Morocco Site Testing for the Cylinder Radio Telescope

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On June 20th and 21st 2009, another RFI testing campaign was made into the Moroccan desert. The goals were to both verify previous results and test new sites. Both sites 4 and 5 are currently very quiet sites, with no significant RFI besides low level GSM at 950MHz.

1 Equipment

The antenna used was a Workman T-601 discone antenna, with a vertical polarization. It was attached to a plastic 3 meter mast mounted to the bed of the truck used, see Figure 1.

The LNA used was a Minicircuits zx60-33ln and zx60-4016-s. It has ∼35 dB of gain and a ∼1.25 dB noise figure. This went through 20ft of L-com 200 series cable. The Gain and noise of the assembly between the antenna and spectrum analyzer is plotted in figure 2.

The Anritsu MS2711 spectrum analyzer was used. It was enclosed in a screen bag to shield from self created RFI, see figure 3. The resolution bandwidth was 10kHz, but data was saved every ∼500kHz, from 50MHz to 1600MHz and the effective resolution bandwidth used in calculation was 30kHz.

2 Data

Sites had been previously selected in Morocco prior to the trip. We decided to revisit site 5 to get a verification and comparison to previous data. We then continued on to measure site 4. We determined in the field to visit many sites around the area of site 4, and did not visit the original site 4 itself. See figures 4, 5 for a map of the locations visited. Table 1 lists the location of all the sites visited.

The data is plotted as a flux density in dBW/m^2/Hz. The conversion requires the effective area of the antenna, which is not precisely known or measured. The antenna gain was assumed to be 1 dBi, a number often quoted for discone gain. The equation for calculating the flux density is:

Figure 1: RFI testing system setup. Workman T-601 discone antenna. Minicircuits zx60-33ln and zx60-4016-s amplifiers. Anritsu MS2711 spectrum analyzer in screen.

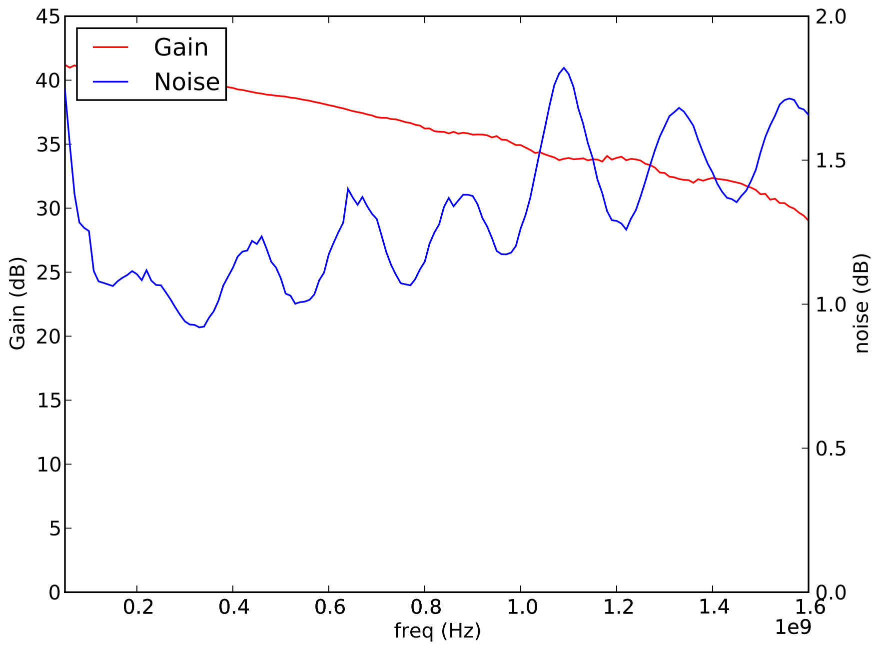

Figure 2: Measured Gain and Noise figure of LNA used

Table 1: Sites visited

name	latitude (deg)	longitude (deg)	elevation (m)
Site 5	32.924749999	-2.878388888	
Site 4b	32.975108333	-2.782691666	1422.5
Site 4c	32.970251666	-2.782175000	1437.8
Site 4d	32.971741666	-2.750146666	1401.8
Site 4e	32.968131666	-2.780384999	1441.5
Site 4f	32.972043333	-2.716898333	1392.5
Maatarka	33.264045000	-2.694946666	1259.1

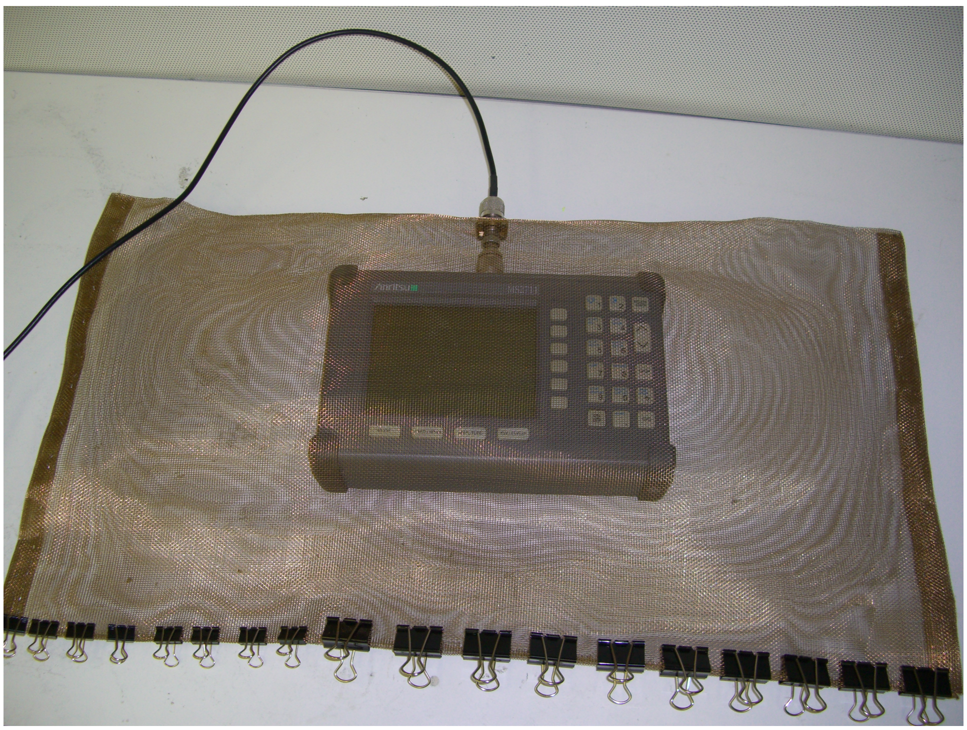

Figure 3: Anritsu MS2711 spectrum analyzer in brass screen RFI shield

$$S\left(\frac{dBW}{m^2Hz}\right) = P(dBm) - 30\left(\frac{dBW}{dBm}\right) - G(dB) - 10log_{10}(BW(Hz)) - 10log_{10}\left(\left(\frac{c}{\nu}\right)^2 \frac{A_g}{4\pi}(m^2)\right) \quad (1)$$

where P is the measured power in dbm, G is the measured gain of the amplifier, BW is the resolution bandwidth, c is the speed of light, ν is the frequency, and A_g is the linear gain of the antenna. Figure 6, figure 8, figure 9, figure 10, figure 11, figure 12, and figure 13 show the normalized spectra. Figure 7 shows a zoom in of the GSM band taken at site 5. All the sites show a similar very low level of RFI. The spectrum taken at Maatarka (figure 13) did not have any more significant lines, however the noise floor did appear to be higher overall. GSM cell towers were said to be set to be turned on shortly in that area. This would also most likely effect the RFI spectrum at the other sites as well.

Figure 14 and figure **??** show the spectrum measured by others for the SKA in South Africa.

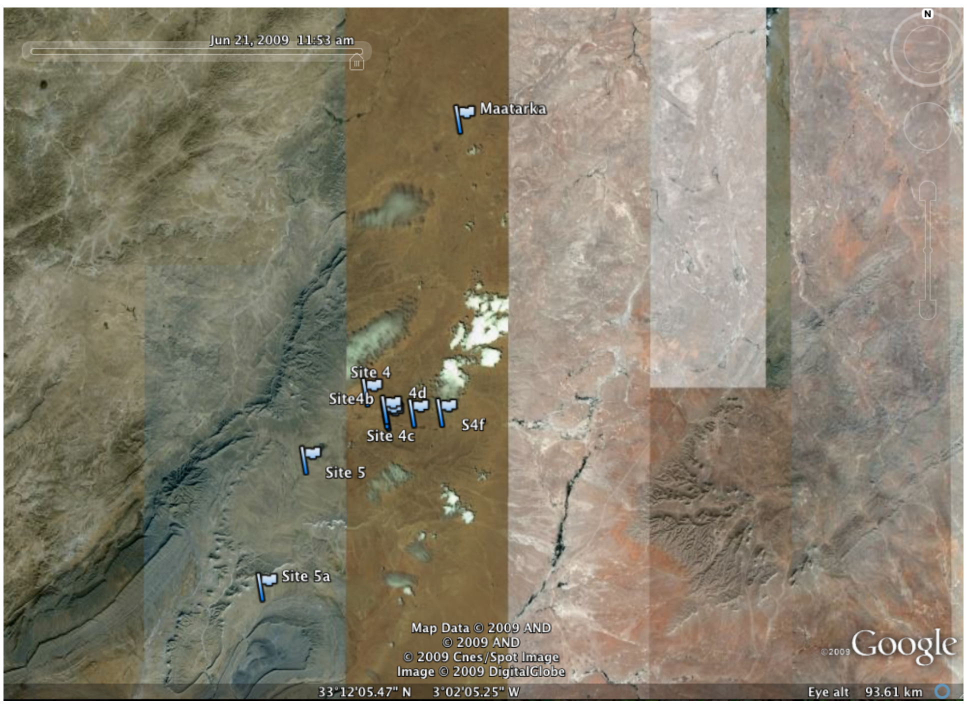

Figure 4: Location of sites visited. No data taken exactly at Site 4

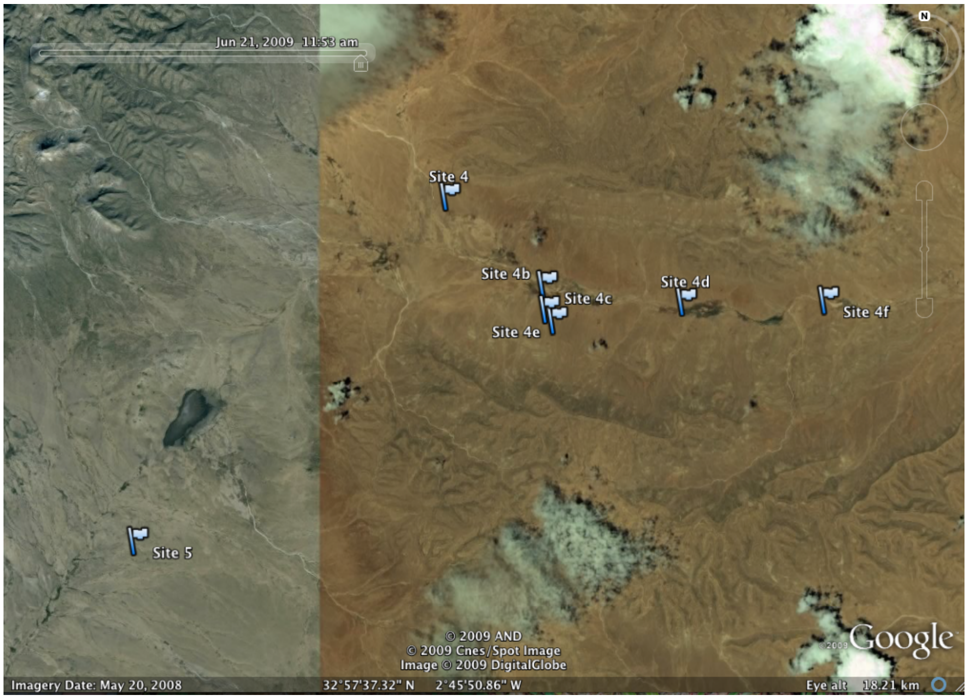

Figure 5: Zoom in of the sites visited. Many datapoints were taken inside the valley near site 4.

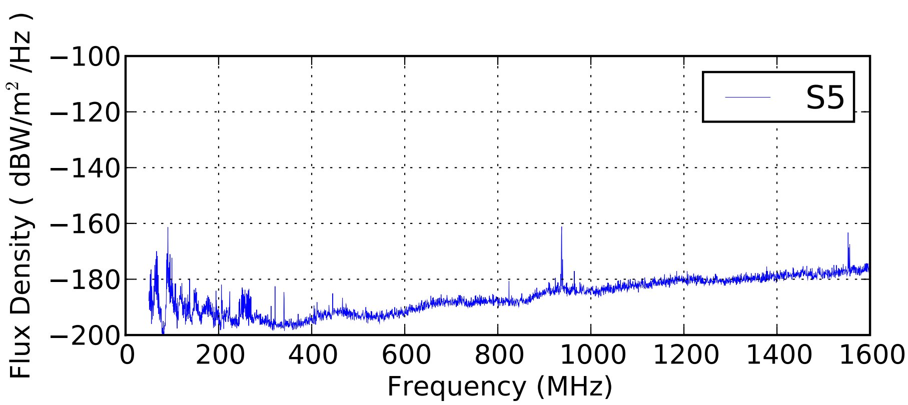

Figure 6: Site 5 Spectrum

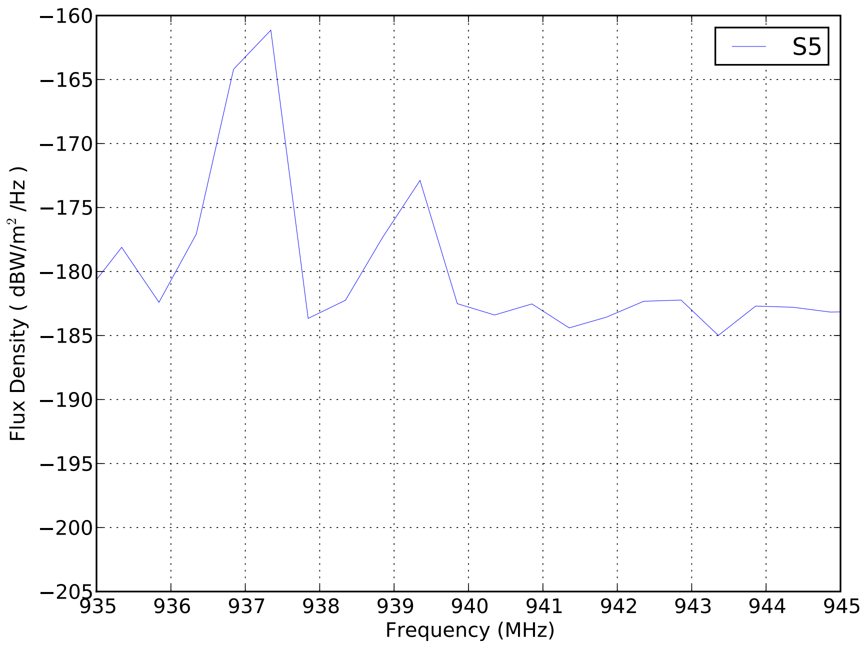

Figure 7: Site 5 Spectrum zoomed to the gsm band

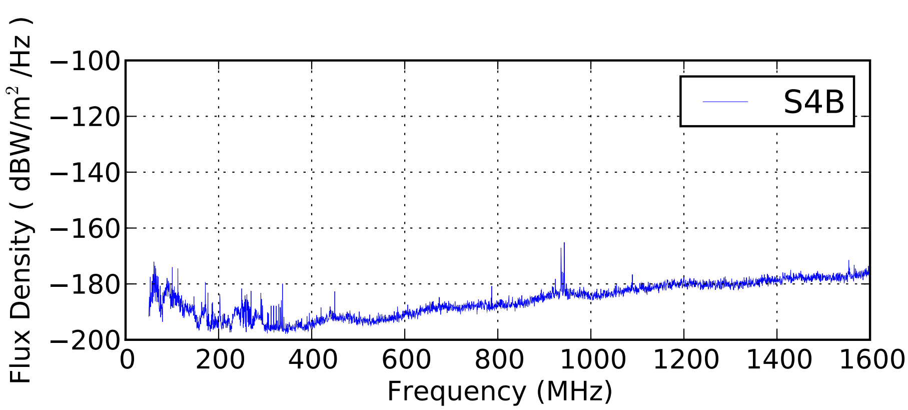

Figure 8: Site 4B Spectrum

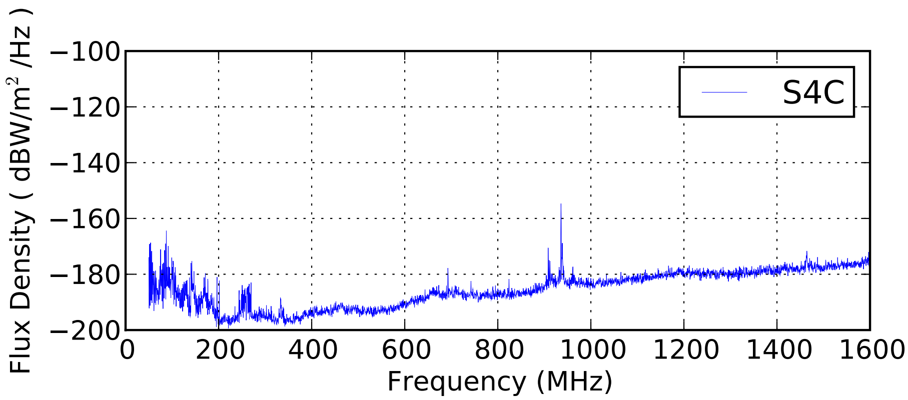

Figure 9: Site 4C Spectrum

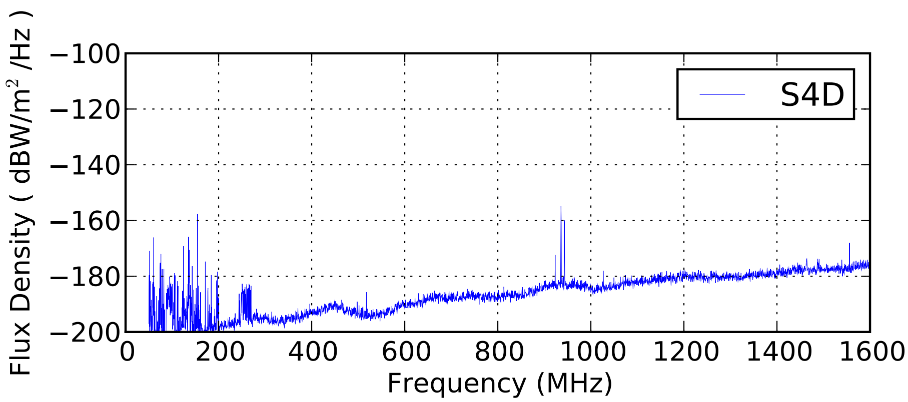

Figure 10: Site 4D Spectrum

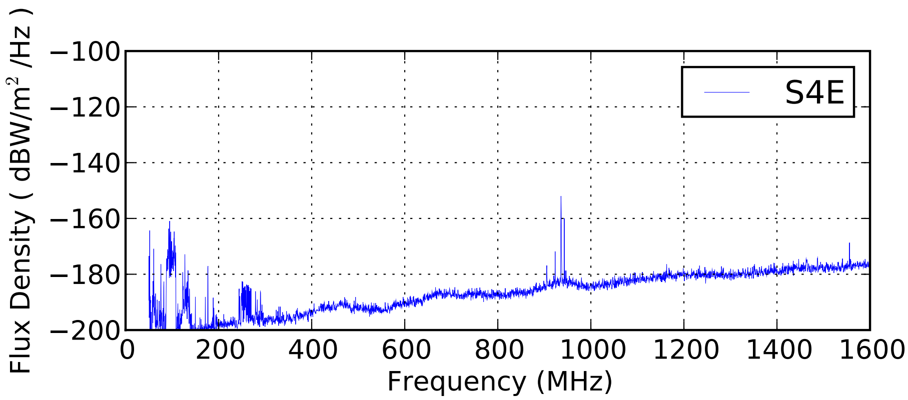

Figure 11: Site 4E Spectrum

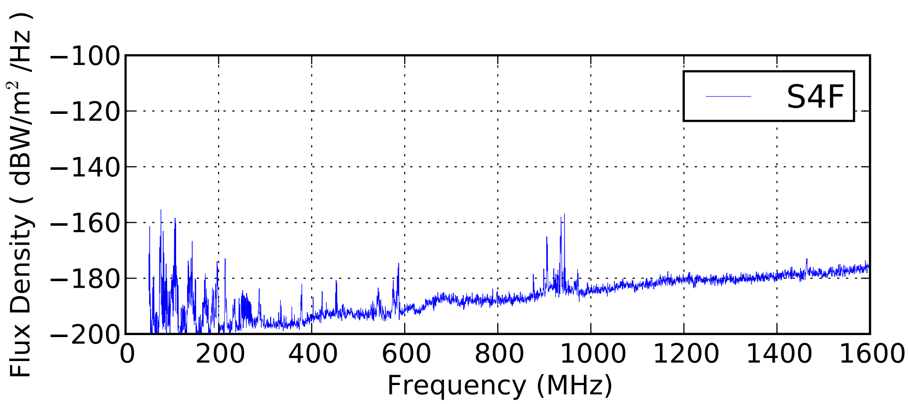

Figure 12: Site 4F Spectrum

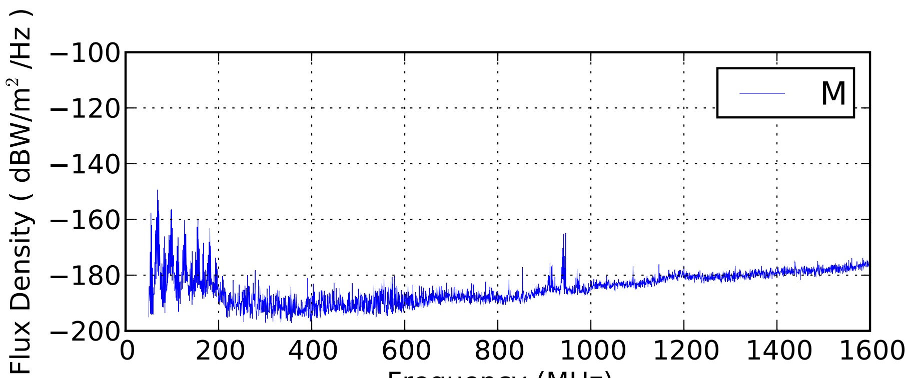

Figure 13: Maatarka Spectrum. Overall noise floor increased compared to the more remote desert sites.

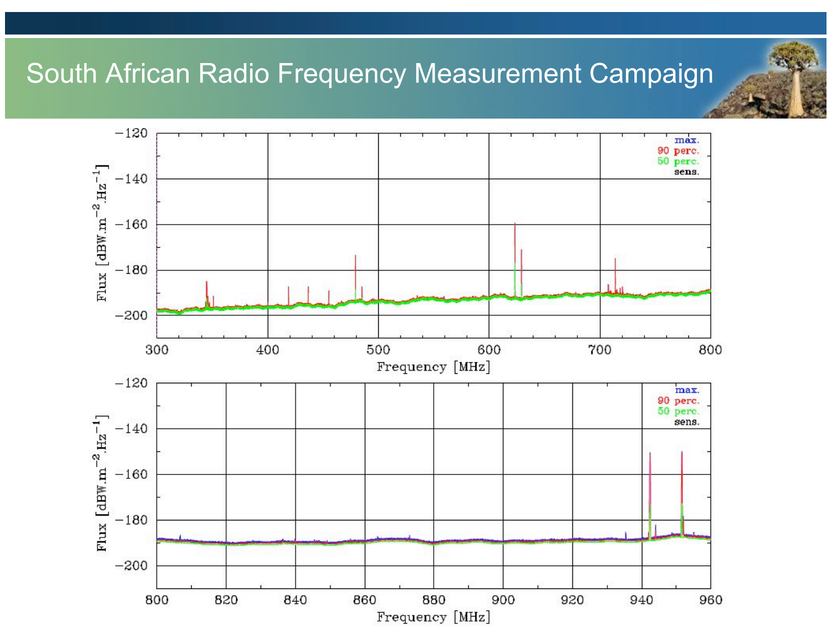

Figure 14: South Africa RFI spectrum. Measured by others for the SKA preparation. Included for comparison of sites. Slide from a presentation by Kobus Cloete

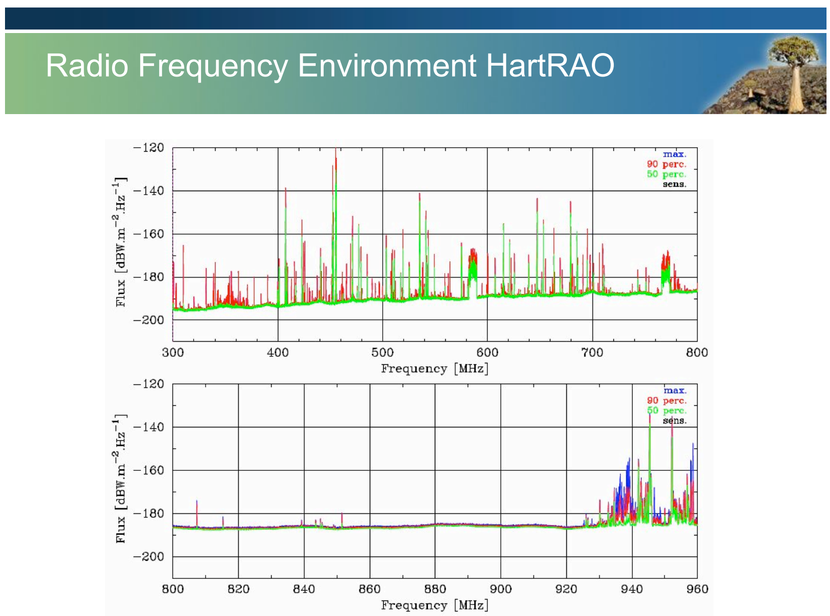

Figure 15: South Africa RFI spectrum at the Hart Radio Observatory. Measured by others for SKA preparation. Slide from a presentation by Kobus Cloete

3 LNA measurements

Previous trips have found the LNA performance to degrade after desert use both with different systems and on multiple occasions. We were careful to terminate all inputs always when not in use and to store the LNA in an anti-static bag. We also always shorted the coax before attaching it to the LNA inputs. The performance of the LNA measured before and after the trip is shown in figure 16. The performance did not seem to change much from use, although the very high-end gain did seem to have an unexplained difference by a couple of dB.

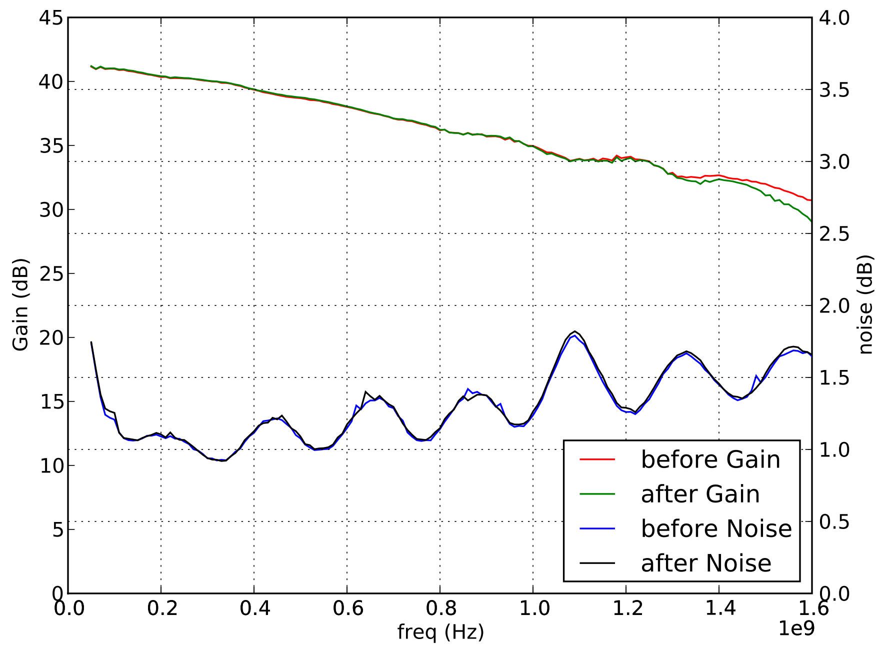

Figure 16: Comparison of amplifier performance before and after trip

4 Spectrum Analyzer Performance

The Anritsu MS2711 Spectrum analyzer was used in a mode with a 10kHz resolution bandwidth. However data was saved in 200MHz sweeps with a step of 501.253kHz, since the spectrum analyzer only will save 400 points per sweep. Data was taken with an ambient temperature 50 ohm terminator on the input of the LNA. This was compared to a theoretical 300K noise source with LNA noise added, and is plotted in figure 17. The two do not seem to coincide. Further tests were conducted with a 50 ohm terminator as the input to the LNA. Data was taken with the same configuration as was used in the field in morocco, called broadband in figure 18. Data was also taken with a 4 MHz sweep, such that a data point was saved every 10kHz. This data was then averaged every 500kHz and plotted,labeled averaged, along with the broadband data. The results show an average of 4.7dB difference, or a factor of three between the two different methods. This implies that the effective resolution bandwidth of the spectrum analyzer was in fact 30 kHz, which was used for the data plots. Using 30kHz as the RBW for the spectrum analyzer, the data was again compared to a theoretical 300K noise source through the LNA, and is plotted in figure 19. This left a discrepancy of 4.5 dB between the expected performance and measurement, so an additional 4.5 dB calibration correction was applied to all data to take this into account. Figure 20 shows the final correction compared to theory.

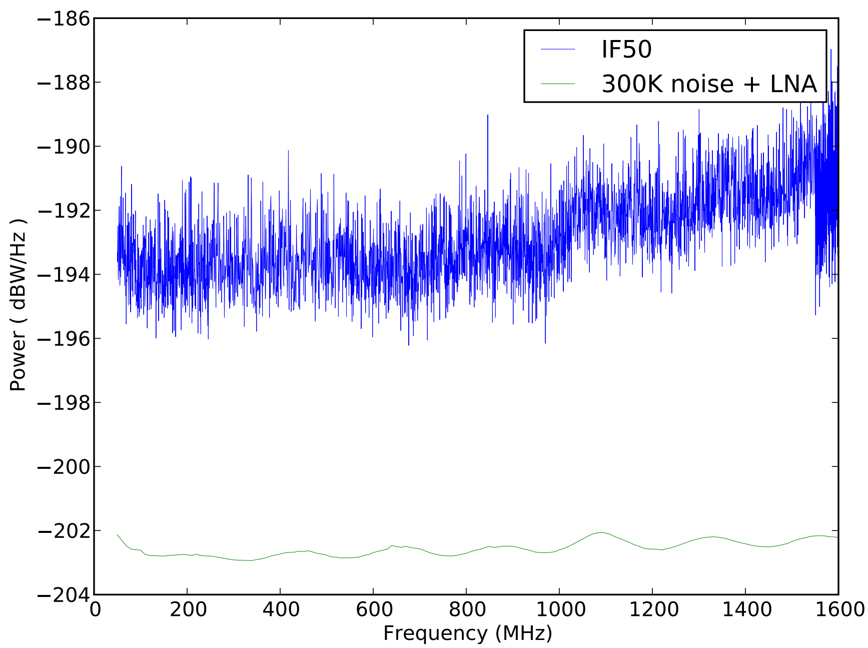

Figure 17: Measured 50 ohm load at ambient temperature assuming a 10kHz RBW vs. predicted 300K noise + LNA

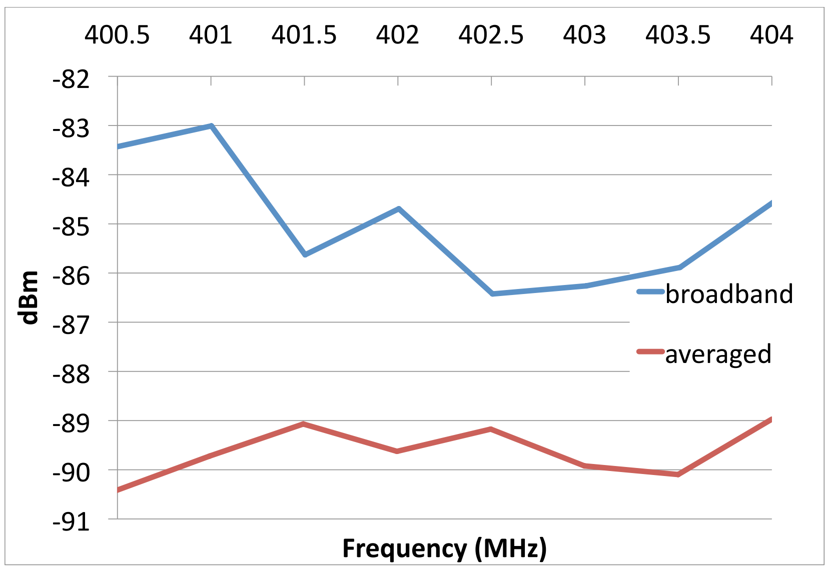

Figure 18: Measurements made of 50 ohm terminator into LNA the Broadband data had a RBW of 10kHz but data was saved every 501.253kHz. The averaged data had a RBW of 10kHz and data was taken every 10kHz, and then averaged to every 500kHz. The results differed by 4.8dB, or a factor of 3.

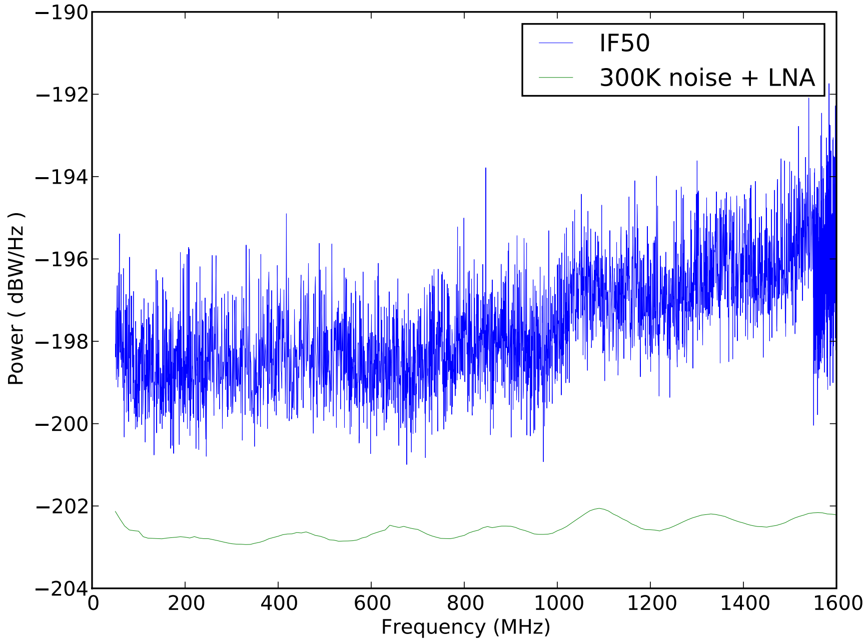

Figure 19: Measured 50 ohm load at ambient temperature assuming a 30kHz RBW vs. predicted 300K noise + LNA

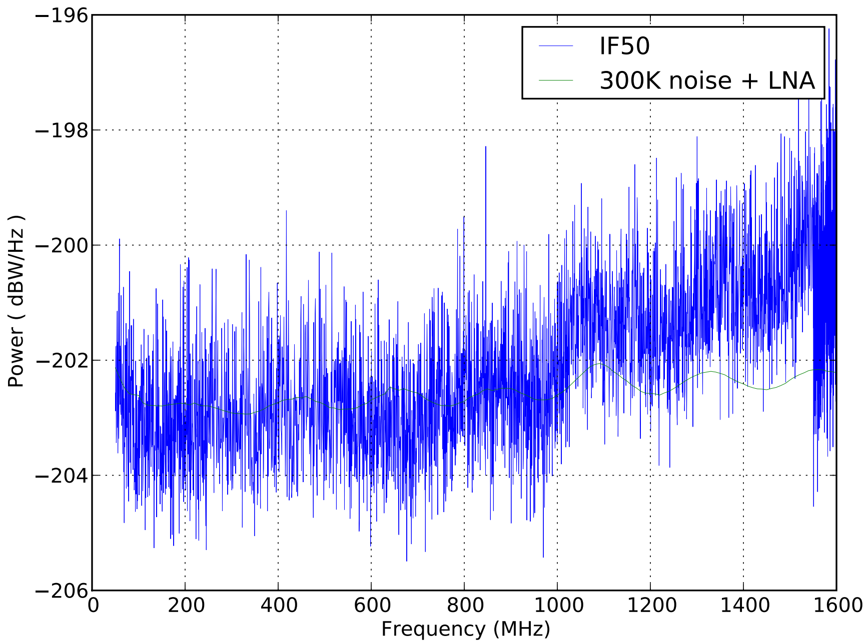

Figure 20: Measured 50 ohm load at ambient temperature assuming a 30kHz RBW with additional 4.5 dB calibration correction vs. predicted 300K noise + LNA