Development of New Microstrip Pseudo-Interdigital Bandpass Filters

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***Abstract*—A new type of miniaturized microstrip bandpass filters with pseudo-interdigital structure without via hole grounded resonators is described. A very compact filter of this type, having a size smaller than quarter-wavelength by quarter-wavelength at a midband frequency of 1.1 GHz was designed and fabricated. The measured and simulated results are presented.**

I. INTRODUCTION

MINIATURIZED microwave bandpass filters are always in demand for systems requiring small size and light weight. This demand is very much increased recently by rapidly expanding cellular communication systems. Although parallel-coupled microstrip filters with half-wavelength resonators are common elements in many microwave systems [1], their large size is incongruous with the systems where the size reduction is an important factor. Conventional microstrip interdigital filters, on the other hand, are extremely compact. However, they require short-circuit (grounding) connections with via holes [2], which is not quite compatible with planar fabrication techniques. It is therefore desirable to develop new types of microstrip bandpass filters which actually meet both requirements of small size and planar fabrication.

In this paper, we present for the first time the development of a new microstrip pseudo-interdigital bandpass filter structure. The new microstrip filter structure has advantages of compactness and simplicity. It gains its compactness from the fact that it has a size similar to that of the conventional interdigital bandpass filter. It gains its simplicity from the fact that no short-circuit connections are required so the structure is fully compatible with planar fabrication techniques. A very compact bandpass filter of this type was designed and fabricated. The measured and simulated results are also presented.

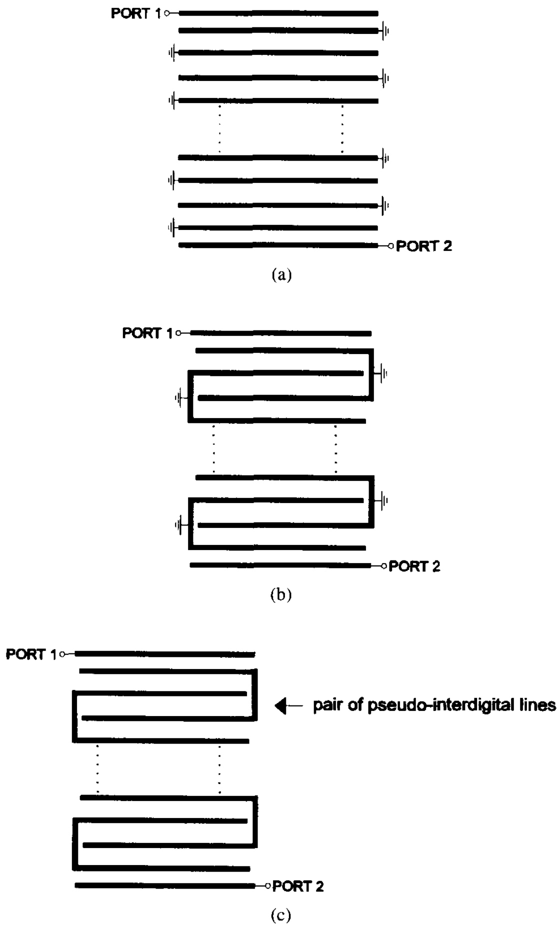

Fig. 1. Progressive steps in developing the new microstrip bandpass filter: (a) conventional interdigital filter; (b) modified interdigital filter; and (c) new pseudo-interdigital filter.

II. DEVELOPMENT OF NEW FILTER

The new filter may be conceptualized from the conventional interdigital bandpass filter [3]. For the demonstration, a conventional interdigital filter structure is schematically shown in Fig. 1(a). Each resonator element is a quarter-wavelength long at the midband frequency and is short-circuited at one end and open-circuited at the other end. The short-circuit connection on the microstrip is usually realized by a via hole to the ground plane. Since the grounded ends are at the same potential, they may be so connected, without severe distortion of the bandpass frequency response, to yield the modified interdigital filter given in Fig. 1(b). Then, it should be noticed that at the midband frequency there is an electrical short-circuit at the position where the two grounded ends are jointed even without the via hole grounding. Thus, it would seem that the voltage and current distributions would not change much in the vicinity of the midband frequency even though the via holes are removed. This operation, however, results in the so-called pseudo-interdigital filter structure as shown in Fig. 1(c),

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which may also be seen as a combination of interdigital- and hairpin-line [4] resonators with cross couplings.

Another way to look at the new filter structure is that of a doubly periodic structure. If each pair of pseudo-interdigital lines is taken as a kind of periodic structure, then the new filter is based on a doubly periodic array composed of several such periodic structures. Thus, the wave interaction in such a doubly periodic structure will exhibit both passband and stopband behaviors.

III. EXPERIMENTS

To verify the concept of the new filter structure, a microstrip pseudo-interdigital bandpass filter was designed and fabricated on a RT/Duriod substrate having a thickness of 1.27 mm and a relative dielectric constant of 10.8. It should be mentioned that at present no simple design procedure is available to design the new filter, nevertheless the existent powerful electromagnetic (EM) simulators enable us to carry out the design using direct EM field simulation without difficulty [5].

Fig. 2 illustrates the layout of the designed filter with a 15% bandwidth at 1.1 GHz. All parallel microstrip lines except for the feeding lines have the same width as denoted by w_2. The spacing for pseudo-interdigital lines is kept the same as indicted by s_2. The separation between pseudo-interdigital structures is denoted by s_3. As can be seen the whole size of the filter is 26.5 mm by 17.6 mm, which is smaller than $\lambda_{go}/4$ by $\lambda_{go}/4$ where λ_{go} is the guided wavelength at the midband frequency on the substrate. This size is quite compact for distributed parameter filters and demonstrates the compactness of the new filter structure. The measured performace of the filter is shown in Fig. 3. It can be observed that the passband frequency response is fairly flat and the frequency skirts are sharp. This is attributed to the multipoles in the vicinity of the midband. It can also be seen that there is an attenuation pole at the edge of the upper stopband. This attenuation pole is an inherent characteristic of this type of filter due to its coupling structure, and enhances the isolation performance of the upper frequency skirt. By examining the measured passband insertion and return losses using the relation of $|S_{21}|^2 + |S_{11}|^2 = 1$ for an ideal lossless filter, it can be found there is about 1.5 dB loss in the passband, which is mainly due to the conductor loss [6]. This is confirmed by the EM simulation as shown in Fig. 4. The parameters for the conductor loss simulation are $R_{dc} = 0.001$ ohms/square and $R_{rf} = 2.6 \times 10^{-7}$ ohms/square as referred to [7]. A lower conductor loss can be obtained either using wider resonator lines or using a superconductor. The slight difference between the measured and simulated results in Fig. 4 may be attributed to the material and fabrication tolerances. The overall performance of the filter is able to be further improved by optimization design.

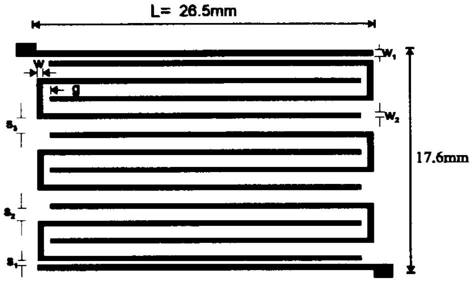

Fig. 2. Layout of a microstrip pseudo-interdigital bandpass filter at 1.1 GHz. (w = 0.5 mm, g = 0.5 mm, w_1 = 0.5 mm, w_2 = 0.4 mm, s_1 = 0.3 mm, s_2 = 1.0 mm, and s_3 = 1.1 mm).

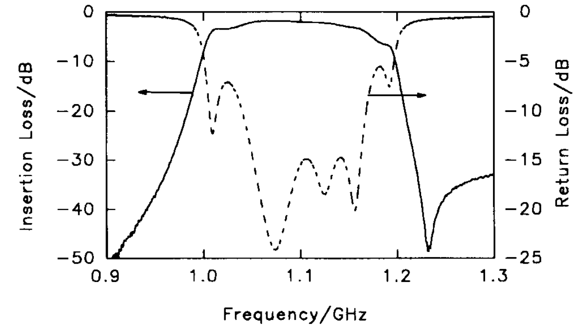

Fig. 3. Measured frequency response. (Full line: insertion loss; broken line: return loss.)

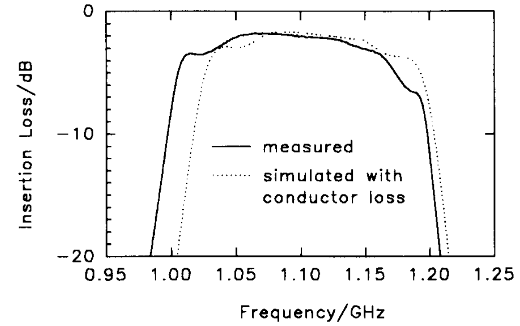

Fig. 4. Measured and simulated insertion loss.

IV. CONCLUSION

A new microstrip pseudo-interdigital bandpass filter structure has been reported. A bandpass filter of this type with a 15% bandwidth at 1.1 GHz has been designed and fabricated to demonstrate compactness (with a size smaller than quarter-wavelength by quarter-wavelength at the midband frequency) and simplicity (without any short-circuit connections) in the filter. It would seem that the new filter structure provides a very attractive means for developing very compact filters with fully planar fabrication techniques. This is especially of benefit for monolithic microwave integrated circuits (MMIC) as well as for the growing numbers of microwave superconductive circuits.

REFERENCES

[1] R. E. Collin, *Foundations for Microwave Engineering*, 2nd ed. New York: McGraw-Hill, 1992, ch. 8.

[2] D. G. Swanson, Jr., "Grounding microstrip lines with via holes," *IEEE Trans. Microwave Theory Tech.*, vol. 40, pp. 1719–1721, 1992.

[3] G. L. Matthaei, "Interdigital band-pass filters," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-10, pp. 479–491, 1962.
[4] E. G. Cristal and S. Frankel, "Hairpin-line and hybrid hairpin-line/half-wave parallel-coupled-line filters," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-20, pp. 719–728, 1972.
[5] J. W. Bandler, R. M. Biernacki, S. H. Chen, D. G. Swanson Jr., and S. Ye, "Microstrip filter design using direct EM field simulation," *IEEE Trans. Microwave Theory Tech.*, vol. 42, pp. 1353–1358, 1994.
[6] G. L. Matthaei and G. L. Hey-Shipton, "Concerning the use of high-temperature superconductivity in planar microwave filters," *IEEE Trans. Microwave Theory Tech.*, vol. 42, pp. 1287–1293, 1994.
[7] *EM User's Manual.* Sonnet Software, Inc., 1993, Version 2.4.