Design of a Double Layer Cavity backed Slot Array Antenna in Gap Waveguide Technology

Peiye Liu, Ashraf Uz Zaman, *Member, IEEE*, Per-Simon Kildal, *Fellow, IEEE*
Dept. of Signals and Systems, Chalmers University of Technology. Gothenburg, Sweden.

***Abstract* – In this paper a double layer cavity backed slot array antenna at K band is presented. The slot antenna is built using ridge gap waveguide feed network and gap waveguide cavity layer. These antenna blocks are manufactured without the requirements of electrical contact between the metal plates. The corporate-feed network is realized by a texture of pins and a guiding ridge in the bottom plate. The 4×4 slot array antenna has been fabricated and measured. The measured reflection coefficient remains below -11dB with reasonably good radiation patterns over the band of interest from 18.2 GHz to 21.2 GHz.**

***Index Terms* — slot array antenna, double layer, gap waveguide.**

1. Introduction

Planar array antennas are suitable for a lot of applications requiring high to moderate antenna gain. Microstrip antenna arrays and waveguide slot arrays are the two main planar antenna technologies, which have been used extensively over a wide range of frequencies. Microstrip arrays are compact, easy to manufacture, cost-effective and easy to integrate with active electronics. However, the microstrip feed networks suffer from high ohmic and dielectric losses at high frequency. Waveguide slot antenna arrays are also popular antenna with their high antenna efficiency and high gain [1-2]. However, the strict requirements of surface to surface electrical contact at high frequency make it costly and complex to manufacture.

To overcome the above mentioned problems, we introduce gap waveguide technology which is a combination of Perfect Electric Conductor (PEC) plate and a Perfect Magnetic Conductor (PMC) plate paralleled with an air gap smaller than a quarter wavelengths in between. There is no need for metal contact which solves the problem of good electric contact between metal layers [3-5]. Till now several antennas have been designed based on gap waveguide technology [6-8]. Also gap waveguide has much less loss compared with normal microstrip lines. Also it is very suitable for RF packaging [9-10].

In the present paper a 4×4 element array antenna is presented where a ridge gap waveguide has been used as a feed network. Shown in Fig.1 is a photo of three parts of the antenna prototype.

2. Antenna Design

a. 2×2 Element Subarray

The 2x2 element subarray is the unit cell of the proposed antenna. The subarray contains three metal layers. On the top is the slot layer. Below the slot layer is the cavity layer and this cavity layer has coupling slots. The coupling slots are excited by a ridge gap waveguide section with a T-section as is shown in Fig. 1. During simulation, two sets of periodic boundary walls are placed in the external region of the unit cell to simulate the mutual coupling in the infinite two-dimensional slot array. Boundary on top and bottom are open and PEC respectively. The cavity is partitioned into four parts by two sets of metal blocks, and the coupling slot is placed at the center of the cavity. Two sets of metal blocks are placed to suppress unwanted higher modes in the cavity. The slot spacing is chosen to be 12mm which is 0.82λ.

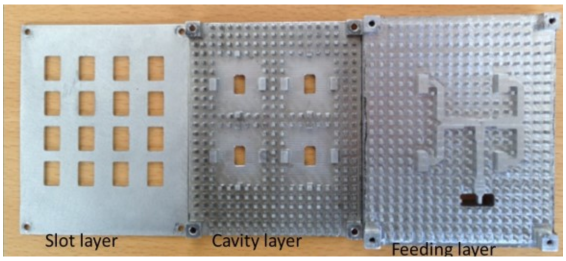

Fig. 1. Prototype in three separate layers.

b. Full Corporate Feed Networks

The full corporate feed network for the 4x4 element array antenna consist of a transition from WR-42, 3-dB power dividers and a T-section to excite the coupling slots of the cavity layer. Shown in Fig.2 are the frequency characteristics of the reflection of each part. The simulated S-parameters for the feed network remain within the acceptable limits.

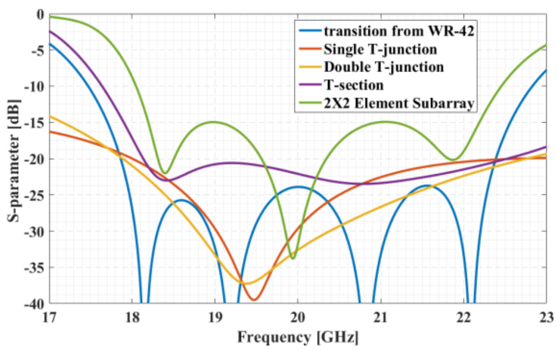

Fig.2. Reflection coefficient of each part.

c. 4×4 Element Array Antenna

The full structure of the 4×4 element array antenna that combines the 2×2 element subarrays and the full corporate feed waveguide is redesigned to comply with manufacturing. All sharp corners in former design are changed into round ones with radius of 0.5mm. The structure has been optimized for good S_{11} and good radiation characteristics. As shown in Fig. 3, the simulated directivity and gain are over 19.5dBi, and simulated aperture efficiency is over 95% for this 4×4 element slot array.

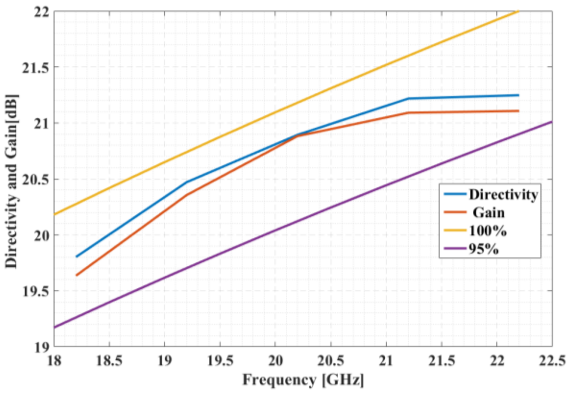

Fig. 3. Directivity and Gain simulated.

3. Measured Results

The prototype is manufactured using Aluminum metal. The reflection coefficient or S_{11} is measured with vector network analyzer (VNA). The measured S_{11} is shown in Fig.4 together with simulated one.

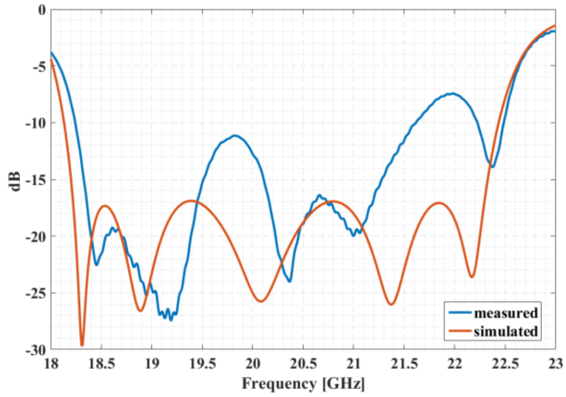

Fig. 4. Simulated and Measured S-parameter of the antenna.

The measures S_{11} is in reasonable agreement with simulated value. The degradation in high frequency is due to the tolerance in air gap between different layers. Also, the waveguide adapter (WR-42) have contribution in higher S_{11} level as the calibration was done up to VNA port only. The antenna radiation patterns are measured in an anechoic chamber at Chalmers university of Technology. As shown in Fig. 5, the sidelobes are higher at higher frequency as the relative element spacing increases.

4. Conclusion

A double layer cavity backed slot array antenna based on gap waveguide technology has been designed and presented in this paper. The prototype achieves a bandwidth of 15% with reasonably good radiation patterns taking into account the measurement accuracy of the anechoic chamber. Measured S_{11} remains below -11dB over the band of interest from 18.2-21.2 GHZ. The present work shows that it should be possible to use ridge gap waveguides to realize high gain, low loss slot arrays consisting of metal plates where there is no need for electrical contact among the metal layers.

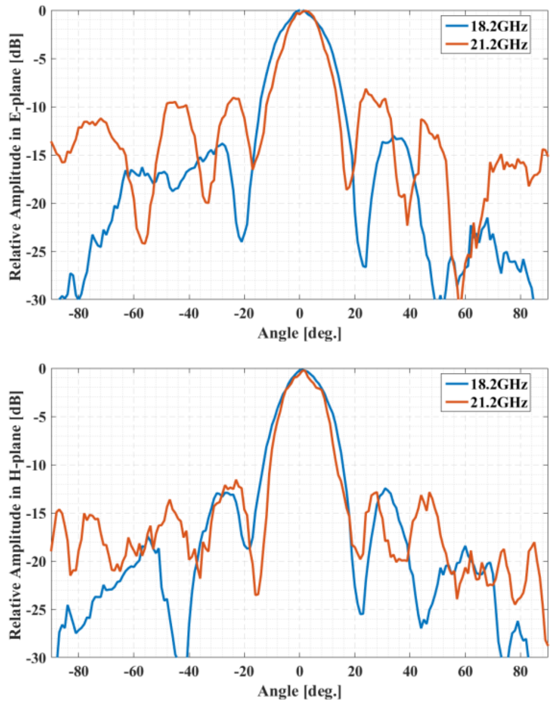

Fig. 5. Measured E-plane (top) and H-plane (bottom) pattern for the proposed antenna.

References

[1] Shang,X.; Ke, M ; Wang, Y.; Lancaster, M.J., "Micro machined W-band waveguide and filter with two embedded H-plane bends," in Microwaves, Antennas & Propagation, IET , vol.5, no.3, pp.334-339, Feb. 21 2011

[2] Becker, J.P.; East, J.R.; Katehi, L.P.B., "Performance of silicon micromachined waveguide at W-band," in Electronics Letters , vol.38, no.13, pp.638-639, 20 Jun 2002

[3] P. S. Kildal, E. Alfonso, A. Valero-Nogueira and E. Rajo-Iglesias, "Local Metamaterial-Based Waveguides in Gaps Between Parallel Metal Plates," in *IEEE Antennas and Wireless Propagation Letters*, vol. 8, no. , pp. 84-87,

[4] P. S. Kildal, "Three metamaterial-based gap waveguides between parallel metal plates for mm/submm waves," *Antennas and Propagation, 2009. EuCAP 2009. 3rd European Conference on*, Berlin, 2009, pp. 28-32.

[5] A. Uz Zaman, P.-S. Kildal, M. Ferndahl, A. Kishk, "Validation of Ridge Gap Waveguide Performance Using in-house TRL Calibration Kit," 4th European Conference on Antennas and Propagation, EuCAP 2010, Barcelona, April 2010.

[6] D. Zarifi, A. Farahbaksh, A. Uz Zaman and P.-S. Kildal, "Design and Fabrication of a Wideband High-Gain 60GHz corrugated Slot Antenna Array with Ridge Gap waveguide Distribution Layer" Accepted for Publication in IEEE Transactions on Antennas and Propagation.

[7] A. Uz Zaman and P.-S. Kildal, "Wideband Slot Antenna Array with Single layer Corporate-Feed Network in Ridge Gap Waveguide Technology," IEEE Transactions on Antennas and Propagation, Vol-62, No.6, pp-2992-3001, June 2014.

[8] A. Uz Zaman and P.-S. Kildal, "Slot Antenna in Ridge Gap Waveguide Technology," 6th European Conference on Antennas and Propagation, Prague, March, 2012.

[9] A. Kishk, A. Uz Zaman, and P.-S. Kildal, "Numerical Prepackaging with PMC lid - Efficient and Simple Design Procedure for Microstrip Circuits including the Packaging," ACES Applied Computational Society journal, vol. 27, no.5, pp. 389-398, May 2012

[10] E. Rajo-Iglesias, P. S. Kildal, A. U. Zaman, and A. Kishk, "Bed of Springs for Packaging of Microstrip Circuits in the Microwave Frequency Range," Components, Packaging and Manufacturing Technology, IEEE Transactions on, vol. 2, pp. 1623-1628, 2012.