

An E-band Slotted Waveguide Monopulse Array Antenna with Corporate-feed Using Diffusion Bonding of Laminated Plates

Xin Xu, Jiro Hirokawa, and Makoto Ando

Dept. of Electrical and Electronic Engineering, Tokyo Institute of Technology
 S3-19, 2-12-1 O-okayama, Meguro-ku, Tokyo 152-8552, JAPAN
 xinxu@antenna.ee.titech.ac.jp

Abstract - In this paper, we demonstrate an E-band plate-laminated 16×16 -element slotted waveguide monopulse array antenna with corporate-feed using the diffusion bonding technology. The proposed antenna architecture combines radiating elements, a corporate-feed circuit and a comparator, which are vertically interconnected to achieve a compact size and a reduced loss. The design, characterization, and experimental results are presented.

Index Terms — Monopulse antenna, slotted waveguide array antenna, E-band.

1. Introduction

Monopulse is an established technique that widely used in tracking radar systems to determine electronically the direction of arrival of echoes and target location. [1], [2]. It can find numerous applications in the area of direction-finding, communication, sonar, missile guidance and so on.

The monopulse array antenna based on traditional transmission line such as microstrip line and dielectric-filled waveguide suffer from the intrinsic losses which greatly degrade the antenna efficiency in the millimeter-wave band [3], [4].

Diffusion bonding is a commercially available multi-layered waveguide fabrication technique, enabling waveguide components with geometric complexity and packaging destiny that traditional machining cannot approach to be implementable. It can provide high precision and mass productivity for millimeter-wave applications [5]. In this paper, a 16×16 -slot corporate-feed waveguide monopulse array antenna with low profile for tracking radar applications in the E-band has been developed.

2. Antenna Structure and Operation Mechanism

Fig. 1 shows the architecture and the stack-up of the proposed monopulse array antenna. The antenna has four input ports for different excitations. The thickness of the antenna is 5.8 mm that laminated by 29 etched metal plates with identical thickness of 0.2 mm. The antenna radiates a 0° -polarized wave through radiating cavities located on the top layer. The radiating cavities are spaced with fixed distance of 3.18 mm in the x - and y -directions. A narrow slot is adopted to excite the radiating cavity to suppress grating lobes caused

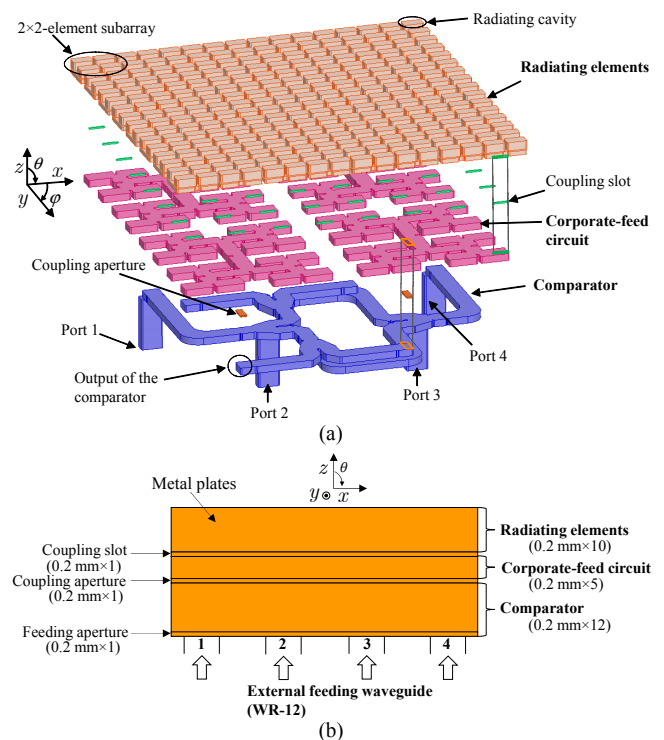


Fig. 1. Proposed monopulse array antenna. (a) Architecture. (b) Stack-up.

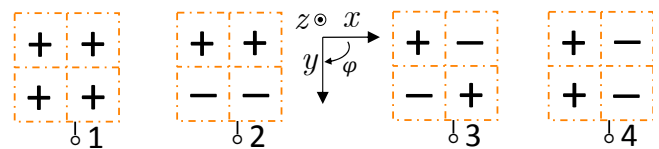


Fig. 2. Operation mechanism of the proposed monopulse array antenna.

by the wide radiating cavity. The 2×2 -element subarrays are uniformly fed with equal amplitude by the corporate-feed circuit. The comparator for monopulse processing is double-layered and is composed of four 180° hybrid magic-Ts.

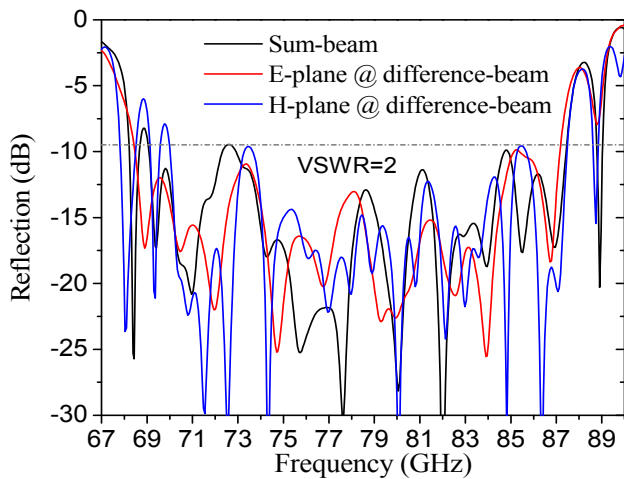


Fig. 3. Measured reflection characteristic.

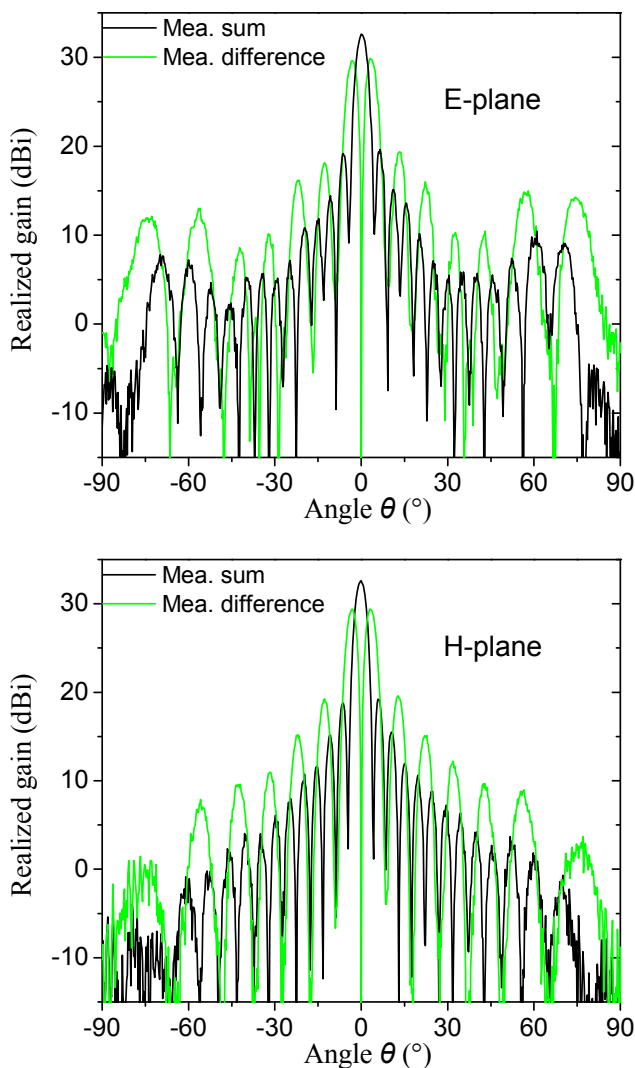


Fig. 4. Measured radiation patterns at 78.5 GHz in the E- and H-planes.

The design frequency is 78.5 GHz. The antenna is fed by standard WR-12 waveguides ($3.10 \text{ mm} \times 1.55 \text{ mm}$) from its back through feeding apertures etched in the bottom plate.

Fig. 2 shows the operation mechanism of the proposed monopulse array antenna. When Port 1 is excited, a sum beam is generated; when Port 2 or 4 is excited, difference beams in the E-plane or H-plane is generated, respectively; when Port 3 is excited, difference beams in the cross-planes (45° - and 135° -planes) are generated.

3. Experimental Results

The antenna is fabricated by diffusion bonding of laminated copper plates. No additional tuning or assembly process is needed after the bonding process. The antenna aperture size is $50.88 \text{ mm} \times 50.88 \text{ mm}$. The result of the Port 3 is not shown here, as the Port 3 is normally terminated with a dummy load in practical applications.

Fig. 3 shows the measured reflection characteristic. The bandwidth for $\text{VSWR} < 2$ is 21.9% (70.0–87.2 GHz), which can fully cover the E-band (71–76 and 81–86 GHz).

Fig. 4 shows the measured radiation patterns at 78.5 GHz in the E- and H-planes. At 78.5 GHz, the realized gain of the sum beam at boresight is 32.6 dBi, corresponding to an antenna efficiency of 83%. The 3-dB beamwidth of the sum beam in the E- and H-planes are 3.95° and 3.85° , respectively, with no grating lobes observed. The amplitude difference of the difference beams in the E- and H-planes are 0.22 and 0.12 dB, with deep null depth of -53.0 and -58.0 dB, respectively.

4. Conclusion

We have demonstrated a plate-laminated 16×16 -slot corporate-feed waveguide monopulse array antenna using diffusion bonding technology. The antenna demonstrates wide operation bandwidth covering the full E-band with high gain, high efficiency, and deep null depth. The antenna is promisingly attractive for monopulse tracking radar applications with ultra-high range-resolution and high data-rate capabilities.

References

- [1] D. D. Howard, "High range-resolution monopulse tracking radar," *IEEE Transactions on Aerospace and Electronic Systems*, AES-11, no. 5, pp. 749–755, Sep. 1975.
- [2] S. M. Sherman and D. K. Barton, *Mono-pulse principles and techniques*, 2nd ed., Artech House, 2011.
- [3] H. Wang, D. G. Fang, and X. G. Chen, "A compact single layer monopulse microstrip antenna array," *IEEE Trans. Antennas Propag.*, vol. 54, no. 2, pp. 503–509, Feb. 2006.
- [4] Y. J. Cheng, W. Hong, and K. Wu, "94 GHz substrate integrated monopulse antenna array," *IEEE Trans. Antennas Propag.*, vol. 60, no. 1, pp. 121–129, Jan. 2012.
- [5] J. Hirokawa, "Plate-laminated waveguide slot array antennas for wireless mobile backhaul," pp. 292–293, *Proc. IEEE 4th Asia-Pacific Conf. on Antennas and Propagat.*, 2015.