

Ultra-Fast Noise Parameter Measurements

**More than 100x Faster
Enhanced Accuracy**

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For a more detailed version of this presentation, go to maurymw.com/presentations.htm

Tuners For RF Device Characterization



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Outline

- Motivation
- Basics of Noise Measurements
- Traditional Noise Parameter Measurement
- The New Noise Parameter Measurement
- Results (**224x Faster and more Accurate**)
- Summary



Noise Parameter Measurement

Motivation for Change

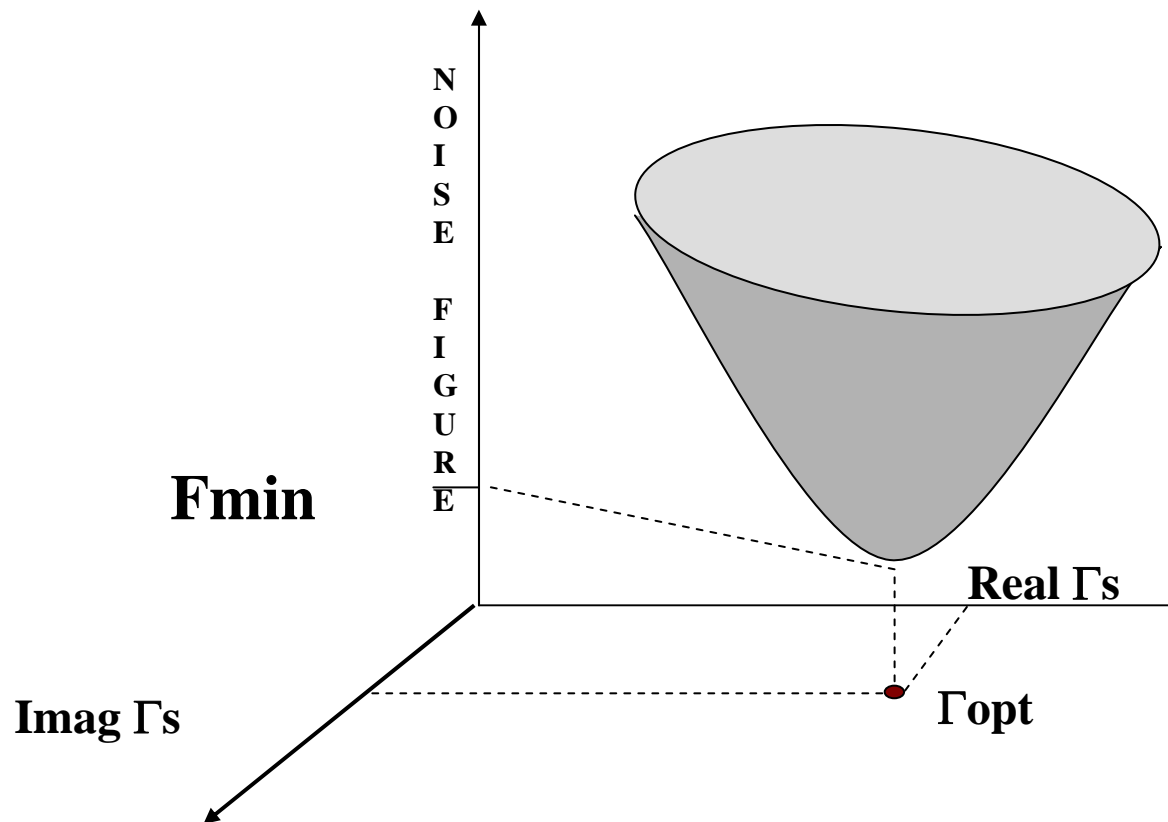
- **Speed Up the Measurement**
 - Traditionally Slow
- **Simplify the Measurement**
 - Traditionally Difficult

Noise Figure

- **Noise Performance at one Impedance**
- **Example – 50 Ohm Noise Figure**

Noise Parameters

Give Noise Figure vs. Impedance



Noise Parameters

Consist of Four Scalar Values

Most Common Set:

- F_{min} – Minimum noise figure
- $|\Gamma_{opt}|$ – Optimum Γ magnitude
- $\angle\Gamma_{opt}$ – Optimum Γ phase
- r_n - Equivalent noise resistance

$$F = F_{min} + 4r_n \frac{|\Gamma_s - \Gamma_{opt}|^2}{|1 + \Gamma_{opt}|^2 (1 - |\Gamma_s|^2)}$$

Noise Parameter Measurement

General Method

- Set 4 Values of Γ_s
- For Each Γ_s , Measure F
- Solve 4 Simultaneous Equations
for the 4 Values

$$F = F_{\min} + 4r_n \frac{|\Gamma_s - \Gamma_{\text{opt}}|^2}{|1 + \Gamma_{\text{opt}}|^2 (1 - |\Gamma_s|^2)}$$

Noise Parameter Measurement Practical Method

Use Over-Determined Data:

- Measurement is Sensitive to Small Errors
- Measure at more than 4 Γ s Values
- Use Least-Mean-Squares to Reduce Data

Noise Parameter Measurement

Practical Method

Use Noise Power Equation:

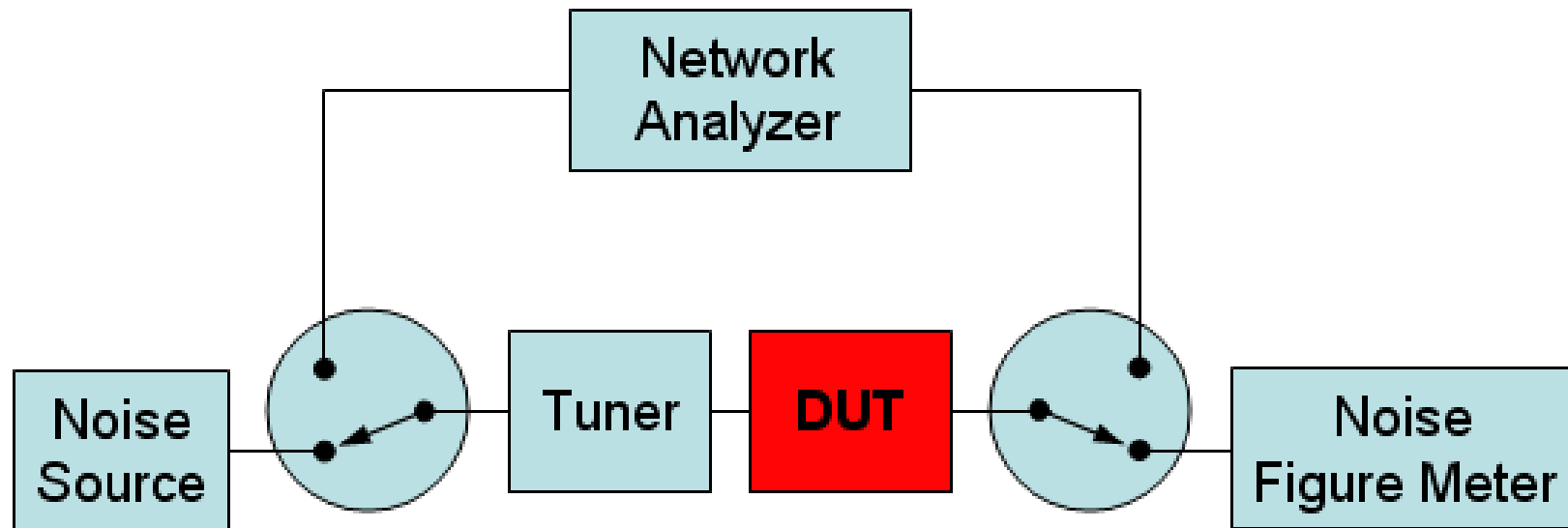
- Rigorous Solution
- Account for Γ_{hot} and Γ_{cold} of Noise Source
- Allows Hot/Cold or Cold Only Approaches

$$P = kB\{[t_{ns} + t_0(F1-1)]Ga1 + t_0(F2-1)\}Gt2$$

Noise Parameter Measurement Sequence

1. System Cal
2. Receiver Cal
3. DUT Measurement

Noise Parameter Measurement Traditional Method



Noise Parameter Measurement

Traditional Method

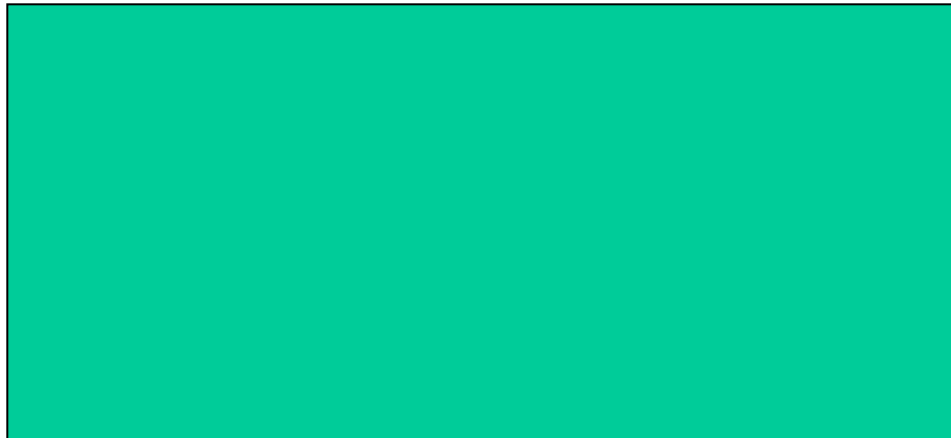
1. System Cal
 - Characterize Tuners Over Entire Chart
 - One Frequency at a Time
2. Receiver Cal and Measurement
 - One Frequency at a Time
 - Allows Ideal Impedance Pattern

Noise Parameter Measurement

Traditional Method

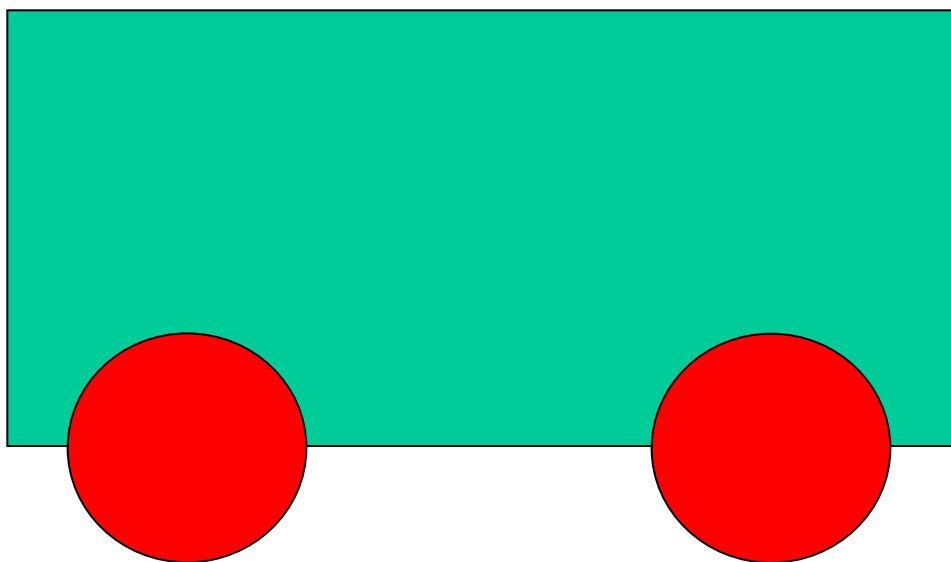
- Time Consuming
 - Can Have Drift Issues
- Use System Cal for Long Time
 - To Save Time
 - Calibrate Parts Separately

History



Heavy Objects are Hard to Move

Innovation



Once Seen, Wheels are Obvious

Noise Parameter Measurement

New Method*

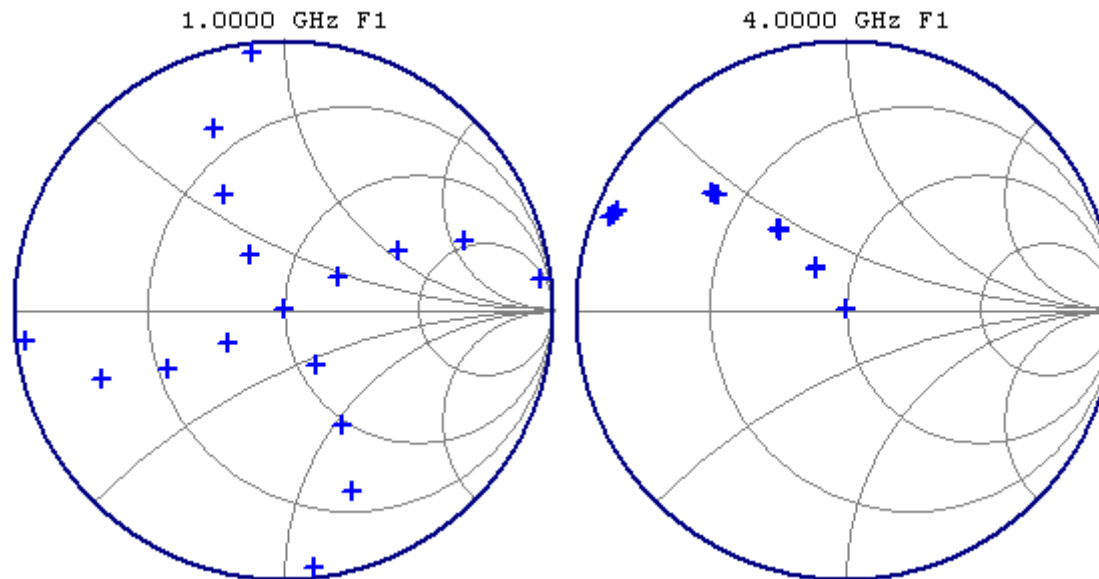
Main Idea:

- Characterize One Set Of Tuner States
- Sweep Frequency at Each State
- Take Advantage of Fast Sweep of Modern Instruments

*Patent Pending

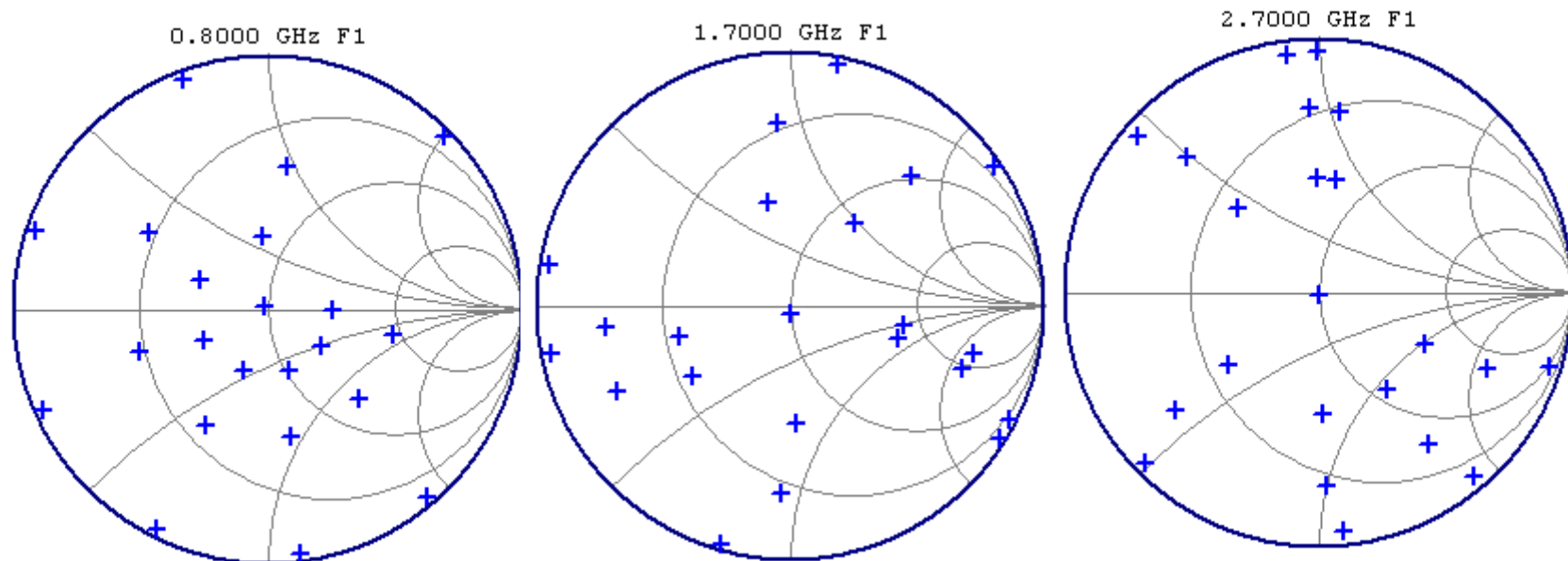
Noise Parameter Measurement New Method

Problem: Impedance Patterns at All Frequencies



Noise Parameter Measurement New Method

Solution: Non-Uniform Phase Spacing



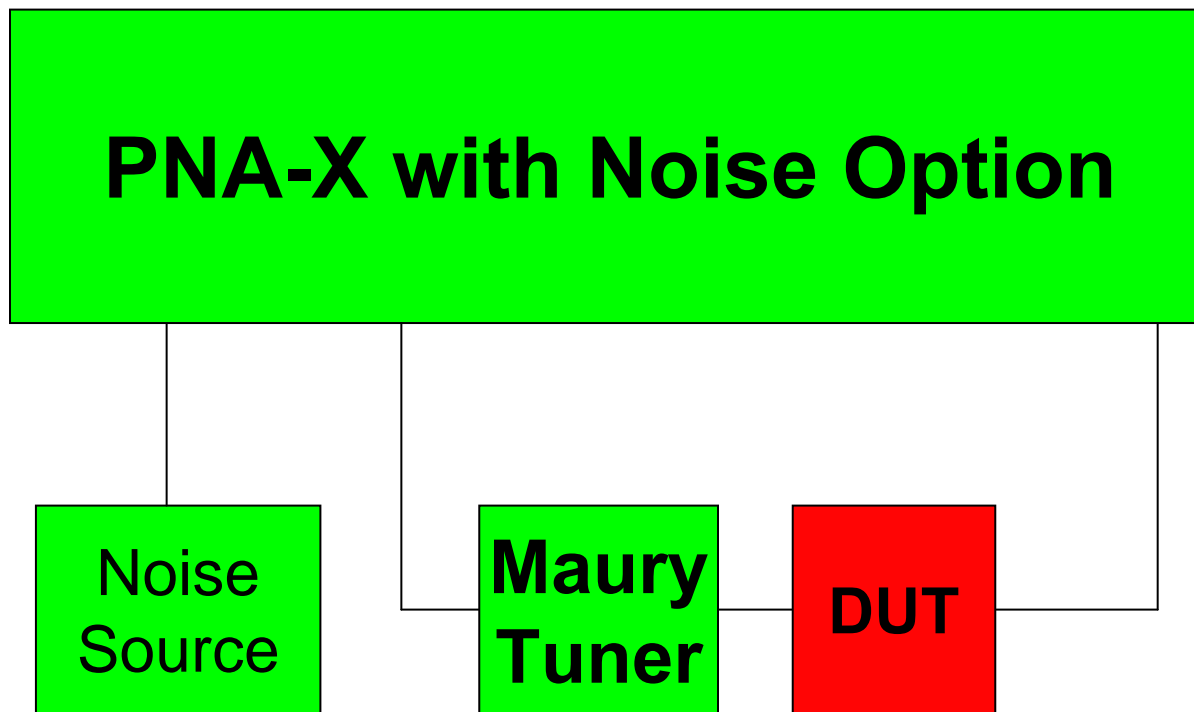
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Noise Parameter Measurement

New Method



Noise Parameter Measurement New Method



Noise Parameter Steps

New Method

1. System Cal
 - 2-Port S-Parameter Cal at DUT Plane
 - 1-Port S-Parameter Cal at Noise Source Plane
 - Tuner Cal (~3-4 Minutes, 73 Freqs)
2. Noise Receiver Cal (< 2 Minutes, 73 Freqs)
3. DUT Measurement (< 2 Minutes, 73 Freqs)

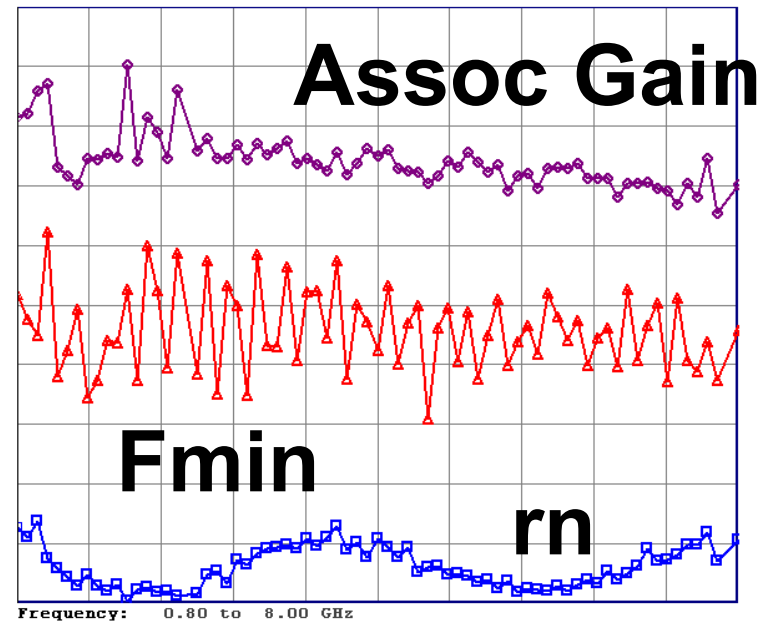
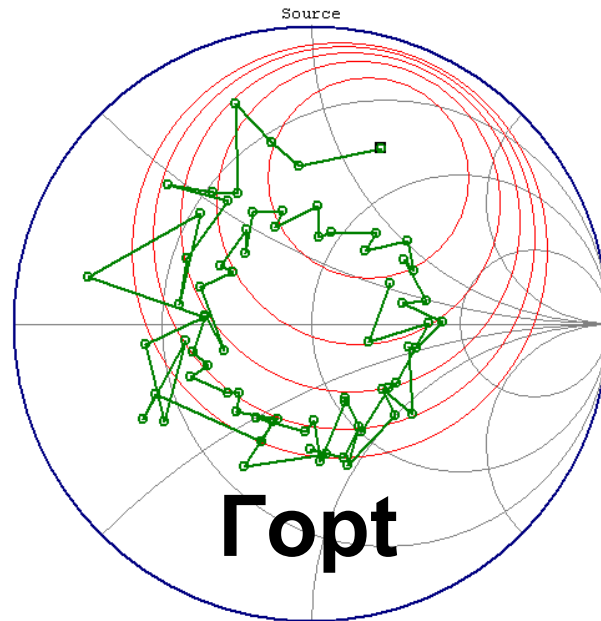
Noise Parameter Results

Old Method

Noise Parameters vs Frequency

△ Fmin: 1.04 dB
0.00 to 2.00 dB
□ rn: 0.32
0.00 to 2.50
◇ Fopt: 0.6336 < 68.25
◆ Assoc_gain: 20.40 dB
0.00 to 25.00 dB

Marker: Frequency = 0.80 GHz



Label:
Coax DUT with traditional method 9-7-2008

73 Frequencies

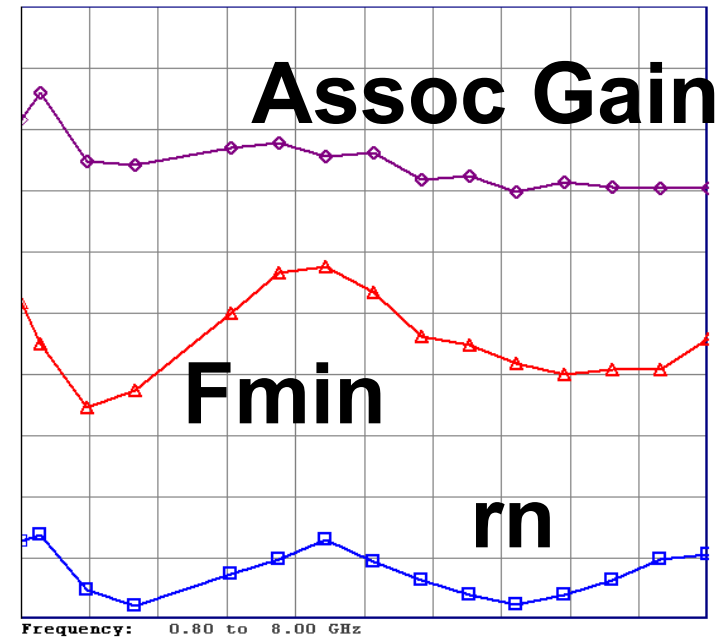
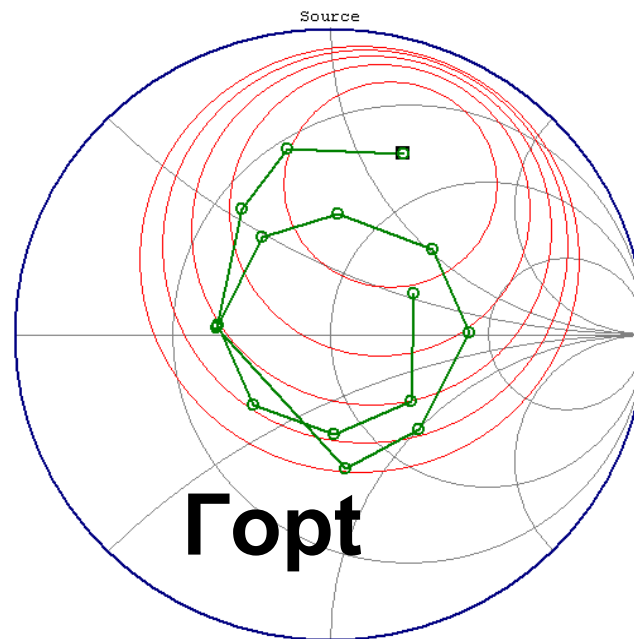
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Label:
Coax DUT with traditional method 9-7-2008

Same Data, 0.5 GHz Steps

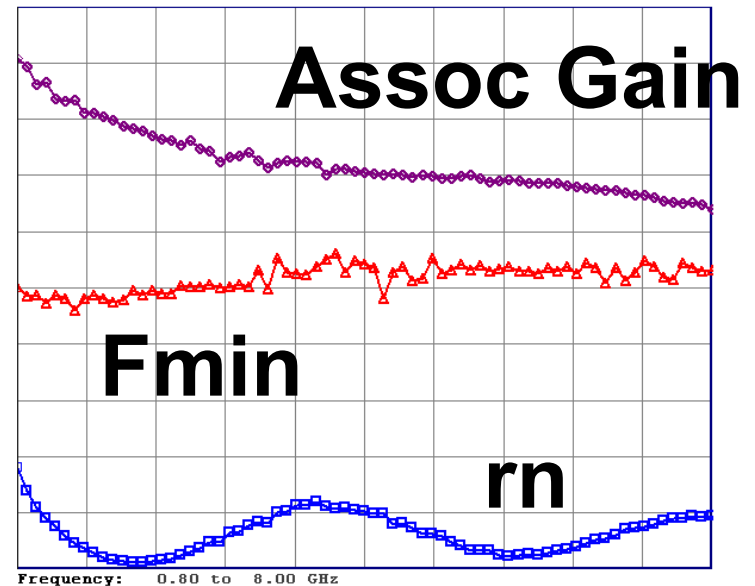
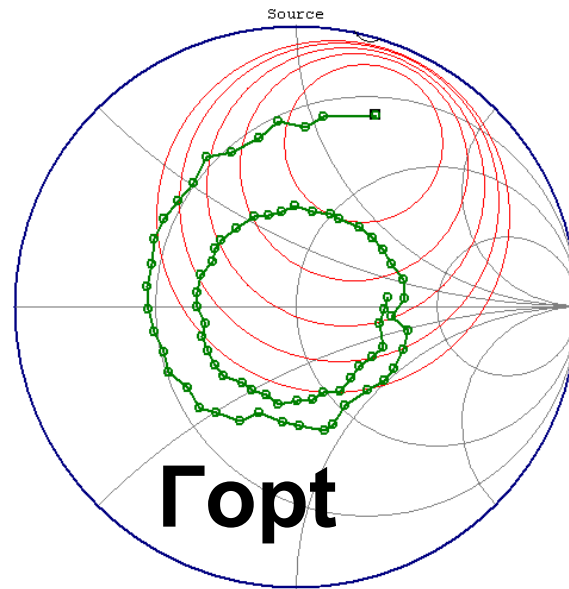
Noise Parameter Results

New Method

Noise Parameters vs Frequency

Δ Fmin: 1.01 dB
0.00 to 2.00 dB
 \square rn: 0.46
0.00 to 2.50
 \diamond Γ_{opt} : 0.7386 < 67.39
 \diamond Assoc_gain: 22.75 dB
0.00 to 25.00 dB

Marker: Frequency = 0.80 GHz



Label:
FET in coax fixture 8-29-2008

73 Freqs, 224x Faster

Tuners For RF Device Characterization



Accomplishment

Success for Motivation:

- **Two Orders of Magnitude Faster!**
- **Setup and Measurement Is Much Simpler!**

In Addition:

- **Results are More Accurate**

Why Better Accuracy?

New Method

- Simpler Setup
 - Fewer Cables and Connections
- Always Do Full In-Situ Cal
 - Removes Accumulated Errors of Multiple S-Parameter Cals
 - Removes Connection Errors
- No Drift
- Always Use Dense Frequency Selection

Summary

- **New Ultra-Fast Noise Parameter Measurement**
 - **Industry Breakthrough (224x Faster)**
- **Simpler Setup and Measurement**
- **Better Accuracy**

Reference

G. Simpson, D. Ballo, J. Dunsmore, A. Ganwani," A New Noise Parameter Measurement Method Results in More than 100x Speed Improvement and Enhanced Measurement Accuracy", 72nd ARFTG Conference, Dec 9-12, 2008.