Preamplifiers for Callisto

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1. Introduction

We investigated the general performance, including noise figure and gain, of three amplifiers for Callisto applications. S-parameters also were measured on two of the amplifiers. The two amplifiers of special importance because of their low noise characteristics are the Mini-Circuits ZX60-33LN-S+ and an unbranded unit obtained from China through eBay from seller “kitmanlaw2008”. We call the Chinese amplifier CxLNA (figure 1). Both amplifiers are advertised as low noise amplifiers with approximately 1.0 dB noise figure and 20 dB gain.

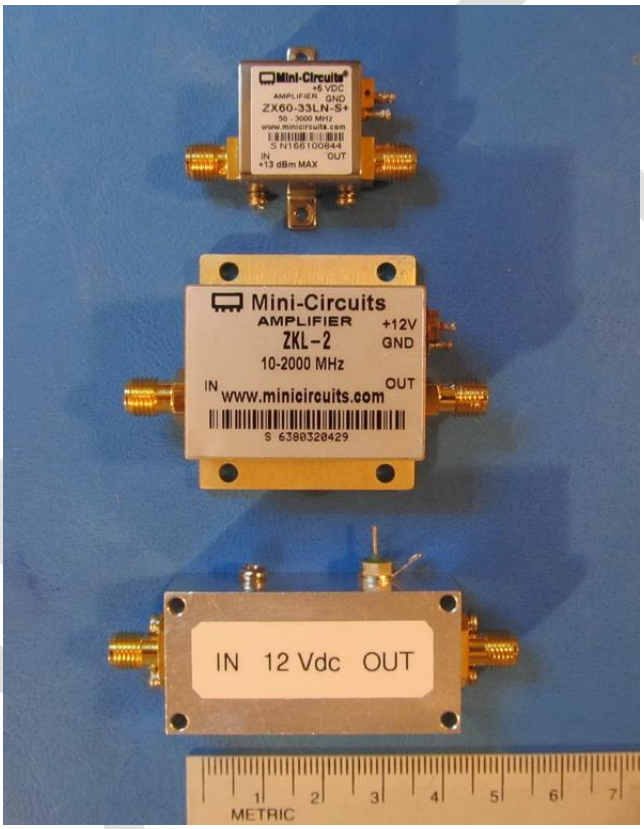


Figure 1 ~ Amplifiers, from top: ZX60-33LN-S+, ZKL-2, and CxLNA

Our measurements show that the performance of these two amplifiers in our labs is very similar. The CxLNA has advantages of cost and an internal voltage regulator that allows it to be used with the same 12 Vdc power supply as the Callisto (the ZX60 has a maximum input voltage of 5.5 Vdc). The CxLNA amplifier also has slightly higher gain than the ZX60 at frequencies below 100 MHz.

We also performed comparative measurements (but not s-parameters) on the Mini-Circuits ZKL-2. This amplifier has much higher gain of 31 dB but a higher noise figure of 4 dB. This amplifier was evaluated for use as an intermediate amplifier where long coaxial cable runs are used between a remote low noise preamplifier, such as the ZX60 or CxLNA, and the Callisto.

The basic data for the three amplifiers are summarized (table 1). Each set of measurements is described in separate sections below followed by a description of the measurement methods. All measurements involving a Callisto were made at Anchorage, Alaska using Callisto s/n NA008.

Table 1 ~ Amplifier basic specifications

Model	Manufacturer	Frequency (MHz)	Gain (dB)	Noise figure (dB)	Voltage (V)	Cost (US$)	Notes
ZX60-33LN-S+	Mini-Circuits	50 to 3000	19	1.1	3.3 to 5.0	80	
CxLNA	Unknown	20 to 1000	20	0.6	8 to 14	61	Note 1
ZKL-2	Mini-Circuits	10 to 2000	33	4	9 to 12	150	

Table notes:
1. The manufacturer and model number of this amplifier is unknown, so it was given the designation CxLNA; LNA1 in the test results indicates one of several amplifiers.

2. Noise Figure

The noise figures were measured at 200 individual frequencies spaced evenly in the Callisto frequency band (figure 2). These measurements agreed quite well with the datasheet values.

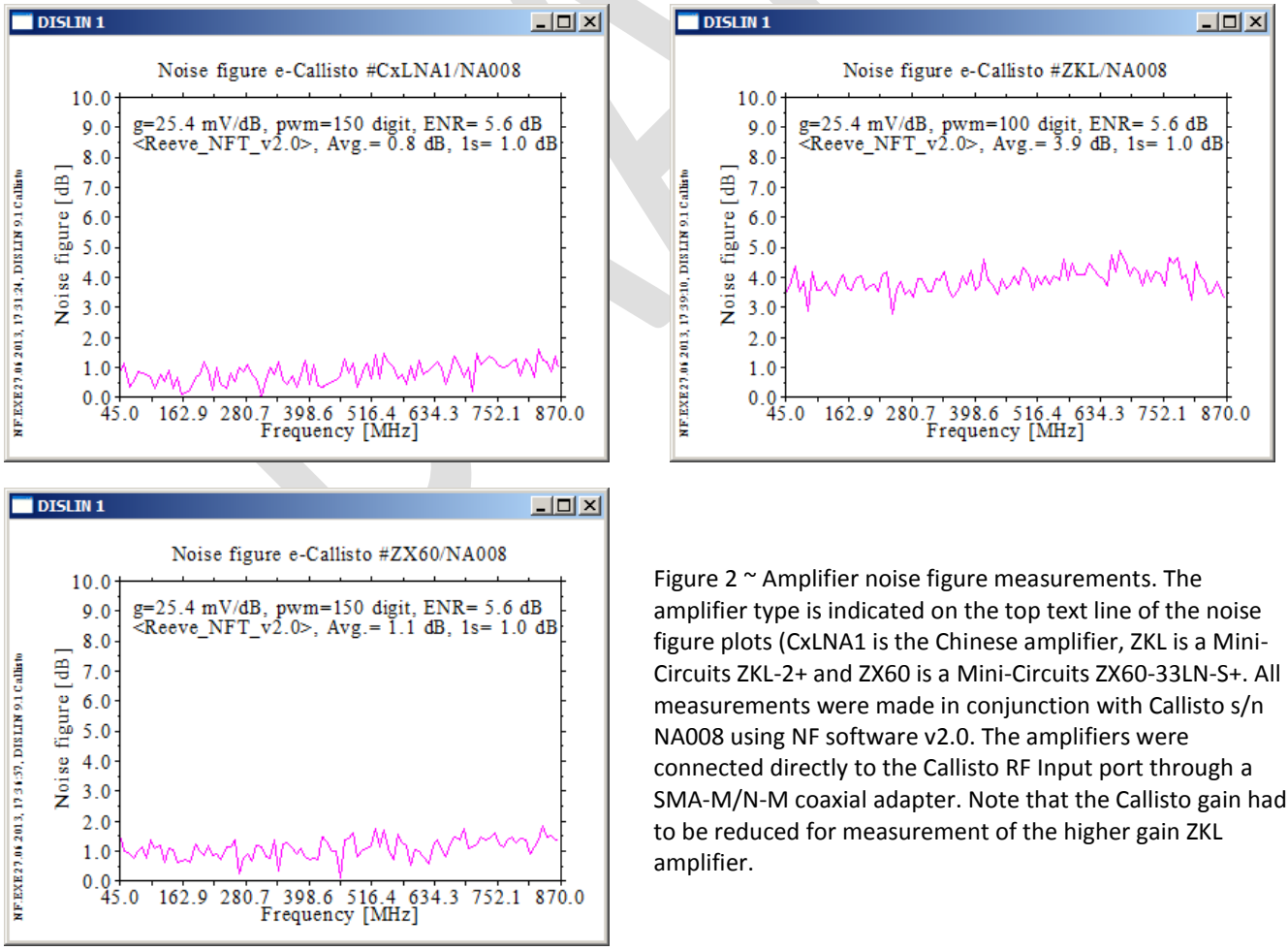
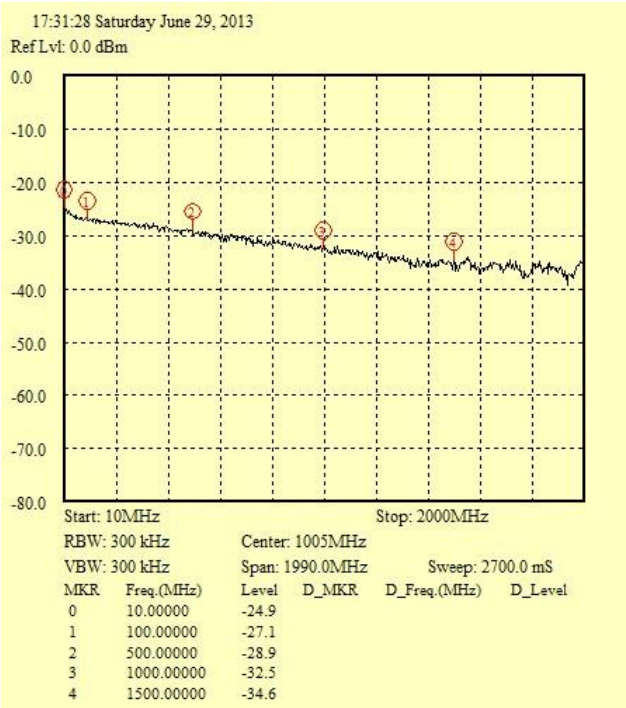
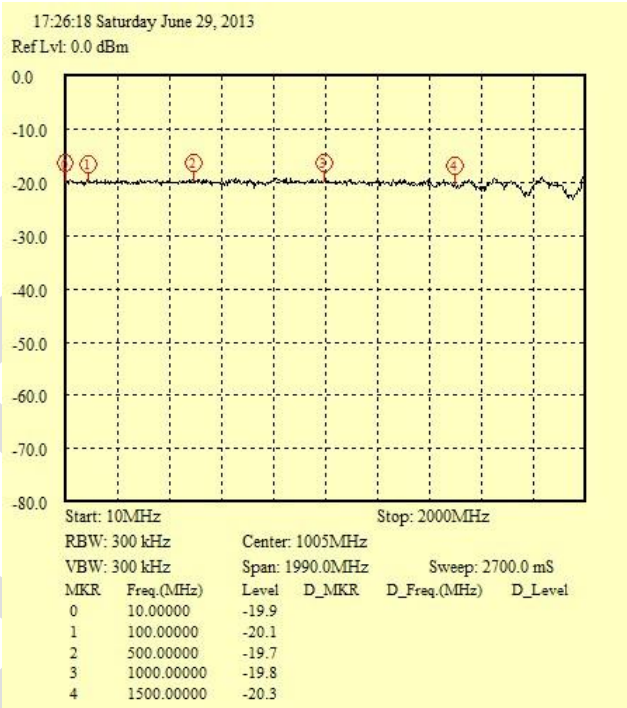


Figure 2 ~ Amplifier noise figure measurements. The amplifier type is indicated on the top text line of the noise figure plots (CxLNA1 is the Chinese amplifier, ZKL is a Mini-Circuits ZKL-2+ and ZX60 is a Mini-Circuits ZX60-33LN-S+. All measurements were made in conjunction with Callisto s/n NA008 using NF software v2.0. The amplifiers were connected directly to the Callisto RF Input port through a SMA-M/N-M coaxial adapter. Note that the Callisto gain had to be reduced for measurement of the higher gain ZKL amplifier.

3. Gain

The power gain of the three amplifiers varies a little with frequency; for the ZX60 and CxLNA, gain decreases with increasing frequency (figure 3).





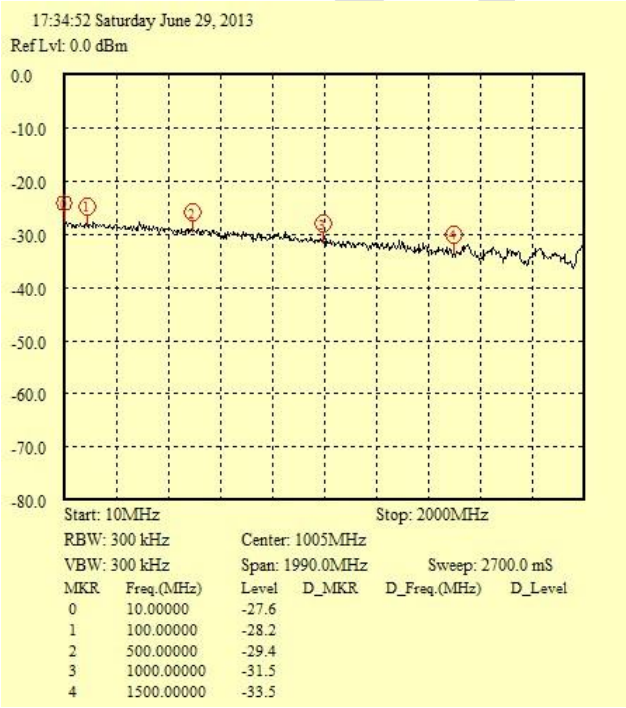


Figure 3 ~ Amplifier gain over the frequency range 10 to 2000 MHz. CxLNA1: Upper-left; ZKL: Upper-right; ZX60: Lower-left.

The tracking generator output level for all measurements was -30 dBm. 10 dB attenuators were placed on the amplifier input and output for isolation. Therefore, gain = Indicated level + 50 dB. Some of the loss indicated on the plots for higher frequencies is due to the connecting cables and connectors.

4. Overload compression

The frequency response of the amplifiers was measured at high input powers to determine the point at which the output becomes compressed due to overload (figure 4). For the ZX60 and CxLNA, the 1 dB compression point is about –2 dBm and for the ZKL is about –12 dbm. Both values are much higher than the expected levels for the Callisto applications as a solar radio spectrometer.

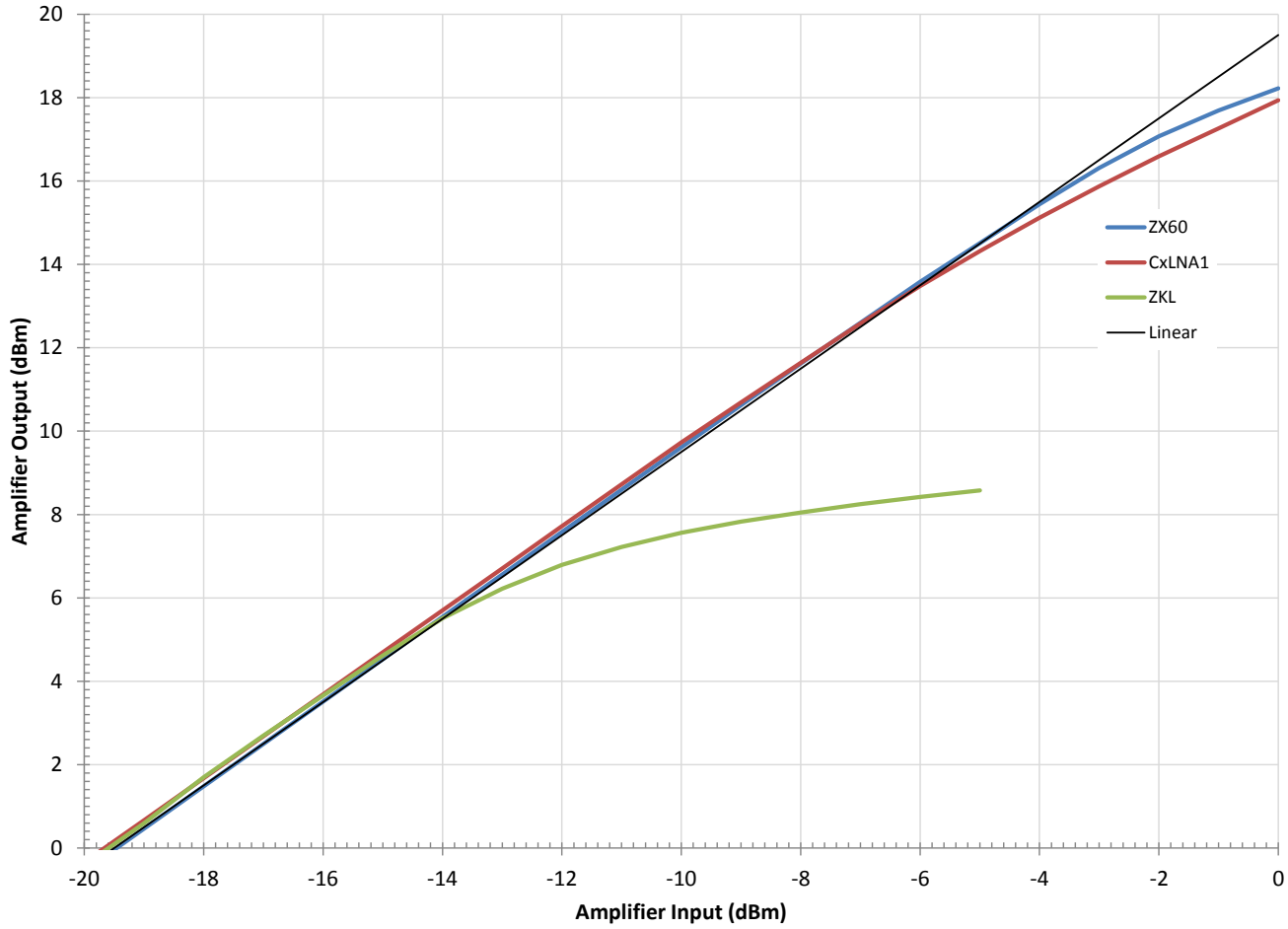


Figure 4 ~ Overload compression for the three amplifiers. A usual measure is the 1 dB compression point, where the linearity of the amplifier changes by 1 dB. The ZX60 and CxLNA have nearly identical performance at high input powers, with the compression point approximately –3 dBm. The higher gain ZKL amplifier has a much lower compression point at approximately –12 dBm.

5. General spectral performance

Several measurements were made to evaluate general performance with live signals received on a collapsible whip antenna. The main purpose of the tests was to find evidence of amplifier overload in a high RFI environment.

The spectrum plots (figure 5) show relative power (Y) as a function of frequency (F). Frequency resolution for these plots is 62.5 kHz. All spectrum plots were taken at Anchorage, Alaska. Very strong signals are apparent in the FM broadcast band (88 to 108 MHz), VHF air navigation and communications band (108 to 137 MHz), TV

broadcast bands (54 to 88, 174 to 216 and 470 to 692 MHz) and mobile radio services above (864 MHz and above).

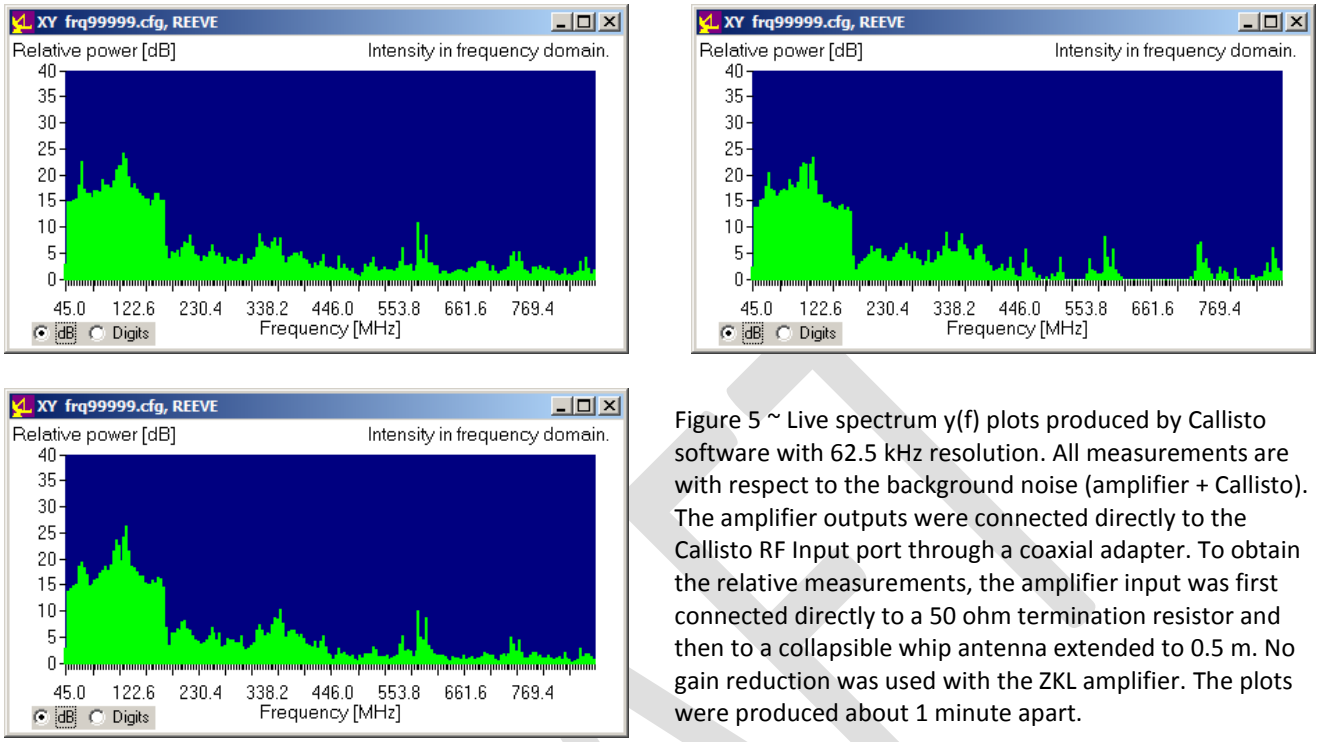


Figure 5 ~ Live spectrum y(f) plots produced by Callisto software with 62.5 kHz resolution. All measurements are with respect to the background noise (amplifier + Callisto). The amplifier outputs were connected directly to the Callisto RF Input port through a coaxial adapter. To obtain the relative measurements, the amplifier input was first connected directly to a 50 ohm termination resistor and then to a collapsible whip antenna extended to 0.5 m. No gain reduction was used with the ZKL amplifier. The plots were produced about 1 minute apart.

The live measurements with the whip antenna also were recorded to a flexible image transport system (FITS) file and then plotted. The FITS file contains one data element for each measurement of the received power (color, Y) as a function of frequency (F) and time (T) (figure 6). The power level has 8-bit resolution. The application used to view the file (RAPP Viewer) allows the pixel associated with these three parameters to be read at the PC mouse position.

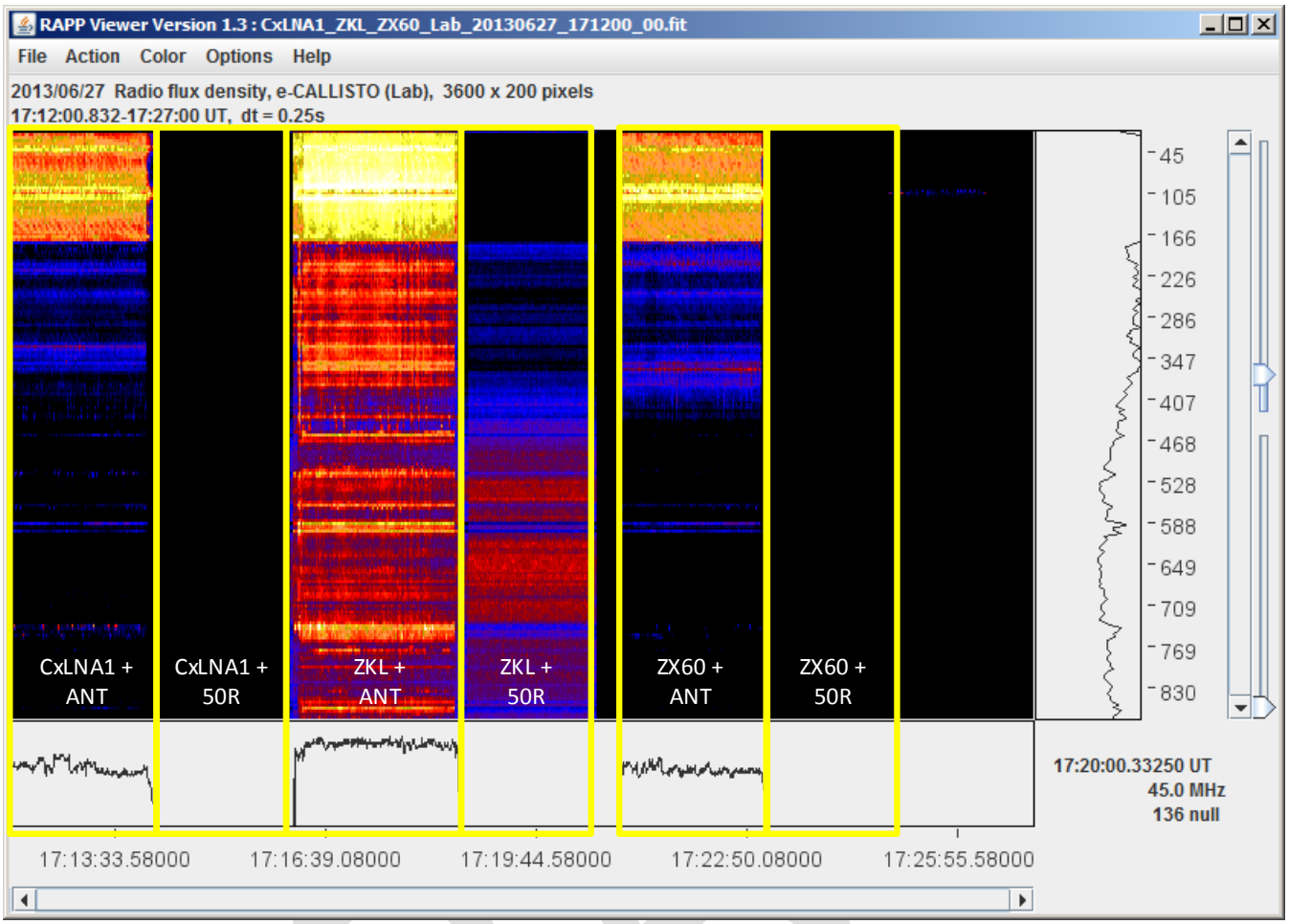


Figure 6 ~ Presentation of the FITS test file using the RAPP Viewer application. The RFI received with the whip antenna in the various frequency bands previously mentioned is readily apparent. Of particular interest are the CxLNA1 at the beginning of the record and the ZX60 at the end. The ZKL is included in between for comparison. The gain was set to one value (150) and not reduced for the ZKL amplifier. For these measurements each amplifier was first connected to the whip antenna for 2 minutes and then to a 50 ohm termination for 1.5 minutes. Pixel comparisons for the CxLNA1 and ZX60 revealed that for a given frequency, the received power level agreed within ±1 digit out of 256 (8 bits).

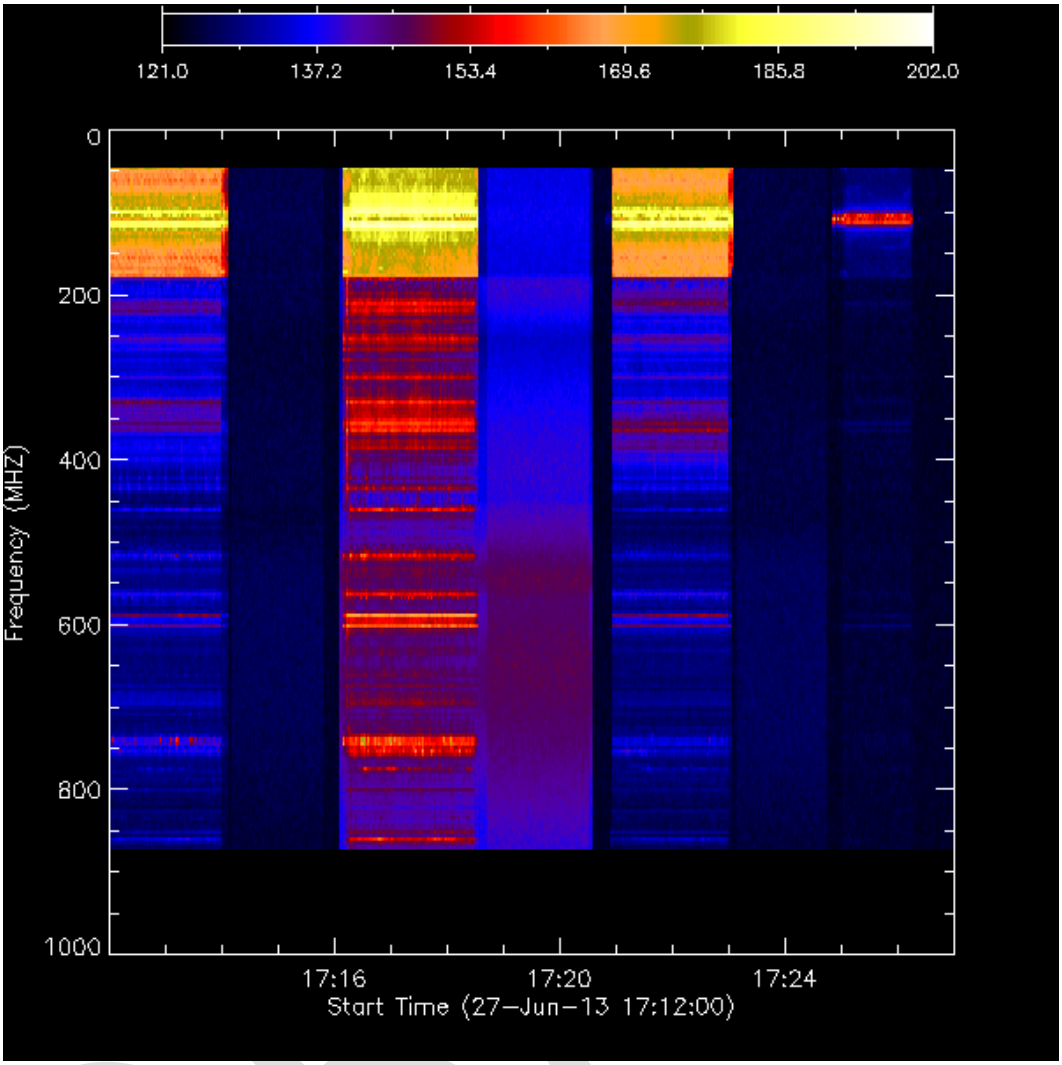


Figure 6a ~ Presentation of the FITS test file using the IDL Solar Soft application.

6. Additional detailed Spectrum Measurements

The 0.5 m whip antenna was again used to measure the power of 200 channels evenly distributed within the Callisto frequency range. The results are plotted for the CxLNA1 and ZX60 amplifiers (figure 7) and ZKL amplifier (figure 8). These plots also show the spectrum response for the Callisto alone.

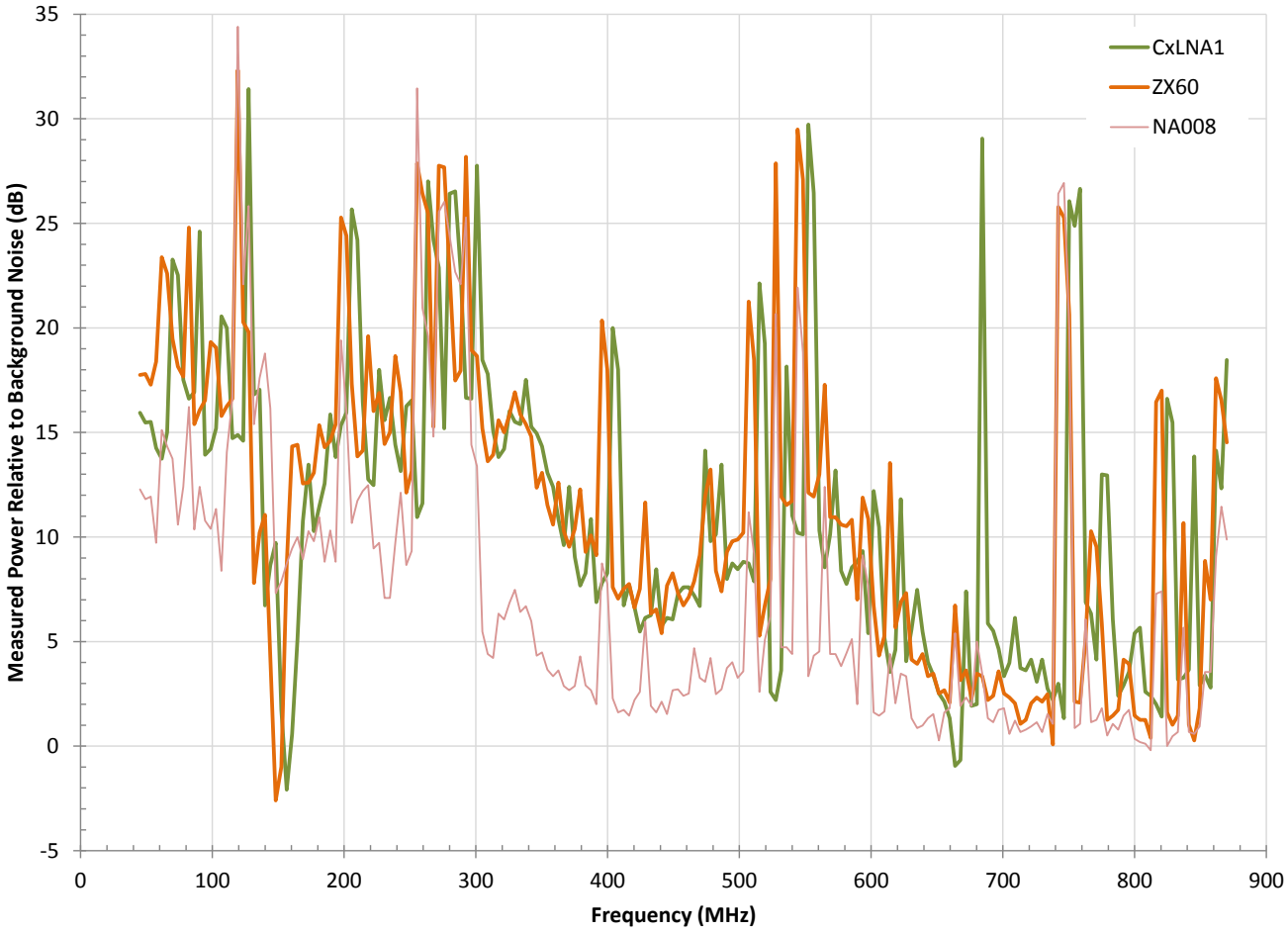


Figure 7 ~ Live spectrum for the CxLNA1 and ZX60 amplifiers and receiver compared to the receiver alone. The Callisto was setup to record the power for 200 channels evenly distributed in the 45 to 870 MHz frequency band. Overload is indicated around 150 MHz.

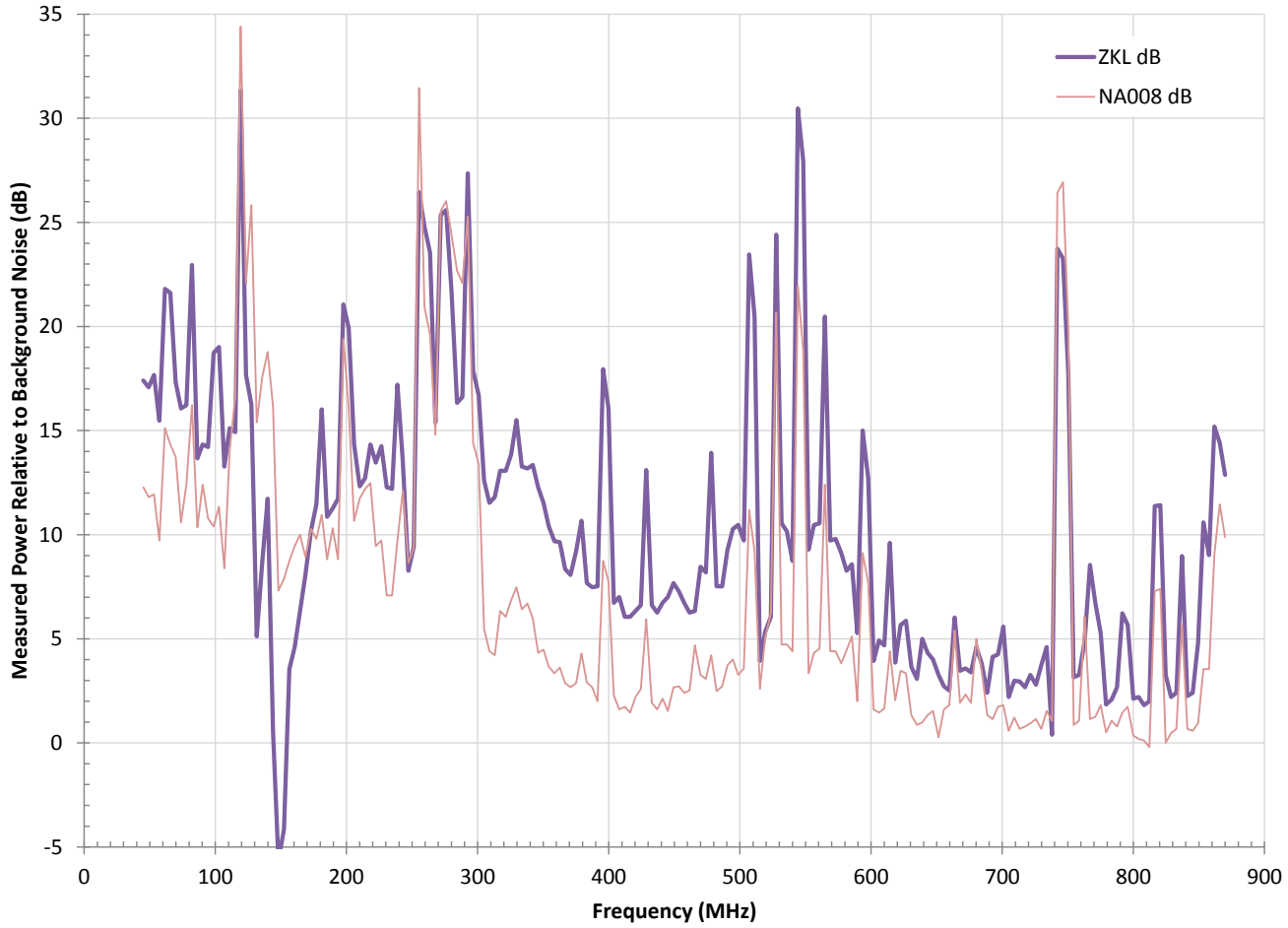
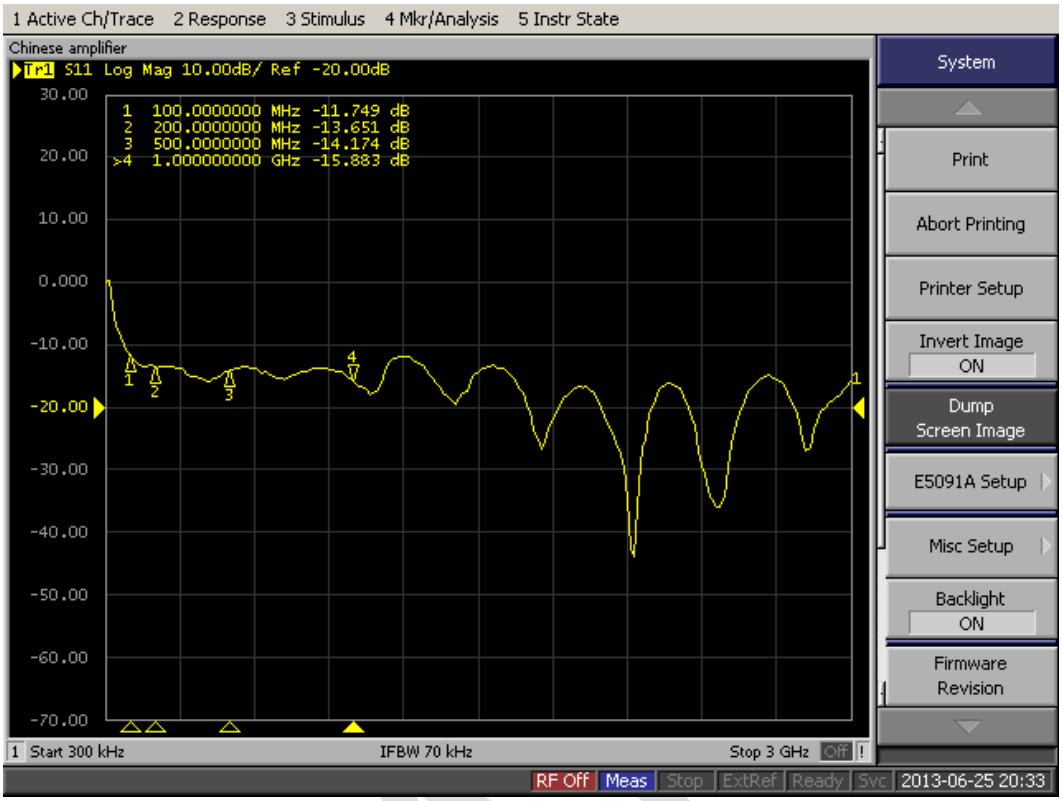
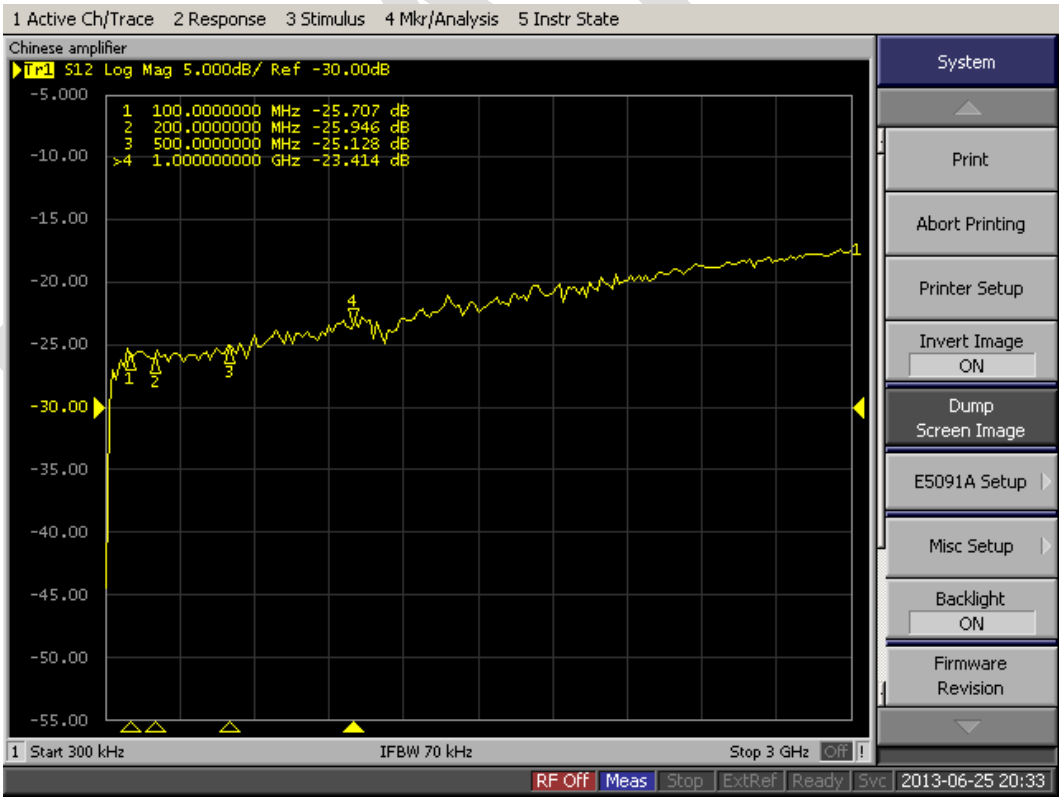


Figure 8 ~ Spectrum for the ZKL amplifier and receiver compared to the receiver alone. The Callisto was setup to record the power for 200 channels evenly distributed in the 45 to 870 MHz frequency band. Overload is indicated around 150 MHz.

7. S-parameter measurements

The s-parameters measurements were taken at Zurich, Switzerland over a frequency range of 300 kHz to 3 GHz for the CxLNA (figure 9) and ZX60 (figure 10). The s21 measurements are equivalent to forward gain measurements and agree with the gain measurements previously discussed. The s11 and s22 measurements indicate how well the input and output are matched to 50 ohm impedance, and the s22 measurement indicates the amount of signal applied to the amplifier output that is coupled back through to the input.


1 Active Ch/Trace 2 Response 3 Stimulus 4 Mkr/Analysis 5 Instr State
Chinese amplifier
Tr1 S11 Log Mag 10.00dB/ Ref -20.00dB
1 100.0000000 MHz -11.749 dB
2 200.0000000 MHz -13.651 dB
3 500.0000000 MHz -14.174 dB
>4 1.000000000 GHz -15.883 dB
30.00
20.00
10.00
0.000
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
1 Start 300 kHz
IFBW 70 kHz
Stop 3 GHz
Off
RF Off
Meas
Stop
ExtRef
Ready
Svc
2013-06-25 20:33
System
Print
Abort Printing
Printer Setup
Invert Image
ON
Dump Screen Image
E5091A Setup
Misc Setup
Backlight
ON
Firmware Revision


1 Active Ch/Trace 2 Response 3 Stimulus 4 Mkr/Analysis 5 Instr State
Chinese amplifier
Tr1 S12 Log Mag 5.000dB/ Ref -30.00dB
1 100.0000000 MHz -25.707 dB
2 200.0000000 MHz -25.946 dB
3 500.0000000 MHz -25.128 dB
>4 1.000000000 GHz -23.414 dB
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
1 Start 300 kHz
IFBW 70 kHz
Stop 3 GHz
Off
RF Off
Meas
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ExtRef
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Svc
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System
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Firmware Revision

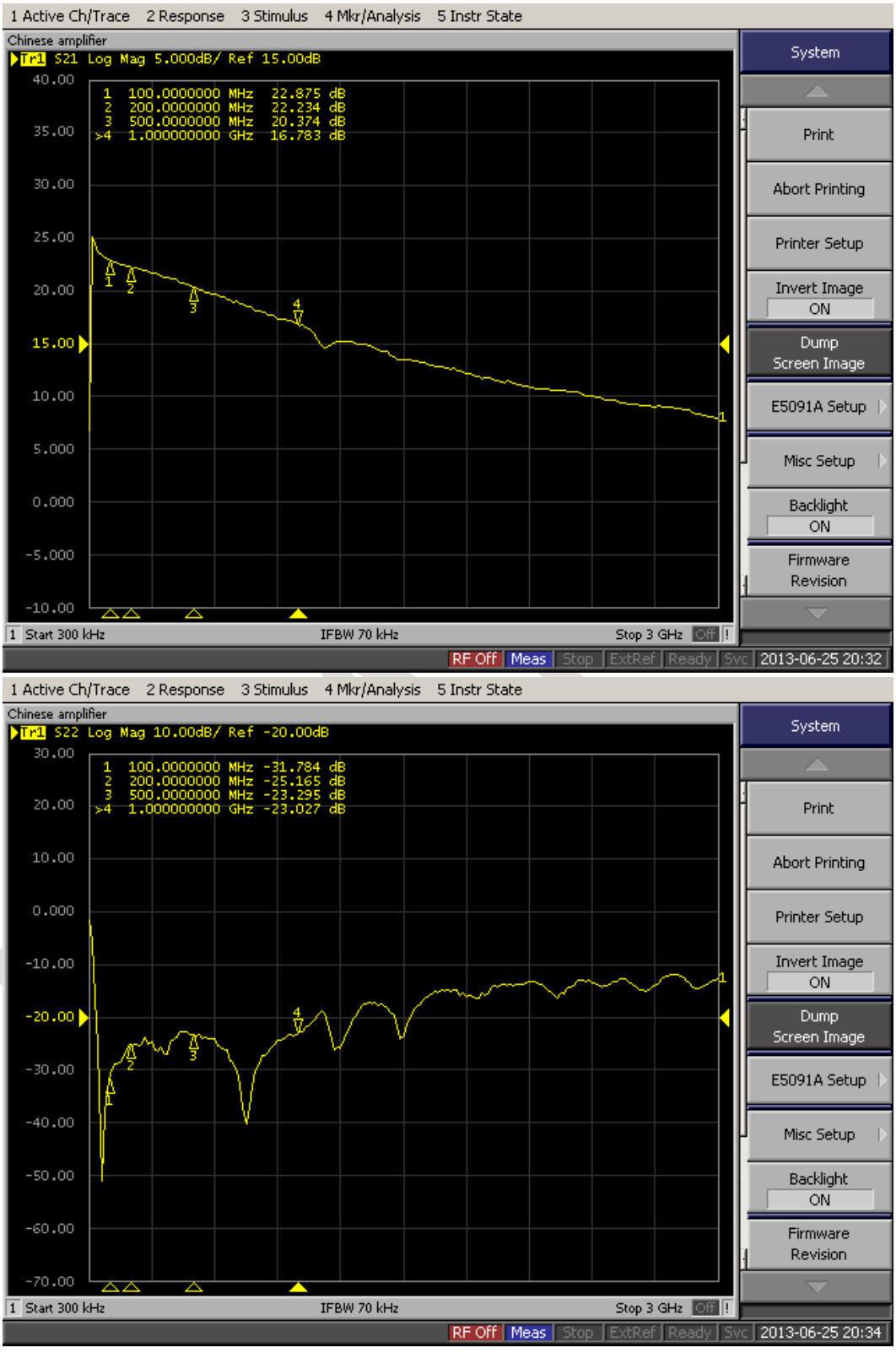
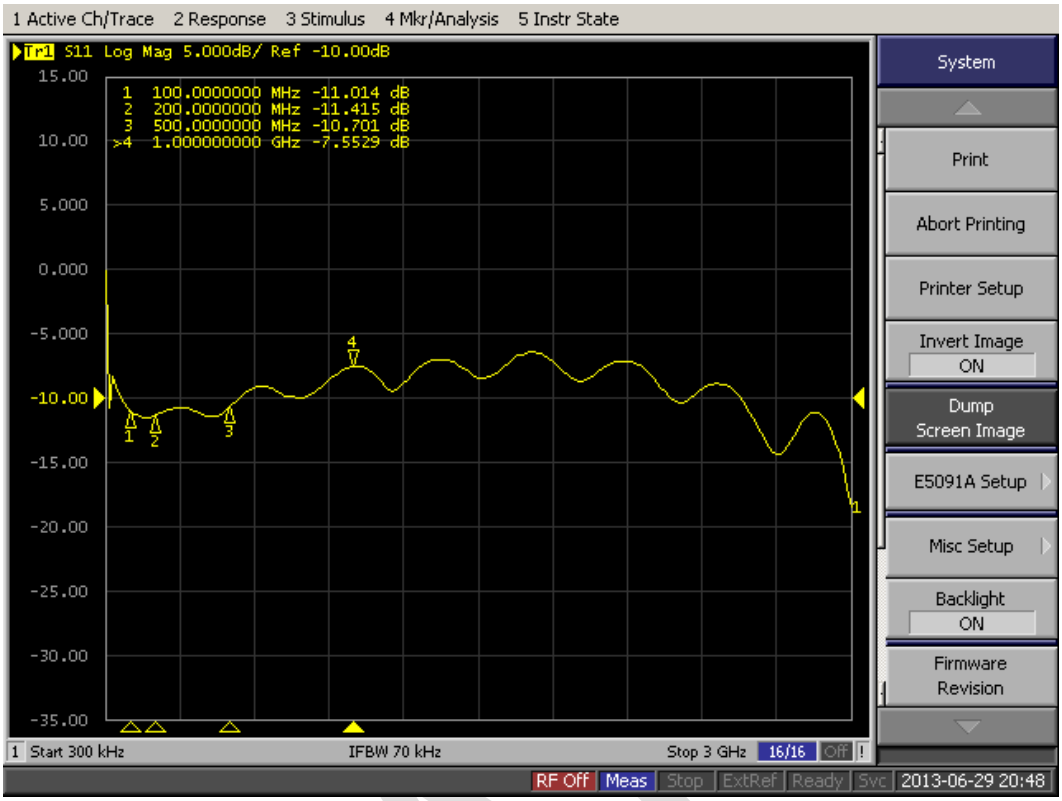


Figure 9 ~ CxLNA S-parameters


1 Active Ch/Trace 2 Response 3 Stimulus 4 Mkr/Analysis 5 Instr State
Tr1 S11 Log Mag 5.000dB/ Ref -10.00dB
1 100.0000000 MHz -11.014 dB
2 200.0000000 MHz -11.415 dB
3 500.0000000 MHz -10.701 dB
>4 1.000000000 GHz -7.5529 dB
15.00
10.00
5.000
0.000
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
1 Start 300 kHz
IFBW 70 kHz
Stop 3 GHz
16/16
RF Off
Meas
Stop
ExtRef
Ready
Svc
2013-06-29 20:48
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Dump Screen Image
E5091A Setup
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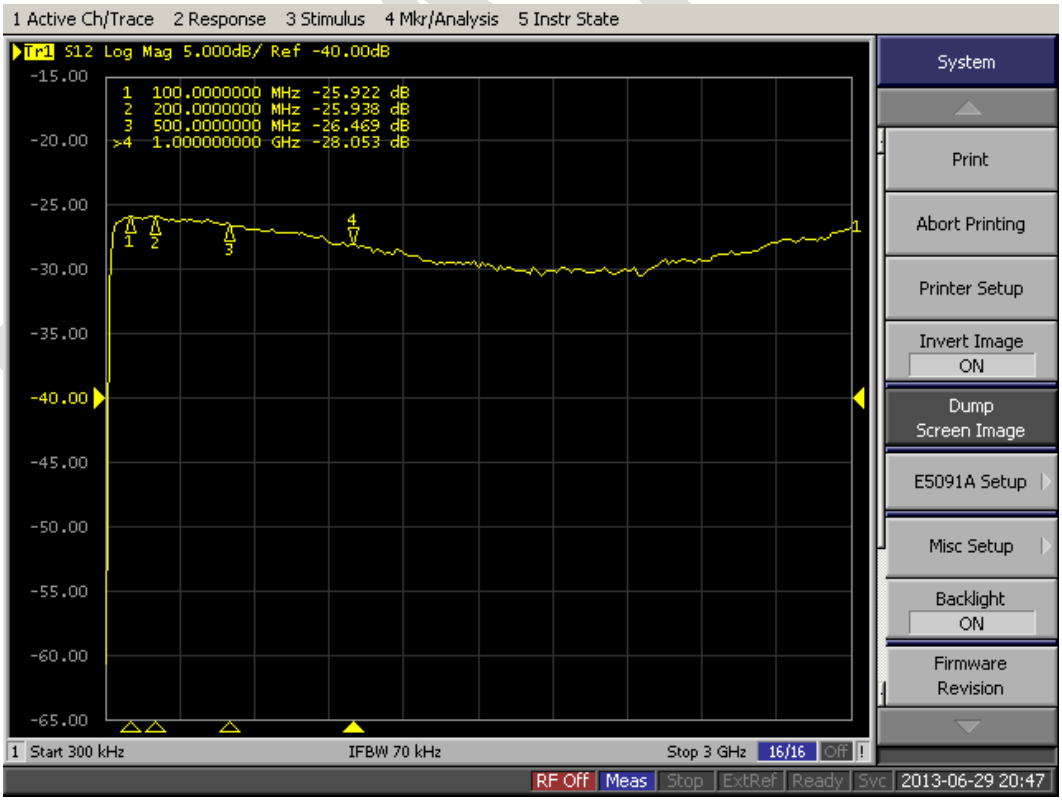
Firmware Revision


1 Active Ch/Trace 2 Response 3 Stimulus 4 Mkr/Analysis 5 Instr State
Tr1 S12 Log Mag 5.000dB/ Ref -40.00dB
1 100.0000000 MHz -25.922 dB
2 200.0000000 MHz -25.938 dB
3 500.0000000 MHz -26.469 dB
>4 1.000000000 GHz -28.053 dB
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
1 Start 300 kHz
IFBW 70 kHz
Stop 3 GHz
16/16
RF Off
Meas
Stop
ExtRef
Ready
Svc
2013-06-29 20:47
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Dump Screen Image
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Misc Setup
Backlight
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Firmware Revision

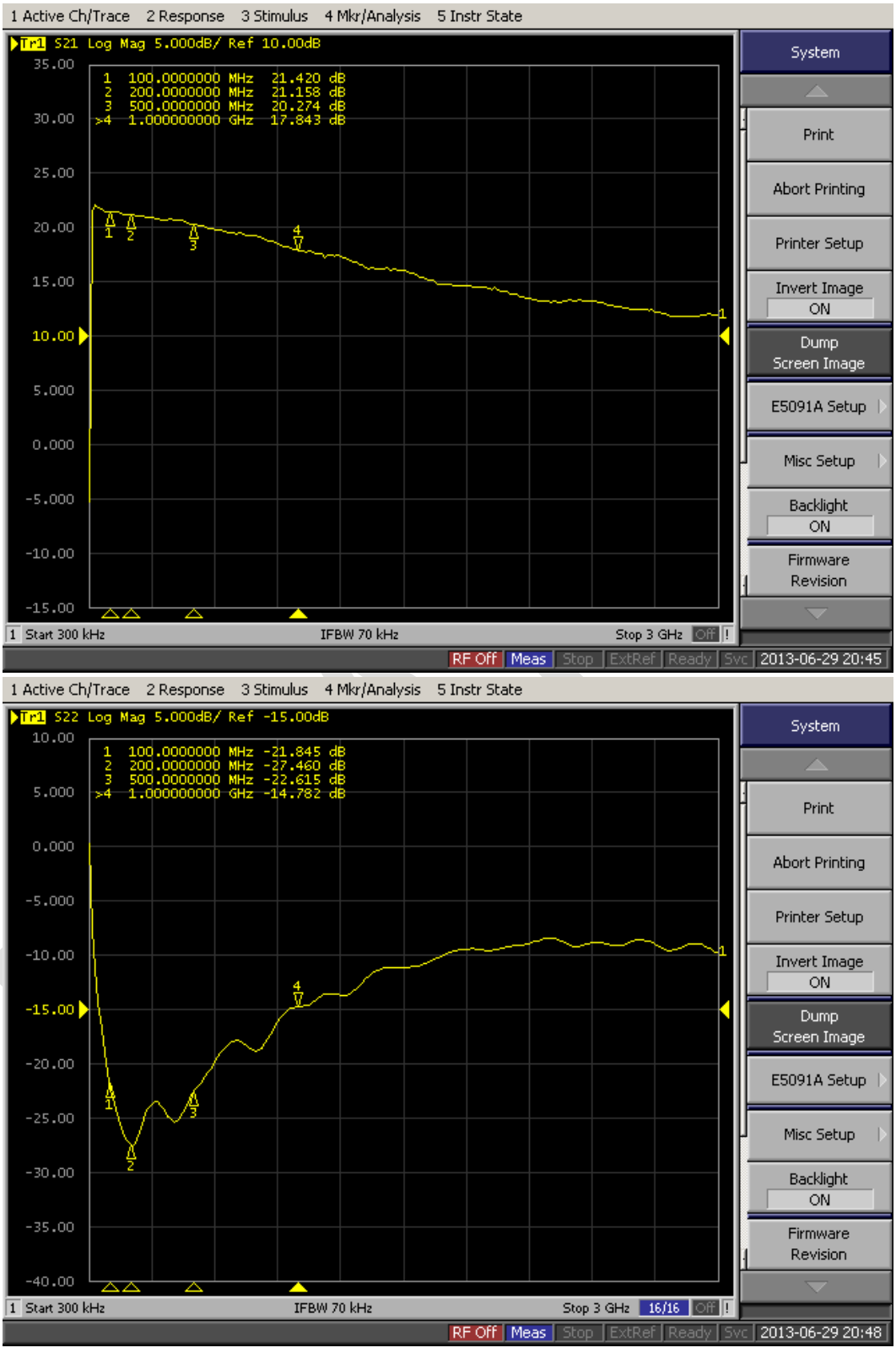

Figure 10 ~ ZX60 S-parameters

8. Methods

Noise figure measurements:

The measurement setup was straight-forward (figure aa). The Callisto software tool NF, which uses the Y-factor method, was used for the measurements. All measurements were taken with the RF Design RFD2305 noise source, which has an excess noise ratio (ENR) of 5.8 dB in the frequency range of interest. This was reduced by 0.2 dB to account for connection losses, giving ENR = 5.6 dB used in the calculations.

The amplifier noise figure measurements include amplifier noise as well as the effects of the Callisto. The gains of the CxLNA1 and ZX60 are 20 dB and the noise figure of the Callisto is 7.5 dB, resulting in a measurement that is a few tenths dB higher than actual. Measurement uncertainty also amounts to at least a few tenths dB.

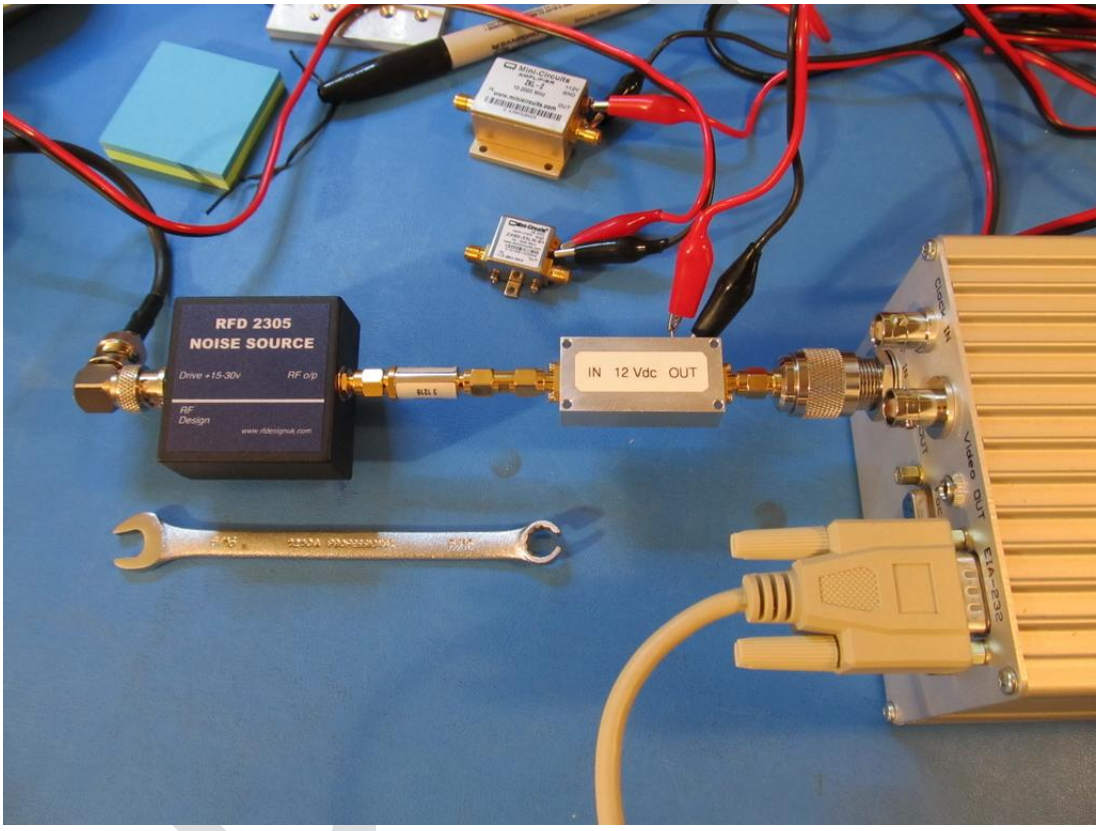

Figure aa ~ Noise figure measurement setup for the CxLNA. Other amplifiers used the same setup. The RFD2305 noise source (blue box on left) was connected directly to the RF Input of the amplifier. The RFD2305 includes a 10 dB attenuator and has ENR = 5.8 dB. The amplifiers were connected to a power supply using temporary leads (middle). The Callisto (right) was setup in the normal way with EIA-232 connection to the PC and power connection to a 12 Vdc power supply.

Spectrum Y(F) measurments:

A 0.5 m whip antenna was connected directly to the amplifier inputs and the amplifier outputs connected directly to the Callisto (figure bb). Callisto gain (PWM value) was set to 150 for all measurements.

Figure bb ~ Spectrum measurements setup.

Gain measurements:

A spectrum analyzer with tracking generator was used for gain measurements (figure cc). An input level of –30 dBm was used for the CxLNA1 and ZX60 and –40 dBm for the ZKL. All amplifiers use SMA-F connectors for input and output, so adapters were used for connect the amplifiers to RG-142 coaxial test cables with N-M connectors.

Figure cc ~ Spectrum analyzer/tracking generator setup.

Overload compression measurements:

The amplifiers were isolated from the tracking generator output and spectrum analyzer input with 10 dB attenuators (figure dd)

Figure dd ~ Overload compression measurements

FITS:

Detailed spectrum measurements:

S-parameter measurements:

Instrument used was Aglient model .....???

Document information

Authors: Christian Monstein, Whitham Reeve

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0.1 (Added tests and s-parameters, 29 June 2013)