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The pursuit for the Perfect Electromagnetic Absorber: A Review

[1]N.Oral Roberts, [2]R. Subashini, [3]D. Deexitha, [4]A. Indumathi, [5]S. Rajarajan

[1,2,3,4,5]Sri Sai Ram Institute of Technology, Chennai, India.

[1]oralrobertz@gmail.com, [2]subashinirc@gmail.com, [3]deexithadurai98@gmail.com, [4]indumathiarumugam311@gmail.com, [5]srajayaganesh@gmail.com

Abstract : Electromagnetic Absorbers (EMA) are widely used in variety of applications. The EMA are capable of suppressing the reflections and the transmissions of the unwanted Electromagnetic (EM) radiations. This review paper conducts a survey on the techniques used in the Absorbers papers, by the authors to design the Ultrathin, bandwidth enhanced and the most economical EM absorber. Many researchers have suggested different methods to reduce the unwanted Electromagnetic disturbances. Several aspects of the designing the absorbers using the nanocomposites and the metamaterials to achieve the near unity absorption have been discussed. These absorbers is capable of reducing the unwanted reflections and the transmissions of the unknown Electromagnetic radiations to the lowest possible levels. Different types of absorbers along with their special features and the output response has been reviewed in this paper. This paper also provides the purpose of the absorbers in the commercial and stealth applications.

Keywords - Electromagnetic Wave Absorbers, Nanocomposites, Metamaterials, Bandwidth Enhanced, Ultrathin.

I. INTRODUCTION

In the recent years, the researchers have turned their attention towards the design of the EMA because of its immense applications like Radar Cross Section Reduction (RCSR), reflection reduction, Cavity resonance reduction and in the design of the anechoic chambers. It is more important to design the ultrathin, bandwidth enhanced, economical EMA. The conventional EMA are widely used to reduce the unwanted EM radiations by suppressing its reflections and transmissions. But the huge thickness of those EMA is considered to be one of its major disadvantages. Recent studies on EMA have used the nanocomposites and metamaterials to reduce the thickness of the absorber (i.e., to design a light weight absorber). With the use of these materials the thin absorber structures comprising of many unit cells can be designed and achieve the near unity absorption. In addition to the unity absorption, the absorber should also possess some additional features such as angle insensitivity, polarization insensitivity, broad angle, Spatial dependence and enhanced bandwidth absorption. These features make the absorber suitable for various stealth applications.

2. Vishal Kumar et al [3], explained, a novel hybrid nanocomposite absorber with enhanced electromagnetic absorption is designed and tested.The hybrid absorberuses aluminum foil asit's ground and it's FSS pattern printed over a dielectric substrate, which is integrated together with a customized dielectric nanocomposite sheet. The dielectric sheet consists of conducting carbon black (CB) nanopowders embedded into the epoxy matrix. The fabricated nanocomposite sheet is first characterized for the effective complex permittivity using the free-space measurement technique, and the measured electromagnetic properties are then used for the design of a hybrid absorber. The hybrid absorber has an overall thickness of 2.6 mm achieves enhanced−10dB absorption bandwidth of 3.5 GHz, which is higher than that of the FSS and CB nanocomposite samples measured individually. The proposed work provides an effective way to combine the absorption properties of FSS with that of a customized dielectric absorber sheet in order to design an efficient hybrid absorber that has reduced thickness with enhanced absorption bandwidth for stealth technology and various strategic applications.

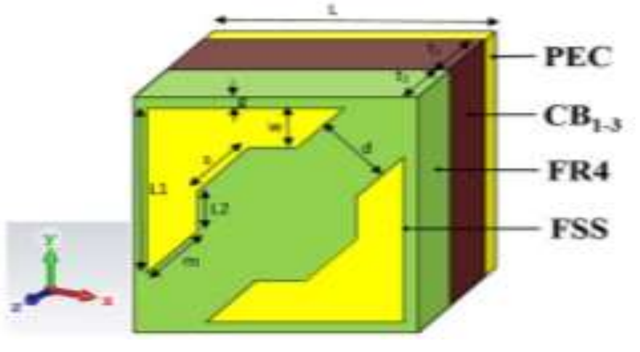

Fig.1. Schematic representation of hybrid absorber with its various dimensions as, L =10, L1 = 6.878, L2 = 1.878, s = 2.828, m = 2.121, d = 3, g = 0.5, ω = 1.5, t1 = 1.8, and t2 = 0.8 (all dimensions are in millimeter).

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The findings of the proposed hybrid absorber demonstrate its potential applications for the enhanced electromagnetic absorption which can be used to reduce the RCS in the field of stealth technology, and for various strategic applications.

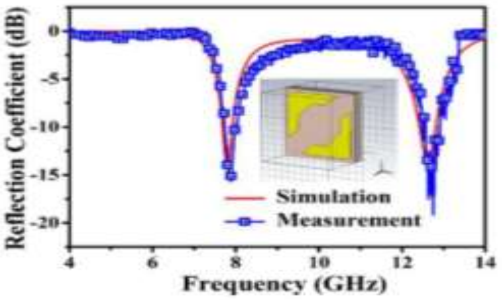

Fig.2.Performances of the proposed FSS absorber

3. Clarie M Watts et al[15], explains, the Metamaterial Perfect Absorber(MPA), which utilises three layers two metallic and a dielectric layer and achieved a simulated absorptivity of approximately 99% at 11.48GHz.The top layer consist of the Electric Ring Resonator(ERR) along with the ground plane. The top layer provides the electric response at the certain resonant frequency by strongly coupled with the incident electric field. The bottom layer separated from the top layer by the polyimidespacer. This study demonstrates that there is a majority of the dielectric losses than the ohmic losses.

This paper further explains the broad angle, Polarization independence and broad bandwidth characteristics of the MPA. This Metamaterial absorber is independent at the type of the polarization. Many of the MPA designs are able to absorb light at an high angle of incidence in the microwave, IR and the THz range. The majority of the MPA designs can absorb for both the TE and the TM modes where the MPA is able to absorb 99% for TM at less than 80° incidence and for TE it's above 90% for angles below 50° of incident angle. The MPA provides the broad bandwidth of absorption as this design utilize a single unit cell that resonates at different spatial area at different frequencies rather than two structures resonating separately.

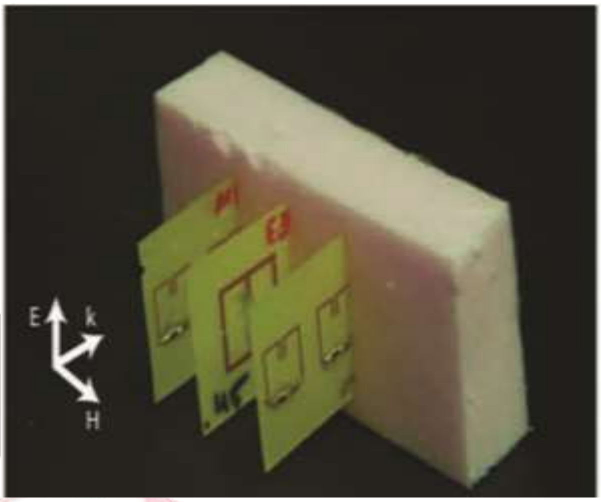

Fig.3.Unit cell consisting of Lumped Elements

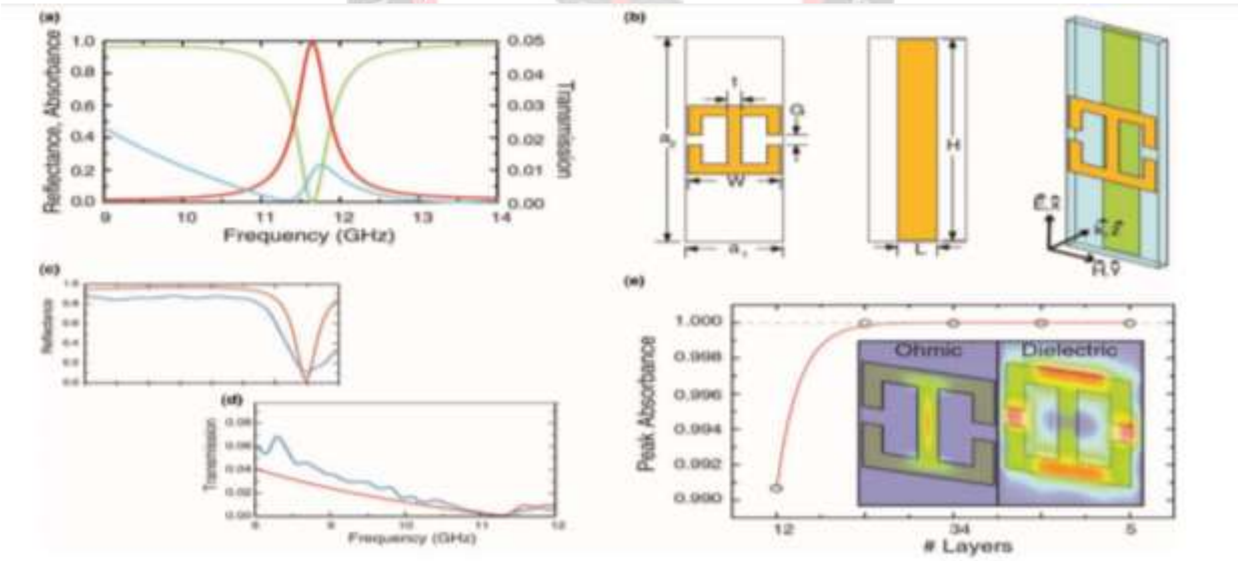

Fig.4. displays results from the experimental demonstration of a Metamaterial Perfect Absorber(MPA) (a)Transmittivity(blue,right axes),reflectivity(green,left axes) and absorptivity(red,left axes); (b)unit cell:top

Metamaterial Layer(dimensions in mm: a_1=4.2,a_2=12,w=4,G=0.6,t=0.6)Cutwire(L=17,H=11.8) and a perspective view(c,d) experimental(blue),simulated (red) results for reflectivity and transmittivity (e)Numerical study on Ohmic Vs Dielectric losses in MPA

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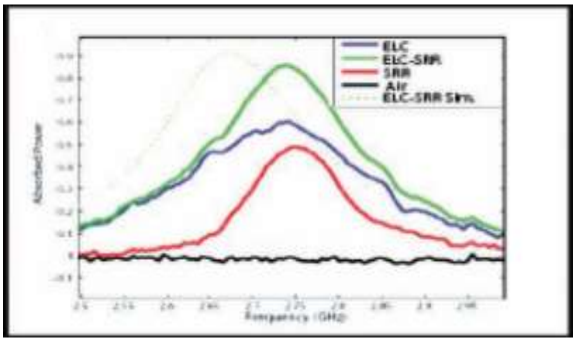

Fig.5.Response of the MPA utilizing lumped elements

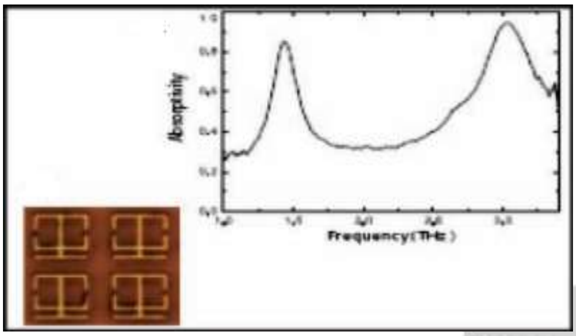

Fig.6.MPA utilizing single structure with dual resonances

4. S.N.Zabri et al[6], worked on recent developments in the manufacture and measured electromagnetic (EM) performance of a new class of thin microwave absorbers based on metal backed resistively loaded Frequency Selective Surfaces (FSS). Ink jet printing technology is shown to be a viable method for creating patterned FSS elements very close to the desired resistance values. This is demonstrated by comparing simulated and measured reflectivity plots for an ink jet and a stencil printed polarization independent absorber that is designed to work in the frequency range 7.1 - 24 GHz. Numerical simulations show that thin FSS absorbers provide radar backscatter suppression, not only in the far field of the illuminating antenna, but also when the EM source is placed very close to the surface of the periodic array. This technology can therefore provide a solution for enhancing the performance of wireless sensors placed close to lossy loads such as the human body. This paper shows that it uses both stencil and ink jet printing techniques to create a thin resistively loaded metal backed FSS absorber. This is a simpler and lower cost manufacturing strategy. The main disadvantage of stencil patterning is attributed to the lack of control of the ink thickness, whereas inkjet printing provides a more repeatable digitally controlled means which is shown to provide surface resistances much closer to the desired values.Integration of the antenna within the FSS absorber structure appears to be feasible and for this arrangement the metal ground plane would provide the necessary electromagnetic shielding.

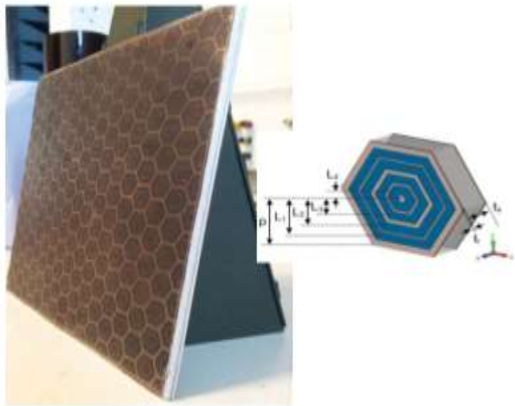

Fig.7.Photograph of the manufactured metal backed FSS absorber and schematic and dimensions of the FSS unit cell; p=6.9 mm, L1=5.6 mm, L2=4.2 mm, L3=2.5 mm, L4=1.1 mm, w1=1.1 mm, w2=1.2 mm, w3=1.1 mm, w4=1.2mm, R=27 Ω/sq, ta=3mm, tt=0.13mm

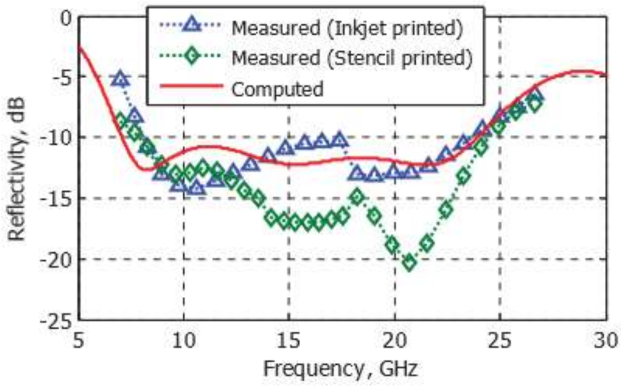

Fig.8.Simulated and measured reflectivity plots at normal incidence

The main disadvantage of stencil patterning is attributed to the lack of control of the ink thickness, whereas inkjet printing provides a more repeatable digitally controlled means which is shown to provide surface resistances much closer to the desired values.Integration of the antenna within the FSS absorber structure appears to be feasible and for this arrangement the metal ground plane would provide the necessary electromagnetic shielding. In future work to increase the Technology Readiness Level (TRL) of this concept, several major issues need to be addressed (i) a reduction in the thickness of the structure, which should be feasible given the less stringent bandwidth requirements and the possibility of using flexible material with a higher permittivity for the spacer, (ii) reduction in the area of the FSS required to give enhanced performance and (iii) modification of the FSS element shape and size and surface resistance to provide a better match (not 377 Ω) to the impedance of the incident wave in the near field of the antenna.

5. RatanakPhon et al[2], explains a multifunctional active frequency selective surface (AFSS) is presented based on

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the switching responses of active components. The proposed structure comprises periodic arrays of metallic patterns imprinted on both sides of an FR4 substrate on which PIN diodes are embedded with parallel feed networks. The novelty of the design lies in its multifunctional characteristics with independent control of the biasing states (ON/OFF) of the diodes mounted on opposite layers. This leads to four different working states (dual-bandpass for OFF-OFF state, single-band absorber for OFF-ON state, single-bandpass for ONOFF state, and reflector for ON-ON state) being facilitated by the proposed reconfigurable AFSS. In this paper, Multifunctional AFSS(MAFSS) structure has been presented in the aim to resolve the limitations based on a compact and unique topology.

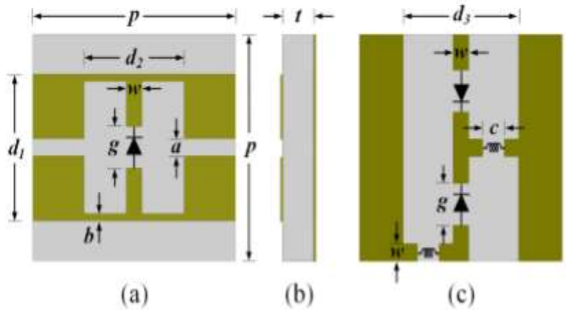
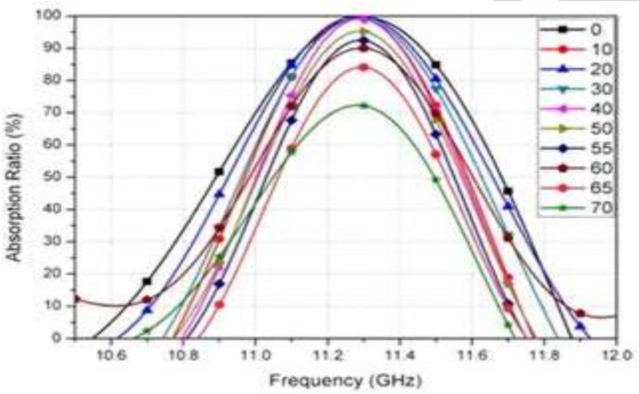


Fig.9. Unit cell geometry of the proposed MAFSS (a) Top view of top layer, (b) side view, and (c) top view of bottom layer.

6. ToanTrunget al[7], presents the design of the incidence angle insensitive metamaterial(MM) absorber using via arrays. The unit cell is initiated from the Split Ring Cross Resonator(SRCR) is insensitive to the polarization angles because of its vertical and horizontal symmetry. However, the unit cell is sensitive to the incidence angles. The outer perimeter of SRCR if loaded with the Via array, the absorptivity and the peak absorption frequency become insensitive to the incident angles.



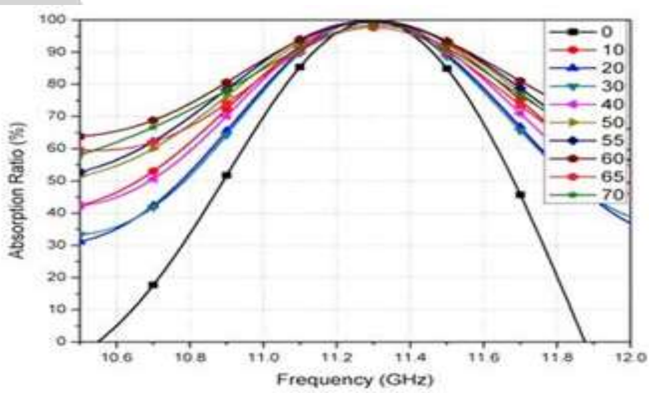


Fig.12. Layout of the Unit cell of an angle insensitive MM Absorber.

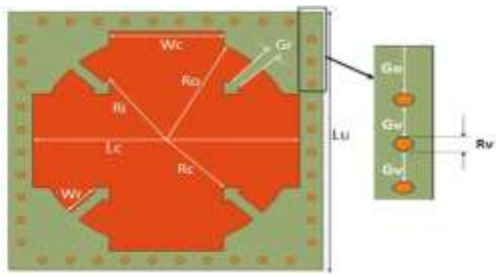


Fig.10.Measurement of the Absorptivity at different Incident Angles

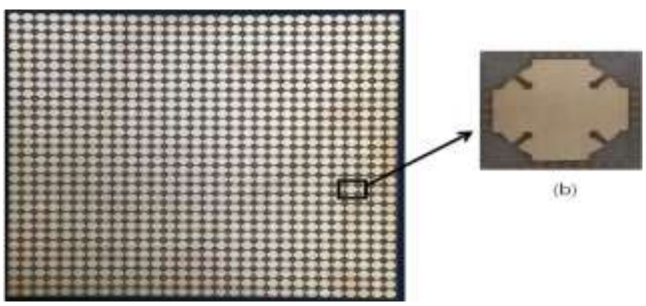


Fig.11.Picture of the Fabricated prototype

The angle sensitivity (SA) with the Via array is 3.57 x10^{-4} at ɵ=70°,while the SA without the via array is 3.64 × 10^{-3} at ɵ=70°incidence angle varies from 0 to 70°, the absorptivity at 11.3 GHz remains higher than 95% up to ɵ=70° and higher than 90% up to ɵ= 60° for the transverse magnetic (TM) and transverse electric (TE) modes, respectively. The incidence angle insensitive MM absorber is proposed using the four circular cross sector as shown in the fig(10).The fig(10) shows the Absorptivity at different incident angles. The simulated absorptivity at the specular angles exceed 90% and the frequency variation is less than 0.7% at approximately 9.26 GHz up to a 70° incidence angle in both TM and TE polarization. It is observed that the measured absorptivity remains above 92% in both TE and TM polarization when the incidence angle is varied from 0° to 70° at 9.26 GHz.In order to increase the bandwidth of the absorber the hybrid unit cells are

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introduced in the four circular cross sector.Owing to the symmetric unit cells high absorptivity is maintained for all the polarization angles. Under oblique incidence the zero reflections for the TE and the TM modes are different andso the unitcell insensitive to the TE and TM polarization must be designed.

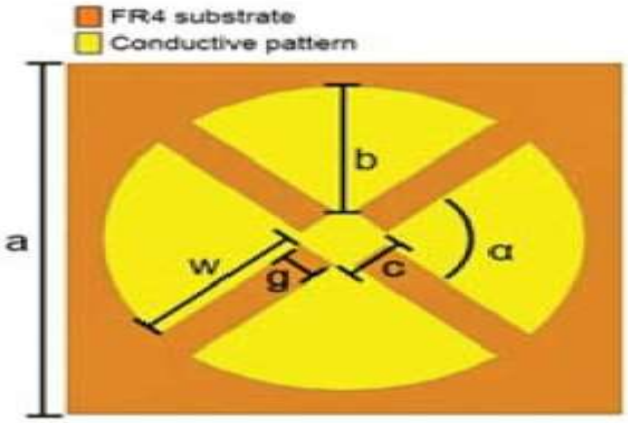

Fig.13.Angle insensitive MM Absorber using four circular sectors

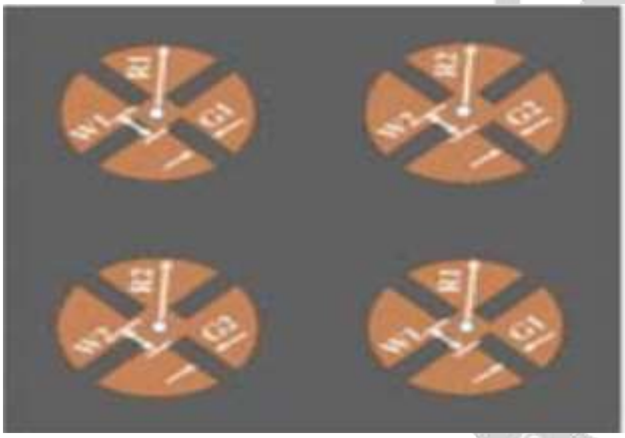

Fig.14.Measured Absorptivity at different incident angles

The simulated absorptivity at the specular angles exceed 90% and the frequency variation is less than 0.7% at approximately 9.26 GHz up to a 70° incidence angle in both TM and TE polarization.This gives the broadband absorption.Under normal incidence,the absorbtivity is greater tha 90% from 8-13 GHz, for all polarization angles.Under oblique incidence, the measured absorptivity is greater than 90% from 8.2–12.2 GHz up to 55° and from 9.2–12 GHz until 65° in the TE mode. For the TM mode, the measured absorptivity is higher than 90% from 9.5–12 GHz when the incidence angle is varied from 0°to 60° and remaining a 90% absorption bandwidth from 10– 11.7 GHz up to 65°.

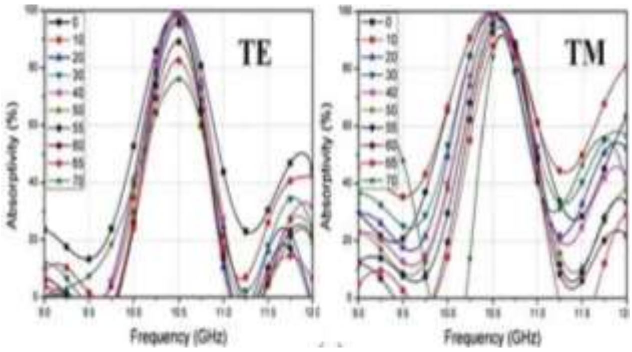

Fig.15.Angle insensitive MM Absorber using Hybrid unit cells

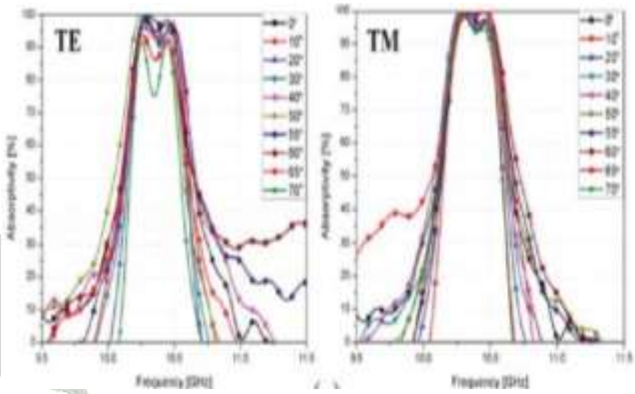

Fig.16.Measured Absortivity at different incident angles

7. M. Wasif Niaz et all[14], explains Lossy frequency Selective surfaces are used to design thin and broadband EM absorbers. FSS of unit cell is based on two concentric Minkowski loops. Two designs have been presented. The first design is designed using Minkowski Loops loaded with lumped resistors in different configurations. The second design uses the concept of resistive sheets for the design of Minkowski Loops. Resistive Minkowski Loops provide very wide bandwidth from 2.2GHz to 9.4GHz and 4.5GHz to 17GHz for reflection loss greater than 10db. Absorber thickness with resistive Minkowski Loops is 0.09λ.

Parameter	Value (mm)
w_1	24
w_2	12.24
w_3	8
w_4	4.08
L_1	4
L_2	2.04
S_1	1.33
S_2	0.68
p	25.74
h_1	12
h_2	0.05

Table1:Physical Dimensions of Unit Cell

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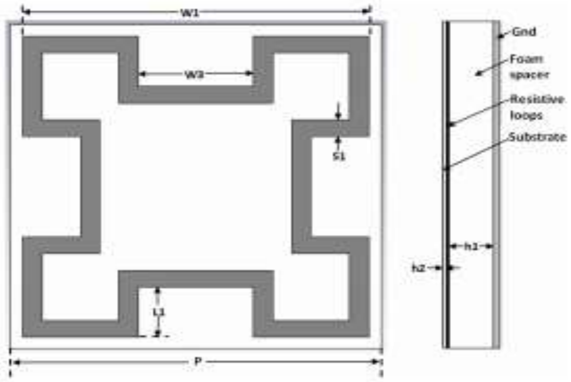

Fig.17.Unit cell of the absorber using single Minkowski loop

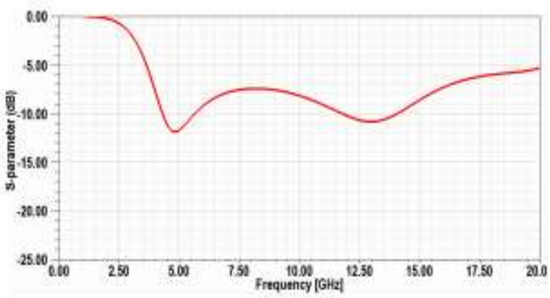

Fig.18. Simulated absorption behaviour of proposed broadband Absorber using single Minkowski loop

A. Broadband Absorber using Minkowski loops with lumped resistors

In this design, a novel unit cell is made upto two Minkowski fractal Loops with three lumped resistors per unit cell. In the unit cell, R_{in}=330Ω, R_{out1}=180Ω and R_{out2}=270Ω.

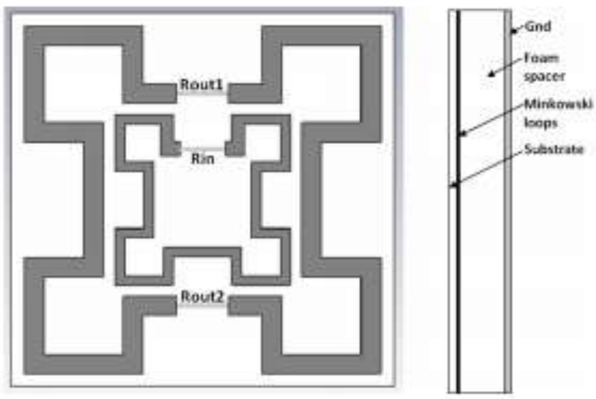

Fig.19.Unit cell of the absorber with only 3 resistors

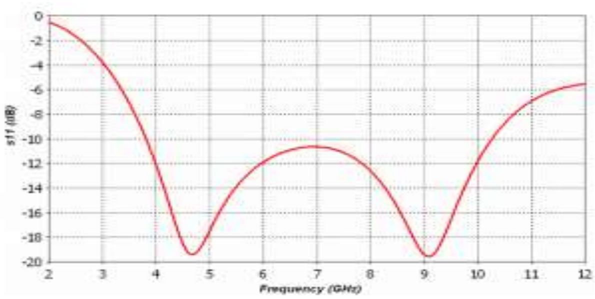

Fig.20.Simulated Reflection lossof the absorber with only 3 resistors per unit cell

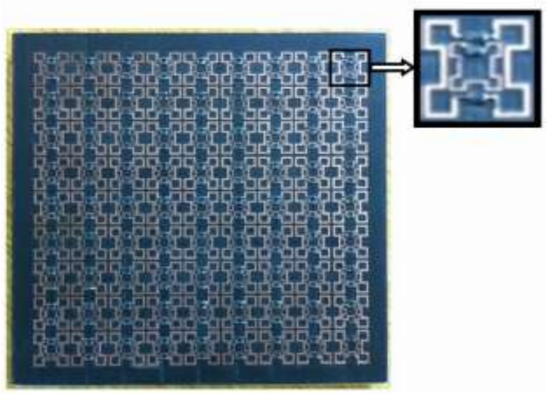

Fig.21.Prototype Broadband Absorber

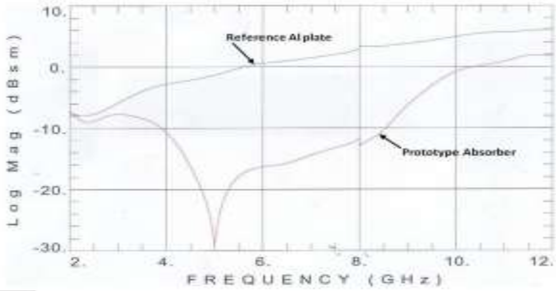

Fig.22.Measured RCS of prototype broadband absorber

B. Broadband Absorber using Resistive Minkowski loops

The absorbers in the previous section are costly and difficult to assemble as Minkowski Loops that are in close vicinity and a large numbers of lumped resistors are used. A new model is proposed in which Minkowski Loops are fabricated through resistive inks. Ansoft HFSS simulation software is used. Resistive ink is set to 10Ω/sq.

Parameter	Value (mm)
w_1	24
w_2	12.24
w_3	8
w_4	4.08
L_1	4
L_2	2.04
S_1	1.33
S_2	0.68
p	25.74
h_1	12
h_2	0.05

Table2:Physical Dimensions of the modified Unit cell

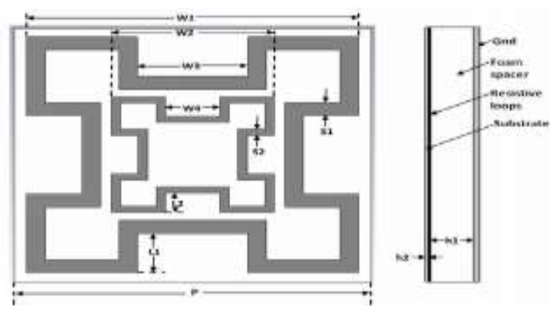

Fig.23.Unit cell of the absorber using two Minskowski loops

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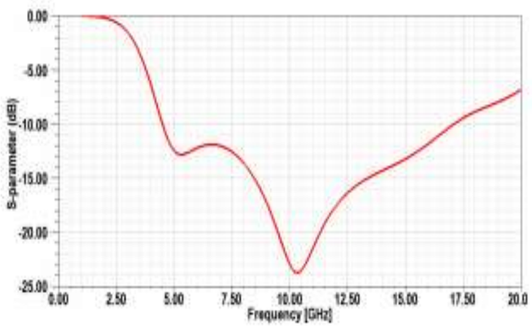

Fig.24.Simulated absorption behaviour of proposed Broadband absorber using two Minkowski loops

II. CONCLUSION

The purpose of this review paper is to bring out the challenging aspects in designing an ultrathin, low cost EMWA to achieve enhanced bandwidth along with the near unity absorption.Various materials like Metamaterials and the Nanocomposites have been used to reduce the thickness of the absorbers.Some absorbers have better absorption but complex structures.The applications of the absorbers in the civilian and defense fields has been presented.Though we can design an ultrathin,lowcost, near unity absorber it is still a challenge to achieve all these features along with the broad angle,angle insensitivity,polarization,insensitivity,perfect absorption.

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