CHAPTER 7

CONCLUSION AND FUTURE WORK

7.1 CONCLUSION

In this research, UWB compact BPFs, single and dual notch filters, reconfigurable filter are developed in microstrip line using PCB technology. In addition, an IIR based digital notch filter is also designed. These filters are designed and developed with the following main goals:

- To cover the entire UWB range with the FBW more than 110%
- To attain the lower scattering losses and constant group delay
- To achieve rejection at the presence of 2.4 GHz and 5 GHz WLAN services (IEEE 802.11a/b)

There are eight new compact BPFs are proposed and developed in accordance with UWB specification. The operations of the developed filters are verified at the chosen frequencies in terms of insertion loss, return loss and group delay using SNA. The size of the developed filters is smaller than the filters reported so far in the literature.

Also, Five UWB BPFs with notch band(s) are proposed and developed to effectively suppress the interference from narrowband services namely, IEEE 802.11a/b, when they coexist. Simulated characteristics of developed notch filters are verified with measured results.
For the reason that there is no global standard or policy for the allocation of UWB spectrum, any interference-mitigation technique developed must have been designed to meet the needs of the different markets. In this connection, a reconfigurable UWB filter is proposed, developed and tested. The measured results are in good agreement with simulated results. Also, a digital notch filter with IIR concept is designed with the UI of customizing notch bands to effectively suppress IEEE 802.11a which is the prime interferer to the UWB systems.

The novelty and significance of these developed filters are listed below:

**UWB bandpass filters:** There are many number of UWB filters designed and developed in this research work using different coupling schemes such as interdigital coupling, parallel coupling, broadside coupling and dual line coupling with various MMRs, namely, discoid, hexagonal, ellipsoid and ring resonators. Though all of the developed filters provide optimal performance in terms of the functional parameters insertion loss, return loss, group delay, phase, and FBW, only eight UWB BPFs have shown significant improvement, hence they are presented in detail in this thesis.

Filters are developed based on interdigital coupling with different MMRs such as discoid, hexagonal and ring. The Type-I filter is developed using discoid resonator with interdigital coupling at both sides. The interdigital coupling is used instead of direct coupling for the reason of strong coupling and to introduce the capacitance effect to obtain wide passband.

Type-II filter consists of feed lines, coupling gaps, and hexagonal structure. The signal power is coupled into and out of the resonator through feed lines and coupling gaps. If the distance between the feed lines and the resonator is large then the coupling gaps do not affect the resonant frequencies of the hexagon.
Type-III is designed using ring resonator with interdigital coupling. The multiple coupled line structure is incorporated with MMR to provide wide passband and improve other performance characteristics of the filter. Type-IV is designed using a dual line coupling structure. The novelty in the filter geometry is the introduction of a wire between the input port to output port through the ring resonator and also two rectangular slots in the resonator for producing series resonance to enhance the flat passband.

Then, the filter based on parallel coupling structure is proposed and developed for different gap size for the end resonators. They consist of transmission line sections having the length of half wavelength at the corresponding center frequency. Half wavelength line resonators are positioned so that adjacent resonators are parallel to each other along with half of their length. This parallel arrangement gives relatively large coupling for the given spacing between the resonators, and thus, the filter structures are particularly convenient for constructing filters having larger bandwidth compared to other structures.

A BPF based on parallel coupling and broadside coupling is designed in LTCC which is suitable for short range UWB applications. Fifth order Chebyshev filter of 0.05 dB passband ripple is designed. In addition, a compact UWB microstrip BPF with wide passband is developed and tested. This filter is developed based on modified MMR, which is formed by transversely attaching three pairs of non-uniform and folded stubs with lowpass and highpass sections. Both sides of the high impedance section are linked with two feed lines via direct coupled lines, resulting UWB BPF.

**UWB filter with notch characteristics:** UWB filters with the capability of suppressing interference from the neighboring and overlapping narrow band systems are developed in this module. Single band and dual band notch filters are developed which are derived from the elemental filters. BPFs with single
A notch band is realized in order to suppress the prime interferer 5 GHz WLAN using interdigital coupling with different MMRs such as discoid and hexagonal. These filters are aimed to suppress the entire band of 5 GHz WLAN. In terms of performance, both filters are good enough to suppress WLAN components. BPF with single notch band using hexagonal MMR has high rejection band 10.97% than the filter with discoid MMR.

Further, BPFs are designed with two notches to remove a particular operating band of WLAN. The dual notch filter is developed using the ring resonator and prolate ellipsoid filter rejects lower (5.15-5.35 GHz) and upper (5.725-5.825 GHz) band of WLAN. We suggest prolate ellipsoid filter as the best choice to integrate with the UWB systems, since it has better attenuation level at requisite band than the filter with ring resonator.

UWB BPF with two notch bands for avoiding interference between the UWB radio system and the NB systems is also designed and developed. This novel UWB dual notch filter is based on a microstrip structure which consists of ring resonator and interdigital coupling (Type-III). The dual notch band operation is implemented by integrating folded stubs in the interdigital coupled microstrip conductors. This structure generates two distinct resonant frequencies to stop 2.4 GHz and 5 GHz WLAN services. The resonance of each stub introduces a narrow rejection band in the UWB passband which then results in dual notch bands.
**UWB reconfigurable filter:** UWB, which is an unlicensed system, coexists with other licensed and unlicensed narrowband systems. To effectively utilize and to meet the different conditions of notch bands by different standards, a reconfigurable UWB filter is required. Hence, the proposed elemental filter (Type-III) is used to develop a reconfigurable filter and detailed studies are carried out. Reconfiguration of the notch bands are achieved by using a pair of PIN diodes at folded open stubs and this method is simple and unique.

**IIR based digital UWB filter:** Typically, IEEE 802.11a operates in three frequency regions in the 5-6 GHz band which is said to be potential interferer to the UWB system. It is highly impractical to have all three WLAN services operating within a small geographical location such as an office or a college campus. At such places, it is a mere waste to eliminate the transmission in all three frequency regions. A digital UWB filter to notch IEEE 802.11a narrowband service, based on user’s choice is discussed in this module.

A digital IIR filter is designed to remove the interference caused. The prototype chosen for the filter design is Chebyshev Type-II. The objective, here, is to pass the UWB spectrum and then to notch out the WLAN service. The filter is designed to cover the entire UWB spectrum (3.1-10.6 GHz) and efficiently notches the 5 GHz WLAN with steeper notches with nearly 40 dB attenuation. The notches can be customized by the user for 5.2 GHz, 5.3 GHz or 5.775 GHz or any other combination of the mentioned frequencies depending upon the prevailing WLAN service. The filter design is concatenated in such a way that it may allow any modification in the elimination of any band in future.

Other than the digital filter, all of the above filters are optimally designed using the electromagnetic (EM) simulator IE3D, which is part of the
Zeland software package. The proposed filters are fabricated using FR4 substrate with a dielectric constant of 4.4 and thickness of 1.6 mm and it is characterized by measuring return loss, insertion loss, and group delay. The measured results are noticeably good agreement with the simulation results. Digital filter is designed using MATLAB.

7.2 SCOPE FOR FUTURE WORK

Based on the conclusion and limitation on the research work discussed in this thesis, the following future work can be further investigated:

- Being an unlicensed service and offering a very wide bandwidth (and hence, very high data rate), the true potential of UWB technology has barely been scratched up on. The work presented in this thesis can serve as a basic guide for beginners to get involved with the technology; the major issues in developing filters and the methods of overcoming NBI suppression using filters can be considered

- Further research may be focused on reducing the interference from other services like PCS, Wi-Fi, WiMAX, HiperLAN etc rather 2.4 GHz and 5 GHz WLAN band services

- Studies should be carried out to find new techniques for further size reduction of the filter to hold it into the compact wireless UWB devices
• In continuation to the work presented here, the digital filter simulated using MATLAB can be translated into physically realizable filter (by fabricating it using any one of the existing technologies, say microstrip) and the response of the fabricated filter can be studied

• Furthermore, the idea of introducing a User Interface before the filter (at the receiver front-end) has not been attempted before and it will be a great path, to implement it in real time, for those minds that are challenge seeking

• A step ahead, the inquisitive mind can also aim to merge technologies like USBs or Bluetooth with UWB technology, so that in the real world, the data transfer experience is enhanced in positive note