Measurements on a Spectrometer
1.6 Sampler Module

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Introduction

Previous investigations of the GBT spectral baselines when observing sources with significant continuum intensity have shown that significant structure is introduced deep in the IF system. One mechanism that could produce these results would require the introduction of significant system noise, and tests attempting to confirm or deny this possibility pointed toward the 1.6 GHz sampler modules which are part of the spectrometer. Baseline shapes were found to depend on the level into the sampler, with general worsening at lower levels. This note describes some subsequent laboratory RF testing of one sampler module, serial number 10.

The RF input section of the sampler modules consists of: a 6dB pad, a length of semi-rigid coax, a Mini-Circuits ZFL 2000 amplifier, a length of semi-rigid coax, a Mini-Circuits ZFRSC-42 resistive power divider, and two short lengths of semi-rigid coax connecting to the two input ports of a comparator module.

Three types of tests were done on the RF input circuitry of the module: gain compression, s-parameter measurements, and spectrum measurements. The gain compression and s-parameter measurements were done with the Anritsu 37397C vector network analyzer, and the spectrum measurements using a noise source chassis supplied by Rich Lacasse, and the HP 8566 spectrum analyzer.

To briefly summarize the results: The gain compression tests showed only about 0.2dB of compression in the module amplifier with the input level 15dB above the nominal operating point, but the compression introduces some gain curvature and ripple. The s-parameter measurements show that reflections from the comparator input ports, together with no isolation in the resistive power divider, introduce gain ripple of about 2dB. And, the spectrum measurements indicate excess level-dependent noise is generated both by the input amplifier, and by the 1600MHz comparator module.

Gain Compression Measurements

Swept gain compression measurements may be done using a network analyzer by measuring the device s21 (forward gain) at a relatively low device output power level, and noting changes in the gain as the device input power is manually increased. The 37397C analyzer provides an application that assists in this process. A split screen displays both the device output power and the device gain normalized to the initial power level.   We setup to measure the gain from the module input to the ZFL-2000 amplifier output connector. Figures 1-4 show the results as the amplifier output power is increased from 0dBm to +15dBm. (The amplifier output power is approximately 0dBm when in the system, set for optimum sampler duty-cycles.)   Perhaps the only notable results are that there is some curvature and ripple induced in the gain as the output power increases.

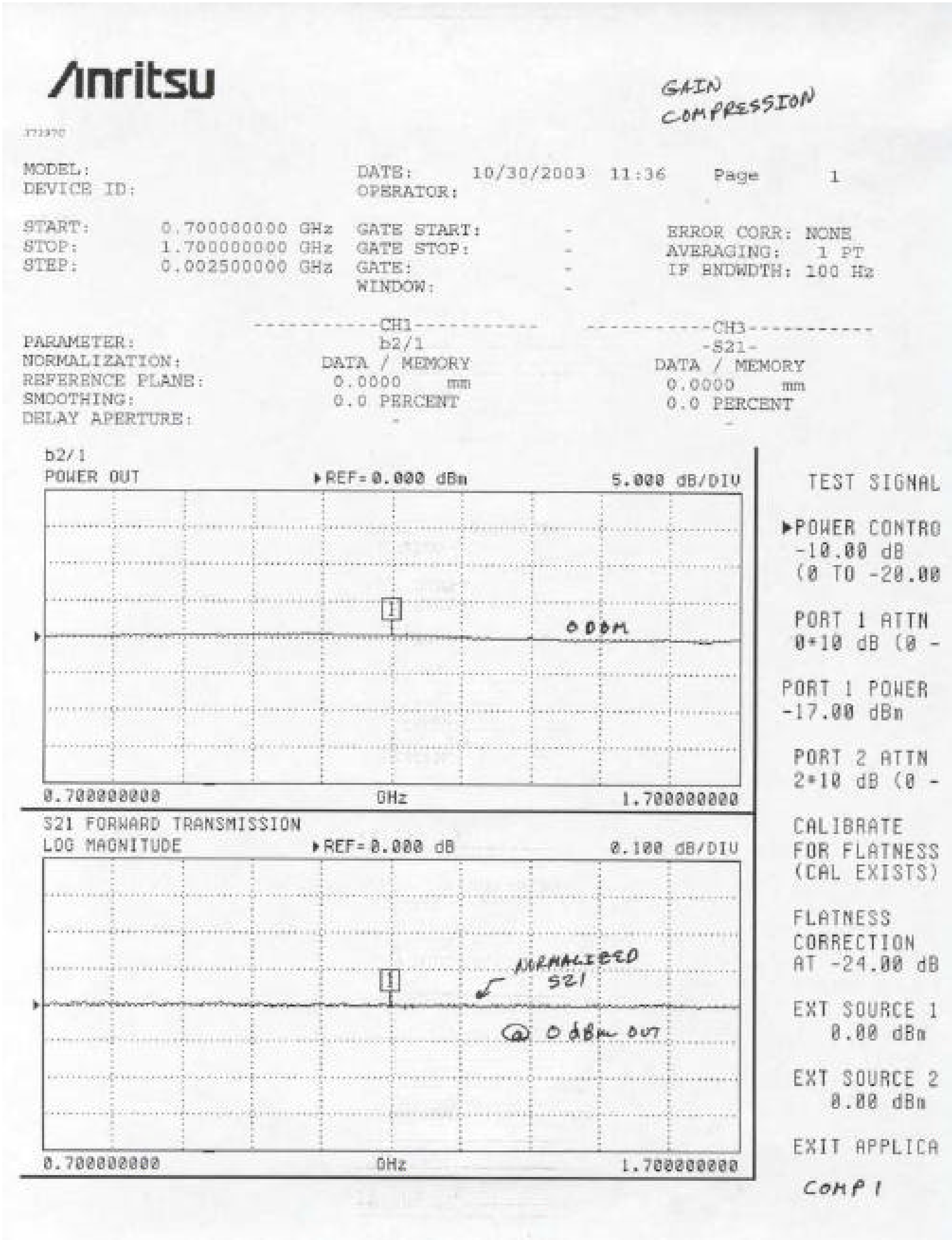

Figure 1. The upper trace is the output power of the sampler module ZFL-2000 amplifier. The lower trace shows the normalized gain through the amplifier.

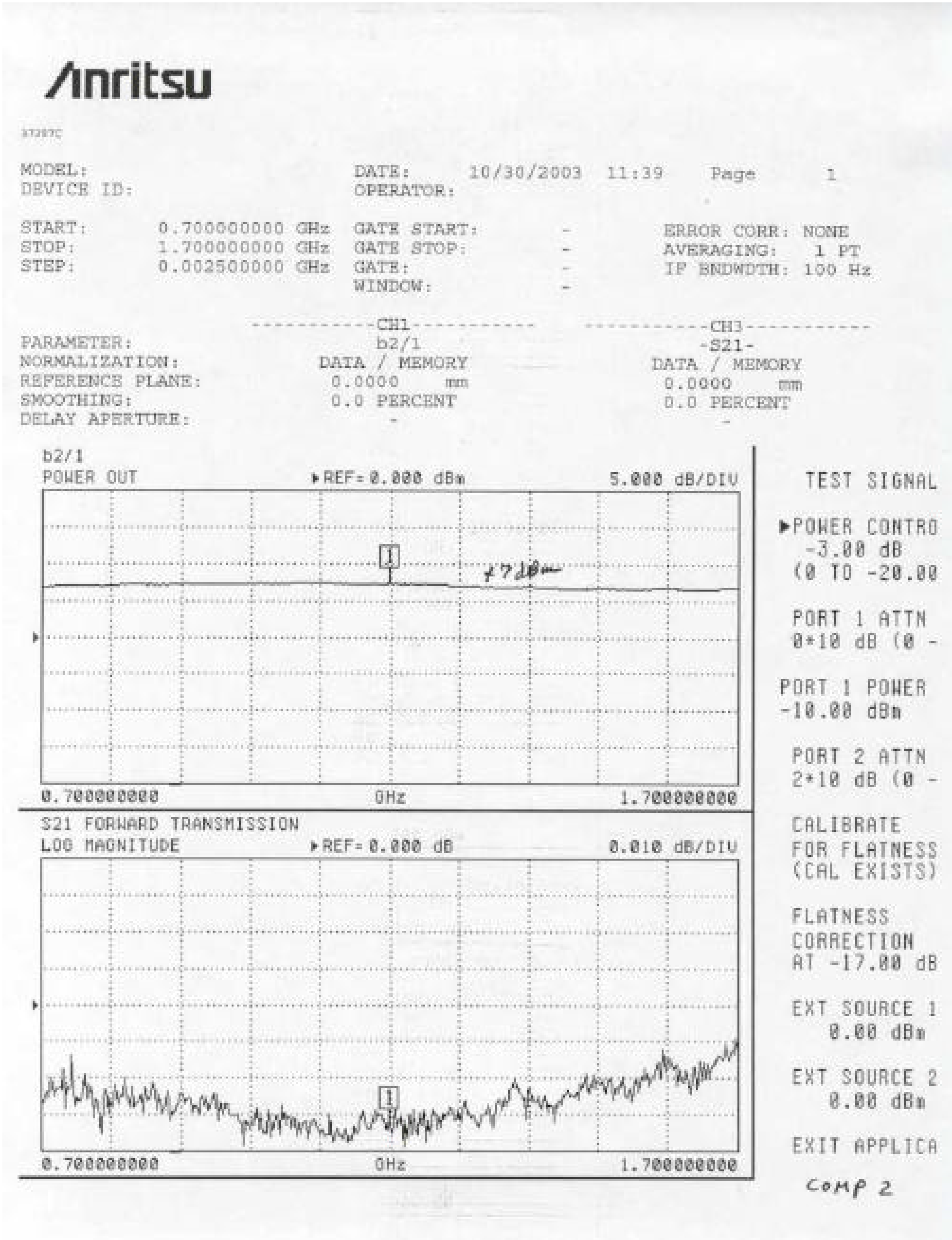

Figure 2. Same as figure 1 except the amplifier output power has been increased to approximately +7dBm by increasing the VNA output power. The gain has decreased, relative to the gain at 0dBm output, by about 0.03dB at midband.

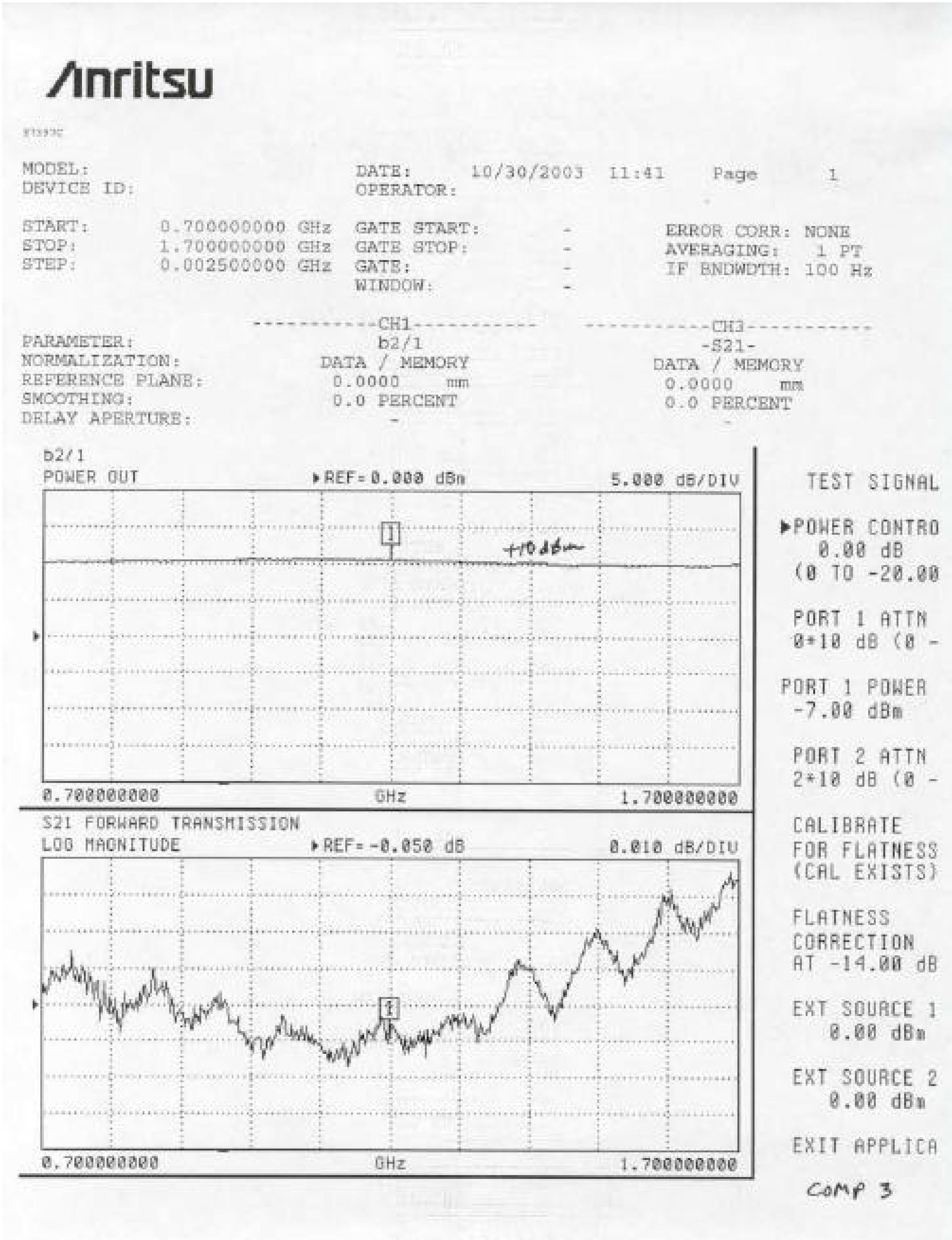

Figure 3. The power level increased again to +10dBm out. The gain has decreased about 0.06dB at midband, and ripples with approximately 100MHz period appear.

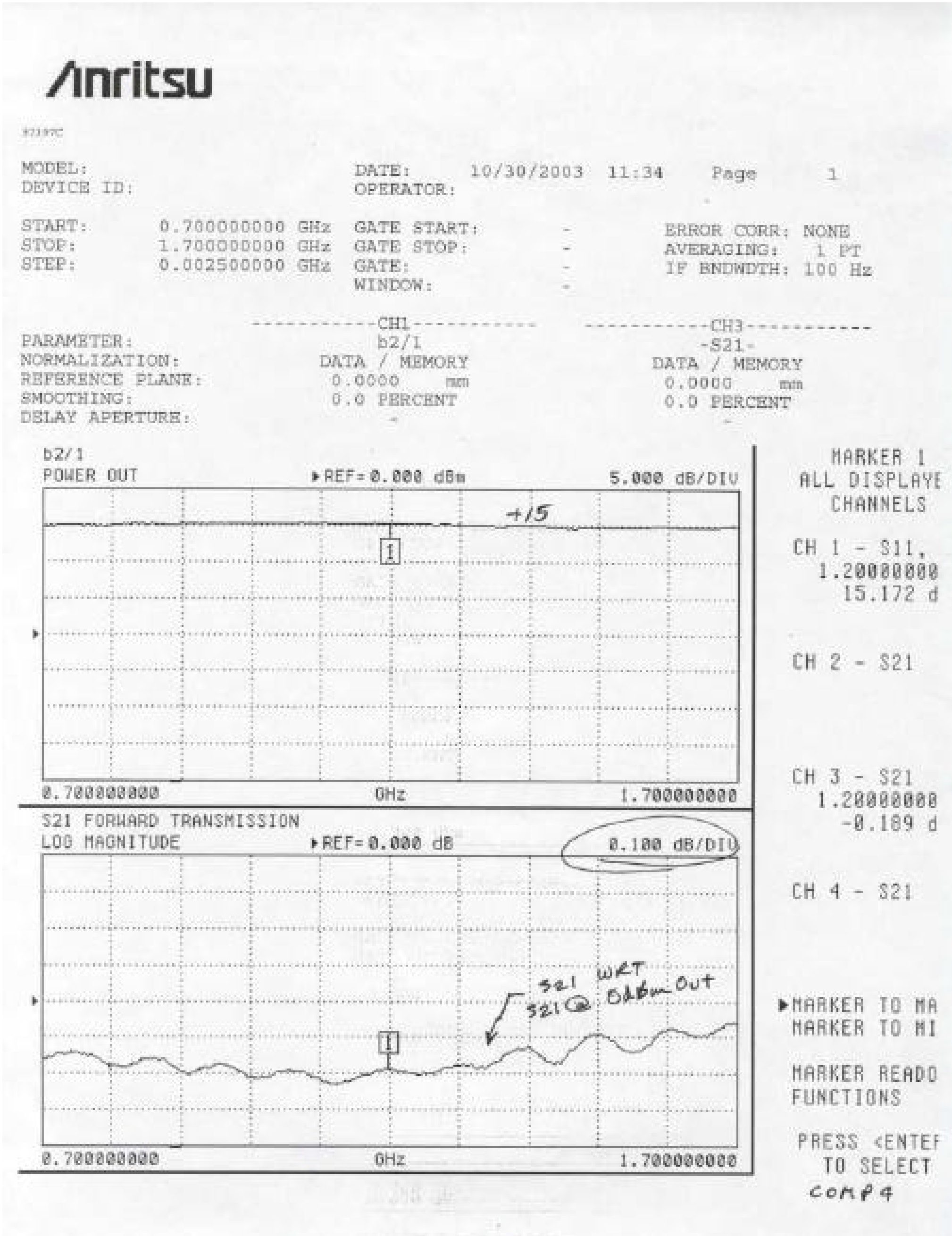

Figure 4. Note the gain scale change from figures 2 and 3. The gain at +15dBm output power has decreased by about 0.2dB at midband, compared to the gain at 0dBm output power. The 100MHz ripple amplitude approaches 0.1dB.

S-Parameter Measurements

A two-port calibration was accomplished on the VNA, and used to measure s-parameters of the module and its components over the 0.7-1.7 GHz frequency range. The VNA output power was set to –17dBm, the nominal level the module sees in the system.

Figure 5 shows the four s-parameters of the ZFL-2000 amplifier. Figure 6 shows, for various conditions, the gain from the module input connector (including the input 6dB pad), to one output of the ZFRSC-42 power divider, as well as the input return loss of the comparator module. The measurements show that reflections off the comparator input ports causes gain ripple.

The ZFRSC-42 power divider is a resistive divider, providing a good broadband match, but it provides essentially no isolation between the output ports. As a trial, we substituted a transformer type power divider which provides at least 18dB of isolation across the band. Figure 7 shows the reduced gain ripple that results. The ZESC-2-11 transformer type power divider does have poorer match at all ports than that of the ZFRSC-42 resistive divider, probably explaining most of the remaining ripple seen in Figure 7. Note also that the transformer type power divider has 3dB insertion loss, compared with 6dB for the resistive type.

These tests show that the module gain flatness could be improved by changing the type of power divider, and perhaps by using shorter interconnecting cables.

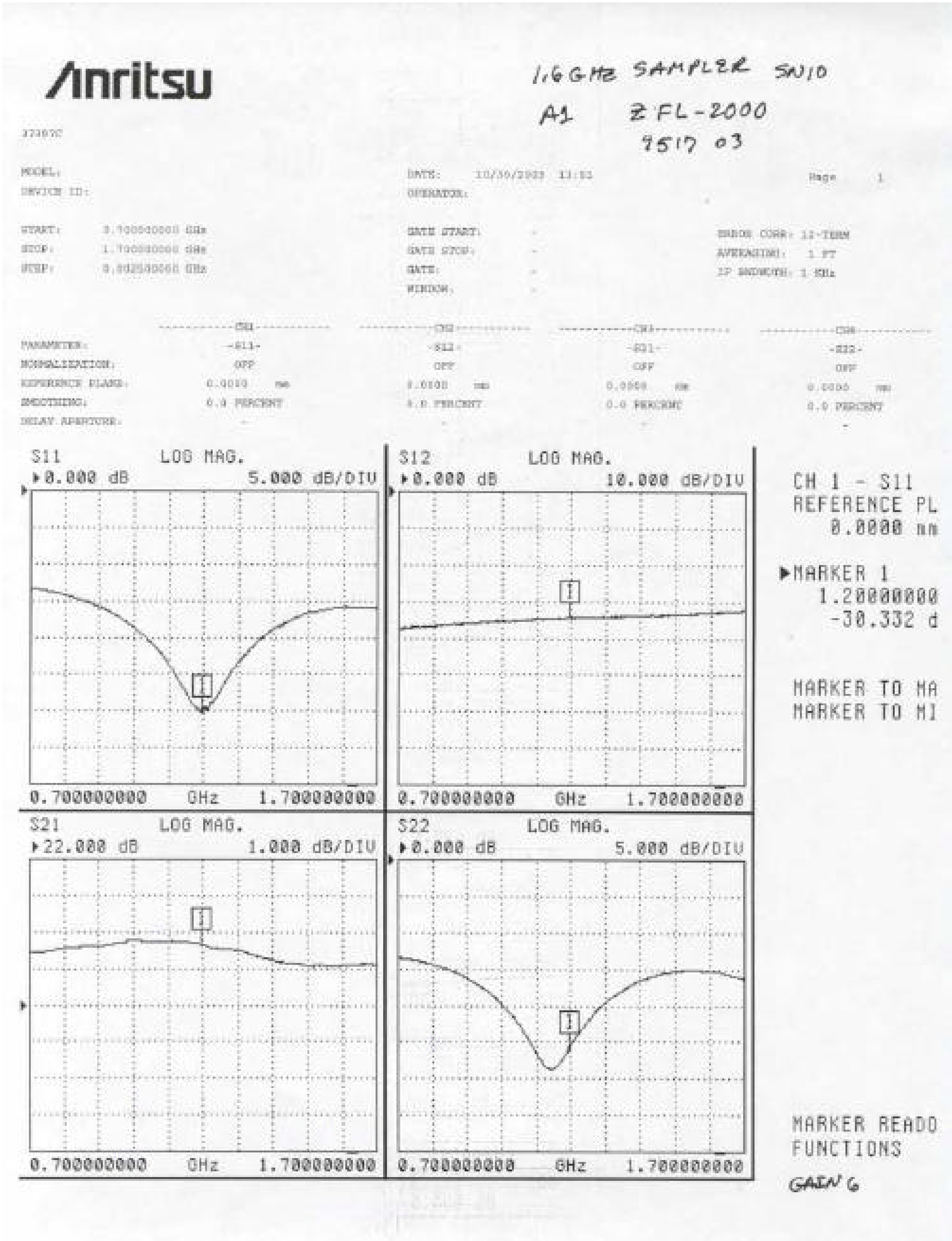

Figure 5. The four s-parameters of the ZFL-2000 amplifier.

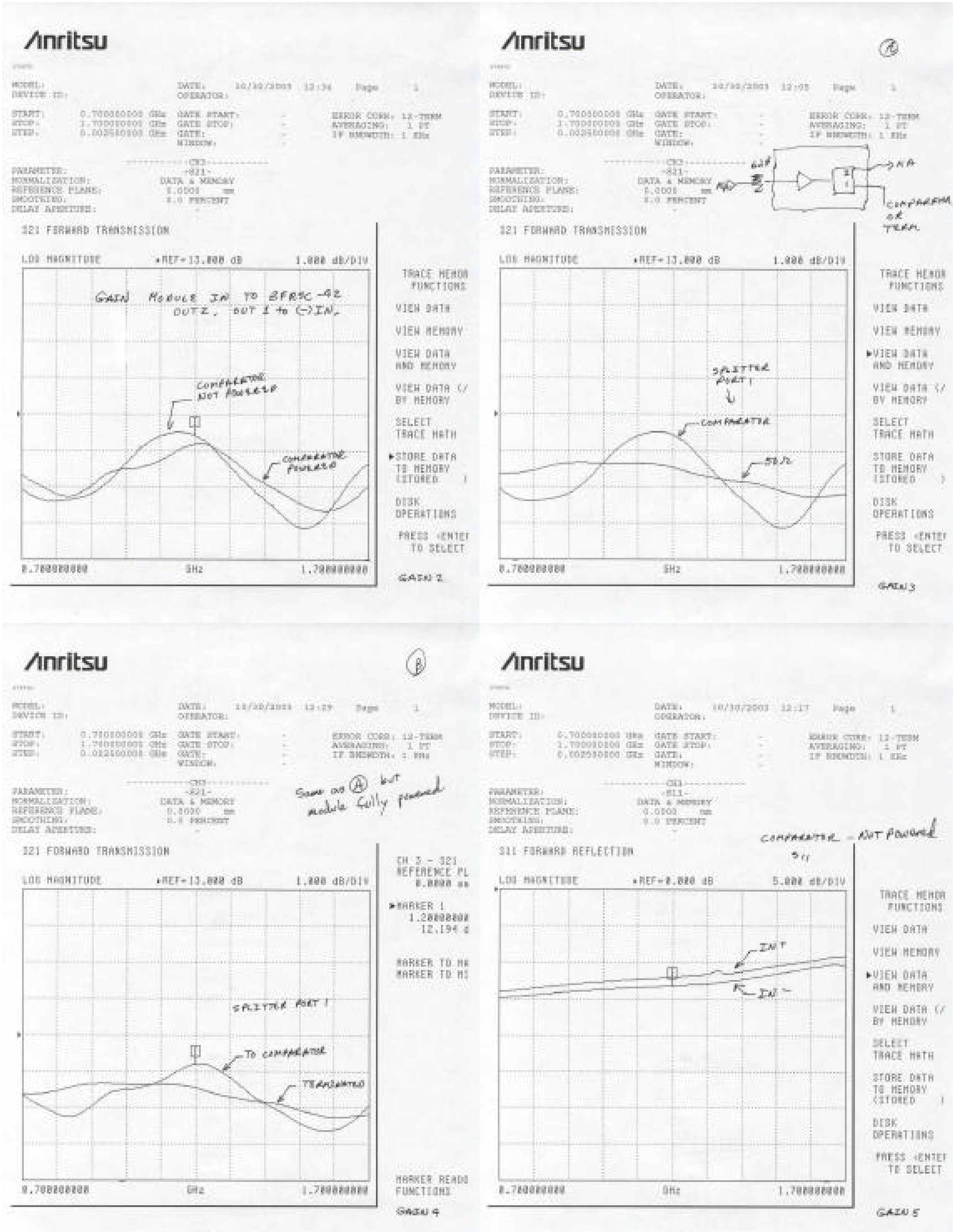

Figure 6. Upper left – Gain from module input to one power splitter output, with and without comparator power. Upper right – Comparing the measured gain with the second splitter output connected to the comparator module, and terminated. Lower left – Same but with comparator powered. Lower right – Comparator input return loss, not powered.

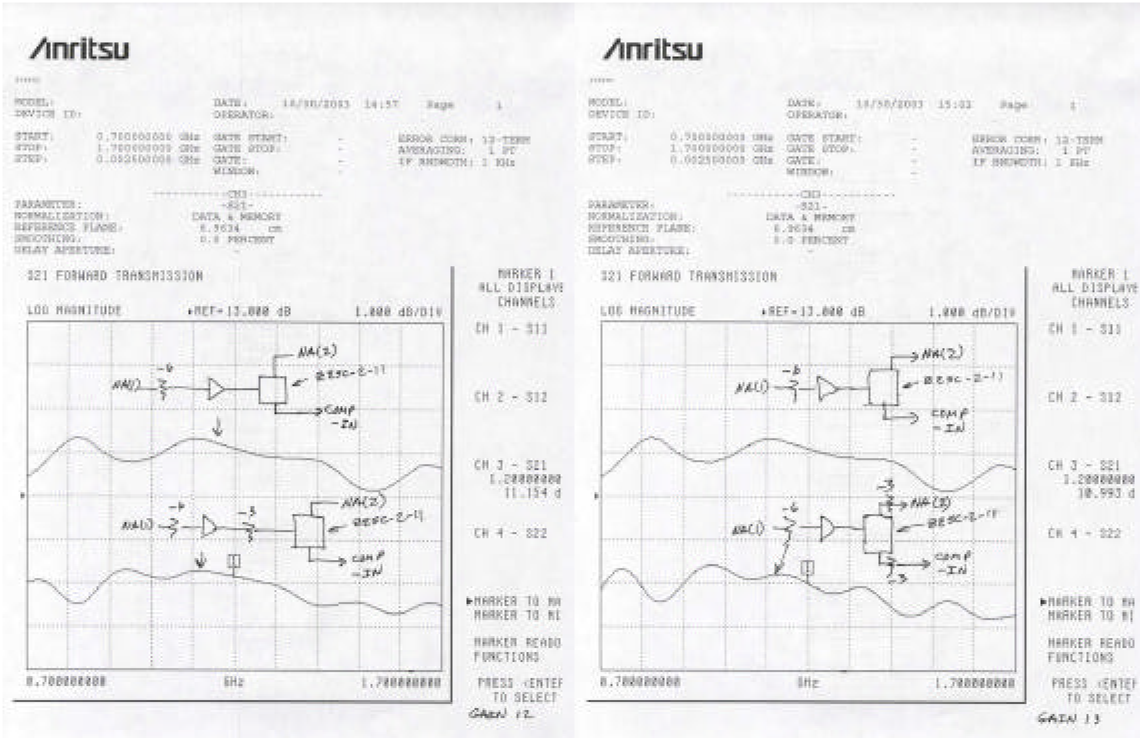

Figure 7. Module gain after changing the type of power splitter used, and for three arrangements using 3dB pads. The ZESC-2-11 splitter is a transformer based power divider, rather than the resistive type ZFRSC-42. The ZESC provides more than 18dB of isolation between the two outputs, while the resistive type has essentially no isolation.

Spectrum Measurements

For this part of the testing, a filtered and amplified noise source provided by R. Lacasse was input to the module, and the HP 8566B spectrum analyzer used to examine the spectral content at several places in the module.

Figure 8 shows the results with the lab noise source connected directly to the analyzer input port. Figure 9 shows the results with the noise source connected to the sampler module input, measuring at the output of the ZFL-2000 amplifier. Note the increase in noise near DC, and toward 2.4 GHz. For Figure 10, the analyzer was connected to one output of the power divider; the other output was connected to a comparator input. Note the bumps in the noise in the DC-800 and 1600-2400 MHz ranges, and the 1.6 GHz clock seen in the trace. Figure 11 shows what happens when the second power divider output is terminated rather than connected to the comparator input. It is fairly clear that measurable noise is flowing out of the comparator input port, and since the ZFRSC-42 has no isolation, it can be seen on the spectrum analyzer. Figure 12 shows what happens when the input noise total power is changed by 3dB. Figure 13 shows the result when the resistive power divider is replaced by the transformer based divider. Note the comparator noise signals are reduced at the measured divider output, due to the divider isolation, but they no doubt still exist within the comparator module.

The sampler will of course fold the DC-800 MHz and the 1600-2400 MHz spectra on top of the desired 800-1600 band. These measurements show that there are apparently two measurable sources of noise within the sampler module. The amplifier exhibits increased noise near DC and to a lesser extent near 2400 MHz. And, there appears to be structured (bumpy) noise in the alias bands which arises within the 1600 MHz comparator module.

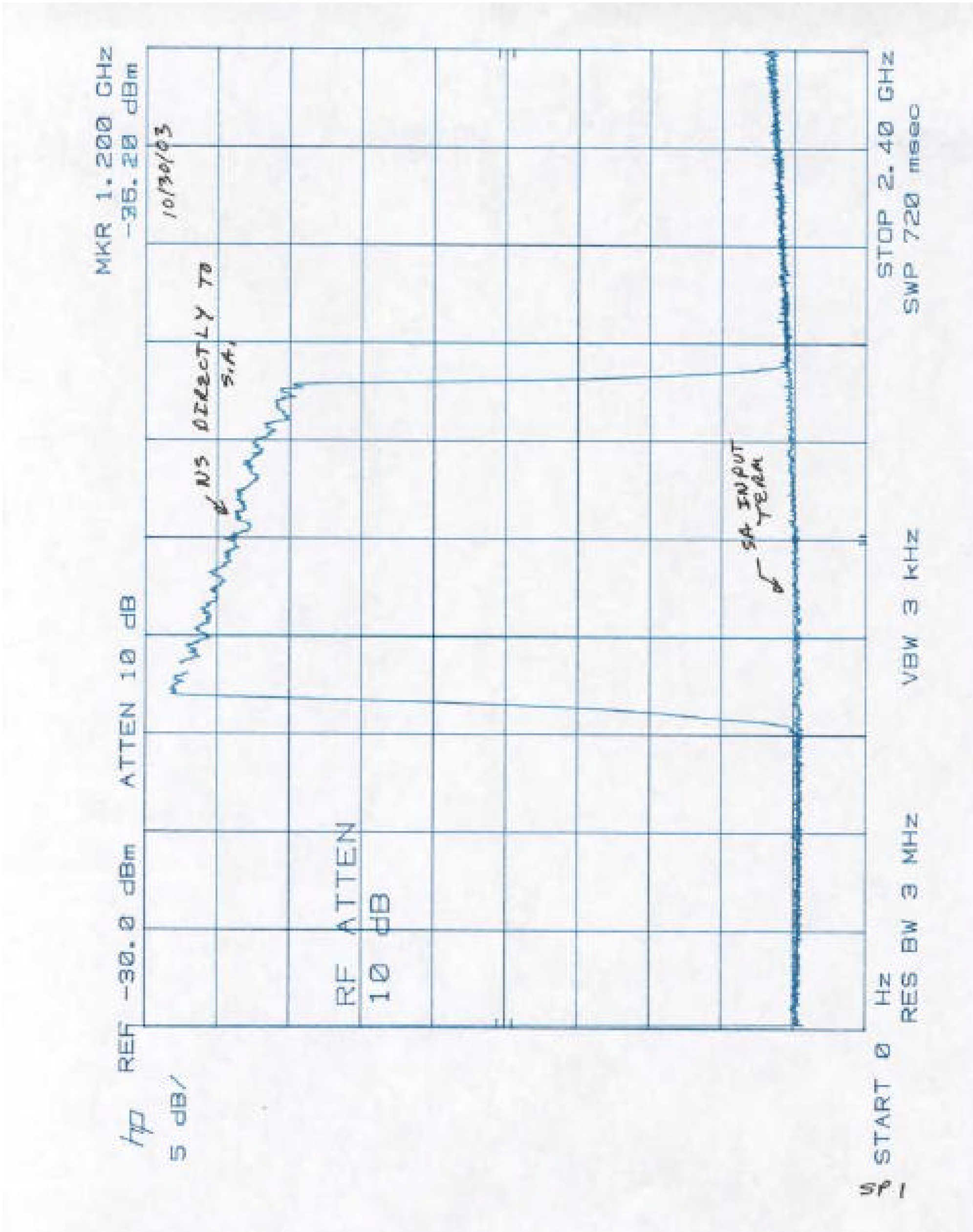

Figure 8. Two overlaid spectrum analyzer traces, comparing the analyzer noise floor with input terminated, to the laboratory noise source spectrum. Vertical scale of 5dB/ is used for this and all remaining plots.

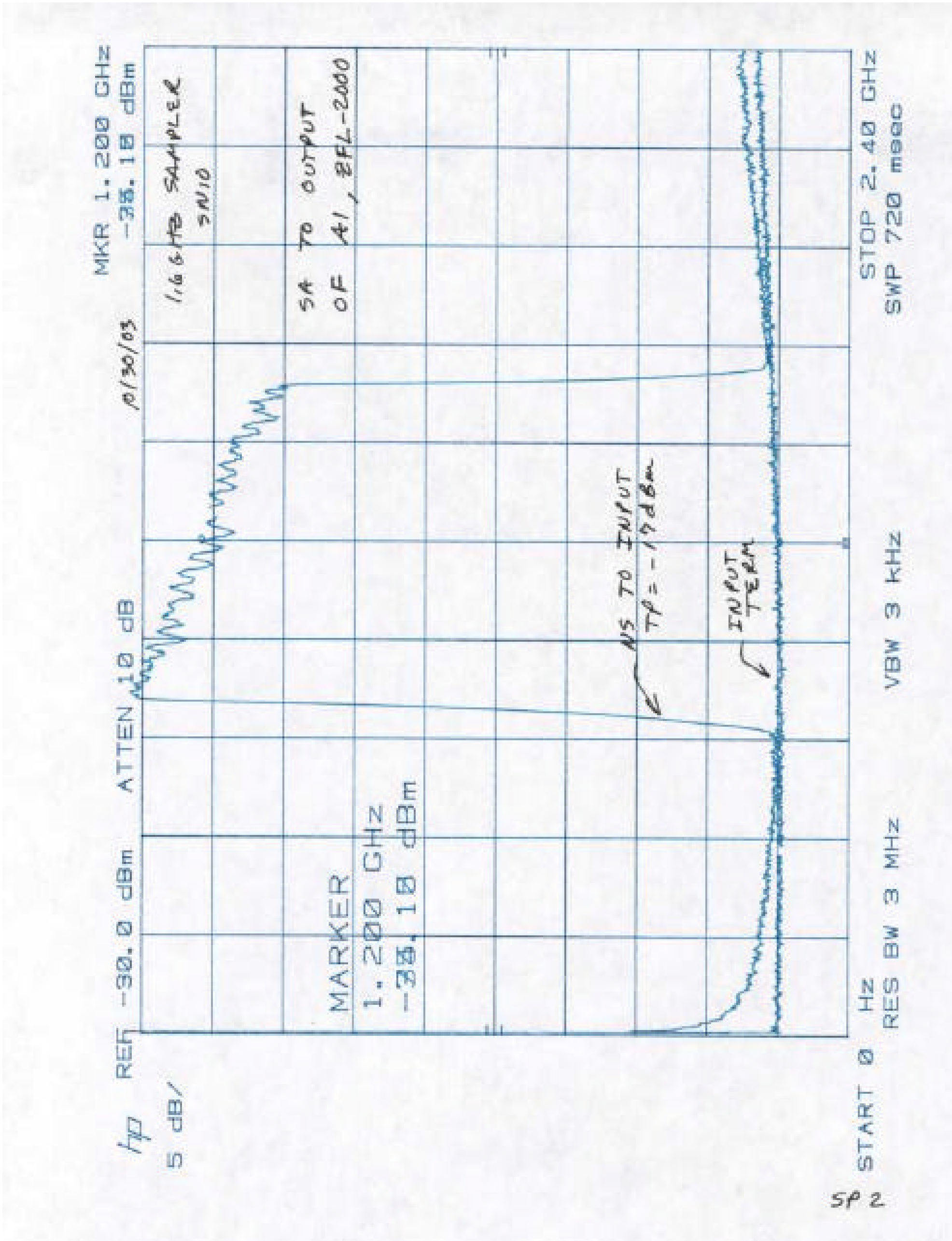

Figure 9. The ZFL-2000 output is connected to the spectrum analyzer. The module input connector is terminated for the lower trace, and connected to the lab noise source for the upper trace. Note the noise floor increase in the DC-800 MHz and 1.6-2.4 GHz ranges.

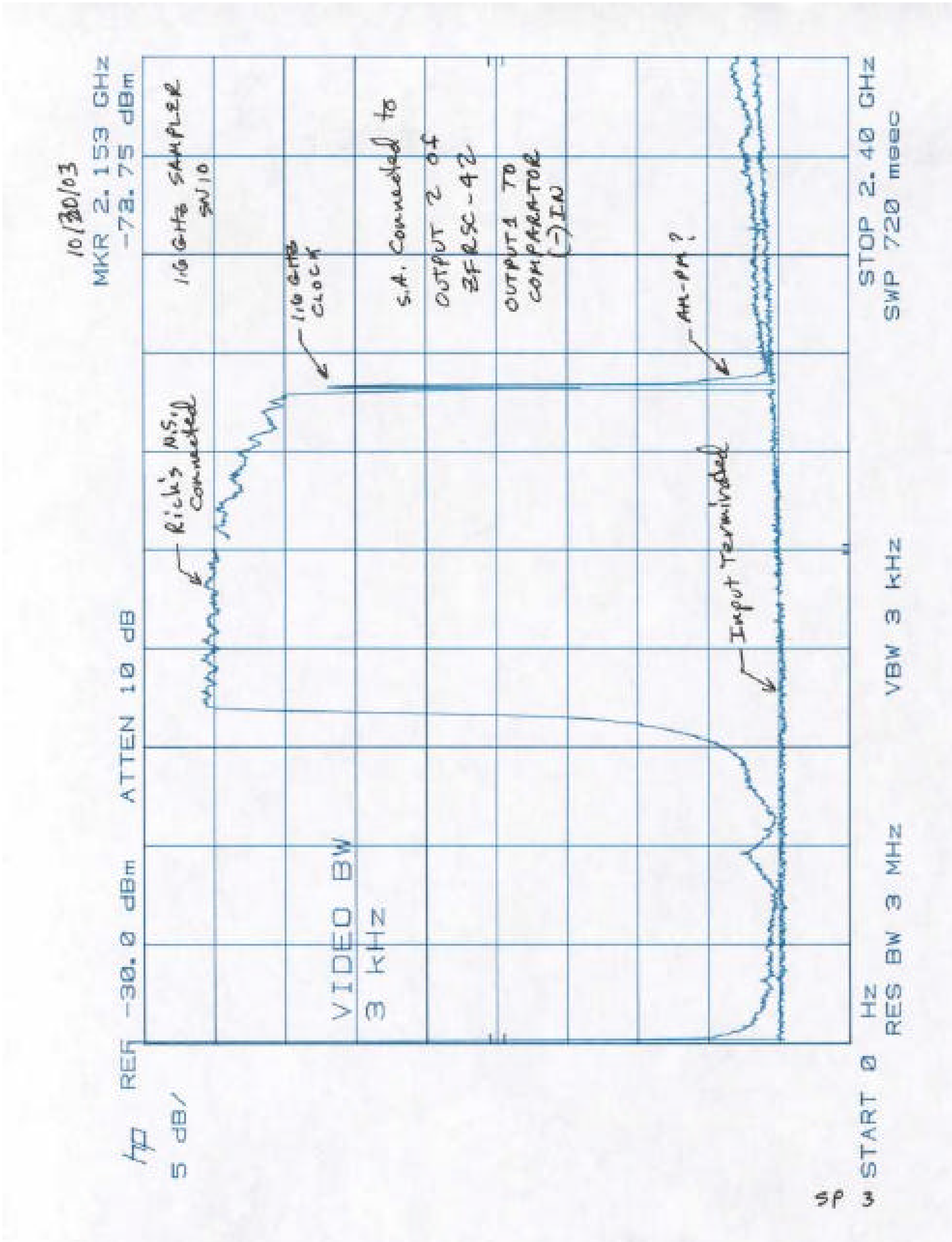

Figure 10. The spectrum analyzer input connected to one power splitter output, with the other connected to one comparator input.

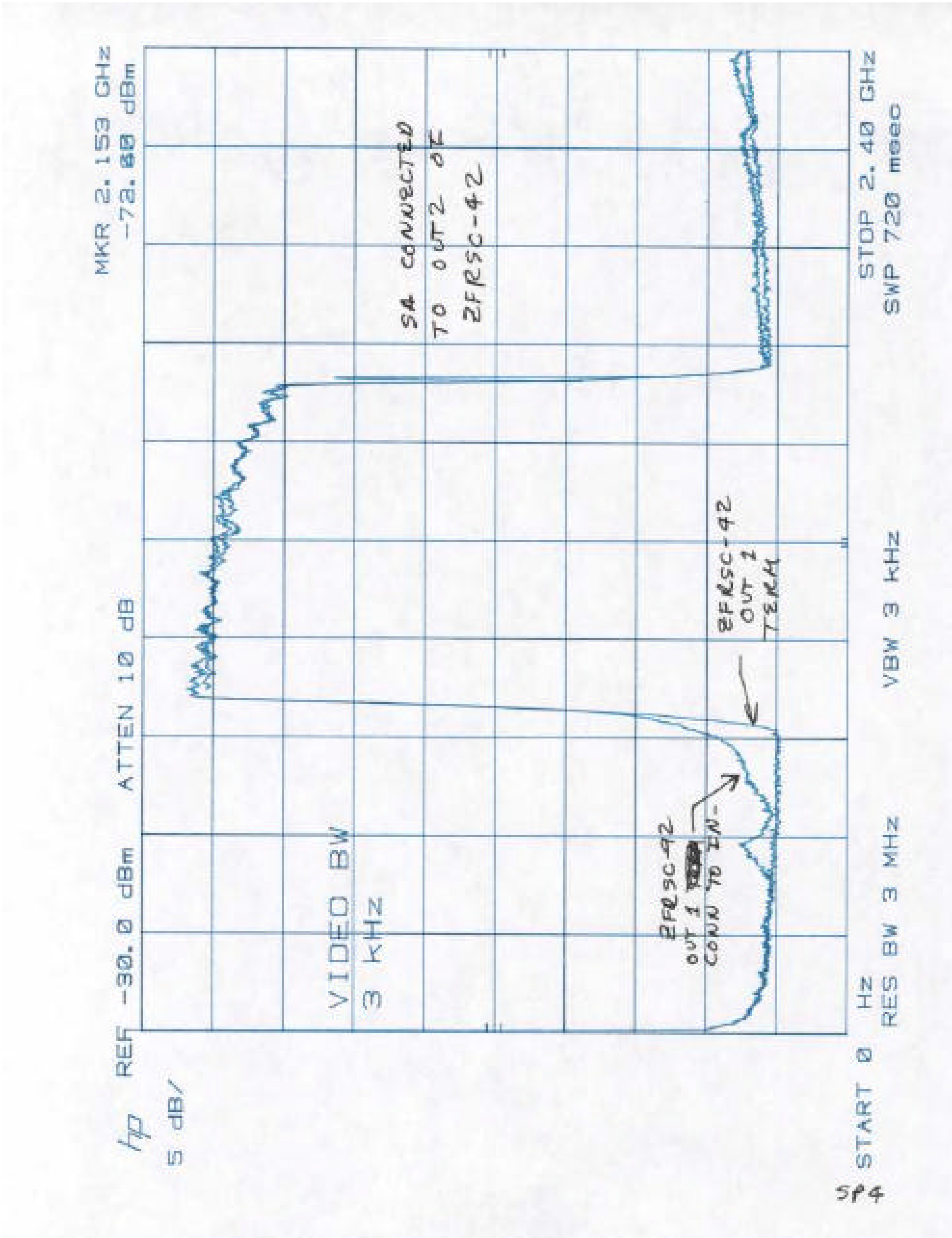

Figure 11. Comparing results with the power divider output connected to a comparator input, and terminated.

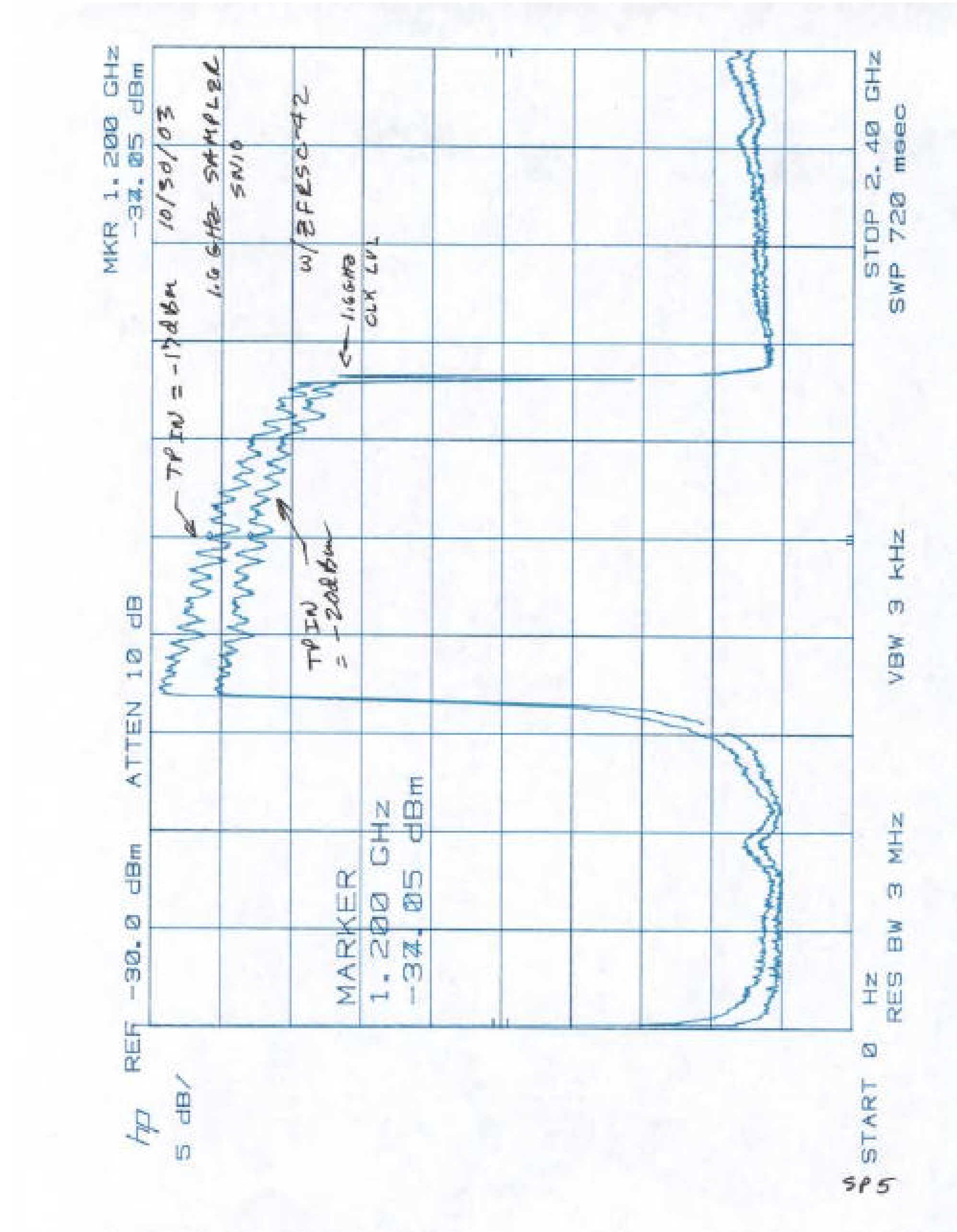

Figure 12. Showing the effects of a 3dB change in total input noise power.

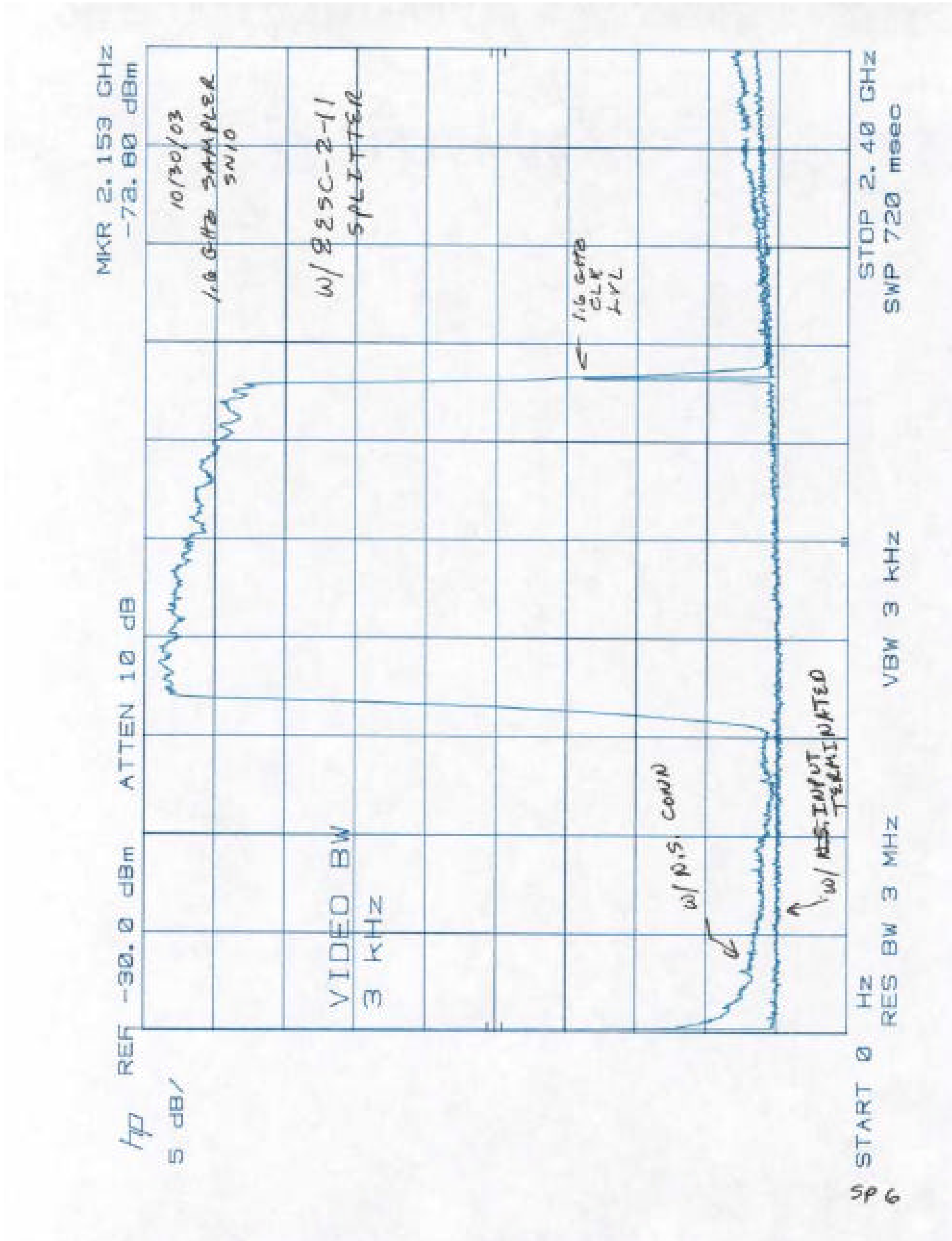

Figure 13. Measurement results substituting a transformer based power divider for the normal resistive divider.