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Magic-T network with left-handed transmission line sections

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Outline

- Goal of the research
- Magic-T networks
- Metamaterial left-handed transmission line
- Model of ideal left-handed transmission line and its finite element approximation
- Broadband magic-T networks as a connection of 3-dB coupled-line directional couplers and left-handed transmission line sections
- Directional couplers with reduced coupling requirements as a connection of coupled-line sections and left-handed transmission lines
- Single-layer coupled-line magic-Ts utilizing left-handed transmission line sections
- Bandwidth improvement of rat-race couplers having left-handed transmission-line sections
- List of publications related to the presented topic

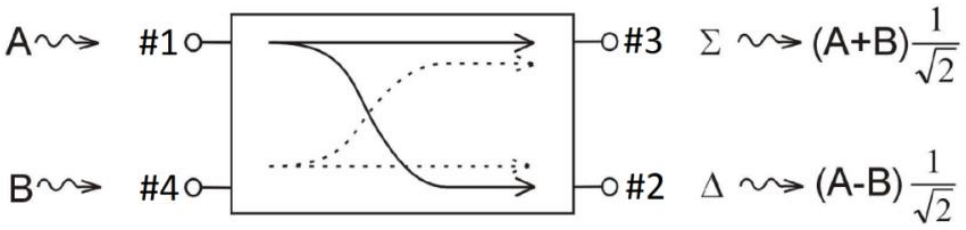
Goal of the research

- Investigation on artificial left-handed transmission lines properties,
- Developement of ideal left-handed transmission line model
- Investigation on potential applications of left-handed transmission line sections in microwave passive devices
- Development of novel magic-T networks taking advantage of metamaterial structures properties

Magic-T network

Magic-T network constitute specific group of microwave directional couplers having following properties:

- A signal injected into the port #3 will be divided equally between ports 1 and 2, and will be in phase. A signal injected into the port #2 will also be divided equally between ports 1 and 2, but will be 180 degrees out-of-phase.
- If signals are fed in both through ports #1 and #4, they are added at the port #3 and subtracted at the port #2

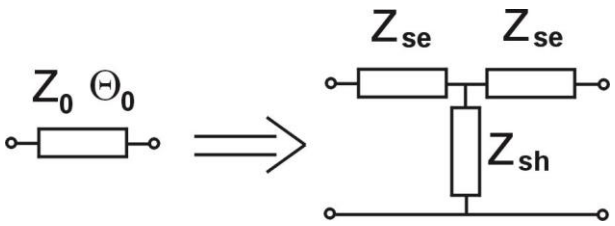


Metamaterial left-handed transmission line*

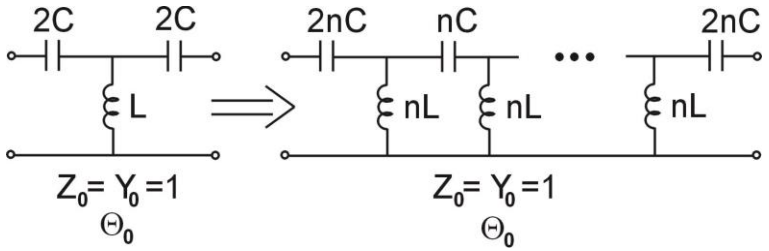
- *Electromagnetic metamaterials (MTMs)* are broadly defined as *artificial effectively homogeneous electromagnetic structures with unusual properties not readily available in nature*. An *effectively homogeneous* structure is a structure whose *structural average cell size p* is *much smaller than the guided wavelength* λ_g.
- If the condition of effective-homogeneity is satisfied, the structure behaves as a real material in the sense that electromagnetic waves are essentially *myopic to the lattice* and only probe the average, or effective, macroscopic and well-defined *constitutive parameters, which depend on the nature of the unit cell*; the structure is thus e*lectromagnetically uniform* along the direction of propagation. The constitutive parameters are the permittivity ε and the permeability μ.
- There are four possible sign combinations in the pair (ε,μ). The first three [(+,+), (+,−), (−,+)] combinations are well known in conventional materials, the last one [(−,−)], with *simultaneously negative permittivity and permeability*, corresponds to the new class of left-handed (LH) materials.
- LH materials, as a consequence of their double negative parameters, are characterized by antiparallel phase and group velocities
- Transmission Line approach to MTM structures can benefit from the efficient and well-established *TL theory* for the efficient design of microwave applications

* C. Caloz, T. Itoh, *Electromagnetic metamaterials: transmission line theory and microwave applications*, Hoboken, NJ: Wiley-IEEE Press, 2006

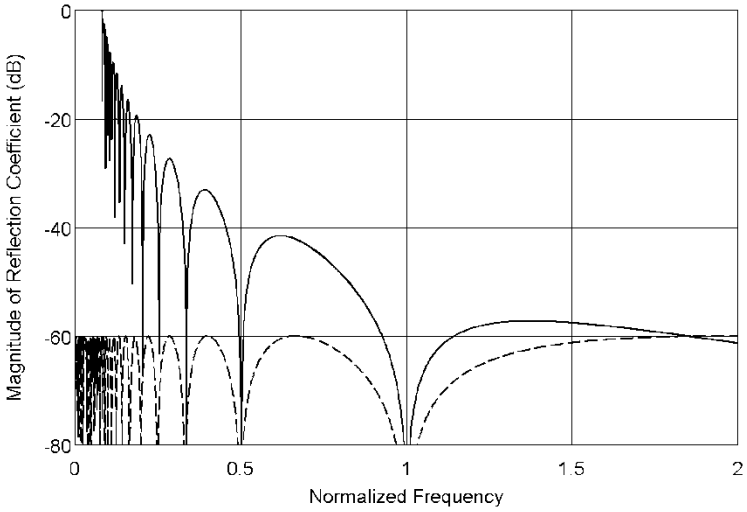
Model of ideal left-handed transmission line and its finite element approximation [1]

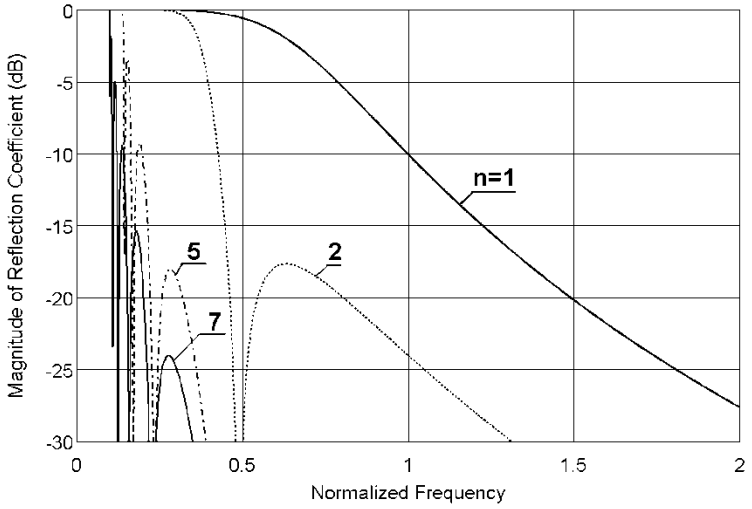


T-type equivalent circuit of ideal left-handed transmission line section

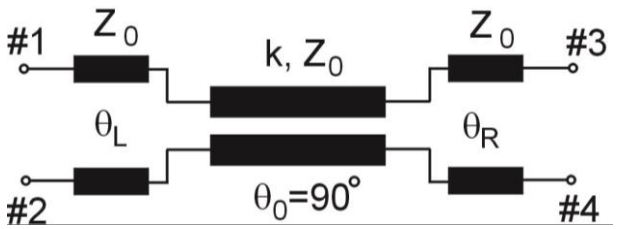


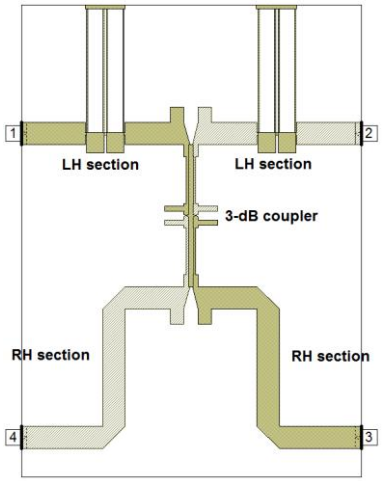
Approximation of ideal left-handed transmission line section with the use of finite number of T-type LC subsections

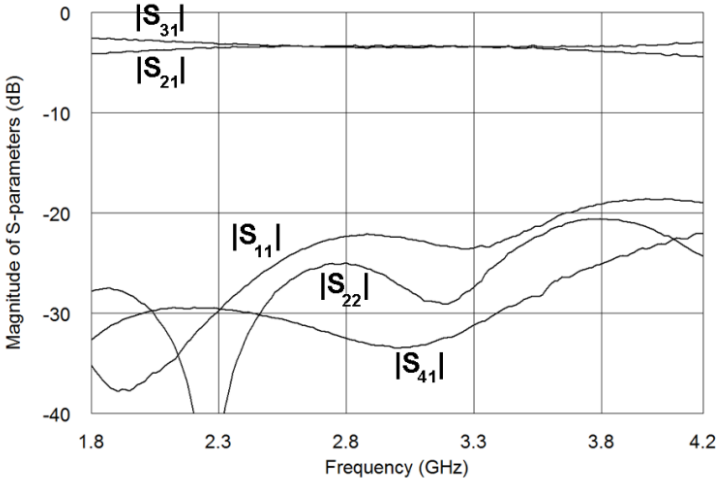


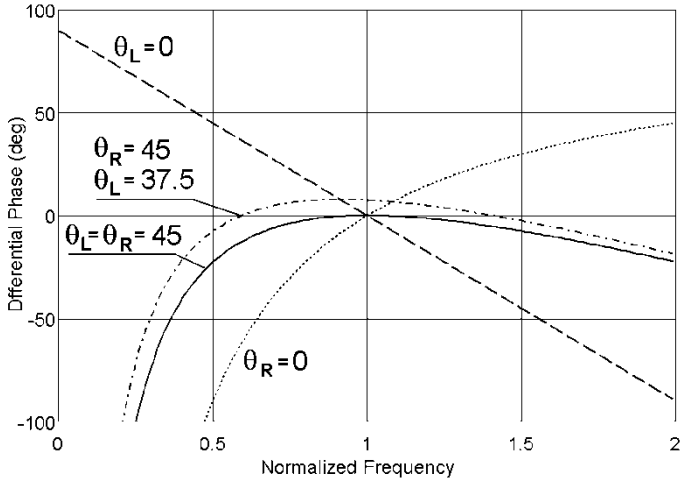


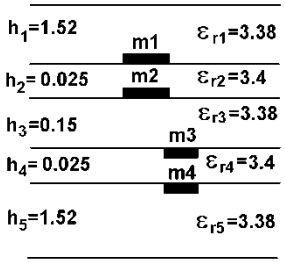
Broadband magic-T networks – application of single-section directional couplers and novel phase shifters [1]

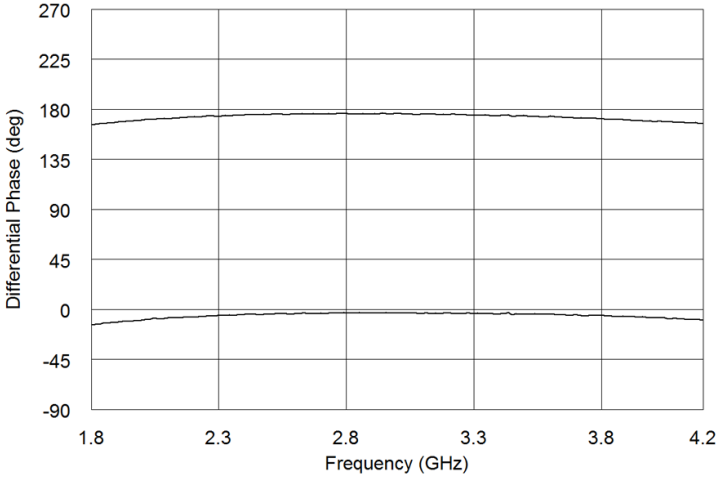




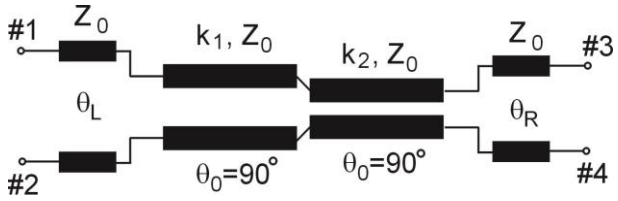


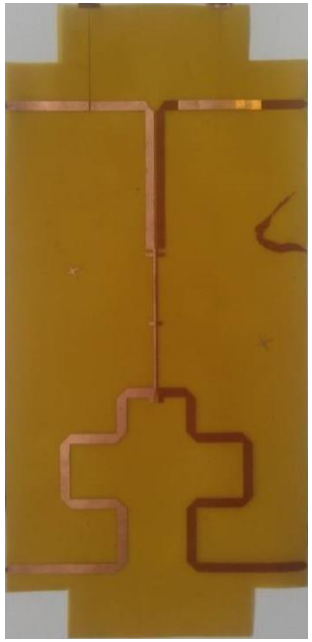


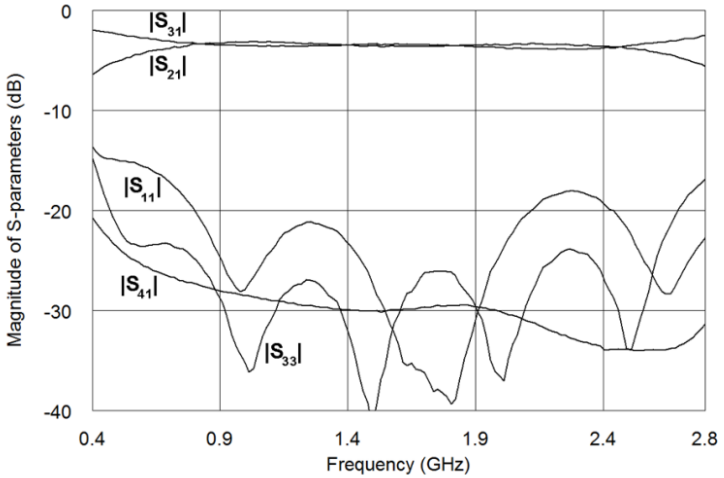


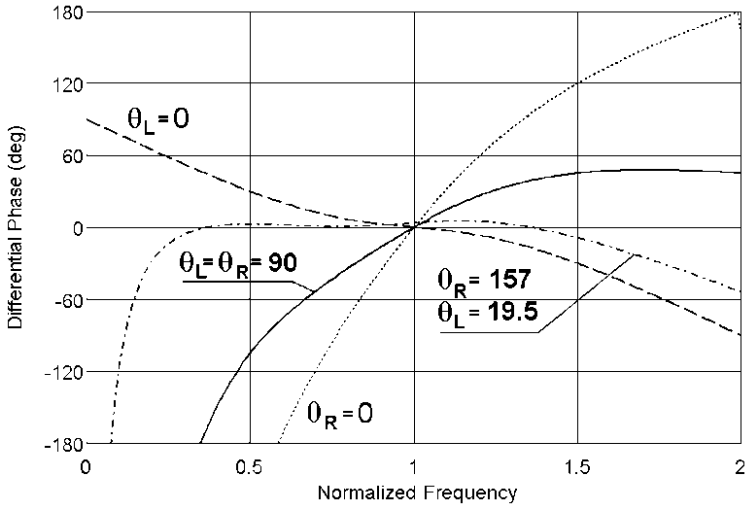


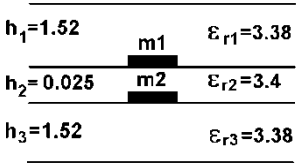
Broadband magic-T networks – application of asymmetric two-section directional couplers and novel phase shifters [1]

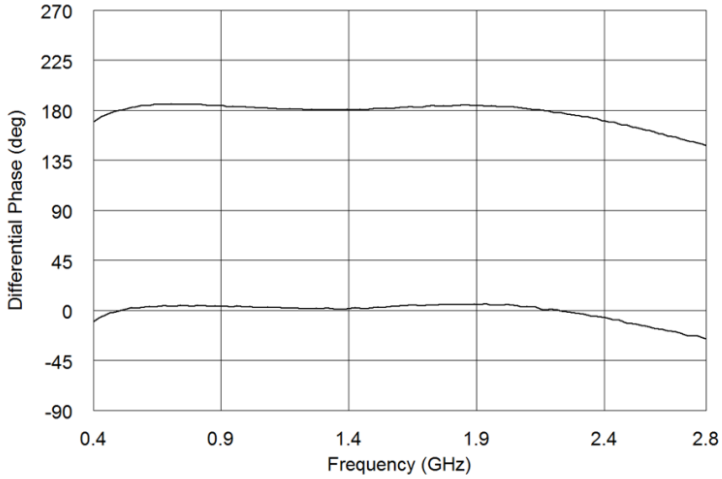




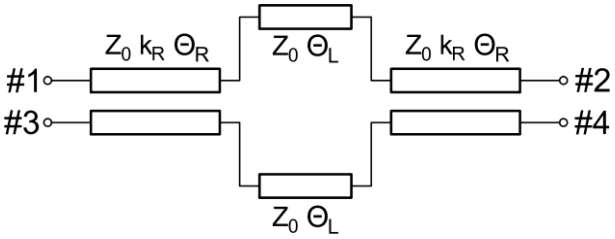


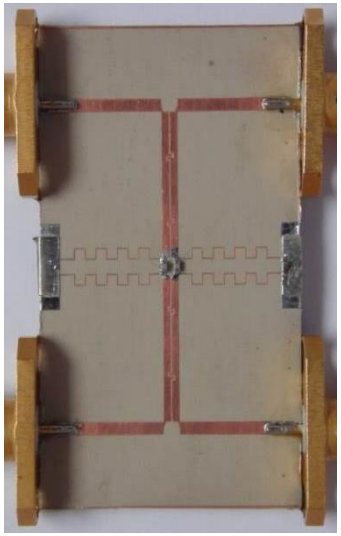


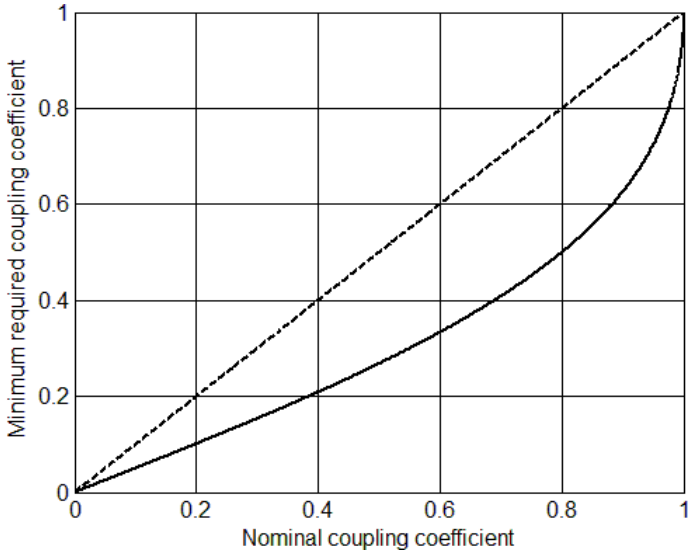


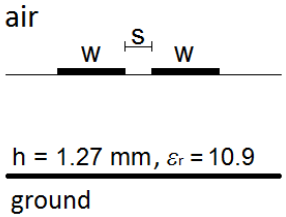


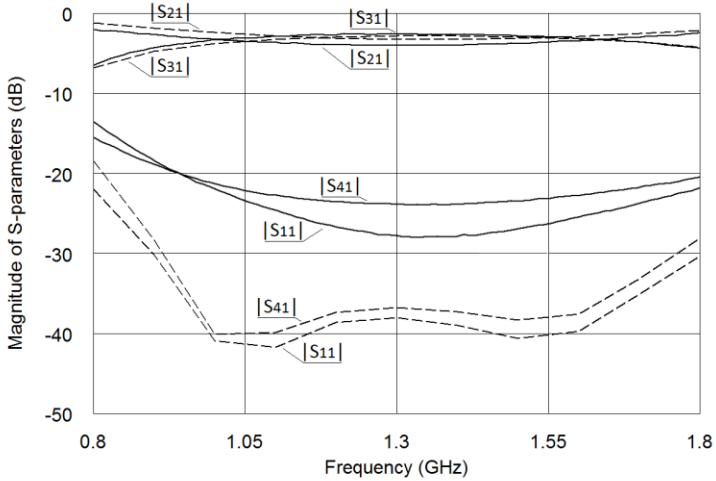
Directional couplers with reduced coupling requirements as a connection of coupled-line sections and left-handed transmission lines [2]

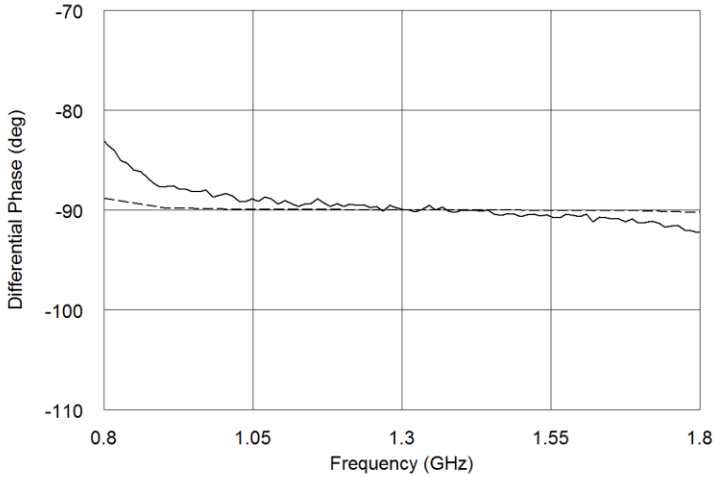




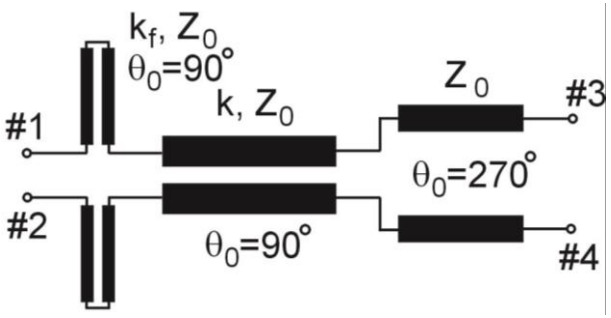


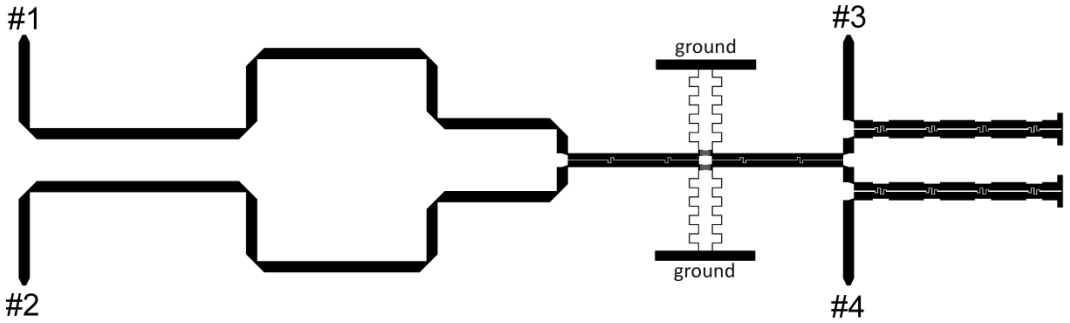


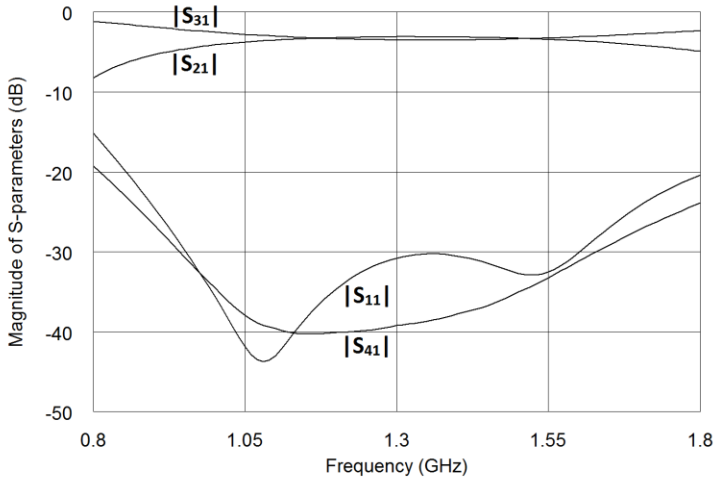


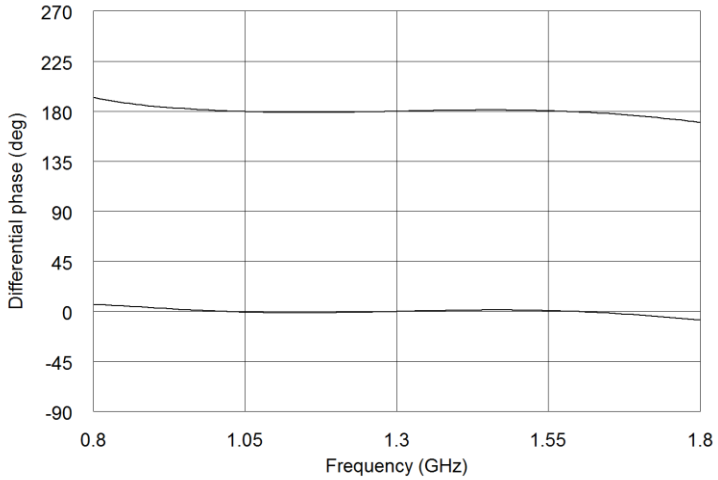


Planar magic-Ts – application of developed coupled-line coupler and Schiffman `C` sections

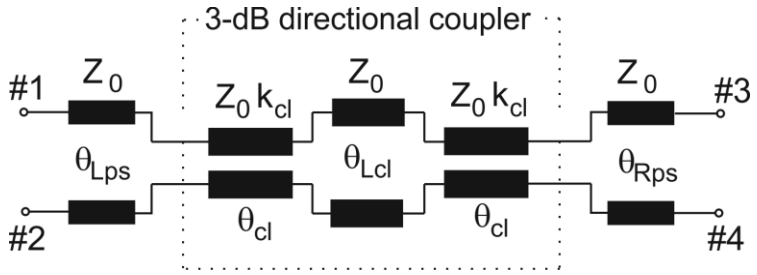


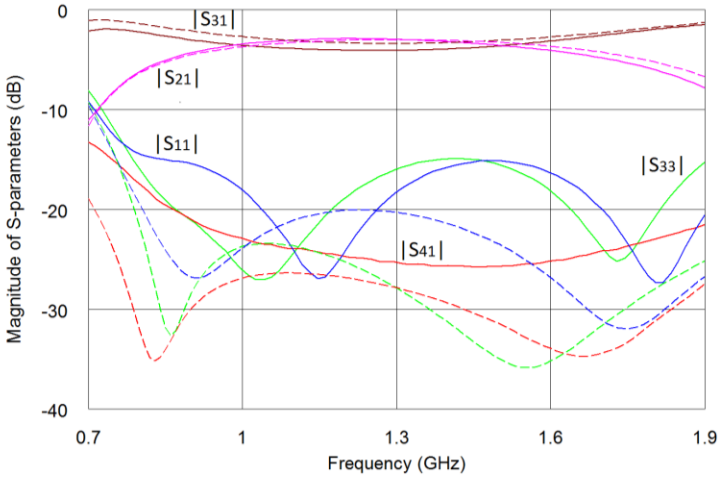


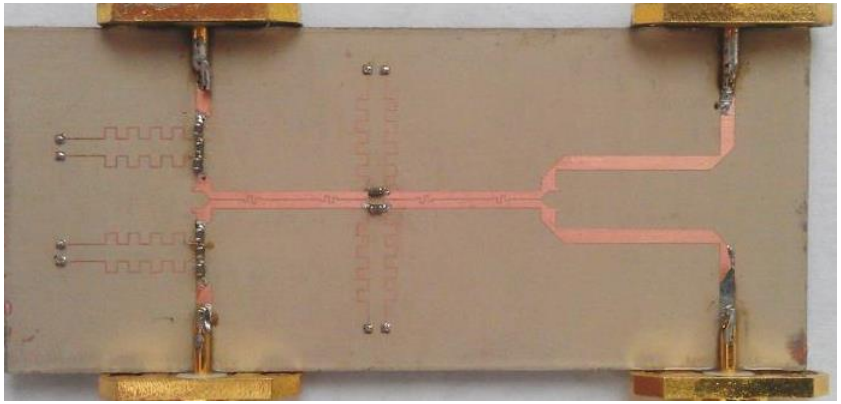


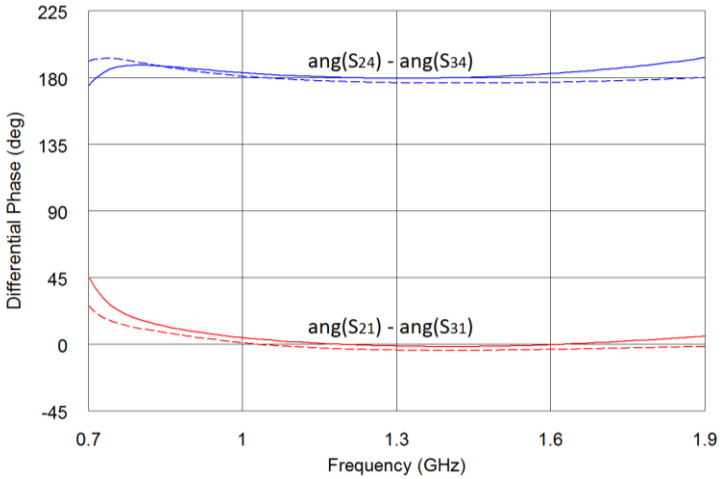


Planar magic-Ts – application of developed coupled-line coupler and novel phase shifters [3]

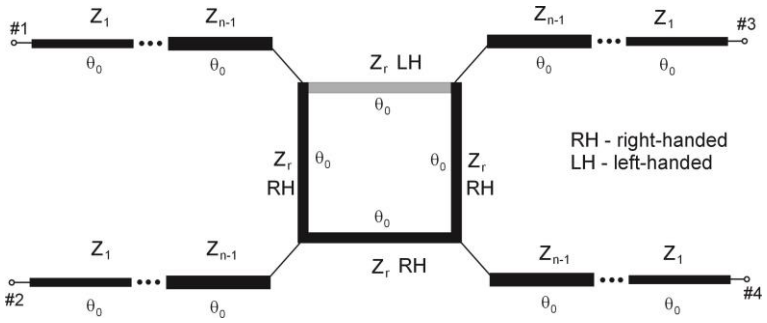


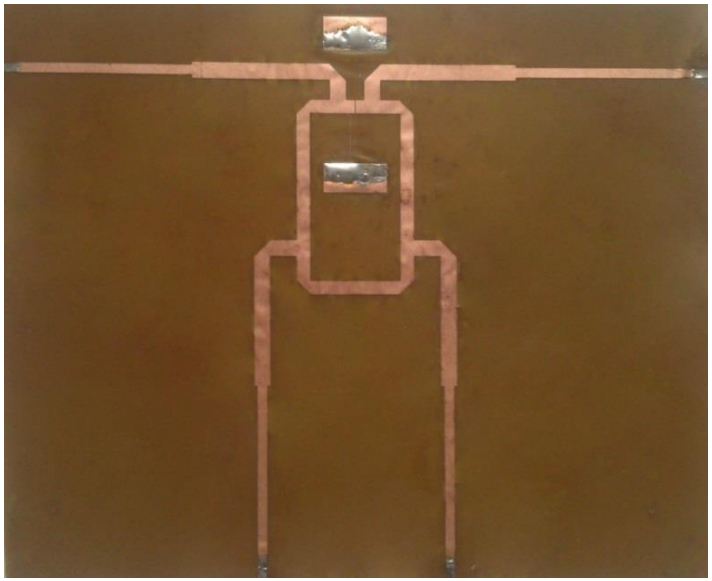


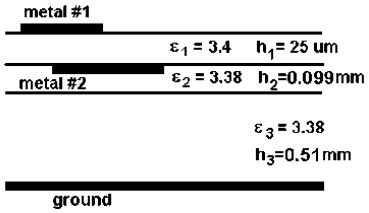


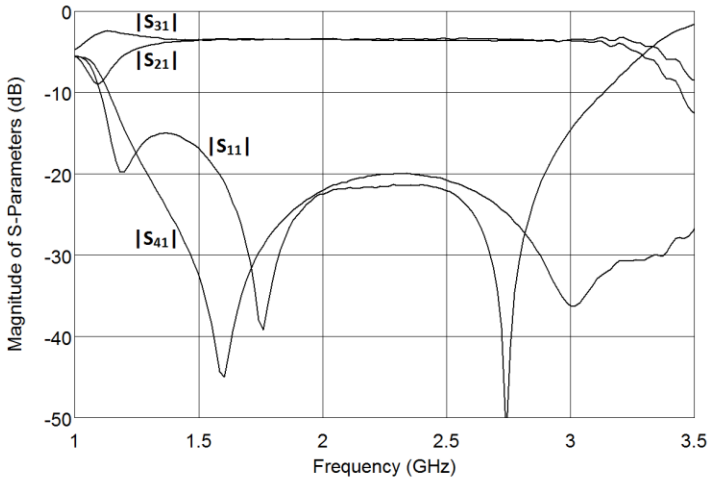


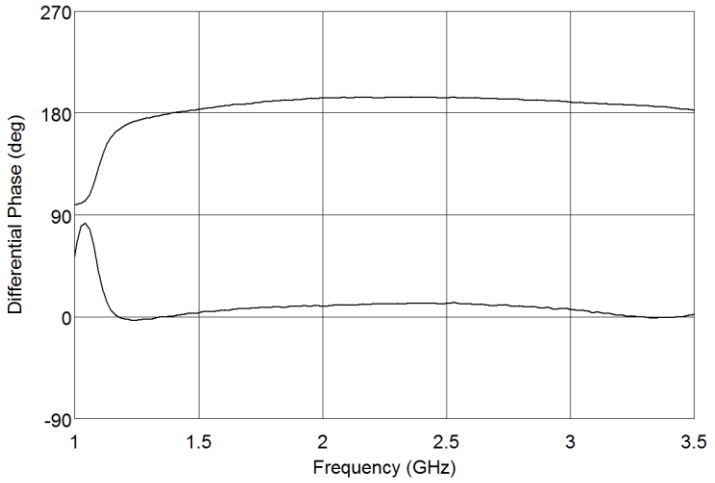
Bandwidth improvement of rat-race couplers having left-handed transmission-line sections [4]











List of publications related to the presented topic

[1] **J. Sorocki**, I. Piekarz, K. Wincza, and S. Gruszczynski, „Broadband magic-T networks as a connection of coupled-line directional couplers and left-handed transmission line sections," *International Journal of RF and Microwave Computer-Aided Engineering, early view.*

[2] **J. Sorocki**, K. Staszek, I. Piekarz, K. Wincza, and S. Gruszczynski, „Directional couplers with reduced coupling requirements as a connection of coupled-line sections and left-handed transmission lines," *IET Microwaves, Antennas & Propagation*, vol. 8, no. 8, pp. 580-588, Jun. 2014.

[3] **J. Sorocki**, I. Piekarz, I. Slomian, S. Gruszczynski, and K. Wincza, „Single-layer coupled-line magic-Ts utilizing left-handed transmission line sections," in Proc. 20th *International Conference on Microwave, Radar and Wireless Communications MIKON*, Gdansk, Poland 2014.

[4] **J. Sorocki**, I. Piekarz, K. Wincza, and S. Gruszczynski, „Bandwidth improvement of rat-race couplers having left-handed transmission-line sections," *International Journal of RF and Microwave Computer-Aided Engineering,* vol. 24, no. 3, pp. 341-347, May 2014.

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Thank you for your attention