



Study of Reconfigurable Multiband Microstrip patch antenna for wireless communication

Mr.Vivek Kapur¹, Mrs. Nilima Bodhaye², Mrs. Devashree Marotkar³, Mr.Shrish Marotkar⁴

Astt.Prof., Electronics & Telecommunication Department, Rajiv Gandhi College of Engg. , Nagpur, India¹

Lecturer, Electronics & Telecommunication Department, Rajiv Gandhi College of Engg. , Nagpur, India²

Lecturer, Electronics & Telecommunication Department, Rajiv Gandhi College of Engg. , Nagpur, India³

CEO,Hrugved Engg Corporation ,Nagpur, India⁴

Abstract: Now a days, Microstrip Patch antennas have become a rapidly growing area of research. Their applications are limitless, because of their light weight, compact size, and ease of manufacturing. One limitation is their inherently narrow bandwidth. Hence the main objective is on to increase the bandwidth of the antenna. Design and analysis of Compact Multiband Microstrip Patch Antennas and a circularly polarized microstrip antenna for many kind of wireless communication applications are studied and presented. The multiband antenna posses 14-dB around the GSM 900 band of operation and greater than 8-dB return loss with bandwidths enough to cover the intended higher operating bands. As the proposed antenna can achieve such wide operating bandwidth with relatively low profile, it is very suitable for multi-band mobile communication handsets. The antenna is suitable for use in hand-held or other mobile devices. The new antenna can be used for several applications, especially in the GSM domain, and for Wi-Fi, Bluetooth, and several other applications, as detailed in this paper.

Keywords: Microstrip antennas, WLAN, GSM, Bluetooth, Bandwidth, Aperture Coupled Feed

I. INTRODUCTION

In modern mobile, satellite and wireless communication systems, there is an increasing demand for smaller low-cost reconfigurable antennas that can be easily integrated with packaging structures. Communications has become the key to momentous changes in the organization of businesses and industries as they themselves adjust to the shift to an information economy. Information is indeed the lifeblood of modern economies and antennas provide mother earth a solution to a wireless communication system [1]. Many wireless products started to be designed to operate in more than one frequency. This technique is cost effective because it is more convenient for a certain design to operate with a single antenna than multiple antennas. Reconfigurability enables to accommodate more than one service in the same antenna. In general reconfigurable antennas have similar radiation patterns for all designed frequency bands and enable efficient use of electromagnetic spectrum and frequency selectivity which is useful for reducing the adverse effect of co-site interference and jamming, also reconfigurability can add advantages of frequency reuse for tripling the system capability and frequency diversity for good performance of reception and transmission or to integrate the receiving and transmitting functions into one antenna. It is well known that planar antennas such as MSAs have a

significant number of advantages over conventional antennas, such as low profile, lightweight, conformability, low production cost and easy fabrication properties [2], [3]. A number of techniques such as shorting walls and shorting pins have been proposed to reduce the physical size of a conventional half-wave to $\lambda/4$ or even further [4]. The most straightforward approach in designing MSAs is to use a high dielectric constant substrate, but it leads to poor efficiency and narrow bandwidth [5]. The metallic patch can generally be made of conducting material such as copper or gold, and it can take many different configurations such as square, rectangular, dipole, circular, elliptical, triangular, disk sector, circular ring, and ring sector. However, the conventional square, rectangular and circular MSAs are the most popular because of simple fabrication, performance prediction and analysis, besides their attractive radiation characteristics such as low cross-polarization radiation.

A conventional MSA consists basically of a radiating metallic patch on one side of a dielectric substrate, and has ground plane on the other side. Figure 1 shows top and side views of a conventional MSA.

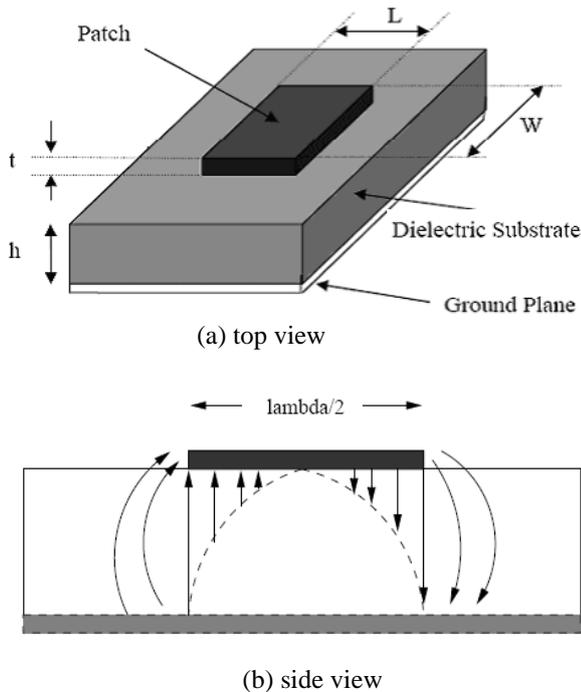


Figure 1: Structure of a conventional rectangular MSA: (a) top view, (b) side view.

II. OVERVIEW OF THE ANTENNA PARAMETERS

In a simple way we can say that “an antenna is the transitional radio b/w free space and a guiding device” [6] [7-8]. For designing a perfect antenna there are certain parameters that are to be considered that define the configuration of the antenna.

Return Loss

It can be said that when the load is mismatched the whole power is not delivered to the load there is a return of the power and that is called loss, and this loss that is returned is called the ‘Return loss’.

This Return Loss is determined in dB as follows: [9]

$$RL = -20 \log |\Gamma| \text{ (dB)} \text{ ----- Eq (1)}$$

Where $|\Gamma|$ is $= \frac{V_0+}{V_0-} = \frac{Z_L - Z_0}{Z_L + Z_0}$

$|\Gamma|$ is the reflection coefficient

+0V The incident voltage

-0V The reflected voltage

Z_L and Z_0 are the load and characteristic impedances.

Radiation Pattern

Microstrip Patch Antenna has radiation patterns that can be calculated easily. The source of the radiation of the electric field at the gap of the edge of the Microstrip element and the ground plane is the key factor to the accurate calculation of the pattern for the patch antenna.

Simply it can be said that the power radiated or received by the antenna is the function of angular position and radial distribution from the antenna [9].

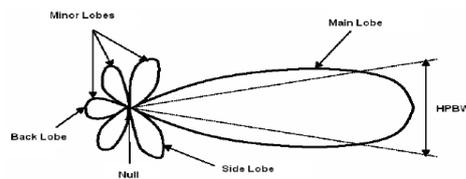


Figure 25: Radiation Pattern of a generic dimensional antenna

Gain & Directivity

The gain of the antenna is the quantity which describes the performance of the antenna or the capability to concentrate energy through a direction to give a better picture of the radiation performance. This is expressed in dB, in a simple way we can say that this refers to the direction of the maximum radiation [9].

The expression for the maximum gain of an antenna is as follows:

$$G = \eta \times D \text{ ----- Eq (2)}$$

η – The efficiency of the antenna

D – Directivity

In order to receive or transmit the power it can be chosen to maximize the radiation pattern of the response of the antenna in a particular direction.

The directivity of an antenna can be defined as – the ratio of radiation intensity in a given direction from the antenna to the radiation intensity averaged in all the directions. And the gain can be known as the ratio between the amounts of energy propagated in these directions to the energy that would be propagated if there is an Omni-directional antenna. [9]

Polarization

The polarization of the electric field vector of the radiated wave or from source V_s time the observation of the orientation of the electric fields does also refer to the polarization. It is defined as” the property of an electromagnetic wave describing the time varying direction and relative magnitude of the electric field vector”.

The direction or position of the electric field w.r.t the ground gives the wave polarization. The common types of the polarization are circular and linear the former includes horizontal and vertical and the latter includes right hand polarization and left hand polarization.

Reflection Coefficient $|\Gamma|$ and Character Impedance (Z_0)

There is a reflection that occurs in the transmission line when we take the higher frequencies in to consideration. There is a resistance that is associated with each transmission line which comes with the construction of the transmission line. This is called as character impedance (Z_0). The standard value of this impedance is 50ohm. Always the every transmission line is being terminated with an arbitrary load Z_L and this is not equivalent to the impedance i.e. Z_0 . Here occurs the reflected wave.

The degree of impedance mismatch is represented by the reflection coefficient [1] at that load and is given by:



$$\Gamma = \frac{v_{o-}}{v_{o+}} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

We can observe here that the reflection coefficient for the shorted load $Z_L=0$, there is a match in the load $Z_L=Z_0$ and an open load $Z_L = \infty$ are -1, 0, +1. [10]
Hence we can say that the reflection coefficient ranges from 0 to +1.

1. Voltage Standing Wave Ratio

There should be a maximum power transfer between the transmitter and the antenna for the antenna to perform efficiently. This happens only when the impedance Z_{in} is matched to the transmitter impedance, Z_s .

In the process of achieving this particular configuration for an antenna to perform efficiently there is always a reflection of the power which leads to the standing waves, which is characterized by the Voltage Standing Wave Ratio (VSWR).

This is given by [10]:

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{1 + |\Gamma|}{1 - |\Gamma|} = \frac{1 + S_{11}}{1 - S_{11}}$$

As the reflection coefficient ranges from 0 to 1, the VSWR ranges from 1 to ∞ .

2. Input Impedance

This is the ratio of the voltage to current at the pair of terminals or the ratio of the appropriate components of the electric fields to the magnetic fields at a point. Or in other words we can say it is the impedance presented by the antenna at the input terminal.

$$Z_{in} = (R_{in} + jX_{in}) \text{----- Eq (3)}$$

R_{in} – the real part, representing the power dissipated though heat or through radiation losses.

X_{in} = imaginary part, representing the reactance of the antenna & the power stored in the near field of the antenna. [9]

3. Bandwidth

Bandwidth can be said as the frequencies on both the sides of the centre frequency in which the characteristics of antenna such as the input impedance, polarization, beam width, radiation pattern etc are almost close to that of this value. As the definition goes [22] “the range of suitable frequencies within which the performance of the antenna, w.r.t some characteristic, conforms to a specific standard”.

The bandwidth is the ratio of the upper and lower frequencies of an operation. According to [10] the bandwidth can be obtained as:

$$BW_{broadband} = \frac{f_H}{f_L} \text{----- Eq (4)}$$

$$BW_{narrowband} (\%) = \left[\frac{f_H - f_L}{f_c} \right] 100 \text{----- Eq (5)}$$

When the ratio $f_L/f_H = 2$ the antenna is said to be broadband. We can judge the antenna’s performance by operating the antenna at a high frequency by observing VSWR, when $VSWR \leq 2$ ($RL \geq -9.5\text{dB}$) the antenna is said to have performed well.

III. METHOD OF ANALYSIS

The most popular models for the analysis of MSAs are the transmission line model, cavity model, and full wave model (which include primarily integral equations / Moment Method) [11]. The transmission line model is the simplest of all and it gives good physical insight but it is less accurate. The cavity model is more accurate and gives good physical insight but is complex in nature. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. These give less insight as compared to the two models mentioned above and are far more complex in nature.

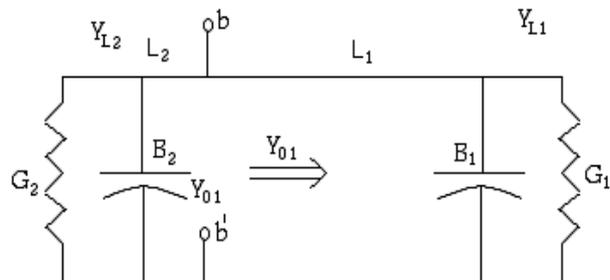


Figure 2.9: Transmission line model for rectangular MSA.

In this model $L1$ Y and $L2$ Y represents the radiating apertures on the edges of the patch antenna, and because they are identical, we get

$$Y_{11} = G1 + jB1 = Y_{12} = G2 + jB2 \Rightarrow B1 = B2, G1 = G2$$

Where $G1$, $G2$ are the aperture conductances and $B1$, $B2$ are the aperture susceptances. Approximate values of $G1$, $G2$ and $B1$, $B2$ can be computed using.

$$G1 = G2 = 0.00836 \frac{W}{\lambda_0}$$

$$\text{And } B1 = B2 = 0.01668 \frac{\Delta L W}{h \lambda_0} \epsilon_{\text{reff}}$$

Where W is the width of a rectangular MSA, ΔL is the length extension, h is the thickness (height) of the dielectric substrate, is the effective dielectric constant and is the wavelength in free space.



The input feed point for the signal must be placed in such a point along the transmission line where the input impedance match 50Ω and the antenna reactance minimized as much as possible.

IV DESIGN OF SINGLE BAND MICROSTRIP ANTENNA

In this section, the procedure for designing a rectangular microstrip patch antenna is explained.

Design specifications:

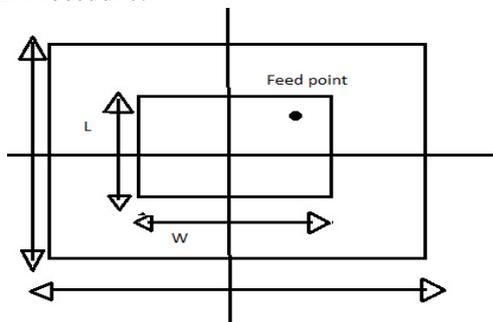
The three essential parameters for the design of a rectangular microstrip patch antenna are:

1. Frequency of Operation (fr): the resonant frequency of the antenna must be selected appropriately. The Global Systems for Mobile communications (GSM) uses the frequency range from 890-960 MHz [8]. Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for this design is 930 MHz.

2. Dielectric Constant of the Substrate (er): the dielectric material applied for this design has a dielectric constant of 4.4. Use of a substrate with a high dielectric constant can reduce the dimensions of the antenna. However, for the radiation modes most used such substrates result in elements, which are electrically small in terms of free-space wavelengths and consequently have relatively smaller bandwidths and low efficiencies.

3. Height of dielectric substrate (h): for the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate selected here is 7mm. The essential parameters of the design are: **fr= 0.93GHz, er= 4.4, and h = 7mm.**

Design Procedure:



The design of a low profile, wide-band multiband patch antenna is very complicated. The fact is that the lowest antenna profile, the widest impedance bandwidth and the most

omni-directional (lowest ripple level) azimuth plane radiation pattern cannot be achieved simultaneously [14]. Fig.3.1 below shows the conventional rectangular microstrip patch antenna, which is presented here for the sake of easy analysis and design of practical microstrip antennas for mobile handsets.

The transmission line model described in this will be used to design the antenna.

Step 1. Calculation of the width (W):

The width of the microstrip patch antenna is given by equation (2.8) as [1]:

$$W = \frac{c}{fr} A = \pi r^2 \sqrt{\frac{2}{\epsilon r + 1}}$$

Step 2: Calculation of effective dielectric constant (TMeff):

Following Equation gives the effective dielectric constant as :

$$\epsilon_{reff} = \frac{\epsilon r + 1}{2} + \frac{\epsilon r - 1}{2} \left[1 + 12 \frac{h}{w} \right]^{-1/2}$$

Step 3: Calculation of the effective length (Leff):

The effective length of antennas can be calculated as:

$$L_{eff} = \frac{c}{2fr \sqrt{\epsilon_{reff}}}$$

Step 4: Calculation of the length extension (DL):

Equation below gives the length extension as :

$$\Delta L = 0.412 h \frac{(\epsilon_{reff} + 0.3) \left(\frac{w}{h} + 0.264 \right)}{(\epsilon_{reff} - 0.258) \left(\frac{w}{h} + 0.8 \right)}$$

Step 5: Calculation of the actual length of the patch (L): the actual length is obtained by subtracting the length extension from the effective length as:

$$L = L_{eff} - 2\Delta L$$

Step 6: Calculation of the ground plane dimensions (Lg and Wg):

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown in many open literatures that similar results for finite and infinite ground planes can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:

$$L_g = 6h + L = 6 \times 7 \text{ mm} + 74.698 \text{ mm} = 116.698 \text{ mm}$$

$$W_g = 6h + W = 6 \times 7 \text{ mm} + 98.16 \text{ mm} = 140.16 \text{ mm}$$

Step 7: Determination of feed point location (xf, yf):

A coaxial probe type feed is to be used in this design. As shown in Figure 3.1, the center of the patch is taken as the origin and the feed point location is given by the



coordinates (xf, yf) from the origin. The feed point must be located at that point on the patch, where the input impedance is 50 Ohms for resonant frequency.

IV CONCLUSION

The aim of this paper is to study the design a reconfigurable Multiband Microstrip patch antenna and to study the responses and the radiation properties of the same. Taking all this in to consideration we can say that there are many aspects that affect the performance of the antenna. Dimensions, selection of the substrate, feed technique and also the Operating frequency can take their position in effecting the performance.

V RECOMMENDATION FOR FUTURE DEVELOPMENTS

We had provided a significant study on the multiband microstrip patch antenna system for mobile communications in this era of wireless communications, there are still other equally important areas that require attention. They include miniaturization of the antenna element with out loss of efficiency, since nowadays the whole apparatus is getting more end more minimized in order to integrate antennas within a minimum space thus requires further research work. Minimizing electromagnetic energy absorption by the user's head can be another important area of study, since there may be health hazards, if the users head is surrounded by a strong electromagnetic energy for a long time.

REFERENCES

- [1] Warren L. Stutzman, Gary A. Thiele, *Antenna Theory and Design*, 2nd edition, John Wiley & Sons, Inc, 1998.
- [2] S. Xiao, B. Z. Wang, and X. S. Yang, "A Novel Frequency Reconfigurable Patch Antenna," *Microwave Opt. and Technol. Lett.*, 36, Feb. 2003, pp. 295-297.
- [3] *Broadband Microstrip Antennas*, 1st edition, Girish Kumar and K.P. Ray, Artech House Publisher, Norwood, 2003.
- [4] *Microstrip Antenna Design Handbook*, 1st edition, R. Garg, P. Bhartia, I. Bahl and A. Ittipiboon, Artech House Publisher, Norwood, 2001
- [5] *Antenna Theory Analysis and Design*, 3rd edition, Constantine A. Balanis, John Wiley & Sons, New York, 1997.
- [6] M. Olyphant, Jr. and T.E Nowicki, "Microwave substratessupport MIC technology" *Microwaves*, Part I, Vol. 19, No. 12, pp 74-80, Nov, 1980.
- [7] Kin-Lu Wong, "Compact and Broadband Microstrip Antenna", John Wiley & Sons, 2002.
- [8] So Dey et al, "A new Circular path Antenna", *IEEE Antennas & Propagation*, international symposium Digest, 1993.
- [9] Z. I. Dafalla, W. T. Y. Kuan, A. M. Abdel Rahman, and S. C. Sudhakar, "Design of rectangular Microstrip patch antenna at 1GHz", Multimedia University, Faculty of engineering and technology, Melaka, Malaysia. 2004, "RF and Microwave Conference, October 5-6", Malaysia.
- [10] Nurulrodziah BT Abdul Ghafar, "Design of a Compact Microstrip Antenna at 2.4 GHz", MSc thesis, Department of Electrical – Electronics & Telecommunications, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Nov, 2005.
- [11] K. Chung, Y. Nam, T. Yun, and J. Choi, "Reconfigurable Microstrip Patch Antenna with Switchable Polarization", *ETRI Journal*, Volume 28, Number 3, June 2006