PERFORMANCE IMPROVED TRIANGULAR MULTI BAND ANTENNA USING REACTIVE IMPEDANCE SUBSTRATE AND FREQUENCY SELECTIVE SURFACE

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In modern world, communication devices need to be operated for more than one frequency bands. Lot of research works were carried out in the field of multiband antennas. The one major concern in the design of multiband patch antenna are the gain and bandwidth. Both gain and bandwidth of the multi band antenna can be improved for the better performance. In this paper a triangular multiband antenna is designed and the gain of the antenna is enhanced by the blend of reactive impedance surface and Frequency selective surface. The proposed antenna resonates 3.4 GHz, 4.2 GHz, 6.75 GHz,7.1 GHz, 7.5 GHz and 9.3 GHz with a better return loss and gain.

Keywords:Triangular Microstrip Antenna (TMSA), Reactive Impedance Surface (RIS) Matematerial (MTM), Frequency Selective surface(FSS)

1. INTRODUCTION

1.1 Multiband Antennas

The development in communication system, provides opportunity for the researchers in developing antenna for multiple operating facility. These Modern antennas can resonate at multiple frequencies which can be used for variety of applications. The feature of patch antennas like low cost, low weight will facilitate the investigators to develop multiband operation in it. Multiband patch antennas are proficient to operate for more than one wireless communication standards in a single device. The multiple resonances are fashioned by making slots in either patch or ground plane [23-24].

1.2 Triangular Microstrip Antenna (TMSA)

The patch of the microstrip antenna come up with variety of shapes using variety of shapes like rectangular, triangular, circular, square, elliptical, annular ring, etc. The patch area required for Triangular patch is half of the area required by the rectangular patch antenna. Triangular patch antenna can be installed much easier in narrow space than rectangular patch. The dual and triple band operations can be implemented easily in Triangular patch antenna.

A CPW fed Triangular patch antenna with dual triangular slots was designed to operate on dual band frequencies was proposed [1]. A compact Fern fractal based Triangular patch antenna for vehicular communication was designed to operate at 5.88 GHz[2]. The Triangular patch antenna loaded with triangular meta surface was intended to operate over multiband operations was proposed [3]. An Equilateral Triangular patch antenna with Defected ground structure was proposed for Frequency reconfigurable operations [4]. The triangular patch structure was presented by Helszajn and James. The patch can be designed either in equilateral or right-angled triangle to form a TMSA. The Triangular patch antenna has very broad radiation characteristics [5].

2. PERFORMANCE ENHANCEMENT OF PATCH ANTENNA

The performance of the antenna can be enhanced by improving the parameters like return loss, gain and bandwidth. The techniques like incorporating the Metamaterials, Defected ground structure (DGS), Electronic Band gap structure (EBG), Reactive impedance structure (RIS), Frequency selective surfaces (FSS), Partially reflective surfaces (PRS), Artificial magnetic (AMC) etc., are proposed to enhance performance of the antenna. This paper presents the use of Reactive impedance surface and Frequency selective surfaces to improve the performance of the antenna.

2.1 Reactive Impedance Surface (RIS)

A periodic arrangement of metallic shapes over the grounded dielectric substrate forms a structure called Reactive impedance surface. The artificial created periodic arrangement of unit cells, forms the Reactive impedance surfaces. This unit cells produce capacitive impedance. RIS layer is placed above the ground plane with a minimal distance (height of the substrate) yield inductive property. The desired impedance of the patch is obtained with the help of this inductive and capacitive impedances. In order to obtain the desired performance,

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the Reactive Impedance Surface can be tuned anywhere between PEC and PMC surfaces. The interaction between the patch and substrate is curtail by RIS layer.
The impedance of the RIS can be obtained by

$$Z_{ris} = \frac{X_L X_C}{X_L - X_C} \quad (1)$$

$$X_L = jZ_d tank_o \sqrt{\varepsilon_r} h_2 \quad (2)$$

$$X_C = \frac{1}{j\omega C_{ris}} \quad (3)$$

Z_{ris} – Reactive impedance of RIS
X_L, X_C - Inductive and capacitive impedance of RIS

The bandwidth can be widened by using inductive impedance of RIS and miniaturization of the antenna can be done using capacitive impedance of RIS. A multiband metamaterial-based antenna was designed and the performance was enhanced using RIS [6]. A Meandered line shaped RIS was used as a ground plane for MPA, which facilitates miniaturization of the antenna [7]. To enhance the radiation characteristics of antenna a multi stacked patch with RIS was designed to operate over triple band frequency [8]. A bandwidth enhanced miniaturized patch antenna using RIS and coplanar parasitic patches was proposed and designed [9]. A high gain wideband array antenna was designed and the performance was improved using RIS and Fabry perot cavity resonator [10-11].A H- shaped Reactive impedance surface was loaded with Koch fractal patch for S and C band applications was presented [12]. A multiband antenna performance was enhanced using RIS layer was presented [13].

2.2 Frequency Selective Surface (FSS)

Frequency selective surfaces are also called as meta surfaces. These meta surfaces are built over the patch with minimal airgap. The surfaces permit or block the electromagnetic waves with respect to the frequency. Due to this Frequency selectiveness property this structure is also called spatial filters. The array of periodically arranged unit cells forms FSS layer. The meta surfaces are high impedance surfaces that are incorporated over the dielectric slab. Meta surfaces exhibits either transmission or reflection properties with respect to the arrangement of unit cells.

Resistive and inductive impedance on the surface are created by the unit cells and the gaps between the unit cells offers capacitive impedance.

During the EM wave transmission, the unit cells will act as equivalent resonance circuit. The frequency of resonance is given as

$$f_{r} = \frac{1}{2\pi\sqrt{LC}} \quad (4)$$

The gain enhanced Multipattern FSS based reconfigurable antenna was proposed and designed [14]. A compact dual band antenna with single layered FSS was proposed and the gain of the antenna was improved over 50% [15]. A triple band antenna with single layer FSS was demonstrated to get high directional characteristics [16]. Transmission properties of FSS based Multiband Fractal antenna was described [17]. Design of High gain wideband resonator cavity antenna using FSS was proposed [18]. A metamaterial based dual band antenna was designed and the gain of the antenna improved with the help of FSS [19]. An improved gain metamaterial superstrate based dual band antenna was proposed and designed [20]. A dual ring shaped FSS was incorporated over rectangular patch to enhance the gain and bandwidth of the antenna [22]. A square slot with stub shaped FSS was intended over rectangular patch to provide multi band operations [22].

3. ANTENNA DESIGN

This paper presents a triangular patch antenna with triangular spilt ring resonator. The performance of the designed antenna was improved with the help of reactive impedance surface and frequency selective surfaces. The combination of RIS and FSS layer is proposed. The proposed antenna, has the geometry of 50*30*1.6 mm^3, which is shown in Figure 1. The antenna designed using FR4 material with relative permittivity of 4.4, loss tangent of 0.02 and thickness of 1.6 mm. The antenna is fed with 50 Ω microstrip line. The antenna was designed in 3D EM simulation tool. The dimensions of proposed antenna are listed in the Table 1.

Table 1 Design parameters of proposed antenna

Parameter	Value (mm)	Parameter	Value (mm)
L	50	W_2	0.2
W	30	L_3	2.8
L_1	22.8	W_3	0.3
W_1	3.05	a	26.4
L_2	5	a_2	6.5

The design flow of antenna as follows. First the triangular patch antenna with triangular split ring resonator was designed. The design equations of the triangular patch antenna is listed below. The schematic of triangular patch antenna is represented in figure 1.

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$$a = \frac{2c}{3f_r\sqrt{\varepsilon_{eff}}} \qquad (5)$$

"ε_{eff}" is effective dielectric constant, and this can be found using

$$\varepsilon_{eff} = \frac{(\varepsilon_r-1)}{2} + \frac{(\varepsilon_r-1)}{4}\left[1 + \frac{12w}{h}\right]^{-(1/2)} \qquad (6)$$

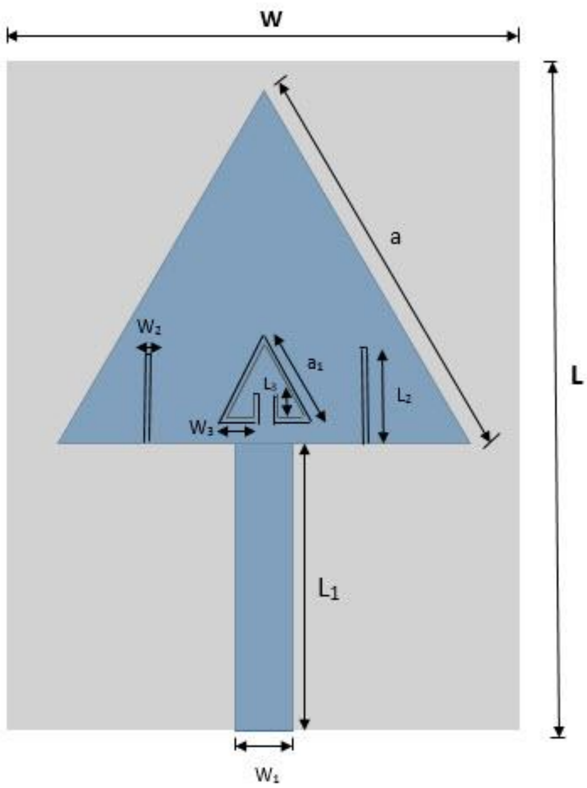

Fig. 1 Schematic of the proposed TMSA

To enhance the performance of the antenna, a reactive impedance surface was introduced between patch and ground plane and a Frequency selective surface was introduced above the patch. The cross-section view of the proposed antenna is shown in the figure 2.

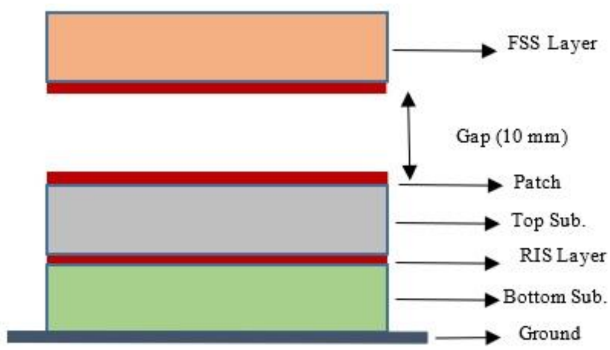

Fig. 2 Cross sectional view of proposed antenna

The proposed structure has 2 substrate each has the height of 1.6 mm. RIS layer has formed on top of the bottom substrate. The triangular patch is positioned over the top substrate and ground plane is positioned below the bottom substrate. The FSS layer formed above the triangular patch with minimal air gap of 10 mm.

Both RIS and FSS structures are formed using array of unit cells with equal spacing. The cross shaped unit cell is introduced in the proposed system which is represented in the figure 3.

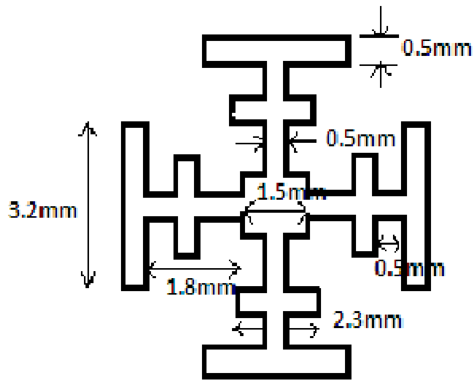

Fig. 3 Structure of unit cell.

Array is formed using 4*3 unit cells as represented in the figure 4. This array is used to form FSS and RIS layer. The FSS layer modify the radiation characteristics of the patch using partial reflection property and RIS layer decreases the coupling between patch and ground plane. There by this combination alters and improve radiation characteristics of the antenna.

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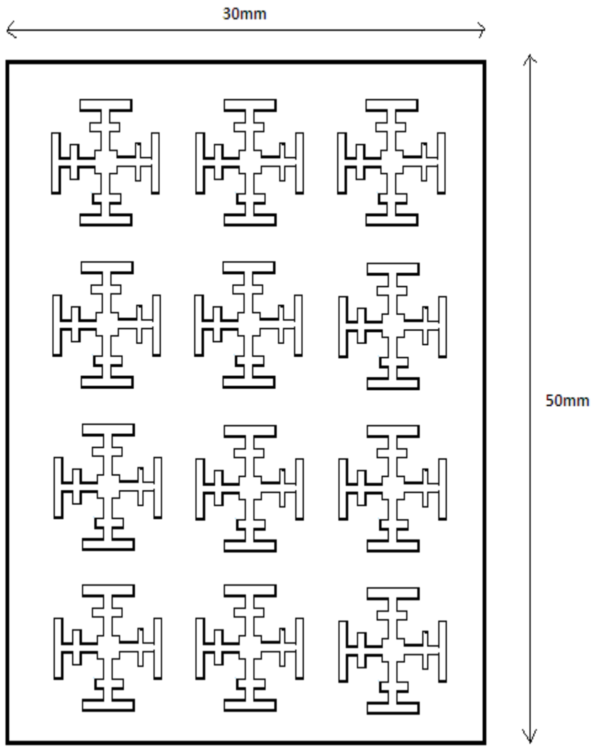

Fig. 4 Structure of RIS and FSS Layer

4. RESULTS AND DISCUSSION

The return loss and VSWR of the proposed antenna both stimulated and measured results are represented in the figure 5 and 6. Both the stimulated and measured results are similar to each other.

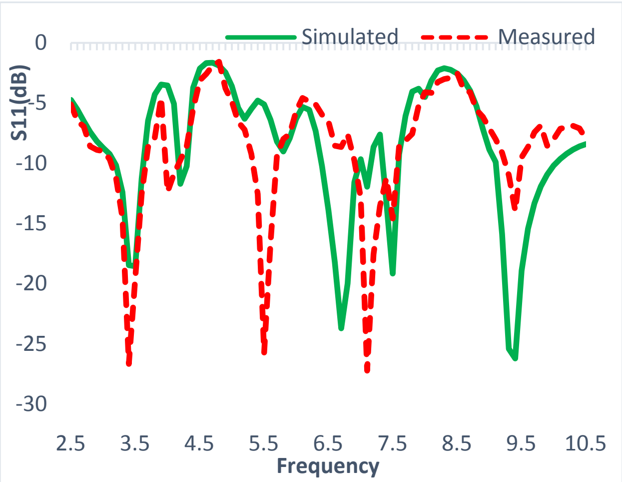

Fig. 5 Return loss of the Proposed Antenna both simulated and measured

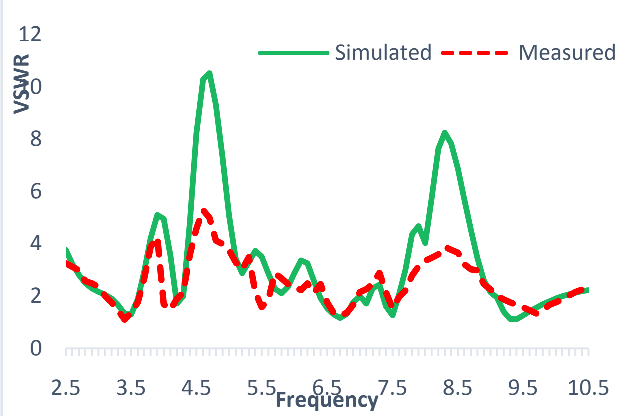

Fig. 6 VSWR of the Proposed Antenna both simulated and measured

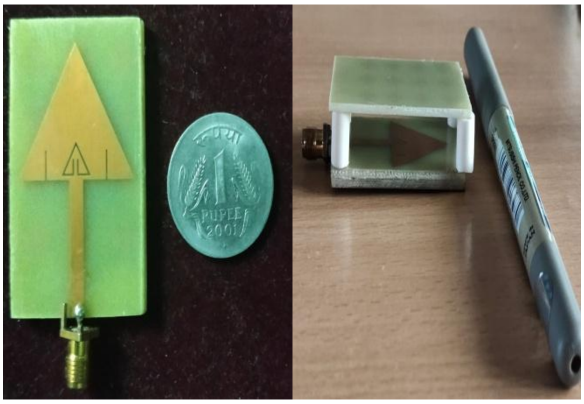

Fig. 7 patch structure and cross-sectional view of fabricated prototype

To ensure the results the antenna is fabricated and then tested using Agilent Vector Network Analyzer (VNA). The patch and cross-sectional view of the prototype is represented in figure 7.

The E and H plane radiation characteristics of the proposed antenna is illustrated in Figure 8&9. The designed antenna gives omni directional radiation characteristics and radiations are also stable in desired bands.

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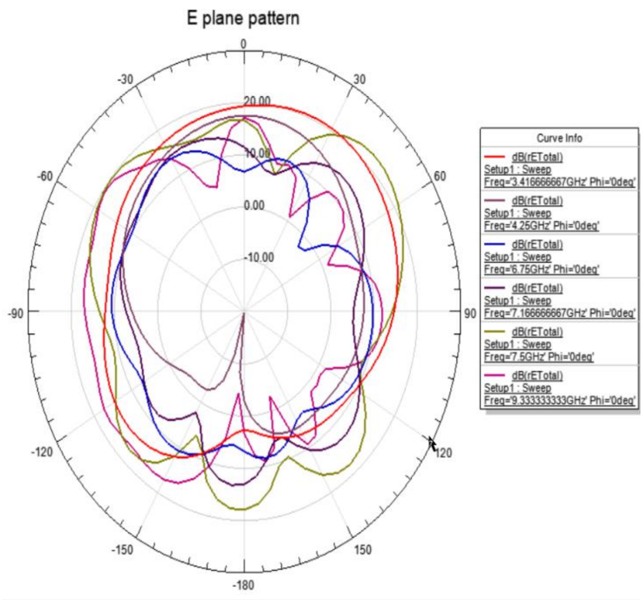

Fig. 8 E- plane Radiation Characteristics for all six operating bands

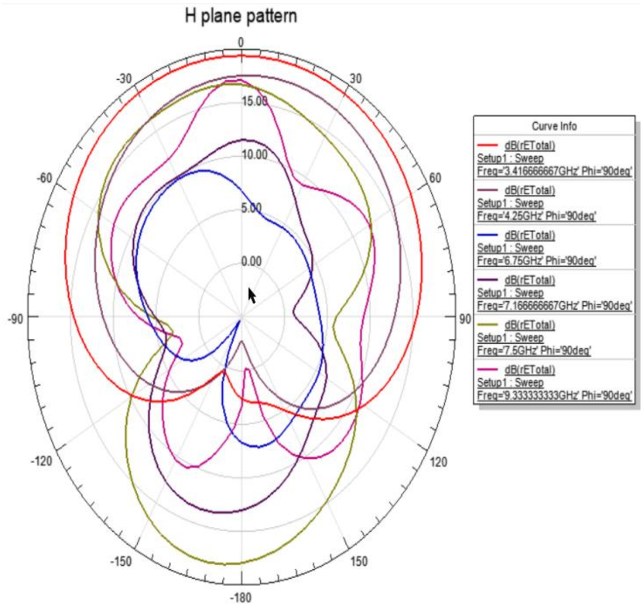

Fig. 9 H- plane Radiation Characteristics for all six operating bands

Table 2 Comparison with previous works

Ref.	**Size of the antenna**	**Frequency bands covered (GHz)**	**Antenna type**	**Peak gain (dB)**	**Applications covered**
[1]	42*46	3/4.4	Dual	1.8 /2.6	GSM/ Satellite Comm.
[3]	30*40	6.6/9.2/10.9/ 11.5/11.9	Multiband	3.4/3.7/8.8/ 6.1/ 4.4	X band satellite comm./ Defence applications
[4]	80*100	1.93/3.7	Dual band	2/ 2.4	L band Satellite comm. / 4G comm.
[5]	24*27	1.7/2.04/2.16 / 2.25	Multiband	5.1/5.86/6.2 /6.3	GSM, S band satellite comm.
[7]	80*80	1.17/1.22/ 1.57	Triple	0.73/1.1/ 3.3	GPS applications
[8]	64*64	2.38/2.68/ 2.98/ 3.18	Multiband	4.3/4.5/5.6/ 5.4	S band wireless comm.
[11]	36*36	3.4/5.35	Dual	3.9/1.84	Air borne SAR system
[12]	100*100	2.45/3.5	Dual	8.4/7.9	Vehicular Comm.
[13]	36*38	2.4/5	Dual	-	WLAN
[18]	56*56	2.4/3.5	Dual	3.2/2.5	WIFI/ WiMAX
proposed	30*50	3.4/4.2/6.7 /7.1/7.5/ 9.3	Multiband	3.4/ 1.62/ 0.4/0.6 1.79/ 2.08	WiMAX/ radio altimeter /RADAR/ X band wireless applications

Table 3 Concluding summary Table

With RIS & FSS	Resonant Frequency	3.4	4.2	6.75	7.16	7.5	9.3
	Return Loss	-13.7	-14.29	-25.63	-12.06	-35.5	-34.4
	Gain (in dB)	3.4	1.62	0.40	0.60	1.79	2.08

5. SUMMARY

A Triangular shaped patch antenna for multiband applications is proposed and designed. The performance enhancement is done by the combination of Reactive impedance surface and Frequency selective surfaces. The proposed antenna operates over six resonances with better return loss and gain.

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