# Wideband Dual Mode Bandpass Filter with Wide Spurious Response Suppression

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## I. Introduction

The dual mode is mostly applied in the planar microwave bandpass filters (BPFs) for all narrow bands and wide band bandpass filters because of compact size, low cost and easy fabrication. Therefore, the dual mode bandpass filters are highly popular to apply in wireless communication system and measurement instrument. The method of an asymmetrical coupling line and notched on the conductor of substrate of the ring resonator was designed to dual mode [1]. In order to excite a dual mode, many methods placed the different types of perturbation at different positions on the ring resonators.To use the small patch and notch perturbations attract at the corners of the square loop [2]. In [3], they have been used the stepped impedance perturbation on the ring resonator for degenerate into the dual mode characteristic. Which the results have narrow band characteristics and high insertion loss affected from coupled feed lines.

Much research proposed the wideband dual mode square ring resonator bandpass filters. The direct connecting orthogonal feed lines are used in designing filters to reduce insertion losses. A square stub perturbation and two tuning stubs connected to square ring resonators produced two sharp stopband [4]. It has been found that changing direct feed lines to be tapped feeds at input/output port results in suppression of harmonics in out off band about $2.5\,f_o$ , where $f_o$ is the fundamental frequency [5]. In [6], they used a piece of aperture by enhancing a parallel-coupled line with length of $\lambda/2$ connected at output port, which it could control the transmission zero to appear at $2f_o$ .

In this paper, we present a new configuration of the wideband dual mode bandpass filters using the properties of microstrip open loop resonator combined a novel perturbation by notching rectangular slots. The properties of microstrip open loop resonator is miniaturized the filter structure, and the perturbation is enhancing the attenuation rates for the sharp cutoff frequency and coupling on square ring resonator structure. To reduce the harmonics in out off band, the interdigital coupled line is used to control the transmission zeros appeared at DC (lower stopband) and at $2f_o$ (higher stopband) for suppression of the first harmonics. The higher harmonics at more than $2f_o$ can be suppressed by adding the quarter wavelength open stubs are used at the input and output feed lines to control multiple transmission zeros, resulting in wide suppressed harmonics.

## II. Design of Wideband Bandpass Filters

This paper presents a new configuration of the wideband dual-mode bandpass filter for wide harmonic suppressions as shown in fig.1. (b), which is modified from the prototype has been designed in [7] as shown in fig.1 (a) with attaching the four small patches to the inner corner of the square loop depicted in fig.1 (b). The small patches are creating the properties of a microstrip open-loop resonator that has a spurious suppresses at first harmonic, due to dispersion and slow wave effects [8]. By increasing attenuation the stop band at the first harmonic and created the DC-choked with an interdigital-coupled line has been employed instead of a direct feed line at input and output port. We have designed the interdigital-coupled line with $\lambda/4$ length at the fundamental frequency. The simulated results as shown in figure 2(b), the interdigital coupled line affect generation of three transmission zeros at f=0, f=11GHz and 22GHz. The second harmonic ($3f_o$) can be suppressed with attaching the two quarter-wavelength open stubs at the end of coupling lines depicted in fig. 2(a), that it increases the transmission zero at f=15GHz shown in fig.2(b), which made a wide rang of spurious response suppression without changing the passband performance. To improve the insertion loss and alter the input impedance has been designed by using the stepped impedance feeds.

The proposed filter is designed at a center frequency of 4.5 GHz and fabricated on GML-1000 substrate with thickness h = 0.762 mm, and a relative dielectric constant $\varepsilon_r$ = 3.2. The dimensions of the square ring with the properties of microstrip open loop resonator can be calculated in [7] and IE3D program [10] is used to optimize the insertion loss and bandwidth which the response of filter are $l_{f1}$ = 5.5 mm, $l_{f2}$ = 2.1mm, $l_{f3}$ = 3.45 mm, $l_{f4}$ =7.75mm, $w_1$ = 2.4 mm, $w_2$ = 1.1mm, $w_3$ =0.5mm, $w_4$ =0.4mm, $w_5$ =1mm, $w_6$ =0.3mm, $w_7$ =0.3mm, $w_8$ =0.8mm, a = 9.20 mm, $l_t$ =9.225mm, and G=0.15mm, g=0.4mm, and s=1.235 mm. The overall dimensions of proposed filter are 28x28 $mm^2$ or 0.497 $\lambda_g$ x 0.497 $\lambda_g$. The dimensions of the square ring with the properties of microstrip open loop resonator is reduced of about 42% and the overall dimension is reduced of about 34% when comparison with the prototype of a square ring resonator and the proposed wide band BPF, respectively. The simulated response of the three different feeds is shown in figure 3(a). It is found that the proposed wide band BPF which used the inter digital coupled feed with a two quarter-wavelength open stubs and stepped impedance feeds can be suppressed spurious response less than 15 dB from 5.7GHz up to 25 GHz. Fig.3 (b) shows simulated result comparison the proposed wide band BPF and the prototype of a wide band dual band pass filter and found that the techniques in order to a wide suppress the spurious response more than $5.6f_0$. And another, the new perturbation is generated the bandwidth of two transmission zeros of about 400 MHz at each side of the edge cut off frequency, a bandwidth of passband about 2.5 GHz, and an insertion loss of -0.245 dB is obtained.

## III. Measurement and Results

The proposed filter was fabricated as shown in figure 4(a). The frequency responses of the filter were measured by a network analyzer of Agilent 8719ES. The measured results (solid line) and simulation results (dash line) of the proposed filters are displayed in figures 4(b) and 4(c). We have found that this filter has a 3-dB fractional bandwidth of 57 % from 3.13 to 5.68GHz, an insertion loss passband is 0.26dB at 4.54GHz, the bandwidth of two transmission zeros greater than 23dB within 2.65 to 3.05GHz and 5.72 to 6.12GHz and the measured lower stopband greater than 23dB with in DC to 3.05GHz, the higher stopband greater than 15 dB within 5.74 GHz to 25 GHz. To observe the measured results it has clearly seen in fig.4(c), there are three transmission zeros appeared lower than -70dB at 9.2GHz, -45dB at13.5GHz and -70dB at 21GHz. This is because the first harmonic has been suppressed from the dispersion and slow wave effects combined the inter digital coupled feeds characteristic. The second harmonic and more than are suppressed by using the bandstop property of the two-quarter wavelength open stubs. This confirms that the measured results are in good agreement with the simulated results.

## IV. Conclusion

The designing of using a new technique to achieve wideband bandpass filters with wide spurious response suppression has been proposed. The properties of microstrip open loop resonator to miniaturize structure and suppressed spurious response of the filter with the dispersion and slow wave effects. The perturbation is to degenerate into dual modes that can produce two transmission zeros on each side of passband, resulting in high sharp cutoff frequency at the lower edge and higher edge of the passband and a low insertion loss in the passband. An interdigital coupled line attached with the two quarter wavelength open stubs have been used to suppress the harmonics outer of band rejection at the lower and higher frequency and the stepped impedance feeds can be improved the insertion loss and alter the input impedance of the filter. This technique can be also applied for several resonators used for high performance filter.

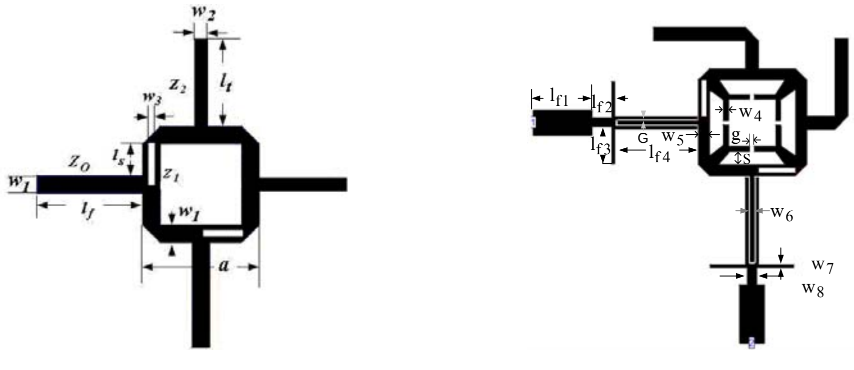



Figure 1. (a) Layout of prototype structure and (b) Proposed wideband BPF structure.

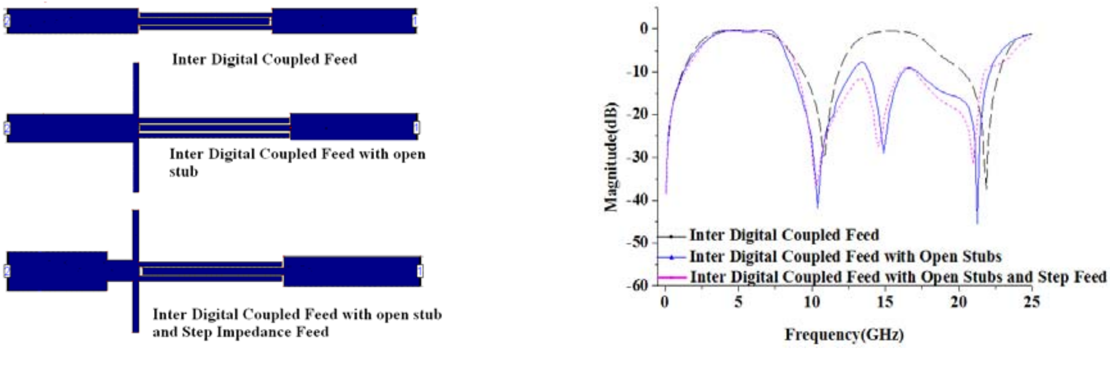



Figure 2. (a) Layout of the three different feed structures and (b) comparison between simulated results by using an interdigital feed, an interdigital with open stubs feed and an interdigital with open stubs and stepped impedance feed.

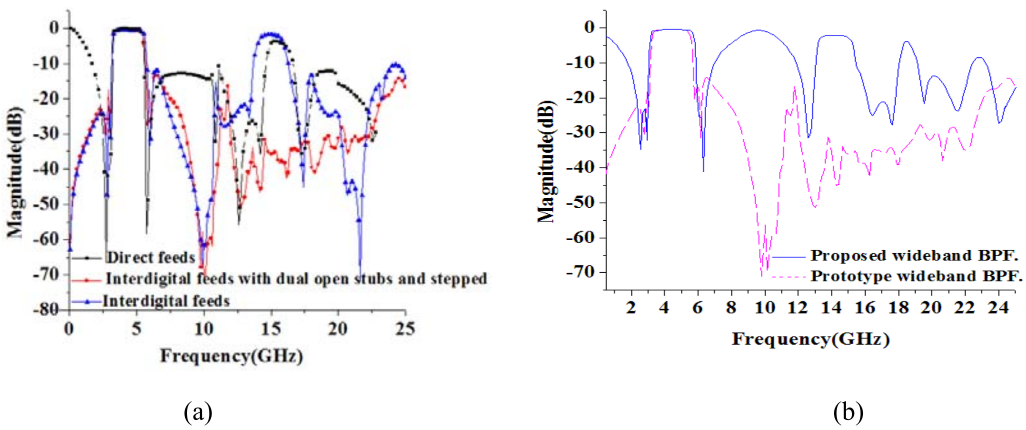
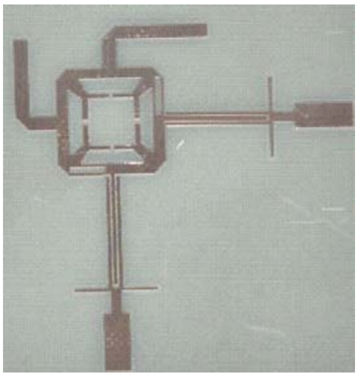
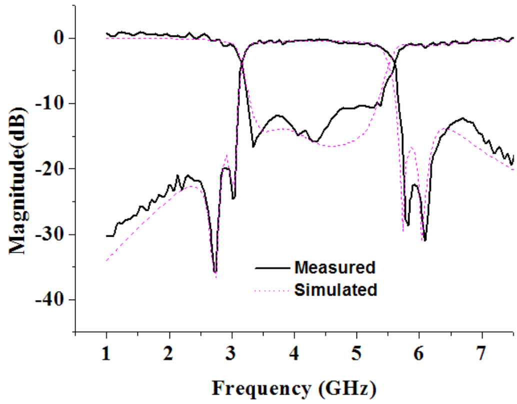


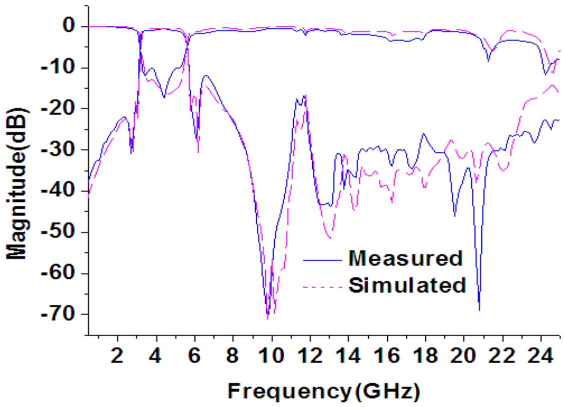

Figure 3. (a) Comparison of the proposed filter with three different feeds and (b) comparison of the simulated frequency responses between the proposed filter and the prototype filter.



(a)




(b)




(c)

Figure 4. (a) Photograph of the proposed wideband BPF and (b) comparison of the simulated and measured narrow band responses and (c) Comparison of the simulated and measured responses of the proposed wideband BPF with wide spurious response suppression.

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