MATH'S NOTES

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WHAT'S NEW AND HOW TO USE IT

Time Domain Reflectometry

When a coax feedline to an antenna breaks, it is obvious to us, since RF is not radiated. If the AC power cord opens, it is also obvious and we replace the cord. These are simple, routine cable-related problems and easily addressed by repairing or replacing the defective cable. Consider the case when the cable is a mile or two long, however, buried under the ground or running up the side of an antenna tower and generally inaccessible. Now the situation is not so simple. The break must be accurately located and repaired. Digging up the entire mile of cable, or replacing the cable that is tie-wrapped to the tower (or in conduit), is really not practical.

c/o CQ magazine

Broken or defective cable problems of this type are common to telephone or cable TV service personnel. The technique they use to find these breaks is easily adaptable for amateur experimenters. The technique is called *time domain reflectometry* (TDR) and is based on the fact that with any mismatch in a transmission line, a portion of a transmitted signal will be reflected back to the source. In the case of transmitters driving antennas, such a mismatch shows up as an SWR that is greater than one. In the case of normal signal-carrying cable, a failure is either an open or a short, and these conditions also result in reflections that are easily detected. It is this fact that is used in TDR equipment. Before going into the actual circuitry of a device that the amateur can build, let's look at exactly how the scheme works.

Fig. 1 is a schematic of a coaxial cable run used to transmit a cable TV signal from a distribution box to the home. If the cable is intact, a signal traveling down the cable will reach the other end, and any reflection (due to a mismatch) will then travel back along the cable to the input. In this case impedances are usually matched fairly well, so there is not much of a reflection. However, since we live in the real world, the match will never be per-

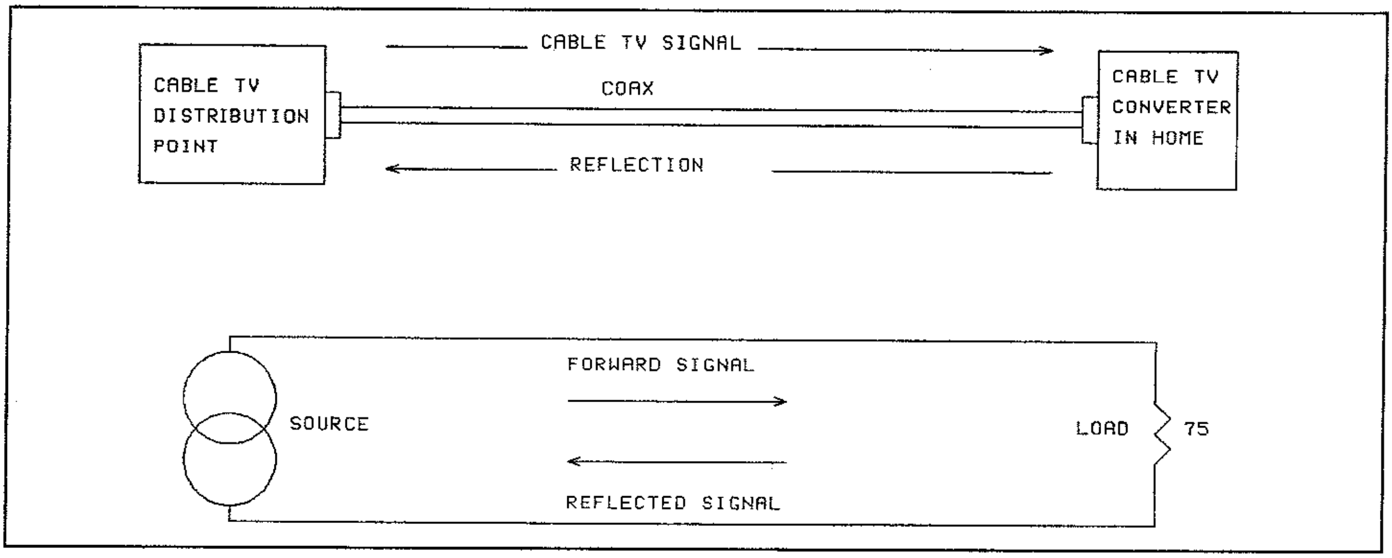

Fig. 1– Simple cable TV distribution system hookup.

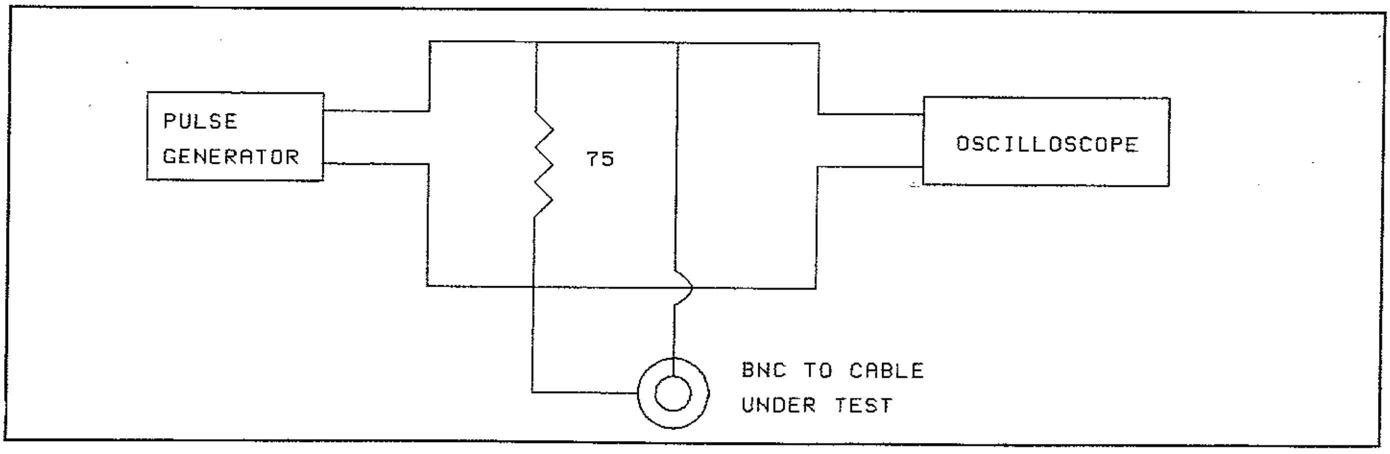

Fig. 2– Setup for time domain reflectometry.

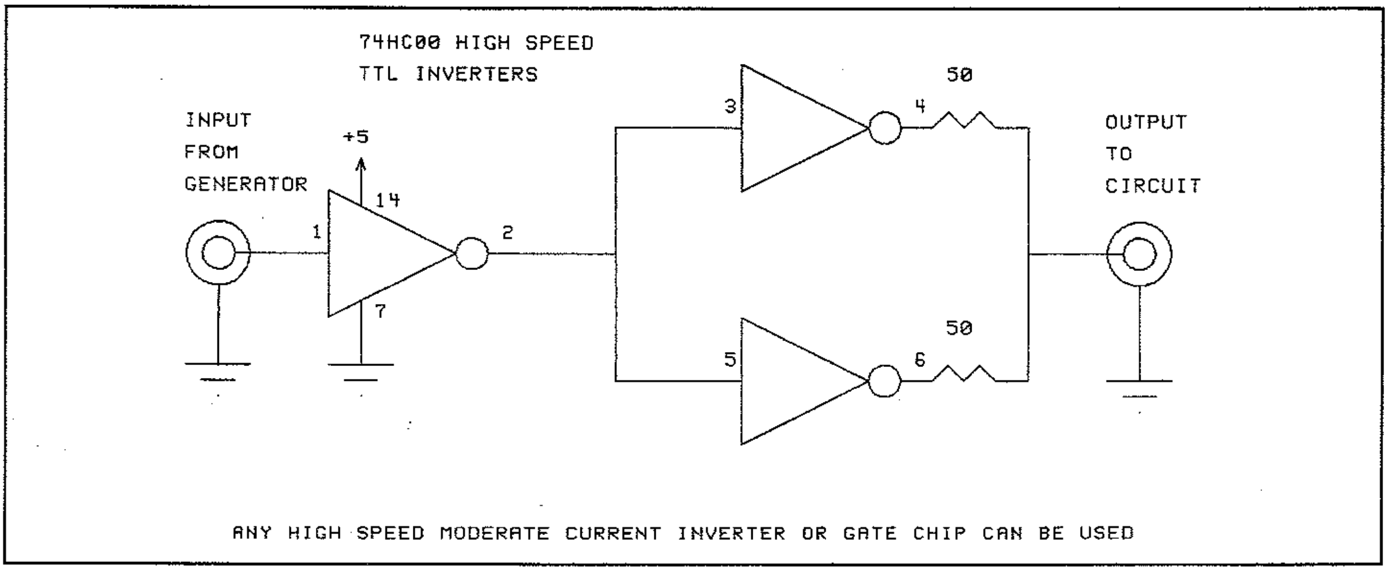

Fig. 3– High-speed output driver for TDR use.

fect, and at least something will be reflected. This "something" is what we measure. If we therefore excite the cable with a fast rise-time pulse, we should be able to observe any reflected portion of the pulse on an oscilloscope, the amplitude of the reflection being proportional to the degree of the mismatch. Since we know how fast the pulse travels through the cable, by looking at the time it takes to make the trip to the end and back, we then easily can calculate the length of the cable. The formula for such a calculation is:

Distance = (0.68) total travel time/2

The factor 0.68 is called the *velocity factor* of the cable and is defined as the ratio of the speed of an RF signal in free space vs. the speed of the same signal in the cable. The exact velocity factor for any cable is usually given in the specification sheet for that cable, but as a rough approximation, 0.68 should get you to within 10% of the distance for most of the common cables that the amateur is likely to encounter. Let's look at how we can set up this system and observe these pulses.

Fig. 2 is a diagram of a simple TDR hookup. A fast rise-time pulse generator is needed, although the frequency (pulse repetition rate) is not critical. The fast rise-time is required so that the transmitted edge of the pulse does not overlap the received edge of the reflected pulse and cause inaccurate results, particularly for short distances. If you do not have such a pulse generator, the circuit of fig. 3 can be used to speed up the output from whatever pulse source you do have. In this circuit you can use any high-speed moderate-output drive inverter or NAND gate chip you might have.

The circuit shown in fig. 4 is a simple experiment that you can perform to see how the time domain reflectometry technique is actually used to find a cable fault. Two 100 foot lengths of coax are connected together with a BNC "T" and the test setup. Fig. 5 shows the oscilloscope pattern that would be obtained from this

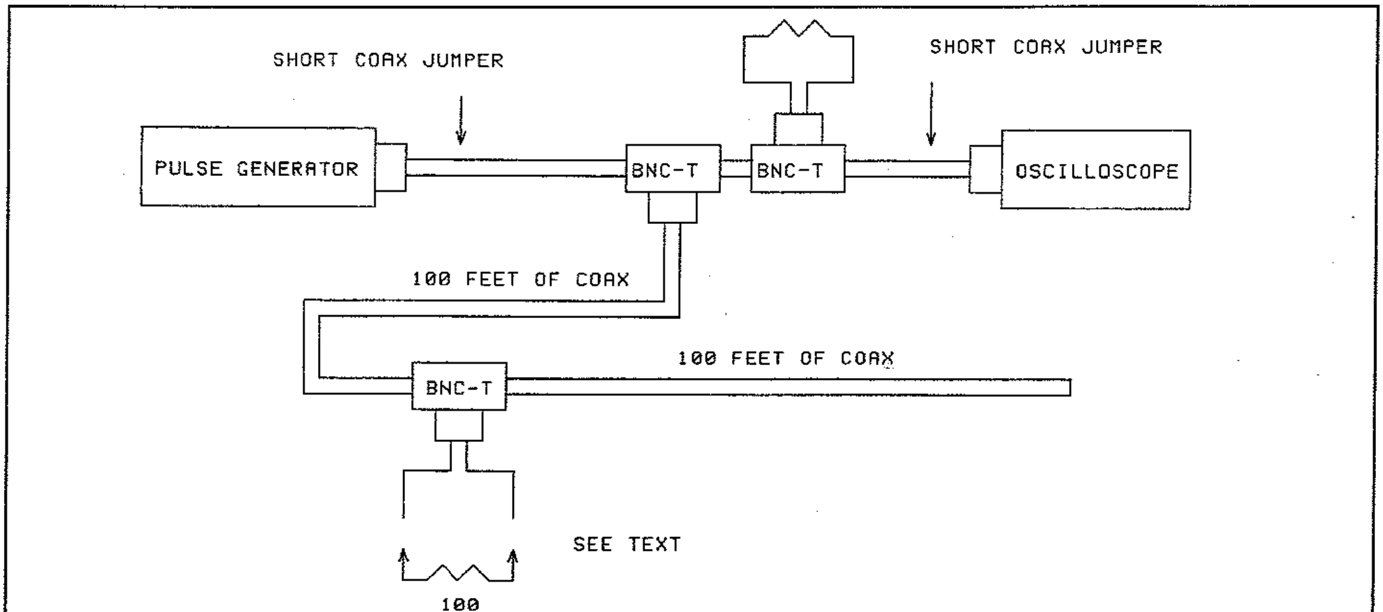

Fig. 4– Experimental setup to test TDR procedure.

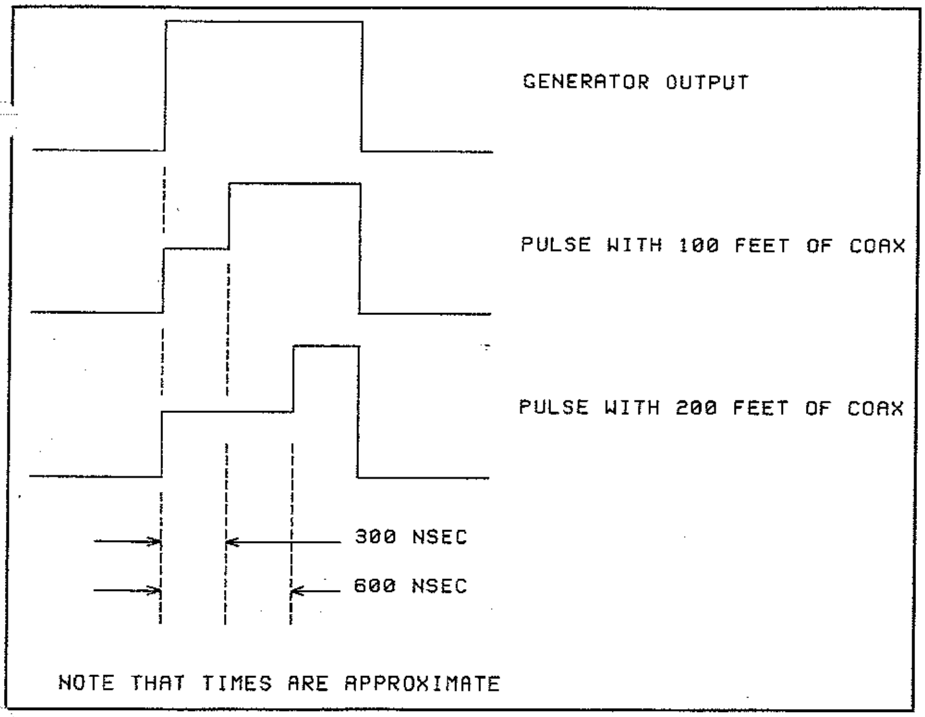

Fig. 5– Typical oscilloscope waveforms from fig. 4.

hookup. The transmitted and received pulses are clearly visible as a step in the resulting waveshape, thereby allowing easy measurement of the time interval between the edges of the two pulses. Once you do this, plugging the data into the formula should result in a distance of 200 feet. Now let's disconnect the second 100 foot length of coax. Immediately the scope picture changes and the distance to the "end" drops to 100 feet (as it should). This clearly demonstrates how cable lengths are measured by TDR methods.

Now reconnect the second 100 foot coax run and partially "short" the coax by connecting a 100 ohm resistor across the open port of the BNC "T." Notice how the scope picture (fig. 6) shows both the "short" at 100 feet and the end of the cable at 200 feet.

The technique demonstrated above is commonly used by most service personnel who deal with cable breaks. Although the examples given are of coax, the technique works with other types of cables as well. Terminations and reflected pulses may differ in appearance on a scope, but if you understand what is going on, you should have little trouble interpreting the results. Since the investment is minimal, you should consider using time domain reflectometry the next time you have to find a break in an inaccessible cable.

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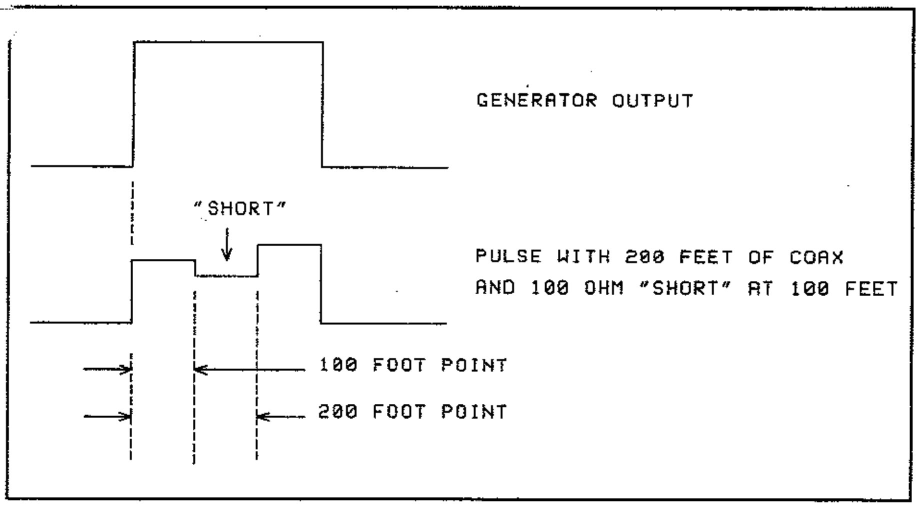

Fig. 6– Waveform with partial "short" at 100 feet.