Miniaturized Dual-Stub Resonator of Bandstop Filter

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Abstract— **in this paper a capacitor is proposed to tune the resonant frequency of dual-stub resonator of bandstop filter to miniaturize the circuit size. The capacitors is attach to an open circuit dual-stub to tune the 2 GHz dual-stub resonant to lower frequency which is 1 GHz. The complete simulated resonator with capacitors and the frequency response using the fabricated circuit on FR-4 substrate is present in this paper. The dual-stub resonator has achieved 50.2% circuit miniaturized and suitable for processor and wireless network system applications.**

Keywords— **Dual-stub, bandstop filter, capacitor, electrical length**

I. Introduction

In the modern technology nowadays people are looking forward for the technology that is occupy a small circuit area. In other word, a compact design for high performance bandstop filter is highly needed to meet the demand of compact size and high-performance filters. Based from[1], it can be found that there is a growing interest for dual-mode filter and their component. In 1972, Wolff is the first to perform a microstrip dual-mode resonator [2]. It is then been use widely in the wireless communication systems until now. Some of other applications are for oscilloscopes, wireless sensor network and processors.

In this paper, a design of dual-stub resonator of bandstop filter is present. Capacitor effect is added to tuned higher frequency of dual-stub resonator to lower frequency to get more compact circuit size and better selectivity than lower frequency. By introducing capacitance effect to the open dual-stub the circuit size can be miniaturized.

A. Electrical Length

Electrical length is one of the electrical parameters. It refers to the ratio of physical length (ℓ) of the transmission line to the wavelength (λ). Stub consists of open and short stub. When the electrical length of open and short stub is less than 90°, they will behave like parallel inductor or capacitor. If the length exceeds 90°, the sign of tangent θ changes repetitively through every 90°. Thus, both open-circuit or short-circuit stub may look like an inductor or capacitor depending on their electrical lengths.

$$\theta = \beta\ell = \frac{2\pi}{\lambda}.l$$

B. Bandstop Filter

Bandstop filter is basically a reversed of bandpass filter. In general, bandstop filter may be designed using single mode or dual mode resonators. Dual mode resonators have been increasingly used in wireless communication systems and other RF applications for the low cost, small size, light weight and high selectivity characteristics. Tunable bandstop filters are useful for a wide range of applications in eliminating unwanted signals and interference.

Because of their double resonant behavior, a dual mode bandstop filter of certain order requires half as many resonators when compared to a classical topology. Dual mode means the first two resonant modes in the physical individual resonator. The basic strategy of dual mode band stop filter design is to place resonators in parallel with main transmission line. When the resonators are in resonance they short circuit the signals at the particular frequencies. At other frequencies they do not load the main transmission line and they are therefore invisible to the signals. Most of the previously published papers report waveguide dual mode band reject filters although there are well-known microstrip dual mode resonators configurations for band pass applications such as the circular ring[2] the meander loop[3] the circular disk and the square patch[4]-[5].

C. Dual-Stub Resonator

Stub is a length of transmission line with end of the stub is either left open-circuit or short-circuited, connected either in parallel or in series with the transmission feed line at certain distance from the load. The shunt tuning stub is easy to fabricate in microstrip form. A dual-stub has more advantages than the single-stub if variable length of line between the load stubs is required.

The stub length used is quarter-wavelength. Based on [6] quarter wavelength sections of transmission line can be used to match a load to a transmission when the resistance of the load is not equal to the characteristic impedance of transmission line.

II. METHODOLOGY

A study of basic response for inductor and capacitor in series and shunt is done. Other than that, characteristic of stub, capacitance effect and bandstop filter also being familiarized. Using Advance Design System (ADS) 2009 software, a microstrip of dual-stub resonator of bandstop filter has been designed. The stub length is λ/4 with the center frequency at 2 GHz. Simulation was done using ADS 2009 circuit simulator on the effect of adding capacitor to determine the frequency response of the bandstop dual-stub resonator and the effect to the circuit size. Then, etching is done for dual- stub resonator at 2 GHz with 3.3pF capacitor microstrip structure on the FR4 substrate. Measurement is done using Vector Network Analysis (VNA). If the measurement response is not match with the simulation response, redesign is needed to be done.

Fig. 1 shows the flowchart of the project as being explained above. The specifications for FR-4 substrate also can be seen in table 1.

TABLE 1. FR-4 SUBSTRATE PROPERTIES

Microstrip Properties	
Dielectric Constant, □	5.4
Permittivity	1
Height	1.6
Loss Tangent	0.002
Roughness	0mm
Operating Frequency (GHz)	2

III. RESULT AND DISCUSSION

The design of the tunable dual-stub resonator of bandstop at 2GHz comprise of λ/4 stub with 50Ω feeder line and loaded with capacitor for tuning at the end of stub is shown in figure 2. By adding a shunt capacitors at both leg of the open stub, its electrical length will increased leading to the shift of the resonance to the left as frequency is inversely proportional to the length. In this researched, the capacitor is tuned until the dual-stub resonator at 2 GHz is moved to 1 GHz. Both side of capacitor in parallel use the same value because it will double the capacitance since capacitance is inversely related to total energy store. The electrical length is 90°. It is noted that for K = 1 (uniform resonator), the total electrical length is 90° and the total length of the non uniform resonator decreases as the impedance ratio K decreases. The characteristic impedance of the stub is 30Ω. The value is as low as possible so that the tuning effect can be seen clearer due to high resonator quality factor.

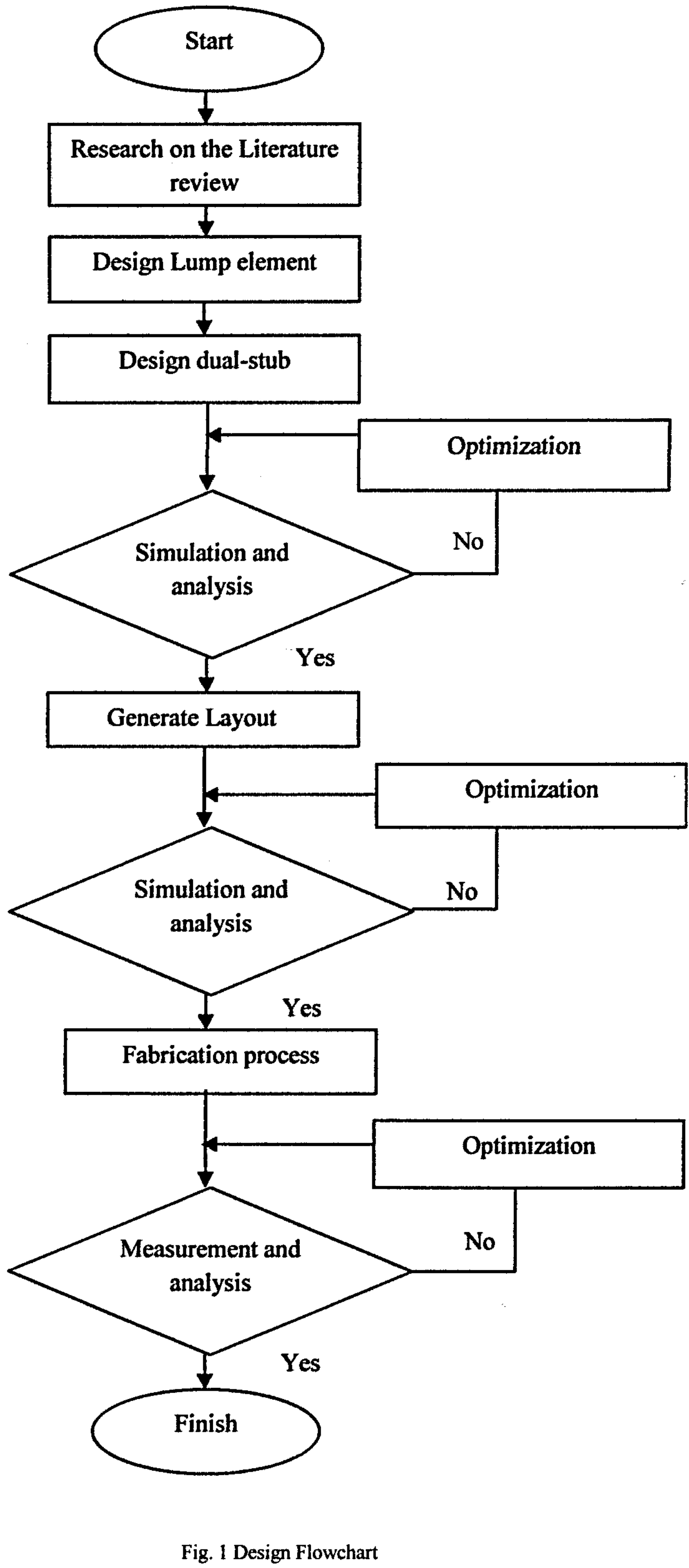


Fig. 1 Design Flowchart

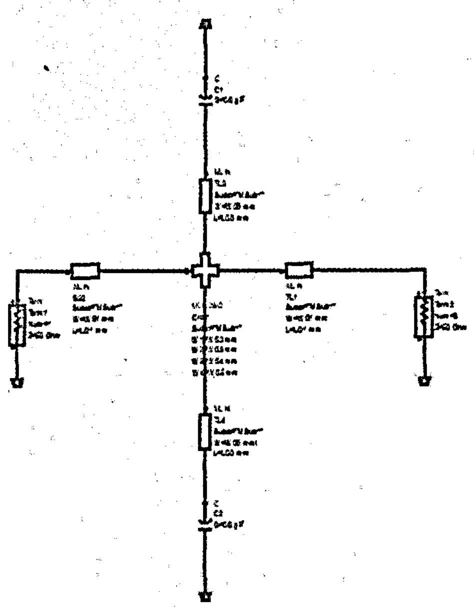


Fig 2. Design of dual-stub resonator of bandstop at 2 GHz

After the accurate capacitor value that can use to tune resonant frequency from 2 GHz to 1 GHz is obtained which is 3.3pF, the microstrip design is transform into a layout as in fig. 3, after that momentum is done on the bandstop filter layout so that the layout frequency response of S_{11} and S_{12} can be obtained.

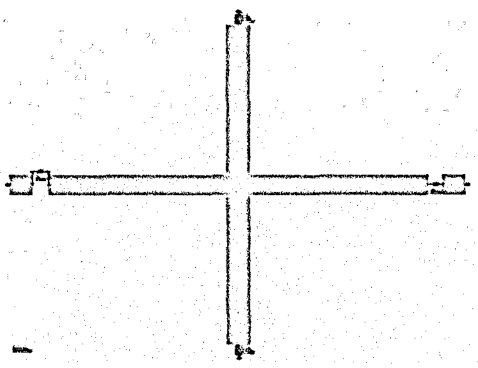
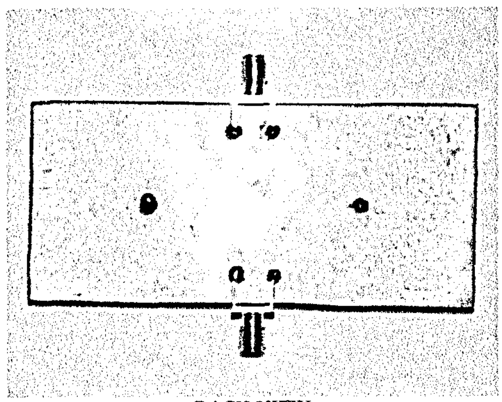
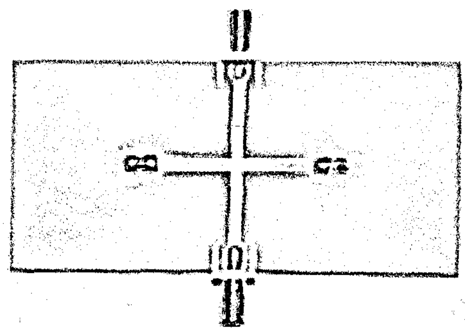


Fig. 3. Layout of dual-stub resonator of bandstop filter

The bandstop filter is fabricated by etching as shown in fig. 4. From the picture it can be seen that a 50Ω SMA connector is soldered to excite the signal. The fabricated circuit dimensions are as follows: width = 4cm and length = 10cm.



BACK VIEW



FRONT VIEW

Fig. 4. Fabricated bandstop filter

Simulations are performed to obtain the frequency response on an open circuit dual-stub resonator without capacitor as shown in fig. 5(a). From the graph, it can be seen that the resonant frequency is exactly at 2 GHz, the insertion loss (S_{12}) is equal to -59.1dB.

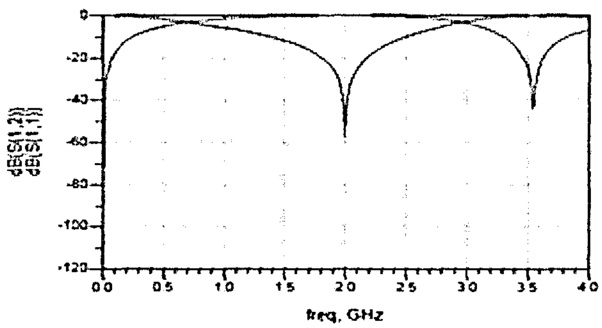


Fig.5(a) open circuit dual-stub resonator without capacitor

In order to achieve a tuning of resonant frequency from 2 GHz to 1 GHz, an analysis of capacitor effect attach to end of stub (stub leg) have been done. A 0.5pF capacitor is use to attach to the stub leg. Fig.5(b) is a response for capacitor at above dual-stub leg and fig. 5(c) show a response for capacitor at bottom dual-stub leg. The response for fig.5(b) and fig. 5(c) is the same. It shows that a tuning to 1 GHz is not successful just by adding one capacitor at particular time.

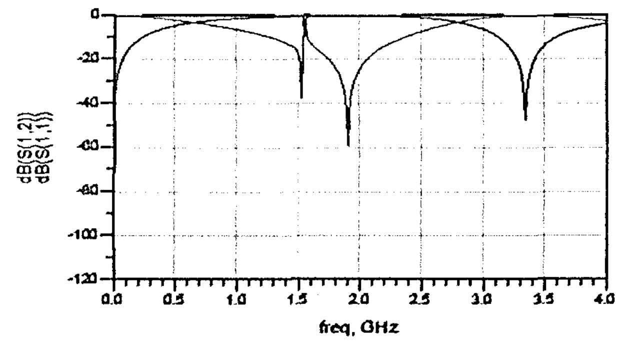


Fig.5(b) 0.5pF capacitor at above dual-stub leg

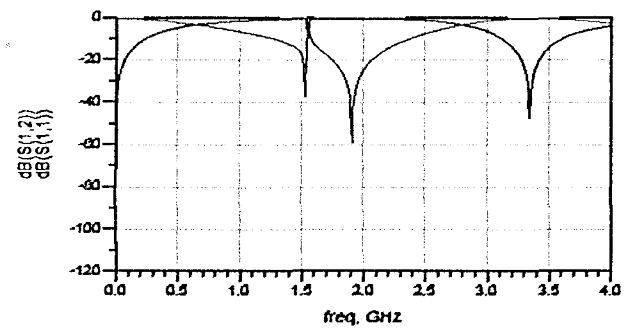


Fig.5(c) 0.5pF capacitor at bottom dual-stub leg

Based on fig.5(d), it can be seen that by adding 0.5pF capacitor at both end of stub, the response has shift slightly to the left. The resonant frequency have shift to 1.77 GHz with lower insertion loss (S_{12}) that is -51.67dB.

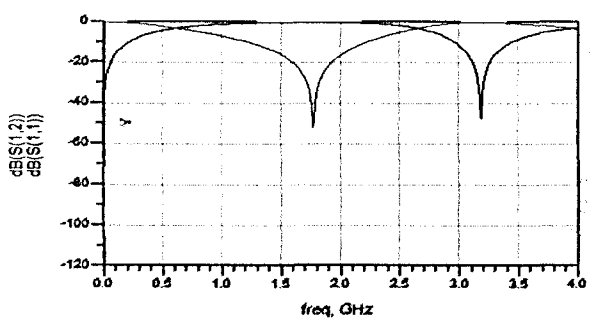


Fig.5(d) dual-stub resonator with 0.5pF capacitor

After that, simulation and measurement are performed to obtained the frequency response with capacitor on both leg (above and bottom) of the resonator. It can be seen at Fig. 6. A 3.3 pF capacitor is attached so that the frequency is successfully tuned from 2 GHz to 1 GHz. The larger the capacitor value will lower the resonant frequency value thus the shorter the dual-stub length (θ) can be achieved.

From research, the miniaturized of 2 GHz dual-stub resonator is at 50.2% compared to using a 1 GHz dual-stub resonator. The dual-stub length for 1 GHz is 38.5984mm while length for dual-stub resonator for 2GHz with capacitor is only at 18.81mm. The dimensions of the 2 GHz dual-stub resonator are shown in table 2.

TABLE 2. DUAL-STUB RESONATOR MEASUREMENT

MEASUREMENT (mm)	
wC0	2.57
WC1	2.57
wC2	2.57
wC3	2.57
wC4	2.57
wC5	2.57
ℓC1	18.8
ℓC0	19.22

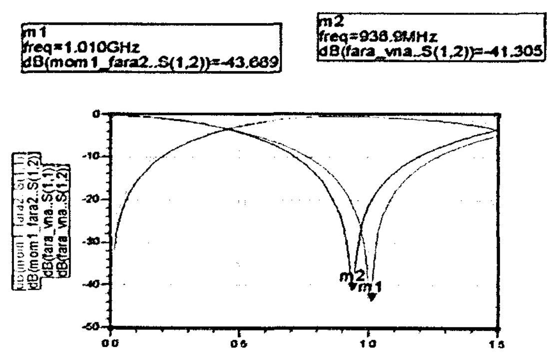


Fig.6 dual-stub resonator with 3.3pF capacitor

The comparison result between measurement and simulation shown in table 3. The response for measurement resonant frequency is only slightly different from simulation, which is with the difference of 740 MHz, the different might be because of the effect of too much lead on the circuit that cause losses. Other than that, it may also causes by human error, technical error and error when calibration is done. Other important reason also because the substrate FR-4 that being use have high dielectric that is μ_r = 5.4 while if using RTD Duroid5880 the μ_r is only 2.2. One of way to overcome it also can be by adding grounding plate so that can produce more stable grounded

TABLE 3. COMPARISON OF SIMULATION AND MEASUREMENT RESULT

Parameters	Simulation	Measurement
Center Frequency	1.01ghz	936.9 Mhz
Insertion Loss (S_{12})	-43.669	-41.305

IV. CONCLUSIONS

A novel miniaturized filter using Dual-mode resonator of bandstop filter with centre frequency at 2 GHz is proposed and construct in this paper. Capacitor is introduced to reach a tuning of frequency from 2 GHz to 1 GHz. Objective to design a miniaturized dual-stub at lower frequency is achieved. By adding capacitor the circuit size can be reduce for 50.2% circuit size compare to 1 GHz . The result can be improved in future in many ways. For example, different substrate can be use and also further study and analyse of the capacitor as biasing circuit can be made. This design is good for wireless communication for which miniaturized size and sharp selectivity is required.

V. FUTURE DEVELOPMENT

The concept can be implementing in a varactor diode with biasing circuit application, where it is proven that by using capacitor the dual-stub resonator can be tuned.

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