COMPACT MICROWAVE HAIRPIN LINE BAND PASS FILTER USING FOLDED QUARTER-WAVE RESONATOR

SAMSUL HAIMI BIN DAHLAN

UNIVERSITI TEKNOLOGI MALAYSIA

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Pelajar Samsul Haimi Dahlan telah melaksanakan projek penyelidikan Sarjana di bawah penyeliaan saya.

Wassalam.

"BERKHIDMAT UNTUK NEGARA"

Yang benar,

PROF. MADYA DR. MAZLINA BINTI ESA
Jabatan Kejuruteraan Perhubungan Radio
Fakulti Kejuruteraan Elektrik
b/p Dekan
☎ : 07-5535262
e-mel : mazlina@fke.utm.my

" I hereby declare that I have read this thesis and in my opinion it is sufficient in terms of scope and quality for the award of the degree of Masters of Electrical Engineering (Electronics & Telecommunications)"

Signature	:	....
Supervisor's Name	:	Dr. Mazlina bt. Esa
Date	:	MARCH 2005

COMPACT MICROWAVE HAIRPIN LINE BAND PASS FILTER USING FOLDED QUARTER-WAVE RESONATOR

SAMSUL HAIMI BIN DAHLAN

A project report submitted in partial fulfillment
of the requirement for the award of the degree of
Masters of Electrical Engineering
(Electronics & Telecommunications)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

March, 2005

I declare that this thesis is entitled " Compact Microwave Hairpin Line Band Pass Filter Using Folded Quarter-Wave Resonator" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature for any other degree.

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For my Mom, Wife, beloved son Akmal Safiy, my little angels Nina, Harith, Irsya, Amirul, Ilham and Sara. To Ajan, Kak Jie, Aca, Kak Nim and Ayu…

I am wealthy beyond measure because I have you all around

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ABSTRACT

Compact microwave hairpin band pass filter using half-wavelength folded resonator as a method to miniaturize resonator structure has been thoroughly studied in this thesis. Design were done by using the mathematic formulas and verified by using *SONNET LITEPlus* 8.0 software. Synthesis of the filter is using the insertion loss method. The initial design of a miniature hairpin filter was achieved by carefully selecting the resonator shape and the initial frequency. The shape was then fine tuned, and the response for the changes was plotted. This would indirectly represent the behavior of the circuit when parameter variation occurs. The step by step procedure to design the filter is presented. The design performance and characteristics in terms of electrical and physical parameters were compared with the conventional hairpin filter. The final design of the miniaturized hairpin filter has an overall size of 46% smaller compared to the conventional hairpin size. Better return loss properties were also observed from the miniaturized version. The first spurious frequency occurs at a higher frequency compared to that of the conventional hairpin filter. It is tunable depending on the value of the even-mode impedance that was chosen at the early stage of the design process. The bandwidth, however, was slightly narrower, which is 80% of the desired100 MHz. In terms of the response, miniaturized hairpin filter is having steeper skirting. However, it is comparable to that of the conventional hairpin filter.

ABSTRAK

Rekabentuk akhir penapis pin rambut model kecil mempunyai saiz keseluruhan yang 46% lebih kecil berbanding saiz pin rambut konvensional. Ciri kehilangan kembali yang lebih baik diperolehi. Frekuensi spurious pertama wujud pada nilai yang lebih tinggi. Ini pula boleh dilaraskan bergantung kepada nilai galangan mod genap yang telah dipilih pada peringkat awal proses rekabentuk. Walaubagaimanapun, lebar jalur adalah sempit sedikit iaitu 80% daripada lebarjalur yang dikehendaki iaitu 100 Mhz. Cerun sambutan pula lebih curam.Namun, ini sebanding dengan penapis pin rambut konvensional.

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LIST OF SYMBOLS

BW	-	Bandwidth
C	-	Capacitance
F	-	Fractional bandwidth
f_i	-	Initial frequency
f_o	-	Centre frequency
g	-	Prototype element
h	-	Substrate thickness
IL	-	Insertion loss
I_e	-	Even mode current
I_o	-	Odd mode current
J	-	Admittance inverter
K	-	Coupling coefficient
L_{AR}	-	Ripple factor
n	-	Number of element
P	-	Net power
P_{in}	-	Input power
P_{LR}	-	Power loss ratio
P_r	-	Reflected power
Q	-	Q-value
S	-	Gap size
S_{11}	-	Return loss at port 1
S_{12}	-	Insertion loss from port 2 to 1
S_{22}	-	Return loss at port 2
S_{21}	-	Insertion loss from port 1 to 2

V_e	-	Even mode voltage
V_o	-	Odd mode voltage
W	-	Width
Z_o	-	Characteristic impedance
Z_{oe}	-	Even mode characteristic impedance
Z_{oo}	-	Odd mode characteristic impedance
Z_t	-	Transmission line impedance
ε_r	-	Dielectric Constant
ε_{eff}	-	Effective dielectric Constant
θ_e	-	Coupled line length of even mode
θ_o	-	Coupled line length of odd mode
θ_t	-	Coupled line length of transmission line
λ	-	Wavelength
λ_g	-	Effective Wavelength

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CHAPTER I

INTRODUCTION

Band pass filter is widely used in telecommunication system, be it in receiving or transmitting devices, to filter out unwanted frequency. Smaller size and high performance filters are always desired to enhance system performance and to reduce the system cost. There are various ways of designing a filter. The most attractive configuration is planar structure due to its compactness and fairly easy to be manufactured [1]. There has been much research on planar resonators, which is the main component of a planar filter. Examples are parallel-coupled resonator, hairpin resonator, stepped-impedance resonator and miniaturized hairpin resonator. The main purpose of all these studies is to make the filters more compact.

The resonator is the main and basic component of a planar filter, hence it is necessary to properly select the resonator type to ensure the compact size of a filter is maximized. Conventional parallel-coupled filter is too space consuming. Hairpin-line resonator was then introduced to reduce the resonator size and shape [2]. The concepts of miniaturize hairpin resonator was introduced by Sagawa *et al* in 1989 [3]. The brilliant concept integrates lumped element capacitor and the planar resonator to reduce the size further. Therefore, this type of resonator posses smaller size compared to conventional hairpin. This type of resonator is actually a variation of stepped-impedance resonator. Thus, combining stepped-impedance resonator in conventional hairpin structure has eliminated the need of the lumped-element capacitor and hence enhanced the whole structure. Consequently, this made it more stable in terms of frequency variations.

This thesis presents the concept pioneered by Sagawa *et al* and improved by CM Tsai in developing a miniaturize hairpin resonator that operates at 2.45 GHz, the common frequency for ISM band application. A method to select proper resonator design is presented. Besides resonator design, filter topology is also taken into consideration. For microwave circuits, parallel-coupled-line and hairpin filters are widely used. These topologies can only be realized by using Chebyshev and Butterworth response. Since miniature hairpin resonator is a modified version of conventional hairpin resonator, the selection of the initial frequency has to be carefully considered. The study of filter parameters and the effect to filter response are also presented. These information is important especially for circuit optimizations.

Finally, SonnetLite Plus [4] software is then used to optimize and simulate the circuits with the aid of MathCAD [5] software for computation of design formulations.

1.1 Project objective

The objective of this project is to design a compact version of hairpin-line resonator configuration operating at 2.45 GHz.

1.2 Project scope

The scopes of the project are:

i) To modify the conventional hairpin resonator structure into more compact design configuration.
ii) To simulate the response and compare the results with the conventional hairpin filter in terms of performance and physical size.
iii) To study circuit behavior in terms of resonator element and in terms of filter configuration.

1.3 Project motivation

The trend of today's telecommunication device is to have high performance but small and handy devices. As people gets busier, electronic devices that allow users to be mobile, has become a necessity. The smaller the size, the easier for them to be carried around. The better the performance, the higher is the reliability. The factor that determines the overall size is the size of the components itself. Hence, if there are ways to reduce component size, this will indirectly compact the overall device appearance. The challenge is to built smaller circuit component but with same material and with minor changes in the manufacturing process and also able to maintain attractive features of the original circuit. One such component is the band pass filter. It is widely used in telecommunications system especially at the receiver and transmitter. Most of electronics components nowadays are made of VLSI technology that make them smaller relative to the band pass filter size that uses microstrip technology. Hence, in order to enhance the overall circuit compactness and integrate them together, compact filter structures have to be designed and developed.

1.4 Layout of thesis

The report consists of five chapters. The first chapter describes the objective, the project scope and project motivation. Chapter two covers theories on filters relevant to this project. This includes S-parameters application in microwave circuits, a brief discussion on the subject and equations concerning the theory were presented. Filter synthesis technique method were described together with discussion on filter response. This chapter also covers theories of resonator miniaturization, hairpin filter realization and characteristics of internal coupled resonator. Design methodology, specification and the discussion on the tools involved for circuit simulation was covered in chapter three. Chapter four discussed the result and analysis of the findings. These include the study of resonator behavior and all parameter variations that affect filter performance. Finally, chapter five covers the project conclusion and discuss in detail on recommendation and possible future work that can be done to enhance the application of miniaturize resonator and improve the performance.