A Switchable FSS Based on Modified Jerusalem-Cross Unit Cell with Extended Top Loading

H. Zahra[1], Syed Muzahir Abbas[1], M. Farhan Shafique[2], Karu P. Esselle[1]

[1] Department of Engineering, Macquarie University, NSW 2109, Australia,

[2] Center for Advanced Studies in Telecommunication, COMSATS Institute of Information Technology, Islamabad, Pakistan

shz535@yahoo.com, syed.abbas@mq.edu.au, farhan.shafique@comsats.edu.pk, karu.esselle@mq.edu.au

***Abstract*— This paper presents a switchable frequency selective surface (FSS) based on a modified Jerusalem-cross (JC) unit cell with extended top loading. Various combinations of switches are considered to make it switchable and the corresponding FSS behavior is analyzed. It is noted that the pass band(s) and stop band can be achieved by turning switches ON or OFF appropriately. For example, as a band pass FSS, it can provide single wide-band operation covering a bandwidth of 1.5GHz (2.97–4.47 GHz). In another mode, two narrower pass bands, one around 2.4GHz and other around 5.4GHz, can be achieved. Third mode allows a very wide stop band. The proposed FSS unit cell has been designed for fabrication on FR-4 to provide an inexpensive reconfigurable solution.**

Index Terms*— Frequency selective surface, FSS, Jerusalem cross, Switchable, Reconfigurable, Switches, Periodic structures.

I. INTRODUCTION

Frequency Selective Surfaces (FSSs) are of great interest over the past decades [1] due to their usage in wide range of applications such as antennas [2-4], filters [5-8], absorbers [9], artificial magnetic conductors (AMC) [10, 11], polarizers [12], planar metamaterials and radomes [13]. FSSs are periodic structures in either one or two dimensions that perform a filtering operation to pass or stop electromagnetic waves. They have the advantages of low profile and ease of fabrication, making them more favorable among periodic structures. Typical unit-cell geometries used for FSS include circular rings, square loops, fractals shapes and dipoles. Jerusalem-cross is also a well-known shape used in FSSs [2, 4, 9-14]. Previously, we have demonstrated a switchable FSS based on modified Jerusalem-cross geometry [14]. By selecting appropriate switches combination, it can provide single and dual pass-band around 2.45GHz and 5GHz. It also shows a stable resonance frequency at lower band while the resonance frequency of the higher band can be varied.

In this paper, we present a switchable FSS unit cell with a modified Jerusalem-cross with extended top loading. The extended top loading is realized by making the length longer at one side of the Jerusalem-cross as shown in Fig. 1. When pass band is desired, either wideband or dual band can be achieved by selecting appropriate switching combinations. Similarly, when stop band operation is desired, it can be achieved using other switch combination. Section II explains the geometry and switch configuration of proposed FSS. Results and analysis are presented in Section III and the paper is concluded in Section IV.

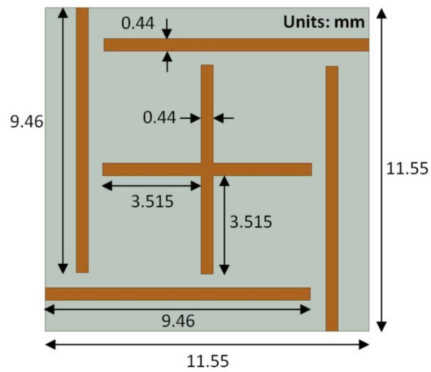

Fig. 1 Geometry of the proposed FSS unit cell.

II. FSS DESIGN

The geometry of the proposed FSS unit cell with modified Jerusalem-cross with extended top loading is shown in Fig. 1. It is designed for FR-4 substrate, which is inexpensive, having a dielectric constant of 4.4 and a thickness of 1.6mm. FSS unit cell has dimensions of 11.55mm x 11.55mm. Two metallic strips, each 7.47 long and 0.44mm wide, are used to form the central cross. A metallic strip with the same width (0.44mm) is used for top loading to the make a T-shape with an extended length at one side. The length of the top strip is 9.46mm, as shown is Fig. 1. To make it switchable, four switches are used at the T-junctions. The location of the switches is shown in Fig. 2.

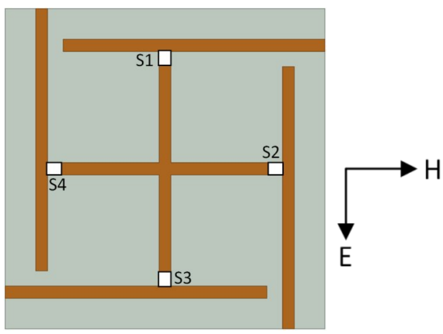

Fig. 2. Switch locations in the FSS unit cell.

III. RESULTS AND ANALYSIS

The simulations of the proposed FSS unit cell are carried out using ANSYS High Frequency Structural Simulator (HFSS). The direction of electric and magnetic field considered in

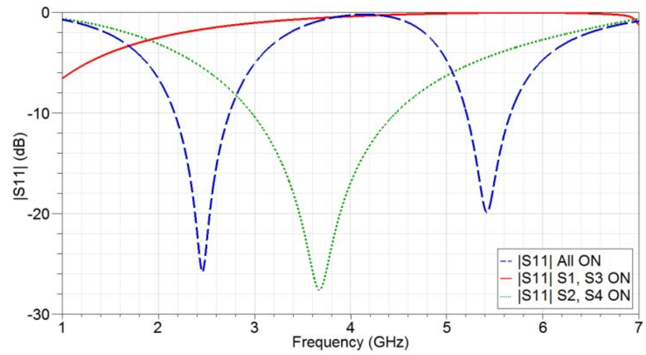

Fig. 3. Predicted |S11| corresponding to different switch combinations.

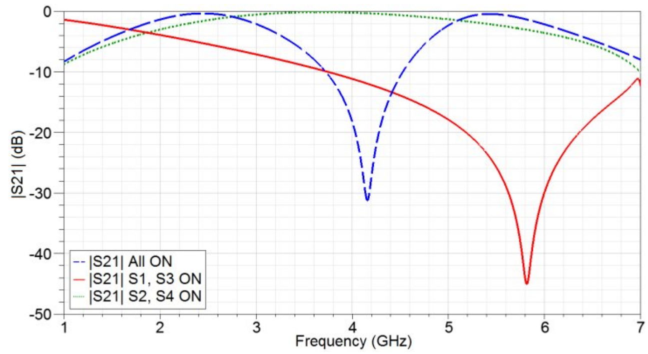

Fig. 4. Predicted |S21| corresponding to different switch combinations.

simulations is shown in Fig. 2. To investigate the characteristics of the proposed FSS, different switch combinations have been considered. The corresponding reflection and transmission coefficients are presented in Fig. 3 and Fig. 4, respectively. The corresponding pass and stop bands are tabulated in Table I. Results show that when all switches are in ON state, dual pass-band is noted around a lower resonance frequency of 2.4GHz and a higher resonance frequency of 5.4GHz. A different pass band with wide bandwidth of 1.5GHz around a resonance frequency of 3.7GHz can be obtained when two switches (i.e. S2 and S4) are ON while the other two switches are OFF. The switches, S2 and S4, are located on the strip that is perpendicular to the E-field. Similarly, when switches S1 and S3 are in ON state while S2 and S4 are OFF, a stop-band behavior is noted over the entire frequency band of 1–7GHz.

TABLE I: PASS AND STOP BANDS CORRESPONDING TO DIFFERENT SWITCH COMBINATIONS.

Switch combinations	Band-1 (GHz)	Band-2 (GHz)
All ON	2.17 – 2.74	5.2 – 5.66
S1, S3 ON	-------------	-------------
S2, S4 ON	2.97 – 4.47	-------------

IV. CONCLUSION

A switchable frequency selective surface based on a modified Jerusalem-cross unit cell with extended top loading is presented. By selecting appropriate switch combinations, different pass- and stop-band responses can be achieved. They include a wide single pass band, two narrower pass bands and very wide stop band. The proposed FSS is easy to fabricate due to its simple geometry and the use of low cost substrate makes it an inexpensive reconfigurable solution.

REFERENCES

[1] A. Mackay, B. Sanz-Izquierdo, and E.A. Parker, "Evolution of Frequency Selective Surfaces," *Forum for Electromagnetic Research Methods and Application Technologies (FERMAT),* vol. 2, pp. 1-7, 2014.

[2] C. Hsing-Yi, T. Yu, H. Kuo-Lun, and C. Hsi-Tseng, "Bandwidth enhancement using dual-band frequency selective surface with Jerusalem cross elements for 2.4/5.8 GHz WLAN antennas," in *IEEE International Conference on Wireless Information Technology and Systems*, 2010, pp. 1-4.

[3] L. Moustafa and B. Jecko, "Broadband high gain compact resonator antennas using combined FSS," in *IEEE International Symposium on Antennas and Propagation*, 2008, pp. 1-4.

[4] C. Hsing-Yi and T. Yu, "Performance Improvement of a U-Slot Patch Antenna Using a Dual-Band Frequency Selective Surface With Modified Jerusalem Cross Elements," *IEEE Transactions on Antennas and Propagation,* vol. 59, pp. 3482-3486, 2011.

[5] I. Sohail, Y. Ranga, K. P. Esselle, and S. G. Hay, "A frequency selective surface with a very wide stop band," in *7th European Conference on Antennas and Propagation*, 2013, pp. 2146-2148.

[6] S. I. Sohail, G. I. Kiani, and K. P. Esselle, "Enhancing RF/microwave efficient transmission through energy saving glass windows using Frequency Selective surface," in *IEEE International Symposium on Antennas and Propagation*, 2011, pp. 2262-2263.

[7] I. Sohail, Y. Ranga, K. P. Esselle, L. Matekovits, and S. G. Hay, "Polarization stable ultra-wide-band Frequency Selective Surface for Ku- and K- band applications," in *International Conference on Electromagnetics in Advanced Applications*, 2013, pp. 802-805.

[8] I. Sohail, Y. Ranga, K. P. Esselle, L. Matekovits, and S. G. Hay, "Ultra-wide band frequency selective surface filter designed for Ku- and K- band applications," in *IEEE International Symposium on Antennas and Propagation*, 2013, pp. 476-477.

[9] S. Li, Y. Sin Han, I. C. Huang, and C. K. C. Tzuang, "Design and on-chip measurement of CMOS infrared frequency-selective-surface absorbers for thermoelectric energy harvesting," in *Asia-Pacific Microwave Conference*, 2011, pp. 461-464.

[10] M. Hosseini and M. Hakkak, "Characteristics Estimation for Jerusalem Cross-Based Artificial Magnetic Conductors," *IEEE Antennas and Wireless Propagation Letters,* vol. 7, pp. 58-61, 2008.

[11] M. K. Taher Al-Nuaimi and W. G. Whittow, "Low profile dipole antenna backed by isotropic Artificial Magnetic Conductor reflector," in *4th European Conference on Antennas and Propagation*, 2010, pp. 1-5.

[12] I. Sohail, Y. Ranga, K. P. Esselle, and S. G. Hay, "A linear to circular polarization converter based on Jerusalem-Cross frequency selective surface," in *7th European Conference on Antennas and Propagation*, 2013, pp. 2141-2143.

[13] F. Costa and A. Monorchio, "A Frequency Selective Radome With Wideband Absorbing Properties," *IEEE Transactions on Antennas and Propagation,* vol. 60, pp. 2740-2747, 2012.

[14] H. Zahra, S. Rafique, M. Farhan Shafique, and Karu P. Esselle, "A Switchable Frequency Selective Surface based on a Modified Jerusalem-Cross Unit Cell," in *9th European Conference on Antennas and Propagation*, Lisbon, Portugal, 2015.