Antenna Measurement with Network Analyzer

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Keywords

- *Antenna*
- *Network Analyzer*
- *Measure*
- *Return Loss*
- *Reflection*
- *Impedance*

1 Introduction

The performance of an antenna will impact the communication range of a RF system. Since range is often a critical factor when designing RF systems, it is important to be able to characterize the antenna. One parameter that is important, and which can easily be measured is the return loss (RL). Impedance mismatch between the feeding transmission line and the antenna causes reflection at the feed point of the antenna. Because of this reflection not all of the available power will reach the antenna, and thus the field strength of the radiated signal will be reduced. RL describes how much of the available power is reflected at the feed point of the antenna. This document describes how RL can be measured, with a network analyzer, and how to interpret the result. The measurement technique described in this document is only applicable to single ended antennas. A brief explanation on how to tune the antenna impedance is also described.

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2 Abbreviations

RC	Remote Control
RL	Return Loss
VSWR	Voltage Standing Wave Ratio

3 Impedance Matching

To ensure that maximum power is delivered from a transmission line with impedance Z_0 to an antenna with impedance Z_a, it is important that Z_0 is properly matched to Z_a. If a signal with amplitude V_{IN} is sent in to the transmission line, only a part of the incident wave will be transmitted to the antenna if Z_0 is not properly matched to Z_a. The remaining part will be reflected back to the generator with amplitude of V_{refl}.

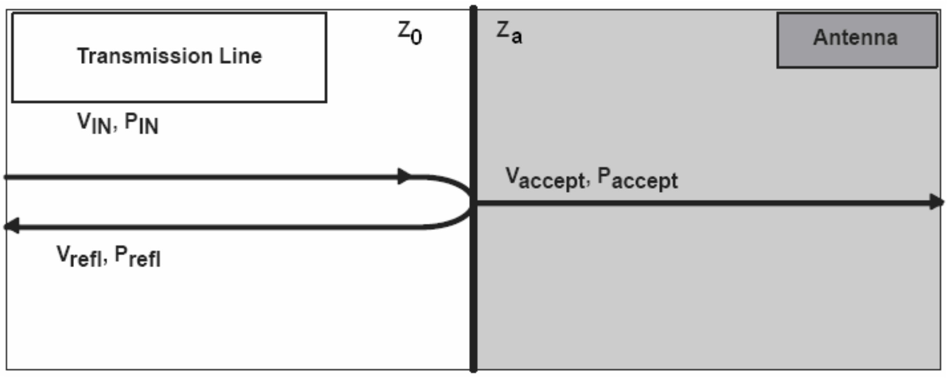

Figure 1. Reflection at the Feed Point of the Antenna

The complex reflection coefficient Γ is defined as the ratio of the reflected waves' amplitude to the amplitude of the incident wave. Γ can be calculated from the impedance of the transmission line and the impedance of the antenna, as shown in Equation 1

$$\Gamma = \frac{Z_a - Z_0}{Z_a + Z_0}$$

Equation 1. Calculation of Γ

The reflection coefficient is zero if the transmission line impedance is the complex conjugate of the antenna impedance. Thus if $Z_a = Z^*_0$ the antenna is perfectly matched to the transmission line and all the applied power is delivered to the antenna. The power ratio of the reflected to the incident wave is called return loss (RL). The RL gives how many dB the power of the reflected wave is below the incident wave.

$$RL = 10 \cdot \log \frac{P_{in}}{P_{refl}} = -10 \cdot \log\left|\overline{\Gamma}\right|^2 = -20 \cdot \log\left|\overline{\Gamma}\right|$$

Equation 2. Calculation of Return Loss

Equation 2 shows that RL only depends on the absolute value of the reflection coefficient. Phase is not evaluated when measuring the RL.

4 How to Measure Return Loss and Impedance

This section describes how to use a network analyzer to measure the impedance and RL of an antenna. It also deals with factors that can affect the measurement result and how to interpret the results. One should be aware that especially placement of the antenna during measurement can affect the result.

4.1 Calibration

It is important to calibrate the network analyzer before doing measurements. The network analyzer should be calibrated for a suitable frequency range containing the band where the antenna will operate. Typically network analyzers have a cable with SMA connector in the end. Calibration is performed by connecting three known terminations, 50 ohm load, short, and open, to this SMA connector. After calibration the reference plane will be at the connection point of the SMA connector. To measure the reflection at the feed point of the antenna, a semi rigid coax cable with SMA connector in one end, can be used. This cable is soldered to the feed point of the antenna and the connector is connected to the network analyzer. RL is only dependent of the absolute value of the reflection coefficient and hence there is no need to move the reference plane to the feed point to make a correct measurement.

To measure the impedance of the antenna it is necessary to move the reference plane from the SMA connector to the feed point of the antenna. This must be done to adjust for the phase change caused by the semi rigid coax cable. On most network analyzers it is possible to choose an electrical delay to compensate for this phase change. The correct delay can be found by watching how the impedance varies, in the Smith Chart, when measuring the impedance with an open and shortened end of the coax cable. With the end of the coax cable short circuited, the electrically delay should be varied until the impedance is seen as a point to the left in the Smith Chart. Theoretically the same electric delay should result in a point to the right in the Smith Chart when the end is left open. If there is a small difference between the optimum electric delay for the opened and short circuited case, the averaged value should be chosen. When the correct electric delay is found, a correct measurement of the impedance can be performed.

4.2 Mounting of Semi Rigid Coax Cable

To ensure correct measurement it is important that the cable is properly mounted. The length of the unshielded centre conductor should be as short as possible to avoid adding extra inductivity to the result. It is also important to solder the shielding to ground as close as possible to the end of the cable. To avoid that the presence of the cable is affecting the result, the cable should be placed as far away from the antennas as possible. Figure 2 shows a typical example on how the cable should be mounted.

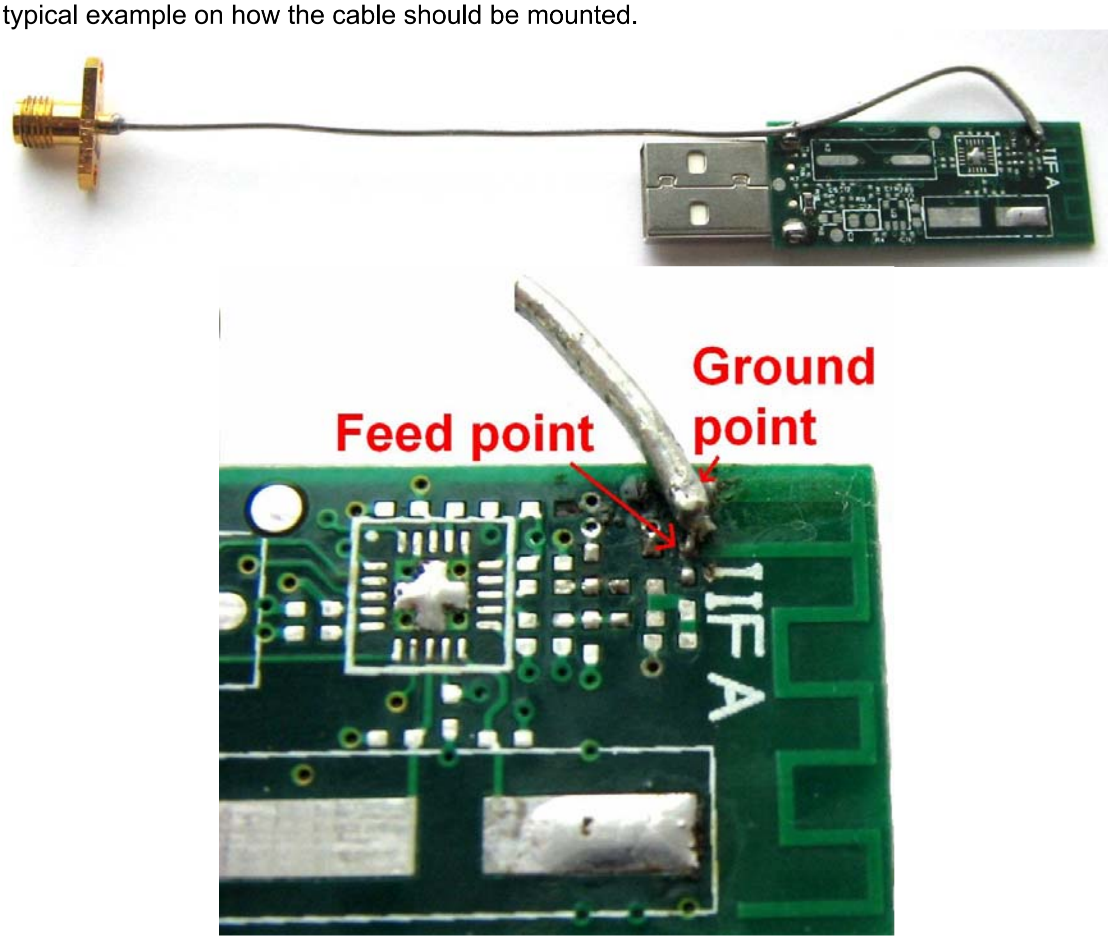

Figure 2. Mounting of Semi Rigid Coax Cable

4.3 Placement of the Device under Test

How the antenna is placed during the measurement will affect the result. Therefore the antenna should be situated in the same manner as it is going to be used when the RL and Impedance is measured. To measure the real performance of an antenna in a remote control (RC) the antenna should be placed inside the plastic casing which is going to be used. The RC should also be held in a hand when conducting the measurement. Even if the antenna is going to be used in a special environment it could also be useful to measure the antenna in free space. This will show how much body effects, plastic casing and other parameters affect the result. To get an accurate result when measuring the antenna in free space, it is important that the antenna is not placed close to other objects. Some kind of damping material could be used to support the antenna and avoid that it lies directly on a table during measurements. Figure 3 shows an example on how the antenna could be mounted during measurement.

Figure 3. Placement of Antenna during Measurement

4.4 Interpreting Measurement Results

To measure an antenna connected to port 1 on a network analyzer, S11 should be chosen. The measured reflection is usually displayed as S11 in dB or as VSWR. A common requirement when defining bandwidth of antennas is reflection less than -10dB or VSWR < 2. This ensures that more than 90% of the available power is delivered to the antenna. Table 1 shows the relation between VSWR, S11dB and reflected power.

VSWR	S11dB	Reflected power %	Delivered power %
1	-∞	0	100
1.1	-27	0.2	99.8
1.2	-21	0.8	99.2
1.5	-14	4	96
2	**-9.5**	**11.1**	**89.9**
3	-6	25	75
4	-4.4	36	64
5	-3.5	44.4	55.6
5.8	-3	50	50
10	-1.7	66.9	33.1

Table 1. Relation between VSWR, S11dB, and Reflected Power

Figure 4 shows results from measurements performed on a PCB antenna intended for a RC. From these results it can bee seen how the performance is affected by the plastic casing and body effects. With S11 < -10dB as a requirement, this antenna has an approximately bandwidth of 400MHz.

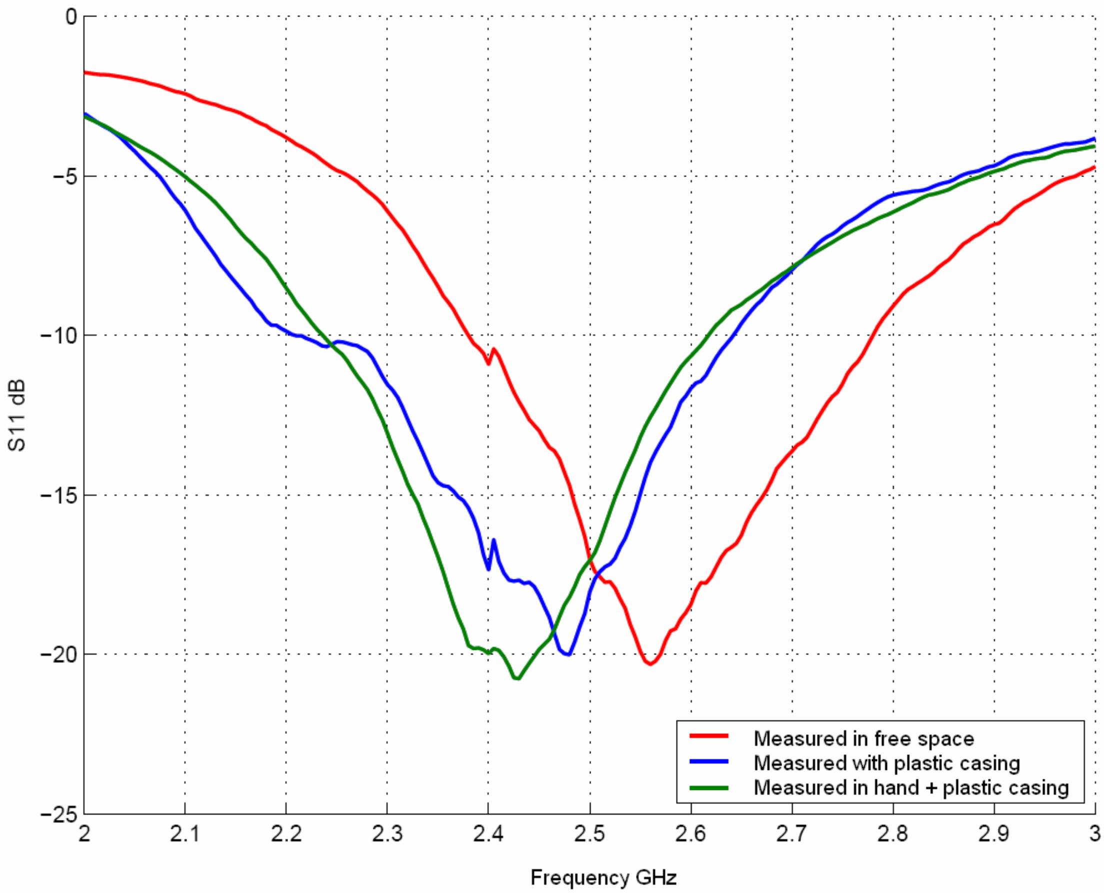

Figure 4. Measurement of Return Loss

The impedance can be measured to see what kind of tuning is necessary to improve the performance of the antenna. Figure 5 shows the corresponding impedance measurements for the RC PCB antenna presented in Figure 4. 2.44GHz is marked width a yellow dot.

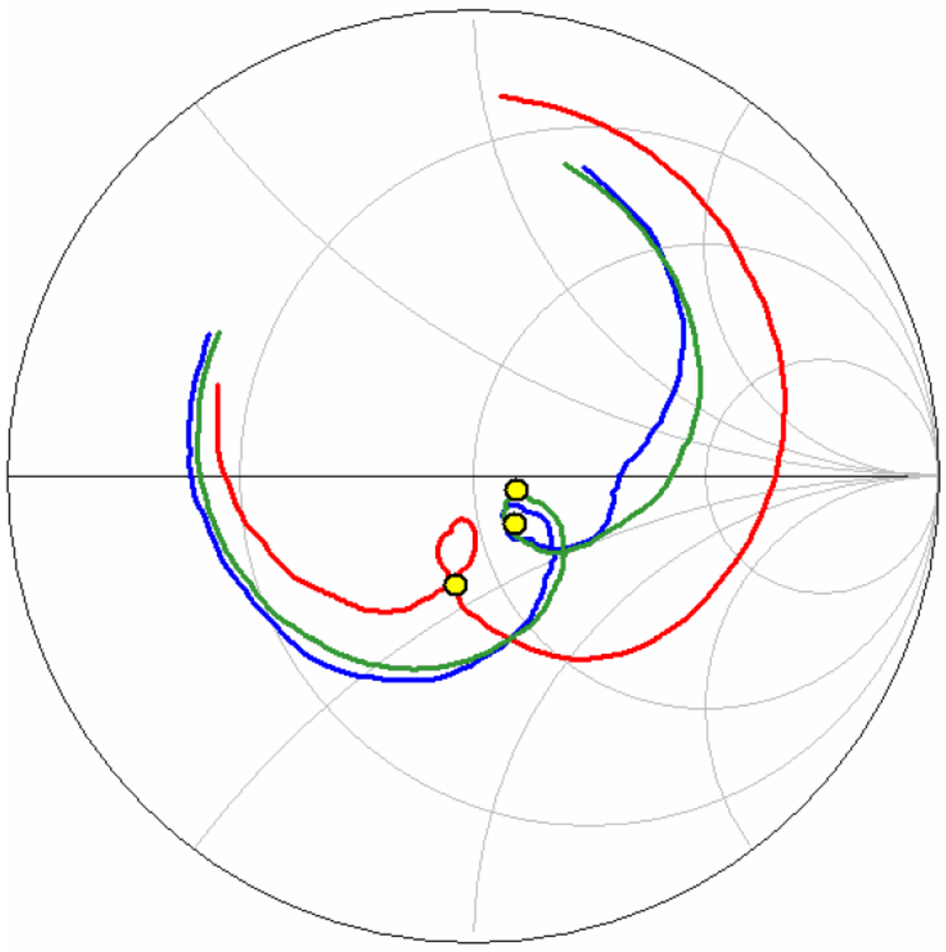

Figure 5. Measurements of Impedance

5 Antenna Tuning

There are several ways to tune an antenna to achieve better performance. For resonant antennas the main factor is the length. Ideally the frequency which gives least reflection should be in the middle of the frequency band of interest. Thus if the resonance frequency is to low, the antenna should be made shorter. If the resonance frequency is too high, the antenna length should be increased.

Even if the antenna resonates at the correct frequency it might not be well matched to the correct impedance. Dependent of the antenna type there are several possibilities to obtain optimum impedance at the correct frequency. Size of ground plane, distance from antenna to ground plane, dimensions of antenna elements, feed point, and plastic casing are factors that can affect the impedance. Thus by varying these factors it might be possible to improve the impedance match of the antenna. If varying these factors is not possible or if the performance still needs to be improved, discreet components could be used to optimize the impedance. Capacitors and inductors in series or parallel can be used to match the antenna to the desired impedance. Figure 6 shows how inductors and capacitors can be used to change the impedance.

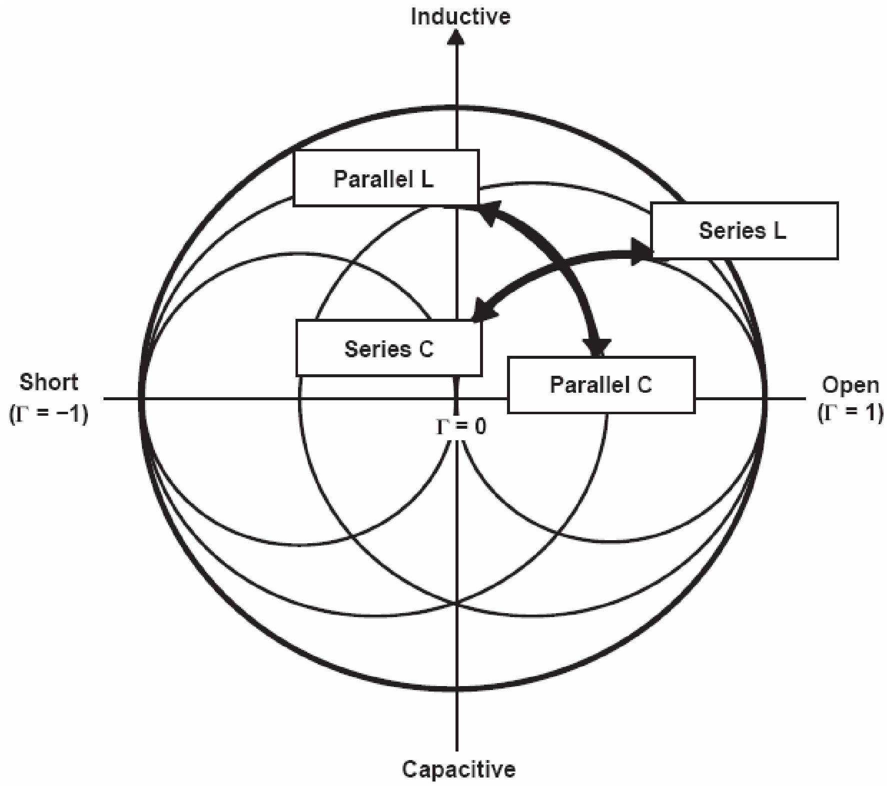

Figure 6. Series and Parallel Capacitors and Inductors in the Smith Chart

It is important that tuning of the antenna is being done when the antenna is placed in the environment where it is going to be used. As shown in Figure 4, the environment around the antenna has a great impact of the performance. This means that optimizing the antenna when it is not placed in the correct environment can result in decreased performance.

6 General Information

6.1 Document History

Revision	Date	Description/Changes
SWRA096	2006.07.06	Initial release.

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