Substrate Integrated Waveguide Antenna for Millimeter-Wave Imaging

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***Abstract*— In this report, a dual polarized square antenna using substrate integrated waveguide (SIW) technology is investigated for a millimeter-wave polarimetric radiometer imaging system. In order to further reduce the size of the antenna, a three-dimensional structure is adopted, enabled by the three-dimensional integration technique developed at the Poly-Grames Research Center. The structure is investigated and tested using Ansys HFSS electromagnetic simulation software at 35 GHz. The antenna shows a maximal gain of 15.5 dBi and a half power beam width of 25 degrees. The recombination structure shows return loss better than 10 dB and isolation better than 18 dB in the Ka-Band between 33.4-35.9 GHz.**

***Index Terms*— dual polarized square antenna, millimeter wave imaging, substrate integrated waveguide, three-dimensional integration technique**

I. Introduction

MILLIMETER-WAVE (MMW) imaging systems stand for one of the most promising fields in high-frequency remote sensing. MMW's advantages over optical and infrared waves make them attractive for applications in the security, biomedical and aerospace sectors. Organic materials and clothing are translucent at certain MMW frequencies, allowing MMW systems to be used for security screening in airports.

Some high-performing MMW imaging systems have been demonstrated [1] [2]. However, most of those systems were implemented using metallic waveguides or microstrip lines. While allowing shielding from interferences and low-loss, metallic waveguides are bulky and expensive, making conventional MMW imaging systems non-compact and tedious. On the other hand, microstrip lines, which are low-cost and integrable, are also lossy and prone to electromagnetic interferences. Recently, a new emerging technology, called substrate integrated waveguide (SIW), has been developed. SIW consists of the combination of two rows of metallic holes within a substrate which enables similar field distribution than rectangular waveguides while maintaining low cost and small size. This makes SIW an ideal candidate for MMW imaging systems.

In this project, a SIW-based dual polarized square antenna is investigated at 35 GHz. To minimize the total size of the antenna, the three-dimensional integration technique is used. A particular focus is given on the integration of the antenna within a polarimetric radiometer in SIW technology [3].

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II. Results

The antenna is one of the most important components of the radiometer as it limits the accuracy with which brightness temperatures can be determined. Therefore, it must meet specific constraints and well-defined characteristics, such as operating over 34.50 GHz – 35.50 GHz in the Ka Band, possessing a good angular resolution which is determined by the half-power beam width (HPBW) and providing two orthogonal polarizations in order to generate the Stokes parameters which are used to compute the image.

The planar SIW Parabolic Tapered Slot Antenna (PTSA) [4] developed at the Poly-Grames Research Center meet those specifications, with a gain of 15.1 dBi and a 36° HPBW while maintaining a small form factor. However, it does not provide the two orthogonal polarizations. To overcome this, four planar PTSAs can be placed to form a square array which has the advantage to improve angular resolution and gain while providing dual polarization and maintaining a small size. The dual polarized square antenna is shown in Fig. 1.

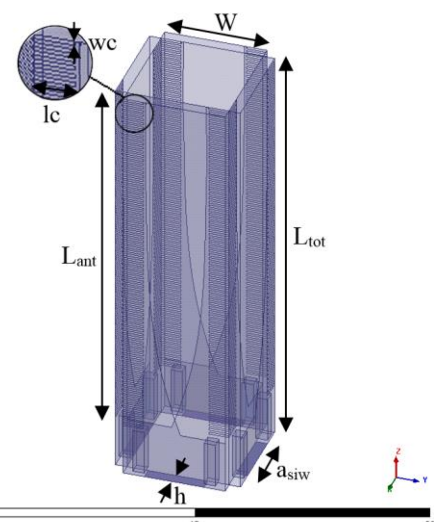

Fig. 1. Three-dimensional view of the dual-polarized square antenna with Ltot = 28.1 mm, W = 6.84 mm, h = 0.762 mm, Lant = 24.5 mm, asiw = 4 mm, lc = 1.23 mm, wc = 0.13 mm.

As seen in Fig. 2, the antenna shows a maximal gain of 15.5 dBi, a round beam [5] and a HPBW of 25° at 35 GHz making it an appropriate design for a polarimetric radiometer. Furthermore, the dual polarized square antenna remains fairly compact, with a volume of 8.36 mm x 8.36 mm x 28.1 mm.

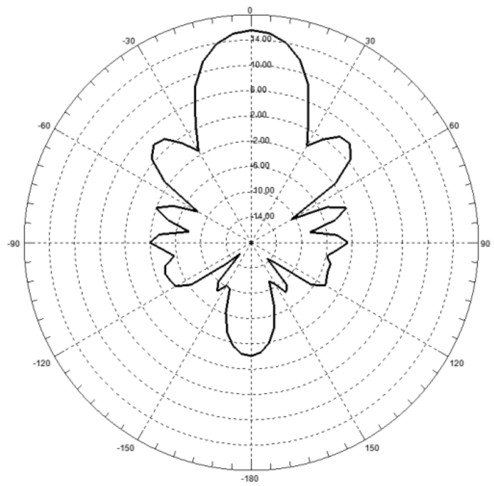

Fig. 2. Radiation pattern at 35 GHz of the dual-polarized square antenna.

In order to connect the dual polarized square antenna to the radiometer, it must output the horizontal and the vertical polarization separately on different ports. For this reason, the signals coming from the opposite planar elements must be combined. This is achieved using a signal recombination structure composed of two substrate layers. Each layer has a height of h = 0.762 mm and is used to recombine two opposite signals from the planar elements. The structure can be seen in Fig. 3.

As seen in Fig. 4, the structure shows return loss better than 10 dB over a 33.4GHz – 35.9 GHz band for both polarizations. Over that same frequency band, the isolation between the two orthogonal polarizations is better than 18 dB. Those characteristics are adequate for a polarimetric imaging radiometer.

The structure takes a small volume of 24.9 mm x 24.9 mm x 1.52 mm. This could be further improved by recombining the signals of the opposite elements at the center of the antenna instead of around it. However, this recombination scheme would be more complex and hard to implement as the available surface would be less than 6.84 mm x 6.84 mm.

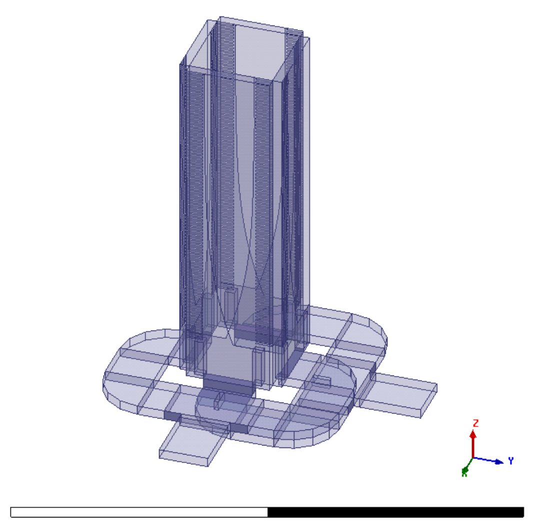

Fig. 3. Three-dimensional view of the recombination structure (and antenna).

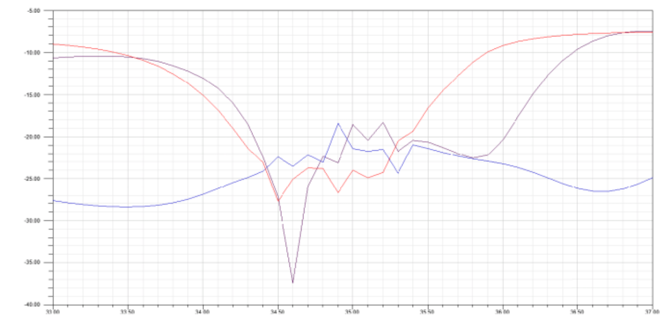

Fig. 4. S-Parameters of the recombination structure, in dB as a function of frequency in GHz. S_{11} is in red, S_{12} is in blue and S_{22} is in purple.

III. Conclusion

In conclusion, a SIW antenna has been designed at 35GHz. The antenna has a maximum gain of 15.5 dBi along with a half-power beam width of 25 degrees. The structure shows return loss better than 10 dB and isolation is better than 18 dB between 33.4 GHz and 35.9 GHz. Further improvements include using a smarter signal recombination scheme that uses the center of the structure instead of its surroundings, which would allow a great reduction of the total size of the system.

IV. Acknowledgements & Future Career Plans

First of all, I would like to thank MTT-S for the support it has provided me through this scholarship. I would also like to thank Dr. Ke Wu and Ali Doghri, who supervised me and took their time to ensure the success of this research.

Unfortunately, I have not been able to attend the International Microwave Symposium 2013 in Seattle as I was doing an internship in France at that time. However, it is an excellent opportunity to stay informed about state-of-the-art microwave technology from industry and academia while developing one's network.

This research project has allowed me to confirm my interests. On the short term, I wish to further my education in engineering, as I still have a lot to learn in that field. On a longer term, I would like to be part of technology-based entrepreneurial endeavors.

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