6.2: AN ACCURATE MILLIMETER WAVE LOSS AND DELAY MEASUREMENT SET

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A point-by-point millimeter wave loss and delay measurement system has been built which combines large dynamic range with high accuracy. Up to 80 db loss and 100 nanoseconds envelope delay can be measured in the 50-60 Gc/s range. The accuracy for 0-40 db loss measurements is ±0.05 db, while beyond that accuracy is progressively diminished to ±0.8 db at 80 db. Delay accuracy for low loss devices (0-20 db) is ±0.2 μsec over the entire 100 μsec range. High accuracy and large range are attained with a substitution heterodyne measurement scheme using rapid RF and IF comparison switching along with calibrated IF loss and delay standards. In addition, high gain, narrow band, IF amplification and differential null detection is employed. Both measurement functions are incorporated into one system with manual waveguide switching and preset IF programs to facilitate conversion from loss to delay.

Figure 1 describes the basic loss measuring setup. Comparison switching at a 12-1/2 c/s rate alternately places the unknown and reference path in the microwave circuit and the loss standard and reference

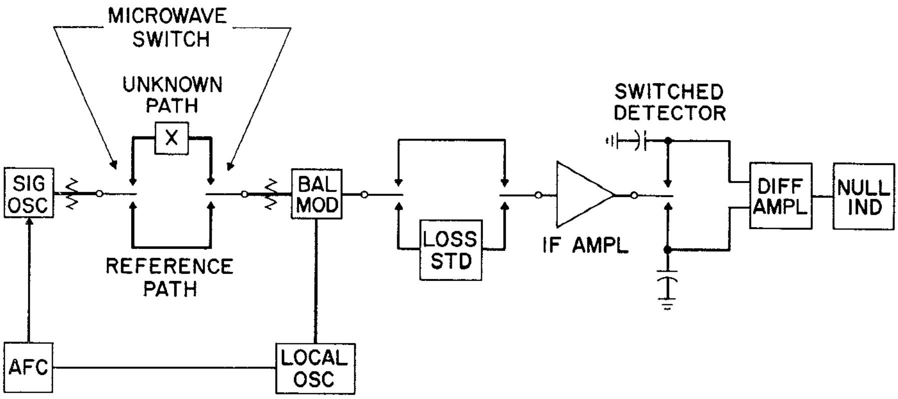

Fig. 1. Basic loss measuring setup.

path in the IF circuit. A microwave balanced modulator and AFC controlled local oscillator generate a fixed 10 Mc/s IF. After high gain narrow band amplification, the IF signal is fed into the switched detector. Signal levels proportional to the losses through the reference and unknown paths, are then sampled and stored on two capacitors. A differential d.c. amplifier and null meter then indicates the degree of level inequality between the two. Sufficient loss is inserted with the IF loss standard until a null indication results. At this point, the loss through the unknown path equals the loss through the reference path and the unknown loss can be read directly from the calibrated standard.

A number of advantages result from this measurement method: rapid comparison switching eliminates the effects of drifts in all components except those in the unknown and reference paths; a fixed low IF permits the use of an accurate calibrated loss standard always operating at one frequency; narrow band IF amplification extends the dynamic range by reducing thermal noise; and differential null detection allows precise presentation of loss unbalance.

Figure 2 describes the basic delay measuring setup. Delay is measured by recovering the envelope of a two-tone RF signal and measuring its phase shift with respect to a reference envelope. The two-tone

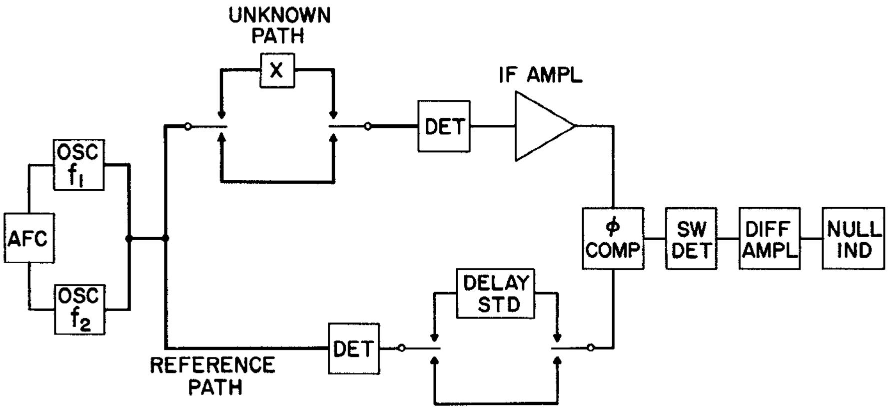

Fig. 2. Basic delay measuring setup.

microwave signal is generated and fed simultaneously into the unknown and reference paths. Comparison switching alternately replaces the unknown device with an equal length of waveguide and at the same time switches the delay standard in and out of the IF reference path.

The envelope resulting from the two-tone signal in the unknown path is recovered by a detector and fed into the phase comparator. The reference envelope is recovered by a second detector and similarly fed into the phase comparator. During half of the switching cycle, the signal through the unknown is compared to the signal through the delay standard. The other half of the switching cycle is used for zeroing purposes and a reference phase comparison is made. Voltages proportional to the two phase comparisons are sampled and again stored on two capacitors. A differential d. c. amplifier and null meter are used to indicate when the phase difference between the two readings is zero. This occurs when sufficient delay has been inserted with the IF standard to equal the delay of the unknown device. Delay in nanoseconds is then read directly on the calibrated standard.

Figure 3 shows a complete system block schematic and Figure 4 is a photograph of the measurement set.

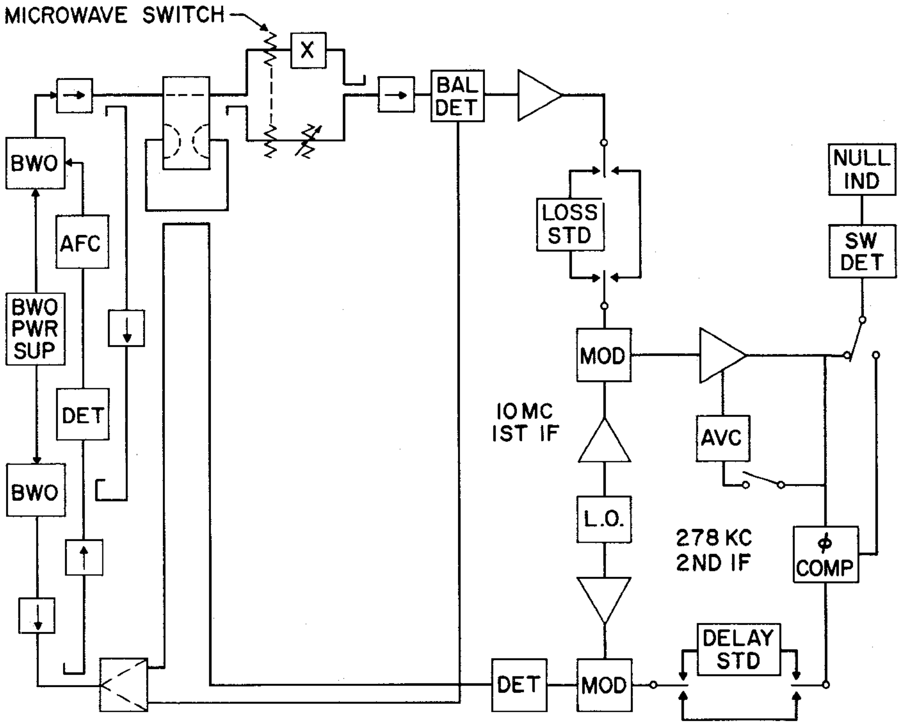

Fig. 3. Complete system block schematic.

A number of new devices were developed specifically for this system: a motor driven rotary microwave switch with 90 db on-off ratio and 1.06 VSWR; a high quality single-pole double-throw manual microwave switch with 1.06 VSWR and negligible leakage; and a frequency and phase control capable of maintaining a constant and exact 10 Mc/s offset frequency between two BWO signals. In addition, a number of microwave components recently developed at BTL for the millimeter wave program were employed in this set: a 50-60 Gc/s BWO with 50 mw of output power, high reverse loss broadband isolators, precision fixed low VSWR pads, and an extremely stable BWO power supply.

The effects of thermal noise, crosstalk, mismatch, calibrated standards, and level distortion on accuracy will be discussed together with means for reducing their effect. The measurements undertaken to evaluate the accuracy of the complete system are described and the actual measurement errors are noted along with a theoretical error estimate.

A series of measurements were performed on some typical components: a rotary vane calibrated attenuator was evaluated; the loss and

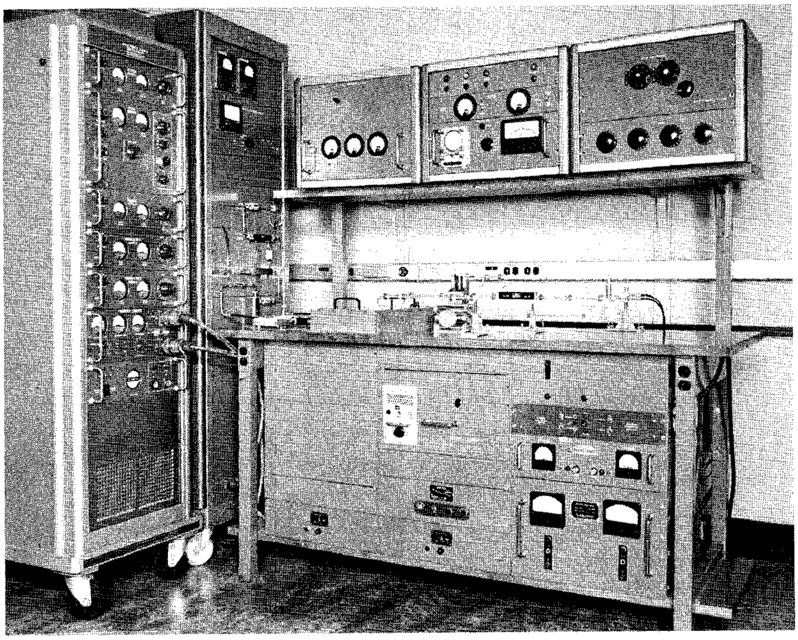

Fig. 4. Millimeter wave loss and delay measurement set.

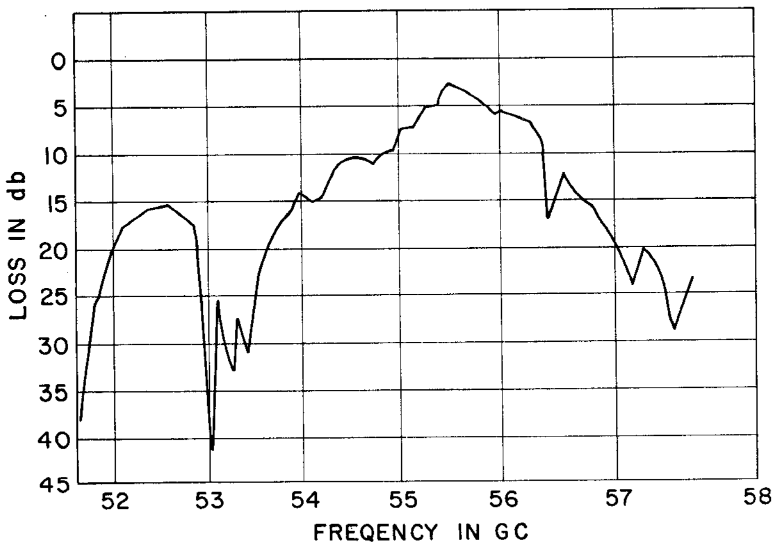

Fig. 5. Loss characteristic of channel dropping filter.

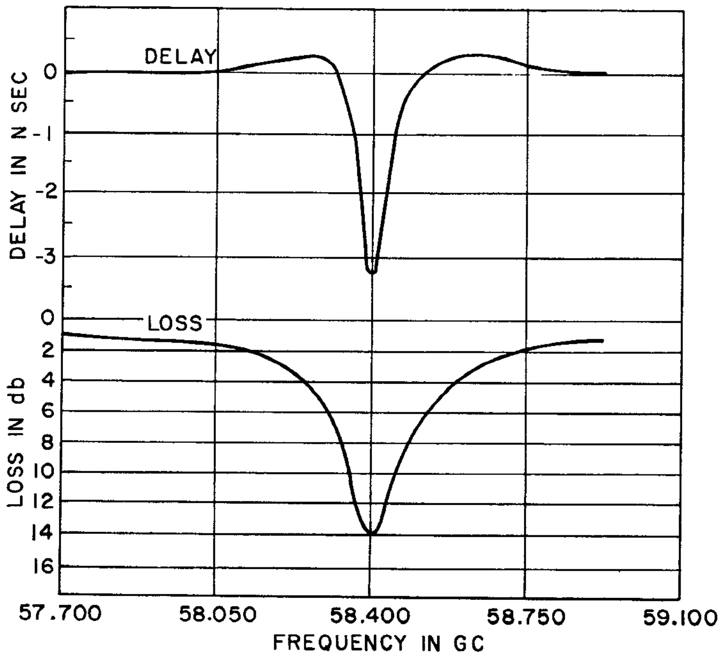

Fig. 6. Insertion loss and delay characteristic of narrow band rejection filter.

delay characteristic of a narrow band rejection filter was measured; the coupling characteristic of a directional coupler was accurately measured and a channel-dropping filter was examined. Figure 5 describes the characteristics of the channel-dropping filter as an example of a broad band loss measurement. Figure 6 describes the loss and delay of the narrow band rejection filter.