THE ACCURATE MEASUREMENT OF RANGE BY THE USE OF MICROWAVE DELAY LINE TECHNIQUES

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Abstract

A novel scheme combining microwave-distributed network techniques and low frequency digital technology to make time duration measurements (i.e., range to a target) with an accuracy previously only obtainable using GHz counters is presented.

A common problem in short range radar applications is the accurate measurement of range to a target. In short pulse BAseband Radar (BAR) applications,[1] a pulse several hundred picoseconds in duration is radiated into free space, reflects off a target that is perhaps several hundred feet away, and returns to a receiver where a threshold detector is activated, producing a reconstituted short pulse. The problem is to cost-effectively measure the time between the two epochs (i.e., the main bang and the output of the threshold detector) and convert this time duration to an accurate range measurement.

Both analog and digital approaches can be employed to solve this problem. In the analog approach, a ramp function is initiated at the start of the main bang and stopped when a target is received; the dc voltage obtained at this point is held until the next pulse. When the ramp duration is measured in nanoseconds and the pulse train period in hundreds of microseconds, it is difficult to accurately hold and read the resulting dc voltage (i.e., the range). A range measurement can also be obtained digitally by counting the number of rf cycles produced by an L-band oscillator, a start command to the counter being given at the time of the main bang and a stop command being issued when a return is received. To count at a GHz rate, however, requires expensive, elaborate hardware, especially if range accuracy in the order of a foot is required.

The purpose of this paper is to describe a scheme involving the use of a tapped microwave delay line which achieves the accuracy obtainable by high-speed digital techniques but at a significant cost reduction (e.g., a factor of ten or more). To explain the scheme, consider the two identical pulse generators connected together through a length L of a TEM-mode transmission line and of characteristic impedance r_o as shown in Fig. 1.

Assume that at $t = 0$ each generator produces a rectangular pulse $p(t)$ whose duration is $\tau \ll L/c$, where c is the speed of light in the line. Then an observer standing $L/2$ meters from either source would experience a voltage $2p(t)$ for τ seconds, and at the other instants the voltage would be identically zero. An observer standing at any other point on the line would experience the pulse $p(t)$ only at two different times, provided the source impedance of each generator equaled r_o, the characteristic impedance of the line (i.e., there are no reflections). Thus, a simple length of TEM-mode line acts as a most efficient summing network.

If a time delay is placed in series with one generator then it is clear from superposition that a doubling of the voltage will occur at some new point on the line. By placing a series of taps along the line, it is possible to estimate this delay by, essentially, utilizing space-time sampling. For example, consider that the generator at the right in Fig. 2 produces a pulse $p(t)$, synchronized with and reconstituted from the main bang of a BAR system. The returned signal from a target in space initiates a reconstituted video pulse T seconds later forming a new pulse $p(t - T)$. If the maximum and minimum ranges to an expected target are D_{MAX} and D_{MIN}, respectively, then for the pulses $p(t)$ and $p(t - T)$ to coalesce somewhere within the line length L two equations must be satisfied; namely,

$$cT + L = 2D_{MAX} \qquad (1)$$

and

$$cT = 2D_{MIN} + L \; . \qquad (2)$$

Solving Eqs. (1) and (2) for cT and L, yields

$$L = D_{MAX} - D_{MIN} \qquad (3)$$

$$cT = D_{MAX} + D_{MIN} \; . \qquad (4)$$

For example, if $D_{MAX} = 250$ ft. and $D_{MIN} = 50$ ft., then from Eq. (3) 200 ft. of line length is required. By placing taps on the line one foot apart, a range-resolving capability of one foot can be obtained. Although the use of 200 taps is an approach, a more desirable alternative involves limiting the number of taps to perhaps twenty and limiting the distance $D_{MAX} - D_{MIN}$ to a twenty-foot increment. In the previous example, the delay length cT would first be set to 120 ft., then to 160 ft., then 200 ft., ..., and then finally to 480 ft.

The stepping of the time delay T can be accomplished by initiating an impulse comb train of pulses in synchronism with the main bang as shown in Fig. 3(a). In the example, the spacing between pulses is 40 ns. The spacing of pulses in the comb oscillator train can be made to depend upon a length of line in the feedback loop of a pulse oscillator and therefore can be accomplished very accurately. A scanning pulse—see Fig. 3(b) and 3(c) selects the desired member of the pulse train (i.e., the delay T). When coincidence occurs at a given tap, the back voltage of a hot-carrier diode current is exceeded and an avalanche transistor is excited. This, in turn, illuminates and latches an indicator lamp.

Thus, by using a number of taps on a transmission line in conjunction with a 25 MHz oscillator (i.e., the reciprocal of the 40 ns delay between pulses in the comb train illustrated in Fig. 3), the resolution previously only obtainable by counting at a GHz rate can be achieved. A model of a ranging unit employing this technique has been built and successfully demonstrated.

Reference

1. G. F. Ross, "BARBI, a New Microwave Sensor for Air-bag Activation in Automobiles," 4th European Micro-wave Conference, Symposium Record, pp. 146-149, Montreaux, Switzerland (September 1974).

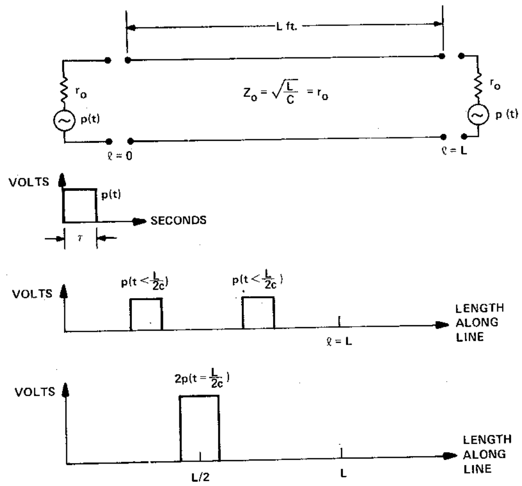

FIG. 1 Basic transmission line concept.

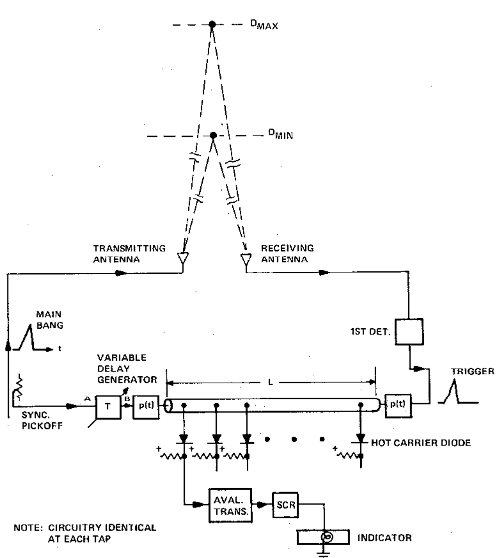

FIG. 2 Block diagram of ranging scheme in BAR system.

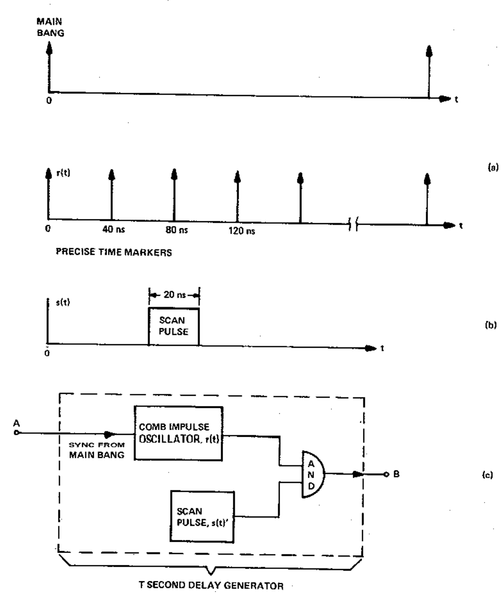

FIG. 3 Description of delay generator.