

Antenna Toolbox™ Release Notes



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Antenna Toolbox™ Release Notes

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R2023a

Version: 5.4

New Features

Compatibility Considerations

Construct and analyze backing structures without exciter

Construct the backing structures for “Cavity Antennas” and “Reflector Antennas” by assigning empty value to the 'Exciter' property. Use these structures as Element in the conformalArray and planeWaveExcitation environments to perform fundamental analysis on them.

Create multifilar dipole helix antenna wound around dielectric core

You can now use the Substrate property to include a dielectric core in the dipoleHelixMultifilar object. This configuration creates a multifilar (bi or quad) dipole helix antenna wound around a dielectric core.

PO solver support for reflector antenna analysis

The below mentioned curved “Reflector Antennas” now support Physical Optics (PO) solver for the pattern and current analysis:

- cassegrain
- cassegrainOffset
- gregorian
- gregorianOffset
- reflectorParabolic
- reflectorSpherical

Use custom incident pattern data to excite curved reflector antennas

Import the measured pattern data of an antenna to the MATLAB workspace using the new measuredAntenna object. Use this object as an exciter for the select curved “Reflector Antennas” from the “Antenna Catalog” as listed below:

- cassegrain
- cassegrainOffset
- gregorian
- gregorianOffset
- reflectorParabolic
- reflectorSpherical

Use eggCrate array as an exciter for cavity and reflector type antennas

You can now use the eggCrate array of vivaldi and vivaldiOffsetCavity antennas as the exciter for all the backing structures in the “Cavity Antennas” and “Reflector Antennas” catalog.

Create triangular shape for the metal layer in the PCB Antennas

Use the new `antenna.Triangle` object to create a triangular shape for the metal layer of the PCB antenna created using the `pcbStack` object.

Calculate RCS of pure dielectric structures using the Fast Multipole Method (FMM) solver

The `rsc` function now can calculate the cross section of pure dielectric structures using the FMM Solver.

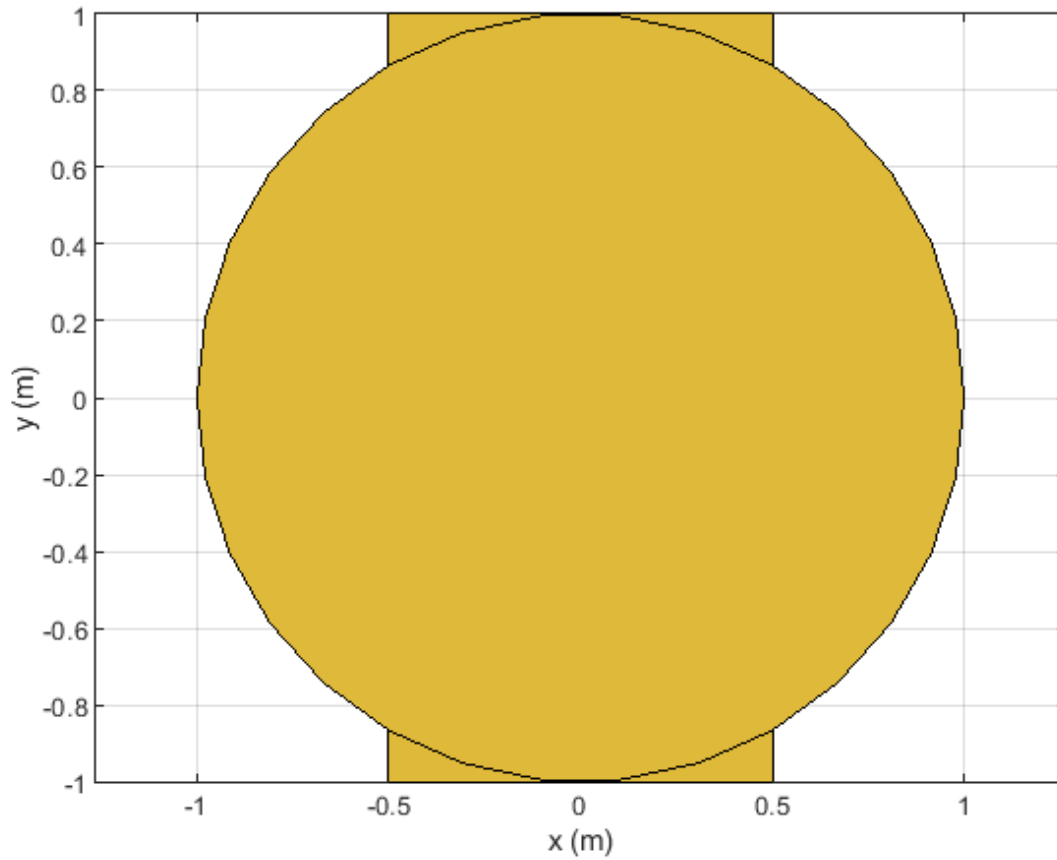
gerberRead update: Support for Aperture Macro (AM), Aperture Block (AB), and Step Repeat (SR)

The `gerberRead` function now supports the AM, AB, and SR commands from the imported gerber files. AM combines multiple basic shapes into a template. AB combines standard flashes and strokes to form a block. SR copies graphic objects along x and y axes.

Display multiple shapes in the same figure

Use the `hold on` functionality to display multiple shapes from the shape catalog on the same figure.

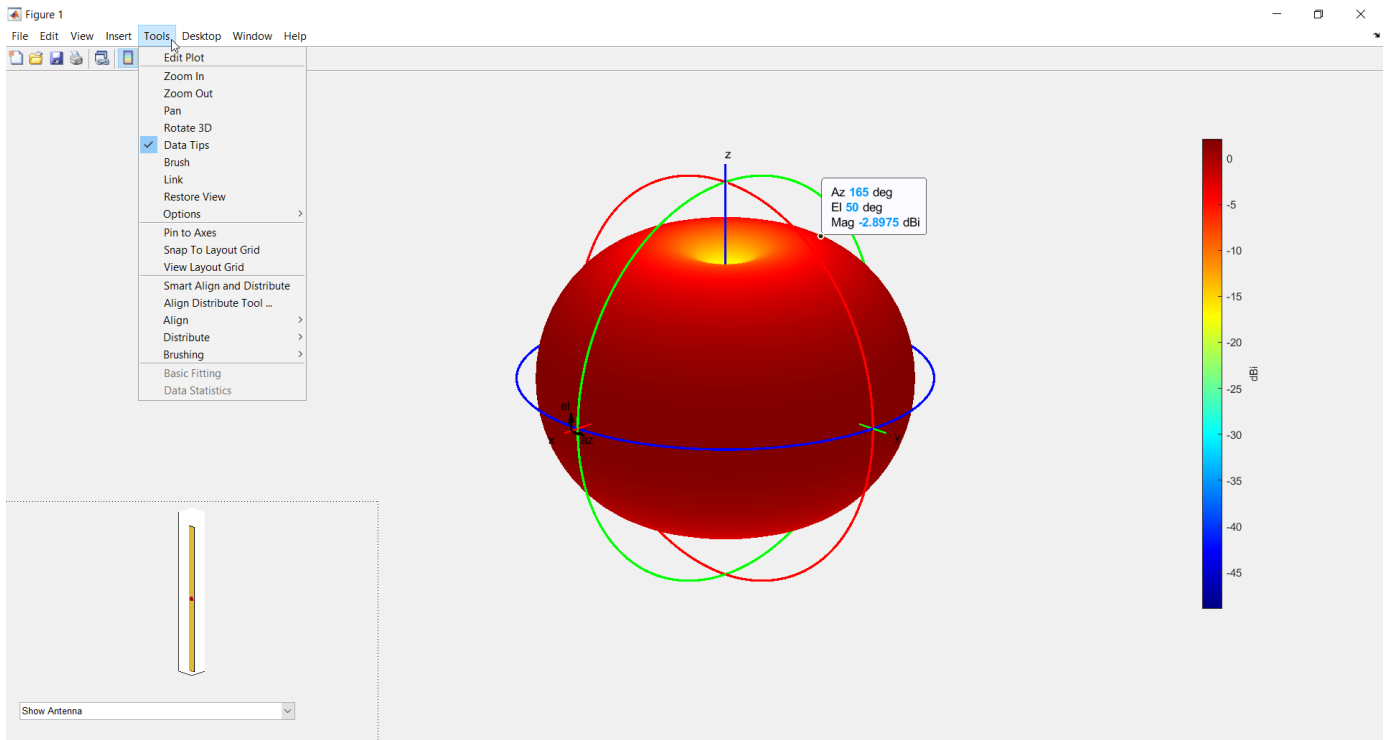
```
show(antenna.Rectangle)
hold on
show(antenna.Circle)
```



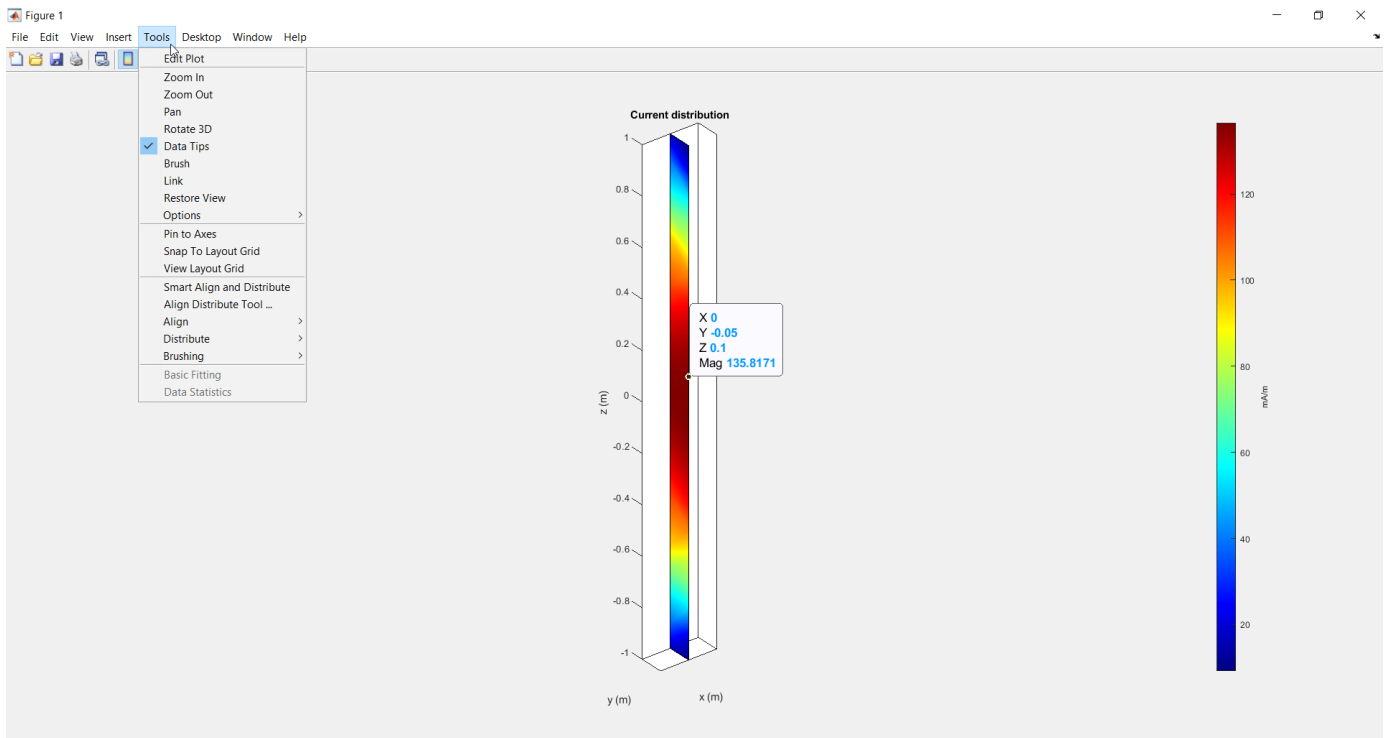
View the position and magnitude data on plots using data tip

Use the *Data Tip* option under *Tools* menu in the figure window to view the values of position and magnitude at that position for pattern, current, and charge plots. Data Tip on a:

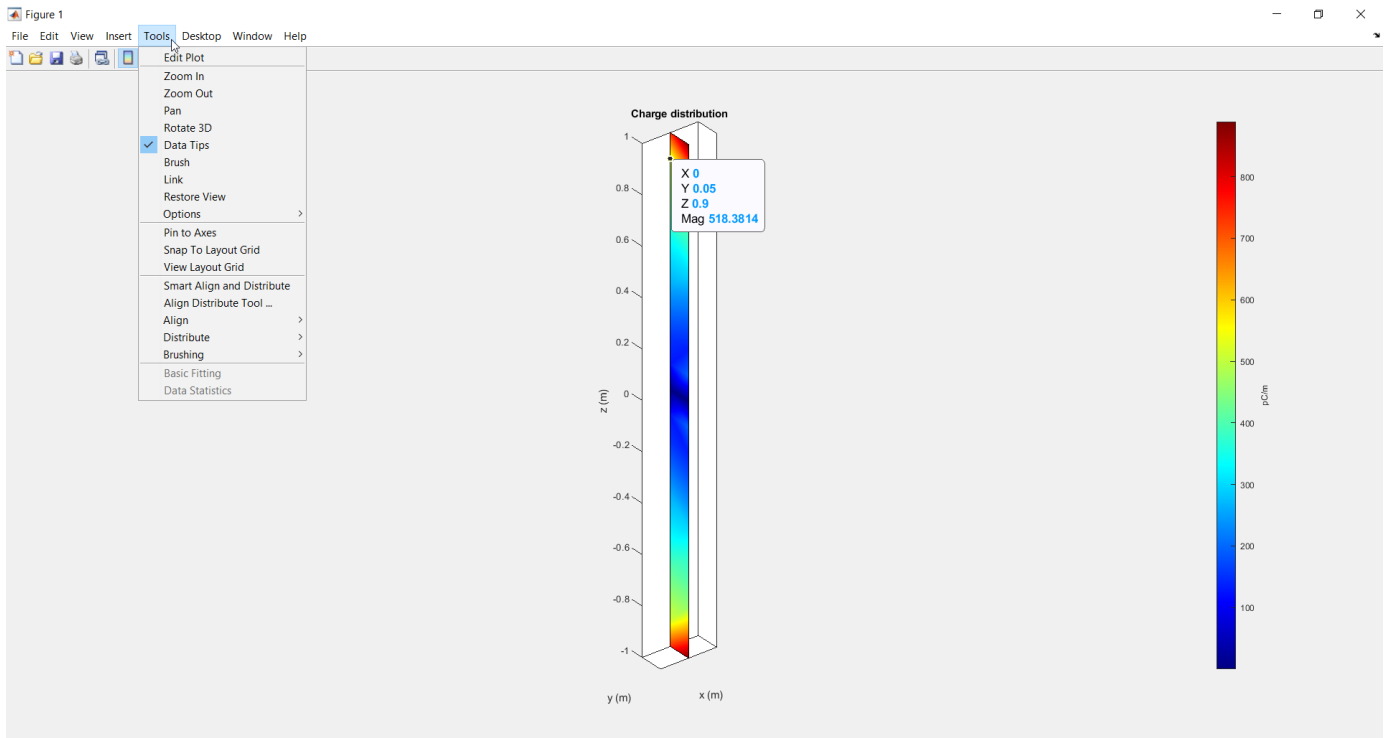
- 1 pattern plot shows azimuth, elevation and magnitude in dBi.



2 current plot shows the coordinates of the selected point and the current density in mA/m. at that point.



3 charge plot shows the coordinates of the selected point and the charge density in pC/m. at that point.



Ray tracing with SBR method supports edge diffractions

Ray tracing models that use the shooting and bouncing rays (SBR) method support the diffraction of rays at surface edges. To specify the maximum number of edge diffractions, create a `RayTracing` object and set its `MaxNumDiffractions` property. For an example that illustrates edge diffractions, see the “Visualize Indoor Propagation Paths” example.

Most analysis functions, such as `raytrace` and `sigstrength`, support up to two edge diffractions. The `coverage` and `sinr` functions support up to one edge diffraction.

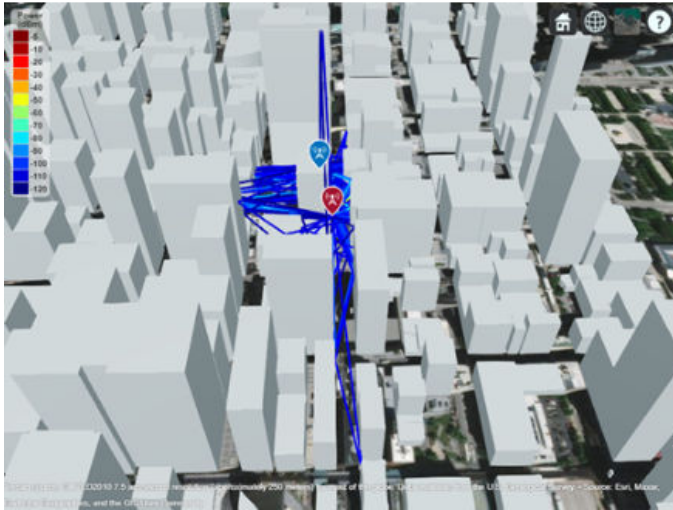
Discard ray tracing paths based on path loss threshold

Ray tracing models enable you to discard propagation paths based on path loss thresholds. To specify the thresholds, create a `RayTracing` object and set its `MaxAbsolutePathLoss` and `MaxRelativePathLoss` properties.

- Specify an absolute threshold by using the `MaxAbsolutePathLoss` property. For example, you can discard paths with more than 100 decibels of path loss by specifying `MaxAbsolutePathLoss` as 100. The default value is `Inf`, which does not discard paths based on absolute path loss.
- Specify a threshold relative to the strongest propagation path by using the `MaxRelativePathLoss` property. The default value is 40, which discards paths that are more than 40 decibels weaker than the strongest path.

This capability can simplify visualizations in Site Viewer. For example, these two images visualize propagation paths for the same transmitter and receiver. The image on the left uses a model where `MaxRelativePathLoss` is `Inf`, and the image on the right uses a model where `MaxRelativePathLoss` is 40 (the default).

Does Not Discard Paths



Discards Paths Relative to Strongest Path



Compatibility Considerations

The default value of the `MaxRelativePathLoss` property is 40. As a result, code from previous releases that does not specify a `MaxRelativePathLoss` value can be affected in these ways:

- The `raytrace` function can return fewer `comm.Ray` objects in R2023a compared to previous releases.
- The `sigstrength`, `coverage`, `sinr`, and `link` functions can return different values in R2023a compared to previous releases.
- The `pathloss` function can return different path loss values in R2023a compared to previous releases.

To avoid discarding propagation paths, set the `MaxRelativePathLoss` property of the ray tracing object to `Inf`.

Ray tracing with SBR method calculates paths using increased precision

When you find propagation paths by using the `raytrace` function with a ray tracing model that uses the shooting and bouncing rays (SBR) method, MATLAB® calculates the results by using double-precision floating-point computations. In previous releases, the function used single-precision floating-point computations.

Compatibility Considerations

The `raytrace` function can return different `comm.Ray` objects in R2023a compared to previous releases.

Functionality being removed or changed

propagationModel("raytracing-image-method") syntax has been removed

Errors

The `propagationModel("raytracing-image-method")` syntax has been removed from the `propagationModel` function.

Use the `propagationModel("raytracing")` syntax instead, which uses the shooting and bouncing rays (SBR) method by default. To use the image method, specify the `Method` name-value argument as `"image"`, for example `propagationModel("raytracing",Method="image")`.

NumReflections name-value argument of the raytrace function has been removed

Errors

The `NumReflections` name-value argument of the `raytrace` function has been removed.

Instead, create a propagation model by using the `propagationModel` function and specify the `MaxNumReflections` name-value argument. Then, use the `raytrace` function with the propagation model as an input. This code shows the recommended workflow.

```
pm = propagationModel("raytracing",MaxNumReflections=3);  
rays = raytrace(tx,rx,pm);
```

Application Examples

This release presents eight new featured examples and one updated example. These examples cover the design, analysis, and fabrication of PCB antennas, the effect of material properties of the conductor on the performance of the antenna, Metasurface antenna, Intelligent Reflecting Surfaces (IRS), wideband Eggcrate array backed by parabolic reflector, performance analysis of the antenna installed on a large platform, Surface Integrated Waveguide (SIW) based Filtenna design, and patch array for S-band monopulse RADAR.

New Examples

- "Modified Sierpinski Monopole Fractal Antenna for Dual-Band Application"
- "Design, Analyze, and Prototype 2x2 Patch Array Antenna"
- "Electromagnetic Analysis of Intelligent Reflecting Surface"
- "Analyze Metal Conductors in Helical Dipole Antenna"
- "Design and Analyze Parabolic-Reflector-Backed Wideband Eggcrate Array"
- "Antennas on A Glider as Platform"
- "Design S-Band Monopulse Tracking RADAR Antenna"
- "Design and Analyze Tapered-Slot SIW Filtenna"

Updated Example

- "Metasurface Antenna Modeling" - Added dielectric substrate and updated analysis plots

R2022b

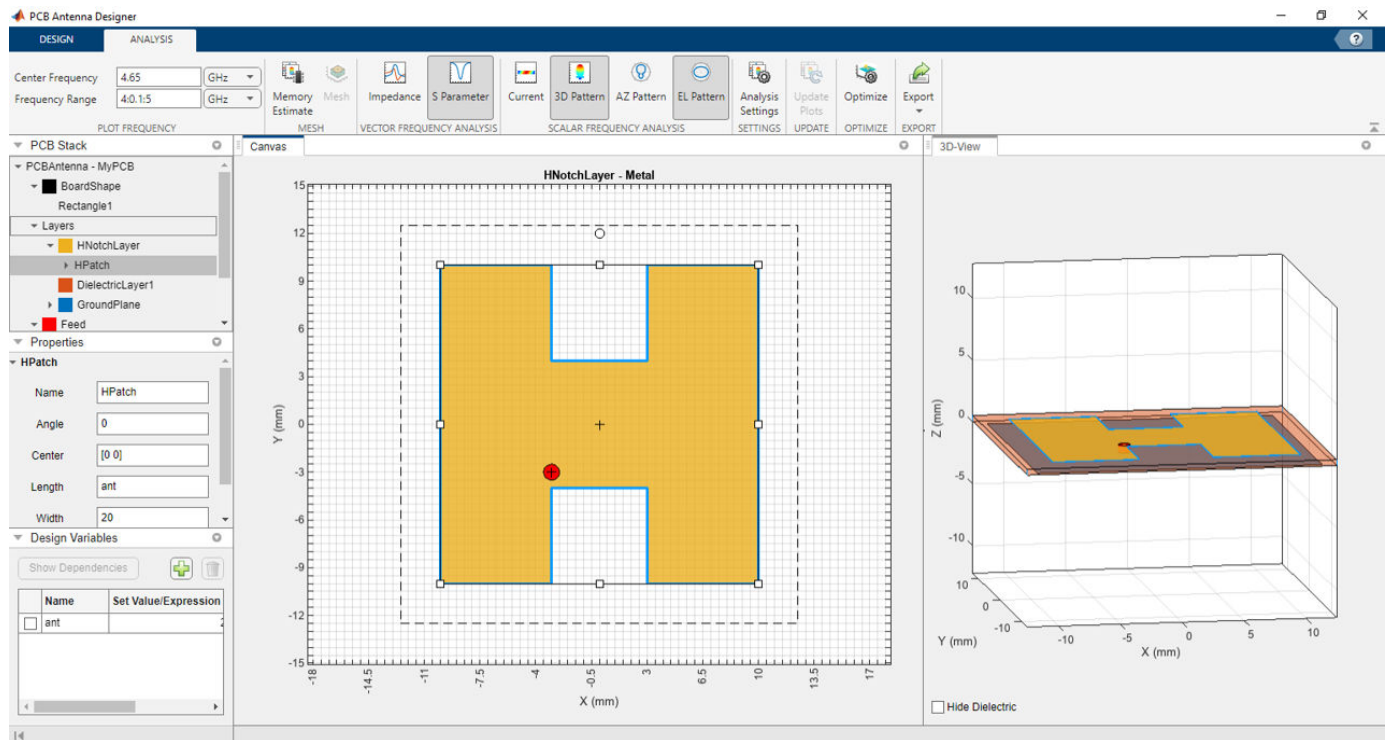
Version: 5.3

New Features

Compatibility Considerations

PCB Antenna Designer App Update: Optimize PCB antenna designs

You can now optimize PCB antenna designs using the SADEA and surrogate optimization methods in the **PCB Antenna Designer** app. Create design variables to enable the optimization process. Optimize your designs for bandwidth, gain, front-to-back-lobe ratio, and area.



Create dipole helix antenna wound around dielectric core

You can now use the Substrate property to include a dielectric core in the dipoleHelix object. This configuration creates a dipole helix antenna wound around a dielectric core.

Add Via to infinite array using pcbStack element

The infiniteArray object now supports pcbStack as an element. Use the pcbStack object to add Via to the infinite array design. Use this functionality to include the vertical component of the surface current in your analysis.

mesh Update: Additional mesh parameters support for all antenna and array elements

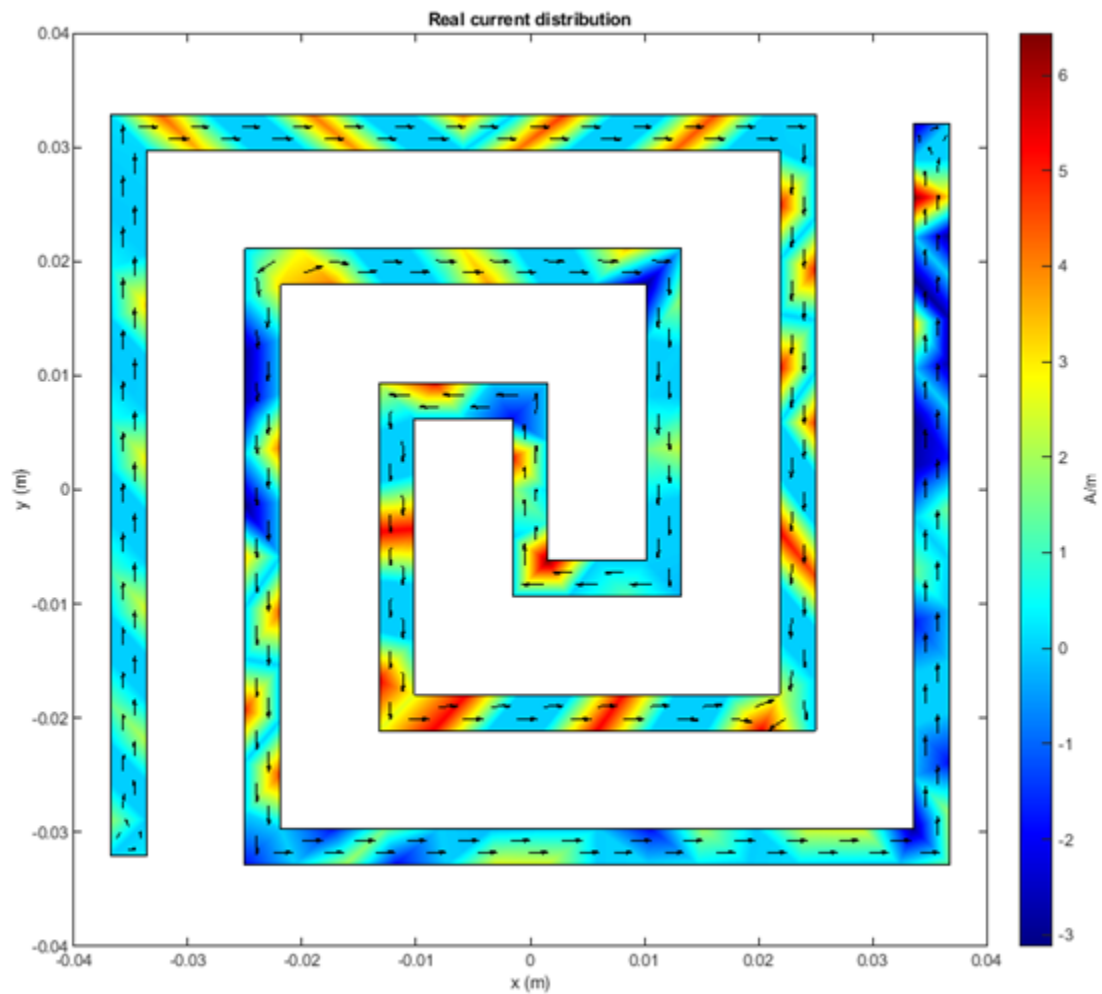
The mesh function now takes these new name-value arguments

- **MinEdgeLength** -- Generate a mesh using the smallest edge length of your feature.
- **GrowthRate** -- Control the growth rate of the mesh. This input defines the gradation in the triangle sizes of the mesh.

current Update: Visualize direction of current flow and complex current on metal surface

The current function now takes these new name-value arguments

- `Type` -- Choose between the absolute, real, or imaginary values of the current vector to plot the current distribution.
- `Direction` -- Plot the direction of the current flow overlaid on the distribution plot.



Determine antenna orientation and polarization to capture maximum power from plane-wave

Use the `design` function of `planeWaveExcitation` object to determine the required orientation and polarization for a receiver antenna to capture the maximum power from an incident plane-wave at a given frequency.

Choose solver for analysis of planeWaveExcitation objects

The planeWaveExcitation object now supports multiple solvers for your analysis. Use the SolverType property to specify the solver.

gerberRead update: Support for new shapes

The gerberRead function now supports three new shapes: clockwise & anticlockwise circular arc, curved regions, and obround aperture.

RF Propagation: Ray tracing with SBR method finds paths with exact geometric accuracy

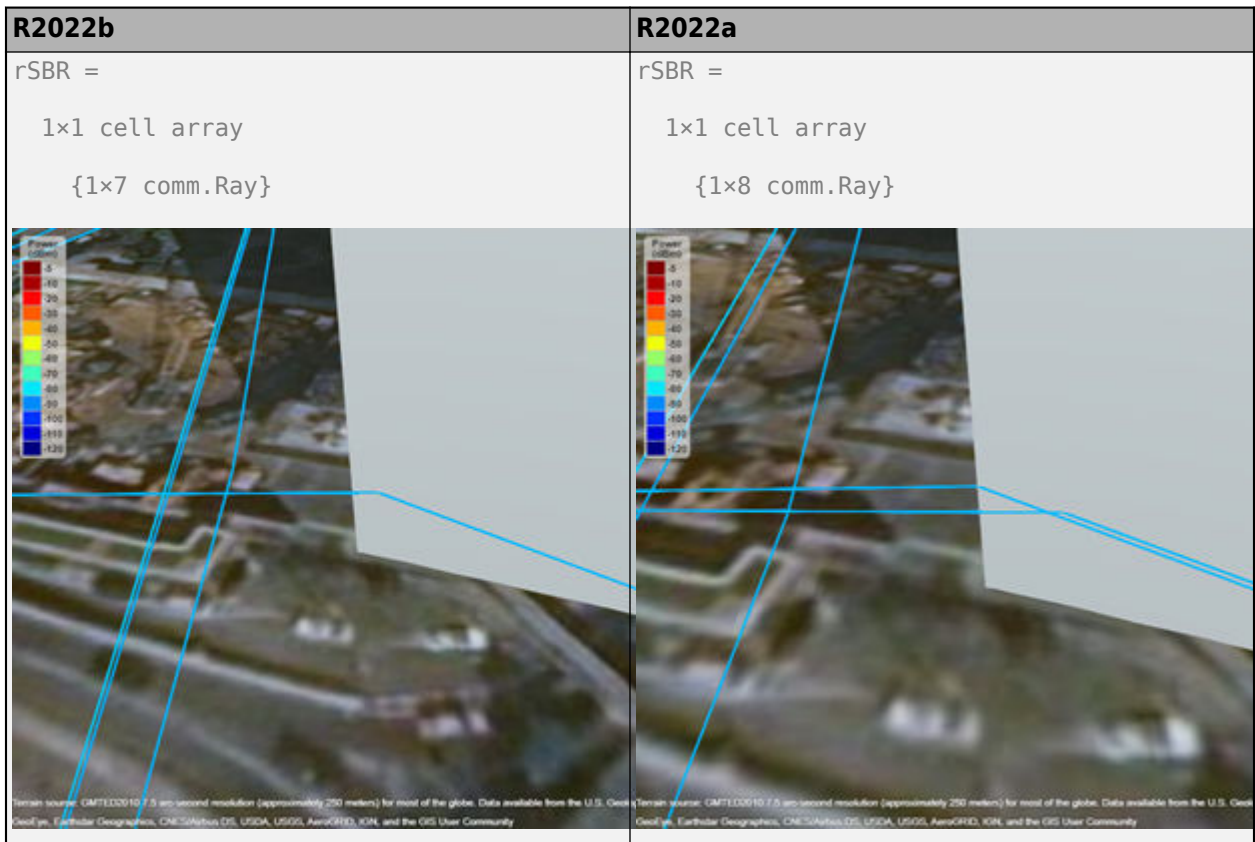
When you find propagation paths by using the raytrace function and the shooting and bouncing rays (SBR) method, MATLAB corrects the results so that the geometric accuracy of each path is exact, using single-precision floating-point computations. In previous releases, the paths have approximate geometric accuracy.

For example, this code finds propagation paths between a transmitter and receiver by using the default SBR method and returns the paths as comm.Ray objects. In R2022b, the raytrace function finds seven propagation paths. In earlier releases, the function approximates eight propagation paths, one of which is a duplicate path.

```
viewer = siteviewer(Buildings="hongkong.osm");

tx = txsite(Latitude=22.2789,Longitude=114.1625,AntennaHeight=10, ...
    TransmitterPower=5,TransmitterFrequency=28e9);
rx = rxsite(Latitude=22.2799,Longitude=114.1617,AntennaHeight=1);

rSBR = raytrace(tx,rx)
raytrace(tx,rx)
```



Paths calculated using the SBR method in R2022b more closely align with paths calculated using the image method. The image method finds all possible paths with exact geometric accuracy. For example, this code uses the image method to find propagation paths between the same transmitter and receiver.

```
viewer = siteviewer(Buildings="hongkong.osm");

tx = txsite(Latitude=22.2789,Longitude=114.1625, ...
    AntennaHeight=10,TransmitterPower=5, ...
    TransmitterFrequency=28e9);
rx = rxsite(Latitude=22.2799,Longitude=114.1617, ...
    AntennaHeight=1);

pm = propagationModel("raytracing",Method="image",MaxNumReflections=2);

rImage = raytrace(tx,rx,pm)

rImage =
1x1 cell array
{1x7 comm.Ray}
```

In this case, the SBR method finds the same number of propagation paths as the image method. In general, the SBR method finds a subset of the paths found by the image method. When both the image and SBR methods find the same path, the points along the path are the same within a tolerance of machine precision for single-precision floating-point values.

This code compares the path losses, within a tolerance of `0.0001`, calculated by the SBR and image methods.

```
abs([rSBR{1}.PathLoss]-[rImage{1}.PathLoss]) < 0.0001
```

```
ans =
```

```
1x7 logical array
```

```
1 1 1 1 1 1 1
```

The path losses are the same within the specified tolerance.

Compatibility Considerations

The `raytrace` function can return different results in R2022b compared to previous releases.

- The function can return a different number of `comm.Ray` objects because it discards invalid or duplicate paths.
- The function can return different `comm.Ray` objects because it calculates exact paths rather than approximate paths.

These differences can also affect the path losses calculated by the `raypl` and `pathloss` functions.

RF Propagation: Ray tracing functions consider multipath interference

When calculating received power using ray tracing models, the `sigstrength`, `coverage`, `sinr`, and `link` functions now incorporate multipath interference by using a phasor sum. In previous releases, the functions used a power sum. As a result, the calculations in R2022b are more accurate than in previous releases.

Compatibility Considerations

The `sigstrength`, `coverage`, `sinr`, and `link` functions can return different results in R2022b compared to previous releases.

RF Propagation: Customize spacing of launched rays for ray tracing with SBR method

When performing ray tracing using the shooting and bouncing rays (SBR) method, you can customize the spacing of launched rays by specifying the `AngularSeparation` property of the `RayTracing` object as a numeric value in degrees. In previous releases, the `AngularSeparation` property supported only the options "high", "medium", and "low".

To improve the accuracy of the number of paths found by the SBR method, decrease the value of `AngularSeparation`. Decreasing the value of `AngularSeparation` can increase the amount of time MATLAB requires to perform the analysis.

Application Example: Custom geometry pcbStack antenna

This release contains a new featured example showcasing the design and analysis of a custom geometry `pcbStack` antenna for ultra-wideband applications:

-
- The Design and Analysis of a Diamond-Shaped Antenna for Ultra-Wideband Applications example shows the design and analysis of a planar diamond shaped monopole antenna with ultra-wide bandwidth, suitable for compact devices.

R2022a

Version: 5.2

New Features

PCB Antenna Designer App Update: Define variables in PCB antenna designer app

You can now define variables in the **PCB Antenna Designer** app and use them to set the properties of the shape and dielectric objects within a layer of a `pcbStack` object. The antenna design along with variables created can be exported for further analysis to a script or a workspace.

infiniteArray Object Update: Faster solution for infinite arrays without ground planes

The method of moments (MoM) solver in the `infiniteArray` object is now about 30 percent faster when solving infinite arrays without the ground plane.

Direction of Arrival Determination: Determine direction of transmission source using mutual coupling effects

You can use the new `doa` function on the `conformalArray` and `planeWaveExcitation` objects to determine the direction of arrival of an incoming signal transmitted from a far-field source, with respect to the center of the receiver array. The `doa` function uses s-parameters to calculate the angles of arrival in the spherical coordinate system. If the transmission source in your model / analysis / use case is:

- An antenna object, then use the `doa` function on the `conformalArray` object.
- A plane wave signal, then use the `doa` function on the `planeWaveExcitation` object.

Both the objects use a uniform homogenous linear or rectangular array in the horizontal plane and centered at the origin, as a receiver.

Slicer Interactivity in Mesh, Charge, and Current Plots: View interior or inaccessible parts of meshed antenna geometry

You can now use the `Slicer` name-value argument in the:

- `mesh` function to see the internal parts of an antenna geometry
- `charge` or `current` functions to see the charge or current distributions over specific cross sections of an antenna geometry.

patternPlotOptions Update: Use pattern plot options on all 3-D pattern visualizations

You can now use the `PatternPlotOptions` on all 3-D pattern plots created using the `patternMultiply`, `arrayFactor`, `patternFromSlices`, and `patternCustom` functions.

Custom Dual-Reflector Antenna: Design, visualize, and analyze dual-reflector antenna using customized properties

The new `customDualReflectors` antenna object creates a dual-reflector antenna with conical horn antenna as the exciter and empty geometries for the reflectors. Use its properties to:

-
- Assign custom geometry to the main and sub reflector.
 - Change the exciter element
 - Change the position and orientation of the reflectors and the exciter.

Dual-Reflector antenna has a very high gain and a low spillover and is used as a ground station antenna in satellite communications.

Helix and Multifilar Helix Antenna Update: Create helix and multifilar helix antennas wound around dielectric core

You can now use the `Substrate` property to include a dielectric core in the `helix` and the `helixMultifilar` objects. This creates helix and multifilar helix antennas wound around a dielectric core.

Monopole Top-Hat Antenna Update: Create monopole top-hat antenna with dielectric substrate

You can now use the `Substrate` property to include a dielectric substrate in the `monopoleTopHat` object. This creates a monopole top-hat antenna with a dielectric substrate placed between the ground plane and the top hat. The `monopoleTopHat` object lets you specify multiple dielectric layers also.

RF Propagation Update: Improved performance for SBR ray tracing point-to-area coverage and point-to-point analysis cases

The shooting and bouncing rays (SBR) ray tracing method shows improved performance for point-to-area coverage and point-to-point analysis cases with low angular separation.

As the angular separation decreases (and the number of launched rays increases), performance improvements are greater for the point-to-area coverage cases. For example, this code runs up to five times faster than the previous release for the point-to-area coverage case with low angular separation:

```
viewer = siteviewer("Buildings","chicago.osm");
tx = txsite("Latitude",41.8800,"Longitude",-87.6295);
pm = propagationModel("raytracing", ...
    "Method","sbr", ...
    "AngularSeparation","low", ...
    "MaxNumReflections",3);

timeit(@() coverage(tx,pm,"MaxRange",250))
```

The approximate execution times are:

- **R2021b**: 182 s
- **R2022a**: 29 s

On the same test platform, this code runs two times faster than the previous release for the point-to-point analysis case with low angular separation:

```
sv = siteviewer("SceneModel","conferenceroom.stl");
tx = txsite("cartesian", ...
```

```
    "AntennaPosition",[-1.45; -1.4; 1.5]);  
rx = rxsite("cartesian", ...  
    "AntennaPosition",[.3; .2; .5]);  
pm = propagationModel("raytracing", ...  
    "CoordinateSystem","cartesian", ...  
    "Method","sbr", ...  
    "AngularSeparation","low", ...  
    "MaxNumReflections",10);  
  
timeit(@() raytrace(tx,rx,pm))
```

The approximate execution times are:

- **R2021b:** 6.3 s
- **R2022a:** 3.0 s

These code segments were timed on a Windows 10, Intel® Xeon® CPU E5-1650 v4 @ 3.60 GHz test system.

Application Examples: Custom geometry pcbStack antenna, Direction of arrival

This release contains three new featured examples showing the design and analysis of custom geometry pcbStack antenna for various applications:

- The Design Series-Fed Patch Antenna for 5G Base Station Antenna example shows the design and analysis of a series fed patch antenna array at 28 GHz which is used as mm-wave band 5G mobile base station antenna.
- The Design PCB Antenna for USB Dongle and BLE Applications at 2.4 GHz example shows the design and analysis of a PCB antenna at 2.4 GHz, used in USB dongles and BLE applications.
- The Miniaturize Patch Antennas Using Metamaterial-Inspired Technique example shows the design of a miniaturized patch antenna with a complementary split-ring resonator (CSRR) loading plane and evaluates the performance of the patch shrunk 16 times the resonant dimension.
- The Design and Analysis of Compact Ultra-Wideband MIMO Antenna Array example shows the design of a compact ultra-wideband (UWB) MIMO antenna array built using two orthogonally placed planar monopole antennas in the horizontal plane.
- The Direction of Arrival Determination Using Full-Wave Electromagnetic Analysis example shows two methods for estimating the direction of arrival of an incoming signal using the `doa` function. This example uses the `conformalArray` object as a receive array when the transmission source is an antenna object and uses the `planeWaveExcitation` object as a receive array when the transmission source is a plane wave.

R2021b

Version: 5.1

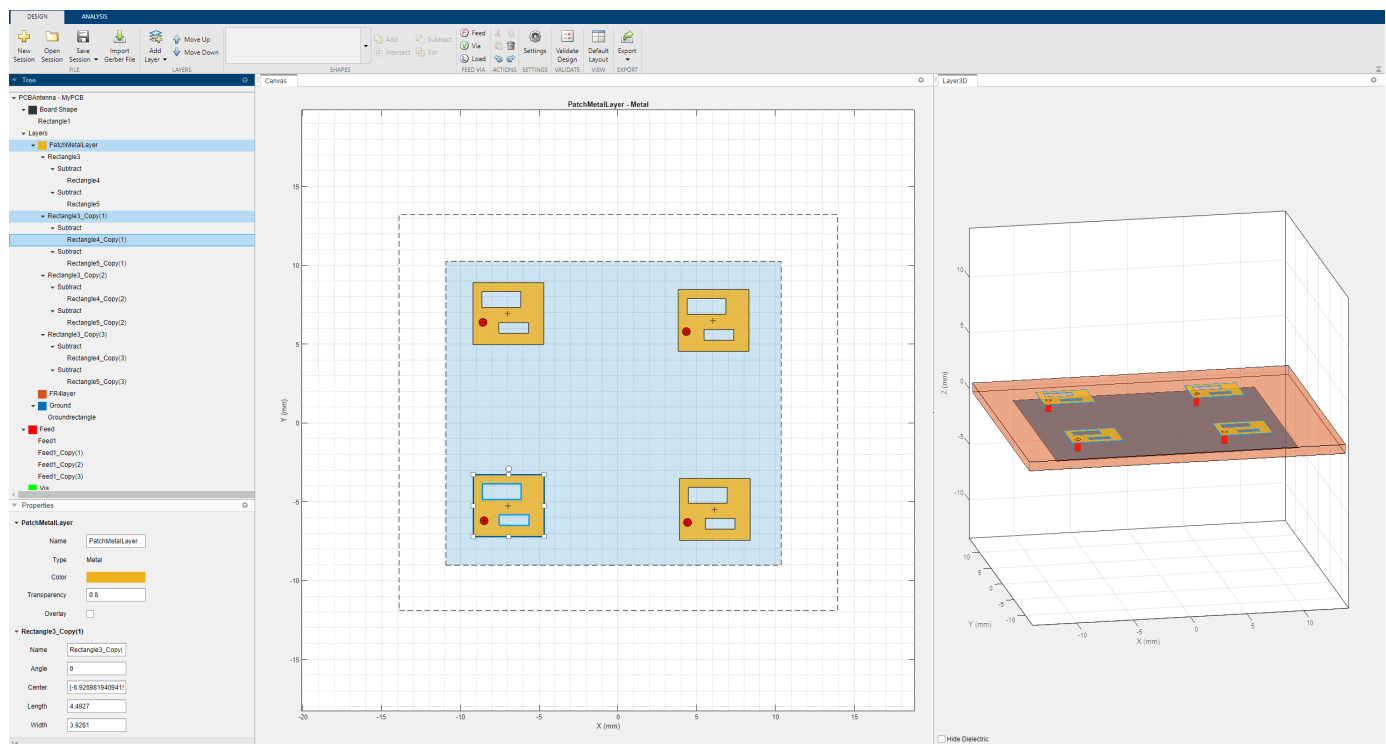
New Features

Compatibility Considerations

PCB Antenna Designer App: Design, analyze, and fabricate PCB antennas

Use the **PCB Antenna Designer** app to:

- Create various shapes for the metal layer of a PCB antenna by using Boolean operations on basic shapes.
- Create a custom PCB stack antenna with multiple metal and dielectric layers.
- Add vias and feeds to metal layers.
- Design a PCB antenna using Gerber files
- Analyze the design at the desired frequency.
- Export a design to the workspace or a MATLAB script.
- Modify the mesh of an antenna using mesh parameters.



STL Files: Detect bad features in STL file

Use the `stlFileChecker` object to detect and enlist bad features in an STL file, such as nonmanifold edges and vertices, slivers, and duplicate vertices.

Fast Multipole Method (FMM): Support for electrically large antennas and installed antennas

The FMM solver allows you to capture higher order effects such as diffraction, creeping wave, and traveling wave effects when you analyze installed antenna and radar cross-sections (RCS). In

addition, the solver now has a reduced memory requirement for large meshes. You can also analyze antennas mounted on platforms using the FMM.

Method of Moments (MoM) Physical Optics (PO): Faster performance for analysis of electrically large structures

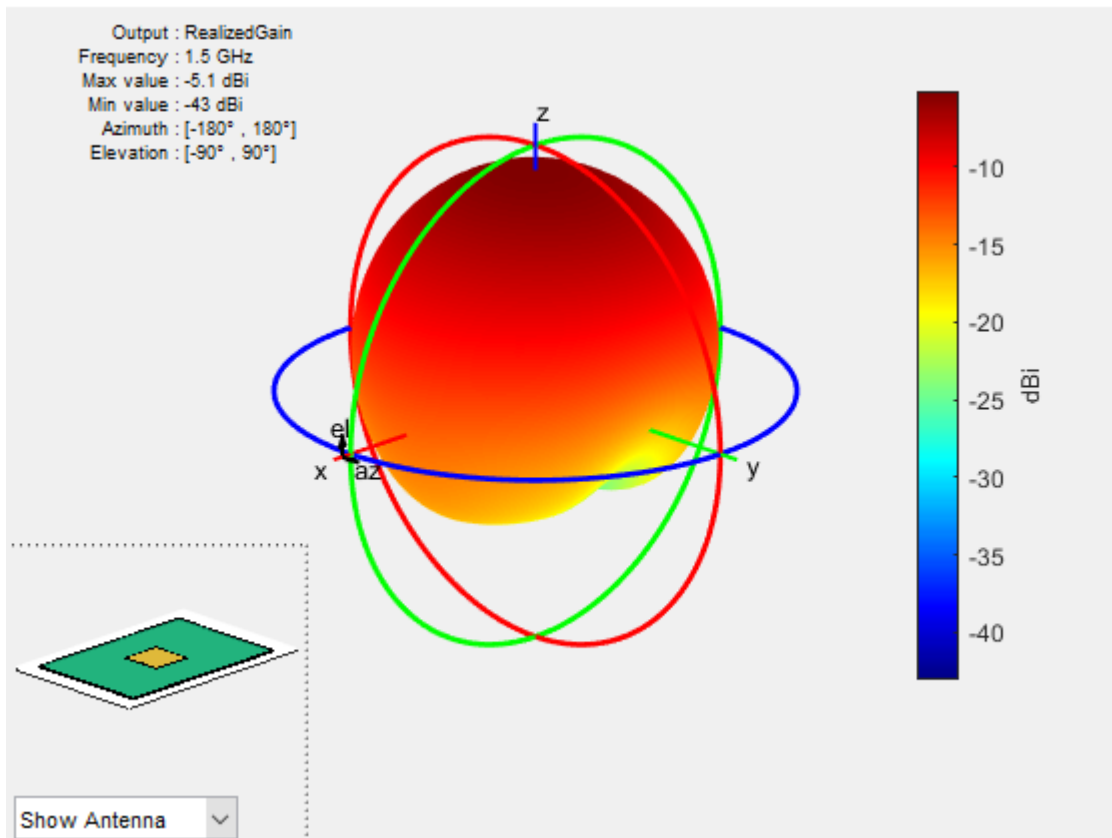
The MoM-PO solver now yields faster performance when you solve and analyze electrically large structures.

Infinite Arrays: Support for metal-dielectric structures and metal antennas without ground plane

You can now design infinite arrays of metal-dielectric structures. Also, starting in R2021b, you can design infinite arrays of metal antennas without an infinite ground plane.

Realized Gain: Calculate and visualize realized gain of antennas and arrays

You can now calculate and visualize the realized gain of antennas and arrays with a single or multiple ports using the pattern function.

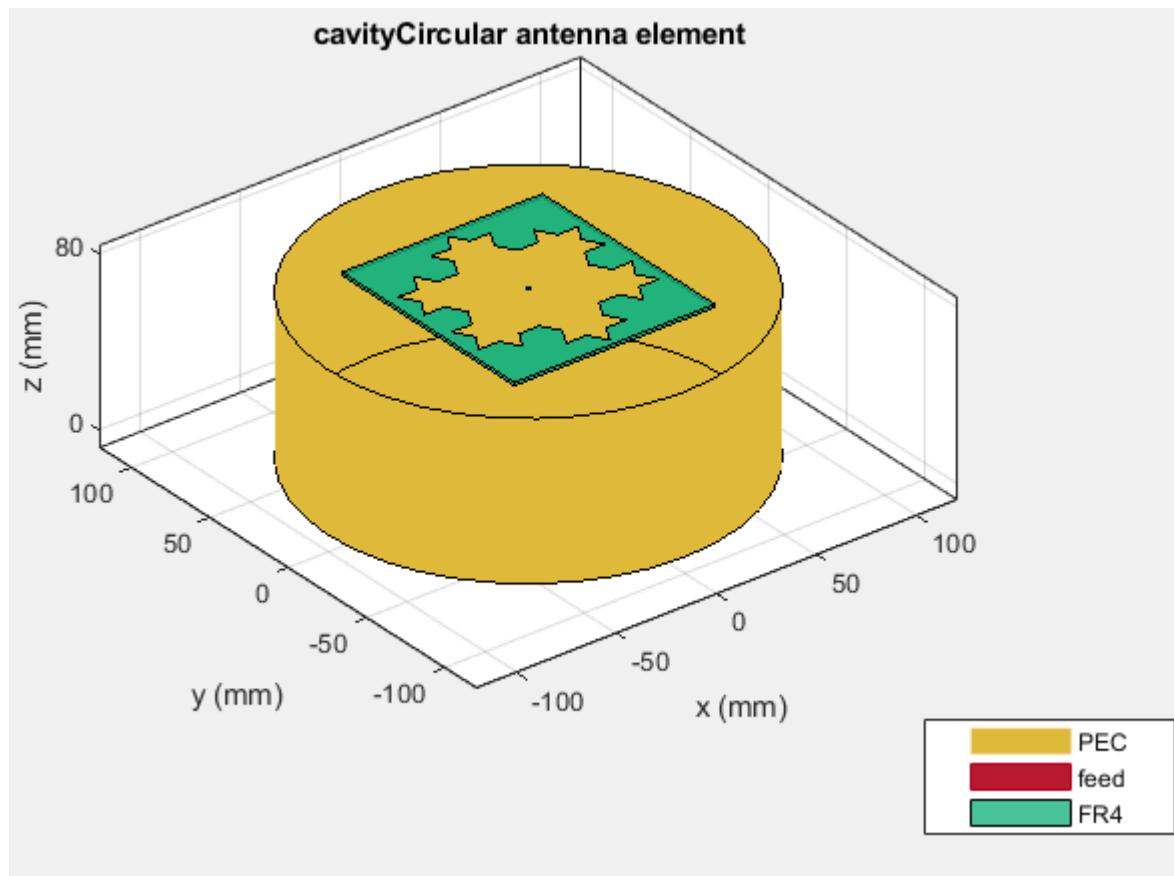


EHfields enhancements: Support for polarization and calculating fields for spherical coordinate system

EHFields now enables you to calculate the electric and magnetic fields of antennas using a spherical coordinate system. EHFields also now supports horizontal and vertical polarization options.

Backing Structures Update: Support for metal-dielectric exciters

You can now use metal-dielectric antennas and array structures as exciters for backing structures.



RF Propagation: Perform ray tracing analysis using SBR method

- The default ray tracing method is now 'sbr' with up to two reflections (instead of 'image' with up to one reflection).
- Minor improvements to ray precision and the number of rays computed.

For more information, see [Choose a Propagation Model](#) and `propagationModel`.

RF Propagation: Import and view propagation paths within indoor scenes

In Site Viewer, you can now import and view standard tessellation language (STL) models or triangulation representations that have Cartesian coordinates by using the `siteviewer` object. The object has these added properties to support Cartesian coordinates.

Property	Description
<code>SceneModel</code>	STL model file or triangulation object
<code>Transparency</code>	Transparency of model
<code>ShowOrigin</code>	Option to show origin
<code>ShowEdges</code>	Option to show edges of model

These functions now support `txsite` and `rxsite` objects that have Cartesian coordinates.

- Display RF propagation rays by using the `raytrace` function.
- Display the line-of-sight (LOS) visibility status between sites by using the `los` function.
- Display the communication link status between sites by using the `link` function.
- Display the radiation patterns for a site by using the `pattern` function.
- Control the visibility of sites by using the `show` and `hide` functions.

When you import a scene using Site Viewer, analysis functions such as `raytrace` and `los` use the scene as the 3-D environment.

Functionality being removed or changed

Meshing infrastructure

Behavior change

Starting in R2021b, you might see a slight variation in antenna analysis results due to an update to the meshing infrastructure.

Default value of Method name-value argument for propagationModel function is now shooting and bouncing rays method

Behavior change

Starting in R2021b, when you create a propagation model using the syntax `propagationModel('raytracing')`, MATLAB returns a `RayTracing` model with the `Method` name-value argument value set to `'sbr'` and two reflections (instead of `'image'` and one reflection as in previous releases). To create ray tracing propagation models that use the `image` method, use the syntax `propagationModel('raytracing','Method','image')`. For more information, see [Choose a Propagation Model](#) and `propagationModel`.

raytrace, coverage, link, sigstrength, and sinr use shooting and bouncing rays method

Behavior change

Starting in R2021b, when you use the `raytrace`, `coverage`, `link`, `sigstrength`, or `sinr` function and specify the `propmodel` argument or `PropagationModel` name-value argument as `'raytracing'`, the function uses the shooting and bouncing rays (SBR) method and calculates up to

two reflections. In previous releases, the functions use the image method and calculate up to one reflection.

If you prefer to use the image method instead of the SBR method, create a propagation model by using the `propagationModel` function. Then, use the `raytrace`, `coverage`, `link`, `sigstrength`, or `sinr` function with the propagation model as input. This example shows how to update your code.

```
pm = propagationModel('raytracing','Method','image');  
coverage(txs,pm)
```

For information about the SBR and image methods, see [Choose a Propagation Model](#).

ReflectionLocations and NumReflections properties of the comm.Ray object have been removed

Errors

The `ReflectionLocations` and `NumReflections` properties have been removed from the `comm.Ray` object. To accommodate reflections, use the `Interactions` property to replace the `ReflectionLocations` property and use the `NumInteractions` property to replace the `NumReflections` property.

NumReflections property of the raytrace function will be removed

Still runs

The `NumReflections` property of the `raytrace` function will be removed in a future release. The `NumReflections` property now applies to only the image ray tracing method. Instead, create a propagation model by using the `propagationModel` function with its `MaxNumReflections` name-value argument. Then, use the `raytrace` function with the propagation model as an input. This example shows the recommended workflow given transmitter site `tx` and receiver site `rx`.

```
pm = propagationModel('raytracing','Method','image','MaxNumReflections',2);  
rays = raytrace(tx,rx,pm);
```


R2021a

Version: 5.0

New Features

Compatibility Considerations

Fast Multipole Method (FMM): New solver added for Radar Cross Section (RCS) analysis

The new solver using the fast multipole method (FMM) in the Antenna Toolbox reduces memory requirements and increases speed of operation for analysis of antennas while achieving the same accuracy as the method of moments (MoM). The FMM solver can be used for RCS analysis.

Finite Conductivity for Metal Structures: Modify conductivity of metal structure in antennas and arrays

Use the `metal` object to specify the conductivity and the thickness of metal structures in antennas and arrays.

For example, this code shows how to define a metal in the antenna design using the `Conductivity` and `Thickness` properties of the `metal` object.

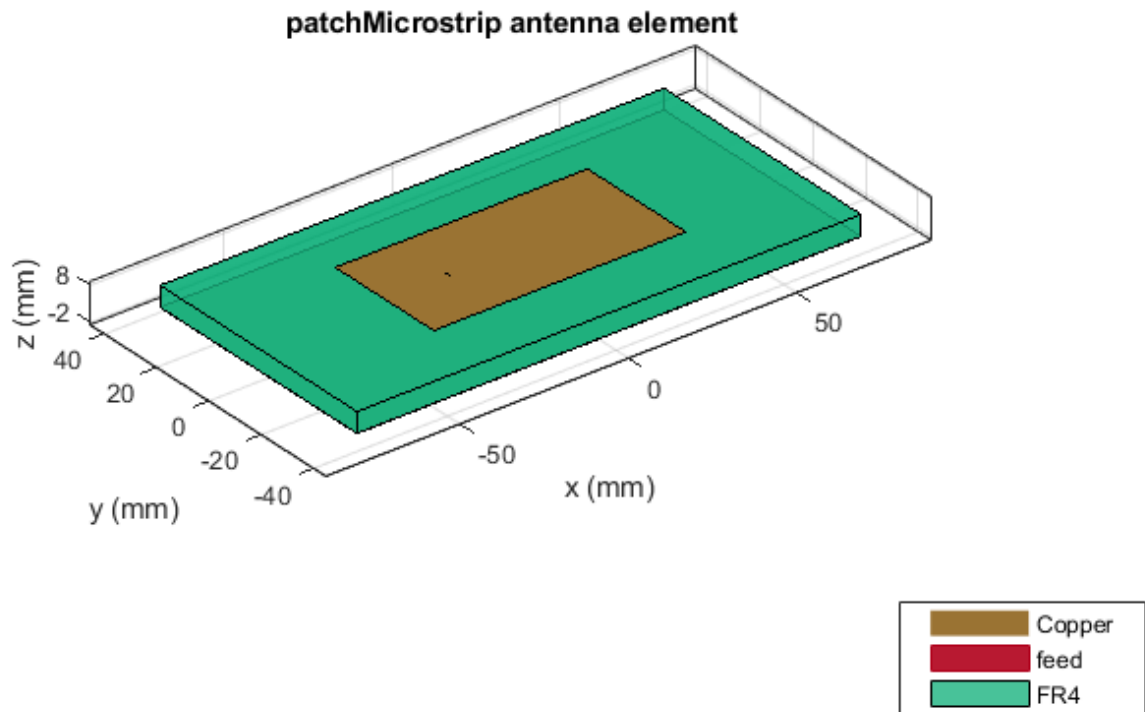
```
m = metal('Copper');  
ant = bicone('Conductor',m)
```

Metal Catalog and Visualization: Choose, customize, and visualize metal using MetalCatalog

Use the `MetalCatalog` function to:

- Select a metal for the antennas or arrays from the metal catalog.
- Use a custom metal for the antennas or arrays and add it to the metal catalog.
- Visualize antennas or arrays created using different metals from the metal catalog.

For example, this figure shows microstrip patch antenna with copper patch selected from the `MetalCatalog`.

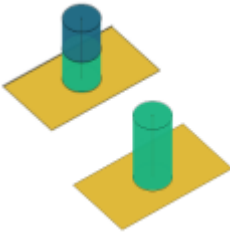
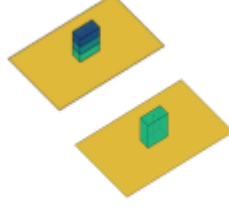
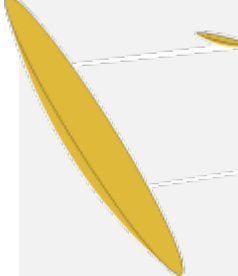

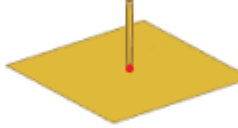



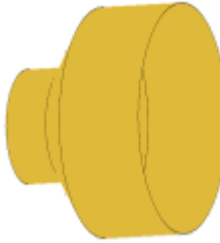


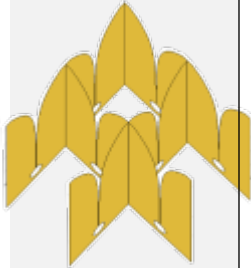
Radiation Efficiency Analysis: Plot radiation efficiency to analyze radiation characteristics of antennas

You can now use the `efficiency` function to calculate and plot the radiation efficiency of antennas to analyze their radiation characteristics.

Dielectric Resonators, Dual Reflectors, Potter Horn, Cylindrical Dipole, and More: Design, visualize, and analyze 10 new antennas using parametrized geometry

This table shows the list of new antenna objects added to the antenna catalog in this release.

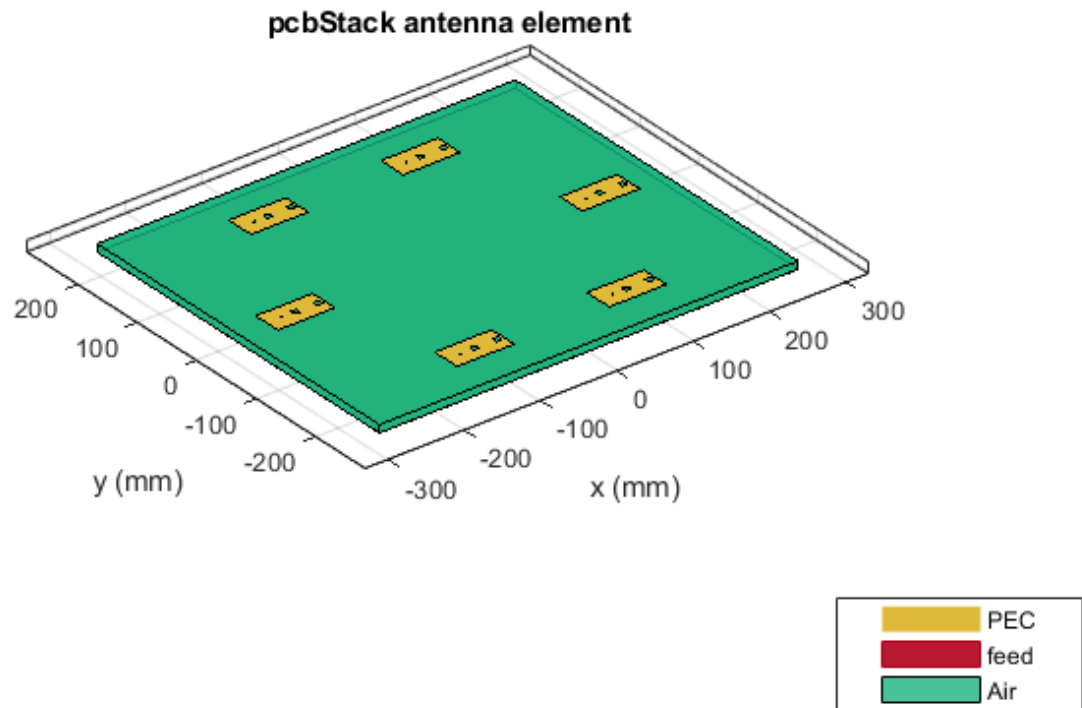
				
<p>draRectangular</p> <ul style="list-style-type: none"> • Creates a rectangular dielectric resonator antenna • Used in satellite and radar systems 	<p>draCylindrical</p> <ul style="list-style-type: none"> • Creates a cylindrical dielectric resonator antenna • Used in medium- and long-range communications due to their ability to handle high power 	<p>cassegrainOffset</p> <ul style="list-style-type: none"> • Creates an offset Cassegrain antenna for high gain and to reduce side lobe level • Used as ground-based antennas in satellite communications 	<p>gregorianOffset</p> <ul style="list-style-type: none"> • Creates an offset Gregorian antenna • Used in radar systems and radio telescopes 	<p>monopoleCylindrical</p> <ul style="list-style-type: none"> • Creates a cylindrical monopole antenna • Used in wireless mobile communication due to its broadband characteristics

				
<p>dipoleCylindrical</p> <ul style="list-style-type: none"> • Creates a cylindrical dipole antenna • Used in wireless mobile communications due to its simple design 	<p>hornPotter</p> <ul style="list-style-type: none"> • Creates a Potter horn antenna • Used in satellite communications for frequency reuse 	<p>hornScrimp</p> <ul style="list-style-type: none"> • Creates a scrimp horn antenna • Used in navigation satellite feeder links due to high aperture efficiency, low cross polarization, and low voltage standing wave ratio (VSWR) over a broad frequency band 	<p>vivaldiOffsetCavity</p> <ul style="list-style-type: none"> • Creates a Vivaldi antenna with an offset cavity • Suitable for ultra-wideband phased arrays used in aviation and aerospace technologies 	<p>eggCrate</p> <ul style="list-style-type: none"> • Creates an array of vivaldi or vivaldiOffsetCavity antenna elements • Suitable for ultra-wideband phased arrays used in radar systems

Array Support for pcbStack: Create and analyze array of pcbStack antenna objects

Use the array function to create a pcbStack object that contains an array of the input pcbStack antenna object.

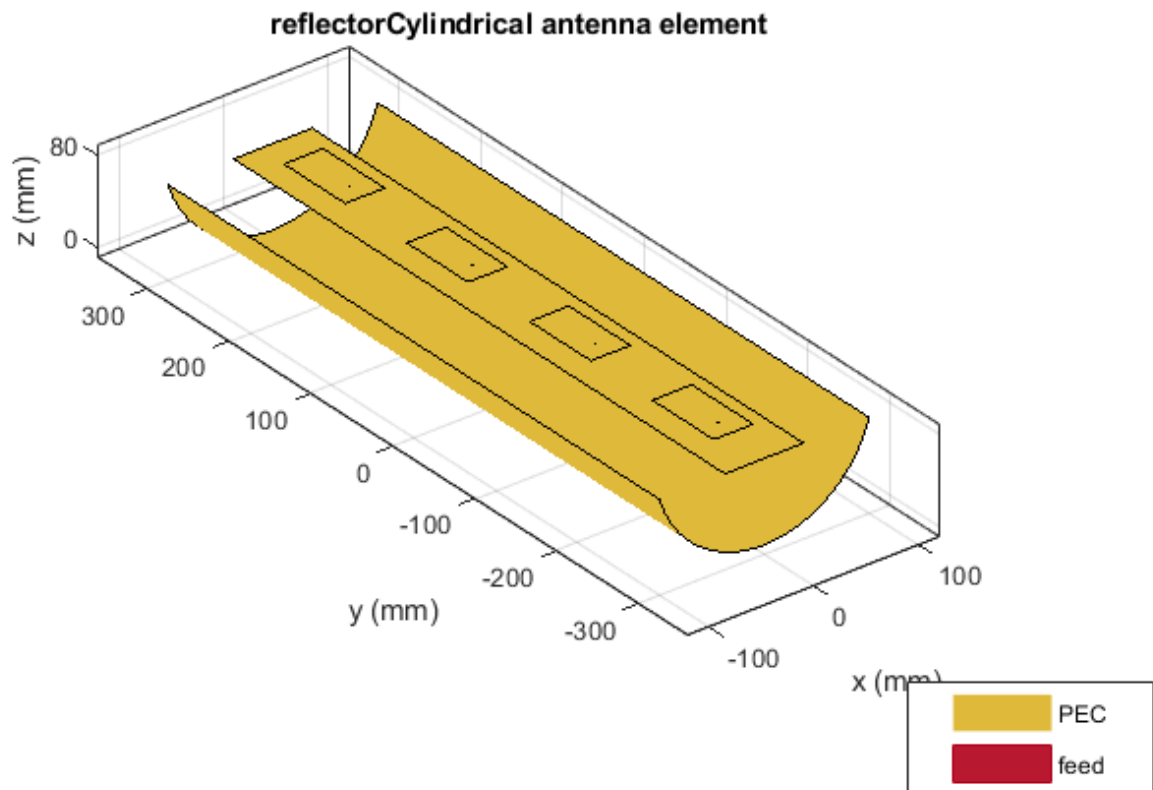
For example, this figure shows the circular array of a pcbStack antenna object.



Arrays as Exciters for Backing Structures: Use arrays as exciters for cavities and reflectors

You can now use arrays as exciters for the backing structures like cavities and reflectors to increase directivity and gain of the combined structure.

For example, this figure shows the linear array of microstrip patch antennas used to excite a cylindrical reflector.



Pattern Plots: Capability to plot both directivity and gain for lossy antennas

The pattern function in the Antenna Toolbox now supports both the directivity and the gain plot options for lossy antennas.

Wire Solver: Faster performance for analysis of dipole and loop antennas

Starting this release, using the wire solver will result in faster performance when solving and analyzing dipole and loop antennas.

RF Propagation: Perform ray tracing analysis using SBR method

You can now perform ray tracing analysis using the shooting and bouncing rays (SBR) method. To display propagation paths or coverage maps using the SBR method, create a ray tracing propagation

model using the `propagationModel` function, and then specify the model as an input when you call the `raytrace` or `coverage` function.

For example, this code shows how to display the coverage map for the transmitter site, `tx`, based on the ray tracing propagation model, `pm`, that uses the SBR method.

```
tx = txsite;  
pm = propagationModel('raytracing', 'Method', 'sbr');  
coverage(tx, pm)
```

Propagation models that use the SBR method support up to 10 path reflections and are generally faster than propagation models that use the image method. Ray tracing propagation models that use the SBR method calculate approximate propagation paths, and ray tracing propagation models that use the image method calculate exact propagation paths. For more information about the SBR and image methods, see [Choose a Propagation Model](#).

Functionality being removed or changed

`propagationModel('raytracing-image-method')` returns a `RayTracing` model

Behavior change

Starting in R2021a, when you create a propagation model using the syntax `propagationModel('raytracing-image-method')`, instead of a `RayTracingImageMethod` model, MATLAB returns a `RayTracing` model with a `Method` property value of `'image'`. All functions that accept `RayTracingImageMethod` propagation models also accept `RayTracing` propagation models, so this change does not affect your existing code.

To create ray tracing propagation models that use the image method, instead of the syntax `propagationModel('raytracing-image-method')`, use `propagationModel('raytracing', 'Method', 'image')`. For more information about creating propagation models, see the `propagationModel` function.

R2020b

Version: 4.3

New Features

Import Gerber Files: Import, modify, and analyze Gerber files Antenna Toolbox

Use the `gerberRead` function to read Gerber files or use the `PCBReader` class to:

- Create a `pcbStack` object.
- Clean up specific metal layers.
- Access objects in different shapes associated with a particular layer.
- Specify the dielectric substrate type.

Grid, Cylindrical, and Spherical Reflectors; Bicone, Discone, and More: Design, visualize, and analyze ten new antennas including reflectors using parametrized geometry

- Use the `reflectorGrid` object to create a reflector made of a grid of parallel wires or bars oriented in one direction. These reflectors can be used as high-gain antennas for point-to-point communications.
- Use the `reflectorCylindrical` object to create parabolic cylindrical reflector antennas. These reflectors are used in designing airborne navigational antennas.
- Use the `reflectorSpherical` object to create a spherical reflector antenna for wide-angle scanning. These antennas are used as multiple beam antennas in satellite communications.
- Use the `biconeStrip` object to create a stripped bicone antenna widely used in emissions testing, field monitoring, and chamber characterization.
- Use the `disconeStrip` object to model a stripped discone antenna. These antennas have low omnidirectional gain and wide to ultra-wide bandwidth and are used in UHF and microwave band applications.
- Use the `rhombic` object to create a rhombus made of parallel wires suspended above the ground to provide high forward gain and wide bandwidth. Rhombic antennas are used in long-distance communications.
- Use the `monopoleRadial` object to create a monopole antenna with the ground plane consisting of a number of radials. These antennas are widely used in cellular communications on account of their omnidirectional characteristics.
- Use the `hornRidge` object to create a horn with ridges on the inside and extending from the center to the sides. The ridges lower the cutoff frequency and increase the bandwidth. Ridged horn antennas are commonly used in electromagnetic interference and compatibility applications for generating electromagnetic fields.
- Use the `hornCorrugated` object to create a corrugated rectangular antenna mostly used in broadcasting. The corrugated horn provides beam symmetry, low side lobe level, and spillover reduction.
- Use the `monopoleCustom` object to create customized radiators on ground planes in a variety of shapes. These antennas are mostly used in airborne and ground-based communication systems.

Cartesian Positioning for txsite and rxsite: Perform point-to-point RF propagation analysis using Cartesian coordinate system

- Use the `CoordinateSystem` and `AntennaPosition` properties of the `txsite` and `rxsite` objects to support Cartesian coordinates in antenna site location.

-
- Use functions like `sigstrength`, `sinr`, and `pathloss` for point-to-point RF propagation analysis when using Cartesian coordinates to locate antenna sites.

Ray Tracing Analysis for Cartesian Coordinates: Import STL files to describe scenarios for ray tracing analysis

- You can use the `Map` and `propagationModel` parameters of point-to-point RF Propagation functions to support an STL file or a triangulation object. This aids ray tracing analysis in any 3-D map environment.
- New properties of the ray tracing propagation model include `CoordinateSystem`, `SurfaceMaterial`, `SurfaceMaterialPermittivity`, and `SurfaceMaterialConductivity`. You can use these properties to define surface materials for a 3-D map surface.

SADEA Optimization Using Command Line Interface: Optimize antennas and arrays by providing access to optimization data

Use the `optimize` function to optimize antennas and arrays in the command line interface. You can use the SADEA optimizer to optimize antennas and arrays with respect to various analysis parameters and the associated required constraints.

Surrogate Optimization in Antenna Designer and Array Designer: Optimize antenna and arrays using surrogate optimizer

You can now use the surrogate optimizer from Global Optimization Toolbox as an alternative to the SADEA optimizer in the **Antenna Designer** app and the **Antenna Array Designer** app.

R2020a

Version: 4.2

New Features

Bug Fixes

SADEA Optimization in Antenna Designer and Array Designer: Optimize antennas and arrays using Antenna Toolbox

Use the **Antenna Designer** App and the **Antenna Array Designer** App to optimize antennas and arrays with respect to various analysis parameters under given constraints.

customAntennaStl Object: Import STL file to create a custom 3D antenna

Use the `customAntennaStl` object to:

- Create a custom 3D antenna object.
- Create a feed for the antenna object using `createFeed` function.
- Select the feeding edge or the feeding contour.
- Run analysis on the antenna object at any desired frequency.

Wire Solver: Analyze and solve dipole like antenna catalog elements

Use the `wireStack` object to create, analyze, and solve a single or multifeed wire antenna.

PCB Stack for Arrays: Convert arrays directly to PCB stack

Use the `pcbStack` object for the conversion of antenna array catalog elements to PCB stack.

Corrugated Horn, Antipodal Vivaldi, Monocone, Elliptical Patch, Fractal Snowflake and More: Design, visualize, and analyze ten new antennas using parametrized geometry

- Use the `hornConicalCorrugated` antenna object to model a corrugated horn antenna, where the corrugations are slots or grooves covering the inner surface of the cone.
- Use the `vivaldiAntipodal` object to create an antipodal vivaldi antenna mostly used in wireless communications and radars. This antenna is a type of end fire tapered slot antenna that provides medium gain with less side lobes and wide bandwidth.
- Use the `monocone` object to create a modified monocone that consists of a merged cone and cylinder on a circular ground plane. The modified monocone as a higher bandwidth and finds uses in airborne as well as ground applications.
- Use the `patchMicrostripElliptical` object to create an elliptical shape microstrip patch antennas for uses in applications that require circular polarization.
- Use the `fractalSnowflake` object to create a snowflake fractal antenna.
- Use the `spiralRectangular` object to create a single or dual arm rectangular spiral antenna mostly used in WLAN applications.
- Use the `waveguideRidge` object to create a double ridge waveguide mostly used in ultra-wideband applications like radio astronomy.
- You can now use the `lpda` object to create a tapered log-periodic dipole antenna with a trapezoidal board shape.

Ray Tracing Propagation Model: New propagation model using ray tracing method of images with material reflection loss

Use `raytracing-image-method` parameter in `propagationModel` for ray tracing analysis to compute propagation paths and their corresponding path losses, including surface reflections losses.

Measurements Data in Site Viewer: Import and visualize measurements data in Site Viewer

Use the `propagationData` object for importing and visualizing geolocated propagation data such as measurement files, data variables in MATLAB, or the output of `coverage` or `sinr` functions.

RF Propagation and Ray Tracing Enhancements: New and updated objects and functions for analysis using ray tracing

New and updated features enable you to:

- Predict the total received power and generate coverage maps using ray tracing.
- Use the command line to access ray tracing analysis info generated by using the `raytrace` function.
- Include permittivity of building materials (`buildingMaterialPermittivity`) and earth surfaces (`earthSurfacePermittivity`) in path loss calculation of reflected waves.
- Include antenna polarization in path loss calculations.

New features include a `comm.Ray` object, `raypl`, `earthSurfacePermittivity`, `buildingMaterialPermittivity`, and `add` functions.

Updated features include `raytrace`, `coverage`, `sinr`, `sigstrength`, `link`, and `pathloss`.

Great Circle Path: geodesic input changed to greatcircle input option

In `distance` and `angle` functions, the `geodesic` option for the `path` input parameter is changed to `greatcircle` option.

R2019b

Version: 4.1

New Features

Physical Optics (PO) and Hybrid MoM: New solvers added for large structure analysis

Antenna Toolbox now has the Hybrid MOM-PO solver for modeling large structures such as parabolic antennas. The antenna element of the large structure is accurately modelled using the Method of Moments (MoM) solver and the effect of electrically large structure is considered using Physical Optics (PO).

Antenna toolbox also uses the PO solver for radar cross section (RCS) analysis. For more information, see Hybrid MoM-PO Method for Metal Antennas with Large Scatterers and Physical Optics Solver.

Radar Cross-Section (RCS) analysis: Generate and visualize RCS of platform, antenna, or array object

Use the `rsc` function to calculate and plot the monostatic or bistatic RCS of a platform, antenna, or an array.

Antenna Array Designer App: Interactively design, analyze, and visualize antenna arrays

Use the **Antenna Array Designer** app to:

- Show different array configurations and layout defining element spacing.
- Compare different array types and responses.
- Pick array configuration to meet specific peak gain, directivity, desired coverage, pattern, port parameters etc.
- Change the spacing between the elements and see the effect on the performance of the array.
- Visualize the effect of mutual coupling at the port and in the far-field.
- Calculate mutual impedance.
- Control the radiation pattern of the array in a desired direction in space.
- Calculate the scan impedance and the scan pattern for different azimuth and elevation values.
- Observe mutual coupling between elements and minimize it to achieve diversity reception.

Buildings Data in Site Viewer: Import and visualize buildings in Site Viewer for point-to-point ray tracing analysis

Use the `siteviewer` object to import and visualize buildings in Site Viewer. Use the `raytrace` function to visualize point-to-point ray tracing analysis.

Cassegrain, Gregorian, Slotted Waveguide, Circular Horn, Quad Custom and More: Design, visualize, and analyze nine new antennas using parametrized geometry

New antenna objects and enhancements to existing objects aid in design and visualization.

- You can now use the existing `biquad` antenna object to model a double biquad antenna.

-
- Use the `bicone` antenna object to model a bicone antenna used in applications such as Electronic Support Measurement (ESM), or electromagnetic interference (EMI) testing.
 - Use the `discone` object to model a discone antenna in which one cone is replaced by a disk.
 - Use the `waveguideCircular` to create a hollow tube of uniform cross section that confines electromagnetic waves.
 - Use the `waveguideSlotted` to create a various types of slots on the waveguide like longitudinal, transversal, centered inclined and inclined slots cut into narrow wall.
 - Use the `hornConical` to create a waveguide shaped like a cone to direct radio waves in a beam.
 - Use the `cassegrain` and the `gregorian` objects to create parabolic antennas in which the feed antenna is mounted at or behind the surface of the main parabolic reflector and is aimed at the secondary reflector.
 - Use the `quadCustom` object to create a Yagi-Uda custom array antenna.

R2019a

Version: 4.0

New Features

Installed Antenna Analysis: Perform analysis of antennas installed on electrically large structures called platforms

Use `installedAntenna` object to integrate the effect of large electrical structures known as platforms on antennas and arrays. Import the `platform` (ship, plane, or car) as an STL file. You can place single or multiple antennas around the platform. Calculate the S-parameters, pattern, charge, and current to see the effect of the platform on the antenna.

Data from STL Files: Import platform objects from STL files and export antenna geometry to STL files

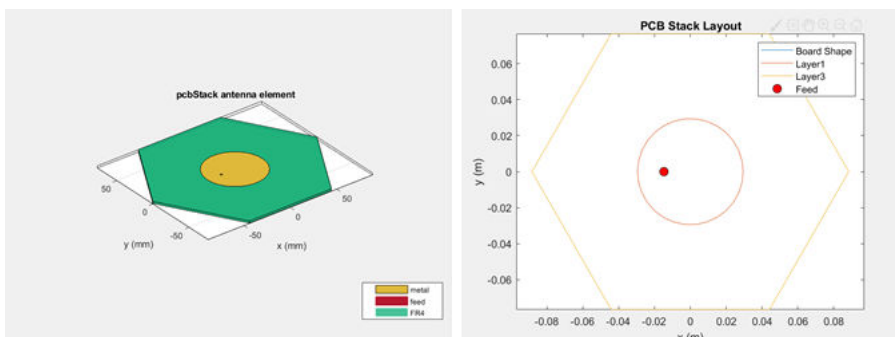
Use `platform` to import STL files as platforms for installed antenna analysis.

Use `stlwrite` to export an antenna or array geometry to an STL file.

Polygonal Board Shape for PCB Stack: Define printed antennas on polygonal board shape

Create printed antennas on polygonal boards and boards with holes. For example, design a circular microstrip patch on a polygonal board.

```
% Design circular microstrip patch using FR4 substrate.
p = design(patchMicrostripCircular,3e9);
p.Substrate = dielectric('FR4');
c = antenna.Circle;
c.NumPoints = 6;
c.Radius = 3*p.Radius;
figure
show(c)
%% Create polygonal stack
v = getShapeVertices(c);
cp = antenna.Polygon('Vertices',v);
pb = pcbStack(p);
pb.Layers{3} = cp;
pb.BoardShape = cp;
% Visualize geometry
show(pb)
axis equal
% Visualize layout of board, layers, feeds, vias etc.
figure
layout(pb)
```



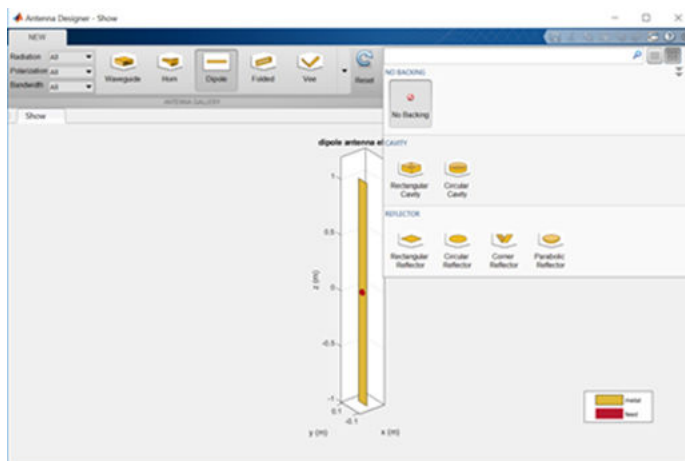
Gerber Files for Arrays: Generate Gerber files with multiple feeds for arrays

Create PCB antennas with more than one feed for a multifeed antenna or an array. Use this PCB antenna to create Gerber files for a connector and manufacturing service.

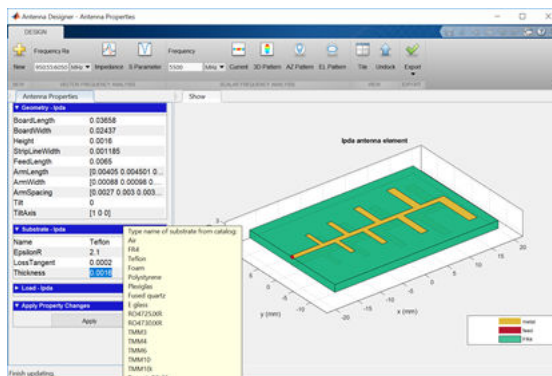
Improvements in Antenna Designer App: Updates to Antenna Designer app supports backing structure gallery, dielectric catalog, and better export to MATLAB scripts

You can now use the **Antenna Designer** app to:

- Choose backing structures such as a cavity or reflector, for an antenna.



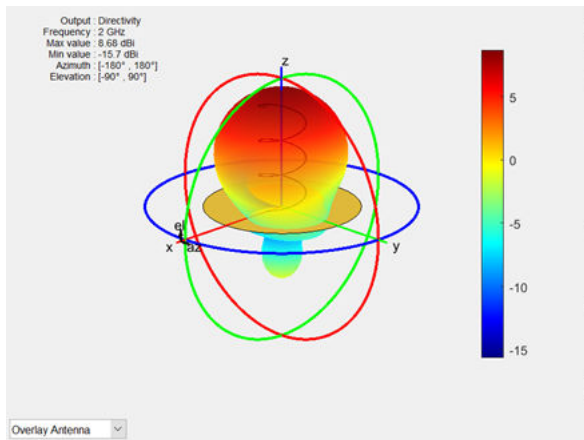
- Auto-fill the dielectric properties by typing the name of the substrate.



- Generate a consolidated MATLAB script that walks you through all the changes made to an antenna using the application.

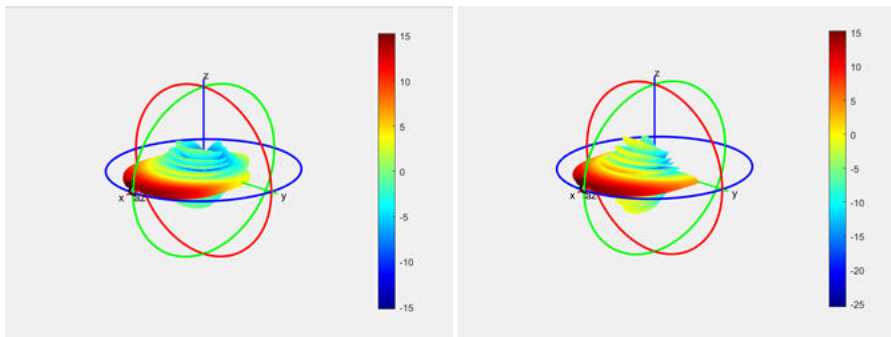
Improvements in Radiation Pattern Visualization: Plot phase in 3-D; overlay antenna, or array and its pattern on same axes

Use the `pattern` function to visualize an antenna or an array with its corresponding radiation pattern on the same axes. Now, you can also customize the radiation pattern.



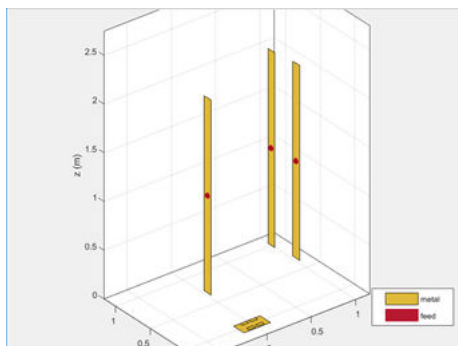
3-D Radiation Pattern of Orthogonal Slices: Generation of 3-D radiation pattern from two orthogonal slices

Use the `patternFromSlices` function to reconstruct a 3-D radiation pattern from azimuth and elevation slices.



Subarrays for Conformal Arrays: Include linear, rectangular, and circular arrays as elements in conformal arrays

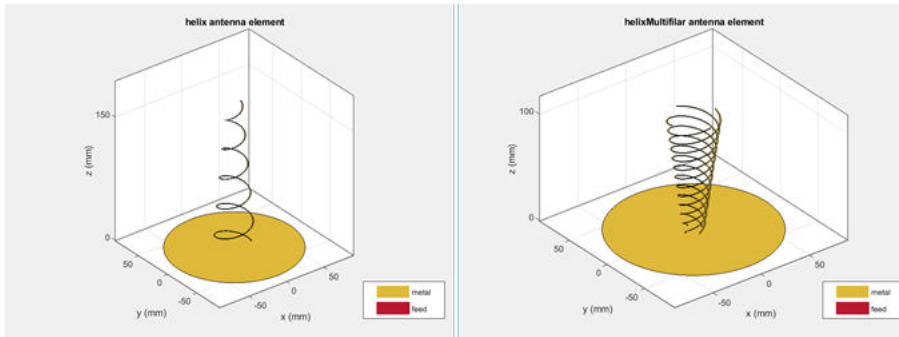
You can now include linear, rectangular, and circular arrays as elements in a `conformalArray` object. You can also modify the conformal array properties, such as `AmplitudeTaper` and `PhaseShift`.



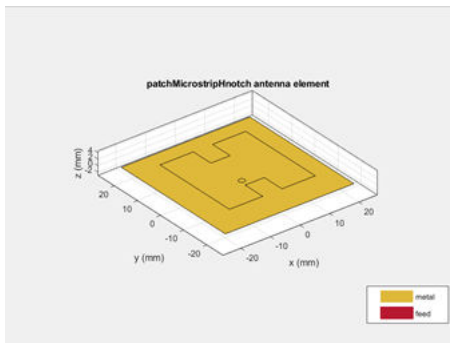
Conical helix, Crossed Dipole, H-Slot Patch, Sierpinski's Carpet, and Minkowski's Loop: Design, visualize, and analyze five new antennas using parameterized geometry

New antenna objects and enhancements to existing objects aid in design and visualization.

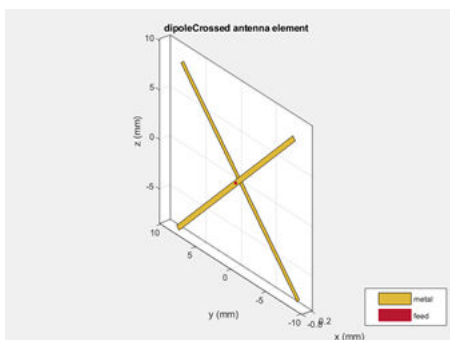
- You can now use the existing `helix` and `helixMultifilar` objects to model helix antennas of increasing or decreasing radius.



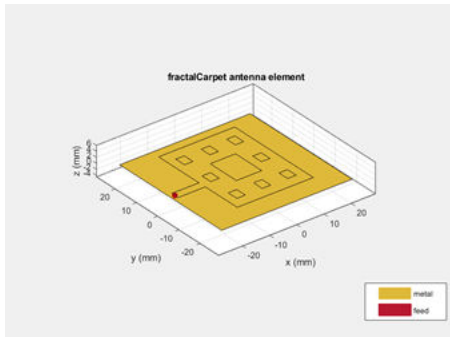
- Use the `patchMicrostripHnotch` object to model a probe-fed H-shaped microstrip patch antenna.



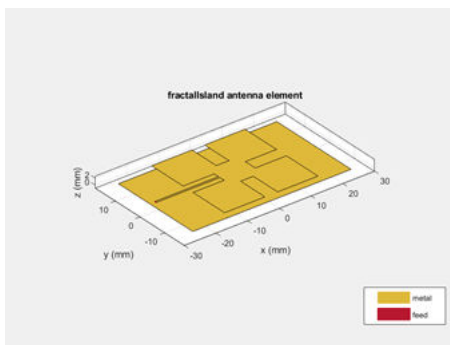
- Use the `dipoleCrossed` object to model a crossed dipole antenna.



- Use the `fractalCarpet` object to model a Sierpinski's carpet fractal.



- Use the `fractalIsland` object to model a Minkowski's loop.



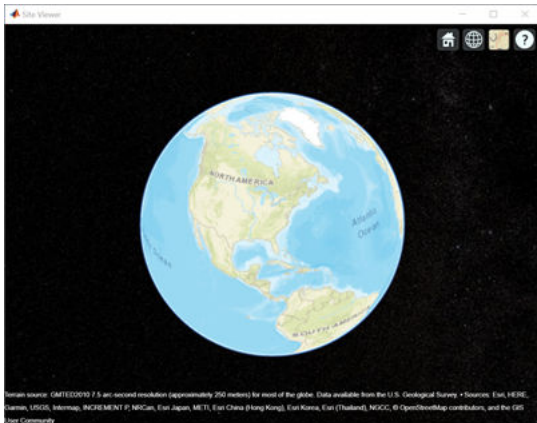
Use the `show` function to view the structures of these antennas.

Logarithmic Current and Charge Plots: Visualize current and charge distributions on antennas in logarithmic scale

Use the existing current and charge functions to visualize current and charge distributions of antennas in a logarithmic scale.

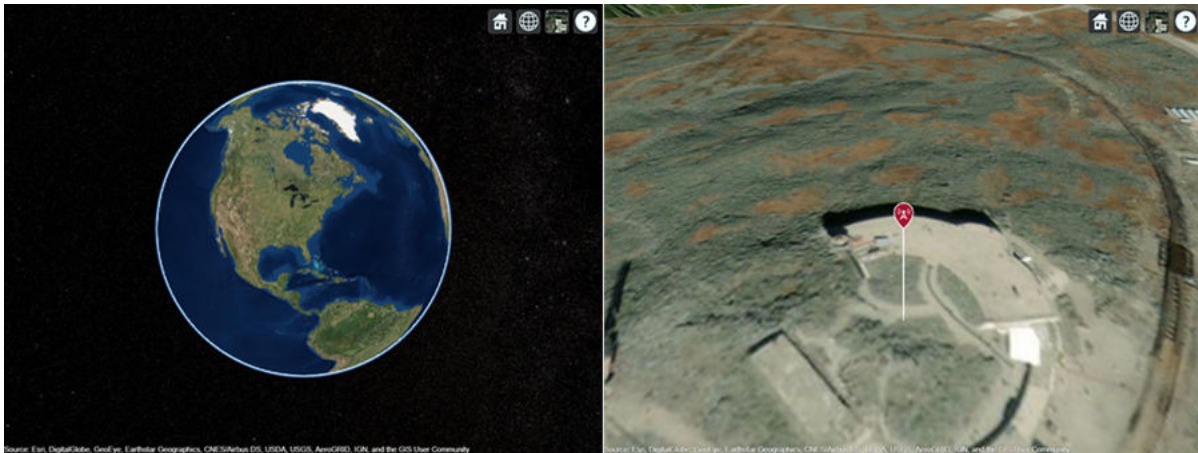
Site Viewer Command Line Interface: Launch, configure, and close Site Viewer windows from MATLAB command line

Use the `siteviewer` function to launch and configure Site Viewer windows. You can create multiple Site Viewer windows to compare visualizations as well as configure basemaps and terrain information.



DTED Terrain Data: Import 3-D terrain data files for use in Site Viewer and RF propagation tools

Use the `addCustomTerrain` function to import terrain from DTED files and specify new terrain in Site Viewer.



TIREM Propagation Model: Visualize path loss computed using TIREM propagation model

help

You can now use the `propagationModel` function to integrate the Terrain Integrated Rough Earth Model™ (TIREM™) in the Site Viewer and visualize the impact on received signal strength.

R2018b

Version: 3.2

New Features

3-D Terrain Visualization: Stream global terrain data in Site Viewer and visualize path loss computed using the Longley-Rice propagation model

You can now visualize terrain features in Site Viewer.

Use the Longley-Rice propagation model in `propagationModel` to visualize the impact of local terrain features on received signal strength.

Use the `elevation` function to calculate the ground elevation at the required site.

Use the `pattern` function to visualize antenna radiation pattern in Site Viewer.

Array Design Function: Design an array configuration with appropriate antenna spacings for a given frequency

You can now use the existing `design` function to create array configurations that operate at a specified frequency.

Array Phase Shift Function: Calculate the phase shifts of the array elements to achieve beam scanning in a particular direction

Use the `phaseShift` function to calculate a set of phase shift values that you can apply to an array operating at a specified frequency.

Bifilar and Quadrafilar Helix, Koch Curve Fractal, Sierpinski' s Gasket, Single Arm Archimedean Spiral: Design, visualize, and analyze five additional antennas with parameterized geometry

The new objects aid in the design and visualization of new antennas:

- Use the `helixMultifilar` object to model a bifilar or quadrafilar helix antenna on a ground plane.
- Use the `dipolehelixMultifilar` object to model a bifilar or quadrafilar helix dipole antenna.
- Use `fractalKoch` object to model a Koch curve fractal antenna in an X-Y plane.
- Use `fractalGasket` object to model a Sierpinski's gasket on the X-Y plane.
- Use the existing `spiralArchimedean` object to model a single arm Archimedean spiral antenna.

Use the `show` function to view the structures of these antennas.

Parabolic Reflector: Design, visualize, and analyze an antenna in the presence of a large parabolic reflector element with parameterized geometry

Use the `reflectorParabolic` object to model a parabolic reflecting backing structure for antenna elements. Parabolic reflectors are large antennas of at least 10 wavelengths in diameter.

R2018a

Version: 3.1

New Features

Compatibility Considerations

SINR Visualization: Visualize transmitter site signal-to-interference-plus-noise ratio (SINR) on a map

Use the `sinr` function to measure the signal-to-interference-plus-noise ratio (SINR) of a receiver and display a map visualization. The SINR value is an important measure of receiver quality.

Antenna Site Visualization: Visualize line-of-sight path between transmitter/receiver sites and clustering of adjacent sites

Use the `los` function to plot the line-of-sight visibility between two sites on a map.

Meshing Engine for Metal Surfaces: Improved performance for analysis of metal antennas

The mesh generator, `mesh`, now uses new algorithms for 2-D geometries of metal antennas.

Compatibility Considerations

Resulting meshes can differ from meshes generated in previous releases. For example, meshes generated with default size controls might have fewer elements than before.

E-Shaped Patch, Triangular Patch, LPDA, and J-Dipole: Design, visualize, and analyze four additional printed antennas with parameterized geometry

The new objects aid in the design and visualization of new antennas:

- Use the `patchMicrostripEnotch`, `patchMicrostripTriangular`, and `lpda` objects to create PCB antennas.
- Use the `dipoleJ` object to model a J-pole antenna that finds applications in ham radio.

Corner Reflector: Design, visualize, and analyze an antenna in the presence of an additional reflector element with parameterized geometry

Use the `reflectorCorner` object to create a corner reflecting backing structure for antenna elements. Antennas using corner reflectors are mostly used in radar and wireless communications systems.

R2017b

Version: 3.0

New Features

PCB Stack Antenna: Design Custom PCB antennas with arbitrary metal-dielectric layers, solid feed/via models, and advanced meshing control

Use the `pcbStack` object to build custom multi-layer metal-dielectric PCB antennas. You can use this object for practical antenna designs such as cell phones, RFID, IoT applications.

Gerber File Generation from `pcbstack`: Prototype and implement antennas using customizable library of RF connectors and PCB manufacturing services

Printed Circuit Board (PCB) antennas are described by a set of manufacturing files collectively known as 'Gerber files'.

Use the `PCBWriter` object or the `gerberWrite` function with the `pcbStack` object to generate Gerber files. Optionally, you can choose the RF connector for the PCB board and PCB viewer or manufacturing service.

Conversion of 2-D/2.5-D Antenna Elements to `pcbStack`: Design custom printed antennas using available library elements

Use `pcbStack` to convert antenna library elements for PCB-based custom printed antennas. You can now customize antenna elements by:

- Adding one or more feed points and control the excitation amplitude, phase.
- Defining one or more vias between different layers.

Inset-Fed Patch, Circular Patch, Cloverleaf, Circular Reflector, and Circular Cavity: Design, visualize, and analyze three additional antennas and two additional backing structures using parameterized geometry

The new objects aid in the design and visualization of new antennas:

- Use the `patchMicrostripInsetfed` object to feed a rectangular patch antenna using inset-feed.
- Use the `patchMicrostripCircular` object to model a circular patch antenna.
- Use `cloverleaf` object to model a wideband circularly polarized cloverleaf antenna.
- Use `sectorInvertedAmos` object to model a sector antenna the pattern of which illuminates a sector.
- Use the `cavityCircular` and `reflectorCircular` objects as backing structures for other antenna elements.

Use the `show` function to view the structures of these antennas.

Birdcage Antenna: Design, visualize, and analyze an additional antenna, including the effects of human heads modeled with phantoms

Use the `birdcage` antenna object to design, analyze, and visualize a birdcage antenna. You can use this antenna to model an MRI coil and study the performance for a loaded and unloaded MRI coil. Use the `show` function to view the structures of these antennas.

Visualization Within Dielectric Volume: Inspect charge and current separately in the metal and dielectric layers

You can now use the `charge` and `current` functions to visualize charge and current separately in metal and dielectric layers.

RF Propagation: Visualize transmitter/receiver sites, links, and coverage on map using outdoor and weather-based path loss models

Use Antenna Toolbox `txsite` and `rxsite` objects to compute and visualize antenna sites and RF propagation on a virtual globe. Computation and Visualization options include:

- Signal strength computation using free-space propagation or your choice of propagation model to include effects due to weather.
- Map-based visualization of sites and signal strength, including links for point-to-point communication and contour maps for area coverage
- High-quality map for visualizations including 3-D virtual globe.

R2017a

Version: 2.2

New Features

Plane Wave Excitation: Compute the scattering solution of antennas and arrays when excited by plane waves

Use the `planeWaveExcitation` object to excite any antenna or array from the library using a plane wave. Plane waves in Antenna Toolbox are specified using a direction vector and a polarization vector.

Antenna Designer App: Interactively select and analyze antennas with desired characteristics

Use the **Antenna Designer** app to interactively explore, design, and analyze antennas in the library. You can also select multiple antennas and compare the analysis of these antennas. Antennas designed using the app can be exported as a variable in the MATLAB workspace, as a live script, or as a function.

Lumped RLC Load for Antenna Elements: Modify the resonant frequency using load elements at an arbitrary location on an antenna surface

You can now use the `lumpedElement` function to modify the resonant frequency of an antenna by adding the load at an arbitrary location.

Array Factor Analysis: Compute the array pattern using pattern superposition of individual antennas

Use `arrayFactor` and `patternMultiply` to calculate the array factor and the full array pattern of an antenna array. `arrayFactor` and `patternMultiply` do not consider the effect of mutual coupling between different elements in an array.

PCB Stack Antenna: Describe custom printed antennas on multilayered substrates

Use the `pcbStack` object to create structures used in the PCB-based design of antennas. Using this object, you can define:

- Multiple metal layers
- Dielectric substrate
- One or more feed points and control excitation amplitude or phase
- Any number of vias between different layers.

Custom Planar Array Geometry: Describe a custom array by defining its geometric boundaries

Use the `customArrayGeometry` function to create an array represented by 2-D custom geometry. Use the `layout` and `show` functions to view the layout and structure of the array.

Custom Ground Plane for Dielectric Structures: Model an infinite ground plane or no ground plane for antennas mounted on substrates

You can now add infinite ground plane or no ground plane to design and analyze antenna structures with dielectric such as patch, cavity, and reflector.

Cycloid Dipole and Blade Dipole: Design, visualize, and analyze two additional antennas using parameterized geometry

Use the `dipoleCycloid` and `dipoleBlade` antenna objects to design and analyze cycloid dipole and blade dipole antennas, respectively. Use the `show` function to view the structures of these antennas.

conformalArray: Build heterogeneous conformal antenna arrays by specifying both balanced and unbalanced antennas

You can now use the `conformalArray` object to design and analyze heterogeneous conformal arrays using balanced and unbalanced antennas. Use the `layout` and `show` function to view the layout and structures of these arrays.

R2016b

Version: 2.1

New Features

MultiLayered Dielectric Substrate: Include multilayered and thick dielectric substrate effects in antennas and antenna arrays

Use the dielectric function to design and analyze patch, cavity, and reflector antennas or array structures that have multi-layered or thick dielectric substrates.

Antenna Design Function: Design the geometric properties of antennas to resonate at a particular frequency

Use the design function to create an antenna object that operates at a specified frequency.

Custom Planar Antenna Geometry: Describe a custom antenna by defining its geometric boundaries

Use the customAntennaGeometry class to define geometric boundaries for custom antenna shapes. Use the antenna analysis functions to analyze the custom antenna geometry for its port, surface, and field characteristics. You can also use this custom antenna geometry in finite and infinite arrays.

Lumped RLC Components for Antenna Elements: Modify resonant frequency using load elements at the antenna feed point

Use the lumpedElement function to change the electric properties of the antenna. For example, you can increase the antenna bandwidth without changing the dimensions using RLC components.

Circular Antenna Array: Position elements of an antenna array on a circle

Use the antenna elements library to design circularArray. Use the layout function to view the placement of the different antenna elements.

Custom Patch Antenna: Create a probe-fed patch antenna with arbitrary shape

Use Double slot cavity patch on TMM10 substrate example to learn how to create an antenna using customAntennaGeometry. This example also shows you how to manipulate properties of an antenna using lumpedElement and multi-layered dielectric substrates.

Dipole Helix, Coplanar Inverted-F, and Coplanar Inverted-L Antennas: Design, visualize, and analyze three additional antennas using parameterized geometry

Use the dipoleHelix, invertedFcoplanar, and invertedLcoplanar antenna objects to design and analyze helix dipole, coplanar inverted-F, and coplanar inverted-L antennas, respectively. Use the show function to view the structures of these antennas.

R2016a

Version: 2.0

New Features

Dielectric Modeling: Account for the effects of the substrate in antennas and finite antenna arrays

Design and analyze patch, cavity, and reflector antenna or array structures by using dielectric material as substrates. Characterize dielectric substrates using the `dielectric` utility function and the constants and properties listed in `DielectricCatalog`.

Import Antenna Arrays as a Planar Mesh: Design antenna arrays with custom planar geometries

Use the `customArrayMesh` class to design a planar array object. Analyze the custom mesh array for its port, surface, and field characteristics using array analysis functions.

Conformal Antenna Arrays: Position the antenna elements of an array at arbitrary position

Design conformal antenna arrays using any antenna elements from Antenna Toolbox as unit cells. You can also specify an array of any shape and antenna arrangements. Analyze unit cells of the array and extract the embedded pattern using array analysis functions.

Multi-Axis Tilt Property for Antennas and Antenna Arrays: Rotate an antenna or an array around any arbitrary axis

Use the `TiltAxis` property to rotate the antenna and array elements around any arbitrary axis.

Polar Plot: Interactively visualize the radiation pattern and perform measurements using `polarpattern`

Use the `polarpattern` function to plot antenna and array characteristics in polar coordinates. In the polar plot, you can:

- Use markers to enable measurements of the plotted data
- Visualize N -dB beamwidth
- Change the orientation of the data

Custom Pattern and Field: Visualize any arbitrary 3-D radiation pattern data or electric/magnetic field data using `patternCustom` and `fieldsCustom`

Use the `patternCustom` function to plot and visualize 2-D or 3-D radiation patterns from user specified or lab-measured antenna data recorded in CSV, text, or MAT files.

Use the `fieldsCustom` function to plot and visualize electric or magnetic fields from user specified or lab-measured antenna data recorded in CSV, text, or MAT files.

Radiation Pattern Import/Export: Import and export radiation pattern data using the MSI file format with msiread and msiwrite

Use the `msiread` function to read data from MSI files that have `.msi` or `.pln` extensions. Use the `msiwrite` function to write data into MSI files that have `.pln` extension.

Rectangular Horn and Waveguide Antennas: Design, visualize, and analyze rectangular horn and waveguide antennas with parameterized geometry

Use the `horn` and `waveguide` antennas class to design and analyze a rectangular horn and waveguide antennas, respectively. To view the structure of horn or waveguide metal antennas, use the `show` function.

R2015b

Version: 1.1

New Features

Infinite Array Object: Analyze a library antenna as a unit cell in an infinite array

Design infinite antenna arrays using antenna elements from Antenna Toolbox as unit cells. Use array analysis functions to analyze unit cells of the array and extract the embedded pattern.

Custom Planar Mesh Object: Import an arbitrary 2-D mesh to describe a custom antenna

Use the `customAntennaMesh` class to design a planar antenna object. Use the antenna analysis functions to analyze the custom mesh antenna for its port, surface, and field characteristics.

Infinite Ground Plane Specification: Model an infinite ground plane for antennas connected to the ground

Analyze and visualize properties of antenna connected to the ground plane, such as patch, monopole, and pifa in the presence of an infinite ground plane.

E-H Field Visualization: Inspect the electric and magnetic fields at an arbitrary distance from the antenna

Use `EHfields` to visualize the electric and magnetic fields of an antenna element in Antenna Toolbox.

Biquad Antenna Object: Design, visualize, and analyze biquad antennas with parameterized geometry

Use the `biquad` antenna class to design and analyze a biquad metal antenna. Use the `show` function to view the structure of the biquad metal antenna.

R2015a

Version: 1.0

New Features

Antenna library for rapid design and visualization of metal antennas using parameterized geometry

Design and analyze the structure of 22 metal antennas including dipoles, monopoles, spirals, and patches. Use the `show` function to view the structure of the metal antennas.

Antenna array design using antenna elements

Use the Antenna Toolbox library of antenna elements to design linear and rectangular antenna arrays. Use the `layout` function to view the placement of the different antenna elements in the array.

Port analysis of antennas and antenna arrays

Analyze the ports of different antennas and antenna arrays using `impedance`, `returnLoss`, and `sparameters` functions.

Field analysis of antennas and antenna arrays

Analyze and visualize the radiation pattern, E-H fields and beamwidth of different antennas and antenna arrays using `pattern`, `EHfields`, `patternAzimuth`, `patternElevation` and `beamwidth` functions.

Surface analysis of antennas and antenna arrays

Determine, visualize and analyze the surface charge and current of different antennas and antenna arrays using `charge`, and `current` functions.

Antenna array analysis for the embedded element pattern and the correlation coefficient of the elements of the array

Determine, analyze, and visualize the embedded element pattern and the correlation coefficient of elements in an array using `pattern`, and `correlation` functions.

Infinite ground plane specification for analyzing balanced antennas

Analyze and visualize balanced antenna properties, such as, dipoles and bowties in the presence of an infinite ground plane.