Memorandum

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Subject: Using Spectrum Analyzers as a Programmable Filter for Noise Temperature Measurements

Introduction

A spectrum analyzer can be used as a programmable filter in noise temperature measurement systems by configuring it for “zero span” mode and routing the IF output to a power meter. Spectrum analyzers offer the following advantages over YIG filters:

1. They are often already available in noise temperature measurement systems because of their utility as a general-purpose test instrument.
2. Almost all are GPIB programmable.
3. They eliminate the custom-designed digital interfacing circuits that are required for YIG filters, which can be costly to develop and to maintain.

Spectrum analyzers do have some disadvantages:

1. Maximum resolution bandwidths, which determine the overall noise bandwidth of the measurement system, are generally limited to 3 or 5 MHz. This means that additional power measurements are required to achieve the same variance that is available from YIG filters. For example, the HP E4408 spectrum analyzer has a maximum resolution bandwidth of 3 MHz while the Omniyig filter has a bandwidth of about 60 MHz, so $\sqrt{60/3} = 4.5$ times more power measurements are required to obtain the same variance.
2. They have poor noise figures (the HP E4408 measured 26 dB), so sufficient overall system gain and dynamic range is required to prevent them from significantly contributing to the system noise temperature.
3. Since they are active devices, careful selection of IF gain is required to achieve acceptable linearity.

In general, only the first disadvantage is significant, since the others can be overcome by proper system design.

Results are presented below showing that, with proper selection of IF levels, a noise measurement system using the HP E4408 spectrum analyzer can achieve the same results as the YIG filter-based system.

Setup

The warm IF plate served as both the noise source and amplifier for the test. The equipment configuration is shown in the drawing inserted in Figure 1. The first amplifier stage and variable attenuator acted as a variable noise source. Changing the variable attenuator altered the noise level and a y-factor was simulated by measuring noise power differences when the attenuator was changed from 0 dB to another attenuation value.

Noise powers were measured with an HP 436 power meter and 8481 high-sensitivity power head. The measurement frequency was fixed at 5 GHz, and the same power head was alternately connected to the YIG filter and IF output of the spectrum analyzer. The noise attenuator was changed in 1-dB steps and the noise power was recorded on a spreadsheet by programmatically reading and averaging 5 power meter measurements at each attenuation setting. The 0-dB reference power was recorded at the beginning and end of each run, and it usually varied less than 0.03 dB over a measurement, but it was still interpolated for the intermediate attenuation values. The reference power was remeasured each time the system was reconfigured to use either the YIG filter or spectrum analyzer.

Results

Figure 1 shows the discrepancies between the YIG and spectrum analyzer when each was used as a filter to measure the y-factors. The three dashed traces in Figure 1 were measured with the spectrum analyzer's RF attenuator set for 0 dB, and their differences from each other may result because they were measured over the span of about an hour.

The smallest differences between the two measurement techniques is shown in the two lower solid traces that were measured with the RF attenuator set for both 5 dB and 10 dB. Perhaps low values of RF attenuation reduce mismatch errors and are sufficiently low so that they don't significantly degrade the overall system noise temperature.

The top solid curve shows how the noise figure of the spectrum analyzer can introduce significant measurement errors when its RF attenuator is set for 20 dB.

All the data in Figure 1 was measured at a fixed frequency of 5 GHz. As a quick check for frequency related changes, the spectrum analyzer was adjusted to sweep from 1 GHz to 12 GHz and the noise power observed on the spectrum analyzer trace was recorded onto disk and transferred to a spreadsheet. Figure 2 gives the results.

Gain slope is shown in the bottom trace, which is system noise power as a function of frequency without any normalization. The spectrum analyzer was then configured to store the noise power with the noise attenuator set for 0 dB. That data was used to normalize the top trace, which was measured with the noise attenuator set for 10 dB. The triangle shows the y-factor obtained with the YIG filter and power meter, and it agrees well with the frequency swept data.

Acknowledgments

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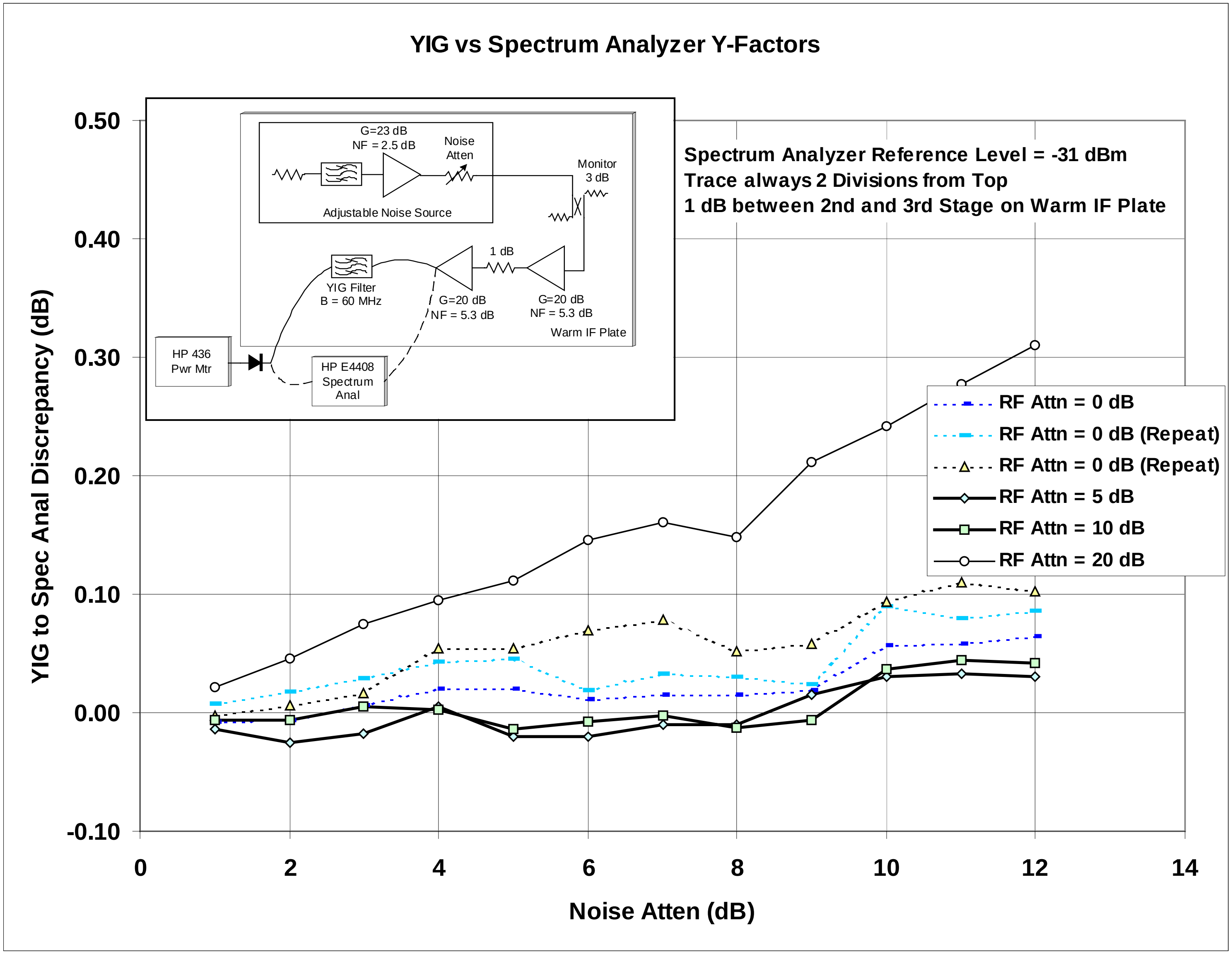
YIG vs Spectrum Analyzer Y-Factors
G=23 dB
NF = 2.5 dB
Noise Atten
Adjustable Noise Source
Monitor 3 dB
1 dB
YIG Filter
B = 60 MHz
G=20 dB
NF = 5.3 dB
G=20 dB
NF = 5.3 dB
Warm IF Plate
HP 436 Pwr Mtr
HP E4408 Spectrum Anal
Spectrum Analyzer Reference Level = -31 dBm
Trace always 2 Divisions from Top
1 dB between 2nd and 3rd Stage on Warm IF Plate
RF Attn = 0 dB
RF Attn = 0 dB (Repeat)
RF Attn = 0 dB (Repeat)
RF Attn = 5 dB
RF Attn = 10 dB
RF Attn = 20 dB
YIG to Spec Anal Discrepancy (dB)
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
2
4
6
8
10
12
14
Noise Atten (dB)

Figure 1

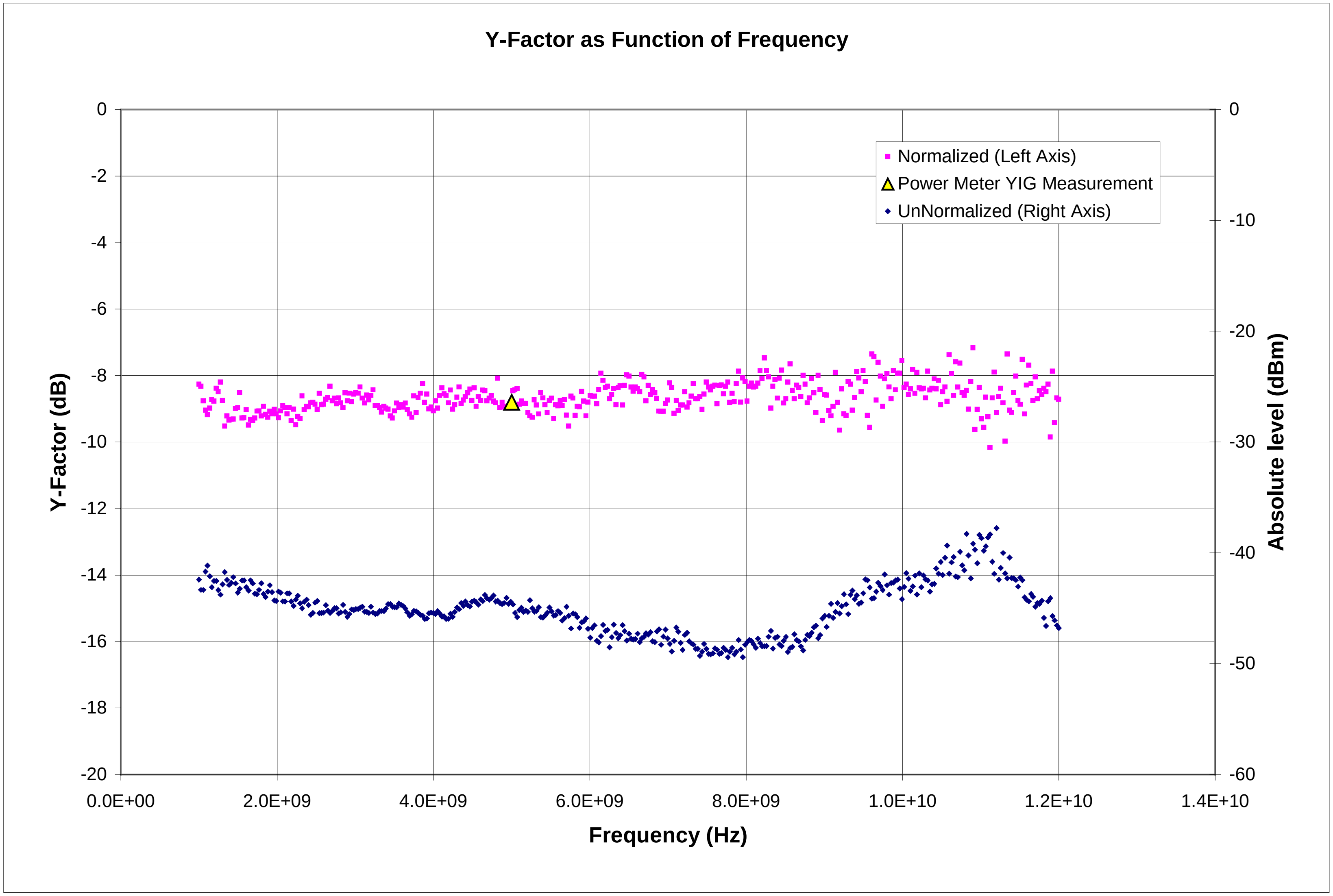
Y-Factor as Function of Frequency
Normalized (Left Axis)
Power Meter YIG Measurement
UnNormalized (Right Axis)
Y-Factor (dB)
Absolute level (dBm)
Frequency (Hz)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
-10
-20
-30
-40
-50
-60
0.0E+00
2.0E+09
4.0E+09
6.0E+09
8.0E+09
1.0E+10
1.2E+10
1.4E+10

Figure 2