Triple Frequency G-Shape MIMO Antenna for Wireless Applications

Sowjanya Kesana, Suneetha Gatikanti, Zia Ur Rahman, Bellam Radhika, Donthamsetti Mounika

Abstract: ***A compact Triple frequency MIMO (Multiple Input multiple Output) antenna is indispensable in modern wireless applications. This paper proposed a Triple frequency micro strip patch antenna for military (X Band) applications in wireless communications. The antenna is designed on FR-4 (Flame Retardant-4) epoxy material with dielectric constant 4.3. The Micro strip patch antenna is designed over a substrate size of 70×70 mm^2. The antenna consists of a micro strip feed line and G shaped patch antenna with partially stepped ground (PSG). The proposed antenna covers Wi-Max, WLAN and X band applications. In order to enhance the narrow bandwidth and gain, we are using Partially Stepped Ground (PSG). PSG is also used to conquer higher order harmonics and the consequences of mutual coupling between radiating elements are reduced by PSG. The proposed antenna structure performs at three different frequencies which extend over distinct communication frequency ranges. The Ansoft HFSS (High Frequency Structure Simulator) Software is used to inspect the results. The parameters of designed antenna exhibit the results like Return loss, VSWR, Radiation pattern, Gain, Directivity and surface current distribution that are optimized within the band of operation.***

Index Terms: ***Micro strip G shape patch antenna, MIMO, PSG, Triple Frequency.***

I. INTRODUCTION

In advance technology of wireless communication, enormous bandwidth, maximum data rate and reliability are main objects for different applications. The number of radio channels concluded multiple inputs and multiple output (MIMO) expertise result in maximum outcome in non-line of sight communications. Due to density of devices, the consequence of number of antennas on the identical substrate cannot be unnoticed. The polarization diversity is one of the methodologies is able to transmit and receive signals in both directions i.e. horizontal and vertical. The densities along with the correct isolation among four radiating elements on the same substrate are exact stimulating problems and the necessities of present MIMO antennas. The micro strip patch antenna related to circular polarization with asymmetric 3D printed substrate achieves a wide 3-dB axial ratio beam width (ARBW) with wide 3db beam width furthermore it gives better results when compared to the supplementary techniques [1],[2]. Moreover, in circular polarization (CP) have one more proposal like the two-way communication i.e. Simultaneous transmit and receive (STAR) consists of two parts like four radiating elements utilized to rotate around the STAR antenna which works under 6.0-7.2 GHz frequency and custom-designed feed network for dividing the power [3].

To design simple, predicable and reasonable antennas, the antenna will have to be shaped in different forms such as L, T, E, U, G, psi, octagon star, truncated and mushroom are being designed and briefly discussed them as stretchy E shaped micro strip patch antenna with L-shaped feeding technique improves a wide band and multiband operation. This flexible E shaped patch antenna and G shape patch antennas are very useful in multiband array configurations with easy fabrication [4]; a 5G broad band patch antenna is designed with L shaped probe feeds. This L shaped feeding techniques are mainly used to reduce the discarded radiation effects [5], and then achieves better radiation patterns in the horizontal and vertical polarizations, in addition to circularly polarized (CP) micro strip patch antenna with octagon star shaped encounters a unidirectional CP radiation pattern.TM11 mode is used in conical shape patch antenna to produce radiation pattern[6]. While designing antennas the gain and bandwidth are taken as major constraints so that antennas are designed specially like a stacked dielectric patch resonator with broad bandwidth and constant gain, is reached due to the ceramic sheets integrated with ground plane and two resonant types attains the better outcome with high permittivity[7], a triple band rectangular patch antenna is designed in accordance with impedance to satisfy the frequencies such that the improvement of gain is reached [8], a new technique like a Fabryperot (FP) resonator antenna is intended by partially reflective surface(PRS).This PRS layer achieves two polarizations like horizontal linear polarization and vertical linear polarization. In this FP cavity produces broadband 3 dB gain bandwidth with the help of PRS layer [9], a new technique with self-mixing antenna arrays achieves a high gain over a broad angular range, and also uses another parameter like parasitic elements are used to achieve large beam width [10]. In this received power is also improved over wide angular range compared with predictable feeding methods, a coupled fed dual patch antenna with stubs and shields. By using these dual patch antennas, it exhibits a constant gain and wide

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bandwidth and low cross polarization and then it appears triple radiation nulls [11], a low profile ultra-wide band antenna with low weight and permissible shape and wide bandwidth are used to design a Wireless Body Area Networks (WBAN) achieves a better transmitting and receiving pulse signals [12],and dynamic wireless devices used in vehicular automobile applications[13], Beam is to be formed by radiating the coupled modes with slots, the beams are radiated in particular direction as compared with supplementary techniques like leaky wave antenna[14], A monopolar patch gives the application with broad impedance bandwidth. Such that this antenna provides good impedance bandwidth and good conical beam pattern [15].

To meet more accuracy and some limitations while occurred due to radiation in the antennas are overcome by using the dual polarized micro strip patch antenna with differential feeding techniques to remove the RF variations and to improve the isolation [16]. This antenna achieves a 90db more isolation for broad bandwidth, implemented in Multi-Function Phased Array Radar (MPAR) applications [17]. By using balanced probe feed and slot coupling techniques, we can stimulate vertical and horizontal polarizations [18],[19]. The antennas with MIMO relevancies can be designed as ultra-wide band (UWB) antenna with multiple input and multiple output (MIMO) achieves the low mutual coupling [20].A millimeter wave (MMW) antenna is used in advancement technologies like fifth generation (5G) wireless MIMO wireless applications. An idea of Defected ground Structure has been implemented in MMW antenna to fulfill the requirements of high bandwidth and low design complexity [21], a compact dual band dual polarized (DBDP) micro strip antenna is used in MIMO applications. One of the development application is MIMO synthetic aperture RADAR(MIMO-SAR),which is used to enhance the resolution and achieves the high bandwidth [22], a broad band micro strip antenna is innovated to produce both broadside and Omni directional radiation patterns to use in even and odd modes, in addition CPW is projected to give a result in both in phase and out phase feedings mainly to improve the bandwidth[23], a micro strip antenna with MIMO application is designed to obtain the high bandwidth according to the requirement at that time. In extra this design provides good isolation and low correlation[24], a new design with millimeter (mm) and Tera hertz (THz) technology is used to generate the waves based on standing assets and overcome the loss and unnecessary elements in the network and also accomplishes with good tuning range and frequency with suitable power[25], the antenna with different specialization like embedded is used to design the automobile applications wirelessly, to reach the good concept they used cavity backed configuration (CBCPA) to draw the attributes of the antenna[26].

II. MIMO ANTENNA PATTERN

The dual element MIMO antenna of polarization diversity technique with FR4 dielectric substrate size of 70*70mm^2.The permittivity of this FR4 substrate is 4.3 and thickness is 1.524mm.MIMO antenna design is fabricated with G shaped patch antenna with partially stepped ground (PSG) structure of 50 ohm impedance and also one vertical slot inserted in each ground plane. PSG means geometrical slots entrenched on the ground plane’s has been incorporated on the ground plane with micro strip line. The projected 2×2 Triple frequency MIMO G-shaped patch antenna with PSG as shown in fig. 2.
The parameters of G shaped patch antenna are listed in I.

I. Parameters of G shaped patch antenna

Parameter	A	B	C	D	E	F	G
Value(mm)	28.4	8.58	12.62	5.92	18.93	15.39	2.96
Parameter	H	I	J	K	L	M	N
Value(mm)	26	11.66	19.74	11.6	7.43	1.48	7.2

Schematic views of G Shaped patch antenna and PSG as shown in fig.1.

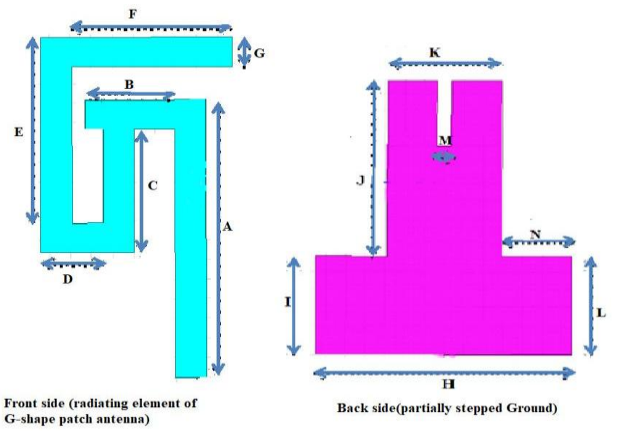

Fig.1 Schematic diagrams of G-Shape patch antenna and PSG

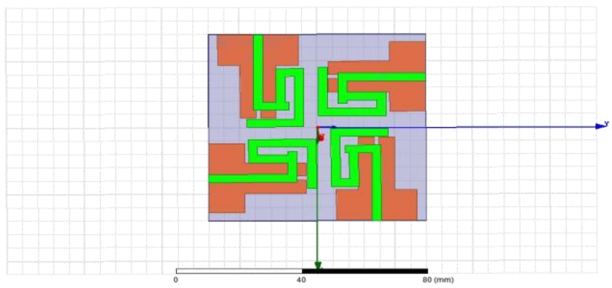

Fig.2 The projected 2×2 Triple frequency MIMO G-shaped patch antenna with PSG

*A. **Projected X band application in micro strip patch antenna***

This Integrated dual band antennas achieves a wider bandwidth, UHF RFID reader antennas which work even under hard levels, the concert of the circularly polarized antennas used in this gives better results. The other techniques with minimized side lobes 4*4 patch array, additionally the aperture size is very less when differentiated with other 4*4 patch arrays. In addition the design requires less number of feed lines, patch impedances and also there is no need of matching transformers and attain required level of side lobes in both E and H planes, an antenna regarding the teaching learning related reconfigurable patch antenna to attain the precise and reliable outcome concerning the frequency, an X band micro strip antenna is designed with the radiating elements which are given through the aperture coupled patch method.

In addition, the power is radiated by using the mono pulse feeding which generates both sum and difference patterns, a broadband omnidirectional dielectric resonator antenna (DRA) for purifying the signal is projected. The DRA is presented along with Circular patch, excited by hybrid feed and a metal disk will provides the wide bandwidth and will enhances the signal quality such that a dual band FDRA results the same, a broadband omnidirectional dielectric resonator antenna (DRA) for purifying the signal is projected. The DRA is presented along with Circular patch, excited by hybrid feed and a metal disk will provides the wide bandwidth and will enhances the signal quality such that a dual band FDRA results the same, full duplex radio implementation design is efficient for low power and short distance two-way communications. In this patch antenna reduces the complexity as compared with the time domain duplexing techniques with single patch antenna.

B. WLAN and Wi-Max Applications

The antennas under WLAN applications are designed as the reconfigurable antennas with high gain and efficiency worked out in two conditions one with zero degrees and 90 degrees, and in second with zero degrees and ±30 degrees utilized for Wi-Max and WLAN purposes, an antenna with horizontal polarization (HP) with omnidirectional inspired meta surface employ with characteristic mode (TCM) to assist the arrangement of three antennas this offers broad band width and if any changes required in the antenna it can be changed easily. And used in the WLAN applications by using 5G network and an antenna with 360^0 reconfigurable beam steering is designed with extra elements.

C. Diversity concert

The diversity concert of the projected 2*2 polarization diversity MIMO antenna is discussed by using the constraints peak gain, efficiency, Envelope Correlation Coefficient (ECC), and mean effective gain (MEG). The calculation of peak gain is done in an anechoic chamber by utilizing the replacement method with two standard horn antennas and the described antenna. The output gains of the SISO antenna in PSG ground is higher than 2.0dBi in both the frequency bands. For the projected MIMO the output has the peak gains at 2.96GHz,5.23GHz and 8.56GHz and resonant frequencies are at 4.66dBi, 1.95dBi and 8.69dBi. The peak gain is the correlation among the radiating components. The calculated and suggested results of peak gain are shown in fig.3.

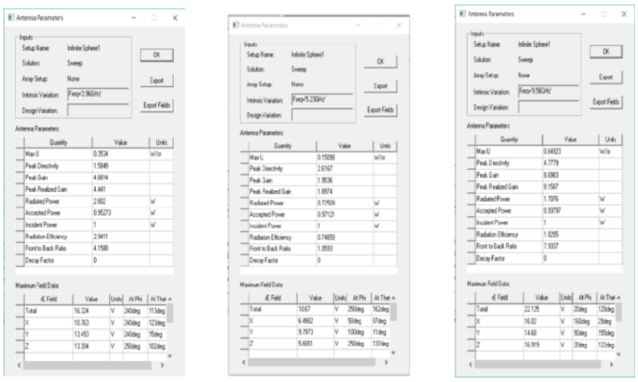

Fig.3. Peak gain and radiation Efficiency values for Triple Frequency ranges

The efficiency is also one of the constraints in the diversity concert. For the projected polarization diversity MIMO antenna, it is attained from the HFSS simulations for lower and higher frequency bands. For the SISO antenna, the resulted radiation efficiency is greater than 85% in lower band and more than 73.49%in higher band. The projected MIMO, as viewed from the figure 3, the radiation efficiencies at 2.96GHz, 5.23GHz and 8.56GHz resonant frequencies are 294.11%, 74.65% and 182.05%. The succeeded diversity constraints are diversity gain, which is attained in tenures of maximum theoretical diversity gain (12 dB) and correlation coefficient is obtained by utilizing equation (1). The maximum the value of diversity gain the better isolation we obtains and vice versa. The calculated values of diversity gain at 2.96GHz, 5.22GHz and 8.56GHz frequencies are 11.94dB, 11.93dB and 11.86dB.the result of diversity gains at the resonant frequencies are 12dB.In three frequency bands the estimated values of diversity gains are higher than 11.86dB.

$$Diversity\ Gain = 10 * \sqrt{1 - |\rho|\ 2} \qquad (1)$$

Likewise, the ECC gives a diversity conduct of the projected MIMO antenna. Lower value of ECC indicates lower correlation among antenna elements and vice versa. The ECC is the major constraint, as it belongs to the S considerations of the proposed MIMO antenna. The calculated values of ECC are gained from the formula given in Equation (2).in this the values a=1 to 4, b=1 to 4 for four components, and K=4(because there are 4 antenna components in total).

$$\rho_e\ (a,b,K) = \frac{\left|\sum_{n=1}^{K} (s_{a,n}^{*} s_{n,b})\right|}{\sqrt{\left|\prod_{k(=a,b)}\left[1 - \sum_{n=1}^{K} (s_{a,n}^{*} s_{n,b})\right]\right|}} \qquad (2)$$

The values of ECC for the adjoining and transverse ports are noted by ρ12, ρ13 and ρ14, where ρ12 is the ECC among antenna facets 1 and 2, likewise ρ13is the ECC among antenna facets 1 and 3 and alsoρ14 is the ECC among antenna facets 1 and 4.Because of the equi-distance situation among two nearby facets,ρ12 = ρ14.

D. ***PSG (partially Stepped ground)***

Difference between the full ground and PSG has been accomplished to expand the consequences of S parameters on return loss and different isolations. By using full ground technique, we can reduce the bandwidth. For the size minimization properties of the ground modification technique, we are using PSG, and to achieve proper resonant conditions. Therefore, the projected MIMO antenna is used for wireless applications. A partially stepped ground method was exploited to diminish the mutual coupling between radiating components to be improved than 22dB.The projected MIMO antenna covers three frequency ranges that are 2.96GHz, 5.23GHz and 8.56GHz.

III. SIMULATION AND EXPERIMENTAL RESULTS

A.S-Parameter (Return Loss):

Return loss is the superlative and suitable technique to compute the input and output of the signal sources; when the load is incompatible the total power is not distributed to the load and reflected power is transmitted and then it denotes the “Return Loss”. The proposed MIMO antenna is designed with G shape patch antenna with Partial stepped Ground (PSG). By using this S parameter, we can calculate returns loss versus frequency. The return loss of the G shape patch antenna design is premeditated using the partially stepped ground.

A plot of simulated and considered S parameters has been shown in fig.4.The simulated S parameter of first frequency (2.96GHz) is -17.85dB,and second frequency(5.22GHz)is -51.60dB,and third frequency(8.56GHz)is -14.26dB.

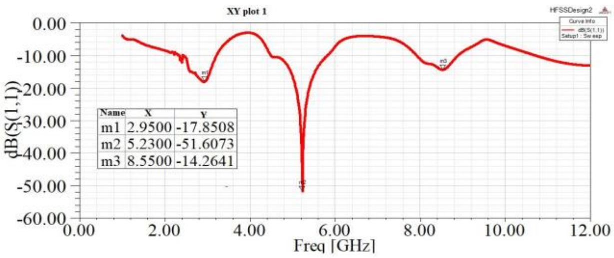

Fig.4 Plot of Simulated S parameters for triple frequency

II. Comparison of existing designs with triple frequency (proposed) design.

S.No	Existing System Resonant Frequency (GHz)	Return Loss(dB)
1.	2.54GHz	-17dB
2.	5.26GHz	-21dB
S.No	**Proposed system Resonant Frequency (GHz)**	**Return Loss(dB)**
1.	2.96GHz	-17.85dB
2.	5.22GHz	-51.60dB
3.	8.56GHz	-14.26dB

B. ***Voltage Standing Wave Ratio (VSWR)***

Voltage standing wave ratio is to display a large power transfer from source to antenna for the antenna to implement robustly. This occurs only when the impedance is terminated to the source impedance. In this antenna produces reflections which indications to the standing waves, it is categorized by the voltage standing wave ratio.
A plot of simulated VSWR has been shown in fig. 5.

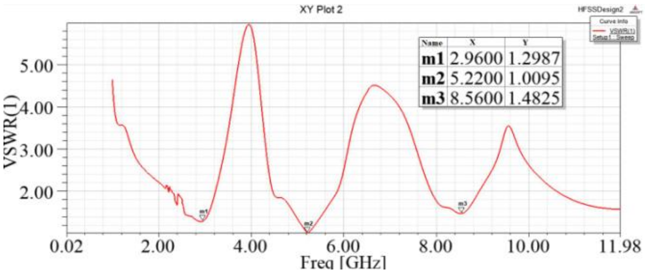

Fig.5: Plot of Simulated VSWR for Triple frequency

C. ***Radiation Pattern***

The Radiation pattern is the best typical value of an antenna. It is defined as a pictorial representation of the radiation possessions as a purpose of space coordinates. Generally, the radiation pattern is simulated in the far field set up. The far field setup is well-defined as the area of an antenna field where the pointed field distribution is liberated from the distance to the antenna.

A plot of simulated radiation patterns has been shown in fig.6.

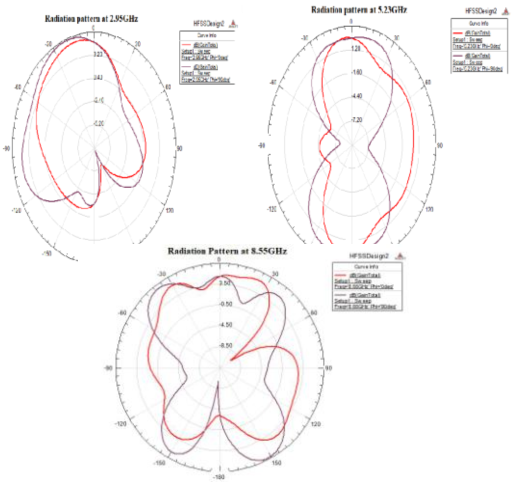

Fig.6: Plot of Simulated radiation patterns for triple frequency

D. ***Gain***

The 3-dimensional polar plots for G shape patch antenna with PSG for triple frequencies are shown in figures. It observes the effect of polarization diversity technique. By verifying these 3 D polar plots for triple frequency, we can observe how much amount of gain is radiated in particular directions, that values are listed in III. A plot of Simulation Results of Gain for Triple Frequency as shown in fig. 7.

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III. 3 D polar plot of G-Shaped Patch Antenna for Triple Frequency

S.No	Frequency (GHz)	Gain (dB)
1	2.95	6.64
2	5.23	2.90
3	8.55	9.51

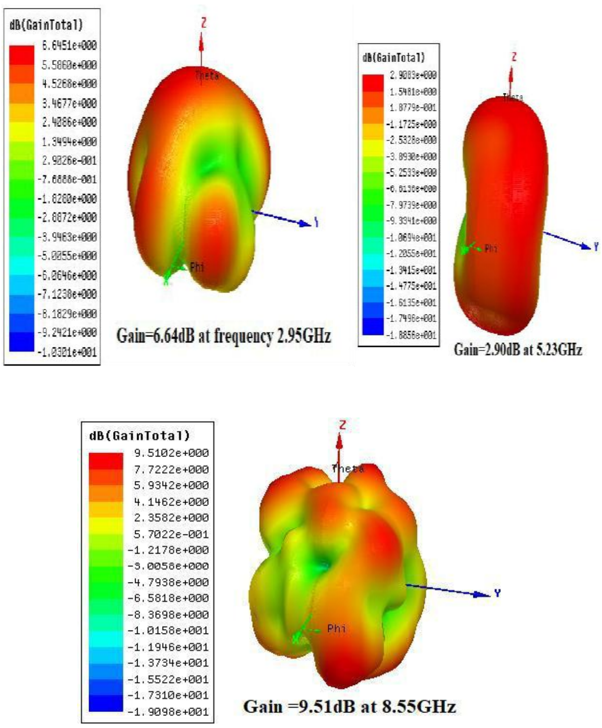

Fig. 7. Plot of Simulation Results of Gain for Triple Frequency

*E. **Surface current Distribution:***

The consequence of surface current distribution on the projected MIMO antenna, out of four ports, one port is electrified and be left over ports are matched terminated by 50ohm.Therefore maximum amount of current focused on the electrified antenna facets.A plot of Simulation Results of surface current distribution for Triple Frequency as shown in fig.8.

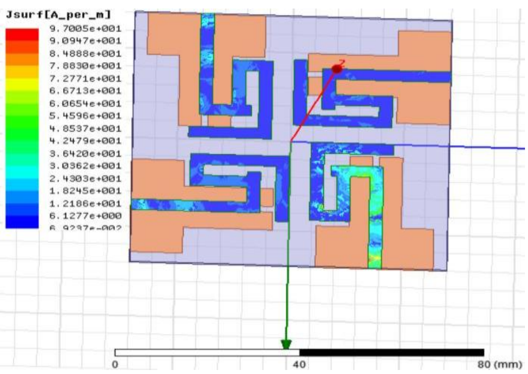

Fig.8.1. Surface current distribution at 2.96GHz frequency

Fig. 8.2. Surface current distribution at5.23GHz frequency

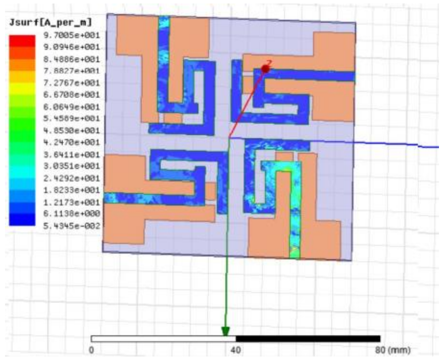

Fig. 8.3. Surface current distribution at 8.56GHz frequency

FFig. 8. A plot of Simulation Results of surface current distribution for Triple Frequency

*F. **Directivity***

The Directivity of an antenna describes the relative radiation power density in a specific distance and direction, radiation power thickness adaptable that an isotropic antenna would exude at the same expanse. This defines the ratio between power radiated to the isotropic power. The plot of Simulation Results of Directivity for Triple Frequency as shown in fig.9.

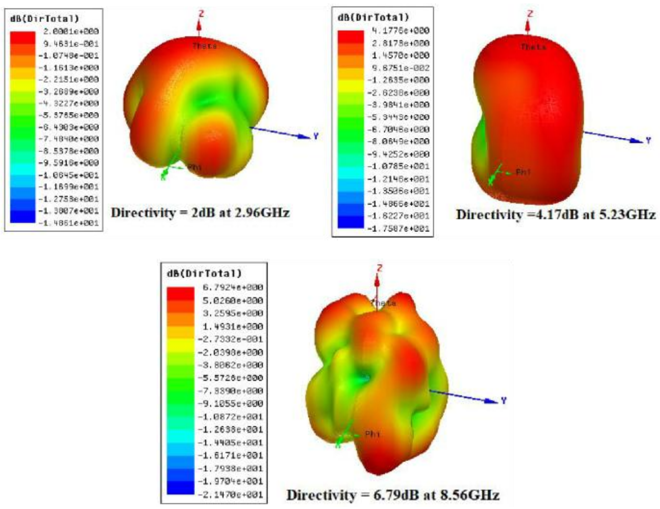

Fig.9. A plot of Simulation Results of Directivity for Triple Frequency

IV. HFSS SOFTWARE

High Frequency Structure Simulator (HFSS) is a Great concert full wave EM field simulator for 3D inert device forming. It incorporates simulation, picturing, dense modeling and automation in a tranquil to learn background where resolution to 3D EM problems are rapidly and exactly acquired. Ansoft HFSS works adaptive interlacing and intense graphs to give concert and vision to all of 3D EM problems. The Ansoft HFSS can be used to compute S,Z,Y parameters, Resonant Frequency, Fields, Radiation Patterns, Gain, Directivity and Surface current distributions.

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V. CONCLUSION

A compact four facet triple frequency MIMO G-Shape patch antenna with PSG is projected with polarization diversity technique for current wireless communications. The three frequencies are obtained by inserting slot in patch. Thus, the resolute gains at 2.96GHz, 5.23GHz and 8.55GHz resonant frequencies are 6.64dB, 2.98dB, and 9.51dB respectively. The projected design covers WLAN, Wi-Max and X-Band frequency ranges. Therefore, the parameters of designed antenna are displayed the results like Return loss, VSWR, Radiation pattern, Gain, Directivity and surface current distribution.

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