Dual Polarization Observations on an MMCR: Implementation and First Results

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Introduction

The Atmospheric Radiation Measurement (ARM) Program's millimeter-wavelength cloud radar (MMCR) is a super-sensitive device capable of measuring extremely weak signals backscattered from small ice crystals and water droplets. Its sensitivity allows the radar to observe thin high cirrus clouds containing small ice particles as well as low-altitude stratus clouds composed of tiny water droplets (Moran et al. 1998). Unfortunately, other particulates suspended in the atmosphere, such as insects, ash, and bits of organic debris, are also readily detected by the radar. These non-hydrometeor targets represent unwanted contaminates for low-altitude cloud observations. Other researchers have used radar polarization measurements to help identify insect echoes (Sekelsky et al. 1998). Recently, dual polarization was implemented on the spare MMCR located in Boulder, Colorado, to demonstrate the ability to use linear depolarization ratio measurements to discriminate the contaminates from cloud droplets. Here, we describe the engineering implementation technique and show results from several initial observations of insects.

Insect Regions

The radar located at the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site encounters insect echoes, in the lower altitudes, commonly from March through November. In Figure 1, "insect rise" is occurring around 6 PM local time at the SGP CART site. Atmospheric conditions have changed in favor of insect flight, and over a 1½-hour period, insects have taken flight and dominate the radar echo through the boundary layer (3 km). The radar echoes from insects are very similar in magnitude to the echoes received from weak cloud regions, such as low-level stratus. Currently, the radar data must be combined with data from optical instruments, such as ceilometers and lidars to distinguish altitudes where insects may be present. (Optical instruments have narrow beamwidths and, in theory, they will not observe individual insects.) Work by Clothiaux et al. (1999) has successfully demonstrated that a combined technique can be used to discriminate regions where there is cloud from regions with insects and no clouds.

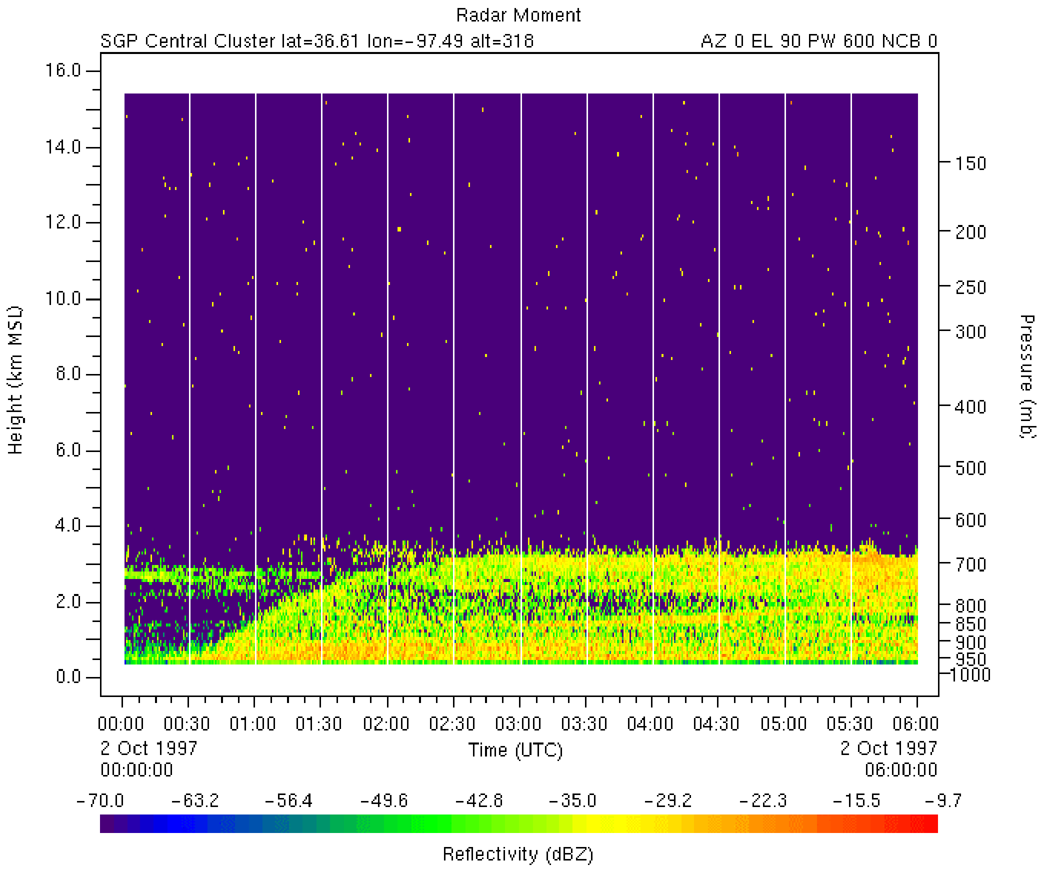


Figure 1. Insect echo from the SGP MMCR.

In May 1998, an experiment was conducted by a team of scientists from the University of Colorado using a balloon and an insect trap to try and measure the size and quantity of insects at the SGP site. The results of the study by Balsley (1998) showed that the concentration and size of the insects captured in the trap were consistent with the echoes received by the radar in the lower atmosphere.

Dual Polarization

One technique that will aid in the identification of irregular-shaped targets, such as insects, is the use of a linear dual polarization receiver. Spherical targets such as cloud water droplets do not change the polarization of the scattered signal, except for a phase reversal. A signal received from a non-spherical or elongated target will be depolarized by the scattering process and the target's shape and orientation influence the amount of depolarization. By transmitting a linearly polarized signal and receiving both the co-polarized and cross-polarized signals, the linear depolarization ratio (LDR) can be computed.

$$LDR = 10 \log (Z_X / Z_C)$$

where Z_X and Z_C are the measured reflectivity on the cross- and co-polarized channels, respectively.

To achieve good polarization measurements, the cross-channel isolation characteristics of the antenna are important in determining the dynamic range of LDR. The antenna used in the MMCR is a back-fed parabolic dish with a Cassegrain sub-reflector mounted on four rectangular spars and protected with a fiberglass cloth radome. A step-tapered circular feed is used to illuminate the sub-reflector and is oriented so that the linear polarization planes bisect the spars. This orientation minimizes the effect of the spars on the linear polarization configuration. Independent tests on a similar antenna indicated that there was about 28 dB of isolation between the two polarizations. This is sufficient to provide useful LDR measurements in clouds.

In the MMCR used for this demonstration, an ortho-mode transducer (OMT; Figure 2) is used to separate the received signal into co-polarized and cross-polarized components. The block diagram for the radar (Figure 3) shows an OMT inserted between the output circulator and the input to the antenna feed. The OMT provides an additional receiver channel for the cross-polarized signal. The receiver in the radar was designed for use with only one polarization, but a special multiple receiver mode in the software is used to separate the two channels. Special switch control hardware was installed on one of the MMCRs located in Boulder as part of the dual polarization demonstration.

An extra switch was added in the receiver chain (switch 3 in the block diagram) to allow the receiver to switch between the two channels on alternate radar pulses. The other switches, #2 and #4, are used for receiver blanking and to protect the low noise pre-amp during the time the transmitter is on. During the data collection cycle, the dwell time is divided between the two channels on alternating pulses providing nearly simultaneous observations on the two polarizations. Half as many observations are made on each channel during the dual polarization mode of operations and thus the measurements are less sensitive by 1.5 dB.

Figure 2. 35-GHz ortho-mode transducer.

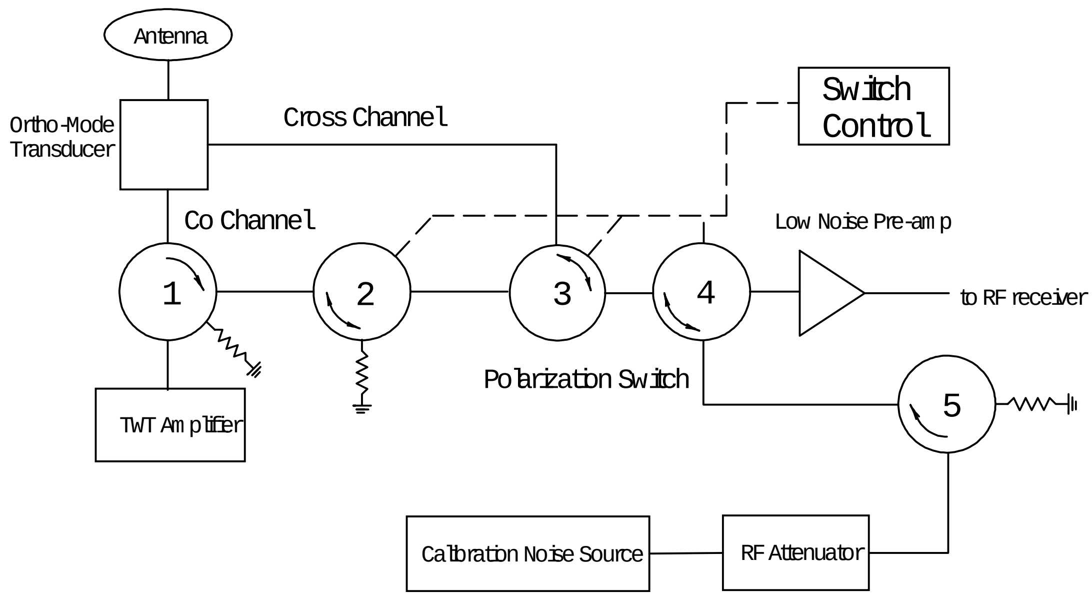


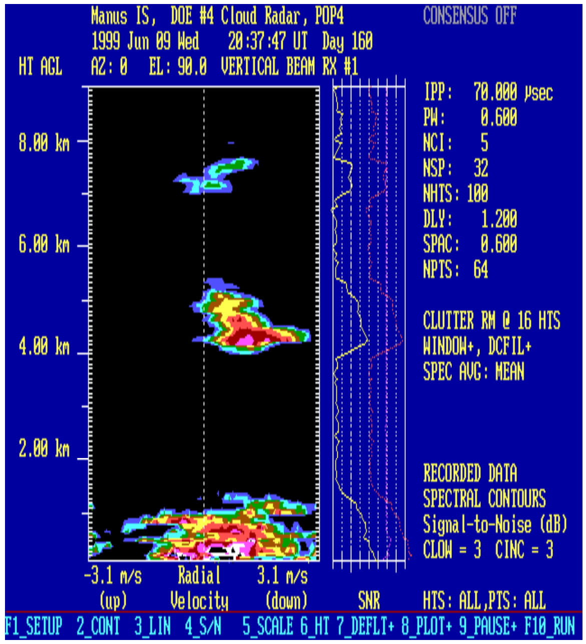
Figure 3. MMCR dual polarization block diagram.

Initial Observations

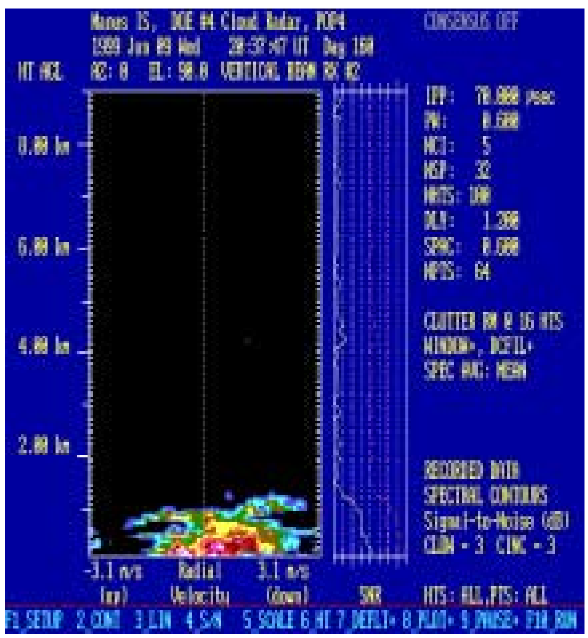
To demonstrate the techniques used in dual polarization measurements with an MMCR, we made use of the spare radar in Boulder, Colorado. In June 1999, the radar was operated in a vertical-only mode, observing clouds and insects overhead. Figure 4 shows the contours of radar signal power as a function of velocity and height for a 5-second average for the co-polarized and the cross-polarized channel. The echoes at 5 km and 7 km in Figure 4a have LDRs < -25 dB, which suggests they are due to cloud droplets. The low-altitude echoes are presumably insects and produce a strong cross-polarized signal. The use of the depolarized data by itself is not sufficient to tell if the insect regions also contain cloud. An optical remote sensor, such as a lidar or ceilometer, can detect the presence of even the weakest cloud signatures embedded in the insect layers. A combination of measurements from an MMCR and an optical instrument, such as a lidar, will be required to obtain the most complete picture of the type of scatters the radar sees (Martner and Moran 2000).

A similar set of measurements was made in September 1999 over a period of a half-hour and the LDR values were computed for the insect echoes in the lowest 2 km. Figure 5 shows the distribution of LDR values with a mean value near -6 dB.

Linear polarization may not be the optimum choice to measure the depolarization ratio of the insects. LDR is strongly influenced by the shape and orientation of the targets. A better choice would be to implement circular polarization and compute the circular depolarization ratio (CDR), which is less sensitive to target orientation (Martner and Moran 2000).



(a) Co-polarized echo



(b) Cross-polarized echo

Figure 4. Dual polarization echo.

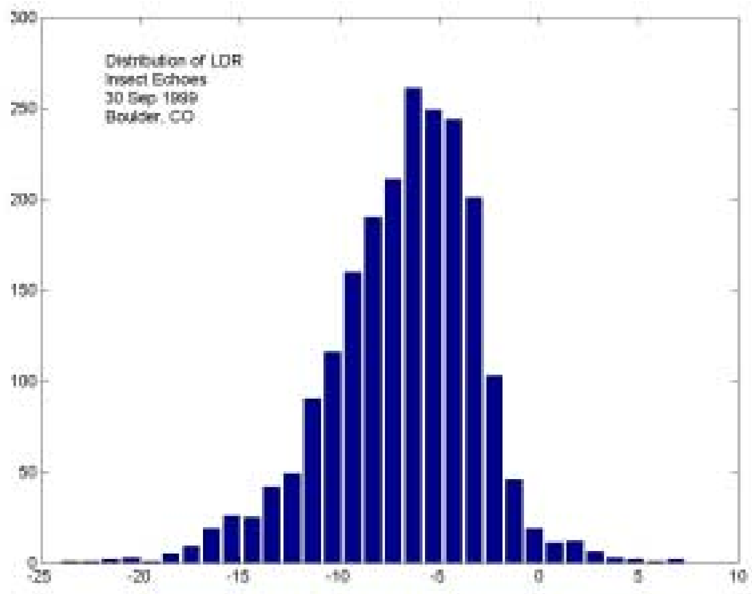


Figure 5. Distribution of LDR for insects.

Summary

A dual polarization receiver has been installed on the ARM Program's spare MMCR to demonstrate the ability of the radar to discriminate between signals from cloud droplets and those of non-hydrometeors, such as insects. Measurements of mean LDR values for insects (-6 dB) were significantly different than the LDR for cloud droplets (-25 dB). Polarization measurements from the MMCR combined with measurements from an optical sensor, such as a lidar, will provide a way to detect regions that are 1) all cloud, 2) all insects, or 3) a mixture of the two. Implementation of an operational dual polarization capability may be part of the next radar upgrade project being planned for the SGP radar.

References

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