

Dual Band Polarization Agile Compact Planar Antenna for Enhanced Bandwidth and Gain

Ayona Chakraborty, Samik Chakraborty¹, and Bhaskar Gupta

Abstract – One major limitation of Microstrip Antenna is its narrow bandwidth (1-5%) making it unsuitable for operation over the entire GSM band for mobile communication. Increasing the bandwidth of the antenna results in reduction of radiation efficiency and in due course antenna gain; making it unsuitable to be used by different devices. Making the antenna structure non-planar may result in enhanced-bandwidth but the radiation patterns get distorted, also causing unwanted power loss and mechanical mounting problems. Moreover monostatic trans-receiver application requires dual band operation, which normally such antennas cannot provide. Polarization versatility if applicable would have added another degree of freedom to their applications. A unique compact single feed dual band (788MHz to 936MHz & 1.12GHz to 1.48GHz), high gain (~8dBi throughout), polarization agile (linear, circular and dual polarization) microstrip antenna is presented here overcoming the above difficulties. Innovative parasitic loading and usage of inductive posts ensures all three features with improved gain and broad radiation patterns.

Keywords – Polarization agility, High gain, GSM, GPS, Parasitic coupling, Shorting post.

I. INTRODUCTION

Adaptive antennas for multi-frequency operation, polarization diversity and high gain throughout the bandwidth are need of the hour; owing to the spurt in development of wireless and satellite communication systems. In suburban areas linear polarization for GSM band communication is sufficient where as in urban environment circular polarization is necessary to maintain adequate SNR for uninterrupted communication due to multipath effects [1]. Moreover, for GPS link dual [2] or circular polarized patch antenna is exceedingly desirable. A unique ultra-low cost solution offering all features (mentioned above) included, intended for vehicular application is presented here. The antenna exhibits high gain and undistorted radiation patterns throughout the GSM and GPS bands. At 800MHz (GSM 800) the antenna is linearly polarized, at 900MHz (GSM 900) it is circularly polarized and at 1.17 GHz (GPS) it is dual polarized.

This enables single antenna to be used for mobile communication, video streaming and calling as well as a position locator using GPS tracker. Generally for parasitically coupled patch antennas the exciter element is kept separate

from the main radiating patch, making the antenna larger in size. The exciter element of capacitively-coupled microstrip antenna reported here is a square cut out of the main radiating element, which is also square in shape; thereby reduction of real estate is also achieved. Two shorting posts of different diameters are added to the main radiating patch for inductive loading ensuring proper bandwidth without disturbing the planar structure. Undistorted radiation patterns and high gain is achieved by means of above design.

II. DESIGN

The detailed diagrammatic design of the inductively-loaded and capacitively-coupled microstrip antenna [3] is shown in Fig. 1. The dielectric constant ϵ_r of the substrate is assumed to be 1, making the antenna low cost and easy to fabricate. The square patch metallization has two parts, the main radiating patch and the capacitively-coupled smaller patch at one corner, as evident in Fig. 2(a), which is a snapshot of the actual fabricated prototype. The smaller patch is the main electromagnetic exciter by virtue of a coaxial probe at the centre as shown in Fig. 2(b). Owing to this configuration dominant mode is generated and capacitive coupling is established between the parasitic patch and exciter patch. Two orthogonal modes are simultaneously excited as the inverse L-shaped slot interrupts the longitudinal current flow. The ensuing design exhibits considerable enhancement of bandwidth and undistorted radiation patterns throughout the dual frequency bands; polarization diversity is achieved as well. This antenna can be widely used in base stations as a single element of an array in sector panels or as vehicle-mounted antennas for vehicle to base station communication and position locator via GPS.

The coupling slot between the exciter patch and parasitic patch generates maximum magnetic coupling field along both orthogonal directions. This develops two degenerate modes (TM_{01} and TM_{10}) of propagation with difference in phase.

The coupling amplitude [4-8] can be determined by,

$$Coupling \cong \iiint_v \vec{M} \cdot \vec{H} dv \cong \sin\left(\frac{\pi x_0}{L_a}\right) \quad (1)$$

here, X_0 is the offset of the slot from the radiating patch edge and L_a is the length of the slot either dimension. The main patch or the radiating aperture is shorted with the ground plane with two shorting pins. The thicker shorting pin is positioned at the centre, where the dominant mode electric field is minimum. The other shorting post acts as a reacting post located near the radiating edge and is positioned to suppress the higher order modes of radiation which maybe generated due to the parasitic coupling. Hence, TM_{01} remains

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the dominant mode of propagation. The dominant mode of propagation can be found by the cavity model approach using vector potential [9-10].

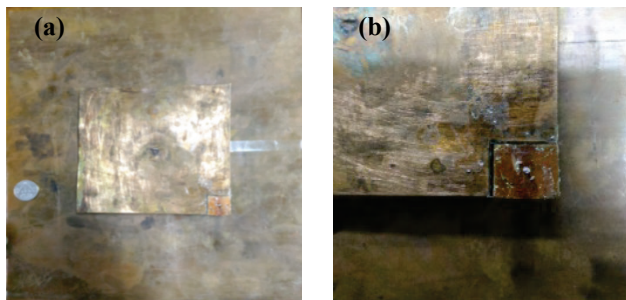
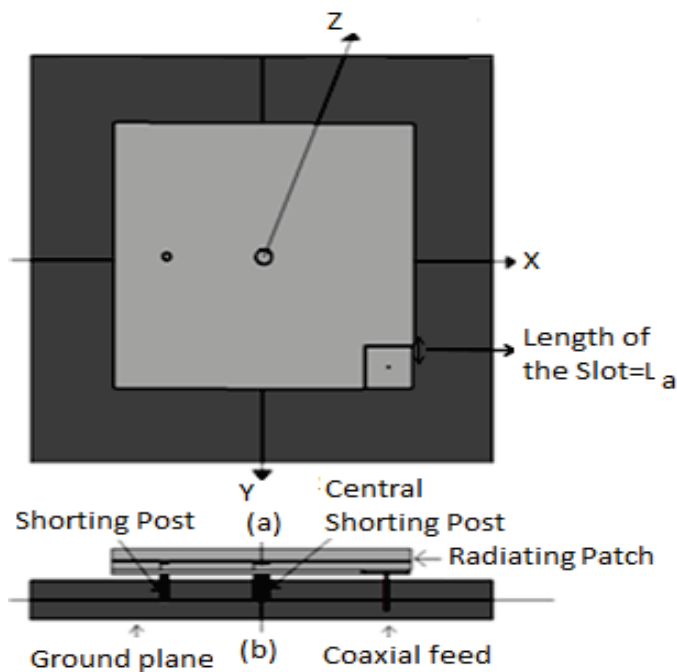


Fig. 2. (a) Top view of the entire fabricated prototype, (b) Exploded view of the fabricated prototype (capacitively coupled smaller patch part)

The two inductive posts and capacitively-coupled slot provide proper loading of the degenerate microstrip cavity to ensure dual and circular polarized radiation [11]. Extensive simulation has been carried out and as a result optimized dimension has been attained to meet the specifications of GSM and GPS bands.

III. RESULTS AND DISCUSSION

Simulation have been carried out using Zeland IE3D ver 10 [12], MoM based software. The patch is made of copper sheet (1mm thickness) of dimension 145 mm square (Fig. 2(a)). The substrate being air ($\epsilon_r = 1$) is of 21mm thickness and the exciter patch is 22 mm square (Fig. 2(b)). The exciter patch is fed by a coaxial probe 50 ohm SMA connector of 1.2 mm thickness at the centre. The slot between the exciter and the

parasitic patch is 0.75mm in width. The exciter patch is situated at (60.5mm, 60.5mm along x and y axes) from the centre of the main radiating patch. The thicker shorting post (8mm diameter) is placed at the centre of main aperture as mentioned above and the less thicker (4mm diameter) post is placed at (-47.5mm, 0mm) from the centre of main aperture. The shorting posts are of solid copper and they extend from ground plane to patch.

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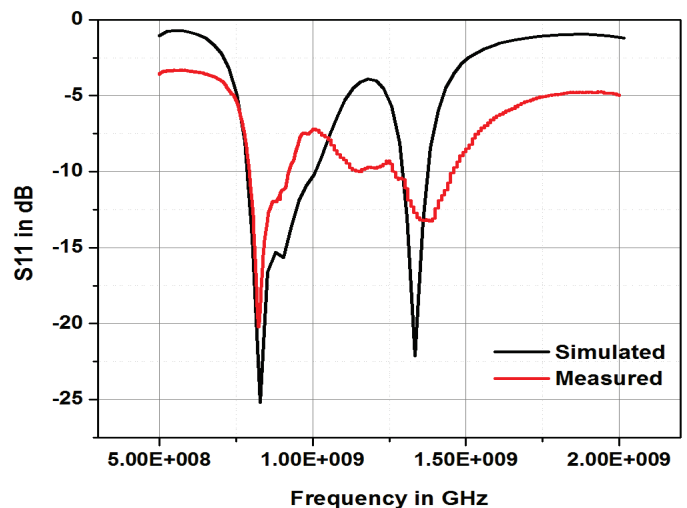


Fig. 3. Comparison of simulated and experimental results of Return Loss

The antenna was measured for its return loss characteristics using Agilent Vector Network Analyzer (Model No. E5071B). Fig. 3 shows the comparison of simulated and measured S11 of the proposed antenna. The antenna exhibits dual resonance as evident from the above patterns. The lower frequency range being 788MHz to 936MHz (16.5% Frequency Bandwidth) and the higher range being 1.12GHz to 1.48GHz (28% Frequency Bandwidth). The lower range covers the P GSM900 and E GSM900 i.e. both primary and extended GSM bands as designated by ITU. The higher frequency range can cater to 1176.45 MHz (L5), 1227.60 MHz (L2), 1381.05 MHz (L3), and 1575.42 MHz (L1) GPS frequencies.

The simulated and measured radiation patterns of the antenna at 800MHz, 900MHz and 1170 MHz are shown in Fig. 4(a), (b) and (c). The patterns are uniform throughout without any significant distortion. Radiation pattern measurement was performed in closed chamber using a turn-table arrangement mounted with a standard antenna, measured results from the Agilent Vector Network Analyzer (Model No. E5071B) were recorded. Table I tabulates the comparative study of measured and simulated values of antenna gain and directivity in the frequencies of interest. All measurements indicate that measured results of the fabricated antenna illustrate good matching with simulated ones and sometimes even betterment.

TABLE I
COMPARISON BETWEEN SIMULATED AND MEASURED GAIN AND DIRECTIVITY

Frequency	Simulated Gain	*Measured Gain	Simulated Directivity	*Measured Directivity
800MHz	7.19 dBi	8.31 dBi	7.70 dBi	9.55 dBi
900MHz	8.45 dBi	7.93 dBi	8.67 dBi	8.49 dBi
1170 MHz	5.5 dBi	7.98 dBi	7.01 dBi	10.18 dBi

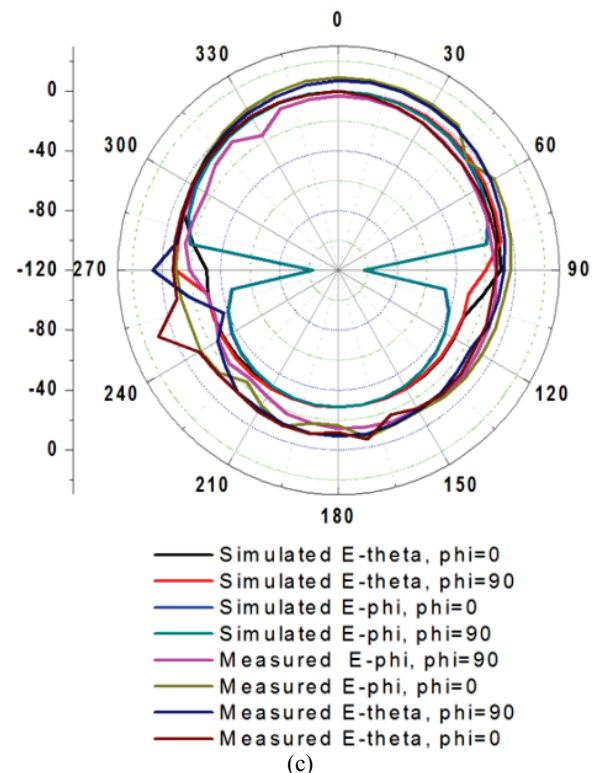
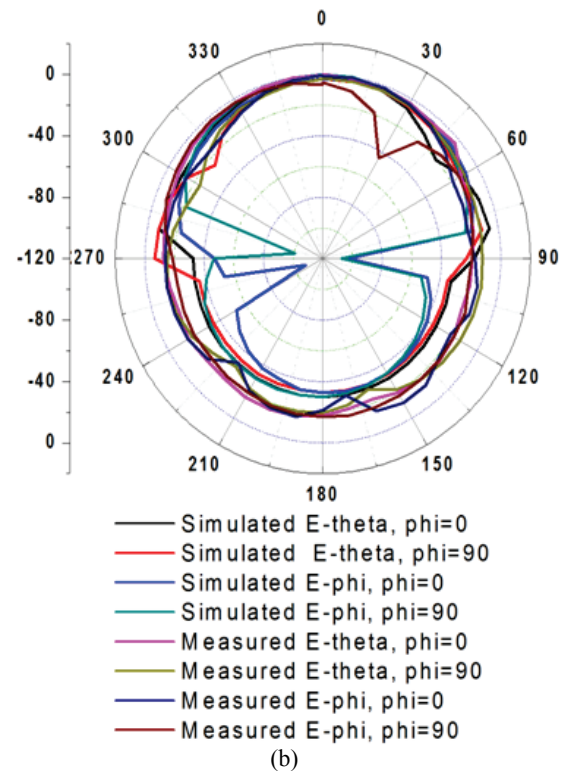
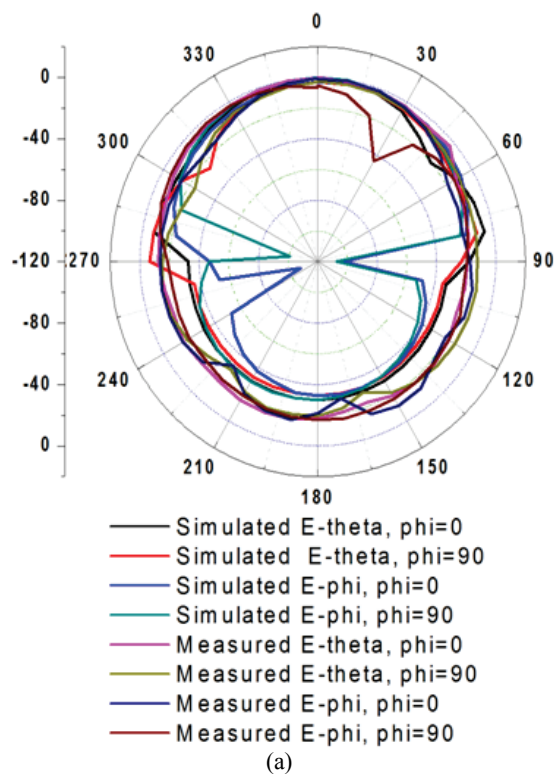


Fig. 4. Radiation Patterns for the proposed antenna at (a) 800MHz, (b) 900MHz, and (c) 1170 MHz

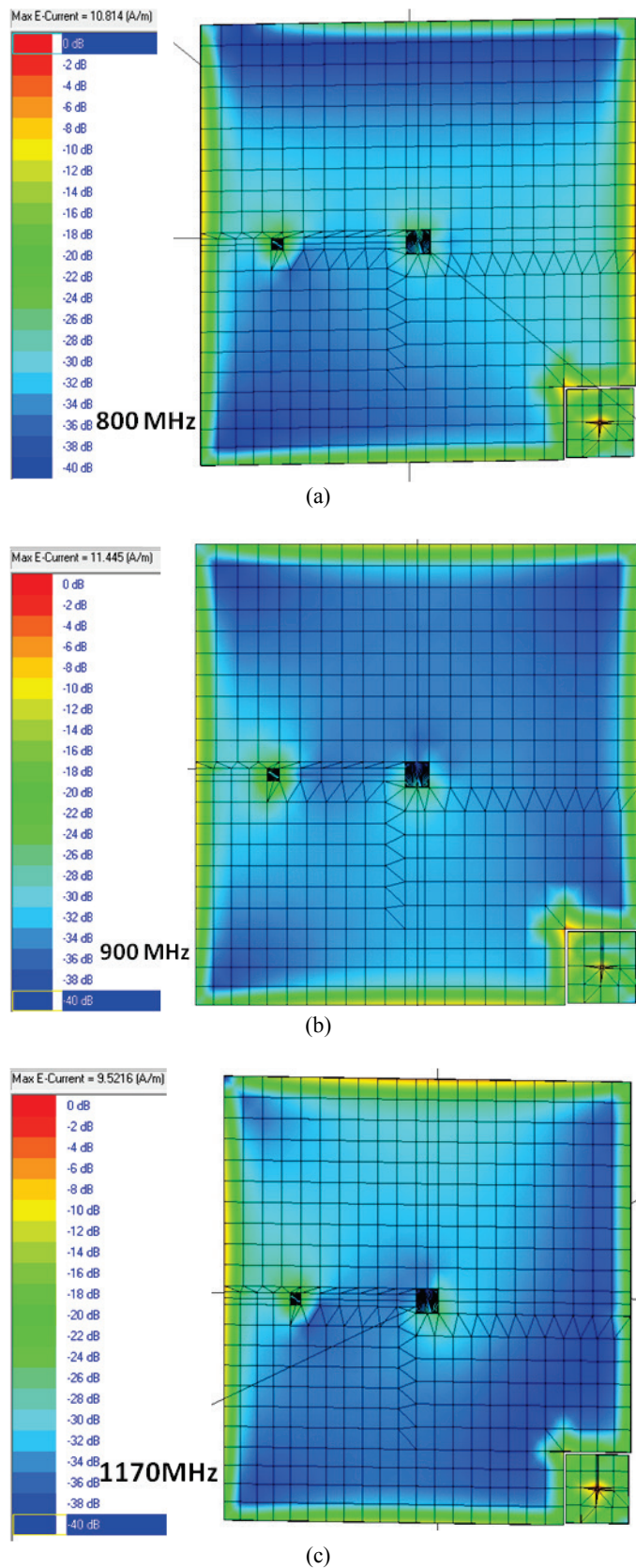


Fig. 5. Current Distribution of the proposed antenna at (a) 800MHz, (b) 900MHz, and (c) 1170MHz

From Table II given below, it is evident that the antenna exhibits linear polarization at 800 MHz (GSM) while at 900MHz (GSM) it gives circularly polarized radiation pattern and at 1170 MHz (GPS L5) dual polarization is observed. The current distribution shown in Fig. 5(a) is at 800 MHz frequency wherein it is observed that maximum current illumination is along the two radiating edges of the patch showing linear polarization.

Similarly Fig. 5(b) is at 900MHz frequency where it is observed that all four edges of the patch show almost same current concentration providing circularly polarized patterns. Lastly in Fig. 5(c) for 1170MHz frequency it is seen that the two perpendicular edges are more current illuminated than the other two giving rise to dual polarized patterns. Although it may be added here that from simulation it is difficult to fully infer whether or not polarization is dual but the measured results shown in Table II proves dual polarization at 1170MHz. Therefore, this single antenna can be used as vehicle-mounted antenna for vehicle to base station communication in GSM mobile band and in GPS band for satellite navigation uninterruptedly, evidently owing to the enhanced bandwidth and high gain.

A comparative study on similar works has been shown in Table III. It can be deduced from the chronological study over past few years considerable enhancement of gain and polarization agility have been achieved with reduced antenna sizes employing various techniques. It can be affirmed that the reported capacitively-coupled antenna in this paper with the achieved high gain and polarization diversity is one of the best attainable in the given domain.

IV. CONCLUSION

Wireless data communication is ubiquitous; therefore emphasis on betterment of communication systems is enormously needed. Seemingly antenna is an integral part of any communication system. Moreover, wireless technology has extended to the moving platform. There is a need of uninterrupted data transfers on-board trains, cars, aircrafts etc. Therefore, multimedia data transfer with high speed, requires wide band width and dual polarized or circular polarized pattern for the antenna used. High gain throughout the bandwidth is also another important criterion. The proposed capacitively coupled shorted patch microstrip antenna can fulfill all these criteria unlike other printed radiators and it is ideally suited for specific application in GSM base stations and also as vehicle mounted antennas. Additionally this antenna can be used as GPS locator also. Moreover, this kind of antenna is useful for large scale production as the fabrication cost is minimal. It has also been reported that considerable betterment in design and output has been achieved as compared to the previously reported antennas.

TABLE II
POLARIZATION AGILITY AT OPERATING FREQUENCIES

Frequency (MHz)	Theta Angle(deg)	Measured Power(dB)				Remarks
		E Theta Phi=0	E Theta Phi=90°	E Phi Theta=0	E Phi Theta=90°	
800	0	-26	-24	-36.19	-33.06	Axial Ratio >3dB, therefore Linear Polarization
	45	-29.9	-27.38	-41.99	-42.5	
	90	-40.76	-36.07	-46.29	-45.38	
	135	-46.81	-41.6	-43.85	-44.91	
	180	-42.52	-40.3	-47.2	-44.8	
900	0	-22.5	-26.5	-23.8	-24	Axial Ratio within 3dB, therefore Circular Polarization
	45	-30.2	-26.8	-29.2	-27	
	90	-36.5	-34.6	-38.4	-34.7	
	135	-45.5	-46.3	-47.8	-48	
	180	-43	-47.1	-41.9	-44.8	
1170	0	-30.5	-31.5	-33	-36	Axial Ratio within 3dB for E Theta at Phi=0 and E Phi at Phi=0, Axial Ratio within 3dB for E Theta at Phi=90° and E Phi at Phi=90°,for other angles it is found to be more than 3 dB therefore, Dual Polarization
	45	-37	-40	-37.5	-35.2	
	90	-49.8	-48	-42.8	-49	
	135	-47	-47.3	-46.2	-50.2	
	180	-48	-52	-49.7	-47.3	

TABLE III
COMPARATIVE STUDY ON SIMILAR WORKS

Reference No. (Please refer References)	Overall Antenna Size (cm)	Frequency Bandwidth (GHz)	Gain(Peak) in dBi	Polarization	Remarks (Comparison with Present Work)
[13] (Year:2004)	11.55x11.55	0.93- 0.99 1.71- 2.43	7.9	DP	Gain Low, Dual polarization
[14] (Year:2012)	22x29x21.4	0.8- 0.99 1.35- 2.74	11.6	DP	Size larger, Dual polarization
[15] (Year:2013)	Diameter=20 Height=11	0.7- 0.96	7.1	DP	Size larger, Non Planar Gain Low, Dual polarization
[16] (Year:2014)	10.16x10.16	0.9- 1.5(LP) 1.1- 1.5(CP)	3	LP, CP	Gain Low, Linear and Circular polarization
[1](Year: March 2017)	~19x19	1.7-2.7	9	DP	Size larger, Non Planar, Dual polarization
Present Work(Year: June 2017)	14.5 x14.5	0.79 to 0.94 1.12 to 1.48	8.31	LP,CP,DP	High Gain, Planar, Size Smaller, Full Polarization Diversity

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