Design of Frequency Selective Surface as Multiband Absorber

Saptarsika Das *[1,2], Ramesh Chandra Tiwari[1], L Lolit Kumar Sing[3] and Partha Pratim Sarkar [4]

[1]Department of Physics, Mizoram University, Mizoram-796004, India

[2]Department of Electronics, Rishi Bankim Chandra College, Naihati, West Bengal-743165, India

[3]Department of Electronics and Communication Engineering, Mizoram University, Mizoram-796004, India

[4]Department of Engineering and Technological Studies, University of Kalyani, West Bengal-741235, India

Abstract- The different studies and surveys concerning the ill effects of electromagnetic radiation has proved that electromagnetic wave is extremely harmful to plant kingdom and animal kingdom including human beings. Frequent usage of mobile phones and other electronic gadgets are responsible for exposure to excessive electromagnetic radiation. The electromagnetic wave is unavoidable in existing situation. So there is no other alternative than to take protective measure from harmful effect of electromagnetic radiation. Design and application of reflective FSS may be a protection to a particular person but it will affect neighbouring people. The design and application of absorbing type FSS solely can be an appropriate measure as a protective device from harmful electromagnetic radiation. Present study describes design of multi absorbing band FSS structure.

1. Introduction

The rapid development of technology is a boon to mankind despite of living amidst electromagnetic pollution. Electromagnetic pollution which is also known as radiation pollution is harmful for human health. Human exposure to electromagnetic radiation results in the absorption of electromagnetic waves by body fluids. The absorption causes localised heating effects within the body which end in drying up of fluids around eyes, brain, joints etc. [1]. The localised heating effects become more adverse if the body is exposed to other sources of heat simultaneously, the body cooling system fails to cope with the excessive heat that consequences to heat stroke. The interaction of electromagnetic field with metallic implants within the body influenced the normal operation of the implants by generating some external pulses [2]. Long time exposure to electromagnetic radiation increases the activity of free radicals that are responsible for changes in enzymes involved in oxidative process and effect genes [3]. Radio frequency exposure increases calcium fluxes into the cell which disrupt synapse formation culminated neurodegeneration. Electromagnetic field team up with toxic chemicals contribute to brain diseases. Sleeping disorder, skin rashes, ear tumour, concentration problem, headaches are the aftermaths of prolong exposure to electromagnetic radiation [4]. The above facts foreshowed the slow devastating effects of electromagnetic radiation on human health and encourage the research of radiation shielding.

The study of radiation shielding initiated with different types of absorbing material that follows the mechanism of reflection and absorption by multiple reflection. Metals, graphene, conductive polymers etc. are purposefully used for shielding electromagnetic radiation [5]. Radiation shielding has been reported to achieve by multiple orthogonally polarised monopole antenna [6]. In recent time, FSS based electromagnetic shielding is the cynosure of all the researchers as absorption of electromagnetic radiation can be achieved at coveted frequency. Conductive resistive combined FSS, resistive FSS, magnetic sheet based FSS, FSS based on resistive ink, nanocomposite FSS, magnetic superstrate based FSS have been reported that fulfils the purpose of electromagnetic radiation absorption [7,8,9,10,11,12,13,14]. The shielding technology rely on either absorptive material or on ground plane. Absorptive material based FSS enhance the cost of the entire structure.

The purpose of this work is to design an absorber without using expensive absorbing material. The bandstop property of conventional FSS has been utilised to obtain absorption. A two layer frequency selective absorber is designed and presented in this paper by embossing simple elemental structure on FR4 epoxy substrate of variable thickness. The FSS absorber attains three absorption bands in the frequency range of 6 GHz to 10 GHz which effectively shields the electromagnetic radiation and is capable to reduce the health hazards caused by it. The simulation of the FSS absorber has been done by ANSYS HFSS software.

2. Design and Evolution

A two layer absorber has been designed in which each layer has the periodicity of 22 mm in both the planes. The lower layer has been designed on FR4 epoxy substrate of thickness 1.6 mm. On the top side of the substrate a loop of L shaped patches of different orientation are bounded by a square loop patch with slots introduced as shown in Fig.1. The width of the outer square patch is 1 mm and the width of each L patch is 1.2 mm. Two slots are introduced in the outer square loop of dimension 1.2 mm X 1 mm. On the lower layer of the substrate a square patch of 21.2 mm X 21.2 mm has been modified introducing slots and slits as shown in Fig.2. The individual responses of each FSS unit cell and combined response of the single layer FSS (combining unit cell of Fig.1 & Fig.2) are shown in Fig.3, Fig.4 and Fig.5.

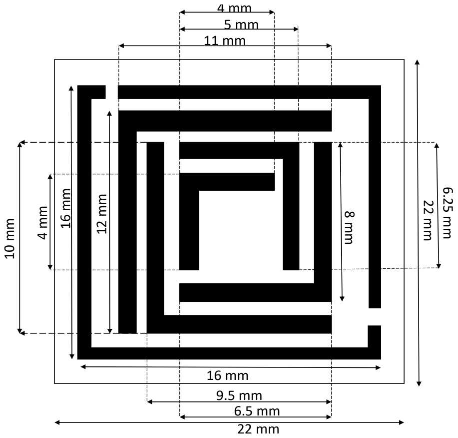

Fig.1. Unit cell imprinted on upper layer of the substrate

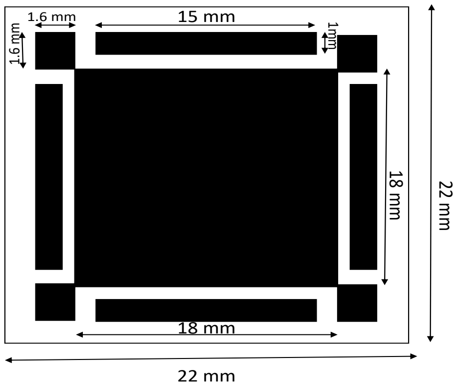

Fig.2. Unit cell imprinted on lower layer of the substrate

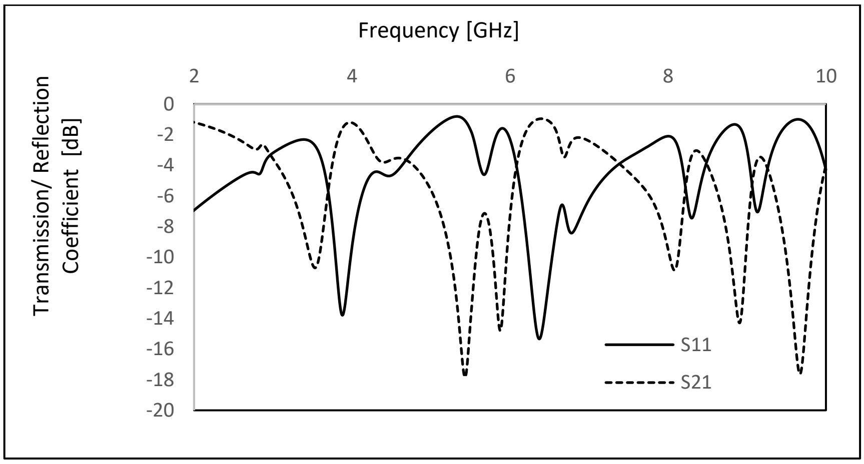

Fig.3. Transmission/ reflection coefficient vs frequency plot for unit cell shown in Fig.1.

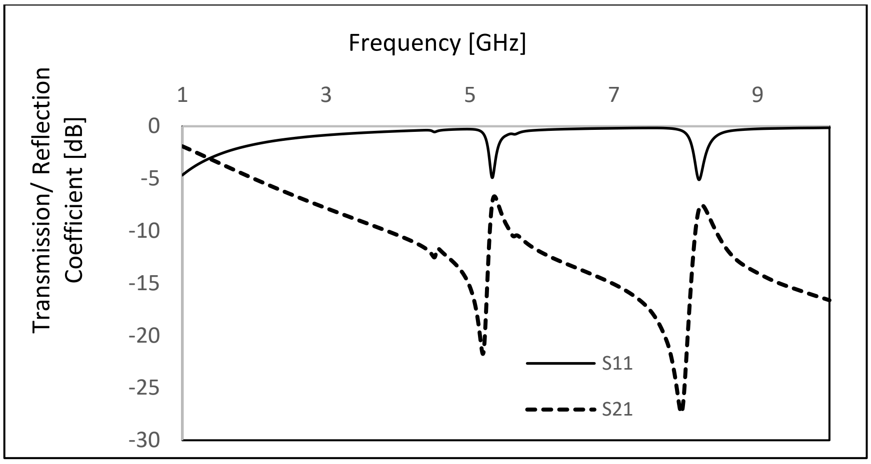

Fig.4. Transmission/ reflection coefficient vs frequency plot for unit cell shown in Fig.2.

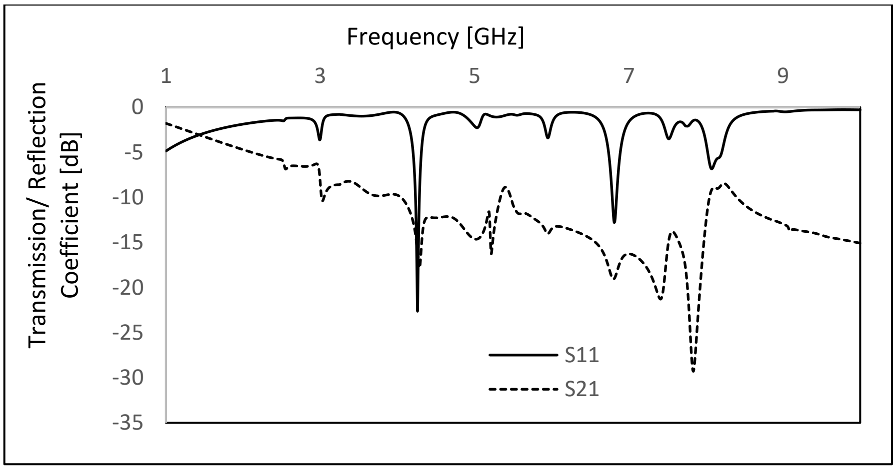

Fig.5. Transmission/ reflection coefficient vs frequency plot for the combined unit cell of Fig.1 & Fig.2

It has been observed from Fig.5 that a single layer FSS achieved two absorption band of bandwidth 50 MHz and 60 MHz in the frequency range of 4 GHz to 7 GHz. Finally a superstrate layer has been added where a square patch of 9.7 mm X 9.7 mm is embossed on lower layer of FR4 epoxy substrate of thickness 0.8 mm as shown in Fig.6.The addition of this layer results into three absorption band and also increases the bandwidth. The cumulative response of the entire FSS absorber has been depicted in Fig.7. The simulation of entire structure has been done by ANSYS HFSS software.

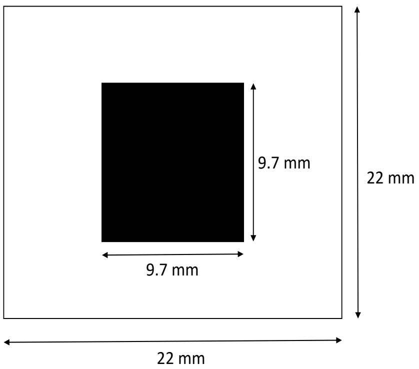

Fig.6. Unit cell of superstrate layer

3. Result and Discussion

Fig.7 depicts the transmission and reflection response of the two layer FSS absorber for an incident electromagnetic field.

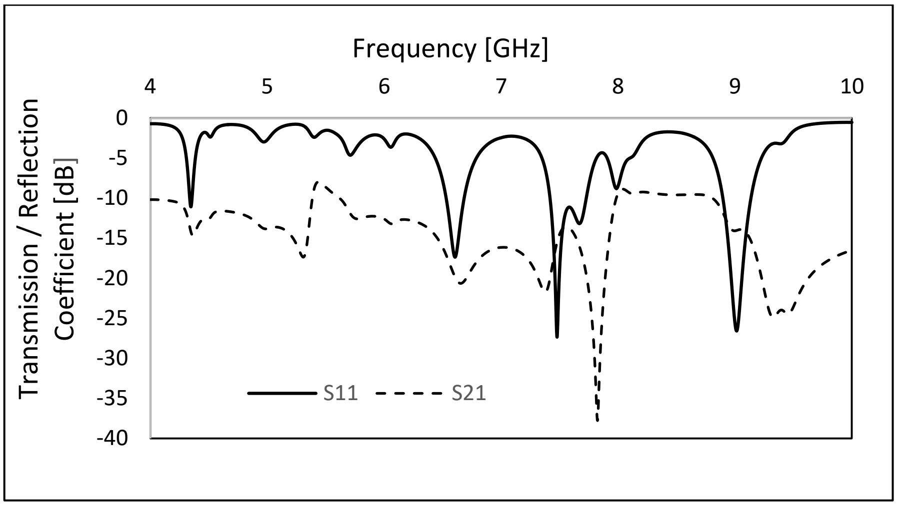

Fig.7. Transmission/ reflection coefficient vs frequency response of FSS absorber

It has been observed from the Fig.7 that the FSS absorber designed and presented here has three absorption band. The first absorption band has been obtained in the frequency range of 6.530 GHz to 6.683 GHz, the second absorption band in the frequency range of 7.418 GHz to 7.727 GHz and the third absorption band in the frequency range of 8.896 GHz to 9.138 GHz. The bandwidth of the three absorption bands are 153 MHz, 309 MHz and 240 MHz. The absorption characteristic of the FSS absorber is shown in Fig.8.

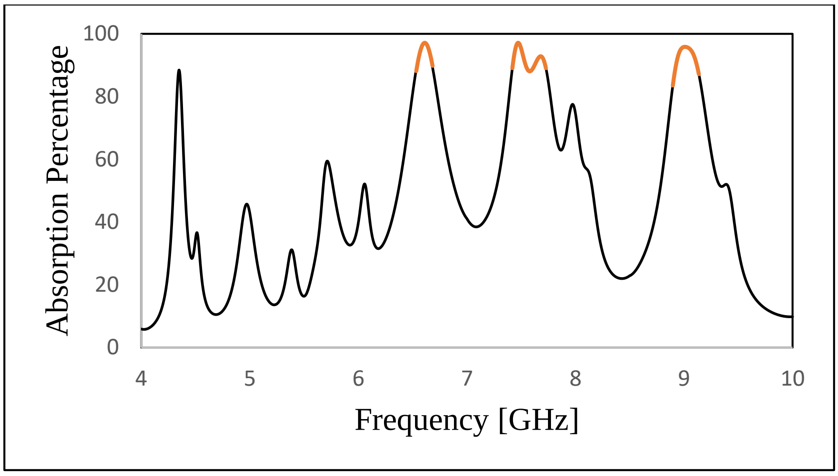

Fig.8. Absorption coefficient vs frequency response of FSS absorber

The orange colour highlighted portion in Fig.8 corresponds to the absorption in the three bands of frequency obtained from Fig.7. From Fig.8, it has been depicted that in the frequency range of 6.530 GHz to 6.683 GHz the minimum absorption is of 88% and maximum being 97%. A minimum absorption of 89% has been obtained in the frequency range of 7.418 GHz to 7.727 GHz, where the maximum absorption is 97%. 83% minimum absorption and 95% maximum absorption are obtained in the 8.896 GHz to 9.136 GHz frequency range. The designed FSS absorber shows good absorption capacity of electromagnetic radiation in all the absorption bands. Thus, the FSS absorber designed and presented in this paper has the high efficiency to absorb electromagnetic radiation with the maximum of 97% and satisfied the requirement of radiation shield that is capable to reduce the health hazard to a great extent.

4. Conclusion

Design of absorber with absorbing material is costly enough. Presently this is a challenge to the society to design low cost absorber. The solution is the design of absorber by using proper frequency selective surface. Novelty of the work is the design of low cost FSS based absorber with three absorbing bands and absorption in all three bands is around 90%. Use of FSS absorber in window screens of hospital, residences will definitely minimise the effect of electromagnetic radiation. The beauty of the FSS absorber is, it allows desired frequencies of electromagnetic radiation by passband nature of FSS and absorb the undesired one. Thus, minimising the exposure to the net electromagnetic radiation and its harmful effects.

Reference

[1] A. B. Sharma, O. S. Lamba, L. Sharma, "A Review: Source and Effect of Mobile Communication Radiation on Human Health.", Advances in Wireless and Mobile Communications, Vol. 10(3), pp. 423-435, 2017.

[2] V. Ganatra, K. Yadav, C. Senjaliya, M. Bhatt, S. Nakum, "Health Hazards Due to Electromagnetic Radiation in The Workplace.", International Journal for Innovative Research in Science & Technology, Vol.1(8), 2015.

[3] D. Rakovic, "The Influence of Electromagnetic (EM) Radiation on Biological Systems and Humans.", International Journal of Prenatal & Life Sciences, Ch.3, 2021.

[4] R. N. Kostoff, C. G. Y. Lau, "Modified Health Effects of Non-ionizing Electromagnetic Radiation Combined with Other Agents Reported in the Biomedical Literature.", Microwave Effects on DNA and Proteins (Springer), pp. 97-157, 2017.

[5] Seyyed Alireza Hashemi, Ahmadreza Ghaffarkhah, Ehsan Hosseini, Sonia Bahrani, Parisa Najmi, Navid Omidifar, Seyyed Mojtaba Mousavi, Majed Amini,Mehrorang Ghaedi, Seeram Ramakrishna, Mohammad Arjmand, "Recent progress on hybrid fibrous electromagnetic shields: Key protectors of living species against electromagnetic radiation.", Matter, Vol.5(11), pp.3807-3868, 2022.

[6] N. Kumar, G. Kumar, "Biological Effects of Cell Tower Radiation on Human Body.", ISMOT, 2009.

[7] G. I. Kiani, K. L. Ford, K. P.Esselle, A. R. Wiley, C. J. Panagamuwa, "Oblique Incidence Performance of a Novel FSS Absorber.", IEEE Transactions on Antennas and Propagation, Vol.55(10), pp. 2931-2934, 2007.

[8] U. Rafique, G. I. Kiani, M. M. Ahmed, S. Habib, "Frequency Selective Surface Absorber for WLAN Security.", Proceedings of the 5th European Conference on Antennas and Propagation (EUCAP), pp. 872-875, 2011.

[9] M. Zhang, T. Jiang, Y. Feng, "Design and Measurement of Microwave Absorbers Comprising Resistive FSS", Journal of Electromagnetic Analysis and Applications, Vol.6, pp.203-208, 2014.

[10] D. Wan, S. Bie, J. Zhou, H. Xu, Y. Xu, J. Jiang, "A Thin and Broadband Microwave Absorber Based on Magnetic Sheet and Resistive FSS.", Progress in Electromagnetics Research, Vol.56, pp.93-100, 2015.

[11] M. Bilal, R. Saleem, Q. H. Abbasi, B. Kasi, "Miniature and Flexible FSS Based EM-Shields for Conformal Applications.", IEEE Transactions on Electromagnetic Compatibility, Vol.62(5), pp.1703-1710, 2020.

[12] C. P. Jain, M.M. Sharma, "Smartphone Frequency Shielding with Penta Bandstop FSS for Security and Electromagnetic Health Applications.", IEEE Transactions on Electromagnetic Compatibility, Vol. 61(3), pp.887-892,2019.

[13] K. R. Jha, P. Jibran, S. K. Sharma, "Absorption Peak Controlled Low-Frequency Wideband Flexible FSS Absorber.", IEEE Transactions on Electromagnetic Compatibility, Vol. 64(4), pp.975-986, 2022.

[14] Ning Liu, Jiaxin Li, Xianjun Sheng and Haoran Fu, "An equivalent circuit model based design method for wideband absorber using resistive FSS." Physica Scripta, Vol. 99(9), 2024.