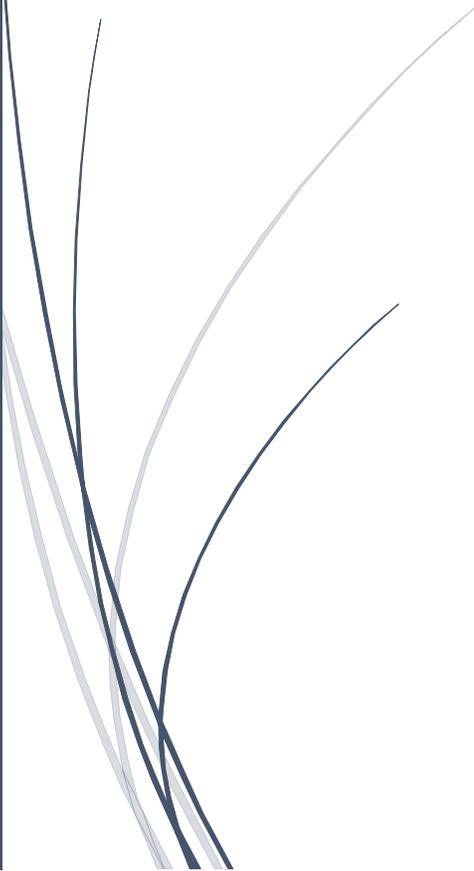
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January 2024 (Rev 1.1)

The Importance of the Transmission Lines at UHF and Above

Transmission lines are an extremely important part of any amateur station. This is especially so for UHF antenna systems. Unfortunately it is one of the systems that is often overlooked, or at the very least given a low priority. The goal of this article is to help the reader understand the importance of the transmission line at frequencies above 400MHz, which include both the 70 cm and GMRS frequencies.

A series of thin, overlapping, curved lines in shades of blue and grey originate from the left side and curve upwards and to the right, creating a decorative, wave-like pattern.

Eugene Morgan
WB7RLX

Contents

1	Introduction.....	1
2	The Decibel.....	1
3	Attenuation.....	2
3.1	What's my real SWR?.....	3
4	Loss at UHF and GMRS Frequencies	4
4.1	Mobile Installations (Coax length of 16 feet).....	4
4.2	Base Station Installation (50 feet).....	5
4.3	Base Station Installations (100 Feet)	6
5	Measuring Loss with Software	7
6	LossCalc	8
7	How Accurate is LossCalc?.....	10
7.1	Results at 448 MHz (70 cm Freq).....	11
7.2	Results at 465 MHz (GMRS Freq)	11
8	Summary.....	12
8.1	Recommendations:.....	12
8.2	Additional Reading	13
9	Installation Instructions:	14



1 Introduction

I decided to write this article after doing some research into the loss in transmission lines at UHF frequencies. In doing that research I came to realize just how critical the selection of the transmission line was for my 70 CM and GMRS antenna. I also realize that this aspect was not well understood by the average ham and in particular by those interested in GMRS communications. In the case of the GMRS users there is no technical training required to get a GMRS license and therefore no expectation the typical GMRS user would have a way to know this. So this article is as much for the GMRS community as it is for the ham radio community, especially those interested in frequencies in the UHF spectrum.

In this article we will look into this further in an effort to help the reader understand the importance of the transmission line at 400 MHz and above. This very important link between the radio and the antenna in a base station installation should not be overlooked or downplayed. To begin our understanding let's start by taking a brief look at the *decibel*.

2 The Decibel

I'll not attempt to get into the math or a deep technical dive into the decibel or its history, for our discussion it's not necessary. However there are several key points the reader should understand which will help in providing a baseline for how loss (attenuation) is quantified.

To begin, the decibel is a comparison of two or more relative quantities and independent of the units of measure. In antennas it may be a comparison of one antenna to another. For example we often see an antenna is said to have a gain of 6 dBi gain, which is a way of saying it has 6 dB of gain when compared to an isotropic antenna¹. You may also see an antenna as having a 3 dBd gain, which is to say it has a gain of 3 dB over a dipole antenna. The second key point to understand about the decibel is that 3dB gain is equal to doubling the power and a -3dB gain is cutting the power in half. For example if we raise the power of our transmitter from 10 watts to 20 watts we have increased our signal by 3 dB. If our transmitter is putting out 10 watts of power but we are only measuring 5 watts at the antenna we are losing 3dB somewhere between the transmitter and the antenna. We will go into this aspect in much more detail later. The third thing to remember is that one S-Unit is equal to 6 dB. What's an S-Unit you ask? On nearly all radios there is a meter that displays the signal strength of the incoming signal. This is called an S-Meter. S-Meters are calibrated in



Figure 1: S-Meter in the Yaesu FTDX-5000. It's showing an incoming signal of 20dB over S-9.

¹ An isotropic antenna is an imaginary antenna that radiates equally in all directions. In short it has zero gain. By comparison a typical dipole antenna in free space has a gain of 2.15 dBi.

such a way that no matter the radio the S-Meter readings mean the same thing. It is a measure of the strength, in microvolts, of an incoming signal. However we don't use the term microvolts when quantifying signal strength. The common practice is to say that a given signal is an S4 or S9 or 10dB over S-9. Most S-Meters go as high as +60dB over S-9.

To recap:

- ✓ A dB is a comparison of two or more relative values.
- ✓ Every 3 dB represents a doubling in power, every -3dB represents cutting the power by half.
- ✓ One S-Unit is equal to 6 dB.

Now that we have the necessary understanding of the dB let's turn our focus on *attenuation*. Attenuation is often measured in dB, which is why we needed to understand the concept of the humble decibel before looking at attenuation.

 If you want to learn more about **decibel** may I recommend the following six minute YouTube video: <https://www.youtube.com/watch?v=G8DpvfEwyGs>

3 Attenuation

Let's begin with the actual definition of the word. Attenuation: the reduction of the force, effect, or value of something. The reduction of the amplitude of a signal, electric current, or other oscillation. In short it means loss in the signal as it traverses the transmission line. Attenuation is measured in decibels, aka: dB. In the US the attenuation is the amount of loss across 100 feet of the line being tested at a specific frequency. In Europe the unit of measure is usually across 100 meters (328 feet). So when looking at vendor provided attenuation values make sure you are clear if the loss values is across 100 feet or 100 meters. You want to make sure you are doing, as we like to say, an apples to apples comparison.

In the case of transmission lines the thing to understand is that every transmission line has some amount of loss regardless of its construction. The lossless transmission line does not exist in the real world, it's only a mathematical construct like the isotropic antenna. The other key thing to know is that loss increases with both frequency and the overall length of the transmission line. To put this into context RG-59 has more loss than RG-8X, which has more loss than RG-8, which has more loss than half inch Heliac. This also means that a given length of transmission line will have more loss at 450 MHz than at 148 MHz.

There is a third factor that affects loss in a transmission line, SWR. The higher the SWR the greater the loss. **At this point it is important to point out that an antenna tuner does NOT change the SWR between the tuner and the antenna.** It ONLY changes the SWR between the transmitter and the tuner. So regardless if your antenna tuner is built into the radio or external to the radio, the SWR between the antenna tuner and the antenna is not affected. This is a concept often overlooked. To be clear if the SWR between your antenna tuner and the antenna is fairly high then the loss will also be fairly high regardless if you're using an antenna tuner or not. This is why we sometimes see the tuner placed at the feed point of the antenna. It is also why the use of a unun or balun transformer is strongly recommended in the case of antennas that inherently have a high feed point impedance such as is the case of the G5RV and its variants, end fed and off center fed antennas and loop antennas.

To recap, there are three factors that affect loss in a transmission line:

- ✓ The length of the transmission line – the longer the line the greater the loss.
- ✓ The frequency – the higher the frequency the greater the loss.
- ✓ SWR – the higher the SWR the greater the loss.

At lower frequencies and with line lengths below a couple of wave lengths this loss is often of little concern. For example the loss in 150 feet for RG8X at 1.9 MHz would only be about 1.29 dB even with a 3:1 SWR. But at 28 MHz and with just a 1.5:1 SWR the loss would be 3 dB, yes nearly 50% of our power would be lost in the transmission line and the same would be true for any incoming signals. But here again if we put that in context of actual signal strength on the S-meter the signal would only be diminished by a half an S-Unit, an amount hardly noticeable on the HF bands.

I should make a comment here with regard to those interested in weak signal propagation specifically FT8, FT4 and so on. When dealing with weak signals on the HF bands the loss of even half an S-Unit in signal strength can make the difference between making a contact or not making a contact. So those interested in weak signal propagation should take note, every dB is important. Every effort should be made to minimize any loss in the entire antenna system even at HF frequencies.

3.1 What's my real SWR?

Most of the loss calculators you will find on line will ask for the SWR. And often the user will enter the SWR as measured in the shack, however that will yield incorrect results. Your real SWR is not what you measured from the comfort of your shack, which is generally where the measurement is taken. Measuring it at that point will not give an accurate reading due to the attenuation that is occurring on the feed line. To get the actual SWR, the measurement should be taken at the antenna feed point. The reading you get in your shack is the apparent SWR and is always less than the actual SWR. Sometimes the difference is considerable if the feedline is long and/or has high loss.

However, putting an SWR meter at the antenna feed point is not easily done, especially when it's at the top of a 50' tower or in a tall tree, or suspended in midair by two thin wires. But there are ways to estimate your real SWR, which we cover later. The subject does get a bit technical which is another reason we will cover it in section 7.

The key takeaway is to know that the SWR as measured in the shack will be less than the actual SWR at the antenna, which is the real determining factor in estimating loss in a transmission line. For now let's look closer at loss estimates in the 70 cm and GMRS frequencies.

4 Loss at UHF and GMRS Frequencies

Before we get started I must offer up a word of warning. The calculations used in the following tables are at best, estimates and were made using the Loss Calculator included with this article. Your actual loss may vary. There are three factors that affect loss which all come down to calculating the SWR at the antenna: transmission line length, frequency, and SWR. What I found was that regardless of the reason, if the antenna end of the transmission line (the load end) had an SWR approaching or in excess of 10:1 the loss predictions became less reliable. In those situations a more accurate and reliable way of estimating loss is recommended. I will cover that in section 5.

4.1 Mobile Installations (Coax length of 16 feet)

In Table 1 we have listed the estimated loss for typical mobile installations using both RG-58 and RG-8X coaxial cables using a standard 16 foot length of cable. For most mobile installation RG-58 or RG-8X will work well. If your mobile installation requires a run longer than 16 feet, which may be typical in a marine application or in a motor home installation then it is recommended you use a good quality RG-8X coaxial cable. It is also recommended that for all mobile installations you use a coaxial cable with a stranded center conductor rather than a solid conductor. The solid core can fatigue and break with repeated flexing over time.

If you look at Table 1 you can see there is very little difference in actual output, however you can see there is a difference between the best and the worst options. Based on these estimates it would appear that UltraFlex 7 would deliver the most power to the antenna during transmission and deliver the strongest signal to the radio during reception. But the difference would be difficult to detect when looking at S-Meter readings.

Conclusion: At cable lengths of 16 feet or less in the 70 cm or GMRS frequencies the difference between the best and the worst coaxial cable would be negligible.

Cable	Type	PWR In	App SWR	Real SWR	PWR Out	Total Loss
LMR 195	RG58	10 Watts	1.5:1	1.95:1	7.15 Watts	1.46 dB
LMR 200	RG58	10 Watts	1.5:1	1.92:1	7.37 Watts	1.32 dB
HyperFlex 5	RG58	10 Watts	1.5:1	1.84:1	7.99 Watts	.98 dB
Wireman CQ129FF	RG58	10 Watts	1.5:1	2.03:1	6.44 Watts	1.91dB

DXE-8X	RG8X	10 Watts	1.5:1	1.94:1	7.22 Watts	1.41 dB
LMR-240-UF	RG8X	10 Watts	1.5:1	1.89:1	7.59 Watts	1.2 dB
UltraFlex 7	RG8X	10 Watts	1.5:1	1.74:1	8.52 Watts	.7 dB

Table 1: Typical Mobile Installations using RG58 & RG8X. Frequency: 448 MHz.

Once again it should be noted that for those interested in weak signal propagation such as in moon bounce (EME), FT8, WSPR, and other weak signal modes, these differences would be considered problematic.

4.2 Base Station Installation (50 feet)

Now that we have considered mobile installations let's look at some base station installations. For Table 2 we will assume the following parameters:

Transmission line length will be 50 feet. The frequency will again be 448 MHz and the SWR 1.5:1. We will also look at an SWR value of 2.5:1 for those who may be considering using the same antenna for both 70 cm and GMRS.

Why an SWR of 1.5:1 you may ask? A 1.5:1 SWR is fairly typical for most UHF installations. Also consider the frequency range of the typical UHF installation. On 70 cm the simplex frequencies are around 446 MHz while the repeater frequencies range from 442 MHz to 448 MHz. In the GMRS spectrum the frequencies range from 462 MHz to 467 MHz. Given these broad frequency ranges an SWR of 1.5:1 would not be unusual on some frequencies.

Cable	Type	PWR In	App SWR	Real SWR	PWR Out	Total Loss
LMR-200	RG58	10 Watts	1.5:1	3.05:1	3.47 Watts	4.6 dB
LMR-240UF	RG8X	10 Watts	1.5:1	2.7:1	3.96 Watts	4.02 dB
Belden 9258	RG8X	10 Watts	1.5:1	3.08:1	3.43 Watts	4.65 dB
LMR-400-UF	RG8	10 Watts	1.5:1	2.03:1	6.41 Watts	1.93 dB
UltraFlex 10	RG8	10 Watts	1.5:1	1.97:1	6.96 Watts	1.57 dB
DXE-400Max	RG8	10 Watts	1.5:1	1.93:1	6.41 Watts	1.93 dB
LDF4-50A	Heliac	10 Watts	1.5:1	1.79:1	8.26 Watts	.83 dB

Table 2: Base Station Options. Cable run is 50 feet. 70 cm Operations

Cable	Type	PWR In	App SWR	Real SWR	PWR Out	Total Loss
LMR-200	RG58	10 Watts	1.5:1	3.13:1	3.37 Watts	4.72 dB
LMR-240UF	RG8X	10 Watts	1.5:1	2.75:1	3.87 Watts	4.12 dB
Belden 9258	RG8X	10 Watts	1.5:1	3.18:1	3.32 Watts	4.79 dB
LMR-400-UF	RG8	10 Watts	1.5:1	2.04:1	6.35 Watts	1.97 dB
UltraFlex 10	RG8	10 Watts	1.5:1	1.98:1	6.9 Watts	1.61 dB
DXE-400Max	RG8	10 Watts	1.5:1	2.04:1	6.35 Watts	1.97 dB
LDF4-50A	Heliac	10 Watts	1.5:1	1.79:1	8.22 Watts	.85 dB

Table 3: Base Station Options. Cable Run 50 feet, GMRS Operations

Cable	Type	PWR In	App SWR	Real SWR	PWR Out	Total Loss
LMR-200	RG58	10 Watts	2.5:1	14.5:1	1.23 watts	9.1 dB
LMR-240UF	RG8X	10 Watts	2.5:1	11.85:1	1.61 watts	7.94 dB
Belden 9258	RG8X	10 Watts	2.5:1	14.83:1	1.19 watts	9.23 dB
LMR-400-UF	RG8	10 Watts	2.5:1	4.56:1	4.96 watts	3.05 dB
UltraFlex 10	RG8	10 Watts	2.5:1	3.91:1	5.82 watts	2.35 dB
DXE-400Max	RG8	10 Watts	2.5:1	4.56:1	4.95 watts	3.05 dB
LDF4-50A	Heliac	10 Watts	2.5:1	3:1	7.69 watts	1.14 dB

Table 4: Loss Calculations at GMRS Frequencies with a 2.5:1 SWR

Conclusion: At 50 feet we can see that the selection of the transmission line is starting to make a difference especially at higher SWR values. At the low end it's easy to see why using RG58 or even RG8X is not a good choice, we lose over half of our signal to attenuation. In the middle we can see there is not a lot of difference between the three RG8 type cables, less than a half a dB. But at the high end the difference is clear, using Andrews LDF4-50 Heliac delivers the most signal. However there would be a significant cost difference. The cable itself would cost around \$3 per foot and the connectors about \$30 each, bringing the estimated total cost of a 50 foot Heliac line to around \$210. The cost of the same length of LMR-400-UF with N-Type connectors would be around \$170. So you have to ask yourself, is the difference in price worth the extra benefit?

If your goal is limited to repeater communication then the investment might not be justified. But if your goal includes simplex operations and maximizing your send and receive capabilities then the investment might be justified. This assumes of course that your feedline is connected to an appropriate high gain antenna such as the Diamond X-700, X-510 or the Comet GP-9 or a high gain directional antenna such as a large Yagi array or dish antenna.

4.3 Base Station Installations (100 Feet)

Although it might be rare to see UHF installations with 100 feet or more between the transmitter and the antenna they do exist. By going through this exercise it will become even clearer how important the selection of the transmission line is. For this illustration we will use the same parameters as before with the exception of a line length of 100 feet rather than 50 feet.

Cable	Type	PWR In	App SWR	Real SWR	PWR Out	Total Loss
LMR-200	RG58	10 Watts	1.5:1	18.39:1	.4 Watts	14.02 dB
LMR-240UF	RG8X	10 Watts	1.5:1	13.33:1	.62 Watts	12.1 dB
Belden 9258	RG8X	10 Watts	1.5:1	18.87:1	.38 Watts	14.18 dB
LMR-400-UF	RG8	10 Watts	1.5:1	2.76:1	3.85 Watts	4.14 dB
UltraFlex 10	RG8	10 Watts	1.5:1	2.33:1	4.75 Watts	3.23 dB
DXE-400Max	RG8	10 Watts	1.5:1	2.77:1	3.85 Watts	4.14 dB
LDF4-50A	Heliac	10 Watts	1.5:1	1.99:1	6.75 Watts	1.71 dB

Table 5: Base Station Options. Cable Run 100 feet, 448 MHz Operations

Cable	Type	PWR In	App SWR	Real SWR	PWR Out	Total Loss
LMR-200	RG58	10 Watts	1.5:1	19.57:1	.36 Watts	14.41 dB
LMR-240UF	RG8X	10 Watts	1.5:1	14.17:1	.57 Watts	12.46 dB
Belden 9258	RG8X	10 Watts	1.5:1	N/A	N/A	N/A
LMR-400-UF	RG8	10 Watts	1.5:1	2.83:1	3.76 Watts	4.25 dB
UltraFlex 10	RG8	10 Watts	1.5:1	2.37:1	4.66 Watts	3.32 dB
DXE-400Max	RG8	10 Watts	1.5:1	2.83:1	3.75 Watts	4.26 dB
LDF4-50A	Heliac	10 Watts	1.5:1	2:1	6.7 Watts	1.74 dB

Table 6: Base Station Operations. Cable Run 100 Feet, GMRS Operations.

Conclusion: It's pretty clear to see that with a transmission line of 100 feet or more the investment in a low loss Heliac transmission line like LDF4-50A is worth the investment. However it should also be obvious that minimizing the distance between the radio and the antenna is crucial. However one sometimes does not have an option, such was the case with the antennas for the Mount Ogden repeater site.

At this point we have delivered the key message of the article, which was to help the reader understand the impact of their decision when it comes to transmission lines and that it is not a decision that should be overlooked or taken lightly. The selection of the transmission line for UHF and GMRS applications matters, especially when the length of the transmission line will be longer than 25 feet.

Now that we have looked at the impact of the transmission line for various base station installations you might be wondering where all these numbers came from. We are going to explore that next. However let me warn you in advance, we are about to get pretty technical and go fairly deeply into some math. You are welcome to skip the deep dive but I do recommend that you at least review section 8 where I provide a list of recommendations.

5 Measuring Loss with Software

If you have done any research into transmission line loss you will know that out on the Internet there are a number of sites that offer loss calculators. Many are based on work that was done by Dan Maguire, AC6LA several years ago. What you may not know is Dan withdrew the code due to some flaws that were uncovered. Dan's withdrawn code, besides the inaccuracies in the formulas, all suffered from the same two issues. The first is they assume the SWR is at intersection of the antenna feed point and the transmission line. Second, the coaxial cable database has not been updated in years. Consequently they don't include many of the different coaxial cables that are on the market today and do include some cable that is no longer available.

There are two programs available today that supersede Dan's code. They are TLW² (written by N6BV) and the other is TLD³. However there is one other challenge using either of these programs. They require the user to enter in the resistance and the reactance values rather than the actual SWR as measure from either the radio or at the antenna. Unfortunately to ascertain the resistance and reactance values you need an antenna analyzer. The average SWR meter will not provide those values, typically they only provide the forward and reflected power readings.

The other issue they also do not have up to date databases of coaxial cables, however they do offer a way for the user to enter in the transmission line specifications. Unfortunately there's an issue with that as well. Part of the specifications needed are what is referred to as the K coefficients, of which there are three, K0, K1, and K2 and they are rarely provided by the vendor or manufacture. However I have found a solution for that as well that I'll discuss in section 6.

Both TLD and TLW are excellent programs and considered the gold standard when it comes to estimating loss in a transmission line. I use both, however TLW is my go to program for calculating line loss when I can't actually physically measure actual line loss. To do that I need access to both ends of the coax. I use TLW with my RigExpert antenna analyzer, which can give me both the R and X values as well as the SWR for a given antenna system.

6 LossCalc

Loss Calculator is a program I wrote in order to overcome some of the short comings of the other loss calculators and is included with this article. What was my justification for developing yet another loss calculator? As I looked at the various loss calculators I kept running into the same issues:

- ✓ Wants SWR measurement at the antenna, not the shack. That measurement is often hard if not impossible to get.
- ✓ Out of date coaxial database. Although TLD and TLW offered a way of entering in cable specifications they wanted parameters that are not typically provided by the vendors
- ✓ In the case TLD and TLW they want the Resistance (R) and Reactance (X) values which most hams and GMRS users have no way of knowing or have little understanding of.

After assessing the field of loss calculators in the wild as well as TLD and TLW I decided to take a different approach. I wanted to develop a program that the average ham could use and didn't require an antenna analyzer and could do the calculations based on the SWR measurements made in the shack. I also wanted to make it possible to be able to include many of the newer coaxial cables that were not included in Dan's original program. This inferred I had to overcome the three issues listed above.

² TLW is a free download from the ARRL for owners of the ARRL Antenna Handbook. You can find the manual on the ARRL web site at: <https://www.arrl.org/files/file/Product%20Notes/Antenna%20Book/tlw.pdf>

³ See: <https://ac6la.com/tldetails1.html>

SWR from the Shack: To overcome that challenge I had to come up with a way to estimate the SWR at the load (antenna). To do that I used a table that was developed by Marcel De Canck, ON5AU⁴. Using his table it was possible to estimate the SWR at the load (antenna) if you also knew the matched line loss properties (mldb) of the coaxial cable at a given frequency. My challenge there was to develop the formula behind the tables. Using a little Microsoft Excel magic (Solver) and some help from a good friend, Neil Klagge, W0YSE, we were able to turn those tables into a formula.

An anomaly I noticed as I was proving the formulas was at higher SWR's the formula was breaking down. In Marcel's tables I noted that at or near 10:1 SWR he listed no values, note the grey areas in Figure 2. What we realized was happening was at that point the formula was changing from a traditional cubic formula to an exponential formula as the SWR at the antenna was approaching or exceeding 10:1. That's when I remembered a note in the ARRL Antenna Book and in AC6LA's notes that the formula became unreliable when the SWR at the load end was approaching 20:1⁵. This was explained further and in much greater detail in a later article by Steve Stearns⁶ and explained in part why I was seeing the formula break as the load end SWR estimates were approaching and exceeding 10:1.

		Apparent SWR											
X Axis		1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	4.0	5.0	6.0	7.0
Matched Loss (100') dB	0.2	1.0	1.2	1.4	1.6	1.9	2.1	2.6	3.1	4.2	5.5	6.8	8.0
	0.4	1.0	1.2	1.4	1.7	1.9	2.1	2.7	3.4	4.7	6.3	8.0	9.5
	0.6	1.0	1.2	1.5	1.7	2.0	2.2	2.9	3.7	5.2	7.5	10.0	
	0.8	1.0	1.2	1.5	1.7	2.0	2.3	3.1	4.0	6.0	9.0		
	1.0	1.0	1.2	1.5	1.8	2.1	2.4	3.3	4.3	7.0			
	1.2	1.0	1.3	1.5	1.9	2.2	2.6	3.6	4.8	8.0			
	1.4	1.0	1.3	1.6	1.9	2.3	2.8	4.0	5.5	9.9			
	1.7	1.0	1.3	1.6	2.0	2.5	3.0	4.3	6.5				
	2.0	1.0	1.3	1.7	2.1	2.8	3.3	5.3	8.4				
	2.5	1.0	1.4	1.8	2.4	3.2	4.0	8.0					
	3.0	1.0	1.4	1.9	2.7	3.7	4.9	9.8					
	3.5	1.0	1.4	2.1	3.1	4.6	6.9						
	4.0	1.0	1.5	2.3	3.7	6.0	9.5						
	4.5	1.0	1.6	2.6	4.7	7.9	10.0						
	5.0	1.0	1.8	3.0	6.0								
5.5	1.0	2.0	3.4	8.5									
Y Axis	True SWR (at the Antenna)												

Figure 2: Marcel De Canck, ON5AU SWR Table

This approach of estimating the load end SWR allowed me to continue to use AC6LA's formulas rather than having to enter in actual R and X values. Yes this still made the results little more than a good estimate of the actual loss but it made it possible for the average ham with little more

⁴ I don't know the source of this table (see: Figure 2.) I had exchanged emails with Marcel a few years ago so I thought I'd ask him. Unfortunately I discovered he is a silent key. If any of you know the source of this table please let me know.

⁵ See ARRL Antenna Hand Book, 24th edition, page 23.13

⁶ See "Loss Formulas for General Uniform Transmission Lines and Paradox 5", QEX, September/October 2021, page 18. This article appears to only be available to subscribers to QEX.

than an SWR meter to make a reasonable loss estimate. So how close does LossCalc come to the estimates in TLW and TLD? We will look at that in section 7.

Updating the Coaxial Database: The other goal I had was to add additional coaxial cables to the database. There was a lot of new coax on the market that was not in the original database. And although both TLW and TLD allowed the user to enter in user defined coaxial parameters the necessary information was rarely provided by the manufacture, specifically the K coefficients in the case of TLD and in the case of TLW specific frequency loss values. Let me explain that in a little more detail.

In the case of TLW the issue was how to estimate match line loss at a specific frequency if the vendor didn't provide that information. What I found was that there was no standard among the various manufactures and vendors to provide loss figures across a specific set of frequencies.

In the case of TLD you had to enter in the K coefficients, K0, K1, and K2, which were very rarely provided by the vendor. So I had to come up with a way of calculating the K coefficients based on the attenuation schedule provided by the vendor.

To solve both those challenges I turned once again to Microsoft Excel and the Solver tool built into Excel. To calculate the K coefficients I had to enter the loss data points the vendors provided into an Excel table and graph the attenuation curve. Most of the vendors provided enough information to be able to graph the attenuation curve with good accuracy. For example Messi & Paoloni provided as many as 15 data points between 1.8 MHz and 1 GHz. Unfortunately a few others only provided loss values for as few as four frequencies below 1 GHz. The more data points the more accurate the coefficient calculation. This was the reason that in some cases the curve fit was perfect match and in other cases why the curve fit was a little off, and generally at the lower end of the frequency spectrum.

After graphing the attenuation curve I was able to use Excel's Solver tool to establish the K coefficients thus making it possible to calculate the loss for any given cable at any given frequency up to 1 GHz.

After I solved those two problems I set about adding the additional cables I wanted to add to the database. AC6LA's code included the K coefficients I needed for all of the coaxial cable in his original database. Where I had his coefficients I used them. I did test several of his coefficients and found my results to be on par with his. This gave me the confidence I needed to proceed. At this point I added the additional coaxial cables to the database I was interested in.

7 How Accurate is LossCalc?

I've been careful to emphasize that LossCalc can only provide an estimate as to the potential loss in a transmission line. And given the inaccuracy of most SWR meters on the market only adds to that emphasis. In spite of that LossCalc should be able to give a reasonable estimate in most cases.

At my QTH I put LossCalc to the test. Using my RigExpert 1000 Antenna analyzer I took the necessary measurements of my UHF antenna system which consists of the following:

- ✓ Four feet of UltraFlex 10
- ✓ 60 feet of LDF4-50 Heliax
- ✓ Two feet of UltraFlex 10
- ✓ Diamond X-700 antenna mounted on a metal tripod 3 feet above my roof at the peak of my house.

7.1 Results at 448 MHz (70 cm Freq)

At 448 MHz I got the following readings from my shack with the RigExpert 1000:

- ✚ SWR 1.6 (at source)
- ✚ R: 32 Ohms
- ✚ X: 6 Ohms

Results at 448 MHz:

Software	Real SWR	Total Loss	Power In/Out
TLW	1.82	1.13 dB	Not Calculated
TLD	1.80	1.09 dB	10 watts / 7.78 watts
LossCalc	1.87	1.11 dB	10 watts / 7.74 watts

7.2 Results at 465 MHz (GMRS Freq)

At 465 MHz (GMRS) I got the following readings from my shack with the RigExpert 1000:

- ✚ SWR: 2.7 (at source)
- ✚ R: 24.3 Ohms
- ✚ X: 25.8 Ohms

Results at 465 MHz:

Software	Real SWR	Total Loss	Power In/Out
TLW	3.81	1.77 dB	Not Calculated
TLD	3.76	1.70 dB	10 watts / 6.76 watts
LossCalc	4.31	1.88 dB	10 watts / 6.49 Watts

Conclusion: Let me begin by saying this is but one test case, but it is a real world test case with a real transmission line connected to a real antenna. What I'm surprised by is how closely my results line up with both TLW and TLD. Given these results I have confidence LossCalc will give a reasonable estimate of the loss that can be expected in most situations. However, as the SWR gets higher at the source the results will become less and less accurate. If the estimated real SWR (load end SWR) exceeds 10:1 the results could be completely unreliable and a more

accurate estimate should be made using either TLD or TLW. Yes that will require the use of an antenna analyzer but the results will be much more reliable.

8 Summary

The initial goal of this article was to help the reader to gain some insights into the impact of the transmission line is at UHF frequencies. By showing actual loss values with various coaxial cables the differences should be easy to see. I hope that your key takeaway from this article is to choose your transmission line carefully and especially at UHF/GMRS frequencies. It matters.

8.1 Recommendations:

- ✓ Keep your transmission line as short as is reasonably possible.
- ✓ Use the lowest loss transmission line you can afford.
- ✓ Buy your cable only from reputable companies that cater to radio community. With companies like Amazon you never know what you are getting. There is a lot of counterfeit LMR-400 being sold from companies like amazon⁷.
- ✓ Use only the best quality connectors. Avoid bargain connectors as we so often see on Amazon. Remember, a chain is only as strong as its weakest link.
- ✓ Avoid using 90 degree connectors. They are often the cause or intermittent issues, especially the cheap ones from Amazon.
- ✓ On base station installations use N-Type connectors and avoid using adapters such as N-Type to UHF. Only use them where absolutely necessary.
- ✓ Guard against water and moisture penetration into your transmission line, use UV resistant cable on all outside cables. Make sure all connections are well protected from moisture penetration by using dielectric grease in UHF connectors and wrapping all outside connectors with a layer of self-vulcanizing tape (rubberized tape) then over wrap with a top quality vinyl electrical tape.
- ✓ Inspect your transmission line yearly looking for cracks or wear spots in the jacket. Be aware that some creatures like Mynocks⁸ and raccoons like to chew on coaxial cables.
- ✓ Install an SWR meter in the transmission line. An SWR meter can be the first indicator of a problem in the antenna system.
- ✓ Follow a best practices approach to installing connectors. If you're not sure how to do it arrange with someone who has the right equipment, experience and know how to do the job right.
- ✓ Always test any factory installed connectors at the time of installation.

⁷ This is a really good video on counterfeit coaxial cable. <https://www.youtube.com/watch?v=4fP94GfqTtk>

⁸ Mynocks (IPA: /'maɪ.nɒk/, Merriam-Webster: \mīnäk\) were a bat-like parasitic species that hailed from the world of Ord Mynock. Even so, they also thrived in asteroids and could survive in real space, with some even living within exogorths. For sustenance, they could eat the energy supply of starships and power cables.

8.2 Additional Reading

Maguire, Dan, AC6LA, "*Additional Loss Due to SWR is in Quotes for a Reason or Think Twice Before Using a Web-Based Line Loss Calculator*", <https://ac6la.com/swrloss.html>

Morgan, Eugene, WB7RLX, "*Transmission Lines: Setting the Record Straight*" available by request – email ee_morgan@outlook.com. Also available on the Northern Utah GMRS site and the Ogden Amateur web Site.

Morgan, Eugene, WB7RLX, "*Setting the Record Straight: SWR*" available by request – email ee_morgan@outlook.com. Also available on the Northern Utah GMRS site and the Ogden Amateur web Site.

Stearns, Steve, K6OIK, "*A Transmission Line Power Paradox and Its Resolution*", https://www.fars.k6ya.org/docs/Stearns_K6OIK-A_Transmission_Line_Power_Paradox_and_Its_Resolution.pdf

Stearns, Steve, K6OIK, "*Loss Formulas for General Uniform Transmission Lines and Paradox 5*", QEX, September/October 2021, page 18. This article appears to only be available to subscribers to QEX.

Hallas, Joel R, W1ZR, "*The Care and Feeding of Transmission Lines*", ARRL Publication, available through ARRL or other book sellers such as Amazon.

W Maxwell, W2DUD, "*Reflection III: Transmission Lines and Antennas*". This book can sometimes be hard to find. When last I checked it was available from CQ Magazine and sometimes comes available at Amazon and other used book stores. If you can find it, buy it. It comes highly recommended.

If you are interested in any of the formulas or Excel spreadsheets that were referenced in this article or if you have any questions, comments or corrections do contact me. I welcome them, especially constructive ones. **ee_morgan@outlook.com.**

9 Installation Instructions:

The installation is pretty simple but if you need some help give me a call: (801) 540-4907. I'll be glad to walk you through it.

- ✓ Download the program from the OARC web site. It should be located in the download area on the OARC web site see: <http://ogdenarc.org/downloads.html>. Look for *LossCalc.zip* in the *Member downloads by Eugene Morgan*.
- ✓ After you have downloaded the *LossCalc.zip* file unzip it.
- ✓ Run the setup program *LossCalcSetUp.exe*. By default the program will be installed to the *Program Files (x86)* folder on the system drive. However you can install it wherever you like.
- ✓ The next step will require that you configure the window size. You will only need to do this one time. After running the installation on your desktop you will find the LossCalc icon. *Right Click* on it and select *Properties*. In the properties window you will see a number of tabs. It's usually defaulted to the *Shortcut* tab.
- ✓ Click on the *Layout* tab. In the middle of the *Layout* tab window you will see a box labeled *Windows Size*: Set the **Width to 140** and the **Height to 43**. Then click on the "*Apply*" button. That's it you are done. From now on all you have to do to run the program is click on the desktop icon.

Potential Warning from your anti-virus program: When executing the program for the first time you may experience a warning from Microsoft Defender or your anti-virus software warning you about this program. Don't worry. In the case of Microsoft Defender just click on the "*More info*" link then click on the "*Run anyway*" link. This only occurs the very first time the program is launched and only on some computers. I do take extreme precautions to make sure that none of my programs are infected. However, if you are concerned use the scan feature in Windows Defender to make sure there are no hitchhikers included in the installation payload.