Metamaterial Based Near-Field Loop Antenna Periodically Loaded with Split-Ring Resonators

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***Abstract* – The transmission line periodically loaded with split-ring resonators (SRR) has been investigated. The phase delay of the wave in the considered transmission line is equal to zero at the frequency slightly above the SRR resonance. This effect was used for designing the near-field loop antenna providing the uniform current distribution along the loop. A comparison of the proposed design and the conventional loop antenna was made.**

I. INTRODUCTION

The space around the antenna can be divided into two zones: the near-field (the reactive field dominates in this zone) and the far-field (the radiation field dominates) [1]. The boundaries of these zones depend on the size of the antenna and the operating frequency.

Loop antennas are widespread, the coupling between them is performed by the magnetic near-field. Such constructions are widely used in UHF RFID-systems due to efficient reading densely placed tags and labeling objects, made from high dielectric permittivity materials.

A key characteristic of the inductive near-field antenna is the magnetic field intensity, which depends on the size of the loop. To obtain the required value of the magnetic field intensity the antenna size should be electrically large so that the loop perimeter is comparable with the wavelength. In this case, the phase of the current along the loop varies considerably. As a result, the total magnetic field intensity can be significantly decreased due a contribution of fields excited by the out-of-phase surface current components. To avoid this situation, it is necessary to provide the uniform current distribution along the loop. The uniform current distribution can be obtained by using additional phase delay stubs [2]. Another way is designing antenna with a segmented structure divided by planar or lumped surface-mount capacitors [3,4].

In this work the structure of the loop antenna periodically loaded with split-ring resonators (SRR) is presented. The proposed structure allows obtaining constant current phase along the loop, thereby forming the uniform current distribution.

II. TRANSMISSION LINE LOADED WITH SPLIT-RING RESONATORS

The basic element of the proposed near-field antenna is a transmission line periodically loaded with SRR (Fig. 1a). For a simulation of the resonant response of the SRR the following dimensions of the structure have been used: the side of the outer ring is a = 13 mm, the width of the metal lines and the gap between the inner and outer rings are w = 0.3 mm, the split gap is g = 0.3 mm. The permittivity of the dielectric substrate material is ε = 10 (Taconic CER 10).

The scattering parameters obtained by electromagnetic simulations of the transmission line loaded with a single SRR are presented in Fig. 1b. The resonance of the SRR is observed at the frequency about f_0 = 880 MHz. Near this frequency (see the section *AB* in Fig. 1b) the transmission line exhibits a left-handed (LH) behavior because its phase delay becomes negative. The line again behaves as a right-handed (RH) object above the point *B*. Hence near the point *B* the transmission line phase delay is zero, and the phase velocity is infinite. This effect can be used to design transmission lines with constant current distribution.

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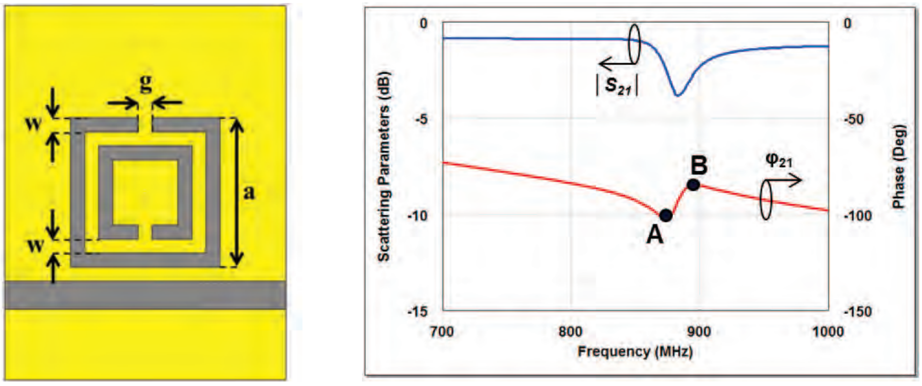

a) b)

Fig. 1. (a) Transmission line loaded with a single SRR, (b) scattering parameters.

The structure of such transmission line loaded with SRRs and the current distribution along it at the frequency f = 890 MHz are presented in Fig. 2. Dimensions of the SRRs are the same as in the case of the single SRR and the length of the transmission line is L = 250 mm. It is clearly seen that the current along the transmission line is almost constant.

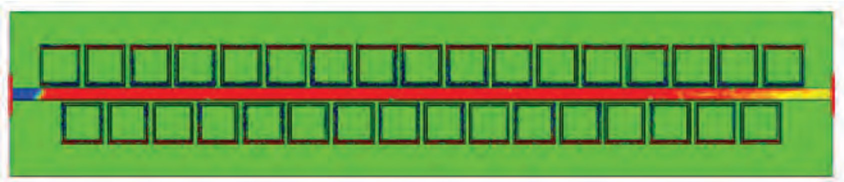

Fig. 2. Current distribution along the transmission line loaded with the SRR array at the frequency f = 890 MHz .

III. Loop Antenna Periodically Loaded with Split-Ring Resonators

After that the loop antenna periodically loaded with SRRs was considered (Fig. 3a). The loop perimeter is P = 360 mm. To compensate the imaginary part of the antenna impedance an additional inductance was included in series with the input port. For the transformation of a balanced antenna input to an unbalanced coaxial cable the LC-Balun was used [5]. The compensating capacitor and the balun are not shown on the antenna structure in Fig. 3. The current distribution along the antenna at the frequency 870 MHz is shown in Figure 4a.

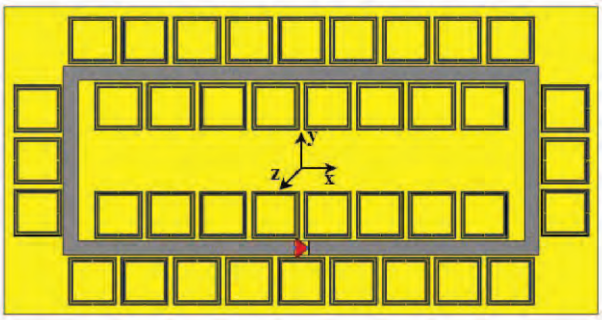

Fig. 3. (a) Loop antenna loaded with the SRRs.

A conventional loop antenna with the same dimensions without SRRs was considered for comparison. The current distribution along the conventional loop antenna at the same frequency 870 MHz is presented in Figure 4b. As one can see, the current distribution in this case is not uniform as in the case of the proposed SRR loaded antenna. This fact leads to a reduction of the magnetic field intensity created by the conventional antenna.

a) b)

Fig. 4. Current distribution at the frequency 870 MHz along (a) the loop with SRRs , (b) the conventional loop.

The comparison of the magnetic field intensity created by the proposed SRR loaded antenna and the conventional loop antenna is demonstrated in Fig. 5. The intensity of the component along the *z* axis *i*s plotted. The red curve corresponds to the case of the new SRR based antenna and the blue curve corresponds to the case of the conventional loop antenna. It is clearly seen that the proposed antenna design provides significantly higher magnetic field intensity due to more uniform current distribution along the loop.

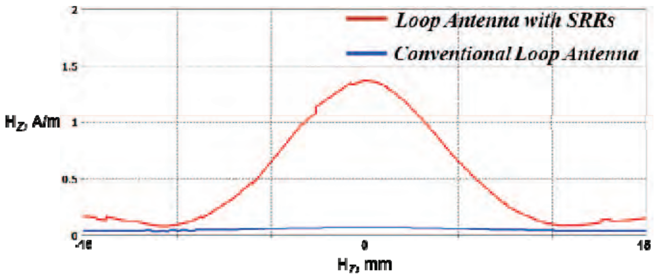

Fig. 5. Magnetic field intensity along *z* axis for two types of antenna.

VI. Conclusion

The scattering parameters of the transmission line loaded with SRR have been investigated. Zero phase delay of the transmission line is observed at the frequency slightly above the SRR resonant frequency. The original design of the near-field loop antenna based on this effect and providing the uniform current distribution along the loop was proposed. The significant increasing of the magnetic field intensity was achieved due to obtained uniform current distribution.

Acknowledgement

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