



## Structures Exhibiting Left-Handed Properties in Microwave Range

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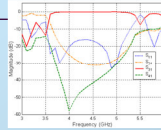
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## Outline

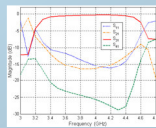
- Investigations on new distributed multilayer microstrip structures based on Stepped Impedance Resonators (SIR) pairs are presented;
- The periodic structures show left-handed properties in a frequency band near to resonance;
- The equally distanced via holes produces an effective negative permittivity in microwaves;
- The resonator pairs behave similarly to the split ring resonators (SRR) leading to a negative magnetic permeability.

## Nonresonant implementation of a left-handed material

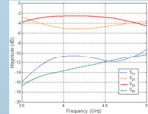


0 dB symmetric coupler

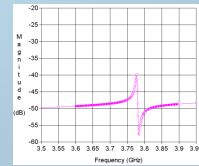
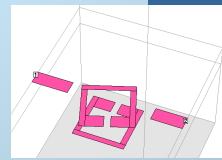
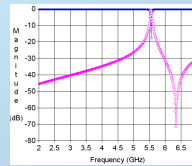
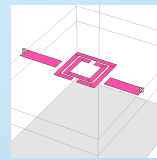
0 dB asymmetric coupler

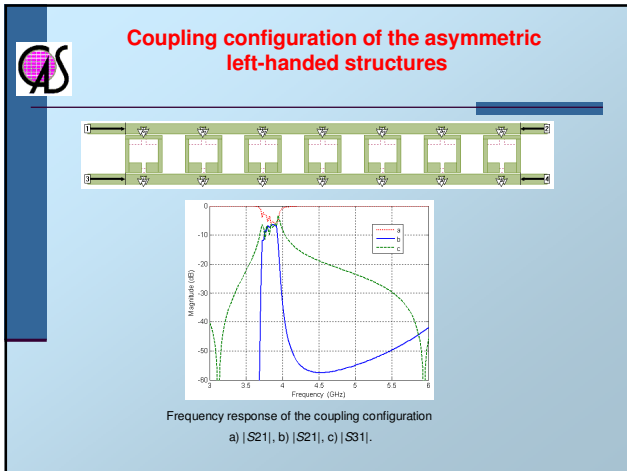
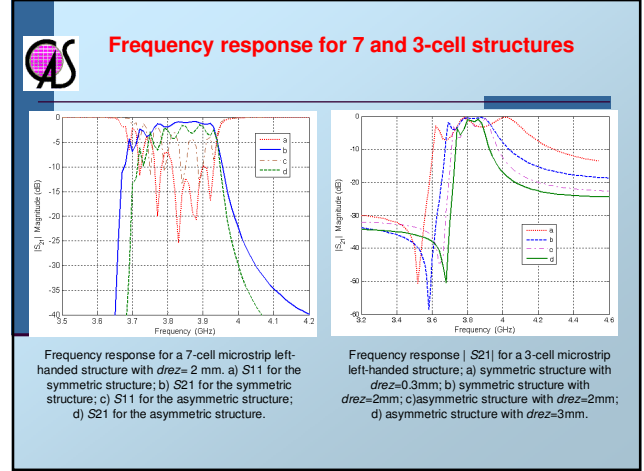
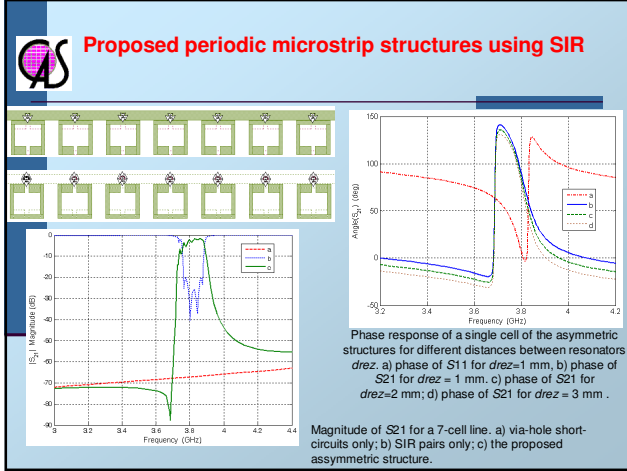


3 dB symmetric coupler



## SIR versus SRR





- ### Conclusions
- Due to the compactness of the Stepped Impedance Resonators (SIR), the proposed structures are more compact than those which use Split Ring Resonators (SRR).
  - The amplitude and phase responses of the proposed structures can be easily controlled by changing the geometrical parameters.
  - For a small gap between SIR and the microstrip line, the frequency response does not show a significant dependence with the coupling gap to the line or with the number of cells. However, the in-band reflections decreases with the decreasing of the coupling between resonators belonging to different cells, or by increasing the thickness of the bottom dielectric substrate between the ground-plane and the middle microstrip plane.
  - The developed effective medium theory was applied to multilayer microstrip structures. The proposed CRLH structures exhibit negative values of the refractive index  $n$  only in a narrow frequency band.