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

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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 variations 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 was 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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| | | |
|---|---|---|
| $f_o$ | - | Center Frequency |
| LN | - | Minimum attenuation |
| $Z_o$ | - | Characteristic Impedance |
| $Z_r$ | - | System Impedance |
| h | - | Dielectric Thickness |
| $\varepsilon_r$ | - | Dielectric Constant |
| N | - | Number of element |
| Y | - | Admittance |
| $\omega$ | - | Fractional Bandwidth |
| $\lambda$ | - | Wavelength |
| $\lambda_g$ | - | Effective Wavelength |
| g | - | Conductance |
| J | - | Admittance Inverter |
| C | - | Capacitance |
| $Z_{oo}$ | - | Odd-mode Impedance |
| $Z_{oe}$ | - | Even-mode Impedance |
| K | - | Coupling Coefficient |
| Q | - | Quality Factor |
| W | - | Width |

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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 filter are always desired to enhance system performance and to reduce the cost. There are plenty of ways to design the filter, and most attractive among them is planar filters due to the compact structure and fairly easy to be manufactured [6]. There has been much research on planar resonator, which is the main component of planar filter. For example, parallel-couple resonator, hairpin resonator, stepped-impedance resonator and miniaturized hairpin resonator. The main purpose of all these studies is to make the filters more compact.

Resonator is the main and basic component of a planar filter, so it is necessary to properly select resonator type to ensure the compact size of a filter is maximized. Conventional parallel-coupled filter was too space consuming. Hairpin-line resonator was then introduced to compact the resonator size and shape [18]. The concepts of miniaturize hairpin resonator was introduced by Sagawa et al in 1989 [13]. The brilliant concept integrates lump 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. So, combining stepped-impedance resonator in conventional hairpin structure has eliminate the need of the lump-element capacitor and hence enhance the whole structure and made it more stable in term of frequency variations.

This thesis introduce 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 is considered in this thesis. The study of filter parameters and the effect to filter response was also presented. These information is important especially for circuit optimization work.

Finally SonnetLite Plus software is used to optimized and simulate the circuits with the aid of MathCad software to calculate related formulae for the design.

## 1.1 Project objective

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

## 1.2 Project scope

The scopes of the project are:

1) To modify a conventional hairpin resonator structure into more compact design configuration.
2) To simulate the response and compare with the conventional hairpin filter in term of performance and physical size.
3) To study circuit behavior in term of resonator element and in term of filter.

## 1.3 Project motivation

The trend of today's telecommunication device is to have high performance but small and handy devices. As people gets more busy, gadget and electronic devices that allow user to mobile has become part of life requirement. The smaller the size, the easier for them to be carried around and the better the performance, the higher the reliability. Factor that determines the overall size is the size of the components itself. So, if there is way to reduce component size, this will indirectly compacts 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 feature of original circuit. One of such components is 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 which make them smaller relative to band pass filter size that used microstrip technology. So, in order to enhance overall circuit compactness and integrates them together, compact filter structure and shape configuration has to be design 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. These include 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 discuss the result and analysis

of the findings. These include the study of resonator behavior and all parameter variations that affect filter performance as whole. Finally, chapter five covers the project conclusion and discuss in deep detail on recommendation and possible future work that can be done to enhance the application of miniaturize resonator and improve the performance.