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Design of a High Gain Circular Patch Antenna for GSM1800 Band

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Abstract- A GSM1800 band antenna using inverted suspended circular patch is presented in this work. The proposed antenna is suitable for some specific used such as energy harvesting systems. The main objective of simulation is to increase the gain of patch antenna. A circular patch antenna of 32 mm radius has been optimized using Ansotf HFSS.v.15. The simulation results of antenna shows the return loss is -21 dB at 1.8 GHz for VSWR≤ 2. The maximum gain of antenna is obtained at 7.5 dB. The gain of antenna is increased by inverted suspended circular patch with same dimension of radiating patch from 7.5 dB to 8.5 dB. The gain of the antenna is increased with increasing the gap between top and bottom patch because of coupling between them. The gain of antenna is increased from 8.2 dB to 8.5 dB when gap is increased from 1 mm to 4 mm.

Index Terms- Antenna, Circular Patch, GSM1800, HFSS, Inverted Suspended.

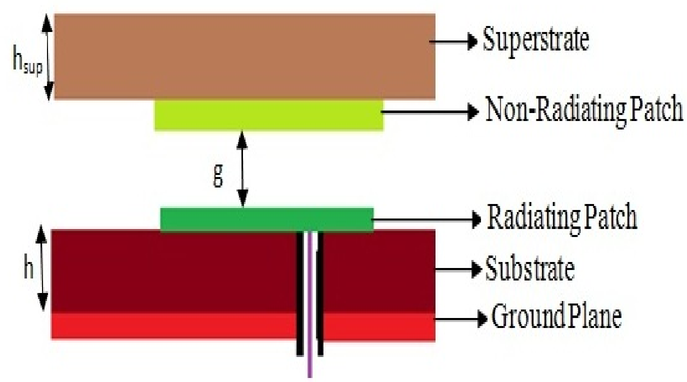
I. INTRODUCTION

In recent year harvesting of RF energy using printed patch antenna gain an attractive solution for wireless communication. RF energies are available in the frequency range of 0.86 to 2 GHz. The main sources are available in different band e.g. 869-890 MHz (CDMA), 935-960 MHz (GSM900), 1810-1880 MHz (GSM1800), 1.92-2.17 GHz (3G), 2.4-2.468 GHz (Bluetooth or WiFi) 3.2 GHz (Radio location 3G), 3.8 GHz (LTE/4G)[1]. Generally these type signals are utilized for mobile communications. There are numbers of printed antenna has been proposed in different literature. The antenna characteristics affect the amount of receiving energy. Therefore appropriate design of antenna is very important.

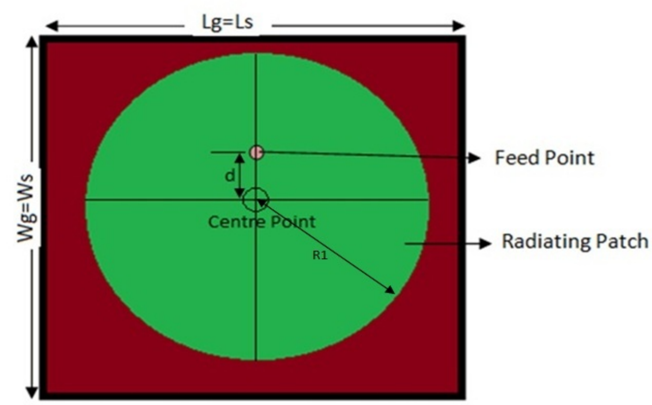
This work presents the design of a circular patch antenna for GSM1800 band. Unlike rectangular patch, the Circular patch has only one degree of freedom to control it characteristics is the radius of antenna [2].The geometry and details simulation of antenna has been presented in this work. The simulation has been done using Ansoft HFSS.15 version. All parameters of antenna have optimized to obtain the maximum gain.

II. ANTENNA DESIGN

Design of proposed antenna and its parameters are shown in Figure 1. The parameters of antenna were optimized using finite element commercial software [3]. The radiating circular patch (R1=31 mm) is printed on 1.6 mm thick RogerRT/Duroid 5880 (ε_r=2.2 and tanδ=0.0009) top substrate (Ls=Ws=70 mm). A ground plane (Lg=Wg=70 mm) is printed back side of the substrate. A 50Ω coaxial cable feed (radius= 1.6 mm) is used to excite the radiating patch. Another non radiating upper circular patch (radius=32 mm) is used to increase the gain of the antenna. Non radiating circular patch is printed on superstrate (Lsup=Wsup= 70 mm) with an air gap (g) of 1 mm from radiating patch. The position of coaxial feed is optimized at distance (d) of 7 mm from the centre point of antenna.



(a)



(b)

Figure 1: Geometry of circular patch antenna (a) Front view with suspended circular patch (b) Top view without suspended circular patch

III. SIMULATION AND RESULTS OF PROPOSED ANTENNA

Radiating circular patch antenna is optimized at radius of 31 mm to obtain GSM1800 band. For a given resonance frequency, the radius of radiating circular patch can be calculated using following equations [4].

$$f_0 = \frac{K_{nm}\, c}{2\pi\, a_e \sqrt{\epsilon_e}} \quad \text{---------------(1)}$$

Where f_0= Resonance frequency of antenna, c= Speed of light in free space= 3x103 m/s, a_e= Effective radius of antenna,ε_e= Effective dielectric constant of substrate, Knm is m-th root of the derivative of the Bessel function of order n [5,6]. The effective radius of antenna can be determined using equation (2).

$$a_e = a\left[1 + \frac{2h}{\pi a \epsilon_r}\left\{\ln\left(\frac{a}{2h}\right) + 1.41\, \epsilon_r + 1.77 + \frac{h}{a}(0.268\, \epsilon_r + 1.65)\right\}\right]^{\frac{1}{2}} \quad \text{---(2)}$$

Where, a= Radius of antenna, h= Thickness of substrate and ε_r= Dielectric constant of substrate. For the fundamental TM11 mode, the value of K_{nm} mode is 1.84118. The value of ε_e can be calculated using equation (3).

$$\epsilon_e = \frac{C(a,h,\epsilon_r \epsilon_0)}{C(a,h,\epsilon_0)} \quad \text{----------(3)}$$

$C(a,h,\varepsilon_r\varepsilon_0)$ and $C(a,h,\varepsilon_0)$ are total capacitance of antenna with and without dielectric substrate respectively. $C(a,h,\varepsilon_r\varepsilon_0)$ of antenna can be calculated using equation (4).

$$\boldsymbol{C(a,h,\epsilon_r,\epsilon_0) = \frac{0.8525 \epsilon_r \epsilon_0 \pi a^2}{h} + 0.5 C_f} \quad \text{-----(4)}$$

C_f can be calculated using equation (5).

$$C_f = 2a\, \epsilon_0 \left[\ln\left(\frac{a}{2h}\right) + 1.41\, \epsilon_r + 1.77 + \frac{h}{a}(0.268\, \epsilon_r + 1.65)\right] \quad \text{-----------------(5)}$$

$C(a,h,\varepsilon_0)$ can be calculated for air. Calculated radius is well agreed with simulated radius of radiating circular patch. Results are not affected if effective permittivity (ε_e) is considered as slightly less than relative permittivity of the substrate instead of calculations using mathematical equations.

A. Return loss:

Antenna is optimized at radius (R1) of 32 mm and feed point at distance (d) of 7 mm from the centre point of antenna. Simulation results shows that return loss is S11= -21dB and input impedance is 48Ω are shown on the Figure 2 and Figure 3 respectively. The antenna has approximately 1% (154 MHz) bandwidth for VSWR≤2 from 1.7934 GHZ to 1.8086 GHz.

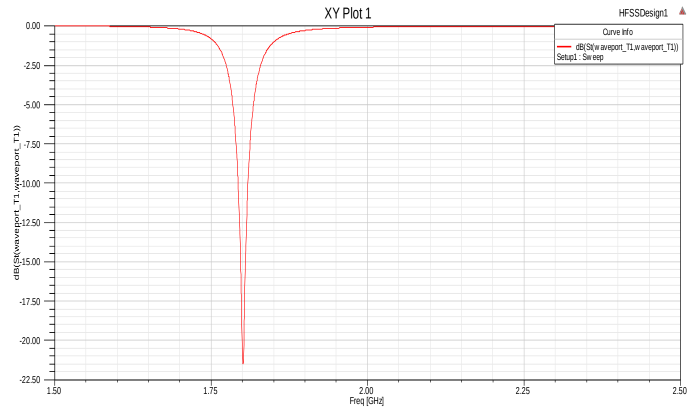


Figure 2: Return loss and frequency

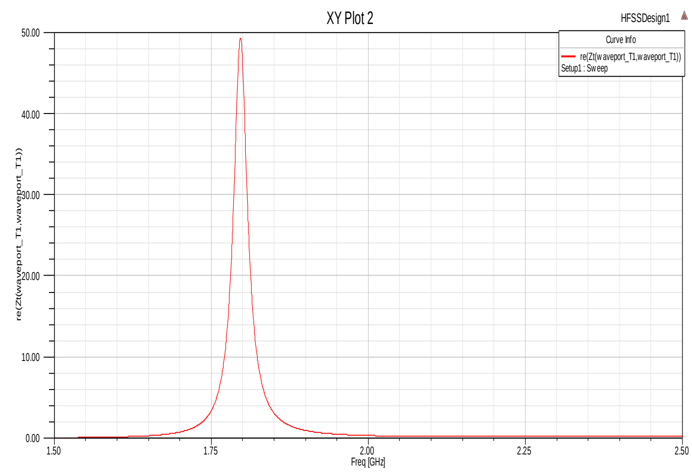


Figure 3: Input impedance of antenna and frequency

B. Co-Pol and Cross-Pol:

With the increasing of the thickness of substrate 1.6 mm to 2 mm, the co-pol and and cross pole both are increasing. But at the thickness of 3 mm, the co-pol and cross-pol both are decreasing. The RogerRT /Duroid 5880 is considered as substrate material for simulation of Co-pol and Cross-pol at 1.8 GHz. Table I. is showing Co-pol and Cross-pol with different thickness of substrate. Co-pol and Cross-pol radiation pattern are shown in Figure 4 and Figure 5 respectively. The gain pattern of antenna is shown in the figure 6.

Table I: Co-pol and Cross-pol with different thickness of substrate

Substrate Thickness (mm)	Phi=0°; H-Plane		Phi=90°; E-Plane	
	Co-pol(dB)	Cross-pol (dB)	Co-pol (dB)	Cross-pol (dB)
1.6	5.5	-38	5.5	-38
2	5.7	-61	5.7	-50
3	4.2	-48	4.2	-44

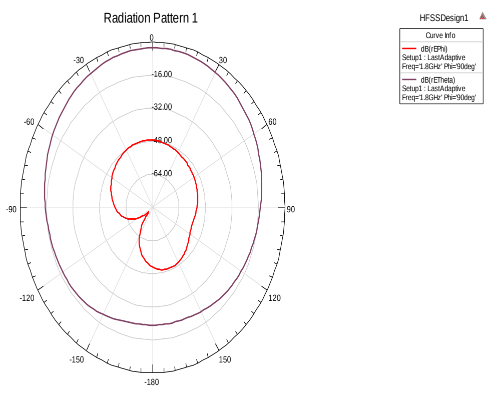


Figure 4: Co-Pol and Cross-Pol radiation pattern at Phi= 90°.

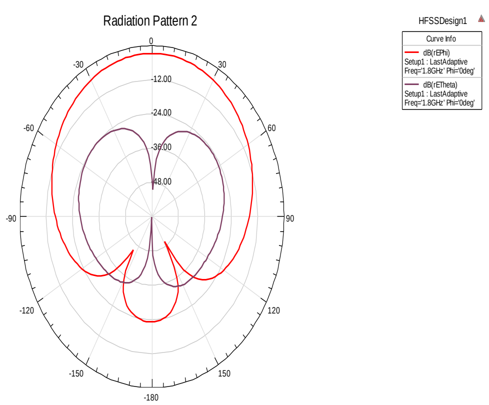


Figure 5: Co-Pol and Cross-Pol radiation pattern at Phi= 0°.

Table II: Gain of antenna with different dielectric constant.

Substrate Materials	Dielectric Constant (ε_r)	tanδ	Gain (dB)
RogerRT/ Duroid(5880)	2.2	0.0009	7.5
RogerRT/ Duroid(5870)	2.33	0.0012	7.2
RogerRT /Duroid(6002)	2.94	0.0012	6.7

IV. Antenna Simulation with Inverted Suspended Circular Patch

Since the bandwidth of antenna is very small. A non radiated circular patch is suspended in air in the top of the radiating circular patch to increase the bandwidth of antenna. The top circular patch is inverted suspended on a dielectric superstrate. The dimension of top patch is same as radiating and they are electromagnetically coupled. The RogerRT/Duroid (5880) superstrate has thickness (h_{sup}) of 1.6 mm with ε_r=2.2 and tanδ=0.0009. The gap between radiating patch and non-radiating patch is g. The variation of Co-pol, Cross-pol, bandwith and gain of the antenna with different value of g is shown on the Table III.

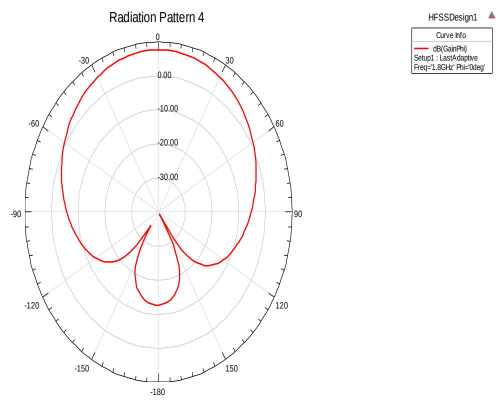


Figure 6: The gain radiation pattern.

Table III: The variation of Co-Pol, Cross-Pol, Bandwith and Gain of the antenna with different value of g.

Gap (g)	Phi=0°,H-Plane		Phi=90°,E-Plane		Band-width	Gain (dB)
	Co-pol (dB)	Cross-pol(dB)	Co-pol (dB)	Cross-pol (dB)		
1 mm	2.9	-34	2.9	-34	70 MHz	8.2
2 mm	3.3	-52	3.3	-52	128 MHz	8.3
3 mm	3.2	-50	3.2	-46	158 MHz	8.4
4 mm	3.4	-52	3.4	-51	174 MHz	8.5

The top patch is electromagnetically coupled with bottom patch which increase the bandwidth of antenna. The effective dielectric constant under top patch is low which increase the gain of antenna. This suspended configuration of antenna provides a dielectric cover for the actual antenna [7,8]. As the coupling between top and bottom patch decreases with increases the gap (g) [9], both the Co-pol and Cross-pol are increasing.

V. Conclusion

In this work, a narrow band patch antenna has been presented for GSM1800 band. This antenna can be used to harvest electromagnetic energy from cell tower. A rectifier circuit is needed to convert RF ac signal to dc signal. A rectifier circuit can be designed according to resonance frequency of antenna using diode network.

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