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REVIEW OF TECHNIQUES FOR DESIGNING PRINTED ANTENNAS FOR UWB APPLICATION

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ABSTRACT

Due to the rapid development in the field of wireless communications there is an increasing demand for higher data rate and large bandwidth. The emerging Ultra Wideband (UWB) is a promising technology as it can accommodate higher data over a large bandwidth. The design of an antenna for UWB system is a challenging task. Many antennas have been designed for UWB with acceptable performance. A suitable UWB antenna should operate over entire UWB allocated by FCC (3.1-10.6 GHz), it should have linear phase, low dispersion and VSWR ≤ 2 throughout the entire band. Feeding the antenna also affect the response of antenna. There are different feeding techniques that have been discussed in this paper. According to the feeding techniques the patch antenna for UWB have been categorized and their results have been concluded which represents comparative analysis of their return loss and other basic parameters. This paper focuses on different UWB antennas, their geometries and design parameters. Studies have been undertaken that covers UWB antenna design fundamentals and techniques and comparison of feeding techniques have been undertaken.

KEYWORDS

UWB, UWB antenna, wideband antenna

I. INTRODUCTION

The antenna is an essential part of any wireless system as it is the component providing transition between a guided wave and a free-space wave. Ultra Wideband (UWB) is an emerging technology for future short-range wireless communications with high data rates as well as radar and geolocation [1]. Indeed, the use of large bandwidths offers multiple benefits including high date rates, robustness to propagation fading, accurate ranging and geolocation, superior obstacle penetration, resistance to jamming, interference rejection, and coexistence with narrow bandwidth systems. These requirements include no spurious interference to licensed systems, adjustable pulse shape, bandwidth and transmitted power, support of various throughputs, provision of adaptive multiple access, and security of information. The regulation for ultrawide band was officially released in 2002 by Federal Communication Commission (FCC) and spectrum of 3.1-10.6GHz is allocated for this band [2]. UWB communication has many advantages over short-distance communication as follows:

1. Higher data rates over large bandwidth (BW) and large channel capacity
2. Better immunity to multipath interference
3. Less complexity and cost
4. Low power consumption

The UWB spectral mask is shown in figure 1 that shows spectral density of –41.3/dBm/MHz throughout the frequency band. The specifications provide many challenges to designers in a variety of fields including circuit and system design and most important antenna design.

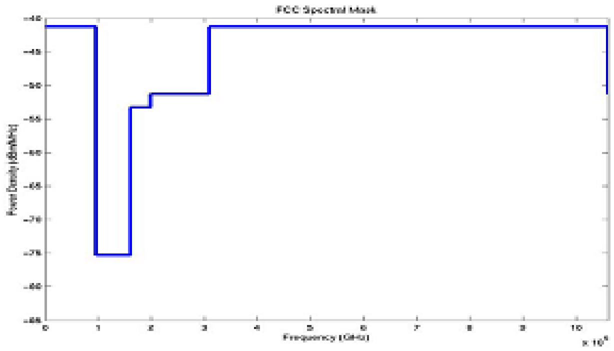


Figure 1: FCC Spectral Mask for indoor unlicensed UWB transmission. [2].

II. MOTIVATION FOR ANTENNA DESIGN

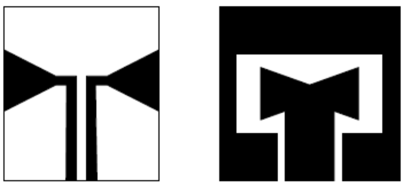
Antenna design has been a challenging issue for UWB radio system. The main issue in UWB antenna design is to achieve wide impedance bandwidth with high radiation efficiency. To attain power loss less than 10% at the antenna terminals it is required that UWB antenna should attain BW greater than 100% of the center frequency. It means BW up to 7.5GHz is required for a workable antenna [3].
Linear phase and sufficient impedance bandwidth is also a requirement for a suitable antenna design in order to minimize pulse distortion during transmission. Power loss should be less than 50% for UWB since the receive end architecture is sensitive to receive UWB signal. A planar antenna is also desired. Given that there are several additional constraints and challenges for the design of a UWB system antenna, motivation for antenna design is clear.

2.1 DESIGN CONSIDERATION FOR UWB ANTENNA

UWB antennas need different requirements due to its applications such as portable electronics and mobile communications. A conventional UWB antenna is not suitable for normal requirements. To satisfy different requirements such as size, gain and radiation patterns, many kinds of the new antennas have been proposed and are shown in figure 2.

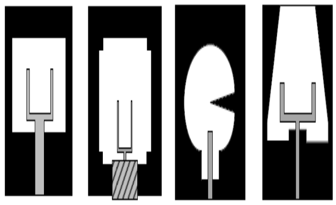
1. Biconical, Bowtie and Monopole Antennas
2. Slot type UWB Antennas
3. Tapered Slot UWB Antennas
4. Fractal UWB Antennas

- Biconical, Bowtie and Monopole Antennas: Many kinds of the planar monopole UWB antennas are introduced. Furthermore, Shiwei et al. (Qu & Ruan, 2005) and Tu Zhen et al. (Tu et al., 2004) are respectively introduced quadrate bowtie antenna with round corners and ultra wideband dipole antenna having a wideband property. The optimized antenna has an 8.5:1 impedance bandwidth and consistent radiation parameters over a 4.5:1 frequency range with excellent polarization purity over the entire 8.5:1 frequency range. And the antennas in figure are good examples of the UWB bowtie antenna (Kwon et al., 2005; Nakasuwan et al., 2008). Their bandwidth achieves more than the 3~10.6 GHz needed for UWB communication systems.



UWB Bowtie Antenna

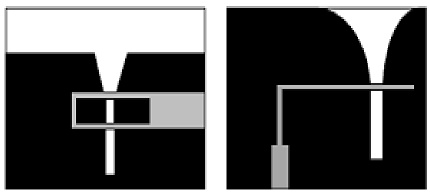
- Slot typed UWB Antennas: Slot antennas are currently under consideration for use in ultra-wideband (UWB) systems due to the attractive advantages such as low profile, light weight, ease of fabrication and wide frequency bandwidth. This type of antenna has been realized by using microstrip line and CPW feeding structures. The antenna in Figure (a) is consisted of the ground plane with wide rectangular slot and microstip feeding line with a fork-shaped tuning stub. Its measured bandwidth covers the UWB band from 2.5 GHz to 11.3 GHz that is a 127 % fractional bandwidth for S11 < -10dB. Its bandwidth is improved by using a tuning pad, which is made of copper as shown Figure (b). The improved antenna covers from 2.3 GHz to 12 GHz. And Figure (c) uses a tapered monopole like slot instead of the rectangular slot to decrease the low resonant frequency. Wen-Fan Chen et al. are introduced new shape UWB antenna, keyhole shaped slot antenna, which is consisted of an indented circular-pie slot, a rectangular stub slot and a microstip feed line as shown in Figure (d).



(a) (b) (c) (d)

UWB Slot Antenna

- Tapered Slot UWB Antennas: Tapered slot antennas (TSA) belonging to the general class of endfire traveling-wave antennas (TWA) has many adventages such as low profile, low weight, easy fabrication, suitability for conformal installation and compatibility with microwave integrated circuits (MICs). In addition, TSA hase multioctave bandwidth moderately high gain and symmetrical E- and H- plane beam patterns



Tapered Slot Antenna

- Fractal UWB Antennas: Many studied are specially concentrated on fractical antennas because they possess small size, light weight and thin shape for portable devices that have a rigorous limitation of space, but also wide bandwidth and good radiation patterns. Thus, the fractal technology is applied to realize the UWB characteristic with its self-similarity and space filling properties. Figure shows two fractal antennas for UWB applications (Naghshvarian-Jahromi & Falahati, 2008; Ding et al., 2006). The former used a circular patch with triangular slot, which is called a crown circular microstrip fractal antenna. The letter selected a pentagonal patch for initial design and then repeated Penta-Gasket Khock (PGK) iteration. These antennas have required properties for UWB communication systems.

Fractal UWB Antenna

Figure 2: Different Design Techniques

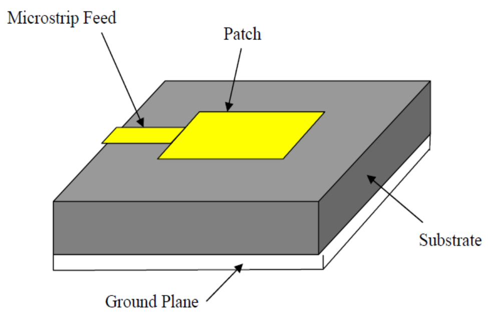
The most serious problem for UWB application is interference. Rejection of interference is necessary for UWB applications with existing wireless technologies such as IEEE 802.11a in USA (5.15-

5.35GHz, 5.725-5.825GHz) [4]. A band stop filter can be used but the use of filter would make the system complex. Many UWB antennas have been designed to overcome this interference problem.

2.2 FEEDING TECHNIQUES FOR MICROSTRIP PATCH ANTENNA:

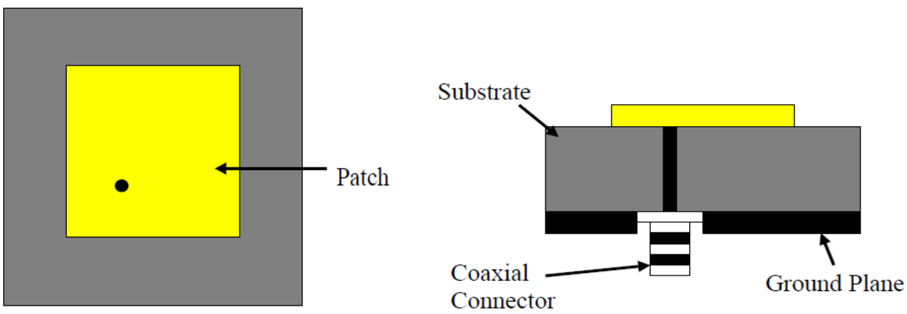
The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

- Microstrip line feed: In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position.



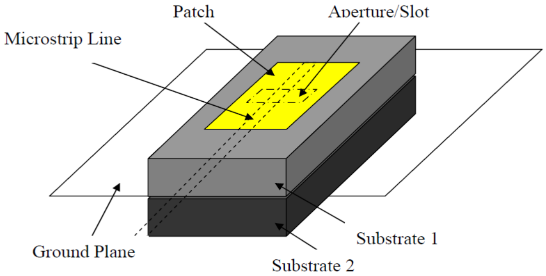
Microsrip line feed

- The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. The inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation.



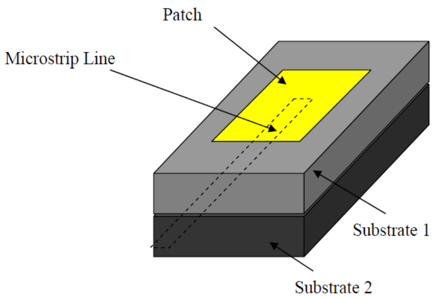
Coaxial/Probe feed rectangular patch antenna

- In this type of feed technique, the ground plane as shown separates the radiating patch and the microstrip feed line. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.



Aperture coupled feed

- This type of feed technique is also called as the electromagnetic coupling scheme. Two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%) due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.



Proximity coupled feed

Figure 3: Types of feeding techniques

III. REVIEW OF DESIGN TECHNIQUES BASED ON FEEDING TECHNIQUES

As mentioned before UWB technology has gained great popularity in the field of research and industrial area due to its higher data rate and large BW. Researchers have investigated many UWB antennas [5-30], which shows that their design would be a big issue. The main challenge to design a UWB antenna comes from the coverage of large bandwidth because the matching and energy transmission require to be verified for the entire bandwidth. However, the traditional trade-offs such as size vs. efficiency and size vs. bandwidth still influences the characteristics and performance of antennas. Some of the techniques are discussed as under:

- Microsrip line feed technique:

A.A compact design for microstrip UWB antenna has been presented. Based on transmission line modal analysis rectangular patch antenna parameters have been calculated. The detailed geometry and parameters are shown as in the table I and figure 3. The proposed antenna design geometry and experimental setup is presented [31].

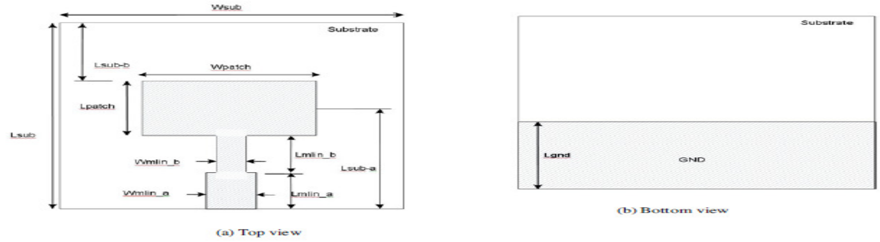


Figure 4: Design of proposed antenna[31]

Table I: Detailed Parameters For Proposed Antenna[31]

Symbol	Size (mm
Wsub	36
Lsub	34
Lsub_a	17
Lsub_b	11.5
Wpatch	18
Lpatch	11
Wmlin_a	3
Lmlin_a	5.5
Wmlin_b	2.5
Lmlin_b	6
Lgnd	11

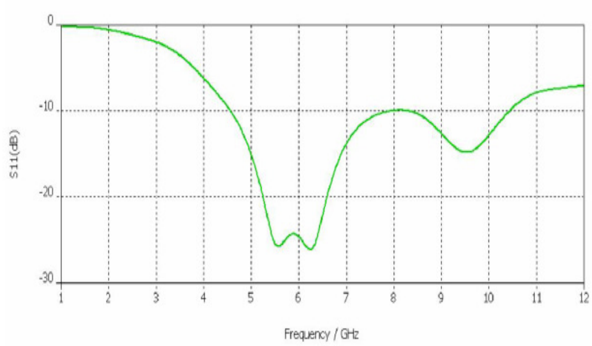


Figure 5: Return loss of proposed antenna[31]

The radiation pattern of the proposed antenna is shown as follows in figure 6

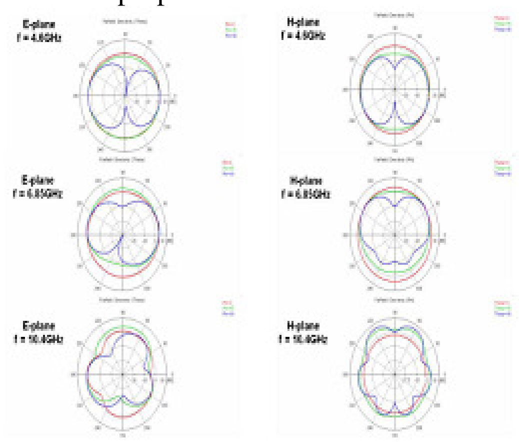


Figure 6: Radiation pattern of proposed antenna[31]

It can support large BW excited by a time domain pulse to ensure better transmission and reception of UWB signal. To provide further enhancement of the antenna performance in terms of impedance BW stepped matching technique is applied on the antenna.

B. The design of an UWB slotted microstrip patch antenna is presented in [32]. It has impedance BW between 1.78GHz to 11.13GHz. Antenna parameters such as slot size, its positin and dimension, feed width and patch shape has been also investigated to obtain better S11 value. Results have been simulated in CST Microwave Studio.

Figure7 show the proposed antenna design. Detailed parameters for this antenna are also given in table II .The antenna is designed on FR4 substrate with the thickness of 1.6 mm and dielectric constant of 4.4. The dimensions of the antenna structure are shown in Table 2.

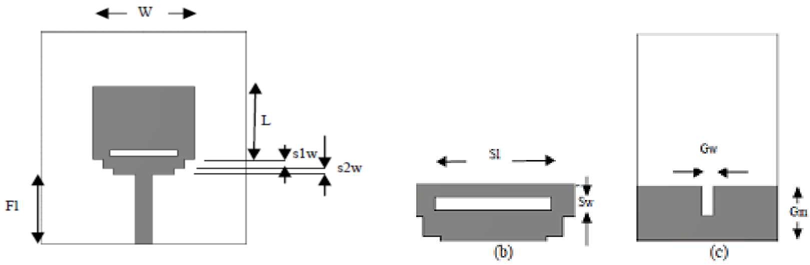


Figure7: Design of proposed antenna[32]

Table II: Detailed Parameters For Proposed Antenna[32]

Basic configuration	Variable	Dimension (mm)
Patch antenna	W	15.0
	L	10.0
	s1w	1.5
	s2w	1.0
	Fl	11.5
Slot	Sl	10.0
	Sw	1.0
Ground plane	Gw	2.4
	Gm	4.0

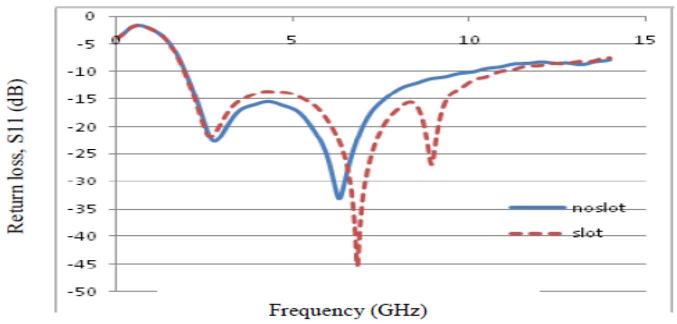


Figure 8: Return loss of proposed antenna

The radiation pattern of the proposed antenna is shown as follows in figure 9

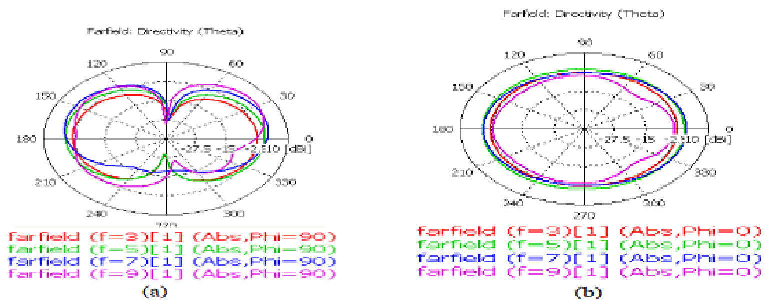


Figure 9: Simulated radiation pattern at *f* = 3 GHz, 5 GHz, 7 GHz and 9GHz at (a) phi = 90º (b) phi = 0º[32]

Better return loss is obtained when slot is placed near to the feed-line. UWB characteristic from 1.78GHz to 11.13GHz is obtained by optimizing antenna parameters.

C.UWB antenna with variable frequency band notch characteristics has been proposed [33]. Two slots are inserted in both sides of the feedline on the ground plane. To generate band notch characteristics H- shaped back plane is used with variable frequency. The proposed antenna operates over the frequency band between 3.1 and 14GHz with band rejection in the frequency band of 5.1 to 5.9GHz.Figure 10 shows the basic design structure. The results obtained are also shown in figure 11.

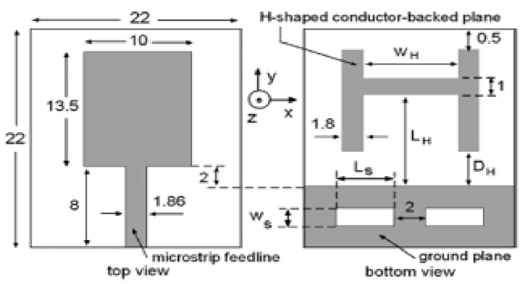


Figure 10: Design of the proposed antenna[33]

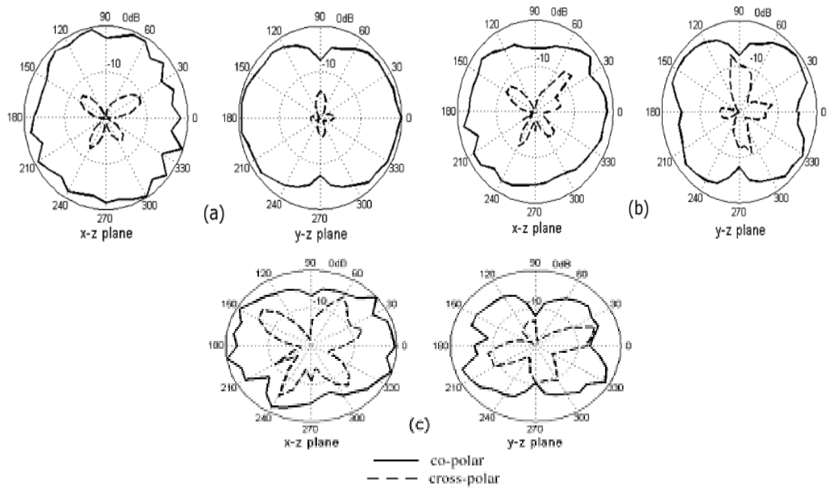


Figure 11: Measured x-z _ plane and _ y-z_ plane radiation pattern for proposed antenna at (a) 4 GHz; (b) 8 GHz; and (c) 11 GHz.[33]

- Coaxial/Probe feed technique:

A wideband U-shaped parasitic patch antenna has been proposed in [34]. In order to achieve wider bandwidth with comparatively small size two parasitic elements have been introduced. For wide band impedance matching coupling between the main patch and parasitic patches have been realized by either vertical or horizontal gaps. The proposed antenna is designed and fabricated on a small size ground plane (25 mm 30 mm) for application of compact transceivers. The fabricated antenna on a FR4 substrate shows an impedance bandwidth of 27.3% (1.5 GHz) at 5.5 GHz center frequency. Comparing with conventional patch antennas slightly higher gains of 6.4dB and 5.2 dB at each resonant frequency have been obtained.

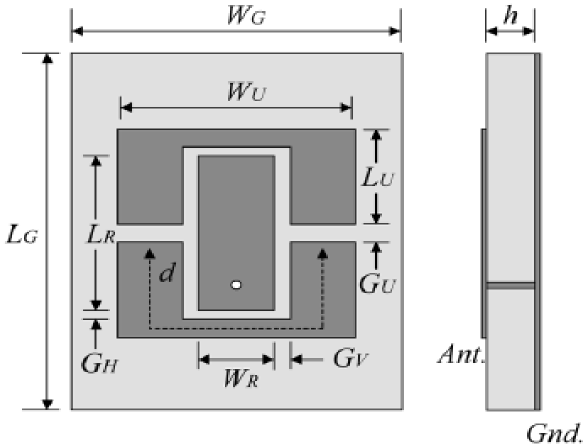


Figure 12: Proposed antenna design [34]

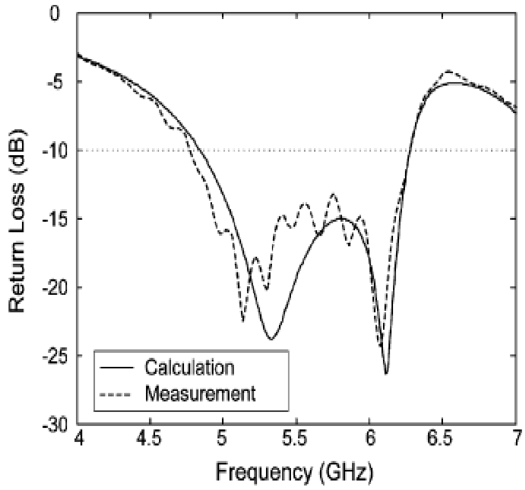


Figure 13: Return loss for the proposed antenna [34]

- Proximity coupled feeding technique:

A single-layer microstrip antenna for ultrawideband (UWB) applications has been presented [35], which is one of the examples for proximity coupled fed microstrip antenna in which an array of rectangular microstrip patches was arranged in the log-periodic way and proximity-coupled to the microstrip feeding line. A large scale factor of 1.1 was first reported and proved highly effective n order to reduce the number of microstrip patches in the UWB log-periodic arrays, a large-scale factor k=1.1 was firstly reported and proved to be highly effective. Detailed parameters study was also presented for better understanding of the proposed antennas. The impedance bandwidth (measured VSWR< 2.5) of an example antenna with only 11 elements is from 2.26–6.85 GHz with a ratio of about 3.03:1. Both numerical and experimental results show that the proposed antenna has stable directional radiation patterns, very low- profile and low fabrication cost, which are suitable for various broadband applications.

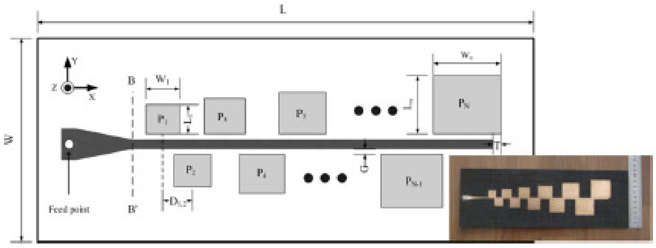


Figure 14: Structure of the proposed antenna [35]

Table III: Detailed Parameters For Proposed Antenna [35]

k=1.1				k=1.05			
n	11	$D_{1,2}$	13 mm	n	11	$D_{1,2}$	13.8 mm
L	320 mm	W	110 mm	L	270 mm	W	80 mm
L1	13 mm	W1	15 mm	L1	13 mm	W1	15 mm
G	0.2 mm	T	-4 mm	G	0.2 mm	T	-5.3 mm

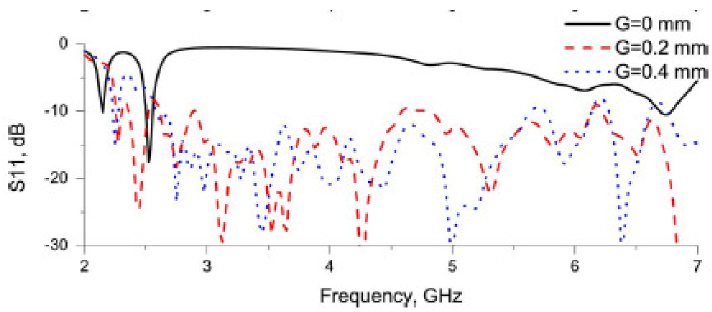


Figure 15: Return loss for the proposed antenna [35]

- Aperture coupled feeding technique:

An aperture coupled microstrip patch antenna has been investigated with a rectangular patch on top of two slots on the ground plane [36]. There is a feedline of having impedance of 50 which is divided into two 100 feed line under the ground plane by microstrip power divider. The parametric study show that the antenna impedance BW (VSWR<2) has been increased to 7.9 GHz and the gain of the proposed structure is above 7db for 5.5-8.8 GHz. Figure 16 shows the proposed antenna structure.

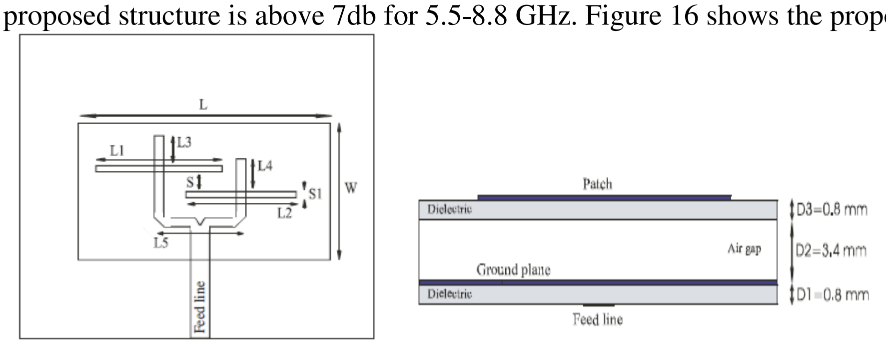


Figure16: Proposed Antenna Design [36]

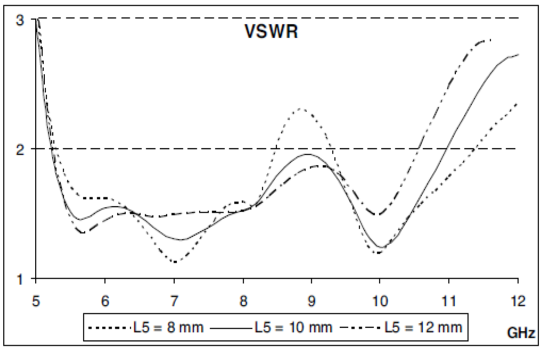


Figure 17: VSWR graph [36]

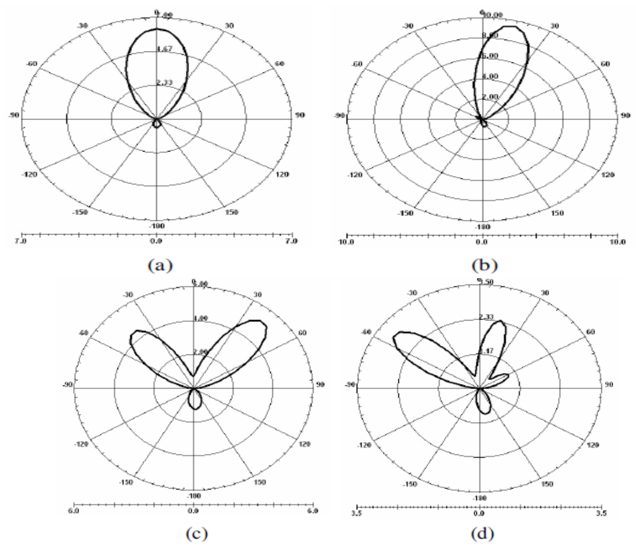


Figure18: Radiation pattern of the antenna at (a) 6 GHz, (b) 8 GHz, (c) 10GHz, (d) 12 GHz [36]

IV. CONCLUSION

This paper presented different techniques for designing UWB microstrip antenna employing different feeding techniques and compact structures in order to improve antenna characteristics for the specified bandwidth. Different antennas that have been discussed show the return loss that is less than –10 dB and VSWR<2. Feeding mechanisms are different for different antennas that affect the results too. The feeding technique should be chosen according to the results required. Comparison of different feeding techniques has been tabulated as follows.

Table IV: Comparison of different feeding techniques

Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture coupled Feed	Proximity coupled Feed
Spurious feed radiation	More	More	Less	Minimum
Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth (achieved with impedance matching)	2-5%	2-5%	2-5%	13%

For the short-range high data rate low power communication systems such as laptops and personal digital assistants UWB antenna research is of common interest. Future developments of UWB antennas are expected to have challenge on the modeling, simulation and design, which have a complicated nature due to the wide bandwidth and highly frequency dependent parameters.

REFERENCES

[1] Yang, L. & Giannakis, G. B. (2004). Ultra-wideband communications: an idea whose time has come. IEEE Signal Processing Magazine, Vol. 21, No. 6, (November 2004), pp. 26-54, ISSN 1053-5888.

[2] First Report and Order (FCC 02-48). Action by the Commission February 14, 2002. New Public Safety Applications and Broadband internet access among uses envisioned by FCC authorization of Ultra-Wideband Technology

[3] Ammann F. R. (2001). The Pentagonal Planar Monopole for Digital Mobile Terminals; Bandwidth Considerations and Modelling, Proceedings of 11th International Conference on Antennas and Propagation, pp. 82-85, ISBN: 0-85296-733-0, Manchester, UK, 17-20 April 2001, Institution of Electrical Engineers, London

[4] Eng Gee Lim, Zhao Wang, Chi-Un Lei, Yuanzhe Wang, K.L. Man "Ultra Wideband Antennas – Past and Present" IAENG International Journal of Computer Science, 37:3, IJCS_37_3_12

[5] L.T. Chang and W.D. Burnside, "An ultrawide-bandwidth tapered resistive TEM horn antenna", IEEE Transactions on Antennas and Propagation, vol.48, 2000, pp.1848–1857.

[6]R.T. Lee and G.S. Smith, "On the characteristic impedance of the TEM horn antenna", IEEE Transactions on Antennas and Propagation, vol.52, 2004, pp.315–318.

[7] M.J. Ammann, "Improved pattern stability for monopole antennas with ultrawideband impedance characteristics", Proceedings of the IEEE Antennas and Propagation Society International Symposium, vol.1, Jun 2003, pp. 818–821.

[8] Z.N. Chen, M.Y.W. Chia, and M.J. Ammann, "Optimization and comparison of broadband monopoles", IEE Proceedings – Microwaves, Antennas and Propagation, vol.150, 2003, pp.429-435.

[9] Z.N. Chen, "A new bi-arm roll antenna for UWB applications", *IEEE* Transactions on Antennas and Propagation, vol.53, 2005, pp.672– 677.

[10] M.J. Ammann, "Impedance bandwidth of the square planar monopole", Microwave and Optical Technology Letters, vol.24, 2000, pp.185–187.

[11] M.J. Ammann and Z.N. Chen, "An asymmetrical feed arrangement for improved impedance bandwidth of planar monopole antennas", Microwave and Optical Technology Letters, vol.40, 2004, pp.156– 158.

[12] K.G. Thomas, N. Lenin, and R. Sivaramakrishnan, "Ultrawideband planar disc monopole", IEEE Transactions on Antennas and Propagation, vol.54, 2006, pp.1339–1341.

[13] S. Su, K. Wong, and C. Tang, "Ultra-wideband square planar antenna for IEEE 802.16a operating in the 2–11GHz band", Microwave and Optical Technology Letters, vol.42, 2004, pp.463–466.

[14] X.H. Wu and Z.N. Chen, "Comparison of planar dipoles in UWB applications", IEEE Transactions on Antennas and Propagation, vol.53, 2005, pp.1973–1983.

[15] M.J. Ammann and Z.N. Chen, “A wideband shorted planar monopole with bevel”, IEEE Transactions on Antennas and Propagation, vol.51, 2003, pp.901–903.
[16] N.P. Agrawall, G. Kumar, and K.P. Ray, “Wide-band planar monopole antenna”, IEEE Transactions on Antennas and Propagation, vol.46, 1998, pp.294–295.
[17] C.Y. Huang and W.C. Hsia, “Planar elliptical antenna for ultrawideband communications”, Electronics Letters, vol.41, 2005, pp.296–297.
[18] P.V. Anob, K.P. Ray, and G. Kumar, “Wideband orthogonal square monopole antennas with semi-circular base”, Proceedings of the IEEE Antennas and Propagation Society International Symposium, vol. 3, July 2001, pp.294– 297.
[19] H.S. Choi, J.K. Park, S.K. Kim, and J.Y. Park, “A new ultrawideband antenna for UWB applications”, Microwave and Optical Technology Letters, vol.40, 2004, pp.399–401.
[20] S.Y. Suh, W.L. Stutzman, and W.A. Davis, “A new ultrawideband printed monopole antenna: the planar inverted cone antenna (PICA)”, IEEE Transactions on Antennas and Propagation, vol.52, 2004, pp.1361–1364.
[21] Z.N. Chen, M.J. Ammann, M.Y.W. Chia, and T.S.P. See, “Circular annular planar monopoles with EM coupling”, IEE Proceedings –Microwaves, Antennas and Propagation, vol.150, 2003, pp.269–273.
[22] D. Valderas, J. Meléndez, and I. Sancho, “Some design criteria for UWB planar monopole antennas: Application to a slotted rectangular monopole”, Microwave and Optical Technology Letters, vol.46, 2005, pp.6–11.
[23] J.Clerk, J.Liang, C.C.Chiau, X.Chen and C.G.Parini, “Study of printed circular disc monopole antenna for UWB systems,” IEEE Transaction on Antennas and Propagation, vol.53, November 2005, pp.3500-3504
[24] J.Jung, W.Choi, J.Choi, “A small wideband microstrip-fed monopole antenna”, IEEE Microwave and Wireless Component Letters. vol.15, Oct 2005, pp.703-705.
[25] K.Chung, H. Park, and J.Choi, “Wideband Microstrip-fed monopole antenna with a narrow slit”, IEEE Microwave and Optical Technology Letters, vol.47, 2005, pp.400-402.
[26] J.N.Lee, J.H.Yoo, J.H.Kim, J.K.Park, J.S.Kim, “A Novel UWB antenna Using PI-Shaped Matching Stub for UWB Applications”, IEEE International Conference on Ultral-wideband (ICUWB2008), vol.1, 2008, pp.109-112.
[27] Z.N.Chen, T.S.P.See, X.Qing, “Small printed ultrawideband antenna with reduced ground plane effect”, IEEE Transactions on Antennas and Propagation, vol.53, Feb 2007, pp.383-388.
[28] Seok H. Choi, Jong K. Park, et al, “A new ultra-wideband antenna for UWB applications”, Microwave and Optical Technology Letters, vol. 40, Mar 2004.
[29] Bahadir S. Yildirim, Bedri A. Cetiner, et al, “Integrated Bluetooth and UWB Antenna”, IEEE antennas and wireless propagation letters, vol. 8, 2009.
[30] Garg, R., P. Bhartia, I. Bahl, and A. Ittipiboon, Microstrip Antenna Design Handbook, Artech House, Norwood, MA, 2001.
[31] K-S. Lim, M. Nagalingam, andC.-P . Tan “Design And Construction Of Microstrip UWB Antenna With Time Domain Analysis” Progress In Electromagnetics Research M, Vol. 3, 153–164, 2008

[32] Lee Chia Ping1, Chandan Kumar Chakrabarty2 & Rozanah Amir Khan3 Design of Ultra Wideband Slotted Microstrip Patch Antenna Proceedings of the 2009 IEEE 9th Malaysia International Conference on Communications 15 -17 December 2009 Kuala Lumpur Malaysia
[33] Reza Zaker, Changiz Ghobadi, and Javad Nourinia “Novel Modified UWB Planar Monopole Antenna With Variable Frequency Band-Notch Function”IEEE antennas and wireless propagation letters, vol . 7, 2008
[34] Sang-Hyuk Wi, Yong-Shik Lee, and Jong-Gwan Yook “Wideband Microstrip Patch Antenna With U-Shaped Parasitic Elements” IEEE transactions on antennas and propagations, vol. 55, April 2007
[35] Qi Wu, Ronghong Jin, and Junping Geng “A Single-Layer Ultrawideband Microstrip Antenna” IEEE transactions on antennas and propagations, vol. 58, no. 1, January 2010
[36] N. Ghassemi J. Rashed-Mohassel M. H. Neshati”Slotted coupled microstrip antenna for ultra wide band applications in C& X bands**”** Progress In Electromagnetics Research M, Vol. 3, 15–25, 2008

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