7.
SUMMARY AND CONCLUSION

This chapter presents the summary and concluding remarks with major findings of the research work carried out by the author followed by scope for future work.

A broadband antenna is one of the essential components of any high speed wireless communication system because wide bandwidth of antenna enhances data transmission/reception rate. The broadband antenna not only provides high data rate but is also useful for multiple wireless services as well as radar and navigation applications. The antenna is the actual component which, transmits and/or receives electromagnetic wave of particular frequency or range of frequencies. The antenna, which provides acceptable performance over wide range of frequencies (bandwidth of 2:1 or more) is generally considered as broadband antenna. The invention and development of frequency independent antenna (FIA) providing a bandwidth of 40:1 or more gave impetus to broadband antenna technology. The frequency independent antenna can ideally provide infinite bandwidth but practically its bandwidth is limited. However, its lower and upper frequency limits are dependent on dimensions of the largest and the smallest elements. The longer antenna elements, which operate at lower frequencies increase the antenna size. In addition, FIAs are non-planar and balanced type of antennas, which require balun with proper impedance matching. Therefore, the research work presented in this thesis was initiated with the design and development of conventional non-planar trapezoidal toothed log-periodic antenna along with appropriate balun for its excitation. Thereafter, dielectric-loaded trapezoidal toothed log-periodic antenna was investigated for bandwidth enhancement without increasing the antenna size.

Though the non-planar unloaded/dielectric loaded trapezoidal toothed log-periodic antenna has many advantages, it suffers from certain limitations. This type of non-planar antenna is bigger in size and is not suitable for use in compact handheld devices. On the other hand, planar monopole antenna with partial ground plane is also a broadband antenna and has many desirable characteristics. It is compact in size and has low profile. It does not require balun. It can easily be mounted on planar surfaces and integrated with other circuit components. The planar antennas are very much suitable for modern communication systems due to the demand of compact, light weight devices which potentially serve multiple wireless services with higher data rate. Since past two decades, the broadband PMA has gained importance in the area of antenna technology due to its aforesaid inherent properties as well as suitability for ultrawideband (UWB) systems. The UWB technology is a promising technology for high speed wireless communication systems which became famous since the release of unlicensed UWB spectrum (3.1−10.6 GHz with power spectral density (PSD) limited to -43.1 dBm/MHz) for commercial use. Apart from many advantages like unlicensed UWB frequency spectrum, low power consumption and simple hardware, it also suffers from interference with standard narrowband communication frequency spectrums and multipath fading due to dense environment. The multiple-input-multiple-output (MIMO) technology combined with UWB offers high data rate with reduced multipath fading. The MIMO technology uses multiple input and output terminals that transmits/receive signals with specific diversity technique. It is almost impossible that all the signals arriving at a terminal are affected by same type of fading. Therefore, combining the signals with different fading characteristics may provide improvement in signal-to-noise ratio in multipath fading environment. Therefore, in the present thesis, an effort has been made to investigate planar broadband antenna with improved bandwidth. Further, some broadband MIMO antennas with/without band-rejection characteristics have also been explored. The antennas can find potential applications in broadband diversity systems and compact wireless communication systems designed to cover UWB along with Bluetooth spectrum.

At the outset, introduction to broadband antennas and modern communication technologies including UWB and MIMO technologies has been presented in this thesis. Initially, broadband antennas and its requirements have been discussed. After that, broadband antennas are classified as non-planar and planar antennas. Furthermore, a little detailed introductory description of conventional trapezoidal toothed log-periodic antenna in the category of non-planar broadband antenna and planar monopole antenna with partial ground plane and quasi-self-complementary antenna in the category of planar broadband antennas is given in this chapter.

After introducing the conventional broadband antennas in chapter 1, the literature survey on these antennas has been presented in chapter 2. At the outset, the evolution of broadband antennas starting from the early stage of development of modified dipole antenna to recently discovered compact planar antennas for modern communication systems is discussed. Thereafter, the literature review about the conventional broadband antennas studied in this thesis is presented in detail. It has been observed through the literature review that non-planar broadband antennas are important for such high speed wireless communication systems where high power handling capability is required and the antenna system is fixed, whereas the planar broadband antennas are promising candidates for compact handheld wireless communication devices that operate with high data rate. Subsequently, the scope for further performance improvement of both non-planar and planar broadband antennas in terms of bandwidth enhancement and compactness as well as suitability for modern communication technology like UWB MIMO is discussed.

The design and development of conventional trapezoidal toothed log-periodic antenna (TTLPA), dielectric loaded trapezoidal toothed log-periodic antenna (DLTTLPA) along with the proposed tapered microstrip line-to-coplanar strip line transition (MS to-CPS transition) and conventional microstrip-to-parallel strip balun used for excitation of the antennas have been discussed in chapter 3. The TTLPA with proposed tapered MS-to-CPS transition has been found to have wider bandwidth compared to TTLPA with conventional microstrip-to-parallel strip balun. Further, the effect of proposed transition on performance of TTLPA has been investigated. The metal TTLPA fed through proposed transition has been found to have -10 dB reflection coefficient bandwidth of 7.67:1 (0.9–6.9 GHz) and bidirectional radiation patterns both in E- and H-planes in middle range of its operating bandwidth. The shape of bidirectional radiation patterns gets distorted at frequencies on either side of the middle frequency range. In the second part of the chapter, DLTTLPA has been proposed and studied for the effect of dielectric loading on performance of metal TTLPA. The dielectric (Rogers RT/duroid 6010) of 5 mm thickness has been used for loading. The dielectric loading increases the effective length of the antenna thereby either reduces aperture size of antenna for same bandwidth or decreases its lower operating frequency for same aperture size. For this purpose, two metal TTLPAs and one DLTTLPA have been designed and their bandwidths are compared. One metal TTLPA has same aperture size as DLTTLPA while another metal TTLPA has same bandwidth as DLTTLPA. It has been found through comparison that the lower cutoff frequency is reduced by 1 GHz from 3.2 to 2.2 GHz, thereby bandwidth enhancement of 1 GHz is achieved through dielectric loading when aperture size of metal TTLPA and DLTTLPA are the same. Similarly, it has been observed that the dielectric loading reduces the aperture size of antenna when bandwidth of metal TTLPA and DLTTLPA are kept same. Though bandwidth enhancement or aperture size reduction of metal TTLPA occurs due to dielectric loading, it slightly increases the volume of antenna and distorts the radiation patterns of the antenna.

In chapter 4, a new flower-shaped planar monopole antenna with partial ground plane using two different kinds of feed configurations: CPW and microstrip line has been described. The flower-shaped patch has been designed in such a manner that its perimeter becomes larger as compared to conventional circular patch while the maximum radius of both the patches is kept same. The patch having larger perimeter should provide less lower cutoff frequency for the antenna because lower cutoff frequency is proportional to perimeter of patch. With this basic idea, proposed flower-shaped patch antenna has been studied. The input characteristics like bandwidth and lower cutoff frequency of CPW fed flower-shaped patch and circular patch antennas of similar dimensions have been compared. It has been found through comparison that the proposed flower-shaped antenna achieved less lower cutoff frequency and wider bandwidth as compared to circular patch antenna. The less lower cutoff frequency and increased bandwidth of the proposed antenna is due to its larger perimeter and multiple smaller segments present in the structure. In the second part of the chapter, proposed flower-shaped patch fed through tapered microstrip line supported by semi-elliptical ground plane has been investigated. The steps involved in the process of obtaining final configuration of feed and ground plane which support widest bandwidth among all configurations have also been discussed. Further, the input and far-field characteristics of MS-fed and CPW-fed flower-shaped patch antenna have been compared. It has been found through comparison that the MS-fed flower-shaped antenna provide wider bandwidth and higher efficiency as compared to CPW-fed flower-shaped antenna due to weaker leakage current between ground plane and the patch. The radiation patterns and gain-frequency characteristics are similar for both the antennas. Owing to the enhanced bandwidth of 2.3−13.6 GHz and higher total efficiency of more than 80 %, the MS-fed flower-shaped antenna has been found to be better than CPW-fed flower-shaped antenna.

In chapter 5, castor leaf-shaped quasi-self-complementary antenna (QSCA) and its MIMO configurations with and without band-notch characteristics have been investigated. Initially, the castor leaf-shaped QSCA with sharp and smooth corners have been designed and compared in terms of bandwidth and size. It has been found through comparison that the QSCA with smooth corners is compact in size than QSCA with sharp corners while the lower cutoff frequency is same for both. Further, two-element MIMO antenna has been designed by placing two QSCAs in side-by-side arrangement. It has been observed that this MIMO antenna provides wide bandwidth of 5.95:1 over the frequency range 2.2−13.1 GHz and its ports are well isolated with isolation of more than or equal to 15 dB without using extra isolation technique. Over the aforesaid frequency range, the antenna is well suited for UWB along with Bluetooth application. The narrowband wireless communication services such as WiMAX and WLAN with centre frequencies of 3.5 and 5.5 GHz respectively have overlapping frequency bands with UWB. These interfering bands are rejected using a slit and hexagonal split ring slot

(HSRS), which are loaded on patches of MIMO antenna. The resonators trap the energy at their resonating frequencies and do not allow significant radiation over interfering bands. The radiation pattern is directional in the antenna plane in the direction of excited patch. Therefore, good diversity performance with reasonable gain and efficiency has been observed over the operating frequency band of the MIMO antenna.

In chapter 6, a two-port MIMO antenna with single patch also known as shared aperture or co-radiator has been described. The proposed shared radiator MIMO antenna has been found to provide broad bandwidth and low mutual coupling between the ports over the frequency range 2.4−12.75 GHz, which covers UWB along with Bluetooth frequency spectrum. Low mutual coupling has been achieved with the help of end-loaded meander line stub attached to ground plane without creating any slot in the shared radiator. The proposed shared radiator MIMO antenna exhibits good realized gain, total efficiency and good diversity performance (ECC < 0.005) over its operating frequency spectrum. Further, the proposed antenna has been found to be compact than many such antennas reported in the literature. Owing to these inherent properties, the proposed low-profile compact MIMO antenna may find usability in broadband diversity systems and compact wireless communication systems requiring UWB along with Bluetooth spectrum.

Future work may be carried out on the aspects discussed below. The tapered MS-to-CPS transition presented in chapter 3 provides wider impedance bandwidth but balanced condition is not achieved over the whole impedance bandwidth of the antenna thereby distorting the bidirectional radiation pattern of TTLPA. Therefore, a balun is required which provides impedance matching as well as balanced condition over the whole frequency range of interest. It would help in the design of a broadband antenna, which retains the desired input and radiation characteristics over its whole operating frequency band. Further, dielectric loading of the TTLPA enhances the bandwidth or reduces the size of the antenna but it distorts the radiation pattern and degrades the efficiency of the antenna. Therefore, some artificial materials may be utilized for improving the radiation characteristics of antenna. Furthermore, reconfigurable techniques may be utilized to further improve the diversity performance of broadband MIMO antennas.