Control of Bandstop Response of Cascaded Microstrip Low-pass-Bandstop Filters Using Arrowhead Slots in Backside Metallic Ground Plane

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Brief

- A new equivalent circuit and modeling method for a uniform arrowhead-defected-ground-structure slot are proposed for the design of a DGS-cascade lowpass or bandstop filter
- The effect of the geometry of a defected ground structure (DGS) on the performance of the cascaded-LPF or BSF and the effect of the cascaded Method are examined.
- The proposed LPF or BSF based on π -arrowhead DGS slot is 70% shorter than a conventional LPF
- It was found that only three cells of the proposed structure are necessary for a 15-dB stopband at 6 GHz
- The validity of the proposed equivalent circuit model is established by comparing their response to the full-wave EM simulation of several structures
- Measured results show that the new designs exhibit better performance by suppressing ripples and enlarging stopband bandwidth

Defected Ground Structures (DGS)

- Defected ground structures (DGS) which are realized by etching defects in the backside metallic ground plane under a microstrip line
- A basic and widely used DGS cell is composed of two wide defected areas and a narrow connecting slot
- A DGS-slot combination has a simple structure and can be modeled as a parallel LC resonator
- Such a structure blocks the signal around its resonant frequency and may be used to introduce a notch or enhance and widen the stopband of lowpass or clean up filters
- The characteristics of such filters are sharp transitions between the passband and the stopband, low insertion loss in the passband and strong attenuation in a wide stopband.
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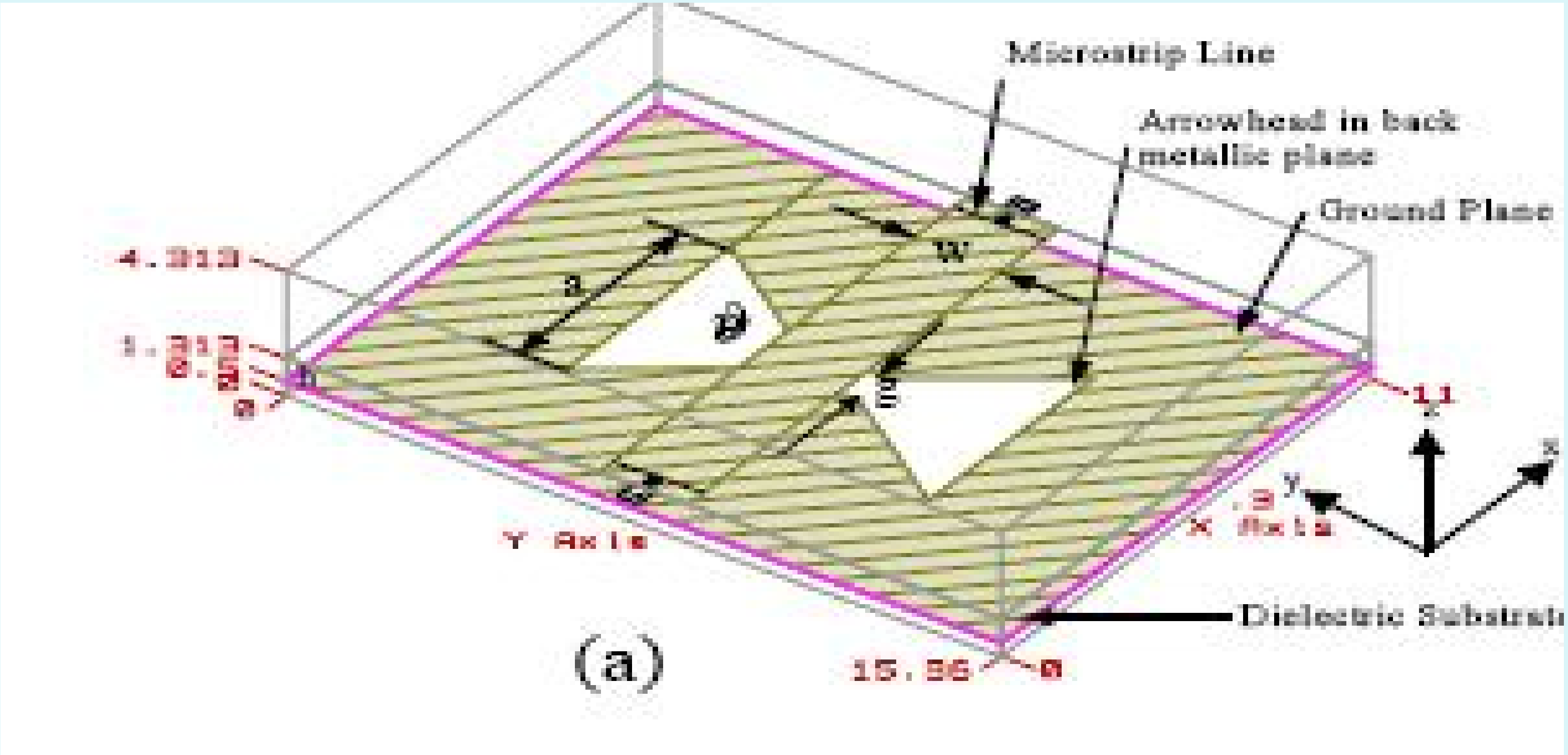
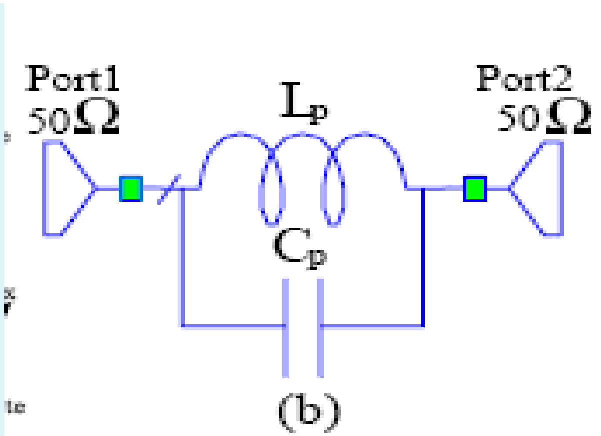
Design Idea

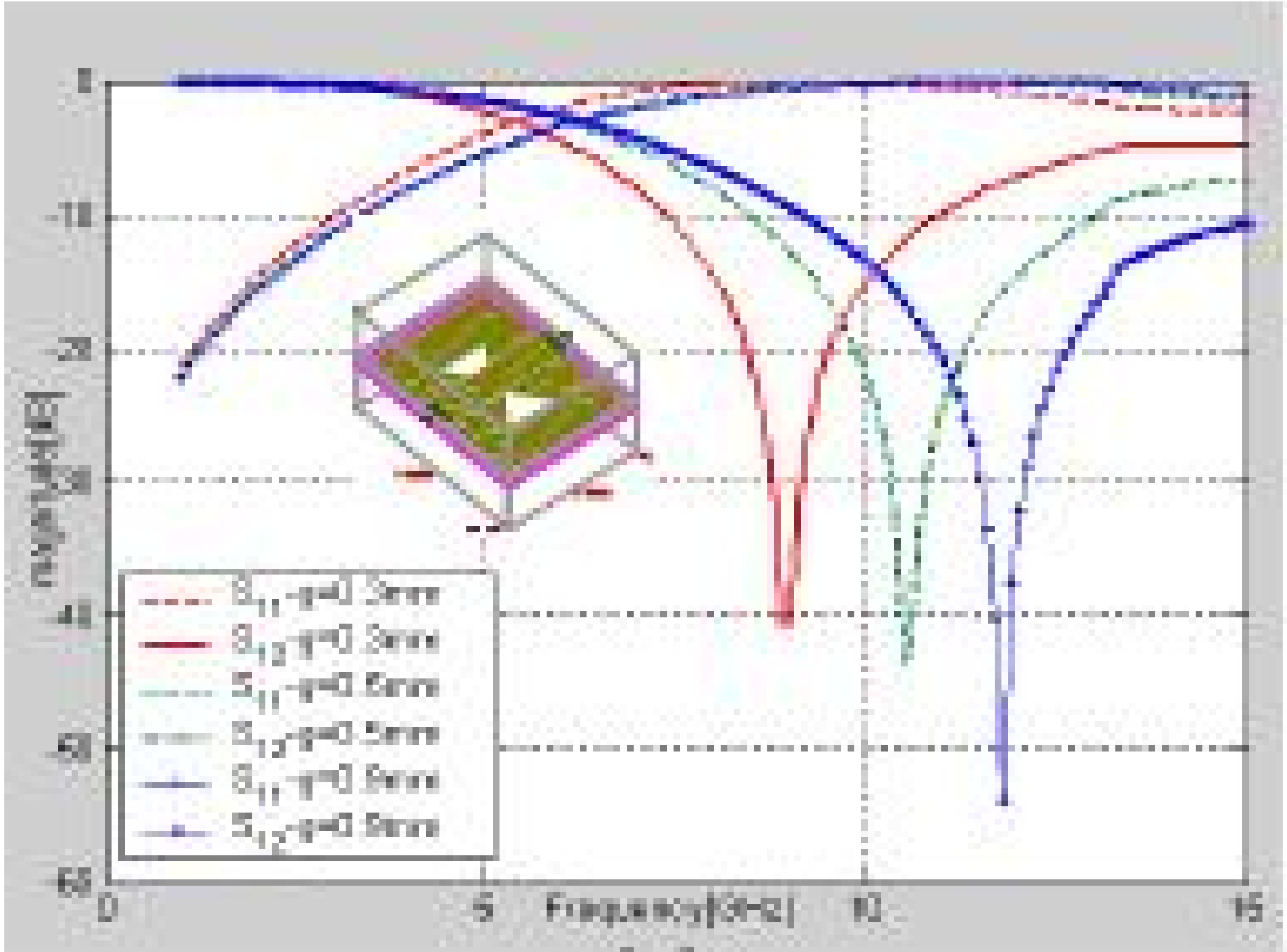
- An arrowhead slot-shape turned around its own horizontal axis by π (180°) is used. The gap (g) and the area of the head shape of the DGS-slot are adjusted to achieve better response.
- The angle θ which controls the area of the arrowhead and the gap g are varied according to the following geometric series

$$\theta_n = (q)^n \theta_0 \text{ with } \theta_0 = 80^\circ = \frac{4\pi}{9},\ \mathrm{q} = \left(\frac{9}{10}\right) and g_0 = (q)^{\frac{n}{2}} g_0 \text{ with } g_0 = 0.9\text{mm}$$





(a) DGS element,
(b) Equivalent circuit of DGS element,



(c)

Simulated S parameters for different values of g

- The comparison, between the fabricated filter, the simulated and the calculated measurements, shows an agreement up to 90%. Measurements, also, show that the filter exhibits better performances by suppressing ripples, widening stopband bandwidth and introducing high sharpness for the transition from passband to stopband.

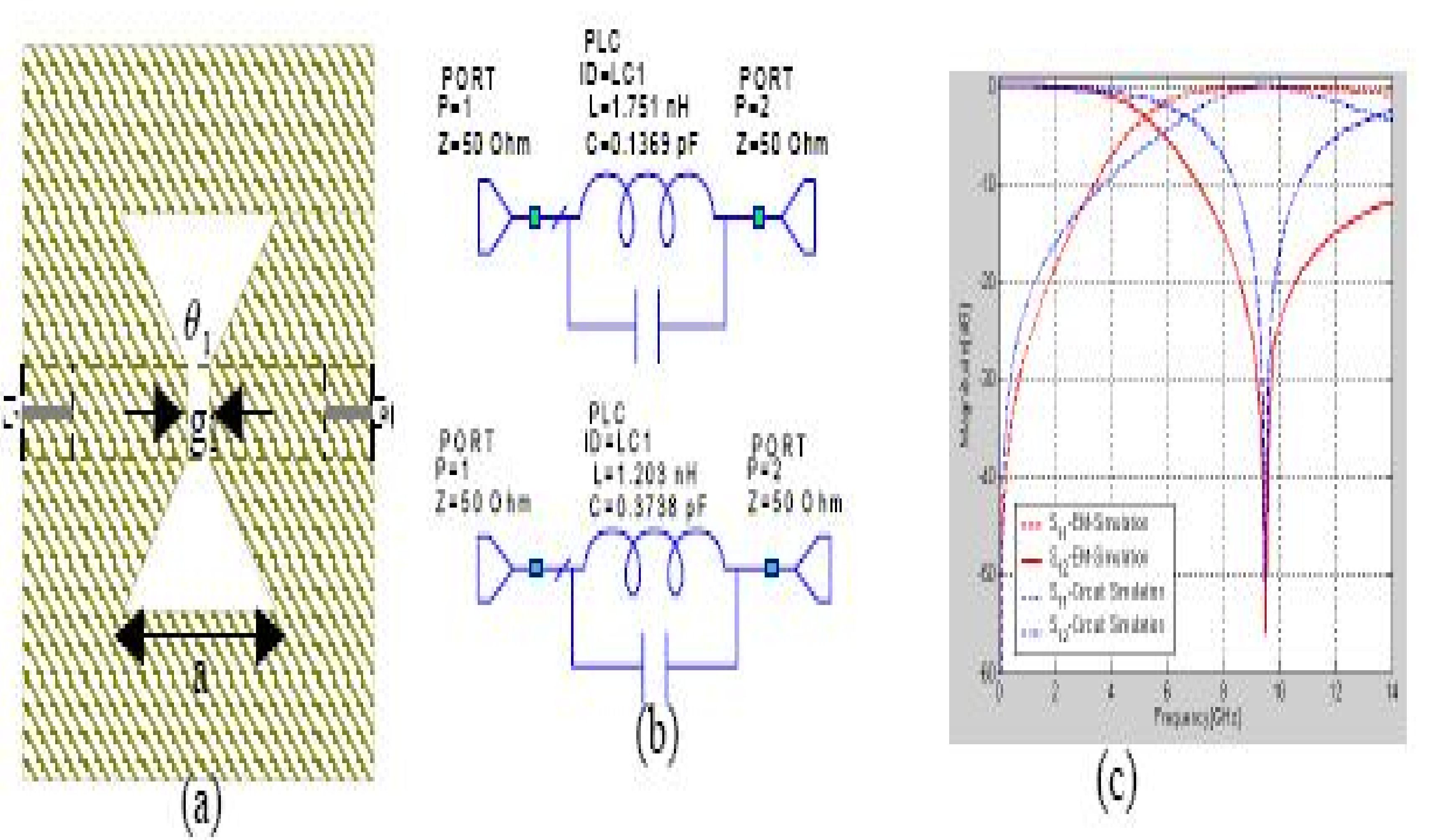
MODELING AND EXTRACTION METHOD

- The parameters of a DGS-slot combination can be extracted from the following procedure.

$$\omega_c = 2\pi f_c \text{ und} y_p = \frac{1}{X_{LC}} = jB_p + \frac{1}{R_{p\longrightarrow}} \approx jB_p = j\omega C_p + \frac{1}{j\omega L_p} \Rightarrow X_{LC} = \frac{1}{\omega_p C_p \left(\frac{\omega_p}{\omega} - \frac{\omega}{\omega_p}\right)}$$

- Therefore, the L-element value, which is scaled to Z_0 and f_C, can be determined from

$$g = \frac{\omega_c L}{Z_0} \Rightarrow L\omega_c = Z_0 g = X_{LC}\Big|_{\omega=\omega_c} = X_{L_{eq}} = \frac{1}{\omega_p C_p \left(\frac{\omega_p}{\omega_c} - \frac{\omega_c}{\omega_p}\right)} \Rightarrow C_p = \frac{\omega_c}{(Z_0 g)(\omega_p^2 - \omega_c^2)}$$

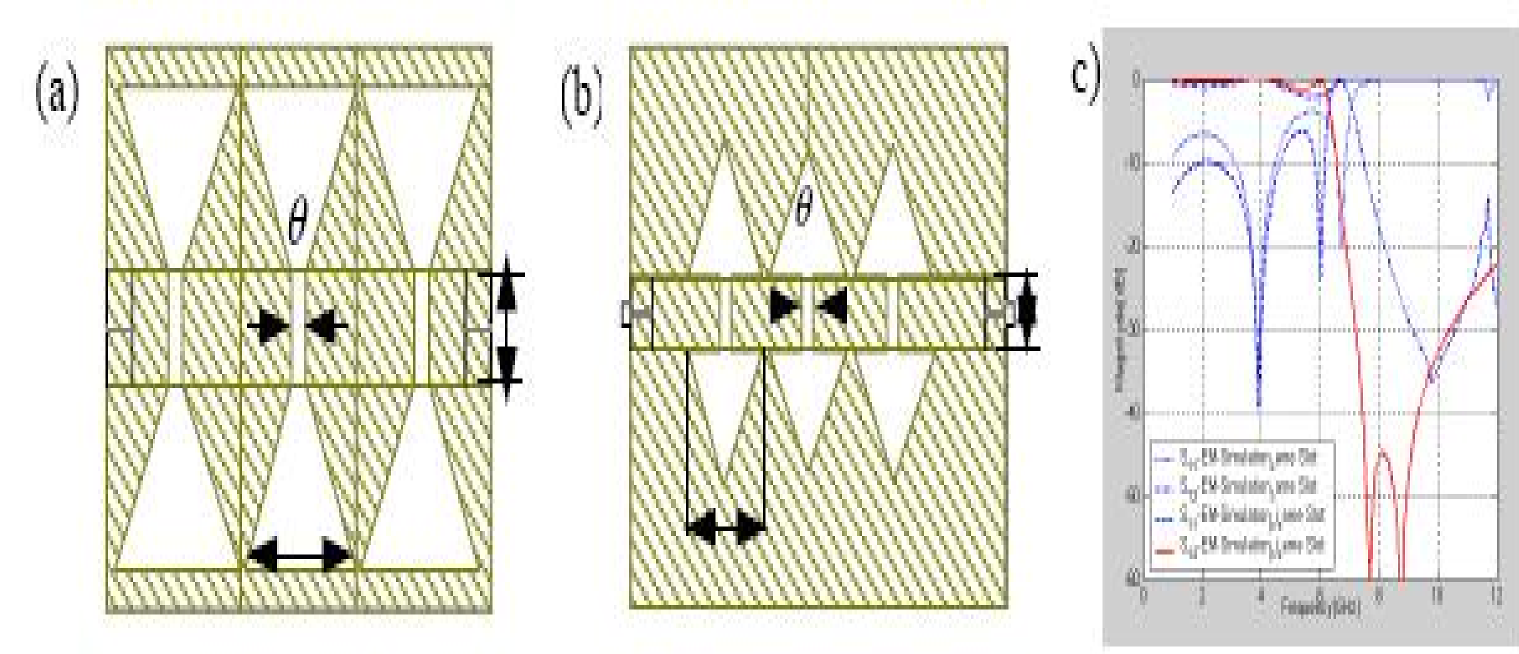


Arrowhead-slot modeling. (a)DGS element (bottom). (b) Extracted equivalent circuit.
(c) S11and S12 for EM- and circuit simulation

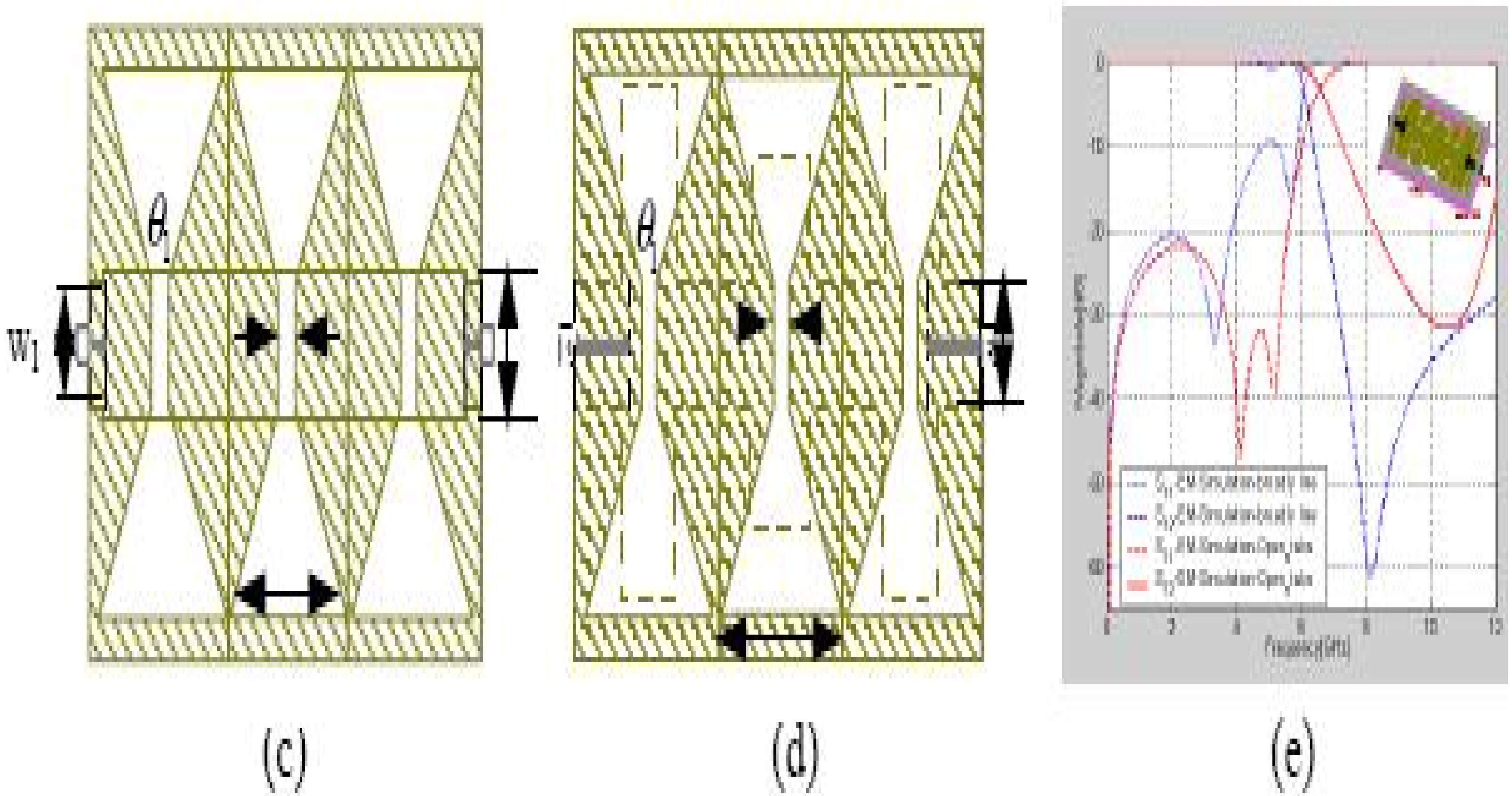
DESIGN OF THE PROPOSED PERIODIC DGS

Table I: Dimensions of proposed filter

Dimension	g_1	g_0	a	w	w_1	p	ϑ_0	ϑ_1
Values	0.07cm	0.09cm	0.5cm	0.92cm	0.22cm	0.3cm	80°	60°

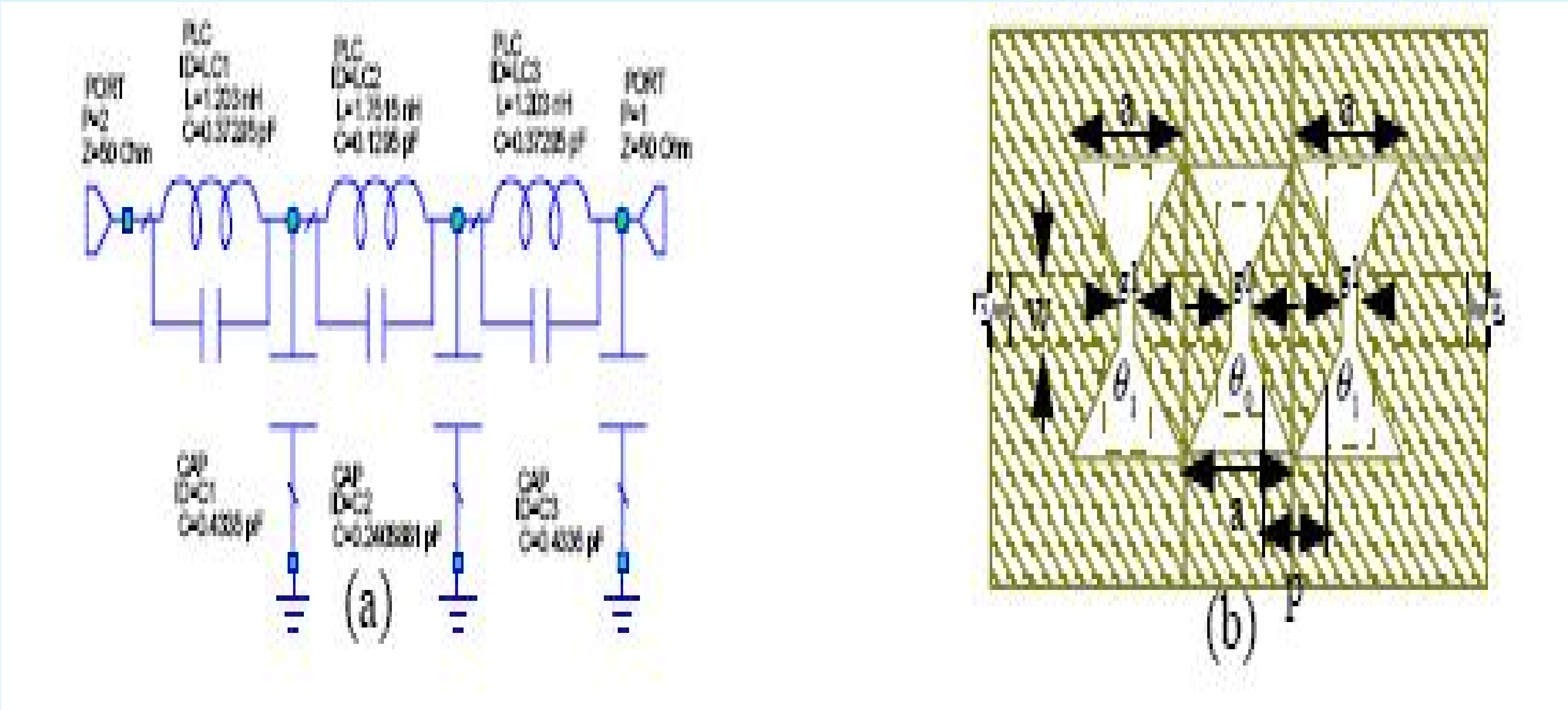


Schematic views of (a) structure 1, (b) structure 2 , and (c) S-parameter of (a) structure 1 and (b) structure 2

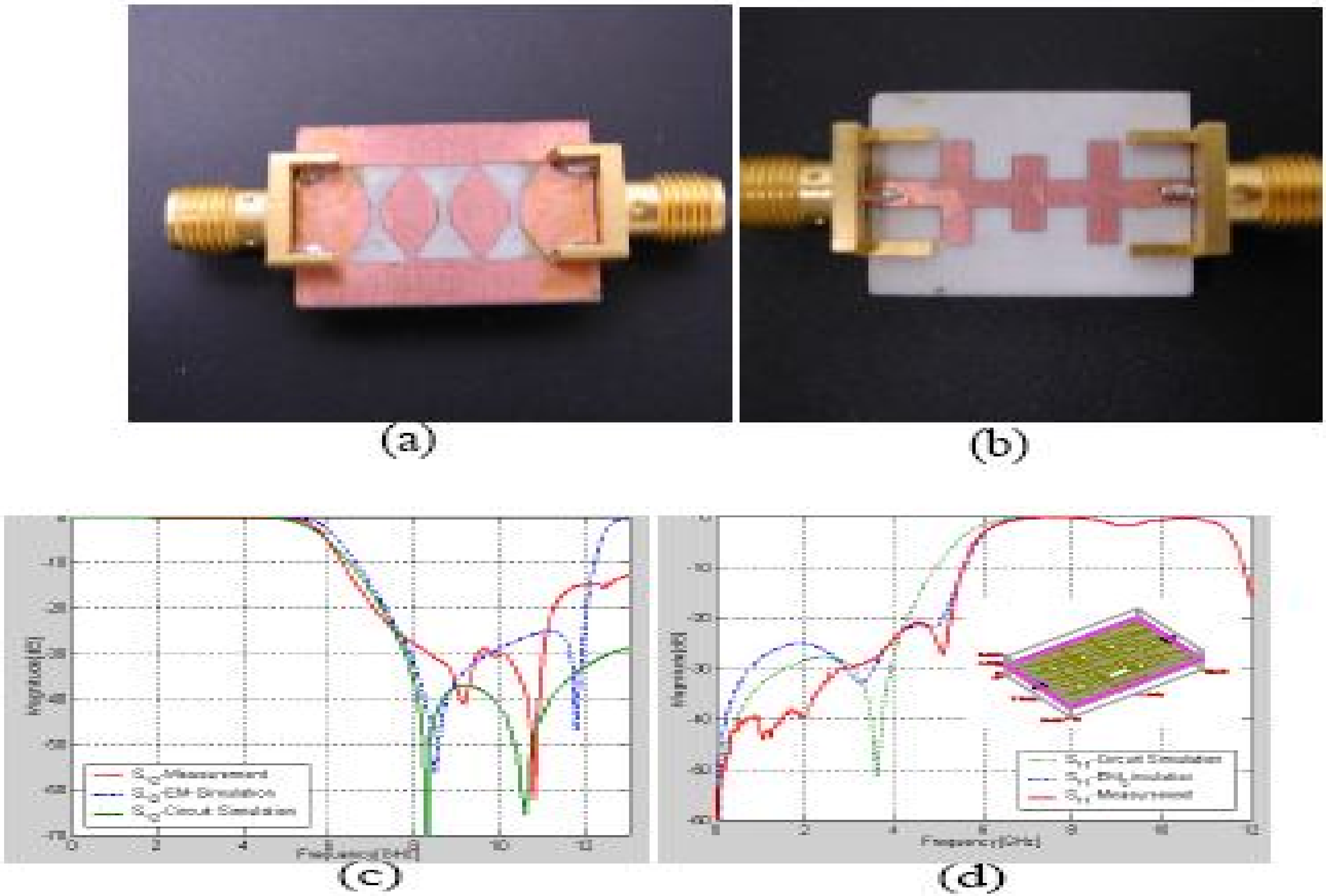


Schematic views of (c) structure 2, (d) structure 3 , and (e) S-parameter of both structures

- Based on structure 4, another improved cascaded open-stub filter have been designed as shown



Schematic of Layout (b) of the cascaded LPF with 3-sectionDGS and
(a) equivalent circuit



Fabricated DGS low-pass filter with cascaded filter using slots and open stubs .
(a) Bottom view. (b) Top view . Measured & Simulated (c)S12 & (d)S11

Conclusion

- An improved triangle-slot DGS which has an inverse arrowhead and non-uniform gap as defect slot in the backside metallic ground plane is presented.
- Lowpass filters with wide stopband can be designed by cascading a suitable number of DGS elements in which the angle of the inverse arrowhead defect and the gap g are varied in the outward direction following a geometric series
- A fabricated LPF shows a stopband from 5.7 to 11.7GHz, 0.3 dB insertion loss without ripples in the passband and a sharp transition between the passband the stopband
- The compactness and simplicity of the structure make the proposed filters a strong candidate for applications in various integrated microwave circuits.