Reprinted from ***NASA Tech Briefs, Winter 1985***

Measuring Antenna Signal Delays

Multipath errors are reduced yielding more precise delay measurements.

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Signal delays in large dish antennas are measured by a method based on a commercial frequency-modulated instrument. Measurements are accurate within 3 ns on primary path lengths of 60 ns or more. A major benefit of the method is that the user can distinguish between the delay along the primary signal path and the delays along the multiple-reflection signal paths (multipaths), so that multipath errors can be minimized or made insignificant in the calibration of antenna delays. Large Cassegrain microwave antennas thus calibrated can measure the ranges of objects very accurately and can be synchronized more precisely with other antennas for very-long-baseline interferometry.

Previously, a horn transmitter on an antenna dish generated a signal, and the time for the signal to reach the receiving horn at the antenna focal point was measured by a conventional phase-slope or amplitude-modulation technique. A major deficiency of this method was that the pattern of the transmitting horn often had poor directivity and large side lobes. The calibration signal therefore followed not only a direct path to the receiving horn, but also other paths because of unintentional illumination of the struts and sides of the receiving-horn housing.

In the improved technique, the instrument is a fault locator, a frequency-modulated radar system that can be operated at any center frequency in the microwave range from 1.7 to 12.4 GHz with sweep band-widths ranging from 40 to 100 MHz. Ordinarily, the instrument is used to locate discontinuities in microwave transmission lines and measure the magnitudes of return losses as functions of the distances to the discontinuities For the antenna measurements, the instrument was modified to operate in a one-way, transmission-only mode instead of its normal two-way, radar mode.

The principle of the operation is illustrated in Figure 1. The oscillator frequency is swept in a sawtooth pattern while the oscillator output is fed to a transmitting antenna and a receiving mixer. The mixer output is fed to a narrow-bandwidth IF amplifier, detected, and recorded. Since the frequency of the transmitted signal varies with time, the delay between the transmitted and received signals can be determined from the frequency differences between them.

The delays can also be determined by varying the modulation rate ($2\Delta F/T$ in Figure 1) by the correct (known) amount such that the frequency difference remains constant.

The primary and multipath delays are determined by first recording the amplitude versus distance in the automatic plotting mode. Then the distance dial is adjusted manually to move the recorder pen to the positions of peak response on the recording and noting the corresponding distance readings on the instrument. The distance values are then converted to time delays. The largest amplitude occurs at the primary delay, while multipath reflections give smaller signal peaks at longer delays.

The modified fault locator is placed inside the antenna feed cone, close to the base of the antenna receiving horn. A 1.8-m cable connects the receiver output to the fault locator. Another cable connects the fault-locator output to the fault-locator transmitting horn at a place on the dish where a delay measurement is to be taken (see Figure 2). Amplifiers along this cable compensate for the airpath loss between the transmitting and receiving horns. In this configuration, the measured delay includes the internal delays of the fault locator. The fault-locator internal delay is measured separately with the cables disconnected from the transmitting and receiving horns and connected to each other through an attenuator. The internal delay thus measured is subtracted from the other measurements to obtain the antenna delays.

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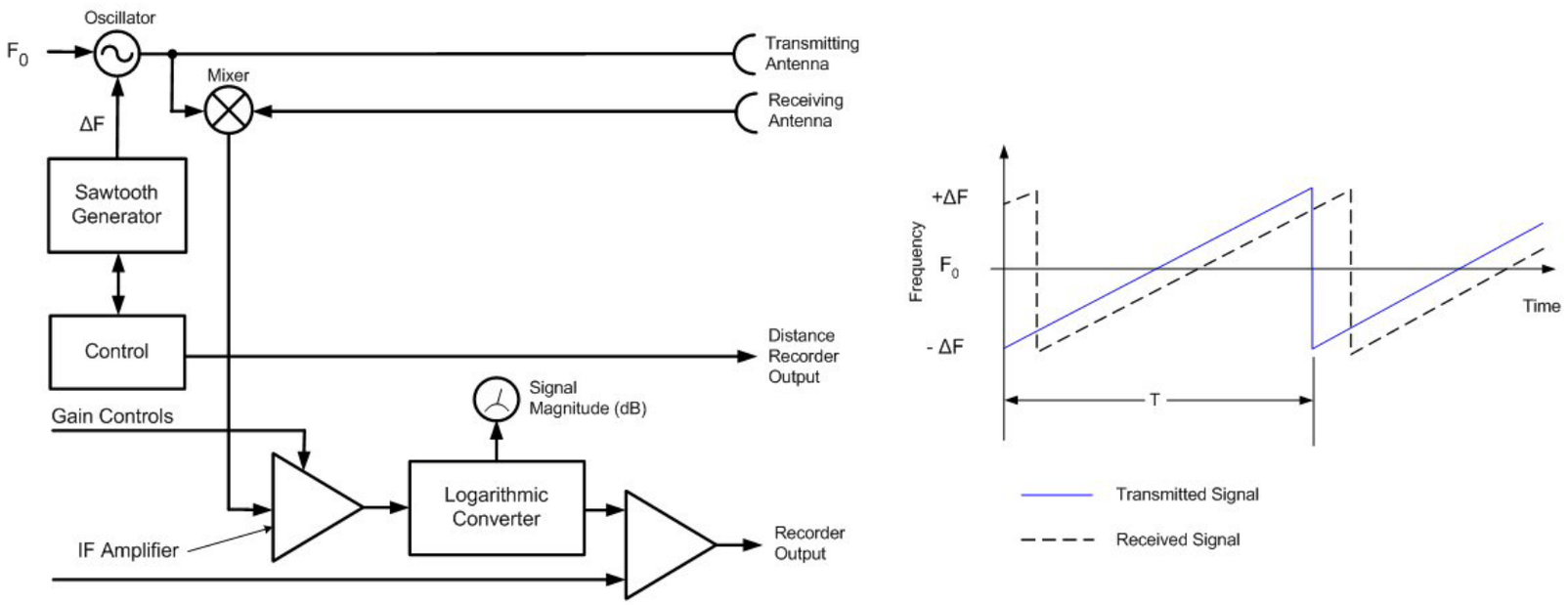

Figure 1. **Antenna Delays Are Measured** with a modified transmission-line-fault locator in terms of the differences in frequency between frequency-modulated transmitted and returned signals.

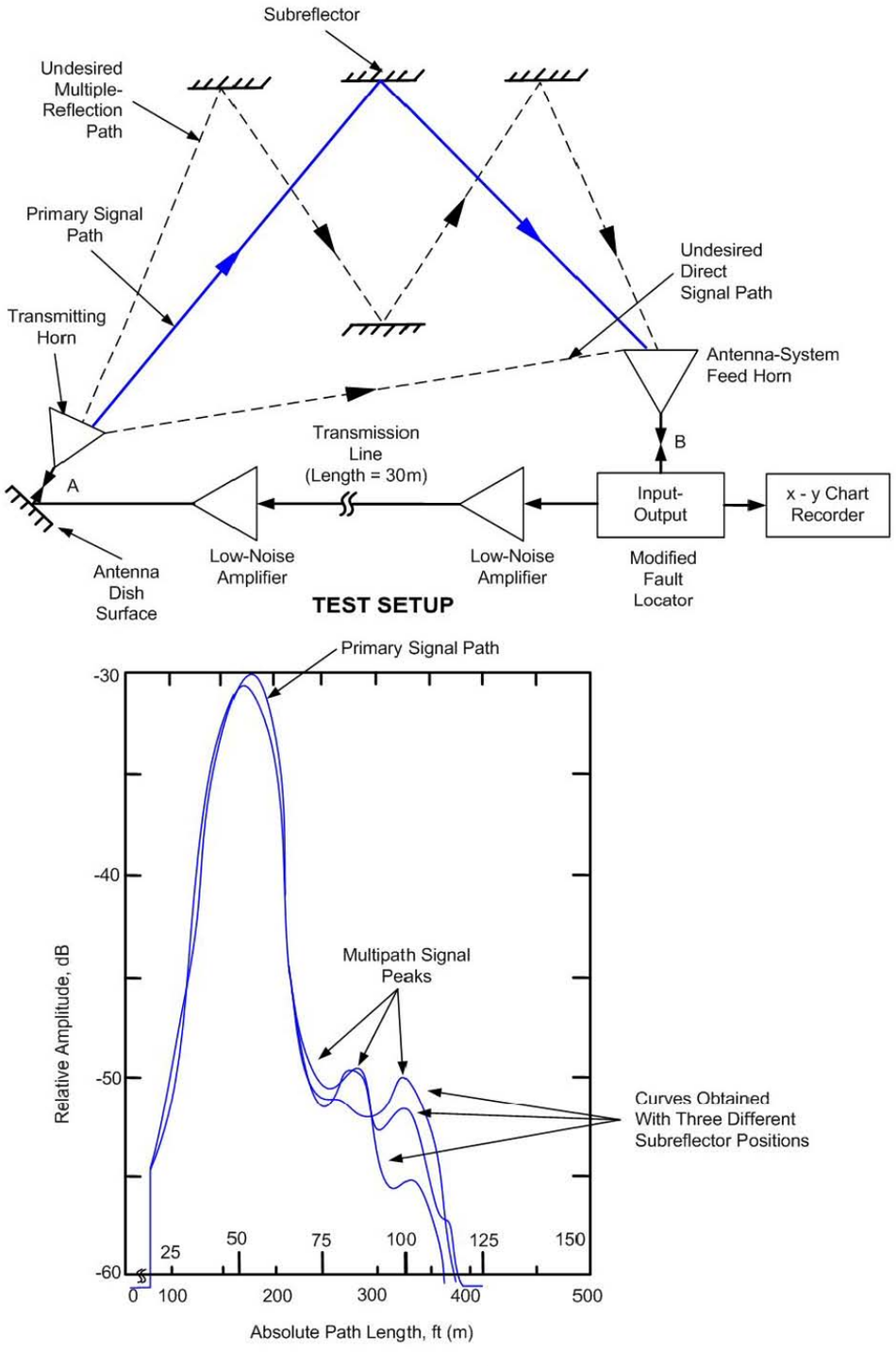

Figure 2. The **Modified Fault Locator** is placed on the antenna to measure the delay in the travel of the primary signal to the receiving horn through the reflector system of the antenna. It also measures the delays of undesired multipath signals that traverse the main signal path more than once or are reflected by structural parts. The recorder prints a plot of the multipath signals are readily distinguishable from the primary one. The plot shown here is for an antenna dish 64m in diameter.