Detuned Dipole Array Backed by Rectangular Plate Applied as Chipless RFID Tag

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Abstract – A chipless RFID tag designed as detuned dipole array backed by rectangular plate is proposed. Its main feature is frequency notched RCS response which provides high read range of the tag. Information encoding ability was investigated on three example bit words. It has been found that proposed structure exhibits narrow resonances with higher bit density than other presented structures and thus seems to be a good candidate for compact high density chipless RFID tags. Performance parameters of the structure has been evaluated by EM simulator Zeland IE3D and verified by monostatic measurement in an anechoic chamber.

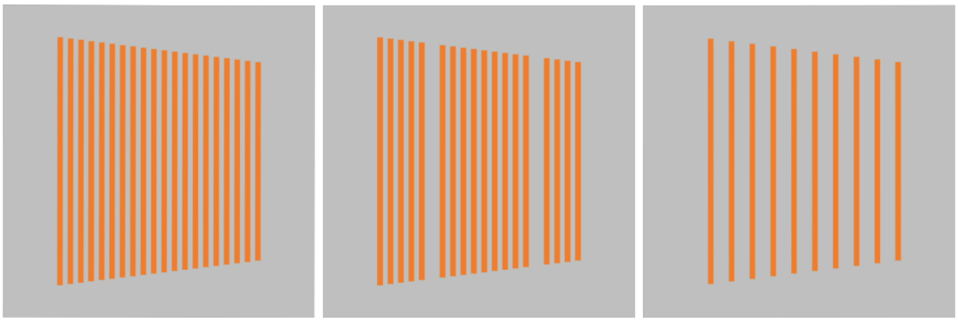
1. INTRODUCTION

Chipless RFID tags provide alternative to chip tags namely due to reduced manufacturing costs. Several scatterer topologies designed with a specific frequency-domain response based on arrays of microstrip dipoles, split ring resonators (SRRs) or C-shaped strip resonators [1-3] have been proposed as chipless RFID tags. However electrically small size array elements provide low value of radar cross section (typ. bellow -30 dBsm) that implicates low read range. On the other hand several works introduced tags based on scattering from larger planar objects such as wideband dipoles or rectangular plates where resonant dips in the RCS response curve are ensured by embedded or closely spaced additional resonators, e.g. incorporated notches in UWB dipole [4, 5] or slots in rectangular plate [6, 7], concentric rings backed by metallic plate forming high impedance surface (HIS) surface [8]. Such scatterers benefit from larger RCS due to the large electrical size (typ. higher than -20 dBsm) which implicates larger read range then small-element array based tags.

This paper proposes a novel chipless RFID tag based on detuned dipole array backed by rectangular plate. The tag behavior was tested by encoding three particular words by simulation and measurement. The structure promises high bit capacity and sufficient read range for chipless RFID application.

2. TOPOLOGY OF THE TAG

Here we introduce compact chipless RFID tag composed of an array of detuned planar dipoles backed by rectangular metallic plate of the size 60 × 60 mm operating in frequency range 3.1 to 3.9 GHz; see Fig. 1. The length of the dipole strips varies from 38.0 to 47.5 mm with the length increment of 0.5 mm. Their width and transverse distance are 1 mm. The height of the dipole array above a plate is 1.1 mm. Dipoles were designed on a Rogers RO4350 substrate with relative permittivity ε_r = 3.66, loss tangent tan δ = 0.003, and thickness of 0.1 mm. Foam layer with relative permittivity ε_r = 1.3, loss tangent tan δ = 0.02, and thickness of 1 mm is inserted between the plate and the substrate.



(a) (b) (c)

Fig. 1. Layouts of investigated 20-bit tags constituted by dipoles backed by rectangular plane coding information a) 11111111111111111111, b) 11111011111111101111 by missing 6th and 16th elements, and c) 01010101010101010101 by missing every odd element.

3. SIMULATED PERFORMANCE

The behavior of designed detuned strip dipole arrays was simulated by EM simulator Zeland IE3D. RCS responses of bit words '11111111111111111111' and '11111011111111101111' are compared in Fig. 2.

RCS responses of bit words ’11111111111111111111’ and ’01010101010101010101’ are compared in Fig. 3. RCS curve of the level of about -15 dBsm is notched by narrow resonant dips of the depth of 2 to 5 dB corresponding to individual dipole resonances. Resonant dips are characterized by remarkable differences in their RCS levels caused by significant mutual coupling between neighboring dipoles. Encoding a logic zero by dipole removal causes frequency shifts of neighboring resonant dips. Their uniformity and frequency stability can be improved by reducing of mutual coupling between the dipoles by one of the presented approaches [7, 10, 11]. It has been found that RCS response uniformity can be improved e.g. by increasing frequency spacing of dipole resonances or by increasing element spacing. However, disadvantage of this solution is a trade-off between RCS uniformity, spectral bit capacity, and footprint size of the tag.

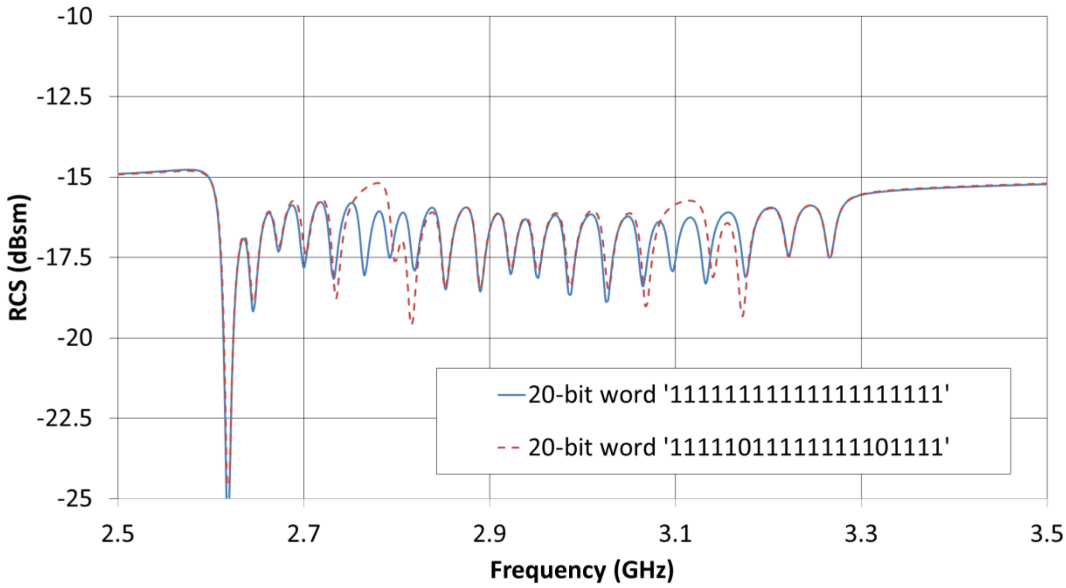


Fig. 2. Simulated RCS response of bit words ’11111111111111111111’ and ’11111011111111101111’.

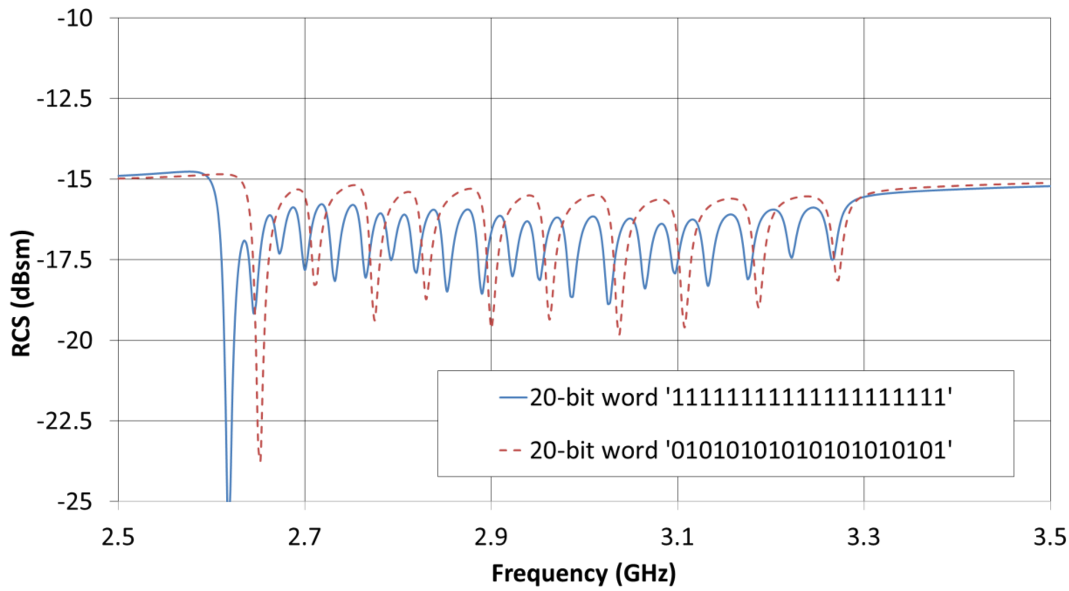


Fig. 3. Simulated RCS response of bit words ’11111111111111111111’ and ’01010101010101010101’.

4. MEASUREMENT

Performances of all three tags were verified by monostatic measurement of tag RCS performance in an anechoic chamber. The measurement was based on the evaluation of a reflection coefficient of the double ridge horn antenna DRH 20 [9] in front of which the scatterer at the distance of 0.25 m was placed. The calculation of RCS response of the tag was performed by the equation used in [3] and modified so that it was applicable to the case of the one-port measurement.

$$\sigma^{tag} = \left(\frac{S_{11}^{tag} - S_{11}^{iso}}{S_{11}^{ref} - S_{11}^{iso}} \right)^2 \sigma^{ref}, \qquad (1)$$

where $S_{11}{}^{tag}$ is the reflection coefficient of the measured tag. $S_{11}{}^{ref}$ represents the reflection coefficient of the reference plate used as a scatterer. $S_{11}{}^{iso}$ symbolizes the reflection coefficient of the antenna itself in case that no scatterer is used, and comprises the residual reflection from the experimental surroundings. σ^{tag} stands for the RCS of the measured tag, σ^{ref} embodies the RCS of the reference scatterer, which is the rectangular metal plate 100×100 mm^2 in size and 0.3 mm in thickness. Its analytical formula for RCS can be expressed as follows:

$$\sigma^{ref} = 4\pi \frac{a^2 b^2}{\lambda^2}. \qquad (2)$$

RCS responses of bit words ’11111111111111111111’ and ’11111011111111101111’ are compared in Fig. 4. RCS responses of bit words ’11111111111111111111’ and ’01010101010101010101’ are compared in Fig. 5. Measured responses have similar properties than the simulated responses.

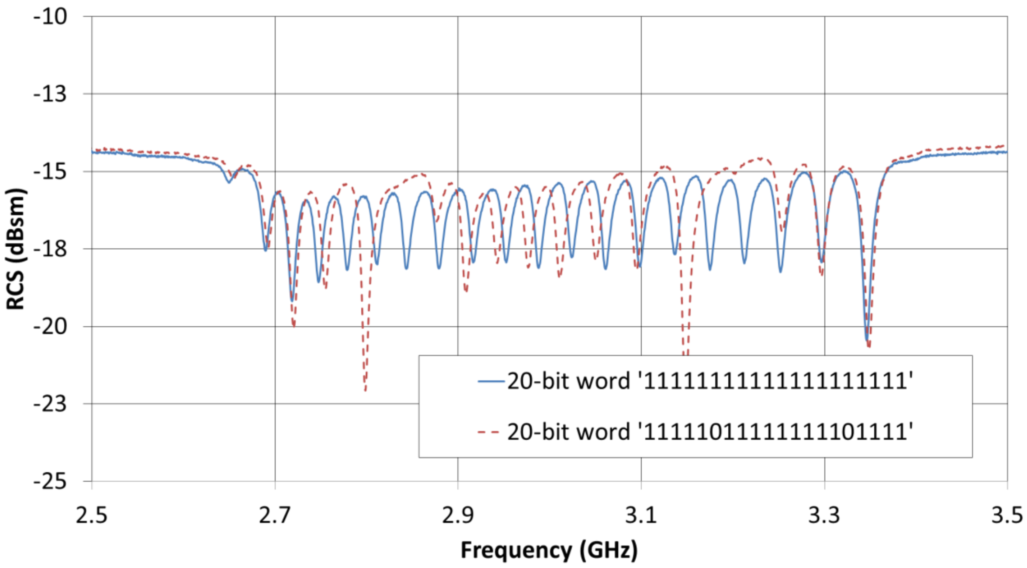


Fig. 4. Measured RCS response of bit words ’11111111111111111111’ and ’11111011111111101111’.

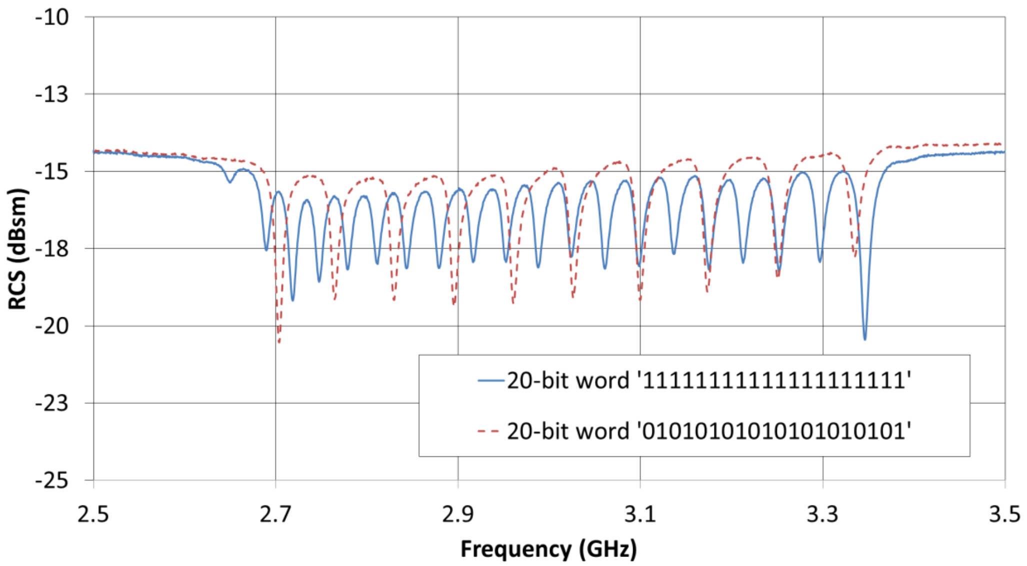


Fig. 5. Measured RCS response of bit words ’11111111111111111111’ and ’01010101010101010101’.

5. CONCLUSION

Proposed detuned dipole array backed by rectangular plate represents a tag with higher level of RCS response and higher spectral bit capacity than arrays of small C-shaped strip scatterers applied as chipless RFID tags. Consequently, the above presented structure represents a suitable candidate for chipless RFID tag which has been also verified in real environment outside of anechoic chamber. Difficulty with insufficient uniformity of the resonant dips and their frequency shifts, both caused by mutual coupling between the neighboring dipoles, is a challenge that must be further solved, e.g. by appropriate elements rearrangement or by increasing frequency spacing of dipole resonances or by increasing the distance between dipole elements.

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