TUNABLE COMBLINE BANDPASS FILTER

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ABSTRACT

This project presents the design of tunable combline bandpass filter. Nowadays, common filter are fixed at certain frequency, so it will be fixed for the fixed applications. To overcome these limitations, electronically tunable filters with fast tuning speed and narrow bandwidth are required for many applications including electronic surveillance system and some wireless communications systems that use multi-channels. In this work, integrated tunable filters using microstrip line resonators are investigated. Filters with low loss, high tunability and small size are designed. The design is based on the combline regarding to the Chebyshev response. The initial procedure involves the development of a low pass prototype with cross couplings between non-adjacent resonators. This frequency is presenting for wireless LAN application and operates in the ISM (Industrial, Scientific and Medical) band which is covering from 2.4 GHz to 2.4835GHz. There are several steps to design this filter that are including by determine filter specifications, order of filter, low pass filter prototype elements, low pass to band pass transformation, physical dimension (width, spacing, length) and wavelength guide.. The explanation details for design procedure, simulated results, methods and techniques are discussed in this report.

ABSTRAK

Projek ini melibatkan rekabentuk penapis *combline* yang dapat ditala frekuensinya. Kini, penapis selalunya beroperasi pada frekuensi yang tetap sahaja, yang di mana aplikasinya juga tetap pada frekuensi yang tertentu. Bagi mengatasi aplikasi terhad pada sesuatu frekeunsi ini, penapis yang dapat mengubah jalur frekuensi pada kadar yang tertentu direka dengan kelajuan ubahan yang tinggi dan lebarjalur yang luas. Ini adalah bertujuan untuk mendapatkan aplikasi yang pelbagai dengan perubahan lebarjalur yang berbeza.Penapis dengan kehilangan yang sedikit dan saiz yang kecil direka. Rekabentuk ini adalah berdasarkan kepada penapis *combline* yang menggunakan sambutan Chebyshev. Frekuensi jalur penapis ini juga adalah untuk aplikasi LAN tanpa wayar dan beroperasi dalam jalur ISM di mana ia merangkumi frekuensi dari 2.4GHz ke 2.4835GHz. Kaedah pengiraan mempunyai beberapa langkah-langkah untuk mereka bentuk filter ini, di antaranya adalah menentukan spesifikasi penapis, bilangan peringkat, penukaran lulus bawah ke lulus jalur, elemen penapis lulus bawah prototaip, dimensi fizikal (lebar, jarak dan panjang) dan panjang gelombang berpandu. Simulasi EM (Elektromagnetik) pada rekabentuk adalah lengkap dengan menggunakan perisian Microwave Office dan dianalisis. Sebarang penerangan secara terperinci terhadap prosedur untuk proses rekabentuk, keputusan simulasi, kaedah dan teknik telah dibincangkan dalam bahagian laporan ini.

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LIST OF ABBREVIATIONS

SYMBOLS	DESCRIPTION
W	Width
h	Dielectric thickness
t	Copper thickness
ε_{-}	Dielectric Constant
Z_o	Characteristics impedance
Δ	Fractional Bandwidth
w/h	Width-to-height ratio
IEEE	(Institute of Electrical and Electronics Engineering)
WLAN	Wireless Local Area Network
MW2004	Microwave Office 2004
FR4	Frame Resistance 4
BW	Bandwidth
fo	Center Frequency
f_L	Lower Cut-off Frequency
f_H	Higher Cut-off Frequency
Z_{in}	Input Impedance
Z_o	Characteristics Impedance

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Tunable combline filters are broadly used as bandpass filter in modern microwave and millimeter wave subsystem due to their compactness, excellent stop band, selectivity performance and ease of integration [4]. It has been investigated for insertion in multifunctional multiband RF and microwave systems. Compared to a bank of fixed filters, a tunable filter promises greater functionality, better channel selectivity, reduced size, and lower weight since the same hardware can be employed at multiple bands. To assure constant filter response shape and bandwidth, coupling coefficients must vary inversely with the tuning frequency[5] If they were built on microstrip, it makes them more attractive for mobile communications cause of very low cost and small size can be achieved. Meanwhile in 2002 and 2003, WLAN products supporting a newer standard called 802.11g began to appear on the scene. 802.11g attempts to combine the best of both 802.11a which support for transferred data to 54Mbps and 802.11b operating at frequency 2.4GHz frequency for greater range to design tunable filter using microstrip substrate which operated in 802.11g frequency range would be discussed in this thesis. Microstrip transmission line is a circuit that has been reduced in size with integrated semiconductor electron devices. The advantages of microstrip have been well established and it is convenient form of transmission line structure for probe measurements of voltage, current and waves.

Microstrip is a nickname for a microwave circuit configuration which is constructed by printed circuit techniques modified where necessary to reduce loss, reflections and spurious coupling but retaining advantages in size, simplicity, reliability and cost which such production techniques afford. Microstrip shares some of the troublesome properties of dispersive waveguide, in that conductor dimensions influence not only characteristics impedance but also the velocity of propagation, also in that, on structures which support propagation in more than one mode, the velocities of the modes are in general unequal.

1.2 Project Background

Microwave filters used to control the frequency response in Radio Frequency, RF and microwave. It is a device which is allowing the transmission at frequency within the passband of the filter and attenuation within the stopband of the filter. Usually in a bandpass filter, it will be operated in one frequency centre, within one range of frequency depends on its bandwidth within the passband and stopband. By tuning the frequency, the filter could be operated for more than one frequency range by different frequency centre [1]. There are two types of tunable filters that are commonly designed it is from mechanically and magnetically tunable microwave filter or electronically tunable microwave filter.

These microwave filters is the basic building blocks with frequency-selective or filtering functionality in the development of various wireless systems that operate at frequency ranges 300MHz.Electronically tunable microwave filter have wide application in modern devices application. Tunable frequency filters are often used as tracking filters for multiband telecommunication systems, radio meters and wideband radar system. Typically, tracking filters are mechanically tuned by adjusting the cavity dimensions of resonators or magnetically altering the resonant frequency [5]. An alternatives to design tunable filter, is using varactor diode and tune the filter electronically. In the case of this project, to design tunable combline bandpass filter tuning by silicon diode component would be discussed.

1.3 Problem Statement

Typically, tracking filters are mechanically tuned by adjusting the cavity dimensions of resonators or magnetically altering the resonant frequency [5]. Neither these approaches can easily by miniaturize or produced in large volumes for wireless communications products. An alternatives to mechanically and magnetically tuned for filter, is electronically tunable filter using varactor diode an electronics components. Moreover, the need of flexibility in commercial and military radio frequency application demands the use of high performance electronically tunable filter with high tuning speed and broad tuning range.

1.4 Objectives

The objective of this project is to understand the concept of tunable microwave filter. Other than that, its purposes are also to design and simulate the design using the RF Microwave simulation software Microwave Office.

1.5 Scopes and Work

Scopes for this project is designation of tunable bandpass combline filter based on detain frequency that we required. Besides, the scopes of this project are the simulation by using the Microwave Office. Before it, the calculation of the required parameters is to be search. Last but not list, these project scopes and work is by analyzing by comparing between the basic combline filter and tunable combline filter.

1.6 Methodology

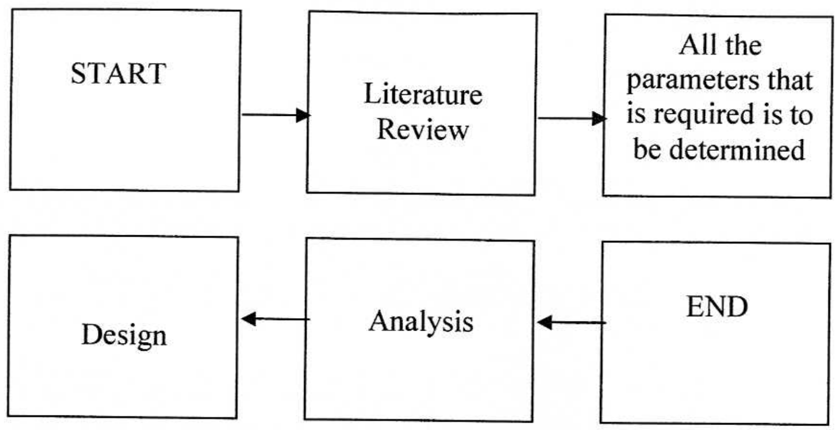

Figure 1.1: Flow Chart of the Project Methodology

This project will involve 4 steps that should be follows:

a. First Phase (Literature Review)
Find the information about the project and to study on filter theories and understanding fundamentals for microstrip structure design which is focusing in combline bandpass filter.

b. Second Phase (Determination of appropriate software)
MathCAD 14 has being chosen as calculation software and Microwave Office as the simulation software
Study on the software

c. Third Phase (Calculation and Analysis)
Determine appropriate formula to be use in order to get all the parameters in designing the combline bandpass filter.

d. Fourth Phase (Software Implementation)
MathCAD 14 software for calculation
Microwave Office software is being used to do simulation analysis and designing filter and to obtain the precise value using this software.

CHAPTER II

BACKGROUND OF STUDY

2.1 WLAN (Wireless Local Area Network)

A wireless LAN or WLAN is simply a local network that doesn't rely on wired Ethernet connections. A WLAN can be either an extension to a current wired network or an alternative to it. A WLAN adds flexibility to networking. A WLAN allows users to move around while keeping their computer connected, without having to depend on Ethernet cables.

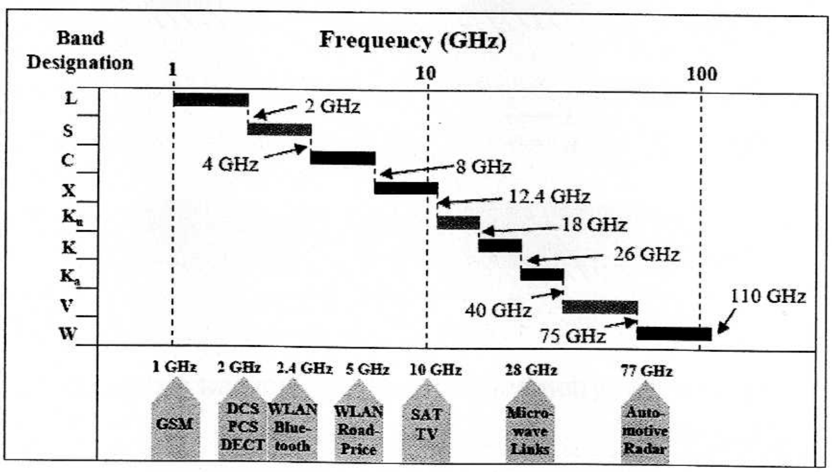

Fig 2.1: Band Designation and applications of microwave

2.2 Definition of microstrip

The microstrip lines is the planar transmission line that are using in distribute high frequency GHz [8]. Hence, more important dimension is width w, height dielectric material h and relative coefficient dielectric ε_r. The width of layout microstrip is too small and can ignore it. dielectric layer. It is used in printed circuit designs where high frequency signals need to be routed from one part of the assembly to another with high efficiency and minimal signal loss due to radiation. They are of a class of electrical conductors called transmission lines, having specific electrical properties that are determined by conductor width and resistivity, spacing from the ground plane, and dielectric properties of the insulating layer. A microstrip transmission line is similar to a stripline, except that the stripline is sandwiched between two ground planes and respective insulating layers. Microstrip can also be designed to launch electromagnetic waves into space, in which in this case it is called microstrip antennas

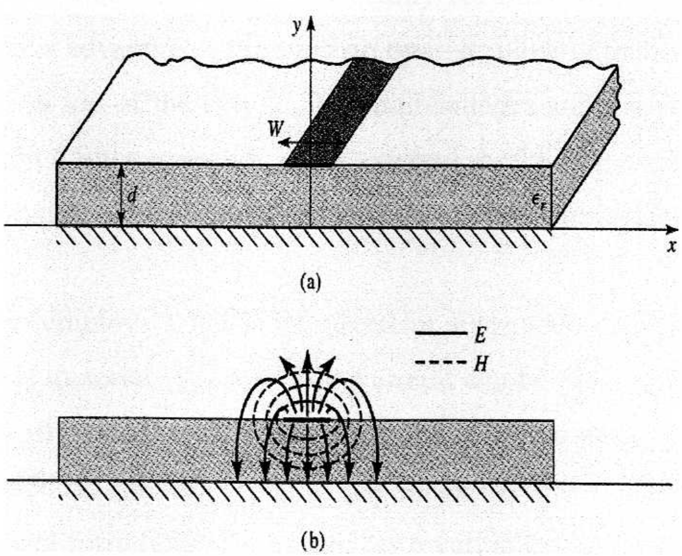

Figure 2.2 : Microstrip transmission line. (a) Geometry. (b) Electric and magnetic field lines

The main problem here for microstrip filter synthesis is to find parameter values such as the width w, element of length L and electrical length that are matching with impedance characteristics at the stage. Which,

L = element of length
w = element of width
h = element of dielectric height
t = element of width microstrip

2.3 Overview of microstrip

Microstrip transmission lines consist of a conductive strip of width (W) and thickness "t" and a wider ground plane, separated by a dielectric layer (a.k.a. the "substrate") of thickness "H" as shown in the figure below. Microstrip is by far the most popular microwave transmission line, especially for microwave integrated circuits and MMICs. The major advantage of microstrip over stripline is that all active components can be mounted on top of the board. The disadvantages are that when high isolation is required such as in a filter or switch, some external shielding may have to be considered. Given the chance, microstrip circuits can radiate, causing unintended circuit response.

Microstrip employs a flat strip conductor suspended above a ground plane by a low-loss dielectric material. The size of the circuit can be reduced through the dielectric constant some 2-10 times that of free space (or air), with a penalty that the existence of two different dielectric constants (below and above the strip) makes the circuit difficult to analyze in closed form (and also introduces a variability of propagation velocity with frequency that can be a limitation on some application.

Table 2.1: Symbol guideline from Figure 2.1

Abbreviation	Meaning
w	Width
s	Space
l	Length
ε_r	Effective Dielectric Constant
H	Height
tan δ	Tangent Loss
T met	Thickness of metal
GND	Ground

The advantages of microstrip have been well established and it is a convenient form of transmission line structure for probe measurements of voltage, current and waves. Some of the particularly useful characteristic of microstrip is include the following: 1) DC as well as AC signals may be transmitted, 2) Active device, diodes and transistors may readily be incorporated (shunt connections are also quite easily made),3) In circuit characterization of devices is straightforward to implement. 4) Line wavelength is reduced considerably (typically by one-third) from its free space value, because of the substrate fields. Hence, distributed component dimensions are relatively small.5) The structure is quite rugged and can withstand moderately high voltage and power levels. Microstrip structures are also used in integrated semiconductor form, directly interconnected in microwave integrated circuits. When two conductors of a coupled line pair are identical, we have a symmetrical configuration as shown in Figure 2.1. This symmetry is very useful for simplifying the analysis and design such a coupled line. If the two lines do not have the same impedance, the configurations called asymmetric.

The effective dielectric constant (ε_r), of a microstrip line is given approximately by [10]

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12\left(\frac{d}{w}\right)}}\right) \tag{2.1}$$

The effective dielectric constant (ε_r) can be interpreted as the dielectric constant of a homogeneous medium that replaces the air and dielectric regions of the microstrip given the dimensions of the microstrip line. The characteristics impedance (Z_o) can be calculated as [10];

$$Zo = \begin{cases} \dfrac{60}{\sqrt{\varepsilon_{eff}}} In\left(\dfrac{8h}{w} + \dfrac{w}{4h}\right) & \text{For w/h < 1} \\ \dfrac{120\pi}{\left[\dfrac{w}{h} + 1.393 + 0.667 In\left(\dfrac{w}{h} + 1.444\right)\right]\sqrt{\varepsilon_{eff}}} & \text{For w/h > 1} \end{cases} \tag{2.2}$$

2.3.1 Substrate Materials.

Important qualities of the dielectric substrate include

a. The microwave dielectric constant
b. The frequency dependence of this dielectric constant which gives rise to "material dispersion" in which the wave velocity is frequency-dependent
c. The surface finish and flatness
d. The dielectric loss tangent, or imaginary part of the dielectric constant, which sets the dielectric loss
e. The cost
f. The thermal expansion and conductivity