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Ultra-Wideband Antenna

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1. Introduction

In 2002, the Federal Communications Commission (FCC) of the United State officially released the regulation for Ultra-wideband (UWB) technology. In this regulation, the spectrum from 3.1 GHz to 10.6 GHz (a fractional bandwidth of 110%) is allocated and the Equivalent Isotropically Radiated Power (EIRP) is less than -41.3 dBm/MHz for the unlicensed indoor UWB wireless communication system. According to the released regulation, UWB technology which is based on transmitting ultra short pulses with duration of only a few nanoseconds or less has recently received great attention in various fields for the short-distance (< 10m) wireless communications. Because of the ultra-wideband property, UWB technology has many benefits, which are high data rate (> 100 Mb/s), low power consumption, compact, low cost, excellent immunity to multipath interference and reduced hardware complexity. Due to these advantages, we need to understand the principle of the UWB systems and then we should research and develop the UWB systems in context of coding, modulation, signal processing architecture and UWB antenna. This chapter is timely in reporting the aspects of the conventional and state-of-the-art antenna design in the UWB system.

This chapter consists of four sections. First, UWB technology is briefly introduced in its advantages, regulation and applications. Second, the UWB antenna plays a crucial role in UWB communication system as well as context of coding and signal processing. Design methods of the conventional UWB antennas such as log-periodic dipole array (LPDA) are overviewed and the UWB antennas which are recently researched are introduced. Third, as UWB frequency range includes existing some narrow frequency bands such as IEEE 802.11a wireless local area networks (WLANs) using the frequency band from 5.15 GHz to 5.825 GHz and new telecommunication technology based on the IEEE 802. 16, Worldwide Inter-operation for Microwave Access (WiMAX) operating on 3.3-3.6 GHz, the coexistence of UWB with other systems has been an important issue. Thus, the UWB antenna should be designed with a notch in the WLAN and WiMAX frequency band because UWB transmitters should not cause any electromagnetic interference to nearby communication systems. Therefore, the principle and design methods to notch the particular frequency band in UWB antenna are summarized and introduced in this part. Finally, we will simply forecast the development and application of the UWB communications in the future.

1.1 Advantages of UWB

UWB communication having ultra-wideband characteristic has many advantages for the short-distance wireless communication as follows:

- ✓ High data rates and large channel capacity
- ✓ Excellent immunity to multipath interference
- ✓ Low complexity and cost
- ✓ Low power consumption
- ✓ Coexistence with other wireless communication

There are three reasons causing the high data rates, which are the ultra-wideband characteristic, high signal power and low noise power. It is evident from Hartley-Shannon's capacity formula:

$$C = B \log_2 \left(1 + \frac{S}{N} \right) \quad (1)$$

where C is the maximum channel capacity, B the signal bandwidth, S the signal power, and N the noise power. Consequentially, the highest channel capacity can be obtained by increasing the signal bandwidth and low signal to noise power. The major advantage of the UWB communication is to use the large bandwidth (large B). And UWB communication is capable of working in harsh communication channels with low SNRs. Thus, these conditions offer a large channel capacity which causes high data rates according to equation (1).

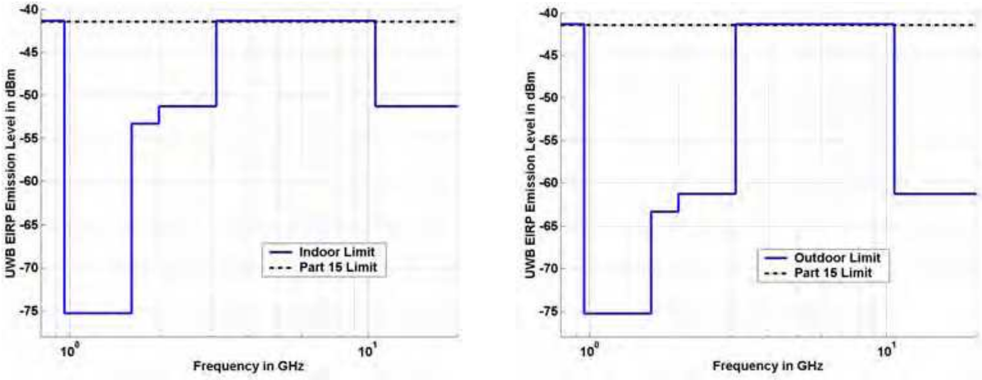
Next, UWB communication has excellent immunity to multipath interference. In the narrow band communication, the fading which is caused by reflected signal from various things is the unavoidable phenomenon and it can make the received signal weak up to -40 dB. On the other hand, impulse signals have low susceptibility to multipath interference in transmitting information in UWB communication system because the transmission duration of a UWB pulse is shorter than a nanosecond in most cases. Even it gives rise to a fine resolution of reflected pulses at the receiver. Therefore, UWB communication system can resolve the fading problem and it is good in multipath diversity like MIMO system.

Furthermore, UWB system is quite simple and low cost due to the carrier-free nature of the signal transmission. In convectional communication system, a carrier frequency is necessary to send the baseband signal at the desired frequency band. It requires an additional radio-frequency (RF) mixing stage in up/down-conversion processes. However, the very wideband nature of the UWB signal means it spans frequencies commonly used as carrier frequency. Thus, the UWB signal will propagate well in the transmitters and will be received well in the receivers without RF mixing stage for the up/down-conversion. It makes the UWB system allow the whole UWB system to be integrated with single-chip CMOS implementation. It contributes to the low complexity and low cost characteristic.

Finally, very low power density (like noise level) obtained through the FCC's radio regulation emission mask of -41.3 dBm/MHz (equal to 75 nanowatts/MHz) for UWB system is the other advantage. It causes the UWB system to enable the signal to consume the low power and to coexist with already deployed narrow-band systems with minimal or no interference. Consequently, UWB communication system is a good candidate for the short-distance wireless communication due to the above-mentioned advantages.

1.2 Regulation

In USA, the FCC approved a UWB spectral mask specified 7.5 GHz of usable spectrum bandwidth between 3.1 GHz and 10.6 GHz for communication devices and protected existing users operating within this spectrum by limiting the UWB signal's EIRP level of -41.3 dBm/MHz (known as Part 15 Limit). In this restriction, the limitation of the power spectral density (PSD) measured in a 1 MHz bandwidth at the output of an isotropic transmit antenna to a spectrum mask is shown in Figure 1 for indoor and outdoor environments, respectively.



(a) (b)

Fig. 1. Spectrum mask of UWB for (a) indoor environments and (b) outdoor environment

Although UWB currently is legal only in the United States, international regulatory bodies are considering possible rules and emission limits that would help it enable worldwide operation of UWB devices. Figure 2 shows the graph of the worldwide spectrum mask that is defined now for UWB communication devices. There is difference in EIRP levels among USA, Europe, Japan and Singapore. In some countries, there is an exclusive obligation to protect the existing communication systems. Countries that have a sole obligation to protect existing users tend to be much more conservative in international fora that are designed to achieve spectrum harmonization, such as the international Telecommunication Union (ITU). Therefore, it is extremely necessary to gain compromises and agreement among all of them for making the international UWB policy because UWB is not only a new technology but also a new regulatory paradigm. In the processes of the compromise for UWB policy, there are two useful technologies to prevent the interference with other signal. One is Detect and Avoid (DAA) and the other is Low Duty Cycle (LDC). The former is a technology to mitigate interference potential by searching for broadband wireless signals and then automatically switching the UWB devices to another frequency to prevent any conflict. The latter reduces interference with other signal by using the UWB signal with very low duty cycle.

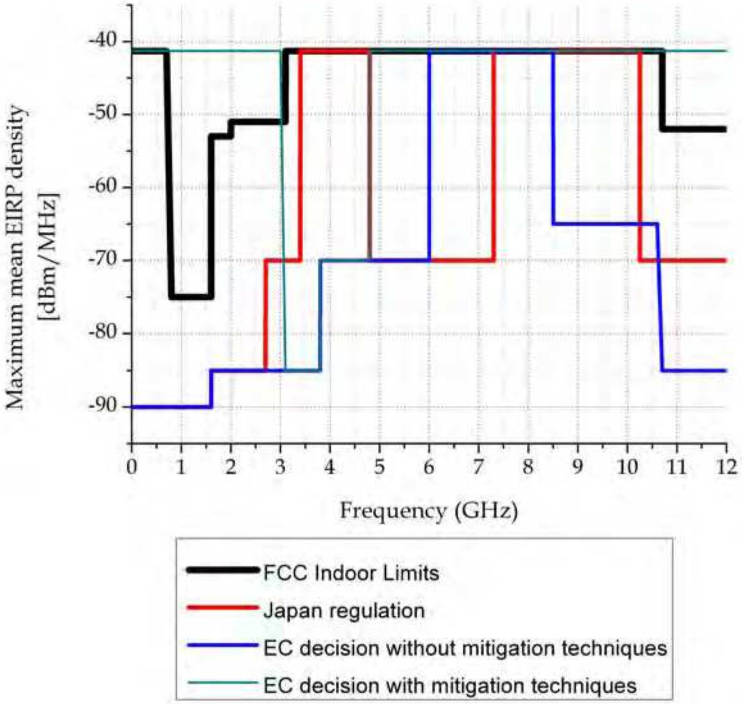


Fig. 2. The worldwide spectrum masks for UWB communication devices

1.3 Applications

UWB technology can be applied in a wide variety of applications. Based on the FCC guidelines, UWB technology is deployed in two basic communication systems.

- ✓ High data rate (IEEE 802.15.3a)
- ✓ Low data rate (IEEE 802.15.4a)

The high data rate WPANs can be defined as wireless data connectivity between the hosts (PC, high quality real time video player and so on) and the associated peripherals (keyboard, mouse, speaker, VCRs and so on). It will remove the wires and cables with high transfer data rate and rapid file sharing or download of images/graphic files. In other hand, the low data rate wireless communications will be primary focused on position location applications because of UWB’s centimetre accuracy in rages of 100m.
In the other aspect, UWB applications are classified three major categories.

- ✓ Communications and sensors
- ✓ Position location and tracking
- ✓ Radar

Applications for wireless communications and sensors are the most attractive one due to the high speed data transmission and low power consumption. UWB will be applied to the movable wireless devices such as keyboard, mouse, printer, monitor, audio speaker, mobile phone and digital camera. It will give us convenient and enrich daily life because the wires will disappear. And sensors which will be used to secure home, automobiles and other property also make our life more comfortable. Specially, it will contribute to patients in the hospital by using the monitoring of their respiration, heart beat and other medical images with wireless devices.
Position location and tracking also have a potential in UWB applications. Due to the centimetre accuracy, UWB can be used to find a lost something or people in a various situations including fire fighters in a burning building, police officers in distress, and injured skiers or climbers and children lost in the mall or amusement park. And with UWB tracking mechanisms, we can not only know item locations and their movement but also secure the high value assets.
UWB signals enable inexpensive high definition radar. This property could be applied to many applications such as automotive sensors, collision avoidance sensor in the vehicular, intelligent highway initiatives, smart airbag and through-the-wall public safety applications. These applications will prevent the accidents and damages from the occurred accidents.

2. UWB Antenna

2.1 Conventional Broadband Antennas

The term "Broadband" has been applied in the past, but has usually described antennas whose radiation and input impedance characteristics were acceptable over a frequency range of 2 or 3:1 before the 1950s. At that time, the bandwidth of the radiation pattern has been the limiting factor since antennas have been developed with an input-impedance that stays relatively constant with a change in frequency. But in the 1950s, a breakthrough in antenna evolution was made which extended the bandwidth to as great as 40:1 or more. The antennas introduced by the breakthrough were referred to as frequency independent, and they had geometries that were specified by angles. These broadband antennas are practically independent of frequency for all frequencies above a certain value as well as impedance. The general formula for their shape is

$$r = e^{a\left(\varphi + \varphi_0\right)} F(\theta) \tag{2}$$

where r, θ, φ are the usual spherical coordinates, a and φ_0 are constants and $F(\theta)$ is any function of θ. Assuming a to be positive, φ ranges from $-\infty$ to ∞ which determines the low frequency limit. For such antennas a change of frequency is equivalent to a rotation of the antenna about θ =0. It appears that the pattern converges to the characteristic pattern as the frequency is raised, if a is not ∞, and that the impedance converges to the characteristic impedance for all ∞ (Rumsey, 1957).
Rumsey's general equation, Equation 2, will be used as the unifying concept to link the major forms of frequency independent antennas. Classical shapes of such antennas include

the equiangular geometries of planar and conical spiral structures and the logarithmically periodic structures.

Fig. 3(a) illustrates a simple example which gives a practical antenna design. Fig. 3(b) also illustrates the case where $F(\theta)$ is periodic in θ with period $2\pi a$. This gives a simple surface like a screw thread which is uniformly expanded in proportion to the distance from the origin: an increase of 2π in φ is equivalent to moving one turn along the screw.

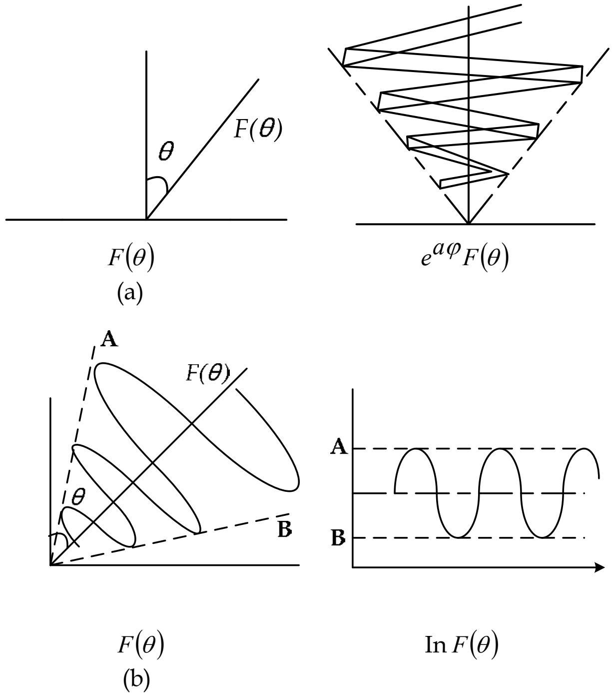


Fig. 3. The surface of the example for a practical antenna design

2.1.1 Equiangular Spiral Antennas

The design of the equiangular spiral antenna is based upon a simple fundamental principle. If all dimensions of a perfectly conducting antenna are charged in linear proportion to a change in wavelength, the performance of the antenna is unchanged except for a change of scale in all measurements of length. Thus, as Rumsey has pointed out, it follows that if the shape of the antenna was such that it could be specified entirely by angles, its performance would be independent of frequency (Balanis, 1997).

Fig. 4 shows the equiangular or logarithmic spiral curve which may be derived by letting the derivative of $F(\theta)$ is

$$\frac{dF}{d\theta} = F'(\theta) = A\delta\left(\frac{\pi}{2} - \theta\right) \tag{3}$$

where A is a constant and δ is the Derac delta function. Using equation (3), equation (2) can be reduced as follows:

$$r_{\theta=\pi/2} = \rho = \begin{cases} Ae^{a\phi} = \rho_0 e^{a(\phi-\phi_0)} & \theta = \pi/2 \\ 0 & elsewhere \end{cases} \tag{4}$$

where

$$A = \rho_0 e^{-a(\phi-\phi_0)} \tag{5}$$

Another form of Equation (4) is

$$\phi = \frac{1}{a}\mathrm{In}\left(\frac{\rho}{A}\right) = \tan\psi \,\mathrm{In}\left(\frac{\rho}{A}\right) = \tan\psi\left(\mathrm{In}\,\rho \text{ - } \mathrm{In}\,A\right) \tag{6}$$

where $1/a$ is the rate of expansion of the spiral and ψ is the angle between the radial distance ρ and the tangent to the spiral, as shown in Figure 4.

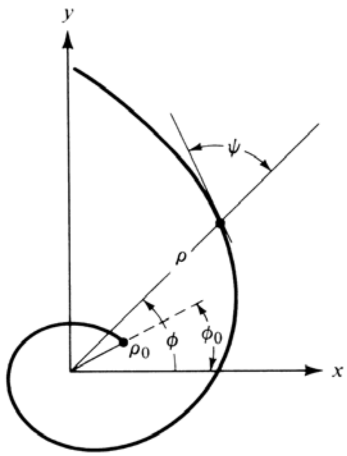


Fig. 4. The equiangular single spiral

If the angle ϕ is increased by one full turn, the radius vector is increased by the factor $e^{2\pi a}$, hence each turn of the spiral is identical with every other turn except for a constant multiplier. Therefore, we can have frequency independent antennas.
At that time, the total length L of the spiral can be calculated by

$$L = \int_{\rho_0}^{\rho_1}\left[\rho^2\left(\frac{d\phi}{d\rho}\right)^2 + 1\right]^{1/2} d\rho = (\rho_1 - \rho_0)\sqrt{1+\frac{1}{a^2}} \tag{7}$$

where ρ_0 and ρ_1 represent the inner and outer radius of the spiral (Dyson, 1959).

2.1.2 Log-Periodic Antennas

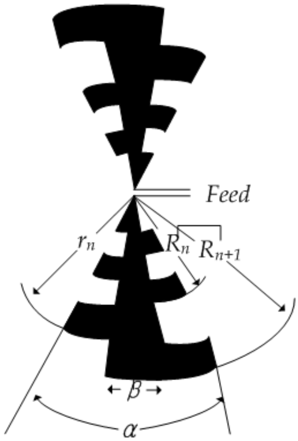


Fig. 5. The logarithmically periodic antenna structure

Next antenna configurations having the frequency independent property are the log-periodic antenna introduced by DuHamel and Isbell (DuHamel & Isbell, 1959; Isbell, 1960). A logarithmically periodic antenna which properties vary periodically with the logarithm of the frequency embody three basic design principles. The first of these is the "angle" concept which is a design approach wherein the geometry of the antenna structure is completely descrived by angles rather than lengths such as an infinite biconical antenna. The second principle makes use of the fact that the input impedance of an antenna identical to its complement is independent of the frequency. These two principles are presented well in reference (Rumsey, 1957) which title is Frequncy independent antenna. The third principle is to design the antenna structure such that its electrical properties repeat periodically with the logarithm of the frequency.

Fig. 5 shows the logarithmically periodic antenna structure. The slots are bounded by the radius R_n, r_n and the subtended angle β. The radius R_{n-1}, R_n, R_{n+1}, ... form a geometric swquence of terms where the geometric is defined by

$$\tau = \frac{R_n}{R_{n+1}} \tag{8}$$

The radius r_{n-1}, r_n, r_{n-1}, ... form a similar sequence having the same geometric ratio. The width of the slot is defined by

$$\sigma = \frac{r_n}{R_n} \tag{9}$$

It can be seen that infinite structures of this type have the property that, when energized at at the vertex, the fields at a freqeuncy (f) will be repeated at all other frequencies given by $\tau n f$ (apart from a change of scale) where n may take on any intergral value. When plotted on a logarithmic scale, these frequencies are equally spaced with a seperation or period of $\text{In}\tau$; hence the name logarithmically periodic structures. At that time, the geometric ratio τ of equation (8) defines the period of operation. For example, if two frequencies f_1 and f_2 ($f_1 < f_2$) are one period apart, they are related to the geometric ratio τ by

$$\tau = \frac{f_1}{f_2} \tag{10}$$

Extensive studies on the performance of the antenna of Fig. 5 as a function of α, β, τ and σ, have been performed (DuHamel & Ore, 1958). In general, these structures performed almost as well as the planar and conical structures. The only major difference is that the log-peiodic configurations are linearly polarized instead of circular.

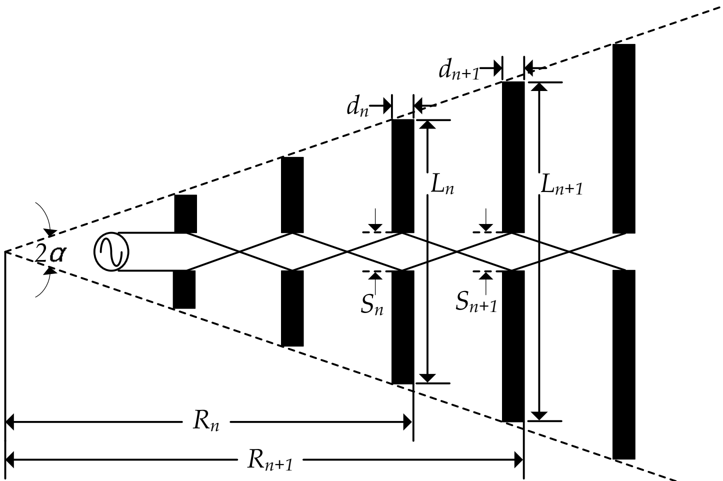


Fig. 6. The log-periodic dipole antenna geometry

The most recognized log-periodic antenna structure is the log-periodic dipole arrays (LPDA) which is introduced by Isbell (Isbell, 1960) as shown in Figure 6 and improved using techniques shown in references(Carrel, 1961; DeVito & Stracca, 1973; DeVito & Stracca, 1974; Butson & Thomson, 1976). The antenna consists of many different length dipoles. They are achievable and maintained over much wider bandwidths by adding more dipole antenna elements. The performance of a LPDA is a function of number of elements as well as element length, spacing and diameter. Antenna element lengths and spacings have proportionality factors given by a scale factor

$$\tau = \frac{L_n}{L_{n+1}} = \frac{R_n}{R_{n+1}} = \frac{s_n}{s_{n+1}} = \frac{d_n}{d_{n+1}} < 1 \tag{11}$$

and spacing factor

$$\sigma = \frac{R_{n+1} - R_n}{2L_n} = \frac{1-\tau}{4}\cot\alpha \tag{12}$$

where the L_n is the length of n^{th} element, R_n is the spacing of elements n^{th}, d_n is the diameter of element n^{th}, and s_n is the gap between the poles of element n^{th}. The frequency limits of the operational band are roughly determined by the frequencies at which the longest and shortest dipoles are half-wave rosonant, that is,

$$L_1 \cong \frac{\lambda_{max}}{2} \quad \text{and} \quad L_N \cong \frac{\lambda_{min}}{2} \tag{13}$$

where λ_{max} and λ_{min} are the wavelengths corresponding to the lower and upper frequency limits. At low frequencies, the larger antenna elements are active. As the frequency increased, the active region moves to the shorter elements. When an element is approximately one half wavelength long, it is resonant. And the number of dipoles can be obtained using

$$N = 1 + \frac{\log(L_1/L_N)}{\log(1/\tau)} \tag{14}$$

This seems to have many variables. But there are only three independent variables for a LPDA. These three parameters, which can be chosen from the directivity, length of the antenna, apex angle and the upper/lower frequency, should come with the design specifications. After extensive investigations, a summary of the optimum design data is produced in Table 1, which can be aid antenna design (Huang & Boyle, 2008).

Directivity(dBi)	Scale factor (τ)	Spacing factor (σ)	Scale factor (α)
7	0.782	0.138	21.55
7.5	0.824	0.146	16.77
8	0.865	0.157	12.13
8.5	0.892	0.165	9.29
9	0.918	0.169	6.91
9.5	0.935	0.174	5.33
10	0.943	0.179	4.55
10.5	0.957	0.182	3.38
11	0.964	0.185	2.79

Table 1. Optimum design data for log-periodic antenna

2.2 Innovational UWB Antennas

As I mentioned above, broadband antennas have been around for many decades and are used extensively. In the past, traditional broadband antennas satisfied the requirements for commercial UWB systems. However, the UWB technology has gained more and more popularity and become a good cadidate for short-distance high-speed wireless communication since the approval of UWB by the FCC in 2002. The proposed commercial UWB radio concept with its frequency 3.1 GHz to 10.6 GHz differs significantly from traditional wideband, short-pulse applications, such as radar. Furthermore, UWB antennas need different requirements due to its applications such as portable electronics and mobile communications. Therefore, the conventional UWB antennas are not suitable. To satisfy different requirements such as size, gain and radiation patterns, many kinds of the new antenna are proposed.

2.2.1 Biconical, Bowtie and Monopole Antennas

Figure 7 shows the developing processes from biconical antenna to disc cone antenna and planar monopole antenna. The biconical antenna formed by placing two cones of infinite extent together as shown in Figure 7 (a) is one of the antennas having broadband characteristics (Balaris, 1996; Stusman, 1997). Since this structure is infinite, it can be analyzed as a uniformly tapered transmission line. With a time varying voltage applied across the gap, currents in tern create an encirculating magenetic field. The input impedace of the transmission line is calculated with them. For a free-sapce medium, the characteristic impedance represented as follow:

$$Z_{in} = 120\,\text{In}\left[\cot\left(\frac{\alpha}{4}\right)\right] \tag{15}$$

where, α is a cone angle. Input impedance is a function of the cone angle and broadband property of the antenna can be obtained when the angle, α, lies between 60° and 120°. Although biconical antennas are attractive due to its broadband charateristics, they are so messive and impractical to use. Therefore, the modified structures of the biconical antennas as shown in Figure 7 (b) and (c) are represented. Many strutures of monopole type UWB antenna having a horizontal ground plane like the sturcture in Figure 7 (c) are introduced. Zhi Ning Chen and Y. W. M. Chia represented trapezoidal planar monopole antenna on the ground plane (Chen & Chia, 2000). Compared to the square monopole antenna, it could have a broad impedance bandwidth, typically of >80% for VSWR=2:1 by controlling the ratio of the lengthes of top side and bottom side. M. J. Ammann introduced the pentagonal planar monopole antenna having 6.6:1 impedance bandwidth ratio (2.1~12.5 GHz) (M. J. Ammann, 2001). The wide bandwidth is achieved by varying the trim angle of the cut of the square patch. Kin-Lu Wong et al. also introduced square planar metal plate monopole antenna with a trident shaped feeding strip (Wong et al., 2005). With the use of the feeding strip, the antenna has a very wide impedance bandwidth. And it is easily fabricated using a single metal plate, thus makin it easy to construct at a low cost. Qit Jinghui et al. presented a circular monopole antenna for UWB systems which is consisted of a 9x9 cm^2 ground plane and a metal plate with a radius of 2.5 cm and 5 cm perpendicular to the ground plane, and fed by a single coaxial cable that passed through the ground plane and connects to the bottom metal plate (Jinghui et al., 2005). The proposed antenna's return loss is better than 10 dB from 1.25 GHz to more than 30 GHz and better than 15 dB from 3 to more than 30 GHz. Daniel Valderas et al. introduced UWB folded plate monopole antenna which is based on the rectangular plate monopole antenna (Valderas et al., 2006). Folded configurations are presented in order to reduce antenna size and improve radiation pattern maintaining the planar monopole broadband behavior.

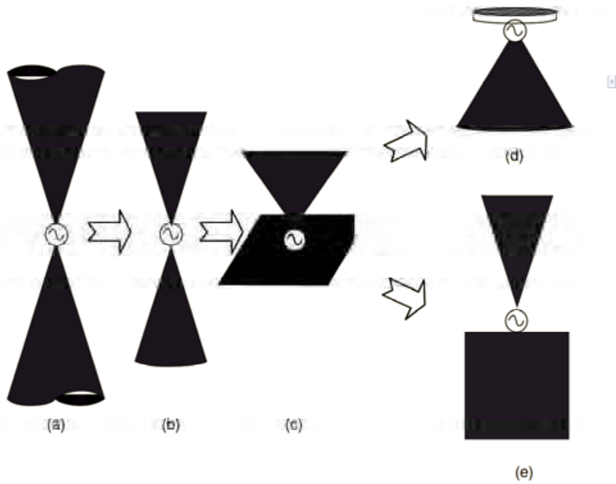
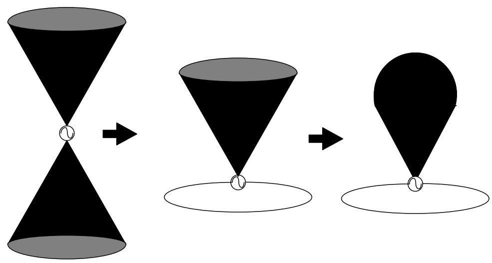
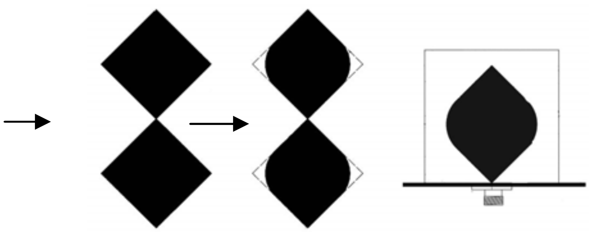


Fig. 7. Evoluation processes from the conical antenna to disc cone antenna and planar monopole antenna



(a)



(b)

Fig. 8. The modified bowtie antenna structures

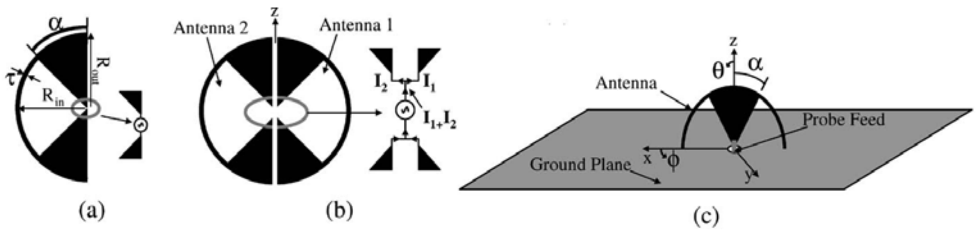


Fig. 9. The developing processes of the folded bowtie antenna

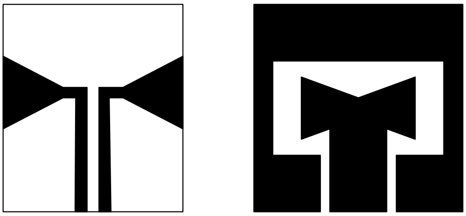
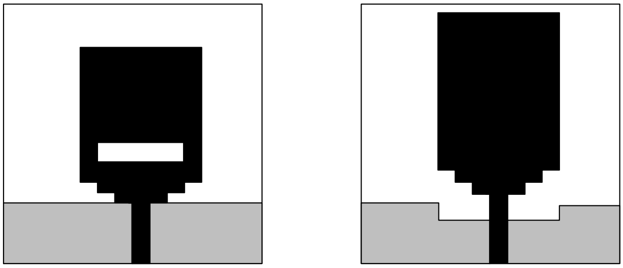


Fig. 10. The UWB bowtie antennas

The structure in Figure 7 (c) developed into the planar monopole structure by replacing an electrically large conducting plate acting as a ground plane as shown in Figure 7 (e). They has received a great deal of attention on the recent UWB literature due to its ease of fabrication, a novel small size and low cost. 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 in Figure 8. The former improved its properties, better return loss in high frequency, smaller size and high gain, by inserting round corners on the rectangular bowtie antenna. The later developed the UWB dipole antenna from the cone antenna. Except that, the folded bowtie antenna in Fig. 9, also called sectorial loop antennas (SLA) is suitable for UWB antenna (Behdad & Sarabandi, 2005). Its preformance is improved by adding a shorting loop to the outside of a bowtie antenna. The optimized antenna has a 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 10 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.

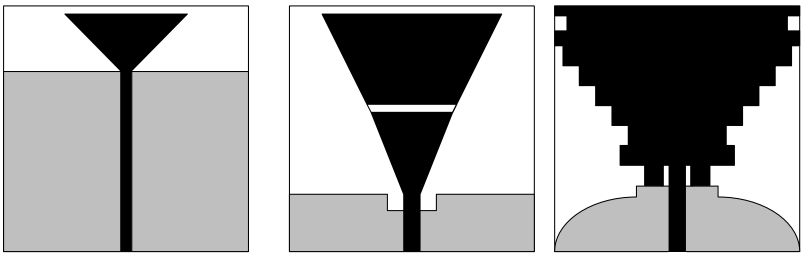
The planar monopole antenna for UWB systems can be sorted by feeding methods, microstrip feeding and coplanar waveguide feeding. There are four types of the patch shape in the microstrip fed UWB antennas such as rectangular, trianglar, circular and elliptical. Figure 11 shows microstrip fed monopole UWB antennas with rectuagular patch. At first, Seok H. Choi et al. proposed a new ultra-wideband antenna as shown in Figure 11 (a) (Choi et al., 2004). Three techniques to achieve wide bandwidth are used: the use of (i) two steps, (ii) a partial ground plane and (iii) a single slot on the patch, which can lead to a good impedance matching. And Jinhak Jung et al. introduced a small wideband microstrip monopole antenna which consists of a rectangular patch with two notches at the two lower corners of the patch and a truncated ground plane with the notch structure (Jung et al., 2005).



(a) (b)

Fig. 11. The microstrip fed monopole antennas with rectangular patch

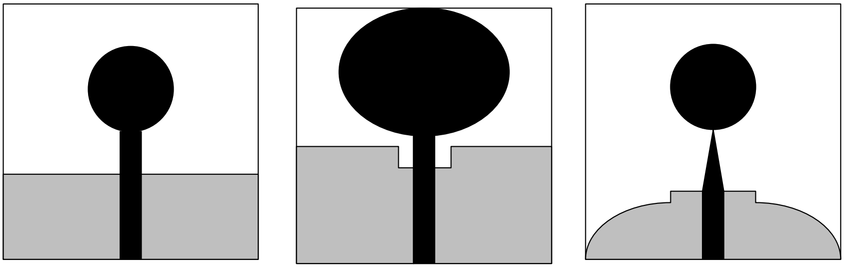
Second, the triangular patch and its modified structures of microstrip fed UWB antenna are introduced as shown in Figure 12 (Lin et al., 20005; Verbiest[b] & Vandenbosch, 2006; Cho et al., 2006). The structure in Figure 12 (a) is based on the triangular monopole antenna. It is consists of a tapered radiating element fed by microstip line. The VSWR of the antenna with the optimized constructive parameters is less than 3 from 4 to 10 GHz. And it was developed by inserting a slot in the patered radiating element and in the ground plane, which yields a wideband property with a relative good matching as shown in Figure 12 (b). In UWB antenna in Figure 12 (c), the broad bandwidth was achieved by triangular shaped patch with the staircases instead of the bowtie patch, a particial modified ground plane and two slits near the 50Ω microstrip line fed by the SMA connertor. Compared with antennas without these techniques, the proposed antennas have the widest bandwidth.



(a) (b) (c)

Fig. 12. The microstrip fed monopole antennas with triangular patch

Third, the circular and elliptical patch antennas fed by the microstrip line are a good candidate for the UWB antenna design. Their structures are presented in Figure 13. The UWB antenna in Figure 13 (a) based on the previous studies (Liang et al., 2004) is designed by using a circular patch, a 50Ω microstrip feed line and a conducting ground plane (Liang[a] et al., 2005). The circular disc monopole UWB antenna is miniaturized by using tapered feeding line and improved ground shape as shown in Figure 13 (b), while the performance of the antenna is maintained (Zhang[b] et al., 2008). With circular disc monopole antenna, a planar elliptical patch monopole antenna structure is also a good for UWB antenna. The ellipical patch caused similar effect of bevelling the radiating element and cutting slot in the ground plane provide an ultra-wideband impedance bandwidth (Huang & Hsia, 2005).



(a) (b) (c)

Fig. 13. The microstrip fed monopole antennas with circular and elliptical patch

Instead of microstrip fed monopole antennas, there are many patch shapes for UWB antenna fed by couplanar waveguide (CPW) feeding method as shown in Figure 14 (Gupta et al., 2005; Liang[b] et al., 2005; Yang & David, 2004; Tran et al., 2007; Liang[c] et al., 2005; Shrivastava & Ranga, 2008; Liang et al., 2006; Wang et al., 2004; Kim et al., 2005). The rectangular and circular patch in Figure 14 (a) are well known for UWB antenna, and Figure 14 (b) shows the modified shapes from the previous shapes. The UWB antennas in Figure 14 (c) are designed using a prapeziform ground plane which has three functions: (1) a ground plane for the monopole and CPW, (2) radiationg element and (3) component to form the distrubuted matching network with the monopole. The antenna in Figure 14 (d) is designed for UWB systems by using FDTD and genetic algorithm.

2.2.2 Slot typed UWB Antennas

Slot antennas are currently under consideration for use in ultra-wideband (UWB) systems due to the attractive adventages 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.

Figure 15 shows various UWB antenna structures using microstrip line feeding (Qing et al., 2003; Chang et al., 2005; Lui et al., 2007; Chen et al., 2008). The antenna in Figure 15 (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 S_{11} < -10dB. Its bandwidth is imporved by using a tuning pad which is made of copper as shown Figure 15 (b). The improved antenna covers from 2.3 GHz to 12 GHz. And Figure 15 (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 15 (d). It also have a reqired bandwidth for UWB communication systems.

Figure 16 shows CPW-fed slot antennas for UWB systems (Pell et al., 2008; Archevapanich et al., 2008; Chen et al., 2006; Gopikrishna et al., 2009). The designed antenna in Figure 16 (a) is based on a simple CPW fed slot antenna which is consisted of two rectangular slots seperated by center strip and the CPW feeding line. In the simple CPW-fed slot antenna, the wide bandwidth can be obtained by inserting L-strip tuning stubs which is etched at the bottom of conner edge in the rectangular slots.

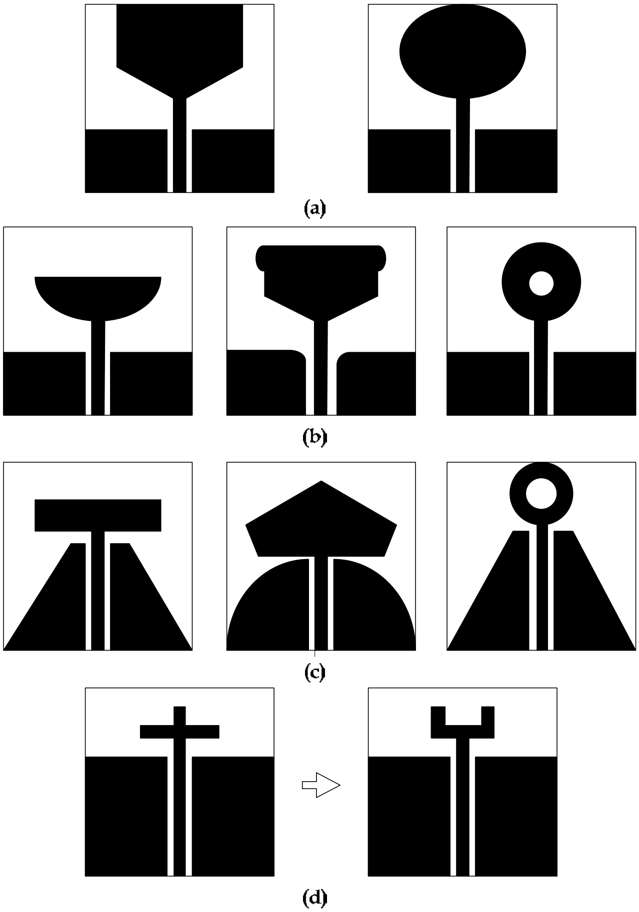


Fig. 14. The CPW-fed monopole UWB antennas

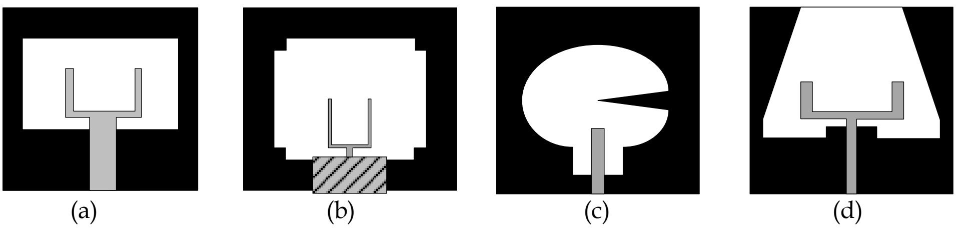
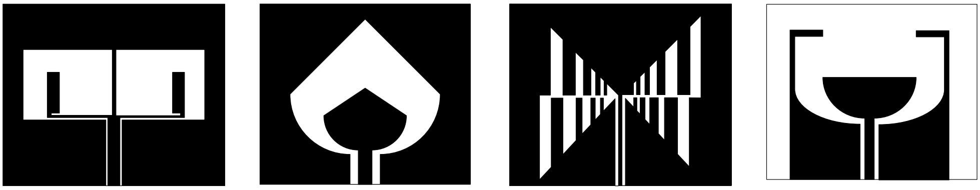


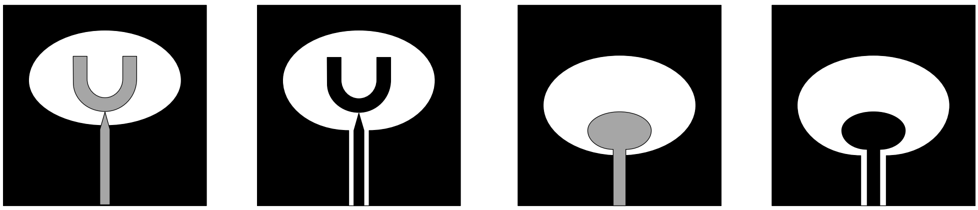
Fig. 15. The UWB slot antennas using microstrip feeding line

The optimized antenna has wide bandwidth, from 1.8 GHz to 11.2 GHz. In Figure 16 (b), Brendan Pell et al. are presented the CPW fed planar inverted cone antenna (PICA) which is composition of a semicircle and an equilateral triangle. Shih-Yuan Chen et al. proposed a CPW-fed log-periodic slot antenna as shown in Figure 16 (c). In this antenna, wide bandwidth can be obtained from log-periodic antenna's properties. And Figure 16 (d) presents a compact semi-elliptic monopole slot antenna. It is consisted of a modified ground plane heaped as a semi-ellipse near the patch and semi-elliptic patch. Its bandwidth is from 2.85 GHz to 20 GHz with omni directional radiation. And then, for the comparision between microstrip line feeding and CPW feeding, Pengcheng Li et al. and Evangelos S. Angelopoulos et al. studied elliptical/circular microstrip-fed/CPW-fed slot antennas as shown in Figure 17 (Li et al., 2006; Angelopoulos et al., 2006).



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

Fig. 16. The UWB slot antennas using CPW feeding line



(a) (b)

Fig. 17. The Microstrip-fed /CPW-fed UWB slot antennas

2.2.3 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 (Lee & Chen, 1997). Thus, many people studied it for the UWB applications. Figure 18 shows the presented TSA for UWB systems (Verbiest[a] & Vandenbosch, 2006; Gopikrishna[a] et al., 2008; Ma & Jeng, 2005; Nikolaou et al., 2006). Antennas in Figure 18 (a) and (b) are the tapered slot antenna consisted of simular structure, tapered slot in the ground plane and microstrip feeding line. But the latter could have a wide bandwidth by inserting rectangular slot on the feeding line. And Figure 18 (c) shows a planar miniature tapered slot fed annular slot antenna. The radiating annular slot and its tapered slot feeding structure are on the top layer of the substrate whereas the microstip line and its open stub are printed on the bottom layer of it. It possesses ultrawide bandwidth, uniform radiation patterns and low profile. Tzyh-Ghuang Ma introduced an ultrawideband CPW fed tapered ring slot antenna in Figure 18 (d) which is formed by a 50Ω couplanar waveguide, a CPW to slotline transition and a pair of curved radiating slots. In this antenna, the very wide bandwidth can be obtained by gradually changing the width of the radiating slots. Symeon Nikolaos et al. proposed a double exponentially tapered slot antenna