A Uniplanar Inductively Loaded Scatterer of Reduced Size for Chipless RFID Tags

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***Abstract*— The aim of this work is to investigate a uniplanar scatterer for RFID chipless tags able to store an increased amount of information per unit surface. This scatterer is a modification of the U-folded dipole – a quarter wavelength resonator - that is shortened by a meander inductor inserted at the position of the short or by an interdigital capacitor connected at the open end. The proposed uniplanar structure is suitable for cheap mass production.**

Keywords—RFID;chipless RFID tag; planar resonator; U-folded dipole; radar cross section

I. INTRODUCTION

RFID technology has a broad field of applications, in commerce, industry, medicine, science and other areas. Basic information can be found, e.g., in [1]. Within these systems, chipless tags have the advantage of a simple and therefore cheap structure [2]. An important problem in the design of chipless tags is the attainable surface/volume density of stored information (in bits). In this field, RFID chipless tags cannot at present compete with optical barcodes. A disadvantage of optical barcodes, however, is the need for direct unscreened contact between the code holder and the reader. In the case of RFID tags, the reader can be screened, since detection is performed by radio waves.

The work presented here has been inspired by the structure of a chipless tag shown in [3], which is composed of uniplanar scatterers in the form of a U-folded dipole. This allows the excitation of a quarter wavelength standing wave mode, when irradiated by an incident electromagnetic wave with an electric field parallel to a shortening segment.

The aim of this work is to design, build and test a chipless RFID tag that is able to store more information than was presented in [3]. This is done by shorting the U-folded dipole by inserting an inductor in the form of a meander at the position of the short, or an interdigital capacitor at the open end. The aim of this study is to verify the idea of reducing the tag size. The tag dimensions can be reduced substantially, or the amount of information stored can be raised considerably. The final structure has a uniplanar layout, so it is simple to fabricate it by printing with the use of a conductive ink, and the structure is suitable for mass production.

II. A SIZE REDUCED U-FOLDED DIPOLE LOADED BY A MEANDER INDUCTOR

The tag presented in [3] is composed of resonators/scatterers in the shape of the U-folded dipole shown in Fig. 1a. The resonant frequency of this resonator is determined namely by length *l* over which the short is transformed to an open circuit, when neglecting the short in length *g*. Consequently the folded resonator represents a quarter wavelength resonator. This resonator can be shorted by the meander inductor connected instead of the shorting segment, and the other end of the resonator is left open, see Fig. 1b. The U-folded dipole, see Fig. 1a, and the U-folded dipole shorted by the meander inductor, see Fig. 1b, were designed and analyzed by the CST Microwave Studio, and then fabricated and measured.

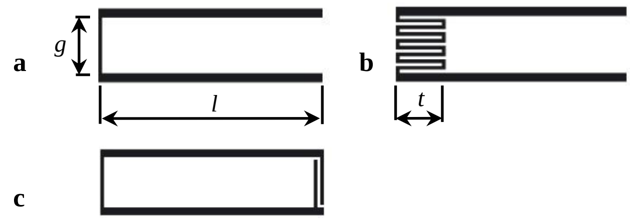

Fig. 1. Layout of the resonator presented in [3] (a), resonator shorted by the inductor (b), by the capacitor (c).

These resonators are 14 mm in length, and 4.2 mm in total width. The width of their arms is 0.5 mm. The length of the inductor meander is $t = 4$ mm, and the width of the meander strips is 0.2 mm. An FR-4 substrate 0.5 mm in thickness and with relative permittivity $\varepsilon_r = 4.4$, 20 mm in length and 9 mm in width is used. The metallization thickness is 0.035 mm, and its conductivity is 10^7 S/m. The resonators were analyzed and measured in an open parallel plate waveguide of width equal to 20 mm and height equal to 10 mm. Both longitudinal and transversal resonator positions were taken into account, see Fig. 2. The resonators are planar, therefore in the longitudinal position, Fig. 2a, can be excited both by the electric and magnetic fields, whereas in the transversal position, Fig. 2b, are excited by only the electric field.

The response of the U-folded dipole, Fig. 1a, and of the dipole shorted by the inductor, Fig. 1b, depends only negligibly on the position in the waveguide. This is due to the fact that these resonators are dipoles excited only by the electric field parallel to the shorting strip with very limited influence of the magnetic field. The scattering parameters of the U-folded dipole, Fig. 1a, are plotted in Fig. 3. The resonator is located in the transversal position, see Fig. 2b. The radar cross section (RCS) σ_{sc} calculated by the CST Microwave Studio of this resonator located in free space is plotted in Fig. 4. The resonant frequency is 3.37 GHz. The resonance of the dipole with the inductor defined above with length equal to 14 mm, the same as the U-folded dipole, Fig. 1a, is shifted to a lower frequency. The measured scattering parameters of this resonator are plotted in Fig. 3; the resonator position is transversal, Fig. 2b. RCS is plotted in Fig. 4. The inductor of length t = 4 mm moves the resonance to frequency 2.6 GHz. RCS calculated by CST gives a higher frequency of 2.67 GHz. A comparison between these results and the results obtained for the U-folded dipole shows that the dipole shorted by the inductor has a smaller effective area, so that its sensitivity is lower than the sensitivity of the U-folded dipole. The RCS is lower by about 10 dB, and the S21 dip is about 3 dB less deep.

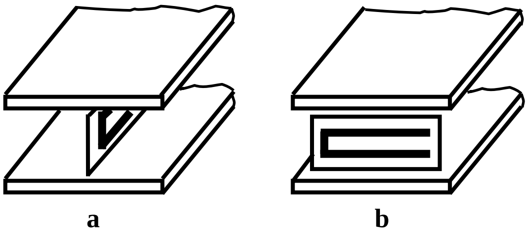

Fig. 2. Positions of resonators in the open parallel plate waveguide, longitudinal (a), and transversal (b).

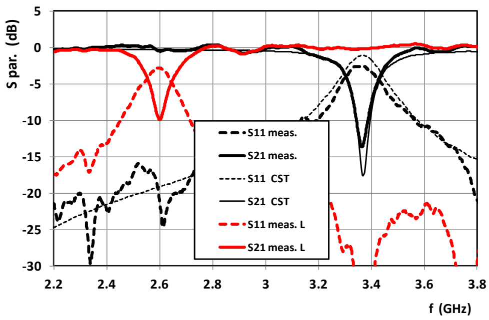

Fig. 3. Measured and calculated scattering parameters of the U-folded resonator 14 mm in length. L means the shorted by inductor.

III. U-Folded Dipole Reduced by an Interdigital Capacitor

The U-folded dipole length was also size-reduced by terminating it by the interdigital capacitor at the position of the open end, see Fig. 1c. A closed loop is created in this way. This loop response is sensitive to the magnetic field perpendicular to its surface. However, the RCS of the designed resonator terminated by the capacitor composed of two fingers located in the longitudinal position, Fig. 2a, is 3 dB lower than the RCS of the resonator with the inductor, but 3 dB higher than for its transversal position, Fig. 2b. The RCS spectra are plotted in Fig. 4. The resonant frequency of the designed resonator is 2.34 GHz. It is therefore more effective to reduce the size of this resonator, but the penalty is the lower RCS value.

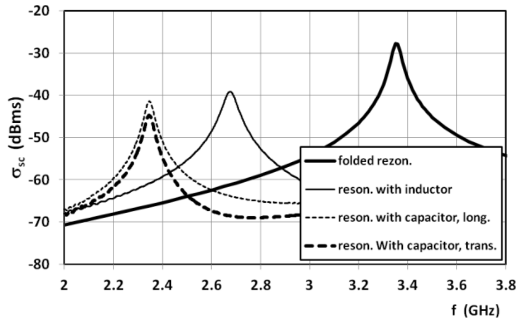

Fig. 4. RCS of the folded resonator, the resonator with the inductor, and the dipole shorted by the capacitor in both longitudinal and transversal positions.

IV. Conclusions

Size-reduced uniplanar U-folded dipole type scatterers loaded by a meander inductor and an interdigital capacitor have been investigated. Samples were designed, fabricated and measured. The area of the tag composed of these resonators is to be reduced by about 20% in the case of the inductor, and by 30% in the case of the capacitor, and therefore the density of the stored information is to be raised by the same amount. The resonator loaded by the inductor has RCS 3 dB or 6 dB higher than the resonator with the capacitor, depending on its position. In comparison with the original design presented in [3], we now have an additional stage of freedom, i.e., the inductor and capacitor geometry, which provides more variety for the final tag design. The experiment verified the behavior of a particular resonator.

Acknowledgment

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