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Investigation of Compact Antenna using Shorting Plates for Wireless Communication

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***Abstract*— Compact structure of Microstrip patch antenna is reported in this paper. A new technique of reducing the size of antenna is investigated with analytical formulation by shorting a patch and ground plane with two plates and insertion of such unit in close vicinity to the feed position achieves a 90% size reduction with additional characteristics such as circular polarization, higher directivity and appropriate bandwidth. This paper describes analytical formulation and presents simulation and measurement results. The simulated and measured impedance bandwidths of proposed antenna is 2-5% and achieves a gain of 1.42dBi at operating frequency of 2.43GHz.**

Keywords— ***Analytical formulation;compactness;circular polarization;shorting plate***

I. Introduction

N early 90s, research on compact antennas for mobile communication devices, such as the portable handset and notebook or laptop computers had been in demand. At that time, mobile communications had started to expand and design of internal antennas for mobile communication applications were becoming a very significant question for achieving better-quality communication. The communications industry had also in huge demand in new internal mobile device antennas with reduced size. Although the reduction in size and achievement of large bandwidth both characteristics are in conflicts. But still Small size with required bandwidth is the most demanding design issue for the internal mobile device antenna.

By inserting a shorting plate along the zero-potential point on the patch at the fundamental resonating mode size reduction can be achieved. This transforms a length (L) of antenna from half-wavelength to a quarter-wavelength. The shorted plate inserted antenna can achieve a bandwidth larger as compared to a conventional half-wavelength resonator, as well as compared to a shorted microstrip antenna realized by placing a shorting post [1-4]. Various conventional researches have been reported until now to reduce size of rectangular microstrip antenna (RMSA) such as insertion of slots of different shapes. The insertion of slot can excite added higher order modes such as TM_{20}, TM_{30}…etc next to the fundamental mode TM_{10} of the patch yields a compact antenna along with a broadband response [5]. Also compact rectangular microstrip antenna can be realized by inserting a slit symmetrical to the feed point axis. Also, K.F.Lee [6] reported that by placing a shorting wall along the null in the electric field across the center of the patch, the resonant length can be reduced by a factor of two and thereby area occupied by the patch will be reduced by a factor of four. A folded shorted-patch antenna also been reported with reduced size [7]. Capacitive loading yields from shorting technique can reduce the size of patch since increasing the height of the patch antenna will increase the impedance bandwidth. However, the thicker the substrate of the antenna, the longer the coaxial probe feed will be used and, thus, more probe inductance will be introduced [8], which limits the impedance bandwidth. Thus, a patch antenna design that can neutralize the probe inductance will enlarge the impedance bandwidth.

In this paper, an analysis of compact rectangular microstrip antenna with two shorting plates is presented. In particular, it is shown that the zeroth mode of the conventional antenna plays an important role for reducing the lowest operation frequency [9-11]. Many papers have been reported with metamaterial structure [12], loading of distributed inductor/ Capacitor [13], using a triangular shaped compact microstrip antenna [14]. A brief analysis of shorting plate technique presented in [15] in terms of impedances and it validated by using smith chart. This paper reports antenna uses at portable handset and notebook or laptop computers with small size and wideband operation covering GSM 900, DCS 1700, PCS 1800, UMTS 1900 and Bluetooth 2.4 GHz bands. The proposed structure is particularly suitable for the thin-profile notebook or laptop computers.

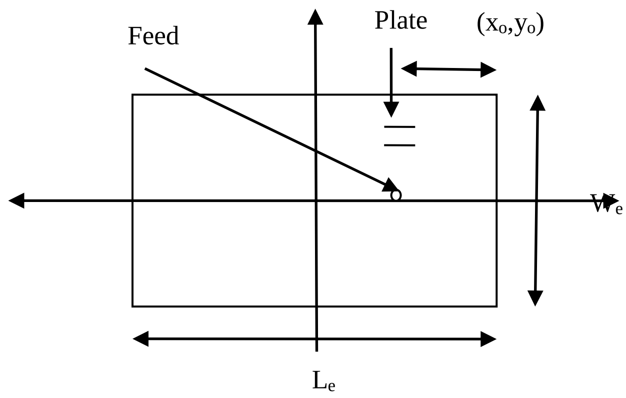


Fig.1a. Layout of patch with two shorting plates

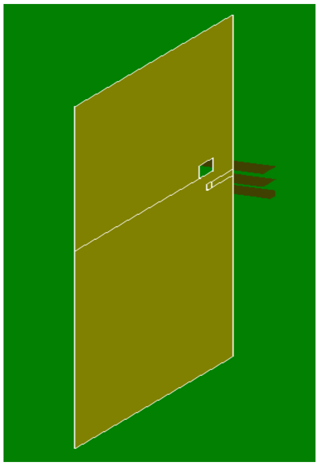
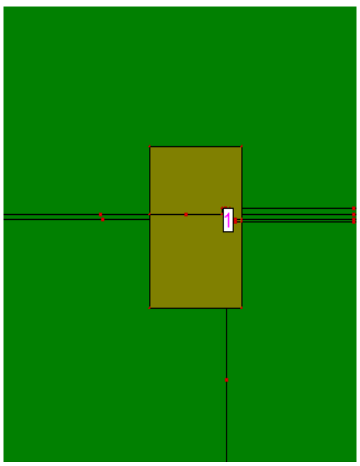


Fig.1b. Top and Side view of the antenna

II. ANTENNA DESIGN AND STURCTURE

A compact rectangular microstrip antenna (RMSA) with two shorted-plates is as shown in Fig 1a. It is made up of FR4 epoxy dielectric substrate with εr = 4.4, h = 1.6 mm. Design is implemented and optimized for Bluetooth 2.4 GHz band with dimension of 8.3*13 sq.mm as shown in Fig 1b. There are two shorting plates joining the ground plane to the upper patch with widths of 2mm each. The plates are placed in close vicinity to the feed position. With an experimental or simulation results, it has seen that the resonance frequency depends mainly on the position and the dimensions of the shorting plate.



III. SIMULATION AND MEASURED RESULTS

It has shown from Fig.2, by insertion of parallel shorting plate at (x_o,y_o) in vicinity of feed position, frequency shifts exactly half of its resonating value. This observation is quoted in an analytical formulation shown by equation 1[see Fig.1a].

$$f_r = \frac{c}{2\sqrt{\varepsilon_r}\left(L_e + W_e + \frac{(x-x_o)+(y-y_o)}{2}\right)} \qquad (1)$$

Previously, the analysis of shorting plate technique has reported many times using transmission line model [10] as well as cavity model [11] which uses Green's function as a solution to the wave equation. Green's function has been described in terms of Eigen frequencies and Eigen modes of shorted microstrip antennas as shown from equation (2)

$$G(xy, x'y') = \sum_{nm} \frac{\psi_{nm}(xy)\psi_{nm}(x'y')}{k_{nm}^2 - k^2} \qquad (2)$$

$$\frac{|\psi_{00}(x_0, y_0)|^2}{-k^2} + \sum_{(n,m)\neq(0,0)} \frac{|\psi_{nm}(x_0, y_0)|^2}{k_{nm}^2 - k^2} = 0 \qquad (3)$$

Rebekka Porath [9] has reported the fact that a shorting post at (xo,yo) nullify the electric field at that position which then explicitly separated the zeroth order mode i.e.TM_{00} below its lowest order fundamental resonating eigen mode i.e. $TM_{10.}$ This can be shown by equation (3). This leads to the important conclusion that there is a frequency below the lowest Eigen value. The insertion of the shorting plate near to the feed position excites that frequency and thereby shifts the operation frequency towards lower side without changing the dimension of antenna.

In this paper, above fundamental fact extended to two shorting plate microstrip antenna i.e. instead of using single shorting plate two shorting plate can provide two null point to the input frequency signal and shift the frequency to its zeroth order mode below the fundamental resonating mode exactly half of its value. Thus, reduces the size of antenna up to 91.38% for Bluetooth 2.4 GHz band which then suitable for thin-profile mobile telecom devices.

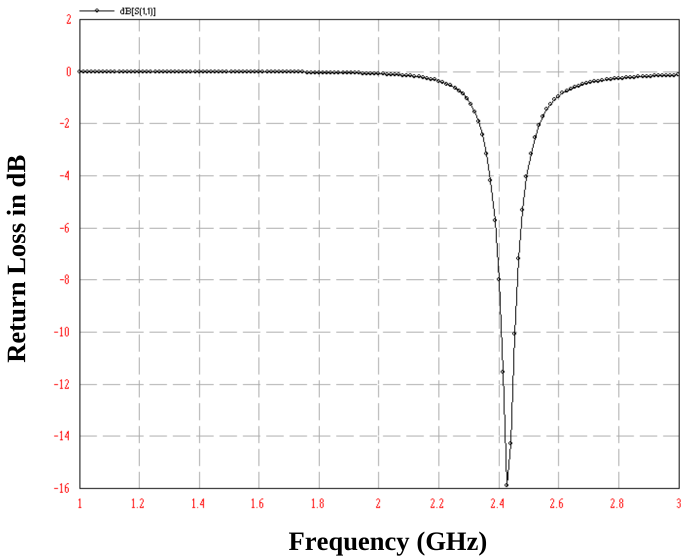


Fig.2. The Return loss plot of the antenna (Bluetooth 2.4 GHz)

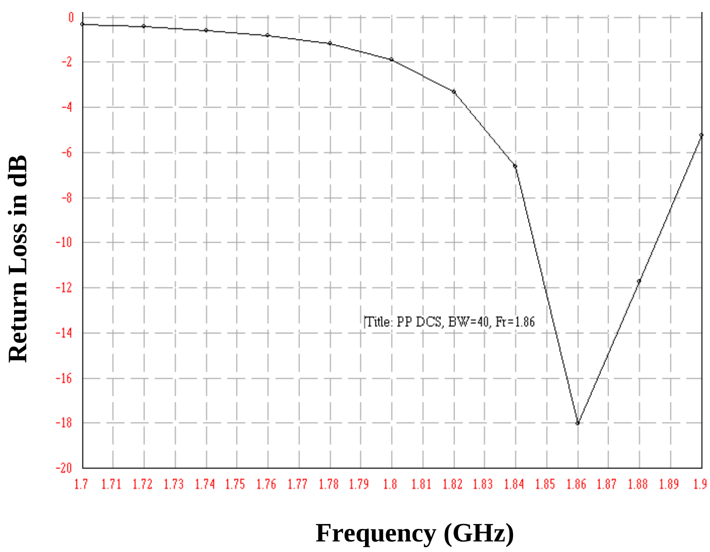


Fig.3a. The Return loss plot of the antenna (DCS 1700 band)

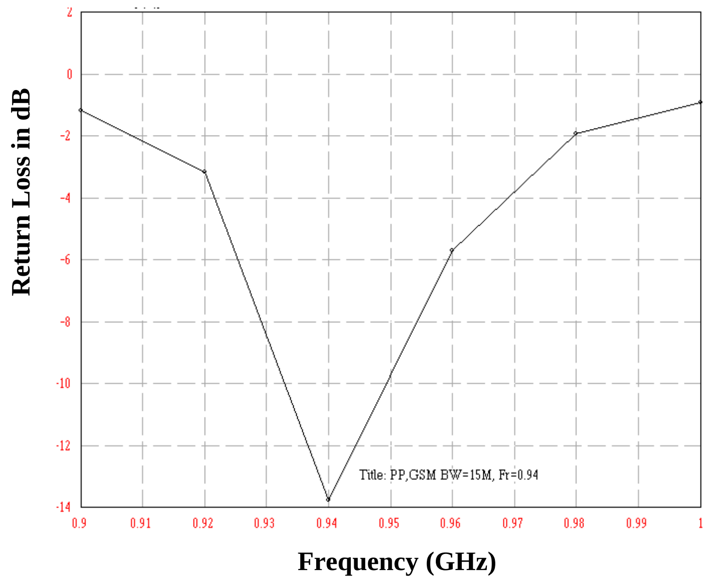


Fig.3b. The Return loss plot of the antenna (GSM 900)

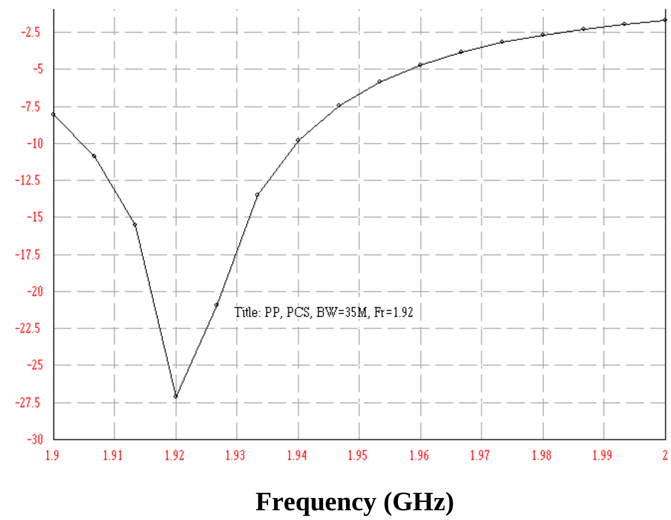


Fig.3c. The Return loss plot of the antenna (PCS 1800)

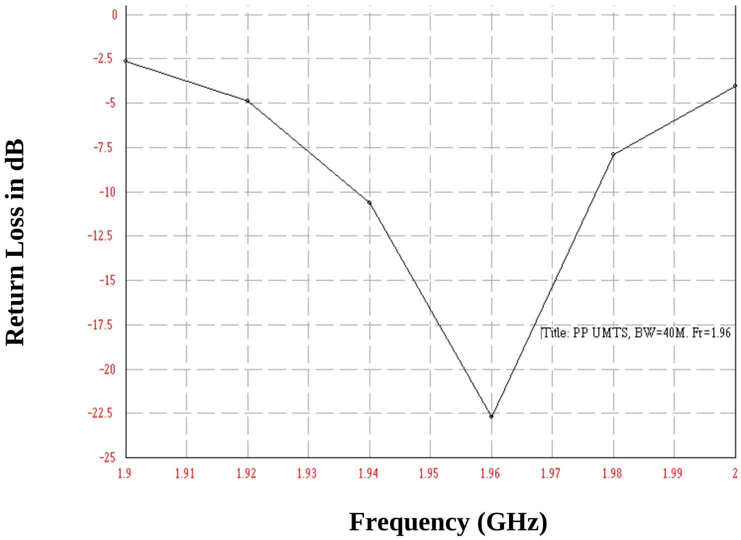


Fig.3d. The Return loss plot of the antenna (UMTS 1900)

The analytical formulation explained by equation 1 is verified for different bands such as DCS 1700, GSM 900, PCS 1800 and UMTS 1900 with two shorting plates, resulting into shifting of resonating frequency exactly half of its value. As a result, size reduction of 90.91%, 93.88%, 89.44% and 90.70% respectively is achieved as compared to the conventional size. The simulated return loss for specified frequency bands are shown in Fig.3a, Fig.3b, Fig.3c and Fig.3d respectively. Table 1 shows the comparison between conventional antenna dimension, with single plate and with parallel plates. Improved Bandwidth is achieved using parallel shorting plates compared to conventional and with single plate antenna.

Table 1: Comparison Table Between Conventional Antenna Dimension, With Single Plate And With Two Plates

Application	L*W (sq.mm)	L*W (with Single Plate)	L*W (with two Plate)	Size reduction % (with plate @ edge)	Size reduction % (with plate @ middle)	Bandwidth (with single plate)	Bandwidth (with parallel plate)
Bluetooth 2.42GHz (2.4-2.45)	29*38	11.5 *12	8.3 *13	87.47%	91.38%	55 M	57 M
UMTS 2, 1.96 GHz (1.920-.170)	37*48	14.8 *12	11 *15	90%	90.70%	37 M	40 M
PCS 1.89 GHz (1.850-.990)	35*46	14.8 *14	10*17	87.13%	89.44%	33 M	35 M
DCS 1.78 GHz (1.710-.880)	39*51	17*13	11.3*16	88.89%	90.91%	27 M	40 M
GSM .9 GHz (0.890-.960)	80*103	25.8 *32.3	18 *28	89.88%	93.88%	20 M	15 M

The compact rectangular microstrip antenna (RMSA) with two shorted-plates with dimension 8.3*13 sq.mm (Bluetooth 2.4 GHz band) is then fabricated with a reduced ground plane size of 20*20 sq.mm and measured its result using vector network analyzer as shown in Fig.4. The radiation pattern of proposed antenna is measured in anechoic chamber which shows a gain of 1.42 dBi as shown in Fig 7.Simulated and measured results are matched very well within a band of 2.40-2.45 GHz shown in Fig. 5.

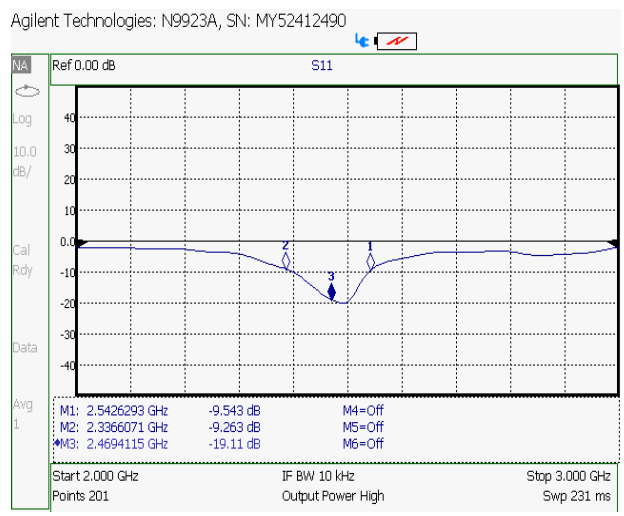


Fig.4. Measured result of the antenna (Bluetooth 2.4 GHz) on VNA

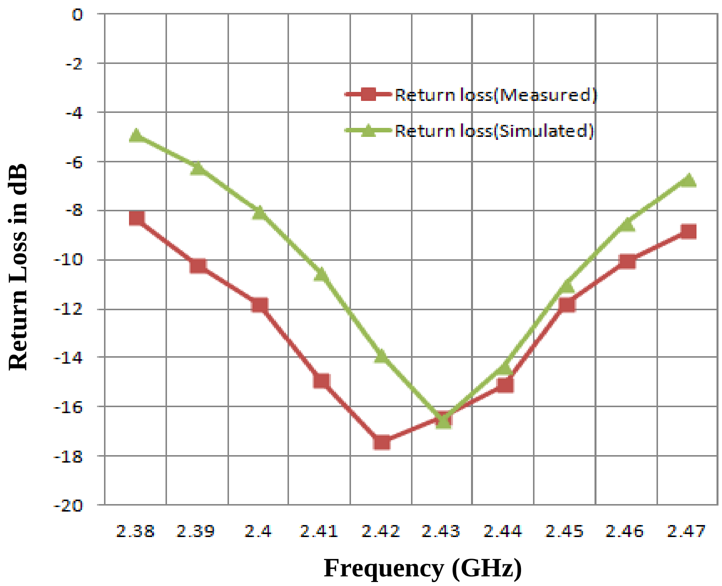


Fig.5. Comparison between Simulated and Measured Return Loss of antenna

The proposed novel method of insertion of two parallel shorting plates gained additional characteristics of circular polarization due to the excitation of two orthogonal modes by shorting plates. As shown in Fig.6, proposed antenna achieved an axial ratio bandwidth of around 100MHz below 3dB for specified band.

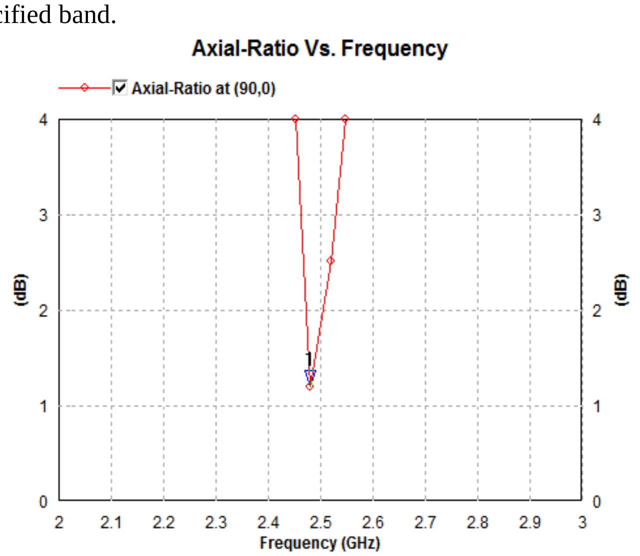


Fig.6. The Axial ratio of the antenna(Bluetooth 2.4 GHz)

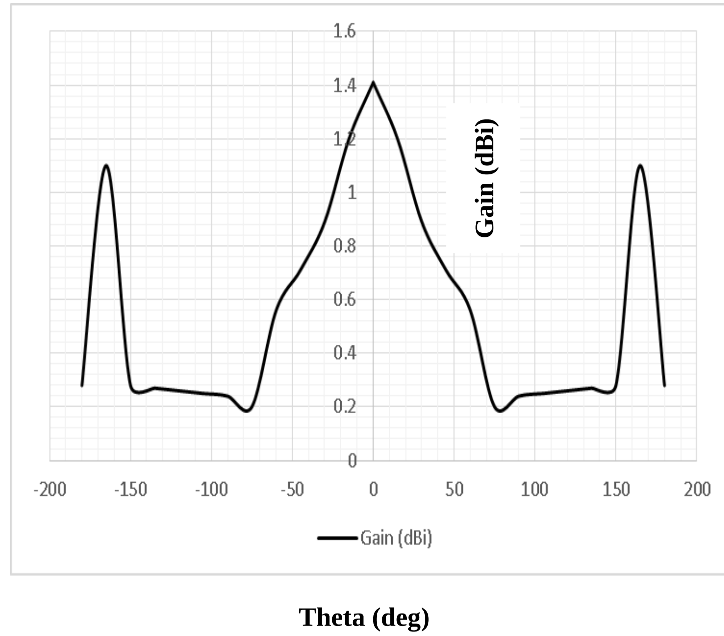


Fig.7. Radiation patterns of the proposed antenna at 2.43GHz

IV. Conclusion

In this paper, a compact rectangular microstrip antenna (RMSA) with two shorted-plates is successfully verified. The proposed antenna has 91.38% size reduction with a 3dB axial ratio bandwidth of 100MHz, which is desirable for thin-profile mobile telecom devices. It also studied that there exist a frequency below the lowest Eigen value. The insertion of the two shorting plates near to the feed position excites that frequency and thereby shifts the resonating frequency towards lower side without changing the dimension of antenna. This technique for antenna miniaturization has fuelled research work in the development of antenna structures with performances considerably enhanced over traditional antenna structure and methodologies. These technique can also beneficial to implement the miniaturized antenna for biomedical application.

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