Design of a Large Dual Polarized Ku Band Reflectarray for Space Borne Radar Altimeter

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I. INTRODUCTION

This paper describes the design of a large dual-beam, dual polarized reflectarray designed for a space-based radar altimeter. This application requires a 2.16 x 0.35 m aperture that can be folded for launch stowage. Low mass and >50% efficiency are also required. A reflectarray antenna offers the best approach but also presents unique technical challenges since a reflectarray has never been used in a space based radar application. In what follows, we describe the design, analysis and measurements of a breadboard test array built to demonstrate the reflectarray concept.

II. DESIGN

Physical Configuration. Figure 1 illustrates the reflectarray configuration. The 2.16 x 0.35m aperture is subdivided into 5 flat panels to facilitate launch stowage [1]. These panels form a piecewise planar approximation of a parabola with a 1.125 m focal length. Square patch reflectarray elements arranged in a half-wavelength grid are etched on 0.81mm (0.032-inch) thick Rogers RO4003 dielectric substrate. Figure 2 illustrates the piecewise parabolic (PWP) panel geometry, and also shows a flat reflectarray configuration. Two separate feeds are used to create a pair of far-field beams.

Electrical Design. Pozar's variable patch design procedure was used for the reflectarray electrical design [2]. The procedure uses infinite array (Floquet mode) reflection coefficients to determine the phase of the field scattered by each patch. This approximation introduces risk because reflectarray element sizes vary over the array face, thus creating a non-periodic array environment. Since patch elements can only generate ~360° phase shift, "phase wraps" occur when the required phase shift exceeds this value.

A piecewise planar (quasi-parabolic) configuration minimizes the number of phase wraps per panel and reduces the local angle of incidence at each patch. This permits one to simultaneously maximize V-pol and H-pol gain, improve pattern performance and reduce sensitivity to tolerances. Figures 3 and 4 compare the aperture of a flat and a PWP reflectarray, respectively. For the latter, one can observe a ring structure in each panel that corresponds to a single phase wrap. At a phase wrap, patch size jumps from minimum to maximum patch size forming a discontinuity that violates the infinite array assumption. However, these patches are well off resonance so that reflection phase shift is relatively insensitive to this discontinuity. For the flat reflectarray configuration, the number of phase wraps per panel increases from the center to the ends of the array. At the ends (x-direction), a phase wrap occurs every three elements, which results in a rapid continuous variation in the mutual coupling environment for every patch.

Figures 3 and 4 also show the predicted V-pol azimuth patterns for flat and PWP configurations. The flat panel exhibits substantial pattern distortion in the sidelobe structure. This antenna was designed for optimum H-pol performance. The V-pol pattern degrades because patch reflection coefficients for V- and H-polarizations are only equal at normal incidence. In contrast, we find the PWP reflectarray equalizes performance of the two polarizations.

The 3.3° elevation beam scan is achieved by displacing each feed by ~6.5cm from the focal point. Calculations indicate that this produced no discernable pattern degradation and resulted in < 0.1 dB gain penalty. A simple microstrip patch array, with integrated microstrip feed, was used in order to expedite development of the breadboard array. This feed produced the desired illumination function (~10 dB edge taper) but imposed a 2.8 dB gain penalty, primarily due to feed transmission line loss.

III. BREADBOARD TEST RESULTS

Sample results comparing the measured and predicted patterns for H-polarization are shown in Figure 5. As can be seen, the results compare very well. The large sidelobe in the elevation pattern was caused by feed blockage, which reflected energy back into the reflectarray and was not accounted for in the calculations. The measured H-pol gain was 37.0dB, corresponding to an aperture efficiency of approximately 25%. However, this includes the 2.8dB feed loss. The flight unit will use a waveguide feed, which reduces the loss to approximately 0.20dB resulting in an overall efficiency of 49%. The table below indicates that the measured data compares favorably with prediction. The V-pol measurements show similar agreement.

	Azimuth		Elevation	
	Measured	Computed	Measured	Computed
Beamwidth		0.59		0.59
Peak SLL	-15.2	-17.5	-15.2	-17.5
Cross-Pol	-28.9	-28.6	-28.9	-28.6

IV. CONCLUSIONS

A dual-beam, dual-polarized, piecewise parabolic reflectarray for a space-based radar altimeter has been designed, built and tested. It was found that the new piecewise parabolic approach has three main advantages: 1) it equalizes the performance between H- and V-polarizations; 2) it reduces drastically the number of phase wraps the reflectarray surface goes through, especially near the ends, thereby more closely resembling the infinite array model used in the design; and, 3) it reduces the angle of incidence at the ends of the reflectarray. The predicted patterns agreed well with measurements. Although the aperture efficiency was only 25% for the initial breadboard, the loss budget shows that 50% efficiency can be achieved with a low loss feed.

REFERENCES

[1] WSOA Phase 2 Brass Board Fabrication and Demonstration Final Report, Document No. 3014D1542, AEC-Able Engineering Company, Inc., Goleta, CA, 2000.

[2] D. Pozar, S. Targonski, and H. D. Syrigos, "Design of Millimeter Wave Microstrip Reflectarrays," *IEEE Transactions on Antennas and Propagation*, vol. 45, pp. 287–296, 1997.

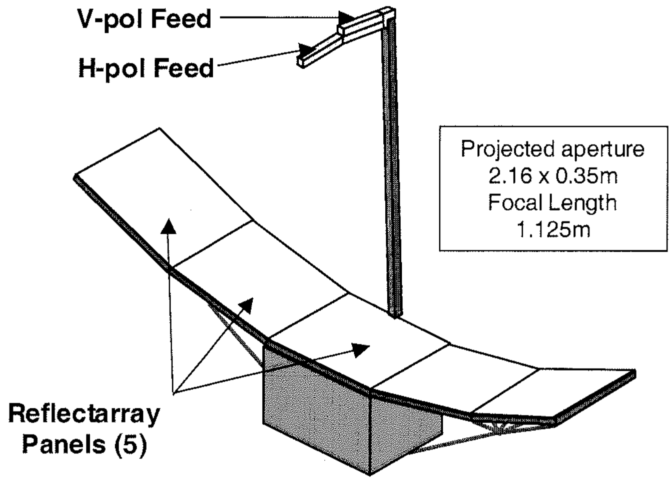

Figure 1. PWP Reflectarray Configuration

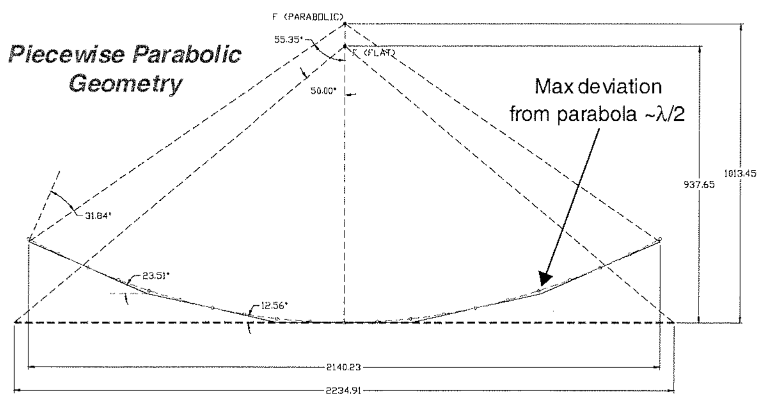

Figure 2. Piecewise Parabolic Geometry

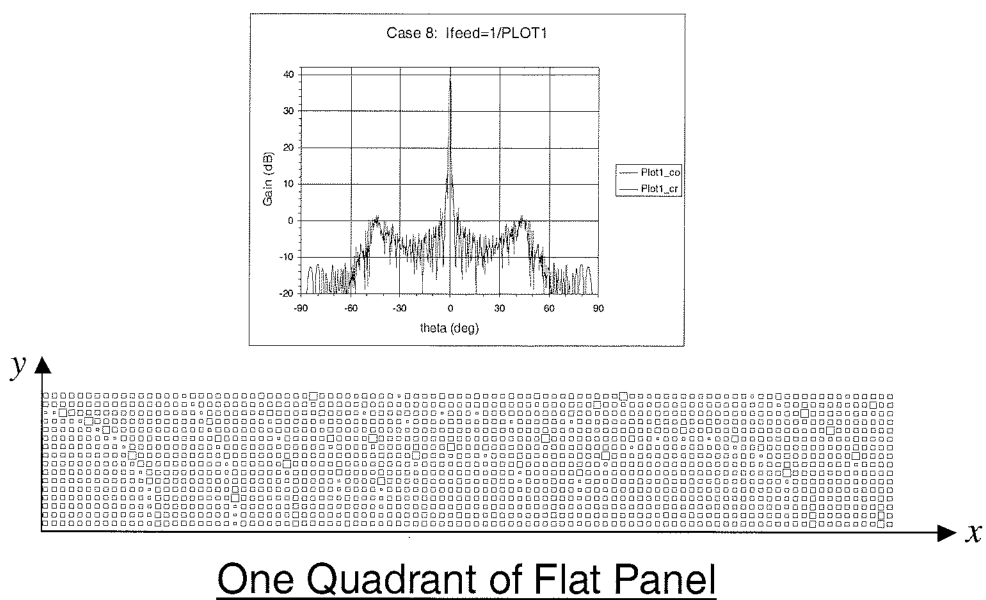

Figure 3. Patch geometry and V-pol Pattern Predictions for Flat Reflectarray

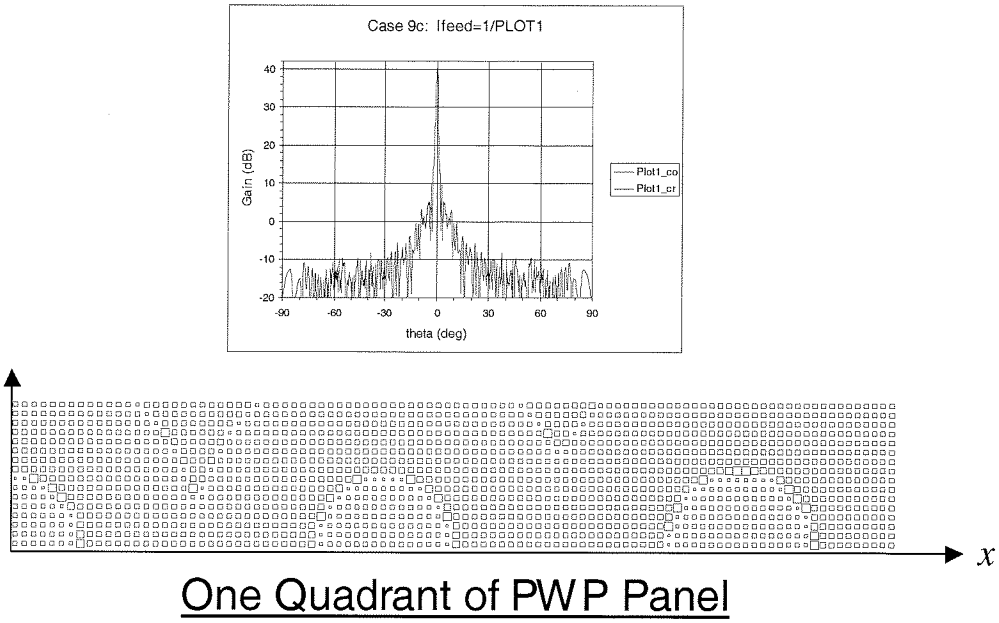

Figure 4. Patch geometry and V-pol Pattern Predictions for PWP Reflectarray

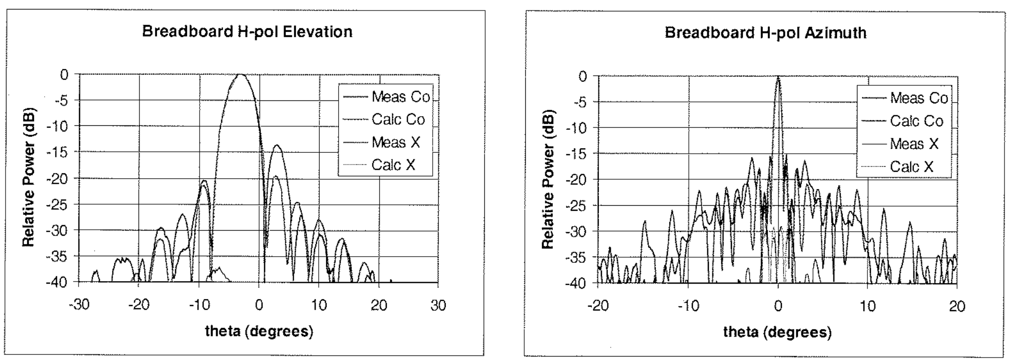

Figure 5. Comparison of measured and calculated results for H-pol

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