Microstrip Bandpass Filter Using Degenerate Modes of a Novel Meander Loop Resonator

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***Abstract*—A novel type of dual-mode microstrip bandpass filter using degenerate modes of a meander loop resonator has been developed for miniaturization of high selectivity narrow-band microwave bandpass filters. A filter of this type having a 2.5% bandwidth at 1.58 GHz was designed and fabricated. The measured filter performance is presented.**

I. INTRODUCTION

MINIATURIZED high-performance narrow-band microwave bandpass filters are highly desirable for the next generation of satellite and mobile commmunications systems. To meet this demand, there has been a growing interest in the dual-mode microstrip filter [1]–[3] because of the advantage of space, weight, and cost savings. Dual-mode microstrip filters are composed of one or more dual-mode microstrip resonators that are conventionally in the form of a ring, a disk or a square patch [1]. At the lower microwave frequency bands, which are used by many satellite and mobile communications syaytems, the configurations of conventional dual-mode microstrip filters can occupy a fairly large circuit areas, which is not quite congruous with the systems where the size reduction is an important factor. Recently, the authors have proposed a dual-mode square loop resonator for miniaturization of the microstrip dual-mode filters [4]. In order to utilize the circuit area in a more efficient manner, especially at relatively low microwave frequencies, as well as to offer alternative designs, we present in this letter a novel dual-mode microstrip filter that uses degenerate modes of a meander loop resonator. The new filter structure has a smaller size as compared with the other dual-mode microstrip filters. The mode splitting of the meander loop resonator, which is important for the filter design, is described. A filter of this type was designed and fabricated. The measured filter performance is also presented.

II. DUAL-MODE MEANDER LOOP RESONATOR

As a key element for the proposed dual-mode filter, a novel dual-mode microstrip meander loop resonator, is shown in Fig. 1. A meander loop consisting of four identical arms (each of which may be taken as a meander line) forms a basic resonator. A small square patch is attached to an inner corner of the loop for exciting and coupling a pair of degenerate modes (having the same propagation constant) so as to form a dual-mode resonator. When $d = 0$, no perturbation is added and only the single mode is excited. The electric field pattern, which was computed using a fullwave EM simulator [5], shows that the excited resonant mode is corresponding to the TM^z_{100} mode in a square patch resonator when port 1 is excited, where z is perpendicular to the ground plane. If the excitation port is changed to port 2, the field pattern is rotated by 90° for the associated degenerate mode, which corresponds to the TM^z_{010} mode in a square patch resonator.

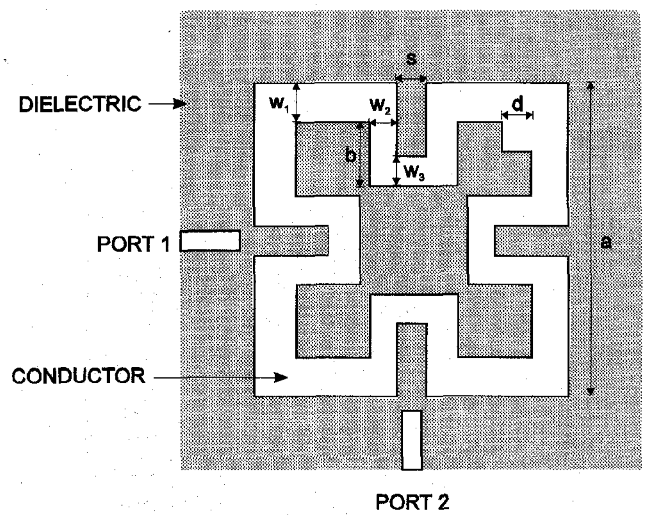

Fig. 1. Dual-mode microstrip meander loop resonator.

When $d \neq 0$, no matter what excitation port it is, both the degenerate modes are excited and coupled to each other, which causes the resonance frequency splitting. The degree of coupling modes depends on the size of d, which in return controls the mode splitting. Fig. 2 plots the frequency characteristics of mode splitting for different values of d. As d is increasing from 1.5 to 2.5 mm, resonance frequency splitting is increased from 35 to 100 MHz. It should be mentioned that, without the square patch ($d = 0$), neither splitting of the resonance frequency nor bandpass response is observed. The reason for the latter is because there is a short-circuit (the zero) at the output port. Fig. 3 shows the computed field pattern ($|E_z|$) of mode 1, which has a lower resonant frequency after mode splitting for $d \neq 0$. As can be seen, the locations of poles and zeros are at the four corners, respectively. The field pattern of mode 2, which has the higher resonance frequency after mode splitting, is rotated by 90° from that of mode 1.

To demonstrate the size reduction of the meander loop resonator, a set of 2-D resonators including a ring, a square patch, and a disk were fabricated and tested. It was measured that all the resonators resonated at around 1.57 GHz. However, the circuit sizes needed to accomodate these resonators are different. On a RT/Duriod substrate with a thickness of 1.27 mm and a relative dielectric constant of 10.8, the sizes are

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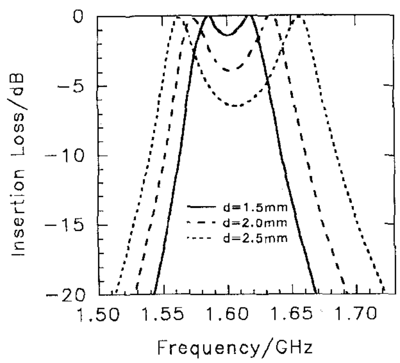

Fig. 2. Characteristics of mode splitting (meander loop: $a = 16$ mm, $b = 3.25$ mm, $w_1 = 2$ mm, $w_2 = w_3 = s = 1.5$ mm).

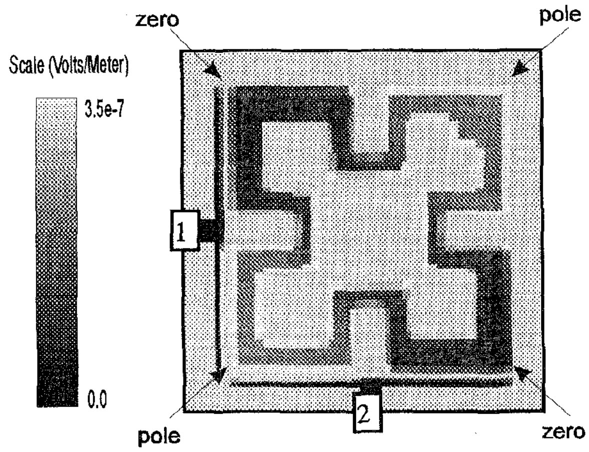

Fig. 3. An electric field pattern of the dual-mode microstrip meander loop resonator.

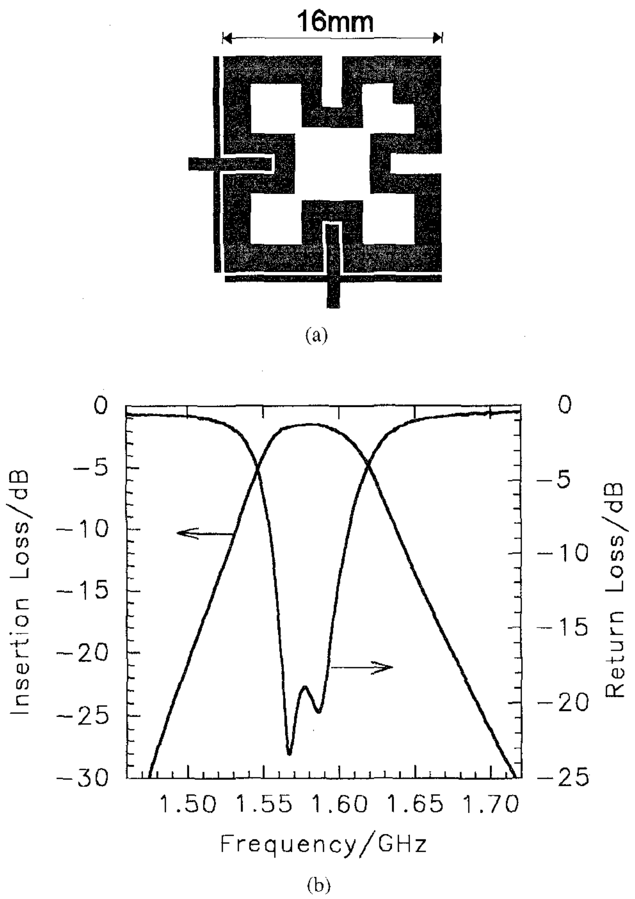

Fig. 4. Layout (a) and measured performance (b) of a two-pole dual-mode bandpass filter.

measured by 16 × 16 mm^2, 23.5 × 23.5 mm^2, 28.5 × 28.5 mm^2 and 33 × 33 mm^2 for the meander loop, the ring, the square patch, and the disk, respectively. The meander loop resonator has the smallest size with the size reduction of 53%, 68%, and 76% against the ring, the square patch, and the disk, respectively. Obviously, this size reduction is significant, especially for those circuits and systems where the size reduction is of importance.

III. Dual-Mode Bandpass Filter

The idea behind the dual-mode filters is that of utilizing a pair of coupled degenerate modes in each single resonator to realize double-tuned resonant circuit [6]. To show this, a two-pole bandpass filter composed of a proposed dual-mode microstrip meander loop resonator was designed and fabricated on a RT/Duriod substrate having a thickness of 1.27 mm and a relative dielectric constant of 10.8. Fig. 4 shows the layout of the filter and its frequency response, which was measured on an HP 8720 A network analyzer. The filter dimensions (refer to Fig. 1) are $a = 16$ mm, $b = 3.25$ mm, $w_1 = d = 2$ mm and $w_2 = w_3 = s = 1.5$ mm. The input/output is introduced by the cross branch having arm widths of 1 mm and 0.5 mm, respectively. The all coupling gaps are 0.25 mm. The filter has a 2.5% bandwidth at 1.58 GHz. The minimum insertion loss is 1.6 dB. The loss is mainly due to the conductor loss. The overall performance of the filter is able to be further improved by optimization design.

IV. Conclusion

A novel type of dual-mode microstrip bandpass filter using degenerate modes of a dual-mode meander loop resonator has been reported. The characteristics of mode splitting have been described. A dual-mode bandpass filter of this type with a 2.5% bandwidth at 1.58 GHz has been designed and fabricated to demonstrate the design of miniaturised microwave filters. It can be expected that the new dual-mode microstrip meander loop resonator is a very attractive structure for developing compact and high performance microwave bandpass filters with fully planar fabrication techniques. This is especially of benefit to the monolithic microwave integrated circuits (MMIC's) as well as the growing microwave superconductive circuits.

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