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DESIGN OF COMPACT MULTIBAND MICROSTRIP PATCH ANTENNAS

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***Abstract*—** Microstrip antennas have become a rapidly growing area of research. Their potential applications are limitless, because of their light weight, compact size, and ease of manufacturing. One limitation is their inherently narrow bandwidth. However, recent studies and experiments have found ways of overcoming this obstacle. Design and analysis of Compact Multiband Microstrip Patch Antennas are presented. The antenna is suitable for use in hand-held or other mobile devices. This antenna has a smaller size, and can be built on a double-sided printed circuit board or stamped from thin sheet metal, our aim is to design a patch antenna for frequency ranges starting from 900 MHz to 5.35 GHz which includes the GSM (880-960) GPS (1568-1592 MHz), DCS (1710-1880 MHz), and PCS (1850-1990 MHz). UMTS (1920-2170 MHz), IEEE 802.11 b/g (2400-2484) and WLAN IEEE 802.11a band (5.15-5.35) in order to meet the demand for newer microwave and millimeter-wave systems and emerging telecommunication challenges with respect to size, performance and cost of an antenna. It offers the advantages of light weight, low cost and ease of fabrication. Design of compact multiband microstrip patch antenna includes the analysis of antenna parameters such as Bandwidth, Gain and Directivity which are related to antenna dimensions and their substrate Material parameters. Further we extend our investigations on various methods of improving the bandwidth and gain of the antenna which is used for mobile communication.

INTRODUCTION

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. The radio antenna is an essential component in any radio system. An antenna is a device that provides a means for radiating or receiving radio waves. In other words, it provides a transition from guided waves on a transmission line to a “free space” wave (and vice versa in the receiving case). Thus information can be transferred between different locations without any intervening structure. Furthermore, antennas are required in situations where it is impossible, impractical or uneconomical to provide guiding structures between the transmitter and the receiver.

Since the dawn of civilization, communication has been of foremost importance to mankind. In first place, communication was accomplished by sound trough voice. However, as the distance of communication increased, numerous devices were introduced, such as horns, drums, and so forth. The radio antenna is a primary component in all radio systems. It may be defined as the structure associated with the region of transition between a guided wave and a free space wave, or vice versa. In other words, radio antennas couple electromagnetic energy from one medium (space) to another (e.g. wire, coaxial cable, or wave guide). Micro strip antennas appeared as a by-product of micro strip circuits, which by then had become a mature technology. Their design and realization took advantage of the techniques developed for micro strip circuits and used micro strip circuit substrates. The increasing demand of multiband personal communications handsets fosters development of small-size [8] integrated multiband antennas. The preferred solutions are usually metallic patches with multiple resonances. These patches allow a great flexibility in the antenna design, as they are cost–effective and straight forward to produce, as well as easy to adapt to the shape of the handset.

The demand for high performance multi-standard communication handsets has led to the research and studies of this interesting topic. Therefore, it is important to study the basic concepts of multiband antenna systems, a system that brings the world of wireless communication to a new era. The first leap to understanding multiband microstrip patch antenna systems lead to the fundamental studies on antenna theory and their design parameters. Laying a good foundation is essential, as we will go through examining the multiband antenna system. The radiation patterns and input return loss of the multiband microstrip patch antennas at different resonant frequencies will have to be investigated and thus, further research will be carried out to bring a better insight by simulation methods. The area of study will conclude with analysis on simulations for the multiband microstrip antenna system.

An antenna is a device that provides a means for radiating or receiving radio waves. In other words, it provides a transition from guided waves on a transmission line to a “free space” wave (and vice versa in the receiving case). Thus information can be transferred between different locations without any intervening structure. Furthermore, antennas are required in situations where it is impossible, impractical or uneconomical to provide guiding structures between the transmitter and the receiver.

Antennas are acting as a transducer which is converting electrical signal (current) in to electromagnetic waves and radiating in to free space. Similarly when an electromagnetic wave is hitting on the antenna, voltages and currents are induced. The RF voltage induced are then passed into the receiver and converted back into the transmitting RF information.

Microstrip patch antennas have been largely used in a lot of useful applications, because of their inherent characteristics of low cost, low profile, ease of fabrication, light, weight, conformability and integration with RF devices. The new cellular telephone generations integrate several communications systems at once such as GSM/DCS, Wi-Fi standards, UMTS…etc, [2] which leads to a large need of a multi frequency microstrip patch antennas.

Several patch designs with single-feed, dual-frequency operation have been proposed recently. Designed tri-band microstrip antenna can be used in various commercial systems such as; Digital Cellular System (DCS) at 900MHz, Automatic Toll Collection at 905 MHz and Wireless Local Area Networks around 2.4 GHz. In this paper, microstrip antenna is considered as a candidate for multi-band operation. After designing an antenna for 900 MHz it was seen that we can excite some modes with proper feeding of the antenna. Patch antenna is designed to support four modes at 0.9, 2.4, 5.2 GHz.

LITERATURE SURVEY

In the existing system patch antenna was designed with operating only specific applications can be carried out with this frequency range. This design is not suitable for supporting the frequency ranges starting from 900MHz.Because this has more difficulties with dimensions, substrate and all other parameters of patch antenna. We should make that patch antenna with high directivity, gain improving radiation patterns and characteristics of patch antenna.

Microstrips are printed circuits operating in the microwave range, over the gigahertz region of the electromagnetic spectrum. Realized by the photolithographic process, they let designers reduce the size, [19] weight, and cost of components and systems for low signal-level applications by replacing the more cumbersome wave-guide components and assemblies. The fabrication process is well suited for series production of circuits and antennas, since lumped circuit and active devices can easily be combined with sections of transmission line. At microwave frequencies, all dimensions become important, so the realization of microstrips requires more care than that of low-frequency printed circuits.

Microstrip lines were first proposed in 1952 and were increasingly used in the late 1960s and 1970s to realize circuits, generally called microwave integrated circuits (MICs) since radiation leakage is most unwanted in circuits, particular care was taken to avoid it, even though its possible application to design antennas had already been suggested in 1953. Microstrip antennas appeared as a by-product of microstrip circuits, which by then had become a mature technology. Their design and realization took advantage of the techniques developed for microstrip circuits and used microstrip circuit substrates.

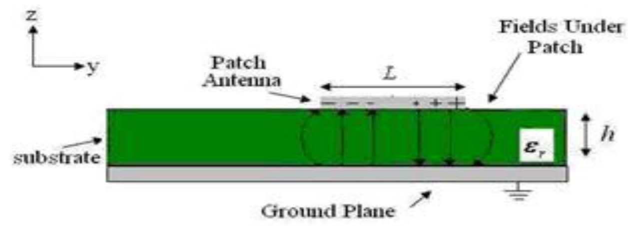

Figure 1. Microstrip Patch Antenna

The rectangular microstrip patch has been extensively studied on. Much material can be found in published literature. The patch is frequently analyzed using the transmission line model and the cavity model. This chapter details the study of the various models used in the analysis of microstrip antennas, and presents the main characteristics and assumptions made in the use of the cavity model to analyze the rectangular patch.

By analogy, the microstrip antenna [7] may be seen as an open circuit element where radiation is caused by the fringing fields at the open circuit ends of the element. This thus allows for far field radiated wave propagation. The conducting patch may be of any arbitrary shape depending on the desired radiation characteristics. This conducting patch is spaced a small fraction of the dielectric wavelength above a conducting ground plane. The patch and the conducting ground plane sandwiched the dielectric substrate. Typically, a microstrip is considered thin if the dielectric height (h) is much smaller than the dielectric wavelength. This parallel configuration of the two conductors resembles that of a capacitor with fringing fields. For a rectangular patch excited in the dominant mode, the field variation along the patch length is about half of the dielectric wavelength with fringing fields at the edges of the patch length.

A microstrip or patch antenna is a low profile antenna that has a number of advantages over other antennas it is lightweight, inexpensive, and easy to integrate with accompanying electronics. While the antenna can be 3D in structure (wrapped around an object, for example), the elements are usually flat; hence their other name, planar antennas. Note that a planar antenna is not always patch antenna. The following drawing shows a patch antenna in its basic form: a flat plate over a ground plane (usually a PC board). The center conductor of a coax serves as the feed probe to couple electromagnetic energy in and/or out of the patch. The electric field distribution of a rectangular patch excited in its fundamental mode is also indicated.

The electric field is zero at the center of the patch, maximum (positive) at one side, and minimum (negative) on the opposite side. It should be mentioned that the minimum and maximum continuously change side according to the instantaneous phase of the applied signal. The electric field does not stop abruptly at the patch's periphery as in a cavity; rather, the fields extend the outer periphery to some degree. These field extensions are known as fringing fields and cause the patch to radiate. Some popular analytic modeling techniques for patch antennas are based on this leaky cavity concept. Therefore, the fundamental mode of a rectangular patch is often denoted using cavity theory as the TM10 mode. Since this notation frequently causes confusion, we will briefly explain it. TM stands for transversal magnetic field distribution. This means that only three field components are considered instead of six. The field components of interest are: the electric field in the z direction, and the magnetic field components in x and y direction using a Cartesian coordinate system, where the x and y axes are parallel with the ground plane and the z axis is perpendicular. In general, the modes are designated as TMnm. The z value is mostly omitted since the electric field variation is considered negligible in the z axis. Hence TMnm remains with n and m the field variations in x and y direction. The field variation in the y direction (impedance width direction) is negligible; Thus m is 0. And the field has one minimum to maximum variation in the x direction (resonance length direction); thus n is 1 in the case of the fundamental.

COMPACT MULTIBAND MICROSTRIP PATCH ANTENNAS DESIGN

We are proposing that compact multiband microstrip patch antenna to design the important wireless applications lie in the band starting from 900 MHz to 5.5 GHz which includes the GSM (880-960) GPS (1568-1592 MHz), DCS (1710-1880 MHz), and PCS (1850-1990 MHz). UMTS (1920-2170 MHz), IEEE 802.11 b/g (2400-2484) and WLAN IEEE802.11a bands (5.15-5.35 GHz, 5.725-5.825 GHz). [1] – [5].

Microstrip patch antennas are commonly used in mobile communications terminals due to their many attractive features, such as simple structure, low production cost, light weight, and robustness. Dual-frequency antenna [12] elements are required, as today's standard mobile terminals operate in two frequency bands, e.g. SM900/GSM1800 in Europe. It is desirable to have more universal phones that operate in multiple systems around the world, but the inherently narrow impedance bandwidth of patch antennas combined with the restricted volume for the antenna element limit their applicability in multiband phones.

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{\vartheta_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \quad (2)$$

$$\Delta L = 0.412 * h * \frac{\left(\varepsilon_{reff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{W}{h}+0.8\right)} \quad (3)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \quad (4)$$

Where

ε_{reff} = Effective dielectric constant
ε_r=Dielectric constant of substrate
h = Height of dielectric substrate
W = Width of the patch

The length L of the patch is usually 0 .3333 $\lambda_o < L < 0.5\ \lambda o$, where λ_0 is the free-space wavelength. The patch is selected to be very thin such that $t \ll \lambda_0$ (where *t* is the patch thickness). The height *h* of the dielectric substrate is usually0 .003 $\lambda_o \leq h \leq 0.05\ \lambda o$. The dielectric constant of the substrate (ε_r) is typically in the range $2.2 \leq \varepsilon_r \leq 12$.

Patch with two 'U' slots:

This antenna consists of a rectangular patch [16] with two u slots. It supports the operation at two bands centered at 2.1 GHz and 5.4 GHz. The integrated approach for a patch with a single U- slot to support the operation. The center frequencies of these bands are controlled by the electrical length of these slots.

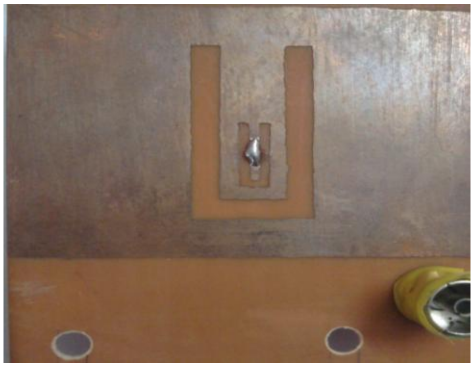

Figure 2. Patch with two 'U' slots

E-Shape and U-Shape Patch:

This E-Shape and U-Shape Patch [1] microstrip patch antenna has been designed with over all dimensions 35mm x 40mm and height of 1.5mm.it supports for a dual band operation at 4.7Ghz and 5.4Ghz.

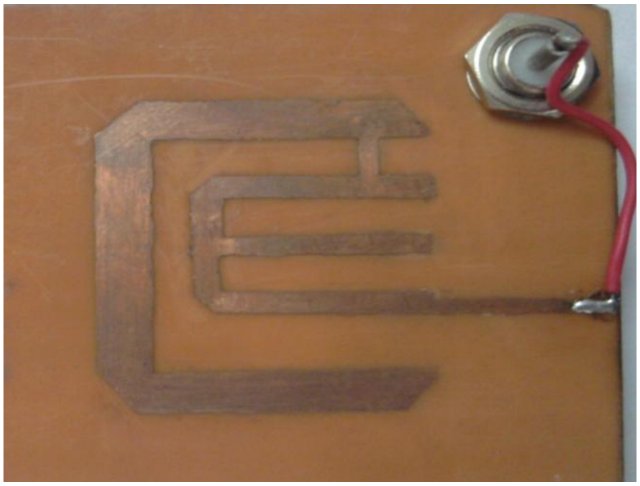

Figure 3. E-Shape and U-Shape Patc

Rectangular Fractal Antenna:

This Fractal Antenna [1] supports a frequency range of 4.3-9.9GHz.Fractals are classes of shapes which do not have characteristic size. Each fractal is designed by carrying out different iterations. It supports wide range of applications.

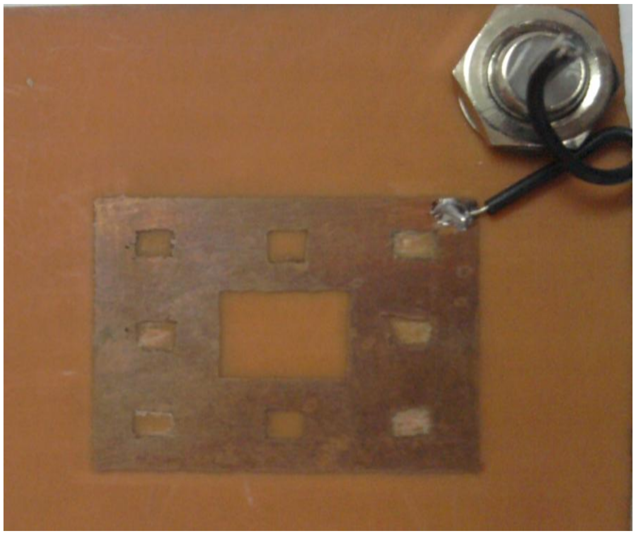

Figure 4. Rectangular Fractal Antenna

Multi-Standard Patch antenna:

New Multi Standard Patch Antenna [11], [13] GSM/PCS/UMTS /HIPERLAN for Mobile Cellular Phones is designed with a length of 50mm and width of 35mm so that separate are not required to support many applications in a single unit.

Figure 5. Multi-Standard Patch antenna

Circularly Polarized Microstrip Patch:

This is a small wideband microstrip patch [6] antenna.The antenna is designed to function in the 5-6Ghz wireless bands.It achieves multi-band functionality through the addition of a slot to a square patch (21mm x 21mm x 2.6mm)

Figure 6. Circularly Polarized Microstrip Patch

METHODOLOGY USED

Steps of the antenna building process:

a. Shape of the antenna is printed (with 1:1 scale) on a copy transparency.
b. A plate of substrate with appropriate dimensions is provided and carefully cleaned.
c. One side of the plate is coated with a photo sensitive lacquer (Positiv 20).
d. It is allowed to dry (20 0 C = 24hours, 700 C = 15 min.) in a dark place. In this design coated plate is allowed for 2 hours to dry in room temperature.
e. The transparency carrying the mask is placed on the board and it is exposed to high UV light for 2 minutes.
f. Board is developed using 7gr NaOH in 1 liter water.
g. Opposite side of the board is covered using nail polish to prevent the ground layer from dissolving in next step.
h. As the last step, the antenna is developed in a solution consisting of 770ml H2 O, 200ml HCL and 30ml H2 O2
i. At the end of the process, both sides of the antenna are cleaned using acetone to remove the remains of the coating on the front side and the nail polish on the back..

RESULTS AND DISCUSSIONS

Readings are taken for each 10 degrees and draw the radiation pattern for respective values. Analyze the different radiation value and plot the radiation, patterns for respective values. Gain, bandwidth and efficiency will be calculated. Improving performance of patch antenna by changing the substrate material height and use the different type of dielectric materials. Impacts of changing the parameters and analyze the design parameters what happens inside the patch antenna design. The proposed antenna was fabricated and experimentally tested. Then using Datascene software radiation pattern was drawn for each antenna.

Gain= (Maximum Power Radiated by Test Antenna / Maximum Power Radiated by Isotropic Antenna)

Directivity= (Maximum Power Radiated by Test Antenna / Average Power Radiated by Isotropic Antenna)

Patch with two 'U'slots:

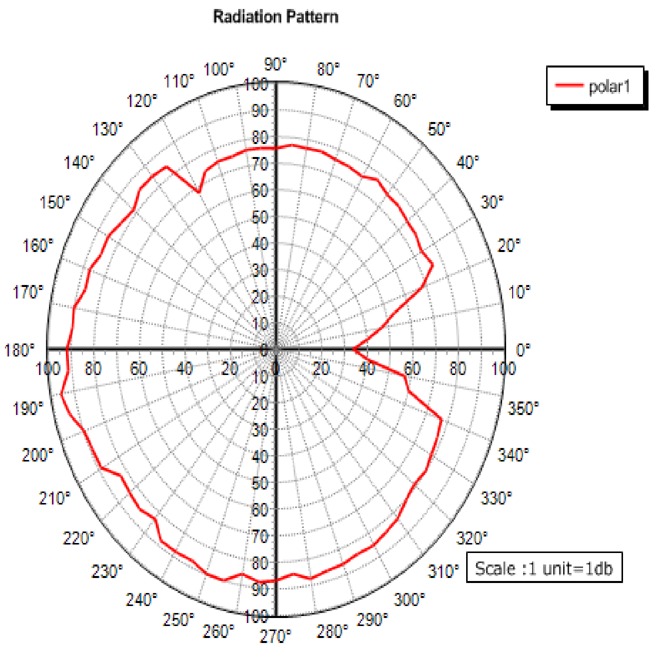

Figure 7. Radiation Pattern of Patch with two 'U'slots

Gain=2.86
Directivity= 3.47

E-shape patch and U-shape Patch:

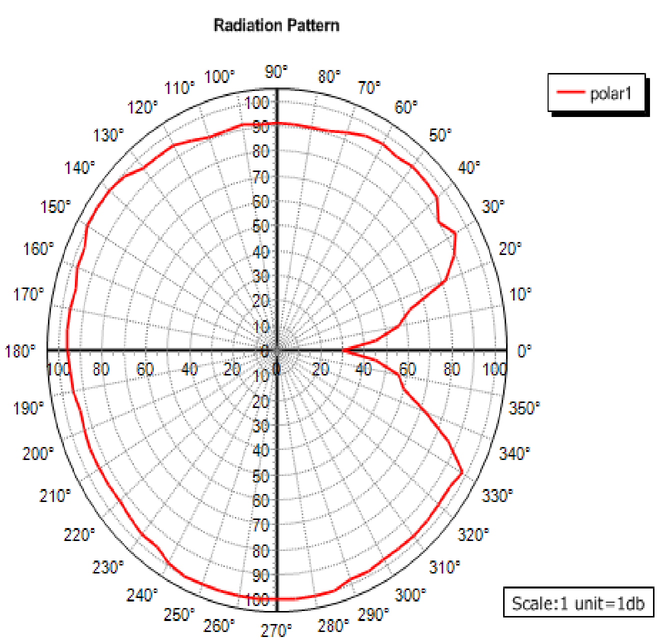

Figure 8. Radiation Pattern of E-shape patch and U-shape Patch

Gain= 3.04
Directivity= 3.6

Rectangular Fractal Antenna:

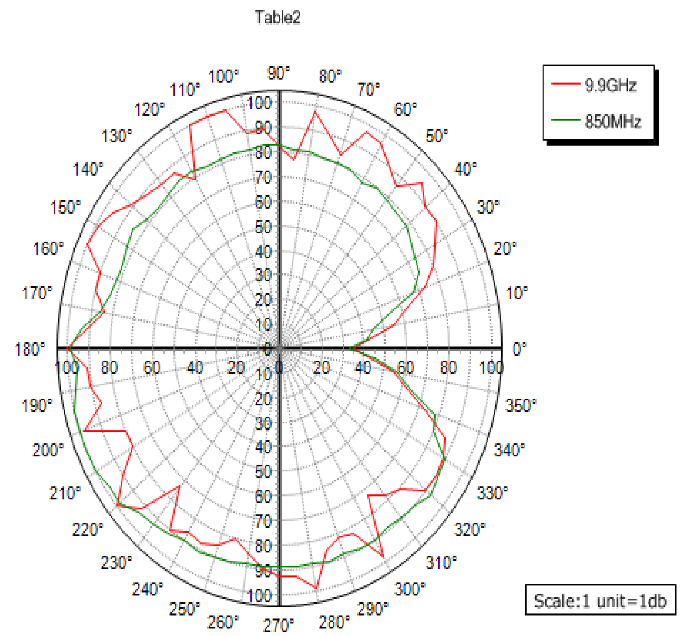

Figure 9. Radiation Pattern of Rectangular Fractal Antenna

Gain= 2.91
Directivity= 3.52

Multi-Standard Patch Antenna:

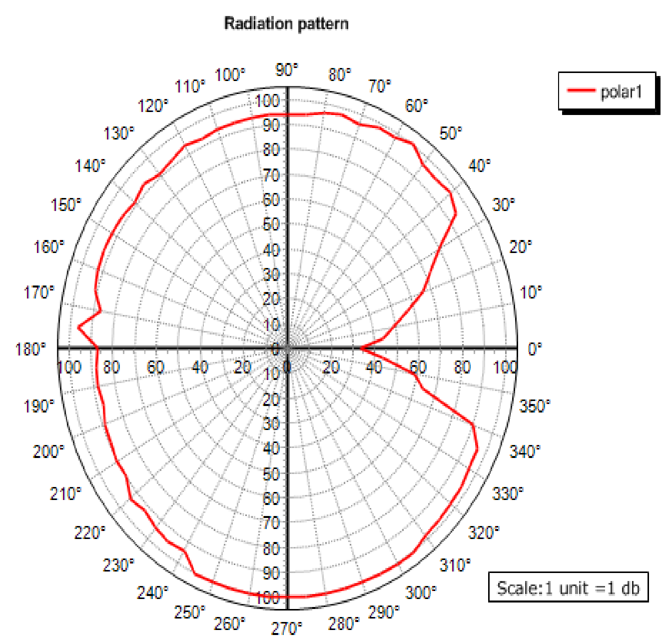

Figure 10. Radiation Pattern of Multi-Standard Patch Antenna

Gain= 2.91
Directivity= 3.52

Circularly Polarized Microstrip Patch:

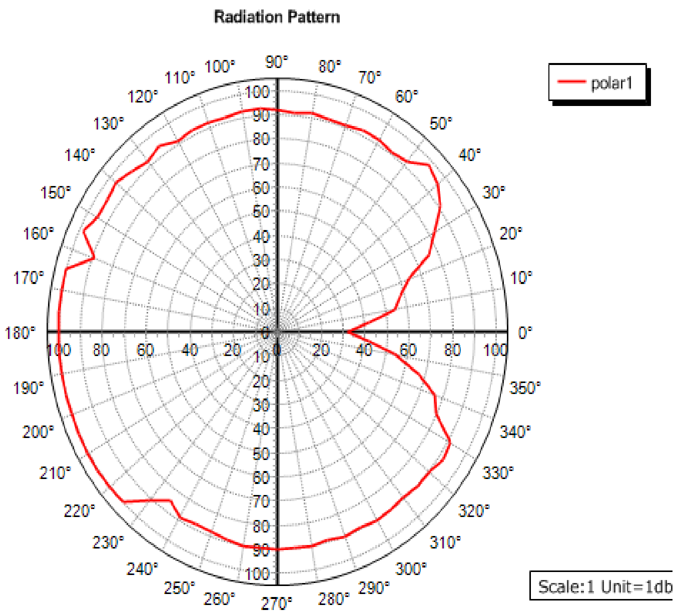

Figure 11. Radiation Pattern of Circularly Polarized Microstrip Patch

Gain= 2.95
Directivity=3.57

CONCLUSION

Microstrip antennas have become a rapidly growing area of research. Their potential applications are limitless, because of their light weight, compact size, and ease of manufacturing. One limitation is their inherently narrow bandwidth. However, recent studies and experiments have found ways of overcoming this obstacle. Compact Multiband Microstrip Patch Antennas was designed and readings were obtained using particular frequency. Then using Datascene software radiation pattern was drawn for each antenna and observed manually too. Parameters like Gain and Directivity is calculated for each antennas. The antenna support multiband operation. A multi band antenna suitable for applications like mobile phones and WLAN has been presented. This will cover wide bands of operation. This antenna can be applied to a multiband wireless communication system due to its small size and low fabrication cost. We are currently implementing the design and experimental data will be shown for comparison with the design data. The antenna gain and radiation pattern are acceptable at almost all bands of operation. Simulations and measurements comparison shows good agreement.

In future work we should make the Microstrip Patch antenna of reduced size. The reason for reducing size is ability to compatible with any kind of devices.

REFERENCES

[1] Nima Bayatmaku, Parisa Lotfi, Mohammadnaghi Azarmanesh, and Saber Soltani, "Design of Simple Multiband Patch Antenna for Mobile Communication Applications Using New E-Shape Fractal", IEEE Antennas and Wireless Propagation Letters, VOL. 10, pp. 873 – 875, 2011.

[2] Hattan F. Abutarboush, R. Nilavalan, S. W. Cheung, Karim M. Nasr, Thomas Peter, Djuradj Budimir and med Al-Raweshidy, "A Reconfigurable Wideband and Multiband Antenna Using Dual-Patch Elements for Compact Wireless Devices", IEEE Transactions on Antennas and Propagation, Vol. 60, No. 1, pp. 36 – 43, January 2012.

[3] K. L. Lau, IEEE, Sai Hoi Wong, and K. M. Luk, "Wideband Folded Feed L-Slot Folded Patch Antenna", IEEE Antennas and Wireless Propagation Letters, Vol. 8, pp. 340 – 343, 2009.

[4] Rashid Ahmad Bhatti, Yun-Taek Im, and Seong-Ook Park, "Compact PIFA for Mobile Terminals Supporting Multiple Cellular and Non-Cellular Standards", IEEE Transactions on Antennas and Propagation, Vol. 57, No. 9, pp. 2534 – 2540, September 2009.

[5] S.Y. Lin and K.C. Huang, "A Compact Microstrip Antenna For GPS and DCS Application", Antennas And Propagation Society International Symposium, IEEE Transactions on Antennas and Propagation, Vol. 53, No. 3, pp. 1227-1229, March 2005.

[6] S L S Yang, K F Lee, and A A Kishk, Design and study of wideband single feed circularly polarized micro strip antennas, Progress In Electromagnetics Research, PIER 80, pp. 45-61, 2008.

[7] B. Smith, K.L.Wong, "An approach to graphs of Compact and Broadband Microstrip antennas', NewYork: Wiley, 2002.

[8] S.L. Latif, L.Shafai, and S.K.Shaema, "Bandwidth enhancement and size reduction of microstrip slot antenna," IEEE Trans. Antennas Propag., vol.53, no.3, pp.994-1003, 2005.

[9] J.Y.Sze, and K.L.Wong, " Slotted microstrip antenna for bandwidth enhancement," IEEE Trans. Antennas Propag., vol. 48, no.8, pp. 1149- 1152, 2005.

[10] Li, J.-Y. and Y.-B. Gan, "Multi-band characteristic of open sleeve antenna," Progress In Electromagnetics Research, PIER 58, pp. 135– 148, 2006.

[11] D. E. Anagnostou, Z. Guizhen, M.T. Chryssomallis, J.C. Lyke, G. E. Ponchak, J. Papapolymerou and C. G. Christodoulou "Design, fabrication, and measurement of an RF-MEMS-based self-similar reconfigurable antenna", IEEE Transactions on Antennas and Propagation, Vol.54, Issue 2, Part 1, pp. 422-432, Feb.2006.

[12] H.Y. Kim, Y.A. Lee, C.H. Won, and H.M. Lee, "Design Of A Compact Dual-Band Microstrip patch Antenna For GPSK-PCS Operation", Antennas And Propagation Society International Symposium, IEEE Transactions on Antennas and Propagation, Vol. 4, No. 6, pp.3529-3532, June 2004.

[13] J. Costantine, "New Multi Wide Band Design for a Microstrip Patch Antenna" Master thesis, American University of Beirut, October 2006.

[14] K R Boyle, et al, Reconfigurable antennas for SDR and cognitive radio, European Conference on Antennas and Propagation, pp. 1-6, Nov. 2007.

[15] T Shanmuganathan, K Balamaniknandan, and S Raghvan, CPW fed slot antenna for wideband applications, International Journal of Antennas and Propagation, Vol. 2008, Article ID: 379247, pp. 1-4, 2008.

[16] D S Javan, M A Salari, and U H Ghoochani, “Cross slot antenna with U shapedtuning stub for ultra-wideband applications”, International Journal of Antennas and Propagation, Vol. 2008, Article ID: 262981, pp. 1-6, 2008.

[17] E Ebrahimi, and P S Hall, A dual port wide-narrowband antenna for cognitive. radio, European Conference on Antennas and Propagation, Berlin, Germany, Mar. 2009.

[18] K. Kim and V. V. Varadan, "Millimeter wave dual-band microstrip antennas with metamaterial substrates using the LTCC process," Metamaterials 2007, pp.242-245, Oct. 2007.

[19] A.Shackelford, K. F. Lee, D. Chatterjee, Y. X. Guo, K. M. Luk, and R. Chair,―Small size wide bandwidth microstrip patch antennas, in IEEE Antennas and Propagation International Symposium, vol. 1, (Boston, Massachusetts), pp. 86–89,IEEE, July 2001.

[20] C. A. Balanis, “Antenna Theory – Analysis and Design”, John Willey & Son, INC, Second Edition, 1997.

[21] A. Phan, “Antenna Theory and Technique”, Science and Technical Press, Hanoi, 2000, pp.

