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165/183 GHz FSS for the MetOp Second Generation Microwave Sounder Instrument

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Abstract—**This paper reports the design of a Frequency Selective Surface (FSS) which simultaneously allows transmission of 175.3 – 191.3 GHz radiation and rejection from 164 - 167 GHz with a loss <0.5 dB for TE wave polarization at 45° incidence. The state-of-the art filter consists of three air spaced perforated screens with unit cells that are composed of nested resonant slots. The FSS satisfies the stringent electromagnetic performance requirements for signal demultiplexing in the quasi-optical feed train of the Microwave Sounder (MWS) instrument which is under development for the MetOp-SG mission.**

Index Terms— **atmospheric science instrumentation, frequency selective surface, FSS, microwave**

I. INTRODUCTION

This research exploits computational electromagnetic modelling and advanced micromachining processes [1-5], that have recently been developed to create ultra-low loss FSS. The aim is to improve the sensitivity of space borne scientific radiometers that are proposed for future Earth observation missions. The purpose of this study is to establish the feasibility of designing an FSS which can separate the 183 GHz and 165.5 GHz channels in the quasi-optical feed train of the MicroWave Sounder (MWS) instrument which is under development for the MetOp-SG mission [6]. This 24 channel instrument with a spectral span of 23 - 229 GHz, provides measurements of temperature and water vapour profiles which are key data requirements for numerical weather predictions. A waveguide diplexer is currently used to separate the 183/165.5 GHz bands, however the measured loss of 0.8 dB is excessive for a microwave sounder instrument which has a requirement for low NEΔT. This study aims to demonstrate that a significant performance improvement can be obtained from a multilayer micromachined FSS.

The MWS-SG instrument layout has separate mixer detectors for the 165 and 183 GHz bands, and since the FSS can provide the required spectral and spatial separation of these two bands, it is compatible with the existing architecture of the quasi-optical receiver. FSS are critical components in passive radiometer instruments and therefore the work reported in this paper also extends to future missions incorporating these.

II. DESIGN

The objectives of the FSS design are to meet the performance specifications that are listed in Table 1. This requires separation of TE polarized waves incident on the FSS at 45° to the direction of propagation with an insertion loss <0.5 dB in two frequency bands; 164 – 167 GHz reflection band and 175.3 – 191.3 GHz transmission band. To meet the low insertion loss requirements freestanding FSS topology was employed. CST Microwave Studio [7] was used to model the problem, using the frequency domain solver within the computer tool. The structure consists of three free-standing periodic arrays of unit cells that are composed of nested resonant slot elements. Fig. 1 shows a schematic of the metal screens in the unit cell of the proposed high aspect ratio 3D array. The spectral response s-parameter plots are shown in Fig.2 (a/b) for both transmission and reflection. The maximum transmission loss in the 183 GHz band is predicted to be < 0.45 dB and in the 165 GHz channel the reflection loss is <0.40 dB.

TABLE I. FSS SPECIFICATION

Parameter	**Requirement**
Transmission Band / Loss Target	175.3 – 191.3 GHz / < 0.5 dB
Reflection Band / Loss Target	164 - 167 GHz / < 0.5 dB
Incident Angle / Polarization	45° / TE
Physical diameter / Optical diameter	100 mm / 80 mm

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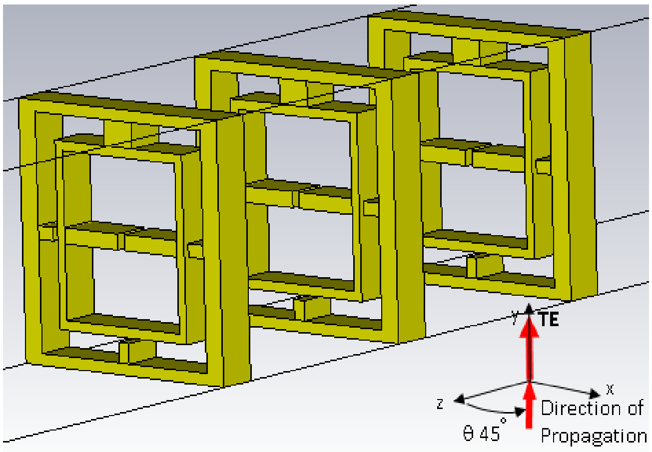
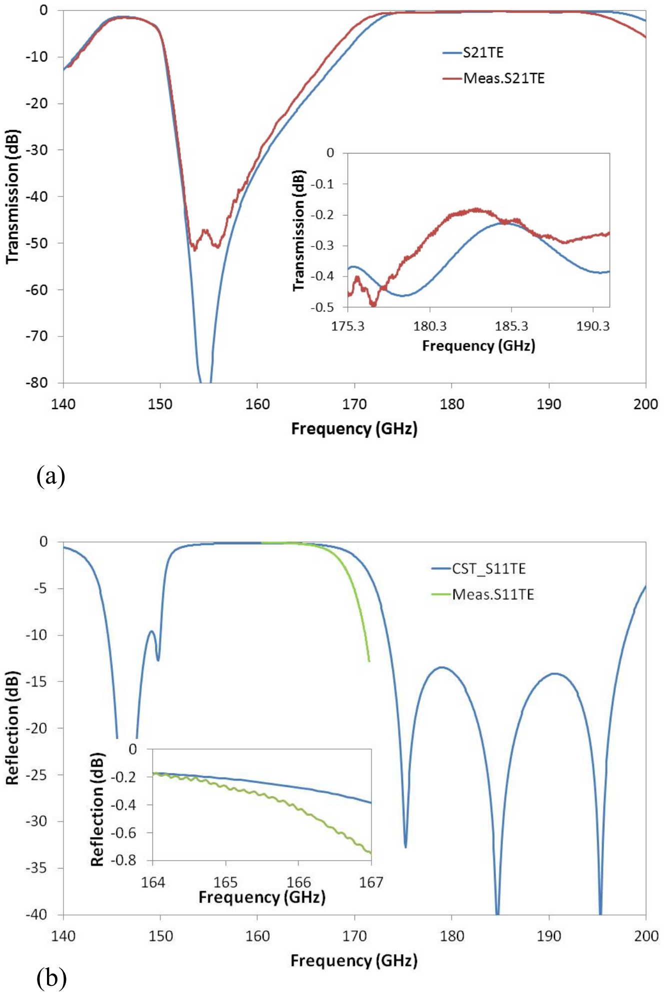


Fig. 1. Unit cell of multilayer FSS (yellow shows metal), polarisation and direction of proagation also identified



(a)

(b)

Fig. 2. Simulated and measured spectral performance of the FSS, (a) transmission results in the frequency range 140 – 200 GHz, (b) reflection results with measurements covering the range 164 – 172 GHz, insets show pass / reflection bands

III. FABRICATION

The required performance can be obtained from a freestanding three-layer FSS structure fabricated using precision micromachining techniques. Silicon on Insulator (SOI) is used as the substrate material and Deep Reactive Ion Etching (DRIE) is employed to pattern the top layer of the substrate with slots, and also remove the silicon under the slots. The micro machined structure is metallised by, a 35 nanometer thick sputter coated titanium adhesion layer, followed by a 0.25 µm thick copper seed layer. The micromachined silicon substrate is then encased with high conductivity 1 µm thick electroplated silver layer. A further 25 – 50 nm layer of gold is applied to prevent oxidation. The selected finish gives an optically smooth surface with almost bulk conductivity values. Finally, the metallised single layers are stacked and aligned to form the deep aperture device as shown in Fig. 3. The interlayer separation is obtained using a composite spacer material that contains glass spheres in an epoxy binder.

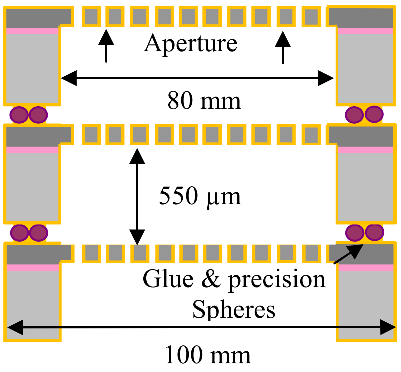


Fig. 3. Schematic of the three layer FSS cross-section, 100 µm thick freestanding aperture

IV. MEASUREMENTS

The 45° incident TE polarised spectral response was measured using a 100 – 700 GHz ABmm [8] wave vector network analyzer (VNA) in conjunction with a Thomas Keating [9] reflective focusing optics test bench. The test bench employs two wideband corrugated feed horns at the waveguide ports of the source and detector. This setup easily covers the operating frequency range of the FSS, 164 GHz to 192 GHz, with over 60 dB of dynamic range. The test bench uses a Gaussian beam focused on the FSS to produce low edge illumination, below 35 dB, thereby beam truncation effects can be neglected. The measurement system, including VNA and test bench are shown in Fig. 4.

The measured results in both the transmission and reflection bands are combined with the predictions and plotted in Fig. 2. Good agreement is observed in the two plots, and the measured passband loss is shown to vary between 0.2 dB and 0.5 dB. In the reflection band the minimum and maximum measured losses are 0.2 dB and 0.75 dB. This increase is due to a slight shift downwards in the frequency of the FSS due to manufacturing tolerances.

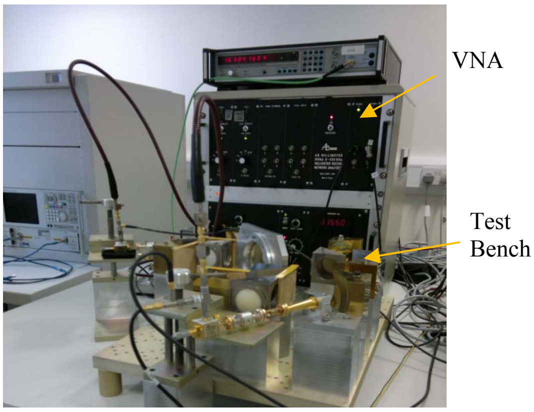


Fig. 4. ABmm VNA and TK test bench

V. CONCLUSIONS

A low loss freestanding FSS has been designed to meet the demanding requirements of the MetOp-SG MWS radiometer. The detailed numerical study has established the optimum geometry that meets the specification listed in Table 1. A three-screen structure is shown to give a maximum insertion loss of 0.45 dB, which is significantly lower than the waveguide diplexer which is currently deployed in the breadboard instrument. The FSS test results have demonstrated good agreement with predictions and the performance is in line with the specification across the passband.

VI. REFERENCES

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