SECTION 54

POLARIZATION EFFECTS WITH A COMBINED RADAR - RADIOMETER

by

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INTRODUCTION

The purpose of this report is to describe a unique microwave sensor. The device uses a coherent X-band radar, a radiometer at the same wavelength and an antenna with a polarization that can be varied electronically. This microwave sensor was developed to acquire polarization signature information about various surfaces in both the active and passive mode simultaneously. One application for the sensor is expected to be the location and identification of plant life.

DESCRIPTION OF THE EQUIPMENT

In Figure 1 the equipment is shown mounted on an aerial platform truck for access to targets in their natural state. The boom height is 10 meters. The antenna parabola is 1.2 meters in diameter and can be positioned to any selected angle of incidence. The advantages of this approach are that the interpretation of the data will be aided by removing uncertainties concerning the geometry, surface conditions and equipment for the active and passive measurements. Furthermore, the detailed polarization measurements will provide a polarization signature for improved surface characterization.

Figure 2 is a simplified block diagram of the equipment which is shared by both the passive and active measurement functions. The center frequency is 8505 Megahertz. An integral part of the antenna is the polarizer. The orientation of the electric field vector can be rotated electronically with the polarizer. This may be compared to an optical polarimeter in which a polarized plate is rotated to analyze the polarization effects of an optically active sample. The radar transmitted signal has a separate polarizer in order to control the polarization of the illumination as well as of the received signal. The receiver is a superheterodyne, solid state design, with an IF bandwidth of 320 MHz and IF center frequency of 1215 MHz. The system noise figure of 8 dB is achieved with a low noise TWT mounted on the antenna. The IF signals are routed to either the radar or radiometer detectors by a special transfer switch which provides greater than 90 dB isolation and minimizes the switching transients. The data conditioning function will be described later.

The operator can select from 5 modes of time sharing and 16 switching rates. Figure 3 is an example of Mode 1 and the 1 KHz switching rate sequence of data acquisition. In Mode 1 the radar is on for 2 μ sec in each radiometer switching cycle. This mode is applicable for studying nearby objects so the echo returns within the 2 μ sec time interval. In Mode 2 the radar is on for 500 pulses then the radiometer for the equivalent time. Mode 4 is radar only and Mode 5 is radiometer only. The maximum PRF is 5000 pulses per second and the minimum is 312. The polarization scan switching rate is either at the PRF or after 8000 pulses by operator selection.

The polarization control, Figure 4, is achieved by adding equal amplitude right and left circularly polarized waves in the feed horn, resulting in a radiated linear polarized wave. The phase shift in one of the paths can be digitally selected by actuating latching ferrite phase shifters of 22.5, 45, 90 or 180 electrical degrees, thus varying the angular orientation of the resultant linearly polarized wave. There are 16 polarization states which will rotate the electric vector in $11\frac{1}{4}$ degree increments for a total of 180°. The circulators separate the transmit and receive signal paths. The reference and phase shifted signals are converted to right and left circular polarized waves in the orthomode transducer and 90° delay section. Figure 5 is a photo of the polarization network, Serial No. 1. It is about 20cm wide. The maximum scan rate is 5000 polarization changes per second.

The polarization data conditioning function may be explained with the aid of Figure 6. The transfer switch connects the IF signal to either the radar or the radiometer channel. The signal is coherently detected and amplified. The operator selects the delay of the sample gate to correspond to the range to the target. A 50 nanosecond sample of the echo is held and read in to the 16 channel processor. The 16 FET read in switches operate synchronously with the antenna polarization switches. The radiometer has a second balanced mixer amplifier in order to filter the radar center frequency. A detector recovers the Dicke switched signal which is amplified and synchronously detected at the PRF. This signal is filtered in individual channels synchronized with polarization.

The read out rate is 8 seconds per channel when operating at the 1 KHz PRF. Each filter is reset after being read out. For slow polarizations scan the read in and out are at the same time, for the fast scan 8000 read ins occur for each read out. Figure 7 is an example of analog data recording of the radar and radiometer outputs with slow and fast polarization scan. The first scan is at the slow rate and the next 2 scans are fast. The polarization state 3 corresponds to vertical and state 11 to horizontal polarization. Figure 8 is an example of a radar echo as observed with a sampling oscilloscope. The 100 nanosec transmitter pulse is blanked by the receiver protector switch.

PRELIMINARY RESULTS

The radiometer was calibrated with hot and cold loads. The configuration for this calibration is shown in Figure 9. The variable attenuator provides a check on the linearity by accounting for the loss factor A at the selected attenuations. After the hot and cold load calibration the waveguide switch is switched to the antenna. The antenna temperature response as seen through the polarizer is given in Figure 10. The polarizer loss is 1.2 dB and it is thermally controlled to 323°K. With this calibration the radiometric temperature seen by the antenna is related to the voltage output of the radiometer. The radiometric temperature observed while looking at an asphalt surface at an incidence angle of 70° and scanning the polarization at the slow rate is shown in Figure 11. The radar and radiometer measurements were time shared at the 1 KHz switching rate in Mode 1.

The radar is calibrated with reflectors of known or calculated radar cross-section. A Luneberg lens reflector of 24.3 dB square meter cross-section produced the amplitude shown in Figure 12. The darker curve is the cosine function with arbitrary amplitude and phase to indicate how close the measured points are to the cosine function. After removing the reflector the radar amplitude of the background is recorded. The radar data is shown in voltage units as measured. The radar backscatter voltage for asphalt at 70° incidence angle, slow polarization scan is seen in Figure 13. The radar data was taken at the same time as the radiometer data of Figure 11. One curve is for the case of transmitting vertically polarized and the other for transmitting horizontally polarized waves. If the amplitude of the sine and cosine coherent detectors are squared and added, the relative echo power as a function of polarization is obtained. Although the angle of polarization is measured, the direction of the electric vector is not. For example with horizontal polarization the vector may be pointing left or right. Thus all polarization states are included in 180 degrees **of vector** angular rotation and in a polar plot the points are symmetrical about the origin. Polarization signatures based on the data in Figure 13 are shown in Figures 14 and 15. These are polar plots of polarization angle verses relative echo power obtained by observing an asphalt surface at an incidence angle of 70°. The radar and radiometer measurements were time shared at the 1 KHz switching rate in Mode 1. Interpretation of the data from various surfaces will be the subject of another paper.

SUMMARY

A microwave sensor with an electronically variable polarized antenna has been described. A coherent X-Band radar and a radiometer share the same antenna and receiver at switching rates up to 5000 per second. The antenna polarization can be switched at the same rate for both the transmit and receive independent signal paths. The equipment is mounted on an aerial platform truck and is ready to make measurements in areas of interest for agricultural, geological and hydrological applications of remote sensing. The additional information due to the polarization modulation is expected to aid the identification of surface conditions. The time sharing of the radar and radiometer will ensure that the geometry, the surface conditions and equipment do not change for the active and passive measurements. The sensor will also provide new information about the relationship between surface reflectivity and emissivity.

Figure 1. The radar radiometer is mounted on an aerial platform truck for access to areas of interest for remote sensing applications. The Luneberg lens and corner reflectors provide calibration targets for radar calibration.

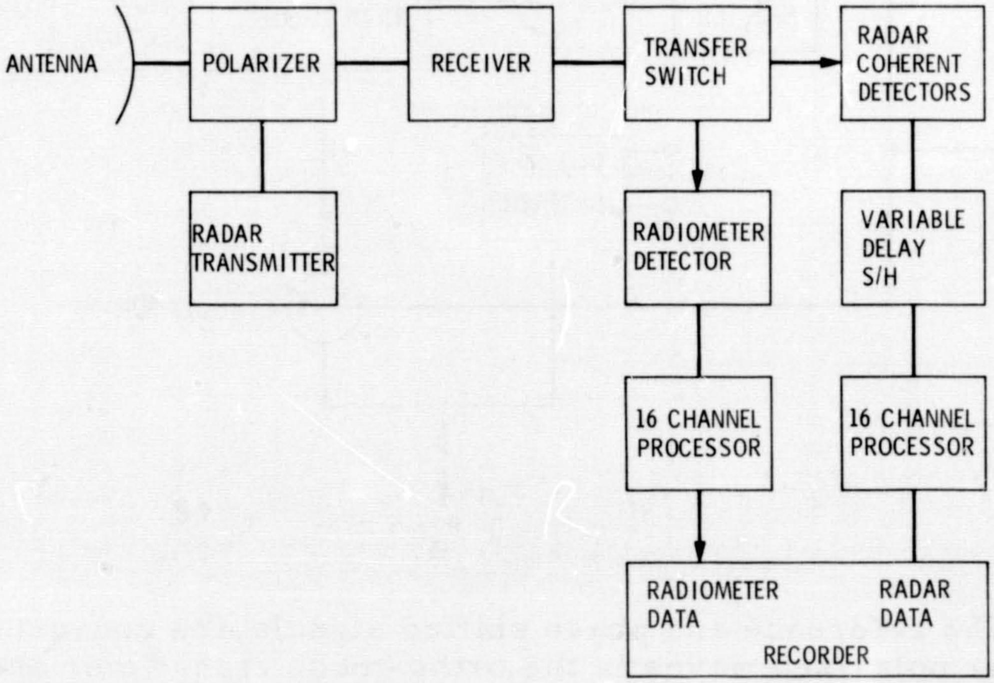


Figure 2. A coherent X-Band pulse radar is time shared with a radiometer. The antenna polarization can be modulated to identify the target polarization signatures for both the radar and the radiometer.

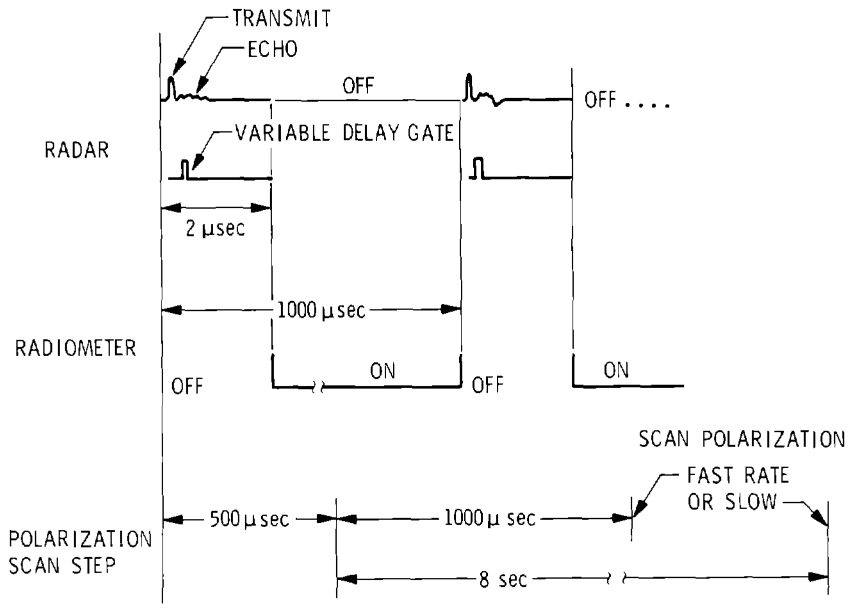


Figure 3. The operator can select from 5 Modes of time sharing and 16 switching rates. This is an example of pulse to pulse time sharing at 1 KHz. Polarization scan step can be either at the PRF or after 8000 pulses.

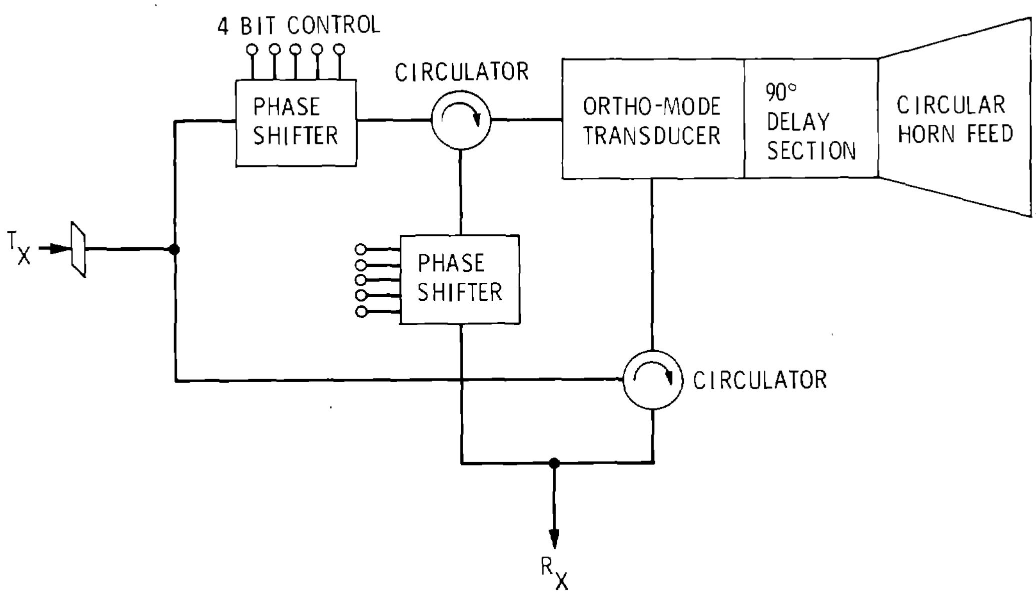


Figure 4. The reference and phase shifted signals are converted to right and left circular polarized waves in the ortho-mode transducer and 90° delay section. The sum of the two waves is a linearly polarized wave with the angular orientation a function of the phase shift. The 16 states rotate the electric vector 180° in 11 1/4° steps.

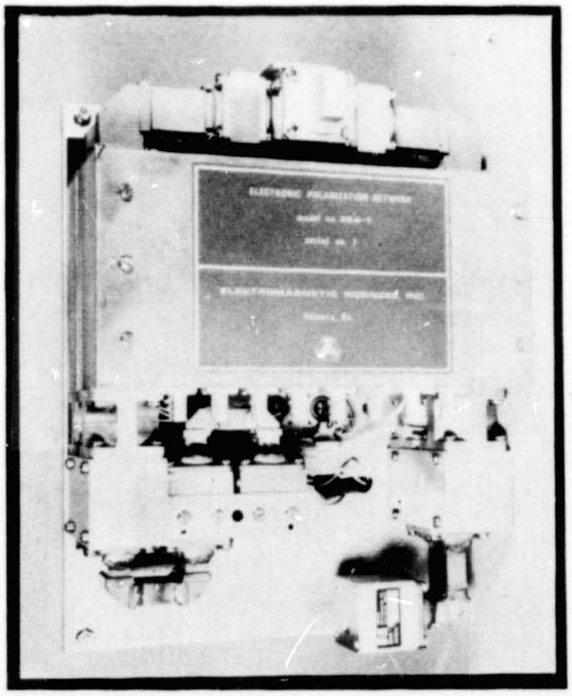


Figure 5. The ferrite phase shifters and X-Band waveguide network provide the antenna polarization control. Sixteen linear polarization states can be scanned at rates up to 5000 changes per second independently for the transmitted and received signals.

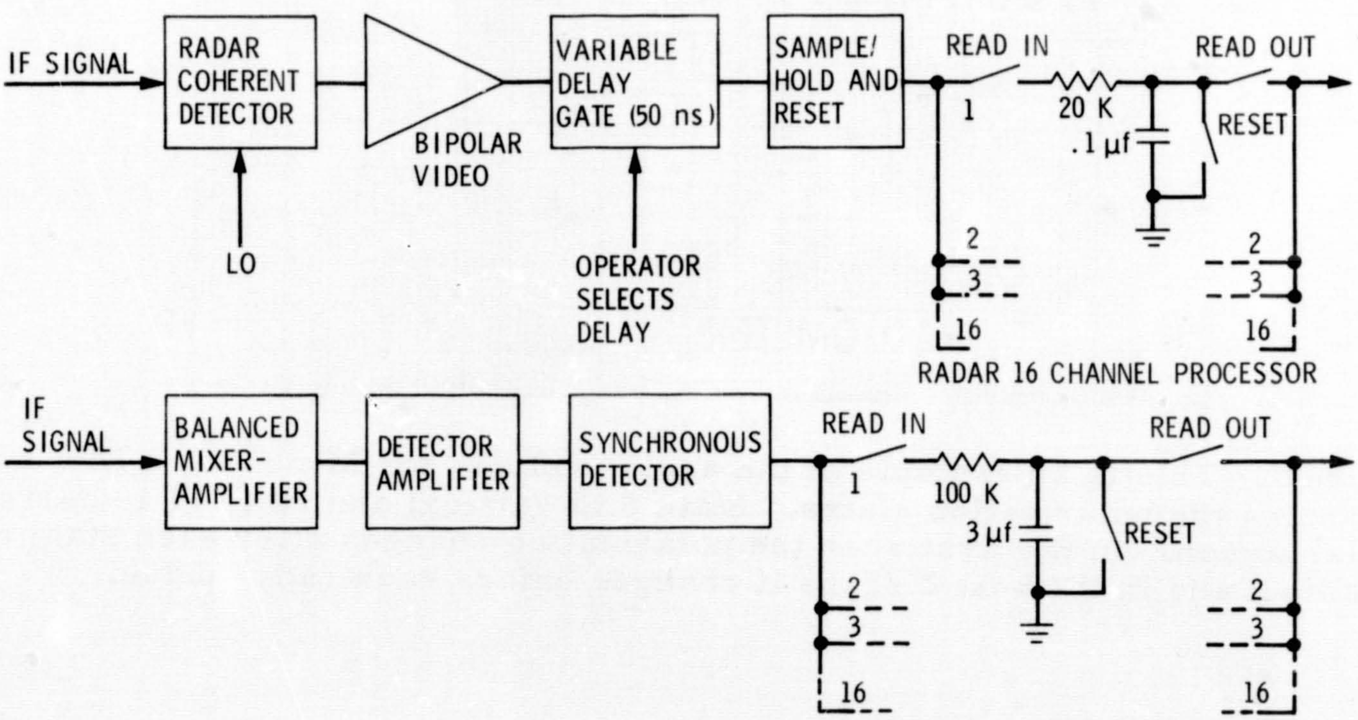


Figure 6. The IF signal from the receiver is switched to either the radar or the radiometer detector. There are 16 filters synchronized with the polarization scan. Each filter is reset after being read out.

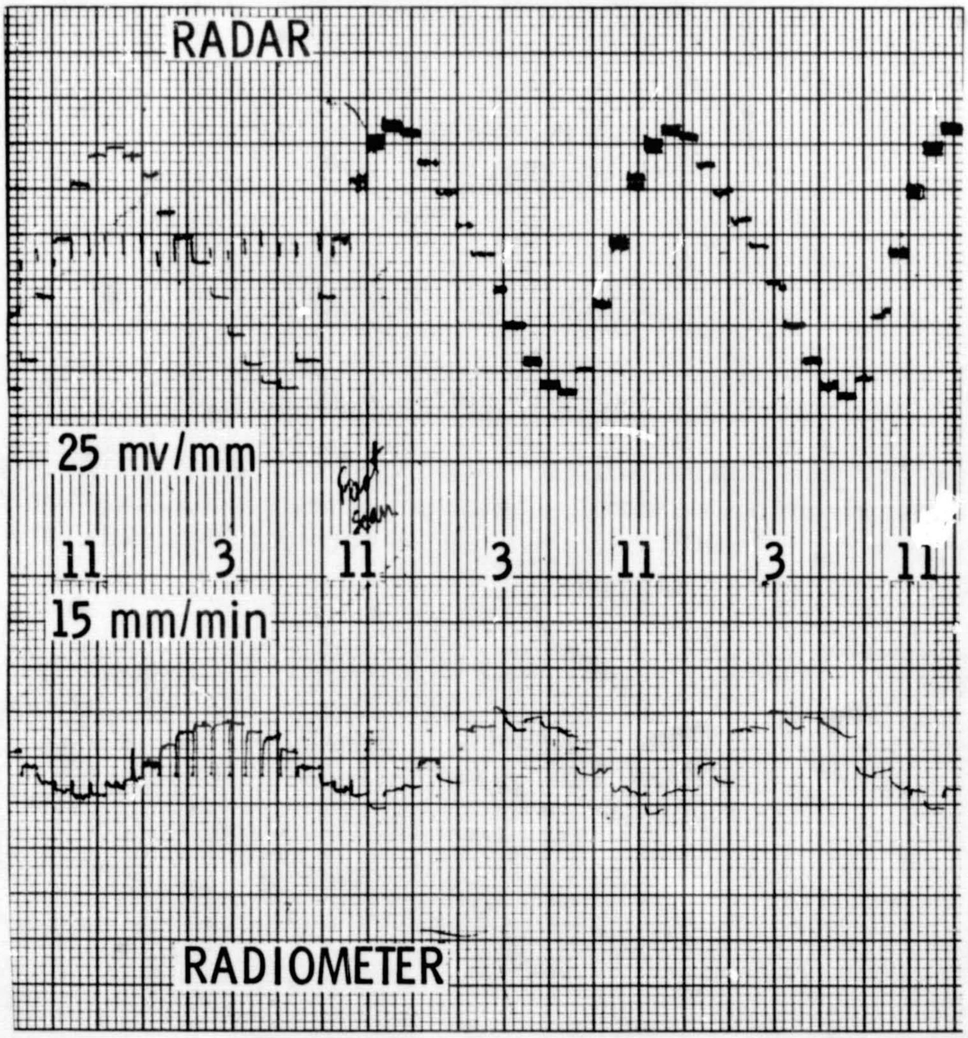


Figure 7. This is an example of the analog voltage for Mode 1 at 1 KHz while scanning the polarization states. State 3 is vertical and state 11 is horizontal polarization. In the first scan the polarization changes after each state is read out and in the next 2 scans it changes before each radar pulse.

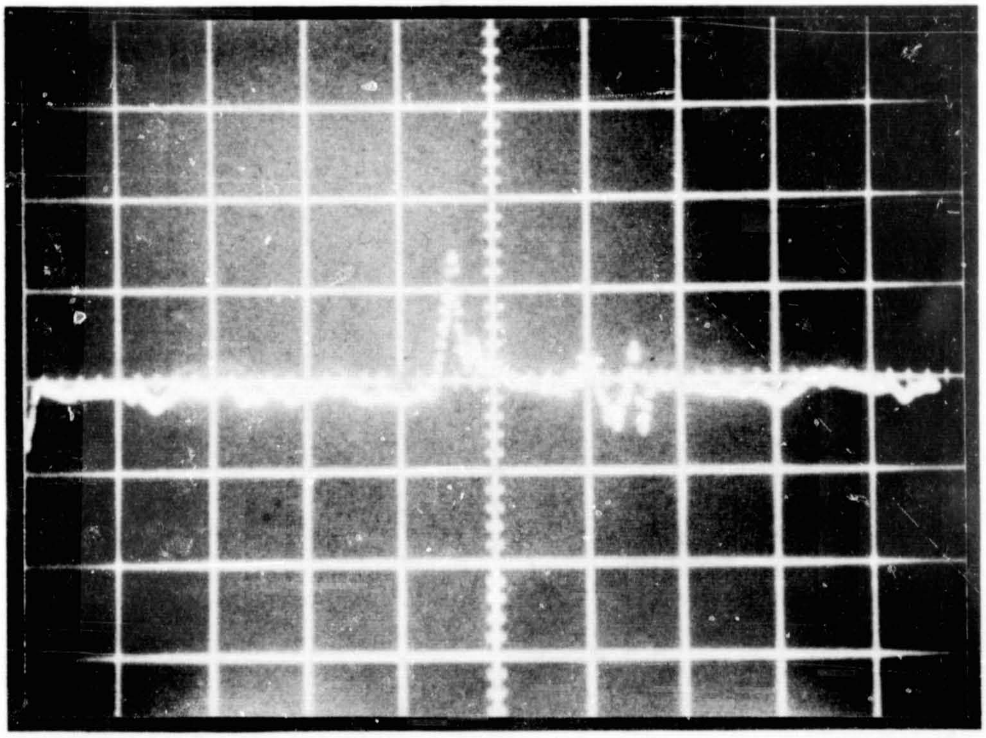
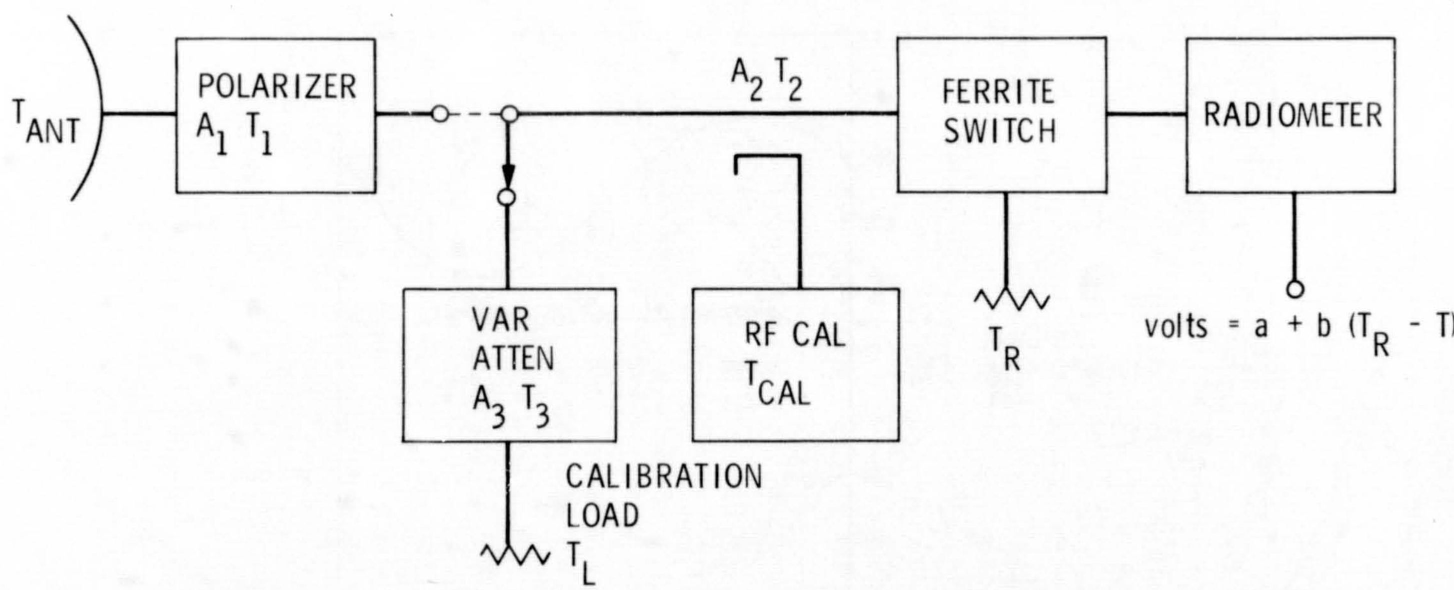


Figure 8. The 100 nanosec wide transmitted pulse is blanked by the receiver protector. The coherent echo is from a gravel surface at an incidence angle of 60°.



$$T_{APPARENT_1} = A_2 \left[A_3 T_L + (1 - A_3) T_3\right] + (1 - A_2) T_2$$

$$T_{APPARENT_2} = A_2 \left[A_1 T_{ANT} + (1 - A_1) T_1\right] + (1 - A_2) T_2$$

Figure 9. A waveguide switch on the antenna is switched to hot or cold loads for the radiometer calibration. The variable attenuator checks the linearity. A noise diode provides a calibration source in the field.

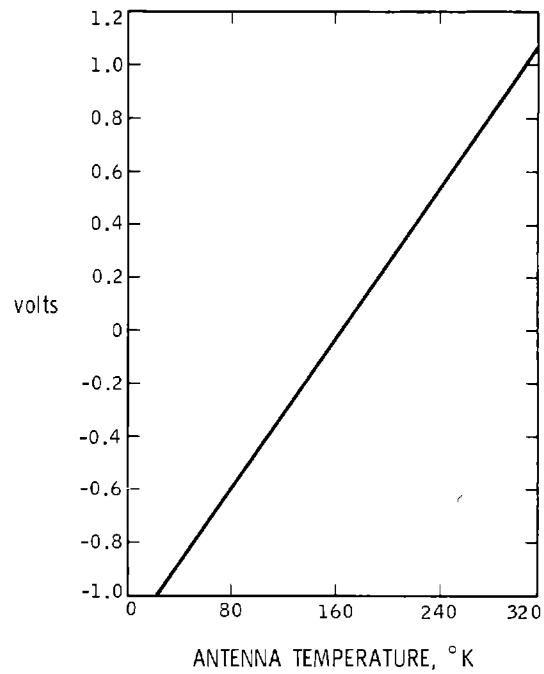


Figure 10. The radiometer output voltage as a function of antenna temperature is obtained by the calibration procedure.

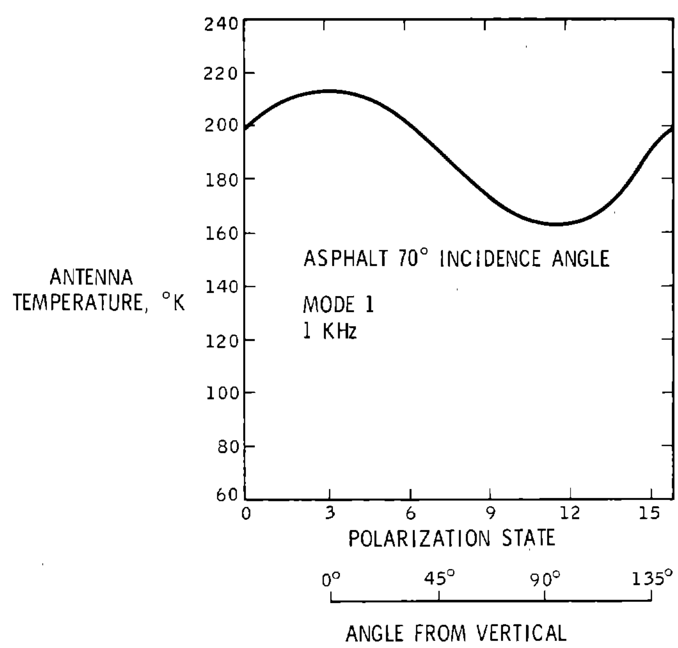


Figure 11. This radiometric temperature was obtained for an asphalt surface observed at a 70° incidence angle while operating in Mode 1 at 1 KHz with slow polarization scan.

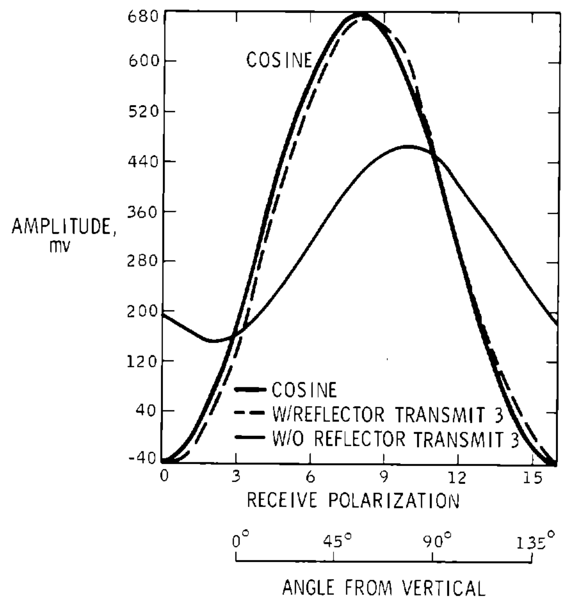


Figure 12. The radar signal obtained with a Luneberg lens reflector is compared to the background signal without the reflector and to a cosine function of arbitrary amplitude and phase.

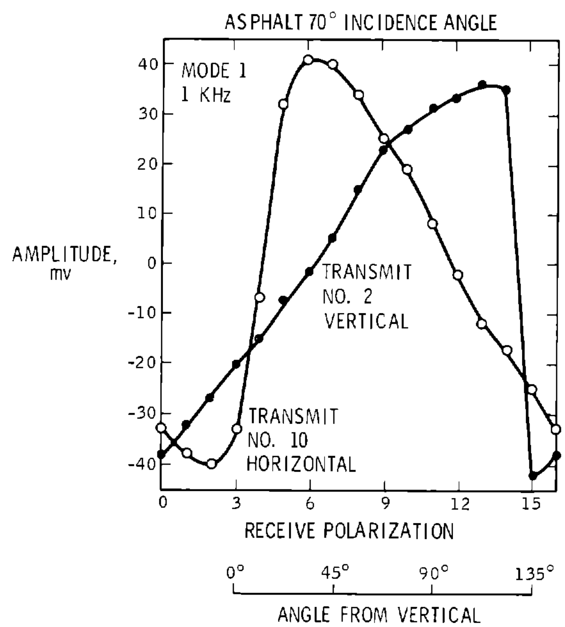


Figure 13. These radar backscatter amplitude curves were obtained for an asphalt surface observed at a 70° incidence angle while operating in Mode 1 at 1 KHz with slow polarization scan. The radar transmitted polarization was horizontal for the open points and vertical for the filled points.

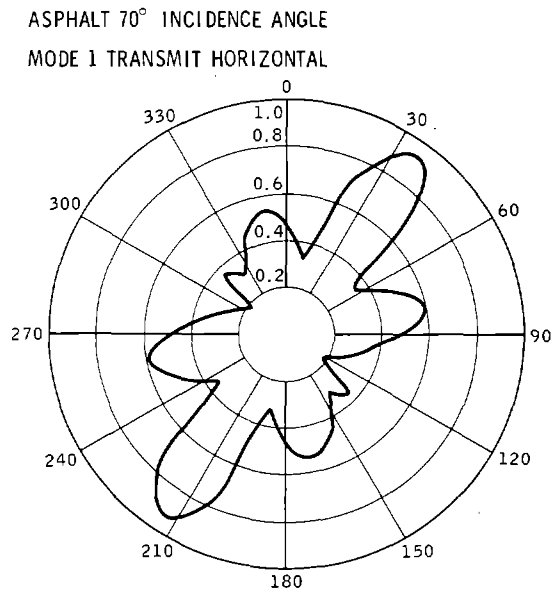


Figure 14. The relative power is plotted as a function of received polarization angle for an asphalt surface observed at a 70° incidence angle while operating in Mode 1 at 1 KHz with slow polarization scan, transmit horizontal polarization.

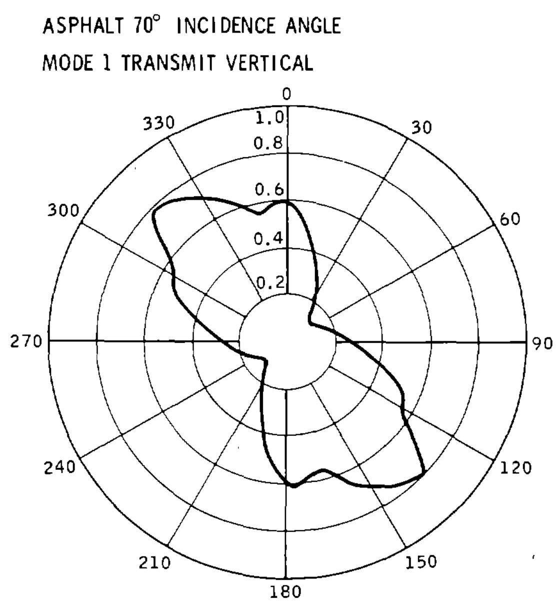


Figure 15. The relative power is plotted as a function of received polarization angle for an asphalt surface observed at a 70° incidence angle while operating in Mode 1 at 1 KHz with slow polarization scan, transmit vertical polarization.

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