Cellular Communication Using Single band Microstrip Patch Antenna Model

Engr. Omer Iqbal, Engr. Abid Hussain Chohan,
Engr. Farhan Fareed Khan
Dept. of Electrical & Electronics Engineering
NFC Institute of Engineering & Technological Training Multan, Pakistan

Abstract

The cellular industry was brought into being about 25 years from today, presently, producing $400 billion in annual revenues, intensifying its growth to the hig hest scale, with superlatively 4.1 billion subscribers from all around the world. Moving back to the 1980's, heavily built cellular handsets that were large and awkward to carry or move, were soon replaced by advancements in VLSI technology which empowered size reduction by using microprocessors chips.

One of the techniques for decreasing the handset size is the usage of compact antennas. A MPA (Microstrip Patch Antenna) made up of a plane called "ground plane" at one side of a patch. The other side of the patch contains dielectric substrate. This type of antenna mostly used in applications like mobile phones, satellite communications and etc. because of its beneficial factors, such as less weight / volume, less construction costs, capability to assimilate with MICs (microwave integrated circuits) and less profile planar configuration. This research study is based on a compact microstrip patch antenna which is radiated at 1.9 GHz for use in cellular phones and established results present a practical antenna model for incorporation in mobile phone.

I. INTRODUCTION

In its original structure, a MPA is basically made up of dielectric substrate which have the plane called "ground plane" at one side and radiating patch on the other side as presented in Figure 1. Radiating patch is usually made up of gold or copper which is conducting in nature, is capable to pick any desired shape. The feed lines are engraved by using a photomechanical process on the dielectric substrate. To reduce the complexity of exploration and performance prediction, the patch is kept circular, square, rectangle, triangular, and ovate or more collective shapes as presented in Figure 2. The rectangular shape patch length *"L"* is taken in the range of $0.333\lambda_o < L < 0.500\lambda_o$, where, the λ_o is "free space wavelength". The patch on MPA is chosen to be narrow such that $t << \lambda_o$ where, "*t*" represents the thickness of patch. Height of dielectric substrate "*h*" is taken in the range of $0.0030\lambda_o \le h \le 0.050\lambda_o$. The ε_r called "constant of the dielectric substrate" (ε_r) is taken to be in the range of $2.20 \le \varepsilon_r \le 12.0$ [1].

MPA radiates predominantly due to the marginal area between edge of the patch and ground plane. A dielectric substrate with a greater bandwidth and low dielectric incessant is advantageous for advanced efficiency but this requires larger antenna size, thus higher dielectric constant for designing the compact antenna must be used [1].

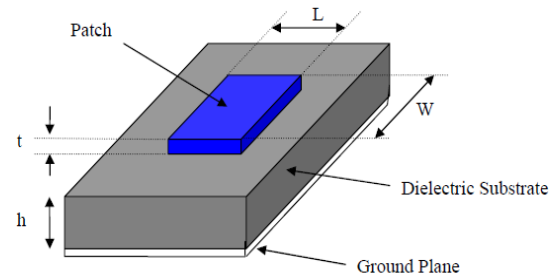


Figure 1 MPA (Microstrip Patch Antenna) structure [1].

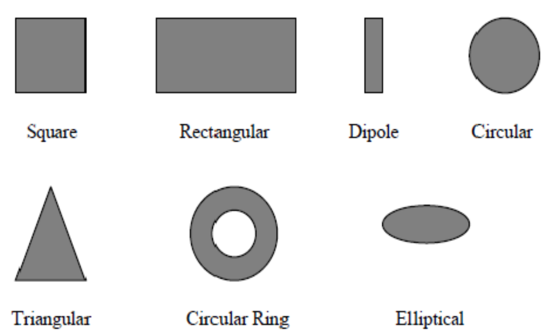


Figure 2 Microstrip patch element shapes [1].

II. DESIGN SPECIFICATIONS

The most basic elements for design of above said rectangular MPA are as follow:

Operational Frequency (f_o): It is designed to be functioning in the range of frequency of PCS (1850-1990 MHz) and the resonant frequency of 1.90 GHz [2].

Dielectric constant of substrate (ε_r): Silicon is dielectric material and is used in this antenna model. ε_r of 11.90 is selected for this model. The higher ε_r is selected because of reduction in size [1].

Dielectric substrate height (h): The dielectric substrate height chosen in this design is 1.50 mm [1].

III. DESIGN PROCEDURE

The model used for this antenna design is transmission line [3-10].

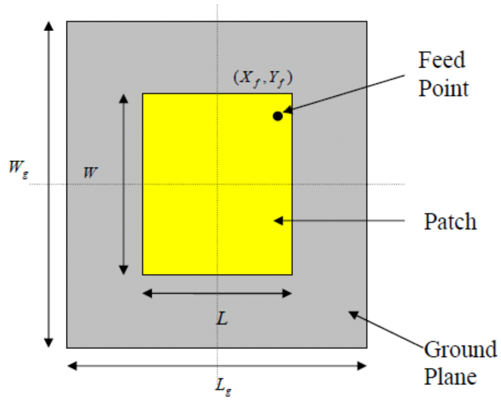


Figure 3 Top view of MPA.

Width Computation (W): The relation given below is used to calculate width of MPA.

$$W = \frac{c}{2 f_o \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad \dots\dots\dots \quad (1)$$

Putting the values of constant in the above equation c = $3x10^8$ m/s, ε_r = 11.90 and f_o = $1.90x10^9$ Hz.

$W = 31.10x10^{-3}$ m or 31.10 mm.

Effective dielectric constant computation (ε_{reff}): The relation given below is used to calculate the effective dielectric constant as:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \quad \dots\dots\dots (2)$$

By putting, ε_r = 11.90, $W = 31.10x10^{-3}$ m or 31.10 mm and $h=1.50x10^{-3}$ m = 1.50 mm we get:

ε_{reff} = 10.78710.

Effective length computation (L_{eff}): L_{eff} of the proposed antenna is computed by using the relation given below:

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}} \quad \dots\dots\dots \quad (3)$$

Putting ε_{reff} = 10.78710, c= $3x10^8$ m/s and f_o = $1.90x10^9$ Hz, we get:

$L_{eff} = 24x10^{-3}$ m = 24 mm.

Computation of length extension (ΔL): Equation used to calculate the extension length is given below:

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \dots\dots\dots \quad (4)$$

Substituting ε_{reff} = 10.78710, $W = 31.10x10^{-3}$ m or 31.10 mm and $h = 1.50x10^{-3}$ m or 1.50 mm we get:

$\Delta L = 6.34550x10^{-4}$ m or 6.34550 mm.

Actual length of patch computation (L): The L is obtained by following relation given below:

$$L = L_{eff} - 2\Delta L \dots\dots\dots \quad (5)$$

By putting $L_{eff} = 24x10^{-3}$m or 24.0 mm and ΔL = $6.34550x10^{-4}$ m or 6.34550 mm we get:

$L = 22.80x10^{-3}$ m = 22.80 mm.

Ground plane dimensions computation (L_g and W_g): The TL model is only relevant to infinite ground planes, but in case of practical deliberation, there must be a finite ground plane. It has been proved that, if the ground plane size is larger than six times the patch dimensions, the results are similar for both finite and infinite ground planes. Ground plane size / dimension for this antenna design would be as:

$$L_g = 6h + L \dots\dots\dots \quad (6)$$

= 6(1.5) +22.8 = 31.8mm

$$W_g = 6h + W \dots\dots\dots \quad (7)$$

= 6(1.5) +31.1 = 40.1mm

Feed point location determination (X_f , Y_f): In this antenna design / model coaxial probe feed type is used. As presenting in Figure 3, the center of the patch is regarded as derivation and feed spot is specified by coordinates (X_f,Y_f) from the derivation. The feed point on the patch must be at that spot, where impedance (input impedance) is 50 Ω at resonant frequency. Therefore, a method called trial and error method is used to determine feed point and feed point is chosen where the R.L (return loss) is proved to be negative. A point is found there beside the patch, where R.L is at the lowest degree. Therefore, Y_f will be zero in this design, and X_f will be assorted to search the optimum feed point.

IV. SIMULATION SETUP AND RESULT

The software which is put to use to conjure up the microstrip patch antenna is FEKO software. It is complete wave electromagnetic simulator which analyzes different shapes of multilayer structure. It is used to plot and calculate current distributions, S_{11} parameters, VSWR and radiation patterns also. Putting it to simplicity, width and length of the ground and patch rounded off to the following values as: L = $22x10^{-3}$ m, W = $31x10^{-3}$ m, L_g = $31x10^{-3}$ m and Wg = $40x10^{-3}$ m.

A. Calculation of Antenna bandwidth and Return Loss:

For feeding, "co-axial probe type feed" is used. It is designed to a radius of $0.50x10^{-3}$ m. $1.70x10^9$ to $2.1x10^9$ Hz frequency range is selected. Approximately 401 points are selected to determine the accurate / precise results.

No.	Feed Location (X_f, Y_f) (mm)	Center Frequency (GHz)	Return Loss (RL) (dB)	Bandwidth (RL > -9.5dB) (MHz)
1	(1,0)	1.9153	-1.1384	-
2	(2,0)	1.9147	-4.5967	-
3	(3,0)	1.9127	-10.9602	9.97
4	(3.25,0)	1.9133	-13.3696	15.32
5	(3.5,0)	1.9127	-16.6242	18.84
6	(3.75,0)	1.9127	-21.2769	21.43
7	(4,0)	1.9120	-31.3585	23.28
8	(4.25,0)	1.9127	-28.5068	24.40
9	(4.5,0)	1.9127	-21.2952	25.16
10	(4.75,0)	1.9120	-17.6845	25.23
11	(5,0)	1.9120	-15.0623	24.30
12	(6,0)	1.9087	-10.2221	13.57
13	(7,0)	1.9087	-7.7754	-
14	(8,0)	1.9087	-6.3367	-
15	(9,0)	1.9073	-5.5806	-
16	(10,0)	1.9073	-5.0228	-

Table 1 Center frequency, bandwidth and return loss calculation for different feed location.

Bandwidth will be accessed from RL plot, whereas, center frequency is chosen where the RL is least. The bandwidth is from the category of frequencies above which the Return loss is superior to -9.50 dB (where -9.50 dB corresponds to a VSWR of 2). The optimum feed point according to the table 1 is found at (X_f, Y_f) = (4, 0) where RL -31.3585 dB is achieved. The antenna bandwidth at this feed point is calculated (shown in Figure 4) to be around 23.28 MHz and the center frequency 1.9120 GHz is achieved. This frequency is near to the required design frequency (1.9 GHz). It is also noted that the maximum bandwidth is obtained at (X_f, Y_f) = (4.75, 0).

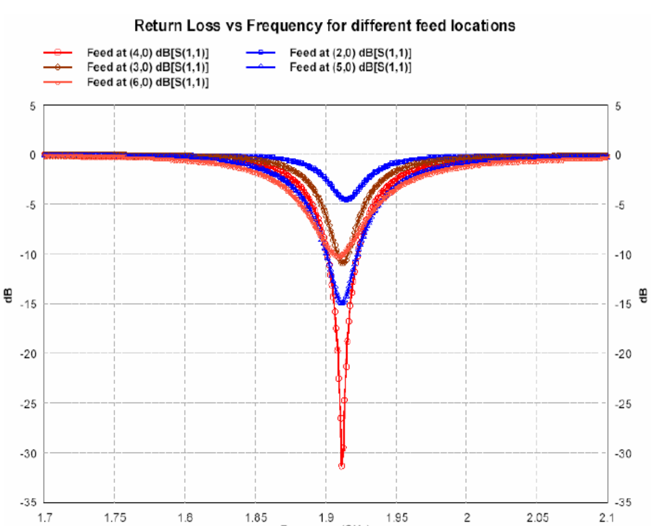


Figure 4 Return losses at different feed locations.

B. Plots of Radiation Pattern:

Elevation pattern for Φ = 90, Φ = 0 is important because MPA radiates to its patch. Figure 5 below presents antenna gain at 1.912x10^9 Hz for Φ = 90, Φ = 0 degrees. The antenna's greatest gain is obtained in broadside direction and this gain is measured to be 1.87 dB both for Φ = 90 and Φ = 0 degrees. The back lobe radiation is measured to be -5.30 dB for above plot which is very small. It also reduce amount of electromagnetic radiations moving towards user's head and this is an additional benefit of using this antenna in cellular phone. The three-Dimensional plots for this proposed antenna are displayed in Figure 6 at different angles.

C. Other Calculated Parameters:

Some other calculated parameters, thus named, 3-dB beam width for the antenna at 1.9120 GHz, gain, antenna efficiency, and directivity are (106.85, 110.24), 1.8717 dB, 42.77%, and 5.56 dB respectively.

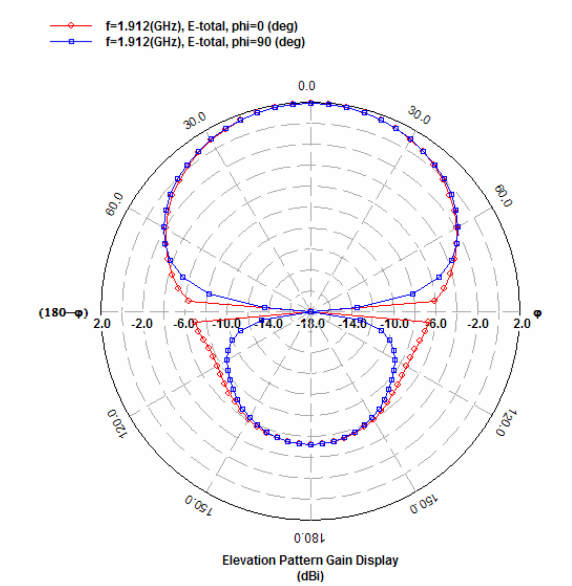
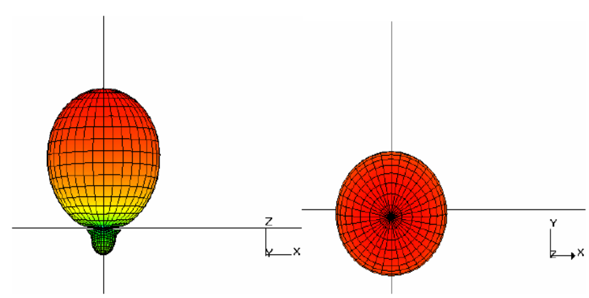


Figure 5 Elevation Pattern of proposed antenna for Φ = 90, Φ = 0 degree's.



(a) (b)

Figure 6 (a) 3-diemensional radiation pattern in XZ plane along Y-axis.
(b) 3-diemensional radiation pattern in XY plane along Z axis.

V. CONCLUSION

The ground plane measurements for patch antenna is devised to be 31 mm by 40 mm, while the patch measurements stand at 22 mm by 31 mm, precisely, the antenna is shrink well in accordance with the adjustment space in a typical cellular phone, measuring about 14.5 cm by 4.5 cm.

For compulsory antenna orientation, radiation pattern plots are obtained. The decreased back lobe radiation saw its remarkable invention, which helps in diminishing electromagnetic energy amount radiated towards the head of the phone holder. An adequate bandwidth of 23.28 MHz is obtained in this proposed antenna design, which is also beneficial for cellular gadgets in the PCS variety since 30 KHz channels are used by GSM and TDMA systems.

Aims have been set to encompass this concept in future to a multiband design. Engineers have foreseen the advanced future of cellular phones, and one of the features would include a single handset to provide a large number of applications. Indoors, the cell phone / handset would function in identical frequency range of a cordless phone, and attached to local telephone exchange. When outdoor, handset would connect to mobile networks, and from a distance, or far from home; the handset would connect via satellite to arrange signals to the user.

VI. References

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Quotations

- Everything that irritates us about others can lead us to an understanding of ourselves.

  Carl Jung

- The mind is its own place, and is itself, can make a Heaven of Hell, a Hell of Heaven

  John Milton

- The object of all psychology is to give us a totally different idea of the things we know best.

  Paul Valey

- Judgment is more than skill. It sets forth on intellectual seas beyond the shores of hard indisputable factual information.

  Kingman Brester

- I have always thought the actions of men the best interpreters of their thoughts to old age.

  Friedrisch Wilhelm Nietzche

- Iron rusts from disuse, stagnant water loses its purity, and in cold weather becomes frozen; ever so does inaction sap the vigors of the mind.

  Leonardo da Vinci

- Everyman who expresses a honest thought is a soldier in the army of intellectual liberty.

  Robert G. Ingersoll

- Learning without thought is labor lost; thought without learning is perilous.

  Walter Lippmann

- One must learn to think well before learning to think afterwards it proves too difficult.

  Anatole France

- When he who hears does not know what he who speaks means, and when he who speaks does not know what he himself means – that is philosophy.

  Voltaire

- The first test of a truly great man is his humility.

  John Ruskin

- Prejudice is the child of ignorance.

  William Hazlitt

- The nobler a man, the harder it is for him to suspect inferiority in others.

  Cicero