Circular polarisation frequency selective surface operating in Ku and Ka band

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Circular Polarization Frequency Selective Surface Operating in Ku and Ka Band

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***Abstract*—Single and double layer frequency selective surfaces (FSS) for Circular polarization (CP) operation were designed. The designed FSS provide reflection in the Ku-band (11.7 – 12.75 GHz) and transmission in the Ka-band (17.3 – 20.2 GHz). CP is conserved in each of the bands. For the double layer design over the Ku-band the reflection loss was less than 0.05 dB for TE and TM polarizations while the axial ratio was below 0.2 dB. Over the Ka-band transmission loss and axial ratio were each less than 0.25 dB.**

***Index Terms*—circular polarization, frequency selective surface, periodic structure.**

I. INTRODUCTION

Multiband operation can be provided in systems such as a reflector antenna by using a quasi-optical diplexer at the feed arrangement. Frequency Selective Surfaces (FSS) have been used as diplexers in reflector antenna systems together with feeds placed at either side of the FSS [1]-[4]. In such a configuration the FSS is designed to be reflective for one of these feeds acting as a subreflector while for the other it is transparent allowing the feed to be placed at the focal point of the main reflector. Both feeds therefore utilize the same main reflector.

Among the identified diplexer systems to date, all operate in Linear Polarization (LP) [1]-[4]. The advantages of Circular Polarization (CP) operation for communication and sensing systems in terms of simplifying alignment and overcoming Faraday rotation are well known [5]. A CP diplexer design should have a transmission and reflection band. To allow CP to be maintained in the reflection/transmission bands the reflection/transmission magnitude in addition to the reflection/transmission phase should be equal for the TE and TM components.

Recently there has been some interest in designing polarization independent frequency selective surfaces. Such designs have similar reflection and transmission magnitudes for TE and TM polarized waves. In [6] a printed crossed dipole array FSS was presented as polarization independent. Excellent polarization properties were achieved for normal incidence but for oblique incidence some differences were observed between the bandwidth and resonance frequency for TE and TM polarizations. An array of Jerusalem cross apertures was presented in [7] which provided a similar response for TE and TM polarizations at 45° over the frequency range, 173-671 GHz. In [8] a single layer array of rings was optimized to give a response which was relatively polarization independent. It has been demonstrated that double square loop arrays and gridded double square arrays can be designed to give coincident TE and TM responses at 45° incidence [9], [10]. FSS consisting of an array of nested slots has recently been developed for the detection of dual-polarized radiation in passive remote sensing space science instruments [11], [12]. FSS elements made up of a pair of nested shorted annular slots allow independent control of the spectral response for TE and TM polarizations at oblique angles of incidence. Although these designs ensure that reflection and transmission magnitude are equal for TE and TM polarizations, they do not consider the phase. For this reason conservation of CP in each band cannot be guaranteed. In this paper single and double layer FSS with a reflection and transmission band are designed. Conservation of a CP signal is achieved in the reflection / transmission bands by ensuring that reflection / transmission magnitudes and phase are equal or similar for TE and TM polarizations.

II. SINGLE LAYER DESIGN

The FSSs were required to reflect over the Ku-band and transmit over the Ka-band. The Ku- and Ka-bands were defined as 11.7 - 12.75 GHz and 17.3 - 20.2 GHz respectively. In addition, conservation of CP was required in each of these bands. The simulation and design of the FSS was carried out using CST Microwave Studio (MWS). A unit cell of the array was created and the y- and x- boundaries were set to unit cell implying that the array was of infinite lateral size. Floquet ports were set at the z- boundaries. The angle of incidence was 45°. A double square loop element was chosen for the single and double layer designs. A unit cell of the single layer design is displayed in Fig. 1 with important dimensions identified.

The single layer design consisted of an array of copper elements on a Fastfilm 27 substrate (thickness = 56 µm, permittivity, $\varepsilon_r = 2.7$ and loss tangent, $\tan\delta = 0.0012$). This substrate was bonded to a sheet of Rohacell foam (thickness = 12 mm, permittivity, $\varepsilon_r = 1.06$ and loss tangent, $\tan\delta = 0.0008$) using a spray glue, which has negligible effect on the electromagnetic performance. The optimized design dimensions (mm) are listed below.

$P_x = 6.655$, $p_y = 6.775$, $w_{x1\_a} = w_{x1\_b} = 0.376$, $w_{x2\_a} = 1.055$, $w_{x2\_b} = 1.047$, $d_{xr\_1} = d_{xl\_1} = 0.840$, $d_{xr\_2} = 0.857$, $d_{xl\_2} = 0.849$, $d_{xr\_3} = d_{xl\_3} = 0.208$, $w_{y1\_a} = 0.479$, $w_{y1\_b} = 0.399$, $w_{y2\_a} = 0.562$, $w_{y2\_b} = 0.604$, $d_{yb\_1} = d_{yu\_1} = 1.145$, $d_{yb\_2} = 0.845$, $d_{yu\_2} = 0.887$, $d_{yb\_3} = 0.395$, $d_{yu\_3} = 0.315$.

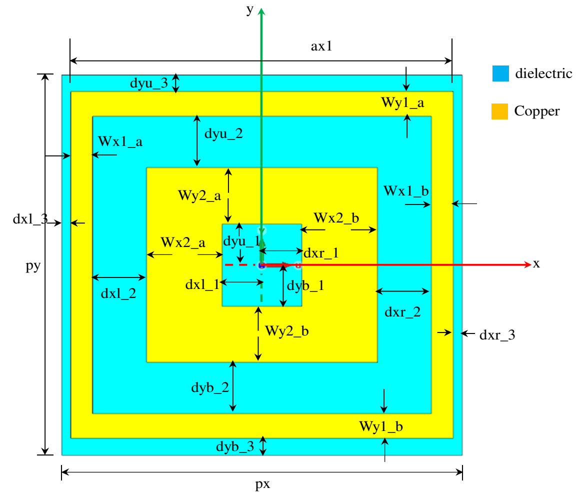

Fig. 1. A unit cell of the single layer FSS with important dimensions indentified – substrate with copper double square loop element.

Fig. 2 shows simulated reflection magnitude of the TE and TM polarized waves in addition to the reflection axial ratio over the Ku band. The transmission magnitudes and axial ratio over Ka band are in Fig. 3. As shown, over the Ku band (11.7 – 12.75 GHz) the reflection loss is less than 0.25 dB for TE and TM polarizations and the reflection axial ratio is less than 0.2 dB. Over the Ka band (17.3 – 20.2 GHz), transmission loss was less than 0.4 dB for both polarizations while a transmission axial ratio of below 0.25 dB was achieved.

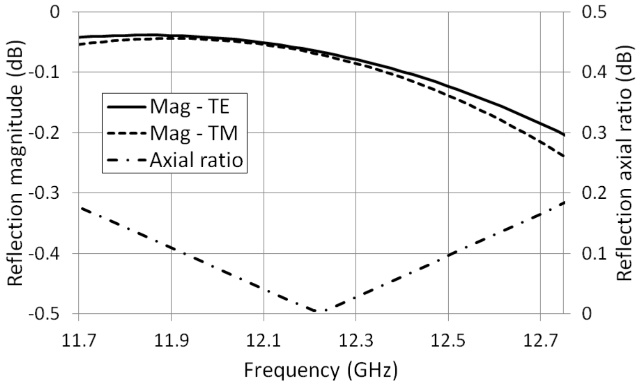

Fig. 2. Simulated reflection magnitude (TE and TM polarizations) and reflection axial ratio for single layer FSS – Ku band, 45° incidence.

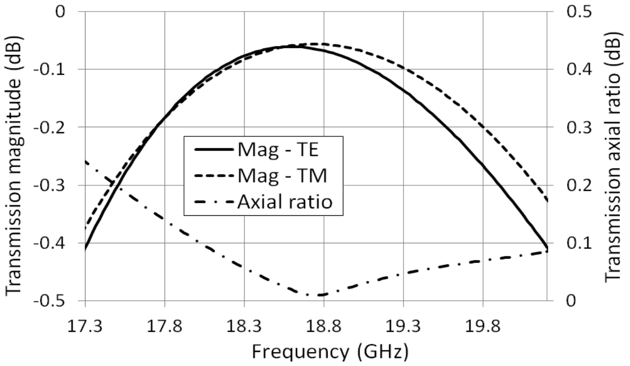

Fig. 3. Simulated transmission magnitude (TE and TM polarizations) and transmission axial ratio for single layer FSS – Ka band, 45° incidence.

III. DOUBLE LAYER DESIGN

A double layer FSS was also designed. CST MWS was used to simulate the structure and optimize the dimensions. The angle of incidence was 45°. The structure consists of two arrays of copper double square loop elements, each patterned on a 56 um thick, Fastfilm 27 substrate. These substrates are bonded to either side of a 5 mm thick sheet of Rohacell foam. A unit cell of the FSS with important dimensions identified is in Fig. 4. This unit cell represents the top and bottom arrays as the same parameter names are used for each.

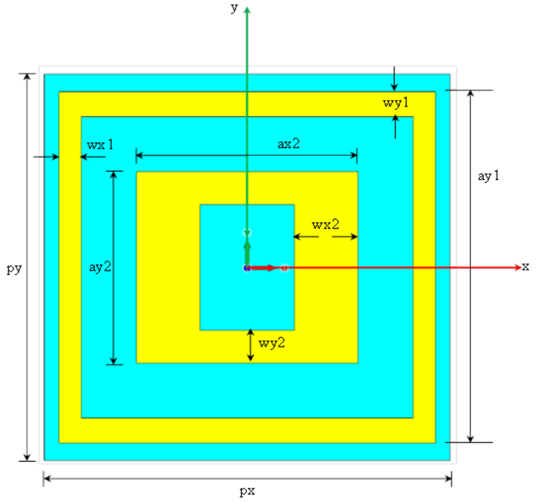

Fig. 4. Unit cell of double layer FSS with important dimensions identified. Unit cell represents top and bottom arrays as the same parameter names are used.

The optimized dimensions (mm) are as follows:
Top array - $p_x = 6.787$, $p_y = 6.764$, $a_{x1} = 6.448$, $a_{y1} = 6.087$, $a_{x2} = 4.004$, $a_{y2} = 3.449$, $w_{x1} = 0.370$, $w_{y1} = 0.446$, $w_{x2} = 1.288$, $w_{y2} = 1.005$.
Bottom array - $p_x = 6.787$, $p_y = 6.764$, $a_{x1} = 6.328$, $a_{y1} = 6.222$, $a_{x2} = 3.722$, $a_{y2} = 3.389$, $w_{x1} = 0.374$, $w_{y1} = 0.444$, $w_{x2} = 1.068$, $w_{y2} = 0.581$.

In Fig. 5 the simulated reflection magnitude of TE and TM polarized waves and reflection axial ratio over the Ku band is presented. Transmission magnitudes and axial ratio over Ka band are in Fig. 6. Over the Ku band a low reflection loss of less than 0.05 dB was achieved for TE and TM polarizations. Reflection axial ratio was below 0.2 dB over the whole band. For the Ka-band transmission loss for both polarizations and axial ratio were each less than 0.25 dB. The double layer design therefore gave improved performance over the single layer design.

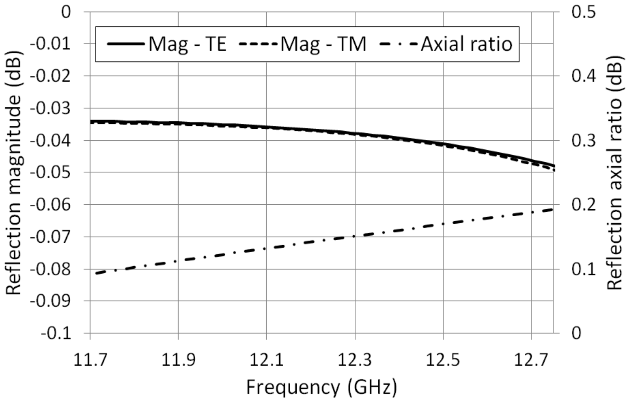

Fig. 5. Simulated reflection magnitude (TE and TM polarizations) and reflection axial ratio for designed double layer FSS – Ku band, 45° incidence.

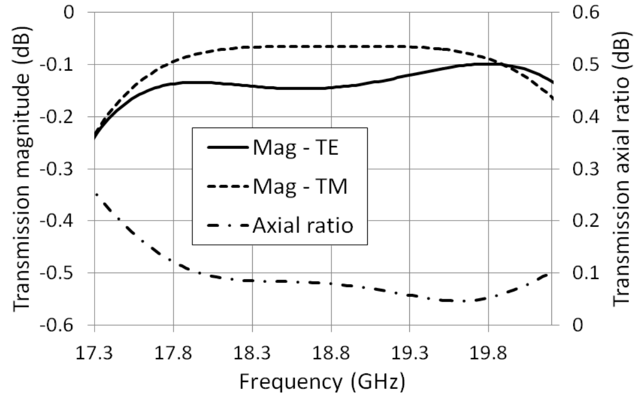

Fig. 6. Simulated transmission magnitude (TE and TM polarizations) and transmission axial ratio for designed double layer FSS – Ka band, 45° incidence.

IV. CONCLUSION

Single and double layer FSS for CP operation have been designed. The FSS were designed to reflect in the Ku-band (11.7 – 12.75 GHz) and transmit in the Ka-band (17.3 – 20.2 GHz) while also conserving CP within these bands. The single layer FSS consists of an array of copper double square loops patterned on a thin substrate and mounted on a Rohacell sheet. The double layer structure consists of two double square loop arrays each patterned on a thin substrate and mounted on either side of a Rohacell sheet. Simulation and design of the FSS was carried out using CST Microwave Studio (MWS).

Single layer structure - Ku-band - reflection loss less than 0.25 dB for TE and TM polarizations and axial ratio less than 0.2 dB. Ka-band - transmission loss less than 0.4 dB for both polarizations and axial ratio below 0.25 dB.

Double layer structure – Ku-band - reflection loss less than 0.05 dB for TE and TM polarizations and axial ratio below 0.2 dB. Ka-band – transmission loss for both polarizations and axial ratio below 0.25 dB.

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