Hybrid-fed Microstrip Loop Resonator with Capacitive Meander Lines

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Abstract

A compact wide-band bandpass filter (BPF) using the degenerate modes of a meander structure printed on the FR4 substrate is proposed. The resonator is based on a capacitive meander loop loaded with a perturbation strip at the center of the resonator for the coupling effects. Besides its simple structure, the filter shows low insertion loss and minified to small size, owing to the meander structure used for lengthening the resonant length. The effect of input/output symmetrically hybrid-fed lines located along a straight line on the proposed filter is studied for dual-mode filter. The proposed filter shows a 22.5% bandwidth at the central frequency of 2355MHz, and it also provides transmission zeros on both sides of the bandwidth. Experimental results are in good agreement with simulated values and bring into focus the problems and solutions of wide-band filter.

1. Introduction

In recent years, dual-mode resonators have been widely used for microwave bandpass filter (BPF) in wireless local area network (WLAN) applications and mobile communications systems. The advantage of the dual resonators is that each resonator can be used as a doubly tuned resonant circuit, thus the number of resonators for a given degree filter is reduced by half [1]. Various types of the dual-mode microstrip filter with patch or ring resonators have been proposed in theory and experiment [2]-[13]. The BPF response has been obtained through the excitation of the two degenerate modes by orthogonal feed lines and adjusting the coupling between the two modes by adding various forms of meander elements within dual-mode resonators. The dual-mode microstrip filters are composed of one or more dual-mode resonators, which are usually in the form of patch or ring with a square, triangular or circular shape. The ring resonator can provide better performance than the patch resonator, such as wide bandwidth in the passband and compact size. There are many forms of perturbation elements such as adding corner patches [2, 3], subtracted corner cuts [4], unequal tuning stubs [5-7] on the ring resonators. There is a new filter using miniature dual-mode microstrip. Open-loop resonator [8-10], dual-mode dual-band bandpass filters [11, 12] and unequal crossed-slot square patch [13] have been proposed for both size and loss reduction.

In this study, a new dual-mode filter with a meander loop resonator loaded a perturbation strip in the loop resonator is proposed and tested. Similar to the conventional dual-mode resonator, the loaded strip perturbs the fundamental mode and splits two resonant paths forming two degenerated modes. The meander structure lowers the resonant frequency, which reduces the filter size. Otherwise, the position of the transmission zeros are easily adjusted by changing the perturbation strip.

2. Design of Bandpass Filter

Fig. 1 shows the configuration of the proposed capacitive meander loop resonator. The proposed resonator consists of a meander rectangular-loop with a perturbation strip at the center of the loop for coupling effects. By inserting a pair of symmetrical L-shaped feed lines into the slits of the meander lines, the loop resonator is formed to facilitate the feeder-to-resonator coupling enhancement. The L-shaped line consists of a direct feed and a coupled feed, forming a hybrid-fed line, to strongly excite the two degenerate modes. For dual-mode excitation, the

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microstrip resonators in the microwave component are fed by a pair of orthogonal feed lines arranged at 90° (or 270°) in order to generate the two degenerate modes and to couple to each other. Nevertheless, the orthogonal feed lines may not be physically suitable for all microwave networks. Instead of the orthogonal feed lines, the feed lines oriented along straight lines can be used as a substitute solution [10], i.e. the dual-mode microstrip filters may be fed by a pair of feed lines arranged at 0° (or 180°) geometrically. Such a straight feed lines well-adjusted to the meander microstrip resonator is investigated to feed the new proposed dual-mode microstrip filter.

The proposed bandpass filter shown in Fig. 1 was fabricated on an FR4 substrate of thickness h = 1 mm and relative permittivity ε_r = 4.4. The dimension of the meander loop resonator is $a \times b$ mm^2 and all the spacing, width of the meander lines is s and W, respectively. For the dual-mode filter operation, the input/output (I/O) ports were spatially separated by 180^0 geometrically, and the perturbation strip was introduced within the meander loop resonator at a symmetrical axis apart from both I/O ports. Two L-shaped microstrip feed lines with coupling stubs (d) were attached to the end of the I/O ports for the tightened coupling between the feeder and resonator. As seen from the proposed filter layout, the coupling stub is to increase the coupling periphery. By adjusting the length of coupling stubs (d) and gap spacing (g_1), the insertion loss and return loss of the filter can be optimized. For the proposed case, the coupling stubs have the length of d = 6.1 mm and gap spacing of g_1 = 0.2 mm. In this study, an FR4 dielectric substrate is chosen, and the feed lines width of W_f, W_g are fixed at 1.9 and 1.1 mm, respectively, in order to achieve 50-Ω and 75-Ω impedance for the impedance matching. The gap spacing g_1 and g_2 of the hybrid-fed line between the coupling stub and the loop resonator has a width of 0.2 and 0.3 mm, respectively.

As is well known, since a rectangular-loop resonator can be considered as a rectangular cavity with magnetic walls on the sides, the fields inside the cavity correspond to those of TM_{mn0} modes. It has been proven that these degenerate modes correspond to TM_{100} (mode 1) and TM_{010} (mode 2) [1]. Also, it can be found that the resonant length corresponds to one-half wavelength of fundamental resonant mode.

3. Simulated and Measured Results

A miniaturized dual-mode BPF is investigated and fabricated using the FR4 substrate. In Fig. 1, the optimal design parameters of the meander loop filter are: a = 18.7 mm, b = 12.4 mm, d = 6.1 mm, s = 0.3 mm, h = 1.0 mm, W = 1.6 mm, W_f = 1.9 mm, W_g = 1.1 mm and feed gap spacing g_1 = 0.2 mm, g_2 = 0.3 mm. In order to reduce experimental cut-and-try design cycles, the simulation software HFSS is used to provide the design dimensions. Since the design of a dual-mode BPF requires the splitting of the two degenerate modes of the resonator, the mode splitting is obtained by introducing a small perturbation strip. The perturbation strip has a size of $p \times s$ mm^2 where the dimension s was kept constant as 0.3 mm. Fig. 2 shows the variation of simulated splitting resonance frequencies of two degenerate modes against different lengths of p. As perturbation length (p) increases from 0 to 1.5 mm, the splitting resonant mode almost decreases from 300 to 90 MHz, in order to control the coupling between the degenerate modes for the dual-mode operation. It is also seen from the figure, as p > 2 mm, the two degenerate modes are combined to a single mode. The coupling coefficient is computed using the relationship between the splitting in the resonant frequencies of the two modes and the coupling coefficient k, as described by [1], [5]

$$k = \frac{f_2^2 - f_1^2}{f_2^2 + f_1^2}$$

where f_1 and f_2 is the resonant frequencies of mode 1 and mode 2, respectively. The coupling coefficient as a function of the length p is also shown in Figure 3. It is seen that at p = 0 (without perturbation), the two degenerate modes have maximum frequency split and coupling coefficient of k = 0.127. In the range of p < 2 mm, the coupling coefficient between the two degenerate modes is zero because only a single mode is excited.

Fig. 4 shows the simulated and measured frequency response of the proposed dual-mode filter. It is seen that the frequency response reduces quickly and efficiently in the either side of the passband and two transmission zeros are generated. In this study, the frequency response shows very wide band. The measured bandwidth is approximately 22.5% (530 MHz) at the center frequency 2355 MHz. The simulated and measured minimum insertion losses (S_{21}) are 0.6 and 1.0 dB, respectively. The existence of insertion loss is mainly due to the circuit loss including conductor, dielectric and radiation losses. The differences between simulated and measured performances are due to fabricated error and unperfected feeding ports soldered in the experiment. Fig. 5 shows a photograph of the proposed bandpass filter, and the total size of the filter is 13 × 20 mm^2. Moreover, it can be seen that the fractional bandwidth of the filter cover the 2.4 GHz (2400-2484 MHz) band for WLAN operation.

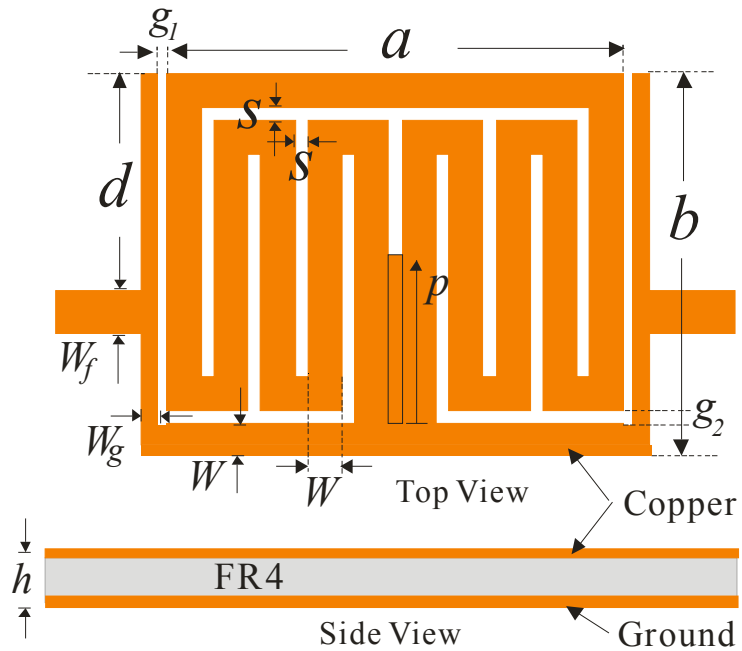

Fig. 1 Geometry of the proposed dual-mode BPF.

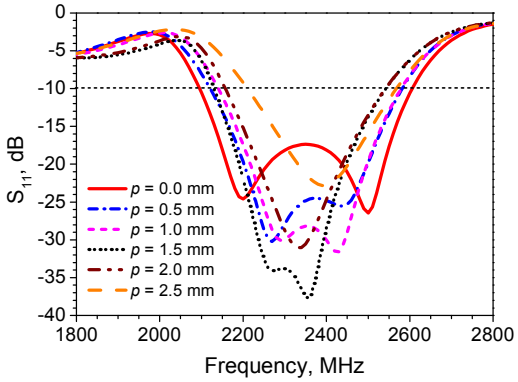

Fig. 2 Simulated filter modes versus the size of coupling length *p*.

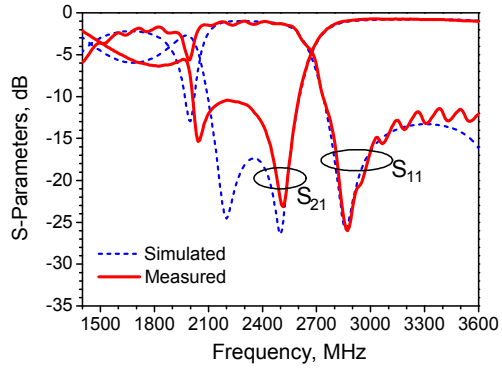

Fig4. Simulated and measured frequency response of the proposed BPF.

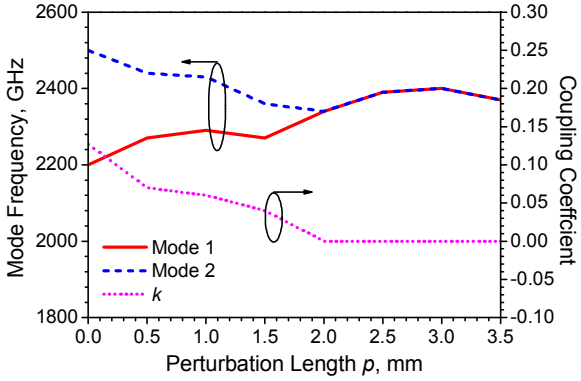

Fig.3 Simulated coupling coefficient of degenerate modes versus the length *p*

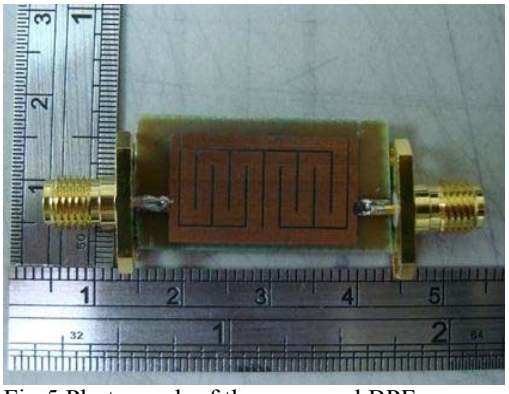
Fig.5 Photograph of the proposed BPF.

4. Conclusion

The BPF was designed to integrate the recent advances made by the various wide band and low cost in the rapidly expanding field of WLAN. In this study, a small-size microstrip filter for very wide band operation is proposed and successfully implemented in the letter. The compact meander BPF is also verified by simulation and experiment with good agreement. The characteristics of mode splitting have been described, and the transmission zeros can be adjusted by shifts the two input feed. The change in the return loss and insertion loss are reflected by a change in the coupling perturbation size. The proposed filter has been designed and fabricated on the FR4 substrate and found to have a 22.5% fractional bandwidth at 2.4 GHz, which covers the 2.4 GHz for the channels of IEEE-802.11b/g/n, making the application of the proposed antenna in future WLAN systems possible.

5. References

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