Structures Exhibiting Left-Handed Properties in Microwave Range

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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
**Proposed periodic microstrip structures using SIR**

- Magnitude of $S_{21}$ for a 7-cell line. a) via-hole short-circuits only; b) SIR pairs only; c) the proposed asymmetric structure.

**Phase response of a single cell of the asymmetric structures for different distances between resonators $d_{rez}$.** a) phase of $S_{11}$ for $d_{rez}=1$ mm, b) phase of $S_{21}$ for $d_{rez}=1$ mm, c) phase of $S_{21}$ for $d_{rez}=2$ mm, d) phase of $S_{21}$ for $d_{rez}=3$ mm.

**Frequency response for 7 and 3-cell structures**

- Frequency response for a 7-cell microstrip left-handed structure with $d_{rez}=2$ mm. a) $S_{11}$ for the symmetric structure; b) $S_{21}$ for the symmetric structure; c) $S_{21}$ for the asymmetric structure; d) $S_{11}$ for the asymmetric structure.

**Frequency response | $S_{21}$| for a 3-cell microstrip left-handed structure; a) symmetric structure with $d_{rez}=0.3$ mm; b) symmetric structure with $d_{rez}=2$ mm; c) asymmetric structure with $d_{rez}=2$ mm; d) asymmetric structure with $d_{rez}=3$ mm.

**Coupling configuration of the asymmetric left-handed structures**

**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.