Measuring cable attenuation over 1 Hz -1.6 GHz for GPS signals and a cosmic ray detector: standard RG58A/U coax and LMR400 low loss cables

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Objective:

To determine why we are unable to receive GPS antenna signals transmitted across some long 100+ foot cables in our lab.

Hypothesis:

We are unable to receive the antenna signals because the long cables are attenuating them, therefore the GPS receiver can’t detect them.

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GPS ACTIVE 28dB MAGNETIC ANTENNA+RG174(5M)+SMA PLUG

RoHS

Ceramic Path Specification:

Operating Frequency	T1 1575.42±1.023 MHz
Output Impedance	50 ohms
Polarization	R.H.C.P.
Bandwidth	10 MHz min. @S11<=-10 dB
Gain at 10° elevation	-1 dBic Typ.
Axial Ratio	3.0 dB Typ.

LNA/Filter Specification:

Operating Frequency	T1 1575.42±1.023 MHz
Gain	28 dB
Noise Figure	1.5 dB
Filter	DR Filter
	20dB 30dB min @ fo±50MHz
	30dB 35dB min @ fo±50MHz
	* fo=1575.42 MHz
Output VSWR	2.0 Max
Voltage	2.3~5.5V
Current	2.5V : 6.6mA Typical
	3V : 8.6mA Typical
	4V : 12.6mA Typical
	5V : 16.6mA Typical

General specification:

Dimensions	L 41.2xW38.5xH13.3 mm
Mount	Magnetic Antenna
Antenna Color	Black
Coaxial Cable	RG174 Length=5M (Option)
Cable Connector	SMA MALE (Option)
Operating Temperature	-30°C to +85°C
Storage Temperature	-40°C to +90°C

The GPS antenna sends out a signal just under 1.6 GHz.

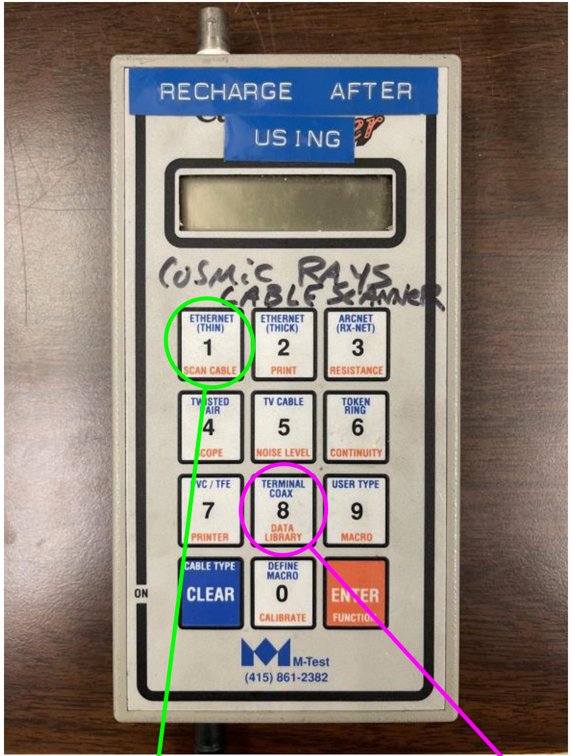
Attenuation (dB per 100 feet)										
	MHz:	**30**	**50**	**100**	**146**	**150**	**440**	**450**	**1000**	**2400**
#2632	**RG-174**	5.5	6.6	8.8	13.0		25.0		30.0	75.0
#0985	**LMR-100A®**	3.9	5.1		[illegible]	[illegible]	15.6	15.8		
#2619	**RG-58A/U**	2.5	4.1	5.3	6.1	6.1	10.4	10.6	24.0	38.9
#3603	**LMR-200®**	1.8	2.3		3.9	4.0	6.9	7.0		16.5
#2910	**RG-59**		2.4	3.5			7.6		12.0	
#2247	**RG-8X**	2.0	2.1	3.0	4.5	4.7	8.1	8.6		21.6
#3604	**LMR-240®**	1.3	1.7		3.0	3.0	5.2	5.3		12.7
#3605	**LMR-240 Ultra®**	1.3	1.7		3.0	3.0	5.2	5.3		12.7
#2248	**RG-8/U FOAM**		1.2	1.8					7.1	
#2929	**RG-213**		1.5	2.1	2.8	2.8	5.1	5.1	8.2	
#0390	**RG-214**	1.2	1.6	1.9	2.8	2.8	5.1	5.1	8.0	13.7
#3606	**LMR-400®**	0.7	0.9		1.5	1.5	2.7	2.7		6.6
#3607	**LMR-400 Ultra®**	0.7	0.9		1.5	1.5	2.7	2.7		6.6
#6512	**DRF-400**	0.7	0.9		1.5			2.7		6.7
#5297	**Bury-FLEX™**		1.1	1.5					4.8	
#0812	**9086**			1.4			2.8	2.8		
#0075	**9913**	0.8			1.5		2.8			7.5

Values indicated are *approximate* and for comparison purposes only.
LMR® is a registered trademark of Times Microwave Systems.

The cables we used at our station 1A (St1A) and station 8B (St8B) were RG-58A/U, which have a specified attenuation of 24.0 dB per 100 feet at 1 GHz.

Frequency (MHz)	30	50	150	220	450	900	1500
Attenuation dB/100 ft	0.7	0.9	1.5	1.9	2.7	3.9	5.1
Attenuation dB/100 m	2.2	2.9	5.0	6.1	8.9	12.8	16.8

The cable used at station 9 (St9) was an LMR-400, which has a specified attenuation between 3.9 dB and 5.1 dB per 100 feet at 1 GHz.



The scanner was set to the ethernet (thin) setting to measure the length of cable St1A and St8B

The scanner was set to the terminal coaxial setting to measure the length of cable St9

The lengths of the cable St1A and St8B were measured with a cable scanner, but not physically measured.

The cable scanner was used to measure the length of each cable.

The length of the cable at St9 was known to be 105.5 ft +/- 0.005%

The cable scanner measured the length of the cable St9 to be 108 feet long, 2.8% more than the known length.

A random RG58 A/U cable, with length 43.5 ft +/- 0.03% was measured with the scanner.

The length measured by the scanner was 47 feet, 7.45% more than the known length.

The lengths of cable St1A and St8B measured by the scanner were both 101 feet, meaning the lengths of both Cable St1A and St8B are between 93.4755 and 108.5245 feet.

Signal Generator Output = 0 dBmW

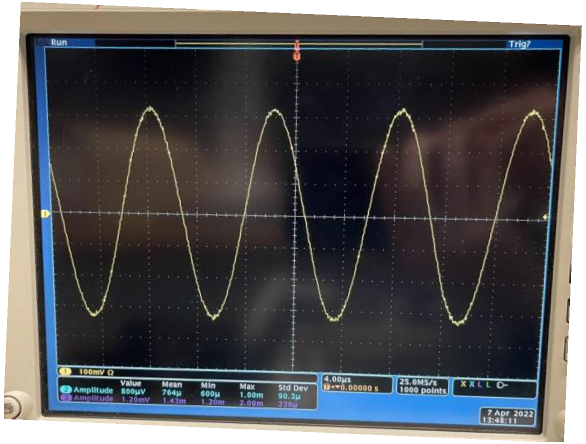
0 dBmW means a 1 mW signal is generated.

A 1mW signal means 316 mV is ran through a 50Ω load resistor.

$$0\ dBmW = 10\log\left(\frac{P}{1\ mW}\right) \rightarrow\ P = 1\ mW$$

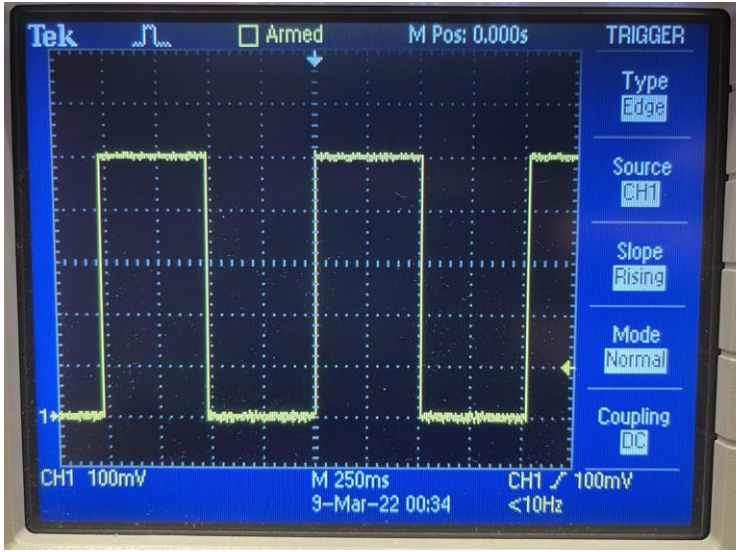
$$1\ mW = \frac{v^2}{R} = \frac{v^2}{50\Omega} = v = \sqrt[2]{50\Omega * .001\ W} = .224\ V = 224\ mV = V_{rms}$$

$$V_{rms} = \frac{V_{peak}}{\sqrt[2]{2}} \rightarrow\ V_{peak} = V_{rms}\left(\sqrt[2]{2}\right) = 224\ mV\left(\sqrt[2]{2}\right) = 316\ mV$$



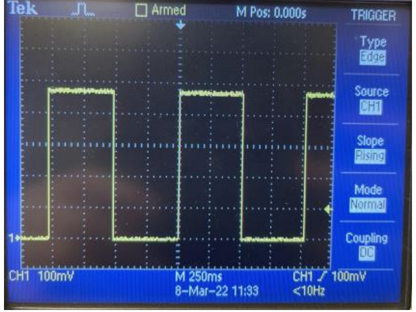
At 0.1 MHz, the signal measured through a 1.5 ft +/- 6.67% cable:
318 mV +/- 1%
Percent difference = 0.63% or ~0.027 dB

Since there is some difference between the value for V_{rms} calc V_{rms} l and observed, we wi V_{peak} ng for calculations.



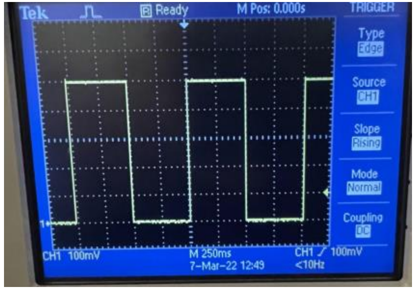
This reading was from an oscilloscope receiving a 1 Hz square wave, with an amplitude of 500 mV.

St1A



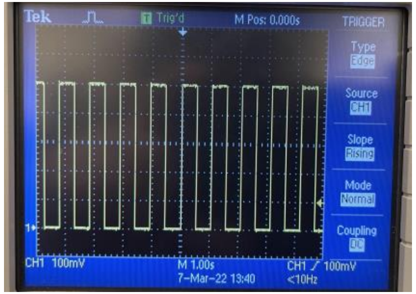
The 1 Hz signal ran through this cable has an amplitude of about 480 mv.

St8B

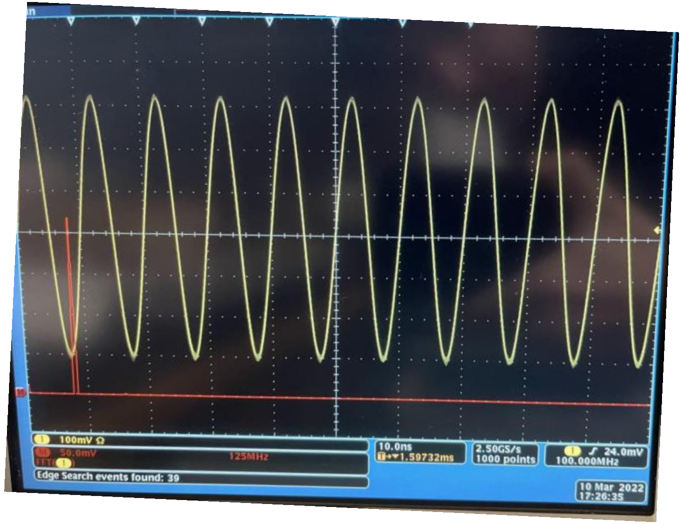


The 1 Hz signal ran through this cable has an amplitude of about 500 mv.

St9

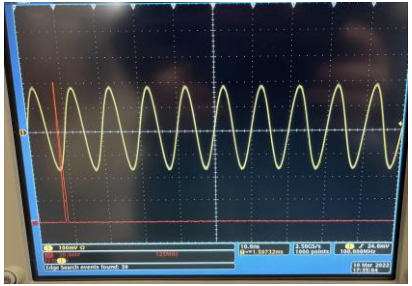


The 1 Hz signal ran through this cable has an amplitude of about 500 mv.



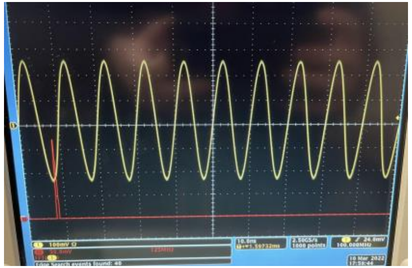
This reading was from an oscilloscope receiving a 100 MHz sinusoidal wave, with a displayed amplitude of ~316 mV.

St1A



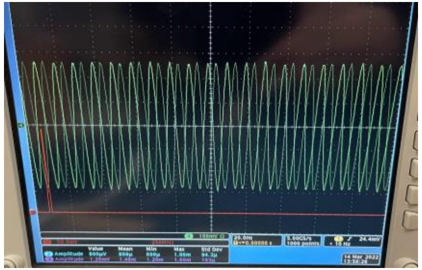
The 100 MHz signal ran through this cable has an amplitude of about 180 mV.

St8B

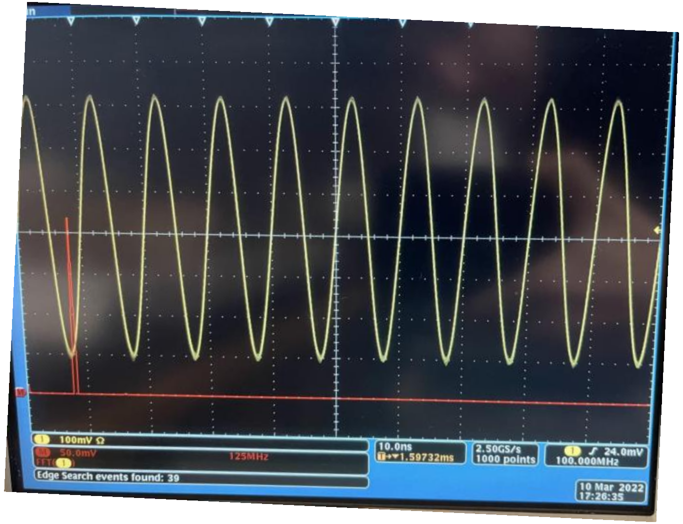


The 100 MHz signal ran through this cable has an amplitude of about 250 mV.

St9

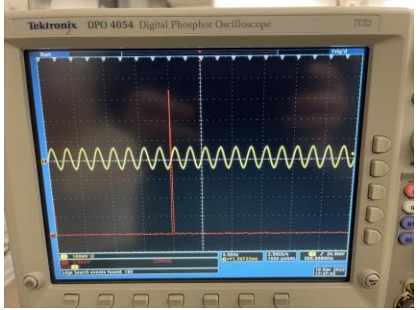


The 100 MHz signal ran through this cable has an amplitude of about 270 mV.



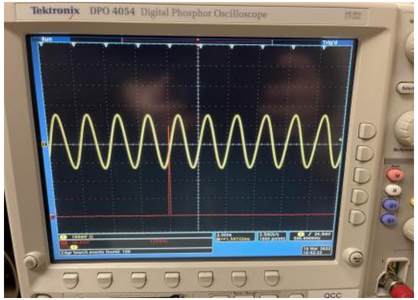
We use the same oscilloscope reading as before for our comparison, since a reading through the oscilloscope at a higher frequency would have attenuation.

St1A



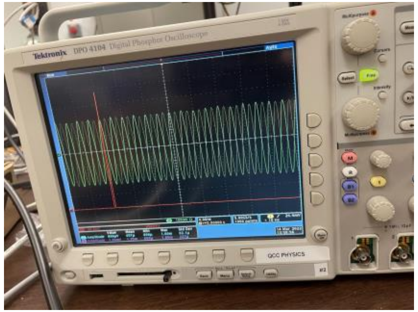
The 500 MHz signal ran through this cable has an amplitude of about 60 mV.

St8B

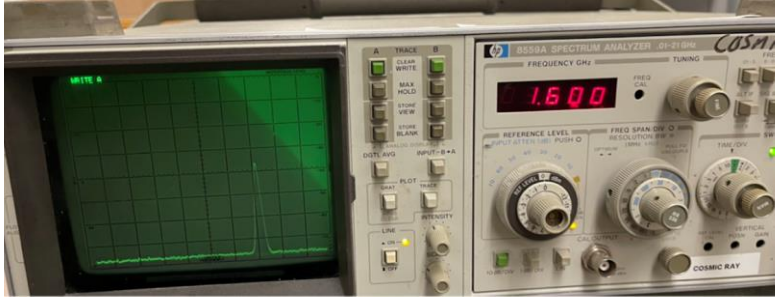


The 500 MHz signal ran through this cable has an amplitude of about 170 mV.

St9



The 500 MHz signal ran through this cable has an amplitude of about 230 mV.

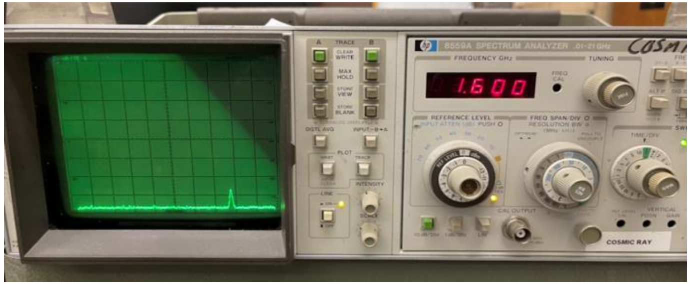


This reading is from a spectrum analyzer, receiving a 1.6 GHz signal. The plot displays -36 dB.

St8B

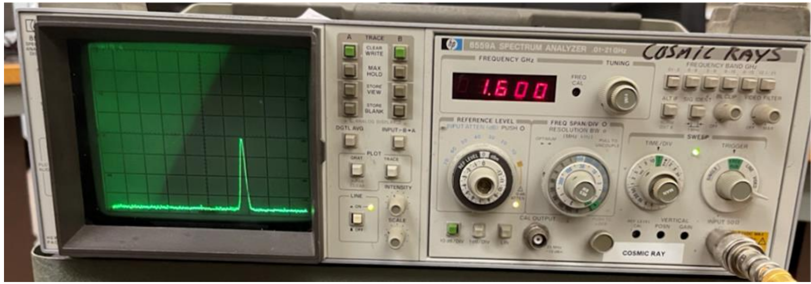
This reading shows the 1.6 GHz signal, ran through cable St8B as - 48 dB.

St1A



This reading shows the 1.6 GHz signal, ran through cable St1A as - 67 dB.

St9



This reading shows the 1.6 GHz signal, ran through cable St 9 as - 41 dB.

The mV difference for each cable at 1 Hz were as follows:

St1A:
500 mV - 480 mV = 20 mV

St8B:
500 mV - 500 mV = 0 mV

St9:
500mV - 500mV = 0 mV

The mV difference for each cable at 500 MHz were as follows:

St1A:
316 mV - 60 mV = 256 mV

St8B:
316 mV - 170 mV = 146 mV

St9:
316 mV - 230 mV = 86 mV

The mV difference for each cable at 100 MHz were as follows:

St1A:
316 mV - 180 mV = 136 mV

St8B:
316 mV - 250 mV = 66 mV

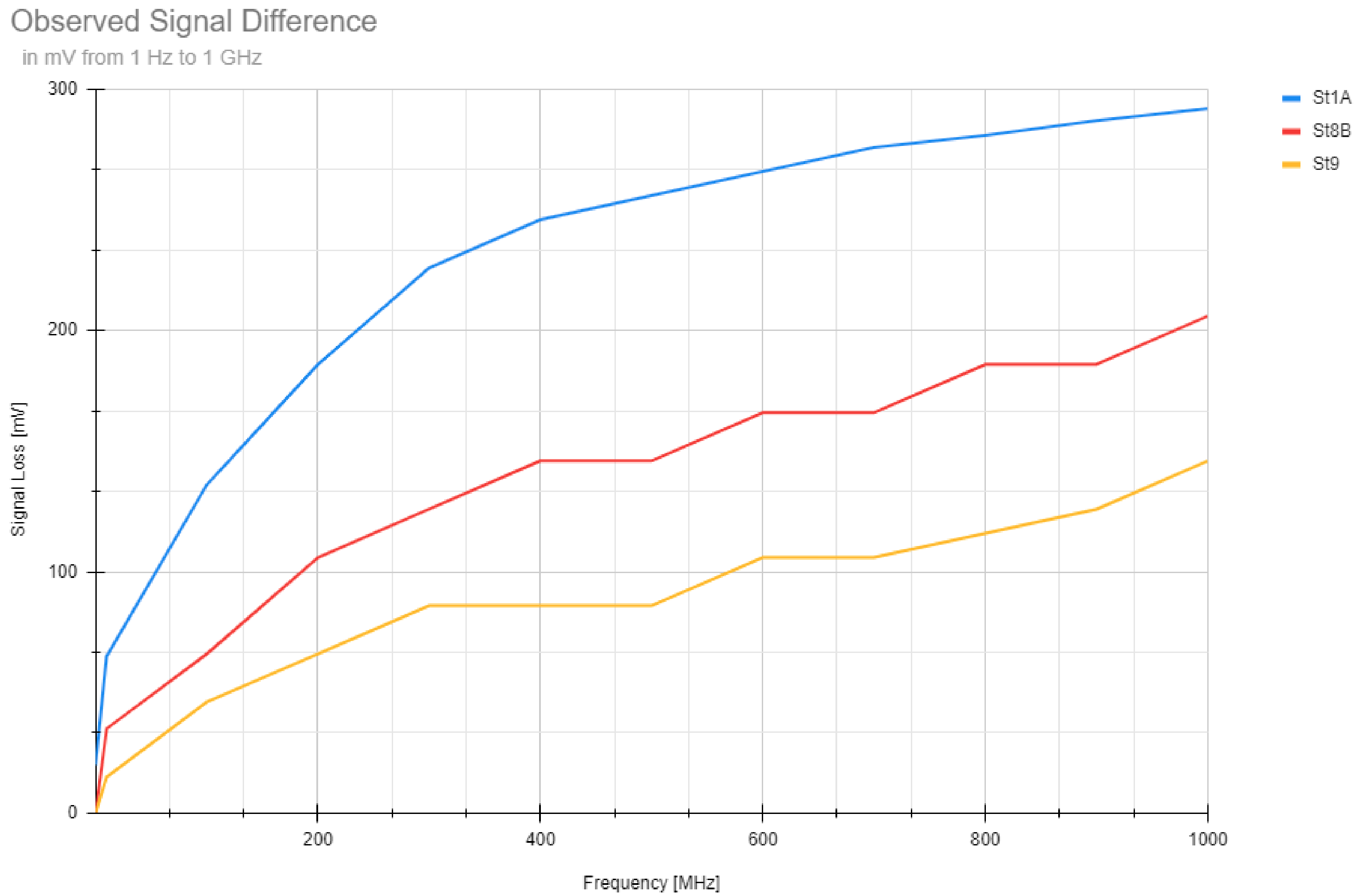
St9 :
316 mV - 270 mV = 46 mV

The dB difference at 1.6 GHz of each cable were as follow:

St1A:
67 dB - 36 dB = 31 dB

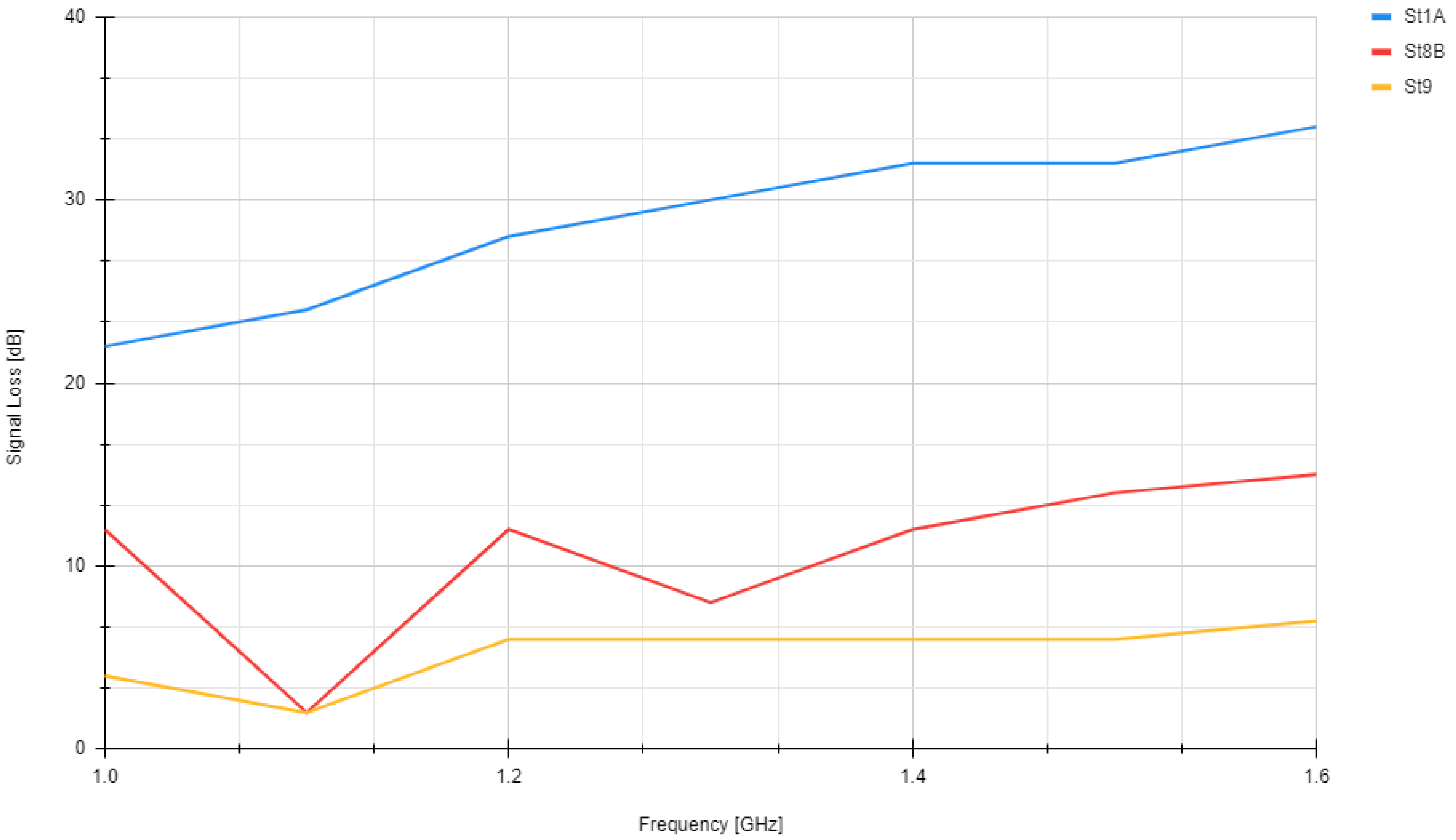
St8B:
48 dB - 36 dB = 12 dB

St9:
41 dB - 36 dB = 5 dB


Observed Signal Difference
in mV from 1 Hz to 1 GHz
Signal Loss [mV]
300
200
100
0
200
400
600
800
1000
Frequency [MHz]
St1A
St8B
St9

Observed Signal Difference

in dB from 1 GHz to 1.6 GHz



The dB loss at 1GHz for each cable were as follows:

St1A:

$$10\log\left(\frac{22^2}{316^2}\right) = -23.4\ dB$$

St8B:

$$10\log\left(\frac{110^2}{316^2}\right) = -9.42\ dB$$

St9:

$$10\log\left(\frac{170^2}{316^2}\right) = -5.62\ dB$$

The attenuation of each cable at 1 GHz were different than what was specified. The percent difference for the attenuations were as follows:

St1A:

$$\left(\frac{24-23.4}{24}\right) * 100\% = 2.5\%\ less$$

St8B:

$$\left(\frac{24-9.42}{24}\right) * 100\% = 60.75\%\ less$$

St9:

$$\left(\frac{5.62-4}{4}\right) * 100\% = 40.5\%\ more$$

The attenuation for each cable, compared to their specified attenuation, varied greatly. The attenuation for cable St1A was mostly similar to its specified attenuation at 1GHz, being only 2.5% smaller. At 1.6 GHz, however, the attenuation is assumedly greater than what is specified. For cable St8B, the attenuation was much less than what was specified, at each frequency. Cable St9's attenuation was higher than the specified attenuation, by nearly 50% at 1GHz, but was assumedly lower than what was specified at 1.6 GHz.

It can be concluded that the reason some long cables were not able to receive a signal is because the attenuation is too high. The cables used at station 1A and station 8B were both RG-58A/U cables, with the same length. The RG-58A/U cable used at station 1A experienced a signal loss of about 31dB, at a frequency of 1.6 GHz, meaning the signal would be only a thousandth of its original strength. The LMR-400 cable, used at station 9, experienced a signal loss of about 5 dB, at a frequency of 1.6 GHz, meaning the signal would about a third of its original strength. It should be noted that the RG-58A/U cable used at station 8B had a lower attenuation than the RG-58A/U cable used at station 1A, for every frequency. The reason for two identical types of cables having different attenuations is unknown, but is also not relevant to what we were trying to prove.

Since the signal attenuation of an LMR-400 cable is less than that of an RG-58A/U cable, for every frequency, it is the cable type that should be used for conducting this type of experiment.