Chapter 1

Introduction

1.1 Background

Bandpass filter (BPF) is one of an important role in Radio Frequency (RF) or microwave systems. Applications can be found in any type of microwave communication, radar, or test and measurement systems. Historically BPFs have been developed massively due to their functions. The first study of filter theory and practice was in the years when the World War II happened (Pozar, 2005)**.** The beginning of designing modern filters was started when Dishal proposed an exhaustive design guidelines for narrowband filter design based on the external quality factors, coupling resonance, and the resonant frequency of resonator (Dishal, 1951).

The main function of BPFs is for limiting or selecting the assigned spectrum of RF/microwave signal. Due to the massive development of RF/microwave systems such as multifunctional wireless communications, the challenge of designing the system is dramatically increased. It poses more strict requirements including smaller size, lighter weight and lower insertion loss. Moreover, filters with a multiband response are highly needed because of the rapid development of multiband and multiservice communication systems.

Modern communication system demands a BPF that has a high selectivity, good stopband rejection and miniaturized size. The transmission zeros (TZs) are required to enhance the frequency selectivity and improve a great stopband rejection effectively. Some efforts have been done to obtain the TZs. Some advanced techniques have been adopted to obtain the TZs, such as cross-coupling (Hong, 2000), separate electric and magnetic coupling (SEMC), and mixed electromagnetic coupling. A mixed electromagnetic coupling has been obtained by combining two coupled resonators with a maximum magnetic field and their maximum electric fields from the open gaps accurately. The coupling coefficient of mixed electromagnetic coupling can be obtained by adjusting the open gaps and the distance between resonators. The SEMC brings out both the electric and magnetic coupling in separated paths. The electric coupling is created by the resonator gap and the magnetic coupling is obtained by using a via hole without additional resonators.

1.2 Motivation

Recently, there has been a tremendous increasing interest in multilayer BPF to meet the challenges of size and requirements. Various researches about BPFs have been proposed, such as multiband and tunable BPFs, for multi-standard communication systems. One of the techniques is to introduce the TZ to achieve an excellent band rejection. To diminish the undesired interference or noise in the stopband, it is usually desired for a BPF to have a wide stopband.

Moreover, the physical dimension of passive components poses a bottleneck to minimize the system size, because shrinking the component size will significantly affect the overall module or package volume. Nowadays, most conventional microstrip BPFs are primarily based on transmission line structures. since the filters get the resonance by using the quarter- or half-wavelength transmission line, these filters require larger area. Some other studies propose novel structures to reduce the filter size, they are stepped impedance resonator (SIR), defected ground structure (DGS) resonator, patch-via-spiral resonator, and net-type resonator.

In the other hand, the design of filter should be able to integrate multiple communication standards into a single chip. Thus, many researches have been done to develop multiband BPFs. The development of multiband BPFs has been gaining much attention for multiservice wireless communication systems, such as Local Area Network (WLAN), IEEE 802.16, even for the proposing 5G communication systems. Multiband BPFs become important building blocks and deeply demanded. It is challenging for designers to implement a multiband BPF with low insertion loss, small size, and good selectivity.

1.3 Structure of Contribution of Thesis

This master thesis focuses on the design and fabrication of miniaturized BPF, single and double substrate using FR-4 and RT Duroid 6010 with dielectric constant of 4.4 and 10.2 respectively. Chapter 1 introduces the research background and motivation that form the basis to initiate this investigation. Chapter 2 gives a thorough review of microwave BPF theory and applications. Chapter 3 explains a detailed BPF design and its properties. Moreover, there is a discussion of the multilayer design techniques and multiband BPF performance. In this mater thesis, there is also a disclosure of simulation and measurements results including the return loss, insertion loss, bandwidth, and TZ position. The simulation results were obtained from the HFSS software and the measured ones were taken from a Performance Network Analyzer (PNA). There is also an introduction of recent researches about multiband BPFs to compare the proposed design with the counterpart designs. Chapter 4 presents the summary of this work.

In this thesis, there are several contributions to the novelty of multi-band BPF design. For instance, additional via holes and ring slots are used to shift the TZs of the BPFs to lower frequencies. Accordingly, we can adjust the TZs without changing the resonator structure. Moreover, multilayer structure is applied to reduce the size of multi-band BPFs significantly. It is easy to control the coupling coefficients between multilayer resonators to meet the bandwidth requirements for multiple passbands because the tuning of these coefficients on an individual layer can affect the specific passband.