MFJ269 Antenna Analyzer Theory And Use

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The MFJ 269 is a handy instrument for checking your antenna, test coax, or to even test tuners. Although it has it's limitations with impedance analysis and tracking errors. It is still a very useful tool to get you "in the ballpark" of resonance or tell you how far off it may be.

Knowing the actual complex impedance of an antenna is far more useful than just SWR which it also provides on the display. It tells you why you are having reflections, allowing one to make the appropriate adjustments without the guesswork. SWR is an unsigned absolute value indicating a match or lack thereof. However that leaves the question of why the mismatch condition exists. It could be a mismatched pure resistance or capacitive or inductive or a combination of issues. This device helps you troubleshoot the reason for the mismatch.

In this article I outline how the machine works and some of the features that I use most often.

Antenna Model



The antenna model above is an example of the components involved in an impedance match. Rs is a lumped wire loss variable comprised of AC and DC resistance of the copper used. In most cases this will be negligible. R radiant is the "engine" that radiates the energy. Maximum antenna power efficiency is obtained when R radiant = Source Resistance.

An antenna will appear as inductive to the source if the source frequency is above resonance, and capacitive if it is below the antenna's resonant frequency.

At resonance, the inductive (+) and capacitive (-) reactance cancel, leaving only the resistive components.

The antenna analyzer displays these very critical interactions, so that we may properly tune the antenna system for maximum performance.

Theory of operation



The Calculations

$$V_{X} := \sqrt{V_{out}^{2} - V_{R}^{2}}$$

$$V_{in}^{2} := (V_{50} + V_{R})^{2} + V_{X}^{2}$$
Expanding:

$$V_{in}^{2} := V_{50}^{2} + 2V_{50} \cdot V_{R} + V_{R}^{2} + V_{X}^{2}$$
Subbing for VX :

$$V_{in}^{2} := V_{50}^{2} + 2V_{50} \cdot V_{R} + V_{R}^{2} + V_{out}^{2} - V_{R}^{2}$$
The VR squared unknown cancels yeilding:

$$V_{in}^{2} := V_{50}^{2} + 2V_{50} \cdot V_{R} + V_{out}^{2}$$
Solving for VR:

$$V_{R} := \frac{\left(V_{in}^{2} - V_{50}^{2} - V_{out}^{2}\right)}{2V_{50}}$$
Current is calculated with:

$$I := \frac{V_{50}}{50}$$
The resistance and reactance are:

$$R := \frac{V_{R}}{I}$$

$$X := \frac{V_{X}}{I}$$

$$A := \sqrt{(R + 50)^{2} + X^{2}}$$

$$B := \sqrt{(R - 50)^{2} + X^{2}}$$

$$SWR := \frac{A + B}{A - B}$$

Interpretation

The MfJ 259/269 series analyzers are not true vector measurement devices. This simply means that they do not measure the phase angle In fact, the display does not show polarity for this reason. It only displays resistance and the absolute value of reactance. (no polarity sign) However, we can still manually determine the phase polarity with some good old human intervention.

Since we know that capacitive reactance is inversely proportional to frequency and inductive reactance is directly proportional to frequency, this can information can be used to test the displayed reactance. The best way to do this is to find the resonant frequency (where Xs=0), then increase the frequency. A increase in Xs will be seen, indicating inductive reactance. Conversely, decreasing frequency from the zero point will result in an increase of Xs, which is capacitive.



Here is a load under test showing us a resistance of 43 ohms and a reactance of 60 ohms.

Now all we have to do in order to determination whether our load is capacitive or inductive, is dial the frequency up or down slightly, noting the change. In this example, the frequency was increased.



The increase in frequency to 10.217 MHZ has resulted in a decrease in reactance. The load is capacitive, so the complex impedance is: 43-j58.

One of the uses of this is to know if the antenna is long or short for a particular frequency.

For instance, as the frequency is increased from the low side of resonance, the reactance will be decreasing (capacitive), zero at the resonant frequency, then will start to increase beyond that, becoming inductive.

Thus, if the antenna is inductive, it is resonating at a lower frequency than the target and can be shortened or pruned, if it's capacitive,

that might be an "oops". It's always more desirable to shorten than to have to add pieces!

At resonance the inductive and capacitive reactances are of equal magnitude but opposite signs, canceling each other out.

The phase angle is zero and the circuit is a pure resistance.

The DTF Function

The DTF or "distance to fault " function is a useful tool for determining unknown lengths of cable or as the name implies, finding a fault in a cable. It doesn't matter if the fault is a short or open, the machine can detect it by finding resonant points!



Select the "Advanced 2" menu by holding down the gate and mode buttons simultaneously and release when it it displays. The analyzer is now asking for the velocity factor of the cable under test. This is critical to obtain the correct result. Use the gate button to increase and the mode button to decrease. Push both to enter and move to the next input.



Here, the 70-114 MHZ range is being used to provide good measurement resolution, yet stay within the RG58/U usability range. In this case, the minimum stub reactance was 1 ohm. With a push on the gate button, it moves on to the third input.



Now tune down the band until a second minimum is found. Once in the "center frequency" of the null, push the gate button to enter the frequency and calculate the result.



Now the analyzer displays the cable length or distance to a fault, depending on your application.

Coax stub calculation

In the following example, the cable under test is open ended. F1 in blue and F2 in red both have a maximum voltage at the end for a certain length measured by detecting Xs (stub reactance) going to zero or close to it. This tells us that the coax length is some nth quarter wave multiple of the test frequencies. The green trace was added to show intersection point minima and maxima of F1, F2 and the half wave calculation.

The difference of F1-F2 yields a harmonic which the half wave intersects the origin and the common maximums which also happens to be the stub length as well. Now the machine can calculate the stub length or "DTF" with the formula below.



Coax Loss

Another interesting feature is the coax loss measurement. If you are wondering if your cable is up to spec or if it's time to replace it, this will tell you. You can also get an idea of now much loss you have in the cables of a working system.

The test can be made at any frequency covered by the range selector.

The cable must be open on the far end with no load in order to make this measurement.



The analyser uses the previously defined calculations to determine the line loss where:

Loss :=
$$10 \cdot \log \left(\frac{\text{SWR} + 1}{\text{SWR} - 1} \right)$$