Measuring cable attenuation over 1Hz to 1.6 GHz for GPS signals and a cosmic ray detector: comparison of standard RG58 A/U coax and LMR400 low loss coax cables

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In the Physics department's cosmic ray group we are designing and troubleshooting a GPS antenna and receiver system used to time-stamp cosmic ray events. This involves measuring the attenuation along ~100-foot-long RG-58A/U and LMR-400 cables, using pulse and frequency generators, an oscilloscope and a spectrum analyzer. We measured the signal loss and selected the cable type suitable for GPS pulse per second (PPS) and NMEA data communication.

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

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.

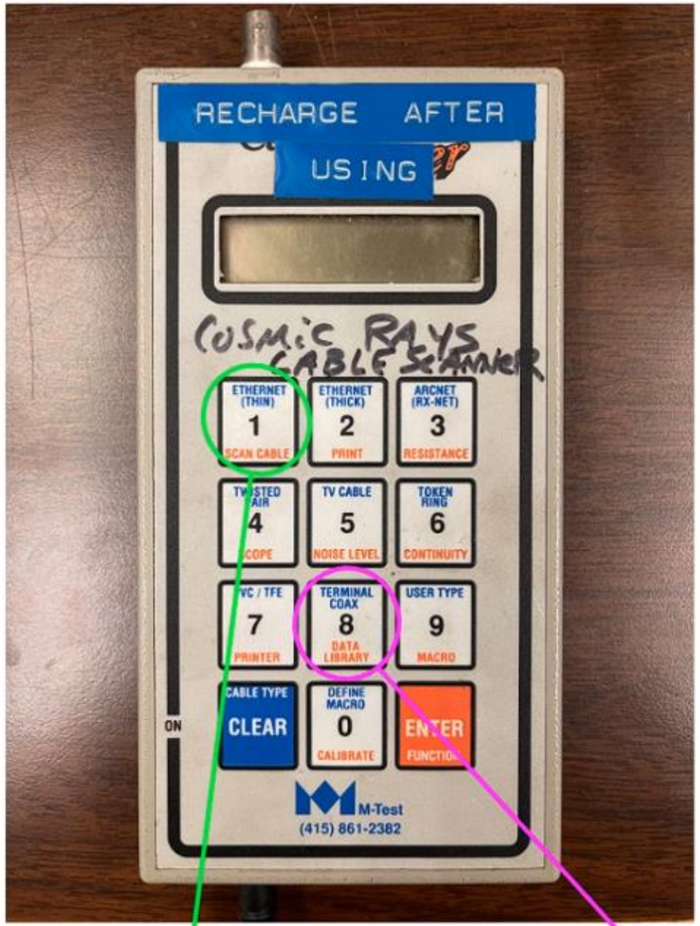
Attenuation (dB per 100 feet)										
	MHz:	30	50	100	146	150	440	450	1000	2400
#2632	**RG-174**	5.5	6.6	8.8	13.0		25.0		30.0	75.0
#0985	**LMR-100A®**	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		
#2619	**RG-58A/U**	2.5	4.1	5.3	6.1	6.1	10.4	10.6	24.0	38.9
#3603	**LMR-200®**	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		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

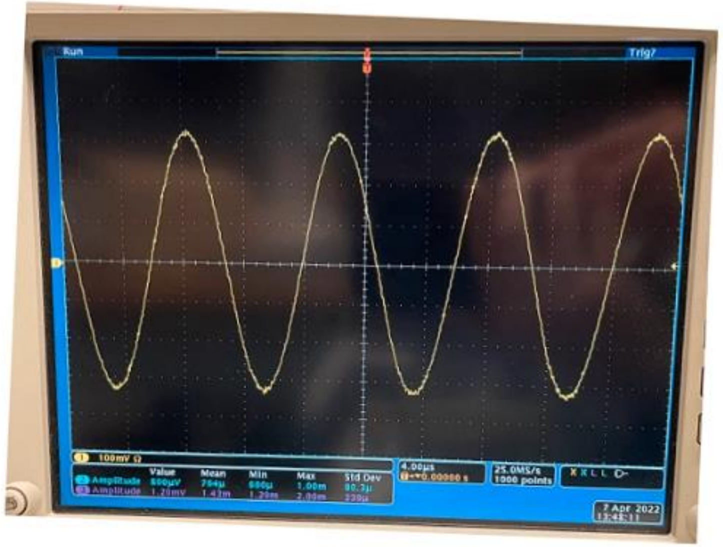
0 dBmW means a 1 mW signal is generated.

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

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

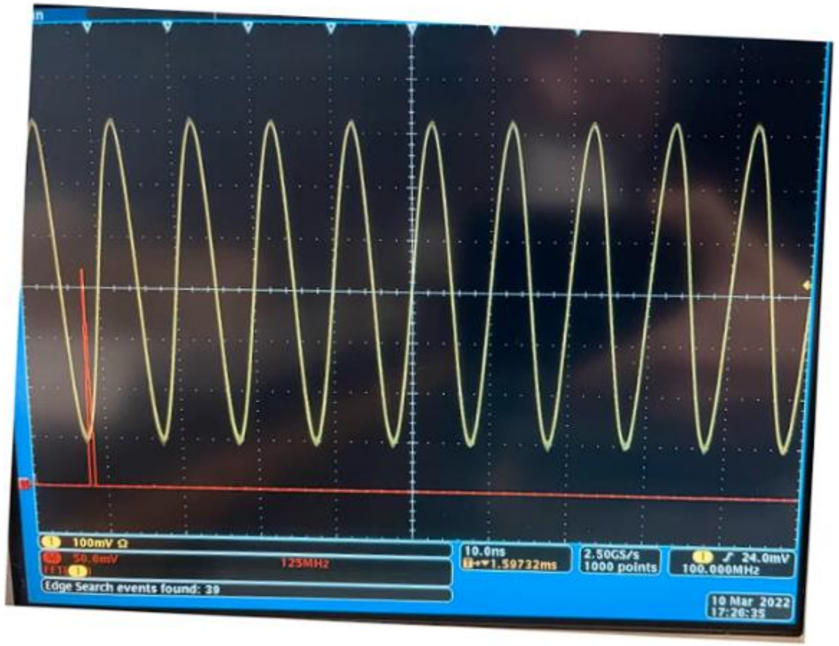
$$1\ mW = \frac{v^2}{R} = \frac{v^2}{50\Omega} = v = \sqrt[2]{50\Omega * .001\ W} = .224\ V = 224\ mV = V_{rms}$$

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



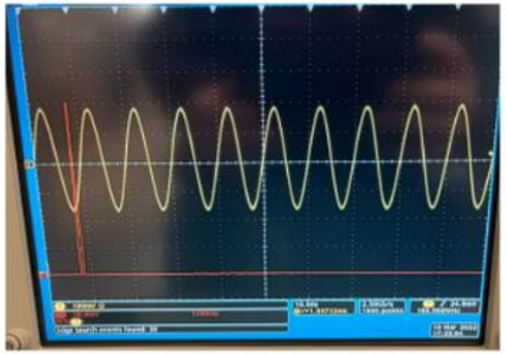
At 0.1 MHz, the signal measured through a 1.5 ft +/- 6.67% cable:
318 mV +/- 1%
Percent difference = 0.63% or ~0.027 dB

Since there is some difference between the value for V_{rms} calculated and V_{rms} observed, we will be using V_{peak} for calculations.



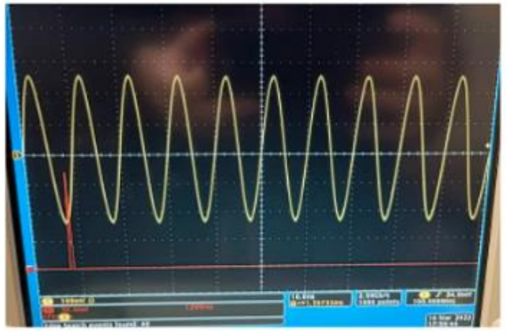
This reading was from an oscilloscope receiving a 100 MHz sinusoidal wave, with a displayed amplitude of ~316 mV.

St1A



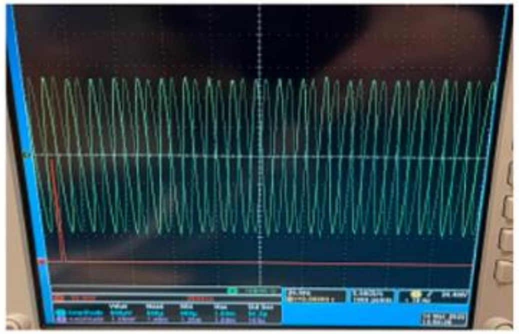
The 100 MHz signal ran through this cable has an amplitude of about 180 mV.

St8B



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

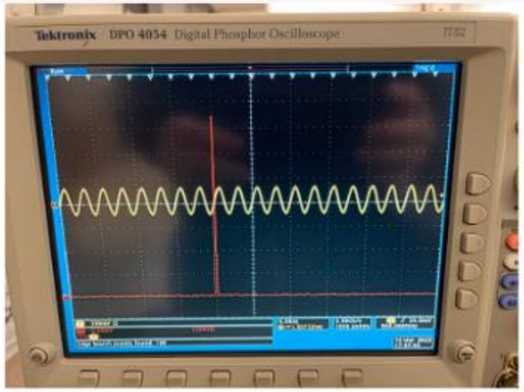
St9



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

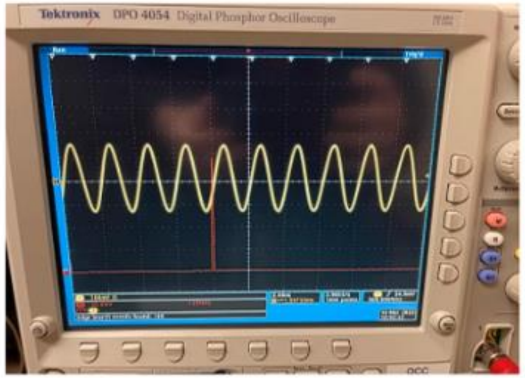
We use the same oscilloscope reading as before for our comparison, since a reading through the oscilloscope at a higher frequency would have attenuation.

St1A



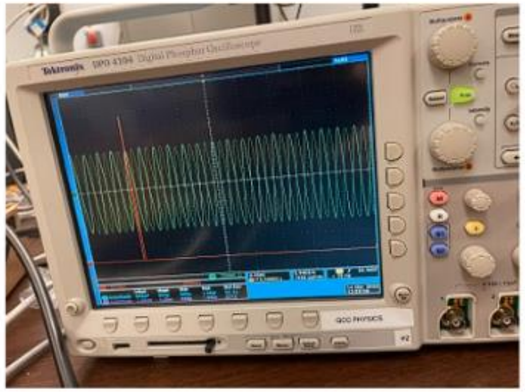
The 500 MHz signal ran through this cable has an amplitude of about 60 mV.

St8B

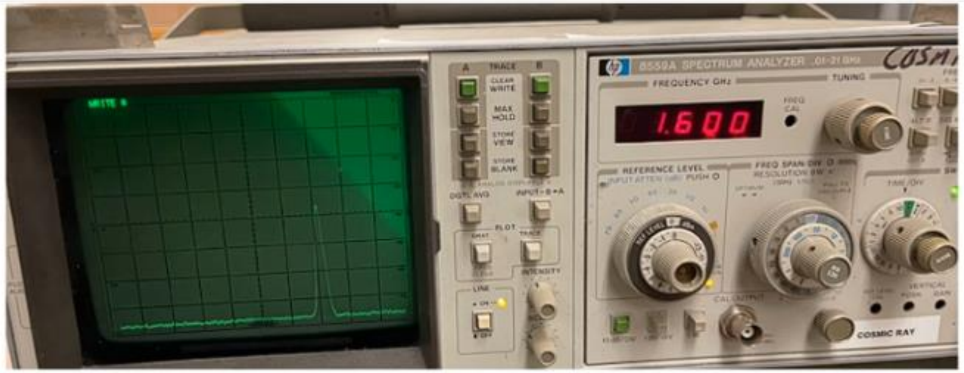


The 500 MHz signal ran through this cable has an amplitude of about 170 mV.

St9



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

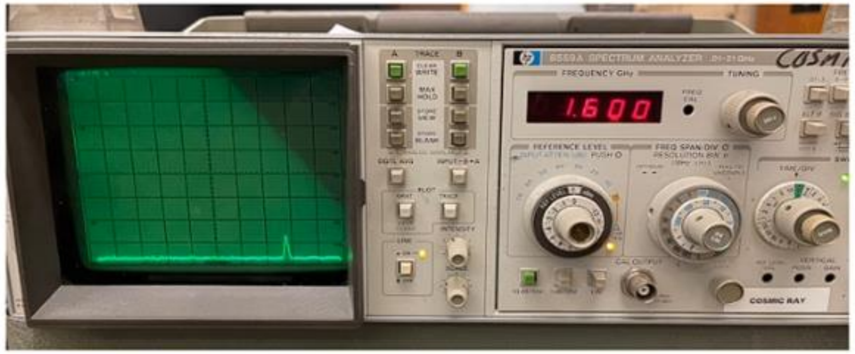


This reading is from a spectrum analyzer, receiving a 1.6 GHz signal. The plot displays -36 dB.

St8B

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

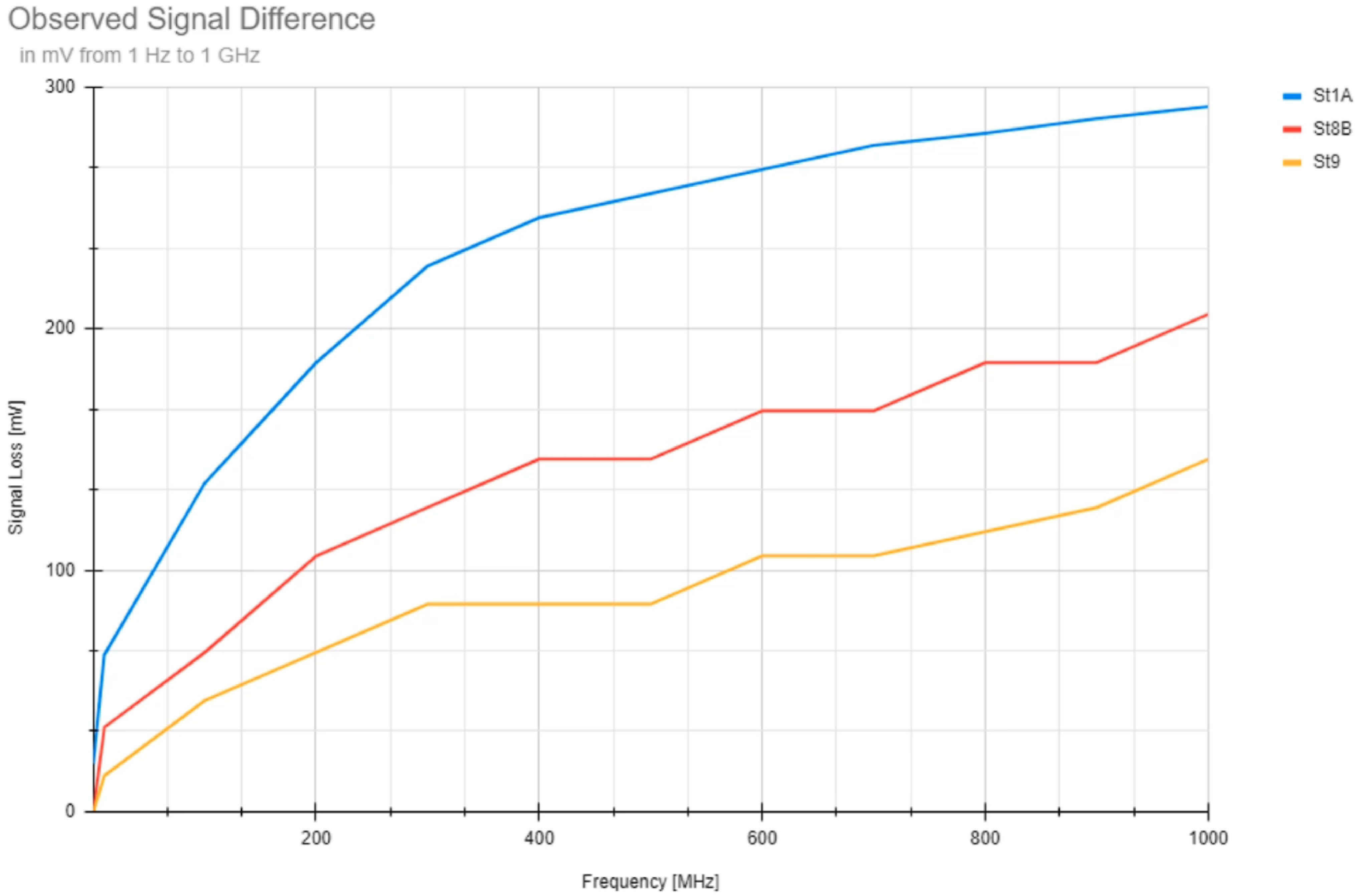
St1A

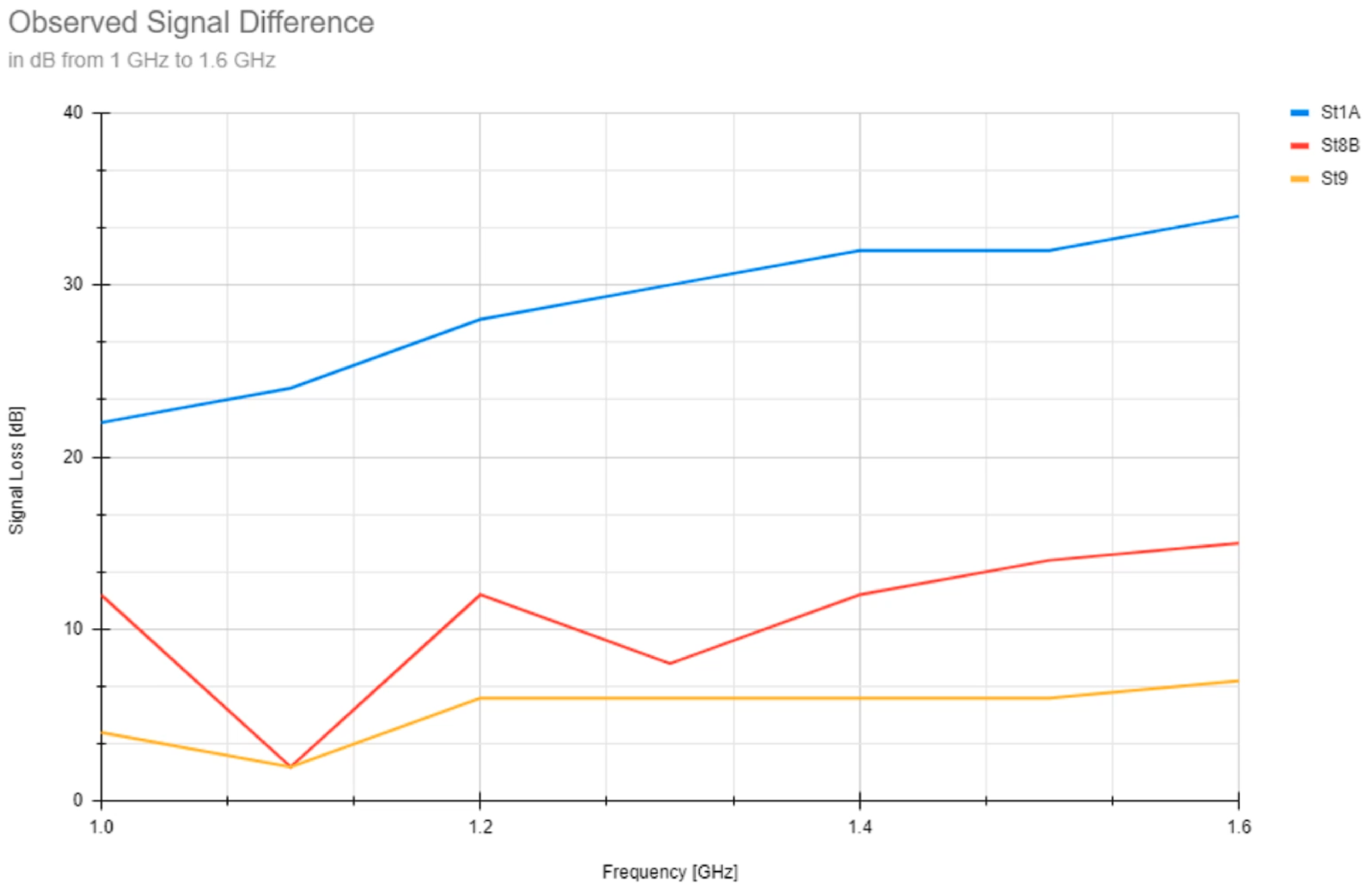


This reading shows the 1.6 GHz signal, ran through cable St1A as - 67 dB.

St9

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


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


Observed Signal Difference
in dB from 1 GHz to 1.6 GHz
Signal Loss [dB]
Frequency [GHz]
40
30
20
10
0
1.0
1.2
1.4
1.6
St1A
St8B
St9

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:

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

It can be concluded that the cable type most suitable for GPS pulse per second and NMEA data communication is the LMR-400 cable, as it has the lowest loss between the two cable types tested and the three individual cables tested as well.