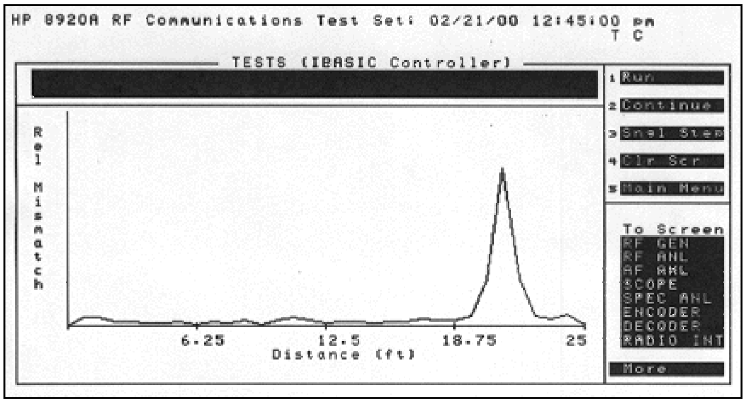
Testing Cables and Feedlines

Having a SiteMaster or network analyzer on hand to test a troublesome feedline is a luxury that most techs do not enjoy. But if you understand the principals of operation behind such tools, it is often possible to duplicate their functions in the field with the tools you do have.

One such function is that of Frequency Domain Reflectometry, or FDR. An FDR function tests a cable for distance to fault by frequency sweeping it, and then by calculating the Fast Fourier Transform, or FFT, on the resulting data. The screen then displays a plot of distance vs. approximate reflection magnitude. This allows the technician to find an open or shorted point in a feedline without having to call someone to climb a tower, or remove connectors and their weather insulation just to inspect them. Unlike Time Domain Reflectometry, or TDR, FDR tests the cable at RF frequencies. This allows the tech to find such cable problems as water inclusion and physical damage that a DC test would not reveal.



Time Domain Reflectometry with results displayed graphically.

The following describes a simple procedure to perform FDR using only a signal generator and signal level meter; specific instructions are given for using an IFR COM120B, with duplex generate capability. (A tracking generator or wideband noise source makes the procedure much easier, but neither is necessary.)

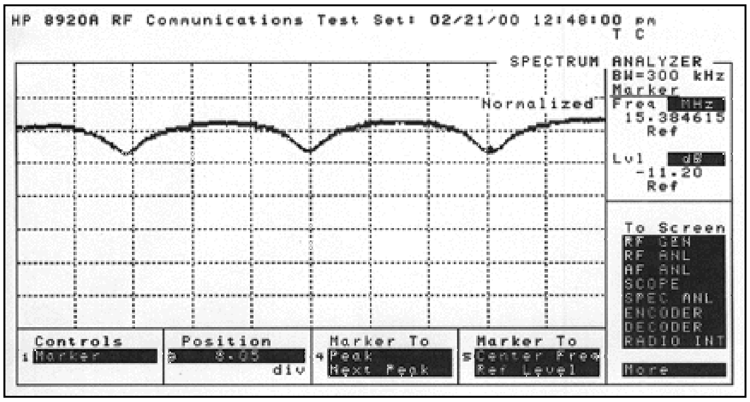
Transmission Line Basics Refresher

Remember that an open quarter wavelength of cable at resonant frequency will reflect power 180 degrees out of phase back to the source. It will "appear" shorted. A signal level meter in parallel with the RF source (connected through a “T”) would read a weak signal. If the cable is lengthened to one-half wavelength, power will be reflected 360 degrees out of phase, which is actually in phase with the source but delayed by one cycle. The line will "appear" open (which it really is). Our signal level meter would show a strong signal. (The incident and reflected signals are added together, and the measured signal will be about 3dB higher than the applied signal, minus cable and other losses.) Each time we lengthen the cable by a quarter wavelength, this cycle will repeat. Losses in the cable will reduce the reflected power measured on each successive peak and dip. These losses will be proportional to the cable losses at a particular frequency, they should be small, but they will be there.

Change the Frequency

Okay. So what? Well, what if instead of changing the cable length, we change the frequency? Say we have a cable of some length that is a multiple of one-quarter wavelength at a frequency of 10 MHz. Our signal generator and signal level meter in parallel set to the same frequency at the source will read a low or null signal, 180 degrees out of phase. As the frequency of the signal generator is increased, the wavelength of the cable remains unchanged. Yet because we are at a higher frequency, you could say that the cable "appears" longer to the new source frequency. At some higher frequency, say around 20 MHz, the cable will be a multiple of a half-wavelength, and our analyzer will read the in phase signal at a peak. Lets keep going, nulls are easier to find than peaks (trust me!). Increasing the frequency further to 30 MHz results in another null reading.

What have we done? We have revealed a ripple pattern whose frequency of repetition is directly related to the length of the cable under test. Or, more to the point, the distance to the largest abrupt impedance change… the end of the cable, possibly the fault, likely the problem! Now that we have the data, lets do the math.



Ripple pattern as seen on a spectrum analyzer

The Math

Now we need to find the difference between the starting null and the *very next* null. In this example, it is 20 MHz. Let's call this number "f". This represents the difference between half-wave nulls. Now for the next part of our equation, we need to know how fast RF travels through our cable. Remember, real cables have velocity of propagation (Vr) somewhat lower than the speed of RF in free space. Let's say our cable is Andrew LDF4-50A, this is a pretty common cable. The book says Vr is 88%. Velocity of RF propagation in free space is equal to the speed of light, 983.571 million feet per second. The velocity for our cable is: 983.571*.88, or 865.542 million fps. Now since we are working with half wave nulls and not full wave nulls, we can divide this number by two: 432.771 million fps. Since we are also working in millions: fps and Hz, let's drop the “million”. What we get is this:

Distance to fault = RF velocity (fps) / frequency spread

Distance to fault = 432.771 / 20

Distance to fault = 21 ft 7.7 inches

Setup Using The IFR

Use a "Tee" connector. Place the Tee directly on the “antenna” connector of the COM120B. Use a very short jumper (shortness here is the highest priority, if choices must be made!) to connect one end of the Tee to the “Auxiliary” RF output connector of the service monitor. The remaining Tee connection is the test port. Get ready to connect it to your cable or feedline as directly as possible (keep the jumpers short!).

Press the Duplex mode key. Set the TX frequency to 10.000 MHz (in many cases, 300 MHz will work better, you can try both), and select the “pair” option offered on the softkeys. Set the offset to 0.000, and the output level to –40.0 dBm.

With the test port unconnected, notice that the measured input level (displayed in the lower left quadrant) is approximately –40 dBm. This is the field where we will take our readings. Now connect the feedline, and play along.

Finding Nulls

Select the TX or RX frequency field and move the cursor to the 100 KHz position (Use the 10 KHz position for cables over fifty feet. The longer the cable, the closer the nulls will be!). By rotating the dial, raise the frequency while watching the measured input level. At some point, the level will begin to dip. Find the center frequency of null by rocking the dial up and down, and write down the frequency as “null 1”. By further increasing the frequency, repeat as above and find the *very next* null. Write down the new frequency as “null 2”.

Now look up the velocity of propagation for the cable under test and write it down as “Vr”.

Results

Time for math:

Find the frequency span between half wave nulls:

frequency = null 2 – null 1

Find one-half the velocity of RF propagation through the test cable:

Velocity = (Vr * 983.571) / 2

Find the distance to fault (or cable end):

Distance in feet = Velocity / frequency

You are done.

A Few Notes / FAQ

- If you have a lighting arrestor in line, this test will tell you how far away it is… bypass it if you want to test the rest of the cable.
- As you may see from the formula, the longer your cable, the closer the peaks and nulls will appear. The inverse is also true.
- **Q.** "Why start at low frequencies?” **A.** First of all, the peaks and nulls are more pronounced at low frequencies, because the cable will have less loss at lower frequencies. Remember that the signal travels to the end of the cable and then back again. Any losses are doubled. Sometimes, interfering RF signals are present at low frequencies, and it may be easier to start at around 300 MHz to avoid the noise.
- **Q.** “Why not start at the operating frequency?” **A.** If your cable is terminated with a fifty-ohm load, (something the antenna is *supposed* to be) then there *will be no reflections* from which to see peaks and nulls. If you have a good antenna, peaks and nulls will be hard to find at resonant frequency!
- That brings up a few more points: you can get an idea of the resonant frequency of your antenna by finding the frequency range where the peaks and nulls are the least pronounced. And, you can get an idea of how closely your antenna is matched to 50 ohms. But beware: most antennas are resonant in more than one band. You can also get an idea of the cable losses at a particular frequency by looking at the level of the peaks and dips. In a perfect cable, the peaks would all be about 3 dB higher than the incident signal and the dips would all be very deep. In real cables, the peaks get weaker and the nulls are less pronounced as losses increase down the line.

Velocity of Propagation For RG/U Cable Types

RG/U	Vr	RG/U	Vr	RG/U	Vr	RG/U	Vr
5	0.659	74	0.659	174	0.659	235	0.695
6	0.659	79	0.84	177	0.659	293	0.659
7	0.659	84	0.659	178	0.695	294	0.659
8	0.659	85	0.659	179	0.695	295	0.659
9	0.659	87	0.695	180	0.695	302	0.695
10	0.659	94	0.695	183	0.91	303	0.695
11	0.659	108	0.659	187	0.695	304	0.695
12	0.659	111	0.659	188	0.695	306	0.8
13	0.659	115	0.695	195	0.695	307	0.8
14	0.659	116	0.695	196	0.695	316	0.695
17	0.659	117	0.695	211	0.695	323	0.8
18	0.659	118	0.695	212	0.659	324	0.8
19	0.659	119	0.695	213	0.659	332	0.8
20	0.659	120	0.695	214	0.659	333	0.8
21	0.659	122	0.659	215	0.659	334	0.8
22	0.659	130	0.659	216	0.659	335	0.8
29	0.659	131	0.659	217	0.659	336	0.8
34	0.659	140	0.695	218	0.659	360	0.8
35	0.659	141	0.695	219	0.659	376	0.8
54	0.659	142	0.695	220	0.659	388	0.659
55	0.659	143	0.695	221	0.659	393	0.695
57	0.659	144	0.695	222	0.659	397	0.695
58	0.659	147	0.659	223	0.659	400	0.695
59	0.659	159	0.695	224	0.659	401	0.695
62	0.84	161	0.695	225	0.695	402	0.695
63	0.84	164	0.659	226	0.695	403	0.695
70	0.659	165	0.695	227	0.695	404	0.695
71	0.84	166	0.695	228	0.695		

Other Cable Types

If the type of cable you are testing is not listed here, keep in mind the following: The velocity of propagation for Teflon dielectric cables is typically 0.695, and for typical cables with polyethylene dielectric, 0.659. Some foam dielectric cables have Vr ratings from 0.78 to 0.88, and air dielectrics from 0.90 to 0.93.