Chapter 1

Introduction

1.1 Prelude

The Federal Communications Commission (FCC) resolution on 14th February 2002, recommended a 7.5 GHz bandwidth ranging from 3.1–10.6 GHz for ultrawideband (UWB) communication systems. Development in UWB technology is enhanced due to the FCC's definition of a spectral mask, to allow operation of UWB radios at the noise floor across a wide spectrum. UWB is adopted for short range communication with EIRP less than -41.3 dBm/MHz. This allocation has stimulated antenna designers to look for challenging designs for low cost UWB antennas.

There is an increasing interest in the use of UWB systems because of their attractive advantages such as large channel capacity, low power consumption, ability to work with low signal to noise ratio, resistance to jamming, and low cost. Antenna plays a vital role in wireless communication systems. As an important part of the UWB system, the UWB antenna must be compact in size and have large impedance bandwidth. The ever developing UWB system and the short range civil applications, working in the frequency band from 3.1–10.6 GHz created demand for a compact transmitter and receiver module. The size of the transmitter and receiver can be made compact by a small size of the antenna. In this perspective, it has become essential to study the electrical characteristics and radiation pattern of small, compact, and low profile UWB antenna. The effective antenna size, operating resonant frequency and impedance bandwidth of the antenna decide its wireless application. Compact antenna design for UWB applications still faces a problem of interference from the existing narrow band wireless communication systems.

The research presented in this thesis is to study and develop a simple compact UWB antenna that covers the FCC specified UWB spectrum with band-notch characteristics. The UWB operating bandwidth is obtained with good impedance matching, in the designs of the monopole, slot, defected ground structure (DGS) and fractal UWB antennas. The investigation on the UWB antennas is carried out by designing novel approaches for achieving band-notch characteristics and segmentation of the wideband. To acquire an interference free UWB band, various band-notch techniques are implemented, viz. the use of extended ground plane, rectangular C-shaped ground plane, parasitically coupled patch, and open ended slots in the antenna geometry. The microstrip and co-planar waveguide (CPW) feed are the major feeding structures used to excite the radiating patch. The various antennas developed are detailed in chapter 4, 5, 6 and 7.

A CPW fed monopole antenna with a thin coplanar ground plane and pentagonal radiating patch, is designed to achieve the 7.5 GHz wideband operation. The wideband can be segmented into multiband using the extended ground plane and open ended slots technique. The band-notch structures are discussed with their equivalent circuits. A convex hexagon shaped CPW fed monopole UWB antenna is introduced for wide dual band operation.

A microstrip fed slot antenna with a pentagon shaped parasitic radiating patch and pentagonal shaped slot in the ground plane is deployed on the easily available FR4 substrate. The pentagonal shaped slot antenna is characterized by its compact size, and wideband operation. The development and investigation of a microstrip fed pentagonal slot antenna is carried out for bandwidth enhancement. A compact design of a convex hexagonal shaped tuning stub rectangular slot antenna is introduced with the novel concept of rectangular C-shaped ground plane as a notch filter. The ground plane variation is important in the slot antenna design and is studied for multiband operation in the UWB.

The concept of multi resonance for UWB operation is studied with the design of elliptically defected ground UWB antenna. The UWB is segmented into multiband with the use of open ended slits in the ground plane and a slot ring in the radiating patch. The UWB characteristic is also realized for the CPW feed pentagon fractal monopole antenna. An electromagnetically coupled parasitic patch as a novel band-notch structure is used for wide bandwidth segmentation of fractal monopole antenna.

All the UWB antennas are designed and their simulation performances are presented along with the experimental study with respect to impedance bandwidth, VSWR, and radiation patterns. The research work concentrates on the development of compact UWB antennas for multiband operation with band-notch characteristics.

1.2 Motivation

A revolution in the UWB technology took place after the spectral mask regulations were laid down by various national, international and government bodies. UWB technology has received significant attention recently for short range and high speed wireless communication. However, this technology can be utilized to its full potential only after overcoming the challenges faced by the UWB antennas.

The frequency independent antennas and impulse radiating antennas are rarely used in wireless mobile devices due to their high radiating power, high directionality, bulky size and cost constraints. The classical straight wire monopole antenna used for UWB systems has a broad bandwidth, typically around 10% - 20%, depending on the radius-to-length ratio of the monopole. Microstrip antennas are not suitable for UWB communication, because of their large size and coaxial feeding technique. The UWB applications created a demand for wideband, multiband, compact size and low cost antennas.

The various monopole and slot type wideband antennas recently developed [17]-[19], [68]-[70], [75], operate as dual or multiband for existing narrow band wireless applications viz. WLAN, Bluetooth, WiMAX and HIPERLAN/2. In this thesis, wide, dual and multiband monopole, slot, DGS and fractal type antennas are investigated using segmentation of the UWB spectrum for short range applications. To achieve the segmentation and remove the interference of existing narrow band applications, simple multiple notch structures are embedded into the antenna geometry. Recently, fractal antennas reported for multiband and UWB applications [134]-[139], used large physical dimensions, which made them difficult to integrate with the MMIC of UWB devices.

General shapes such as the circular, elliptical and rectangular shaped radiating patches can be used to achieve UWB characteristics. These antenna designs use notch filter for rejection of WLAN 802.11a (5– 6) GHz band [46], [49], [54], [109], [111] and [118]. But the potential interference occurring from other bands such as WiMAX and satellite uplink and down link frequency etc. in the UWB spectrum is required to be considered. The inherent notch-band features in the simple slot antenna and parasitic notch structure used in the fractal monopole antenna are versatile and make the antenna structure simple.

1.3 Problem Statement

With the advent and escalating growth of ultrawideband systems, wideband antennas find increasing applications in short range communication. The compact size and interference from existing narrow band communication systems are major challenges to the UWB antenna design. A compact UWB antenna design to generate multiple operating bands is desirable. Therefore the problem statement is to study, design and develop a compact UWB antenna with band-notch and multiple operating band characteristics for indoor wireless applications.

1.4 Objectives

To fulfil the requirement of UWB wireless gadgets, the antenna design must be compact with multi-operational characteristics. This research has identified the following objectives for study and development of UWB antennas;

I. To study and develop UWB antennas with respect to -10 dB impedance bandwidth, VSWR, gain (dBi), and radiation pattern.
II. To achieve ultrawideband (UWB) impedance bandwidth
III. To accomplish a compact size
IV. To convert the achieved UWB into multi-band operation
V. To reject potential interference of existing wireless narrow bands

The above objectives for UWB antennas will be achieved through the design of various Monopole Antennas, Slot Antennas, Defected Ground (DFG) Antennas and Fractal Antennas.

1.5 Expected Outcome

I. UWB Fractional bandwidth more than 20%
II. Antenna size reduction of 20% to 80% with respect to substrate dimension
III. Segmentation of UWB into dual or Triple band operation
IV. Wide notch band to minimize the interference of WLAN, WiMAX, and satellite communication systems

1.6 Methodology

1.6.1 Literature Review

- Literary review is adopted to understand the various types of wideband antenna designs.
- A detailed study of planar antennas investigated by several researchers for WLAN, WiMAX, multiband, wideband, UWB and frequency notch applications was carried out.
- From the literature review of the various antennas, observation and findings are noted for the development of compact segmented UWB antennas.

1.6.2 Modeling of an UWB Antenna

- Hypothetical model of an UWB antenna is developed based upon literature review.
- A hypothetical antenna model is subjected to simulation using 3D Electromagnetic Simulator: Ansoft HFSS v.11, to confirm its UWB and band-notch performance.
- The antennas are designed for multiple operating wide bands using band-notch structures.
- The center rejection frequency of the band-notch structure is determined from the antenna models.
- Surface current distribution is studied, to understand the UWB and frequency notch operation of the antenna.

1.6.3 Fabrication and Laboratory Testing

- Based on the simulation results, fabrication of antenna prototypes are undertaken at the laboratory level.
- The fabricated antenna prototypes are subjected to laboratory testing with the help of Vector Network Analyzer for reflection coefficient measurement and the anechoic chamber for radiation pattern measurement.

1.7 Organization of the Thesis

Chapter 1 introduces the entire research, and the organization of the thesis.

Chapter 2 presents the literature review of the Monopole, Slot, Defected Ground Structure and Fractal Antennas. Research survey is carried out for each of these antennas in the multiband, dual band, wideband, ultrawideband categories and band-notch based on applications for the IEEE standard 802.11a/b/g WLAN, WiMAX and IEEE 802.11.3a upper UWB band.

Chapter 3 deals with the background of UWB technology and systems, UWB standards, basic characteristics of UWB, advantages and benefits of UWB communication, and various wireless applications for indoor and outdoor environment.

Chapter 4 presents a novel approach for design and development of monopole UWB antennas with band-notch characteristics. This antenna uses an extended ground plane, and an open ended rectangular slot embedded in the ground plane, as well as in the radiating patch for band-notch characteristics to segment the UWB. This chapter contributes the design of coplanar waveguide (CPW) fed pentagonal and convex hexagonal shaped monopole UWB antennas with 3.5 GHz, 5.2 GHz 7.5 GHz and 8 GHz band-notch characteristics to avoid the potential interference of narrow bands .

Chapter 5 discusses the design of various slot antennas. The investigation of microstrip feed pentagon slot antenna for bandwidth enhancement is carried out. CPW feed convex hexagon and pentagon shaped tuning stub rectangular slot antennas are discussed for wide multiband operation using a novel concept of inherent frequency notch characteristic. The frequency notch avoids the interference of 802.11a WLAN and WiMAX respectively.

Chapter 6 deals with the design of the UWB antenna with defection in the ground plane and radiating patch for multi resonance and multiband operation. The bandwidth of Elliptically Defected Ground UWB antenna is segmented into multiband operation using band-notch characteristics at 3.5 GHz and 5.2 GHz to minimize the interference of WiMAX and WLAN.

Chapter 7 presents a design of CPW feed inscribed pentagon monopole fractal antenna for UWB operation. A novel electromagnetically coupled parasitic patch for designing the band-notch filter at 5.6 GHz is proposed and investigated for avoidance of potential interference from 802.11a WLAN.

Chapter 8 discuss conclusion and suggestions for future work.