Design and Performance of Novel Printed-Circuit Spurline Bandpass Filters

Cam Nguyen, *Senior Member, IEEE*

Abstract—**Novel spurline bandpass filters are presented. Approximate design equations are derived. Two microstrip spurline bandpass filters employing two- and three-conductor spurline resonators, with pass bands centered near 5 GHz, have been designed and tested with less than 1- and 1.3-dB insertion losses and more than 20- and 15-dB return losses in the pass bands, respectively. Good agreement between the measured and calculated results has been observed. The filters behave very similar to the conventional open-circuited shunt-stub bandpass filters, but are more compact and less radiative, sensitive to the adjacent objects, and dispersive, making them more attractive.**

I. Introduction

Microwave integrated circuit filters are important components in many microwave systems. Miniaturized high-performance microwave filters have always been sought to fulfill the increasing demand for systems with reduced size and weight. Spurline resonators consisting of two and three parallel-coupled lines [1]–[5] are attractive candidates for the miniaturization of filter structures. Compared to the conventional open-circuited shunt-stub elements normally employed in filters, they are very compact. In addition, they have less radiation, susceptibility to nearby elements, and dispersion due to the fact that their operation is determined mainly by the odd-mode of propagation [1]–[4], as evidenced from the exact equivalent circuit of the symmetrical spurline resonator [4]. They have been used to realize various spurline band-stop filters [1]–[5].

In this letter, we present the development of new bandpass filters using the spurline elements. The use of those spurline resonators in realizing bandpass filters has not been attempted yet. Approximate design equations for two-resonator spurline bandpass filters are derived, based on the conventional bandpass filters with half-wavelength open-circuited shunt stubs and quarter-wavelength connecting lines [6]. As for the conventional shunt-stub filters, the spurline bandpass filters also have additional pass bands near dc and second harmonic of the center frequency, f_0, and maximum rejection at 0.5 f_0 and 1.5 f_0. They are particularly useful where the pass bands around dc and 2 f_0 are not objectionable, and where there is a relatively narrow band of signals to be rejected.

Manuscript received July 13, 1992.

The authors are with the Electromagnetics and Microwave Laboratory, Department of Electrical Engineering, Texas A&M University, College Station, TX 77843-3128.

IEEE Log Number 9204124.

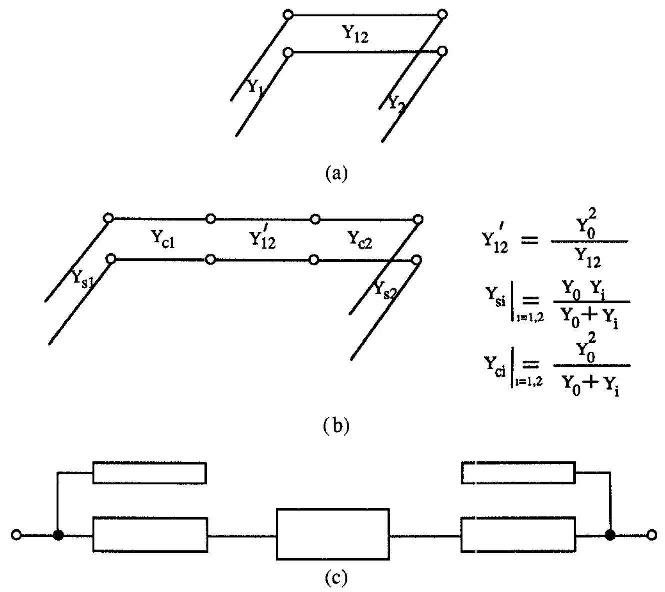

Fig. 1. Realization of the two-conductor spurline bandpass filter from a conventional shunt-stub filter. Connecting lines of characteristic admittances Y_{12} and Y'_{12} are quarter-wavelength long. All others are half-wavelength long.

II. Filter Design and Performance

A spurline bandpass filter, employing two two-conductor spurline resonators, can be derived from a conventional bandpass filter consisting of two half-wavelength open-circuited shunt stubs connected by a quarter-wavelength line, as described in Fig. 1. First, the conventional filter (Fig. 1(a)) is converted to its dual comprising of two half-wavelength short-circuited series stubs and a quarter-wavelength connecting line. Next, inserting half-wavelength lines of characteristic admittances Y_0, equal to the filter source and load admittances, at the filter ends and applying Kuroda's identity [7] give the circuit of Fig. 1(b). Finally, using the equivalent circuit of the asymmetrical two-conductor spurline resonator [8] yields the spurline realization of Fig. 1(c). The last step is only approximate for an inhomogeneous medium such as microstrip line due to the assumption of equal mode velocities. Accurate filter responses for both homogeneous and inhomogeneous media can be obtained by employing the chain matrix of the two-conductor spurline resonator, characterized in terms of the c- and π-mode characteristic admittances and electrical lengths [5].

Fig. 2 describes the transformation in obtaining the two-resonator three-conductor spurline bandpass filter. First, we replace each shunt stub of the conventional filter (Fig. 1(a)) with two shunt stubs of half the characteristic admittance and then convert to the dual case. Second, adding a half-

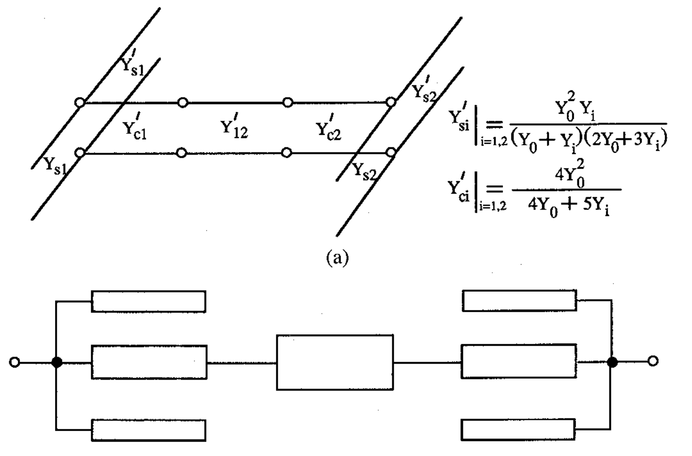

Fig. 2. Transformation of a conventional shunt-stub filter into the three-conductor spurline bandpass filter. All lines are half-wavelength long, except the middle connecting line which is quarter-wavelength long.

wavelength line of characteristic admittance Y_0 at each end of the filter and invoking Kuroda's identity twice yields the circuit of Fig. 2(a). Finally, folding the stubs parallel to the main line for coupling to occur produces the spurline bandpass filter in Fig. 2(b). By equating the chain matrix of the three-conductor spurline resonator, characterized by the characteristic admittances and electrical lengths of the a-, b-, and c-modes [5], to that of its equivalent network consisting of two open-circuited shunt stubs and a line, the required spurlines' mode characteristic admittances and lengths can be determined numerically.

Two two-resonator microstrip spurline bandpass filters, with passband center frequencies around 5 GHz, were designed and tested. The filters were fabricated on a Duroid substrate with a relative dielectric constant of 10.5 and a thickness of 0.025 in. The performance of the three-conductor spurline filter is shown in Fig. 3. Insertion losses of less than 1.3 dB and return losses of greater than 15 dB were achieved in the pass band. For the two-conductor spurline filter, less than 1-dB insertion losses and more than 20-dB return losses were measured in the pass band. Good agreement between the experimental and theoretical responses for both filters was obtained. The calculated performances were obtained through the use of the chain matrices of the spurline resonators [5]. Fig. 4 shows photographs of the filters.

III. Conclusion

Novel spurline bandpass filters have been presented. Approximate design equations for the two-resonator filters have been derived. Two two-resonator spurline bandpass filters have also been developed using microstrip lines. Passband insertion losses of less than 1 and 1.3 dB and return losses of more than 20 and 15 dB have been measured for the two- and three-conductor spurline filters, respectively. Measured and calculated performances are also in good agreement. This class of filters, while behaves very similar to its counterparts that employ open-circuited shunt stubs, is more compact and possesses less dispersion, sensitivity to close objects, and radiation, and thus is attractive for applications requiring high performance and reduced size and weight.

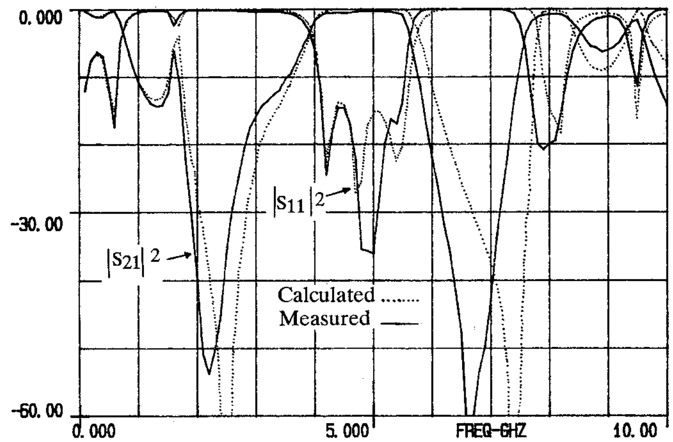

Fig. 3. Measured and calculated performances of the microstrip three-conductor spurline bandpass filter.

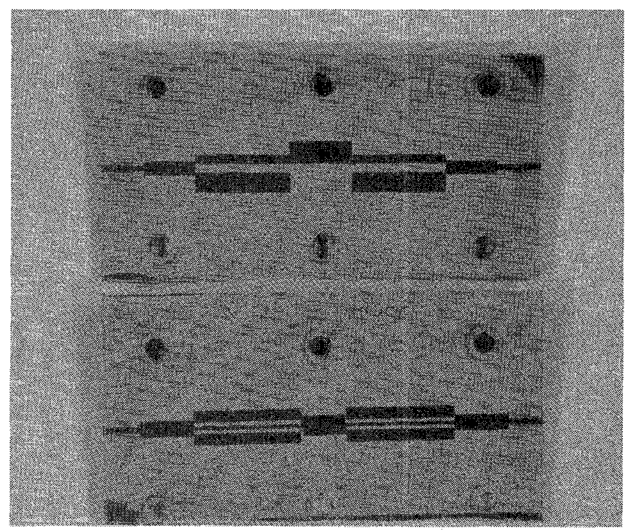

Fig. 4. Photographs of the microstrip two-conductor (top) and three-conductor (bottom) spurline bandpass filters.

Acknowledgment

The author wishes to thank M. Tran and L. Fan for their technical support.

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