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Comments on "Development of Cross-Polar Orientation-Insensitive Chipless RFID Tags"

O. Rance, N. Barbot, and E. Perret

***Abstract*— In [1], the authors present a technique for designing resonant scatterers that display a cross-polarization reflection that remains consistent (i.e. non-zero) regardless of the orientation of the target. The authors claim that this property can be obtained simply by duplicating, rotating and arranging the position of a unit cell. We will show in this comment that all the design techniques presented in [1, Sec. III] lead to multiple cancellations of the cross-polarization component of the backscattered E-field. Therefore, the measurement results presented in [1] cannot be justified by the theory presented in section III of the same article.**

***Index Terms*—Chipless RFID tag, cross-polar RCS, orientation-insensitive, polarized, resonator, unit cell.**

First of all, it should be noted that [1, eq. (3)], which gives the RCS of a scatterer as a function of the roll angle, is valid only for thin dipoles and does not take into account the phase of the backscattered E-field. Therefore, this expression cannot be used to justify the approach introduced by the authors to obtain a cross-polar orientation-insensitive chipless tags. A more general tool for the study of radar targets is the polarization scattering matrix $\boldsymbol{S}$ (Sinclair matrix) which relates the scattered electric field vector $\boldsymbol{E}^s$ to the incident field vector $\boldsymbol{E}^i$:

$$\begin{bmatrix} E_v \\ E_h^s \end{bmatrix} = \begin{bmatrix} S_{vv} & S_{vh} \\ S_{hv} & S_{hh} \end{bmatrix} \cdot \begin{bmatrix} E_v^i \\ E_h^i \end{bmatrix}, \tag{1}$$

where S_{vv}, S_{hh}, S_{vh} and S_{hv} are complex quantities that depend on frequency. For a passive target, $\boldsymbol{S}$ is symmetric, i.e. $S_{vh} = S_{hv}$. When the target is rotated from an angle θ along the line of sight, the scattering matrix is modified following [2]:

$$\boldsymbol{S}(\theta) = \boldsymbol{\Omega}^t \cdot \boldsymbol{S}(0) \cdot \boldsymbol{\Omega}, \tag{2}$$

where Ω^t denotes the transpose of Ω which is the rotation matrix of angle θ. The explicit form of S_{vh} (cross-polarization component) as a function of the roll angle θ is then given by:

$$S_{vh}(\theta) = \frac{S_{hh} - S_{vv}}{2} \sin 2\theta + S_{vh} \cos 2\theta. \tag{3}$$

S_{vv}, S_{hh}, and S_{vh} are the components of the scattering matrix $\boldsymbol{S}$ for the reference orientation $\theta = 0$. Note that (2) describes exactly the rotation that the authors perform on the reference resonator to obtain different scatterer arrangements supposed to be cross-polar orientation-insensitive. Three such examples are given: [1, Fig. 3] for the arrangement of two resonators, [1, Fig. 4-a] for the arrangement of strip coupled line resonators in triangle configuration (three resonators) and [1, Fig. 5-f] for the flower-shaped tag with an arrangement of two flower resonators. Following the methodology of [1], we will neglect the couplings, as well as the influence of the ground plane in the remainder of the comment.

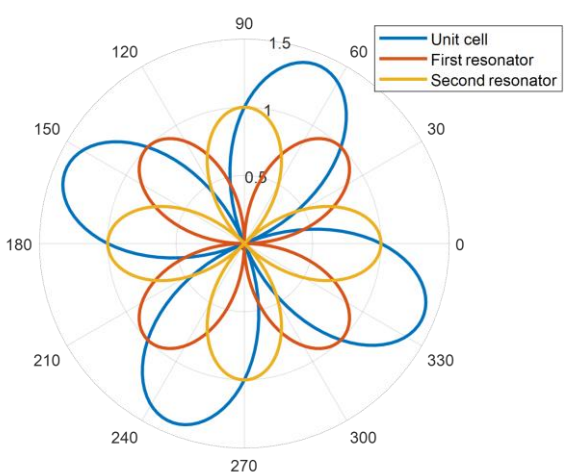

Fig. 1. Angular coverage of the individual dipoles and of the total unit cell. This figure should be compared with [1, Fig. 3] which uses scalar summation.

The methodology introduced by the authors to design cross-polar orientation-insensitive chipless tags is illustrated in [1, Fig. 3]. Two dipoles type scatterers oriented respectively at 0° ($\boldsymbol{S}_1$) and 45° ($\boldsymbol{S}_2$) are combined in order to improve the angular coverage of the total unit cell. The scattering matrix of the total target is given using superposition principle by:

$$\boldsymbol{S}(0) = \boldsymbol{S}_1(0) + \boldsymbol{S}_2(0) = A \cdot \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} + A/2 \cdot \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \tag{4}$$

Using (3), this gives:

$$S_{vh}(\theta) = A/\sqrt{2} \cdot \cos(2\theta + \pi/4) \tag{5}$$

which appears to be zero for $\theta = 22.5°$ [90°]. The graphical representation of $S_{vh}(\theta)$ normalized by A has been plotted in Fig. 1 for comparison with [1, Fig. 3]. The curves are identical for the first and the second resonators but the unit cell exhibits four nulls contrary to the scalar summation presented in [1]. Therefore, the unit cell shows no improvement in terms of angular coverage compared to the individual dipoles.

We now consider the triangle arrangement presented in [1, Fig. 4]. The triangular arrangement has a 3-fold symmetry and should theoretically have a null cross-polarization component whatever the value of θ, as demonstrated in [3].

Finally, regarding the unit cell presented in [1, Fig. 5-f], it should be noted that applying a rotation of angle $\pi/2$ to any type of scatterer modifies its scattering matrix as:

$$\boldsymbol{S}(\pi/2) = \begin{bmatrix} S_{hh} & -S_{vh} \\ -S_{hv} & S_{vv} \end{bmatrix}. \tag{6}$$

In such a way that the complete target, composed of the two flower shapes rotated at 90° with respect to each other, gives from superposition principle:

$$\boldsymbol{S}_{\text{flower}} = \begin{bmatrix} S_{vv} & S_{vh} \\ S_{hv} & S_{hh} \end{bmatrix} + \begin{bmatrix} S_{hh} & -S_{vh} \\ -S_{hv} & S_{vv} \end{bmatrix} = (S_{vv} + S_{hh}) \cdot \boldsymbol{I} \tag{7}$$

where $\boldsymbol{I}$ is the identity matrix. The cross polarization component $S_{vh}(\theta)$ of the scatterer presented in [1, Fig. 5-f] is therefore theoretically zero for any value of θ.

We have shown that the different design approaches proposed in [1, Sec. III] all lead theoretically to cancellations of the cross-polarization component of the backscattered E-field. We therefore believe that the methodology introduced by the authors cannot adequately justify the measurement results presented in the remainder of the article. A rigorous approach to obtain a scatterer with an invariant cross-polar component with respect to orientation has been introduced in [4].

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