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MOBILE ANTENNA WITH REDUCED RADIATION HAZARDS TOWARDS HUMAN HEAD

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Abstract—A Coplanar Wave guide (CPW) fed printed monopole antenna with reduced radiation hazard from a mobile handset is presented. The printed metal stripes in the back side of the monopole modify the far field pattern ideal for mobile handset. The antenna offers a bandwidth of 200 MHz when printed on a substrate of dielectric constant (ε_r) 4.4 and thickness 1.6 mm with an overall dimension of $42 \times 31.7\,\mathrm{mm}^2$. Experimental and simulation studies of the antenna radiation characteristics 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.

1. INTRODUCTION

Due to the rapid growth in the use of mobile phones and other wireless communication systems, there is a great concern about the harmful radiation from these devices. Therefore, it is necessary to decrease the interaction of electromagnetic energy towards human head when mobile handset is in operation. Different methods are used for reducing this type of radiations. Adding an external shield [1] to mobile phones is the most common method adopted for reducing the unnecessary radiations. Here, shielding structure has to be integrated with the antenna to provide better shielding effectiveness and the material selection and position of the external shield is also very important. A ferrite sheet attached [2] to the front side, close to head can also

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reduce radiation, however, the parameters such as attaching location, size and material properties of ferrite sheet played an important role in the reduction effectiveness. Highly directive antennas [3, 4] 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 [5] to get end fire pattern throughout the operating band. In [6], a folded vertical copper wire of length 0.48λ as a reflector is used. But the very large reflector is a major problem in compact devices. Researchers have explored PIFA (Planar Inverted F Antenna) with EBG (Electromagnetic Band Gap) surface [7] on the ground plane to reduce radiation towards human head. But this deteriorates the structure simplicity and compactness, and also there is no appreciable reduction in radiation towards human head. An antenna which reduces radiation tremendously towards human head by suitably adding vertical stripes on the backside of CPW fed monopole antenna without sacrificing the radiation characteristics, which is required for a mobile handset is discussed.

2. ANTENNA DESIGN

Antenna is basically a monopole strip fed by coplanar waveguide (CPW) feed. The antenna geometry and the associated parameters are shown in Figure 1(a). The main radiating element is a vertical stripe of length $L_1 = 25\,\text{mm}$ and width $W_1 = 3\,\text{mm}$. This is acting as a $\lambda g/4$ monopole, where λg is the wavelength in the substrate. The ground plane dimension are $L_2 = 17\,\text{mm}$ and $W_2 = 14\,\text{mm}$. The gap between monopole strip and ground plane (g) is 0.35 mm. Figure 1(b) and Figure 1(c) show the back and side view of the antenna. Thirteen metal stripes with length $L_3 = 30\,\text{mm}$ and width $W_3 = 0.3\,\text{mm}$ with a separation (d) of 0.5 mm is off sited by (P) 4.5 mm from the top of the monopole and $Q = 8.5\,\text{mm}$ are printed at back side. By properly choosing the metal strip position the radiation pattern can be modified. The prototype was fabricated on a substrate of dielectric constant (ε_r) 4.4 and $h = 1.6\,\text{mm}$ with an overall dimension of $42 \times 31.7 \times 1.6\,\text{mm}^3$.

3. RESULTS AND DISCUSSION

Return loss characteristics of the antenna with and without back side vertical stripes are shown in Figure 2. Return loss measurements indicate that the proposed antenna offers a 2 : 1 VSWR bandwidth of 200 MHz (1.76 GHz to 1.96 GHz). The conventional strip monopole

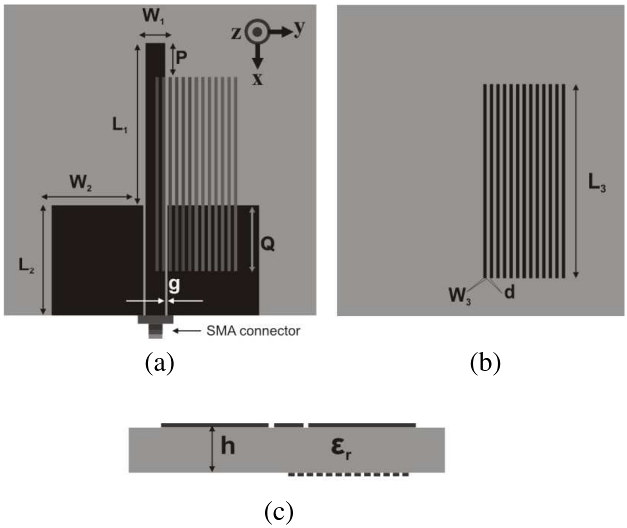


Figure 1. Geometry of the proposed antenna (a) 3D schematic diagram, (b) bottom view, (c) side view ($L_1 = 25\,\text{mm}$, $W_1 = 3\,\text{mm}$, $L_2 = 17\,\text{mm}$, $W_2 = 14\,\text{mm}$, $g = 0.35\,\text{mm}$, $L_3 = 30\,\text{mm}$, $W_3 = 0.3\,\text{mm}$, $d = 0.5\,\text{mm}$, $h = 1.6\,\text{mm}$, $\varepsilon_r = 4.4$.).

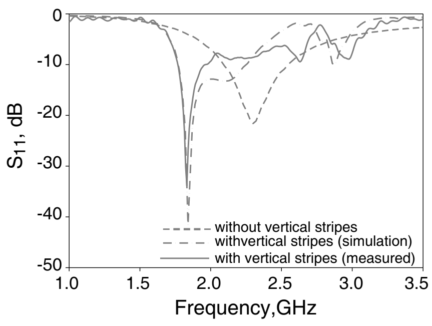


Figure 2. Return loss characteristics of the antenna.

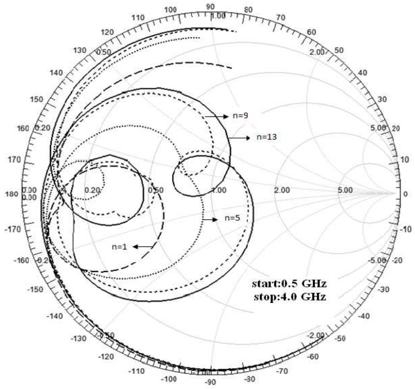


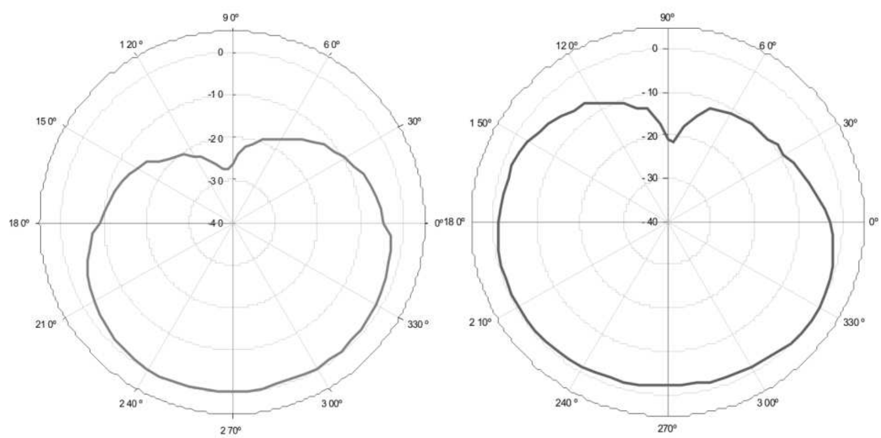
Figure 3. Variation of input impedance with number of stripes.

is operating at 2.3 GHz. The introduction of metallic stripes reduced the resonant frequency to 1.8 GHz. Therefore, metallic stripes 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. The measured value is validated by Ansoft HFSS simulation tool and all antenna measurements were carried out with HP8510C network analyzer.

Variation of the input impedance of the antenna with number of stripes (n) is shown in Figure 3. Additional parasitic stripes [8] increase the inductive reactance which shifts resonant frequency to lower side. An optimized strip number of $n = 13$ is chosen by considering application and compactness.

Measured 2D radiation patterns of the antenna in YZ and XY plane at the resonance frequency are shown in Figures 4(a) and (b) respectively. It is observed that, the radiation pattern of the conventional monopole gets modified by the addition of the metallic stripes. The fringing field between the monopole and any of the lateral ground plane is affected by adding the stripes, but the coupling on the other lateral ground plane remains same. As a result, the electric field gets redistributed giving a null along positive Y direction and filling the original two nulls of the conventional monopole. This change in radiation pattern can be conveniently employed to reduce the EM interaction towards the head of a mobile phone user.

The measured antenna patterns in YZ plane with and without vertical stripes are shown in Figure 5. From figure, it is clear that, the figure of eight pattern in YZ plane is modified to a pattern with single null. A 20 dB reduction in radiated power is observed at the beam minima, with appreciable power in all other directions.



(a) (b)

Figure 4. (a) and (b) Measured radiation pattern of the proposed antenna in YZ and XY plane.

The parameter of the antenna was studied on substrate with different permittivity at 1.8 GHz using Ansoft HFSS is presented in Table 1.

The parameters of the antenna at the required resonant frequency are given below (Equations (1)–(5)). Where λ_g is the dielectric

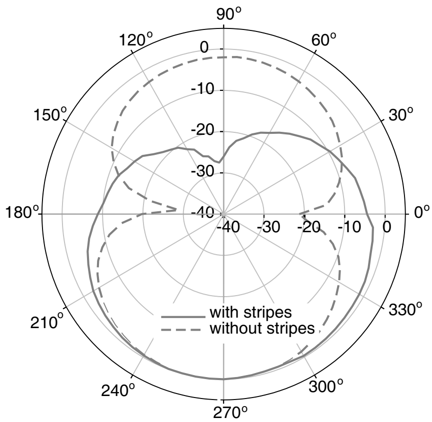


Figure 5. The radiation patterns of the antenna with and without stripes in YZ plane.

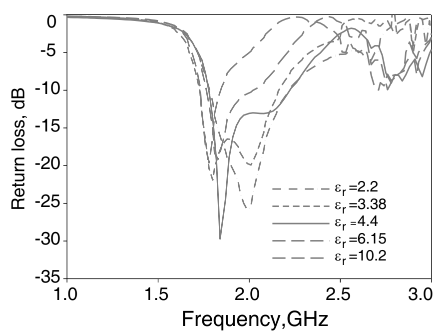


Figure 6. Variation of S_{11} with different substrate.

Table 1.

Dielectric Material	Relative dielectric constant (ε_r)	L_1 mm	G mm	h mm	L_2 mm	W_2 mm	L_3 mm	W_3 mm
RT Duroid 5880	2.2	31	0.15	1.6	21.08	17.36	37.2	0.37
Rogers RO 4003	3.38	28.5	0.25	1.6	19.38	15.96	34.2	0.34
FR4 epoxy	4.4	25	0.35	1.6	17	14	30	0.3
Rogers RO 3006	6.15	23.75	0.53	1.6	16.15	12.5	28.5	0.29
RT Duroid 6010 LM	10.2	18.38	1	1.6	12.49	10.29	22.05	0.22

wavelength.

$$L_1 = 0.25\lambda_g \quad (1)$$
$$L_2 = 0.17\lambda_g \quad (2)$$
$$W_2 = 0.14\lambda_g \quad (3)$$
$$L_3 = 0.31\lambda_g \quad (4)$$
$$W_3 = = 0.0031\lambda_g \quad (5)$$

The return loss characteristics of the different antenna as computed in Table 1 is shown in Figure 6. It is noticed that, as ε_r increases the matching corresponding to the second resonance decreases, together with a shift towards lower frequency.

Variation of reflection coefficient with substrate height is also studied. From Figure 7, it is observed that, as h increases the length contributing the second resonance $(L_1 + (L_3 - Q) + h)$ increases and hence the resonance shifts towards the lower side and merge with the first resonance. The radiation pattern remains same in the required application band.

From Figure 8, it is observed that, the parameter w_3 does not contributing to the resonance. Hence, in the proposed design an optimized width of 0.3 mm is employed with $w_3 + d_3 = 0.8$ mm a constant value.

The influence of the separation between the stripes d on the S_{11} is presented in Figure 9. From the figure, it can be seen that, as d increased, the entire band shifts to lower side without changing bandwidth. It is due to increase in the capacitive coupling between stripes and ground plane. Its value is optimized to 0.5 mm according to the resonance in the application band.

The effect on radiation pattern with the number of the stripes is

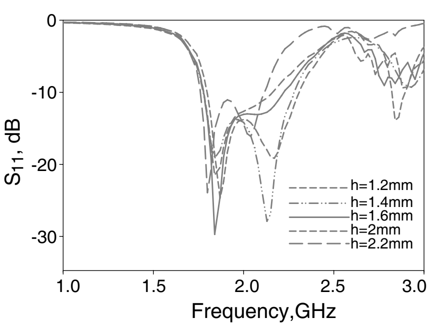


Figure 7. Variation of S_{11} with substrate height (h).

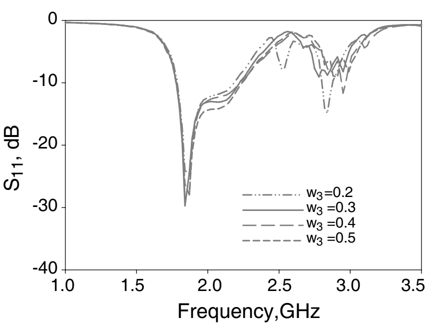


Figure 8. Variation of S_{11} with width of the stripes.

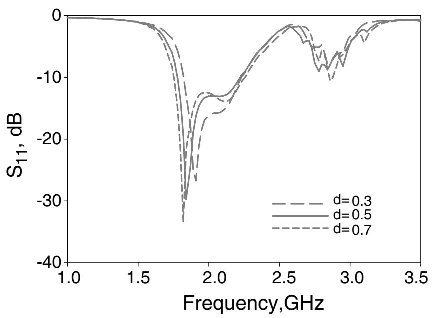


Figure 9. Variation of S_{11} with separation between the stripes.

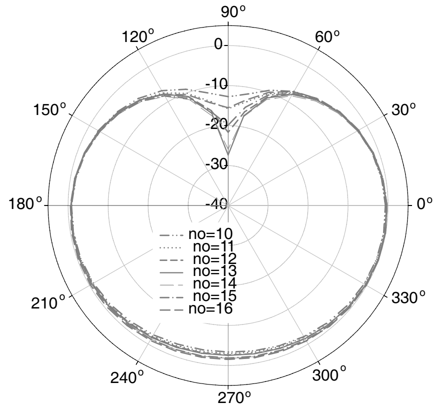


Figure 10. Study of the radiation pattern with number of stripes.

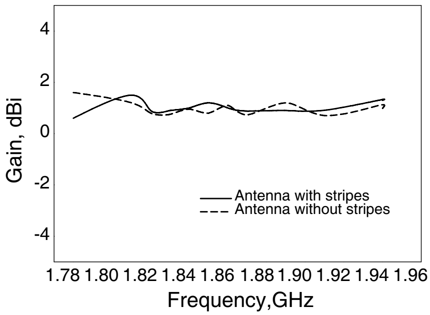


Figure 11. Measured gain of the antenna.

also varied and studied. The simulated result shows (Figure 10) that the maximum reduction is obtained when the numbers of stripes is 13.

Figure 11 shows the measured gain plot of the antenna with and without metallic stripes. While adding metallic stripes the direction of radiating power gets redistributed without affecting much on the gain of the antenna. The proposed antenna shows an average gain of 1.04 dBi.

4. CONCLUSION

A CPW fed monopole antenna with printed vertical stripes 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 and can efficiently be used in mobile handset.

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