Chapter 8

Conclusion and Future Scope

8.1 Conclusions

The study of planar Monopole, Slot, Defected Ground, and Fractal antennas has been carried out to achieve the research objectives. These UWB antenna designs are characterised by their compact size, multiple wide band, and multi band-notch functions. The study of the UWB antennas developed is with respect to impedance bandwidth, FRB, gain, and notch bandwidth. Their comparison is given in Appendix B. The proposed antenna designs are experimentally validated and have shown their performance enhancement in comparison with the earlier reported research.

The study and development of UWB antennas for wireless communication system performed in this thesis are summarised as follows;

In chapter 4, two monopole antenna designs namely CPW fed pentagonal shaped compact UWB monopole antenna (PSCUMA) and convex hexagonal shaped UWB antenna are discussed for ultra-wide operating bandwidth. The segmentation of the UWB of both antennas into either multiband or dual band is achieved by the band-notched antenna designs. The 10 dB impedance bandwidth of PSCUMA is 7.65 GHz (2.8–10.45), which corresponds to FRB of 115.47%. The measured bandwidth is 6.53 GHz, which corresponds to FRB 105.23%. The measured difference is due to the soldering effect, fabrication tolerance with small ground plane dimension and variation in dielectric constant of substrate. The potential interference of existing narrow bands at 3.5 GHz, 5.2 GHz and 7.5 GHz is minimized by designing triple band-notched PSCUMA using three open ended slots as notch filters. The 10 dB impedance bandwidth of the four operating bands is 594 MHz, 990 GHz, 1.12 GHz and 3.1 GHz respectively. The gain of four operating bands is 5.32 dBi, 2.53 dBi, 3.01 dBi, and 2.9 dBi respectively. The maximum gain of the triple band-notched PSCUMA is more by 4.94 dBi compared with the PSCUMA gain. Size reduction of 56%, 71% and 75.72% is achieved, as compared with the pentagon shaped monopole antennas discussed in [18], [21], and [22] respectively, with respect to the substrate dimension.

A compact CPW fed convex hexagonal shaped UWB monopole antenna design uses an extended thin ground plane for wide band operation. A vertical open ended slot 5.705 mm in length, embedded in a radiating patch rejects the interference occurring from X-band satellite communication downlink and uplink bands. The notch bandwidth is 1.8 GHz (6.47–8.27) GHz. It segments the UWB into two operating bands and has a 10 dB impedance bandwidth of 3.38 GHz and 3.40 GHz, which correspond to FRB of 69.54% and 33.83% respectively. The antenna gain at these two bands is 2.16 dBi and 6.5 dBi respectively. Compared with the triple band-notched PSCUMA, the gain of band notched convex hexagonal shaped UWB monopole antenna is more by 1.18 dBi. The wide notch bands of both the monopole UWB antennas eliminate the need for closely associated multi-notch bands. Both these UWB monopole antennas have group delay of less than 1ns, except at band notch frequencies and can be used for wireless indoor applications like WPAN.

In chapter 5, three slot antenna designs namely pentagonal slot antenna, convex hexagonal shaped stub rectangular slot antenna and pentagonal shaped stub rectangular slot multiband antenna are designed for UWB and multiband operation.

The first design of a vertex feed compact pentagonal slot antenna is investigated for bandwidth enhancement. The antennas' absolute bandwidth of 4.21 GHz (3.24–7.45) GHz is enhanced by 1.08 GHz and 2.01 GHz compared with the microstrip fed rotated square design [74] and square parasitic patch design [75] respectively. The size reduction with respect to the ground plane dimension of 87.24% and 54.34% is achieved when compared with [74] and [75] respectively. Antenna has a gain of 4.24 dBi with 70% efficiency. The group delay variation is almost flat and not exceeding 0.5 ns over the wide operating band. The antenna is suitable for wireless applications such as WiMAX, 802.11a WLAN and HIPERLAN/2 and customized indoor wireless applications.

Secondly, a new technique to obtain segmentation of UWB for various wireless applications using modified ground as the filter element is demonstrated in a convex hexagonal shaped rectangular slot antenna design. A rectangular C-shaped ground is used as a notch filter at 5.2 GHz. The convex hexagonal shaped rectangular antenna provides triple band operation. The segmented triple operating band has a -10 dB impedance bandwidth of 239 MHz (1.769–2.008) GHz, 2.2126 GHz (2.6527–4.8653) GHz and 5.5548 GHz (6.0–11.5548) GHz, which corresponds to FRB of 12.64%, 58.86% and 63.28%. The respective gain at these operating bands is 4.95 dBi, 1.47 dBi and 5.30 dBi. The notch band centred at 5.2 GHz bandwidth of 956 MHz, which covers 802.11b WLAN and HIPERLAN/2 band applications. The antenna gain as well as bandwidth of this antenna is enhanced in comparison with the vertex fed pentagonal slot antenna. The antenna design can be used for GSM-1900 (1850–1990) MHz, WiMAX (3.3–3.6) GHz and upper UWB (6–10) GHz applications.

The third design of a CPW fed rectangular slot antenna with pentagon shaped tuning stub is demonstrated for triple band operation using the effect of ground plane width variation. The segmentation of UWB into multi-band operation without use of any extra band-notch element in the antenna geometry, makes the antenna design simple. The three operating bands centred at 2.66 GHz, 5.27 GHz and 8.78 GHz has a gain of 7.5 dBi, 1.09 dBi and 5.28 dBi respectively. The VSWR bandwidth ≤ 2 of these operating bands is 620 MHz, 860 MHz, and 3.67 GHz, which corresponds to a FRB of 23.57%, 16.22%, and 43.76% respectively. The group delay variation is almost flat and does not exceed 1ns over the wide operating band. The antenna design can be used for WLAN and upper UWB applications.

In chapter 6, a microstrip fed EDG UWB antenna is designed for enhancement in the bandwidth and gain. Results shows that the antenna enriches the FRB of 150% and covers the FCC specified UWB band at (3.1–10.6) GHz. The antenna gain achieved in the broadside direction within the lower UWB spectrum is 8.7 dBi, while that in the upper UWB spectrum is 4.58 dBi. The designed microstrip fed EDG UWB antenna is further made compact by reducing the substrate size. Further, the UWB bandwidth is segmented by embedding dual notch bands across the UWB spectrum spaced at 3.5 and 5.2 GHz. The compact antenna provides an FRB of 150%. The defected ground (DFG) band-notched antenna rejects the interference of WiMAX and WLAN. It is observed that the group delay variations are within the 0.5 ns over the operating bands, except for the notch bands. Size reduction of 20.25%, 55.75%, 49.20%, and 87.59% has been achieved compared to the EDG UWB antenna, microstrip feed crescent and circular patch antenna [121], Printed Elliptical/Circular slot antenna [90] and E shaped slot antenna [76] respectively with respect to the ground plane dimension.

An novel design of a CPW fed Inscribed pentagonal fractal antenna (IPFA) is discussed in chapter 7 for UWB operation. The wide bandwidth (8.73 GHz) of the proposed IPFA is segmented into multi-band operation using an electromagnetically coupled pentagon shaped parasitic patch as a frequency notch element. The electromagnetically coupled IPFA generates two notch bands of bandwidth 1.01 GHz centred at 5.6 GHz and 820 MHz centred at 9.3 GHz, which rejects the entire 802.11a WLAN and lower X-band applications respectively. The maximum gain over the operating bands is 8 dBi and it reduces at notch frequencies. The electromagnetically coupled IPFA shows a size reduction of 76.65%, 83.23%, 20.72%, 90.22% and 76.85% as compared with [133], [134], and [137]-[139] respectively with respect to their substrate dimensions. The differences between the measured and simulated values are due to fabrication error, variation in dielectric constant and thickness of the available FR4 substrate.

The objectives of the research are attained through the design and development of various planar monopole, slot, DGS, and fractal compact antennas. Their mapping with the research objectives is given in Appendix C. All the antenna designs have shown performance in the UWB and multi-band characteristics with the FRB of each band of more than 20%. The fabricated UWB antennas also perform well to avoid the potential interference of existing narrow bands. The UWB antennas show novelty in the design of the radiating patch and band-notch structure for simple antenna geometry compared with the research in [42]-[44], [48], [55]-[57], [60], [62], [92], [93], [97]-[98], [94]. All the designed band-notched antennas show enhancement in gain as well as in notch bandwidth compared with antennas reported previously. The designed antennas have achieved size reduction as compared with earlier reported antennas with respect to their physical substrate dimension. The almost flat group delay with variation less than 1ns over the wide operating band except notch bands shows signal integrity and indicates phase linearity. The radiation patterns of the designed antennas are omni directional in H-plane and bidirectional with a figure of eight in the E-plane. The various antenna designs investigated in this thesis are compact in size and can be used for various indoor applications due to their multiband and wide band-notch characteristics over 3.1 GHz to 10.6 GHz. These antennas will be good candidates for short range WPAN applications.

8.2 Future Scope

Various types of compact UWB antennas have been designed, fabricated, and tested for UWB wireless applications in this thesis. Most of these antennas can be integrated with the MMIC of portable wireless devices. Therefore, as the antenna measurements in this thesis are conducted inside an anechoic chamber, investigation subject to the effect of various covering materials and devices on the resonant characteristics of the antenna need to be studied.

Another key requirement of UWB antennas is good time domain behavior, i.e. a good impulse response with minimal distortion. Studies can be carried out to investigate the antenna effect on the transmitted signal and improve the time domain behavior by optimizing the antenna configuration. Therefore study of group delay and phase of antennas needs to be investigated for identifying distinct nonlinear characteristics at the most resonant points.

This research work has illustrated prototypes of various compact UWB antennas. Further work can be carried out for the development of an UWB antenna array as a directional system with high gain for high-quality communication link.

Scattering effect is more in the case of fractal antenna with bends and corners than in the conventional microstrip. Since this type of antenna can be mounted on the aircraft and missile body, it is essential to study the backscattering characteristics of the fractal antennas to understand its probable usage in the defence sector, as the minimal backscattering RCS helps reducing the possibility of being detected.

Moreover, the designed UWB antennas find application in wireless personal communication systems and indoor wireless communication; hence, it becomes imperative to study the effect of antenna radiation on the human body.