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Practical Noise Figure Measurements

Including an example LNA design

Agenda

- Motivation
- Model a low noise amplifier block on ADS
- Practical noise figure measurements of the prototype amplifier
- Narrow band noise figure measurements
- Measurement Uncertainty

Motivation

- RF Communications
- Point to Point Radio / Wireless LAN
- Satellite Communications
- Wireless LAN
- Global Positioning System
- Defense and Radar

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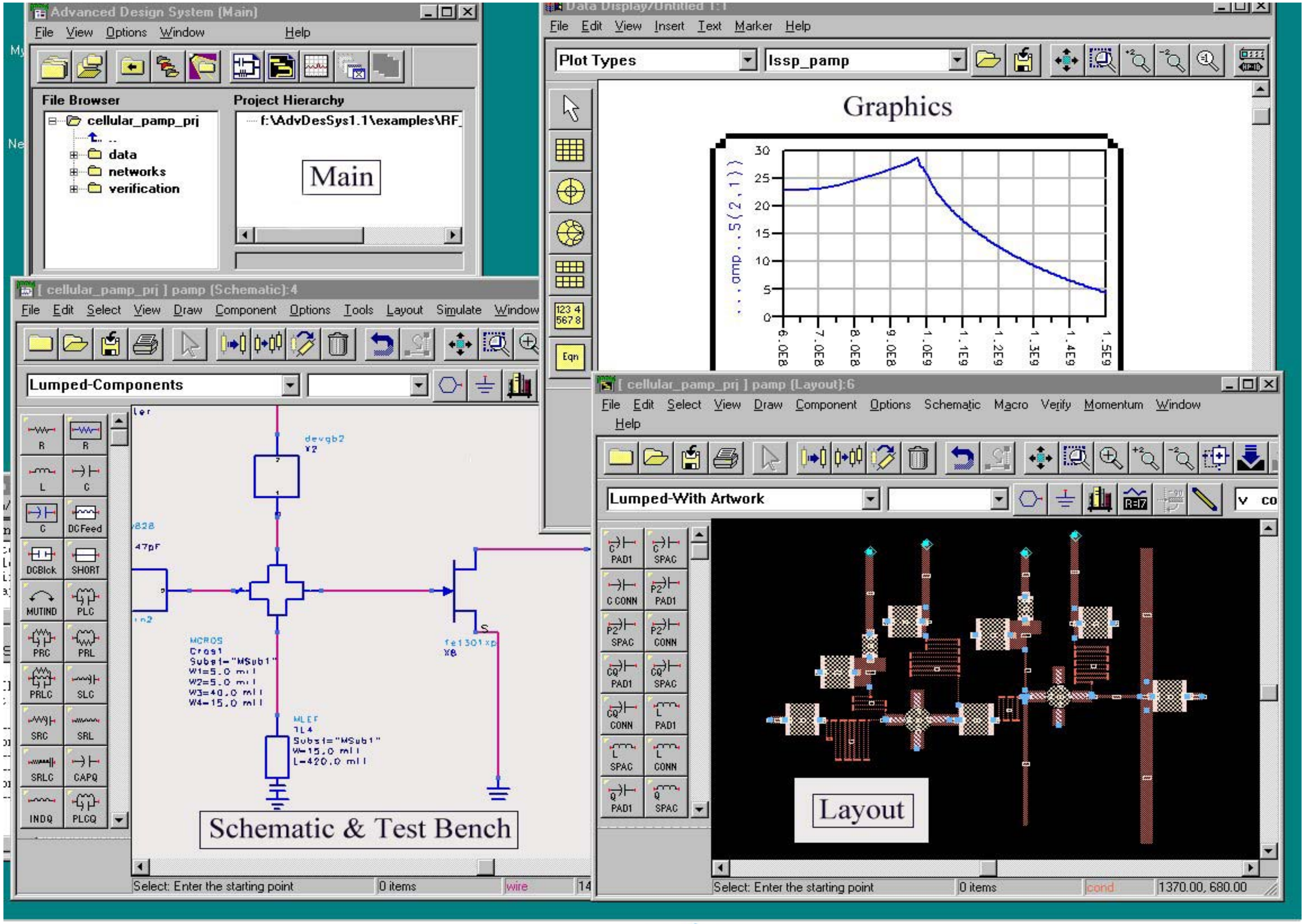
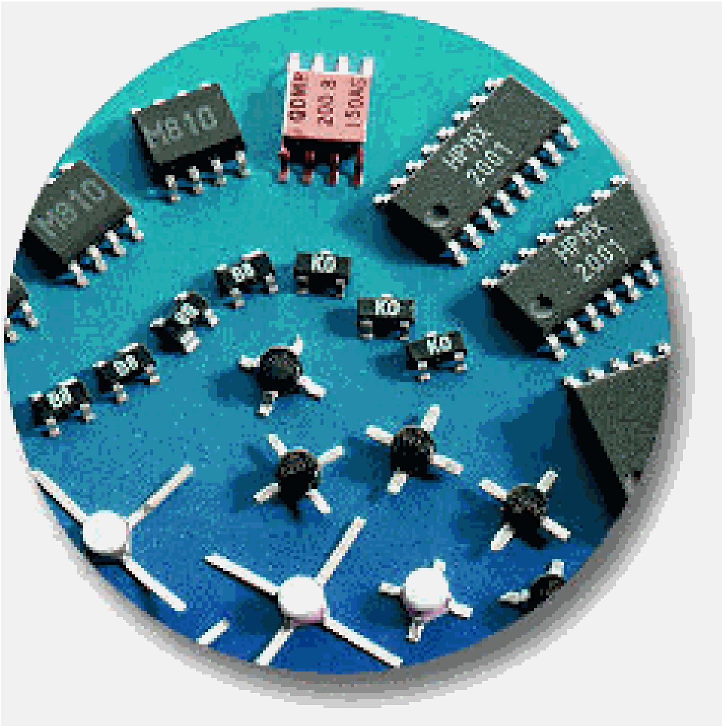
ADS Presentation Windows



Example Low Noise Amplifier Design Process using ADS

- Functional requirements
- Device selection
- Design
- Layout
- Performance analysis and optimization



Amplifier Functional Requirements

- Frequency Range : 1.5GHz to 2.5GHz
- Noise figure : < 1dB
- Gain : > 10dB
- VSWR : < 2.0:1
- Low voltage supply : ideally 3v
- Distributed matching (microstrip) to reduce cost

Device Selection

- GaAs, SiGe, HEMPT, PHEMPT?
- S-Parameter/Noise data on Web
- Choose ATF34143 PHEMPT from Agilent
  - 0.5dB Noise Figure
  - Good Dynamic Range
  - Reasonably easy to match

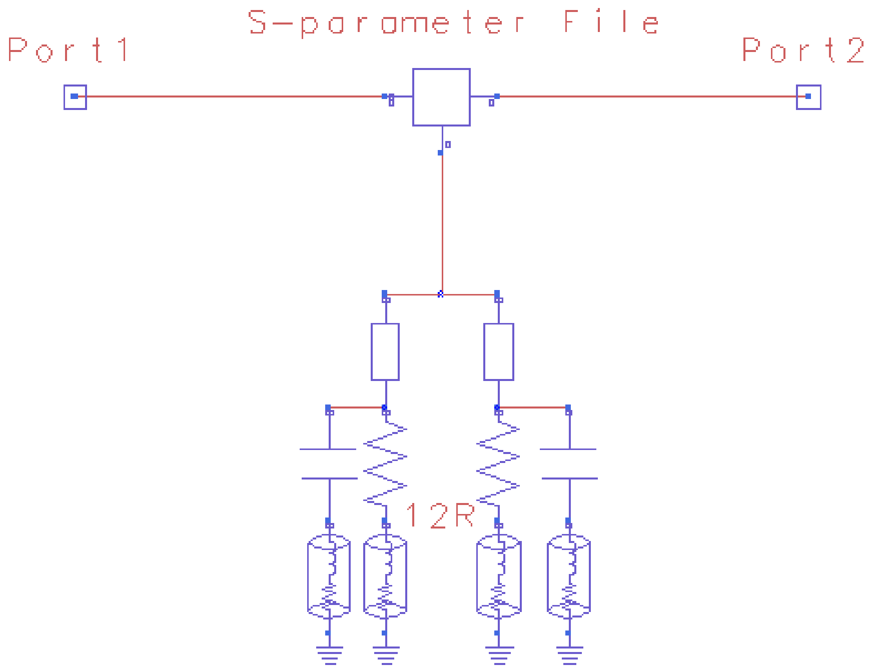
Noise and
S-Parameters File

```
!         ATF-34143          S PARAMETERS
!         Id = 20 mA         LAST UPDATED 2/6/99
```

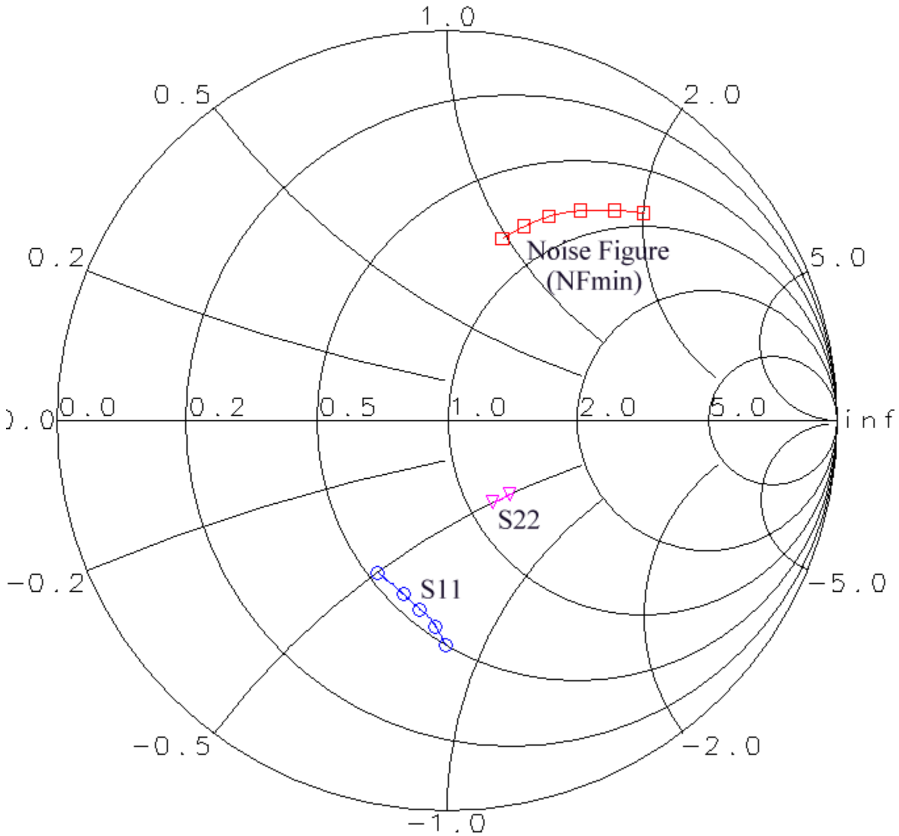
!FREQ	S11		S21		S12		S22	
!GHz	MAG	ANG	MAG	ANG	MAG	ANG	MAG	ANG
0.50	.96	-37	10.08	153	.035	68	.4	-35
0.80	.91	-60	9.642	137	.050	56	.34	-56
1.00	.87	-76	8.867	126	.061	48	.32	-71
1.50	.81	-104	7.443	106	.077	34	.29	-98
1.80	.78	-115	6.843	98	.083	28	.28	-110
2.00	.75	-126	6.306	90	.088	23	.26	-120
2.50	.72	-145	5.438	75	.095	15	.25	-140
3.00	.69	-162	4.762	62	.102	7	.23	-156
4.00	.65	166	3.806	38	.111	-8	.22	174

Modeling the raw device

- Model of raw device with Source Resistance for self bias



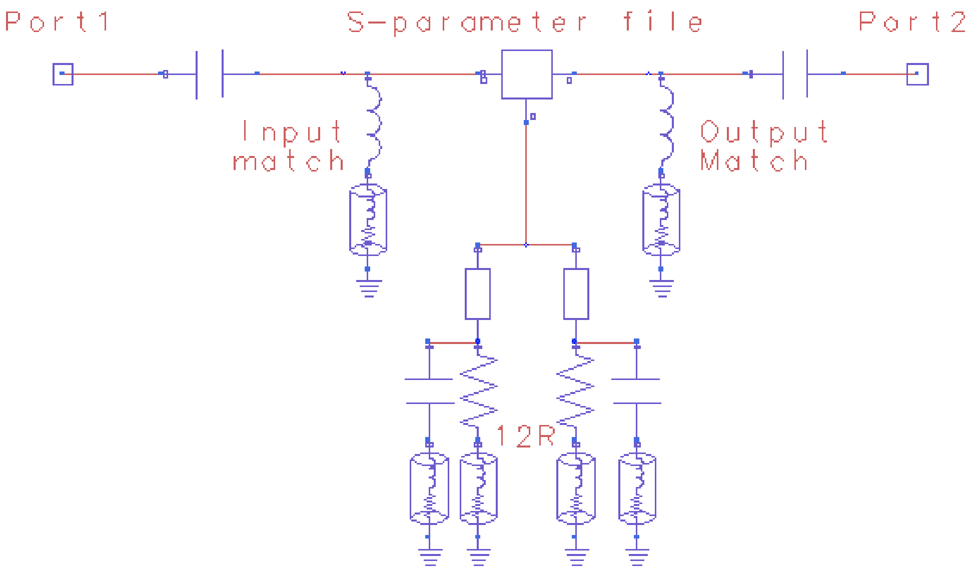
- Noise and S-Parameters



Matching the device

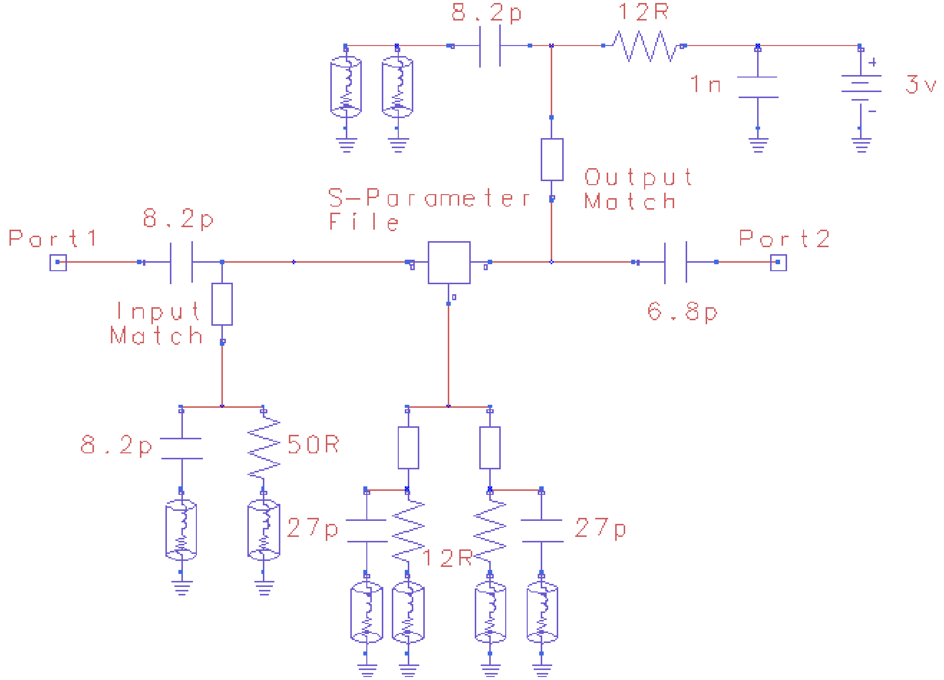
- Circuit looks capacitive
  - Use High-pass arrangement
- To synthesize matching networks
  - Calculator
  - Smith chart
  - Use Esyn in ADS
  - Use Optimizer in ADS

Simple high-pass impedance match



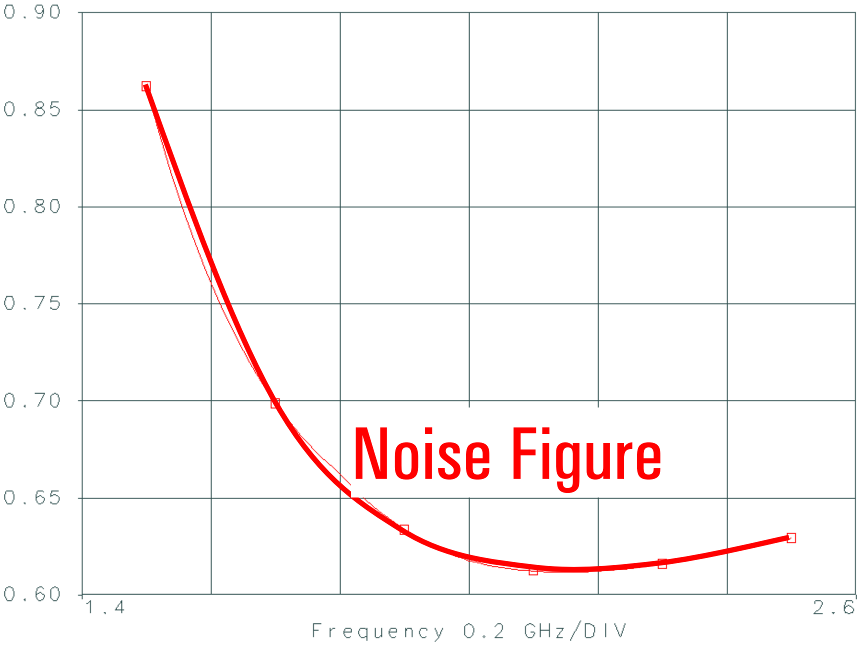
Complete Model of the Amplifier

- Inductors replaced by distributed elements
- Discretes replaced by vendor parts
- Output match
- Through hole vias included
- Stabilization added
- ADS Optimizer to re-tune values

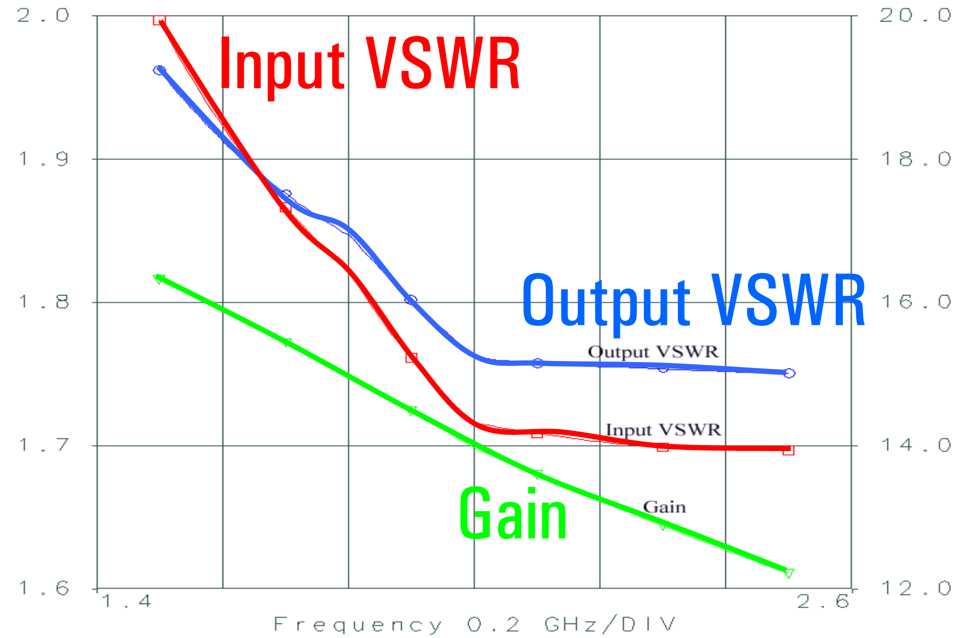


Simulation Results

Noise Figure



Gain and Match



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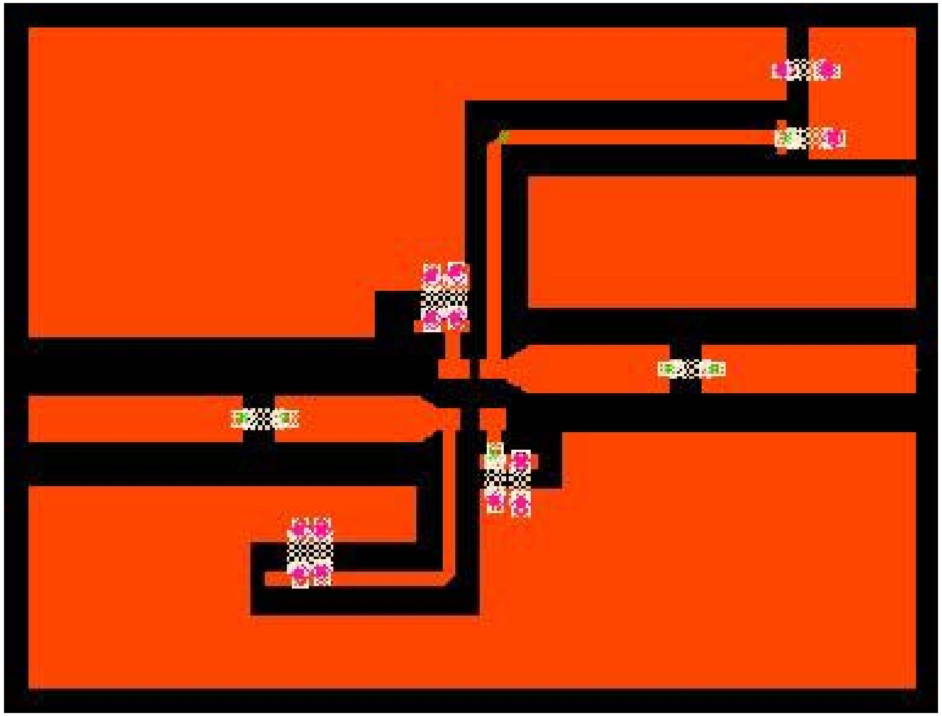
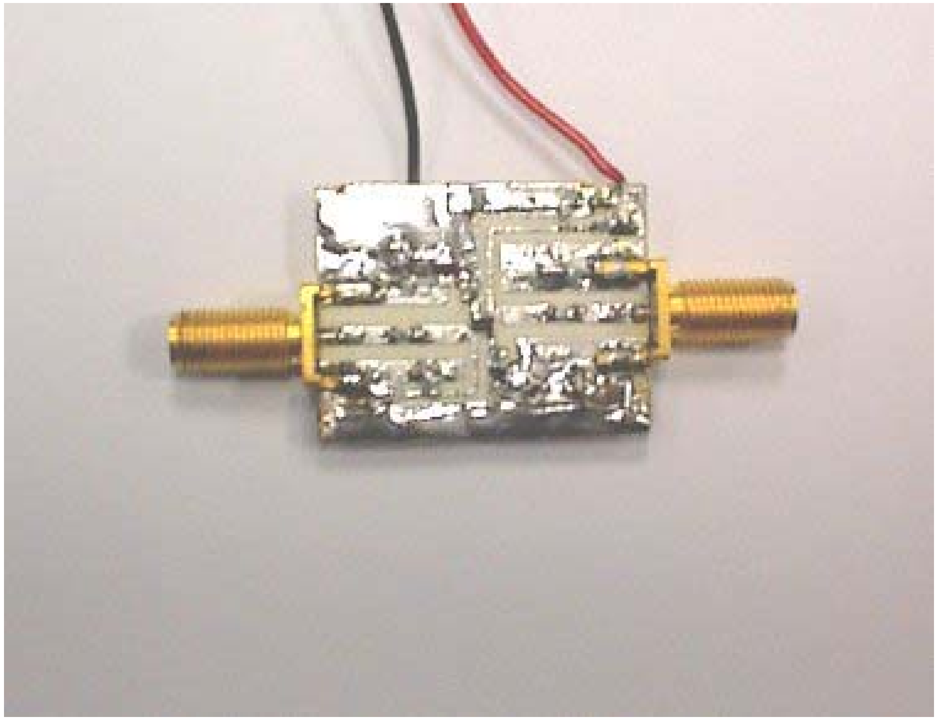
Layout and Prototype

Layout generated from schematic

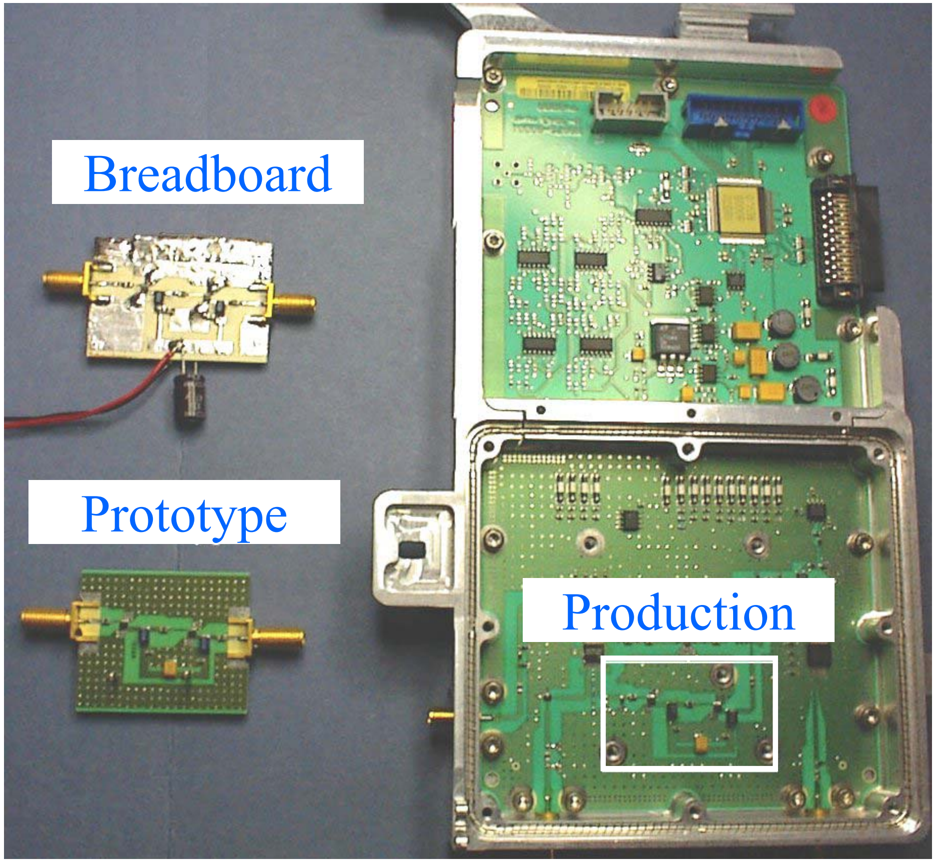


Breadboard amplifier



NFA Series RF Development Iterative design Process

- Model on ADS
- Build a breadboard
- Measure on an 8970B and make modifications
- Build a Prototype
- Measure on an 8970B and make modifications
- Production



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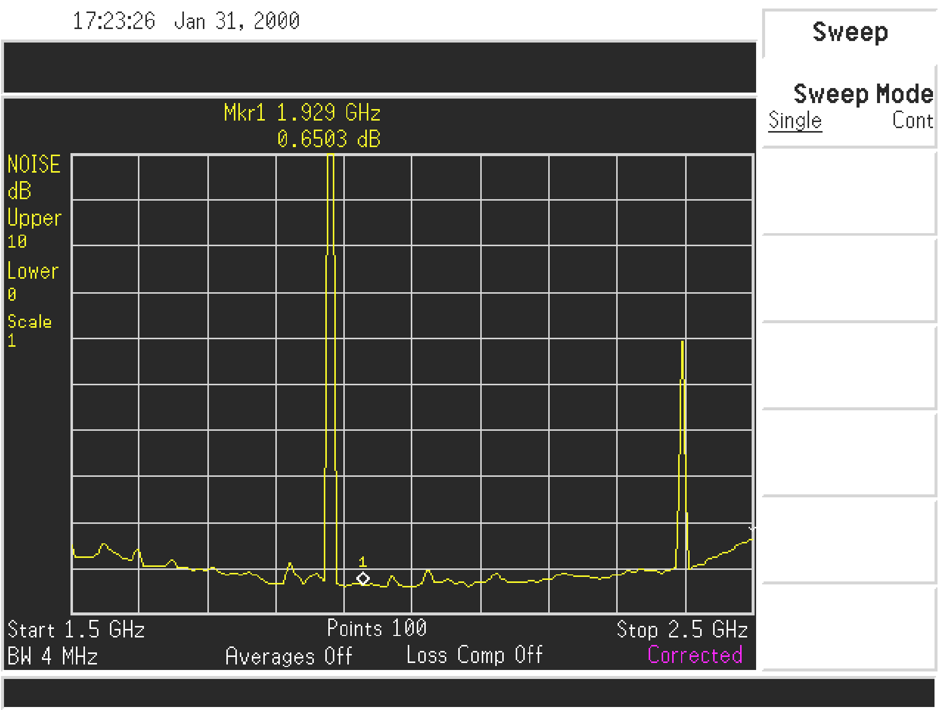
Noise Figure Measured on the NFA-Series N8973A

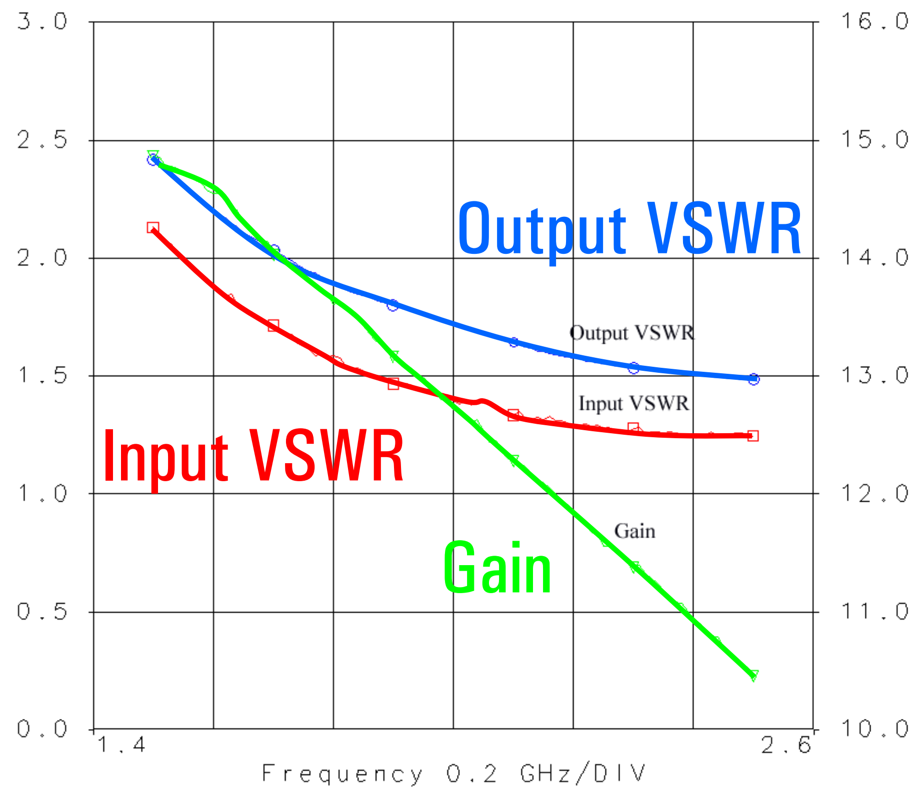
- Connect the noise source
- Perform a user calibration
- Connect the LNA between the noise source and the instrument
- Measure corrected Noise Figure, gain,
- Spikes are mobile phone transmissions getting into the unscreened circuit



Network Measurements

- Gain and Match
- Network Analyzer connected to ADS via GPIB

- Gain and Match pulled into ADS



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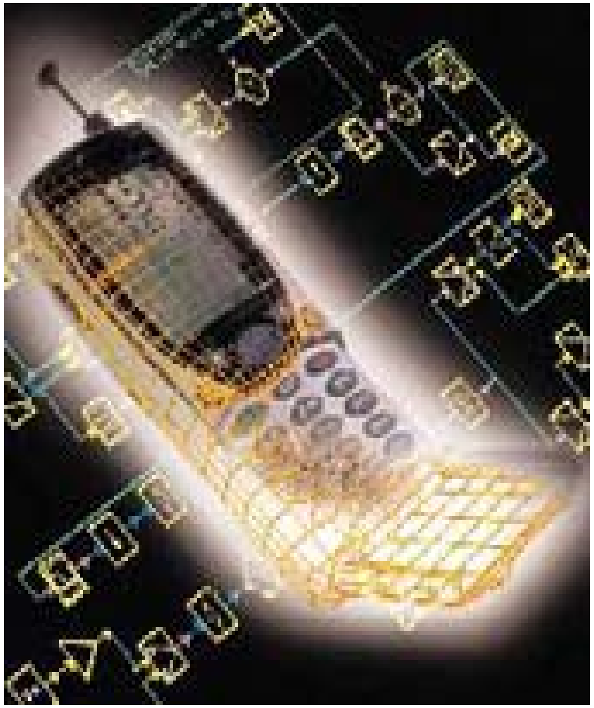
Narrow Band Noise Figure

- Noise Figure in a 4MHz band
  - Measurement time
  - Accuracy
  - Device bandwidth
- Modern applications are much more demanding
  - Measurement bandwidth
  - Narrow band measurement technique required



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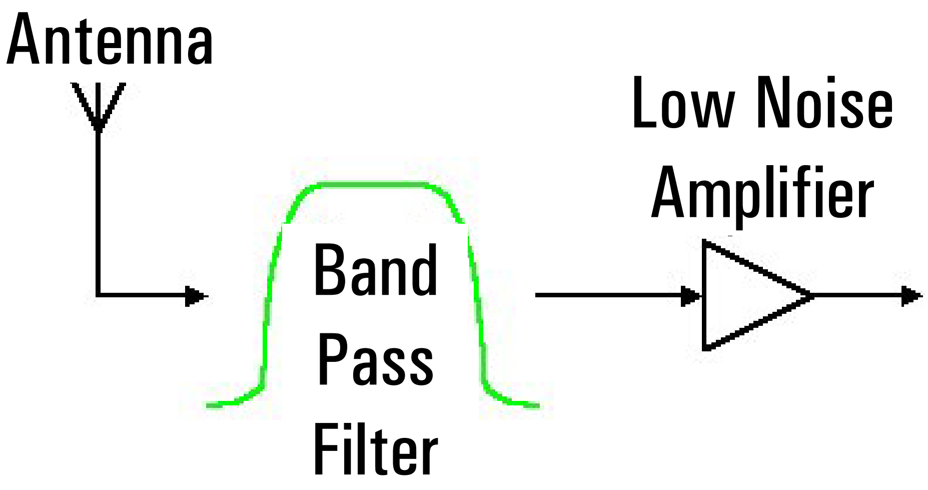
Base Station/Mobile Front-end

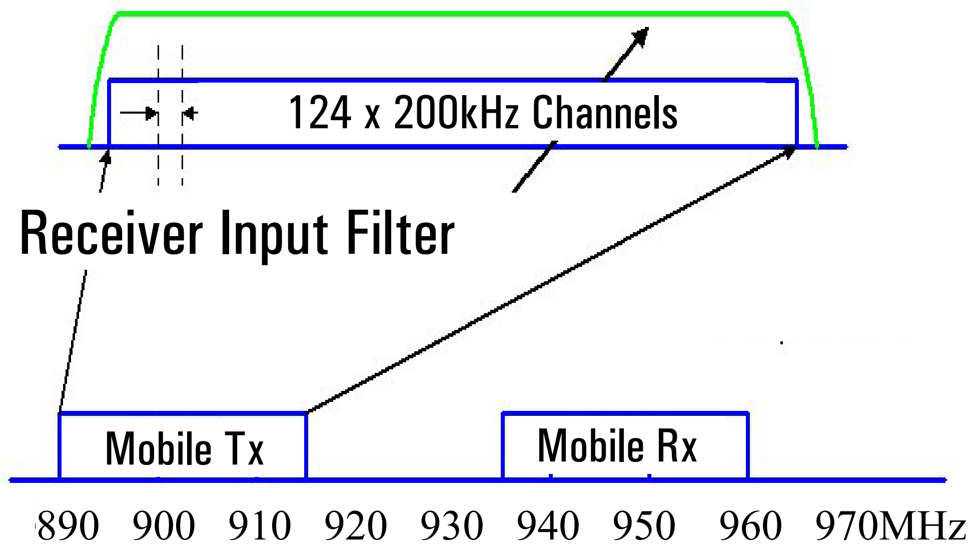
- Noise Figure critical
  - Isolator
  - High Q bandpass filter
- Very low noise amplifier
- Beyond Front-end, Noise Figure less important
  - Front-end gain reduces the effects



Simplified Receiver Front End

Why are Narrow Band measurements important?

- Using GSM as an example
  - Band is 25MHz wide
  - 124, 200kHz channel
- Filter rolls off
  - Risk of higher loss before LNA
  - Risk of higher noise figure
  - Risk of poor performance in channels near band edges



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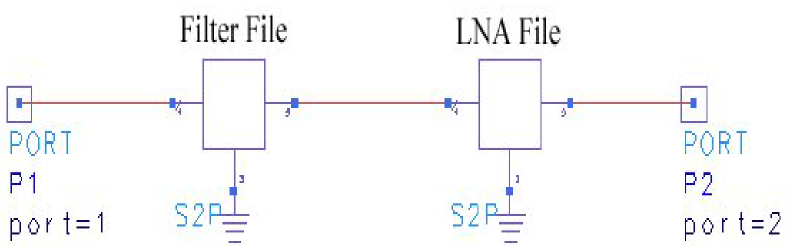
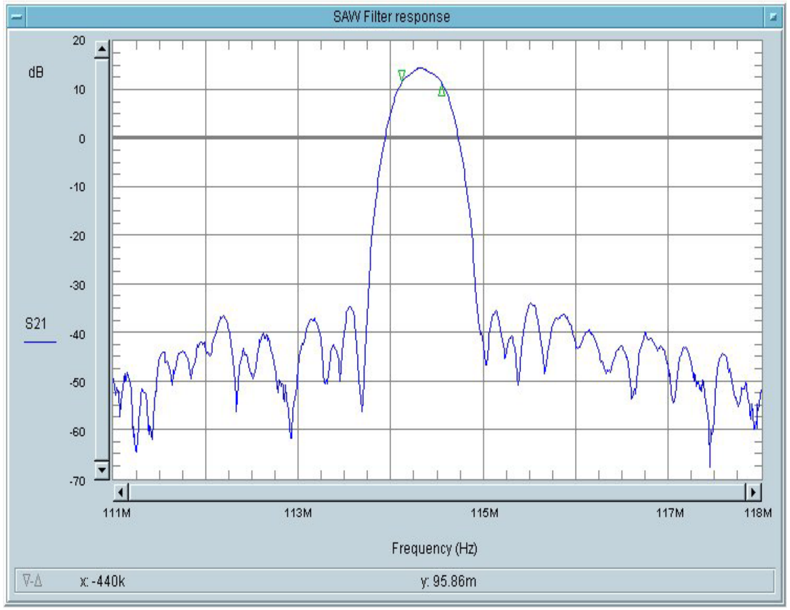
Narrow Band Example

- Combine a narrow band filter (~440kHz) with an amplifier
- Model using ADS
- Check the response on a network analyzer for reference

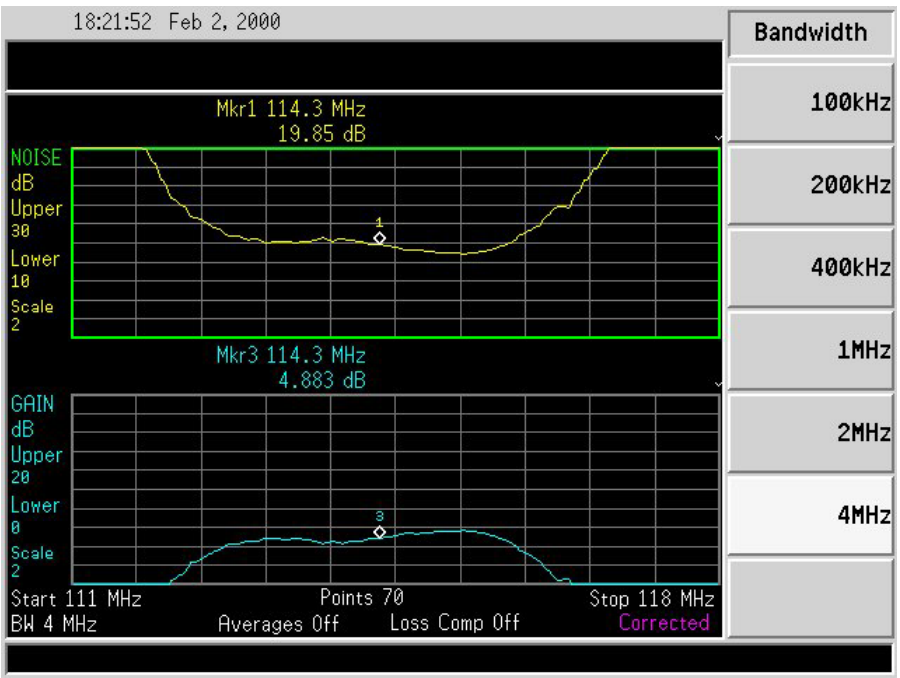


- Network measurement of Filter/Amplifier

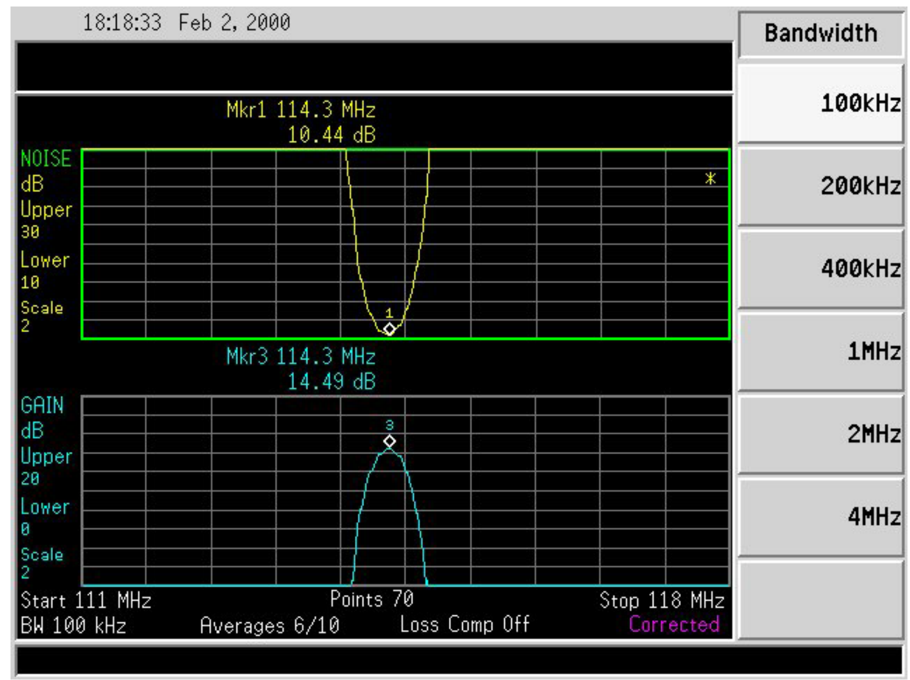


Narrow band Measurements using the NFA-Series N8973A

Measurement with 4MHz bandwidth



Measurement with 100kHz bandwidth



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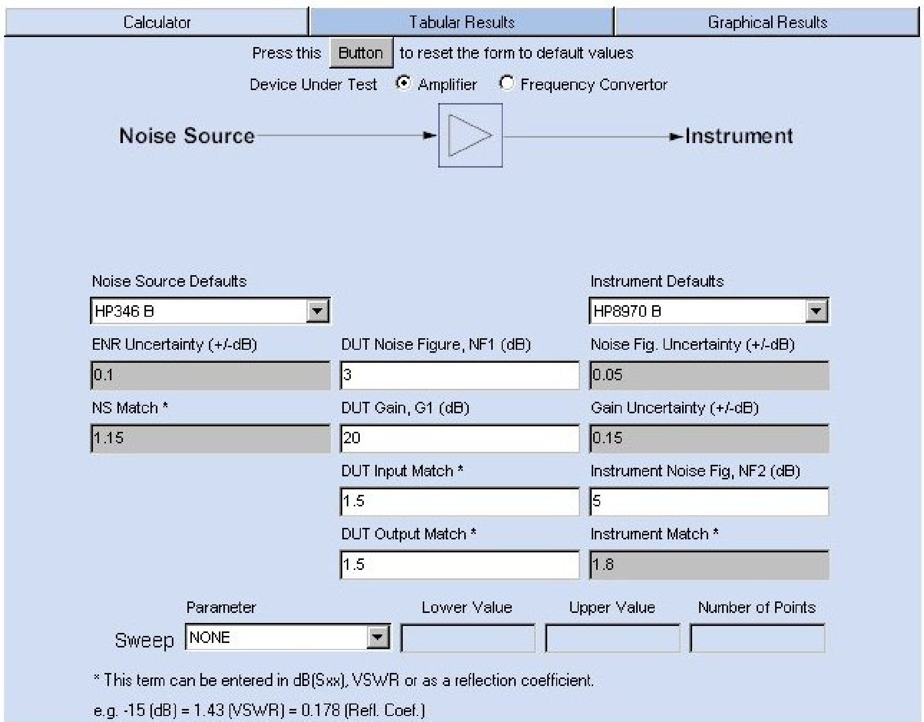
Measurement Uncertainty

- Extraneous signals
- Non-linearity's
- Instrumentation uncertainty
- ENR uncertainty
- Mismatch
- Measurement architecture
- Instrument Noise Figure
- Unwanted in-band power

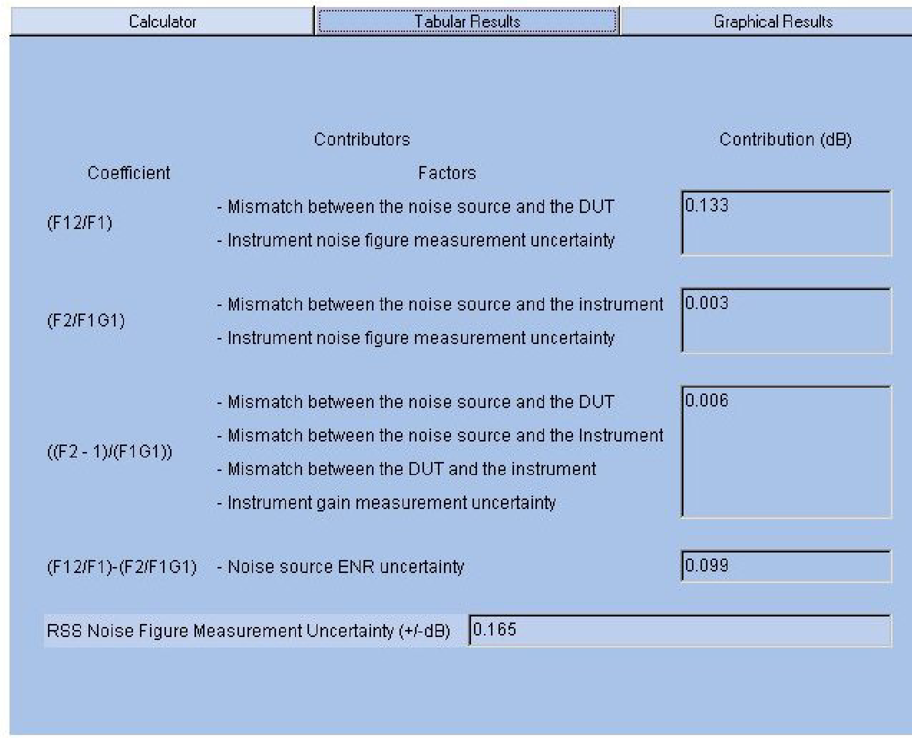
$$\left\{\left[\left(\frac{F_{12}}{F_1}\right)\delta NF_{12}\right]^2 + \left[\left(\frac{F_2}{F_1 G_1}\right)\delta NF_2\right]^2 + \left[\left(\frac{F_2 - 1}{F_1 G_1}\right)\delta G_1(dB)\right]^2 + \left[\left(\frac{F_{12}}{F_1} - \frac{F_2}{F_1 G_1}\right)\delta ENR\right]^2\right\}^{0.5}$$

Web Based Measurement Uncertainty Calculator

Data Entry



Results



The uncertainty calculator can be found at www.agilent.com/find/nfu

Noise Figure Test Solutions from Agilent

- NFA-Series Noise Figure Analyzers
  N8972A - 10MHz to 1.5GHz
  N8973A - 10MHz to 3.0GHz
  N8974A - 10MHz to 6.7GHz
  N8975A - 10MHz to 26.5GHz

- SNS-Series Noise Sources
  N4000A - 10MHz to 18GHz nominal ENR 6dB
  N4001A - 10MHz to 18GHz nominal ENR 15dB
  N4002A - 10MHz to 26.5GHz nominal ENR 15dB