CABLE LOSS MASKING EFFECT

Masking Effect of Cable Loss on Antenna VSWR and Return Loss Measurements

Jim Norton, Applications Engineer
Bird® Technologies Group
Tel: 866.695.4569 / www.bird-electronic.com

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Application Note

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By: Jim Norton, Applications Engineer
Bird Electronic Corporation

Introduction

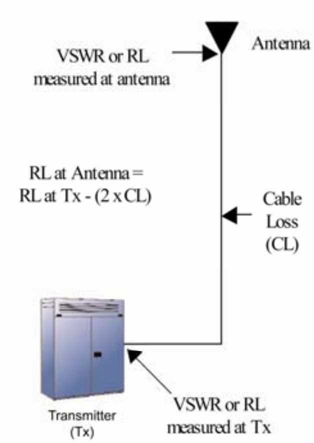
The masking effect of cable loss may cause your antenna to "appear" to perform more efficiently than is actually the case. In fact, it is possible to measure apparently acceptable VSWR or return loss levels even though your antenna may be completely out of operation. The purpose of this article is to provide an understanding of cable loss masking effect and explain how to avoid these pitfalls.

Figure 1 and Examples 1 & 2 illustrate the masking effects of cable loss. As you can see, 3 dB of cable loss will produce measurements with a significant error offset. Given that a typical antenna is designed to operate at 1.5 VSWR (-14.0 dB return loss) or better, this could make the difference between judging your antenna as in or out of specification. Furthermore, 7 dB of cable loss could render the measurement meaningless. This worst-case scenario may allow an antenna failure to go undetected!

A step-by-step procedure to arrive at these figures is discussed later in this paper. For your convenience, the "Cable Loss Masking Effect Chart" may be found in the appendix of this application note. You can also readily perform this analysis and several others for your specific application by downloading a complimentary copy of the "RF Calculator" at www.bird-electronic.com (under "Support" and "Technical Application Notes" tabs).

Figure 1: Cable Loss Masking Effect

Cable loss will mask antenna VSWR or Return Loss (RL) measurements taken at the transmitter end of the cable.



Example 1: Cable Loss of 3 dB	**Example 2: Cable Loss of 7 dB**
Cable loss: 3.0 dB	Cable loss: 7.0 dB
VSWR measured at transmitter: 1.50 VSWR (-14.0 dB return loss) Antenna VSWR (actual): 2.33 VSWR (-8.0 dB return loss) VSWR measurement error: *0.83 VSWR (6.0 dB return loss)*	VSWR measured at transmitter: 1.50 VSWR (-14.0 dB return loss) Antenna VSWR (actual): 100+ VSWR (0.0 dB return loss) VSWR measurement error: *98.5+ VSWR (14.0 dB return loss)*
Forward power measured at transmitter: 100.0 W Forward power at the antenna (actual): 50.1 W Forward power measurement error: *99.6 % W*	Forward power measured at transmitter: 100.0 W Forward power at the antenna (actual): 20.0 W Forward power measurement error: *400.0 % W*
Reflected power measured at transmitter: 4.0 W Reflected power at antenna (actual): 8.0 W Reflected power measurement error: *-50.0 % W*	Reflected power measured at transmitter: 4.0 W Reflected power at antenna (actual): 20.0 W Reflected power measurement error: *-80 % W*

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Masking Effect

The masking effect of cable loss causes an error offset when measuring antenna VSWR or return loss levels. This error offset may be corrected with the following equation:

RL at Antenna = RL at Transmitter - (2 x CL)

RL = Return Loss
CL = Cable Loss

VSWR levels may be corrected by converting to/from equivalent return loss levels.

Cable Loss

Cable loss is the total insertion loss of your transmission cable system. This will typically include insertion loss of the transmission cable, jumper cables, connectors and lightning protection. Note, loss of other components (e.g. VSWR/power monitor, duplexer, combiner or filter) may also come into play.

As an example, the transmission cable system for an 800 MHz antenna mounted at the 200 ft (61 m) level of a tower may include the following:

Transmission Cable: 7/8" Andrew LDF5-50A, 1.13 dB/100 ft (3.69 dB/ 100 m) @ 824 MHz

Jumper Cable: 1/2" Andrew FSJ4-50B, 3.23 dB/100 ft (10.6 dB/ 100 m) @ 824 MHz

230 ft (70 m) of transmission cable =	2.60 dB
20 ft (6 m) jumper at transmitter =	0.65 dB
10 ft (3 m) jumper at antenna =	0.32 dB
Connection pairs x 4 = 0.1 x 4 =	0.4 dB
Lightning protection =	0.1 dB
Cable loss (total insertion loss) =	4.07 dB

In this case, a 1.17 VSWR (-22.1 dB RL) measured at the transmitter end of the cable would indicate that the antenna measurement is actually 1.50 VSWR (-14.0 dB RL). This would be acceptable as a typical antenna is designed to operate at 1.50 VSWR (-14.0 dB RL) or better.

Similarly, a 1.50 VSWR (-14.0 dB RL) measured at the transmitter would equate to a 3.09 VSWR (-5.8 dB RL) at the antenna. This would signify that the antenna in not performing to the 1.50 VSWR (-14.0 dB RL) specification.

Finally, a 2.29 VSWR (-8.1 dB RL) at the transmitter yields an antenna with a 100+ VSWR (0.0 dB RL). This measurement should alert the user that the antenna has failed and requires immediate attention!

Measuring Cable Loss

Cable loss can be measured with the same equipment used to measure your antenna VSWR or return loss levels. A vector network analyzer (VNA) with a cable loss mode streamlines this measurement. Simply connect one end of your cable to the VNA, place an open or short at the far end of the cable, and perform the cable loss test.

A VNA with a distance-to-fault (DTF) or fault location mode will automatically correct for cable loss. The cable loss per meter or foot parameter is entered during the setup of the DTF measurement. Once setup, connect one end of your cable to the VNA with the antenna connected at the far end of the cable and perform the DTF test. The result is an antenna VSWR or return loss measurement corrected for cable loss.

A power meter may also be used to calculate cable loss. Measure the power levels at the input and output of your cable, convert to units of dBm, and calculate the difference. As an example, input power of 100 W (50 dBm) and output of 50 W (47 dBm) yields a cable loss of 3 dB (50 dBm - 47 dBm).

Cable loss may also be estimated as we did in the previous section of this paper. Sum the insertion loss parameters for each component of your transmission cable system at your operating frequency. Note, insertion loss increases as frequency increases.

Step-by-Step Procedure

To review, cable loss has a masking effect on antenna VSWR and return loss measurements. The end result is an error offset that must be corrected. The following exercise walks you through this process with a step-by-step procedure.

Referring to Figure 1 and Example 1 at the introduction of this paper, a 100 W transmitter is connected to a cable and antenna. Cable insertion loss is known to be 3 dB. Measurements taken at the transmitter end of the cable indicate a VSWR of 1.5 (-14.0 dB return loss). What is the actual antenna VSWR or return loss?

Step 1) Forward Power at Antenna

We will begin by calculating the forward power present at the antenna.

1a) List Known Values

Forward Power at Transmitter = 100.0 W

Cable Loss = 3.0 dB

1b) Forward Power

Forward Power at Transmitter
= 100.0 W
Convert W to dBm
= 10 x Log 100.0 W + 30
= 50.0 dBm

Forward Power at Antenna
= Forward Power at Transmitter - Cable Loss
= 50.0 dBm - 3.0 dB
= 47.0 dBm
Convert dBm to W
= $10^{(47.0\text{ dBm} - 30) / 10}$
= 50.1 W

Step 2) Reflected Power at Antenna

2a) List Known Values

Measurement at transmitter
= 1.50 VSWR
= -14.0 dB Return Loss

Forward Power at Transmitter
= 100.0 W
= 50.0 dBm

Cable Loss = 3.0 dB

2b) Reflected Power

Reflected Power at Transmitter
= Forward Power x $10^{(\text{Return Loss} / 10)}$
= 100.0 W x $10^{(-14\text{ dB} / 10)}$ = 4.0 W
Convert W to dBm
= 10 x Log 4.0 W + 30
= 36.0 dBm

Reflected Power at Antenna
= Reflected Power at Transmitter + Cable Loss
= 36.0 dBm + 3.0 dB
= 39.0 dBm
Convert dBm to W
= $10^{(39.0\text{ dBm} - 30) / 10}$
= 8.0 W

Step 3) VSWR and RL at Antenna

3a) List Known Values

Forward Power at Antenna
= 50.1 W
= 47.0 dBm

Reflected Power at Antenna
= 8.0 W
= 39.0 dBm

3b) VSWR and RL at Antenna

Rho at Antenna
= Sqrt (Reflected / Forward Power)
= Sqrt (8.0 W / 50.1 W)
= 0.4

VSWR at Antenna
= (1 + Rho) / (1 - Rho)
= (1 + 0.4) / (1 - 0.4)
= 2.33

Return Loss at Antenna
= 10 Log (Reflected / Forward Power)
= 10 Log (8.0 W / 50.1 W)
= -8.0 dB

Summary

As expected, the results of this step-by-step procedure agree with those listed in Example 1 at the beginning of this article. The "Cable Loss Masking Effect Chart" (see appendix) and "RF Calculator" (www.bird-electronic.com) will confirm as well.

After performing a number of calculations or reviewing the chart you will see a few trends that are worthy of note:

1) As cable loss increases the error offsets increase as well.

2) As VSWR or return loss levels increase the error offsets also increase.

3) Error offsets are independent of power levels. As an example, 3 mW, 50 W and 1 kW applications are all equally affected by the masking effect of cable loss.

In conclusion, cable loss causes a masking effect when measuring antenna VSWR and return loss levels. Cable loss can be measured with the same vector network analyzer or power meter used for your antenna measurements. Correcting for this error offset is essential to determine your antenna's actual performance level.

Appendix

See the following attachment:

Cable Loss Masking Effect Chart

Cable Loss Masking Effect Chart

Application Note: Masking Effect of Cable Loss on Antenna VSWR and Return Loss Measurements

Cable insertion loss (CL) will mask antenna VSWR or Return Loss (RL) Measurements taken at the Transmitter (Tx) end of the cable. Specifically, RL at Antenna = RL at Transmitter – (2 x CL).

Example: If the cable loss is 3.0 db, a VSWR of 1.50 (-14.0 dB RL) Measured at the transmitter end of the cable yields an antenna VSWR of 2.33 (-8.0 dB RL).

Note, CL may include insertion loss from cables, connectors, lightning protectors, duplexers, combiners, etc.

CL	VSWR at:		RL (dB) at:	
(dB)	Tx	Ant	Tx	Ant
0.5	1.05	1.06	-32.3	-31.3
1.0	1.05	1.06	-32.3	-30.3
2.0	1.05	1.08	-32.3	-28.3
3.0	1.05	1.10	-32.3	-26.3
5.0	1.05	1.17	-32.3	-22.3
7.0	1.05	1.28	-32.3	-18.3
9.0	1.05	1.48	-32.3	-14.3
0.5	1.10	1.11	-26.4	-25.4
1.0	1.10	1.13	-26.4	-24.4
2.0	1.10	1.16	-26.4	-22.4
3.0	1.10	1.21	-26.4	-20.4
5.0	1.10	1.35	-26.4	-16.4
7.0	1.10	1.63	-26.4	-12.4
9.0	1.10	2.22	-26.4	-8.4
0.5	1.20	1.23	-20.8	-19.8
1.0	1.20	1.26	-20.8	-18.8
2.0	1.20	1.34	-20.8	-16.8
3.0	1.20	1.44	-20.8	-14.8
5.0	1.20	1.81	-20.8	-10.8
7.0	1.20	2.67	-20.8	-6.8
9.0	1.20	6.20	-20.8	-2.8
0.5	1.30	1.34	-17.7	-16.7
1.0	1.30	1.39	-17.7	-15.7
2.0	1.30	1.52	-17.7	-13.7
3.0	1.30	1.70	-17.7	-11.7
5.0	1.30	2.40	-17.7	-7.7
7.0	1.30	4.78	-17.7	-3.7
9.0	1.30	100+	-17.7	0.0
0.5	1.40	1.46	-15.6	-14.6
1.0	1.40	1.53	-15.6	-13.6
2.0	1.40	1.72	-15.6	-11.6
3.0	1.40	2.00	-15.6	-9.6
5.0	1.40	3.23	-15.6	-5.6
7.0	1.40	11.14	-15.6	-1.6
9.0	1.40	100+	-15.6	0.0
0.5	1.50	1.58	-14.0	-13.0
1.0	1.50	1.67	-14.0	-12.0
2.0	1.50	1.93	-14.0	-10.0
3.0	1.50	2.33	-14.0	-8.0
5.0	1.50	4.44	-14.0	-4.0
7.0	1.50	100+	-14.0	0.0
9.0	1.50	100+	-14.0	0.0

CL	VSWR at:		RL (dB) at:	
(dB)	Tx	Ant	Tx	Ant
0.5	1.60	1.70	-12.7	-11.7
1.0	1.60	1.82	-12.7	-10.7
2.0	1.60	2.15	-12.7	-8.7
3.0	1.60	2.71	-12.7	-6.7
5.0	1.60	6.40	-12.7	-2.7
7.0	1.60	100+	-12.7	0.0
9.0	1.60	100+	-12.7	0.0
0.5	1.70	1.82	-11.7	-10.7
1.0	1.70	1.97	-11.7	-9.7
2.0	1.70	2.39	-11.7	-7.7
3.0	1.70	3.14	-11.7	-5.7
5.0	1.70	10.10	-11.7	-1.7
7.0	1.70	100+	-11.7	0.0
9.0	1.70	100+	-11.7	0.0
0.5	1.80	1.94	-10.9	-9.9
1.0	1.80	2.12	-10.9	-8.9
2.0	1.80	2.66	-10.9	-6.9
3.0	1.80	3.65	-10.9	-4.9
5.0	1.80	19.73	-10.9	-0.9
7.0	1.80	100+	-10.9	0.0
9.0	1.80	100+	-10.9	0.0
0.5	1.90	2.07	-10.2	-9.2
1.0	1.90	2.28	-10.2	-8.2
2.0	1.90	2.94	-10.2	-6.2
3.0	1.90	4.25	-10.2	-4.2
5.0	1.90	100+	-10.2	-0.2
7.0	1.90	100+	-10.2	0.0
9.0	1.90	100+	-10.2	0.0
0.5	2.00	2.19	-9.5	-8.5
1.0	2.00	2.45	-9.5	-7.5
2.0	2.00	3.24	-9.5	-5.5
3.0	2.00	4.97	-9.5	-3.5
5.0	2.00	100+	-9.5	0.0
7.0	2.00	100+	-9.5	0.0
9.0	2.00	100+	-9.5	0.0
0.5	2.50	2.85	-7.4	-6.4
1.0	2.50	3.34	-7.4	-5.4
2.0	2.50	5.24	-7.4	-3.4
3.0	2.50	12.80	-7.4	-1.4
5.0	2.50	100+	-7.4	0.0
7.0	2.50	100+	-7.4	0.0
9.0	2.50	100+	-7.4	0.0