MODELING METAMATERIAL MICORWAVE RESONATORS

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ABSTRACT

The work is aimed to simulate, build and measure microwave resonators using meta-materials. Results of simulations in the commercial software and results of measurements are compared with published results. Finally, the optimization of the number of segments needed for the design of the resonator with respect to the resultant parameters is performed.

1. INTRODUCTION

Forty years ago, Russian scientist Veselago [1] was thinking of a material possessing special qualities, i.e. a negative permittivity and a negative permeability. The practical effect of having a material with these qualities causes that the light propagating through such a material would ostensibly propagate backwards and would behave in many unusual ways those would oppose our intuition. Since all known materials possess positive values of permittivity and permeability, Veselago didn't succeed nor after years of research. Recent research introduced an approach which suggests that this material doesn't have to be just a slab of one material. Desired qualities could be achieved by arranging small structures, which produce effects otherwise unreachable.

2. ANALYSIS

In order to understand what negative values of permittivity and permeability cause [2], we will concentrate on so called coupled right-left handed transmission lines (CRLH TL). Fig. 1 shows a composite structure, where a layer with the thickness d_1 is a conventional material, and a layer with the thickness d_2 is a meta-material. Arrows S_1 and S_2 show directions of the Poyinting vector, arrows k_1 and k_2 are directions of the phase velocity. We assume that at some frequencies, material used for the layer d_2 exhibits negative values of permittivity and permeability, what means that the direction of the Poyinting vector (the direction of the power flow) is anti-parallel compared to the orientation of the phase velocity vector. Considering conventional materials, the direction of the Poyinting vector and the phase velocity vector are identical.

Resonators designed and investigated in this project are composed of both the LH and RH transmission lines. Designing such a resonator in the planar form, LH TL is replaced by series capacitors and shunt inductors. The resonator exhibits then a nonlinear phase response. The phase response can be further shaped according to our requirements by changing properties of transmission lines.

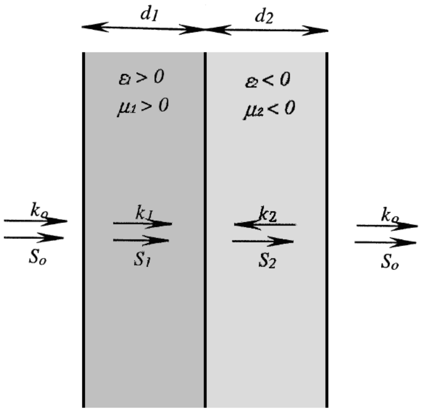


Fig. 1 *The CRLH resonator [2]*

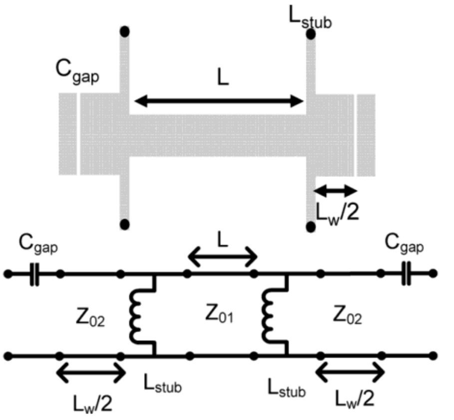
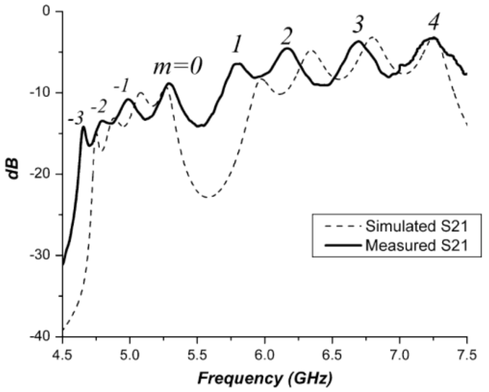


Fig. 2 *Analyzed sample resonator [3]*

The structure of the resonator is depicted in Fig. 2. Resonant frequencies of the cascade composed of four cells was simulated and measured in [2], results are depicted in Fig. 3. We are going to verify those results by designing a similar, slightly modified structure. First, the model of a single cell was simulated using Zeland IE3D full wave simulation software (substrate used for the simulation and later fabrication of unit cell was Arlon D600) and measured (for excitation were used 50Ω ports for waves; for results see Fig. 4). Observed parameters were S_{21} and S_{11}, which are transfer and reflection coefficients (reflection from input gate). Measurement of fabricated structure was done using network analyzer Arnitsu 54147A connected according to the schematic depicted in Fig. 5.



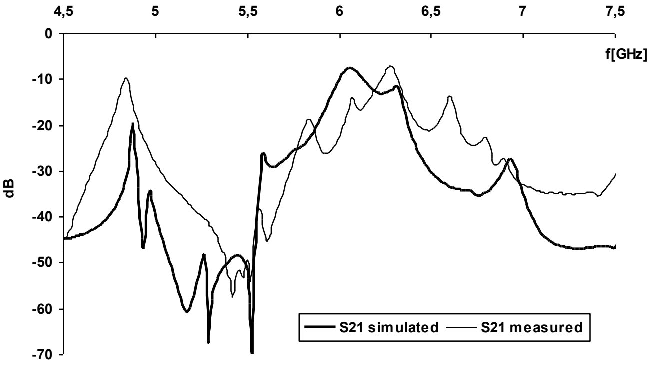


Fig. 3 *Results for cascaded CRLH resonator [3].*

Fig. 4 *Results for one cell CRLH resonator*

Difference between measurement and simulation was caused by inaccurate fabrication and possible variance of characteristic impedance because shunt inductors were connected to the ground using wires bent over the edge of structure. After designing and verifying a single cell of the CRLH resonator (with the resonance around 6.0 GHz), we decided to design and simulate another cell of the resonator published (tuned at 6.5 GHz). Both the cells were cascaded, simulated and measured. Results for the cell tuned at 6.5 GHz can be seen in Fig. 6, and the results for the cascaded cells are shown in Fig. 7.

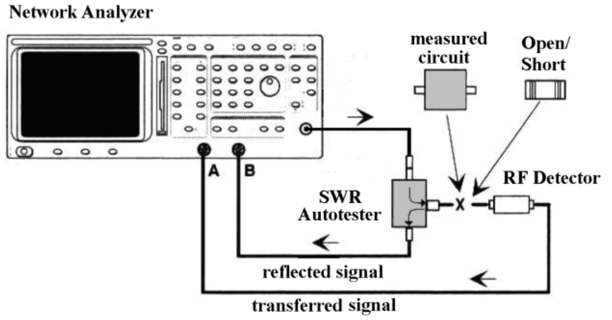
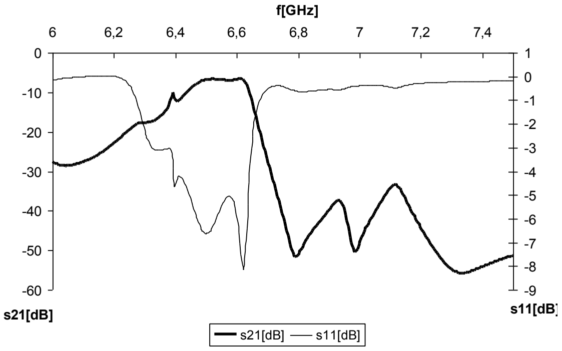


Fig. 5 *Measurement site setting*



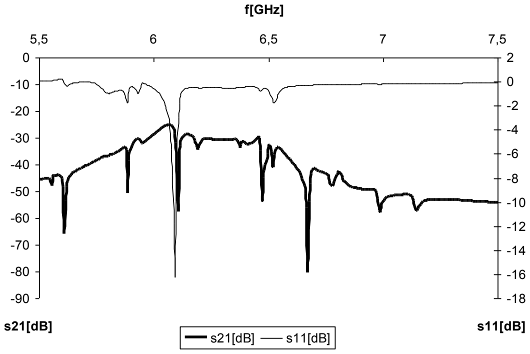


Fig. 6 *Results for one cell tuned at 6.5 GHz.*

Fig. 7 *Results for cascade of two cells.*

3. CONCLUSION

The design, simulation and measurement of a microwave resonator using unbalanced CRLH TL were presented. This design allows us to obtain resonators with either increased Q factor or increased higher modes spacing. The fact, that this technique of resonator design was demonstrated entirely composed of microstrip components provides good means for integration into microstrip structures.

REFERENCES

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