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Analysis of Compact Multi-band and Ultra-Wide Band Rectangular Microstrip Patch Antenna for S, C and X Band Frequency Ranges

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***Abstract*: A compact design and simulation of rectangular multiband and ultra-wide band microstrip patch antenna with circular polarisation is presented here. The suggested antenna resonates primarily in S, C and X frequency band region having notches at 2.6GHz, 5.0GHz, 6.5GHz and 10.8GHz. The return loss is approximately less than -10db for large band i.e. from 2.5GHz to 12 GHz, so this design is also characterised as ultra-wide band antenna. This antenna is used to fulfil the need for wireless LAN, broadband, satellite, radar communication and multimedia applications. The ascendable EM design and validation platform IE3Dsoftware is utilized for simulation purposes.**

***Keywords*: Return Loss, Circular Polarization, Multiband, Ultra-wide band, Microstrip Patch Antenna.**

1. Introduction

An antenna is an assortment of accompanying elements, electrically associated to the receptive side or broadcaster. Antennas can be premeditated to transfer and obtain electromagnetic waves in all directions correspondingly or favourably in a precise direction. An antenna comprises of reflectors and elements that are possessed by electrical modules for specific purposes of transmission and reception. It acts like transducer providing interactive platform between waves proliferating through interplanetary and electric currents moving in electrodes, used with a broadcaster and an output junction. During the transmition the electric current should be supplied to the transmitter antenna by the broadcasting system and the antenna discharges the electromagnetic wave depend on the input current to the transmitting antenna in free space. At receiver, an antenna captures some of the electromagnetic wave in order to harvest a current at its depots that is the function of receiver and that has to be enhanced. The applications of antenna vary from Radio broadcasting to Navigational systems. It is also widely used in the applications such as Radio transmission and reception, GPS, and Satellite communication as well as frequency identification. There are various modifications that can be made to a conventional antenna. Based on those variations, the antenna can be classified under different groups. These groups are mentioned in the following table.

The main stream antennas are designed on the principle of resonance. This banks on the conduct of moving electrons, which imitate through exteriors where the dielectric constant vicissitudes, which is quite alike to the manner in which light reflects when optical properties varies. In these projects, the reflective surface is fashioned by the end of a conductor, most probably a thin metal wire or rod, which in the most circumstances has a feed point at one end where it is associated to a transmission line.

Table 1
Different types of antenna

1. LOG PERIODIC ANTENNAS			
BOW TIE ANTENNAS		LOG PERIODIC DIPOLE ARRAY	
2. WIRE ANTENNAS			
SHORT DIPOLE ANTENNA	DIPOLE ANTENNA	MONOPOLE ANTENNA	LOOP ANTENNA
3. TRVELLING WAVE ANTENNAS			
HELICAL ANTENNA		YAGI UDA ANTENNA	
4. MICROWAVE ANTENNAS			
RECTANGULAR MICROSTRIP ANTENNA		PLANAR INVERTED F ANTENNA	
5. RE LECTOR ANTENNAS			
CORNER REFLECTOR		PARABOLIC REFLECTOR	

Wireless LAN 802.11 is used for transmission of signals at particular frequencies for pre-requisite ranges. On the other hand, C band is widely exploited for satellite communication between Ground station and satellite for effective up-linking and downlinking of frequencies. Over the past few years, C band's most significant contribution has been demonstrated via VSAT. There are many satellites providing C Band that includes Asia Satellite, INSAT and many more. Very Small Aperture Terminal (VSAT) is a divulgence apparatus used for commercial and personalized purposes. The user requires a vessel that confederates the antenna with the user's application device with the help of a transceiver. The transceiver is accountable for broadcasting and receiving signals to a transducer. The earth station acts as a central node in this chain of events. Each end user is reticulated with the central node via the satellite in a star topology arrangement. The primary lead of

S and C band over other frequency assortments is the fact that it is less liable to rain waning and its conforming interference and comprises of cheaper bandwidth Studding in [1]-[12]. The frequency band at which the antenna is performing can also be utilized for Curative Disaster Management in the healthcare sector. These services can work at real time in operations varying from formation of still images to broadcasting signals over global system for mobile communication.

The frequency range where the antenna predominantly resonates can also be utilized for the operations carried out under the communication standard WiMAX studding in [13-18]. WiMAX stands for Worldwide Interoperability for Microwave Access. It is a family of communication principles centred on the IEEE 802.16 set of standards, which provide several physical layer and Media Access Control possibilities. The main principle behind the WiMAX standard is to create last mile wireless broadband access and connectivity. WiMAX was originally premeditated to deliver 30 to 40 megabit-per-second data rates, but with the recent updates, it has started delivering up to 1Gb/s of data speed.

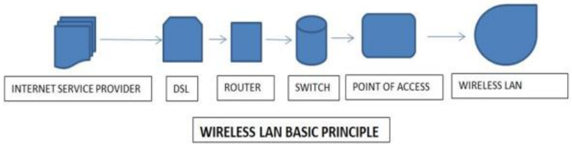

Fig. 1. Wireless Lan Basic Principal

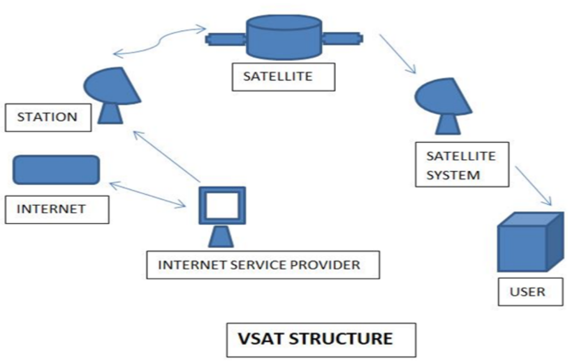

Fig. 2. VSAT Structure

2. Design approach and discussion

A microstrip patch antenna is a metallic stripe or patch equestrian on a dielectric layer (substrate) over a ground plane. The microstrip patch antennas can be utilized for the functioning of Aircraft, Satellite, Missiles, Cell phones, Sophisticated electronic devices and many more applications. There are some advantages of microstrip patch antenna. They are conformable, modest and low-cost to manufacture, mechanically vigorous, and very adaptable. With this addition there are some limitation also with it that is low efficiency, low power, high Quality factor, poor polarization purity, poor scanning properties, spurious radiation, very narrow frequency bandwidth, still large dimensions at high frequency. Taking all the merits and demerits in consideration the requirement for Multiband and ultra-wide band Microstrip Patch Antenna are in high demand in the present situation.

Multi band antennas have lots of real-world uses, particularly for mobile devices for many applications. These antennas function on several bands or frequencies and can either operate on these different frequencies one at a time or concurrently, depending on the competence of the specific antenna. The principle advantage to multi band antennas is their capacity to afford a durable, steady wireless connection in often challenging to reach localities. There is some mathematical approach to find the basic dimension like length and width for the proposed antenna illustrated in table 2. To achieve the basic design dimension, the following equations are utilized:

Table 2
Basic Mathematical Approach for designing

Length 'L_{eff}' of the patch	$L = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0}\sqrt{\varepsilon_{reff}}} - 2\,\Delta L$	For the calculation of Length 'L_{eff}' of the patch
Extension 'ΔL' of the patch	$\Delta L = h \times 0.412\left[(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right) \Big/ (\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)\right]$	For the calculation of length extension 'ΔL' of the patch
Width 'W' of the Patch	$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$	For calculation of the actual Width 'W' of the Patch
Characteristic impedance	$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{reff}}\left[\frac{W}{h} + 1.393 + 0.667\ln\left(\frac{W}{h} + 1.444\right)\right]}$	For the calculation of Characteristic impedance of transmission line
Effective dielectric constant	$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 \Big/ \sqrt{1 + 12h/w}\right]$	For calculation of effective dielectric constant of the Substrate

To achieve the basic design of the microstrip antenna the above mathematics is applied and to attain the multiband characteristics the slot loading method is used. Slot loading method helps in improving the performance of antenna in comparison to conventional rectangular patch antenna as it has different electrical length for the same dimension of antenna due to slot. It improves the efficiency at resonance frequency, return loss and helps in reducing size of antenna. There are many more advantages of slot loading concept that it provides simplicity, transmission of high-power levels of signals, high production capabilities and Omni-directional nature of antenna can be achieved by this technology. The conventional methods to achieve multi-band characteristics in a rectangular microstrip patch antenna are Reactive Loading, Utilization of multiple patches, Using Specific orthogonal modes. In the case of the rectangular multi-band antenna that is under study, the technique that has been utilized is reactive slot loading.

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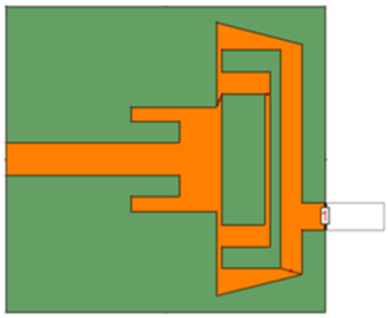

Fig. 3. Top view of Proposed Antenna

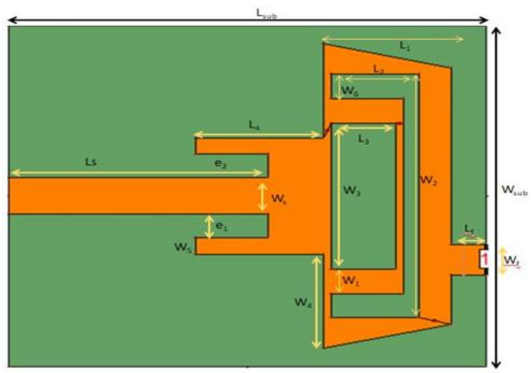

Fig. 4. View of Proposed Antenna with Detailed Dimension

A. Dimensions of Proposed Antenna

The rudimentary scheme of the antenna is a design that correlates to rectangular shaped patch antenna. The Length of the main patch is16mm and Width of the main patch is 25mm has been founded. These dimensions were extracted from the following equations:

Table 3
Detailed Dimension of Proposed Antenna

Antenna Part	Parameters	Dimensions[mm]
Patch	L_1	8
	L_2	5.5
	L_3	4
	L_4	8
	E_1	1.95
	E_2	1.95
	W_1	25
	W_2	20
	W_3	12
	W_4	7.75
	W_5	1.3
	W_6	2
Substrate	L_{sub}	30
	W_{sub}	28
	h	1.6
Feed Line	W_f	2.5
	L_f	2.2

3. Results and discussion

These dimensions of suggested antenna were accustomed to attain the resonance around primarily in S, C and X frequency band region having frequencies at 2.6 GHz, 5 GHz, 6.0 GHz and 10 GHz. The return loss is approximately less than -10db for large band i.e. from 2.5 GHz to 12 GHz so, this design is also characterised as ultra-wide band antenna. This antenna consists of notches at four different frequencies to confirm the variation and feeding was accomplished by a 50 Ohm micro-strip line for matching purpose that is one of the main concerned. The detailed dimension for design of this proposed antenna has been represented above. The radiating portion and the feed line are Perfect Electric Conductor which is 0.035 mm thick. It is printed on an Epoxy FR-4 substrate.

To achieve these outcomes, structural changes in the basic shape of the antenna were made. Slots and truncations were implanted in the shining element and the ground plan, width and length of the notches had also been reformed. These alterations made it possible to accomplish adaptation in multi resonant frequencies of 2.6 GHz, 5.0 GHz, 6.0 GHz and 10 GHz. So, our requirement for S and C band frequency ranges has been accomplished.

A. Current distribution

The patch is a small reverberating dimension of low-resistance microstrip with an open route at each end. At those points, the electric field is adjacent to an anti-node, so it surrogates between positive and negative values. The magnetic field is close to a node, so it is quite insignificant. Under the midpoint of the patch there is an electric field lump, and a magnetic field point which is opposite in characteristics of that lump, so there is a contour with no electric field and alternating high magnetic field. The current density at each position on the subordinate surface is equivalent to the magnetic field under the patch. The radiation from the patch is generally treated as radiation from two dipoles, one in the gap at each end of the patch, where the metier of the magnetic dipole field is represented by the displacement current. The magnetic dipoles are associated along the span of each slot, and are in segment with each other. So, the patches behave as successions of circuits with a capacitor to earth at the gaps and an inductor in the middle.

The current distribution pattern as observed through the IE3D simulation tool is shown below.

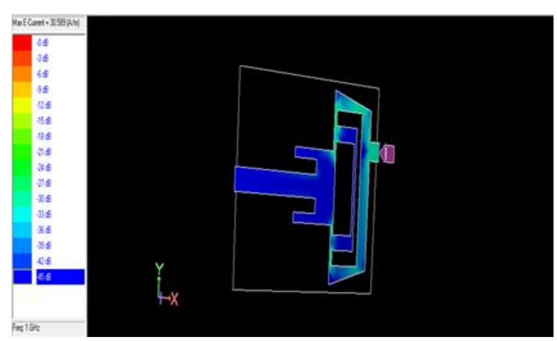

Fig. 5. Current Distribution Pattern

B. Return loss

Return loss is the quantity that determines to what level the signal has drifted, misplaced or vanished while it is redirected back to the source of origin. This incoherence between the signal from source and redirected signal can be due to the incongruity with the terminating load or with an instrument implanted in the line. Return loss is related to both standing wave ratio (SWR) and reflection coefficient (Γ). Increasing return loss corresponds to lower SWR. Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high. A high return loss is desirable and results in a lower insertion loss. Return loss is used in modern practice in preference to SWR because it has better resolution for small values of reflected wave.

The return loss is approximately less than -10db for large band i.e. from 2.5 GHz to 12 GHz, so this design is also characterised as ultra-wide band antenna.

C. *Axial ratio*

The axial ratio is the ratio of orthogonal constituents of an Electric field. A circularly diverged field consists of two orthogonal Electric field constituents of equivalent amplitude and perpendicular in reference to the phase. Due to the fact that components are equal in magnitude, the axial ratio comes out to be 1 (or 0 dB). This ratio for an ellipse is larger than 1 (>0 dB). The axial ratio for unmodified and undeviating polarization is infinite, because the orthogonal components of the field are zero. Axial ratios are habitually cited for antennas in which the anticipated polarization is circular. The best value of the axial ratio for circularly polarized fields is 0 dB (that is 1). The axial ratio inclines towards the behaviour of degradation when they are away from the main beam of an antenna. This indicates that the deviation from circular polarization is less than 3 dB over the specified angular range. Axial Ratio determines the level of polarization of antenna under study. The polarization ellipse consists of minor and major axis. The ratio of these two quantities gives axial ratio. If the minor and major axis are equal, then the said antenna is said to be perfectly circularly polarized.

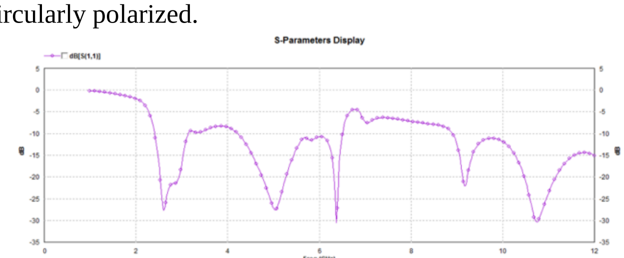

Fig. 6. S (1,1) Return Loss of Proposed Antennas

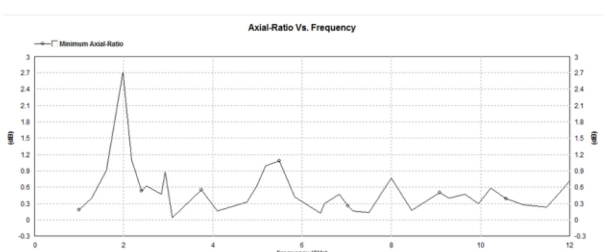

Fig. 7. Axial Ratio vs. Frequency of Proposed Antenna

D. *Efficiency of antenna*

In antenna model, antenna efficiency is furthermost used to reflect the concept of antenna radiation and its associated radiation efficiency. It is a degree to which an antenna alters the frequency power acknowledged at its terminals into radiated power. In a recipient antenna, it designates the quantity of the radio wave's power captured by the antenna which is truly conveyed as an electrical signal. The antenna efficiency is quantified with the help of an anechoic chamber by supplying power to the antenna feed plugs and determining the metier of the radiated electromagnetic field in the adjoining space.

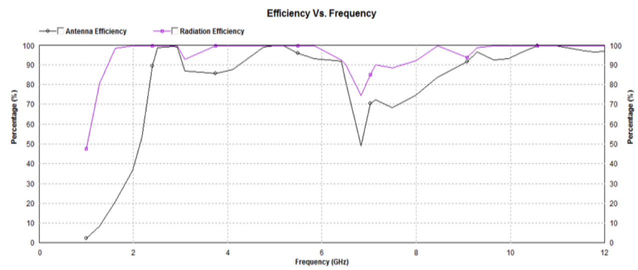

Fig. 8. Efficiency vs. Frequency graph of Proposed Antenna

E. *Gain*

For a broadcasting antenna, the gain pronounces in what manner and to which extent, the antenna translates input power into radio waves led in an identified course. For receptive antenna, the gain describes how competently the radio waves have been transformed into electrical power in a determined direction. When no direction is specified, "gain" is understood to refer to the peak value of the gain, the gain in the direction of the antenna's main lobe. Gain is continuously positive for all frequency from 2.5GHz onwards which is desirable.

F. *Directivity*

It is a quantity that determines the directional nature of antenna's radiation pattern. An antenna that emits correspondingly in all directions would have least directional characteristics and the directivity of the antenna would be 1 (or 0 dB). The directivity of an antenna is a parameter that can be utilized based on the requirements and commercial or non-commercial applications. If there is a requirement for transmission and reception of antenna energy from different directions, then directivity should be significantly lower. For targeted transmission of signal over a particular range, the directivity should be on the higher side.

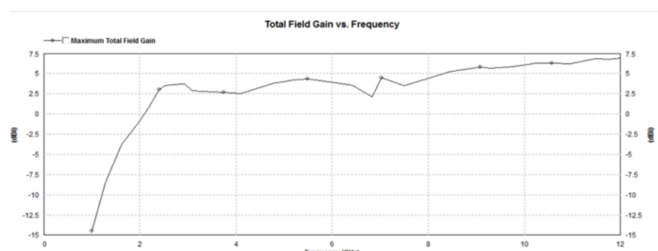

Fig. 9. Gain vs. Frequency of Proposed Antenna

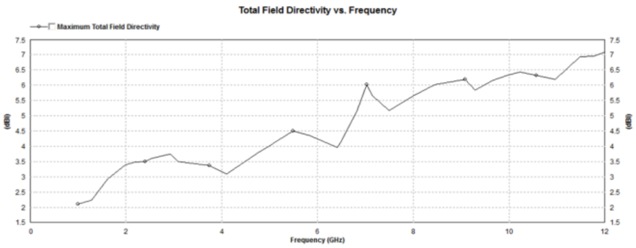

Fig. 10. Directivity vs. Frequency of Proposed Antenna

4. Conclusion

In this work, the design of a multi-band rectangular patch antenna has been performed by inserting slots and modifying the ground plan parameters. The simulated resonates at S, C and X frequency band region having notches at 2.6GHz, 5.0GHz, 6.5GHz and 10.8GHz with circular polarisation. The return loss is approximately less than -10db for large band i.e. from 2.5GHz to 12 GHz, so this design is also characterised as ultra-wide band antenna. This antenna is used to fulfil the need for wireless LAN, broadband, satellite, radar communication and multimedia applications. The carried-out simulation results showed that the proposed antenna validates the specifications of the proposed design which can lead to the practical realization of this antenna. This antenna has reached good performances in term of adaptation parameters.

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