Study of CO_2Z Hexaferrite Magnetodielectric Material as Substrate for RFID Reader Antenna

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Abstract— In this paper, Co_2Z material as the substrate is applied to design a microstrip patch antenna at 920 MHz for UHF RFID reader antenna application with simulation software CST. The simulation and measurement results show that this innovative magnetodielectric material is useful in antenna miniaturization, beneficial to achieve greater bandwidth, and there will have more performance optimizations in the design.

1. INTRODUCTION

The antenna's miniaturization is one of the challenges for antenna design. Due to the advantages such as planar structure, small volume, light weight, microstrip patch antennas have become increasingly sophisticated. Typically, patch antenna miniaturization can start from structure or substrate materials. Structurally, innovation and improvement are mainly for the resonance characteristics of the antenna design. In substrate material, according to the antenna design theory, the material with specific permeability and permittivity has a significant help for miniaturization. When using a single high dielectric constant substrate material, although the size of the antenna is reduced, but the antenna's radiation efficiency and bandwidth will be affected so that the difficulties of the antenna design increase. In antenna design, remarkably, a low loss substrate material with high permittivity and magnetic permeability is both possible to achieve antenna miniaturization and to ensure the improvement of radiation efficiency and bandwidth.

In this article, an UHF RFID reader antenna is simulated and designed with a low-loss Co_2Z material with high dielectric constant and magnetic permeability as substrate material. According to the theory and practical simulation, we can observe that Co_2Z material as a new material is beneficial to bandwidth and significantly reduces the dimension.

2. ANTENNA DESIGN

Normally, the length and width dimension of the antenna is considered first. According to experience in the design [1], the value of the width **W** should be designed with reference to the final dimension of the length **L** in order to generate the circular polarization effect. According to the equation $\mathbf{L} = \frac{\mathbf{c}}{2\mathbf{f}\sqrt{\boldsymbol{\varepsilon\mu}}}$, there is an estimate of the length dimension **L** of the antenna. And $\boldsymbol{\varepsilon}$ is the permittivity of the dielectric substrate, $\boldsymbol{\mu}$ is the magnetic permeability of the substrate material. The parameter $\sqrt{\boldsymbol{\varepsilon\mu}}$ is Miniaturization factor [2]. The permittivity of the substrate material and the magnetic permeability influence the antenna length dimension at the same time [3]. In order to meet the performance of the circular polarization, it keeps the length and width of the antenna

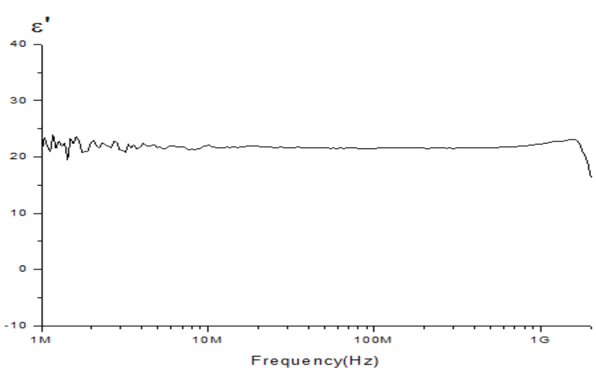

Figure 1: Permittivity of Co_2Z.

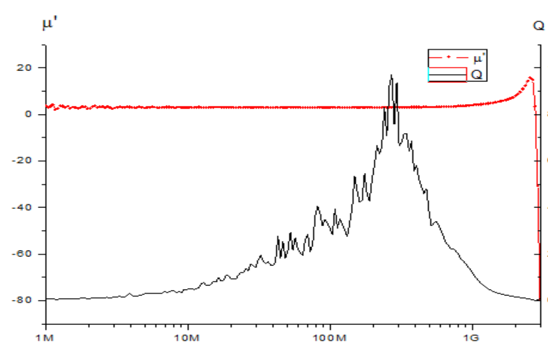

Figure 2: Permeability of Co_2Z.

as the same size. Here the dimension of the dielectric substrate is set as an experimental value, the length of the substrate will be set as $\mathbf{LG} = \mathbf{L} + 0.2\boldsymbol{\lambda}_{\mathbf{g}}$, where $\boldsymbol{\lambda}_{\mathbf{g}} = \boldsymbol{\lambda}_0\sqrt{\boldsymbol{\varepsilon\mu}}$. Figure 1 and Figure 2 show the measured values in preliminary tests on the material properties. At 900 MHz, the permittivity is 22, the permeability is 3. So the value of the miniaturization factor is approximately 8. According to the characteristic of the substrate material and the resonance frequency of the proposed antenna designed at 920 MHz, therefore the valuation of the length is 21 mm.

Meanwhile, in order to achieve circular polarization, an additional degeneracy separation unit $\boldsymbol{\Delta}\mathbf{S}$ is needed. According to the existing confirmed formula, with additional degeneracy separation unit $\boldsymbol{\Delta}\mathbf{S}$, the resonance frequencies of orthogonal polarization mode driven by the patch antenna generate separation. The separation depends on the value of $\boldsymbol{\Delta}\mathbf{S}/\mathbf{S}$. Therefore, the effective value of $\Delta\mathbf{S}$ can make the antenna produce circularly polarized radiation. A simplified equation: $|\boldsymbol{\Delta}\mathbf{S}/\mathbf{S}|\mathbf{Q}_0 = 1/2$, where $\mathbf{Q}_0$ is unload quality factor of the antenna. This formula can be used when the position of the feeding point is on the X-axis or Y-axis direction. So the valuation of the degeneracy separation unit $\boldsymbol{\Delta}\mathbf{S}$ is 4 mm^2.

Emulated and debugged with software CST, simulation dimensions of the patch antenna are obtained with the antenna length and width of 23.9 mm, degeneracy separation unit length of 2.3 mm, substrate length of 45 mm, and substrate thickness of 3 mm. Figure 3 shows the simulation geometry of the patch antenna.

Notably, the substrate thickness affects the bandwidth, radiation and other indicators [4, 5]. When the size of the antenna is fixed, a reasonable thickness of the substrate provided for the patch antenna is critical. How to make the patch antenna get enough bandwidth and good radiation performance should be concerned by setting the thickness of magneto-dielectric material as substrate.

3. SIMULATION RESULTS

Figure 4 shows the simulated S_{11} parameters.

In order to verify the effects of the magnetic permeability of Co_2Z material on the antenna dimension, a hypothetical high-k material is simulated to compare with Co_2Z material. The high-k material has same permittivity as Co_2Z, but its permeability value is 1. Compared with the high-k

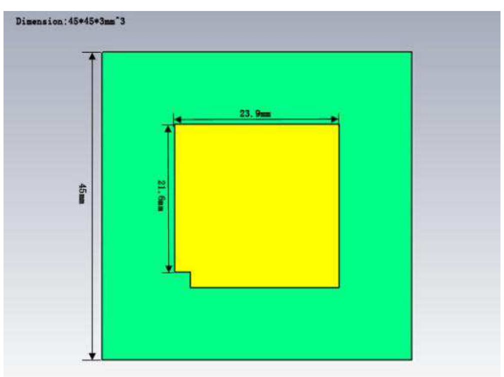

Figure 3: Geometry of the proposed antenna.

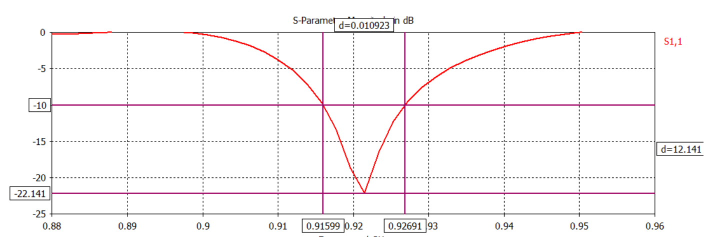

Figure 4: Simulated S_{11} of the proposed antenna.

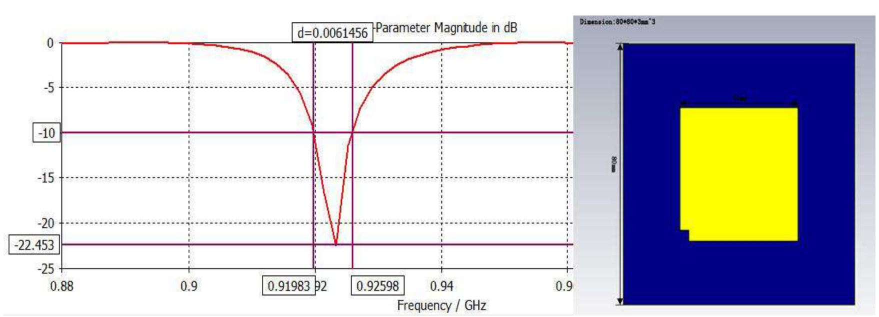

Figure 5: Geometry of high-K antenna and simulated S_{11} parameters.

Table 1: Performance of compared simulation antennas.

Material	Property	Dimension	Bandwidth ($S_{11} \leq 10\,\mathrm{dB}$)
Co_2Z	$\varepsilon = 22$, $\mu = 3$	$45 * 45 * 3\,\mathrm{mm}^3$	915.9–926.9 MHz
High-K	$\varepsilon = 22$, $\mu = 1$	$80 * 80 * 3\,\mathrm{mm}^3$	919.8–925.9 MHz

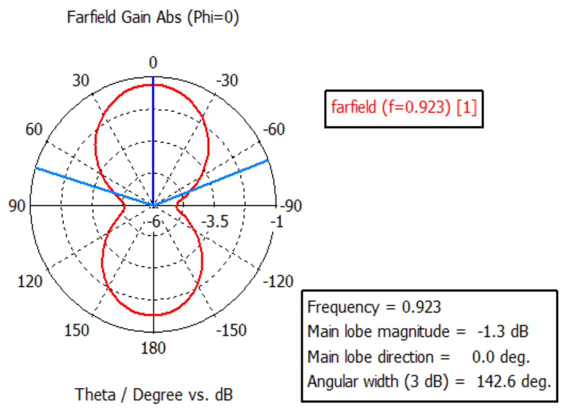

Figure 6: Farfield gain of the proposed antenna.

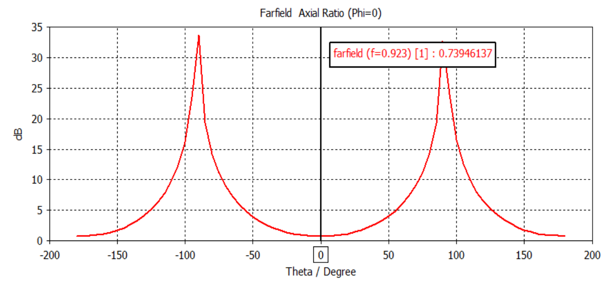

Figure 7: Axial ratio of the proposed antenna.

material antenna, the dimension of the Co_2Z antenna has been significantly reduced. And the bandwidth of Co_2Z antenna is wider than high-K antenna. Figure 5 shows the simulation geometry of high-K antenna and simulated S_{11} parameters. Table 1 shows the different performance between two simulation antennas with different material as substrate.

The Co_2Z antenna's radiation efficiency does not play a distinct advantage in the simulation, which will be focused and improved in the subsequent measurement. Figure 6 shows the antenna simulated Farfield gain.

Simulation antenna achieved circular polarization at 920–925 MHz. Figure 7 shows the antenna axial ratio.

4. CONCLUSION

In this paper, an UHF RFID reader antenna with Co_2Z magneto-dielectric material as substrate is designed and simulated. This antenna exhibited a more excellent property on miniaturization, bandwidth performance and circular polarization characteristic. In the simulation, the radiation characteristic receives some limit, which will be optimized and improved in the subsequent experiment. At the time of this writing, the antenna is being machined. The measurement results and data will be complemented before this article published. Overall, Co_2Z magneto-dielectric material has a sufficient development space in antenna design.

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