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A Ku-Band, Low-Sidelobe Waveguide Array Employing Radiating T-Junctions

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***Abstract*— The design of a 16-element waveguide array employing radiating T-junctions that operates in the Ku band is described. Amplitude weighting results in low elevation sidelobe levels, while impedance matching provides a satisfactory VSWR, that are both achieved over a wide bandwidth (15.7-17.2 GHz). Simulation and measurement results, that agree very well, are presented. The design forms part of a 16 x 40 element waveguide array that achieves high gain and narrow beamwidths for use in an electronic-scanning radar system.**

I. Introduction

Design equations for *optimum horn* antennas have long been established [1]. This concept has been employed in an electronic-scanning ground surveillance radar system for nominal elevation beamwidths of 10° and 20°. Unfortunately, for narrower beamwidths, the optimum horn becomes impractically long for a man-portable system (e.g. for a desired 5° beamwidth, the length is ~1.5 m). Because the antenna forms part of a 40-element array that defines the azimuth beamwidth, a 16-element waveguide array with a corporate-feed structure was selected to achieve the desired 5° elevation beamwidth with a short physical length.

To achieve low elevation sidelobe levels, amplitude weighting is employed that necessitates the use of many different asymmetric T-junctions in the corporate feed. The design of asymmetric T-junctions is well documented (e.g. [2][3][4]). However, these designs assume matched terminations in a bounded system (i.e. not radiating). In order to achieve gain, low sidelobes and impedance matching over a wide bandwidth (15.7-17.2 GHz), engineering trade-offs are necessary because the asymmetric T-junction characteristics vary with frequency.

II. Design Process

The radiating aperture size is 14.8 x 6 mm with a vertical pitch of 15.8 mm. For 5° elevation beamwidth, 16 vertical apertures are needed. Broadband matching is applied very close to each radiating aperture to ‘reverse’ the Smith Chart impedance direction [5]. Dolph-Tschebyshev weighting was chosen in order to define the individual T-junction split ratios in the corporate feed [6]. The target sidelobe level was -40 dB, although these degrade acceptably due to the various design trade-offs. Double-iris H-plane T-junctions [3] and H-plane 90° bends [7] are used throughout.

Figure 1 shows the SEMCAD X model of the 16-element waveguide array that is 121 mm long. Also shown is the simulated rms E-field through the structure at 16.5 GHz. The simulated return loss shown in Figure 2 is satisfactory over the desired part of Ku band. Simulated 2D elevation radiation patterns for 15.7, 16.5 and 17.2 GHz are shown in Figure 3. Owing to the nominal 0.87 λ_0 aperture pitch, grating lobe levels are calculated to be ≤ -50 dB.

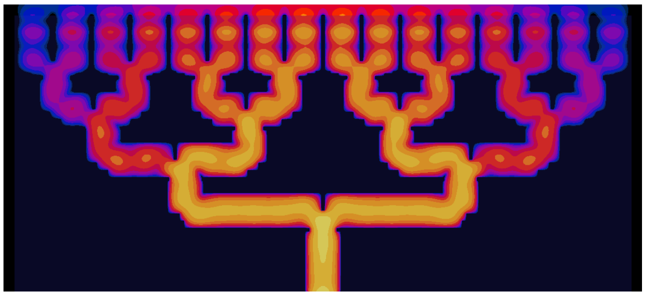

Figure 1. SEMCAD X model of 16-element waveguide array with simulated rms electric field strength at 16.5 GHz

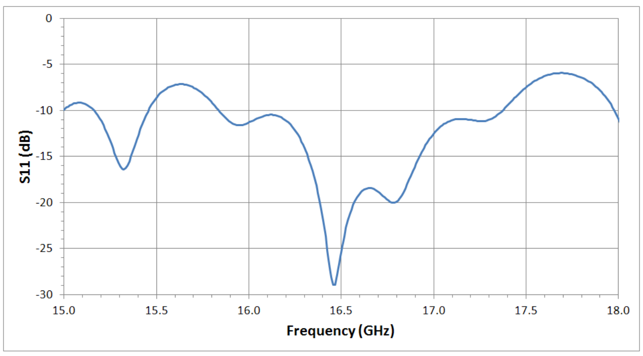

Figure 2. Simulated return loss

The complete 16 x 40 element waveguide array is machined from aluminium in layers from front to back. Waveguide losses are minimized by making inter-layer joins occur where transverse currents are zero [6]. Each layer is drilled from both sides, resulting in rounded corners (which were included in the EM simulations). Overall dimensions of the machined antenna (including radome) are 465 x 295 x 130 mm.

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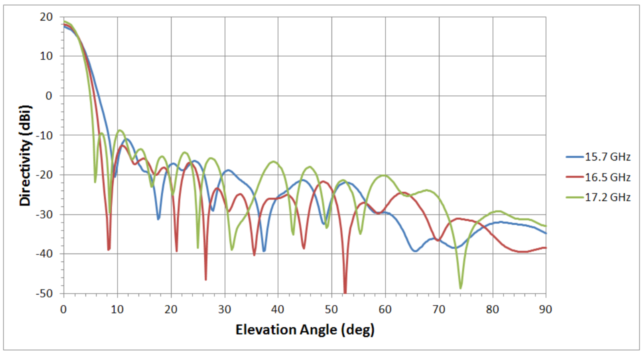

Figure 3. Simulated 2D radiation pattern (15.7/16.5/17.2 GHz)

III. MEASUREMENT RESULTS

Figure 4 shows the measured elevation pattern at 16.5 GHz with relative sidelobe levels of ~−29 dB (typically −25 to −30 dB over the frequency range of interest). Cross-polarization is very low. The nominal 3 dB beamwidth is 5° and the measured gain improvement for the 5° antenna over the 10° antenna is shown in Figure 5 (in line with expectations). The observed frequency ripple is due to the gain variation of the 10° horn antenna. Differences between measurements and simulations are due to machining tolerances (up to ±0.1 mm).

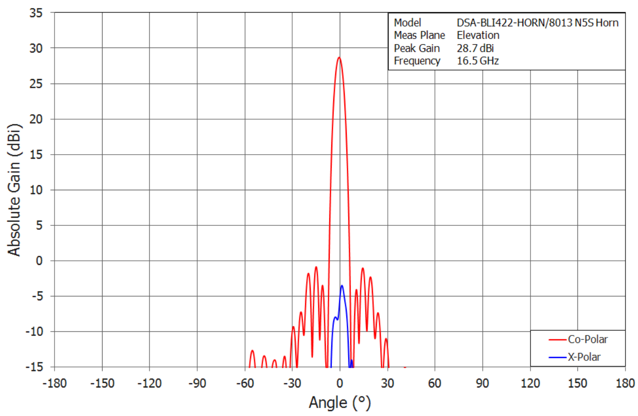

Figure 4. Measured elevation pattern at 16.5 GHz

IV. SUMMARY

The design of a low-sidelobe waveguide array for Ku band using radiating T-junctions has been presented. Measurements and simulations agree well for the new 5° elevation beamwidth waveguide array antenna.

The new antenna forms part of a modular antenna system deployed in an electronic-scanning ground-surveillance radar system. Figure 6 shows two such antennas deployed on the radar system. The new design complements the existing 10° and 20° beamwidth antennas, resulting in a modular system that allows flexibility in radar configuration for different surveillance applications.

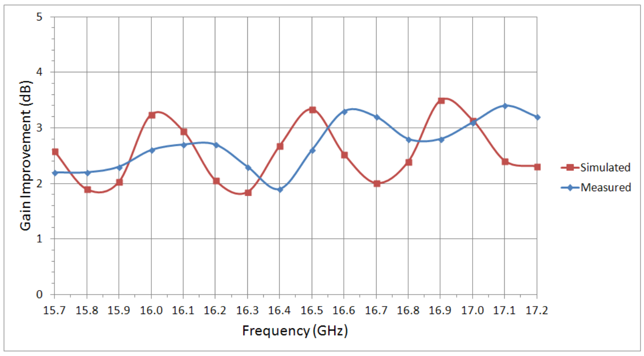

Figure 5. Simulated and measured gain improvement of 5° waveguide array over 10° horn antenna

Figure 6. Two 5° beamwidth antennas deployed on radar

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REFERENCES

[1] J. D. Kraus, Antennas for All Applications, 3rd Ed., McGraw-Hill, 2002.

[2] J. Hirokawa, K. Sahurai, M. Ando and N. Goto, “An Analysis of a Waveguide T Junction with an Inductive Post”, IEEE Transactions on Microwave Theory and Techniques, Vol. 39, No. 3, pp. 563-566, March, 1991.

[3] J. Joubert and S. R. Rengarajan, “Design of Unequal H-plane Waveguide Power Dividers for Array Applications”, Proceedings of the 1996 IEEE International Symposium on Antennas and Propagation, pp. 1636-1639, Baltimore, MD, USA, 1996.

[4] S. Yang and A. E. Fathy, “Design Equations of Arbitrary Power Split Ratio Waveguide T-Junctions Using a Curve Fitting Approach”, Wiley InterScience, 5 June 2008.

[5] B. A. Munk, Finite Antenna Arrays and FSS, John Wiley & Sons, 2003.

[6] J. Volakis, Antenna Engineering Handbook, 4th Ed., McGraw-Hill, 2007.

[7] A. R. Kerr, “Elements for E-Plane Split-Block Waveguide Circuits”, ALMA Memo 381, NRAO, USA, 5 July 2001.

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