ANTENNA TOPICS

BUYING, BUILDING AND UNDERSTANDING ANTENNAS

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Time-Domain Reflectometry on a Budget

One technology useful for evaluating some aspects of antenna feedline is known as "time-domain reflectometry," or "TDR." And, as an added bonus, cable runs on non-antenna systems, such as computer networks, can also be checked out with this device.

The Basic TDR System

An inexpensive, triggered oscilloscope is adequate for the basic TDR system described here in fig. 1A. The pulse generator (fig. 1B) generates a periodic (repetitive) direct current (DC) pulse (fig. 1C) which is fed to the input end of the cable under test. I built a similar generator some time back, but I don't recall the source of the construction article. However, it is not unlike the one in the 17th edition of the *ARRL Antenna Book*.

The transistor called for is a general-purpose NPN (negative-positive-negative); any you have handy is likely to work OK.

It's good to mount the generator in a small metal case; connect all the ground connections together, and connect this common ground to the case. It's also best if the resistance of R1 is the same value as the impedance of the cable under test (usually 50 ohms). There are two outputs from the generator: one for the scope, and one for the cable under test. Check your scope and cable to see which connector types you will need.

The vertical input of a triggered oscilloscope is also connected to the input end of the cable. The scope will display a stationary pulse pattern (fig. 1C). As a pulse travels down the tested line, electrical irregularities in the line will cause a portion of the forward-traveling pulse to be reflected back toward the input end of the line. These reflected portions of the pulse appear on the oscilloscope pattern along with the pulse.

In other words, the scope continuously monitors the pulse throughout its duration as it enters the line, and simultaneously monitors any returning reflections of that pulse returning from the line. The scope trace therefore is a pattern whose shape is determined by the combining of the original pulse and the reflections of that pulse caused by irregularities (shorts, open circuits, etc.) on the line.

Interpreting the TDR Trace

If the far end of the cable is shorted, or terminated with a resistance less than the value of the line's impedance, the trace will appear depressed as in fig. 1D. If the far end of the line is open circuited, or is terminated with a resistance higher than the value of impedance of the line, the reflection caused will show up on the trace as an elevated portion (fig. 1E). Don't be surprised if your traces don't look as neat as these figures, but the sketches show the general shapes to look for. You may even see multiple reflections combining with the pulse.

There are only two conditions where there is no reflection returning from the line to the input. One is when the load connected to the far end of the line is a resistive load perfectly matched to the line's characteristic impedance (i.e., a 50-ohm resistor terminating a 50-ohm line, a 72-ohm resistor terminating a 72-ohm line, etc.). In this case the pulse remains unchanged as in fig. 1C. This matched condition represents the value of resistance or impedance at which the SWR on the line is

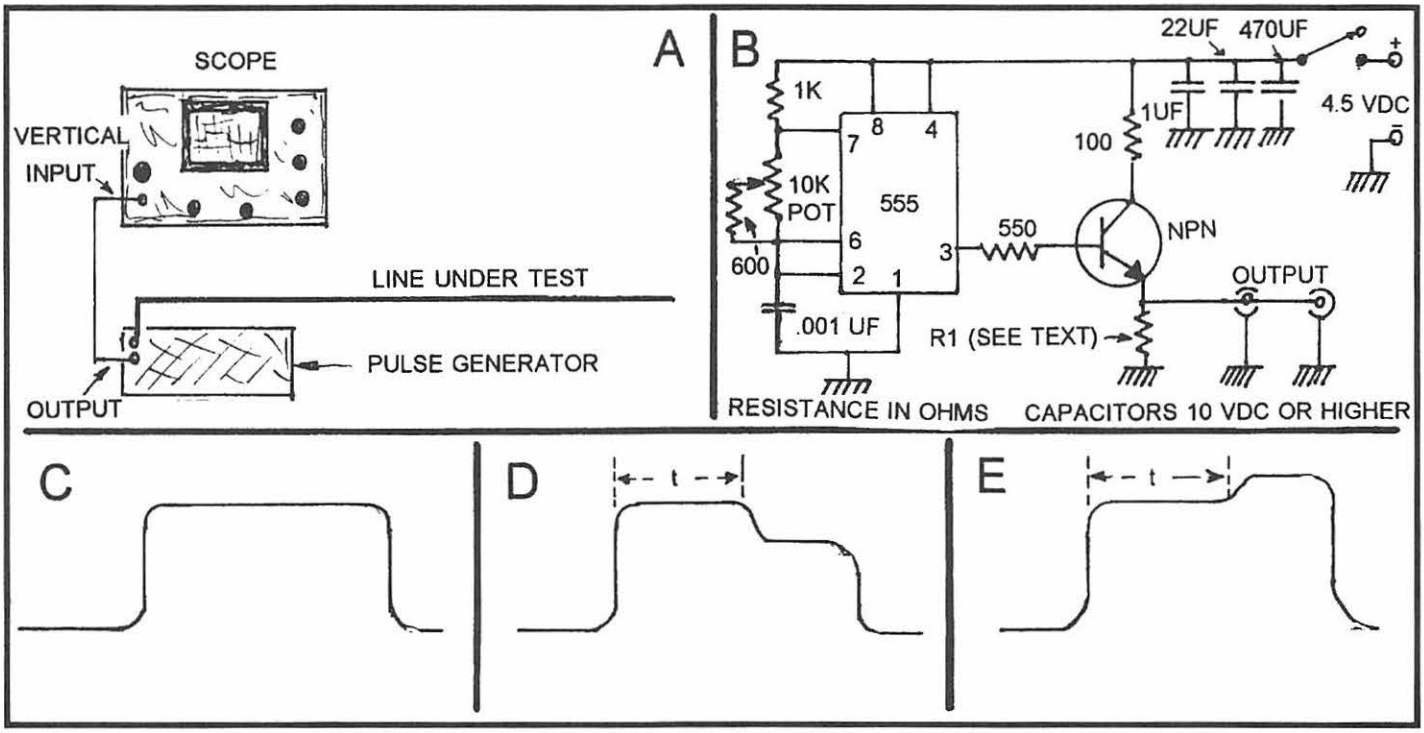

FIGURE 1. *A basic TDR system (A), pulse generator diagram (B), typical pulse shape (C), shape of pulse combined with reflections from short-circuited cable (D), shape of pulse combined with reflections from open-ended cable (E)*

optimum (minimum).

The other case of no reflection is when the cable under test is so lossy that it attenuates the signal so much that there is essentially no signal to reflect back!

Shorts, open-circuits and other abnormalities on the tested line show up on the trace, and their distance from the input can thus be computed. Measuring this distance along the cable will tell you where along the cable's length to look for the cause of the problem. With the simple system described here the accuracy is not great, but with care you can get reasonably close.

The distance to an abnormality can be determined by first reading the travel time from the oscilloscope. This is the number of microseconds between the start of the pulse and the start of the return blip (shown as "t" on figs. 1D and 1E). Then compute the distance along the line from the input to the abnormality using the formula below. C is the speed of electrical waves in space (984 for feet/microsec, 300 for meters/microsec); VF is the line velocity factor, which is the fraction of C that the pulse travels in the cable. (This is usually .66 for ordinary coaxial cable, .78 to .80 for foam coaxial cable, .86 for ordinary RG-62 computer cable and .79 for foam RG-62).

Distance to reflecting condition = (VF x C) (t/2)

Limitations of TDR

As discussed above, TDR operates by sending pulses of DC down the tested line. This means that we must use resistors, open circuits, or short circuits as loads for the tested line. An antenna at the load end of the line, even if it is a perfect match for the line at its radio frequency (RF) of operation, will not present its RF impedance to the DC pulse. An antenna's input impedance is not DC resistance and can only be measured using an RF signal of the appropriate frequency. TDR is not designed to use RF.

There is a technology which can test lines terminated with antennas. That technology is called "Frequency Domain Reflectometry" or "FDR." FDR, instead of sending a DC pulse down the tested line, actually sends an RF signal which is swept across the frequency range of interest.

Unfortunately, although commercial systems for both TDR and FDR are now much less expensive than they once were, their cost is still beyond the means of almost all experimenters, SWLs and hams. Although homebrewing an FDR system would be fairly difficult, TDR is a different story. As we have seen, it is possible to put together a TDR system such as the one we have described for cable testing at a modest investment of time and money.

RADIO RIDDLES

Last Month:

I said that "we've been talking about the standing wave ratio (SWR) at the junction of an antenna feedpoint and the feedline. In practice we usually measure SWR at the end of the feedline near the receiver or transmitter. Does this give us the value of the SWR at the antenna feedpoint-feedline, or is it a different thing? Why or why not?"

The answer is that it is a different thing. SWR is measured by sending an RF signal into a system and then comparing the amount of signal originally fed to the system to the amount of returned signal. When we do this by connecting directly to the antenna we get an accurate measurement of antenna-line SWR.

When we first connect a length of feedline to the antenna and then input the test signal to that feedline, the signal must travel through the feedline to the antenna-feedline junction and back through the feedline to the SWR testing device. Thus, any loss of signal caused by the feedline reduces the amount of signal that reaches the antenna and also reduces the value of the returned signal as that signal travels back from the antenna-feedline junction to the input end of the line.

This means that the value of returned signal has a weaker value than when testing directly at the antenna, and the SWR will be deceptively low as compared to the SWR obtained by connecting directly to the antenna. In fact, using very lossy line, it is possible to measure a 1:1 SWR at the end of the line when actually the SWR at the antenna-feedline junction is very high!

Next Month:

What is the relationship between a matched line with low SWR values and the uni-directional Beverage antenna?

You'll find an answer for this month's riddle, and much more, in next month's issue of *Monitoring Times*. Til then Peace, DX, 73
