Compact Planar Antennas for various wireless applications

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Abstract – This paper provides brief introduction to circularly polarized, reconfigurable and UWB antennas. The various antenna designs discussed are having very compact size and provides different aspects of designing a miniaturized antenna. Further, the bandwidth enhancement requirement for these antennas have been also discussed. The applications of these antennas can be found in mobile communication, microwave imaging and ground penetrating RADAR etc. Moreover, the types of these antennas have been presented and their difference in design strategy is also mentioned.

1. Introduction

Traditional microstrip antennas generally have a radiating patch printed on a ground substrate, and have the striking features of low profile, conformability, light weight, and easy fabrication. Though, microstrip antennas essentially have a narrow bandwidth, and bandwidth enhancement is generally required for real-world applications [1]. Furthermore, applications in contemporary mobile communication systems typically want reduced antenna size so as to encounter the shrinking requirements of mobile units. Thus, size contraction and bandwidth enhancement are striking main design attentions for real-world applications of these antennas. Therefore, studies to attain compacted and wideband operations of microstrip antennas have significantly improved [2-3]. Much substantial development in the design of compact microstrip antennas with wideband, and circularly polarized operations have been described over the past several years [1-5]. Additionally, various microstrip antenna designs with reconfigurable capability are available in the open literature [10-17]. This paper classifies and presents few designs techniques for compact microstrip planar antennas.

2. Wideband circularly polarized planar antenna

Circularly polarized antenna lessens the effect of multipath reflections for the mobility of both the receiver and the transmitter. Circularly polarized radiation field achieved with the combination of both radiation fields of microstrip patch and slots [6-7]. The orientation of the slots can be dynamically changed and polarization state can be switched from RHCP to LHCP.
In general, wireless communication if the gain of the antenna is increased then its consequences the decrease of errors, decreases the battery consumption, increases the bit error rate and also increases the coverage. One of the foremost issues in improving this gain is matching the polarization of the receiving and transmitting antenna [6]. For the polarization matching, both receiver and transmitter should have same axial ratio. Circularly polarized antennas might be matched in an extensive range of alignments since the transmitted waves oscillate in a circle which is perpendicular to the propagation direction. For circular polarization microstrip antenna is t frequently used antenna. Microstrip antennas do not generate circular polarization on their own [7]. Circular polarization is achieved in microstrip antenna by either feeding the antenna by twin feed identical in magnitude but having phase shift of 90° by adding a perturbation section to a basic solitary fed microstrip antenna [8].

2.1 Design of circularly polarized antenna

Geometrical plan of the proposed antenna has appeared in Fig.1. For antenna, FR4 with a stature of 1.6 mm and relative permittivity of 4.4 is utilized as a substrate. On the upper surface of FR4, a 50 Ω microstrip feedline having a width of 3 mm is printed and on the base of the FR4, there is ground plane comprising a vast rectangular opening. At that point, a rectangular stub is annoyed from the right edge of the ground plane toward its center. To conquer the coupling between ground plane and feedline, a hole is made over the feedline in the ground plane. The general size of the proposed antenna is 25×25 mm^2. The microstrip feedline is set in the right edge of the antenna underneath the annoyed stub to acknowledge wide band circularly energized activity.

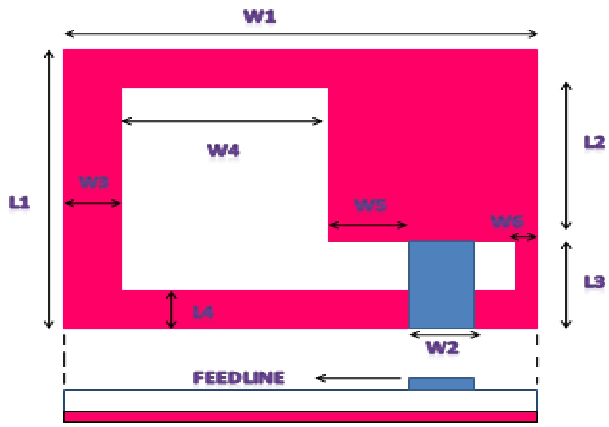
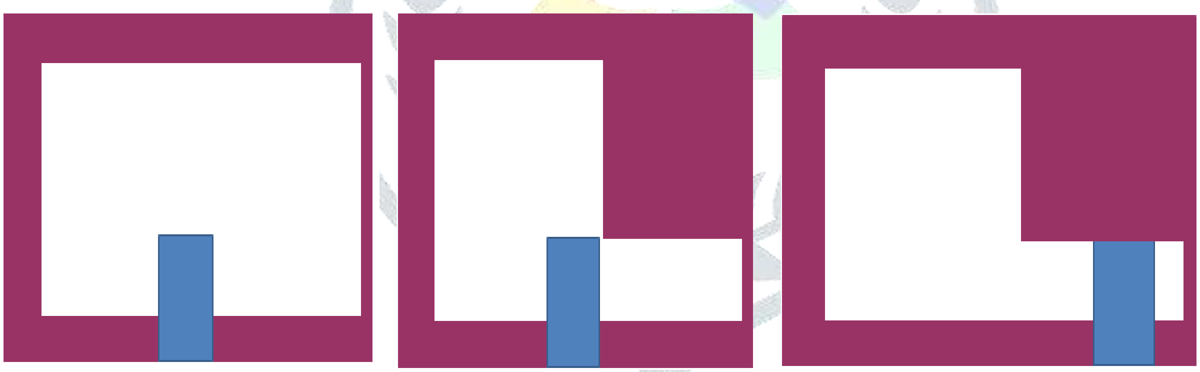


Fig.1 Design of circularly polarized antenna

Upgrade of the antenna configuration appears in Fig. 2 which clarifies the wide data transfer capacity and CP attributes of the proposed design. Three different antennas have been talked about here. Antenna 1 is a basic structure with an opening in the ground plane and microstrip feedline is given in the middle. In Antenna 2, a level stub is bothered toward the center of ground plane. In last Antenna 3 feedline is moved towards right edge from the middle as described in Fig. 2.



(a) (b) (c)

Fig. 2. Enhancement of proposed antenna (a) Antenna 1 (b) Antenna 2 (c) Antenna 3

3. Planar Reconfigurable antenna

With the headway in the rise of the wireless communication over the last years, there lies the need of miniaturization in antenna's size, multiband and low cost. So as to meet all these requirements, Fractal antenna design is preferred. Along with these advantages, realization of the fractal antenna can be enhanced with the concept of reconfiguration. Parameters of antenna like frequency, radiation pattern, polarization are reconfigured so as to meet the requirement [8-11]. The reconfigurable antennas are considered due to of its cost effectiveness and effortless fabrication and are very propitious in next centuries of wireless communication system. The exceptional features are its reconfigurable capability, low cost, alteration in size that has given reconfigurable antennas the superiority to be used in wireless communication systems. Reconfigurable antennas mend their characteristics in terms of performance by correctly modifying the current flow on an antenna by the use of movable parts mechanically, attenuators, diodes, switches, active materials etc. A reconfigurable antenna can take the form of an array or a single antenna [8]. A reconfigurable antenna commonly inserts a null in pattern of antenna and change the operating frequency from 2.0 to 2.40 GHz and too has the potential of transforming from left hand circularly polarized to right hand circularly polarized, so as to attain multiple goals by renewal of two or more elements [9]. Frequency reconfigurability is commonly designed for the sake of operating at six different frequency bands that range from 2 GHz to 5 GHz having its radiation pattern bidirectional. Switches like PIN diodes or varactor diodes are chiefly used to obtain reconfigurability [10]. Though the decrease in the electrical size of antenna that makes a single wideband antenna unrealizable due to limitations on the bandwidth. However, separate as well as different antennas for different operating frequency are not practicable, but single frequency reconfigurable antenna can obtain this. By this way it came into reality and is ideal for satisfying requirements of multiband antenna. Lately reconfigurable antennas have aggregated a heavily amount of interest in research for applications like Cognitive radio, radar system, cellular radio system, satellite communication system [11]. It has also been supporting a huge number of standards such as Wi-Fi, WiMAX, LTE, etc. The layout of reconfigurable antennas is shown in Fig.3

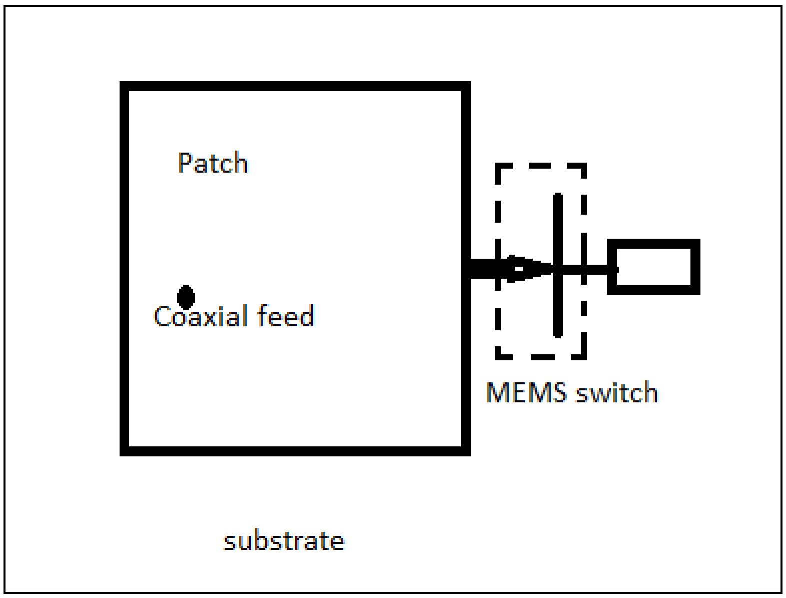


Fig.3 A layout of Reconfigurable Antenna

3.1 Planar reconfigurable Antenna Types

Primarily three basic types of reconfigurable Antenna are there: Frequency, Polarization and Pattern and the have been discussed below:

3.1.1 Frequency Reconfigurable Antenna

These antennas are capable of reconfiguring the operational frequencies with roughly the fixed radiation patterns. This sort of antenna is applicatory for frequency agile or multi-frequency systems [12]. Whenever rectangular patch antenna is loaded on the non-radiating edges will permit it to operate at different frequencies whenever the intensity of loaded slots is altered as shown in Fig.4.Therefore, Reconfigurable patch antenna is also used for multiband applications [13]. Nearly 6 to 8 switches have been installed in the slot. The distance among all the slits is ‘d’. By regulating the switches in various configurations; antenna is reconfigured and regulates its operational frequencies from 0.6 GHz to 1.2 GHz.

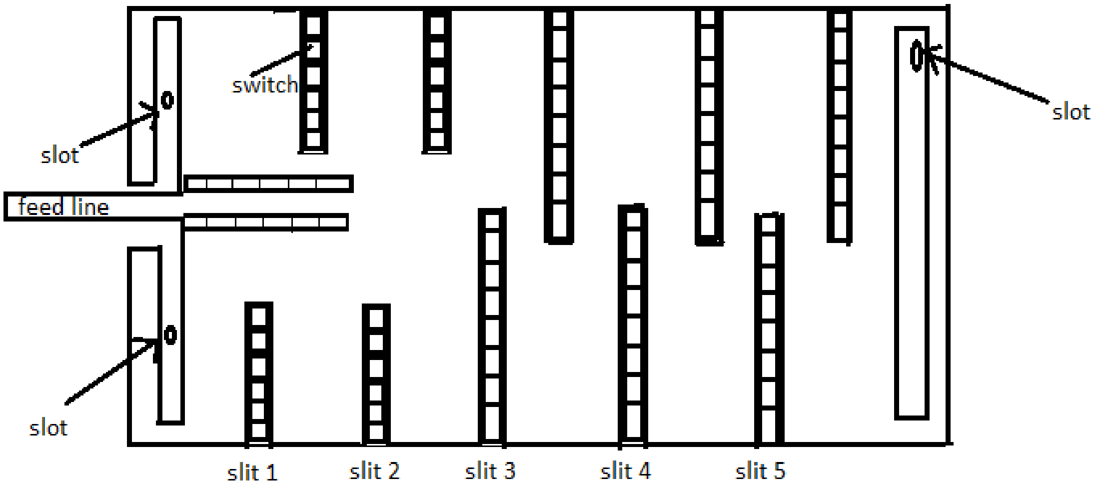


Fig. 4 Frequency Reconfigurable Antenna

3.1.2 Pattern Reconfigurable Antenna

This type of antennas provides the copious radiation patterns at the same operational frequency.

They have the tendency to modify the characteristics of radiation pattern like polarization, antenna gain, etc. by altering its physical configurations. These antennas also have the tendency to avoid noise from the outdoor environment, enhance the security, and also save energy by regulating the signals to the dedicated users [14]. In pattern reconfigurable antenna, polarization changes along with the radiation pattern. They emend the performance of the system by using the numerous paths like switched combining, loop slots as shown in Fig.5. A reconfigurable antenna with loop slots has the tendency to shift the radiation pattern while maintaining its operational frequency. 12 switches are positioned on right side besides on the loops left side [15]. They operate in two states where in State 1, all the switches that are on the left side will be switched off and right side is switched on. Likewise, in State 2, all the switches that are positioned on the left side are turned on and on the right side are turned off. By the use of these states different radiation pattern can be obtained thereby providing the pattern reconfigurable antenna [16].

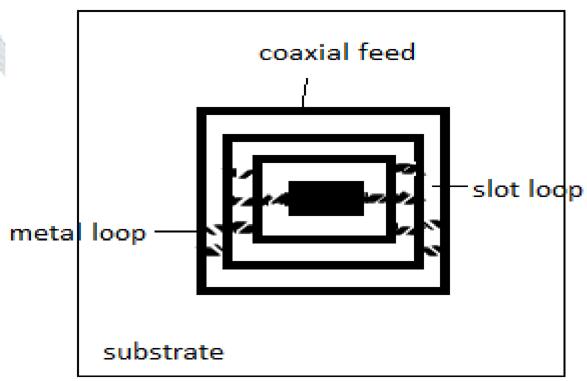


Fig.5 Pattern Reconfigurable Antenna having slots

3.1.3 Polarization Reconfigurable Antenna

Polarization can be varied electronically in this type of antenna. Basically, there are three different ways by which it can be achieved: by emending the current distribution of an antenna, by altering the path of the current of the antenna, by using the reconfigurable phase shifter in order to control the phase [17-19]. This antenna is very much proficient of switching into different modes of polarization like as Linear Polarization (LP), Left hand (LH), Right Hand (RH), and Circular Polarization (CP). They have tendency of lending polarization diversity. Whenever these antennas are having polarization diversity, they can very well use the theory of frequency reuse in order to increase the response of communication systems, and is serviceable only when the frequency band is limited [18]. Polarization reconfigurable antenna with loop slot is shown in Fig. 6 which is adequate enough to switch to different modes of polarization [19]. In this Fig, there are two pin diodes namely P1, P2 that has been loaded on the loop slot. LHCP will result when diode P1 is turned off and P2 is turned on and likewise RHCP will result when P1 is turned on and P2 is turned off. Similarly, Linear Polarization will result when both the diodes are either on or off [20].

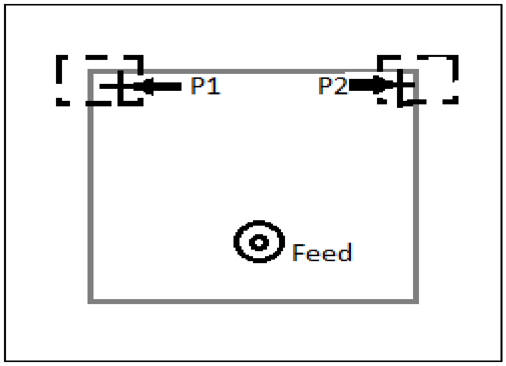


Fig. 6 Polarization reconfigurable Antenna

4. Planar UWB antennas

Ultra-wideband technique is gaining prominence in the recent years because of the wide band it provides as well as high data rates for short range communication [21-23]. Federal Communication Commission has regulated frequency spectrum ranging from 3.1 GHz to 10.6 GHz as an unlicensed range for UWB applications. Mainly it was intended for use in military and RADAR applications. But with increasing demand for higher data rates by the users, ultra-wideband had gained great importance in the present era. First ultra-wideband antenna was presented by Oliver Lodge in the year 1898 in the numerous forms of dipole like rectangular dipoles, spherical dipoles, bow-tie and biconical dipoles. But after that, there was tremendous increase in design of ultra-wideband antennas in the recent years [22]. The major prerequisite for design of ultra-wideband antenna is to have an omnidirectional pattern because of of movement of user in addition to to deliver liberty for setting up of receiver and transmitter at any position [23-24]. Fig.7 is used to present a top view of planar UWB antenna.

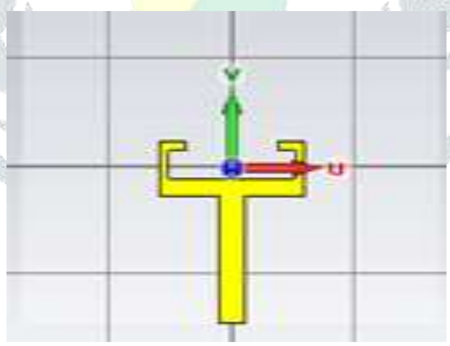


Fig 7. C-stub ultra-wideband antenna

4.1 Characteristics of UWB Systems

The two major reasons for the use of ultra-wideband reasons is the people's increasing demand for higher data rates in the recent years as well as low power transmission required for ultra-wideband. For these systems, UWB antennas are required [21-24]. The following are the major characteristics of ultra- wideband antenna:

- **Large bandwidth**: Since Federal Communication Commission has provided frequency spectrum ranging from 3.1 to 10.6 GHz, so a wider bandwidth is available for use. It exceeds 500 MHz or has minimum 20% of the central frequency.

- **High data rates**: Ultra-wideband technology results in higher data rates for short range communication which is 150 Mbps for 30 feet (10 m). This property can be explained via the Shannon capacity theorem which is given as:

$$C = B\ log2(1 + SNR)$$

Here C=capacity
B=Bandwidth
SNR= Signal to Noise ratio

Now in the above equation capacity is in direct relationship with bandwidth. So, with the increase in bandwidth, capacity increases which result in an increase in data rate. Since ultra-wideband provides wider bandwidth, thereby it provides high capacity in accordance with above equation.

- **Short pulse transmission**: In comparison with the conventional narrowband systems like 802.11a, Bluetooth where information was transmitted in the form of sinusoidal waves, here in case of ultra-wideband technology, information is transmitted over a channel in the form of pulses of very short duration. This makes them suitable for providing very fine time resolution.
- **Low power transmission**: Power is a major constraint while the design of any system for the wireless application. But ultra-wideband requires power for transmission of data less than 1mW. This causes the battery life to last longer. As a result of this, UWB technology can be used for wireless applications where replacement of the battery is not possible and this technology can operate for a longer duration due to low power consumption.
- **Immunity for multipath effects**: Ultra-wideband involves the transmission of pulses which are of very short duration. So, this reduces the probability of overlapping of the original or incident signal with the reflected signal. So, the effect of multiple signal superpositions at the receiver end is minimized.
- **Voltage Standing Wave Ratio:** Standing waves are produced as a result of the incident wave with the reflected wave. These reflected waves are generated due to the losses present in the transmission line or the improper termination of the line. These standing waves account for the inefficiency in the antenna. UWB provides VSWR<2.

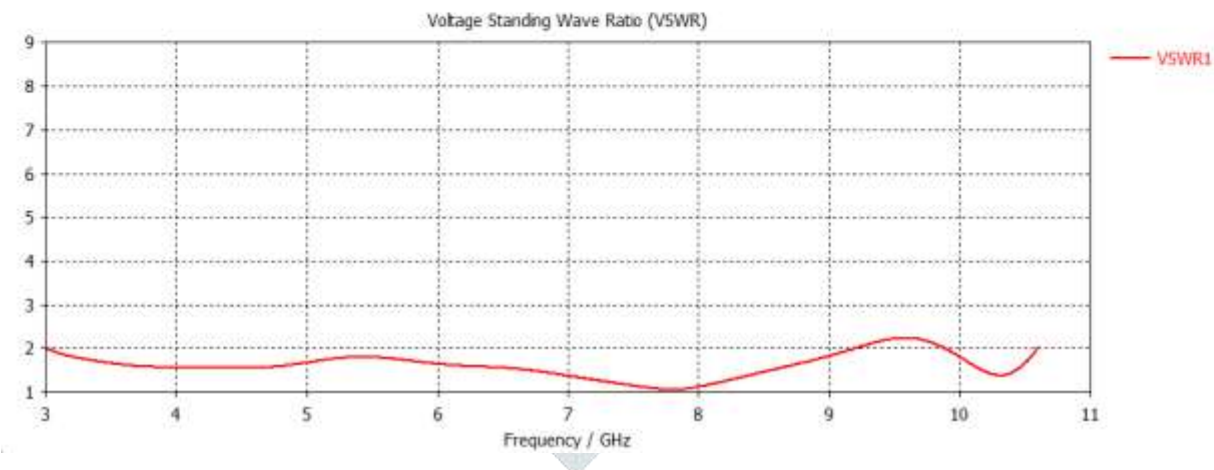


Fig 1.2: VSWR plot in Ultra-wideband antenna

4.2 Band notching in UWB antenna

Federal Communication Commission has allocated diversified range for UWB applications. So there exist certain bands like WLAN, WiMAX, C and X band which have the operating frequency which lies in the same band of UWB antenna, thereby resulting in overlap of these frequencies [23-24]. Some of the frequency bands overlapping with ultra-wideband are listed in Table 1.

Table 1 Comparison of different bands

Bands for unlicensed use	Operating frequency (GHz)
Ultra-wideband	3.1-10.6
WiMAX	3.43-3.7
WLAN	5

Due to the overlapping of these bands, there exists interference which disrupts the normal working of these specified bands. So, it is necessary to avoid these interferences which are known as band notching. In the older days, the very first method to avoid this interference is to utilize filters to prevent overlapping. But the use of the filters in the design leads to increase in the complexity of the design and thereby increasing the cost. The length of slot is given as

$$L = \frac{c}{2fb\sqrt{\varepsilon e}}$$

Next step to avoid the interference was the embedding of slots either in the radiating patch or the ground plane. This serves the purpose of two things. Firstly, it leads to avoidance of interference of band within same frequency spectrum as that of Ultra-wideband. Secondly, insertion of slots leads to improvement in the antenna characteristics like Bandwidth, gain, return loss, VSWR etc.

The slot can be of any shape like U-shaped slot, L-shaped, pie shaped, E shaped etc. But there is one major disadvantage in the use of slots[23-26]. These slots tend to leakage of the electromagnetic wave, thereby producing an interference with the devices connected adjacent to the antenna or other electronic components present in the equipment. Apart from this, the leakage due to the introduction of slots affects the radiation pattern of ultra-wideband antenna.

Various shapes of stubs were incubated in the design pattern of ultra-wideband antenna. These act as resonant filters. But it is not an easy job to insert a stub of any particular shape like C in the patch of the antenna[25-26]. Apart from these methodologies, parasitic elements can be used.

4.3 Use of the UWB antenna in wireless systems

Ultra-wideband antenna, also known as a ultra-band antenna, operates on a wide bandwidth ranging from 3.1 to 10.6 GHz. The major use of Ultra-wideband system is in wireless communication as it provides no line of sight communication, i.e., it can penetrate through doors and walls. It is a major advantage for its use as wireless communication systems are preferred if they provide the same range in the room of its location as well as the next room instead of a system which requires the installation of a transmitter in each room [22].

Another reason for use of UWB systems is its short-range communication as it is capable of transmitting a large amount of information across a wider range of frequency. Moreover, power in the order of -41.3 dBm/MHz is required as the signal is sent in the form of short pulses thereby reducing the effects of interference [24]. In other words, the amount of energy required for transmission is less for providing internet access, video telephony, and digital voice services.

Rather than this, there is very less probability of eavesdropping and jamming of the signal. This is due to two reasons. The first reason being the short range of about 30 feet is provided by UWB. This makes it difficult to jam the signal as the jammer needs to be in the very close vicinity of the antenna. Secondly, short pulses are transmitted and the data rate is very high which makes it difficult to be accessed by a hacker [25]. The benefits of UWB antenna is specified in Table 2.

Table 2 Merits and benefits of UWB systems

S.No	Merits	Benefits
1	Reduced multipath issues	High-performance capability in adverse conditions
2	Less power requirement	Highly secure with very less probability of detection
3	Works with even low signal to noise ratio	Makes it useful for noisy environment
4	Capacity of channel is high	Provision of high data rates by UWB makes it useful in wireless personal area networks
5	Resistance to jamming	Highly reliable
6	Simple design	Facilitates low power
7	Coexistence with current narrow and wide band systems	No requirement of license

4.4 Applications of UWB antennas

Due to changing the environment of wireless communication, UWB antenna has been considered as the most promising technology with a wide range of applications which include:

- **Radar Imaging**: UWB is used in radar imaging due to various reasons. First of all, it transmits very short pulses which help in providing a very fine time resolution. This can help in detection of any location precisely. Moreover, the probability of intercept signals is very less and there is detectable material penetration which makes it useful for ground penetrating radar and wall radar.
- **Impulse based Technology**: These antennas can be used in locating systems and positioning applications like precision altimetry. These can be used in Radio Frequency Identification (RFID) for tracking and identify the tags attached to the objects. This can be used for personal localization. Higher security is provided by this as acceptation of login credentials takes place when badge of person is next to the computer.
- **Military use:** The transmission of narrow pulses is modulated in time and encoded using certain algorithms making them reluctant to security attacks. These picoseconds pulses are transmitted at very less power thereby snoopers need to be in close vicinity of the antenna. Due to these reasons, it is used for tactical handheld and Low Probability of Interception and Detection (LPID) radios which are desirable for governmental and military use.

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