White Paper

ANDREW®
A CommScope Company

Calculating Antenna System Return Loss As Viewed Through The RF Path

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1. Introduction

Return loss (RL), reflection coefficient (Γ) and voltage standing wave ratio (VSWR)[1] are all common mathematically related specifications for RF components. They are especially important in antenna systems, where return loss and VSWR play critical roles, not only in the overall antenna performance but in its design, installation, selection, and preventive maintenance.

The ability to compare actual system performance to expected system performance is a key to monitoring and optimizing overall transmission efficiency. But as more components are introduced into the antenna system, it becomes more and more difficult to accurately gauge how well the entire system should be performing. In today's complex antenna systems, the ability to accurately and precisely predict system return loss and VSWR are compounded by several factors.

Historically, the antenna itself was the major contributor to return loss. So poor system-wide VSWR readings were normally attributed to the antenna. Therefore, in deriving an acceptable level of system performance, RF engineers could account for this major variance. Now, however, the use of additional components at the top of the tower, such as tower mounted amplifiers (TMA), create significant uncertainty in estimating how the system should perform. Additional components at the bottom, such as surge protectors, jumpers, and diplexers only compound the problem of establishing an accurate and acceptable level of return loss.

Further complicating the issue are questions regarding the correct testing procedures to be used on individual system components, such as how the test equipment is to be calibrated, and the acceptable specifications and performance levels of the test cables used.[2]

These challenges have created a need for a standard and accepted mathematical tool that can account for each individual component in the RF path and calculate the typical and worst-case scenario for cascaded return loss for an antenna system. This mathematical standard can then be compared to the observed return loss in order to gauge RF efficiency performance of the entire antenna system.

It is critical to note that, due to the wide number of variables affecting cascaded return loss, this mathematical estimate can only be calculated on an individual basis. In other words, the number and variety of components in today's RF path makes it impossible to reduce the ideal cascaded return loss into one or even a handful of equations, thus illustrating the need for a tool that can assess a virtually infinite number of unique scenarios.

This paper introduces one such tool, the Andrew System VSWR Calculator. We will describe how this tool accepts the pertinent characteristics of the various components in the RF path and then calculates the cascaded system return loss.

2. Description of the Andrew System VSWR Calculator Tool

The Andrew System VSWR Calculator Tool is a benchmarking software solution that enables RF engineers to quickly and accurately estimate acceptable cascaded return loss for any basic or complex RF antenna system with certain known characteristics.

Even though any out-of-spec component in the RF path can cause a failed system return loss, the VSWR Calculator is normally used as a diagnostic tool to determine the status of the antenna. This calculation tool is meant to be used with passive components only and will not provide correct results if downlink power amplifiers or low noise tower mounted amplifiers (TMAs) are active. TMAs can be included only if they are switched to the bypass mode.

3. Cascaded Return Loss in the RF Path

In a basic antenna system, the RF path from top to bottom generally includes: the antenna; a flexible jumper cable connected to a more rigid, low-loss main transmission line; and a second flexible jumper cable that attaches to the radio transmitter. More complex systems include additional components in the RF path such as TMAs, surge arrestors, crossband couplers (CBCs), and duplexers.

Regardless of how precise the design, no individual component in the antenna system perfectly matches the characteristic impedance of the entire system. As a result, each component reflects some power back toward the source in the form of return loss. With the exception of the antenna itself, each component also creates some insertion loss that affects the outbound signal and can mask return loss occurring further along the RF path. The process continues until the signal reaches its termination point—the antenna—where the remaining signal is radiated into free space.

Because RF signals consist of sinusoidal waveforms, each reflection is modified in amplitude and phase. When multiple signals with different amplitudes and phases are combined, they form a complex composite waveform with time varying amplitude. This waveform is commonly quantified and expressed by the root of the sum of the squares (RSS) of the reflection amplitudes converted to VSWR/Return Loss.

The Andrew System VSWR Calculator Tool uses this same approach to calculate the typical system return loss. These values, indicated in green in Figures 1–7 below, are expressed as first order approximations of typical reflection coefficient. To derive a worst case condition reflecting the maximum system loss, the individual reflection coefficients are summed and converted to VSWR/Return Loss.

$$\textit{Typical System Reflection Coefficient} = \left[(\Gamma_1)^2 + (\Gamma_2)^2 + (\Gamma_3)^2 \ \ldots\ldots + (\Gamma_n)^2\right]^{0.5}$$

$$\textit{Worst Case System Reflection Coefficient} = \left[\Gamma_1 + \Gamma_2 + \Gamma_3 \ \ldots\ldots + \Gamma_n\right]$$

The “worst case” estimates, shown in yellow in Figures 1–7, represent a theoretical approximation for the system. It should be noted that the worst case estimate requires the contributions from all components be exactly in phase. Therefore, these conditions are rarely encountered in the field. Many times, however, components in the field actually outperform the “typical” system reflection.

When combined, the first order approximation for the typical and the worst case scenarios form a statistical approximation that is consistent with actual measurements.

4. Required Values

The Andrew System VSWR Calculator Tool allows the RF engineers to select or de-select a number of Andrew or CommScope manufactured RF components by type. For each component selected, the engineer must know the return loss or VSWR, as well as the insertion loss for components other than jumpers and transmission lines. This is the stated VSWR, return loss, and insertion loss where applicable, as published by the manufacturer. For the antenna, only the VSWR value is required.

Other required values include the desired frequency and specific lengths for jumper cables and main transmission line cable. If the system is to include a receive-only TMA, engineers should use the VSWR and insertion loss values reflected in the bypass mode. For a dual-duplex TMA, data from the transmit mode is normally used.

5. Sample System Return Loss Calculations

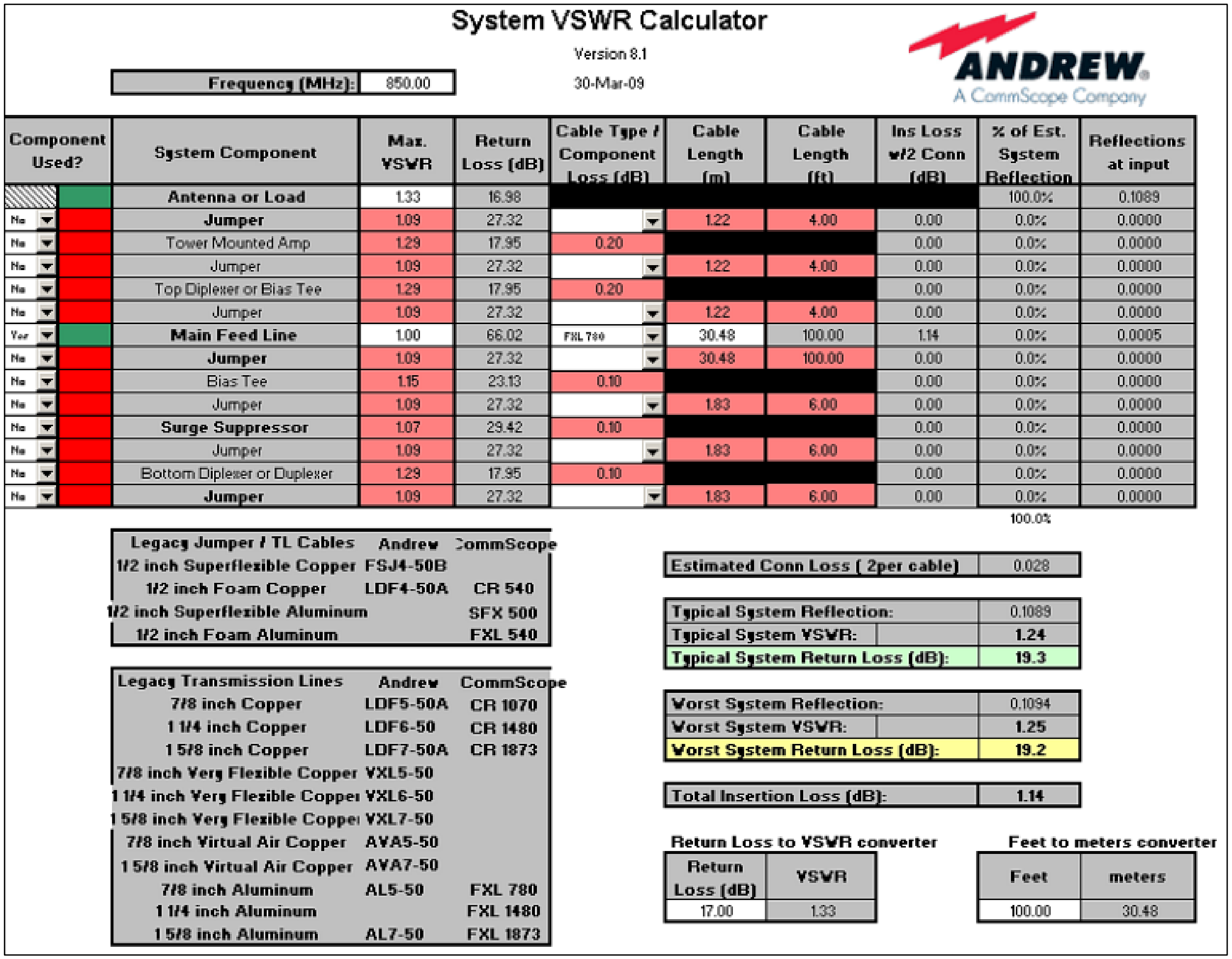
A look at the calculations in Table 1 emphasizes the need to evaluate each system based on exact parameters. Conversely, it underscores the dangers of extrapolating and generalizing between systems that “appear” to be similar.

Figures 1–7 illustrate how the total return loss is affected as system components are added and/or altered. Figure 1 shows calculations for a basic system consisting of a 100-foot length of 7/8” FXL-780 HELIAX® Transmission Line Cable connected to a typical antenna with a 17 dB return loss. In this sample case, a transmission line cable with a VSWR of 1.00 was used to demonstrate what the expected performance would be for a system using a “perfect” transmission cable. Figure 2 assumes the same basic setup but reflects a VSWR of 1.10 for the transmission line cable. As a result, the system return loss drops by 0.8 dB.

Figure 3 illustrates what happens to the setup in Figure 2 when one four-foot LDF and one six-foot FSJ 1/2” jumper cable are added to either end of the transmission line. In Figure 4, a surge protector has been added to the system, decreasing total return loss by only 0.1 dB. Figure 5 illustrates the effects of adding a tower-mounted amplifier. In Figures 6 and 7, a top-diplexer (or crossband coupler) and a bottom-diplexer (or duplexer) have been added respectively.

For each scenario, the antenna VSWR was set to 1.33:1 (16.98 dB return loss) and the transmitting frequency was set to 850 MHz.

Figure 1: Antenna and Main Transmission Line Only
(Line has 1.001 VSWR or ~66 dB return loss.)



System VSWR Calculator

Version 8.1

30-Mar-09

Frequency (MHz): 850.00

Component Used?	System Component	Max. VSWR	Return Loss (dB)	Cable Type / Component Loss (dB)	Cable Length (m)	Cable Length (ft)	Ins Loss w/2 Conn (dB)	% of Est. System Reflection	Reflections at input
🟩	**Antenna or Load**	1.33	16.98					100.0%	0.1089
No 🟥	**Jumper**	1.09	27.32		1.22	4.00	0.00	0.0%	0.0000
No 🟥	Tower Mounted Amp	1.29	17.95	0.20			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.22	4.00	0.00	0.0%	0.0000
No 🟥	Top Diplexer or Bias Tee	1.29	17.95	0.20			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.22	4.00	0.00	0.0%	0.0000
Yes 🟩	**Main Feed Line**	1.00	66.02	FXL 780	30.48	100.00	1.14	0.0%	0.0005
No 🟥	**Jumper**	1.09	27.32		30.48	100.00	0.00	0.0%	0.0000
No 🟥	Bias Tee	1.15	23.13	0.10			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
No 🟥	**Surge Suppressor**	1.07	29.42	0.10			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
No 🟥	Bottom Diplexer or Duplexer	1.29	17.95	0.10			0.00	0.0%	0.0000
No 🟥	**Jumper**	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
								100.0%	

Legacy Jumper / TL Cables	Andrew	CommScope
1/2 inch Superflexible Copper	FSJ4-50B	
1/2 inch Foam Copper	LDF4-50A	CR 540
1/2 inch Superflexible Aluminum		SFX 500
1/2 inch Foam Aluminum		FXL 540

Legacy Transmission Lines	Andrew	CommScope
7/8 inch Copper	LDF5-50A	CR 1070
1 1/4 inch Copper	LDF6-50	CR 1480
1 5/8 inch Copper	LDF7-50A	CR 1873
7/8 inch Very Flexible Copper	VXL5-50	
1 1/4 inch Very Flexible Copper	VXL6-50	
1 5/8 inch Very Flexible Copper	VXL7-50	
7/8 inch Virtual Air Copper	AVA5-50	
1 5/8 inch Virtual Air Copper	AVA7-50	
7/8 inch Aluminum	AL5-50	FXL 780
1 1/4 inch Aluminum		FXL 1480
1 5/8 inch Aluminum	AL7-50	FXL 1873

Estimated Conn Loss (2per cable)	0.028
Typical System Reflection:	0.1089
Typical System VSWR:	1.24
Typical System Return Loss (dB):	19.3
Worst System Reflection:	0.1094
Worst System VSWR:	1.25
Worst System Return Loss (dB):	19.2
Total Insertion Loss (dB):	1.14

Return Loss to VSWR converter

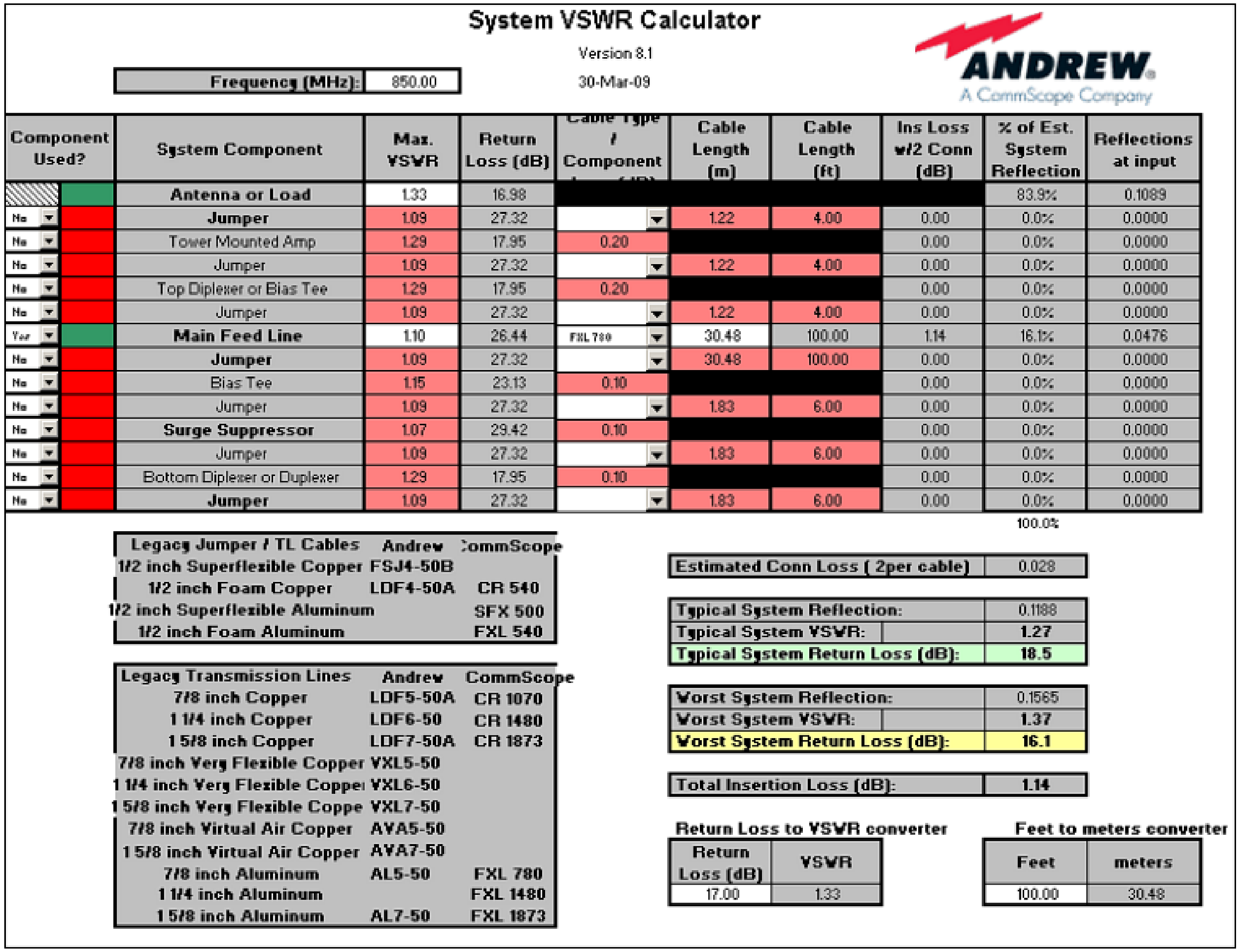
Return Loss (dB)	VSWR
17.00	1.33

Feet to meters converter

Feet	meters
100.00	30.48

With this ‘perfect VSWR’ transmission line (VSWR=1.00), the system return loss equals the antenna return loss plus twice the transmission line loss (power lost up to the antenna plus the antenna return loss plus the power lost back down to the measurement device). Some industry charts are still based on this concept.[1]

Figure 2: Antenna and Main Transmission Line Only (Line has realistic 1.11 VSWR or ~25 dB return loss.)



System VSWR Calculator

Version 8.1

30-Mar-09

Frequency (MHz): 850.00

Component Used?		System Component	Max. VSWR	Return Loss (dB)	Cable Type / Component	Cable Length (m)	Cable Length (ft)	Ins Loss w/2 Conn (dB)	% of Est. System Reflection	Reflections at input
▨	🟩	**Antenna or Load**	1.33	16.98					83.9%	0.1089
No ▼	🟥	**Jumper**	1.09	27.32	▼	1.22	4.00	0.00	0.0%	0.0000
No ▼	🟥	Tower Mounted Amp	1.29	17.95	0.20			0.00	0.0%	0.0000
No ▼	🟥	Jumper	1.09	27.32	▼	1.22	4.00	0.00	0.0%	0.0000
No ▼	🟥	Top Diplexer or Bias Tee	1.29	17.95	0.20			0.00	0.0%	0.0000
No ▼	🟥	Jumper	1.09	27.32	▼	1.22	4.00	0.00	0.0%	0.0000
Yes ▼	🟩	**Main Feed Line**	1.10	26.44	FXL 780 ▼	30.48	100.00	1.14	16.1%	0.0476
No ▼	🟥	**Jumper**	1.09	27.32	▼	30.48	100.00	0.00	0.0%	0.0000
No ▼	🟥	Bias Tee	1.15	23.13	0.10			0.00	0.0%	0.0000
No ▼	🟥	Jumper	1.09	27.32	▼	1.83	6.00	0.00	0.0%	0.0000
No ▼	🟥	**Surge Suppressor**	1.07	29.42	0.10			0.00	0.0%	0.0000
No ▼	🟥	Jumper	1.09	27.32	▼	1.83	6.00	0.00	0.0%	0.0000
No ▼	🟥	Bottom Diplexer or Duplexer	1.29	17.95	0.10			0.00	0.0%	0.0000
No ▼	🟥	**Jumper**	1.09	27.32	▼	1.83	6.00	0.00	0.0%	0.0000
									100.0%	

Legacy Jumper / TL Cables	Andrew	CommScope
1/2 inch Superflexible Copper	FSJ4-50B	
1/2 inch Foam Copper	LDF4-50A	CR 540
1/2 inch Superflexible Aluminum		SFX 500
1/2 inch Foam Aluminum		FXL 540

Legacy Transmission Lines	Andrew	CommScope
7/8 inch Copper	LDF5-50A	CR 1070
1 1/4 inch Copper	LDF6-50	CR 1480
1 5/8 inch Copper	LDF7-50A	CR 1873
7/8 inch Very Flexible Copper	VXL5-50	
1 1/4 inch Very Flexible Copper	VXL6-50	
1 5/8 inch Very Flexible Copper	VXL7-50	
7/8 inch Virtual Air Copper	AVA5-50	
1 5/8 inch Virtual Air Copper	AVA7-50	
7/8 inch Aluminum	AL5-50	FXL 780
1 1/4 inch Aluminum		FXL 1480
1 5/8 inch Aluminum	AL7-50	FXL 1873

Estimated Conn Loss (2per cable)	0.028
Typical System Reflection:	0.1188
Typical System VSWR:	1.27
Typical System Return Loss (dB):	18.5
Worst System Reflection:	0.1565
Worst System VSWR:	1.37
Worst System Return Loss (dB):	16.1
Total Insertion Loss (dB):	1.14

Return Loss to VSWR converter

Return Loss (dB)	VSWR
17.00	1.33

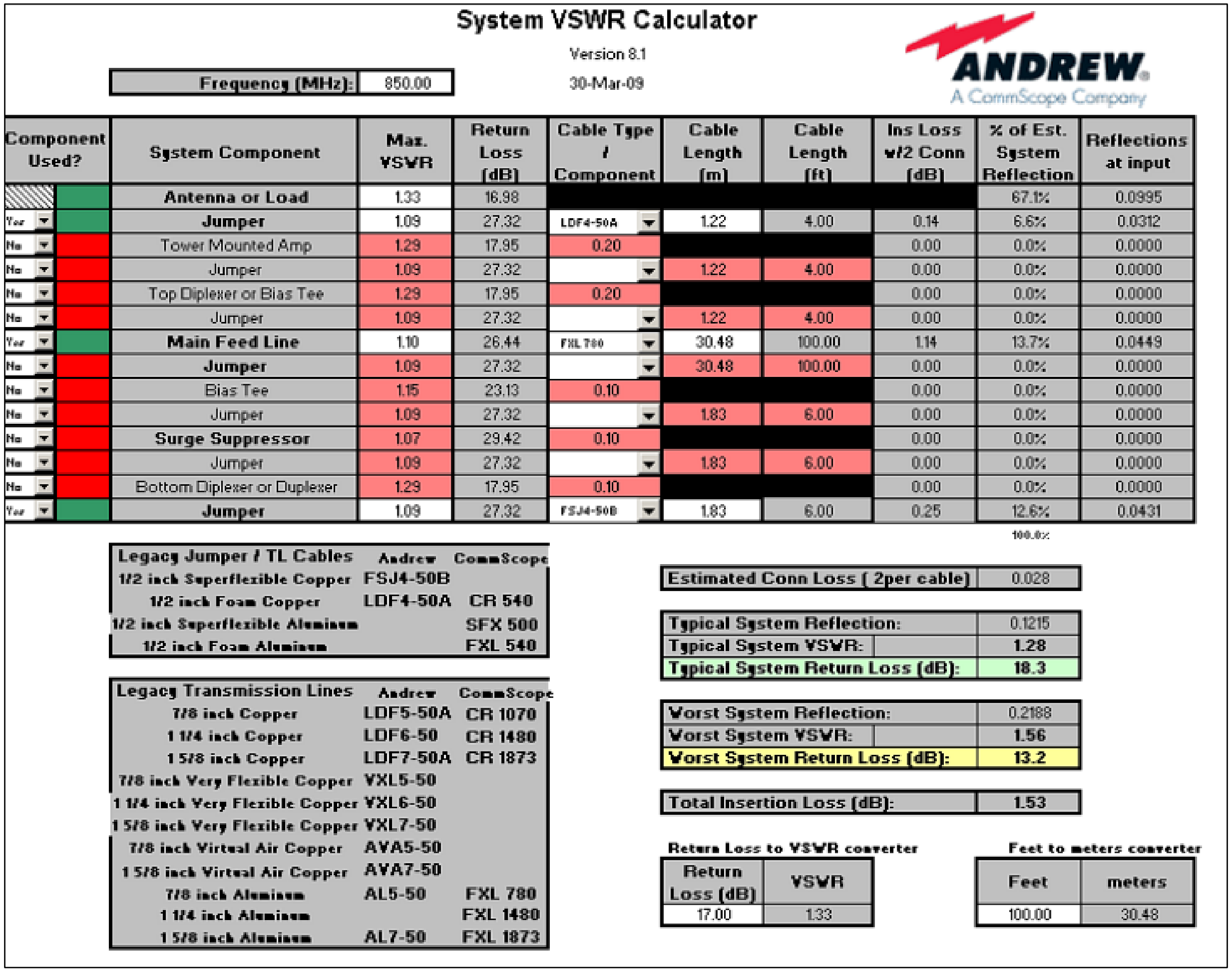
Feet to meters converter

Feet	meters
100.00	30.48

Compared to Figure 1 results, the system return loss drops 0.8 dB in this 100-foot FXL-780 example when a typical transmission line VSWR of 1.10 is used.

Visit our Web site at www.andrew.com or contact your local Andrew Solutions representative for more information.

Figure 3: Antenna, Main Transmission Line (1.1 VSWR), and Two Jumpers



System VSWR Calculator

Version 8.1

30-Mar-09

Frequency (MHz): 850.00

Component Used?	System Component	Max. VSWR	Return Loss (dB)	Cable Type / Component	Cable Length (m)	Cable Length (ft)	Ins Loss w/2 Conn (dB)	% of Est. System Reflection	Reflections at input
🟩	Antenna or Load	1.33	16.98					67.1%	0.0995
Yes 🟩	Jumper	1.09	27.32	LDF4-50A	1.22	4.00	0.14	6.6%	0.0312
No 🟥	Tower Mounted Amp	1.29	17.95	0.20			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.22	4.00	0.00	0.0%	0.0000
No 🟥	Top Diplexer or Bias Tee	1.29	17.95	0.20			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.22	4.00	0.00	0.0%	0.0000
Yes 🟩	Main Feed Line	1.10	26.44	FXL 780	30.48	100.00	1.14	13.7%	0.0449
No 🟥	Jumper	1.09	27.32		30.48	100.00	0.00	0.0%	0.0000
No 🟥	Bias Tee	1.15	23.13	0.10			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
No 🟥	Surge Suppressor	1.07	29.42	0.10			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
No 🟥	Bottom Diplexer or Duplexer	1.29	17.95	0.10			0.00	0.0%	0.0000
Yes 🟩	Jumper	1.09	27.32	FSJ4-50B	1.83	6.00	0.25	12.6%	0.0431
								100.0%	

Legacy Jumper / TL Cables	Andrew	CommScope
1/2 inch Superflexible Copper	FSJ4-50B	
1/2 inch Foam Copper	LDF4-50A	CR 540
1/2 inch Superflexible Aluminum		SFX 500
1/2 inch Foam Aluminum		FXL 540

Legacy Transmission Lines	Andrew	CommScope
7/8 inch Copper	LDF5-50A	CR 1070
1 1/4 inch Copper	LDF6-50	CR 1480
1 5/8 inch Copper	LDF7-50A	CR 1873
7/8 inch Very Flexible Copper	VXL5-50	
1 1/4 inch Very Flexible Copper	VXL6-50	
1 5/8 inch Very Flexible Copper	VXL7-50	
7/8 inch Virtual Air Copper	AVA5-50	
1 5/8 inch Virtual Air Copper	AVA7-50	
7/8 inch Aluminum	AL5-50	FXL 780
1 1/4 inch Aluminum		FXL 1480
1 5/8 inch Aluminum	AL7-50	FXL 1873

Estimated Conn Loss (2per cable)	0.028
Typical System Reflection:	0.1215
Typical System VSWR:	1.28
Typical System Return Loss (dB):	18.3
Worst System Reflection:	0.2188
Worst System VSWR:	1.56
Worst System Return Loss (dB):	13.2
Total Insertion Loss (dB):	1.53

Return Loss to VSWR converter

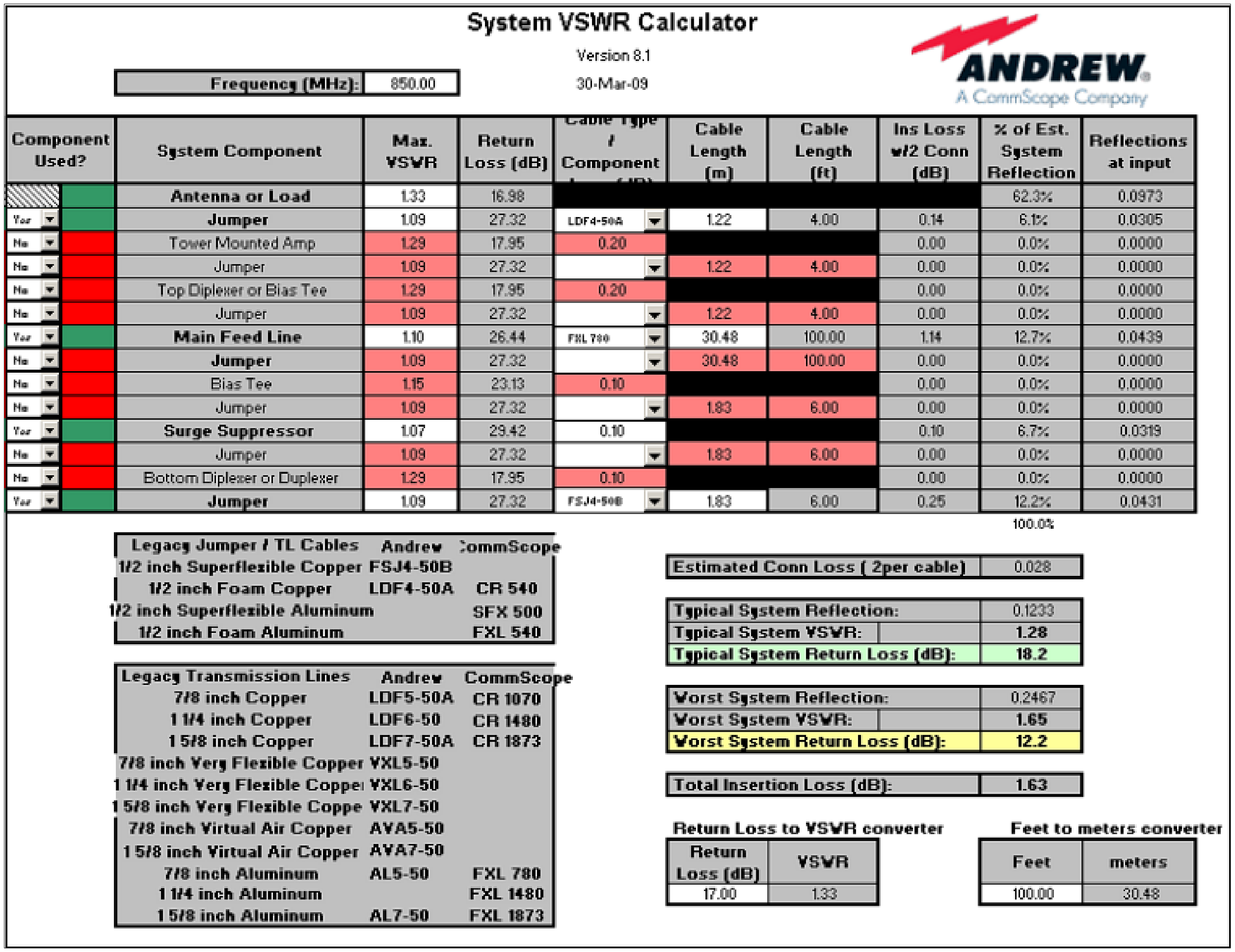
Return Loss (dB)	VSWR
17.00	1.33

Feet to meters converter

Feet	meters
100.00	30.48

For the longer 100- and 175-foot transmission lines, the values come close to a rule of thumb that states the system return loss will be the antenna return loss plus the one-way transmission line loss. However, for the 50-foot length, the rule of thumb is off by over 0.5 dB.

Figure 4: Surge Protector Added to Figure 3



System VSWR Calculator

Version 8.1

30-Mar-09

Frequency (MHz): 850.00

Component Used?	System Component	Max. VSWR	Return Loss (dB)	Cable Type / Component	Cable Length (m)	Cable Length (ft)	Ins Loss w/2 Conn (dB)	% of Est. System Reflection	Reflections at input
🟩	**Antenna or Load**	1.33	16.98					62.3%	0.0973
Yes 🟩	**Jumper**	1.09	27.32	LDF4-50A	1.22	4.00	0.14	6.1%	0.0305
No 🟥	Tower Mounted Amp	1.29	17.95	0.20			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.22	4.00	0.00	0.0%	0.0000
No 🟥	Top Diplexer or Bias Tee	1.29	17.95	0.20			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.22	4.00	0.00	0.0%	0.0000
Yes 🟩	**Main Feed Line**	1.10	26.44	FXL 780	30.48	100.00	1.14	12.7%	0.0439
No 🟥	**Jumper**	1.09	27.32		30.48	100.00	0.00	0.0%	0.0000
No 🟥	Bias Tee	1.15	23.13	0.10			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
Yes 🟩	**Surge Suppressor**	1.07	29.42	0.10			0.10	6.7%	0.0319
No 🟥	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
No 🟥	Bottom Diplexer or Duplexer	1.29	17.95	0.10			0.00	0.0%	0.0000
Yes 🟩	**Jumper**	1.09	27.32	FSJ4-50B	1.83	6.00	0.25	12.2%	0.0431
								100.0%	

Legacy Jumper / TL Cables	Andrew	CommScope
1/2 inch Superflexible Copper	FSJ4-50B	
1/2 inch Foam Copper	LDF4-50A	CR 540
1/2 inch Superflexible Aluminum		SFX 500
1/2 inch Foam Aluminum		FXL 540

Legacy Transmission Lines	Andrew	CommScope
7/8 inch Copper	LDF5-50A	CR 1070
1 1/4 inch Copper	LDF6-50	CR 1480
1 5/8 inch Copper	LDF7-50A	CR 1873
7/8 inch Very Flexible Copper	VXL5-50	
1 1/4 inch Very Flexible Copper	VXL6-50	
1 5/8 inch Very Flexible Copper	VXL7-50	
7/8 inch Virtual Air Copper	AVA5-50	
1 5/8 inch Virtual Air Copper	AVA7-50	
7/8 inch Aluminum	AL5-50	FXL 780
1 1/4 inch Aluminum		FXL 1480
1 5/8 inch Aluminum	AL7-50	FXL 1873

Estimated Conn Loss (2per cable)	0.028
Typical System Reflection:	0.1233
Typical System VSWR:	1.28
Typical System Return Loss (dB):	**18.2**
Worst System Reflection:	0.2467
Worst System VSWR:	1.65
Worst System Return Loss (dB):	**12.2**
Total Insertion Loss (dB):	1.63

Return Loss to VSWR converter

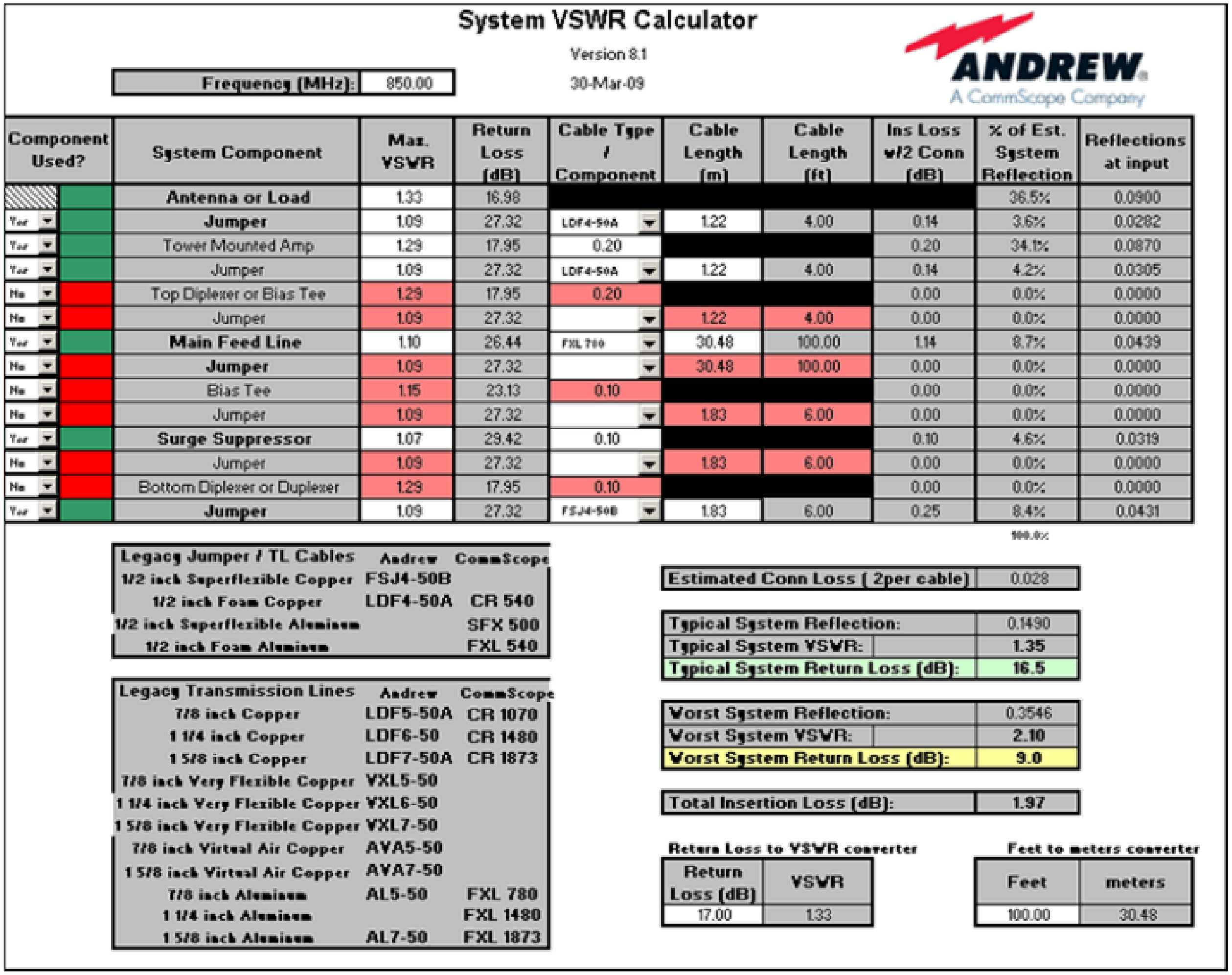
Return Loss (dB)	VSWR
17.00	1.33

Feet to meters converter

Feet	meters
100.00	30.48

Typical system return loss decreases by only 0.1 dB.

Figure 5: TMA Added to Figure 4



System VSWR Calculator

Version 8.1

30-Mar-09

Frequency (MHz): 850.00

Component Used?		System Component	Max. VSWR	Return Loss (dB)	Cable Type / Component	Cable Length (m)	Cable Length (ft)	Ins Loss w/2 Conn (dB)	% of Est. System Reflection	Reflections at input
▨	🟩	Antenna or Load	1.33	16.98					36.5%	0.0900
Yes	🟩	Jumper	1.09	27.32	LDF4-50A	1.22	4.00	0.14	3.6%	0.0282
Yes	🟩	Tower Mounted Amp	1.29	17.95	0.20			0.20	34.1%	0.0870
Yes	🟩	Jumper	1.09	27.32	LDF4-50A	1.22	4.00	0.14	4.2%	0.0305
No	🟥	Top Diplexer or Bias Tee	1.29	17.95	0.20			0.00	0.0%	0.0000
No	🟥	Jumper	1.09	27.32		1.22	4.00	0.00	0.0%	0.0000
Yes	🟩	Main Feed Line	1.10	26.44	FXL 780	30.48	100.00	1.14	8.7%	0.0439
No	🟥	Jumper	1.09	27.32		30.48	100.00	0.00	0.0%	0.0000
No	🟥	Bias Tee	1.15	23.13	0.10			0.00	0.0%	0.0000
No	🟥	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
Yes	🟩	Surge Suppressor	1.07	29.42	0.10			0.10	4.6%	0.0319
No	🟥	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
No	🟥	Bottom Diplexer or Duplexer	1.29	17.95	0.10			0.00	0.0%	0.0000
Yes	🟩	Jumper	1.09	27.32	FSJ4-50B	1.83	6.00	0.25	8.4%	0.0431
									100.0%	

Legacy Jumper / TL Cables	Andrew	CommScope
1/2 inch Superflexible Copper	FSJ4-50B	
1/2 inch Foam Copper	LDF4-50A	CR 540
1/2 inch Superflexible Aluminum		SFX 500
1/2 inch Foam Aluminum		FXL 540

Legacy Transmission Lines	Andrew	CommScope
7/8 inch Copper	LDF5-50A	CR 1070
1 1/4 inch Copper	LDF6-50	CR 1480
1 5/8 inch Copper	LDF7-50A	CR 1873
7/8 inch Very Flexible Copper	VXL5-50	
1 1/4 inch Very Flexible Copper	VXL6-50	
1 5/8 inch Very Flexible Copper	VXL7-50	
7/8 inch Virtual Air Copper	AVA5-50	
1 5/8 inch Virtual Air Copper	AVA7-50	
7/8 inch Aluminum	AL5-50	FXL 780
1 1/4 inch Aluminum		FXL 1480
1 5/8 inch Aluminum	AL7-50	FXL 1873

Estimated Conn Loss (2per cable)	0.028
Typical System Reflection:	0.1490
Typical System VSWR:	1.35
Typical System Return Loss (dB):	16.5
Worst System Reflection:	0.3546
Worst System VSWR:	2.10
Worst System Return Loss (dB):	9.0
Total Insertion Loss (dB):	1.97

Return Loss to VSWR converter

Return Loss (dB)	VSWR
17.00	1.33

Feet to meters converter

Feet	meters
100.00	30.48

Typical system return loss decreases by an additional 1.7 dB.

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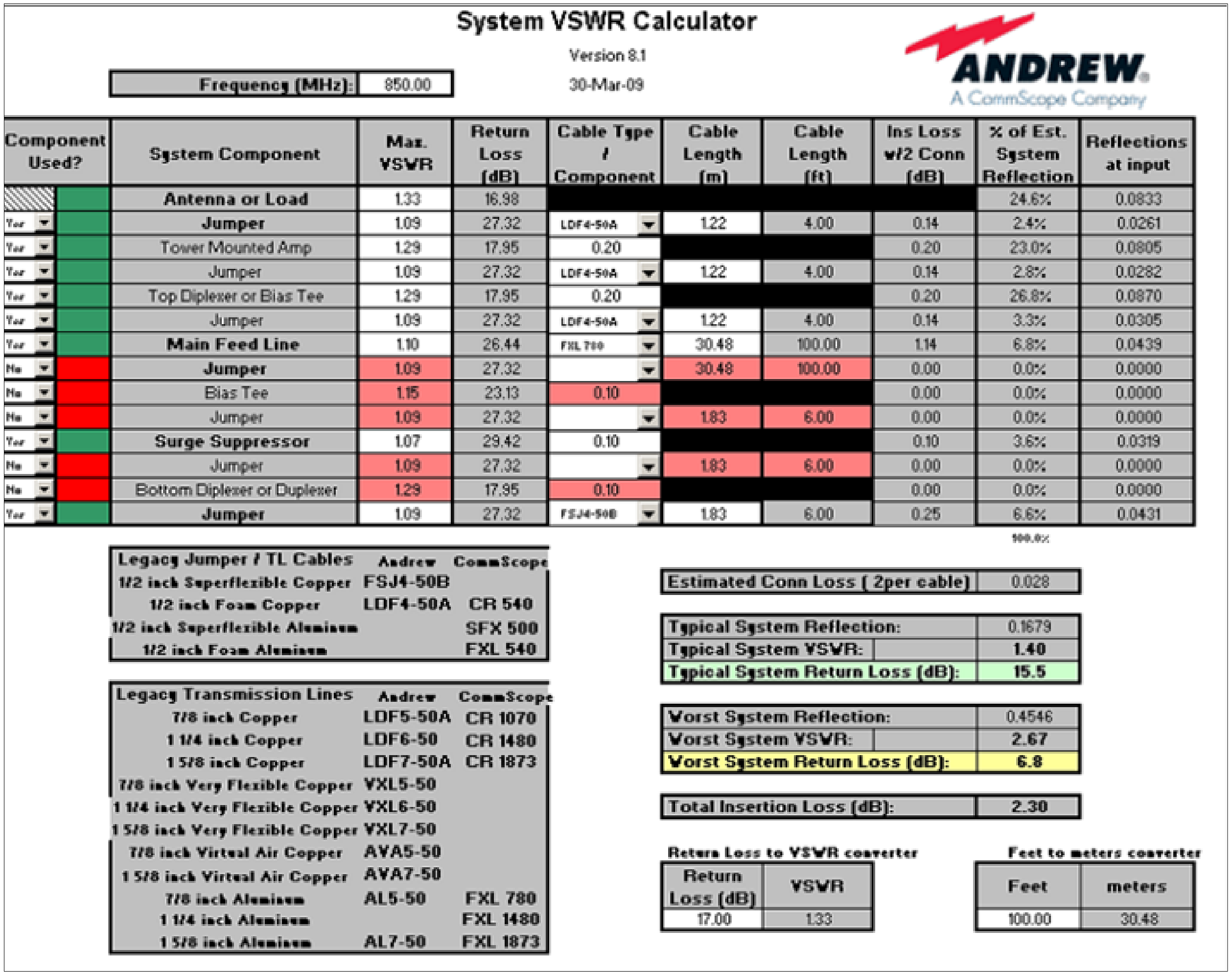
Figure 6: Top Diplexer (or Crossband Coupler) Added to Figure 5



System VSWR Calculator

Version 8.1

30-Mar-09

Frequency (MHz): 850.00

Component Used?	System Component	Max. VSWR	Return Loss (dB)	Cable Type / Component	Cable Length (m)	Cable Length (ft)	Ins Loss w/2 Conn (dB)	% of Est. System Reflection	Reflections at input
	Antenna or Load	1.33	16.98					24.6%	0.0833
Yes	**Jumper**	1.09	27.32	LDF4-50A	1.22	4.00	0.14	2.4%	0.0261
Yes	Tower Mounted Amp	1.29	17.95	0.20			0.20	23.0%	0.0805
Yes	Jumper	1.09	27.32	LDF4-50A	1.22	4.00	0.14	2.8%	0.0282
Yes	Top Diplexer or Bias Tee	1.29	17.95	0.20			0.20	26.8%	0.0870
Yes	Jumper	1.09	27.32	LDF4-50A	1.22	4.00	0.14	3.3%	0.0305
Yes	**Main Feed Line**	1.10	26.44	FXL 780	30.48	100.00	1.14	6.8%	0.0439
No	**Jumper**	1.09	27.32		30.48	100.00	0.00	0.0%	0.0000
No	Bias Tee	1.15	23.13	0.10			0.00	0.0%	0.0000
No	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
Yes	**Surge Suppressor**	1.07	29.42	0.10			0.10	3.6%	0.0319
No	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
No	Bottom Diplexer or Duplexer	1.29	17.95	0.10			0.00	0.0%	0.0000
Yes	**Jumper**	1.09	27.32	FSJ4-50B	1.83	6.00	0.25	6.6%	0.0431
								100.0%	

Legacy Jumper / TL Cables	Andrew	CommScope
1/2 inch Superflexible Copper	FSJ4-50B	
1/2 inch Foam Copper	LDF4-50A	CR 540
1/2 inch Superflexible Aluminum		SFX 500
1/2 inch Foam Aluminum		FXL 540

Legacy Transmission Lines	Andrew	CommScope
7/8 inch Copper	LDF5-50A	CR 1070
1 1/4 inch Copper	LDF6-50	CR 1480
1 5/8 inch Copper	LDF7-50A	CR 1873
7/8 inch Very Flexible Copper	VXL5-50	
1 1/4 inch Very Flexible Copper	VXL6-50	
1 5/8 inch Very Flexible Copper	VXL7-50	
7/8 inch Virtual Air Copper	AVA5-50	
1 5/8 inch Virtual Air Copper	AVA7-50	
7/8 inch Aluminum	AL5-50	FXL 780
1 1/4 inch Aluminum		FXL 1480
1 5/8 inch Aluminum	AL7-50	FXL 1873

Estimated Conn Loss (2per cable)	0.028
Typical System Reflection:	0.1679
Typical System VSWR:	1.40
Typical System Return Loss (dB):	15.5
Worst System Reflection:	0.4546
Worst System VSWR:	2.67
Worst System Return Loss (dB):	6.8
Total Insertion Loss (dB):	2.30

Return Loss to VSWR converter

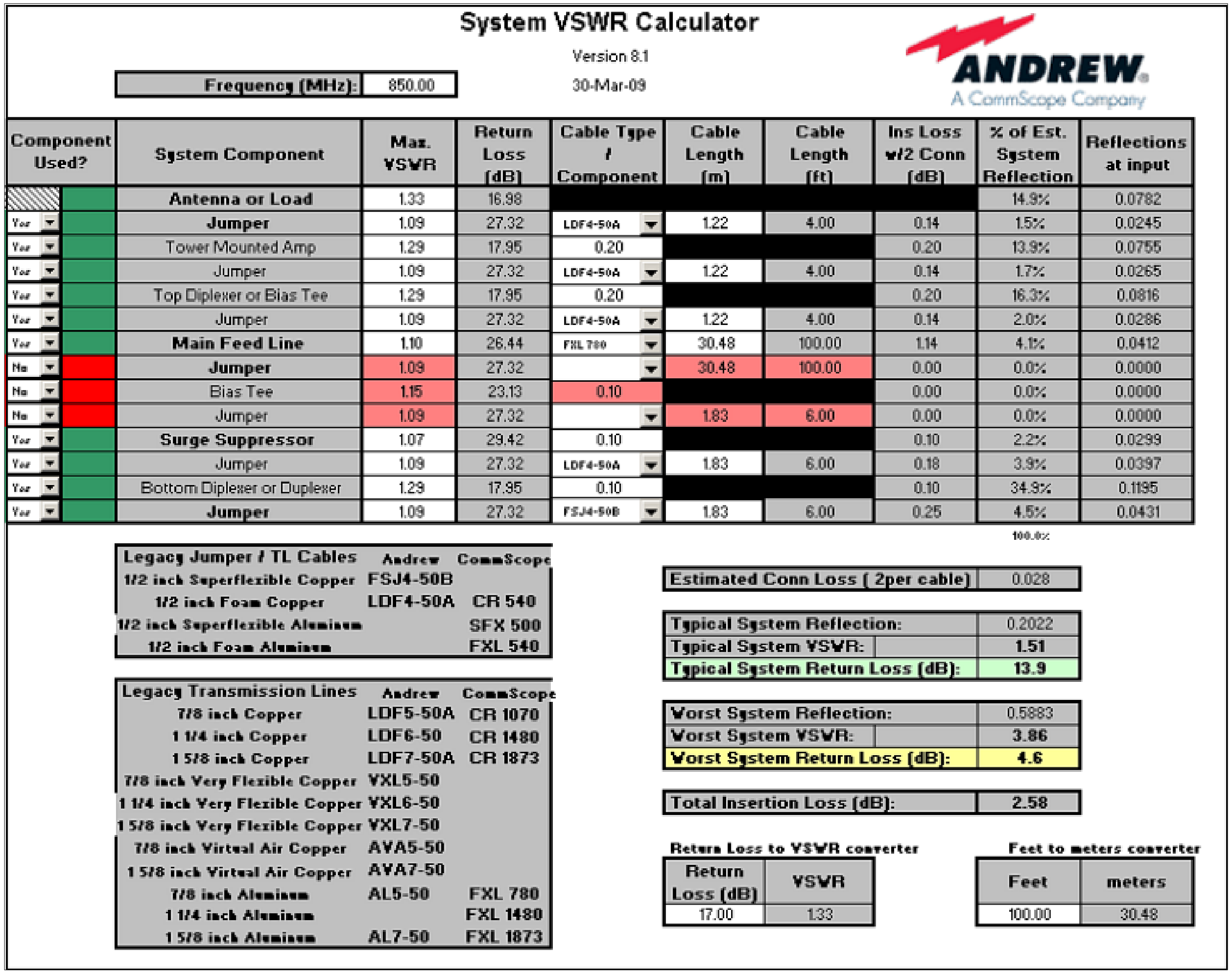
Return Loss (dB)	VSWR
17.00	1.33

Feet to meters converter

Feet	meters
100.00	30.48

Typical system return loss decreases by an additional 1.0 dB.

Figure 7: Bottom Diplexer or Duplexer Added to Figure 6



System VSWR Calculator

Version 8.1

30-Mar-09

Frequency (MHz): 850.00

Component Used?	System Component	Max. VSWR	Return Loss (dB)	Cable Type / Component	Cable Length (m)	Cable Length (ft)	Ins Loss w/2 Conn (dB)	% of Est. System Reflection	Reflections at input
🟩	**Antenna or Load**	1.33	16.98					14.9%	0.0782
Yes 🟩	**Jumper**	1.09	27.32	LDF4-50A	1.22	4.00	0.14	1.5%	0.0245
Yes 🟩	Tower Mounted Amp	1.29	17.95	0.20			0.20	13.9%	0.0755
Yes 🟩	Jumper	1.09	27.32	LDF4-50A	1.22	4.00	0.14	1.7%	0.0265
Yes 🟩	Top Diplexer or Bias Tee	1.29	17.95	0.20			0.20	16.3%	0.0816
Yes 🟩	Jumper	1.09	27.32	LDF4-50A	1.22	4.00	0.14	2.0%	0.0286
Yes 🟩	**Main Feed Line**	1.10	26.44	FXL 780	30.48	100.00	1.14	4.1%	0.0412
No 🟥	**Jumper**	1.09	27.32		30.48	100.00	0.00	0.0%	0.0000
No 🟥	Bias Tee	1.15	23.13	0.10			0.00	0.0%	0.0000
No 🟥	Jumper	1.09	27.32		1.83	6.00	0.00	0.0%	0.0000
Yes 🟩	**Surge Suppressor**	1.07	29.42	0.10			0.10	2.2%	0.0299
Yes 🟩	Jumper	1.09	27.32	LDF4-50A	1.83	6.00	0.18	3.9%	0.0397
Yes 🟩	Bottom Diplexer or Duplexer	1.29	17.95	0.10			0.10	34.9%	0.1195
Yes 🟩	**Jumper**	1.09	27.32	FSJ4-50B	1.83	6.00	0.25	4.5%	0.0431
								100.0%	

Legacy Jumper / TL Cables	Andrew	CommScope
1/2 inch Superflexible Copper	FSJ4-50B	
1/2 inch Foam Copper	LDF4-50A	CR 540
1/2 inch Superflexible Aluminum		SFX 500
1/2 inch Foam Aluminum		FXL 540

Legacy Transmission Lines	Andrew	CommScope
7/8 inch Copper	LDF5-50A	CR 1070
1 1/4 inch Copper	LDF6-50	CR 1480
1 5/8 inch Copper	LDF7-50A	CR 1873
7/8 inch Very Flexible Copper	VXL5-50	
1 1/4 inch Very Flexible Copper	VXL6-50	
1 5/8 inch Very Flexible Copper	VXL7-50	
7/8 inch Virtual Air Copper	AVA5-50	
1 5/8 inch Virtual Air Copper	AVA7-50	
7/8 inch Aluminum	AL5-50	FXL 780
1 1/4 inch Aluminum		FXL 1480
1 5/8 inch Aluminum	AL7-50	FXL 1873

Estimated Conn Loss (2per cable)	0.028
Typical System Reflection:	0.2022
Typical System VSWR:	1.51
Typical System Return Loss (dB):	13.9
Worst System Reflection:	0.5883
Worst System VSWR:	3.86
Worst System Return Loss (dB):	4.6
Total Insertion Loss (dB):	2.58

Return Loss to VSWR converter

Return Loss (dB)	VSWR
17.00	1.33

Feet to meters converter

Feet	meters
100.00	30.48

Typical system return loss decreases to below 14 dB (1.5 to 1 VSWR).

Visit our Web site at www.andrew.com or contact your local Andrew Solutions representative for more information.

6. Effects of Cable Length and Type on System Performance

Cable length and type can have a significant effect on overall system performance. Table 1 below demonstrates the degree of variance associated with different cable lengths and cable types. The results from Figures 1–7 are indicated in the 100 ft FXL-780 columns below. The additional data has been included for comparative purposes. It also demonstrates how the Andrew System VSWR Calculator may be used in evaluating a variety of possible RF design scenarios.

Table 1. Return Loss / Insertion Loss Comparison Chart

Antenna Return Loss 16.98 dB — Transmission Frequency 850 MHz									
		50 ft 7/8” FXL-780		**100 ft 7/8” FXL-780**		**175 ft 1 5/8” FXL-780**		**175 ft 1 5/8” AVA7-50**	
		RL	**IL**	**RL**	**IL**	**RL**	**IL**	**RL**	**IL**
Figure 1	Antenna, Main @ 1.001 VSWR	18.2	0.60	19.30	1.14	20.9	1.96	19.3	1.15
Figure 2	Antenna, Main @ 1.11 VSWR	17.6	0.60	18.50	1.14	19.8	1.96	18.5	1.15
Figure 3	Antenna, Main, Jumpers	17.5	0.99	18.30	1.53	19.4	2.35	18.3	1.54
Figure 4	Antenna, Main, Jumpers, Surge	17.4	1.09	18.20	1.63	19.2	2.45	18.2	1.64
Figure 5	Antenna, Main, Jumpers, Surge, TMA	15.7	1.42	16.50	1.97	17.8	2.78	16.5	1.98
Figure 6	Antenna, Main, Jumpers, Surge, TMA, Top CBC	14.6	1.76	15.50	2.30	16.8	3.12	15.5	2.31
Figure 7	Antenna, Main, Jumpers, Surge, TMA, Both CBC	13.3	2.04	13.90	2.58	14.6	3.40	13.9	2.59

The observations indicated in Table 1 above highlight several interesting phenomena. While each scenario must be evaluated on its own, the data suggests a few common and noteworthy characteristics.

- In virtually every scenario in which TMAs, diplexers, or duplexers were included, the system return loss degraded when compared to the stand-alone antenna. While this is to be expected due to the additional components in the RF path, it is interesting to note the degree of change due to the specifications of the individual components.
- Scenarios in which only jumper cables and transmission lines longer than 100 feet are used, system return loss nearly equals the sum of the antenna return loss plus the one-way system insertion losses. This is important to note because it is the only situation in which the oversimplified idea that system loss can be expressed as the sum loss comes close to being accurate.
- All else being equal, the shorter the transmission line—the worse the system return loss. This is due to the fact that as the insertion loss from the transmission line increases, the masking effect of components further along the RF path also increases. This suggests that components toward the base of the tower have a greater effect on system return loss than those higher up.

7. Dual-Duplex TMA Concerns

When conducting full-band return loss sweeps in the field, there will generally be a relatively better return loss in the transmit (downlink) band than in the bypassed receive (uplink) band. More importantly, there will be a significant return loss degradation in the guard band between transmit and receive, since this is the area where duplex filter selectivity is present. Any sweep readings noted over this guard band range should be discarded.

8. Conclusions

The growing complexity of today's antenna systems has had a significant impact on everything from RF system design and implementation to system maintenance and optimization. As more components are added to the RF path, the aggregate affect on cascaded return loss increases, making it more difficult to determine if the system as a whole is performing up to its capabilities.

As the data here has shown, it is quite possible for a multi-component RF path system to yield a system return loss that is worse than the industry accepted maximum of 1.5 to 1 VSWR (14 dB return loss). This may be true even though each component in the system is meeting its individual specifications. All too often RF engineers are quick to place the blame on the antenna instead of using a rigorous method for calculating what the typical and worst case scenario for return loss should be.

The Andrew System VSWR Calculator enables engineers to input the specific parameters of any antenna system and calculate both typical and worst case return loss for a number of possible design scenarios. The data generated gives the system engineer or field technician a better understanding of what VSWR or return loss results should be expected for a given RF path architecture and frequency. It also allows the RF system designer to look at performance comparisons for various main transmission line and jumper cable combinations.

While it is important that engineers resist the temptation to over-generalize based on data from specific scenarios, careful analysis of the data may yield insights that will allow engineers to increase RF efficiency and performance for subsequent systems.

References:

[1] Electronic Warfare and Radar Systems Engineering Handbook, Microwave / RF Components, Voltage Standing Wave Ratio (VSWR) / Reflection Coefficient / Return Loss / Mismatch Loss. https://ewhdbks.mugu.navy.mil/VSWR.htm

[2] Andrew Solutions Application Note: *Minimum Field Testing Recommended for Antenna and HELIAX® Coaxial Cable Systems Operating in the 800 to 2000 MHz Range.*