P5.8 A "VENETIAN BLIND" POLARIZATION GRID REFLECTOR LENS FOR DUAL-BEAM 95-GHZ AIRBORNE RADAR MEASUREMENTS[1]

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1. INTRODUCTION

The Microwave Remote Sensing Laboratory (MIRSL) at the University of Massachusetts (UMass) and the University of Wyoming (UWyo) Atmospheric Science Department constructed and tested a low profile polarization grid lens. The purpose of the lens is to provide the 3-mm wavelength UWyo Cloud Radar (WCR) with dual-beam Doppler and reflectivity measurement capability on-board the UWyo King Air aircraft. The concept of the lens is based on conventional polarization grid reflectors which have the unique property of being almost perfectly transparent to incident electromagnetic fields when the electric field lines are perpendicular to the grid lines, but reflective when are parallel. The WCR can electronically switch (from pulse-to-pulse) the polarization of the transmitted field between vertical and horizontal, so a conventional polarization grid reflector plate could be used to switch the radar beam between 0 and 45 deg when placed in front of the antenna at a steep, 22.5 deg, angle. However, the problem with using a conventional grid plate in this geometry is that it would have to be over 0.9 m in size along the radar beam for it to deflect the 0.3 m diameter antenna beam of the WCR. Such a large object cannot be mounted on the King Air so, as an alternative, a collapsed reflector plate was designed with the concept of the venetian blind structure.

2. DESIGN PARAMETERS

The structure of this collapsed "venetian blind" polarization grid lens is illustrated in Figure 1. A stacked set of copper grid coated rexolite strips are sandwiched between two solid blocks of rexolite wedges.

The polarization grid lines on each strip are oriented across the strips to minimize return loss of the defected beam by taking advantage of the Brewster angle at parallel polarization. The overall thickness of the lens is machined to multiple half wavelength to also minimize the return loss of the direct beam. To match the phase of the deflected beam from each strip, the spacing (*S*) of the strips is determined by the wedge angle (θ), dielectric constant of the rexolite ($\varepsilon_r \approx 2.53$) and wavelength ($\lambda$) according to

$$S\sqrt{\varepsilon_r}\,\sin(\theta) = n\frac{\lambda}{2}, \qquad (1)$$

where *n* is a positive integer, and the ratio of the spacing and the width (*W*) of the strips is related to the wedge angle as

$$S/W = \tan(\theta). \qquad (2)$$

The deflected beam angle (ϕ) can be calculated using Snell's law:

$$\sin(\phi) = \sqrt{\varepsilon_r}\,\sin(2\theta). \qquad (3)$$

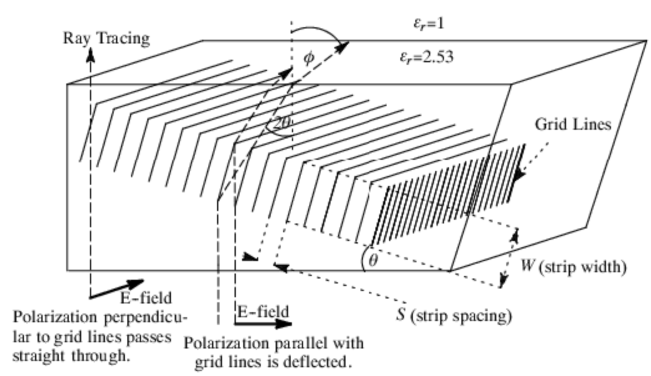

Figure 1. Structure of the "venetian blind" polarization grid lens.

[1] This work in part was funded by NSF grants ATM-0095163 at UMass and ATM-0094956 at UWyo.
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3. GROUND TEST

A prototype lens, shown in Figure 2, was constructed out of a pair of solid rexolite wedges and 48 strips of 0.5 oz copper coated sheets of rexolite. The copper coated rexolite strips were etched to a grid of 0.002” wide lines spaced 0.01”. The thickness of the 0.3 m diameter lens turned out to be 0.1 m – significantly smaller than the height (0.9 m) of a conventional polarization grid reflector for this application. The beam pattern of the lens was measured with the WCR in Laramie, Wyoming using a pole mounted trihedral corner reflector. The two-way insertion and return loss of the lens reduced the sensitivity of the radar by about 5 dB and the isolation between the 43 deg deflected and the direct beams was only 3 dB when the deflected beam was transmitted, making the lens a beam splitter rather than a beam switch. During airborne measurements, however, the forward motion of the aircraft induces different Doppler shifts in the two beams which can be used to increase isolation to above 20 dB. By transmitting in the deflected beam direction, but also transceiving a 3 dB weaker signal in the direct beam, the received signal from both beams can be simultaneously sampled and then separated using spectral processing. The 3 dB reduction in the direct beam signal power, however, further reduces sensitivity, totaling an 8 dB drop in the direct beam (5 dB drop in the deflected beam) compared to the normal sensitivity of the radar without the lens.

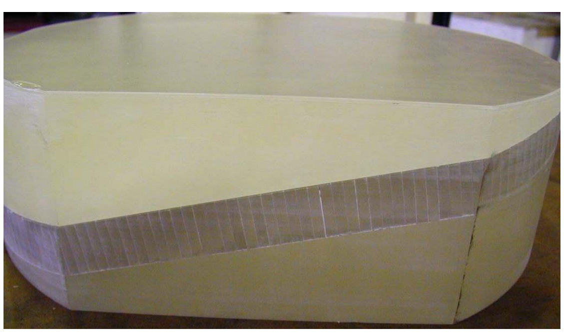

Figure 2. The prototype venetian blind polarization grid reflector lens (side view)

4. FLIGHT TEST

In November 2000 the lens was mounted on the UWyo KingAir and during two flights dual beam radar data were collected in ice clouds. A photograph of the lens, mounted in the side window of the radar antenna pod is shown in Figure 3.

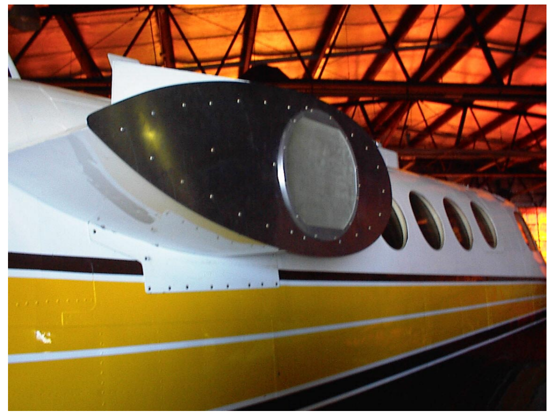

Figure 3. The venetian blind polarization grid reflector lens mounted in the side window of the antenna pod of the University of Wyoming King Air aircraft.

The radar transmitted bursts of 64 horizontally polarized pulses which were split by the lens into the “side” (direct) and “side-aft” (deflected) beams. The 64 profiles of complex voltage samples were Fourier transformed in each range gate to separate the received signals from the two beams. Both beams sampled the horizontal plane on the right side of the aircraft at flight level; the “side” and “side-aft” beams pointing about 2 deg and 45 deg, respectively, towards the rear of the aircraft relative to aircraft lateral axis. The approximately 90 m/s airspeed of the King Air induced a strong Doppler shift in the side-aft beam causing multiple folding even with the fastest, 20 kHz, pulse repetition frequency (PRF) of the radar. A typical Doppler spectrum collected with the lens on November 11, 2000 is shown in Figure 4 and a spectrum collected without the lens, in normal, side looking operating mode on November 19, 2000 is shown in Figure 5. The Doppler shifted returns from the two beams are distinct and clearly identifiable in Figure 4 as the three times folded side-aft beam peak appears at -13 m/s (indicating a radial Doppler velocity of

-65.7 m/s), while the side beam peak is at -4 m/s. For 2-D Doppler velocity field estimation [1] the centroid of each peak can be tracked and for the estimation of the attenuation field using Stereorad processing [2][3][4][5], the power in the peaks can be integrated.

The spectral width (calculated as two times the standard deviation of a peak on the linear scale for comparison purposes) of the side-aft and side beams is 0.62 and 0.76 m/s, respectively, indicating a two way antenna beam width of 0.54 deg for the back side-aft and 0.48 deg for the side beam. This shows only a slight beam broadening compared to the 0.47 deg two-way beamwidth of the antenna, measured without the lens.

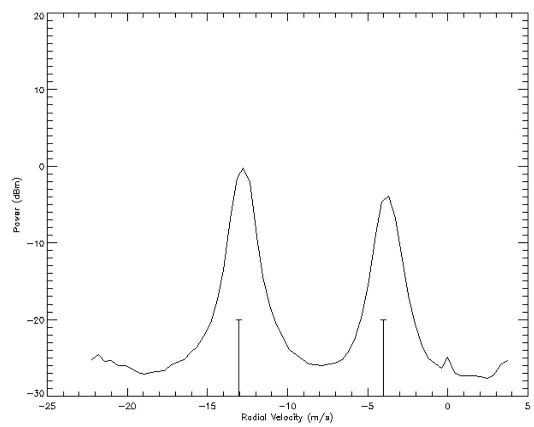

Figure 4. Dual-beam Doppler spectrum collected in an ice cloud on November 11, 2000 with the 95 GHz WCR radar on board the UWyo King Air aircraft. The 45 deg side-aft beam (left peak) is folded three times due to the 90 m/s airspeed of the aircraft. The slightly back pointed (not folded) side beam peak is at –4 m/s.

5. CONCLUSIONS

A novel, low-profile, "venetian blind" polarization grid reflector lens was designed, constructed and successfully tested with a 95 GHz airborne radar system. The lens split the beam of a single aperture radar, to collect dual-beam radar reflectivity and Doppler velocity data in ice clouds from an aircraft. The benefit of a "venetian blind" lens over a conventional polarization grid reflector or two antennas is its relatively compact, 10x30x40 cm, size. However, the two-way loss of the lens reduced radar sensitivity by 5 and 8 dB in the side-aft and side beams respectively and the aircraft flight speed induced Doppler shift was needed to increase isolation between the side and side-aft beams to above 20 dB.

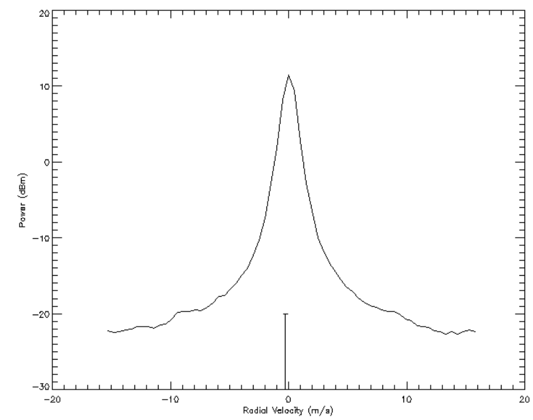

Figure 5. Single beam Doppler spectrum collected in ice clouds without the venetian blind lens on November 19, 2000.

6. REFERENCES

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