Compact Triple band Patch Antenna for wireless Applications

Khalid Muzaffar
Assistant Professor
Department of Electronics & Communication Engineering,
Islamic University of Science & Technology, Awantipora-192122, J&K, India.

Abstract : This paper proposes the use of defected ground structure for multiband operation in patch antennas. The technique also leads to reduction of patch size and improvement in bandwidth. Based on this approach a triple band antenna is designed that resonates at three frequencies 1.82, 2.4 and 5.52 GHz. The antenna is modeled and designed using Computer Simulation Technology (CST) Microwave Studio 2014 electromagnetic solver. The simulation results of the antenna show that gain and return loss have almost doubled with previous reported results. The size of the radiating patch is also reduced by about 80.75 %. The antenna has also improved in terms of bandwidth by about 70.5%, 490.5 % and 377.25 % at 1.82, 2.4, 5.52 GHz respectively with earlier reported literature. The designed antenna can be used in communication applications involving IEEE 802.11 a/b/g/n bands and GSM 1.8 GHz band.

IndexTerms – ***Microstrip Patch Antenna*, VSWR, GSM, Computer Simulation Technology (CST)**

I. Introduction

In recent years, In any wireless communication system the number of users is not constant and it is increasing with the use of new technologies and other developments so for obtained, so there is need of large channel capacity or bandwidth to accommodate large users. Since in any wireless communication system the end terminal used to transmit signal is antenna, hence it should be able to transmit and receive over a large bandwidth. Nowadays, systems like personal communication systems (PCS), universal mobile telecommunication system (UMTS), Bluetooth, 4G, global system for mobile communication (GSM), wireless local area network (WLAN), digital cellular services (DCS), personal communication systems (PCS) and other systems are integrated into one another, so the transmitting structure must cover a number of frequency bands. Microstrip antennas (MSA) have a number of useful and desirable characteristics including their little expenditure on fabrication, small weight and minute dimension etc. Irrespective of aforementioned advantages MSA also exhibit a number of weaknesses like low gain, narrow bandwidth, surface wave etc. [1] but still MSA are a prime candidate for antenna designers and engineers. The basic outline of it is a metallic patch generally copper printed on a grounded substrate which radiates only at specific frequency decided by the dimensions of the patch. A number of methods and techniques have been proposed by different researchers from time to time to obtain various band operations in single transmitting element like the use of multiple patches as reported by Long and Walton [2]. Radiating patches with slots also exhibit multiband operation as reported by Lee et al [3]. The literature in [4] reveals the use of uneven inductive or capacitive loads to the patch for same purpose. Loading with shorting walls at different locations [5, 6], stub loading method [7], changing air gap between patch and ground plane [8] are other techniques to obtain multiband operations in MSA. Multiple patches largely add to the thickness of antenna whereas cross-polarization tends to increase with slotted patch generally in the H-plane. The size of the patch is usually reduced by use of shorting wall in electric field of patch over its center [9-11], embedding the shorting pin in close proximity with feed [12]. The measures to enhance the bandwidth of patch antenna are based on the use of parasitic elements or slots [13] and use of thick substrate with low permittivity [14]. Low permittivity thick substrates suffer from high levels of radiation from feed lines whereas use of parasitic elements lead to high cross-polarization.

A periodic or aperiodic defect in the ground plane of a transmission line commonly called as Defected Ground Structure (DGS) is also used to obtain multiband operation in microstrip patch antennas, this defect changes the current distribution and the typical capacitance and inductance [15] of transmission line that gives rise to a new resonance. A number of patch antennas with different patch shapes like G, E and triangle have been reported with different feeding techniques using DGS. These antennas with unique patch shape together with thick substrate and bigger ground can be employed for WiMax and WLAN. The radiation properties of these antennas are stable and bandwidth is also quite high. However, due to their large size it becomes complicated to implant them with small sized devices used in mobile communications. The major objective of this paper is to use DGS for three frequency band operation simultaneously with decrease in patch size and enhancement in bandwidth. The proposed antenna is created by means of a simple unique H-shaped DGS in the ground plane of the antenna for a broad range of GSM 1.8 GHz, Bluetooth 2.4 GHz and IEEE 802.11 a/n bands. Triple band response is suitably generated by varying the perpendicular and parallel dimensions of the DGS. A qualitative analysis of the structure is performed to realize the special effects of various dimensions of the DGS. Proposed method used is presented in Section II. Section III provides the discussion and results obtained from simulation software and the last section IV is confined to conclusion.

II. Methodology

The Proposed antenna is designed using the equations (1), (2) and (3) [11] to determine different dimensions of the patch. A dual band microstrip patch antenna as reported in [1] is first modeled and designed; the ground plane of it is loaded with H-shaped DGS (HSDGS). The integration of inverted L-DGS linked with HSDGS in the ground plane of same antenna generates a third resonating frequency of interest. The plane geometry of the proposed antenna with three resonating frequencies is shown in Fig 1. The optimized values of different parameters of this triple band antenna are listed in Table I. Center line feeding technique is used to excite the patch. The substrate material used is Flame retardant (FR-4) of 1.6mm thickness having a relative permittivity and loss tangent of 4.4 and 0.02 respectively. Equations (1) and (2) decide the width W and length L of radiating patch respectively.

$$w = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (2)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{\frac{-1}{2}} \quad (3)$$

Where
c speed of light;
Δl the extended length of main rectangular patch;
f_r resonating frequency
ε_r relative permittivity of dielectric substrate ;
ε_{reff} effective permittivity of dielectric substrate.

Parameter	W_g	L_g	w_p	l_p	w_f	l_f	L_{c2}
Value [mm]	34	32	22	14	3	20	6
Parameter	l_{c1}	l_{c2}	L_{c4}	n_1	W_c	L_c	
Value [mm]	7	2	1.5	13	29	16	

Table I Optimized Values of Proposed Triple - Band Antenna

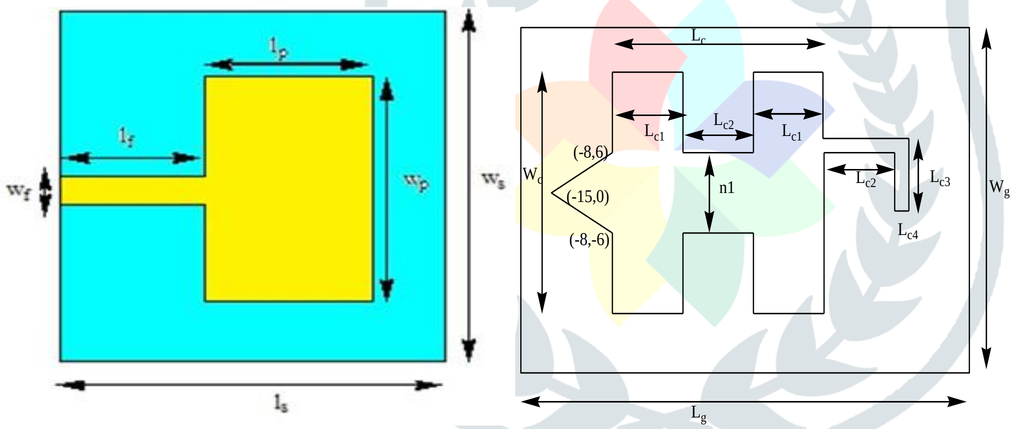

Fig. 1: Geometry of Designed Triple–Band Antenna (a) Front-View (b) Back –View

III. Results and Discussion

Computer Simulation Technology (CST) electromagnetic solver used to model, design and study the proposed microstrip patch antenna. The model is analyzed with Finite integration technique of Full wave Model of CST 2014. In order to arrive at final design various simulations have been carried out to get the optimized antenna and substantiate our results of interest. The parameters that marked reasonable effects on the performance of antenna Lc1, Lc2 and n1 are studied in detail. The simulated antenna parameters at various resonant frequencies are listed in Table II. The three band frequency response of the proposed antenna is observable from Fig. 2 with patch radiating at 1.82 GHz, 2.4GHz and 5.52 GHz. The desirable properties, return loss and bandwidth at frequency of interest are generated if size of Lc1, Lc2 and n1 of HSDGS are 7mm, 6mm and 13mm respectively. Return loss less than -10 dB of the designed antenna at three resonating frequencies obtained from simulation is -23.75 dB, -28.72 dB and -41.51dB at 1.82 GHz, 2.4 GHz and 5.52 GHz respectively. From the return loss curve the calculated bandwidth at three frequencies is approximately 34.1MHz (1.806 GHz-1.8401 GHz), 236.2 MHz (2.2541GHz-2.4903 GHz) and 763.6 MHz (5.1469GHz - 5.9105 GHz) respectively. The power fed to antenna to power reflected is usually described by return loss, thus power given to an antenna should be absorbed rather than being reflected, However, the best value of return loss if the power is absorbed must be negative. The S_{11} parameter at these center frequencies indicates that the transmission efficiency have reached to higher value. The Fig. 2 also shows the center frequencies of triple bands of interest for GSM, WLAN and WiMAX corresponding to S_{11} values better than -10 dB, this ensures good antenna operation within the specified frequency bands. The VSWR of this antenna is shown in Fig. 3 which falls in the acceptable limits when observed for desired bands. The VSWR curves show that the proposed antenna delivers high power. This VSWR gives the mismatch between antenna and the transmission line and this should be a small value and nearly equal to unity. The gain of this antenna is shown in Fig. 4 which shows that maximum gain occurs at 5.52 GHz which is about 4.51 dB. The antenna shows an improvement of gain by about 76.87 % at 1.8 GHz, 7.36

% at 2.4 GHz and 114.76 % at 5.5 GHz when compared to [16]. The designed antenna is compared with the reported in [16] and compared results are listed Table III. The size of the radiating patch of the proposed antenna is also smaller when compared to patch size reported in [17]. Further the size of the patch has also been reduced by about 80.75 %

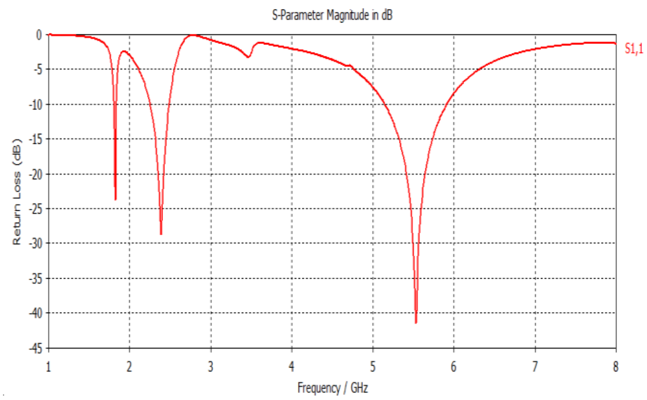

Fig 2: Simulated Return Loss (dB) against Frequencyfor Proposed Triple Band Antenna

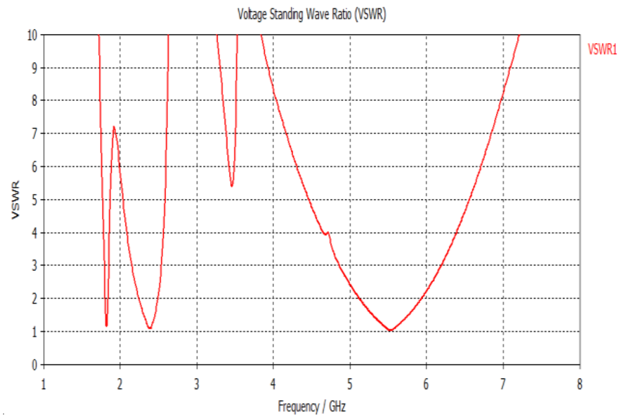

Fig. 3 Simulated VSWR of Triple Band Antenna

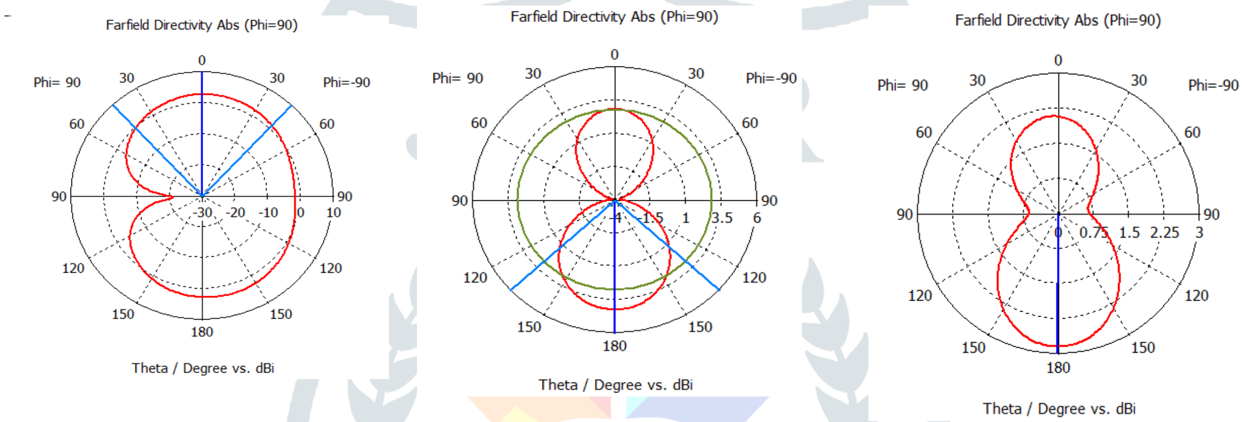

Fig. 4: Radiation Pattern at (a) 1.82 GHz (b) 2.4 GHz (c) 5.52 GHz

Parameters	Operating Frequency in 1.8 GHz Range		Operating frequency in 2.4 GHz Range		Operating frequency in 5.5 GHz Range	
	Antenna Proposed in [16]	**Proposed Antenna**	**Antenna Proposed in [16]**	**Proposed Antenna**	**Antenna Proposed in [16]**	**Proposed Antenna**
Return loss (dB)	-18.31	-23.75	-17.1	-28.72	-35.4	-41.51
Bandwidth (MHz)	20	34.1	40	236.2	160	763.6
Gain (dB)	1.6	2.83	1.9	2.04	2.1	4.51

Table III Comparison of the proposed antenna with [16]

IV. CONCLUSION

In this paper, a simple triple band antenna with defected ground structure is designed and studied. The miniaturization technique includes the use of H- shaped DGS together with inverted L-DGS in the ground plane of antenna so as to increase the electrical current path. The simulation results obtained from the CST software show that the antenna exhibits stable radiation pattern and the antenna parameters obtained for the GSM, WLAN and WiMAX bands were good compared with the earlier results reported in literature.

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