Metamaterial Surfaces for Integrated Multiband Horn Applications

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Abstract— Novel (Integrated Multiband Horn) IMH antenna designs using artificial metamaterial surfaces (FSS, EBG) are presented. A 'horn within a horn' concept is introduced whereby miniaturised metamaterial surfaces (of double ring elements) are embedded in the IMH.

1. INTRODUCTION

For some time now Electromagnetic Band Gap (EBG) properties of passive metallodielectric arrays or Frequency Selective Surfaces (FSS) have been studied [1, 2]. Metallic EBG (MEBG) structures have been used for the performance enhancement of mictrostrip antennas and circuits. Element miniaturisation also allows the unitisation these structures in realistic antenna applications [3]. This is only valid when the unit cell of the array smaller ($< \lambda/7$) than the wavelength. Here, we introduce a concept that utilises such structures to invoke a four band horn antenna. Each array was made from concentric ring elements and tested over a range of angles of incidence and polarisation prior to inserting them in the horn. Measured results are shown of the outer horn incorporating the high frequency horns.

2. INTEGRATED MULTIBAND HORN (IMH) CONCEPT

The main requirement was to produce a multiband antenna, with an overall volume and weight less than that made up of discrete antennas, operating at 2.4 GHz (E-band) 5.0 GHz (G-band) 10.5 GHz (J-band) 28.0 GHz (K-band). Fig. 1 shows two possible solutions for IMH, an embedded IMH where FSS form partial wall and a demultiplexer design, whereby the FSS/MEBG used as passive filters. The antennas are proposed to be mounted within the same overall physical housing, where there will be a trade-off physical size (environmentally/aesthetically pleasing mechanically robust design) against RF performance. Here the former was chosen for simplicity of use.

The EBG properties of periodic loading of concentric circular ring elements were assessed experimentally in a plane wave chamber. The unit cell is hexagonal. Fig. 2 shows the measured TE bandgaps for the arrays which are stable for up to 80° angle of incidence.

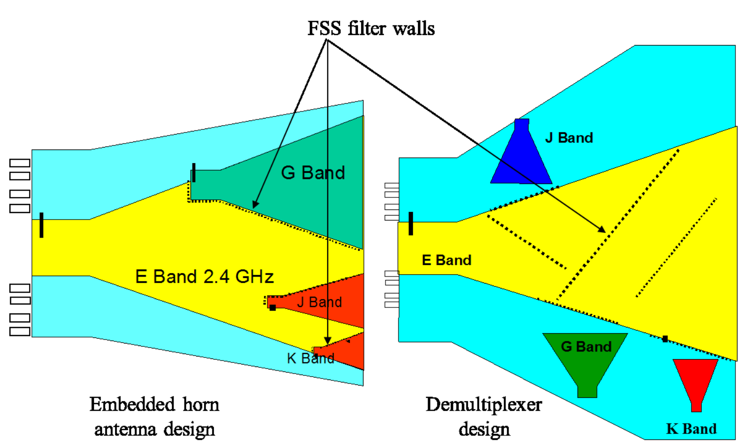


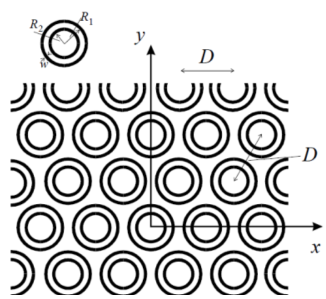
Figure 1: Two IMH concepts for G, E, J and K bands.

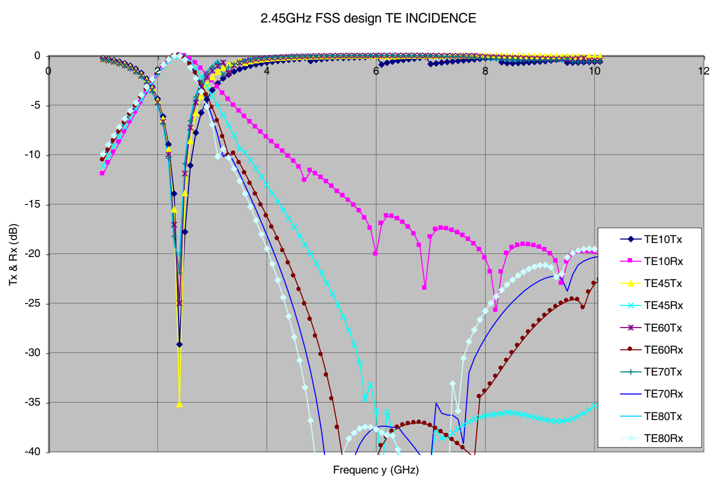
3. PROTOTYPES

The dimensions of the prototype built were as follows:

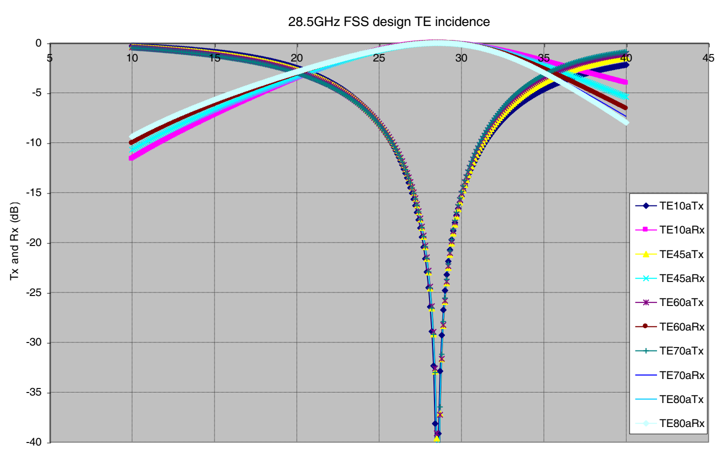
Table 1: The dimensions of individual horns chosen.

	E-band	G-band	J-band	K-band
a_1 (mm)	156.25	69.59	37.33	15
b_1 (mm)	265.62	118.29	63.46	45
d_1 (mm)	400	178.12	95.56	90





(a)



(b)

Figure 2: Plane wave of ring FSS Tx/Rx response of (a) E band and (b) K band.

4. RESULTS

4.1. E Band Horn

Average gain was 10 dB (worst 9 dB: best 11.06 dB) and the S_{11} was worst — 7.54 dB at 2.4 GHz (covered 8.32% @15 dB level), Fig. 3. The required BW of 4% was achieved. The probe diameter could be increased to improve the BW. The elevation plane pattern was slightly wider due to the

FSS horns worst case X polar -13.6 dB, Fig. 4. The azimuth patterns were narrower and the worst case X polar -16.8 dB was measured.

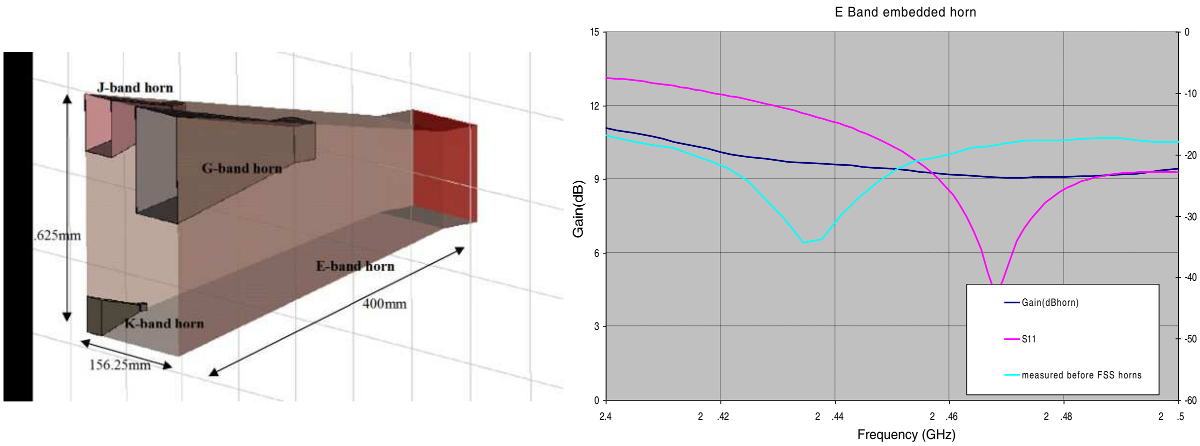


Figure 3: CAD model and gain of the E-band IMH.

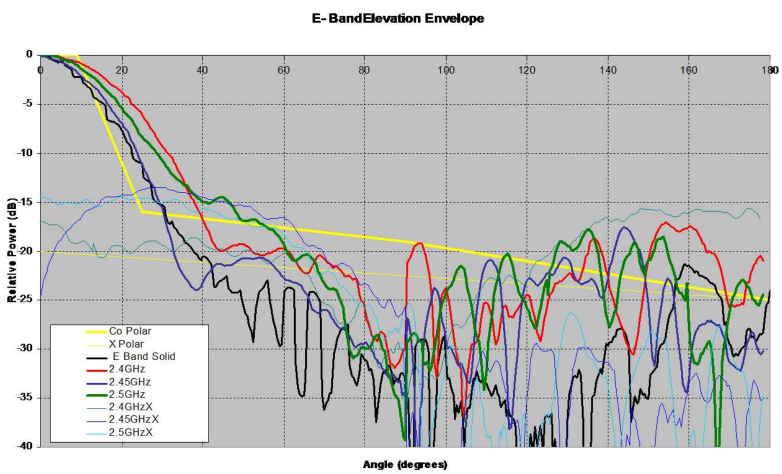


Figure 4: Elevation envelope of E-band horn.

4.2. G Band Horn

Average gain of the horn: 10.45 dB (worst 9.27 dB: best 11.68 dB), S_{11} worst — 5.32 dB at 5.1 GHz (covered 11.48% @10 dB level), BW 14.54% @15 dB, elevation plane pattern slightly wider than envelopes, worst case X polar -17.36 dB, azimuth patterns narrower than specified worst case X polar -15.53 dB.

4.3. J Band Horn

Average gain of the horn: 9.8 dB (worst 7.73 dB: best 11.66 dB), S_{11} worst — 10.08 dB at 10.28 GHz (covered band @10 dB level), BW 4.878%, elevation plane pattern wider than envelope, high side lobes worst case X polar -15.45 dB, a Azimuth patterns narrower than specified worst case X polar -17.84 dB.

4.4. K Band Horn

Average gain of the horn: 14.43 dB (worst 11.08 dB: best 16.08 dB), S_{11} worst — 4.44 dB at 27.5 GHz (covered 2% @10 dB level) Required BW 7%. Elevation plane pattern slightly wider than envelopes, azimuth patterns narrower than specified.

5. CONCLUSIONS

Results from the embedded IMH concept indicate that the utilization of FSS/EBG structures is a good prospect in a constrained illumination and polarization environment. The IMH did not suffer for undue inter scattering effects and produced moderate gain and bandwidth. The IMH horn used conventional coax-waveguide transformers and it is suggested that, for a more targeted design, these transformers to be specifically designed to meet the frequency bandwidth requirements.

REFERENCES

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2. De Maagt, P., R. Gonzalo, J. C. Vardaxoglou, and J. M. Baracco, "Photonic bandgap antennas and components for microwave and (sub)millimetre wave applications," *Special issue on Metamaterials, IEEE Trans. on Antennas and Propagation*, Vol. 51, No. 10, 2667–2677, Oct. 2003.
3. Capolino, F., *Applications of Metamaterials*, CRC Press, 2011.