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Comparative Analysis of Metamaterial Substrate and Fabric Substrate

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Abstract: Fractal structures have the property ofself-similarity and ease of repetitiveness; they remain less used in planar patterned metamaterial structures. A fractal antenna is design based on the metamaterial for multiband applications. The Fractal Antenna design is consist a metamaterial layer with FR4 substrate with $\varepsilon_r = 4.4$ .The proposed antenna consists of a octagonal radiating patch and a partial ground plane. The substrate of the proposed antenna is made of Dacron fabric with permittivity 3.The dimension of the proposed antenna substrate is 40×34×1.7 mm^3 and the bandwidth 10.969 GHz starting from 38.965 GHz to 49.9333 GHz for return loss less than -10 dB. The gain variation is from 3.2 dB to 11.2147 dB.

Key words: HFSS, Fractal, Metamaterial, Return Loss, Bandwidth, Gain

I. INTRODUCTION

The technology of ultra-wide band is very old , but in wireless communication system. The technology has high data rate & avoiding more spectrum scarcity. The main application of such technology in traffic regulation, ground penetrating and mine detection . [1] To design an antenna, different feeding and coupling methods are used. These techniques provide higher bandwidth but unfortunately gain is to be degraded. In such situations, new types of material are used known as metamaterial. These are artificial material which shows negative permittivity & negative permeability.[2]

Enhancing the gain is done by left handed material, also known as negative refractive index material. Metamaterial property can be obtain in two way , one is split ring resonator and another one is metal wires.

Now, these materials provides lossy and narrow band. For wide band operations fractal antennas are used [3] .

Fractal antenna is designed with the help of LC circuits. So, operating frequency of antenna is tuned using L and C parameters. So, fractal antenna is used for two purposes, multiband operation and wideband according to requirement. Fractal shape antennas have some unique characteristics i.e have various geometry and properties of fractals. These are define by structures whose dimension is not a whole numbers. Fractals antenna have unique geometry whose features occurring in whole numbers. These antennas can be used to describe branches of tree leaves and plants and rough terrain [5].

Metamaterials are design in accordance to electromagnetic properties. In electromagnetic, different metamaterial is used to design the fractal antenna in applied electric field. For EM characteristics of wave, permittivity and permeability are sufficient descriptor and predictor. These are defining by Maxwell equation[4]. The Maxwell equation is given as

$$\nabla \times H = \epsilon \frac{\partial E}{\partial t}$$

$$\nabla \times E = -\mu \frac{\partial E}{\partial t}$$

$$\nabla . D = \rho$$

$$\nabla . B = 0$$

The main challenging task of antenna is to achieve minimum return loss & maximum gain. This problem can be solved using metamaterial & fractal antenna in integrated form. Previously reported works are based on single frequency band radar antennas [3] and later dual frequency band radar antennas [4]. In the recent researches, Wideband, UWB and SWB technology is one of the most fascinating choices for WBANapplications. Many of SWB antennas using rigid substratematerial [5-6], large in size and small bandwidth [7-10][12-13]have been reported. However, it is quite difficult to obtainlarge bandwidth with compact size and a very low thickness in case of air bone antenna system . In this paper, a novel and compact design of SWB antenna is proposed for WBAN applications by merging the SWB technology with radar technology.This paper is motivated from the above reported papersand presents a novel design of a wearable Octagonal SWBtextile antenna. Novelty of this work is the slotted area ofhexagonal patch that represents the “wireless antenna” iconwhich is unique and also compact in size. The bandwidth ofthe proposed antenna operates in the wide range, achieving the SWB system requirements.The rest of paper is design as follows. The related work of fractal antenna & metamaterial is described in section II. Frame work of overall paper is describe in section III. Simulation results & analysis is described section IV. The overall conclusion of review describe in section VI.

II. LITERATURE SURVEY

BikashRanjan*et.al* in 2016 has tried to showcase out the impact of various substrates on Metamaterial Antenna for various dimensions with differ in applications irrespective of the use of same applications. FR-4, Rogers RO 3003 and Rogers RT Duroid5870 was used to design the antenna. The T shaped antenna is used. The designed antenna was give return loss is -47.3db and gain was 7.05 db. The bandwidth was achieved up to 26.2 MHz[1].

G.K Pandey*et.al* in 2014propose a new metamaterial based antenna with ε_r = 4.4. The antenna had pi shape slots on the radiating patch & cross shaped patch on the ground. The overall antenna result was -38.5 db for getting scattering loss. The antenna was used for ultra-wide band operations. The bandwidth was achieved up to 3.7 GHz [2].

BalamatiChoudhury*et.al* in 2013designed a SRR metamaterial based antenna. Practical swarm optimization is used to analysis the results The return loss, directivity and bandwidth of antenna were -31.52 db , 7.79 dbi and 340 MHz respectively [3].

R.-B. Hwang *et.al* in 2009proposed a splitter, had double negative level substrate. Rogger FSS layer was used to design the substrate. The return loss , gain , bandwidth was achieved upto -21.5 db , 9.1 db and 511 MHz respectively. The antenna was designed for wireless local area network [4].

SiddharthBhat*et.al* in 2014 presented a fish shaped UWB antenna. The FR4 metamaterial was used with 6×2 metamaterial units on the ground plane. The Return loss and bandwidth of antenna was -26.1db, 3.1 GHz respectively. The antenna was designed for WLAN and mobile phones [5].

Zuhura Juma Ali *et.al* in 2014proposed Taconic RF-30(tm) based metamaterial having relativity permittivity 3. The return loss , gain and bandwidth was -27.5 db , 6.57 db and 642 Mhz. The antenna is designed for multiband operation applications [6].

Jingtao Zhu *et.al* in 2016proposed zero refractive index metamaterial. The gain, efficiency and bandwidth was achieved upto 7.17 db , 70% and 11.346 GHz. The different meshing operations are performed [7].

M. I. Ahmed *et.al* in 2016 proposeda square shape metamaterial with FR4 substrates. The return loss and efficiency was achieved upto -23.54 db and 39.1 %. The antenna was designed for GPS system and WBAN system [8].

Karthikeya G S *et.al* in 2016 proposed 1d antenna metamaterial array. The antenna was operated a range from 56.2 GHz to 62.76GHz. The antenna was work for ultra-wide band operation with bandwidth 6.5 GHz [9].

Natalya N. Kisel*et.al* 2016proposed a ring resonator fractal antenna. The return loss, directivity and bandwidth of antenna were -18.223 db , 6.09 dbi and 403 MHz respectively [10].

Udaykumar*et.al* in 2016 proposed a metamaterial based on diagonally connected square split ring resonator. The return loss, gain , bandwidth and efficiency of antenna was -18 db , 1.2 dbi , 28 MHz and 17.5 % [11] .

Zain Bin Khalid *et.al* in 2016 proposed zero index antennas. The return loss, gain, bandwidth and efficiency of the antenna were -22.36 db, 1.41 dbi , 3 GHz and 50% respectively [12].

III. FRAME WORK OF PAPER

The metamaterial substrates are used in the antenna. Metamaterial are substrates which show negative permittivity & negative permeability. The propose methodology of research work is optimized design of antenna with proper feed. In proposed antenna coaxial feed applied to obtain gain & bandwidth.

The steps of design of metamaterial based fractal antenna are as shown in the fig 1. The firstly we design the substrate having dimension 46.4 × 32.6 × 1.6 mm^3 .The substrate having material FR4 with relative permittivity 4.4. After designing the substrates, metamaterial is design with square shape with small slots all around it.

Fractal antenna is designed with 6mm length. These antenna is design with two square cut with 45° angular rotation.

An Dacron substrate with 4.4 and thickness 1.7 mm was used in this design. The dimensions of the patch antenna were chosen in such way that when octagon radiate energy.

A patch of area 30 ×30 mm was selected. Such a patch resonated at 42.04 GHz in normal operating mode. To reduce the resonant frequency of the patch antenna, zero iteration was etched out from its radiating patch at its center. After that it is compare with second iteration which was etched out from its radiating patch as in star form.

In the design of the zero iterationpatch, the dimension of the star length was varied and the antenna was tuned to resonate at 42.04 GHz using the commercial software HFSS. The final design obtained is shown in Fig. 1. The length of each side was 11.078 mm. The feed line width was 13.49 mm, which gives a characteristic impedance of 50 **Ω**. The top view of octagonal patch antenna is as shown in the fig 1.

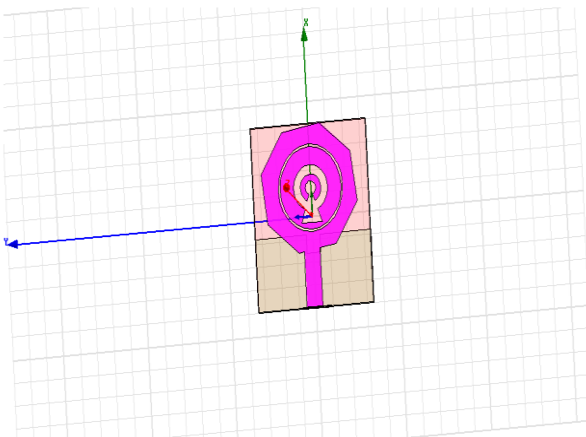

Fig 1. Top View of Octagonal Patch Antenna

The proposed antenna is compare with ground slotted patch antenna as shown in fig 2.Dimension of ground is 16 × 34 mm. A square notch is cut into the ground surface. This notch enhances the gain & minimizes the return loss.

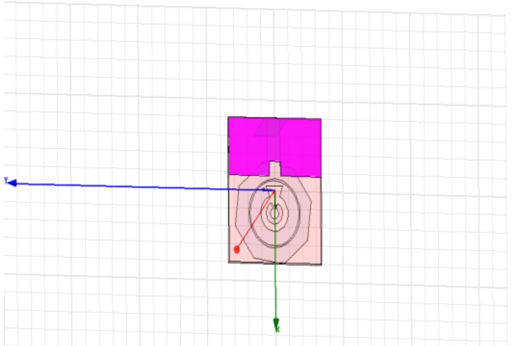

Fig 2. Bottom View of Octagonal Patch Antenna

The main objectives of the work are to design a fractal antenna with metamaterial substrates. The return loss of antenna should be minimum & gain should be maximum. The main aim of the overall work to enhance the bandwidth [13-16].

The overall design is based on the irregularity of design with iteration form. The antenna is design up to 2nd iteration with three level of the antenna. The return loss is obtained from this fractal antenna. The return loss is to be minimum. It is obtained by changing the feed position. The feed position is alternated by set a variable to position. The position is rotate in complete plane. The best optimized position is set by simulation tool. At this feed position minimum return loss and maximum gain is obtain.

IV. SIMULATION RESULT & ANALYSIS

Fractal Antenna is designed with repeating iteration antenna. This shape provides identical results of an antenna. The fractal antenna having 6mm edge. The edge length is reducing according to iteration. The fractal antenna design is given in fig 3.

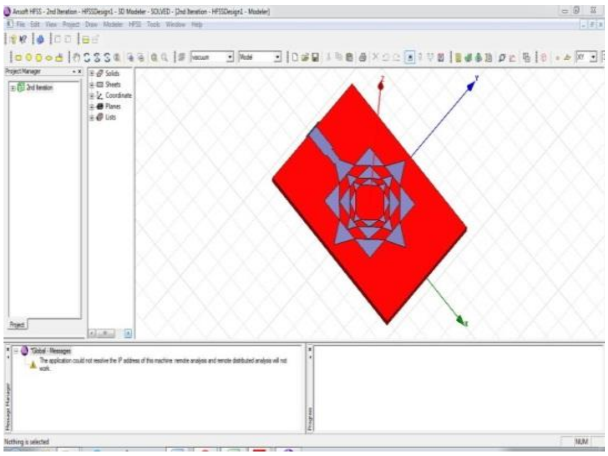

Fig 3. Fractal Antenna design with Metamaterial Substrates

The return loss of metamaterial based fractal antenna is -17.4276 db. The return loss of proposed antenna is given by fig 4. This graphs shows that return loss becomes more negative as compared to previous results.

Gain is improved with repeating shape. Radiation pattern of gain given in fig 5. Gain of proposed fractal antenna is 15.8533 db.

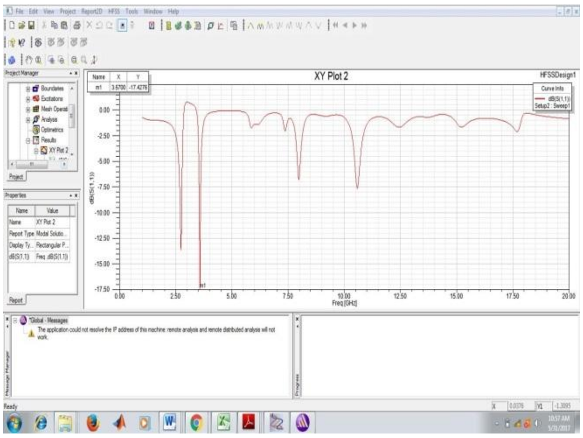

Fig 4 Return loss of antenna

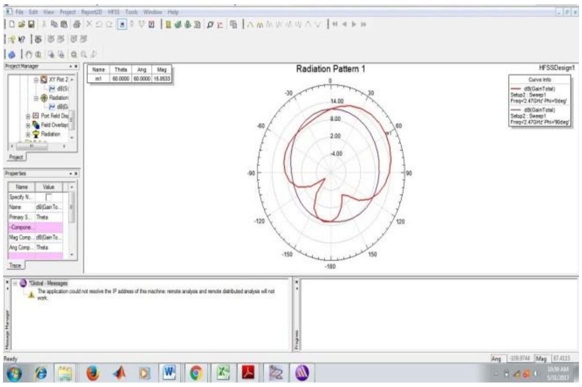

Fig 5 Gain of Antenna

Return Loss is important parameter for an antenna design. The ideal return loss is assumed to be -10db. Return loss should be minimum. The antenna is simulated in HFSS tool and return loss is measure. In case of octagonal patch antenna return loss is -15.0988 db. The return loss of octagonal patch is given by fig 6. This graphs shows that impedance matching of port to the antenna

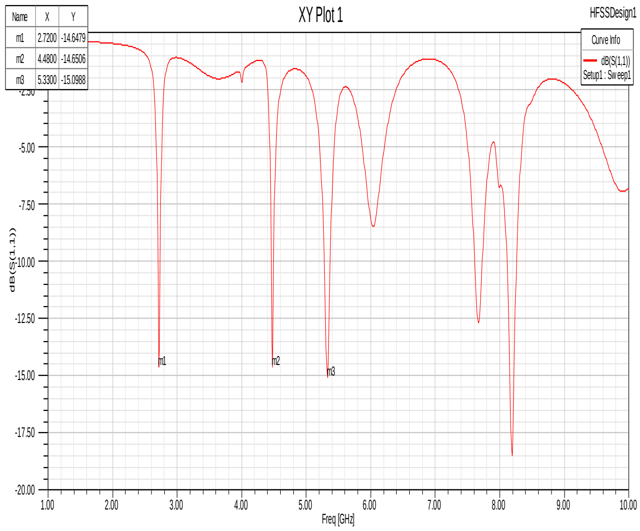

Fig 6. Return Loss of Octagonal Patch Antenna

Gain is also an important parameter to design an antenna. The Gain enhanced by drawing different slots. Radiation pattern of gain given in fig 7. Gain of zeroth iteration antenna is 1.2841db

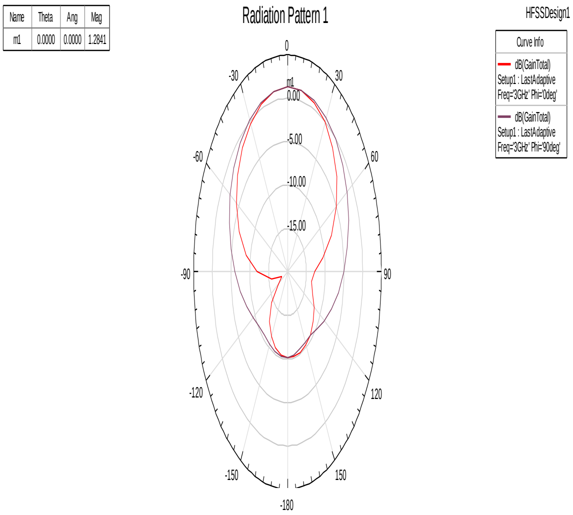

Fig 7. Radiation Pattern of Gain of Octagonal Patch Antenna

In case of slotted antenna, return loss is -32.711 db. The return loss of slotted antenna is given by fig 8. This graphs shows that return loss becomes more negative as compared to simple octagonal antenna.

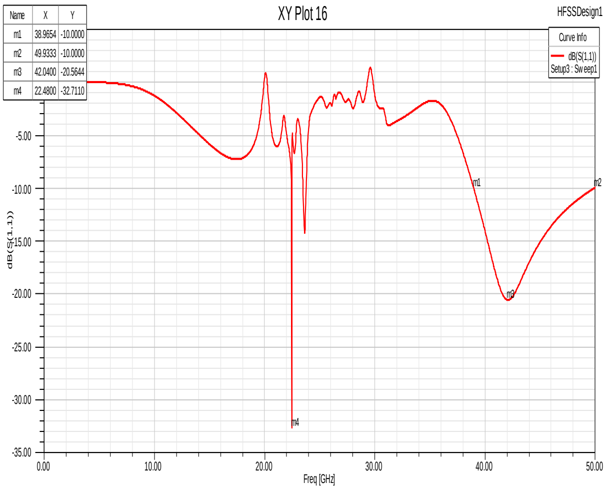

Fig 8. Return Loss of Octagonal Patch Antenna with Ground Slot Antenna

Gain is improved with designing name initial slots. Radiation pattern of gain given in fig 9.Gain of slotted antenna is 11.2147 db.

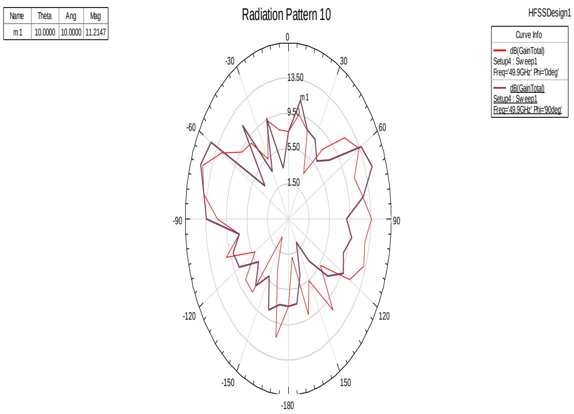

Fig 9. Radiation Pattern of Gain of First Iteration Antenna

The comparison of the result of antenna is done on the basis of return loss, gain, and bandwidth. The comparison analysis with previous result is given in the table 1.

Table 1. Comparative analysis of different iteration of Fractal Antenna

Sr. No	Parameter	Reference Paper [1]	Proposed Antenna
1.	F_L	3.12	2.97
2.	F_H	3.68	4.12
3.	F_0	3.45	3.45
4.	% B.W	16.23	33.33
5.	Return Loss	-13.220	-17.4276
6.	Gain	7.6309	15.8533

Table 2. Comparative analysis of different iteration of Octagonal Antenna

Sr. No	Parameter	Simple octagonal Patch Antenna	Simple octagonal Patch Antenna with initial slots
1.	F_L	14.9	13.05
2.	F_H	19.67	23.52
3.	F_0	17.45	17.45
4.	% B.W	27.33	60
5.	Return Loss	-15.0988	-32.711
6.	Gain	1.2841	11.2147

V. CONCLUSION

The antenna is designed for improving gain & bandwidth. The antenna operates at 3.45 GHz. The return loss of the antenna is -17.427. The gain of the antenna is 15.8533 db. Future scope of antenna is to use in multiband frequency operations.After Simulation, it is found that Octagonal patchantenna has low return loss with high gain andbandwidth. Simulated return loss is -32.711 with gain 11.2147 db and bandwidth 60% is obtained from slotted patch antenna. This range of frequency is used in air bone radar system.

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