Inverted Defected Ground Structure for Microstrip Line Filters Reducing Packaging Complexity

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Introduction

Defected ground structures (DGS) for microstrip lines have been attracting researchers in recent years. They have been presented in a number of different shapes for filter applications [1], [2]. This technique is suitable for periodic structures, and both for low-pass and band-pass filters were presented, e.g., [3]-[8].

In general these structures are designed by opening slots under the main layout of a circuit to improve its performance, in addition, to reduce the size of a circuit. However, such structures increase a packing complexity, since they need to have a recessed region a carrier block under the defected ground slot or sometimes under the overall filter structure. Moreover, the resonant frequency of the DGS depends on the dimensions of this region.

This paper introduces a DGS of a new form. The original ground plane of the circuit is left fully metallized, whereas DGS slots are etched on an additional substrate – superstrate, which is placed on the top the substrate. The ground planes of both substrates are connected together by via holes. This structure has the great advantage for packaging since it reduces its complexity needed in the case of classical DGS filters, in addition it has higher Q-factor than that for the classical DGS structures. As an example, a quasi-elliptic microstrip filter is designed using an interdigital DGS structure. The filter is designed and fabricated on an RO4003c substrates 0.831 mm in thickness and relative dielectric constant of 3.38.

DGS and Packaging

To find the relation between the dimensions of the recessed region under the DGS and its resonant frequency a simple study has been done using an interdigital slot introduced and studied in [9]. The main parameters that affect the resonance frequency of the slot are the length of the fingers, spacing between fingers, and the number of the metallic fingers, see [9]. The microstrip line with the DGS of the dimensions shown in Fig. 1 that has resonant frequency of 5.95 GHz in free space was used. A recessed region in a metallic block bearing the structure under the DGS affects its resonant frequency, the dimensions of the grove are 10 mm length and 10 mm width. Fig. 2 shows the calculated relation between the depth of this recessed area under the DGS and the resonant frequency of the structure. This simulation was done by the commercial MoM simulator SONNET [10].

Structure with Simplified Packaging

To avoid the need of using a recessed area in the carrier block, the original ground plane of the circuit is kept fully metallized, and the interdigital slot is etched on a superstrate, which is placed on the top of the substrate. The ground plane of the substrate is connected with the metal on superstrate by via holes. Fig. 3 shows a 3D view of this structure. This structure has higher quality factor than that for the classical DGS structures, since it has narrower stop-band. Simulated response of the proposed structure in comparison with the standard structure described in [9] is shown in Fig. 4. The interdigital slot dimensions are defined in Fig. 1. The

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proposed structure has lower resonant frequency and narrower stop-band than the standard DGS.

Low-Pass Filter

In general, the cut-off frequency of the low-pass filter is determined by the lumped elements of the filter [11]. Capacitances and inductances of the filter elements can be represented by segments of transmission lines. To do that, the characteristic impedance Z_0 and effective dielectric constant ε_{eff} of the high/low-impedance transmission lines have to be calculated. For that, a commercial MoM simulator was used [10]. Then the transmission line lengths $l_{k,j}$ are calculated as

$$C_k = \frac{l_k}{Z_{ok}.v_{ph,k}} , \tag{1}$$

$$L_j = \frac{l_j.Z_{oj}}{v_{ph,k}} , \tag{2}$$

Considering $l_{k,j} << \lambda$, where C_k , L_j , are the capacitances and inductances of the elements, and $v_{ph} = c_o / \sqrt{\varepsilon_{eff}}$, c_o is the speed of light.

Having calculated the transmission line lengths, the filter can be constructed, however, optimization is still needed. Fig. 5 shows the filter built on the substrate fully metallized on the rear side. Fig. 6 shows the metallization layout on the superstrate consisting of two interdigital slots and one aperture. The rear side of the superstrate is non-metallized. The slots introduce transmission zeros [9], while the aperture increases the central transmission line inductance [12]. The superstrate is placed directly on the substrate. The metallization is connected to the ground by via holes. Fig. 7 shows the photograph of the structure. Insertion and return losses of the filter are plotted in Fig. 8. The cut off frequency is about 3 GHz, and the transmission zero is located at about 5.75 GHz. The group delay variation of the filter at the pass-band is about 0.15 ns. Fig. 9 shows in a fine scale the insertion loss at the pass-band, which is better than 0.4 dB. The measured group delay variation in the passband is about 0.157 ns.

Conclusion

A new defected ground structure for microstrip line circuits was introduced by keeping the ground plane of the circuit fully metallized and etching the slots on the superstrate, which is directly lain on the top of the substrate. The metal of the superstrate is connected by via holes to the ground plane. The structure has the great advantage in reducing the packaging complexity, since it can be directly based on the carrier block without the need of machining a recessed region in it. Moreover, a higher Q-factor is obtained for this kind of structures. The low-pass filter based on this structure was designed, fabricated and measured. The DGS structure located on the superstrate provides the transmission zeros improving the steepness of the transmission characteristic and the attenuation in the stop-band. The filter insertion losses are better than 0.4 dB. The measured data fit well the results of MoM simulation.

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References

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Figures

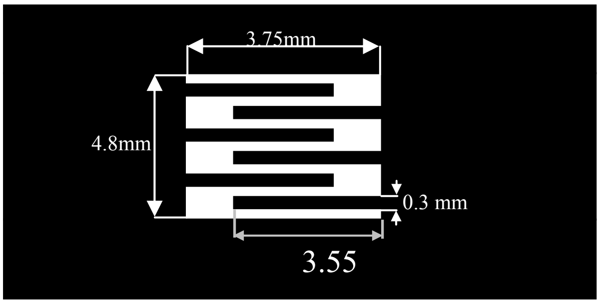

Fig. 1 Rear side layout of the interdigital DGS structure.

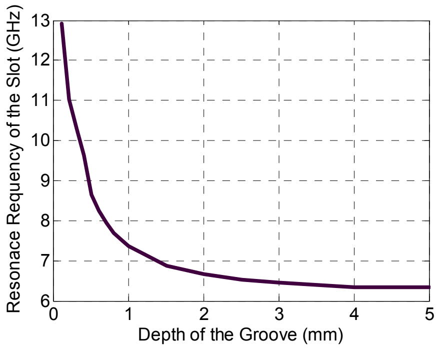

Fig. 2 Calculated relation between the resonance frequency of the interdigital slot and the depth of the recessed region under DGS.

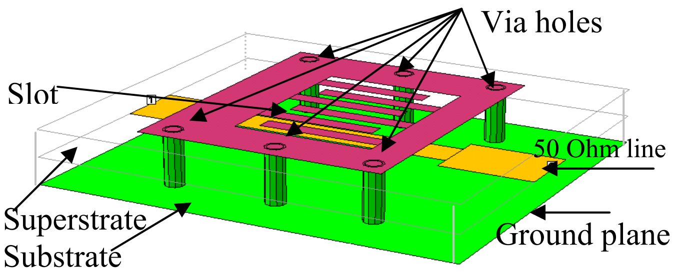

Fig. 3 3D view of the proposed structure with an interdigital slot.

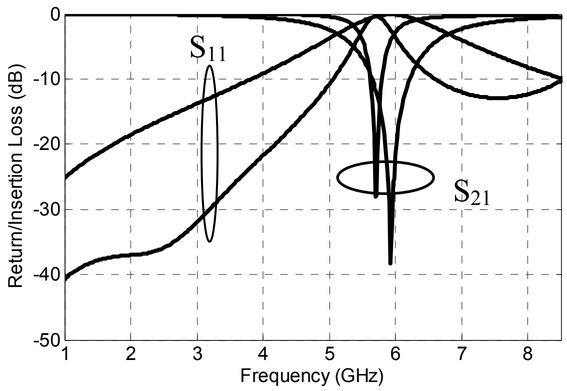

Fig. 4 Simulated insertion and return loss of the proposed structure (solid) in comparison with the standard DGS structure (dashed) [9].

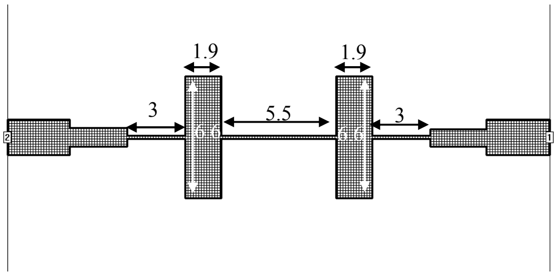

Fig. 5 Top layout of a fifth order low-pass filter, the rear of the substrate is fully metalized.

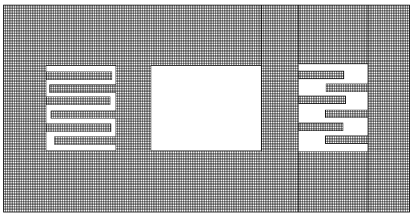

Fig. 6 Metallization of the additional substrate, which contains two slots with finger lengths 3.55, and 2.45 mm, and one aperture.

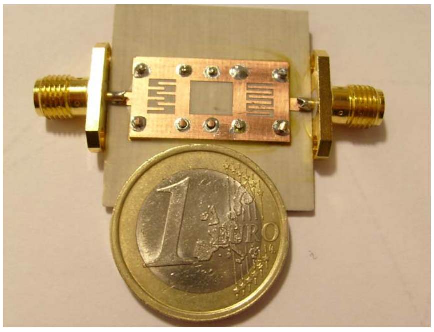

Fig. 7. Photograph of the fabricated low-pass filter.

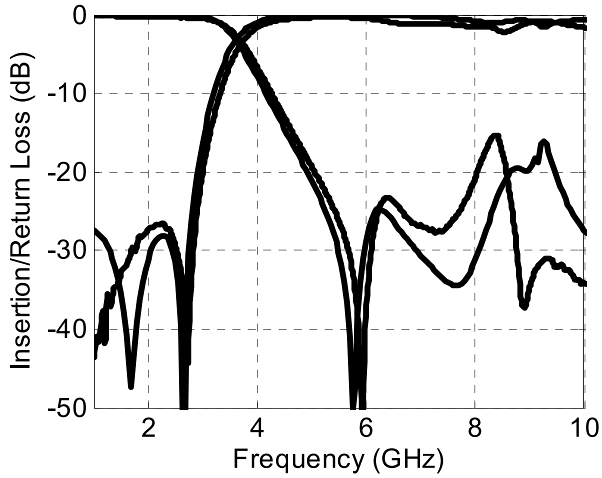

Fig. 8 Simulated (dashed) and measured (solid) insertion and return loss of the low-pass filter additional transmission zeroes.

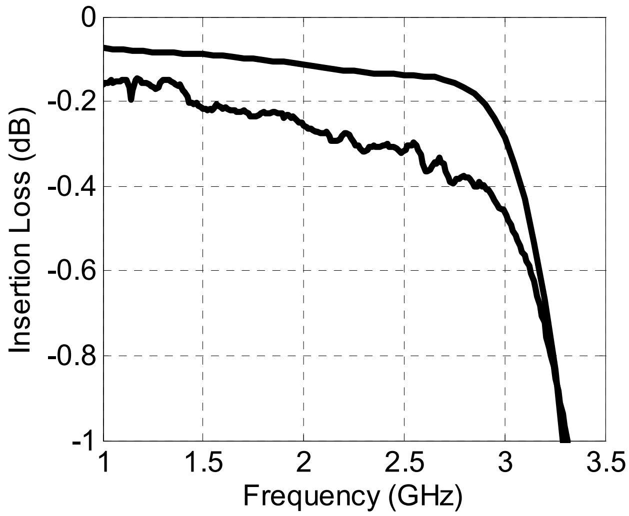

Fig. 9 Simulated (dashed) and measured (solid) insertion loss of the low-pass filter at the pas-band.