Modified CPW Fed Monopole Antenna with Suitable Radiation Pattern for Mobile Handset

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Abstract –**A coplanar wave guide (CPW) fed printed monopole antenna with reduced radiation hazard for mobile handset is presented. The antenna offers a bandwidth of 150MHz when printed on a substrate of dielectric constant (εr) 4.4 and thickness 1.6mm with an overall dimension of 0.41λg X 0.31λg.The printed metal strip in the back side of the monopole modifies the radiation pattern suitable for mobile handset. Experimental and simulation studies of the proposed antenna are presented and discussed. A 20 dB reduction of radiated power in one quadrant of the radiation pattern offers a reduction of radiation towards the users head.**

Keywords – **CPW fed, low radiation hazard antenna, planar monopole antenna.**

I. Introduction

With the explosive growth of cellular phones and mobile wireless communication technology, there have been concerns about the safety aspects of the devices and the potential hazardous effects of EM radiation on the human tissue. Therefore, it is necessary to decrease the interaction of electromagnetic energy towards human head from mobile handset when in use. There are different methods to reduce radiation towards the user from handsets. Adding an external shield [1] to mobile phones is the most common method adopted for the reduction of unnecessary radiations. But the material selection and position of the external shield is very important. A ferrite sheet attached [2] to the front side, close to head can also reduce radiation, however, the parameters like attaching location, size and material properties of ferrite are very critical factors. Highly directive antennas [3] can also reduce radiation towards human head significantly. However, the adoption of highly directive antennas certainly causes degradation in signal reception from other directions. Parasitic elements are also used to get end fire pattern. Complicated truncated ground plane is used in [4] to get end fire pattern throughout the operating band. An array of Split Ring Resonators (SRRs)[5] are placed between the antenna and human head to reduce the electromagnetic interaction between them. All of the above methods are either complicated or bulky in nature.

In this paper the radiation towards human head is reduced tremendously by suitably adding a small metal strip on the backside of a CPW fed monopole antenna without sacrificing the radiation characteristics for a mobile handset.

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II. Antenna Design

A schematic of the proposed antenna is shown in Fig 1. The antenna is fed by coplanar wave guide (CPW) feed. The dimensions of the proposed antenna are given below. The main radiating element is a vertical strip of length L_1=25mm and width W_1=3mm.This is acting as a $\lambda_g/4$ monopole. The ground plane dimension are L_2=17mm and W_2=14mm.The gap between monopole strip and ground plane (g) is 0.35 mm. Fig1(b) shows the back side view of the antenna. The metal strip with length L_3=26mm, widthW_3=9.9mm with a separation (S) of 2mm and off sited by (P) 4.5mm from the top of the monopole are printed at back side. By properly choosing the metal strip position the radiation pattern can be modified. The prototype of the antenna was fabricated on a substrate of dielectric constant (ε_r) 4.4 and h=1.6mm with an overall dimension of 42 x 28 x 1.6mm^3.

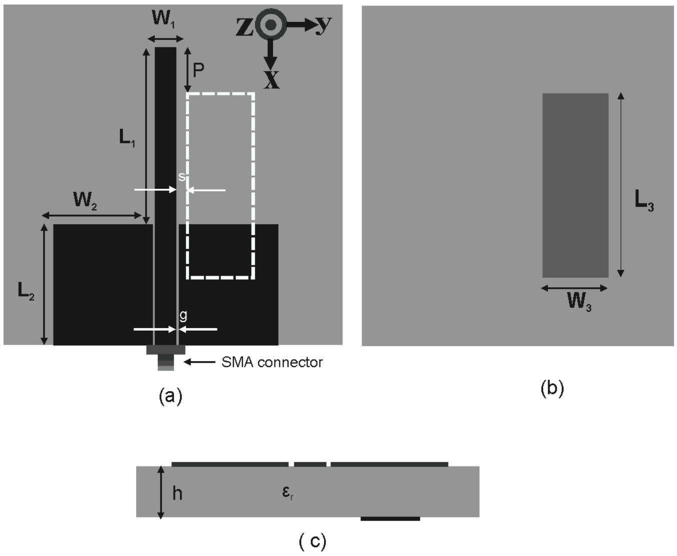


Fig. 1. Geometry of the proposed antenna(a)3D schematic diagram (b)bottom view (c) Side view (L_1=25mm,W_1=3mm,L_2=17mm, W_2=14mm,g=0.35mm,L_3=26mm,W_3=9.9mm,h=1.6mm, ε_r= 4.4, P=4.5mm and S=2mm.)

III. Results and Discussion

Fig.2 shows the reflection characteristic of the antenna with and without metal strip at the back side. Conventional strip monopole is operating at 2.3GHz. The introduction of metallic strip reduced the resonant frequency from 2.3GHz to 1.8GHz. That means the metallic strip can reduce the overall size of the antenna. It also modifies the directional pattern of the monopole antenna in the elevation plane to a pattern suitable for mobile- handset.

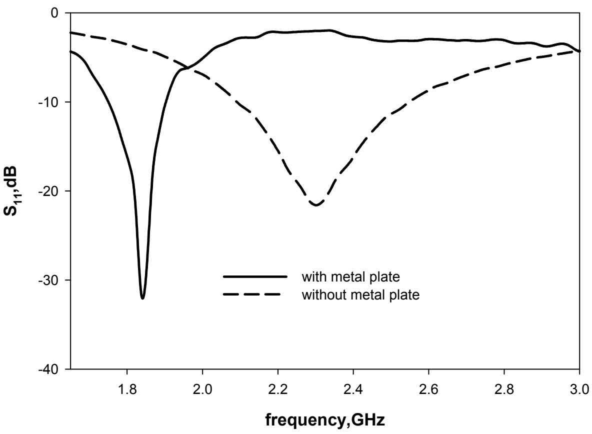


Fig. 2. Reflection characteristics s of the antenna with and without metal stripe

Simulated and experimental result of return loss characteristics of the antenna is shown in Fig.3. Return loss measurements indicate that the antenna offers a VSWR bandwidth of 150MHz (1.75GHz to 1.90GHz). The simulations of the antenna are carried out using Ansoft HFSS and are validated by HP8510C network analyzer.

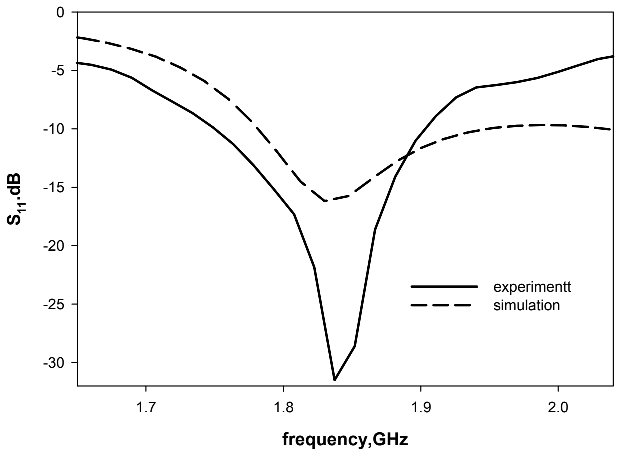


Fig. 3. Return loss characteristics (simulated and experiment)

The simulated 3D far field radiation pattern at 1800MHz of the proposed antenna is shown in Fig.4. There is a considerable reduction of radiated electric field along the positive Y direction for the antenna. Moreover, there is only one null appeared in the pattern. This reduction is nearly 20dB as evident from the figure.

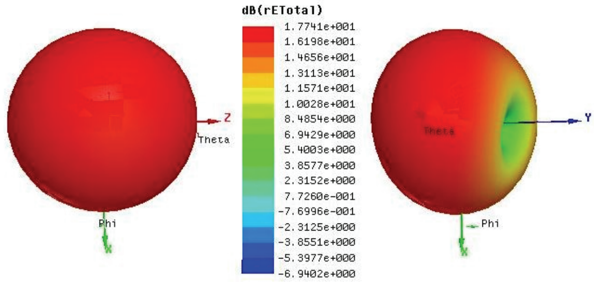


Fig 4 Simulated 3D pattern of the antenna

Measured 2D radiation patterns of the antenna in XY and YZ plane at the resonance frequency is shown in Fig 5(a) and (b) respectively. The measured pattern is very suitable for mobile handset with good radiation in three space quadrants with reduced radiation in one quadrant. This property can be conveniently employed to reduce the EM interaction towards the head of a mobile phone user.

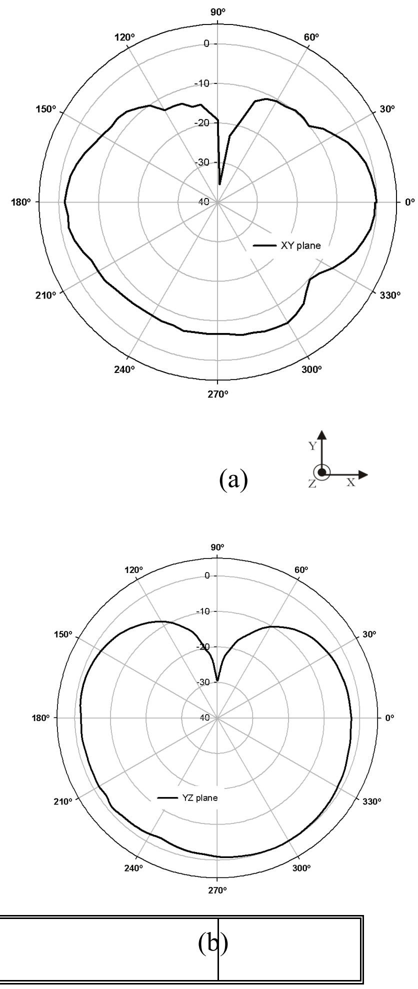


Fig. 5. Measured radiation pattern of the proposed antenna in (a) XY and (b) YZ plane.

TABLE I.
ANTENNA PARAMETERS FOR DIFFERENT DIELECTRIC SUBSTRATES

Dielectric Material	Relative dielectric constant(εr)	L_1 mm	W_1 mm	G mm	h mm	L_2 mm	W_2 mm	L_3 mm	W_3 mm
RT Duroid 5880	2.2	31	5	0.2	1.575	21.08	17.36	32.2	12.276
Rogers RO 4003	3.38	26.25	3	0.24	1.524	17.85	14.7	27.3	10.395
FR4 epoxy	4.4	25	3	0.35	1.6	17	14	30	9.9
Rogers RO 3006	6.15	22.5	3	0.5	1.28	15.3	12.6	23.4	8.91

Design Eqs (1)-(7) are developed and which can be effectively used to design antenna at other frequencies.

$$L_1=0.25\ \lambda_g \quad (1)$$

$$L_2= 0.17\ \lambda_g \quad (2)$$

$$W_2= 0.14\lambda_g \quad (3)$$

$$L_3= 0.26\lambda_g \quad (4)$$

$$W_3=0.097\lambda_g \quad (5)$$

$$d=0.0197\ \lambda_g \quad (6)$$

$$p=0.059\ \lambda_g \quad (7)$$

where λg is the dielectric wavelength.

The parameters of the antenna were studied on substrate with different permittivity at 1.8GHz using Ansoft HFSS is presented in Table I. In all the cases the simulated radiation pattern is suitable for a mobile hand set.

The antenna patterns in YZ plane with and without vertical strip at 1.8GHz are shown in Fig.6. The induced current in the metal strip will also reradiate electromagnetic energy and the total far field electric field gets redistributed giving a null along positive Y direction and filling the original two nulls of the conventional monopole. Thus omnidirectional characteristic of the monopole antenna is modified.

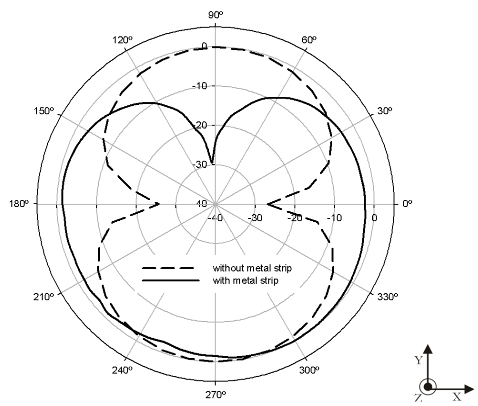


Fig. 6. The radiation patterns of the antenna with and without strip.

Fig. 7 shows the measured gain of the antenna with and without metallic strip. While adding metallic strip the direction of radiating power gets redistributed without affecting much on the gain of the antenna. The proposed antenna shows an average gain of 1.12dBi.

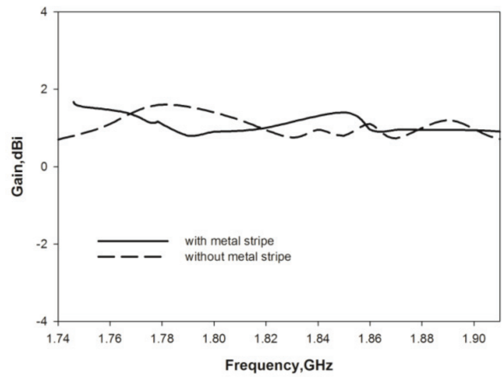


Fig. 7. Measured gain of the antenna with and without metal strip.

The radiation patterns of the antenna for substrate with different loss tangents are shown in Fig. 8. It is found that the pattern remains unaltered with respect to the losses in the dielectric substrate but the gain is reduced by 0.1dB for tanδ=0.02, when compared to lossless substrate.

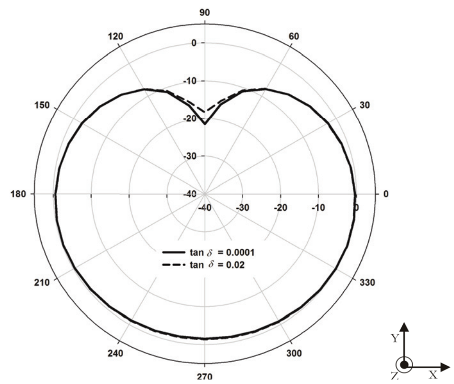


Fig. 8. Radiation pattern of the antenna for different loss tangent.

The photo graph of the proposed antenna and the radiation pattern measurement set up are shown in Fig 9 and Fig 10 respectively. A standard wideband horn antenna (1-18GHz) is used as receiving antenna for radiation pattern measurements. The antenna measurements are done in an Anechoic chamber to avoid reflections from nearby objects.

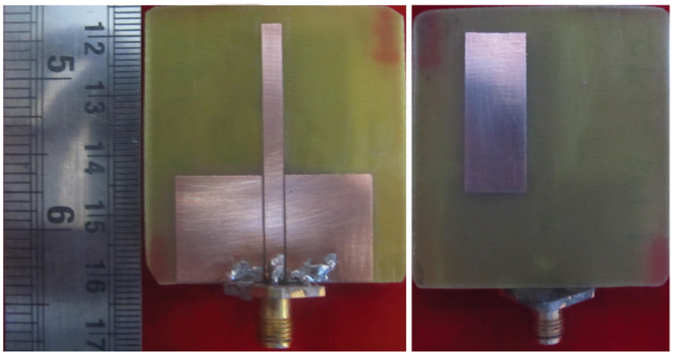


Fig. 9. Photograph of the antenna.

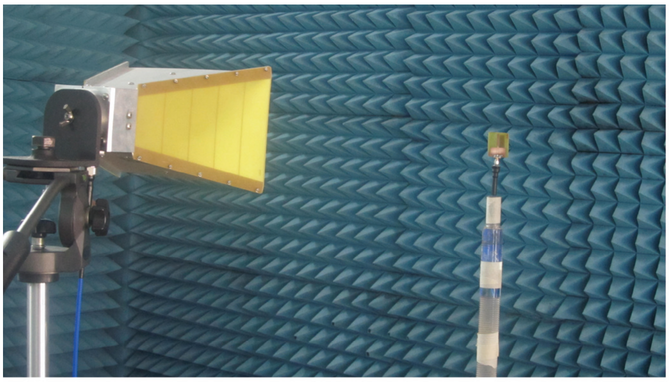


Fig. 10. Radiation pattern measurement set up of the antenna.

IV. SAR CALCULATION WITH PHANTOM HEAD MODEL

The simulation model of SAM phantom head model provided by CST Microwave Studio®(CST MWS) with planar monopole antenna with and without printed strip for a distance of 10mm from head model is also studied and are shown in Figure 11 (a) and (b) respectively. The SAR [9] in human head is defined as follows,

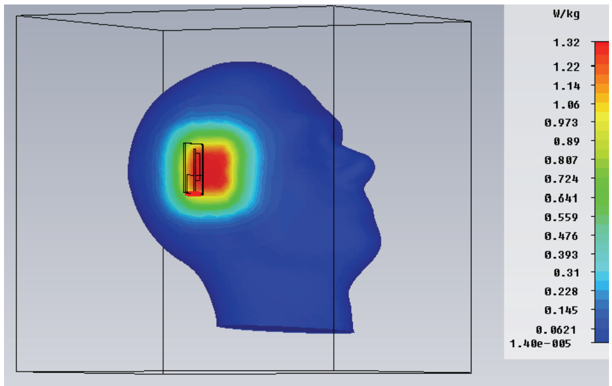
$$SAR = \frac{\sigma|E|^2}{\rho} \text{ W/Kg.} \quad (8)$$

where σ = conductivity of the tissue (S/m)

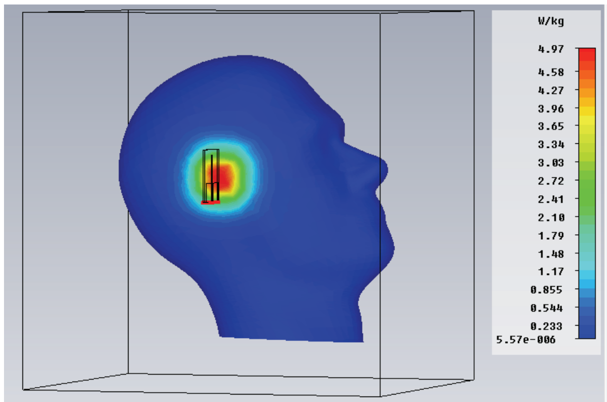
ρ = mass density of the tissue (kg/m^3)

E = rms electric field strength (V/m)

Simulated SAR value of the proposed antenna is compared with monopole antenna of same dimension for different distances are shown in Table II.



(a)



(b)

Fig. 11. Planar monopole antenna with (a) and without (b) printed strip for a distance of 10mm from head model.

TABLE II

SIMULATED SAR VALUE OF THE ANTENNA WITH DISTANCE

Distance from phantom model to antenna	SARw/kg(1gm) Planar monopole antenna	SARw/kg(1gm) Planar monopole antenna with printed metal strip at the back
10mm	4.97	1.32
20mm	2.616	0.595
30mm	1.074	0.348
40mm	0.707	0.272

From the SAR value of the proposed antenna with phantom head model for different distance as shown in Table II, It is observered that SAR value decreases with distance and for the proposed antenna SAR value is less than FCC recommended value, even for a distance of 10mm.

V. CONCLUSION

A CPW fed monopole antenna with printed vertical strip at the back side, producing radiation characteristics suitable for a mobile handset is presented. The proposed antenna operates at GSM 1800 band. A good agreement between measurement and simulation is obtained. This antenna structure is very simple with single null and can efficiently be used in mobile handset.

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