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Novel Metamaterial Cell-Based Resonator Antenna with Broadside Radiation Pattern

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1. Introduction

One of the first metamaterial (MTM) cell-based antenna has probably been proposed by Schussler et al. [1] as patch loaded with LC cell to realize transmission line with negative phase velocity to shorten the patch radiator size. Similar structure has been then proposed by Sanada et al [2] in composite right/left-handed transmission line (CRLH TL) planar technology [3] as so called zero-order resonator antenna. Further similar arrangement with two parallel MTM cells vertical vias has been proposed latter by Qureshi et al. [4]. In [4] the main current source areas are concentrated on the vias that are excited in-phase so that the antenna exhibit monopole-like radiation pattern. One of the further presented design [5] has brought just realization with MTM transmission line that exhibit either negative permittivity or negative permeability. The monopole-like radiation pattern remains the same.

Here we present novel ZOR MTM radiation structure in composite right/left-handed micro-coplanar transmission line (CRLH MC TL) [6] which exhibits both-side broadside radiation pattern (radiation maximum is normal to the structure surface). Description of the MTM unit cell, the whole structure itself, current distribution, measured antenna parameters as well as comparison with simple half wavelength microstrip patch is presented here.

2. ZOR MTM Antenna with broadside radiation pattern

The size of the MTM cells and the whole four element structure has been chosen so that the antenna matches the criteria of electrically small antenna ($ka < 1 => a < \sim\lambda/6$). The CRLH MC unit cell with its equivalent circuit can be seen in Figure 1.

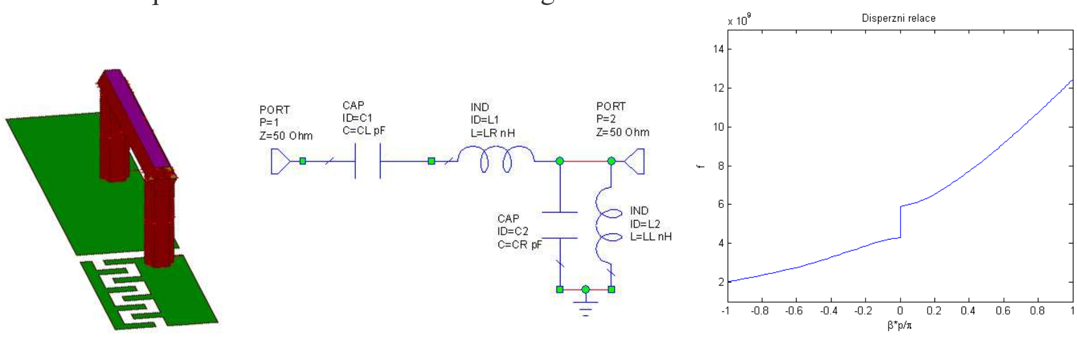

Figure 1: Unit cell of designed ZOR MTM Antenna, designed as unbalanced case, C_L = 0.6 pF, L_R = 2.35 nH, C_R = 1.0 pF, L_L = 0,7 nH (a) view and equivalent circuit (b) dispersion relation

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It is designed as unbalanced as the balanced one require higher value of left-handed inductor L_L (~ 4 nH) which corresponds with the approx. wire length of 10 mm which is consider to much for intended electrically small antenna. That's why the stop-band occurs in the dispersion relation (see Figure 1b). The whole structure with four MTM cells can be seen in the figure 2a) and occupies the footprint size approx. 9.35 x 9.35 mm. The height 3.5 mm consist of 1.5 mm of dielectric substrate (GML 1000 with ε_r = 3,05, h = 1,5 mm a tg δ = 0,003) and the wire air bridges of the 2 mm heigth. The maximal current distribution is concentrated along the slot of the MC TL (see Figure 2c) that indicates both-side broadside radiation pattern which has been confirmed by the measurement.

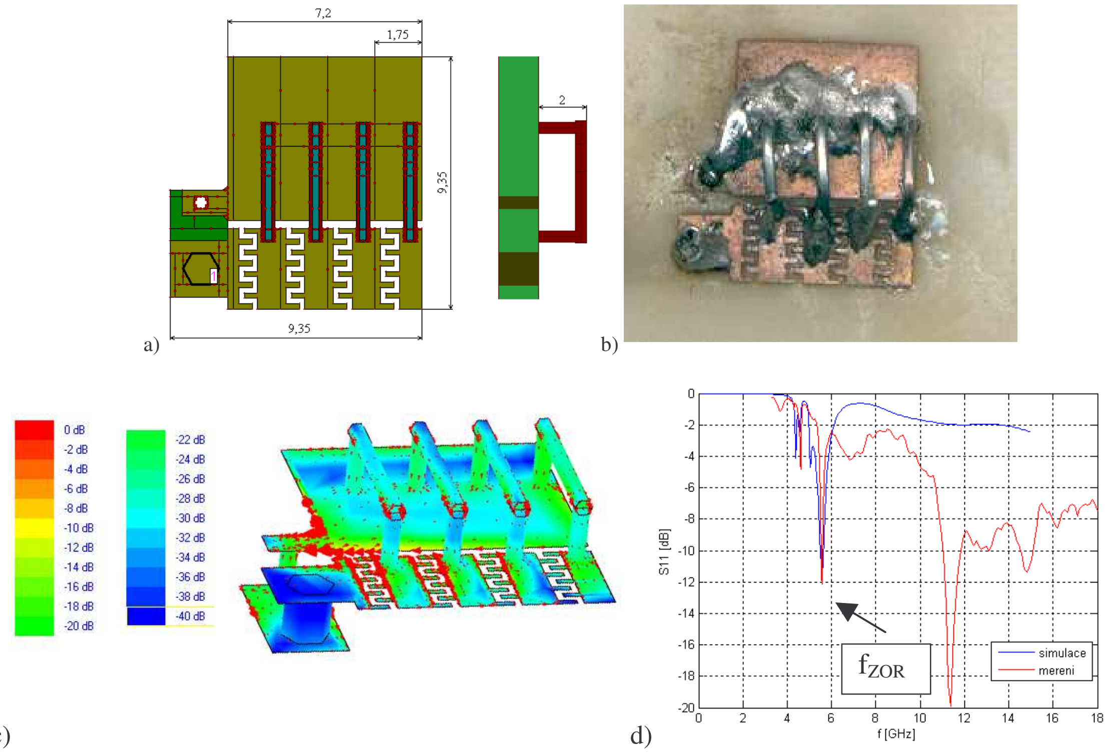

Figure 2: Sketch (a), photograph (b), the current distribution (c) and reflection coefficient of the designed four-element ZOR MTM antenna

The zero order resonance has been design to be at f_{ZOR} = 5.6 GHz. The agreement of simulated and measured f_{ZOR} has been found perfect while the negative resonances has been a little bit shifted and positive resonances has not been distinguished in simulation to well. The measured antenna efficiency has been evaluated from measured radiation pattern and gain (see Table 1).

Table 1: Simulated and Measured directivity and gain of the ZOR MTM antenna

	Frequency [GHz]	Radiation efficiency [%]	Antenna efficiency [%]	Directivity [dBi]	Gain [dBi]
Simulated	5,6	61	58	2.6	0.1
Measured	5,6	-	54	4,8	2.1

The simulated and measured radiation patterns can be seen in figure 3. The minima in simulated pattern are due to the infinite extent of the dielectric substrate used by the IE3D simulator.

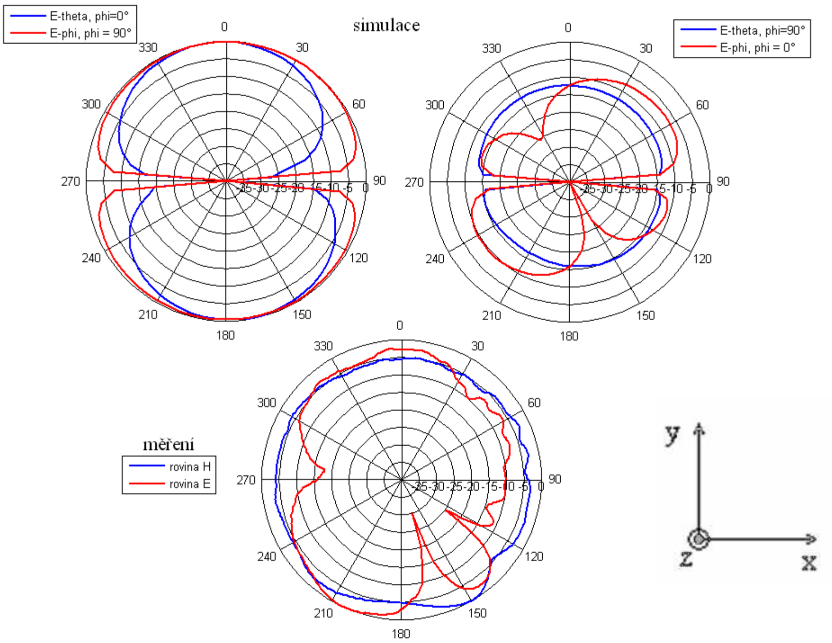

Figure 3: Simulated (IE3D) and measured radiation patterns at $f = 5.6$ GHz.

3. Comparison of ZOR MTM antenna with simple patch antenna

Comparison of the designed ZOR MTM antenna with the same sized half wave-length patch antenna is presented in Figure 4. The decreasing of resonant frequency of the ZOR MTM antenna is done by factor of a 2.21 which represent possible size reduction of the ZOR MTM antenna ~ 45 % when the same resonant frequency is considered.

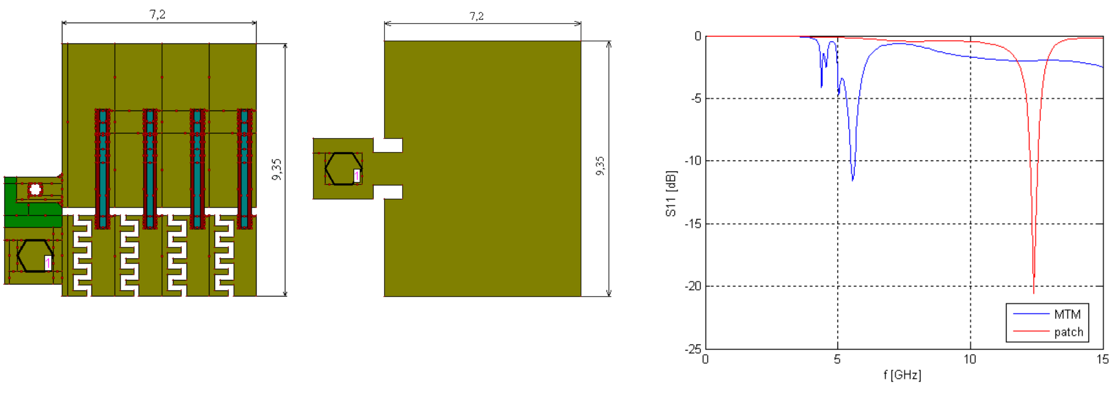

Figure 4: Comparison of simulated resonant frequencies of ZOR MTM antenna ($f_r = 5.6$ GHz) with half wavelength patch ($f_r = 12.4$ GHz) of the same size. Decreasing of resonant frequency of ZOR MTM antenna is done by factor of 2.21

5. Conclusion

A novel electrically small low-profile (~ 0.18 x 0.18 x 0.065 λ_0) ZOR MTM antenna in micro-coplanar TL with both-side broadside radiation pattern has been developed. Its type of radiation characteristic is considered unique compared to previously published designs. Its measured radiation efficiency and gain as one the main antenna parameters are 54 % and 2.1 dBi, respectively. Compared to the same sized simple patch antenna The ZOR MTM exhibit decreasing of resonant frequency by a factor of 2.21.

Acknowledgement

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