Analysis of Jove Dipoles and TFD Antennas

Dave Typinski, August 2014

This article analyzes the performance of several wire antennas for use in the upper HF band: the Jove dipole, the 18-foot terminated folded dipole (TFD), and the 24-foot TFD. SWR and real world galactic background is measured and compared. Observed spectra are compared to the theoretical galactic background and measured for diurnal change. The results of the Jove dipole tests serve as a benchmark, while the TFD test results enable future comparison with the LWA-style antennas.

All testing was performed at AJ4CO Observatory in High Springs, Florida. It is believed that the soil conditions in terms of RF ground are average to poor.

The SWR sweeps are discussed, results of galactic background observations at 20 MHz is presented, then the spectra produced by the antennas is covered.

SWR – The Jove Dipole

The Jove array, being constructed from two half-wave dipole antennas, is necessarily a narrow banded antenna. This works well for use near 20.1 MHz, and passably well for feeding a spectrograph as long as the bandwidth is kept to a few MHz. The question is, how narrow? One approach is to look at the SWR at the dipole feed point.

For this series of tests, a 22-foot 8-inch half-wave dipole was swept using a VNA-2180 vector network analyzer calibrated to the dipole feed point. The dipole was tested at 10 and 12 feet height, both with and without a ground plane (see Figure 1 below), with and without the presence of a second dipole 20 feet away parallel to the antenna under test, with and without a 50 ohm load on the parallel dipole. The resulting SRW sweeps are show in Figures 2 through 5.

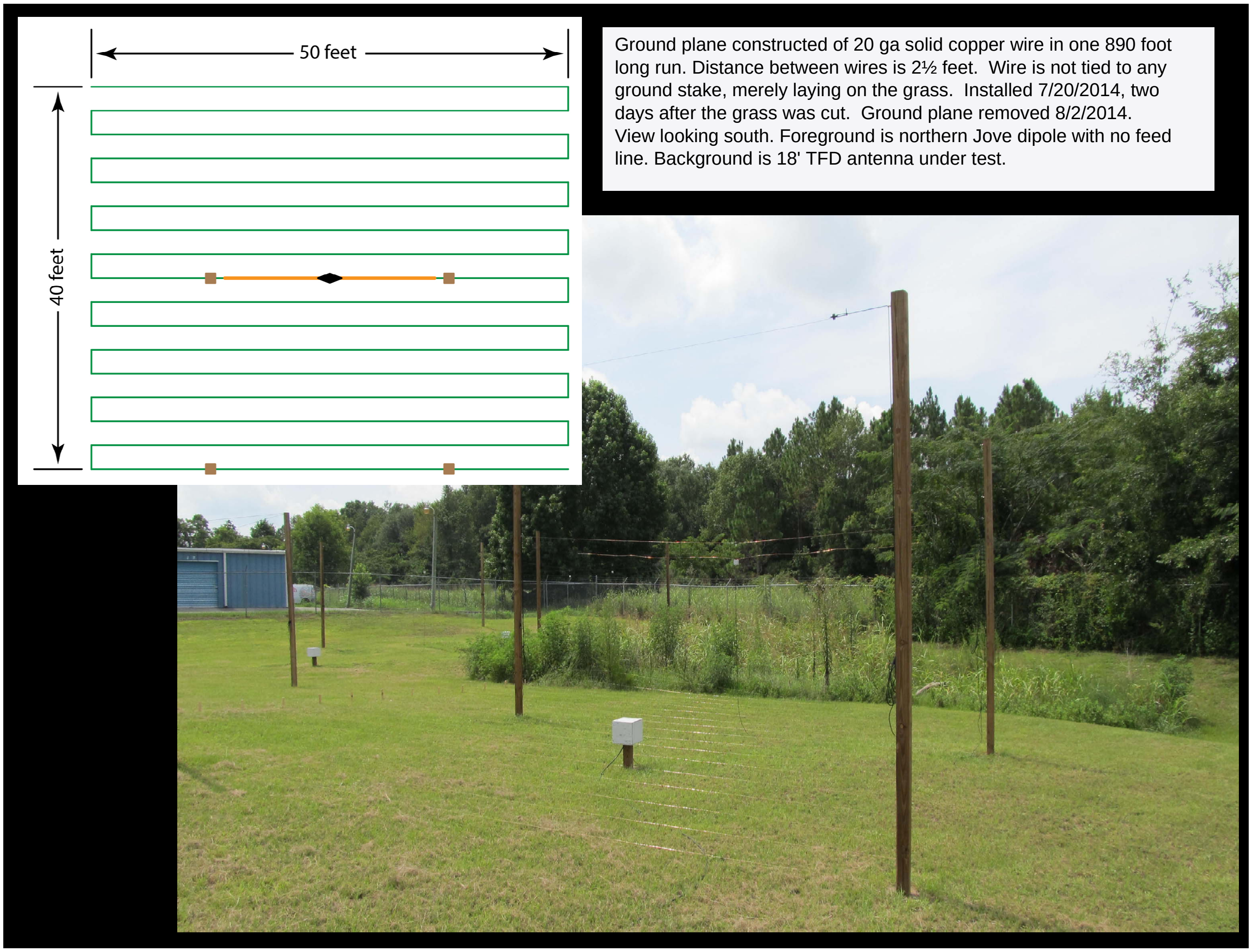

Figure 1 – Ground plane installation.

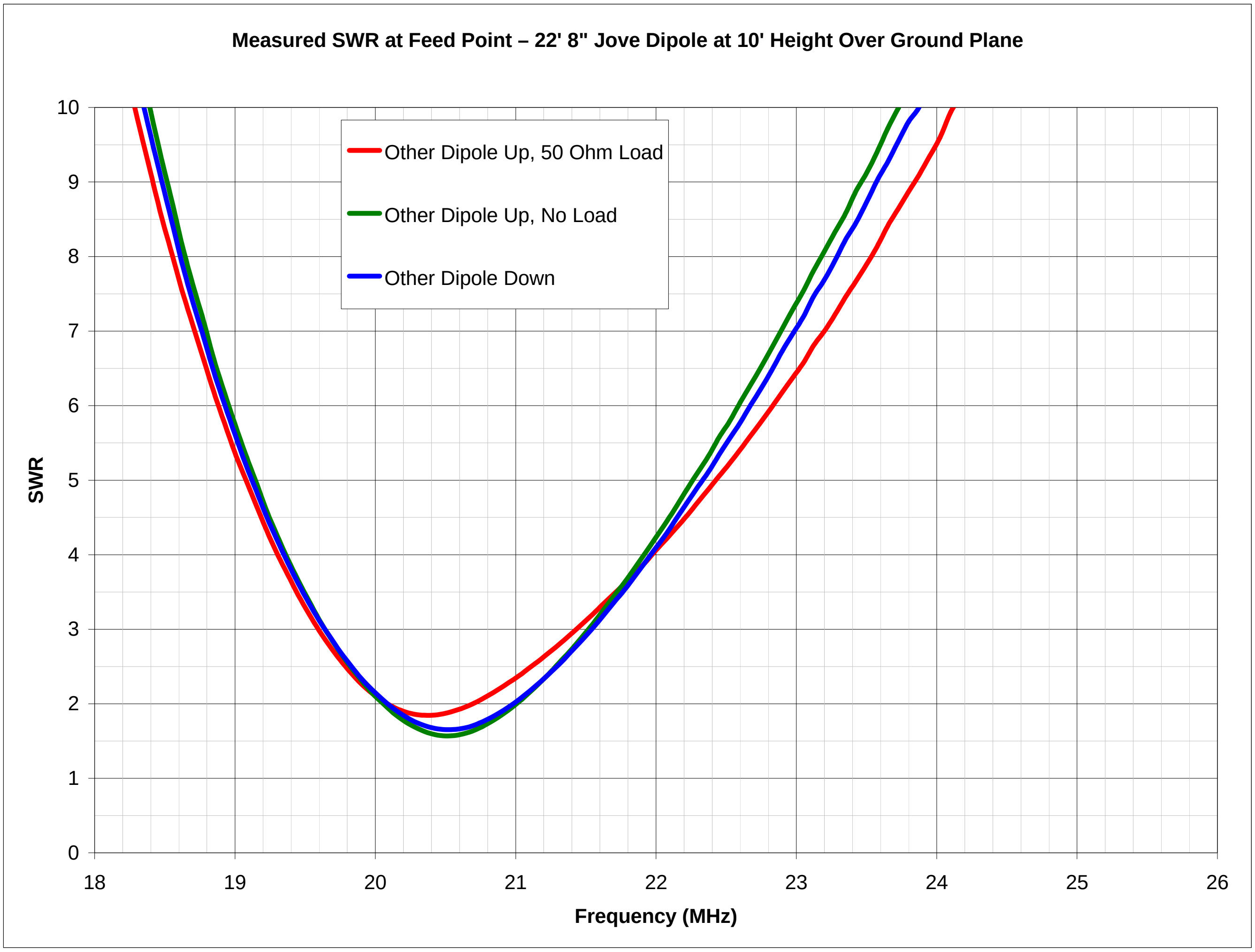

Figure 2 – Jove dipole 10′ over ground plane.

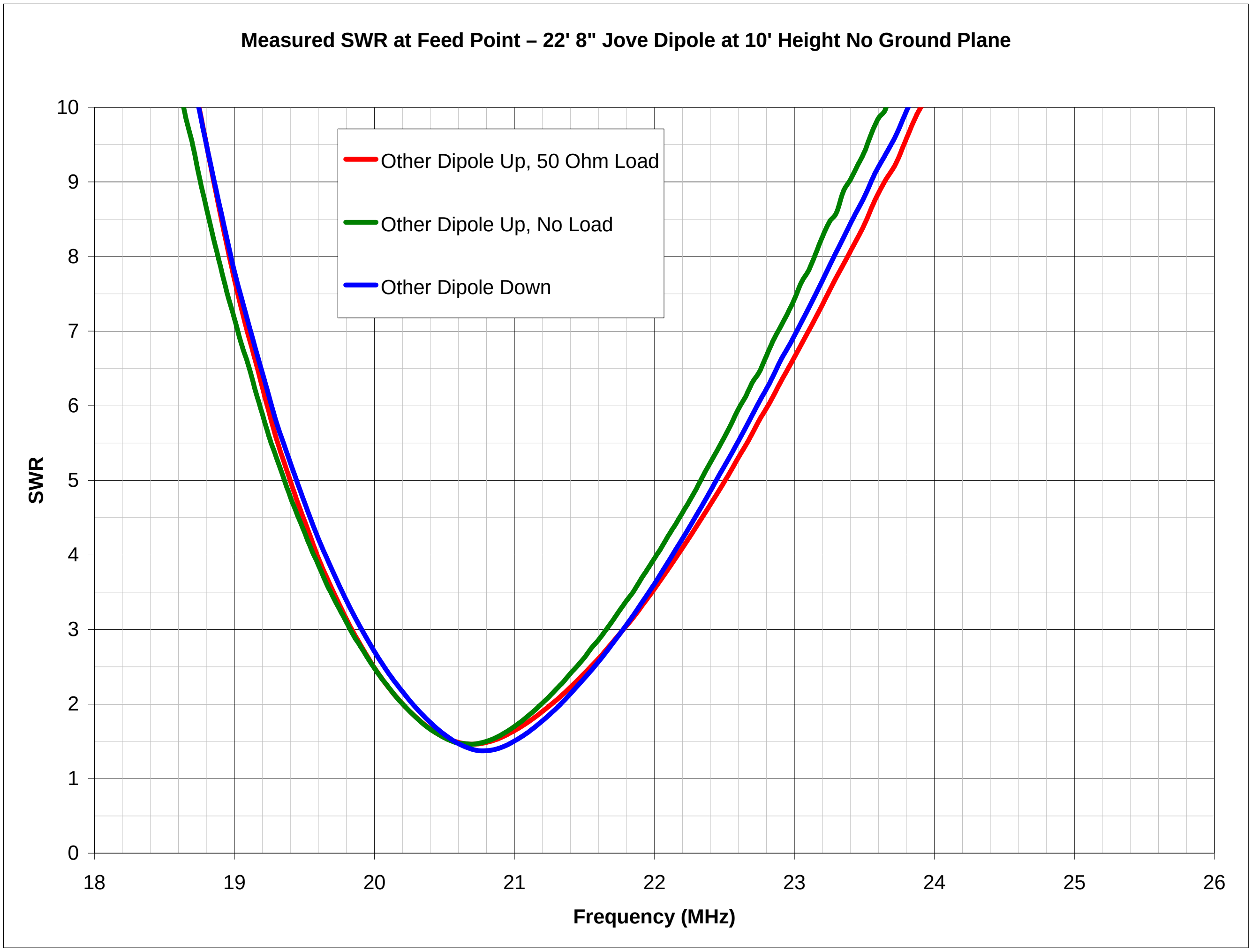

Figure 3 – Jove dipole at 10′ height, no ground plane.

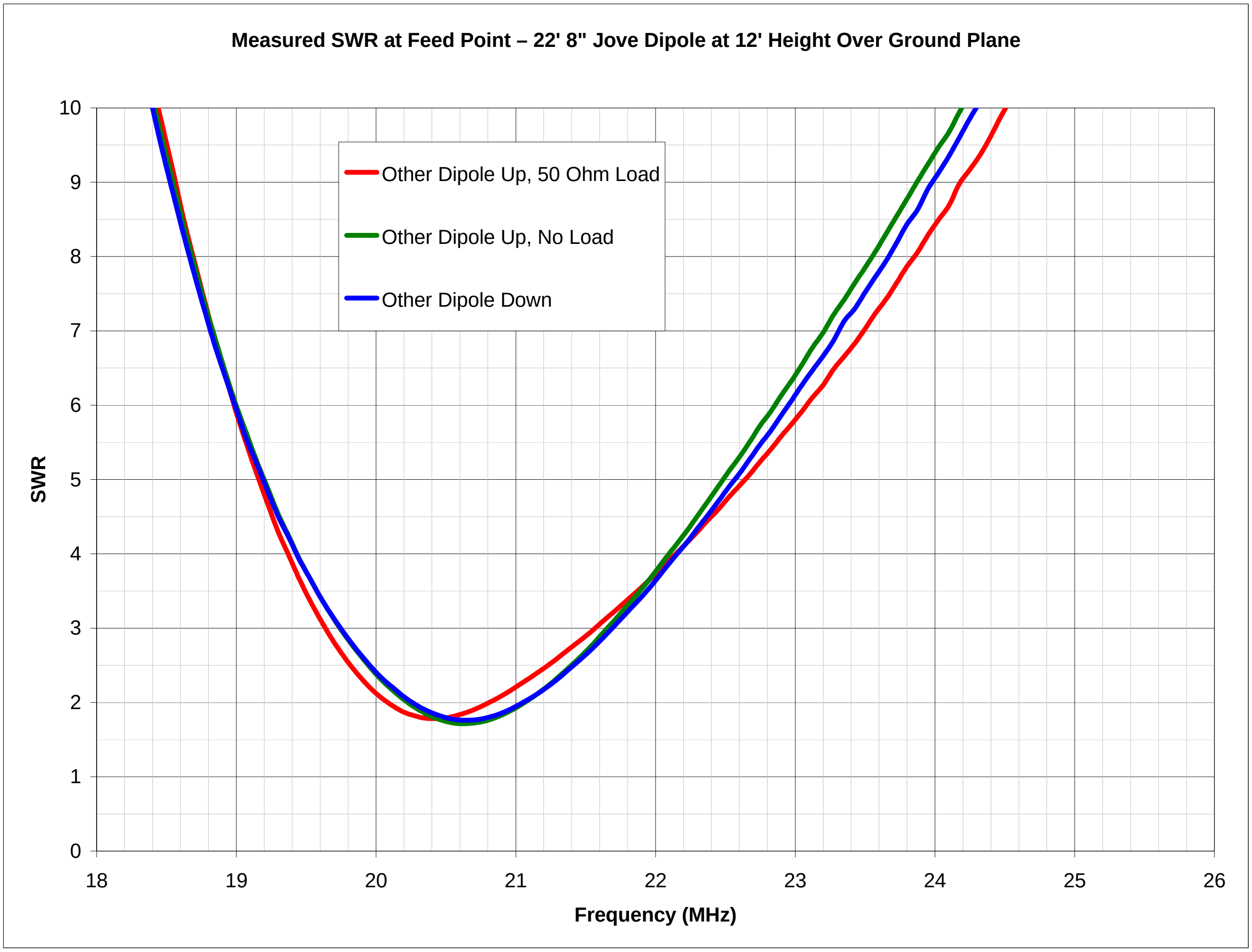

Figure 4 – Jove Dipole 12′ over a ground plane.

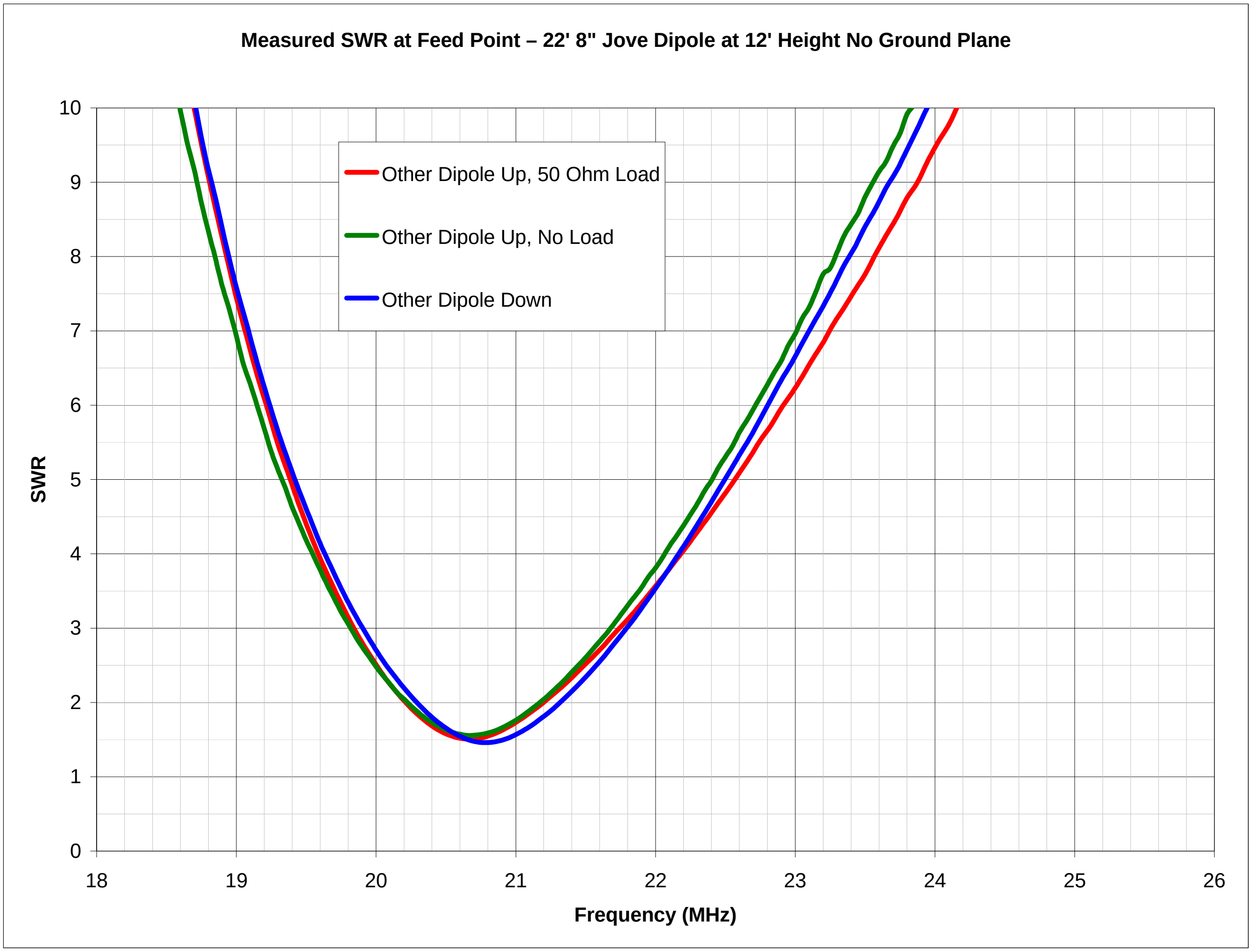

Figure 5 – Jove dipole at 12′ height, no ground plane.

We can see that the presence of the other dipole – with no load makes little difference. The presence of the other dipole with a 50 ohm load reduces the resonant frequency by 200 to 400 kHz and very slightly increases the SWR at resonance – but only when the antenna is over a ground plane. For the lone dipole (no parallel dipole present), the ground plane reduces the resonant frequency by a similar amount compared with the lack of a ground plane. These are minor effects that can safely be ignored, but it's nice to know what it is that we're ignoring.

To compare the 10′ and 12′ dipole heights, with and without a ground plane, the data from the lone dipole tests (tests in which the other dipole was lowered to the ground) is plotted together in Figure 6.

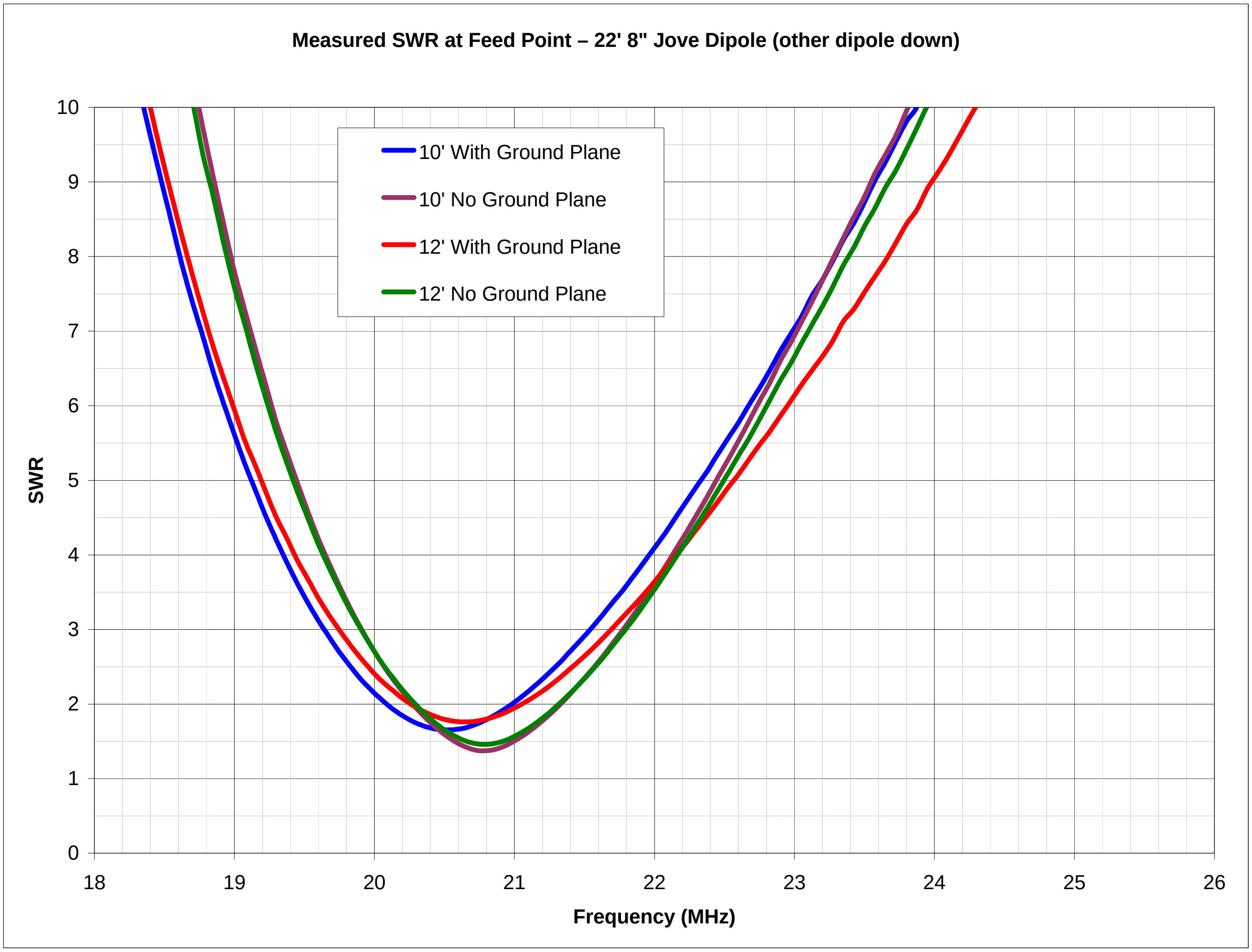

Figure 6 – Comparison of the Jove dipole tests without the presence of another dipole.

Since the SWR at 10′ height is a little better than the SWR at 12′ height, and since having a ground plane is an easily reproducible configuration while the characteristics of natural ground vary with station location, the 10′ height Jove dipole over a ground plane is chosen as the reference antenna for the remainder of this analysis.

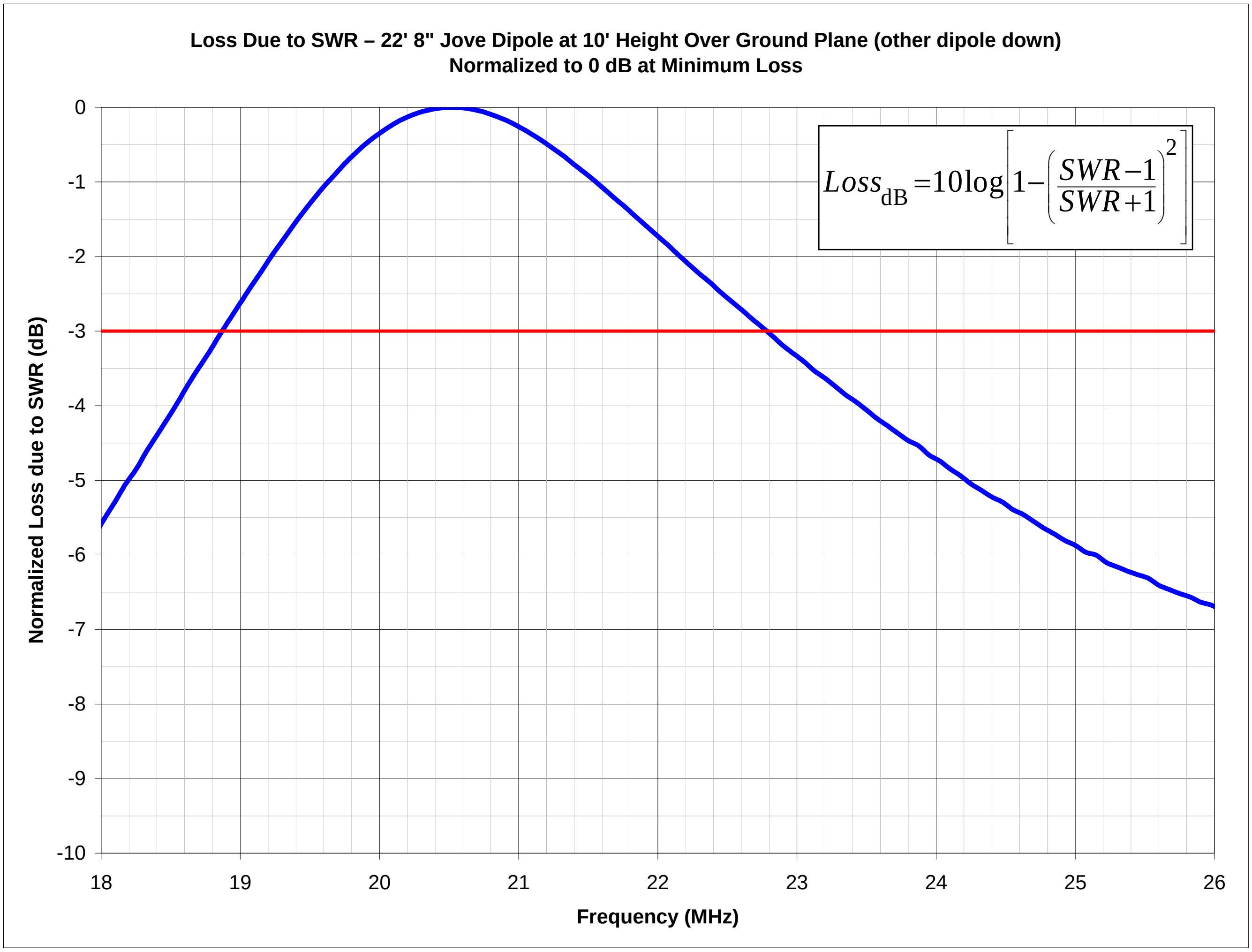

Figure 7 – Attenuation due to SWR in the 10′ high Jove dipole.

We can calculate the amount of attenuation produced by the impedance mismatch at the antenna feed point (given in terms of SWR) across the RF spectrum by using the equation shown in Figure 7. Since the SWR at resonance (about 23.5 MHz) is not a perfect 1:1, but more like 1.7:1, the loss is normalized to indicate 0 dB loss at resonance. This allows us to easily obtain the 3 dB bandwidth – which in this case is 4 MHz, from 19 to 23 MHz.

SWR – The TFD Antennas

A TFD antenna has a much wider bandwidth than a half wave dipole. In keeping with the universal law of no free lunches, this comes at a price: the efficiency of a TFD is quite poor compared to a half wave dipole. How poor? Once again, some SWR sweeps help us find out.

For this series of tests, 18’ and 24’ TFD antennas were swept using a VNA-2180 vector network analyzer calibrated to the TFD balun output. For details of the TFD design and construction, see “The DPS and TFD Array”, Typinski (RJ, 2014). The TFD’s were tested at 9’2” top wire height, both with and without a ground plane (see the following TFD section for a description of the ground plane), with and without the presence of a Jove dipole 20 feet away parallel to the antenna under test, with and without a 50 ohm load on the parallel dipole. The resulting SRW sweeps are show in Figures 8 through 11.

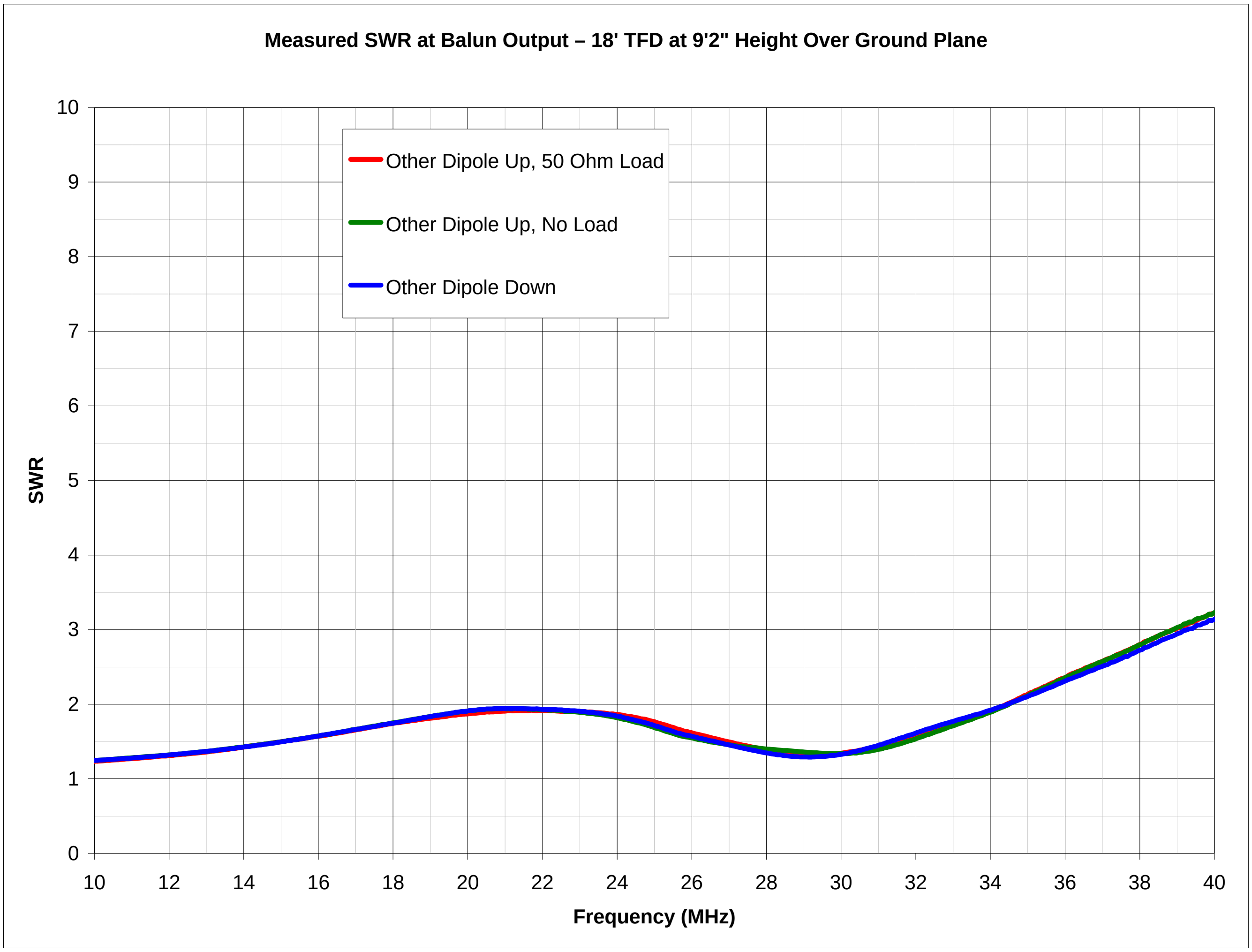

Figure 8 – 18’ TFD over ground plane. Remember: SWR does not tell the whole story: the efficiency of this antenna is actually quite poor. The apparently low SWR below 20 MHz is probably due to the VNA measuring the terminating resistor in the TFD. It certainly does not represent the real radiation performance of the antenna at those lower frequencies. For example, a 50 ohm resistor has a perfect 1:1 SWR, but it makes a lousy antenna.

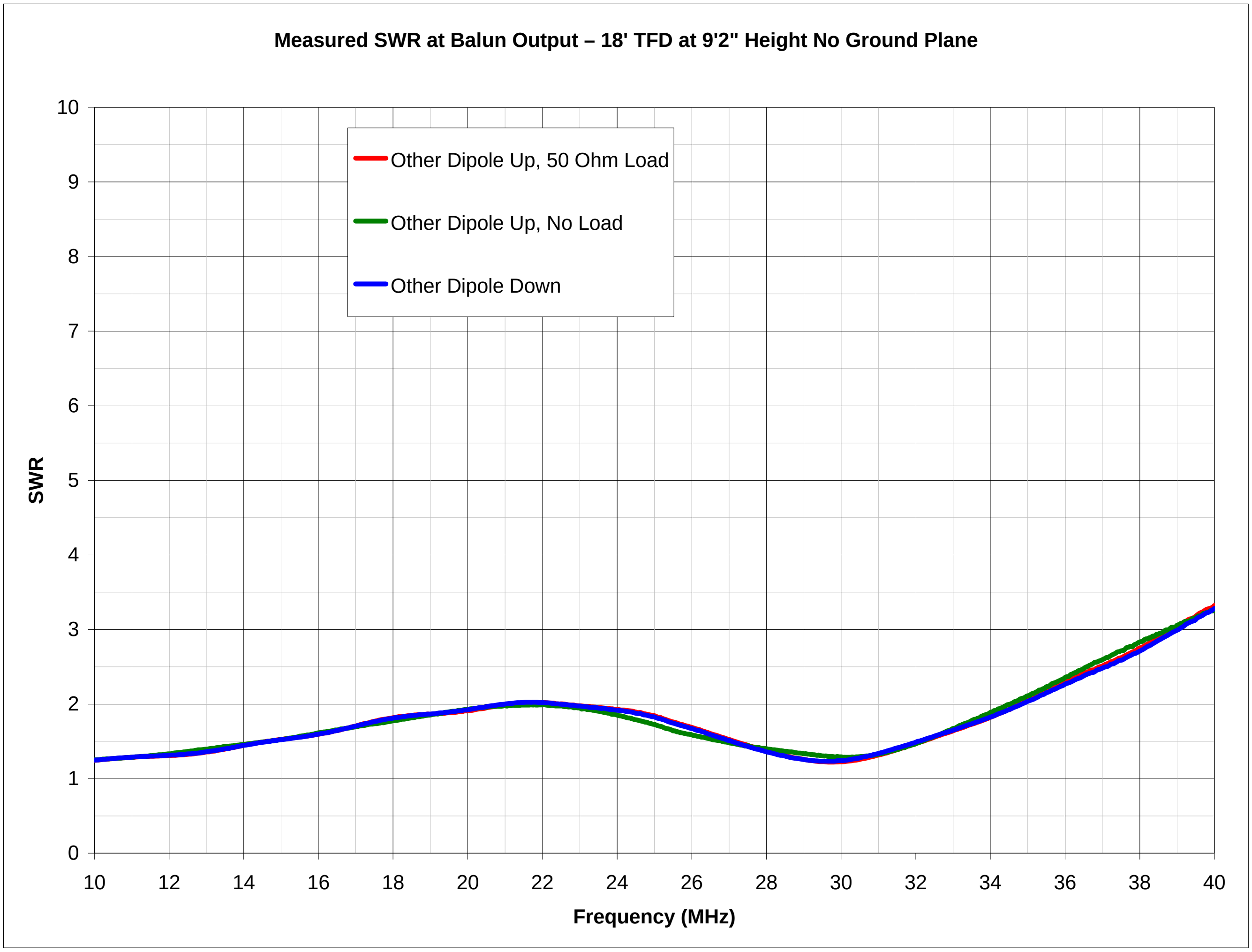

Figure 9 – 18′ TFD without a ground plane.

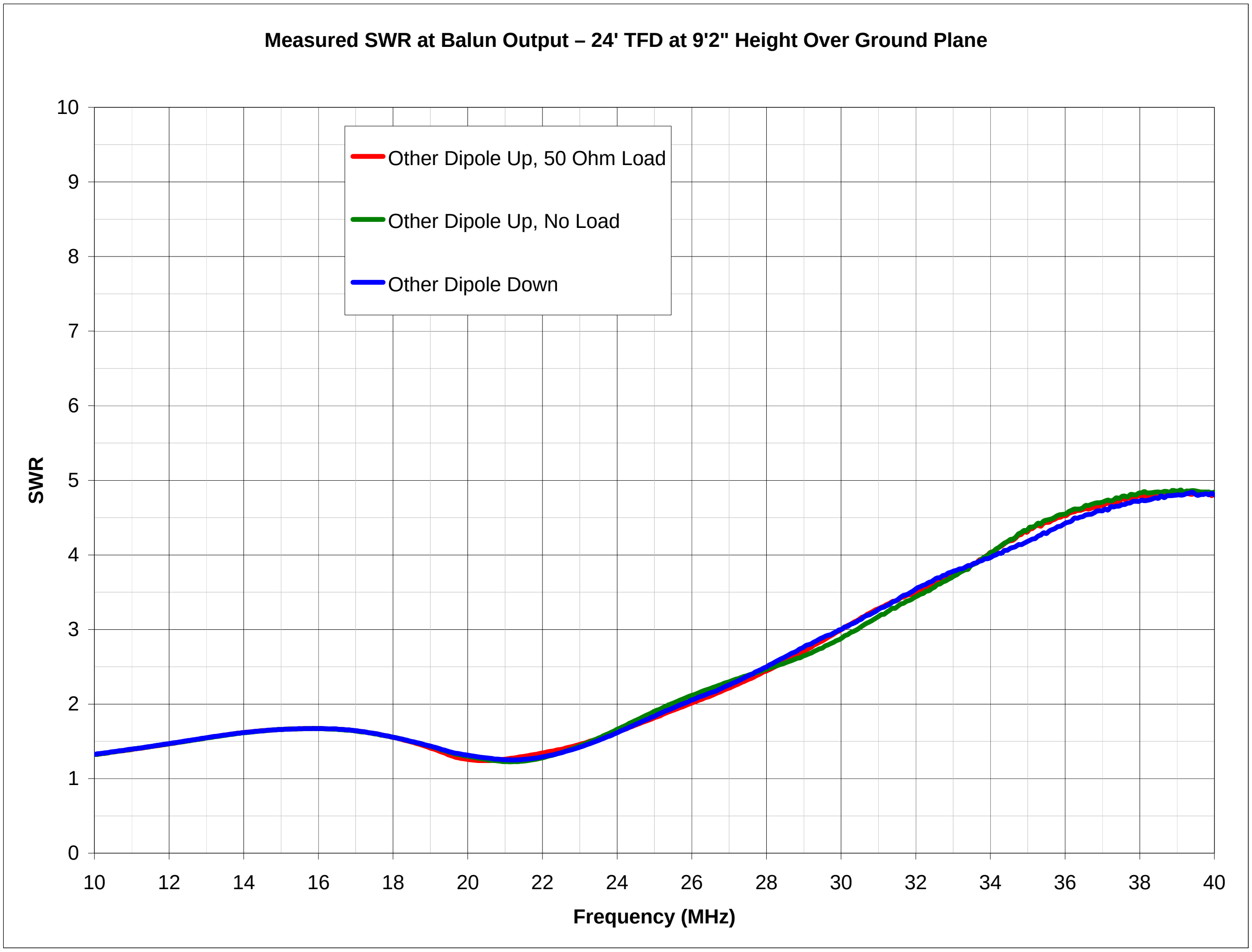

Figure 10 – 24′ TFD over a ground plane.

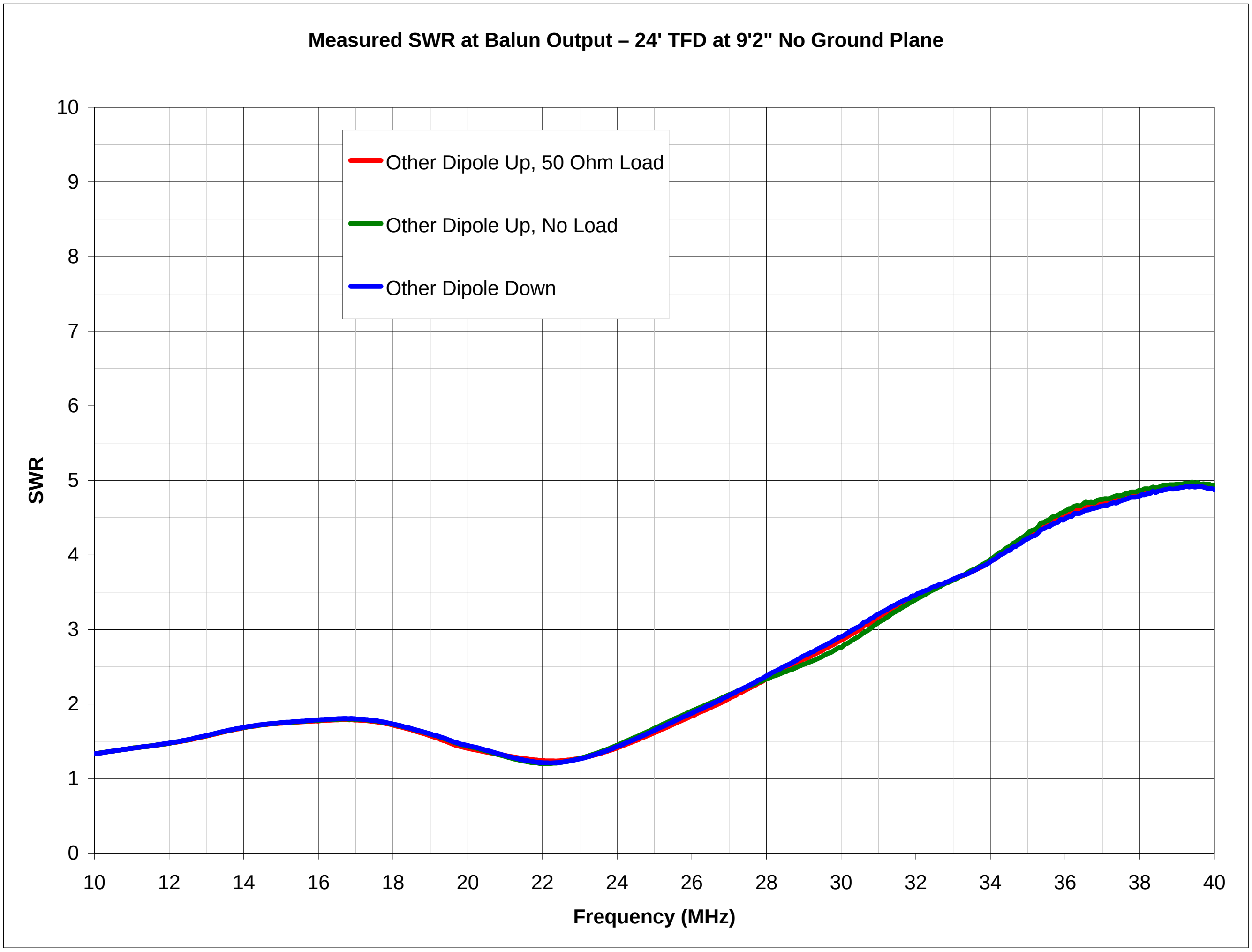

Figure 11 – 24′ TFD without a ground plane.

To compare the 18′ and 24′ TFD antennas, with and without a ground plane, the data from the lone dipole tests (tests in which the other dipole was lowered to the ground) is plotted together in Figure 12.

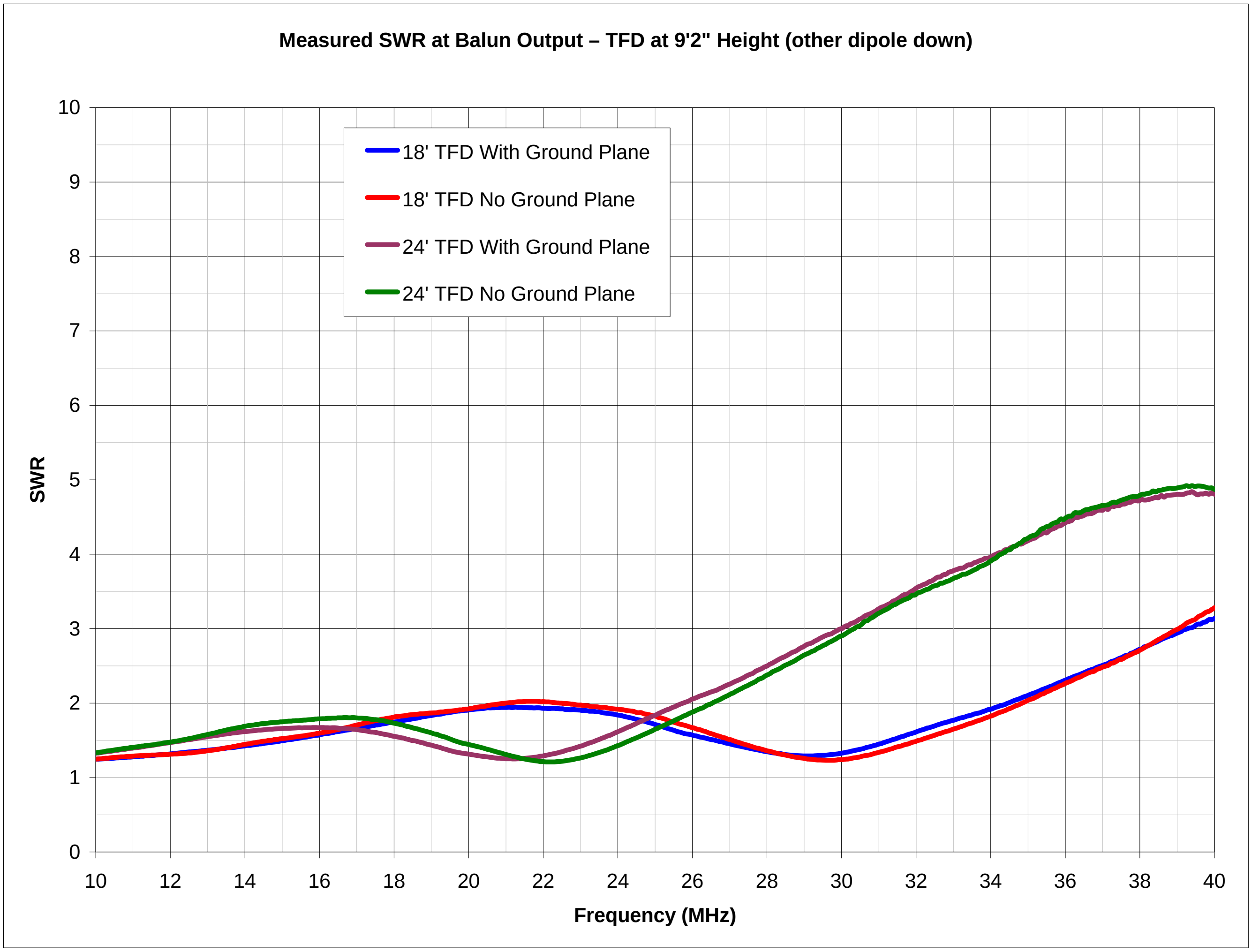

Figure 12 – Comparison of the 18′ and 24′ TFD antennas without the presence of another dipole. Remember the caption for Fig 8 regarding false SWR readings at lower frequencies.

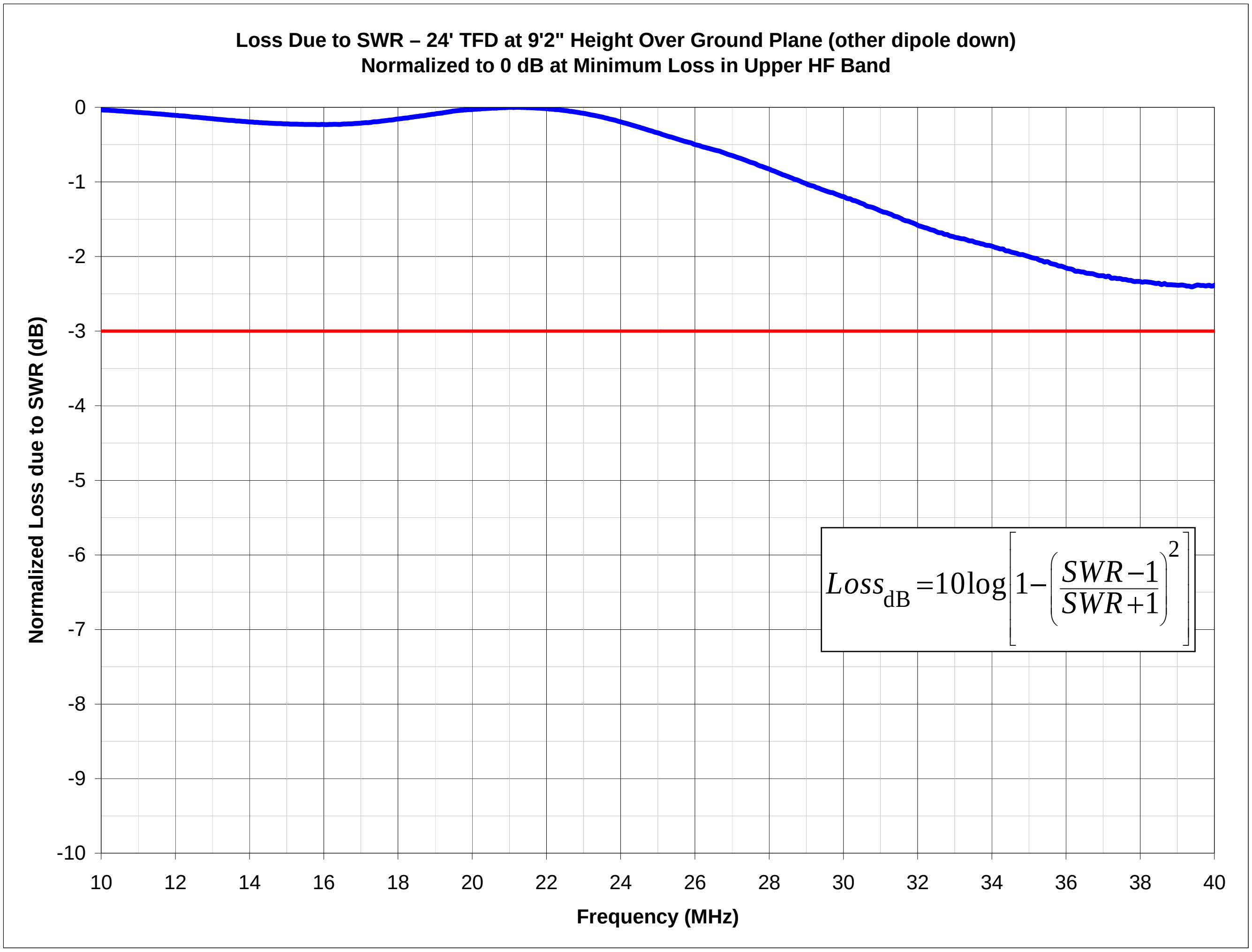

Figure 13 – Loss due to SWR for the 24′ TFD antenna.

We can calculate the amount of attenuation produced by the impedance mismatch at the balun output (given in terms of SWR) across the RF spectrum by using the equation shown in Figure 13. In contrast to the Jove dipole, there is no clearly resonant frequency for a TFD. However, the same normalization process is used for sake of clarity: the loss is normalized to indicate 0 dB loss at 21 MHz, the lowest meaningful SWR.

The same plot for the 18′ TFD can be made – but to no avail. Even the plot above does not tell most of the story. Since this antenna is non-resonant, there is much more than 0.1 dB of attenuation between the sky and the balun output at 20 MHz. Tests with the galactic background relative to a Jove dipole (assumed to have very little loss at 20 MHz) show that the true attenuation for the 24′ TFD at 20 MHz is about 3.7 dB. The 20 MHz attenuation of the 18′ TFD is 9 dB. This makes the 18′ TFD of questionable value. The galactic background results are covered in the next section.

Galactic Background Analysis

The signal from the antennas described above were fed to a calibrated Jove receiver to compare the reported antenna temperature and to see how much of a diurnal change in the galactic background (GB) was produced by each antenna. The results are summarized below.

For these tests, the antennas were above a ground plane with no other dipole present. There was 1.9 dB feed line loss between the feed point (Jove dipoles) or balun outputs (TFD antennas) and the input to Multicoupler C (MC-C, see station diagram here). The Jove receiver was connected to the MC's +5.4 dB port for the Jove dipole test and the +9.4 dB port for the TFD tests. The strip chart (Radio Sky Pipe) was calibrated with a 17.7 kK noise source at the input to MC-C.

An identical test series is currently being performed without a ground plane. It is not yet complete as of this writing.

The results shown below in Table 1 indicate that the 24′ TFD is about 3.7 dB down compared to the Jove dipole. This is an acceptable trade-off for the much wider bandwidth of the TFD.

In contrast, the 18′ TFD has much less efficiency; it is 9 dB down compared to the Jove dipole. This antenna would work in a pinch, but it is hard by the upper limit of acceptable loss. If total loss to a spectrograph or Jove receiver should not exceed 12 dB, this leaves only 3 dB for feed line losses.

Use of a multicoupler with some gain ahead of the receiver can alleviate this problem. As we see in Table 1, even the poorly performing 18′ TFD saw the same diurnal change in the GB as the other two antennas, a little under 2 dB. Note that the TFD in this case was connected to a multicoupler with 9.4 dB of gain ahead of the Jove receiver.

	Avg Ant Temp kK @ UTC Date	0400 (kK)	1100 (kK)	0400 UTC Norm to 5 dB Port (kK)	0400 UTC Relative Response at 20 MHz (dB)	1100 UTC Norm to 5 dB Port (kK)	1100 UTC Relative Response at 20 MHz (dB)
Single 22' 8" Jove Dipole at 10' Height with Ground Plane (Single Element REFERENCE ANTENNA)							
MC-C Port (dB):		5.4					
	24-Jul-14	60.95	39.70				
†	25-Jul-14	56.50	37.07				
	26-Jul-14	52.86	33.83				
	3-day avg	56.77	36.87	56.8	**0.0**	36.9	**0.0**
	Diurnal Change (dB):		**1.9**				
18' TFD at 9' 2" Height with Ground Plane							
MC-C Port (dB):		**9.4**					
	21-Jul-14	18.39	12.07				
†	22-Jul-14	17.36	11.67				
	23-Jul-14	17.86	11.64				
	3-day avg	17.87	11.79	7.1	**–9.0**	4.7	**–8.9**
	Diurnal Change (dB):		**1.8**				
24' TFD at 9' 2" Height with Ground Plane							
MC-C Port (dB):		**9.4**					
	27-Jul-14	63.52	39.68				
†	28-Jul-14	62.83	40.07				
	29-Jul-14	62.26	39.83				
	3-day avg	62.87	39.86	25.0	**–3.6**	15.9	**–3.7**
	Diurnal Change (dB):		**2.0**				

Normalization removes increased MC gain from TFD tests so temperature can be compared to that of the reference antenna.
E.g., 11.79 kK * 10^((5.4 dB – 9.4 dB) / 10) = 4.7 kK

† indicates dates for which spectral analysis was performed

Table 1 – Relative antenna responses via analysis of observed galactic background.

Spectral Analysis

Another way to get a good idea of an antenna's performance is to see what the output of a spectrograph looks like. In opposition to the theoretical performance derived from measured SWR, this method offers a real-world look at the antenna's end-to-end performance.

For this series of tests, an SDR-14 was connected to another 5 dB port on the multicoupler used for the galactic background observations described above. The SDR was calibrated using a hot noise source and a step attenuator. The calibration procedure is described here.

Spectrograms on the days indicated in Table 1 (pink crosses) were generated and plots made of the continua at 0400 UTC (galactic core in the beam) and 1100 (galactic pole in the beam).

The results are shown in Figures 14 to 17 and Figures 21 and 22.

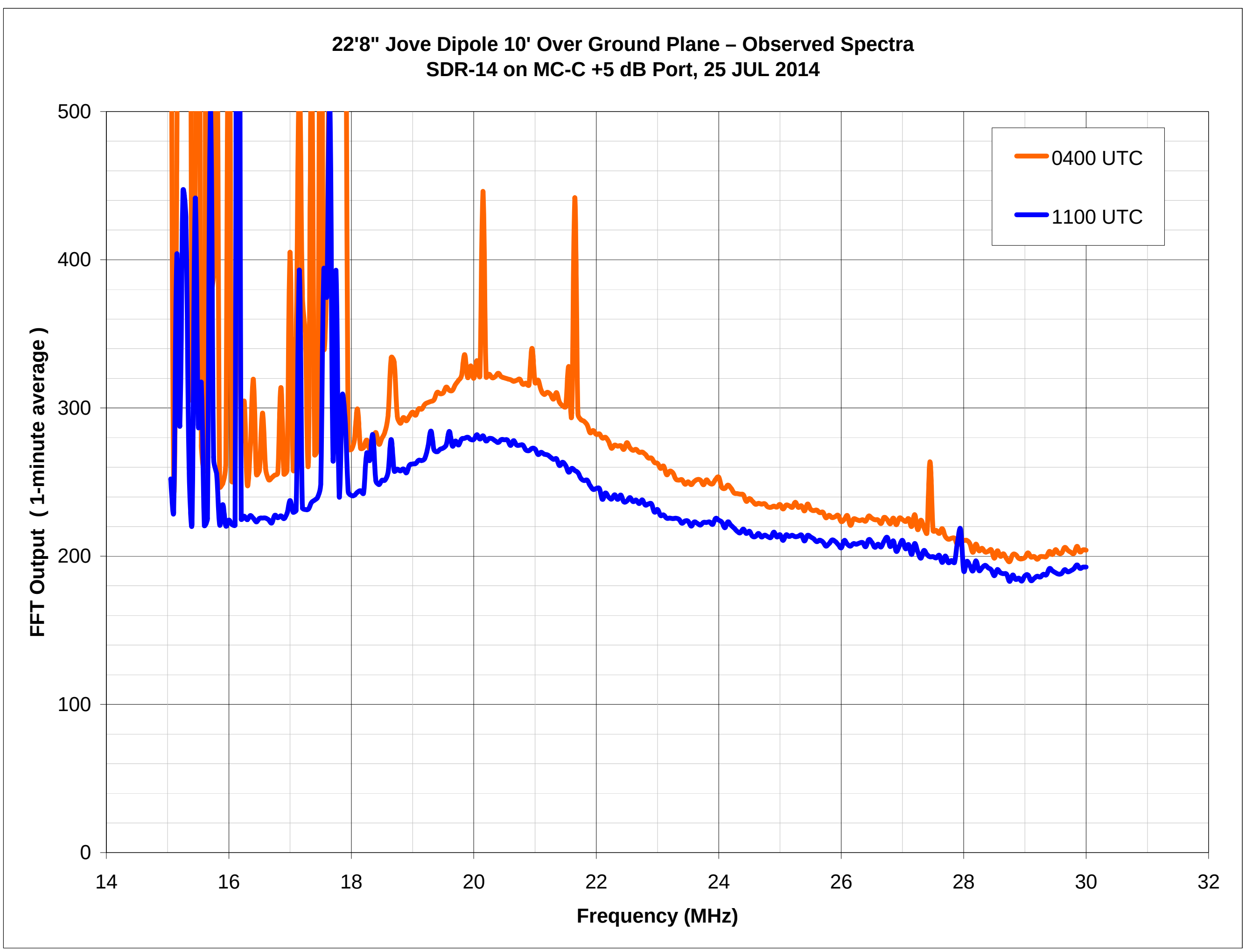

Figure 14 – Continua for the Jove dipole.

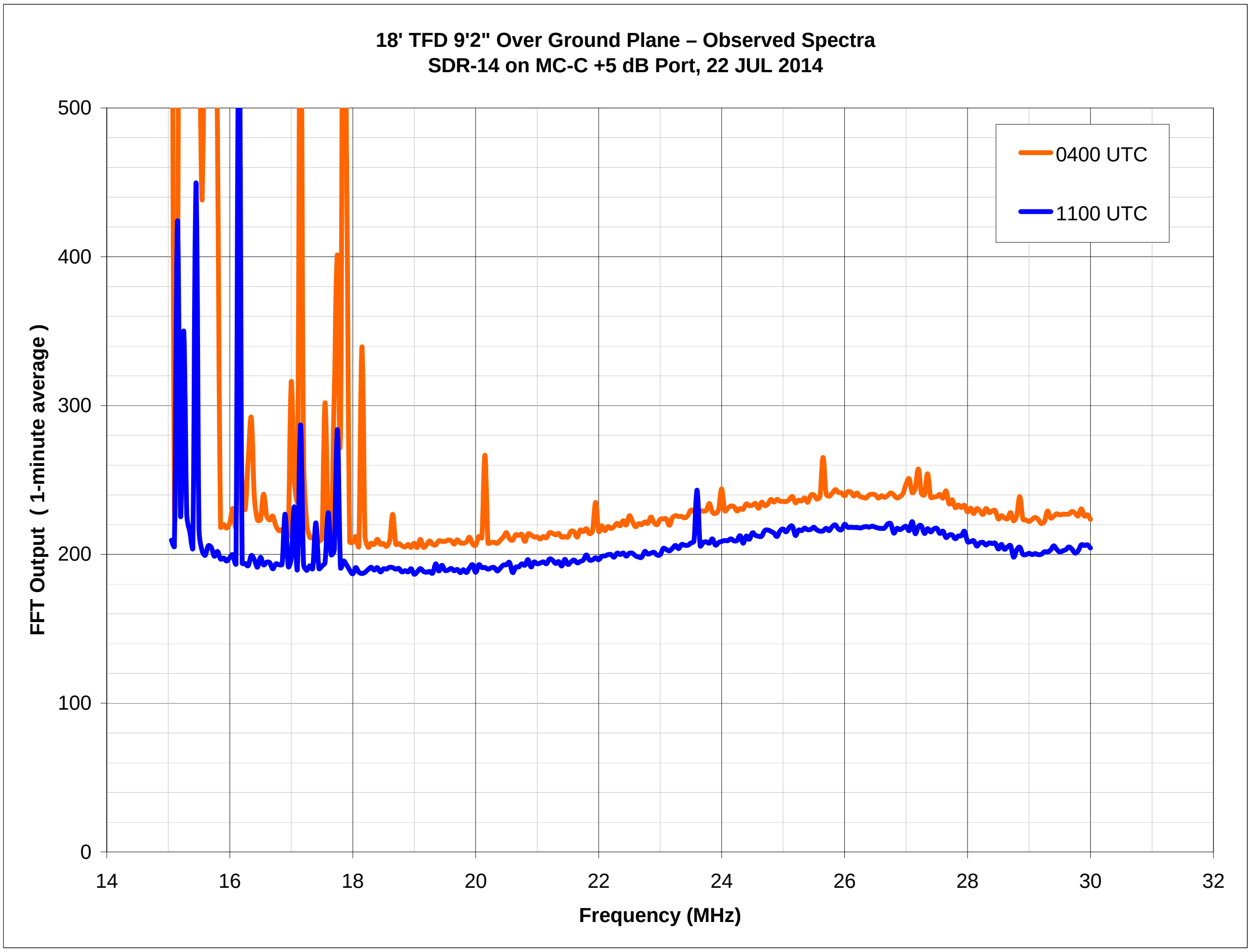

Figure 15 – Continua for the 18′ TFD.

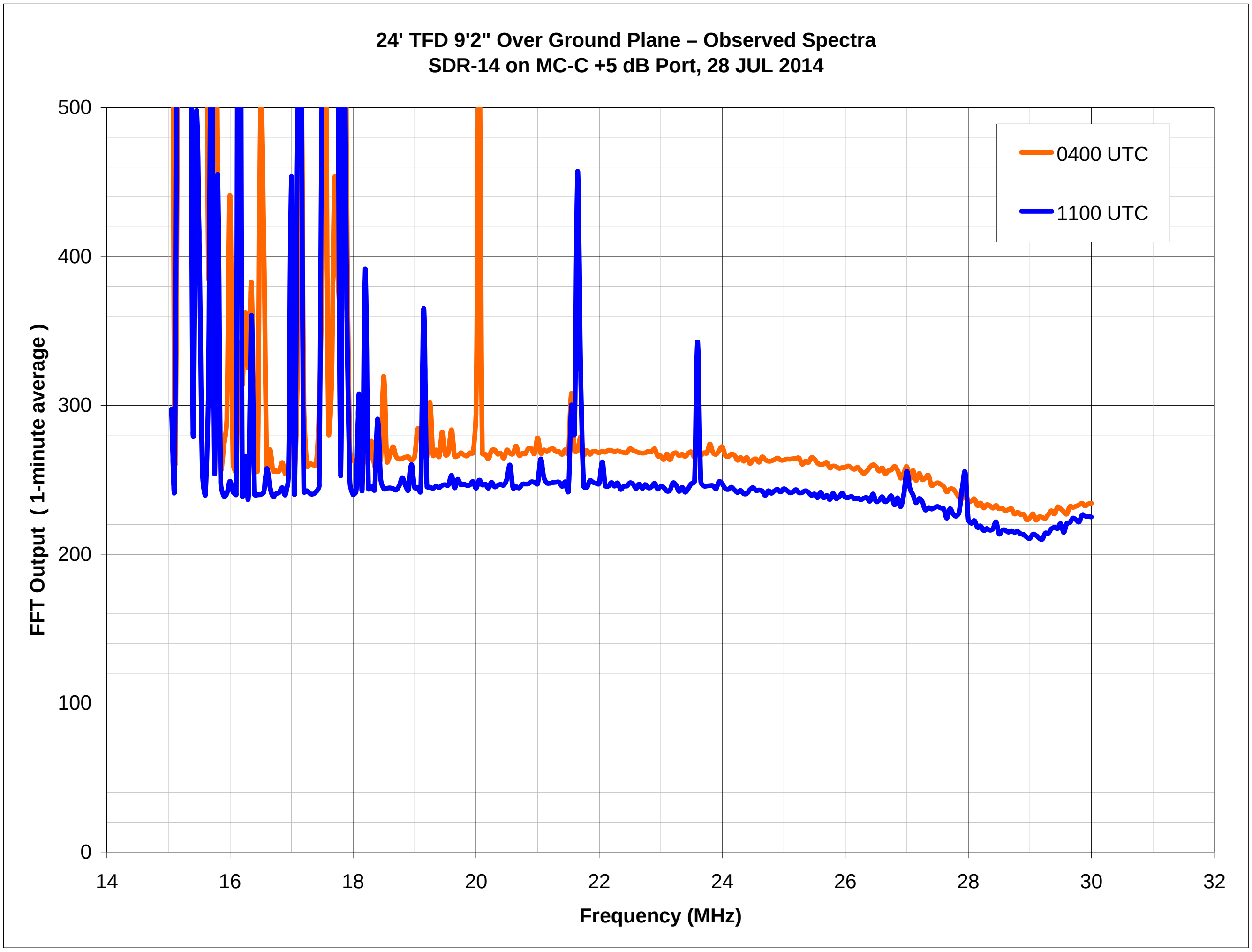

Figure 16 – Continua for the 24′ TFD.

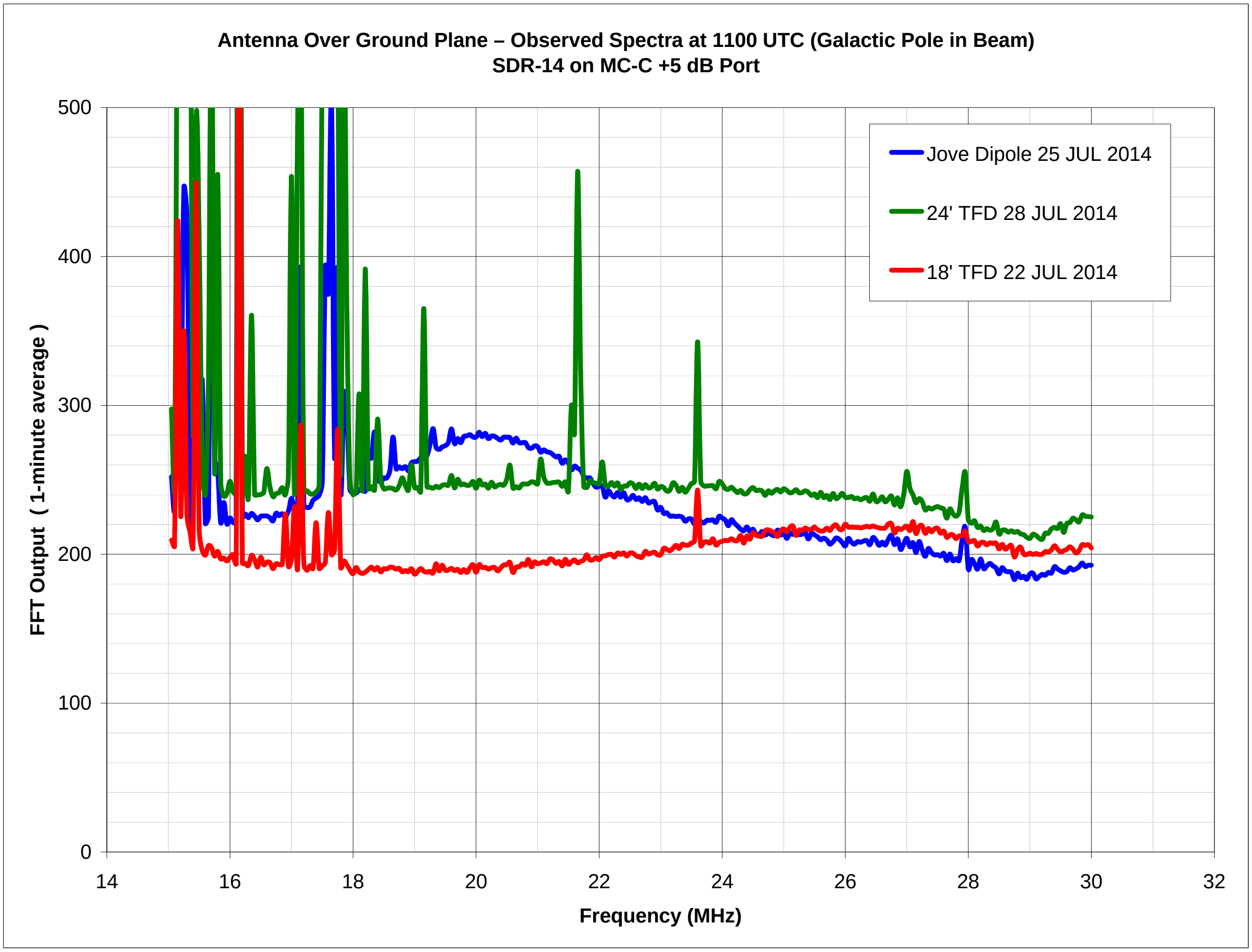

Figure 17 – Comparison of the continua produced by the three antennas under test.

One should note that the apparent flatness of the 24 MHz TFD is only a happy coincidence. The slope of the galactic background and the response curve of the antenna work together to produce an apparently flat continuum by pure luck (but we'll take it). All three antennas have some roll-off above 27 or 28 MHz. It is unknown if the lower GB is being seen, or if this is the shoulder of the 0 to 30 MHz anti-aliasing filter in the SDR-14.

The abrupt increase from 29 to 30 MHz is an artifact of RFI, seen in the spectrograms in Figures 21 and 22.

The diurnal changes and the absolute antenna temperatures shown in the continua plots agree well with those shown in Table 1 from the strip chart data.

For example, in Figure 14, the 20 MHz GB goes from 280 to 320 (raw FFT output). At this output level, the response of the FFT output is about 20 units per dB, so we see a 2 dB change.

Also, 280 units is about 40 kK antenna temperature and 320 units is about 60 kK antenna temperature. The values reported by the strip chart are 37 kK and 57 kK respectively – very good agreement between two completely independent instruments.

The calibration data for the SDR-14 is show in Figures 18 to 20. This calibration accounts for the 1.9 dB of feed line loss between the antenna under test and the input to the multicoupler.

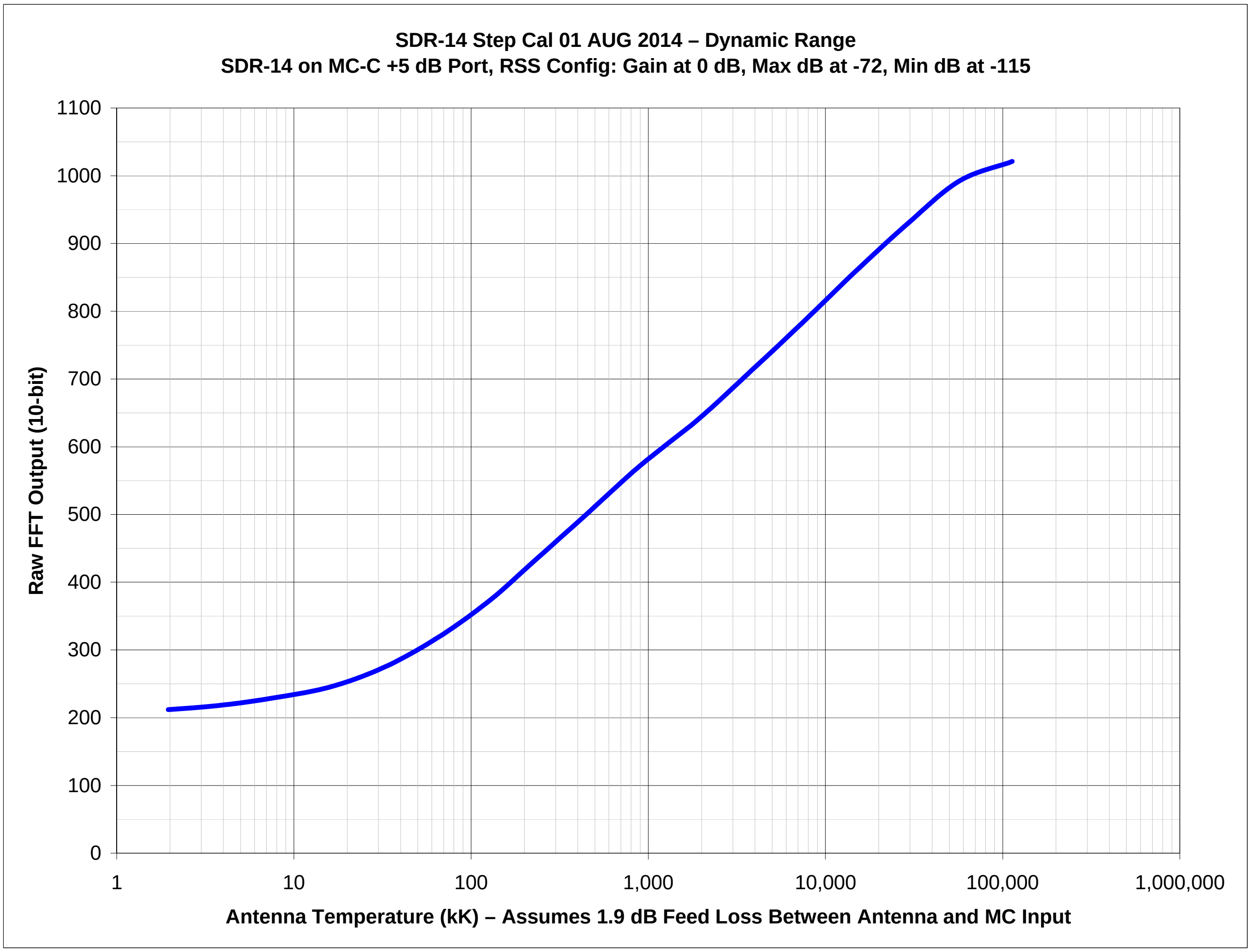

Figure 18 – SDR-14 calibration, raw FFT output showing approximately 30 dB dynamic range.

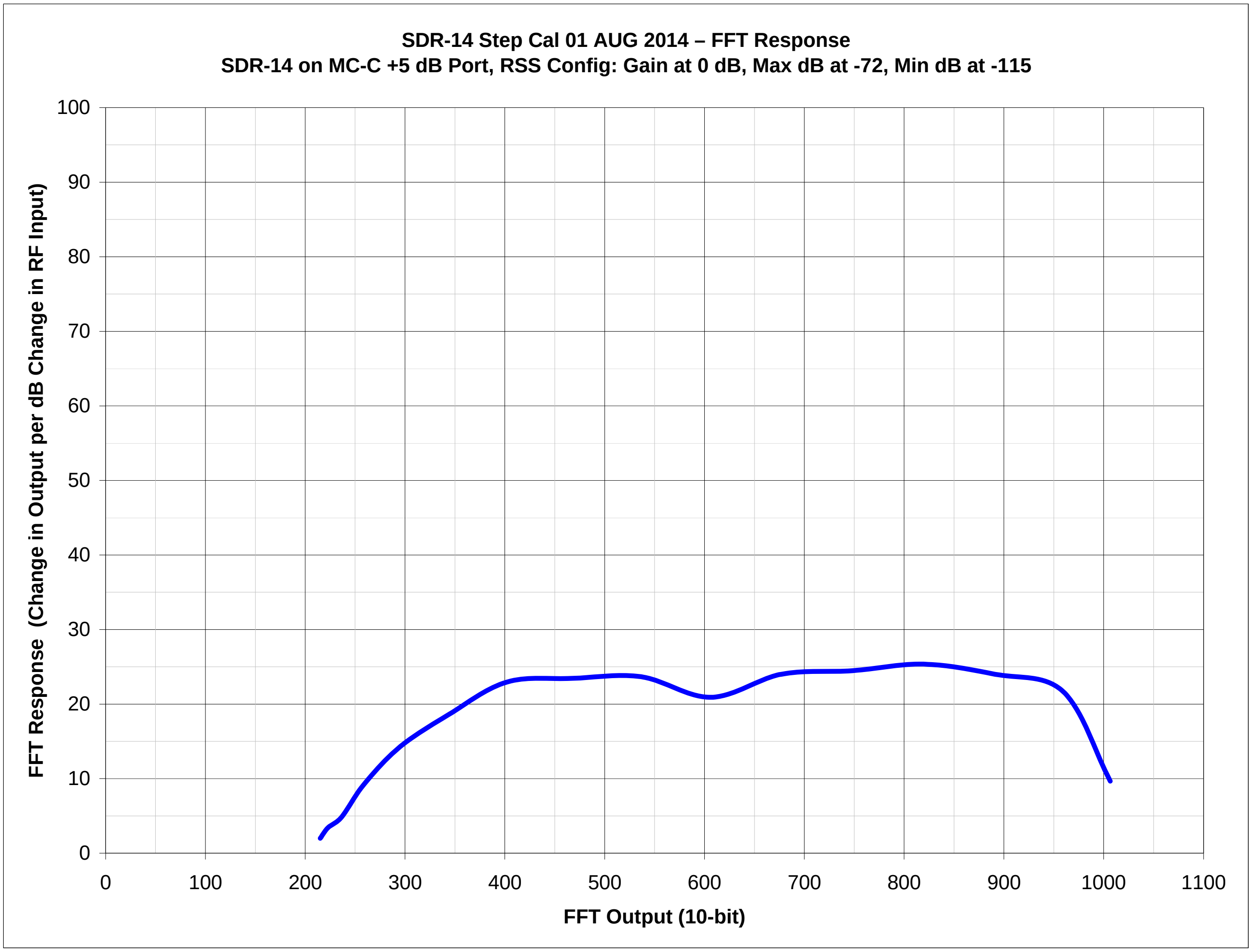

Figure 19 – SDR-14 calibration, FFT response. This is equivalent to the "detector response" of a swept frequency spectrograph. We can see from this that the GB tests were down in the less sensitive bottom end of the curve. To convert the horizontal axis to antenna temperature, see Figure 18. The horizontal axis here is given in terms of FFT output value to make the diurnal changes in the daily continua easier to calculate.

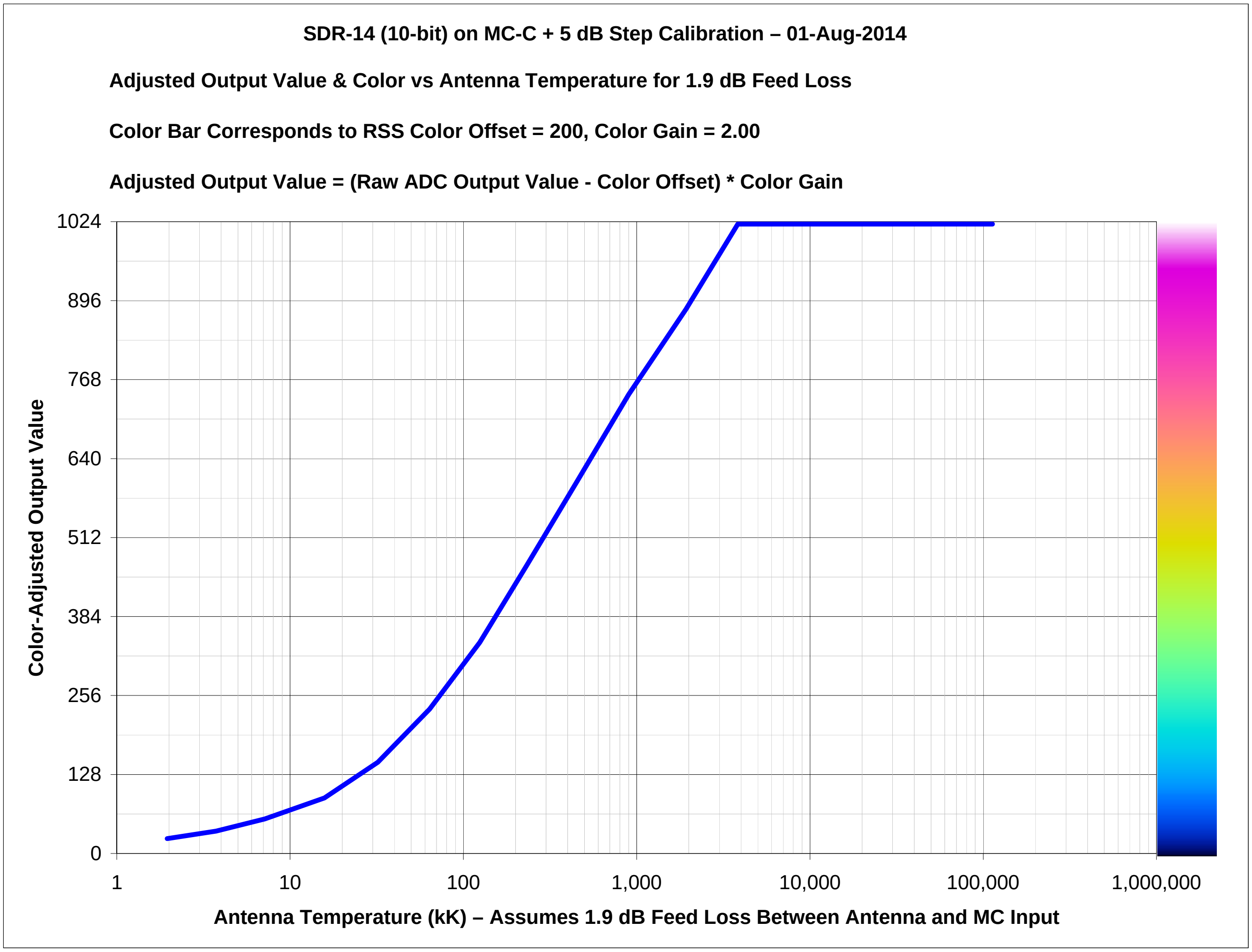

Figure 20 – SDR-14 calibrated temperature color scale for the spectrograms shown below.

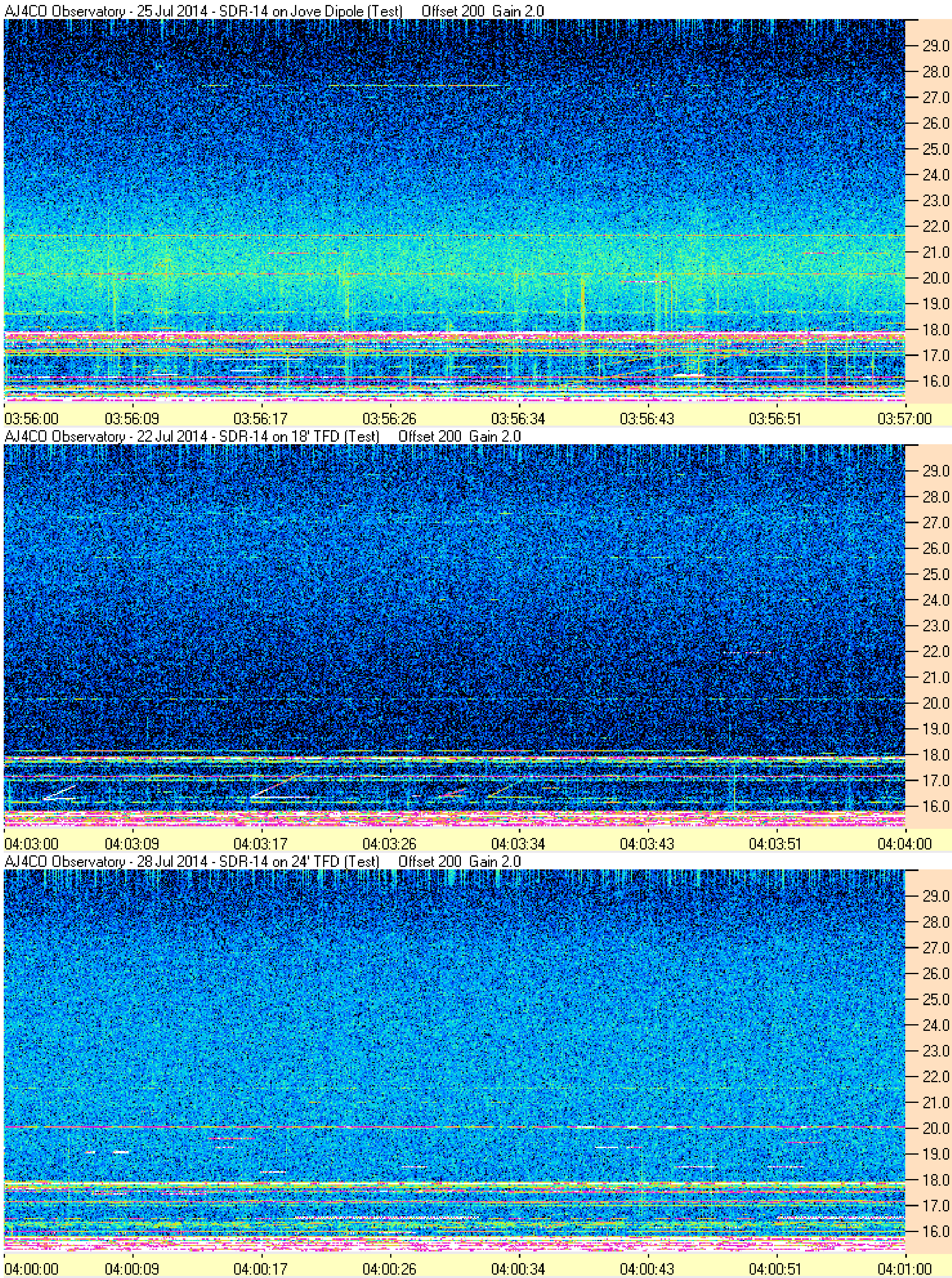

Figure 21 – Spectrograms showing the lucky flatness of the 24′ TFD, the narrow bandwidth of the Jove dipole, and the weak signal produced by the 18′ TFD. These spectrograms were made when the galactic core was in the beam.

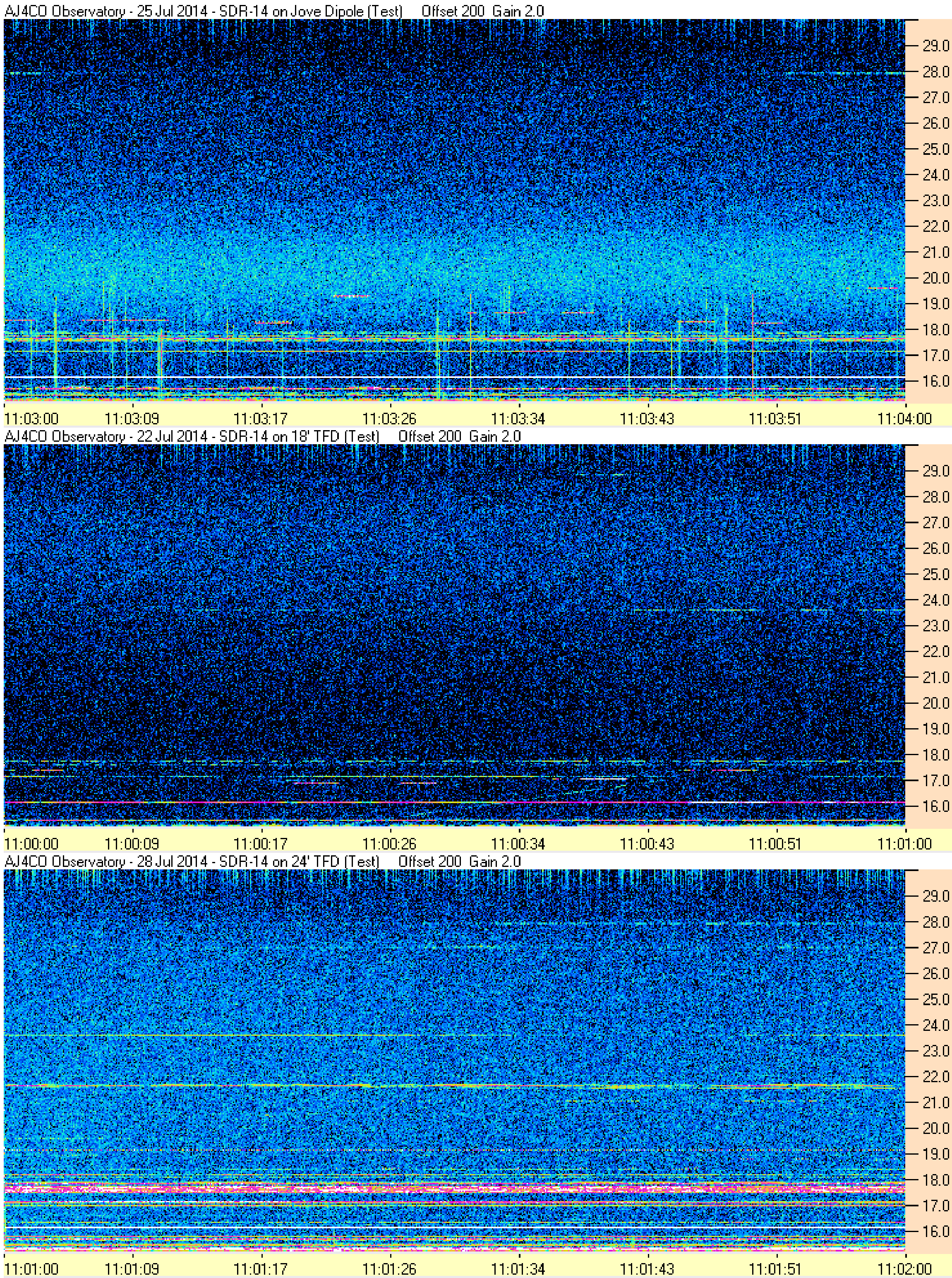

Figure 22 – Spectrograms with the galactic pole in the beam. Same relative characteristics as described in Figure 21, but this time about 2 dB colder.

Conclusion

The Jove dipole – and by extension, the Jove array – is the perfect antenna for single frequency operation. It is simple, inexpensive to build, and it works great.

For spectrograph operation – i.e., wideband observing, a narrow band antenna like the Jove dipole will work, but with some contraints to the spectrograms as shown in this article.

The 18′ TFD is a bit short to have a good response at the frequencies monitored by the Radio Jove program unless one uses a multicoupler or preamp with around 10 dB gain

30′ TFD elements, while not tested in this series, probably have a better response at the lower frequencies; however, arrays made from them suffer from undesirable grating lobes at the upper end of the HF band due to their large size. More inconveniently, they will not fit between existing Jove array masts.

The 24′ TFD has been shown to be a well-performing wide band antenna. It has the nice feature of being small enough to fit between pre-existing Jove array masts. The 24′ TFD does not require the added gain of a multicoupler or preamp unless feed line loss is very large (greater than around 8 dB).