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Design of FSS-Based Flexible Polarizer for ISM Band and Wireless Body Area Network Applications

D Arun Kumar | G Sai Swaroop | G Nireesha | B Hema | B Prashanth | B Tejeswar Reddy

Department of Electronics and Communication Engineering,Raghu Institute of Technology, Visakhapatnam, Andhra Pradesh
Corresponding Author Email Id: saiswaroop060401@gmail.com

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ABSTRACT

This study proposes a low-profile flexible linear to circular polarizer constructed from a paper substrate. The polarizer is made up of Frequency Selective Surface (FSS) elements with crossed dipoles. The proposed structure is designed for a specific application at f=5.8GHz. The ISM (Industrial, Scientific, and Medical) band is reserved only for these purposes. The Frequency Selective Surface dimension of one unit cell is 25mm×25mm×2mm and is simulated using HFSS 13.0 software and the simulation of the unit cell is performed using periodic boundary conditions and Floquet port excitation. The goal of this article is to create a polarizer that can operate at 5.8GHz and also, and our proposed design gives a dual-band response for frequencies 5.8GHz and 4.8GHz. Furthermore, the suggested flexible polarizer has a consistent response for up to 30 degrees of angular incidences

KEYWORDS: ***Frequency Selective Surface, Crossed dipole Structure, Polarizer.***

1. INTRODUCTION

Polarization is defined as the orientation of an Electromagnetic wave in a specific direction. To carry out polarization, a polarizer needs to be used. They are of two types i) Reflecting type ii) Transmitting type. Polarization plays a pivotal role in Wireless communication. Improperly polarized waves may damage the quality of the signal on receiving side. Polarizers made of Frequency Selective Surfaces are the best choice to solve the problem of polarization. Over the years concept of polarization broadly impacted the field of communication, especially in radars, satellite communications, wireless communications, and antennas. But the antennas which employ linear polarization cannot be predicted due to the orientation of linearly polarized signals [2]. Due to this concept of circular polarization came into significance. It offers lower susceptibility, provides multipath, and the effect of fading is minimal.

Polarization converters (Polarizers) are the alternative way of achieving circular polarization. A linearly polarized signal is transformed into a circularly polarized signal. The transmitting polarizers are anisotropic media that require the incoming call to pass through the geometry to attain circular polarization. These are important in some antenna applications [8]. There are many ways to achieve this polarization using different geometry. These geometries include polarizers made of dipole arrays [1], alternating dielectric plates [4], lattice structures [4], grid plates [6], and meander line technology [6]. A quarter-wave plate is another approach to achieving linear to circular polarization. A simple broadband performance of a quarter-wave plate is shown in reference [6], which is operating at a frequency of 75GHz. Also, in A single-layer quarter-wave plate-based polarizer with a low-profile design used in broadband efficiency, perfect circular polarization is shown in reference [5].

Frequency Selective Surfaces are infinite planar periodic surfaces made up of an array of elements in 2D or 3D. The electromagnetic characteristics of these surfaces are unique. FSS has grown in importance in contemporary applications and antennas over time. The addition of FSS improves gain, bandwidth, and directivity, design compactness, miniaturization, ease of manufacture, and low profile while keeping essential performance characteristics. Filters, absorbers, reflectors, shielding materials, and polarizers are all examples of FSS applications. One of its uses, a polarizer, was disclosed in this paper. Because of its consistent effectiveness under a variety of incidence angles. This FSS can only twist the polarization by 90º in contrast to a quarter-wave plate polarizer which produces a continuously rotating clock or anticlockwise circular polarization [6].

The choice of the structure depends on the type of FSS that we are going to design, which is slot, patch, or dipole type. In this paper, slot type geometry is used, which can be used for reflection type and transmission type polarizers. In this paper, the proposed structure is of slot-type geometry. The novelty of the proposed design is that it is a thin, low profile, and single-layered structure.

The polarizer has a transmission loss of 2.4 dB at 70.70 GHz, with a passband of 69.29 to 71.78 GHz. The reference [1] describes a 70 GHz dual-layer polarization converter with a transmission loss of 0.3dB. The suggested FSS comprises crossed dipole components of varying lengths produced on a paper substrate. Our Flexible Polarizer is intended for use in ISM bands with a frequency of

f = 5. 8GHz.As a result, our suggested structure's simulated response was in good agreement with the proposed frequency. In addition to this, we got a dual-band frequency for the proposed unit cell simulation.

2. DESIGN OF FSS POLARIZER

Figure 1 depicts the unit cell of the FSS polarizer. The FSS element here is a cross dipole of different arm lengths. The dimensions are P=25mm, L1=10mm, L2=8mm, and W=2mm. Due to different arm lengths, the structure introduces a phase difference of 90° between the two perpendicular components of the incoming electromagnetic waves. The Frequency Selective Surface is created on a less rigid substrate which is a paper substrate of dielectric constant(ε_r) = 3.4 with a thickness of 2 mm.

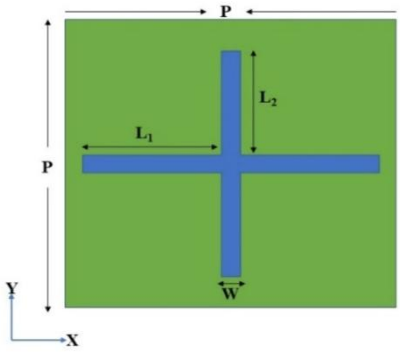

Fig.1: Unit Cell Representation of FSS Polarizer

TABLE 1: Physical Parameters of FSS Polarizer

Symbol	*Description*	*Dimension*
P	Unit cell Size	25mm
t	Thickness of Substrate	2mm
ε_r	Substrate Relative permittivity	3.4
L_1	Length of Crossed dipole1	10mm
L_2	Length of Crossed dipole 2	8mm
W	Width	2mm

3. SIMULATION SETUP

HFSS (High-Frequency Structure Simulator) Software simulates the FSS unit cell with periodic boundary conditions with floquet port excitation. The unit cell of the FSS polarizer consisting of crossed dipole elements on the substrate is shown below figure. Periodic boundary conditions in both the X and Y directions are assigned to the unit cell and designated with master and slave boundaries accordingly. Setting master-slave boundaries enable you to model periodicity planes so that one surface's electric field matches perfectly with the electric field of another surface. This type of boundaries can only be assigned to planar faces of

2-Dimensional or 3-Dimensional geometries. They are instrumental in simulating devices comprised of infinite arrays. Also, set a Perfect E boundary to the slot created on the substrate so that the surface acts as a perfectly conducting surface. An incident EM wave is used as the excitation to achieve polarization by assigning floquet ports in both the top and bottom. Floquet port is an exclusive port that provides excitation, especially for planar phased arrays and frequency selective surfaces.

The below figure depicts the simulation model of the proposed model of our FSS Polarizer with necessary boundary conditions and excitations

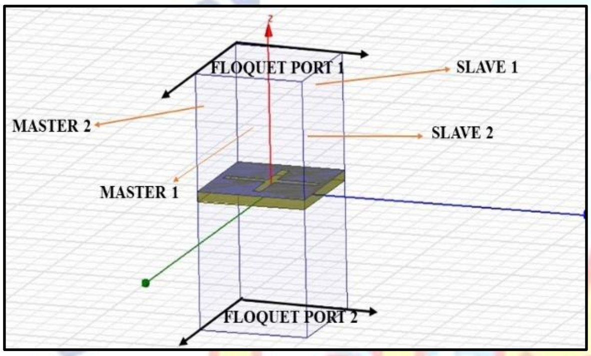

Fig.2: Simulation Model of Proposed FSS Polarizer

The Simulated transmission characteristics for both TE and TM modes are shown in Figure 3. It is observed that the proposed FSS polarizer gives a dual-band response for the given solution frequency at 4.8GHz and 5.8 GHz.

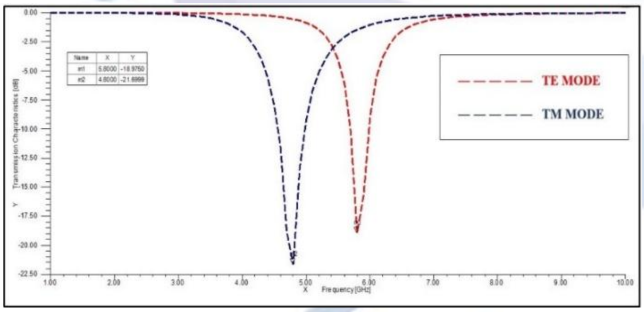

Fig. 3: Simulated Transmission Characteristics of both TE and TM modes of proposed FSS Polarizer

The difference in transmission characteristics is caused by uneven crossed dipole lengths in this case. This provides a 90° phase difference between the TE and TM mode responses, allowing them to function as FSS Polarizers. Transmission loss at frequency f=5.8GHz and f=4.8GHz is -18.97dB and -21.97dB, respectively. As a result, the generated response may be used as a dual-band at f=4.8GHz. Biomedical Telemetry Tracking and Body Area Networks are two specific uses. Similarly, at f=5.8GHz, ISM band applications can be used.

4. PARAMETRIC STUDY

Optometric features are crucial to studying the performance characteristics of varying physical parameters of our FSS polarizer structure. So, this kind of optimization helps the user to get optimal designs and low-profile features. All these variations help designers improve in creating a structure and also for creating precision designs while saving cost and time.

A. Varying Length (L_1)

The purpose of this operation is to investigate the impact of Length L1 on the proposed polarizer design while keeping other parameters like Thickness (t), Width(W), and Length(L2) held constant. Transmission Characteristics TE and TM mode of flexible polarizer were depicted in figure 4 and figure 5. This study aims to verify our flexible polarizer characteristics for different variations and understand polarizers' stability and correctness. It is to measure the extent of variation for which our proposed structure is in good agreement with the requirement of our application.

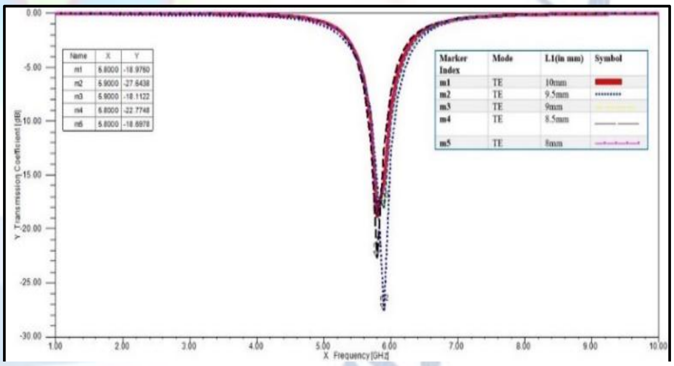

Fig. 4a: Simulated TE mode response of proposed FSS Polarizer for varying Length L_1

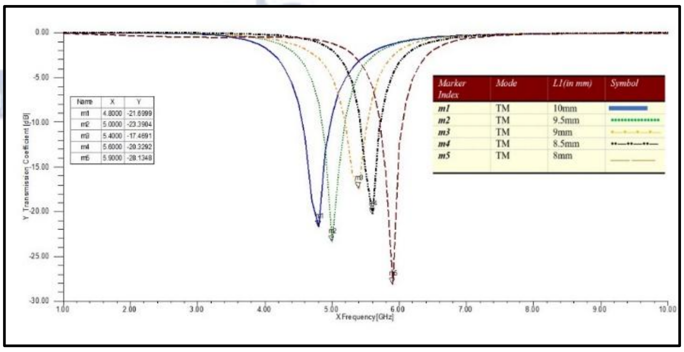

Fig. 4b: Simulated TM mode responses of proposed FSS Polarizer for varying length L_1

In Observing Figure 4 and Figure 5, the Varying Length L1 of the unit cell doesn't significantly differ in operating frequency in response to polarizer in both TE and TM modes. The variation in Length L1 has a minimal effect in both transmission modes. However, the change in L1 impacts TM mode transmission characteristics but not TE mode transmission characteristics. Decrease in Length L1 shifts operating frequency. Variation in L1 from 10mm to 9.5mm causes the operational frequency to move from 4.8GHz to 5.0GHz. Similarly, the interpretation for 9.5mm to 10mm is 5.0GHz to 5GHz. when in TM mode.

B. Varying Thickness "t"

In this Parametric variation, we study the effect of variation in substrate thickness. Procedurally the Thickness of a substrate is reduced. The responses of transmission characteristics in both TE and TM modes are shown in figures 5(a) and 5(b).

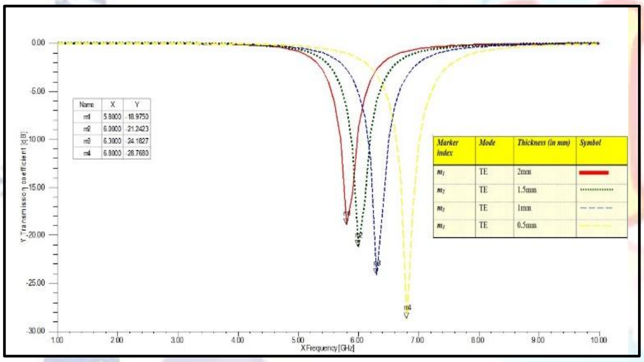

Fig.5a: Simulated TE mode response of FSS Polarizer for varying "t"

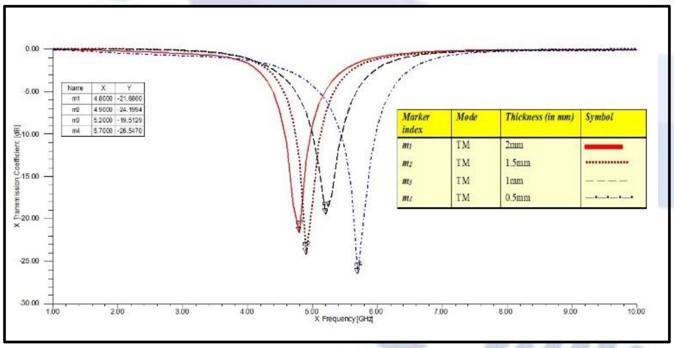

Fig. 5b: Simulated TM mode response of FSS Polarizer for varying "t"

In this Operation, the effect of the thickness of the substrate has a considerable change in operating frequencies for both TE and TM transmission modes. The Thickness of the substrate is inversely proportional to both modes. For T=2mm to 1.5mm, there is a variance in operating frequency from 5.8GHz to 6.0GHz in TE mode and 4.8GHz to 4.9GHz in TE mode. However, the FSS polarizer's simulated responses were in good accord with a range of operating frequencies required for the specific application

C. *Varying Incident angles (θ)*

The axial ratio is a parameter to measure the perfectness of a polarizer. It is the ratio between the major and minor axis of the polarization antenna pattern. For a circularly polarized wave, the ideal AR value is 0 dB, with a range of 3 dB allowed for practical implementation [2]. For a properly polarized wave, the variation of theta should be very minimal to carry out proper polarization. Simulating the response between Axial ratio and frequency would help us to give a clear picture of FSS performance to work as a polarizer. The simulated response of Theta variation is shown in figure6.

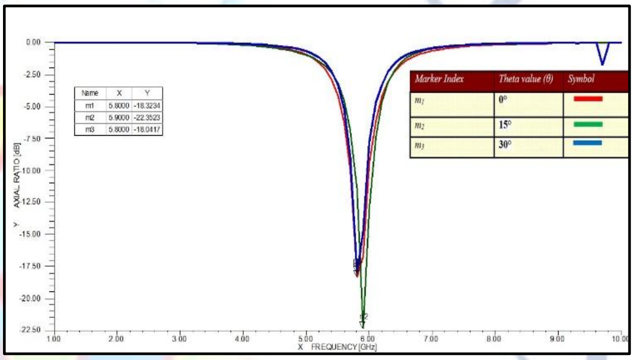

Fig.6: Simulated response of FSS Polarizer for various angles of incidence (θ)

The above figure shows that the FSS polarizer shows an accurate response with minimal loss for various incidences. It is also observed that at an angle of incidences θ=0° to θ=30°, the proposed structure works perfectly as a polarizer and can polarize up to θ=30° with significantly less marginal bandwidth compared to the normal EM wave incidences. We can infer that our proposed FSS polarizer works fine and is in good agreement with different theta(θ) variations. Thus, it can be utilized at operating Frequency f=5.8GHz supporting perfect polarization for the specified application.

5. APPLICATIONS

A. Industrial, Scientific, and Medical Band

ISM frequency is the radio frequency band reserved internationally by the ITU radio regulations. These Bands are set aside for RF purposes rather than using it for telecommunication purposes. The most commonly used ISM band is the 2.4GHz ISM band, but due to more interference by telecommunications, it was designated as 5.8GHz. It offers low latency and faster transmission, so it was employed for the ISM band. The frequency range is 5.725GHz-5.8GHz with a center frequency of 5.8GHz and is a license-free band. Applications include radio-frequency process heating, microwave Owens, Medical diathermy machines, induction heating, softening of the plastic, and hyperthermia radiolocation. Its increasing demand contributes significantly to RFID technology, mainly in highway RFID systems, door control at malls, and wireless communication like headsets, wearables, and NFC systems.

B. Body Area Networks and Biomedical Telemetry Tracking

These specific applications work at the Frequency f=4.8GHz[19]. Our proposed FSS polarizer also works in the frequency band in this study. A body area network is a wireless communication that specifically works for monitoring human organs remotely. These networks mainly intend on sensors to keep a continuous track of human data. So, these networks can be wearable or implantable on a human body. Over the years, it has had potential applications in the medical industry like remote patient health monitoring and timed notifications for health control.

Another critical application is biomedical telemetry tracking, a subset of these Wireless Body Area Networks. The Word "Tele" means "remote," and "meter" represents "Measure". So, the main aim of these applications is to use the advancement in electronics and communications and incorporate it into medical devices having biomedical functionalities. Technological innovations like preventive diagnostics, remote health care monitoring, Warning patient of an important event, ease of measuring parameters like glucose level, Blood, heart rate, etc. These advancements help people get quality of life and help in doctor-patient understanding.

6. CONCLUSION

Hence, A low profile, thin and flexible new class of FSS polarizer was designed and presented. The proposed Flexible polarizer operating at frequency f=5.8GHz works perfectly and can be utilized for specific ISM band applications. Along with this study, we obtained another frequency band, f=4.8GHz, at which our flexible polarizer finds applications in Biomedical telemetry tracking and Body area networks. In this paper, we performed various parametric studies to understand the flexibility of our FSS Polarizer. We have also investigated the structure's performance at different angles of incidences(θ). These studies were carried out to confirm the flexibility of our FSS Polarizer. As a result, the proposed Flexible FSS Polarizer is capable of working in specific ISM band applications (Industrial, Scientific, and Medical) and for Body Area Network applications.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Sivasamy R, Kanagasabai M. "Design and fabrication of flexible FSS polarizer", Int J RF MicrowComput Aided Eng. 2019; e22002.

[2] Arnaud E, Chantalat R, Koubeissi M, Monediere T, Rodes E, Thevenota, "Global design of an EBG antenna and meander-line polarizer for circular polarization", IEEE Antennas Wireless Propag Lett. 2010; 9:215-218.

[3] Ben A. Munk, Frequency Selective Surfaces-Theory and Design. John Wiley; 2000.

[4] Euler M, Fusco V, Cahill R, Dickie R, "325 GHz single layer submillimetre wave FSS based split slot ring linear to circular polarization convertor". IEEE Trans Antennas Propag. 2010;58(7):2457-2459.

[5] Mangi, F. A., Xiao, S. Q., Wang, Y. Q., Jamro, D. A., & Memon "Transmission characteristics of quarter-wave plate circular polarizer based on Frequency selective surface for high-frequency applications", International Conference on Computer Information Systems and Industrial Applications; 2015; Atlantis Press. 197-199.

[6] G. Kiani and V. Dyadyuk. "Low loss FSS polarizer for 70 GHz applications", Proceedings of the Antennas Propagation Society International Symposium (APSURSI); 2012

[7] Euler M, Fusco V, Cahill R, Dickie R. "Comparison of Frequency selective screen-based linear to circular split-ring polarisation converters", Microwave Antennas Propag. 2010;4(11):1764-1772.

[8] M. Euler and V. Fusco. "Sub-millimetre wave is a linear to circular polariser converter", Antennas and Propagation Conference, 2008.LAPC 2008;pp-77-80.

[9] Niemi T, Karilainen AO, Tretyakov SA., "Synthesis of polarization transformers", IEEE Trans Antennas Propag. 2013;61(6):3102-3111.

[10] E. Arnieri, F. Greco and G. Amendola, "A Broadband, Wide-Angle Scanning, Linear-to-Circular Polarization Converter Based on Standard Jerusalem Cross Frequency Selective Surfaces", IEEE Transactions on Antennas and Propagation, vol. 69, no. 1, pp. 578-583, Jan. 2021

[11] Letizia M, Fuchs B, Zorraquino C, Zurcher J-F, Mosig JR. "Oblique incidence design of meander-line polarizers for dielectric lens antennas", Prog Electromag Res B. 2012; 45:309-335.

[12] Momeni Hasan Abadi SMA, Behdad N, "Wideband linear-to circular polarization converters based on miniaturized-element frequency selective surfaces", IEEE Trans Antennas Propag. 2016;64(2):525-534.

[13] Li L, Li Y, Wu Z, Huo F, Zhang Y, Zhao C. "Novel polarization reconfigurable converter based on multilayer frequency-selective surfaces", Proceed IEEE. 2015;103(7):1057-1070.

[14] Orr R, Goussetis G, Fusco V, Saenz E. "Linear-to-circular polarization reflector with transmission band", IEEE Trans Antennas Propag. 2015;63(5):1949-1956.

[15] Y. Youn and W. Hong. "Planar dual-band is linear to circular polarization converter using radial-shape multilayer FSS", IEEE International Symposium on Antennas and Propagation &USNC/URSI National Radio Science Meeting; 2018; Boston, MA;1465-1466.

[16] W. Wang, Q. Huang and X. Shi. "A low-insertion-loss circular polarizer based on frequency selection surface", International Conference on Microwave and Millimetre Wave Technology (ICT); 2018; Chengdu; 1-3.

[17] Mirza H et al. "Single layered swastika-shaped flexible linear-to circular polarizer using textiles for S-band application", Int J RF Microwave Computer-Aided Eng. 2018;28(7): e21463.

[18] Mirza H et al. "Deployable linear-to-circular polarizer using PDMS based on unloaded and loaded circular FSS arrays for Pico-satellites', Access. 2019; 7:2034-2041.

[19] John Blauert, Asimina Kiourti, "Dual-Band (2.4 / 4.8 GHz) Implantable Antenna for Biomedical Telemetry Applications", May 24, 2018

[20] Nickolas M. Littman, Steven G. O'Keefe, Amir Galehdar, Hugo G. Espinosa, David V. Thiel, "Ultra-Thin Broadband Transmission FSS for Linear Polarization Rotation", vol. 9 August 9, 2021