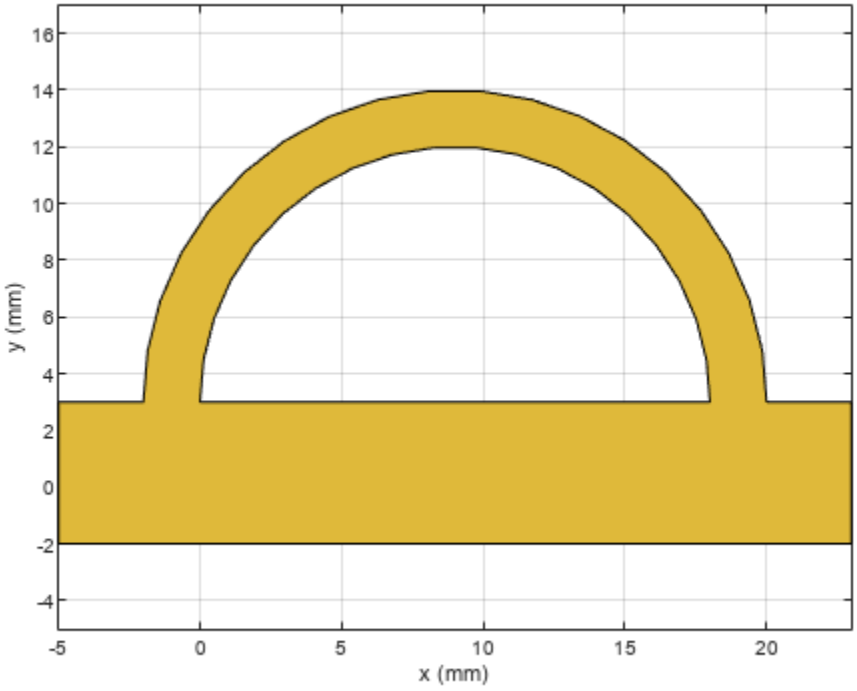
Display the shape.

```
show(shapeSum)
```




Specify a translation vector, then translate the shape in the X-Y plane. Display the result.

```
t = [9 3 0]*1e-3;
shapeTrans = translate(shapeSum,t);
show(shapeTrans)
```




## Input Arguments

### `shape` — RF PCB shape

object

RF PCB shape created using custom elements and shape objects of RF PCB Toolbox, specified as an object.

Example: `shape = bendCurved;` specifies the shape as a `bendCurved` object.

### `offset` — Translation vector

vector

Translation vector, specified as a vector.

Data Types: `double`

# Version History

**Introduced in R2021b**

## See Also

add | subtract | area | intersect | rotate | rotateX | rotateY | rotateZ | show | mesh | plot | scale

# meshconfig

Change mesh mode of PCB component or shape structure

## Syntax

```
meshconfig(rfpcbobject,mode)
meshconfig(shape,mode)
m = meshconfig( ___ ,mode)
```

## Description

`meshconfig(rfpcbobject,mode)` changes the meshing mode of the PCB component according to the text input mode.

`meshconfig(shape,mode)` changes the meshing mode of the PCB shape according to the text input mode.

`m = meshconfig( ___ ,mode)` returns the mesh structure after changing the meshing mode of the PCB component or shape according to the text input mode.

## Examples

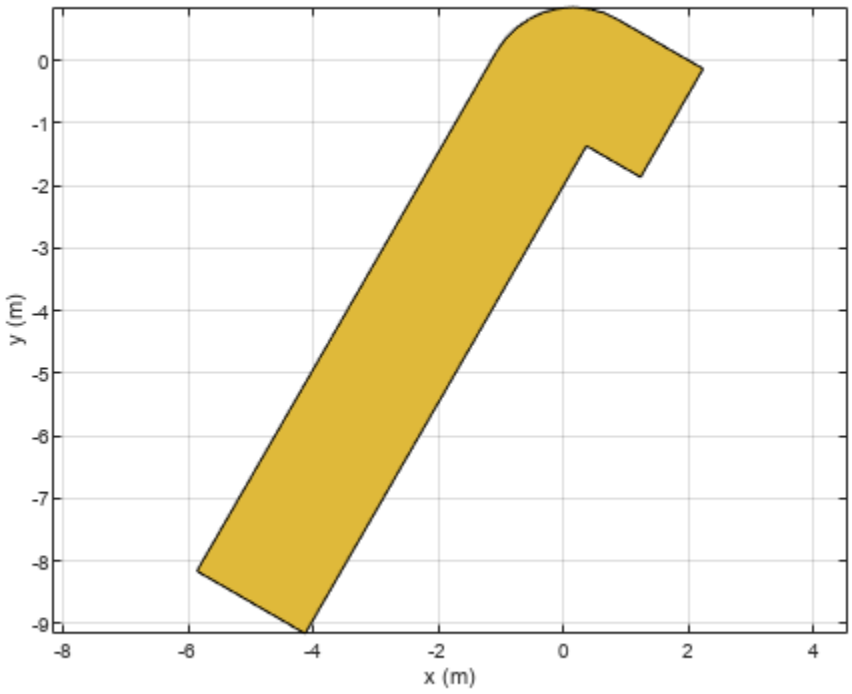
### Mesh Rotated Curved Bend Shape

Create a curved bend shape of lengths of 10 m and 2 m, width of 2 m, and rotate it about the Z-axis by 60 degrees.

```
bend = bendCurved(Length=[10 2],Width=[2 2],CurveRadius=1)
```

```
bend =
  bendCurved with properties:

              Name: 'myCurvedbend'
    ReferencePoint: [0 0]
            Length: [10 2]
             Width: [2 2]
       CurveRadius: 1
```

```
bend = rotateZ(bend,60);
show(bend)
```

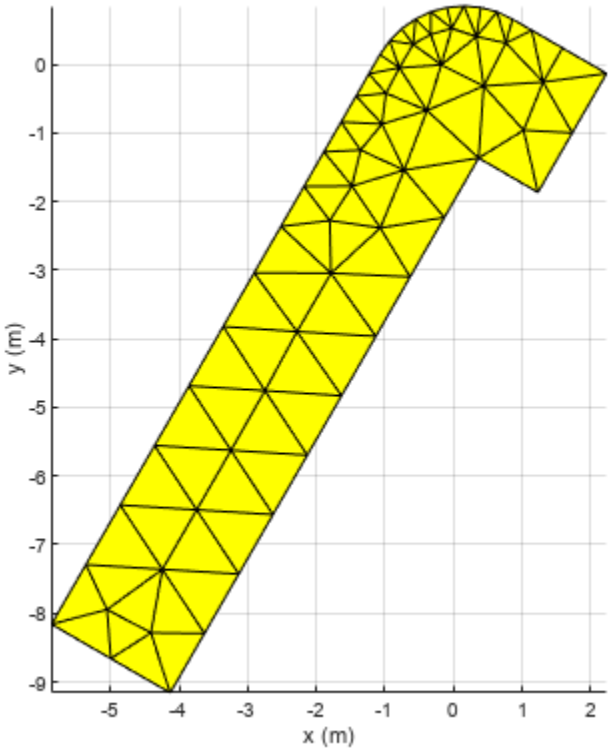



Mesh the curved bend shape at a maximum edge length of 1 m.

```
meshconfig(bend,"manual")
```

```
ans = struct with fields:
     NumTriangles: 0
    NumTetrahedra: 0
         NumBasis: []
    MaxEdgeLength: []
    MinEdgeLength: []
       GrowthRate: []
         MeshMode: 'manual'
```

```
mesh(bend,MaxEdgeLength=1)
```




## Input Arguments

### `rfpcbobject` — PCB component object

RF PCB object

PCB component object, specified as an RF PCB object. For a complete list of the PCB components, see "PCB Components Catalog".

### `shape` — Shape created using custom elements and shape objects

object handle

Shape created using custom elements and shape objects, specified as an object handle. For a complete list of the custom shapes, see "Custom Geometry and PCB Fabrication".

Example: `c = bendCurved; mesh(c)`

### `mode` — Meshing mode

`'auto'` (default) | `'manual'`

Meshing mode, specified as `'auto'` or `'manual'`.

Data Types: `char`

## Version History

**Introduced in R2021b**

## See Also

`mesh`

# info

Display information about PCB component structure

## Syntax

```
info(rfpcbobject)
```

## Description

`info(rfpcbobject)` displays information about the PCB component. as a structure:

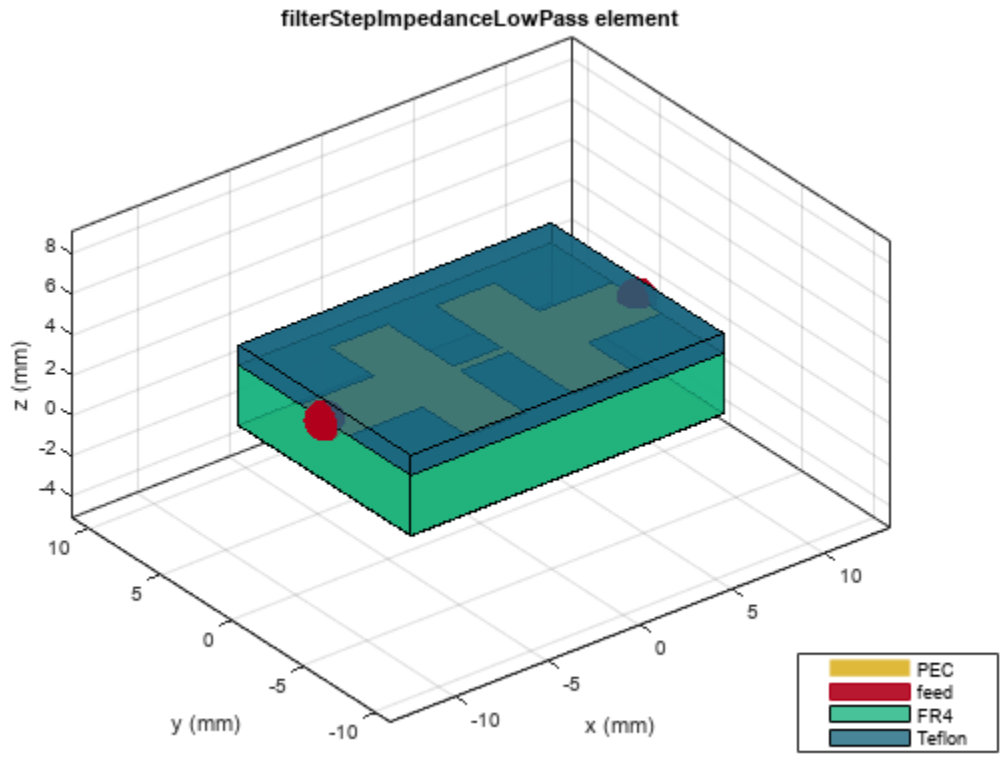
- `isSolved` – Logical specifying if an PCB component is solved.
- `isMeshed` – Logical specifying if an PCB component is meshed.
- `MeshingMode` – String specifying the meshing mode.
- `HasSubstrate` – Logical specifying if an PCB component uses a substrate.
- `HasLoad` – Logical specifying if an a PCB component has a load
- `PortFrequency` – Scalar or vector of frequencies used for port analysis.
- `FieldFrequency` – Scalar or vector of frequencies used for field analysis.
- `MemoryEstimate` – Approximate memory requirement for solving the antenna.

## Examples

### Create Stepped Impedance Lowpass Filter with Multilayer Dielectric Substrate

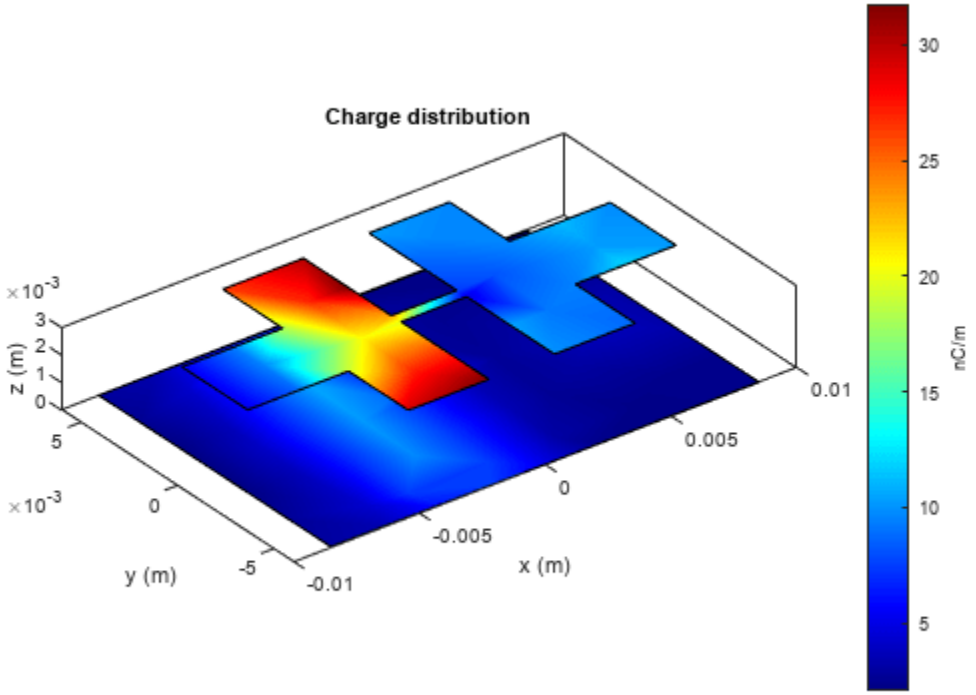
Create and view a stepped impedance lowpass filter with a multilayer dielectric substrate.

```
sub = dielectric("FR4","Teflon");
sub.Thickness =[0.003 0.001];
steppedfilter = filterStepImpedanceLowPass;
steppedfilter.Height = 0.003;
steppedfilter.Substrate = sub;
figure
show(steppedfilter)
```

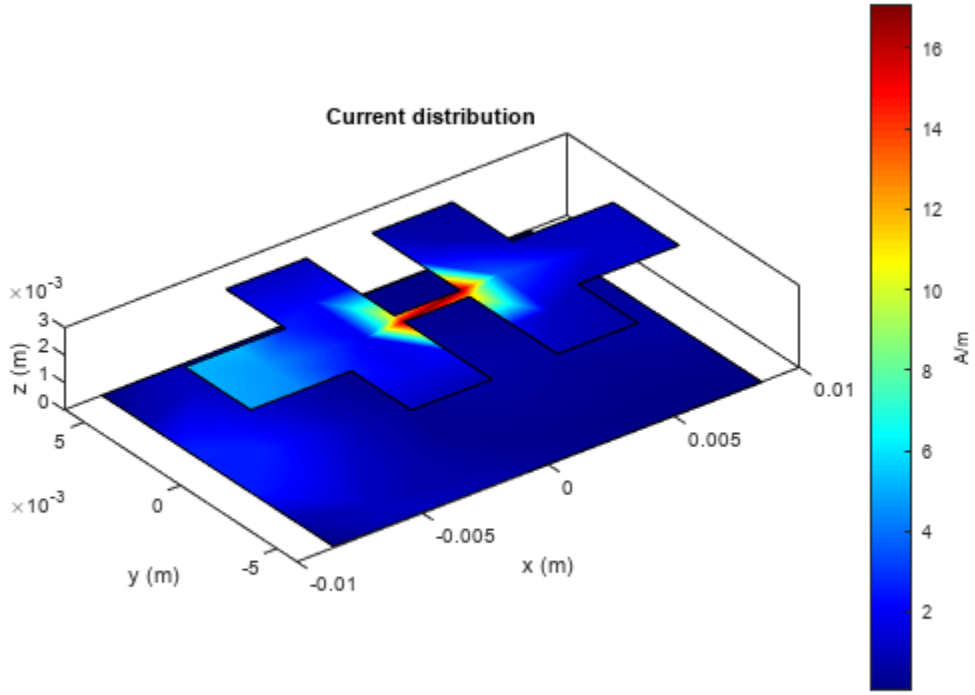



Plot the charge and current on the filter at 5 GHz.

```
figure
charge(steppedfilter,5e9)
```




```
figure
current(steppedfilter,5e9)
```




```
info(steppedfilter)
```

```
ans = struct with fields:
          IsSolved: "true"
          IsMeshed: "true"
       MeshingMode: "auto"
      HasSubstrate: "true"
           HasLoad: "false"
     PortFrequency: []
    MemoryEstimate: "790 MB"
```

## Input Arguments

### `rfpcbobject` — PCB component object

RF PCB object

PCB component object, specified as an RF PCB object. For a complete list of the PCB components, see “PCB Components Catalog”.

# Version History

**Introduced in R2021b**

## See Also

show

# cylinder2strip

Cylinder equivalent width approximation

## Syntax

```
w = cylinder2strip(r)
```

## Description

`w = cylinder2strip(r)` calculates the equivalent width of a strip approximation for a cylindrical cross section.

## Examples

### Calculate Cylinder to Strip Approximation

Calculate the width of the strip approximation to a cylinder of radius 20 mm.

```
w = cylinder2strip(20e-3)
```

```
w = 0.0800
```

## Input Arguments

### `r` — Cylindrical cross-section radius

scalar | vector

Cylindrical cross-section radius, specified as a scalar or vector in meters.

Example: 20e-3

Data Types: `double`

## Output Arguments

### `w` — Equivalent width of strip

scalar | vector

Equivalent width of strip, returned as a scalar or vector.

Data Types: `double`

# Version History

**Introduced in R2021b**

# voltagePort

Create voltage source with N-ports

## Syntax

```
v = voltagePort(N)
v = voltagePort( ___ ,Name=Value)
```

## Description

`v = voltagePort(N)` creates a voltage port source with *N* number of ports that you can use for excitation in an N-port PCB component.

`v = voltagePort( ___ ,Name=Value)` creates a voltage port source using additional name-value arguments.

## Examples

### Create Voltage Source

Create a voltage source with three ports.

```
v = voltagePort(3)
```

```
v =
  voltagePort with properties:

         NumPorts: 3
      FeedVoltage: [1 0 0]
        FeedPhase: [0 0 0]
    PortImpedance: 50
```

## Input Arguments

### `N` — Number of ports

positive scalar

Number of ports, specified as a positive scalar.

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `FeedVoltage=1`

**`NumPorts` — Number of ports**
positive scalar

Number of ports, specified as a positive scalar.

**`FeedVoltage` — Magnitude of voltage applied at each port**
positive scalar | vector

Magnitude of the voltage applied at each port, specified as a positive scalar or vector.

**`FeedPhase` — Phase shift applied to voltage at each port**
positive scalar | vector

Phase shift applied to the voltage at each port in degrees, specified as a positive scalar or vector.

**`PortImpedance` — Impedance to terminate each port**
positive scalar | vector

Impedance to terminate each port in ohms, specified as a positive scalar or vector.

## Version History

**Introduced in R2021b**

## See Also

`current` | `feedCurrent` | `charge`

# design

Design microstrip transmission line around specified frequency

## Syntax

```
mline = design(mlineobj,frequency)
mline = design( ___ ,Name=Value)
```

## Description

`mline = design(mlineobj,frequency)` designs a microstrip transmission line around the specified frequency.

`mline = design( ___ ,Name=Value)` designs a microstrip transmission line with additional options specified using name-value arguments.

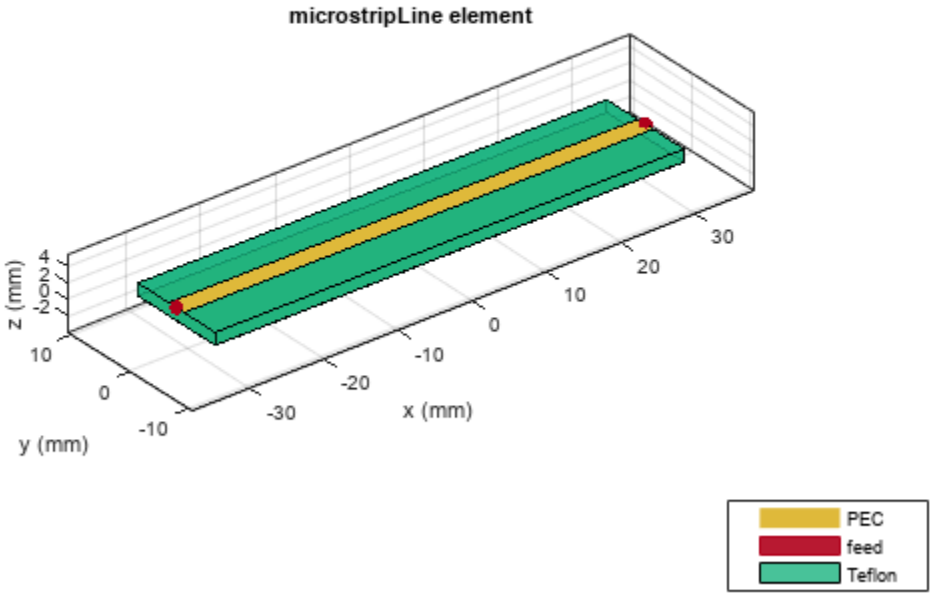
**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

### Design Microstrip Transmission Line Around 1.8 GHz

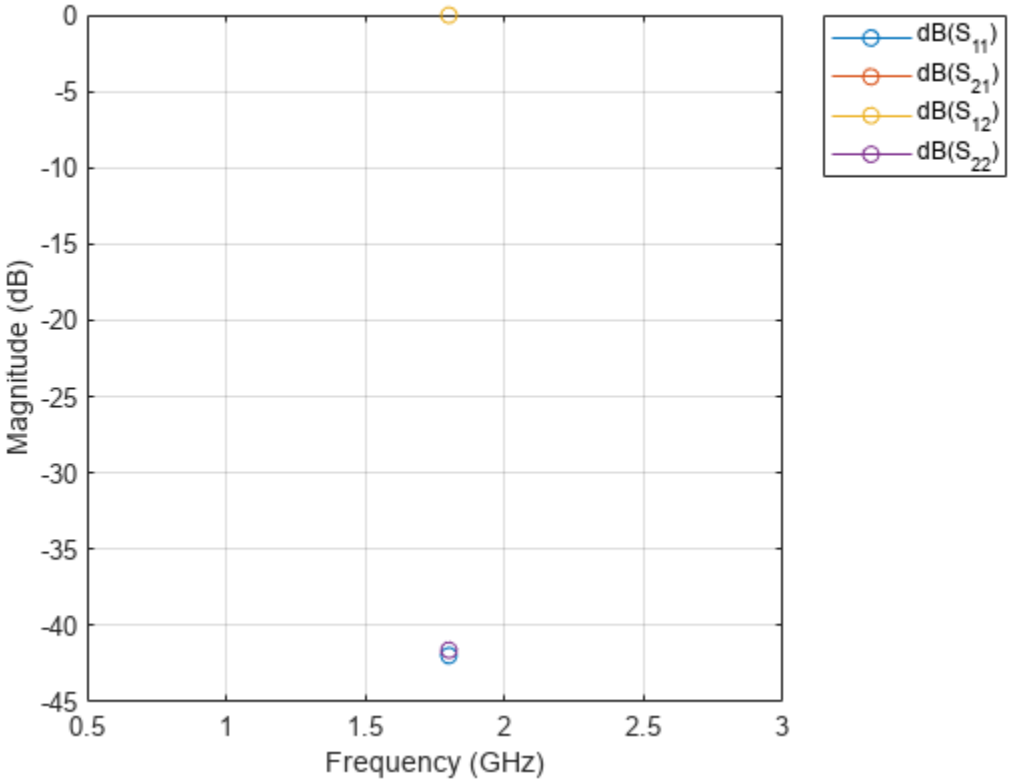
Design a microstrip line around 1.8 GHz and with a characteristic impedance of 75 ohms.

```
mline = design(microstripLine,1.8e9,Z0=75);
figure;
show(mline);
```




Plot the S-parameters of this line.

```
spar = sparameters(mline,1.8e9);
rfplot(spar)
```




## Input Arguments

### `mlineobj` — Microstrip transmission line

`microstripLine` object

Microstrip transmission line, specified as a `microstripLine` object.

Example: `mline = microstripLine; design(mline,2e9)` designs a microstrip transmission line around a frequency of 2 GHz.

### `frequency` — Design frequency of transmission line

real positive scalar

Design frequency of the transmission line, specified as a real positive scalar in hertz.

Example: `55e6`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=70`

**`Z0` — Characteristic impedance of microstrip transmission line**
`50` (default) | positive scalar

Characteristic impedance of the microstrip transmission line, specified as a positive scalar in ohms.

Data Types: `double`

**`LineLength` — Length of line**
`0.5` (default) | positive scalar

Length of the line, specified as a positive scalar in Lambda.

Data Types: `double`

## Output Arguments

**`mline` — Microstrip transmission line operating around specified frequency**
`microstripLine` object

Microstrip transmission line operating around the specified frequency, returned as a `microstripLine` object.

# Version History

**Introduced in R2021b**

## See Also

`sparameters`

# design

Design coplanar waveguide transmission line around particular frequency

## Syntax

```
waveguide = design(cpw,frequency)
waveguide = design( ___ ,Name=Value)
```

## Description

`waveguide = design(cpw,frequency)` designs an coplanar waveguide line around the specified frequency.

`waveguide = design( ___ ,Name=Value)` designs a coplanar waveguide with additional options specified using name-value arguments.

---

**Note** PCB components designed using the `design` function operates around the specified frequency with a 10-15% tolerance.

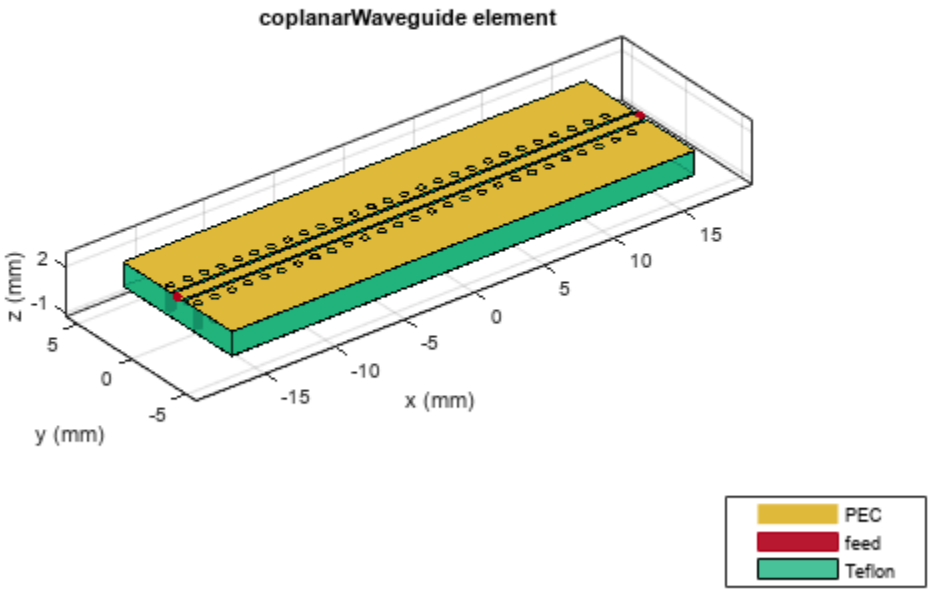
---

## Examples

### Design Coplanar Waveguide Around 1.8 GHz

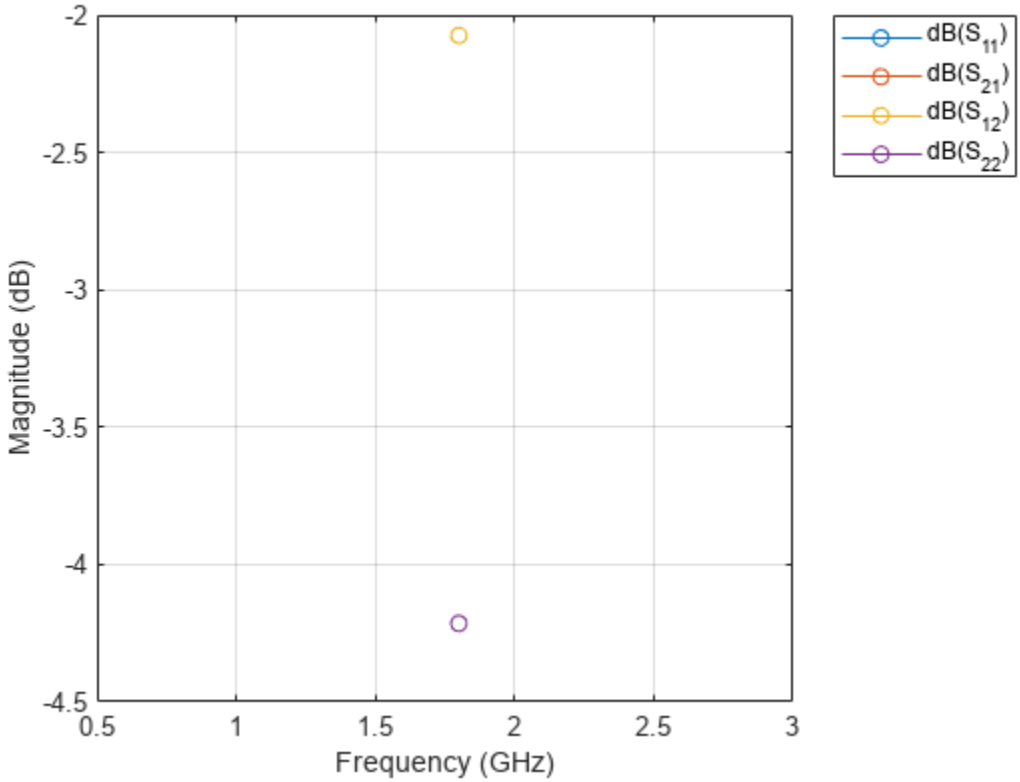
Design a lambda/4 coplanar waveguide at 1.8 GHz with a characteristic impedance of 75 ohms.

```
cpw = design(coplanarWaveguide, 1.8e9,Z0=75,LineLength=0.25);
figure;
show(cpw);
```




Plot the s-parameters of the waveguide at 1.8 GHz.

```
spar = sparameters(cpw,1.8e9);
rfplot(spar)
```




## Input Arguments

### `cpw` — Coplanar waveguide

`coplanarWaveguide` object

Coplanar waveguide transmission line, specified as a `coplanarWaveguide` object.

Example: `waveguide = coplanarWaveguide; waveguide = design(waveguide,2e9)` designs a coplanar waveguide around a frequency of 2 GHz.

### `frequency` — Design frequency of transmission line

real positive scalar

Design frequency of the transmission line, specified as a real positive scalar in hertz.

Example: `3e9`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=75`

**`Z0` — Characteristic impedance of line**
`50` (default) | positive scalar

Characteristic impedance of the line, specified as a positive scalar in ohms.

Data Types: `double`

**`LineLength` — Length of coplanar waveguide**
`0.5` (default) | positive scalar

Length of the coplanar waveguide, specified as a positive scalar in terms of Lambda.

Data Types: `double`

## Output Arguments

**`waveguide` — Coplanar waveguide operating around specified reference frequency**
`coplanarWaveguide` object

Coplanar waveguide operating around the specified reference frequency, returned as a `coplanarWaveguide` object.

# Version History

**Introduced in R2021b**

## See Also

`sparameters`

# design

Design coupled microstrip transmission line around particular frequency

## Syntax

```
cline = design(clineobj,frequency)
cline = design( ___ ,Name=Value)
```

## Description

`cline = design(clineobj,frequency)` designs a coupled microstrip transmission line around the specified frequency.

`cline = design( ___ ,Name=Value)` designs a coupled microstrip transmission line with additional options specified using name-value arguments.

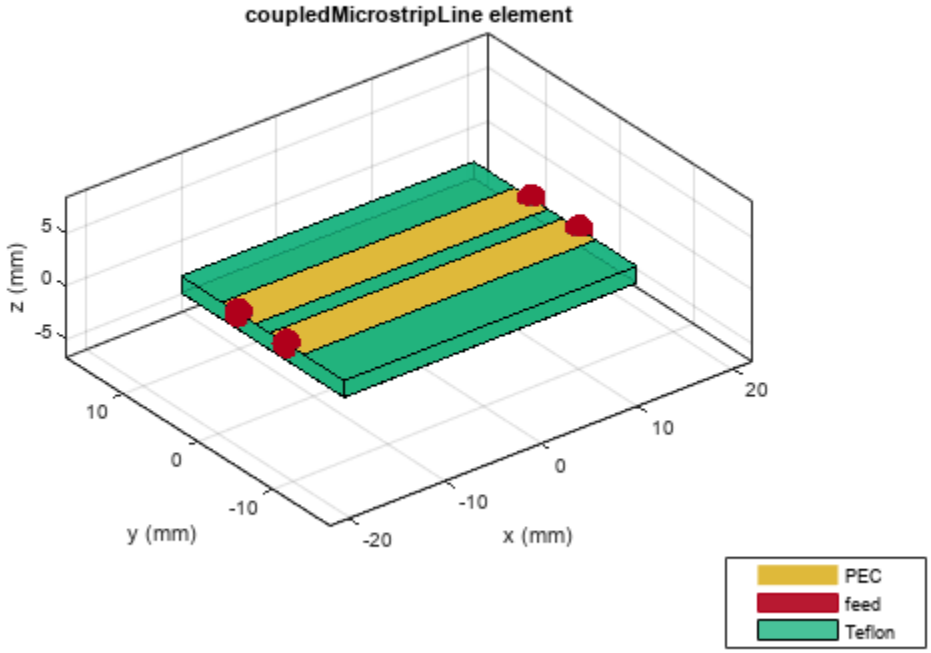
**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

### Design Coupled Microstrip Transmission Line Around 1.8 GHz

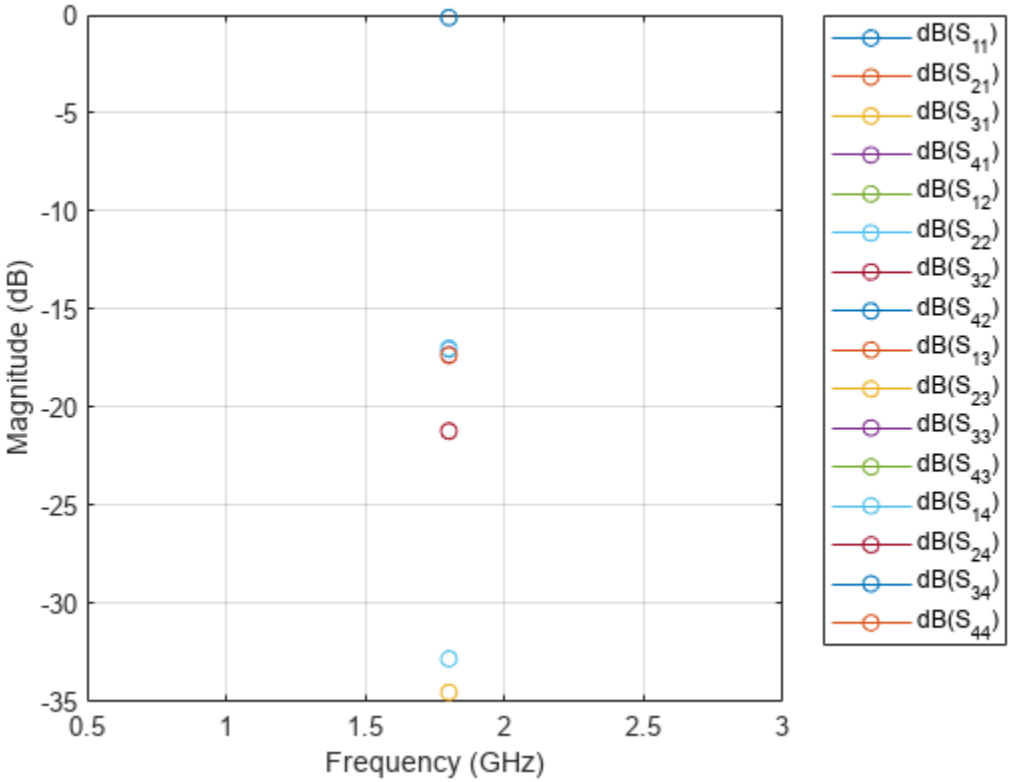
Design a coupled microstrip line at 1.8 GHz with an even mode impedance of 60 ohms.

```
cline = design(coupledMicrostripLine,1.8e9,Z0e=60);
show(cline);
```




Plot the S-parameters of the transmission line.

```
spar = sparameters(cline,1.8e9);
rfplot(spar)
```




## Input Arguments

### `clineobj` — Coupled microstrip transmission line

`coupledMicrostripLine` object

Coupled microstrip transmission line, specified as a `coupledMicrostripLine` object.

Example: `cline = coupledMicrostripLine; design(cline,2e9)` designs a coupled microstrip transmission line around a frequency of 2 GHz.

### `frequency` — Design frequency of transmission line

real positive scalar

Design frequency of the transmission line, specified as a real positive scalar in hertz.

Example: `2e9`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0e=45`

**Z0e — Even mode impedance**
52 (default) | positive scalar

Even mode impedance of the transmission line, specified as a positive scalar in ohms.

Data Types: `double`

**Z0o — Odd mode impedance**
48 (default) | positive scalar

Odd mode impedance of the transmission line, specified as a positive scalar in ohms.

Data Types: `double`

## Output Arguments

**cline — Coupled microstrip transmission line operating around specified frequency**
`coupledMicrostripLine` object

Coupled microstrip transmission line operating around the specified frequency, returned as a `coupledMicrostripLine` object.

# Version History

**Introduced in R2021b**

## See Also

`sparameters`

# design

Design branchline coupler around particular frequency

## Syntax

```
coupler = design(couplerobj,frequency)
coupler = design( ___ ,Name,Value)
```

## Description

`coupler = design(couplerobj,frequency)` designs a branchline coupler around the specified frequency.

`coupler = design( ___ ,Name,Value)` designs a branchline coupler line with additional options specified using name-value arguments.

---

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

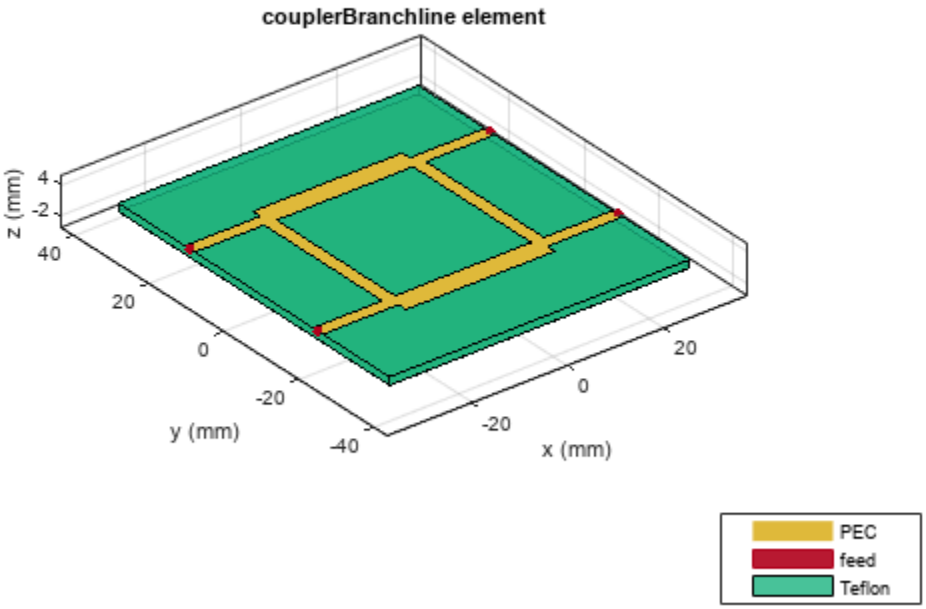
---

## Examples

### Design Branchline Coupler Around 1.8 GHz

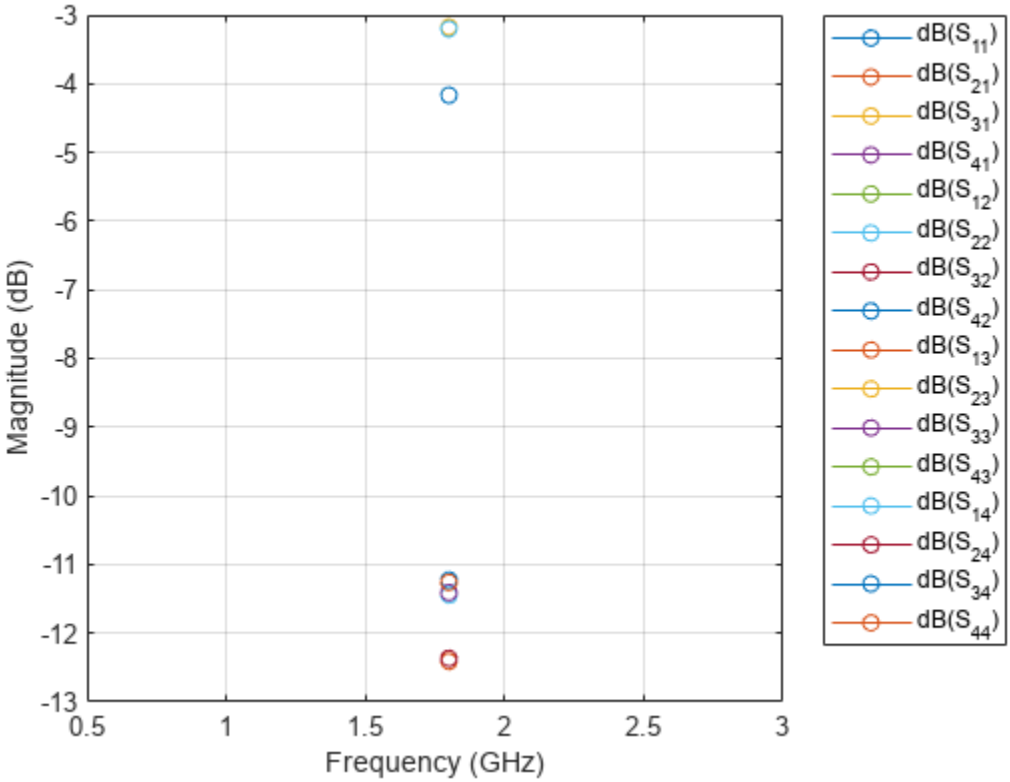
Design a branchline coupler at 1.8 GHz and with a Z0 of 75 ohms.

```
coupler = design(couplerBranchline,1.8e9,Z0=75);
show(coupler);
```




Plot the s-parameters of the coupler at 1.8 GHz.

```
spar = sparameters(coupler,1.8e9);
rfplot(spar)
```




## Input Arguments

### `couplerobj` — Branchline coupler

`couplerBranchline` object

Branchline coupler, specified as a `couplerBranchline` object.

Example: `coupler = couplerBranchline; design(coupler,2e9)` designs a branchline coupler around a frequency of 2 GHz.

### `frequency` — Design frequency of coupler

real positive scalar

Design frequency of the coupler, specified as a real positive scalar in hertz.

Example: `3e9`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=70`

**`Z0` — Characteristic impedance of coupler**
`50` (default) | positive scalar

Characteristic impedance of the coupler, specified as a positive scalar in ohms.

Data Types: `double`

## Output Arguments

**`coupler` — Branchline coupler operating around specified frequency**
`couplreBranchline` object

Branchline coupler operating around the specified frequency, returned as a `couplreBranchline` object.

# Version History

**Introduced in R2021b**

## See Also

`sparameters`

# design

Design rat-race coupler around specified frequency

## Syntax

```
coupler = design(couplerobj,frequency)
coupler = design( ___ ,Name=Value)
```

## Description

`coupler = design(couplerobj,frequency)` designs a rat-race coupler around the specified frequency.

`coupler = design( ___ ,Name=Value)` designs a rat-race coupler line with additional options specified using name-value arguments.

---

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

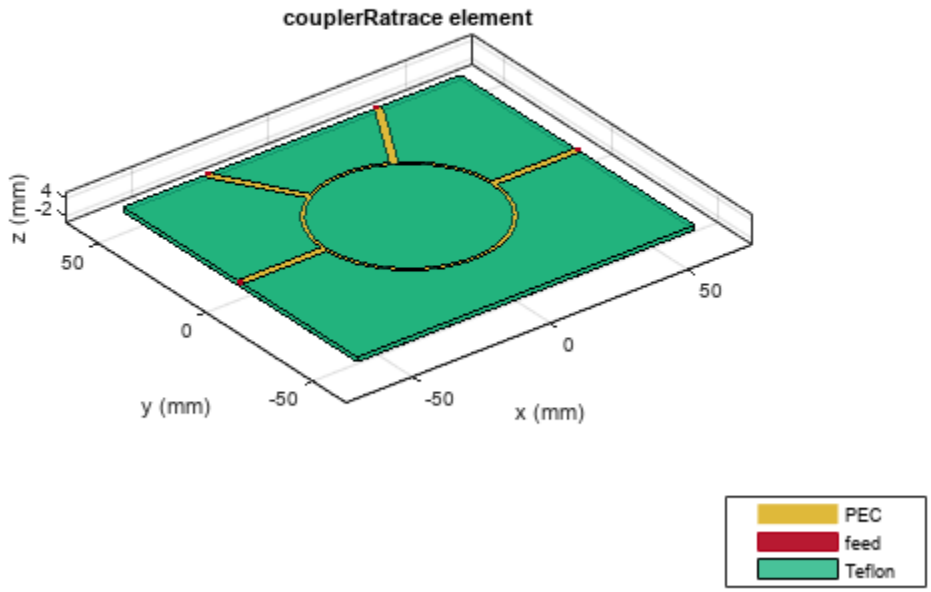
---

## Examples

### Design Rat-race Coupler Around 1.8 GHz

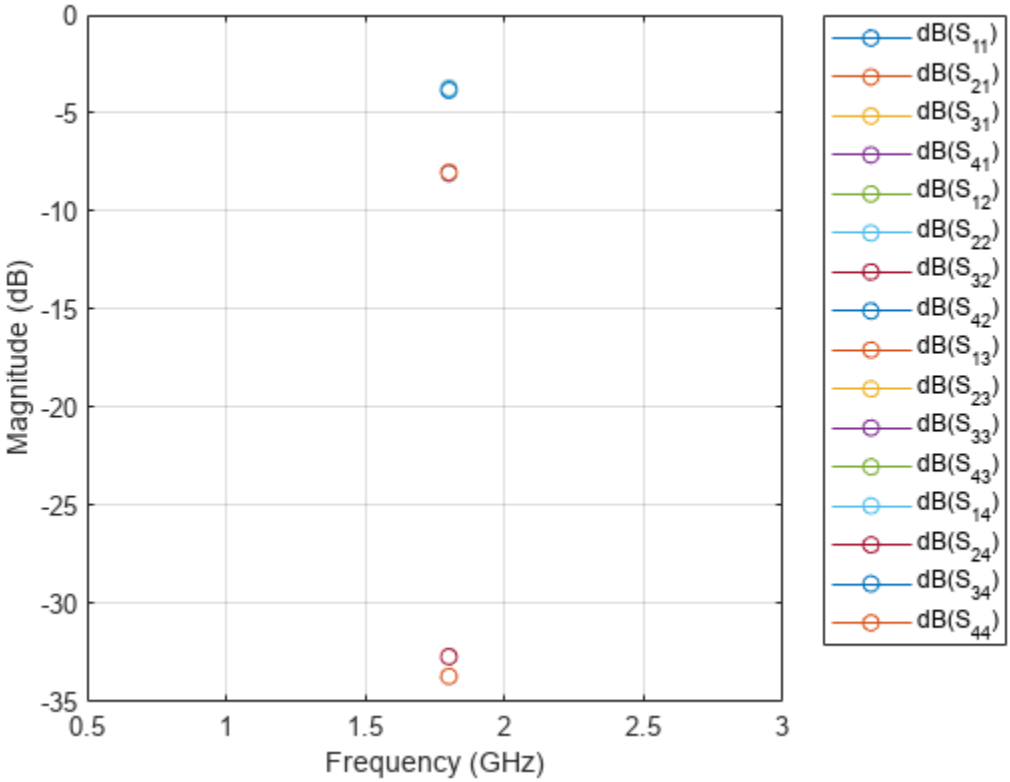
Design a rat-race coupler at 1.8 GHz and with a charecteristic impedance of 75 ohms.

```
coupler = design(couplerRatrace,1.8e9,Z0=75);
show(coupler);
```




Plot the S-parameters of the coupler at 1.8 GHz.

```
spar = sparameters(coupler,1.8e9);
rfplot(spar)
```




## Input Arguments

### `couplerobj` — Rat-race coupler

`couplerRatrace` object

Rat-race coupler, specified as a `couplerRatrace` object.

Example: `coupler = couplerRatrace; design(coupler,2e9)` designs a rat-race coupler around a frequency of 2 GHz.

### `frequency` — Design frequency of rat-race coupler

real positive scalar

Design frequency of the rat-race coupler, specified as a real positive scalar in hertz.

Example: `2.5e9`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=70`

**`Z0` — Characteristic impedance of coupler**
`50` (default) | positive scalar

Characteristic impedance of the coupler in ohms, specified as a positive scalar.

Data Types: `double`

## Output Arguments

**`coupler` — Rat-race coupler operating around specified reference frequency**
`couplerRatrace` object

Rat-race coupler operating around the specified reference frequency, returned as a `couplerRatrace` object.

# Version History

**Introduced in R2021b**

## See Also

`sparameters`

# sparameters

Calculate S-parameters for RF PCB objects

## Syntax

```
sobj = sparameters(rfpcbobj,freq)
sobj = sparameters( ___ ,Z0)
sobj = sparameters( ___ ,Name=Value)

sobj = sparameters(data,freq)
sobj = sparameters(data,freq,Z0)

sobj = sparameters(filename)
```

## Description

`sobj = sparameters(rfpcbobj,freq)` calculates the S-parameters for the RF PCB object `rfpcbobj` over the specified frequency values.

`sobj = sparameters( ___ ,Z0)` calculates the S-parameters for the reference impedance `Z0`.

`sobj = sparameters( ___ ,Name=Value)` calculates S-parameters using one or more name-value arguments in addition to any of the input argument combinations in previous syntaxes

`sobj = sparameters(data,freq)` creates an S-parameter object from the S-parameter data provided in `data` over the specified frequencies values.

`sobj = sparameters(data,freq,Z0)` creates an S-parameter object for the reference impedance `Z0`.

`sobj = sparameters(filename)` creates an S-parameter object from the data provided in the Touchstone file specified in `filename`.

## Examples

### Calculate S-parameters for Wilkinson Power Splitter

Create a Wilkinson power splitter object.

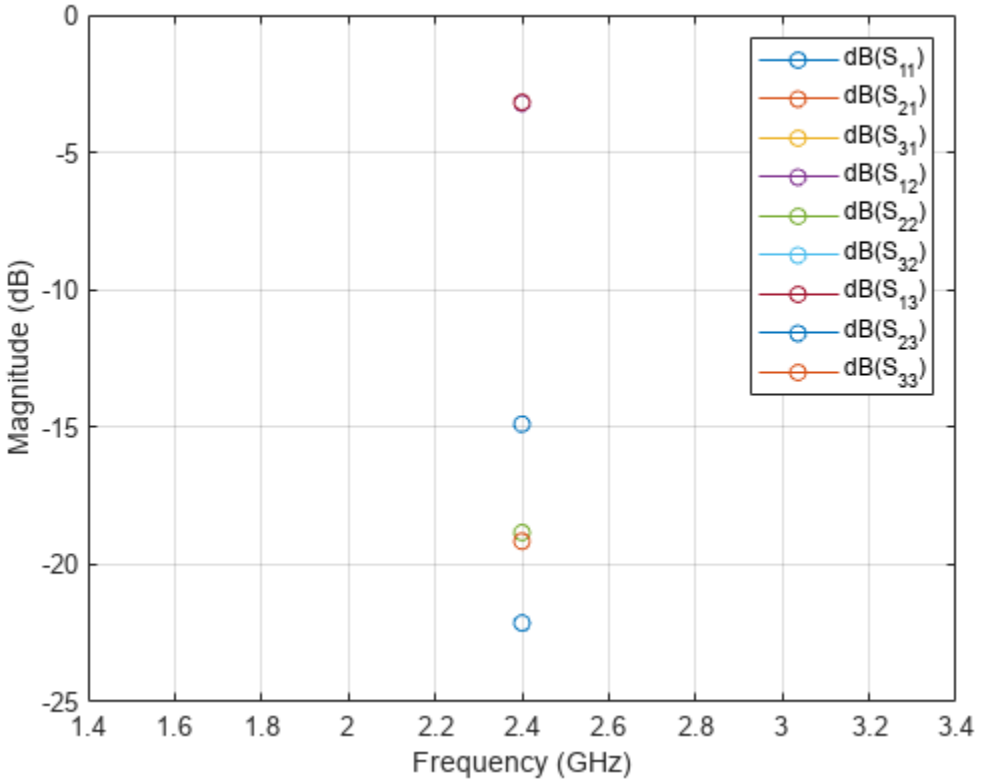
```
rfpcbobj = wilkinsonSplitter;
```

Calculate the S-parameters for the Wilkinson power splitter at 2.4 GHz with the reference impedance of 50 ohms.

```
Sobj = sparameters(wilkinsonSplitter,2.4e9,50);
```

Plot the S-parameters using the `rfplot` function.

```
rfplot(Sobj)
```




### Calculate S-Parameters of Right Angle Bend

Design a microstrip transmission line at 3 GHz with 75 ohms impedance.

```
m = microstripLine(Length=0.0379,Width=0.0027,Height=0.0016,GroundPlaneWidth=0.0133);
```

Create a right angle bend with length equal to half the length of the transmission line and width equal to the width of the transmission line.

```
layer2d = bendRightAngle( Length=[m.Length/2 m.Length/2],...
Width=[m.Width m.Width]);
```

Convert the right angle bend to a 3-D component.

```
robj = pcbComponent(layer2d);
```

Add thickness and substrate layers to the board.

```
robj.BoardThickness = m.Substrate.Thickness;
robj.Layers{2} = m.Substrate;
```

Define frequency points to calculate the S-parameters.

```
freq = (1:2:40)*100e6;
```

Calculate the S-parameters of the right angle bend using the behavioral model.

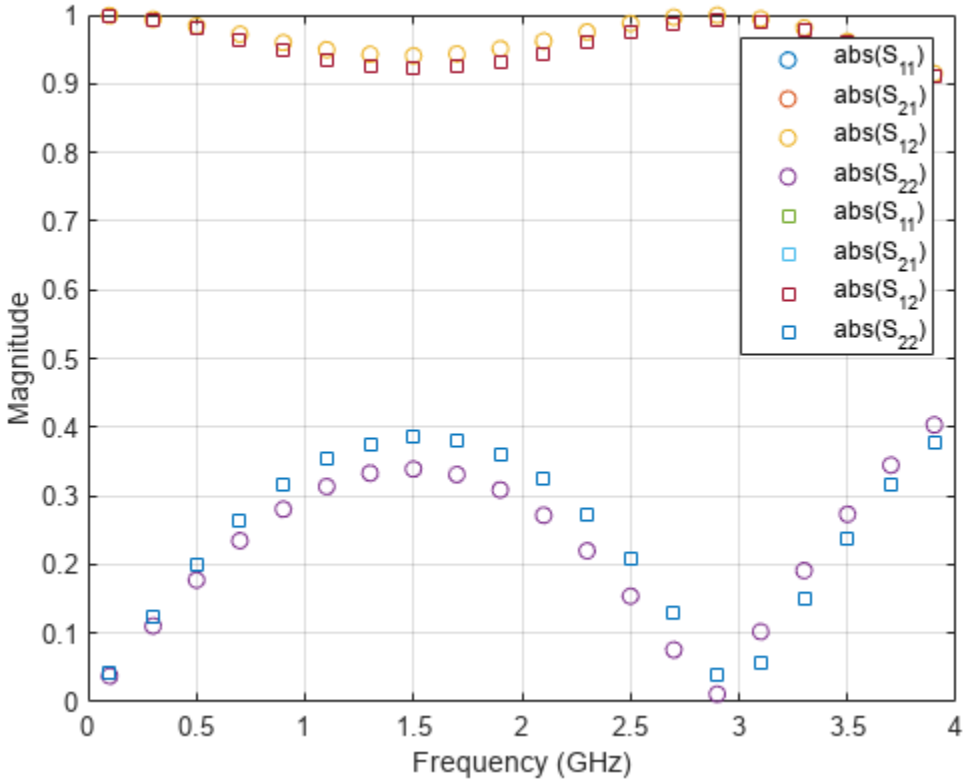
```
Sckt1 = sparameters(robj,freq,Behavioral=true);
```

Calculate the S-parameters of the right angle bend using the electromagnetic solver.

```
Sem1 = sparameters(robj,freq);
```

Plot the S-parameter data using the `rfplot` function.

```
rfplot(Sckt1,'abs','o')
hold on
rfplot(Sem1,'abs','s')
```




## Input Arguments

### `rfpcbobj` — Input object

RF PCB object

Input object, specified as a RF PCB object. You can specify either a PCB component, a microstrip bend, or a trace. For complete list of PCB components, microstrip bends, and traces, see “PCB Components Catalog” and “Custom Geometry and PCB Fabrication”.

### `data` — S-parameter data

array of complex numbers

S-parameter data, specified as an array of complex numbers of the size *N*-by-*N*-by-*K*, where *K* represents number of frequency points.

**`freq` — S-parameter frequency**
scalar | vector

S-parameter frequencies, specified as a scalar or vector of positive real numbers in the ascending order.

**`Z0` — Reference impedance**
`50` (default) | positive real scalar

Reference impedance in ohms, specified as a positive real scalar.

**`filename` — Name of Touchstone file**
character vector | string scalar

Name of the Touchstone file containing network parameter data, specified as a character vector or string scalar. If the file is in the current folder or in a folder on the MATLAB® path, specify the file name. If the file is not in the current folder or in a folder on the MATLAB path, then specify the full or relative path name.

Example: `sobj = sparameters('defaultbandpass.s2p');`

**Name-Value Pair Arguments**

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

*Before R2021a, use commas to separate each name and value, and enclose* `Name` *in quotes.*

Example: `Sobj = sparameters(robj,freq,Behavioral=true)`

**`Behavioral` — Behavioral model of RF PCB component and bend**
`false or 0` (default) | `true or 1`

Behavioral model of an RF PCB component and bend, specified as `true` (`1`) or `false` (`0`). You can compute the behavioral model for these `rfpcb` objects:

| | |
|---|---|
| Bends | • `bendRightAngle`<br>• `bendCurved`<br>• `bendMitered`<br><br>**Note** The `sparameters` function does not support the behavioral model for objects with unequal widths such as `bendRightAngle`, `bendCurved`, and `bendMitered` objects. |
| Traces | • `traceTee`<br>• `traceCross`<br><br>**Note** The `sparameters` function does not support the behavioral model for Asymmetric tee- and cross-junction traces. |

| | |
|---|---|
| Transmission line objects | • `microstripLine`<br>• `coplanarWaveguide` |
| Inductor | `spiralInductor` |
| Capacitor | `interdigitalCapacitor` |
| Splitter and Couplers | • `couplerRatrace`<br>• `couplerBranchline`<br>• `wilkinsonSplitter`<br>• `wilkinsonSplitterUnequal`<br>• `splitterTee` |
| Vias | • `viaSingleEnded` |

**Note**

- Before using the `sparameters` function to calculate S-parameters for bends and traces, convert bends and traces to PCB components using the `pcbComponent` function.
- The `sparameters` function does not support using the behavioral model argument for:
  - Objects with unequal widths like `bendRightAngle`, `bendCurved`, and `bendMitered`
  - Asymmetric tee and cross-junction traces

Example: `Sobj = sparameters(microstripline,freq,Behavioral = true)`

## Output Arguments

### `sobj` — S-parameters

S-parameter object

S-parameters, returned as an object with the following properties:

- `NumPorts` — Number of ports, *N*, returned as an integer. The function calculates this value automatically when you create the object.
- `Frequencies` — S-parameter frequency, returned as a scalar or row vector of length, *K*, in the ascending order. The function sets this property from the `filename` or `freq` input arguments.
- `Parameters` — S-parameters, returned as an *N*-by-*N*-by-*K* array of complex numbers. The function sets this property from the `filename` or `data` input arguments.
- `Impedance` — Reference impedance in ohms, returned as a positive real scalar. The function sets this property from the `filename` or `Z0` input arguments. If you do not provide reference impedance,, the function uses a default value of `50`.

# Version History

**Introduced in R2021b**

## See Also

`current` | `getZ0`

# layout

Plot all metal layers and board shape

## Syntax

```
layout(rfpcbobject)
```

## Description

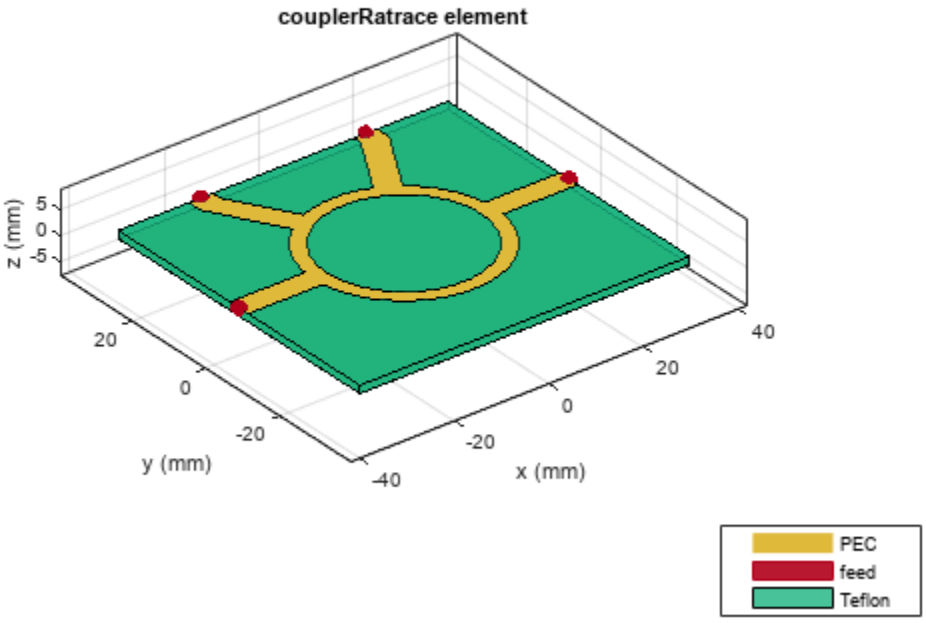
`layout(rfpcbobject)` displays all the metal layers and the PCB shape in the figure window. The red filled circle correspond to PCB feed points and the blue filled circles correspond to vias.

## Examples

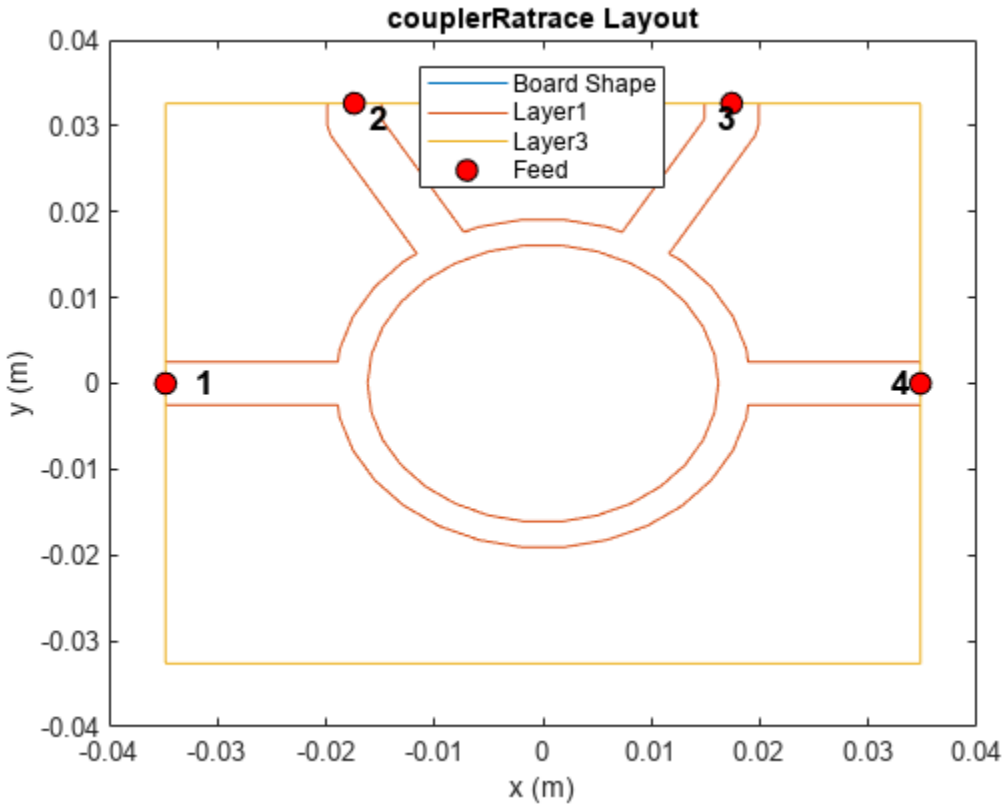
### Display Ratrace Coupler Layout

Display the layout of a ratrace coupler.

```
coupler = couplerRatrace;
show(coupler)
```



```
layout(coupler)
```




## Input Arguments

### `rfpcbobject` — PCB component

object handle

PCB component, specified as an object handle. For complete list of PCB components and shapes, see “PCB Components Catalog”

# Version History

**Introduced in R2021b**

## See Also

`show` | `info`

# shapes

Extract all metal layer shapes of PCB component

## Syntax

```
shapes(rfpcbobject)
```

## Description

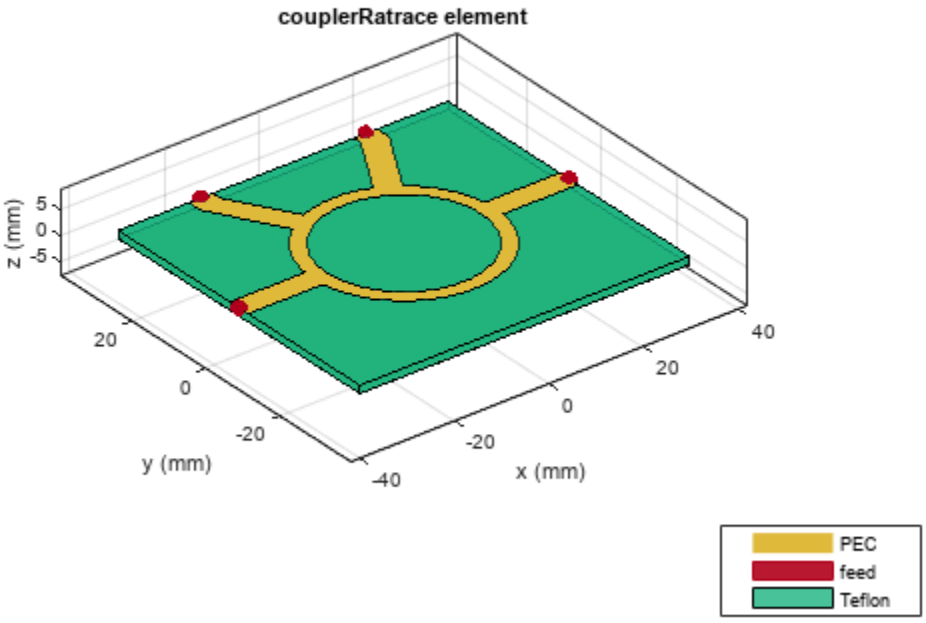
`shapes(rfpcbobject)` extracts all metal layer shapes of a PCB component and organizes them into an output structure.

## Examples

### Extract Rat-race Coupler Shapes

Extract the shapes of a rat-race coupler.

```
coupler = couplerRatrace;
show(coupler)
```



```
s = shapes(coupler)
```

```
s = struct with fields:
    Layer1: [1x1 antenna.Polygon]
    Layer2: [1x1 antenna.Rectangle]
```

## Input Arguments

### `rfpcbobject` — PCB component object

RF PCB object

PCB component object, specified as an RF PCB object. For a complete list of the PCB components, see “PCB Components Catalog”.

# Version History

**Introduced in R2021b**

## See Also

`layout` | `show`

# design

Design Wilkinson splitter around specified frequency

## Syntax

```
wsplitter = design(wsplitterobj,frequency)
wsplitter = design( ___ ,Name=Value)
```

## Description

`wsplitter = design(wsplitterobj,frequency)` designs a Wilkinson splitter around the specified frequency.

`wsplitter = design( ___ ,Name=Value)` designs a Wilkinson splitter with additional options specified using name-value arguments.

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

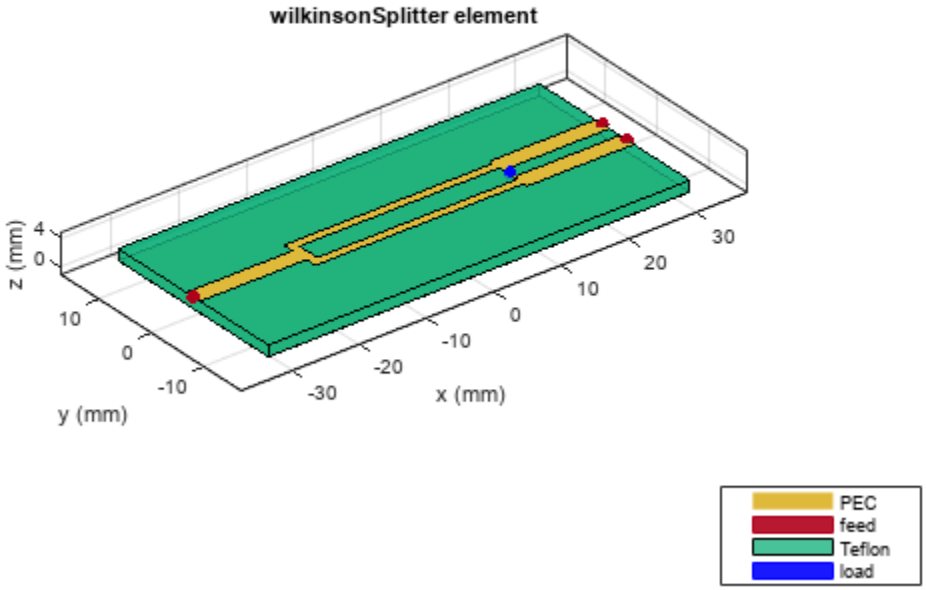
### Design Wilkinson Splitter at 1.8 GHz

Design a Wilkinson splitter at 1.8 GHz and with a Z0 of 75 ohm.

```
wsplitter = design(wilkinsonSplitter,1.8e9,Z0=75);
```

View the splitter.

```
figure;
show(wsplitter);
```




## Input Arguments

### `wsplitterobj` — Wilkinson splitter

`wilkinsonSplitter` object

Wilkinson splitter, specified as a `wilkinsonSplitter` object.

Example: `wsplitterobj = wilkinsonSplitter; design(wsplitterobj,2e9)` designs a Wilkinson splitter around a frequency of 2 GHz.

### `frequency` — Design frequency of Wilkinson splitter

real positive scalar

Design frequency of the Wilkinson splitter, specified as a real positive scalar in hertz.

Example: `55e6`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=2`

**`Z0` — Characteristic impedance of splitter**
`50` (default) | positive scalar

Characteristic impedance of the splitter, specified as a positive scalar in ohms.

Data Types: `double`

## Output Arguments

**`wsplitter` — Wilkinson splitter operating around specified frequency**
`wilkinsonSplitter` object

Wilkinson splitter operating around the specified frequency, returned as a `wilkinsonSplitter` object.

# Version History

**Introduced in R2021b**

## See Also

`sparameters`

# design

Design unequal Wilkinson splitter around specified frequency

## Syntax

```
uwsplitter = design(uwsplitterobj,frequency)
uwsplitter = design( ___ ,Name=Value)
```

## Description

`uwsplitter = design(uwsplitterobj,frequency)` designs a unequal Wilkinson splitter around the specified frequency.

`uwsplitter = design( ___ ,Name=Value)` designs a unequal Wilkinson splitter with additional options specified using name-value arguments.

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

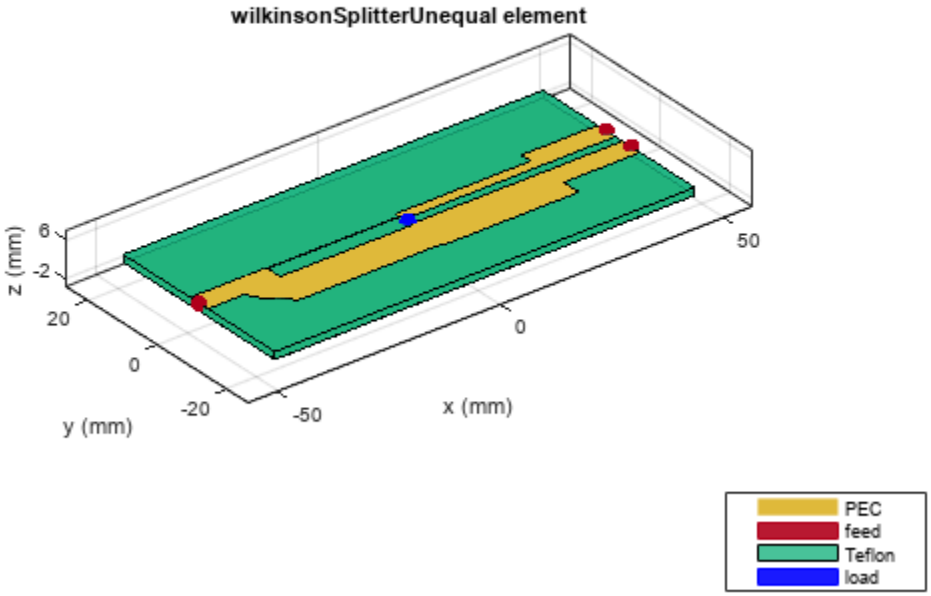
### Design Unequal Wilkinson Splitter at 1.8 GHZ

Design an unequal wilkinson at 1.8 GHz with a characteristic impedance of 50 ohms and a PowerRatio of 6.

```
uwilk = design(wilkinsonSplitterUnequal,1.8e9,Z0=50,PowerRatio=6);
```

View the splitter

```
show(uwilk);
```




## Input Arguments

### `uwsplitterobj` — Unequal Wilkinson splitter

`wilkinsonSplitterUnequal` object

Unequal Wilkinson splitter, specified as a `wilkinsonSplitterUnequal` object.

Example: `uwsplitterobj = wilkinsonSplitterUnequal; design(wsplitterobj,2e9)` designs a unequal Wilkinson splitter around a frequency of 2 GHz.

### `frequency` — Design frequency of unequal Wilkinson splitter

real positive scalar

Design frequency of the unequal Wilkinson splitter, specified as a real positive scalar in hertz.

Example: `2.5e9`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=75`

**`Z0` — Characteristic impedance of splitter**
`50` (default) | positive scalar

Characteristic impedance of the splitter, specified as a positive scalar in ohms.

Data Types: `double`

**`PowerRatio` — Power division ratio between two output ports of splitter**
`2` (default) | positive scalar

Power division ratio between the two output ports of the splitter, specified as a positive scalar.

Data Types: `double`

## Output Arguments

**`uwsplitter` — Unequal Wilkinson splitter operating around specified frequency**
`wilkinsonSplitterUnequal` object

Unequal Wilkinson splitter operating around the specified frequency, returned as a `wilkinsonSplitterUnequal` object.

# Version History
**Introduced in R2021b**

# design

Design coupled line filter around specified frequency

## Syntax

```
clfilter = design(clfilterobj,frequency)
clfilter = design( ___ ,Name,Value)
```

## Description

`clfilter = design(clfilterobj,frequency)` designs a coupled line filter around the specified frequency.

`clfilter = design( ___ ,Name,Value)` designs a unequal Wilkinson splitter with additional options specified using name-value arguments.

---

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

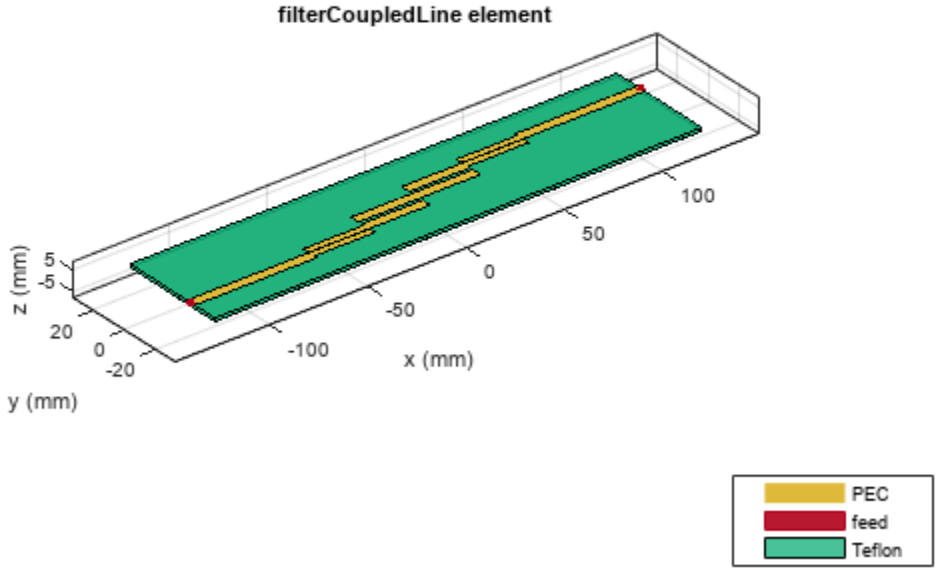
---

## Examples

### Design Coupled Line Filter Around 1.8 GHz.

Design a coupled line filter around 1.8 GHz and a fractional bandwidth of 10 percent.

```
clfilter = design(filterCoupledLine,1.8e9,FBW=10);
show(clfilter)
```




## Input Arguments

### `clfilterobj` — Coupled line filter

`filterCoupledLine` object

Coupled line filter, specified as a `filterCoupledLine` object.

Example: `clfilterobj = filterCoupledLine; design(clfilterobj,2e9)` designs a coupled line filter around a frequency of 2 GHz.

### `frequency` — Design frequency of coupled line filter

real positive scalar

Design frequency of coupled line filter, specified as a real positive scalar in hertz.

Example: `5e9`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `FilterType='ButterWorth'`

**`FilterType` — Type of filter**
`'Butterworth'` (default) | positive scalar

Type of filter, specified as `'Butterworth'`, `'Chebyshev'`, or `'InverseChebyshev'`.

Data Types: `double`

**`FBW` — Fractional bandwidth of filter response**
`10` (default) | positive scalar

Fractional bandwidth of the filter response, specified as positive scalar in percents.

Data Types: `double`

**`RippleFactor` — Passband factor of Chebyshev filter**
`0.01` (default) | positive scalar

Passband factor of the Chebyshev filter, specified as positive scalar in decibels. For Butterworth filter, the passband factor is not required.

Data Types: `double`

## Output Arguments

**`clfilter` — Coupled line filter around specified reference frequency**
`filterCoupledLine` object

Coupled line filter around the specified frequency, returned as a `filterCoupledLine` object.

# Version History

**Introduced in R2021b**

## See Also

`sparameters`

# design

Design stepped impedance low pass filter around desired cut-off frequency

## Syntax

```
sifilter = design(sifilterobj,frequency)
sifilter = design( ___ ,Name=Value)
```

## Description

`sifilter = design(sifilterobj,frequency)` designs a stepped impedance low pass filter around the cut-off frequency.

`sifilter = design( ___ ,Name=Value)` designs a stepped impedance low pass filter with additional options specified by name-value arguments.

**Note**

- PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.
- The design for stepped impedance low pass filter is based on analytical equations. Analyzing the parameters using EM-simulation model causes a shift in the cut-off frequency towards the lower end of the frequency range. This is an expected behavior due to the coupling effect.

## Examples

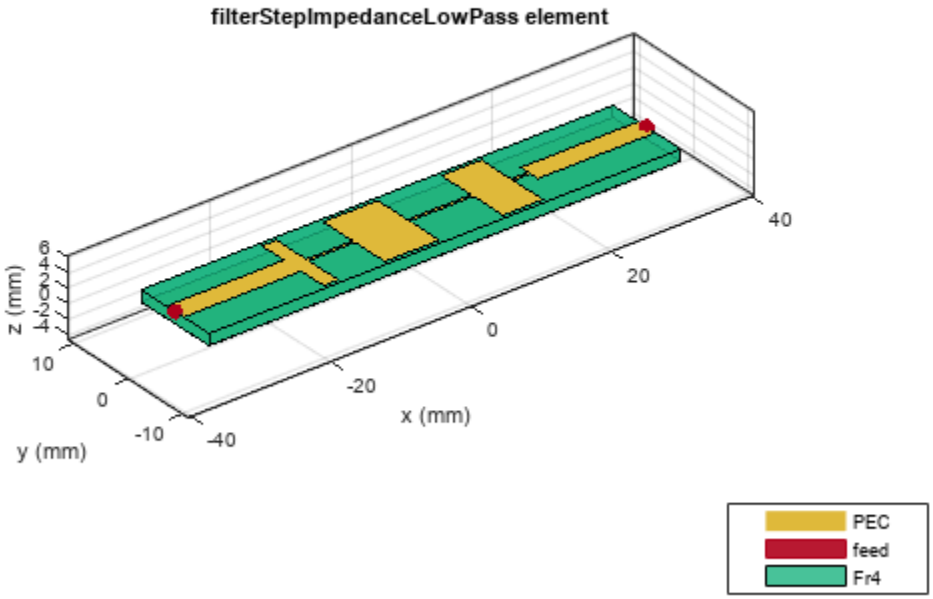
### Design Stepped Impedance Low Pass Filter at 2.5 GHz

Design a sixth order stepped impedance low pass filter at 2.5 GHz with 20 ohm low impedance line, 120 ohm high impedance line on FR4 substrate of thickness 1.58 mm.

```
sifilter = filterStepImpedanceLowPass(FilterOrder=6,Height=1.58e-3) ;
Sub  = dielectric(Name='Fr4',EpsilonR=4.2,LossTangent=0.02,Thickness=1.58e-3);
sifilter.Substrate = Sub;
sifilterobj = design(sifilter,2.5e9,Z0=50,LowZ=20,HighZ=120);
```

View the filter.

```
show(sifilterobj);
```




## Input Arguments

### `sifilterobj` — Stepped impedance low pass line filter

`filterStepImpedanceLowPass` object

Stepped impedance low pass filter, specified as a `filterStepImpedanceLowPass` object.

Example: `sifilterobj = filterStepImpedanceLowPass; design(sifilterobj,2e9)` designs a coupled line filter around a frequency of 2 GHz.

### `frequency` — Design frequency of stepped impedance low pass filter

real positive scalar

Design frequency of the stepped impedance low pass filter, specified as a real positive scalar in hertz.

Example: `5e9`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=75`

**Z0 — Reference impedance**
50 (default) | positive scalar

Reference impedance, specified as a positive scalar in ohms.

Data Types: double

**LowZ — Low impedance line**
20 (default) | positive scalar

Low impedance line, specified as a positive scalar in ohms.

Data Types: double

**HighZ — High impedance line**
120 (default) | positive scalar

High impedance line, specified as a positive scalar in ohms.

Data Types: double

**FilterType — Type of filter**
'Butterworth' (default) | positive scalar

Type of filter, specified as 'Butterworth', or 'Chebyshev'.

Data Types: char | string

**RippleFactor — Passband factor of Chebyshev filter**
0.01 (default) | positive scalar

Passband factor of the Chebyshev filter, specified as positive scalar in decibels. For Butterworth filter, the passband factor is not required.

Data Types: double

## Output Arguments

**sifilter — Stepped impedance low pass filter around specified frequency**
filterStepImpedanceLowPass object

Stepped impedance low pass filter around specified frequency, returned as a filterStepImpedanceLowPass object.

# Version History

**Introduced in R2021b**

## See Also

sparameters

# design

Design hairpin filter around specified frequency

## Syntax

```
hpfilter = design(hpfilterobj,frequency)
hpfilter = design( ___ ,Name=Value)
```

## Description

`hpfilter = design(hpfilterobj,frequency)` designs a hairpin filter around the specified frequency.

`hpfilter = design( ___ ,Name=Value)` designs a hairpin filter with additional options specified by name-value arguments.

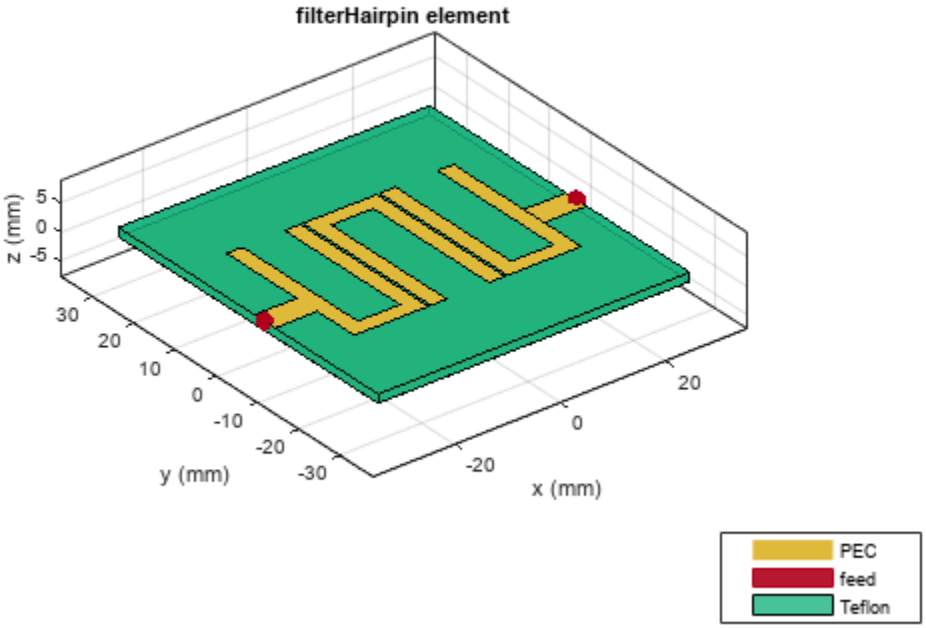
**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

### Design Chebyshev Hairpin Filter at 1.8 GHz

Design a Hairpin filter with a Chebyshev response at 1.8 GHz and a fractional bandwidth of 10 percent.

```
hpfilt = design(filterHairpin,1.8e9,FBW=10,FilterType='Chebyshev');
show(hpfilt);
```




### Design Fifth Order Hairpin Filter

Design a 5th order tapped input hairpin filter with a Chebyshev response at 1.8 GHz and a fractional bandwidth of 10 percent.

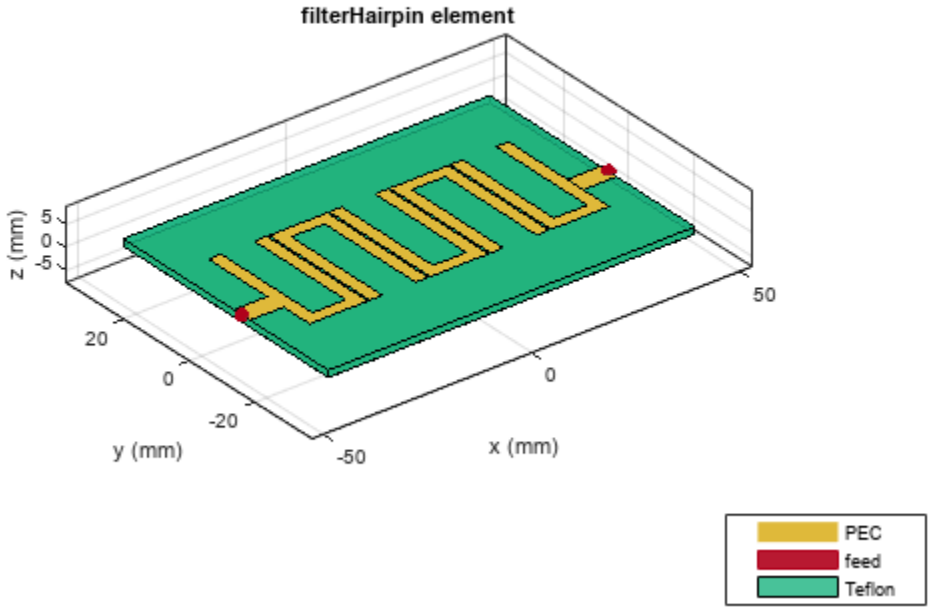
```
hpfilt = filterHairpin(FeedType='Tapped')
```

```
hpfilt =
  filterHairpin with properties:

          Resonator: [1x1 ubendRightAngle]
        FilterOrder: 3
    ResonatorOffset: [0 0 0]
            Spacing: [4.0000e-04 4.0000e-04]
     PortLineLength: 0.0080
      PortLineWidth: 0.0050
         FeedOffset: [-0.0055 -0.0055]
           FeedType: 'Tapped'
             Height: 0.0016
   GroundPlaneWidth: 0.0567
          Substrate: [1x1 dielectric]
          Conductor: [1x1 metal]
```

```
hpfilt.FilterOrder = 5;
hpfilt = design(hpfilt, 1.8e9,FBW=10,FilterType='Chebyshev');
```

View the filter.

```
show(hpfilt);
```




## Input Arguments

### `hpfilterobj` — Hairpin filter

`filterHairpin` object

Hairpin filter, specified as a `filterHairpin` object.

Example: `hpfilterobj = filterHairpin; design(hpfilterobj,2e9)` designs a hairpin filter around a frequency of 2 GHz.

### `frequency` — Design frequency of hairpin filter

real positive scalar

Design frequency of the hairpin filter, specified as a real positive scalar in hertz.

Example: `5e9`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `RippleFactor=0.02`

#### `FilterType` — Type of filter

`'Butterworth'` (default) | positive scalar

Type of filter, specified as `'Butterworth'`, or `'Chebyshev'`.

Data Types: `char` | `string`

#### `RippleFactor` — Passband factor of Chebyshev filter

`0.01` (default) | positive scalar

Passband factor of the Chebyshev filter, specified as positive scalar in decibels. For Butterworth filter, the passband factor is not required.

Data Types: `double`

## Output Arguments

#### `hpfilter` — Hairpin filter operating around specified frequency

`filterHairpin` object

Hairpin filter operating around the specified frequency, returned as a `filterHairpin` object.

# Version History

**Introduced in R2021b**

## See Also

`sparameters`

# pcbcascade

Create new component using cascade operation

## Syntax

```
combinedcomponent = pcbcascade(component1,component2)
combinedcomponent = pcbcascade(component1,component2,m,n)
```

## Description

`combinedcomponent = pcbcascade(component1,component2)` creates a new component by using a cascade operation along port 2 of the first component and port 1 of the second component.

`combinedcomponent = pcbcascade(component1,component2,m,n)` creates a new component by using a cascade operation along port *m* of the first component and port *n* of the second component.

---

**Note**

- `pcbcascade` only supports: 2-metal layer PCB components, feeds specified at the edge of components, and identical substrate properties in both components.
- If either of the components is an antenna, the new component that the object creates is a `pcbStack` object.
- To use `pcbStack` object you require Antenna Toolbox.

---

## Examples

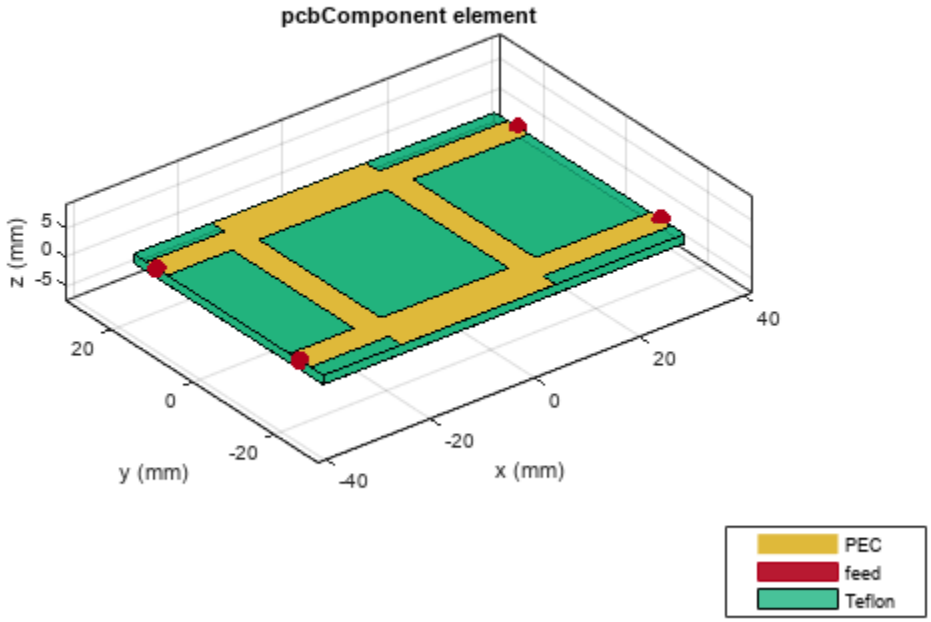
### Create Component From Branchline Coupler and Coupled Microstrip Line

Create a new component by cascading a branchline coupler with a coupled microstrip line.

```
c = design(couplerBranchline,5.6e9);
mc = design(coupledMicrostripLine,5.6e9);
mc.Spacing = c.ShuntArmLength;
r = pcbcascade(c,mc);
```

View the new component.

```
figure
show(r)
```




## Input Arguments

### `component1` — PCB component or antenna

PCB component object | antenna object

PCB component or antenna, specified a PCB component object or antenna object. For a complete list of the PCB components, see “PCB Components Catalog”.

Example: `mline1 = microstripLine; mline2 = design(microstripLine,3e9); component = pcbcascade(mline1,mline2)` creates a new component by cascading `mline1` and `mline2`.

Data Types: `char` | `string`

### `component2` — PCB component or antenna

PCB component object | antenna object

PCB component or antenna, specified a PCB component object or antenna object. For a complete list of the PCB components, see “PCB Components Catalog”.

Example: `mline1 = microstripLine; mline2 = design(microstripLine,3e9); component = pcbcascade(mline1,mline2)` creates a new component by cascading `mline1` and `mline2`.

Data Types: `char` | `string`

**`m` — Port number of first component**
1 (default) | positive scalar

Port number of the first component, specified as a positive scalar.

Example: `coupler = couplerRatrace;mline = microstripLine;component = pcbcascade(coupler,mline,3,1)` creates a new component by cascading Port 3 of the coupler to Port 1 of the microstrip transmission line.

Data Types: `double`

**`n` — Port number of second component**
1 (default) | positive scalar

Port number of second component, specified as a positive scalar.

Example: `coupler = couplerRatrace;mline = microstripLine;component = pcbcascade(coupler,mline,3,1)` creates a new component by cascading Port 3 of the coupler to Port 1 of the microstrip transmission line.

Data Types: `double`

## Output Arguments

**`combinedcomponent` — PCB component or antenna after cascading two components**
PCB component object | antenna object

PCB component or antenna after cascading two components, returned as a PCB component object or antenna object.

Data Types: `char` | `string`

# Version History

**Introduced in R2021b**

## See Also

`pcbComponent`

# design

Design PCB component around particular frequency

## Syntax

```
rfpcbcomponent = design(rfpcbobject,frequency)
```

## Description

`rfpcbcomponent = design(rfpcbobject,frequency)` designs a PCB component around the specified frequency.

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

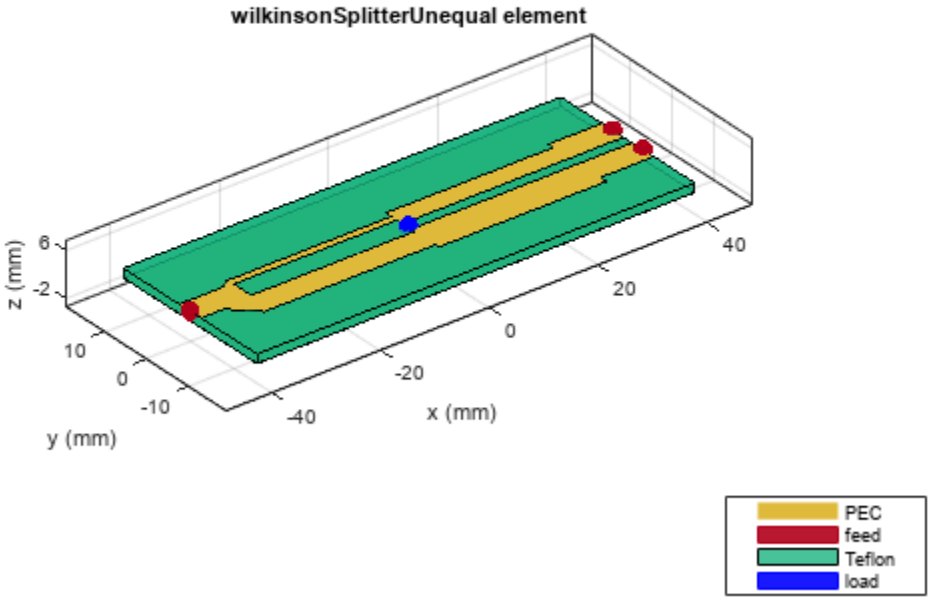
### Design Unequal Wilkinson Splitter at 1.8 GHZ

Design an unequal Wilkinson around 1.8 GHz.

```
uwilk = design(wilkinsonSplitterUnequal,1.8e9);
```

View the splitter

```
show(uwilk);
```

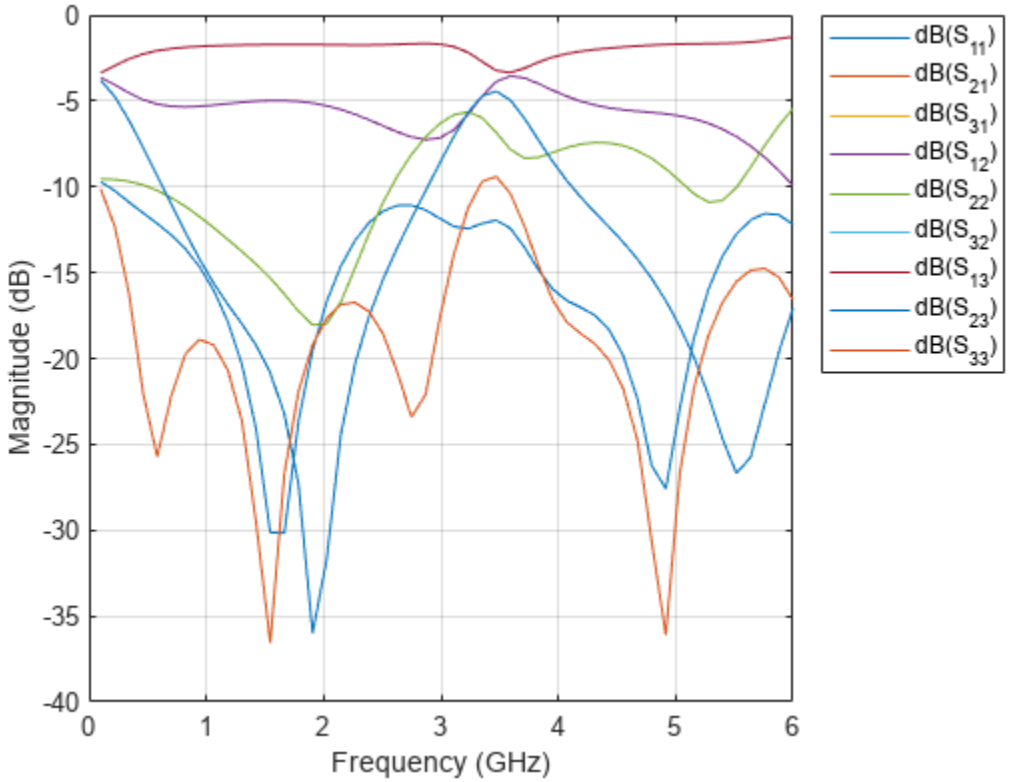



Plot S-parameters between the frequency range of 0.1 GHz to 6 GHZ.

```
spar = sparameters(uwilk,linspace(0.1e9,6e9,50))
```

```
spar =
  sparameters: S-parameters object

       NumPorts: 3
    Frequencies: [50x1 double]
     Parameters: [3x3x50 double]
      Impedance: 50

  rfparam(obj,i,j) returns S-parameter Sij
```

```
rfplot(spar)
```




## Input Arguments

### `rfpcbobject` — PCB component object

object handle

PCB component object, specified as a RF PCB object. For complete list of PCB components, microstrip bends, and traces, see “PCB Components Catalog”.

**Note** The following PCB catalog components are not supported by this function: `spiralInductor`, `interdigitalCapacitor`, and `stubRadialShunt`.

### `frequency` — Design frequency of PCB component

real positive scalar

Design frequency of the PCB component, specified as a real positive scalar in hertz.

Example: `3e9`

Data Types: `double`

## Output Arguments

**`rfpcbcomponent` — PCB catalog component operating around specified frequency**
object handle

PCB catalog component operating around specified frequency, returned as a object handle.

# Version History

**Introduced in R2021b**

## See Also

`sparameters`

# mirrorX

Mirror shape along X-axis

## Syntax

```
mirroredshape = mirrorX(shape)
```

## Description

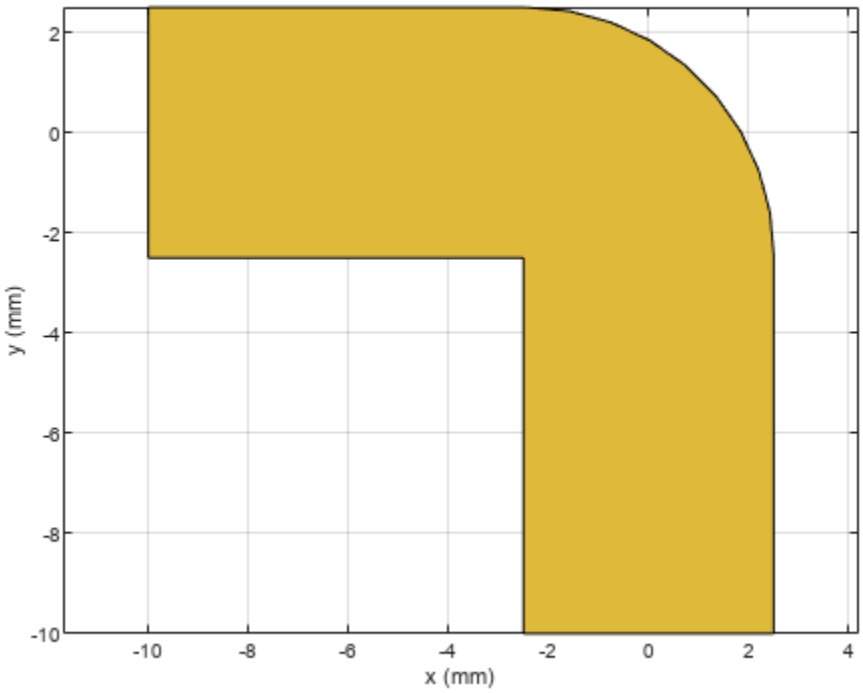
`mirroredshape = mirrorX(shape)` mirrors a shape along the X-axis.

## Examples

### Mirror Curved Bend Shape Along X-Axis

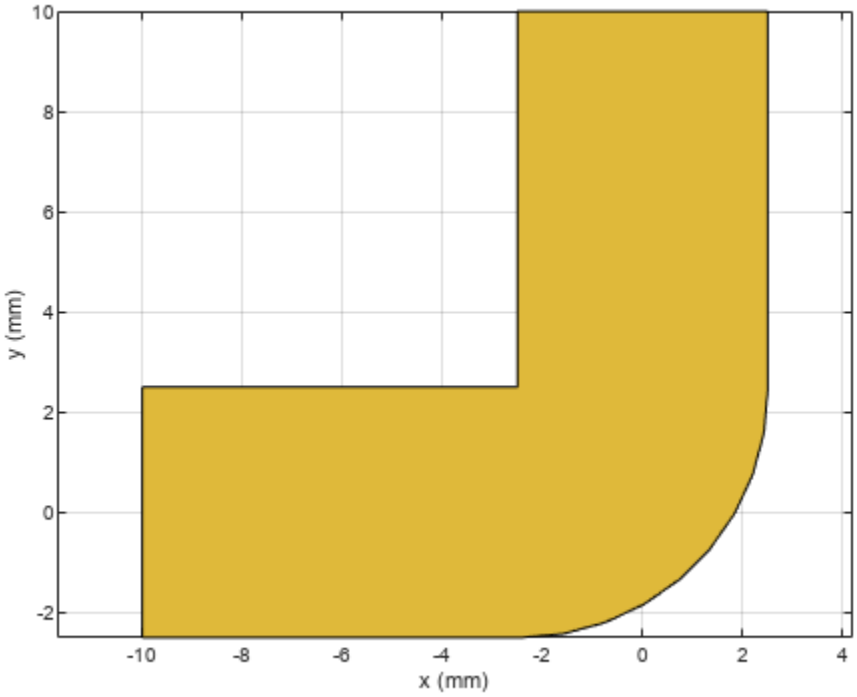
Create a curved bend and view it.

```
shape = bendCurved;
show(bendCurved)
```




Mirror the shape slong the X-axis.

```
mirrorX(shape)
```




## Input Arguments

### shape — Shape to mirror

shape or PCB object

Shape to mirror, specified as `shape` or `PCB` object You can specify any of the shapes in “Custom Geometry and PCB Fabrication”.

Example: `shape = bendCurved;` creates a `bendCurved` shape object.

# Version History

**Introduced in R2022a**

## See Also

`add` | `subtract` | `area` | `rotate` | `rotateX` | `rotateY` | `rotateZ` | `translate` | `show` | `mesh` | `plot`

# mirrorY

Mirror shape along Y-axis

## Syntax

```
mirroredshape = mirrorY(shape)
```

## Description

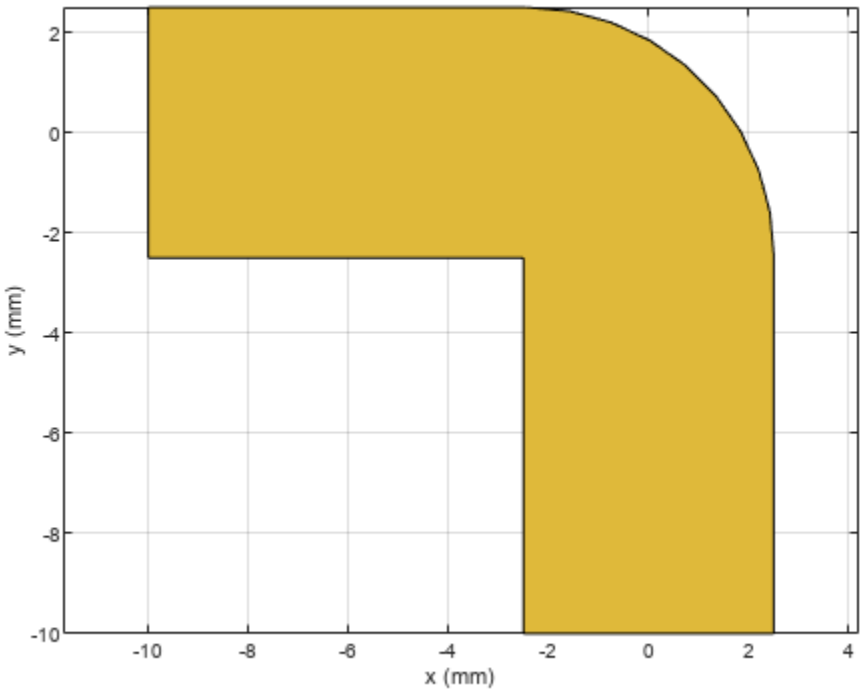
`mirroredshape = mirrorY(shape)` mirrors a shape along the Y-axis.

## Examples

### Mirror Curved Bend Shape Along Y-Axis

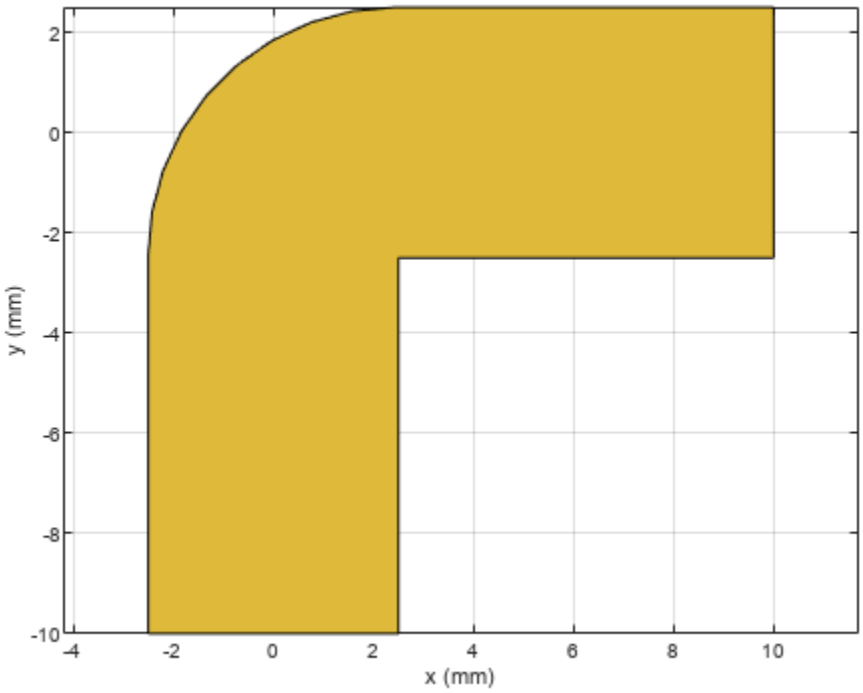
Create a curved bend and view it.

```
shape = bendCurved;
show(bendCurved)
```




Mirror the shape along the Y-axis.

```
mirrorY(shape)
```




## Input Arguments

### shape — Shape to mirror

shape or PCB object

Shape to mirror, specified as `shape` or `PCB` object You can specify any of the shapes in “Custom Geometry and PCB Fabrication”.

Example: `shape = bendCurved;` creates a `bendCurved` shape object.

# Version History

**Introduced in R2022a**

## See Also

`add` | `subtract` | `area` | `rotate` | `rotateX` | `rotateY` | `rotateZ` | `translate` | `show` | `mesh` | `plot`

# coupling

Calculate coupling factor of coupler

## Syntax

```
coupling(coupler,frequency)
c = coupling(coupler,frequency)
```

## Description

`coupling(coupler,frequency)` calculates and plots the coupling factor of a coupler over the specified frequency values.

`c = coupling(coupler,frequency)` returns the coupling factor of a coupler over the specified frequency.

## Examples

### Coupling Factor of Branchline Coupler

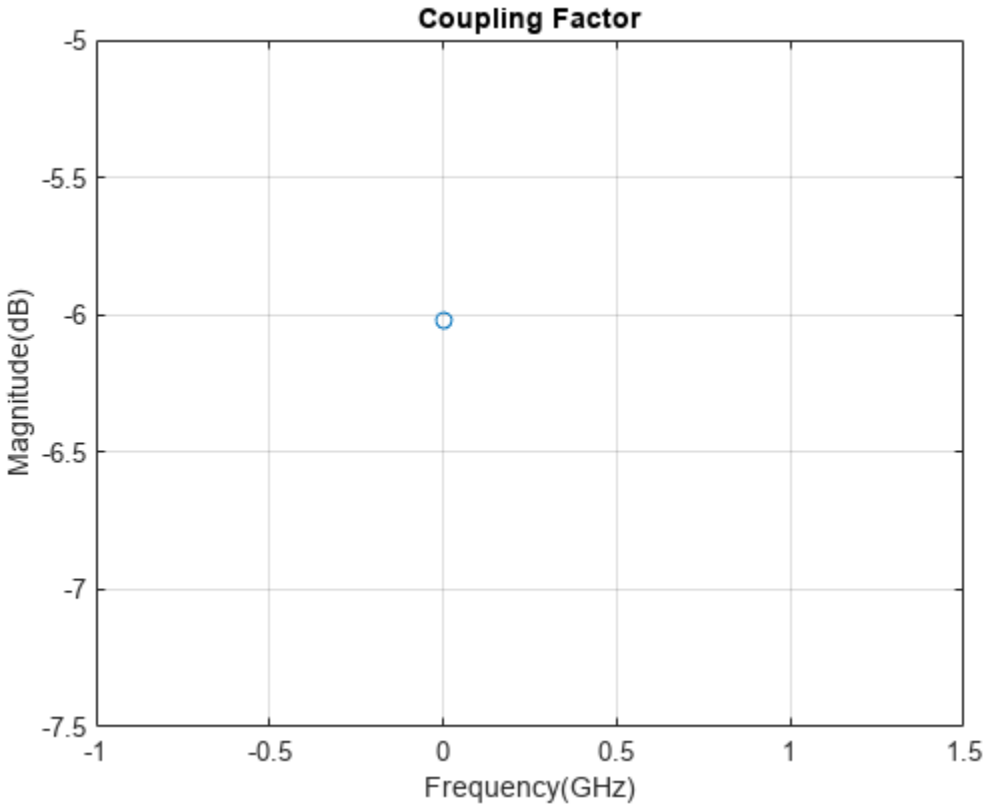
Create a branchline coupler with default values.

```
coupler = couplerBranchline
```

```
coupler =
  couplerBranchline with properties:

      PortLineLength: 0.0186
       PortLineWidth: 0.0051
     SeriesArmLength: 0.0184
      SeriesArmWidth: 0.0083
      ShuntArmLength: 0.0186
       ShuntArmWidth: 0.0051
              Height: 0.0016
    GroundPlaneWidth: 0.0600
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

Calculate the coupling factor of the coupler at 2 GHz.

```
coupling(coupler,2e6)
```




**Coupling Factor of Rat-Race Coupler**

Create a rat-race coupler with default values.

```
coupler = couplerRatrace;
```

Calculate the coupling factor of the coupler at 3 GHz.

```
c = coupling(coupler,3e6)
```

```
c = -6.0206
```

## Input Arguments

### `coupler` — Coupler

coupler object

Coupler, specified as a coupler object. For a complete list of couplers, see “Splitters and Couplers”.

### `frequency` — Frequency to calculate coupling

scalar | vector

Frequency to calculate the coupling, specified as an integer in Hz or as a vector with each element specified in Hz.

## Version History

**Introduced in R2022a**

## See Also

`directivity` | `isolation`

# directivity

Calculate directivity of coupler

## Syntax

```
directivity(coupler,frequency)
d = directivity(coupler,frequency)
```

## Description

`directivity(coupler,frequency)` calculates and plots the directivity of a coupler over the specified frequency values.

`d = directivity(coupler,frequency)` returns the directivity of a coupler over the specified frequency.

## Examples

### Directivity of Branchline Coupler

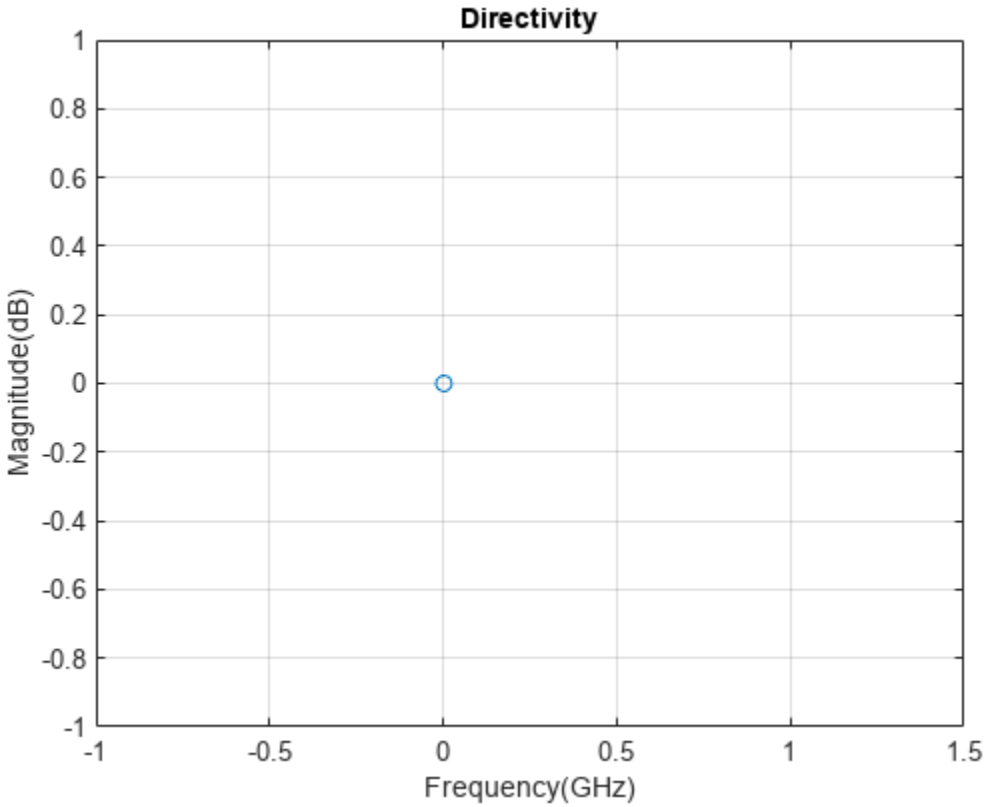
Create a branchline coupler with default values.

```
coupler = couplerBranchline
```

```
coupler =
  couplerBranchline with properties:

      PortLineLength: 0.0186
       PortLineWidth: 0.0051
     SeriesArmLength: 0.0184
      SeriesArmWidth: 0.0083
      ShuntArmLength: 0.0186
       ShuntArmWidth: 0.0051
              Height: 0.0016
    GroundPlaneWidth: 0.0600
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

Calculate the directivity of the coupler at 2 GHz.

```
directivity(coupler,2e6)
```




**Directivity of Rat-Race Coupler**

Create a rat-race coupler with default values.

```
coupler = couplerRatrace;
```

Calculate the directivity of the coupler at 3 GHz.

```
c = directivity(coupler,3e6)
```

```
c = -7.3653e-06
```

## Input Arguments

### `coupler` — Coupler

coupler object

Coupler, specified as a coupler object. For a complete list of couplers, see “Splitters and Couplers”.

### `frequency` — Frequency to calculate directivity

scalar | vector

Frequency to calculate the directivity, specified as an integer in Hz or as a vector with each element specified in Hz.

## Version History

**Introduced in R2022a**

## See Also

`coupling` | `isolation`

# isolation

Calculate isolation of coupler

## Syntax

```
isolation(coupler,frequency)
i = isolation(coupler,frequency)
```

## Description

`isolation(coupler,frequency)` calculates and plots the isolation of a coupler over the specified frequency values.

`i = isolation(coupler,frequency)` returns the isolation of a coupler over the specified frequency.

## Examples

### Isolation of Branchline Coupler

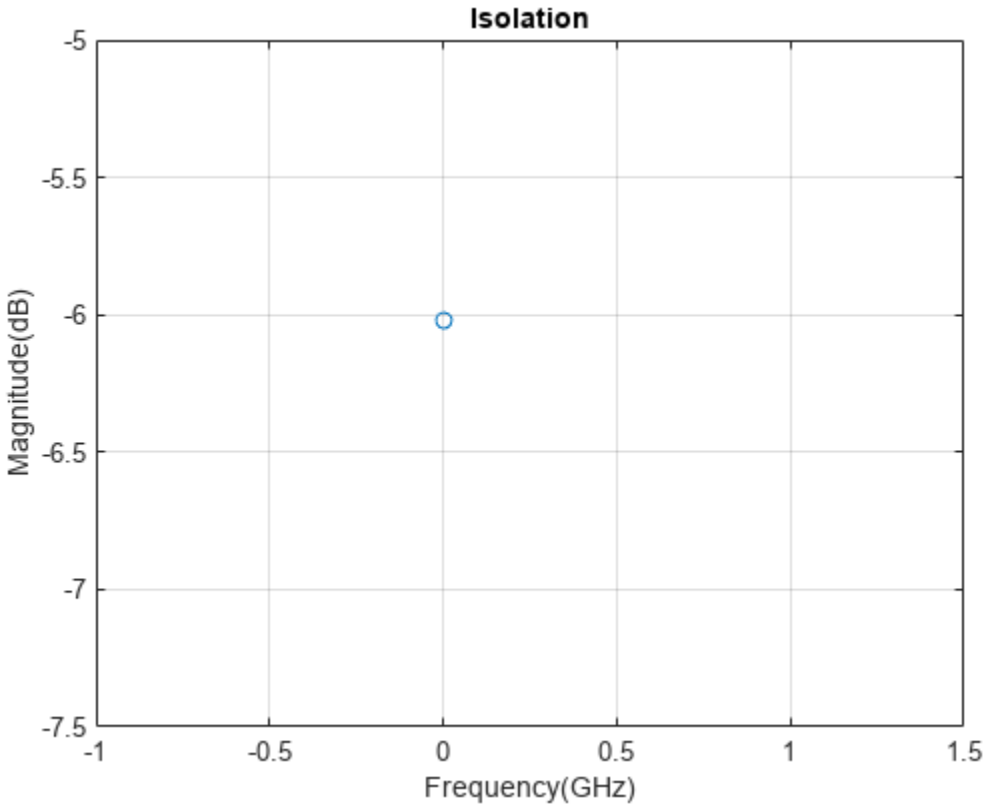
Create a branchline coupler with default values.

```
coupler = couplerBranchline
```

```
coupler =
  couplerBranchline with properties:

      PortLineLength: 0.0186
       PortLineWidth: 0.0051
     SeriesArmLength: 0.0184
      SeriesArmWidth: 0.0083
      ShuntArmLength: 0.0186
       ShuntArmWidth: 0.0051
              Height: 0.0016
    GroundPlaneWidth: 0.0600
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

Calculate the isolation of the coupler at 2 GHz.

```
isolation(coupler,2e6)
```




**Isolation of Rat-Race Coupler**

Create a rat-race coupler with default values.

```
coupler = couplerRatrace;
```

Calculate the isolation of the coupler at 3 GHz.

```
i = isolation(coupler,3e6)
```

```
i = -6.0206
```

## Input Arguments

### `coupler` — Coupler

coupler object

Coupler, specified as a coupler object. For a complete list of couplers, see “Splitters and Couplers”.

### `frequency` — Frequency to calculate isolation

scalar | vector

Frequency to calculate the isolation, specified as an integer in Hz or as a vector with each element specified in Hz.

## Version History

**Introduced in R2022a**

## See Also

`coupling` | `directivity`

# design

Design corporate power divider around specified frequency

## Syntax

```
divider = design(dividerobj,frequency)
divider = design( ___ ,Name=Value)
```

## Description

`divider = design(dividerobj,frequency)` designs a corporate power divider around a specified frequency.

`divider = design( ___ ,Name=Value)` designs a corporate power divider splitter with additional options specified using name-value arguments.

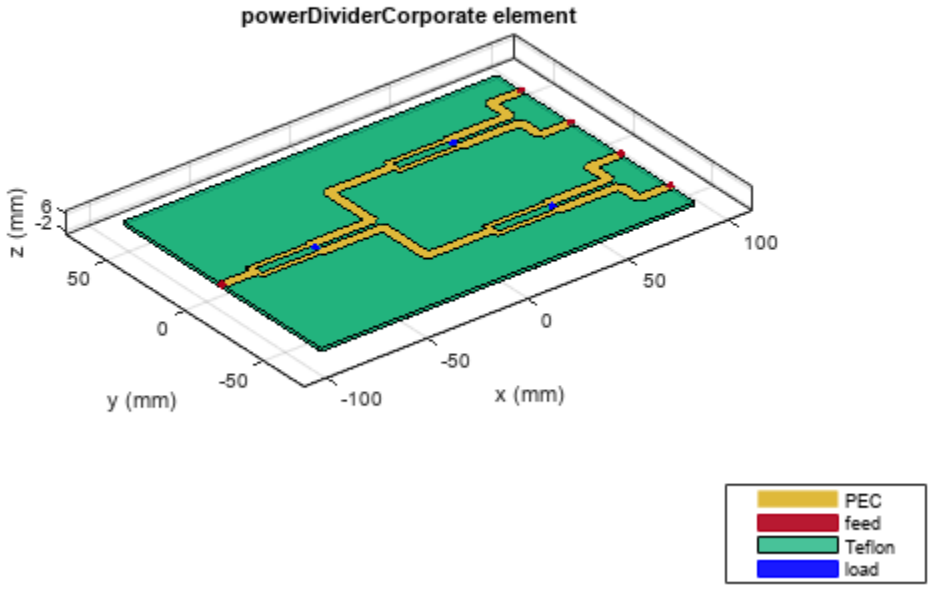
**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

### 1.8 GHz Corporate Power Divider

Design a corporate power divider at 1.8 GHz frequency and 50 ohms impedance.

```
pd = design(powerDividerCorporate,1.8e9,Z0=50);
figure;
show(pd);
```




## Input Arguments

### `dividerobj` — Corporate power divider

`powerDividerCorporate` object

Corporate power divider, specified as a `powerDividerCorporate` object.

Example: `dividerobj = wilkinsonSplitter; design(dividerobj,2e9)` designs a corporate power divider around a frequency of 2 GHz.

### `frequency` — Design frequency of corporate power divider

real positive scalar

Design frequency of the corporate power divider, specified as a real positive scalar in hertz.

Example: `55e6`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=2`

**`Z0` — Characteristic impedance of power divider**
`50` (default) | positive scalar

Characteristic impedance of the power divider, specified as a positive scalar in ohms.

Data Types: `double`

## Output Arguments

**`dividerobj` — Corporate power divider operating around specified frequency**
`powerDividerCorporate` object

Corporate power divider operating around the specified frequency, returned as a `powerDividerCorporate` object.

# Version History

**Introduced in R2022a**

## See Also

`sparameters`

# designCoupledLine

Calculate dimensions of coupled-line section for specified frequency

## Syntax

```
[Length,Width,Spacing] = designCoupledLine(balunobj,frequency)
___ = designCoupledLine( ___ ,Name=Value)
```

## Description

`[Length,Width,Spacing] = designCoupledLine(balunobj,frequency)` calculates the dimensions of the coupled line section of a coupled-line balun around a specified frequency.

**Note** `designCoupledLine` is the first step in designing a coupled line balun. This function is succeeded by `designUncoupledLine` and `designOutputLine` as the second and third step, respectively.

`___ = designCoupledLine( ___ ,Name=Value)` calculates the dimensions of the coupled-line section of a coupled-line balun with additional options specified using name-value arguments.

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

### Design Coupled Line Balun at 4 GHz

Define the frequency at 4 GHz.

```
f = 4e9;
```

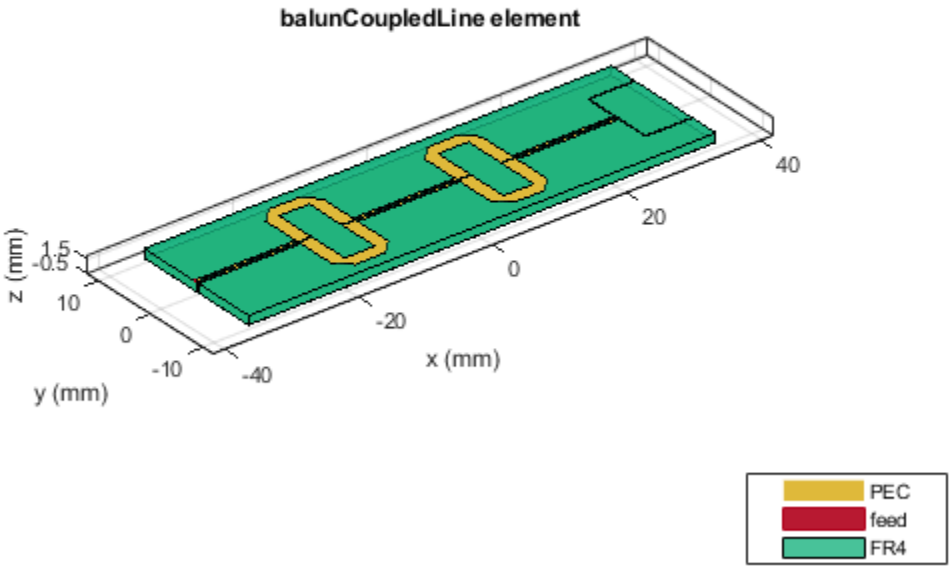
Create a coupled line balun object.

```
balun = balunCoupledLine
```

```
balun =
  balunCoupledLine with properties:

    NumCoupledLineSection: 3
        CoupledLineLength: 0.0153
         CoupledLineWidth: 4.0000e-04
       CoupledLineSpacing: 1.4000e-04
       UncoupledLineShape: [1×1 ubendMitered]
         OutputLineLength: 0.0124
          OutputLineWidth: 1.5300e-04
        OutputLineSpacing: 0.0110
                   Height: 0.0013
```

```
          GroundPlaneWidth: 0.0200
                 Substrate: [1×1 dielectric]
                 Conductor: [1×1 metal]
```

```
show(balun)
```




### Step 1: Design coupled line section

Design the coupled line section of the balun with an even mode impedance of 159 ohms and an odd mode impedance of 51 ohms. Use the helper function **designCoupledLine**.

```
[ClineL,ClineW,ClineS] = designCoupledLine(balun,f,'Z0e',159,'Z0o',51)
```

```
ClineL = 0.0107
```

```
ClineW = 4.2682e-04
```

```
ClineS = 1.4374e-04
```

### Step 2: Design uncoupled line section

Design the uncoupled line section of the balun with the even and odd mode impedance of 59 ohms. Use the helper function **designUncoupledLine**.

```
[unclineL,unclineW] = designUncoupledLine(balun,f,'Z0',59,'LineLength',0.25)
```

```
unclineL = 0.0103
```

```
unclineW = 0.0018
```

### Step 3: Design output line section

Design the output line section of the balun at the same frequency to extend the port 2 and port3. Use the helper function **designOutputLine**.

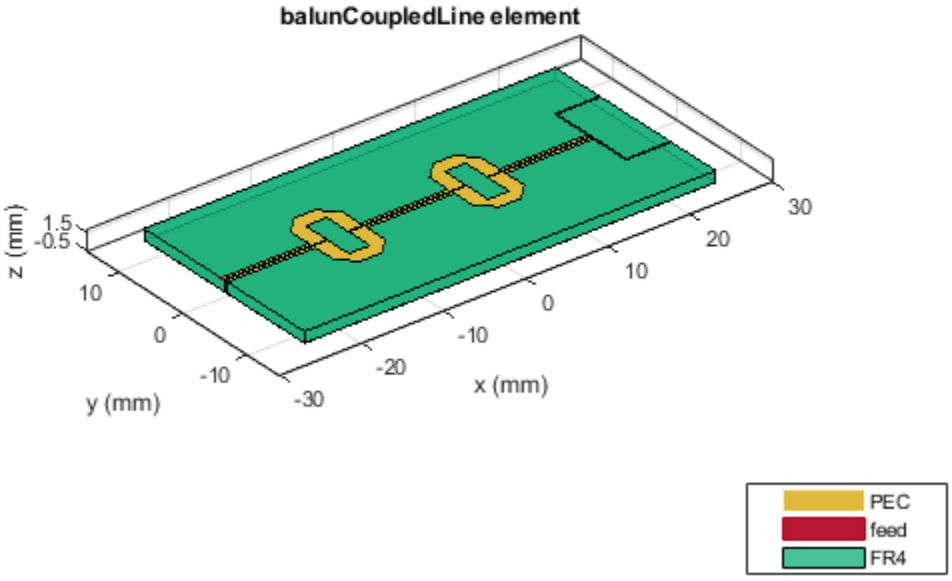
```
[OutL,OutW] = designOutputLine(balun,f,'Z0e',159,'Z0o',51,'Z0',59,'Zref',50)
```

```
OutL = 0.0109
```

```
OutW = 1.6115e-04
```

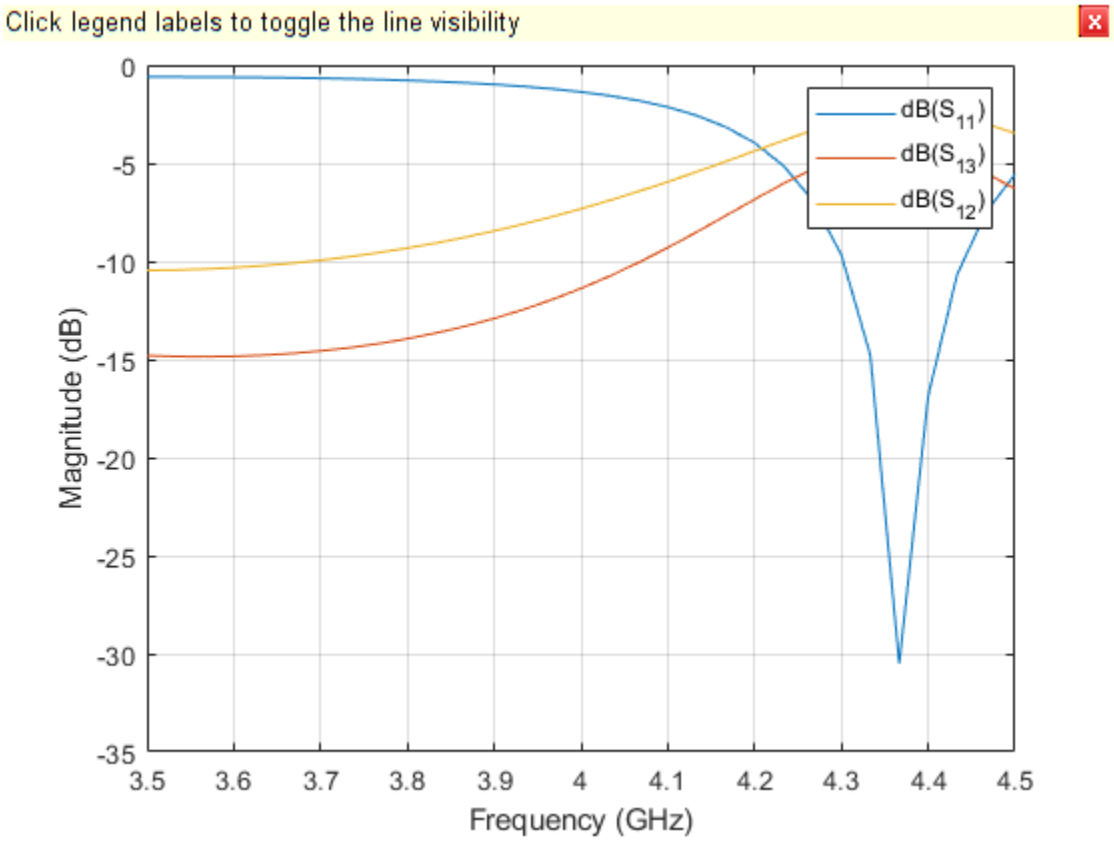
Set all the design dimensions to the coupled balun object.

```
balun.CoupledLineLength  = ClineL;
balun.CoupledLineWidth  = ClineW;
balun.CoupledLineSpacing  = ClineS;
UnCoupledLine = ubendMitered;
UnCoupledLine.Length  = [unclineL/2,unclineL/4,unclineL/2];
UnCoupledLine.Width   = [unclineW,unclineW,unclineW];
balun.UncoupledLineShape = UnCoupledLine;
balun.OutputLineLength = OutL;
balun.OutputLineWidth = OutW;
balun.OutputLineSpacing = OutL+ClineS;
gndW = 25e-3;
balun.GroundPlaneWidth = gndW;
show(balun)
```



Analyze and plot the S-paramters of this balun.

```
s11 = sparameters(balun,linspace(3.5e9,4.5e9,31));

figure; rfplot(s11,1,1);
hold on; rfplot(s11,1,3)
hold on; rfplot(s11,1,2)
```




## Input Arguments

### `balunobj` — Coupled-line balun

`balunCoupledLine` object

Coupled-line balun, specified as a `balunCoupledLine` object.

Example: `balunobj = balunCoupledLine; design(balunobj,2e9)` designs a coupled-line balun around a frequency of 2 GHz and returns the CoupledLineLength, CoupledLineWidth, and CoupledLineSpacing dimensions of the coupled line balun.

### `frequency` — Design frequency of coupled-line balun

real positive scalar

Design frequency of coupled-line balun, specified as a real positive scalar in hertz.

Example: `55e6`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0o=61`

#### `Z0e` — Even mode impedance
`159` (default) | positive scalar

Even mode impedance, specified as a positive scalar in ohms.

Data Types: `double`

#### `Z0o` — Odd mode impedance
`51` (default) | positive scalar

Odd mode impedance, specified as a positive scalar in ohms.

Data Types: `double`

## Output Arguments

#### `Length` — Length of coupled-line section
positive scalar

Length of the coupled-line section, returned as a positive scalar.

#### `Width` — Width of coupled line section
positive scalar

Width of the coupled-line section, returned as a positive scalar.

#### `Spacing` — Spacing between coupled-line sections
positive scalar

Spacing between the coupled-line sections, returned as a positive scalar.

# Version History
**Introduced in R2022a**

## See Also
`designOutputLine` | `designUncoupledLine`

# designUncoupledLine

Calculate dimensions of uncoupled-line section for specified frequency

## Syntax

```
[Length,Width] = designUncoupledLine(balunobj,frequency)
___ = designUncoupledLine( ___ ,Name=Value)
```

## Description

`[Length,Width] = designUncoupledLine(balunobj,frequency)` calculates the dimensions of the uncoupled-line section of a coupled line balun around a specified frequency. In the `balunCoupledLine` object, the uncoupled line dimensions are incorporated into the UncoupledLineShape property.

**Note** `designUncoupledLine` is the second step in designing a coupled line balun. This function is preceded by `designCoupledLine` and succeeded by `designOutputLine`.

`___ = designUncoupledLine( ___ ,Name=Value)` calculates the dimensions of the uncoupled-line section of a coupled-line balun with additional options specified using name-value arguments.

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

### Design Coupled Line Balun at 4 GHz

Define the frequency at 4 GHz.

```
f = 4e9;
```

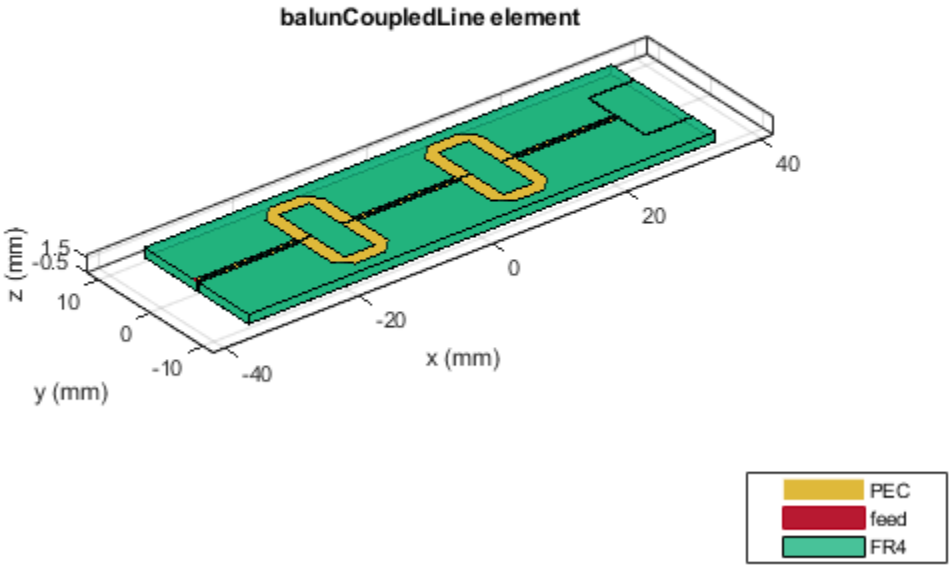
Create a coupled line balun object.

```
balun = balunCoupledLine
```

```
balun =
  balunCoupledLine with properties:

    NumCoupledLineSection: 3
        CoupledLineLength: 0.0153
         CoupledLineWidth: 4.0000e-04
       CoupledLineSpacing: 1.4000e-04
       UncoupledLineShape: [1×1 ubendMitered]
         OutputLineLength: 0.0124
          OutputLineWidth: 1.5300e-04
        OutputLineSpacing: 0.0110
```

```
                Height: 0.0013
    GroundPlaneWidth: 0.0200
           Substrate: [1×1 dielectric]
           Conductor: [1×1 metal]
```

```
show(balun)
```




### Step 1: Design coupled line section

Design the coupled line section of the balun with an even mode impedance of 159 ohms and an odd mode impedance of 51 ohms. Use the helper function **designCoupledLine**.

```
[ClineL,ClineW,ClineS] = designCoupledLine(balun,f,'Z0e',159,'Z0o',51)
```

```
ClineL = 0.0107
```

```
ClineW = 4.2682e-04
```

```
ClineS = 1.4374e-04
```

### Step 2: Design uncoupled line section

Design the uncoupled line section of the balun with the even and odd mode impedance of 59 ohms. Use the helper function **designUncoupledLine**.

```
[unclineL,unclineW] = designUncoupledLine(balun,f,'Z0',59,'LineLength',0.25)
```

```
unclineL = 0.0103
```

```
unclineW = 0.0018
```

### Step 3: Design output line section

Design the output line section of the balun at the same frequency to extend the port 2 and port3. Use the helper function **designOutputLine**.

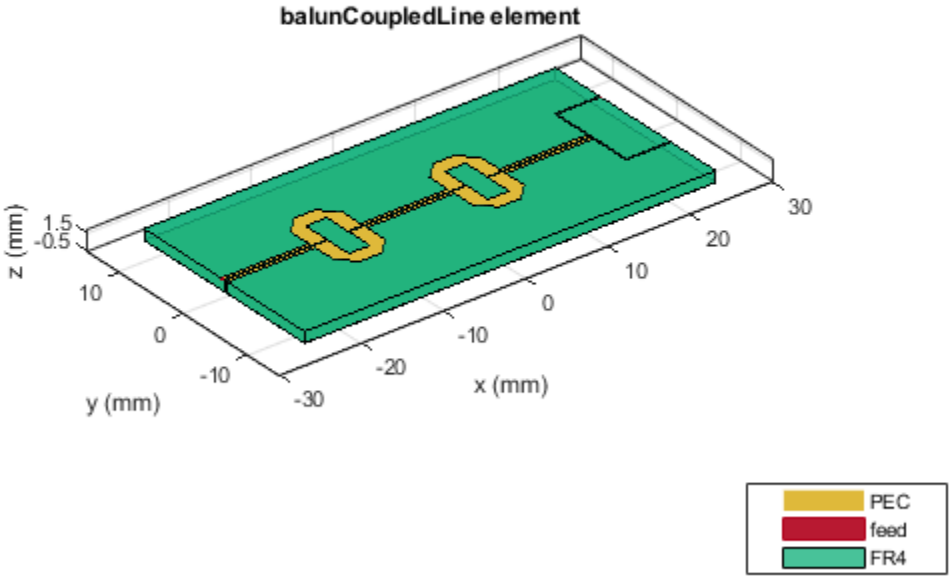
```
[OutL,OutW] = designOutputLine(balun,f,'Z0e',159,'Z0o',51,'Z0',59,'Zref',50)
```

```
OutL = 0.0109
```

```
OutW = 1.6115e-04
```

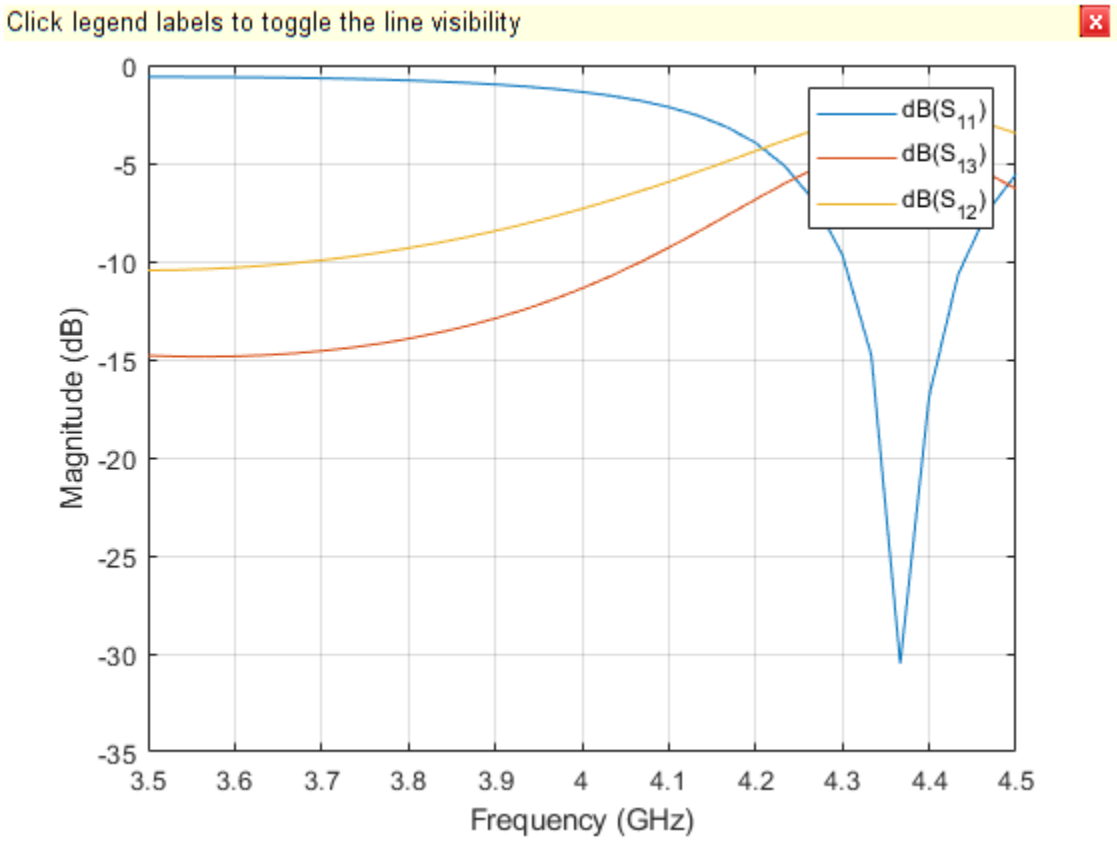
Set all the design dimensions to the coupled balun object.

```
balun.CoupledLineLength  = ClineL;
balun.CoupledLineWidth  = ClineW;
balun.CoupledLineSpacing  = ClineS;
UnCoupledLine = ubendMitered;
UnCoupledLine.Length  = [unclineL/2,unclineL/4,unclineL/2];
UnCoupledLine.Width   = [unclineW,unclineW,unclineW];
balun.UncoupledLineShape = UnCoupledLine;
balun.OutputLineLength = OutL;
balun.OutputLineWidth = OutW;
balun.OutputLineSpacing = OutL+ClineS;
gndW = 25e-3;
balun.GroundPlaneWidth = gndW;
show(balun)
```



Analyze and plot the S-paramters of this balun.

```
s11 = sparameters(balun,linspace(3.5e9,4.5e9,31));

figure; rfplot(s11,1,1);
hold on; rfplot(s11,1,3)
hold on; rfplot(s11,1,2)
```




## Input Arguments

### `balunobj` — Coupled-line balun

`balunCoupledLine` object

Coupled-line balun, specified as a `balunCoupledLine` object.

Example: `balunobj = balunCoupledLine; design(balunobj,2e9)` designs a coupled-line balun around a frequency of 2 GHz and returns the length and width of the uncoupled line section.

### `frequency` — Design frequency of coupled-line balun

real positive scalar

Design frequency of coupled-line balun, specified as a real positive scalar in hertz.

Example: `55e6`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=60`

#### `Z0` — Impedance of uncoupled-line

`50` (default) | positive scalar

Impedance of uncoupled-line, specified as a positive scalar in ohms.

Data Types: `double`

#### `LineLength` — Length of uncoupled-line

`0.25` (default) | positive scalar

Length of uncoupled-line specified as a positive scalar in multiples of lambda. In the `balunCoupledLine` object, the uncoupled line dimensions are incorporated into the UncoupledLineShape property. `UncoupledLineShape.Length` is the vector of size `3` and the `LineLength` property should be splitted accordingly.

Data Types: `double`

## Output Arguments

#### `Length` — Length of uncoupled-line section

positive scalar

Length of the uncoupled-line section, returned as a positive scalar.

#### `Width` — Width of uncoupled-line section

positive scalar

Width of the uncoupled-line section, returned as a positive scalar.

# Version History

**Introduced in R2022a**

## See Also

`designCoupledLine` | `designOutputLine`

# designOutputLine

Calculate dimensions of output line section for specified frequency

## Syntax

```
[Length,Width] = designOutputLine(balunobj,frequency)
___ = designOutputLine( ___ ,Name=Value)
```

## Description

`[Length,Width] = designOutputLine(balunobj,frequency)` calculates the dimensions of the output line section of a coupled-line balun around a specified frequency.

**Note** `designOutputLine` is the third step in designing a coupled line balun. This function is preceded by `designCoupledLine` and `designUncoupledLine` as the first and second step, respectively.

`___ = designOutputLine( ___ ,Name=Value)` calculates the dimensions of the output line section of a coupled-line balun with additional options specified using name-value arguments.

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

### Design Coupled Line Balun at 4 GHz

Define the frequency at 4 GHz.

```
f = 4e9;
```

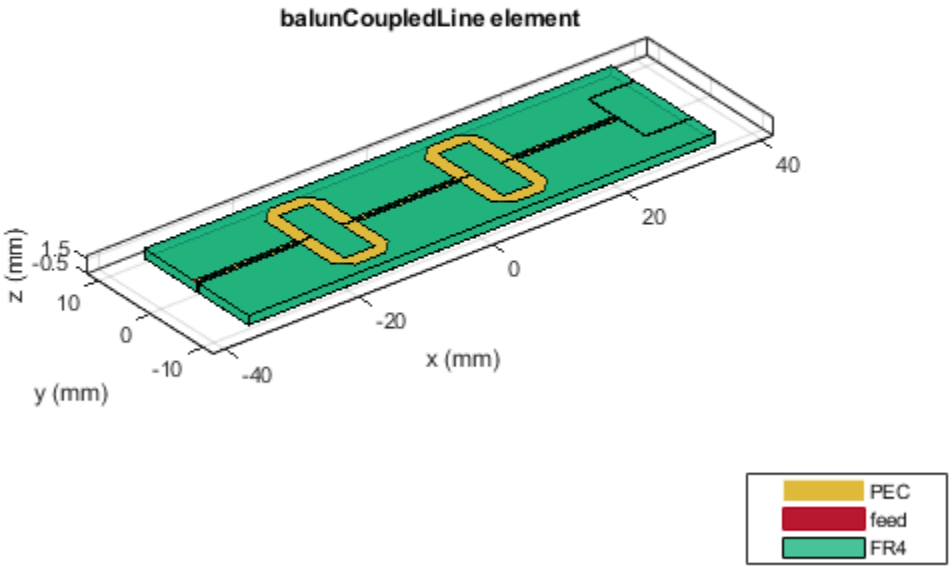
Create a coupled line balun object.

```
balun = balunCoupledLine
```

```
balun =
  balunCoupledLine with properties:

    NumCoupledLineSection: 3
        CoupledLineLength: 0.0153
         CoupledLineWidth: 4.0000e-04
       CoupledLineSpacing: 1.4000e-04
       UncoupledLineShape: [1×1 ubendMitered]
         OutputLineLength: 0.0124
          OutputLineWidth: 1.5300e-04
        OutputLineSpacing: 0.0110
                   Height: 0.0013
```

```
    GroundPlaneWidth: 0.0200
           Substrate: [1×1 dielectric]
           Conductor: [1×1 metal]
```

```
show(balun)
```




### Step 1: Design coupled line section

Design the coupled line section of the balun with an even mode impedance of 159 ohms and an odd mode impedance of 51 ohms. Use the helper function **designCoupledLine**.

```
[ClineL,ClineW,ClineS] = designCoupledLine(balun,f,'Z0e',159,'Z0o',51)
```

```
ClineL = 0.0107
```

```
ClineW = 4.2682e-04
```

```
ClineS = 1.4374e-04
```

### Step 2: Design uncoupled line section

Design the uncoupled line section of the balun with the even and odd mode impedance of 59 ohms. Use the helper function **designUncoupledLine**.

```
[unclineL,unclineW] = designUncoupledLine(balun,f,'Z0',59,'LineLength',0.25)
```

```
unclineL = 0.0103
```

```
unclineW = 0.0018
```

### Step 3: Design output line section

Design the output line section of the balun at the same frequency to extend the port 2 and port3. Use the helper function **designOutputLine**.

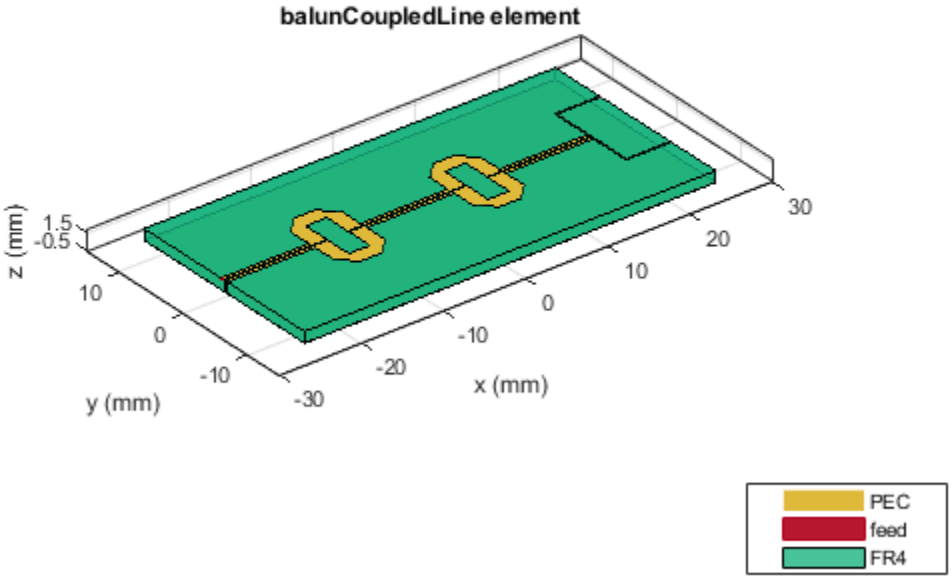
```
[OutL,OutW] = designOutputLine(balun,f,'Z0e',159,'Z0o',51,'Z0',59,'Zref',50)
```

```
OutL = 0.0109
```

```
OutW = 1.6115e-04
```

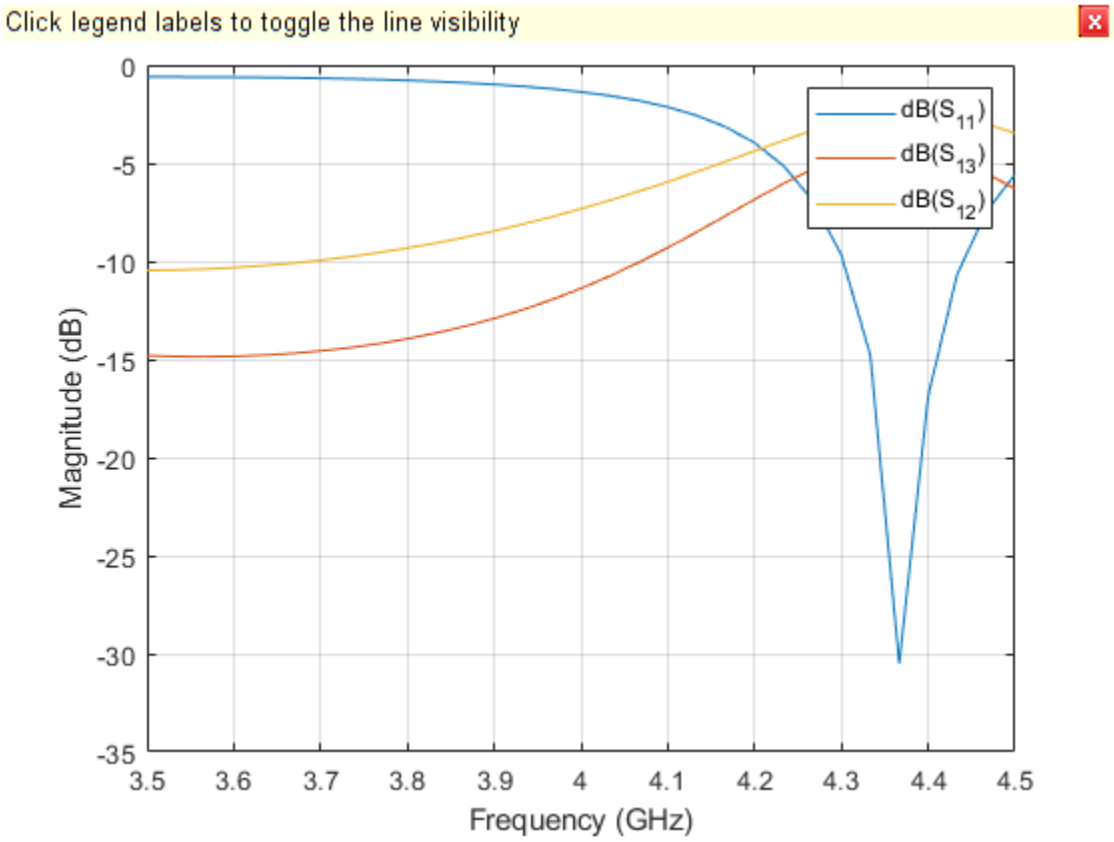
Set all the design dimensions to the coupled balun object.

```
balun.CoupledLineLength  = ClineL;
balun.CoupledLineWidth  = ClineW;
balun.CoupledLineSpacing  = ClineS;
UnCoupledLine = ubendMitered;
UnCoupledLine.Length  = [unclineL/2,unclineL/4,unclineL/2];
UnCoupledLine.Width   = [unclineW,unclineW,unclineW];
balun.UncoupledLineShape = UnCoupledLine;
balun.OutputLineLength = OutL;
balun.OutputLineWidth = OutW;
balun.OutputLineSpacing = OutL+ClineS;
gndW = 25e-3;
balun.GroundPlaneWidth = gndW;
show(balun)
```



Analyze and plot the S-paramters of this balun.

```
s11 = sparameters(balun,linspace(3.5e9,4.5e9,31));

figure; rfplot(s11,1,1);
hold on; rfplot(s11,1,3)
hold on; rfplot(s11,1,2)
```




## Input Arguments

### `balunobj` — Coupled-line balun

`balunCoupledLine` object

Coupled-line balun, specified as a `balunCoupledLine` object.

Example: `balunobj = balunCoupledLine; design(balunobj,2e9)` designs a coupled-line balun around a frequency of 2 GHz and returns the OutputLineLength andOuputLineWidth properties of the coupled line balun.

### `frequency` — Design frequency of coupled-line balun

real positive scalar

Design frequency of coupled-line balun, specified as a real positive scalar in hertz.

Example: `55e6`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0o=61`

#### `Z0e` — Even mode impedance of coupled-line

`159` (default) | positive scalar

Even mode impedance of the coupled-line, specified as a positive scalar in ohms.

**Note** The even mode impedance should be same as the even mode impedance of the coupled line section.

Data Types: `double`

#### `Z0o` — Odd mode impedance of coupled-line

`51` (default) | positive scalar

Odd mode impedance of the coupled-line, specified as a positive scalar in ohms.

**Note** The odd mode impedance should be same as the odd mode impedance of the coupled line section.

Data Types: `double`

#### `Z0` — Impedance of uncoupled-line

`50` (default) | positive scalar

Impedance of the uncoupled-line, specified as a positive scalar in ohms.

**Note** The impedance should be same as the impedance of the uncoupled line section.

Data Types: `double`

#### `Zref` — Reference impedance to match output

`50` (default) | positive scalar

Reference impedance to match the output, specified as a positive scalar in ohms.

Data Types: `double`

## Output Arguments

#### `Length` — Length of output line section

positive scalar

Length of the output line section, returned as a positive scalar.

**`Width` — Width of output line section**
positive scalar

Width of the output line section, returned as a positive scalar.

# Version History
**Introduced in R2022a**

## See Also
`designCoupledLine` | `designUncoupledLine`

# design

Design wideband Wilkinson splitter around specified frequency

## Syntax

```
wsplitter = design(wsplitterobj,frequency)
wsplitter = design( ___ ,Name=Value)
```

## Description

`wsplitter = design(wsplitterobj,frequency)` designs a wideband Wilkinson splitter around the specified frequency.

`wsplitter = design( ___ ,Name=Value)` designs a wideband Wilkinson splitter with additional options specified using name-value arguments.

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

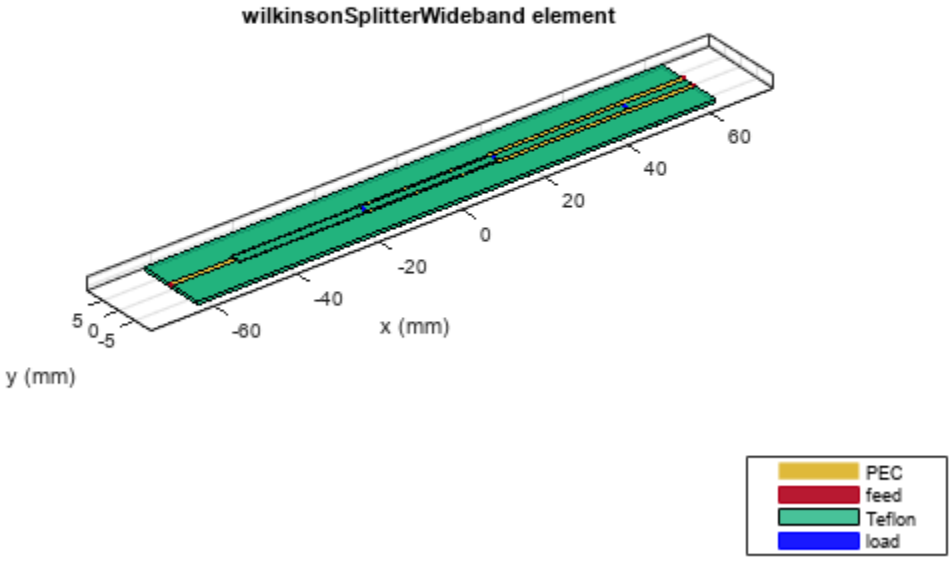
### Design Wideband Wilkinson Splitter at 1.8 GHz

Design a wideband Wilkinson splitter at 1.8 GHz and with a Z0 of 75 ohm.

```
wsplitter = design(wilkinsonSplitterWideband,1.8e9,Z0=75);
```

View the splitter.

```
figure;
show(wsplitter);
```




## Input Arguments

### `wsplitterobj` — Wideband Wilkinson splitter

`wilkinsonSplitterWideband` object

Wideband Wilkinson splitter, specified as a `wilkinsonSplitterWideband` object.

Example: `wsplitterobj = wilkinsonSplitterWideband; design(wsplitterobj,2e9)` designs a wideband Wilkinson splitter around a frequency of 2 GHz.

### `frequency` — Design frequency of wideband Wilkinson splitter

real positive scalar

Design frequency of the wideband Wilkinson splitter, specified as a real positive scalar in hertz.

Example: `55e6`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=60`

**`Z0` — Characteristic impedance of splitter**
`50` (default) | positive scalar

Characteristic impedance of the splitter, specified as a positive scalar in ohms.

Data Types: `double`

## Output Arguments

**`wsplitter` — Wideband Wilkinson splitter operating around specified frequency**
`wilkinsonSplitterWideband` object

Wideband Wilkinson splitter operating around the specified frequency, returned as a `wilkinsonSplitterWideband` object.

# Version History

**Introduced in R2022a**

## See Also

`sparameters`

# rlgc

Compute resistances, inductances, conductances, and capacitances

## Syntax

```
rlgcparams = rlgc(txline,frequency)
```

## Description

`rlgcparams = rlgc(txline,frequency)` returns the resistances, inductances (L), conductances (G), and capacitances per unit length of a transmission line at the specified frequency.

## Examples

### RLGC of Microstrip Transmission Line

Create a microstrip transmission line using a copper conductor.

```
txline = microstripLine;
txline.Conductor.Name = 'Copper';
txline.Conductor.Conductivity = 5.8e7;
txline.Conductor.Thickness = 0.001;
```

Calculate the RLGC values of microstrip transmission line at 1 GHz.

```
freq = 1e9;
RLGCparams = rlgc(txline,freq)
```

```
RLGCparams = struct with fields:
    R: 1.4649
    L: 2.0565e-07
    G: 9.6413e-05
    C: 9.5171e-11
```

## Input Arguments

### `txline` — Transmission line

transmission line object

Transmission line, specified as a `coupledMicrostripLine`, `microstripLine`, or `microstripLineCustom` object.

Example: `txline = microstripLine;rlgc(txline)` calculates the RLGC values of the microstrip transmission line object with handle `txline`.

Data Types: `char` | `string`

### `frequency` — Frequency to calculate RLGC values

scalar

Frequency to calculate the RLGC values, specified as an integer in Hz.

## Output Arguments

**`rlgcparams` — RLGC values of transmission line**
structure

RLGC values line per unit length of the transmission line, returned as a structure with field names for the R, L, G, and C values. Each field contains an *n*-by-*n* double precision matrix where *n* is the total number of traces in the transmission line object. Diagonal and nondiagonal entries in the matrix are self and coupled elements in the traces, respectively.

# Version History

**Introduced in R2022b**

## See Also

`coupling` | `directivity`

# getZEven

Calculate even mode impedance of differential PCB transmission line

## Syntax

```
zeven = getZEven(txline,frequency)
```

## Description

`zeven = getZEven(txline,frequency)` calculates the even mode impedance of the transmission line at the specified frequency.

## Examples

### Even Mode Impedance of Coupled Microstrip Line

Create a coupled microstrip line with copper traces.

```
txline = coupledMicrostripLine;
txline.Conductor.Name = 'Copper';
txline.Conductor.Conductivity = 5.8e7;
txline.Conductor.Thickness = 0.001;
```

Calculate the even mode impedance of coupled microstrip line at 1 GHz.

```
freq = 1e9;
evenImp = getZEven(txline,freq)
```

```
evenImp = 49.1537
```

## Input Arguments

### `txline` — Transmission line

transmission line object

Transmission line, specified as a `coupledMicrostripLine`, `microstripLine`, or `microstripLineCustom` object.

Example: `txline = microstripLine;getZEven(txline)`. Calculates the even mode impedance of the microstrip transmission line object with handle `txline`.

Data Types: `char` | `string`

### `frequency` — Frequency

positive scalar

Frequency to calculate the even mode impedance, specified as a positive scalar in hertz.

## Output Arguments

**zeven — Even mode impedance of transmission line**
complex scalar

Even mode impedance of the transmission line, returned as a complex scalar.

Data Types: `double`

# Version History

**Introduced in R2022b**

## See Also

`sparameters` | `getZOdd` | `getZ0`

# getZOdd

Calculate odd mode impedance of differential PCB transmission line

## Syntax

```
zodd = getZOdd(txline,frequency)
```

## Description

`zodd = getZOdd(txline,frequency)` calculates the odd mode impedance of the transmission lines in “Transmission Lines” at the specified frequency.

## Examples

### Odd Mode Impedance of Coupled Microstrip Line

Create a coupled microstrip line with copper traces.

```
txline = coupledMicrostripLine;
txline.Conductor.Name = "Copper";
txline.Conductor.Conductivity = 5.8e7;
txline.Conductor.Thickness = 0.001;
```

Calculate the odd mode impedance of coupled microstrip line at 1 GHz.

```
freq = 1e9;
oddImp = getZOdd(txline,freq)
```

```
oddImp = 42.5414
```

## Input Arguments

### `txline` — Transmission line

transmission line object

Transmission line, specified as a `coupledMicrostripLine`, `microstripLine`, or `microstripLineCustom` object.

Example: `txline = microstripLine;getZOdd(txline)`. Calculates the odd mode impedance of the microstrip transmission line object with handle `txline`.

Data Types: `char` | `string`

### `frequency` — Frequency

positive scalar

Frequency to calculate the odd mode impedance, specified as a positive scalar in hertz.

## Output Arguments

**zodd — Odd mode impedance of transmission line**
complex scalar

Odd mode impedance of the transmission line, returned as a complex scalar.

Data Types: `double`

# Version History

**Introduced in R2022b**

## See Also

`sparameters` | `getZEven` | `getZ0` | `coupledMicrostripLine` | `microstripLine` | `microstripLineCustom`

# design

Design phase shifter around specified frequency

## Syntax

```
ps = design(psobj,frequency)
ps = design( ___ ,Name=Value)
```

## Description

`ps = design(psobj,frequency)` designs a phase shifter around the specified frequency.

`ps = design( ___ ,Name=Value)` designs a phase shifter with additional properties specified using name-value arguments.

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

### Design Phase Shifter at Specified Frequency

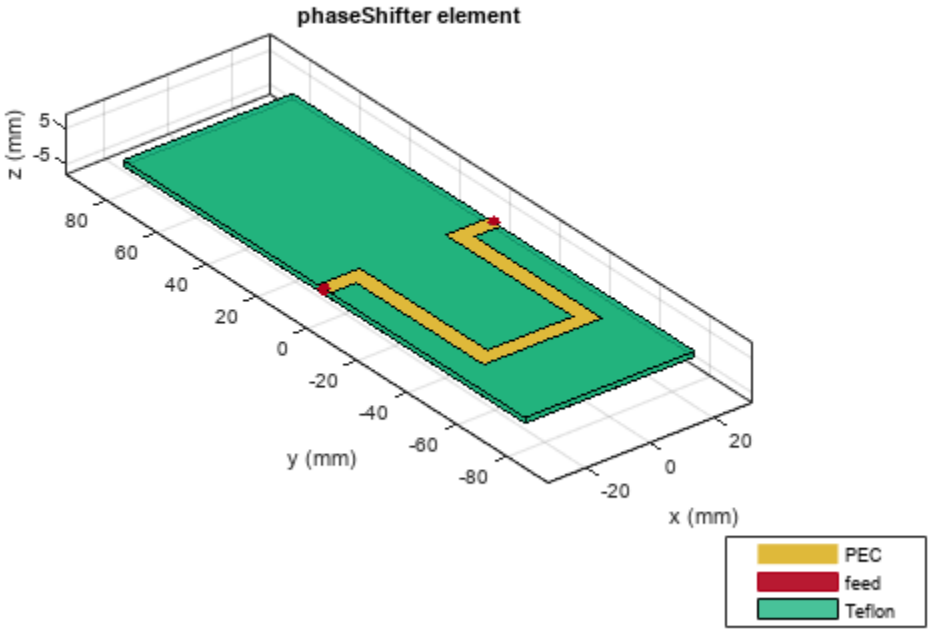
Design a phase shifter at 1.8 GHz with a phase shift of 75 degrees.

```
ps = design(phaseShifter,1.8e9,PhaseShift=75)
```

```
ps =
  phaseShifter with properties:

         NumSections: 1
        SectionShape: [1x1 ubendRightAngle]
      PortLineLength: 0.0080
       PortLineWidth: 0.0051
              Height: 0.0016
    GroundPlaneWidth: 0.1607
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

Show the phase shifter.

```
show(ps)
```




## Input Arguments

### `psobj` — Phase shifter

`phase` object

Phase shifter, specified as a `phaseShifter` object.

Example: `psobj = phaseShifter; design(psobj,2e9)` designs a phase shifter around a frequency of 2 GHz.

### `frequency` — Design frequency of phase shifter

real positive scalar

Design frequency of the phase shifter, specified as a real positive scalar in hertz.

Example: `55e6`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=70`

**`Z0` — Characteristic impedance of phase shifter**
`50` (default) | positive scalar

Characteristic impedance of the phase shifter, specified as a positive scalar in ohms.

Data Types: `double`

**`PhaseShift` — Phase shift value**
`90` (default) | positive scalar

Phase shift value, specified as a positive scalar in degrees.

Data Types: `double`

## Output Arguments

**`psobj` — Phase shifter operating around specified frequency**
`phaseShifter` object

Phase shifter operating around the specified frequency, returned as a `phaseShifter` object.

# Version History
**Introduced in R2022b**

## See Also
`sparameters`

# design

Design T-junction power splitter around specified frequency

## Syntax

```
splitter = design(splitterteeobj,frequency)
splitter = design( ___ ,Name=Value)
```

## Description

`splitter = design(splitterteeobj,frequency)` calculates the dimensions of a T-junction power splitter around the specified frequency.

`splitter = design( ___ ,Name=Value)` designs a T-junction power splitter with additional options specified using name-value arguments.

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

## Examples

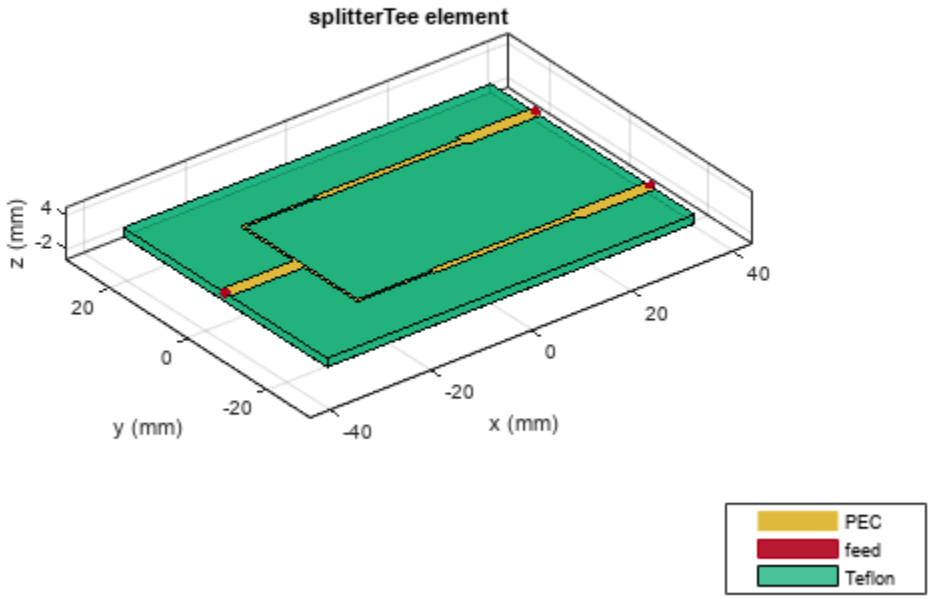
### Design T-Junction Power Splitter

Design a T-junction power splitter at 2 GHz with a characteristic impedance Z0 of 75 ohms.

```
splitter = design(splitterTee,2e9,Z0=75);
```

View the power divider.

```
show(splitter);
```




## Input Arguments

### `splitterteeobj` — T-junction power splitter

`splitterTee` object

T-junction power splitter, specified as a `splitterTee` object.

Example: `splitterteeobj = splitterTee; design(splitterteeobj,2e9)` designs a T-junction power splitter around a frequency of 2 GHz.

### `frequency` — Design frequency of T-junction power splitter

real positive scalar

Design frequency of the T-junction power splitter, specified as a real positive scalar in hertz.

Example: `55e6`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=70`

**`Z0` — Characteristic impedance of T-junction power splitter**
`50` (default) | positive scalar

Characteristic impedance of the T-junction power splitter, specified as a positive scalar in ohms.

Data Types: `double`

## Output Arguments

**`splitterteeobj` — T-junction power splitter operating around specified frequency**
`splitterTee` object

T-junction power splitter operating around the specified frequency, returned as a `splitterTee` object.

# Version History

**Introduced in R2022b**

## See Also

`sparameters`

# design

Design ring resonator around specified frequency

## Syntax

```
resonator = design(ringresonatorobj,frequency)
splitter = design( ___ ,Name=Value)
```

## Description

`resonator = design(ringresonatorobj,frequency)` calculates the dimensions of a ring resonator around the specified frequency.

`splitter = design( ___ ,Name=Value)` designs a ring resonator with additional options specified using name-value arguments.

---

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

---

## Examples

### Ring Resonator at 1.8 GHz

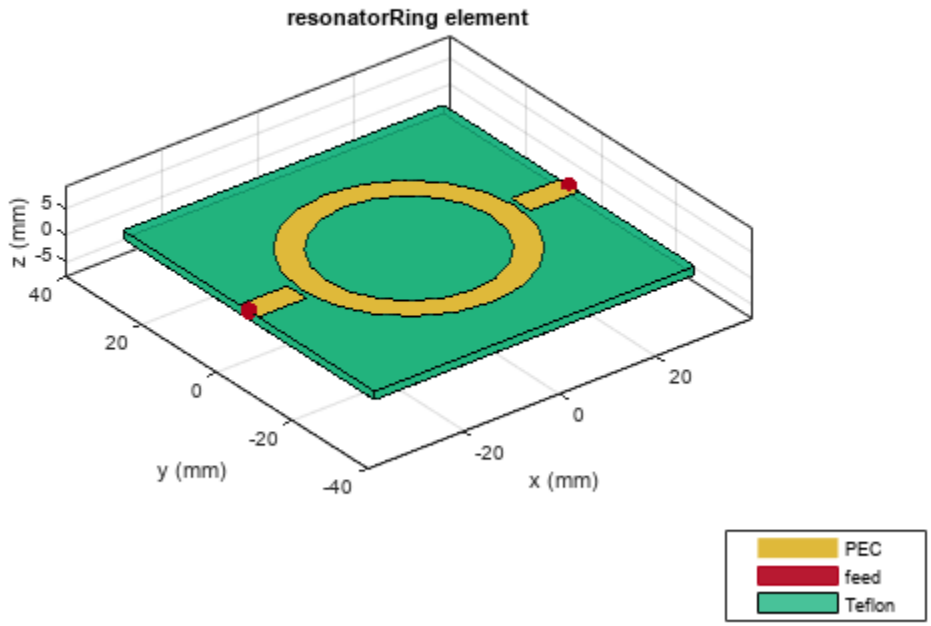
Design a ring resonator at 1.8 GHz.

```
resonator = design(resonatorRing, 1.8e9)
```

```
resonator =
  resonatorRing with properties:

      PortLineLength: 0.0100
       PortLineWidth: 0.0051
         CouplingGap: 1.0000e-03
     RingRadiusOuter: 0.0223
           RingWidth: 0.0051
              Height: 0.0016
    GroundPlaneWidth: 0.0669
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the resonator.

```
show(resonator);
```




### Ring Resonator at 2.5 GHz

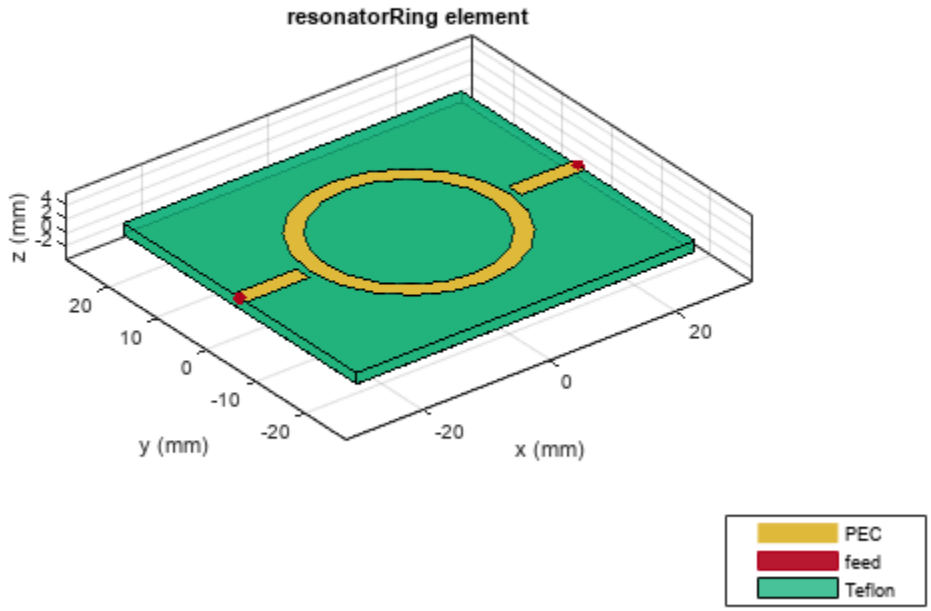
Design a ring resonator at 2.5 GHz with a characteristic impedance at 75 ohms.

```
resonator = design(resonatorRing,2.5e9,Z0=75)
```

```
resonator =
  resonatorRing with properties:

      PortLineLength: 0.0100
       PortLineWidth: 0.0027
         CouplingGap: 1.0000e-03
     RingRadiusOuter: 0.0158
           RingWidth: 0.0027
              Height: 0.0016
    GroundPlaneWidth: 0.0474
           Substrate: [1x1 dielectric]
           Conductor: [1x1 metal]
```

View the resonator.

```
show(resonator)
```




## Input Arguments

### `ringresonatorobj` — Ring resonator

`resonatorRing` object

Ring resonator, specified as a `resonatorRing` object.

Example: `resonator = resonatorRing; design(resonator,2e9)` designs a ring resonator around a frequency of 2 GHz.

### `frequency` — Design frequency of ring resonator

real positive scalar

Design frequency of the ring resonator, specified as a real positive scalar in hertz.

Example: `55e6`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=70`

**`Z0` — Characteristic impedance of ring resonator**
`50` (default) | positive scalar

Characteristic impedance of the ring resonator, specified as a positive scalar in ohms.

Data Types: `double`

## Output Arguments

**`resonator` — Ring resonator operating around specified frequency**
`resonatorRing` object

Ring resonator operating around the specified frequency, returned as a `resontorRing` object.

# Version History

**Introduced in R2022b**

## See Also

`sparameters`

# propagationDelay

Compute propagation delay of transmission line

## Syntax

```
pd = propagationDelay(txline,frequency)
```

## Description

`pd = propagationDelay(txline,frequency)` returns the propagation delay of a transmission line

## Examples

### Propagation Delay of Microstrip Transmission Line

Create a microstrip transmission line with a copper trace of conductivity and thickness specified.

```
m = microstripLine;
m.Conductor.Name = "Copper";
m.Conductor.Conductivity = 5.8e7;
m.Conductor.Thickness = 0.001;
```

Calculate the propagation delay at 1 GHz.

```
freq = 1e9;
pd = propagationDelay(m,freq)
```

```
pd = 4.4240e-09
```

## Input Arguments

### `txline` — Transmission line

transmission line object

Transmission line, specified as a `coupledMicrostripLine`, `microstripLine`, or `microstripLineCustom` object.

Example: `txline = microstripLine; propagationDelay(txline)` calculates the propagation delay of the microstrip transmission line object with handle `txline`.

Data Types: `char` | `string`

### `frequency` — Frequency to calculate propagation delay

scalar

Frequency to calculate the propagation delay, specified as an integer in Hz.

## Output Arguments

**pd — Propagation delay of transmission line**
scalar double

Propagation delay of the transmission line in seconds per meter, returned as a scalar double.

Data Types: `double`

# Version History

**Introduced in R2022b**

## See Also

`coupling` | `directivity` | `coupledMicrostripLine` | `microstripLine` | `microstripLineCustom`

# design

Design wideband branchline coupler around particular frequency

## Syntax

```
coupler = design(couplerobj,frequency)
coupler = design( ___ ,Name,Value)
```

## Description

`coupler = design(couplerobj,frequency)` designs a two or three-section wideband branchline coupler around the specified frequency.

`coupler = design( ___ ,Name,Value)` designs a wideband branchline coupler line with additional options specified using name-value arguments.

---

**Note** PCB components designed using the `design` function operate around the specified frequency with a 10-15% tolerance.

---

## Examples

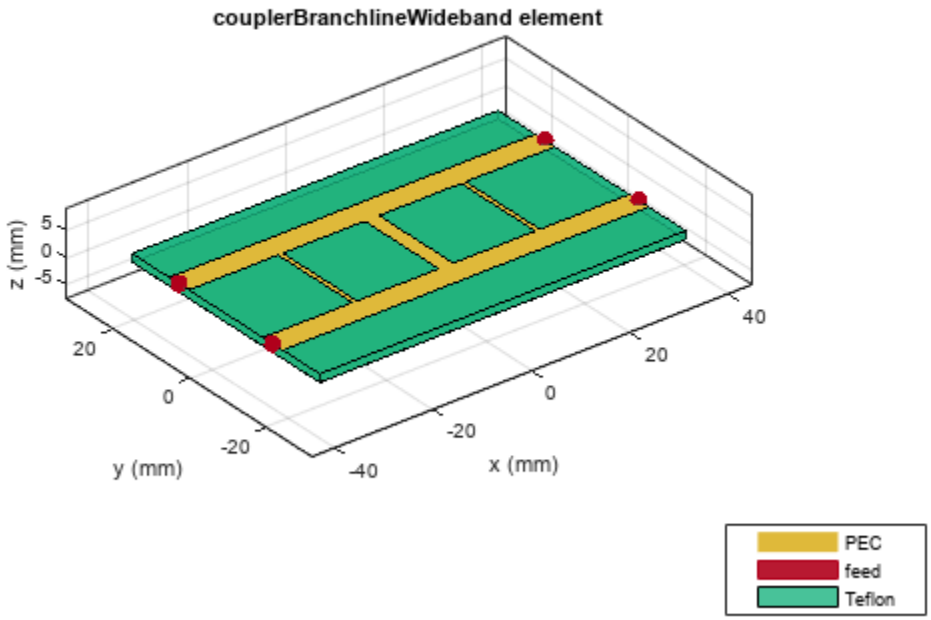
### Wideband Branchline Coupler at 3 GHz

Design a two-section wideband branchline coupler at 3 GHz.

```
coupler = design(couplerBranchlineWideband,3e9);
```

View the coupler.

```
figure;
show(coupler);
```



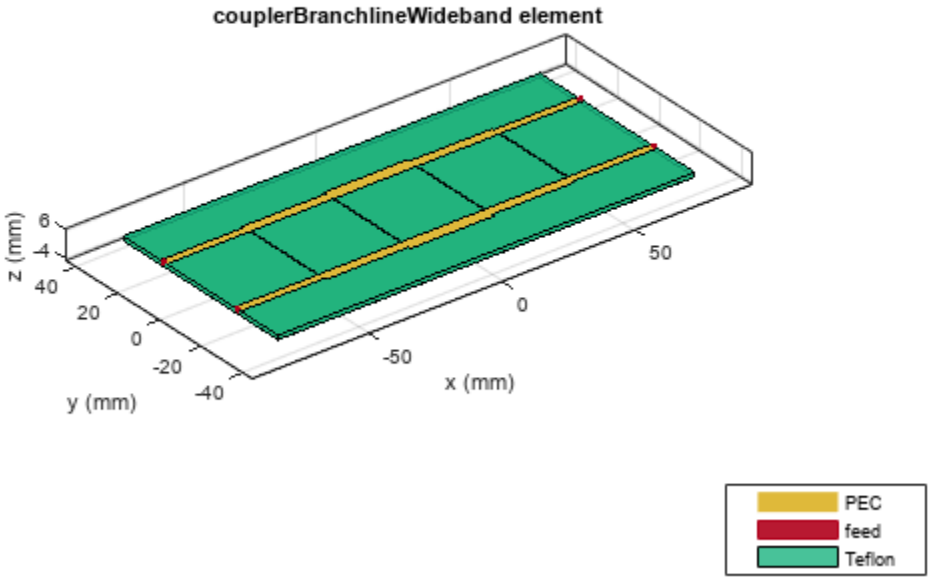

### Three-Section Wideband Branchline Coupler at 1.8 GHz

Design a three-section wideband branchline coupler at 1.8 GHz with a Z0 of 70 ohms.

```
coupler = design(couplerBranchlineWideband(NumSections=3),...
   1.8e9,Z0=70);
```

View the coupler.

```
figure;
show(coupler);
```




## Input Arguments

### `couplerobj` — Wideband branchline coupler

`couplerBranchlineWideband` object

Wideband branchline coupler, specified as a `couplerBranchlineWideband` object.

Example: `coupler = couplerBranchlineWideband; design(coupler,2e9)` designs a wideband branchline coupler around a frequency of 2 GHz.

### `frequency` — Design frequency of coupler

real positive scalar

Design frequency of the coupler, specified as a real positive scalar in hertz.

Example: `3e9`

Data Types: `double`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Example: `Z0=70`

**Z0 — Characteristic impedance of coupler**
50 (default) | positive scalar

Characteristic impedance of the coupler, specified as a positive scalar in ohms.

Data Types: double

## Output Arguments

**coupler — Wideband branchline coupler operating around specified frequency**
couplreBranchlineWideband object

Wideband branchline coupler operating around the specified frequency, returned as a couplreBranchlineWideband object.

# Version History

**Introduced in R2023a**

## See Also

sparameters

# dgs

Create defected ground structure of PCB element

## Syntax

```
pcbobject = dgs(rfpcbobject,shape)
```

## Description

`pcbobject = dgs(rfpcbobject,shape)` creates a defected ground structure (DGS) of the PCB element specified in rfpcb object using the shape object in shape as the DGS structure.

## Examples

### Dumbbell-Shaped DGS

Create a dumbbell-shaped DGS of a microstrip line.

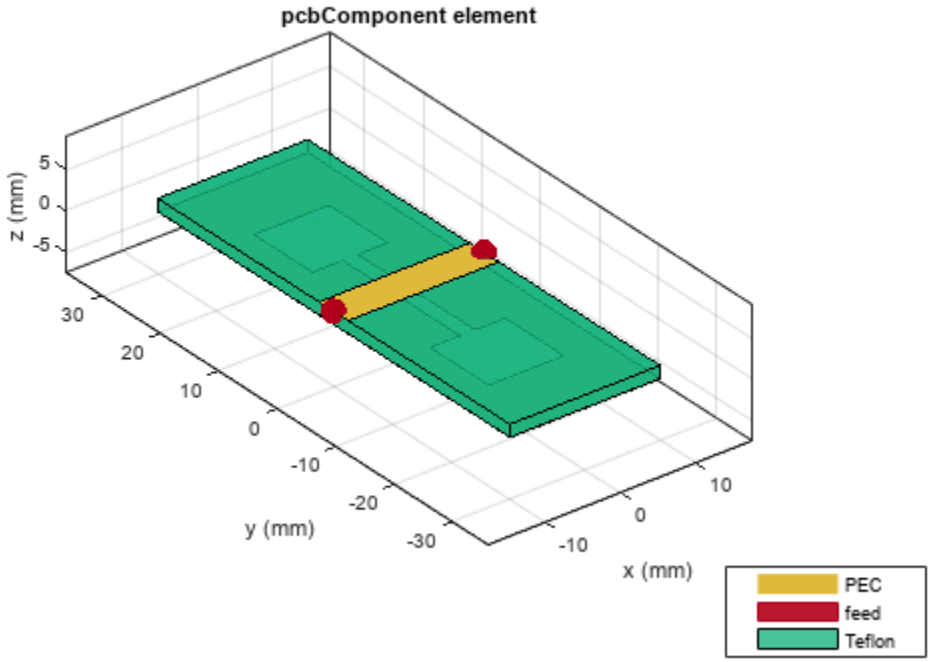
```
obj = microstripLine('GroundPlaneWidth',60e-3);
shape = {dumbbell}
```

```
shape = 1x1 cell array
    {1x1 dumbbell}
```

```
pcb = dgs(obj,shape);
```

View the PCB.

```
show(pcb)
```



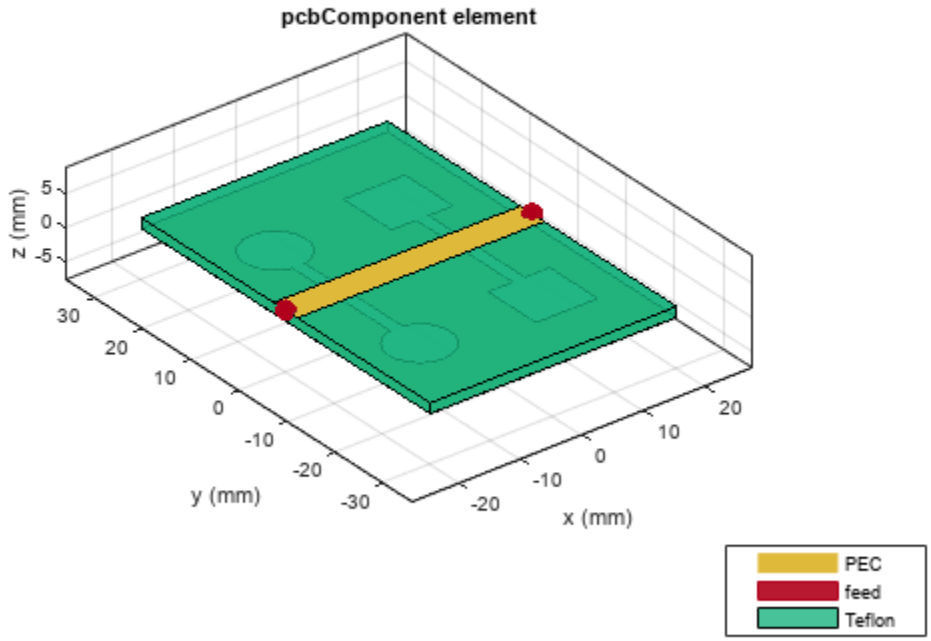

### Create DGS Using Square and Circular Dumbbell

Create a DGS of a microstrip line using a square and circular dumbbell.

```
pcbobj = microstripLine('Length',40e-3,'GroundPlaneWidth',60e-3);
shape = {translate(dumbbell('Type','Circle'),[-10e-3 0 0]),translate(dumbbell,[10e-3 0 0])};
pcb  = dgs(pcbobj,shape);
```

View the PCB.

```
show(pcb);
```




## Input Arguments

### `rfpcbobject` — PCB element

RFPCB object

PCB element, specified as an RF PCB object. For a complete list of PCB components, see “PCB Components Catalog”.

### `shape` — PCB shape

cell array of shape object

PCB shape, specified as a cell array of a shape object. For a complete list of PCB shapes, see “Shapes”.

## Output Arguments

### `pcbobject` — PCB element with DGS

RFPCB object

PCB element with DGS, specified as a RF PCB object.

# Version History

**Introduced in R2023a**

## See Also

`directivity` | `isolation`

# gapratedistance

Gap rate distance metric

## Syntax

```
gapratedistance(via,frequency)
gapratedistance( ___ ,criticalwavelength)
```

## Description

`gapratedistance(via,frequency)` calculates the maximum center-to-center (c2c) distance between the signal via and its nearest ground return via required to stay within a specified critical wavelength up to a specified maximum frequency. This metric is defined in mils. The consequences of exceeding a specified gap rate distance is described in [1].

`gapratedistance( ___ ,criticalwavelength)` calculates the gap rate distance using the critical wavelength specified.

## Examples

### Gap Rate Distance of Single-Ended Via

Calculate the gap rate distance of a single-ended via at 20 GHz and a critical wavelength of 0.3.

```
obj = viaSingleEnded;
freq = 20e9;
cw_desired = 0.3;
gapratedistance(obj,freq,cw_desired)
```

```
ans = 80.8086
```

## Input Arguments

### `via` — Single-ended via

`viaSingleEnded` object

Single-ended via, specified as a `viaSingleEnded` object.

### `frequency` — Frequency to calculate gap rate distance

vector

Frequency to calculate gap rate distance in hertz, specified as a vector.

### `criticalwavelength` — Number of wavelengths between signal via and ground return vias

`0.25` (default) | scalar

Number of wavelengths between signal via and ground return vias at a given frequency, specified as a scalar. This metric analyzes the resonant responses in the structure.

# Version History

**Introduced in R2023a**

## References

[1] Steinberger, Telian, Tsuk, Iyer and Yanamadala, “Proper Ground Via Placement for 40+ Gbps Signaling”, *DesignCon 2022*, April 2022.

[2] Ramo, Whinnery and Van Duzer, *Fields and Waves in Communications Electronics*, third edition, section 9.3, John Wiley and Sons Inc., copyright 1994

## See Also

`viaSingleEnded` | `criticalwavelength`

# criticalwavelength

Number of wavelengths between signal via and ground return vias

## Syntax

```
criticalwavelength(via,frequency)
criticalwavelength(via,frequency,SignalViaChoic=n)
```

## Description

`criticalwavelength(via,frequency)` returns the number of wavelength between signal via and ground returns vias at a given frequency to analyze for resonant responses or structures. The critical wavelength is given by the equation:

$$CW = d * f * \sqrt{\frac{(E_r)}{c}}$$

where:

- $d$ — Center to center distance between signal via and ground via.
- $f$ — Operating frequency.
- $E_r$ — Relative dielectric constant.
- $c$ — Speed of light.

You can use this function to quickly determine the maximum wavelength for a given layout. The consequences of exceeding a specified wavelength is given in [1].

`criticalwavelength(via,frequency,SignalViaChoic=n)` returns the number of wavelengths based on the choice of signal via.

## Examples

### Critical Wavelength of Single-Ended Via

Calculate the critical wavelength of a single-ended via at 20 GHz.

```
obj = viaSingleEnded;
criticalwavelength(obj,20e9)
```

```
ans = 0.2067
```

## Input Arguments

### via — Single ended via

`viaSingleEnded` object

Single ended via, specified as a `viaSingleEnded` object.

**`frequency` — Frequency to calculate initial wavelength**
scalar | vector

Frequency to calculate initial wavelength, specified as a scalar or vector integer in Hz.

**`n` — Choice of signal via**
1 (default) | positive scalar integer

Choice of signal via, specified as a positive scalar integer.

Data Types: `double`

# Version History

**Introduced in R2023a**

## References

[1] Steinberger, Telian, Tsuk, Iyer and Yanamadala, “Proper Ground Via Placement for 40+ Gbps Signaling”, *DesignCon 2022*, April 2022.

[2] Ramo, Whinnery and Van Duzer, *Fields and Waves in Communications Electronics*, third edition, section 9.3, John Wiley and Sons Inc., copyright 1994

## See Also

`gapratedistance` | `viaSingleEnded`

# Apps

# Transmission Line Designer

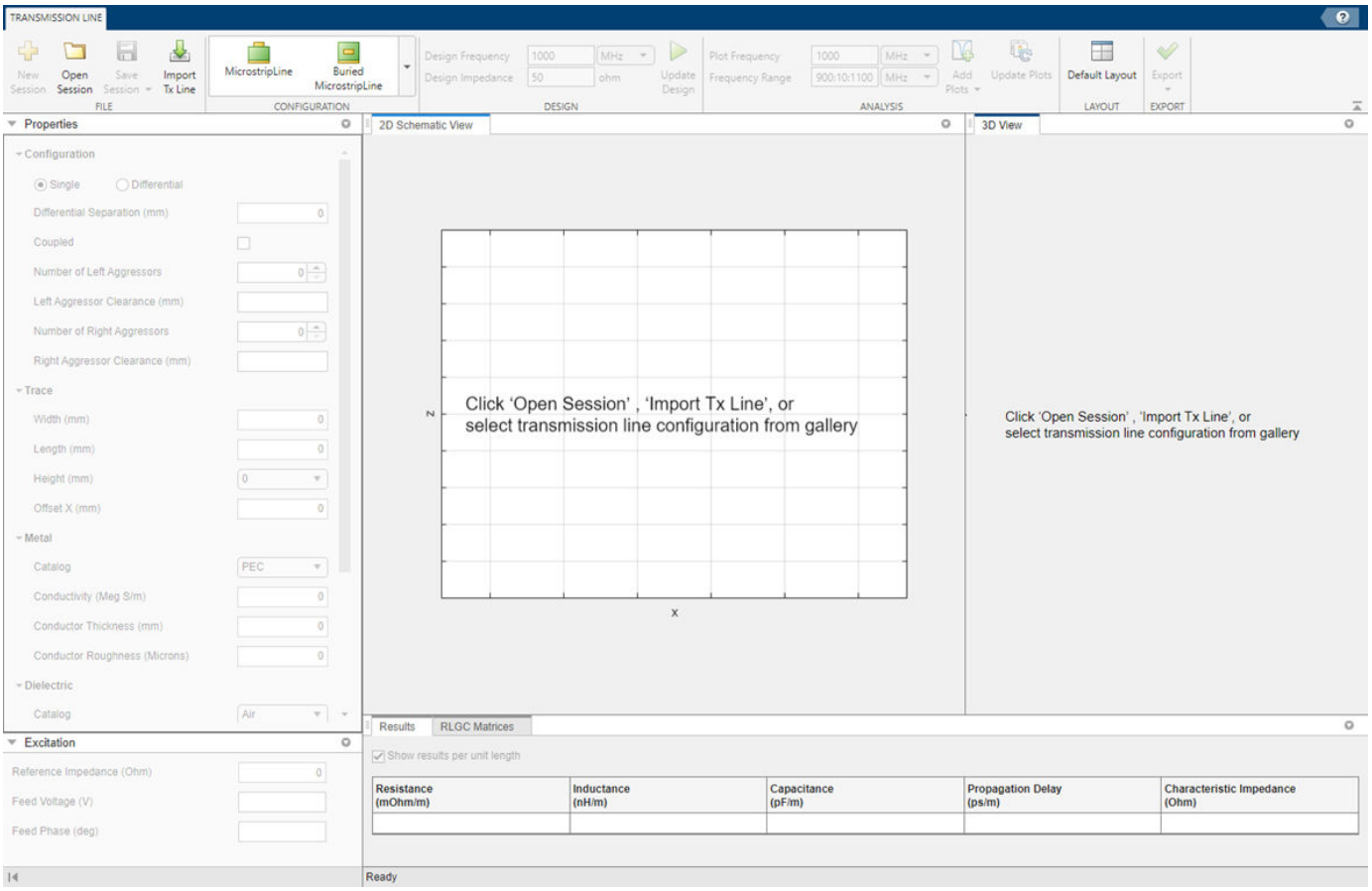
Design, visualize, and analyze transmission lines

## Description

The **Transmission Line Designer** app lets you design, analyze, and visualize transmission lines.

Using this app you can:

- Select transmission line configuration and visualize the geometry.
- Design the transmission line for a specified frequency and impedance.
- Analyze the transmission line based on RLGC values, propagation delay, S-parameters, current, charge, and layout.
- Export selected transmission line variable to MATLAB workspace.
- Export a script for the transmission line design and analysis.
- Export S-parameters to a Touchstone file.
- Export RLGC values to the MATLAB workspace.



# Open the Transmission Line Designer App

- MATLAB Toolstrip: On the **Apps** tab, under **Signal Processing and Communications**, click the **Transmission Line Designer** app icon.
- MATLAB command prompt: Enter `transmissionLineDesigner`.

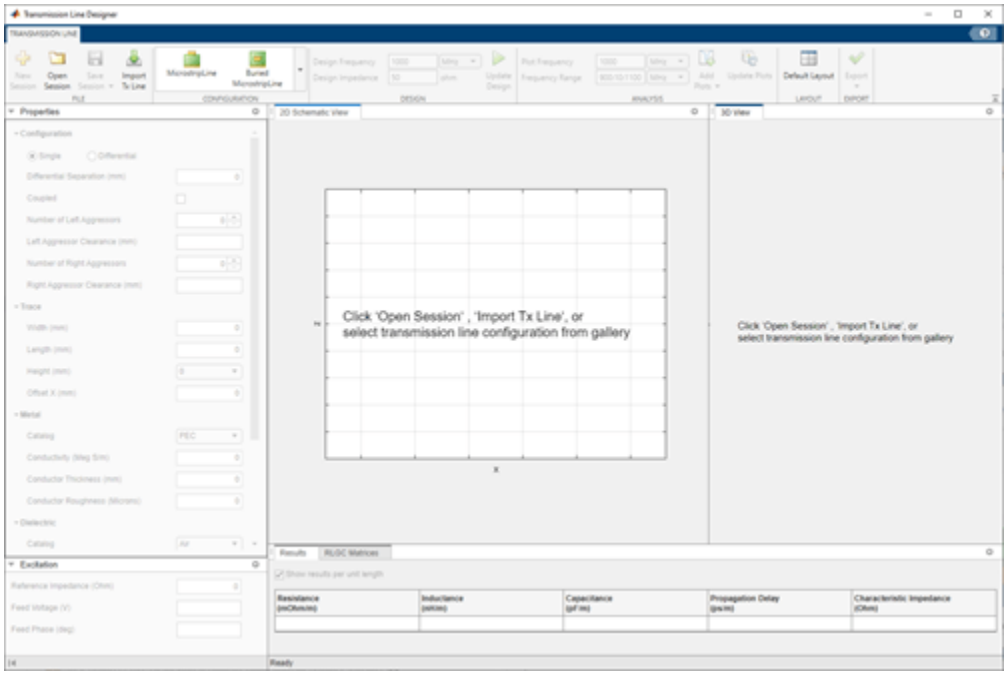
## Examples

### Design Microstrip Transmission Line

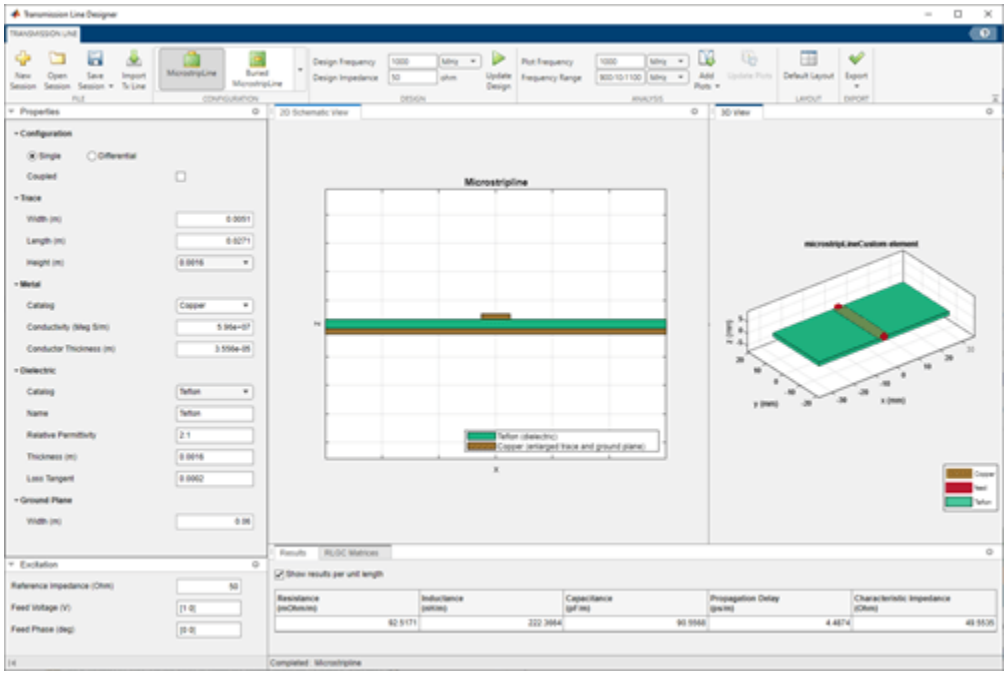
Create a microstrip transmission line using the transmission line designer app.

Launch the `Transmission Line Designer` app.

```
transmissionLineDesigner
```

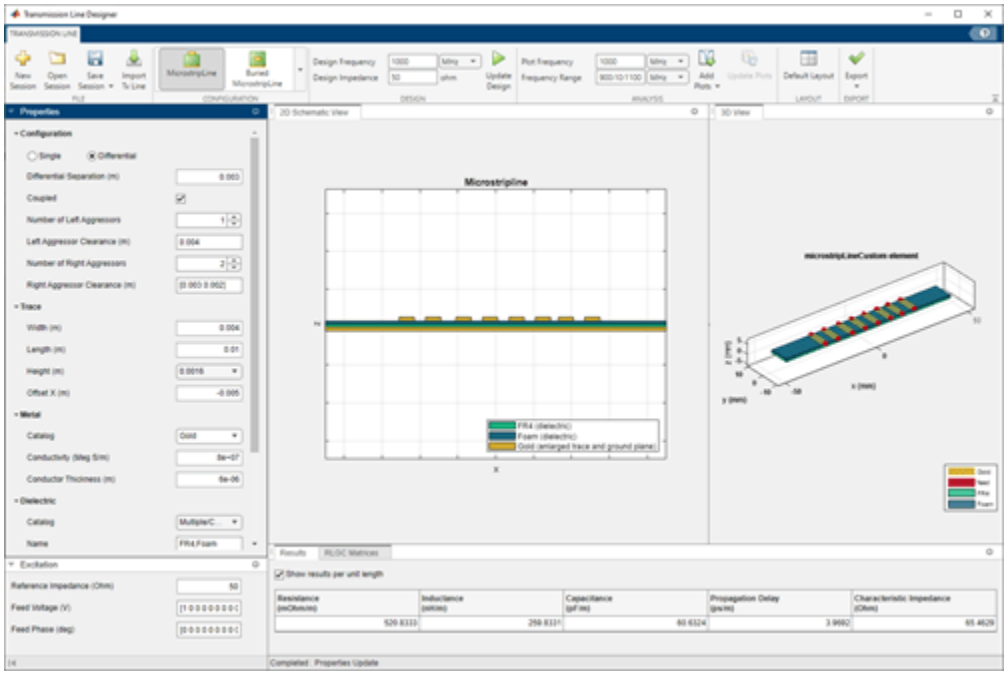



Click **Microstrip line** in the `Configuration` section.

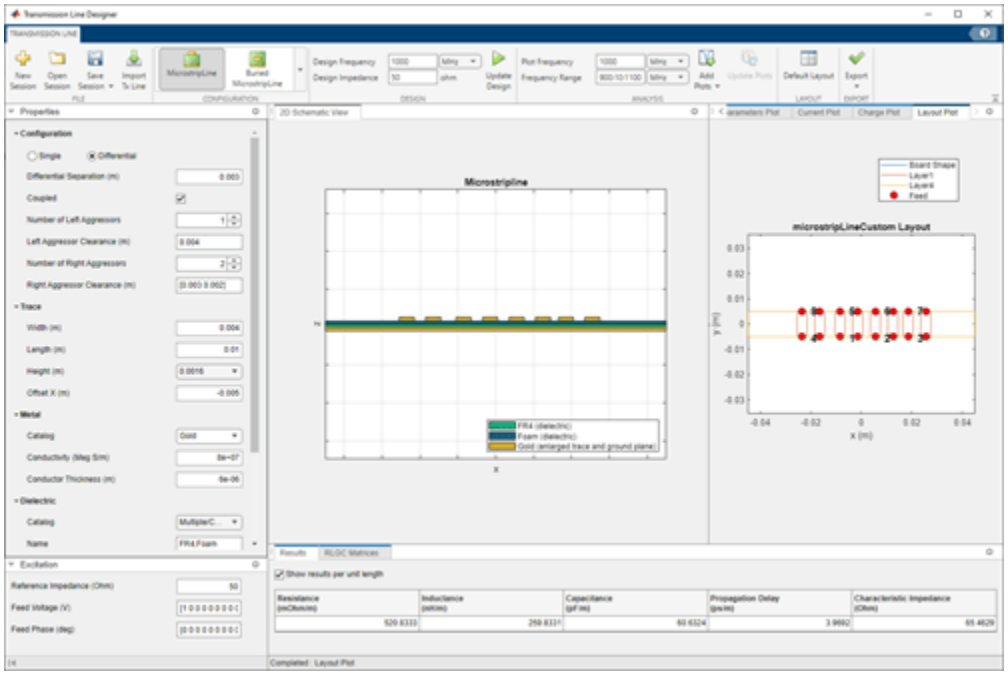



Use the `Properties` pane to add these parameters:

1. **Ground Plane Width** = 90mm
2. Set `Configuration` to **Differential.**
3. **Differential Separation** = 3mm
4. Select **Coupled**. For the left trace, set **Number of Left Aggressors** to 1 and **Left Aggressor Clearance** to 4 mm. For the right trace, set **Number of Right Aggressors** to 2 and **Right Aggressor Clearance** to 3 mm and 2 mm**.**
5. In the **Trace** section, set these properties: **Width** = 4mm, **Trace Length** = 10mm, **Trace X offset** = -5mm
6. In the **Metal** section, set these properties: **Metal** = Gold :: **Conductivity** = 8e+7 ::**Thickness = 6e-6m**
7. In `Dielectric` section, under **Catalog,** select **Multiple/Custom**. Set `Name` to **FR4,Foam**.

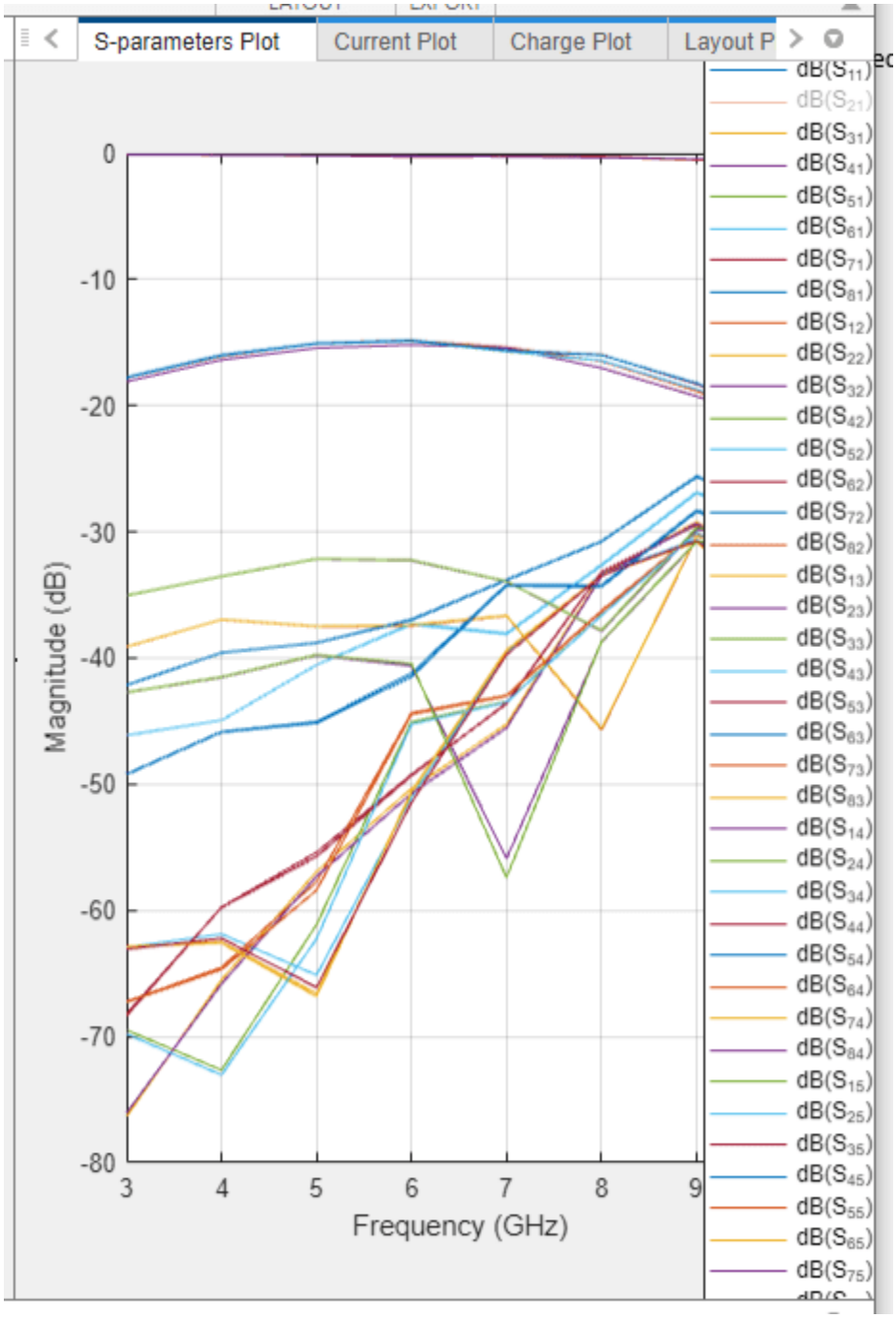


On the app toolstrip, in the **Analysis** section, click `Add Plots` to add S-parameters, current, charge, and layout plots.

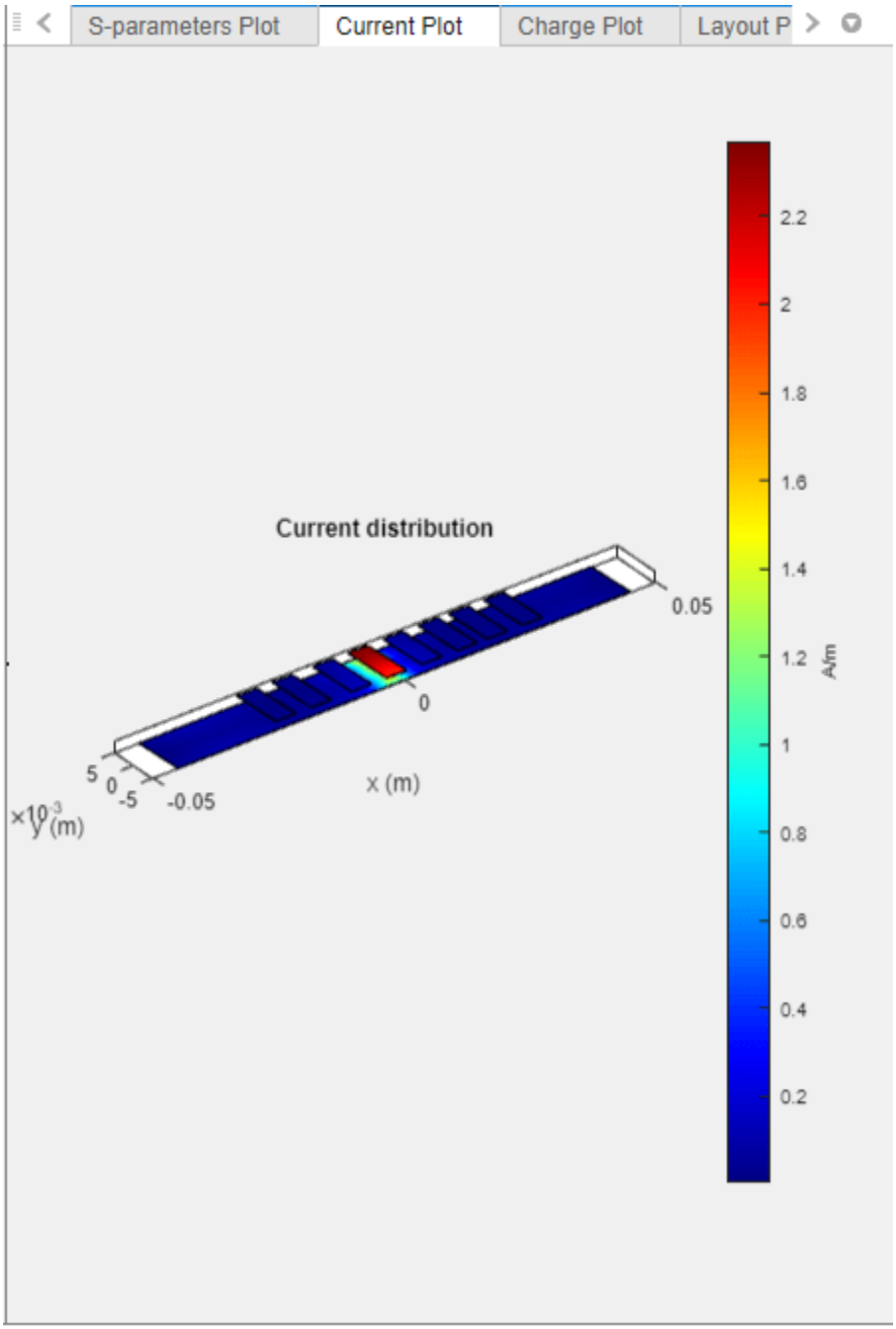


In the **`Analysis`** section, change the `Plot Frequency` to 5 GHz and the `Frequency Range` **to** (3:1:10) GHz. Click `Update Plots` to update all the plots to the new frequency.

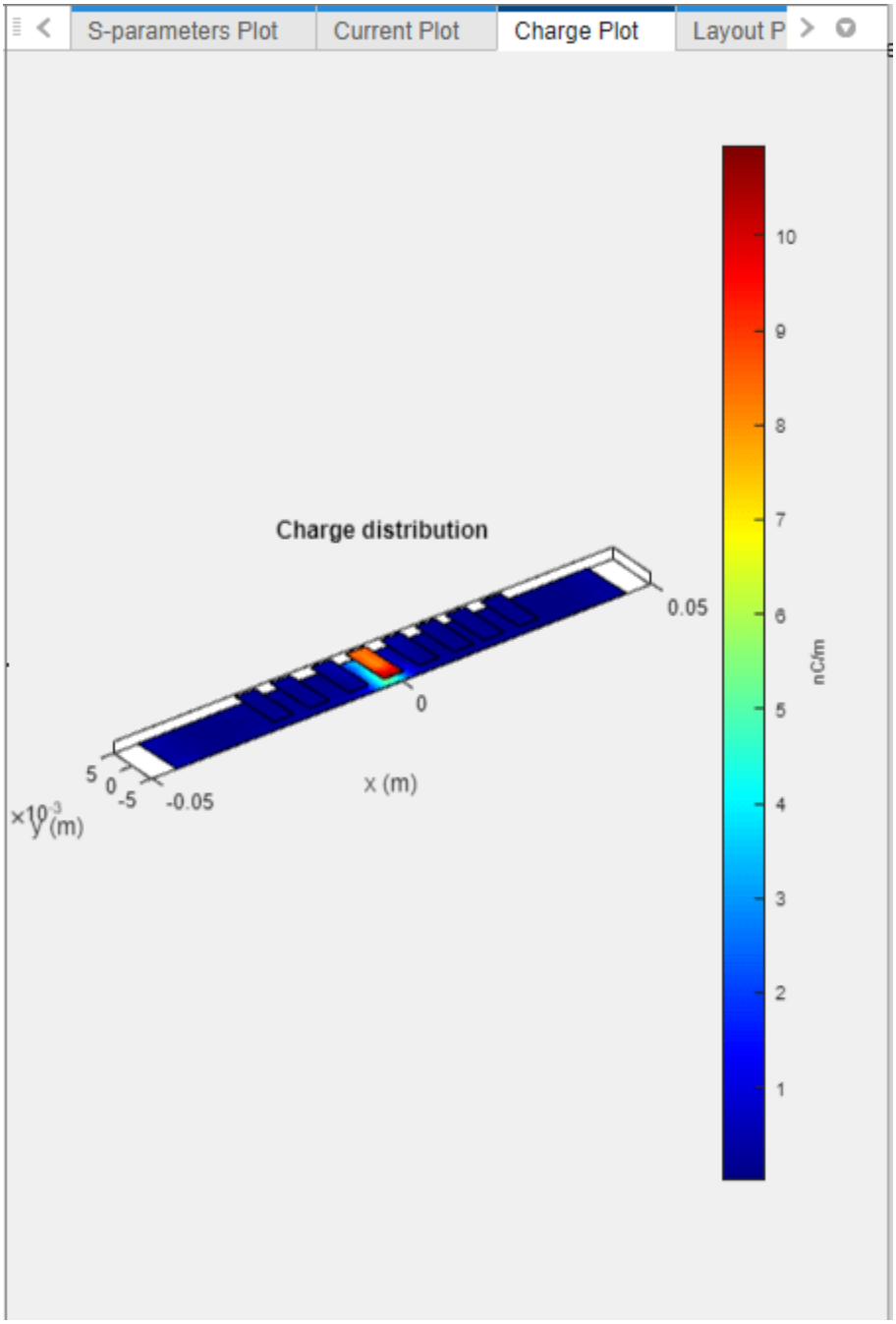
View the S-parameter plot.



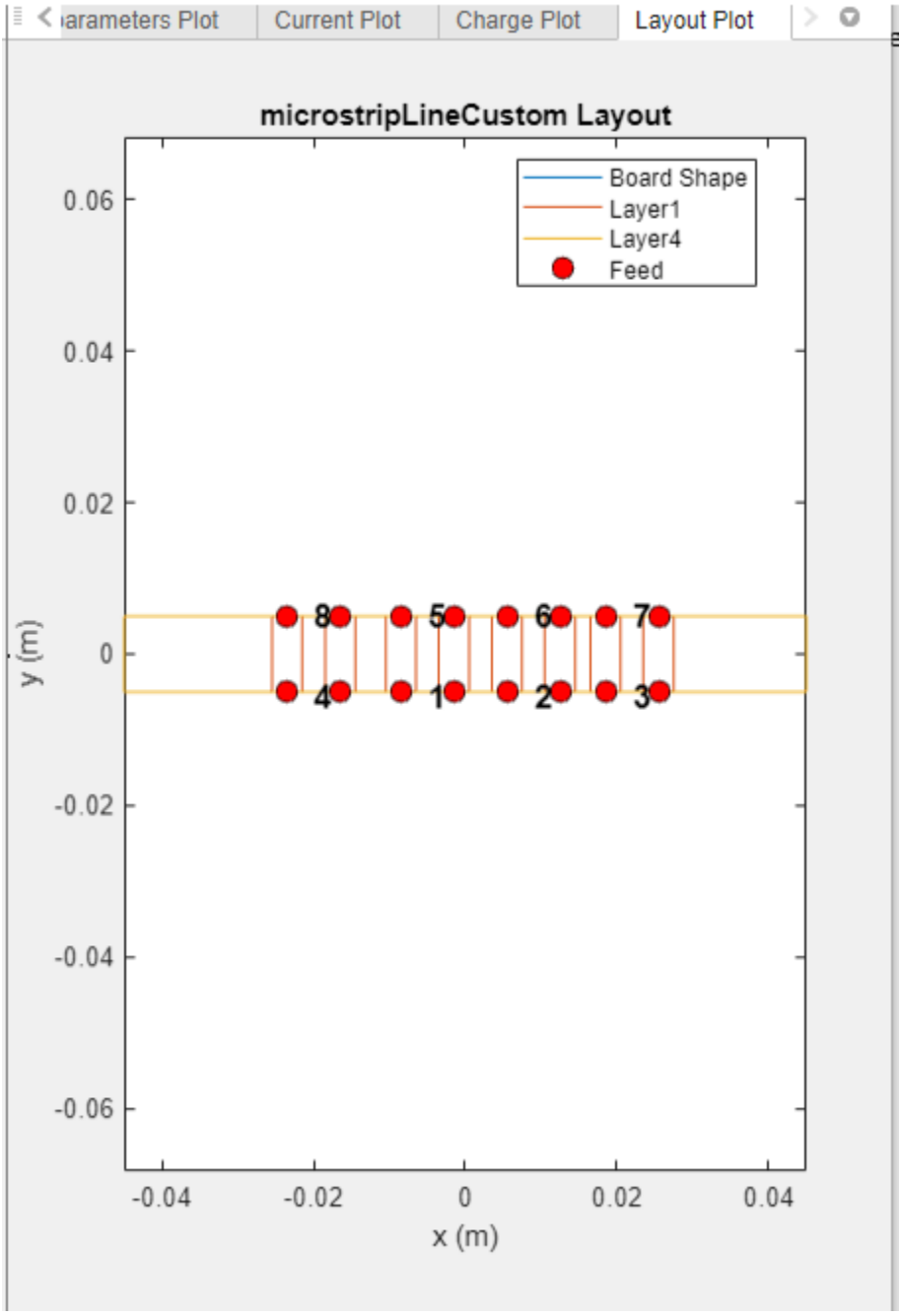

View the current plot.




View the charge plot.




View the layout plot.




## Programmatic Use

`transmissionLineDesigner` opens the **Transmission Line Designer** app.

`transmissionLineDesigner (SavedSession.mat)` opens a saved **Transmission Line Designer** app session from the command line.

# Version History

**Introduced in R2023a**

### Functions