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# Gain and Bandwidth Enhancement Techniques in Microstrip Patch Antennas - A Review

Alok Kumar
Research Scholar
CT Group of Institutions
Jalandhar, Punjab

Nancy Gupta
Assistant Professor
CT Group of Institutions
Jalandhar, Punjab

P. C. Gautam
Scientist 'E'
DRDO
Chandigarh, Punjab

## ABSTRACT
Today antenna designers are paying more focus on microstrip patch antennas, because of its numerous advantages in field of communication, such as high reliability, light weight, ease of fabrication etc. But despite of its bountiful advantages, patch antennas also experience some drawbacks viz low gain and narrow bandwidth. These drawbacks can be overcome by taking care of some parameters in the design of antennas. There are numerous designing factors affecting the radiating characteristics of antenna such as patch height, feeding techniques, substrate used in manufacturing of antenna etc. The paper is focused on various bandwidth enhancement techniques. The paper comprises of a brief study in feeding techniques, parasitic patch elements, introduction of slots, dual feed, shorting pin, air gap and recently introduced concept of defective ground structure that enhances the gain and bandwidth of antenna without increasing its height.

## Keywords
Microstrip patch antennas, feeding techniques, gain, bandwidth

## 1. INTRODUCTION
With the wide spread development in wireless communication technology in recent years, the requirement of compact size, low profile and broad bandwidth antenna has augmented drastically. To meet up with this requirement, the Microstrip patch antennas have been proposed [1]. Microstrip patch antennas are attaining pronounced publicity due to its many alluring features such as light in weight, low volume, low cost, low profile, small dimensions and ease of fabrication and conformity etc. [2-4]. Microstrip patch antennas are highly valuable and have better prospects as compared to other conventional antennas. Moreover, the microstrip patch antennas can provide frequency agility, broad band-width and feed line flexibility [5-6]. Microstrip antennas are used in numerous applications, ranging from biomedical diagnosis to wireless communications [7]. But in spite of many advantages, one major problem of gain and bandwidth is concerned. Significant research work has been reported till now on increasing the gain and bandwidth of microstrip antennas e.g. probe fed stacked antenna, microstrip patch antennas on electrically thick substrate, slotted patch antenna, air gap, parasitic patch and stacked shorted patch have been proposed and investigated [8-9]. Recently defective ground structure is introduced, that includes advantages such as reduction in patch size and increase in gain and bandwidth [10].

## 2. POPULAR FEEDING TECHNIQUES
Microstrip patch antennas can be fed by a variety of methods. These methods can be broadly classified into two categories- contacting feed and non-contacting feed methods. In contacting feed method, the patch of the antenna is directly feed with RF power. The popularly used contacting feed methods are microstrip feed and co-axial feed. On the other hand in non-contacting feed method, the patch of the antenna is indirectly fed with the RF power and the RF power is transported to the patch through electromagnetic coupling. The most commonly used non-contacting feeding techniques are aperture coupled feed and proximity coupled feed [11-13]. These popular feeding methods are discussed briefly as follows:

### 2.1 Microstrip feed
In this type of feeding method, a conducting strip is linked directly to the boundary of the Microstrip patch. The conducting strip is having smaller width as compared to the patch. This feed arrangement has a key advantage, that the feed and patch can be etched on same substrate which makes it a planar structure [14].

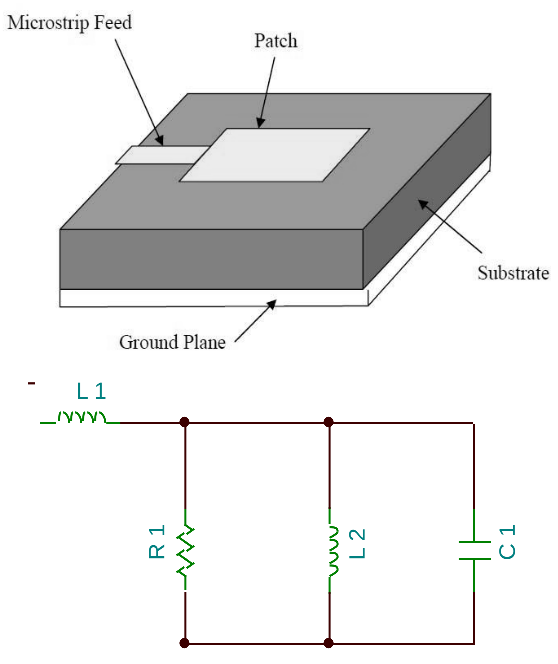



**Fig 1 Microstrip fed patch antenna and its equivalent circuit [9-20]**

Secondly, it can also be transformed into inset cut patch. The purpose of the inset cut in the patch is to match the impedance of both the feed line and the patch. It doesn't require any supplementary matching element. Inset cut position and dimensions should be adjusted properly to achieve perfect impedance matching [15]. Since it is an easy feeding scheme, it can also give ease of fabrication and simplicity in modeling. The major inconvenience with this feeding technique is, if the thickness of the substrate is increased then surface waves and spurious feed radiation also increases, which directly hampers the bandwidth of the antenna [16].

## 2.2 Coxial feed

The Coaxial feed also called probe feed is broadly used technique for feeding Microstrip patch antennas. In this technique the internal conductor of the coaxial connector is pulled out through the dielectric and soldered on the radiating patch, whereas the external conductor is attached to ground plane.

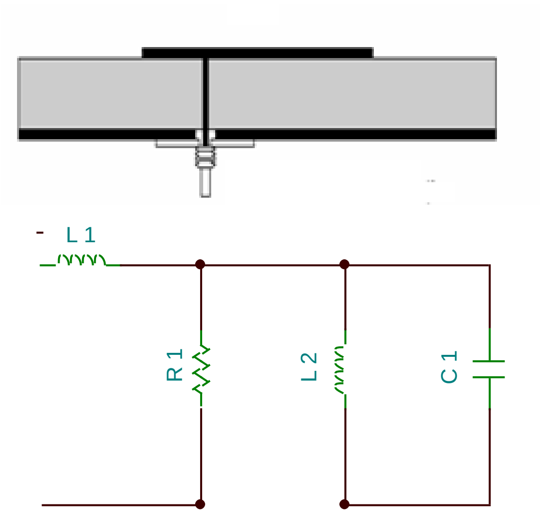



**Fig.2. Coaxial fed patch antenna and its equivalent circuit [17-20]**

The key advantage of this coaxial feeding scheme is that it can be placed at any desired position inside the patch to facilitate its match with input impedance. However, main hindrance to this feeding technique is that it is complicated to model. Since a hole has to be drilled in the substrate and the connector stick outside the ground plane, which is not making it a complete planar structure for thick substrates. Also, for thicker substrates, the augmented probe length makes the input impedance more inductive that leads to impedance matching problems [17].

## 2.3 Aperture Coupled feed

In aperture coupling feed and ground plane with aperture is sandwiched between two different substrates, to provide electromagnetic coupling from feed to the radiating patch structure. The radiating patch element is etched on the top of the antenna substrate and the microstrip feed line is etched on the bottom of the feed substrate in order to obtain aperture coupling. The thickness and dielectric constants of these two substrates would be chosen separately to optimize the different electrical functions of radiation and circuitry. The coupling aperture is placed preferably at the center location under the patch that leads to lesser cross-polarization due to symmetricity in configuration.

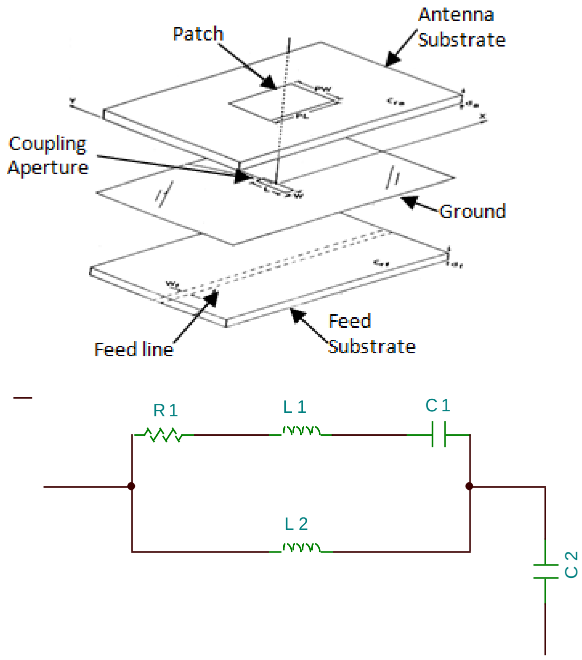
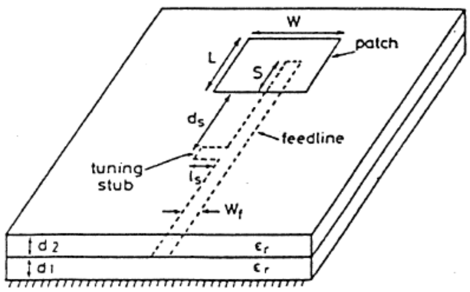



**Fig.3.Aperture coupled fed patch antenna and its equivalent circuit [18-20]**

The percentage of coupling from the feed line to the patch is determined by the shape, size and position of the aperture. Since the ground plane isolates the patch and the feed line, it leads to minimization of the spurious radiation. Generally, a high dielectric material is utilized for bottom substrate and a thick low dielectric constant material is employed for the top substrate to optimize the radiation from the patch [18]. The major disadvantage of aperture coupled feeding technique is complication in fabrication of the design due to its alignment problem in multiple layers.

## 2.4 Proximity Coupled feed

Proximity coupled feed is also called as the electromagnetic coupling scheme. In this technique, two dielectric substrates are used such that the feed line is placed between the two substrates and the radiating patch is located on top of the upper substrate. The major advantage of this feeding technique is that it eliminates spurious feed radiation and provides very high bandwidth. This scheme also provides alternative between two different dielectric media, one for the patch and another one for the feed line to optimize the individual performances. The major disadvantage of this feeding scheme is that it is complex to fabricate because both the dielectric layers need proper alignment [19].



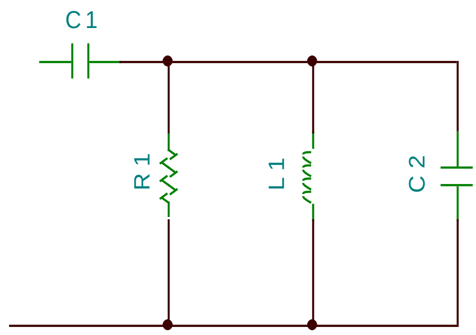



**Fig.4.Proximity fed patch antenna and its equivalent circuit [19-20]**

## 3. ADMIRED GAIN AND BANDWIDTH ENHANCEMENT METHODS

Apart from the different feeding techniques, there are various other methods adopted in recent times, to improve the inherent issue of gain and bandwidth in microstrip antennas. A brief insight about such popular methods is outlined as below:

### 3.1 Parasitic Patch

Parasitic patch technique is used to improve bandwidth and gain of Microstrip patch antennas. Two different configurations in parasitic patch technique are available: one is coplanar technique and other is stacked technique. In coplanar technique, there are different patches incorporated on single plane above dielectric substrate. One patch among different patch radiators is given excitation, which is called main patch. In stacked technique, one patch is employed above another patch with superseding dielectric layer in between. This allows two or more than two patches to share common aperture area [21-22].

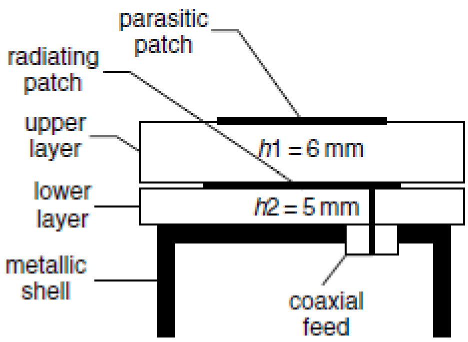



**Fig 5. Stacked Patch antenna with Parasitic element [25]**

In stacked antenna configuration, parasitic stacks of lower dielectric constant are generally added above the radiating patch. This minimizes the overall effective permittivity of the multilayer antenna and increase gain of antenna [23]. Multi-layered microstrip antennas are able to maintain the size and helps reduce the effect of surface waves. [24]

### 3.2 Air Gap

The air as a dielectric has lower permittivity, thus when it used as dielectric substrate between reflecting ground and radiating patch, it gives an effective radiation pattern and low return loss. These outcomes indicate maximum amount of input power is converted into electromagnetic waves [26-27].

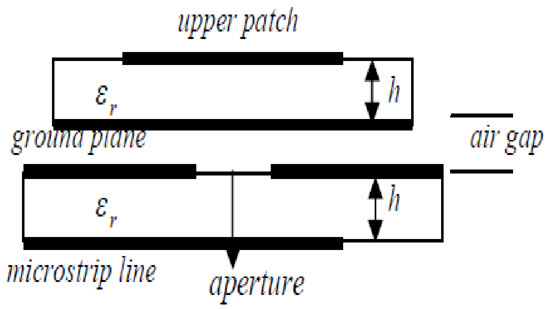



**Fig.6 Microstrip Patch antenna with air gap[28]**

It is observed that placing an air gap in between single patch antenna and aperture coupled antenna helps to resonate them on two different frequencies. Moreover, by increasing the height of air gap the ratio of two different resonating frequencies decrease and they come closer to each other [28]. This shows air gap is an useful factor to enhance bandwidth of Microstrip Patch Antenna.

### 3.3 Slots

The slots are implanted on the patch radiator to improve the impedance matching, particularly at higher frequencies. The slots cut from the radiator patch change the current distribution, so that the current path length and impedance at the input point changes [29].

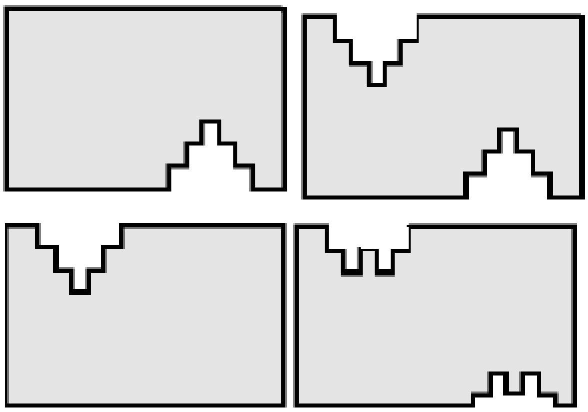


**Fig.7 Slots with irregular shapes [21]**

Adding slots into the patch of the antenna add a new resonance frequency. By adding more slots, two or more resonance regions are created, which is after proper optimization yield an enhanced bandwidth [21].

### 3.4 Dual Feed

Dual feed structure is another available technique to enhance bandwidth, especially at higher resonating frequencies [30].

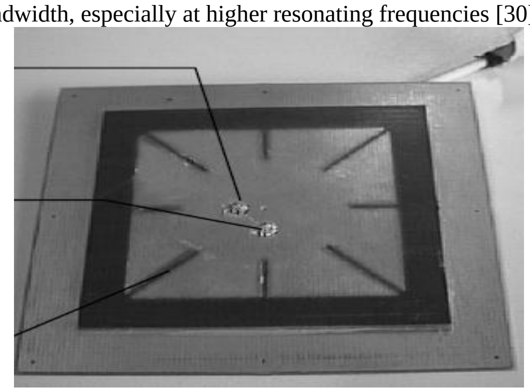


**Fig. 8 Microstrip patch antenna with dual feed [32]**

Double feeding configuration in antenna structure is used to enforce the vertical current mode. It also prevent other modes such as horizontal and asymmetrical current modes from being excited. These horizontal and asymmetrical current modes degrade the polarization properties and reduce the impedance and gain performance of the antenna [31].

## 3.5 Dielectric Substrate

Selection of appropriate substrate material is a significant task in designing of microstrip patch antenna. By selecting appropriate dielectric material for substrate, some critical parameters like bandwidth, efficiency, and radiation pattern of patch antenna is improved [33]. The substrates are used in microstrip antenna primarily to provide mechanical strength to antenna. Moreover, by selecting appropriate dielectric mediums we can also reduce the propagation of surface wave. Surface waves extract some part of total power available for radiation which degrades the electrical properties of antenna [34].

## 3.6 Shorting Pin

Adding shorting pin on patch antenna leads to decrease the resonating frequency of antenna without reducing antenna size [38]. In order to attain high impedance matching, location of the shorting pin must be chosen nearer to the feed point of the antenna. Otherwise, input impedance augments rapidly [35]. Shorting pin can also be act like feed line of the microstrip antenna. Shorting pin is modeled as an inductive part parallel to the resonant LC circuit. Larger the inductive part smaller will be the resulting resonance frequency. That ultimately augments the degree of miniaturization attained for a fixed operating frequency [36-37].

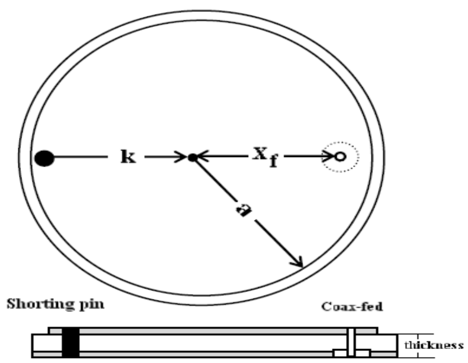



**Fig. 9 Circular patch with shorting pin [39]**

The shorting pin not only augments bandwidth performance but it also helps to decrease cross-polarization level. The cross-polarized level in the H plane can be cancelled out by using anti-phase shorted pins [38].

## 3.7 Defective Ground Structures

Defected ground structures concept has been developed recently and they are achieved by engraving a simple defect of any shape on ground plane. Due to these structures the current is disturbed in the ground plane. This ultimately results in handling excitation and propagation of radio waves across the substrate layer. DGS configuration also helps to change transmission line parameters viz. inductance and capacitance [18]. The defect in ground can be changed accordingly from simple shape to complex shape in order to achieve desired performance. In microstrip antennas, defective ground structures have numerous advantages in the field of transmission lines, couplers, dividers, power amplifiers, oscillators and combiners [40].

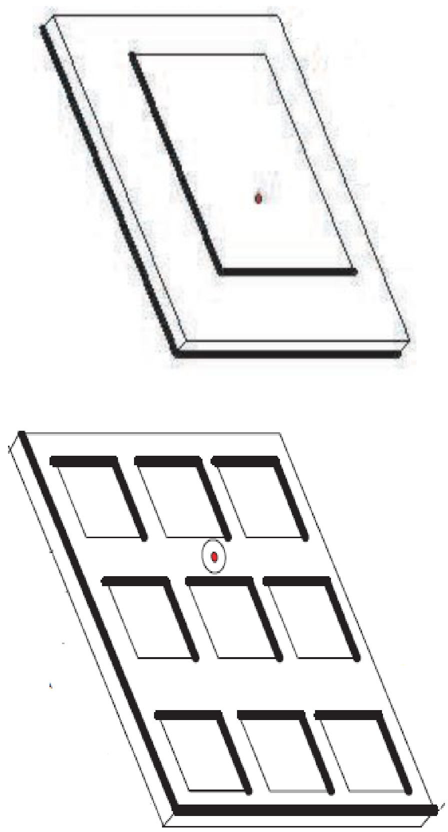


**Fig. 10 Front and back view of defective ground plane [41]**

## 4. CONCLUSION

Popular feeding techniques for giving excitation signal to microstrip patch antennas are summarized in the paper. Also, the paper appraises different methods that are being currently used to enhance gain and bandwidth of patch antennas. It is observed that contacting techniques viz. microstrip feed and coaxial feed are easy to design and implement. Whereas, non-contacting techniques viz. aperture feed coupling and proximity coupling provide wider bandwidth and gain but they are difficult to implement due to their alignment between two substrates. In some antenna designs, only feeding technique isn't enough to enhance gain and bandwidth. There are several other techniques viz parasitic patch, slot, dual feed, shorting pin, air gap, dielectric and defective ground structures are available to enhance bandwidth and improve gain of the antenna, The techniques such as parasitic patch and slot cutting are also used to improve the impedance matching of antenna, thereby resulting in multiband and broadband performances. The methods such as dual feed and shorting pin are prevalently used to change the reactive impedance of antenna. Whereas, air gap and perfect dielectric substrate material helps to reduce the propagation of surface wave effects on antenna. Recently, the idea of defective ground structure is getting popular, for enhancement in gain and bandwidth of antenna without increasing its height and volume.

# 5. REFERENCES


[1] Jagdish. M. Rathod, “Comparative Study of Microstrip Patch Antenna for Wireless Communication Application”, International Journal of Innovation, Management and Technology, Vol. 1, No. 2, June 2010.

[2] D. R Jahagirdar and R D. Stewart, “Non-Leaky Conductor Backed Coplanar Wave Guide-Fed Rectangular Microstrip Patch Antenna,” IEEE Microwave and Guided-Wave Letters. Vol 3, pp. 115-117, Mar. 1998.

[3] N. Herscovici, “New considerations in the design of microstrip antennas”, IEEE Transactions on Antennas and Propagation,vol. 6, pp. 807-812, Jun. 1998

[4] S. S. Pattnaik, GianlucaLazzi, and Om P. Gandhi, “ On the Use of Wide-Band High-Gain Microstrip Antenna for Mobile Telephones”, IEEE Antennas and Propagation Magazine, vol 40, pp. 88-90, feb 1998.

[5] D. Sanchez-Hernandez and I. D. Robertson, “A Survey of Broadband Microstrip Patch Antennas,” Microwave Journal, pp. 60-84, sept 1996.

[6] Dipak K. Neog, Shyam S. Pattnaik, Dhruba. C. Panda, SwapnaDevi, BonomaliKhuntia, and Malaya Dutta, “Design of a Wideband Microstrip Antenna and the Use of Artificial NeuralNetworks in Parameter Calculation”, IEEE Antenna and Propagation Magzine, vol. 47, No. 3, pp. 60-65, june 2005

[7] S. S. Pattnaik, D. C. Panda, and S. Devi. 2002. “Radiation Resistance of Coax-Fed Rectangular Microstrip Patch Antenna Using Artificial Neural Networks. Microwave and Optical Technology Letters”, vol. 15, pp. 51-53, Jul. 2002.

[8] D. Sanchez-Hernandez and I. D. Robertson, “A Survey of Broadband Microstrip Patch Antennas”, Microwave Journal, , pp. 60-84, Sep. 1996.

[9] Dipak K. Neog, Shyam S. Pattnaik, Dhruba. C. Panda, Swapna Devi, BonomaliKhuntia, and Malaya Dutta, “Design of a Wideband Microstrip Antenna and the Use of Artificial Neural Networks in Parameter Calculation”, IEEE Antennas and Propagation Magazine, Vol. 47, No.3, June 2005

[10] H. R. Gajera, Anoop C.N, M M Naik. G, Archana S. P, Nandini R, Pushpitha B.K, Ravi Kumar M.D, “The Microstrip Fed Rectangular Microstrip Patch Antenna (RMPA) with Defected Ground Plane for HIPERLAN/1, International journal of electronics and communication technology, Vol. 2, Issue 3,pp. 172-175, Sept. 2011

[11] Yang, F., X. Zhang, X. Ye, and Y. Rahmat-Samii, “Wide-band E-shaped patch antennas for wireless communications”, IEEE Transactions on Antennas and Propagation, Vol. 49, No. 7, pp. 1094-1100, Jul. 2001.

[12] Ge, Y., K. Esselle, and T. Bird, “E-shaped patch antennas for high speed wireless networks”, IEEE Transactions on Antennas and Propagation, Vol. 52, No. 12, pp. 3213-3219, Dec. 2004.

[13] S K Behera, “Novel Tuned Rectangular Patch Antenna As a Load for Phase Power Combining” PhD Thesis, Jadavpur University, Kolkata, 2012.

[14] Gurdeep Singh, Jaget Singh, “Comparative Analysis of Microstrip Patch Antenna with Different Feeding Techniques”, International Conference on Recent Advances and Future Trends in Information Technology, Proceedings published in InternationalJournal of Computer Applications® (IJCA), 2012.

[15] Prof. Mahesh M. Gadag, Mr. Dundesh S. Kamshetty, Mr. SureshL. Yogi “Design of Different Feeding Techniques of Rectangular Microstrip Antenna for 2.4GHz RFID Applications Using IE3D”,Proc. of the Intl. Conf. on Advances in Computer, Electronics and Electrical Engineering, 2012

[16] Garg, R., Bhartia, P., Bahl, I., Ittipiboon, “A., Microstrip Antenna Design Handbook”, Artech House, Inc, 2001.

[17] Fong, F.S.,H.F. Pues and M.J. wither, “wideband multilayer coaxial-feed Microstrip antenna element”. Electronics letters, vol 21, pp. 497-498, 1985.

[18] Yoshita Gupta , “Stacked Microstrip Patch Antenna with Defected Ground Structures for W-lan and Wimax Applications” Thesis work in Department of Electronics and Communication Engineering, THAPAR UNIVERSITY, PATIALA, June, 2014

[19] Pozar, D.M. and B. Kaufman, “Increasing the bandwidth of a Microstrip antenna by proximity coupling”, Electronics letters, vol 23, no. 8, pp. 368-369, April 1987

[20] Gurdeep Singh, Jaget Singh, “Comparative Analysis of Microstrip Patch Antenna with Different Feeding Techniques”, International Conference on Recent Advances and Future Trends in Information Technology, pp. 18-22, 2012.

[21] Hatem H. Abbas, Jabir S. Aziz, “Bandwidth enhancement of Microstrip patch antenna”, Journal of mobile communication, vol. 4, pp. 54-59, 2010.

[22] Abbak, M.; Rezaeieh, S.A.; Akduman, I., "Broad-band three layer suspended plate antenna," in Telecommunications Forum (TELFOR), vol. 19, pp.951-954, 2011

[23] Bhattacharyya, Arun K. "Characteristics of Circular Patch on Thick Substrate and Superstrate." Antennas and Propagation, IEEE Transactions, vol 7, no. 39, pp. 1038-1041, 1991

[24] J. Anguera, G. Font, C. Puente, C. Borja, and J. Soler, “Multifrequency microstrip patch antenna using multiple stacked elements,” IEEE Microwave and Wireless Components Lett., vol. 13, no. 3, 13(3), pp. 123-124, March 2003.

[25] Hao Jiang, Zhenghui Xue, Weiming Li and Wu Ren, “Broad beamwidth stacked patch antenna with wide circularly polarised bandwidth”, Electronics Letters, Vol. 51, No. 1, pp. 10–12, 8th January 2015.

[26] Dahele, J. S., and Kai F. Lee. "Theory and Experiment on Microstrip Antennas with Airgaps." IEEE Proceedings on Microwaves, Antennas and Propagation, Vol. 132, No. 7, 1985.

[27] Chakraborty, Shatabdi, and Shweta Srivastava, "High Gain Annular Ring Antenna", International Conference on Devices and ommunications (ICDeCom), 2011.

[28] Rajesh Kumar Vishwakarma, Sanjay Tiwari, “Aperture coupled stacked patch antenna for dual-band”, International Journal of Electronics and Computer science Engineering, vol 1, no. 3, pp. 933-939, 2012

[29] Chen, D. and C. H. Cheng, "A novel compact ultra-wideband (UWB) wide slot antenna with via holes" Progress In Electromagnetics Research, Vol. 94, pp. 343-349, 2009.

[30] E. Antonino-Daviu, M. Cabedo-Fabres, M. Ferrando-Bataller, A Valero-Nogueira, "Wideband Doubke fed Planar monopole antenna", Institution of Engineerring and Technology, vol. 39,2003.

[31] H. Ghannoum, R. D. Errico, C. Roblin, A. Sibille, "Small semi direrctional antenna for UWB terminal Application", First European Conference on Antenna and Propagation, pp.1-6, 2006

[32] E.Alboni, M. Cerretelli, "Microstrip ptach antenna for GPS application" Ancona, Italy, pp 16-19, 2004

[33] K.P. Kumar, K.S. Rao ,V.M. Rao, K.Uma, A.Somasekhar , C.M. Mohan, "The effect of dielectric permittivity on radiation characteristics of co-axially feed rectangular patch antenna: Design & Analysis", International Journal of Advanced Research in Computer and Communication Engineering, Vol. 2, Issue 2, pp. 1254-1258, February 2013

[34] Y.T. Lo. and S.W. Lee, "Antenna Handbook Theory, Applications and Design", Van Nostrand Reinhold Company New York, 1988.

[35] Uzer D. "Investigation on Favourable Methods for Wideband Microstrip Patch Antenna Designs", PhD. Thesis, Dept. Elect. and Electro. Eng., Graduate School of Natural Sciences, Selcuk University, Konya, Turkey,

[36] Dilek Uzer, Seyfettin Sinan Gultekin, " An Investigation of Shorting Pin Effects on Circular Disc Microstrip Antennas", International Journal of Applied Mathematics, Electronics and Computers, vol. 3, pp. 216-222, 2015

[37] R. Porath, "Theory of miniaturized shorting-post micro-strip antennas," IEEE Transactions, Antennas and Propagation, Vol. 48, No. 1, pp. 41-47, 2000.

[38] KS Ruy, AA Kishk, "A dual-polarized shorted microstrip patch antenna for wideband application", Dept of Electronical Engineering the University of Mississippi, 2008

[39] Malekpoor, H.; Jam, S., "Enhanced Bandwidth of Shorted Patch Antennas Using Folded-Patch Techniques," Antennas and Wireless Propagation Letters, IEEE , vol.12, pp.198-201, 2013

[40] Constantine A. Balanis , "Antenna theory Analysis and Design", 2nd edition, John Wiley and Sons, 2009.

[41] J. P. Geng, J. J. Li, R. H. Jin, S. Ye, X. L. Liang and M. Z. Li, "The Development of Curved Microstrip Antenna with Defected Ground Structure", Progress In Electromagnetics Research (PIER), vol. 98, pp. 53-73, 2009.