Antenna Testing with the MSA

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This is a quick overview of antenna testing with the MSA. This is not intended as a tutorial, but rather an overview of the capabilities of the MSA.

As a vector network analyzer, the MSA can measure various performance characteristics of antennas, by sending a test signal to the antenna and seeing how it responds. Let's start at low frequency, with an antenna consisting of a loosely strung piece of wire in the workshop. The first thing to look at is the reflection coefficient of the antenna (S11), expressed in dB/angle format.

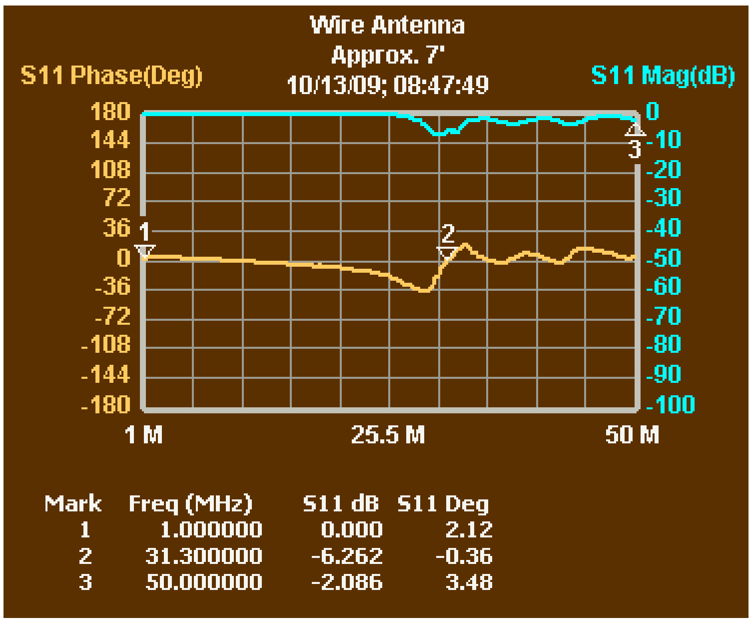

Figure 1—A simple wire antenna at low frequency

S11 Magnitude is blue; phase is orange

Figure 1 shows the performance of the wire antenna, as viewed by S11. The graph is fairly straight, with a couple of wiggles. What does it mean? First of all, whenever the phase of reflection is zero, such as at marker 2, there is resonance. What that means is that the impedance of the antenna at the resonance frequencies is purely resistive. Resistance means energy is being dissipated. Reactance means energy is being temporarily stored and then re-released. An antenna is dissipating energy when it is radiating. So an antenna must present resistance if it is doing its job. That doesn't mean that resistance guarantees it is doing its job. But with a simple wire antenna, with no significant coaxial cable connecting it to the MSA, there is not much that can be creating resistance other than radiation.

Now for a Smith chart, showing the same data as Figure 1.

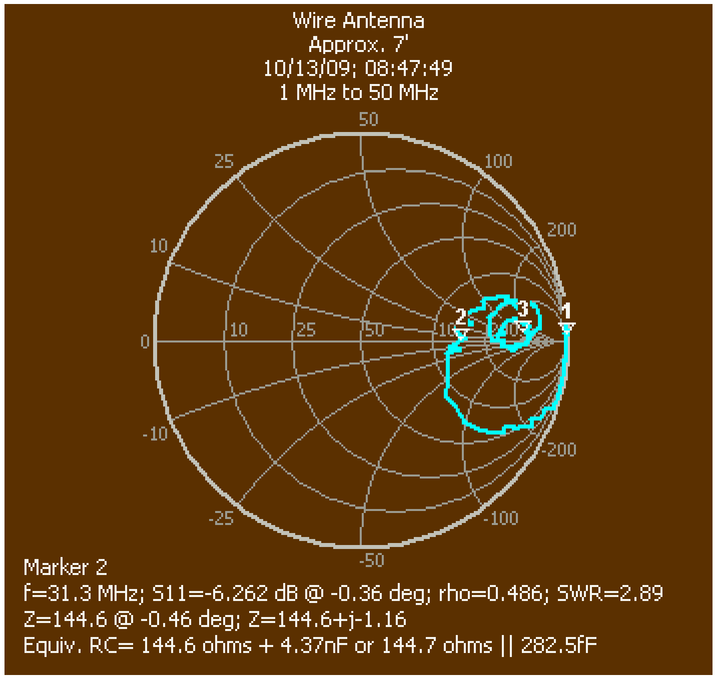

Figure 2—Smith chart of Figure 1

Starts at marker 1 and proceeds clockwise. Markers match Figure1

On the Smith chart, which is explained in more detail elsewhere, the horizontal axis through the center of the chart represents pure resistances. Marker 2 here is highlighted, and is the same marker 2 as in Figure 1. Again, it is virtually a pure resistance, of about 115 ohms. There are obviously other points that cross the horizontal axis, and also represent resistances. Even the other points between markers 2 and 3 that are not on the horizontal axis, are not terribly far off.

So we have significant resistance, but it is not all that close to 50 ohms. What does that mean? Simple voltage divider math shows that a source with 50-ohm impedance, which is the common approximate impedance of an RF source, delivers maximum power if the load is 50 ohms. If only we could transform these antenna impedances to something near 50 ohms, we could be transferring more power. Looking at the horizontal axis of Figure 2, the resistances are roughly in the 150-300 ohm range. A balun with a 4:1 ratio would likely do the trick to transform the antenna impedances to a broad area in the 50-ohm range, and achieve reasonably good transfer of power. Fancier impedance matching could be used to target a more narrow frequency range and bring it very close to 50 ohms.

We could go into more detail about exactly how to optimize the impedance transform, but here we are looking at an MSA overview. Let’s look at another antenna at a higher frequency. The next few scans are of a dual-band cell phone antenna that covers the general areas near 900 MHz and 1900 MHz.

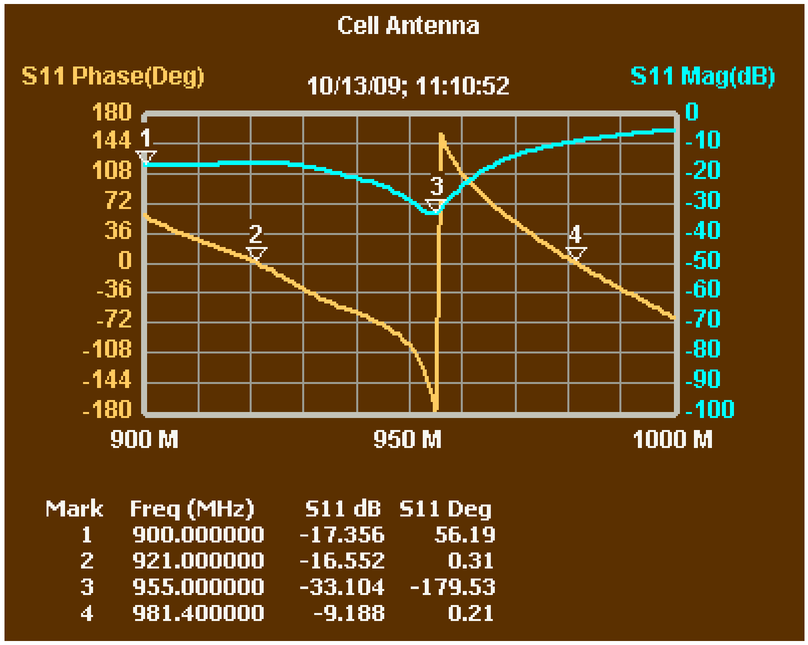

Figure 3—Cell phone antenna near 950 MHz

Figure 3 shows a resonance of the cell phone antenna in the area of markers 2, 3 and 4. Whenever S11 phase equals 0 or 180 degrees (or -180 degrees, which is equivalent to +180 degrees), the reactance is zero and we have a pure, energy-dissipating (hopefully, radiating), resistance.

Let's take a couple of other views of this antenna in the 950 MHz range. Figure 4 shows a Smith chart graphing the same data as Figure 3:

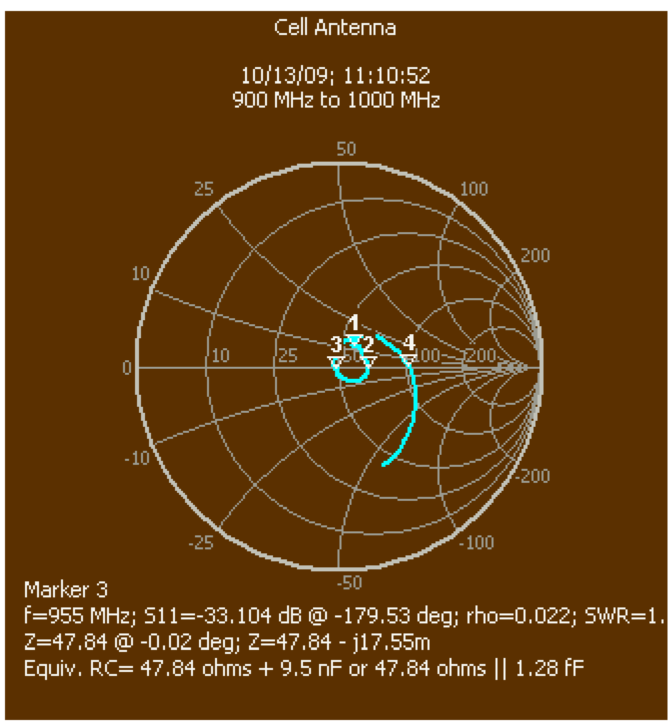

Figure 4—Smith chart of the cell phone antenna near 950 MHz
Markers match Figure 3

Figure 4 shows that in the range from marker 1 to marker 3 (which are the same as in Figure 3), the antenna S11 is very near the center of the Smith chart, meaning the impedance is close to a resistive 50 ohms. We can confirm this by graphing impedance directly, as in Figure 5.

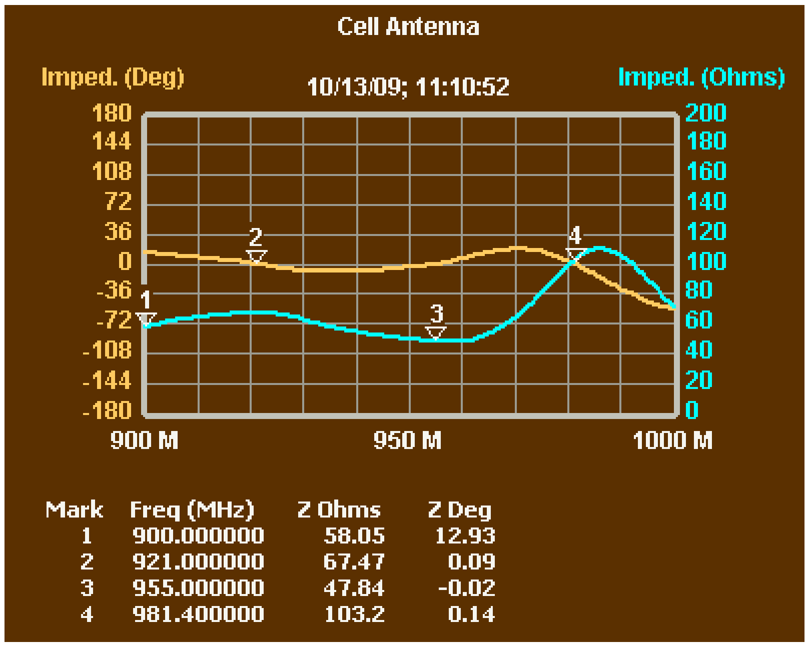

Figure 5—Blue shows impedance magnitude
For most of the graph, Z is near 50 ohms with near-zero angle

Figure 5 shows that the impedance is within 10 ohms of 50, with a small angle, until we reach the high frequency end near marker 4.

Many people like to look at VSWR of antennas, which is just another way of looking at how close the impedance is to 50 ohms. Figure 6 shows a graph of VSWR of our antenna.

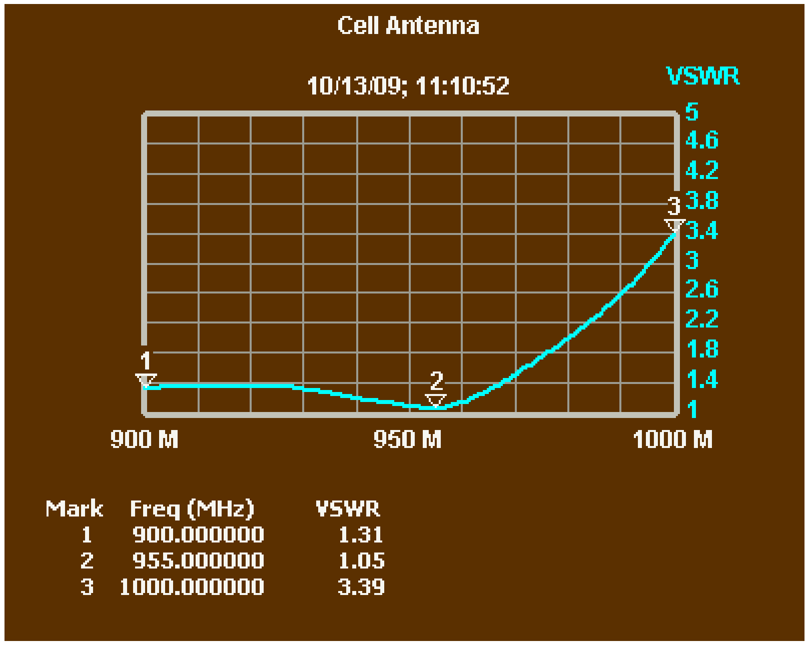

Figure 6—VSWR produced by same data as Figures 3, 4 and 5

VSWR can be viewed as a rough measure of the efficiency of power transfer. 1 is perfect; the higher it is the worse it is. Figure 6 shows good VSWR to somewhere above 970 MHz. It should perform well without impedance matching where its VSWR is low (or, equivalently, where its impedance is near a resistive 50 ohms).

It was mentioned above that this same cell antenna will cover a range near 1900 MHz. The MSA is designed primarily for a 0-1GHz range. That is called 1G mode. However, with a simple cable change, it can cover a 1-2 GHz range, known as 2G mode. Figure 7 shows the same cell antenna, focusing on a range near 1900 MHz.

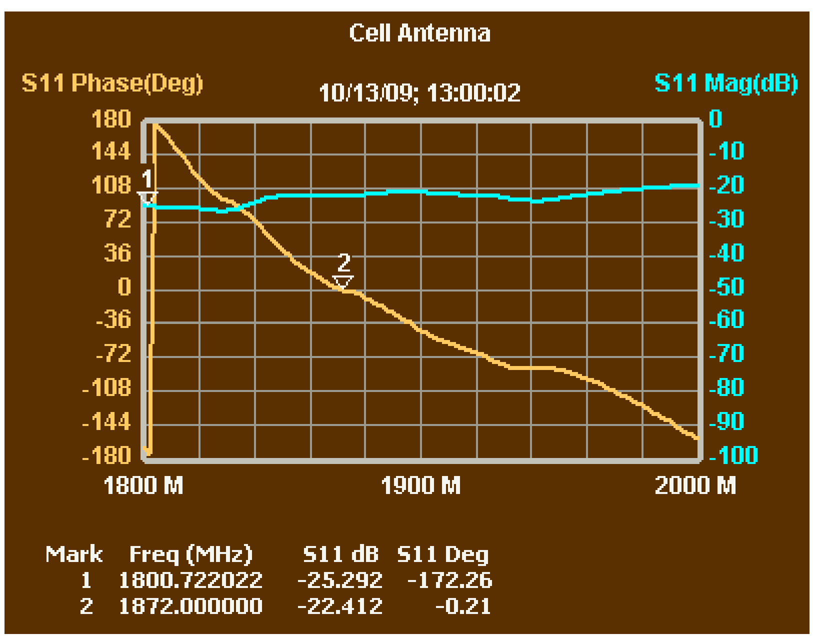

Figure 7-Cell antenna near 1900 MHz in 2G mode

Figure 6 shows that S11 is near -20 dB for the entire range. Marker 2 shows a point of resonance, with phase zero. The Smith chart in Figure 8 tells a much clearer story.

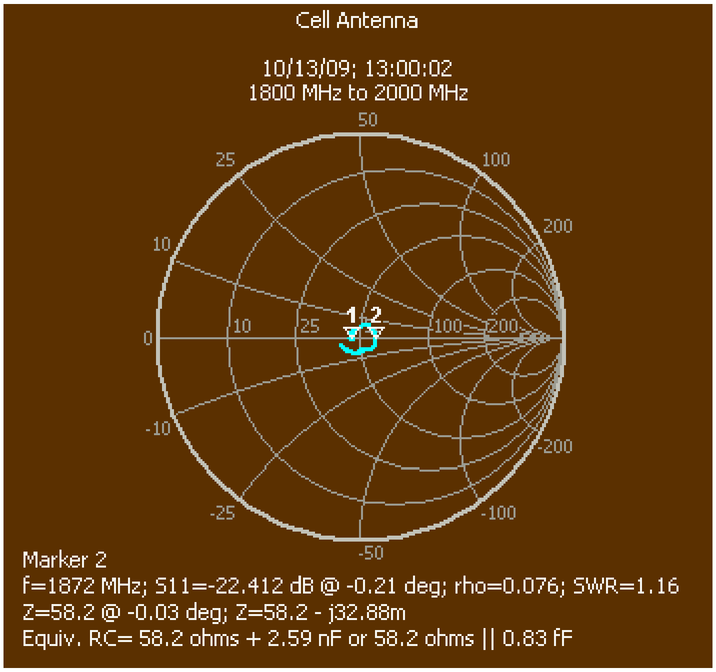

Figure 8—Smith chart of the data in Figure 6
Impedance at all frequencies is near 50 ohms.

Figure 8 shows that the response circles 50 ohms, in the center of the Smith chart, meaning its impedance is always reasonably close to a resistive 50 ohms. That means that for good power transfer from a 50-ohm source, we don't need to make any adjustments.

Finally, we have been viewing the antenna as a device to be tested by stimulating it with a test signal from the MSA. Now, let's use Spectrum Analyzer mode and look at a signal received by the antenna. Where to get such a signal? LO3 of the MSA is unused in Spectrum Analyzer mode, and can be arbitrarily assigned to a frequency. We do this by setting the Signal Generator frequency in the sweep parameters window (double-click under the frequency axis). Normally, the signal generator outputs whatever frequency we specify, from zero to 1000 MHz. But in 2G mode, we don't actually use the signal generator (tracking generator) output, but rather use the LO3 output itself. Or, we could use the signal generator (tracking generator) output, which contains a significant LO3 component. Figure 9 shows a spectrum analyzer scan in 2G mode, with the signal generator set to 900 MHz and the LO3 output run with hookup wire across the cell phone antenna.

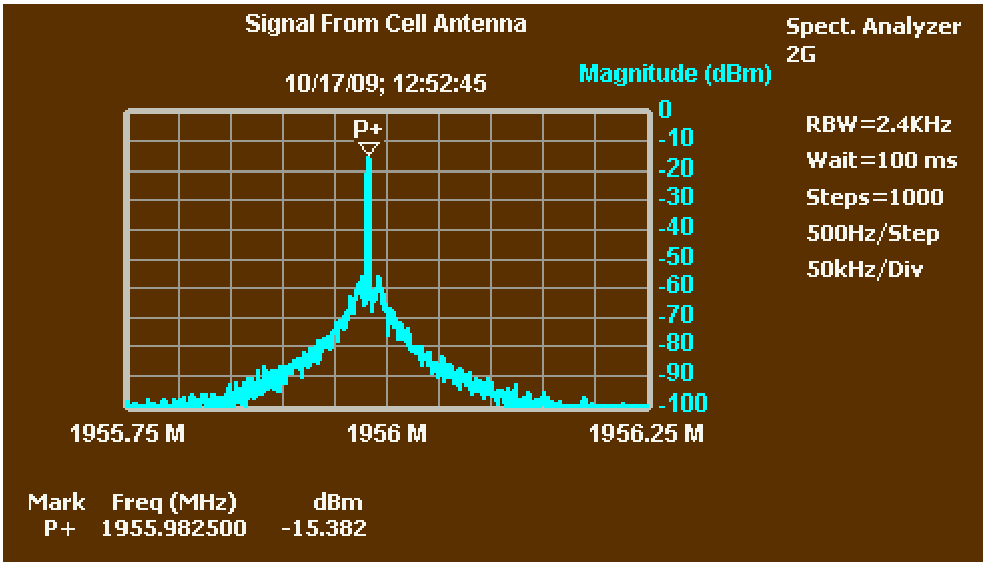

Figure 9—PLO3 output received by cell phone antenna
Signal generator set to 900 MHz.

Figure 9 shows that in 2G mode, the MSA has very good dynamic range as a spectrum analyzer. The LO3 signal is at 900 MHz plus the value of LO2, which in my MSA is a nominal 1056 MHz, but due to Master Oscillator deviation from 64 MHz, is actually very slightly below that level. Therefore, the peak comes out at 1955.98 MHz.

Conclusion

The MSA has the ability to measure various aspects of antenna performance within the normal 0-1GHz range of the MSA. But the MSA can also perform such analysis within the extended 2G mode. For higher frequencies, we present no data here, but the MSA can also analyze antennas in the 2-3 GHz range in 3G mode.