2
Review of Literature

Wireless technology has gained great attention from both academia and industry in the past decades. The ultimate goal of communications is to improve the spectrum utilization and efficiency. Due to the scarcity of broadcast spectrum, government regulations are required to allocate the available spectrum appropriately. One approach to improve the spectrum utilization is to allow a secondary use of the spectrum without causing interference to the legacy users. The solution of this problem in short range application is UWB technology. UWB technology gets major attention among research community after February 2002, when Federal Communication Commission (FCC) authorized the unlicensed use of 3.1-10.6 GHz in order to meet the demand of high data rate in short distance communications for various applications [FCC, 2002].

The electromagnetic characteristic of the radio waves in the transmission medium always puzzles many people. Antenna is the link between electric circuitry and the transmission medium. This chapter presents a brief introduction of UWB technology with its fundamentals, advantages, regulations and its potential areas of applications. Moreover, the importance of the fractal geometry in wideband antenna design is also discussed.

2.1 UWB Technology

2.1.1 Introduction

UWB is a radio technology, which operates in the frequency range of 3.1 GHz to 10.6 GHz at very low power level for short-range communications without causing interferences to the licensed users [Chong *et al.*, 2006]. People require greater liberty and suitability in connecting all types of devices such as handheld consumer electronics, personal computer and cell phone etc. when the user is moving into the home and office. The UWB technology provides the real wireless freedom with existing long range radio technologies such as Wi-Fi, worldwide interoperability for microwave access (WiMAX), wireless local area network (WLAN), and cellular wide area communications by replacing short wired links. UWB offers the desirable low cost, power-efficient, wide bandwidth solution for transmitting multiple digital video and audio streams data among the short range devices.

In a communication system, antenna is one of the most important constituent. In order to design an UWB antenna, whose behavior must be predictable and consistent across the entire operating range offers great challenges to the antenna designers.

2.1.2 Characteristics

UWB is a new technology, which has substantial development potential in elementary areas like Communication, Automotive, Localization services, Security, Imaging and sensors. The growing number of media-intensive devices in the wireless personal area networks (WPANs) such as PCs, digital camcorders, digital cameras, high-definition TVs (HDTVs), gaming systems as well as the office devices such as Cordless connection to peripherals, Notebook, printer, PDA, fax machine, mouse, keyboard need a wideband wireless solution for easy connection and media exchange. UWB radio is predicted as one of the most promising technologies for above mention applications, due to its several advantages such as:

- **High Bandwidth**: According to the FCC definition of UWB system, any transmitting system, which transmits signals in a bandwidth greater than 500 MHz or 20% bandwidth. UWB technology works in the bandwidth range of 3.1 GHz to 10.6 GHz [Chen, 2007].
- **Low power spectral density**: The main reason of the UWB technology to co-exist without causing interference to other services such as GPS, WLAN, WiMAX, Wi-Fi and cellular network system is low power spectral density [Giuliano and Mazzenga, 2002].
- **Low Cost**: UWB technology did not require any carrier signal for transmission. Also, there is no need for a Radio Frequency (RF) converter or modulator. Hence, transmitters and receivers are simpler and easier to design and implement at low cost.
- **Low Power Consumption**: UWB technology needs less than 1 mW of power to transmit hundreds of Kbps as far as 5 meters due to absence of carrier signal. Thus, UWB devices operate efficiently at low power levels.
- **High Data Transfer Rates**: The data transmission is done over high transfer rates of 500Mb/s over 5m, 250Mb/s over 10m, 200Kb/s over 50m, 10Kb/s over 100m due to availability of enormous amount of bandwidth.
- **Secure**: UWB technology operates on a wide bandwidth at very low power level, which generates low probability for intercept and thus making it highly secure. Practically, it is highly difficult to filter a pulse signal from a background of electronic noise [Mckinstry and Buehrer, 2002].

2.1.3 How UWB Works?

UWB data transmission behavior is significantly different from conventional narrowband RF and spread spectrum (SS) technologies like Bluetooth and Wi-Fi, as it does not required carrier signal to transfer information. A UWB transmitter generally sends billions of low duty cycles pulses across 3.1 GHz to 10.6 GHz at a low power level of -41dBm/MHz, which transmits with power level less than one thousand times of an average cell phone. Due to the low emission limit on power, the other radio systems consider UWB signal as noise, which results in a low probability of interception and detection. At the receiving terminal receiver translates the received sinusoidal pulses into data. These pulses are carrying information in coded form and extremely brief with a capacity of almost unlimited number of users, which improves the speed by attending a familiar pulse sequence sent by the transmitter [Fontana, 2004].

UWB share the same wireless transmission medium with a number of users simultaneously transmitting pulses by using spread spectrum technology [Hamalainen et al, 2008]. Therefore, UWB provides a superior wireless connectivity among WPAN devices due to its high data throughput potential in short-range at very low power. UWB operates in single-band mode and multi-band mode; single-band mode is similar to spread spectrum technology, whereas, in case of multi-band mode whole frequency spectrum is divided into smaller, non-overlapping bandwidths above 500 MHz [Nekoogar, 2005]. Multi-band is favored because it uses complete UWB spectrum to send coded pulses.

One of the biggest advantages of UWB technology is improved channel capacity compared to other technology, which can be explained using Shannon's capacity limit Eq. (1). UWB systems information is transferred through the RF spectrum channel. Shannon's equation shows capacity increasing as a function of bandwidth faster than the signal to noise ratio [Nekoogar, 2005].

$$C = BW * log_2(1+SNR) \tag{1.1}$$

$$SNR = \frac{P}{BW * N_0} \tag{1.2}$$

where C is channel capacity, BW displays channel bandwidth in Hz, P is received signal power, N_0 is the average noise or interference power over the bandwidth, and SNR represents signal to noise ratio.

It is observed from Shannon's equation that increase in channel capacity requires linear increases in bandwidth. Whereas, to achieve similar channel capacity using power level, requires a multifold increase in power. Due to this reason, UWB is capable of transmitting high data rates with low power consumption.

2.1.4 UWB Antenna System

Antenna plays a key role in the implementation of wireless communications systems. It is a single device that works as an intermediate between wired transmission lines and free space for design and setting up of wireless communication systems. The appropriate selection of antennas with proper orientation and their subsequent mounting location improves system coverage and performance. Thus, UWB system requires an antenna that is capable of receiving pulses at all operating frequencies, whose behavior must be predictable and consistent across the entire operating range. The antenna requires different characteristics such as compactness in dimensions, steady gain and good radiation behavior, etc., for different applications.

The initial history of UWB antenna development was studied in [Schantz, 2012]. UWB antenna design got a spark after the 1930, when practical feasibility of UWB antenna becomes possible with the developments in RF technology. The emergence of UWB was noticed after the 1960s, when military research laboratories applied UWB technology to improve the radar and surveillance operations [Skolnik *et al*, 1995; Mokole, 1996]. The Department of Defense (DoD) was the only user of UWB until the FCC authorized its use for police and fire fighting in 1998. The commercial use of UWB started in 2002 after the approval from FCC. So far, many UWB antennas designes like horn [Nguyen *et al*, 2001], elliptical [Marindra *et al*, 2012], biconical, monocone, discone [Taniguchi and Kobayashi, 2002], bow-tie [Yarovov *et al*, 2002], fractals [Cohen *et al*, 2003] and vivaldi [Sorgel *et al*, 2003] have been proposed and analyzed. The applications of UWB, in indoor wireless communication have been studied in [Win *et al*, 1997]. Fractal antennas have shown great ability to exhibit resonance compression and multiband characteristics, which shows a lower operating resonant frequency than a same-sized Euclidean antenna [Best, 2003].

2.2 Fractal Geometry

2.2.1 Introduction

The fractal term is coined by Benoit Mandelbrot in 1975 and it is originated from the Latin word fractus, it means "broken" or "fractured" [Amin *et al*, 2012]. The mathematical modeling of fractal is based on an equation that undergoes iteration to generate the structure. Fractal geometry often shows the following properties [Vinoy, 2002]:

- It shows a fine structure at any arbitrarily small segment.
- It is highly irregular compared to traditional Euclidean geometry.
- It shows self-similarity or self-affinity property in geometry.
- It define fractal dimension greater than its original dimension.
- Effective length of geometry increases with each recursive operations.

Fractal geometry is defined mathematically using fractal dimension and effective length for a self-similar geometry. The fractal dimension (D) of a curve is calculated using Hausdorff-Besicovitch equation [Lopes, 2009]:

$$D = \frac{log(N)}{log(r)} \tag{1.3}$$

The effective length (l) of a curve is calculated by:

$$l = h\left(\frac{N}{r}\right)^n \tag{1.4}$$

where N shows the number of segments the geometry has, r is the number that each segment is divided on each iteration, h is the initial length of the curve and n represents the number of iterations. Fractals are constructed from the repetition of its self-similar copies of itself. Some fractal structures are generated using an iterative function system (IFS).

2.2.2 Iterated Function System (IFS)

IFS are an extremely useful method to generate a wide variety of structures. IFS work by applying a series of transformations based on an affine linear transformation in the Euclidean plane such as scaling, rotation and translation [Gianvittonio and Rahmat-Samii, 2002]. The transformation W is defined as:

$$W\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} \frac{1}{r}\cos(\theta) & -\frac{1}{s}\sin(\theta) \\ \frac{1}{r}\sin(\theta) & \frac{1}{s}\cos(\theta) \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \tag{1.5}$$

where coordinates x and y shows initial point belonging to object, coordinates X and Y displays a point belonging to the transformed object, r and s is the scaling factor in x and y respectively, θ is the rotation angle in same x-y plane, e and f is the linear translation in x-axis and y-axis respectively.

2.2.3 Advantage of Fractal Geometry in Antenna Design

As the effective length of antenna increases, the operating frequency range at the lower frequencies improves. Whereas, the self-similarity of fractal geometry results in multi-resonant characteristic which in turn helps to achieve wideband phenomena. Thus, wideband operational bandwidth of antenna can be obtained using fractal geometry. Fractal antennas have greater bandwidth and compact size as compared to conventional antennas.

Fractal concept in antenna was given first time by Nathan Cohen in 1988 [Cohen, 1997]. Fractal is used to design a compact, multi-resonant, wide-band antenna within a smaller area. Fractal dimensions are associated with size of the structure. Using the fractal geometry, the effective length of the antenna increases in a smaller physical area with consecutive iterations [Werner and Ganguly, 2003]. A fractal antenna is capable of operating at different frequencies simultaneously. Fractal geometry possesses several curves and bends in the structure, where a small part of geometry is repeated, and this helps to enhance the radiation characteristics of the antenna.

2.3 History of UWB Antenna Design

Design and analysis of UWB antenna is more challenging as compared to narrowband antennas because it possess a wide operating band as specified by FCC and require compactness in antenna with the desired antenna characteristics. Such design and development of UWB antenna possesses several advantages over conventional data transmission in case of indoor communication. Hence, a compact UWB antenna has to be designed very carefully to enhance the system performance. The size of the antenna can be reduced significantly with the use of high dielectric (ε_r) substrates [Balanis, 2005]. High ε_r substrates help to reduce size but at the same time it also deteriorates the radiation efficiency of the antenna. [Bokhari *et al.*, 1996] uses the meandering technique in antenna design by cutting slots in the non-radiating part of the design to achieve compactness. This technique helps to increase the effective electrical path length but reduces the operating bandwidth due to capacitive loading. It is demonstrated that by etching rectangular [Zaker *et al.*, 2008; Amiri *et al.*, 2012] and L-shaped [Zaker *et al.*, 2009] slot in the ground plane; fractional bandwidth up to 125% is achieved. However, most of these antennas are larger in dimensions, which make them difficult to integrate with portable commercial devices. Thus, these techniques are not very efficient for compact wideband antennas.

The applications of UWB technology for indoor communication are very promising. However, it offers a great challenge among the antenna designer community because of its detrimental interference issues with other existing narrowband systems and services such as worldwide interoperability for microwave access (WiMAX) in 3.3-3.8 GHz, wireless local area network (WLAN) in 5.15-5.85 GHz and X-band in 7.9-8.4 GHz, which operates in the frequency range of 3.1-10.6 GHz. It is desirable in wireless communications to avoid any interference between different users present in the UWB spectrum. Although, FCC has allowed UWB devices operation in this wide range with a restricted power level compliant with the emission mask, to avoid the concern related to potential interference. UWB antenna should have band rejection characteristics in the possible interfering bands. Hence, the design of a compact UWB antenna with multiple band notch characteristics is an essential requirement.

The band rejection characteristics in above discussed bands can be achieved by introducing a notch structure either in the monopole or in the ground plane of an antenna. So far, many band notch UWB antennas are present in the literature [Gao *et al.*, 2013; Chu and Yang, 2008; Abdollahvand *et al.*, 2010; Ojaroudi and Ojaroudi, 2013; Azim *et al.*, 2014; Cho *et al.*, 2006]. Fractal geometry based notch are reported in the antenna to obtain the desired band notch characteristics in UWB band [Karmakar *et al.*, 2008; Song *et al.*, 2010]. These antennas are large in size and have complex design. Thus, design of compact UWB antenna with single or dual band notch characteristics is required.

However, UWB band faces the electromagnetic interference with existing narrowband systems. Sometimes, in the no interference scenario, UWB bandwidth is not utilized efficiently. Therefore, there is a need of reconfigurable band rejection antenna to utilize the frequency spectrum efficiently. Thus, the use of single antenna in different operating frequency bands is highly desirable. Moreover, wideband antennas with narrowband reconfigurability are desirable for software defined radio (SDR) and cognitive radio (CR) applications. CR requires a sensing antenna to monitor the system as well as a communicating antenna which can be reconfigured to transfer the data in a chosen spectrum [Mitola, 1999]. Hence, the design of a compact antenna, which has reconfigurable band notch characteristics or reconfigurable narrowband characteristics, is very challenging problem for antenna designers.

In order to overcome the interference problems, several UWB antennas with band notch characteristics are presented [Peng *et al.*, 2013; Abdollahvand *et al.*, 2010; Azim *et al.*, 2014]. However, these antennas are not able to utilize the UWB band effectively in case of no interference issues. Thus, the design of UWB antenna with reconfigurable single or dual band notch characteristics is highly desirable for efficient utilization of UWB spectrum. In [Valizade *et al.*, 2012] and [Badamchi *et al.*, 2014], the reconfigurable band notch antenna are presented and they are large in size. In addition, the researchers have proposed to integrate sensing and narrowband communication in the UWB spectrum for CR applications [Erfani *et al.*, 2012; Boudaghi *et al.*, 2012; Ebrahimi *et al.*, 2011; Tawk *et al.*, 2011; Zamudio *et al.*, 2011]. In [Erfani *et al.*, 2012] and [Boudaghi *et al.*, 2012], varactor diodes and p-i-n diodes are used for reconfigurable narrowband within the UWB band, respectively. However, these antennas are large in dimensions and complex in design, which leads to increase in the cost of the systems. The commercial application of UWB technology requires compactness in antenna dimensions, so that; it can be easily integrated with other portable devices. In order to achieve the reconfigurable performance in rejection bands, different types of switches such as RF MEMS, RF MESFET, varactor diodes and p-i-n diodes are used [Erfani *et al.*, 2012; Boudaghi *et al.*, 2012]. Hence, design of a compact UWB antenna with reconfigurable operating bands as well as reconfigurable band notch characteristics is essential for efficient utilization of UWB spectrum.

The rapid growth in wireless communication forces the regulatory authorities to allow the transmission in higher and wider frequency spectrum to achieve high wireless channel capacity. It is achieved by using the diversity/MIMO technology in rich scattering environment without additional power or spectrum. MIMO technology uses multiple antennas at the transmitter and receiver terminal of transmission system. The UWB system is also susceptible to multipath fading problems similar to other wireless communication systems. The use of MIMO technology helps to improve diversity gain and multipath fading [Wallace and Jensen, 2001; Ben *et al*., 2012]. UWB MIMO technology requires high isolation among antenna elements to combat multipath fading. However, the compact UWB MIMO antenna for portable applications in a given smaller area causes the degradation in diversity performance due to presence of various mutual coupling among the antenna elements. In addition, UWB system faces the severe interference challenges with existing narrowband system such as WLAN from 5.15-5.825 GHz, which lies in the UWB spectrum. Hence, the design of a compact UWB MIMO antenna with band notch characteristics is a very challenging task.

UWB system faces multipath fading challenges in the communication channel because of reflection and diffraction of signal between receiver and transmitter. Thus, in order to realize the high data transmission capacity and to overcome the multipath fading limitation of short distance communication, MIMO is combined with UWB technology [Najam *et al*., 2011; Bolin *et al*., 2005; Foschini and Gans, 1998]. MIMO systems use multiple antennas to transmit and receive signals with different fading characteristics, which help to enhance the system reliability and channel capacity [Rajagopalan *et al*., 2007; Ben *et al*., 2012]. During the past few years, several UWB MIMO antennas have been proposed to resolve the issues such as wideband isolation, compact size and filtering of interfering bands [Hong *et al*., 2008; See and Chen, 2009; Zhang *et al*., 2009; Li *et al*., 2011; Kelly *et al*., 2011; Jiangand and Che, 2012; Peng *et al*., 2014; Lee *et al*., 2012]. However, the use of multiple antennas in a compact area degraded the antenna characteristics because of several mutual couplings. In [See and Chen, 2009; Zhang *et al*., 2009], the decoupling structures are placed between monopoles to enhance the isolation. To achieve WLAN band rejection in the UWB range, different methods have been used such as by introducing the different shaped slots or strips in the UWB antennas. Some of these are split-ring resonators [Li *et al*., 2011], open loop resonators [Kelly *et al*., 2011], and U-shaped structures [Jiangand and Che, 2012]. However, the application of these techniques to achieve band rejection could affect the mutual coupling between radiating structures. The UWB MIMO antennas with band rejection in WLAN band are reported in [Peng *et al*., 2014; Lee *et al*., 2012]. In [Li *et al*., 2013; Lihong *et al*., 2014], compact UWB MIMO antennas are reported in the literature. Moreover, these antennas with acceptable isolation are difficult to integrate with modern portable UWB systems because of their larger dimensions. However, the majority of these antennas [Ben *et al*., 2012; Zhang *et al*., 2009; Li *et al*., 2011; Kelly *et al*., 2011; Jiangand and Che, 2012; Peng *et al*., 2014; Lee *et al*., 2012] are 2×2 UWB MIMO antenna and did not enhance the quality of communication channel significantly. In order to increase the channel capacity, more number of antennas is required [Karaboikis *et al*., 2008]. On the other hand, 4×4 UWB MIMO antennas are reported in [Kiem *et al*., 2014; Mao and Chu, 2014]. The dimensions of the antenna presented in [Kiem *et al*., 2014] are very large, whereas [Mao and Chu, 2014] does not have the band notch characteristics. Hence, the design of a compact UWB MIMO antenna with band rejection and low mutual coupling in a given smaller area for portable electronic devices is required.

Antenna plays an important role in wireless personal communication devices. Thus, to understand the antenna performance in the proximity of human body, the study of electromagnetic interaction between antenna-human bodies is required. When the antenna is close to human body, it radiates towards the human body also. One of the utmost promising applications of UWB technology is in Body Area Network (BAN). It is due to its high data transmission capacity at low power level. An extremely low power is required in proximity of human body to avoid any electromagnetic interaction. It is evident that antenna characteristics are influenced because of water and body tissues present in the human body. The effect of the electromagnetic radiation on human body is studied in terms of Specific Absorption Rate (SAR), which indicate the power absorbed by the body tissues [IEEE Std. C95.1-2005, 2006]. SAR is the mass normalized rate at which EM energy is absorbed by the body tissues of a specific location and expressed as:

$$SAR = \frac{\sigma}{\rho}|E|^2 \quad (1.6)$$

where σ (S/m) represents tissue conductivity, ρ (kg/m³) shows tissue density and E is root mean square value of electric field. The international standards set a restriction on power transmission level of the devices in order to reduce the SAR level in a safe mode. The threshold SAR levels defined by regulatory authorities are different. European standard is 2W/Kg averaged over 10 gm of tissue [ICNIRP Guidelines, (1998)] and American standard is 1.6 W/Kg averaged over 1 gm of tissue [FCC Technical Report, (2003)]. Moreover, the RF signals characteristics changes with the variation in operating frequency due to changes in dielectric properties of human tissues with frequency [Quig *et al.*, 2006]. The performance of antenna system decreases in the proximity of human body. In the frequency-domain, antenna efficiency, radiation pattern, gain and input impedance get deteriorated; whereas in the time-domain, the received signal waveform is distorted [Klemm and Troester, 2006].

Several studies on this topic are reported in [Chahat *et al.*, 2011; Tuovinem *et al.*, 2012; Alomainy *et al.*, 2005; Tuovinem *et al.*, 2013]. In [Chahat *et al.*, 2011], a rectangular shaped phantom model, which discards the skin effect, is used for a very small ground UWB antenna. The effect of different body tissues such as skin fat, muscle, and bone thickness for the proximity of on-body communication is carried out in [Tuovinem *et al.*, 2013]. In [Alomainy *et al.*, 2005] and [Tuovinem *et al.*, 2012] a comparative study for different antenna types in the context of on-body communication is performed. In order to achieve the miniaturization in antenna design, some techniques are reported in [Bahadori *et al.*, 2007; Abbosh *et al.*, 2009]. However, the dimensions of these antennas are still too large for commercial UWB system in the context of WBAN. The compact antenna structures can be easily integrated with portable UWB systems. Thus, the design of compact UWB antenna is essential, which can work near to human body in 7.5 GHz bandwidth with desired antenna characteristics in both frequency-domain and time-domain.

The above mentioned challenges can be resolved by using fractals in UWB antenna design. The use of fractal geometry concept in UWB antenna design is a combination of antenna technology and fractal geometry, which helps to accomplish the above requirements. The fact that most fractals have infinite complexity, which can be utilized to design compact, low profile and low weight antennas. Most fractals are self-similar, so fractal antenna can achieve multiple frequency bands [Guterman *et al.*, 2004; Werner *et al.*, 1999; Ding *et al.*, 2007; Hashemi *et al.*, 2006]. The space filling property is used to miniaturize the antenna size by increasing the effective electrical path length [Anguera *et al.*, 2005; Hashemi *et al.*, 2006]. A number of fractal geometries, for example, Koch snowflake [Anguera *et al.*, 2005], hexagonal shaped [Werner *et al.*, 1999], and Sierpinski triangle [Werner *et al.*, 1999; Anguera *et al.*, 2005] are used to design UWB antenna. The application of fractals in antenna design also helps to stabilize the radiation pattern at higher frequencies [Fereidoony *et al.*, 2012]. Thus, the application of the infinite complexity and self-similarity characteristics of fractals in design makes it possible to achieve wideband performance. Therefore, fractal UWB antenna is a promising topic and needs to be genuinely investigated and developed.

2.4 Application of UWB Technology

UWB offers some unique and distinctive characteristics such as low power consumption and high data transfer capacity make it an appropriate choice for various applications. It will provide ultra-fast WPANs with cable less connections. Recent technological progress can be used in a wide spectrum of applications.

(1). Medical Wireless ICT Application

The health care expenditures are rising every year. Wireless communication in health care and fitness, improves the quality of service with the substantial cost reduction. Due to the very low power spectral density of UWB signal, its utilization at hospital environment should not be a threat to patient's safety [Hamalainen et al, 2008]. Low UWB signal power level does not cause harmful impact to human body nor interfere sensitive medical devices.

(2). Radar Applications

Radar is one of the most potential applications of UWB technology. The positioning property of narrow UWB pulses enables them to offer higher-resolution radar of 2cm over 20m /10mm over 2m for military and civilian applications. UWB signal easily penetrate various obstacles, due to its very wide frequency spectrum band. This property is used in making of ground-penetrating radar (GPR), which helps rescue and disaster recovery teams to find the survivors [Nekoogar, 2005].

(3). **Military Application**

The low transmission power of UWB pulses makes them most appropriate choice for covert military communications, because at very low power level detection or interception of pulses becomes extremely difficult therefore, unauthorized person will not be able to access secure military information. It can be very helpful in the recognition of biological agents or enemy tracking on the battlefield [Nekoogar, 2005].

(4). Wireless Sensor Networks

Wireless Sensor system requires more security, flexibility, less installation, minimum maintaining efforts and low operational cost. A sensor device requires high reliability equipment at extremely low power consumption with minimum size and weight of sensors. Such sensor networks works by detecting a physical occurrence in an inaccessible area and transmit the information to the destination center [Nekoogar, 2005].

(5). Medical Imaging Systems

It is possible to see inside of a human body through the use of Medical Imaging Systems that are similar to CT Scans and X-rays. UWB is a possible alternative technology to remote sensing and imaging, compared with X-ray imaging. UWB radar probes use non-ionizing electromagnetic waves at very low average power level which proved to be harmless to human body [MCewan, 1996]. By 1999, many application of UWB for medical use can be cardiology, breath pathways, arteries, obstetrics, habitat monitoring, environment observation, health monitoring, and home automation [Nekoogar, 2005].

(6). Communication Systems

The UWB devices in multipath scenario can offer accurate geo-location capability for indoor and obscured environments, where GPS receivers will not work properly. The UWB communication devices provide a more secure communication link that law enforcement, police, and the military find useful. Communication devices can be used to distribute services such as the phone, cable, and internet network [Nekoogar, 2005]. It can also include children monitoring and tracking devices that uses a remote unified messaging system. The precise location-finding characteristics of UWB systems can be helpful in inventory control and asset management applications, such as RFID tags [Toccafondi and Giovampaola, 2012].

(7). WPAN and WBAN

The high data transmission capability of UWB in short range has various uses for home networking and multimedia communications in the form of WPAN applications [Chen *et al*, 2006]. UWB systems make the wireless connectivity by replacing cables connecting camcorders, as well as other personal applications such as laptops, DVDs, digital cameras and portable HDTV monitors. It also supports transmission of streaming videos [Nekoogar, 2005]. UWB devices that are connected close to the human body such as MP3 players and cell phones create a network topology that is known as the WBAN. A body-centric network is formed by integrating with sensors consuming extremely low power to monitor the person and transmitting this information to the control station for observation and monitoring [Chahat *et al*, 2011].

2.5 Summary

In the past, several techniques have been proposed to achieve the wideband operating bandwidth at the cost of low quality factor, low efficiency and low gain. Moreover, to achieve wideband with constant or good radiation characteristics is very difficult in antenna design. By increasing the area of the antenna, to achieve wideband characteristics, makes them larger in size and they become difficult to integrate with portable systems. The needs of other potential concepts and potential application of various technologies in the design of UWB antennas are presented. These concepts and technologies are wideband with band-notch characteristics, reconfigurable band notch characteristics, reconfigurable narrowband characteristics, MIMO techniques and application in WBAN. Furthermore, the introductory concepts of fractal geometry are presented. In addition, the reasons behind application of fractal geometry in UWB antenna design are also discussed. As we know, fractal geometry shows an increment in effective path length and multiband phenomena in a given smaller area with an increase in iteration order. UWB has been very effective from public safety point of view and it shows great promises for diverse applications. UWB holds great potential for a wide range of applications such as cordless technology, RFID (active, passive), consumer IT market systems, office networking replacement, home networking appliances, PC peripheral links, etc.

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