

Review of Various Designs of Periodic Structures for Frequency Selective Surfaces

Avneet Kaur¹, Er. Garima Saini²

¹M.E. Scholar, ²Assistant Professor

Department of Electronics & Communication Engineering,

National Institute of Technical Teachers' Training & Research, Chandigarh, India-160019

Abstract - With the growing recent trends in communication, different types of antennas for various frequency ranges are being developed. Other than the operating frequency; antenna gain, return loss, VSWR and bandwidth are some of the parameters that are to be looked upon for the practicality of a particular antenna design. This review paper targets an antenna design that uses a frequency selective surface (FSS) to modify the various antenna parameters. An FSS is an array of periodic structures of either metallic patches on a substrate or a conducting screen perforated with apertures, which exhibits filter characteristics for the EM wave incident upon it. In this paper, a number of frequency selective surfaces with different shapes and sizes of periodic structures have been reviewed.

Keywords - Frequency selective surfaces, Gain, Patch antenna, Slot antenna.

I. INTRODUCTION

Many researchers have shown keen interest towards the development of the wireless industry. The antennas being used in wireless applications must be small in size, light in weight and low in cost. Moreover, the antenna must practically provide improved directivity and gain. A patch antenna is a low profile type of radio antenna. It can easily be mounted on a flat surface. Common shapes of the patch are square, rectangular, circular and elliptical. Because of the simple physical geometry, the design and manufacturing cost of patch antennas is relatively less. A single patch antenna is capable of providing a maximum directive gain of around 6-9 dBi [1]. The suppression of surface waves is a property that periodic structures can offer.

II. FREQUENCY SELECTIVE SURFACE

A frequency selective surface (FSS) can be defined as any thin, repetitive surface that has

been designed to reflect, transmit or absorb electromagnetic fields based on frequency. Basically, there are two types of FSS - the bandpass FSS (mesh-type) and the bandstop FSS (patch-type) [2]. The FSS structures may further be classified as follows:

- infinite periodic FSS structure
- cascaded FSS or multilayered FSS structure
- finite periodic and electrically large FSS structure
- curved FSS (CFSS) structure [3].

FSSs are fabricated by chemically etching a dielectric sheet. This sheet may be of fiberglass ($\epsilon_r = 4.4$), teflon ($\epsilon_r = 2.1$), or various forms of duroid ($\epsilon_r = 2.2, 10.2$) [2]. During the past few decades, FSS technology has been widely used in various areas such as aerospace engineering, communication systems, medical instrumentation, and high-power microwave systems. These periodic surfaces are being used as radomes, spatial filters, antenna reflectors and absorbers. FSSs are also used as electromagnetic bandgap materials because of their bandpass or bandstop responses [4]. The operation and application of frequency selective surfaces may vary depending upon a number of factors like analysis techniques, operating and design principles and manufacturing techniques [3].

Frequency selective surfaces have been designed using different techniques such as perturbation, multi-element unit cells, multi-resonant unit cells, genetic algorithm design techniques and using complementary structures [5]. FSSs with composite unit cells have been designed. In these type of designs, the unit cell is made up of two or more structures. The operational frequency bands of such FSSs are determined by the resonant frequencies of the individual structures [6]. Various configurations such as ring, patch, square loop, strip and slot shapes have been used to design the FSS layer [7]. Fractal structures constituting the unit cells of frequency selective surfaces have shown to

be capable of providing multi-band operation [8]–[11]. A fractal geometry as shown in Fig. 1. can help in miniaturization of the structure. X. L. Bao et al. [8], used fractal shapes generated by the Minkowski loop generator.

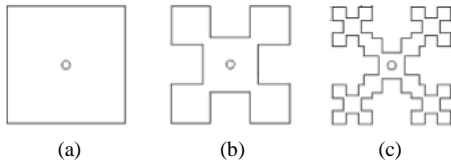


Fig. 1. The fractal iteration structures for (a) 0th, (b) 1st and (c) 2nd iteration.

The transmission characteristics for the zeroth, first and the second fractal iterations were simulated and compared in [8]. The axial ratio bandwidth of the antenna improved by 3 MHz than that of the same patch antenna without the EBG surface. Emmanuel Rodes et al. [12], chose two close frequency bands 5.15–5.35 GHz and 5.725–5.825 GHz for the design. Due to the closeness of the two required frequency bands, a highly selective FSS was necessary and this led to the choice of a Hilbert curve [13].



Fig. 2. The Hilbert Curve.

A miniaturized periodic element, as depicted in Fig. 3, for a bandpass frequency selective surface (FSS) was presented in [14]. An FSS of the same periodicity, made up of an array of metallic patches was proposed in [15]. The patches were separated by thin air gaps backed by a wire mesh. Also, an FSS of the same periodicity, made up of metallic loop and a wire grid was presented in [16].



Fig. 3. Top view of the unit cell in [14].

In [14], the FSS was tested using two horn antennas working between 2 to 8 GHz. The structure proved to be stable corresponding to different polarizations and incident angles.

A bandstop frequency selective surface (FSS) using octagonal fractal structures as shown in Fig. 4. was presented in [17]. The perimeter of the unit cell of the FSS has been effectively elongated by bending the edges inside and outside. Also, the miniaturization can further be improved by changing the position and number of the inside loops.

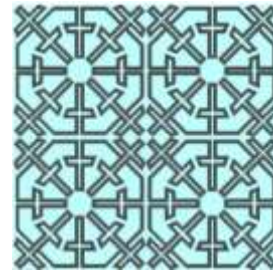


Fig. 4. FSS structure proposed in [17].

Wentao T. Wang et al. [18], used hexagonal fractal structures to present a compact FSS. The FSS was small in size and had great stability. Also, because of its simple structure it was easy to fabricate. This FSS presented a promising method to create a miniaturized FSS by elongating the resonant length in a unit cell. Wolfgang Kiermeier et al. [19] proposed a new element for dual bandstop frequency selective surfaces. The FSS was composed of the square loop type elements as shown in Fig. 5. The two mobile communication frequency ranges GSM900 and GSM1800 have been shielded. The FSS showed a good shielding performance and high stability with respect to the angle of incidence and polarization.



Fig. 5. Dual band element proposed in [19].

A multiband frequency selective surface (FSS) constituting of multiring patch elements was presented in [6]. The patch elements were

perfectly conducting. Parker et al. [20] presented a similar type of analysis for a single screen FSS with circular ring patch element. Narrow rings with dielectric substrates only on one side of the metallic screen were analysed. The aim in [6] was to design a ring element FSS that provided maximum transmission loss for frequencies higher than 32 GHz and minimum transmission loss for frequencies lower than 14 GHz. The performance of the designed double ring element FSS was found to be much better as compared to the single ring element FSS in [21]. Due to the larger ring, the FSS exhibited resonance at a lower frequency and due to the smaller ring, the FSS exhibited resonance at a closely separated higher frequency.

Hsing-Yi Chen et al. [22] studied the impact of a regular Jerusalem cross element FSS on the bandwidths and resonant frequencies of a U-slot patch antenna. Based on the results of the study, a new FSS with modified Jerusalem cross elements as shown in Fig. 6. was proposed. The aim was to improve the antenna gains, bandwidths and return losses of a smaller U-slot patch antenna at 2.45 and 5.8 GHz. The modified U-slot antenna implanted with modified Jerusalem cross element FSS, was verified to provide dual-band and higher gain performance for Bluetooth and WLAN applications. At 2.45GHz, the gain increased from 3dB to 4.69dB and at 5.8GHz, the gain was found to increase from 2 dB to 6.54 dB. Poorwa Bhagat et al. [23] used FSS constituting the modified Jerusalem cross elements to improve the gain of a dual U-slot patch antenna. Mingbao Yan et al. [4] proposed a new anchor-shaped loop unit cell structure for compact frequency selective surfaces for WLAN frequencies 2.4 GHz and 5.0 GHz. Excellent miniaturization of the unit cell was achieved.

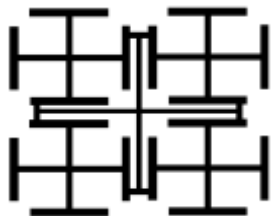


Fig. 6. The modified Jerusalem cross element in [22].

Moufida Bouslama et al. [24] presented the design of a new frequency selective surface used for the enhancement of gain of a microstrip antenna operating at 5.2 GHz. In this

design, the pattern on FSS was a discontinuous circular shape as depicted in Fig. 7. and it was placed above the conventional microstrip patch antenna. The gain was found to be increased by 9.4 dBi, 7.94dBi (initially) to 17.4dBi (finally).

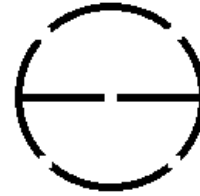


Fig. 7. Structure of the unit cell proposed in [23].

Y. Ranga et al. [25] used a multilayer frequency selective surface for the enhancement of gain of a semicircular slot antenna. A semicircular slot antenna was taken as the reference antenna and its gain enhancement due to the FSS reflector concept for the overall UWB frequency range was shown. The unit cell of the FSS is shown in Fig. 8. The minimum gain enhancement was found to be at the lower end of the UWB band (about 2.5 dB) and the maximum gain enhancement was at 4.2 GHz (about 4 dB). The maximum gain achieved at 4.2 GHz was 9.5 dBi.



Fig. 8. Structure of the unit cell proposed in [24].

III. SCOPE

Recently, the focus of researchers in the communication field is towards hotspot frequencies. Patch antenna is being widely used for hotspot applications. In such applications, the patch antenna performance is destroyed by its ground plane as the thickness of the substrate is much smaller as compared to half of the operating wavelength. To avoid this, the patch antenna can be implemented using frequency selective surface. The FSS structure is a high impedance surface that has the property of reflecting the plane wave in-phase and suppressing the surface wave. Thus, when an electromagnetic wave passes through an FSS, some frequencies are transmitted while others are reflected. Frequency selective surfaces have

become an area of increasing attention over the last decade. FSSs with different lattice geometry and element periodicity have been studied. One of the problems that prohibits the application of an FSS at frequencies in WLAN bands and below, is the large size of the element constituting the FSS. For practical applications, the periodic element of an FSS must be miniaturized corresponding to the operating wavelength. Further, FSSs with composite unit cell structures can be created to improve the antenna performance. Various new designs of elements may be possible. FSSs with some different element shapes can be designed and tested for practical applications.

IV. CONCLUSION

The use of frequency selective surfaces has been researched extensively. An antenna implemented using an FSS can be regarded as a filtering antenna, which not only improves its performance in the required frequency band, but also effectively suppresses the signal frequencies that are not required. Different shapes of element structures have been studied. Also, miniaturization of some element patterns has been seen. FSS structures are being implemented to enhance the radiation pattern, gain and bandwidth of an antenna. The improvement in the performance of an antenna using a frequency selective surface depends on the lattice geometry, periodicity of the elements and the electrical properties of the substrate material.

REFERENCES

- [1] Y.T. Lo, D. Solomon and W.F. Richards, "Theory and Experiment on Microstrip Antennas", IEEE Transactions on Antennas and Propagation, Vol. 27, No. 2, pp. 137-149, 1979.
- [2] Benedikt A. Munk, "Frequency Selective Surfaces: Theory and Design", John Wiley, 2nd edition, pp. 1-20, 2000.
- [3] Shiv Narayan and Rakesh Mohan Jha, "Electromagnetic Techniques and Design Strategies for FSS Structure Applications", IEEE Antennas & Propagation Magazine, Vol. 57, No. 5, pp. 135-158, 2015.
- [4] Mingbao Yan, Shaobo Qu, Jiafu Wang, Jieqiu Zhang, Hang Zhou, Hongya Chen and Lin Zheng, "A Miniaturized Dual-Band FSS With Stable Resonance Frequencies of 2.4 GHz/5 GHz for WLAN Applications", IEEE Antennas and Wireless Propagation Letters, Vol. 13, pp. 895-898, 2014.
- [5] Mudar A. Al-Joumayly and Nader Behdad, "Low-Profile, Highly-Selective, Dual-Band Frequency Selective Surfaces with Closely Spaced Bands of Operation", IEEE Transactions on Antennas and Propagation, Vol. 58, No. 12, pp. 4042-4050, 2010.
- [6] Te-Kao Wu, and Shung-Wu Lee, "Multiband Frequency Selective Surface with Multiring Patch Elements", IEEE Transactions on Antennas and Propagation, Vol. 42, No. 11, pp. 1484-1490, 1994.
- [7] Abbas Pirhadi, Hadi Bahrami and Javad Nasri, "Wideband High Directive Aperture Coupled Microstrip Antenna Design by Using a FSS Superstrate Layer", IEEE Transactions on Antennas and Propagation, Vol. 60, No. 4, pp. 2101-2104, 2012.
- [8] X. L. Bao, G. Ruvio, M. J. Ammann, and M. John, "A Novel GPS Patch Antenna on a Fractal Hi-Impedance Surface Substrate", IEEE Antennas and Wireless Propagation Letters, Vol. 5, pp. 323-326, 2006.
- [9] D. H. Werner and S. Ganguly, "An overview of fractal antenna engineering", IEEE Antennas and Propagation Magazine, Vol. 45, No. 1, pp. 38-57, 2003.
- [10] F. Frezza, L. Pajewski, and G. Schettini, "Fractal two-dimensional electromagnetic bandgap structures", IEEE Transactions on Microwave Theory and Techniques, Vol. 52, No. 1, pp. 220-227, 2004.
- [11] G. Goussetis, Y. Guo, A. P. Feresidis, and J. C. Vardaxoglou, "Miniaturised and multiband artificial magnetic conductors and electromagnetic bandgap surfaces", Proceedings of IEEE Antennas and Propagation Society International Symposium, Vol. 1, pp. 20-25, 2004.
- [12] Emmanuel Rodes, M. Diblanc, E. Arnaud, T. Monédière, and B. Jecko, "Dual-Band EBG Resonator Antenna Using a Single-Layer FSS", IEEE Antennas and Wireless Propagation Letters, Vol. 6, pp. 368-371, 2007.
- [13] J. McVay, N. Engheta, and A. Hoorfar, "High impedance metamaterial surfaces using Hilbert-curve inclusions, IEEE Microwave and Wireless Component Letters, Vol. 14, No. 3, 2004.
- [14] Guohui Yang, Tong Zhang, Wanlu Li, and Qun Wu, "A Novel Stable Miniaturized Frequency Selective Surface", IEEE Antennas and Wireless Propagation Letters, Vol. 9, pp. 1018-1021, 2010.
- [15] K. Sarabandi and N. Behdad, "A frequency selective surface with miniaturized elements", IEEE Transactions on Antennas and Propagation, Vol. 55, No. 5, pp. 1239-1245, 2007.
- [16] F. Bayatpur and K. Sarabandi, "Single-Layer high-order miniaturized element frequency-selective surfaces," IEEE Transactions on Microwave Theory and Techniques, Vol. 56, No. 4, pp. 774-781, 2008.
- [17] Tong Zhang, Guo-hui Yang, Wan-lu Li, Qun Wu, "A Novel Frequency Selective Surface with Compact Structure and Stable Responses", International Symposium on Antennas Propagation and EM Theory, pp. 932-935, 2010.
- [18] Wentao T. Wang, P. F. Zhang, S. X. Gong, B. Lu, J. Ling, and Tingting T. Wan, "Compact Angularly Stable

Frequency Selective Surface Using Hexagonal Fractal Configurations”, Microwave and Optical Technology Letters, Vol. 51, No. 11, pp. 2541-2544, 2009.

[19] Wolfgang Kiermeier and Erwin Biebl, “New Dual-Band Frequency Selective Surfaces for GSM Frequency Shielding”, Proceedings of the 37th European Microwave Conference, pp. 222-225, 2007.

[20] E. A. Parker and S. M. A. Hamdy, “Rings as elements for FSS”, Electronics Letters, pp. 612-614, 1981.

[21] T. K. Wu, K. Woo, S. W. Lee, “Multiring element FSS for multiband applications”, IEEE Antennas and Propagation Society International Symposium, Vol. 4, pp. 1775-1778, 1992.

[22] Hsing-Yi Chen and Yu Tao, “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, No. 9, pp. 3482-3486, 2011.

[23] Poorwa Bhagat, Prashant Jain, “Performance Improvement of Dual U-Slot Microstrip Patch Antenna Using Frequency Selective Surface with Modified Jerusalem Cross Elements”, International Journal of Engineering Trends and Technology (IJETT), Vol. 17, No. 3, pp. 124-129, 2014

[24] Moufida Bouslama, Moubarek Traii, Ali Gharsallah and Tayeb A. Denidni, “High gain Patch Antenna using a Frequency Selective Surface (FSS)”, International Journal of Communications, Vol. 8, pp. 16-20, 2014.

[25] Y. Ranga, K. P. Esselle, L. Matekovits and S. G. Hay, “Increasing the Gain of a Semicircular Slot UWB Antenna Using an FSS Reflector”, IEEE Conference on Antennas and Propagation in Wireless Communications, pp. 478-481, 2012.