

Design of the Circularly Polarized UHF RFID Reader Antenna with High Isolation

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Abstract

A new RFID (Radio Frequency Identification) reader antenna with high isolation is considered. The antenna consists of a pair of patch radiators apart which are fed by 90° hybrid couplers. The efficient structure and proper arrangement of two radiators as well as feed points are proposed to achieve good isolation between transmit and receive ports. The proposed design minimizes the distance between two patch radiators for the required isolation level, and reduces the overall size of the RFID reader antenna.

1. INTRODUCTION

Radio frequency identification (RFID) has recently attracted much interest in supply chain management by retailers and manufacturers. In a passive UHF RFID system, tags are powered up by a continuous-wave (CW) RF signal transmitted by a reader and backscatter transmission from the reader to send back their data [1]. In a backscatter reader, the transmitted CW signal may be directly coupled to the receiver and induce a significant amount of additional noise, thereby drastically reducing the receiver sensitivity. The directly-coupled CW signal is much larger than the backscattered signal from tags, and the receiver should detect the weak signal close to such a strong in-band interferer. Therefore, it is very critical to have a high isolation between the transmitter and receiver for a high performance reader. In this paper, we present a novel design of a small backscatter reader antenna with circular polarization and high Tx/Rx isolation. Although several designs have been proposed successfully to improve the isolation of the dual linearly-polarized antenna [2], few papers have been reported on the circularly-polarized antenna with high isolation. In practice, a circularly-polarized reader antenna is desired to offer more tag orientation insensitivity.

2. ANTENNA DESIGN

The geometry of the proposed reader antenna is shown in Fig. 1. The antenna consists of two dual-feed radiating patches fed by branch-line hybrid couplers. The radiating patches are circular metal plates placed over the ground plane at a height of h_p . Each branch-line coupler is printed on a thin PTFE substrate ($\epsilon_r = 3.5$) and inset between the radiating patch and the ground plane. As shown in Fig. 1, the ground body of the proposed antenna is comprised of a pair of hexahedral cavities surrounding the radiating patches to reduce the mutual coupling between the patches. The cavities have a circular aperture with the same size of the radiating patch in the broadside direction. The overall size of the proposed antenna is only $W \times L \times H = 20 \times 45 \times 3$ cm, and this is very compact compared to commercially available RFID reader antennas [3].

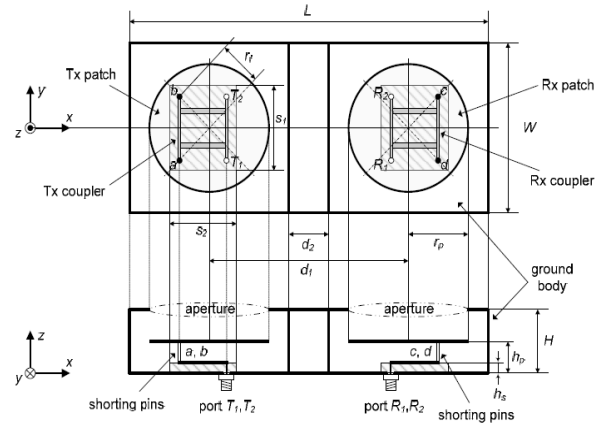


Fig. 1 Antenna structure (Type A) : $L=450$ mm, $W=200$ mm, $H=30$ mm, $r_p=80$ mm, $r_f=48$ mm, $h_p=15$ mm, $d_1=250$ mm, $d_2=50$ mm, $s_1=90$ mm, $s_2=70$ mm, $h_s=0.76$ mm.

In Fig. 1, two feed points (a, b) of the Tx patch are fed 90° out of phase with respect to each other by the Tx coupler.

There are two possible Tx ports (T_1, T_2). The LHCP (left hand circular polarization) wave is radiated when T_1 is used as a Tx port, while the RHCP (right hand circular polarization) wave is radiated for T_2 . In the same manner, two feed points (c, d) of the Rx patch are fed by the Rx coupler with two possible Rx ports (R_1, R_2), and RHCP wave is received by the port R_1 and LHCP wave by the port R_2 .

Fig. 2 shows the equivalent circuit of the proposed antenna. Two equivalent 4-port networks of the branch-line coupler and one equivalent 4-port network representing the mutual coupling between four feed points (a, b, c, d) are cascaded.

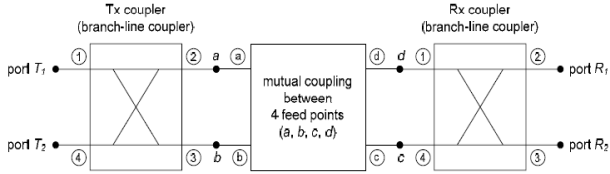


Fig. 2 Equivalent circuit

The scattering matrix $[S^c]$ for the ideal 3dB branch-line coupler is as follows when all ports (①, ②, ③, ④) are matched:

$$[S^c] = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix} = \frac{-1}{\sqrt{2}} \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix} \quad (1)$$

The scattering matrix $[S^M]$ for the equivalent 4-port network representing the mutual coupling between four feed points (a, b, c, d) is expressed as follows when all ports (Ⓐ, Ⓑ, Ⓒ, Ⓓ) are matched:

$$[S^M] = \begin{bmatrix} 0 & S_{ab} & S_{ac} & S_{ad} \\ S_{ba} & 0 & S_{bc} & S_{bd} \\ S_{ca} & S_{cb} & 0 & S_{cd} \\ S_{da} & S_{db} & S_{dc} & 0 \end{bmatrix} \quad (2)$$

From Eqs. 1 and 2, the transmission coefficients of $S_{R_1T_1}$ and $S_{R_2T_1}$ are given as follows:

$$S_{R_1T_1} = -\frac{1}{2}(S_{da} - S_{cb}) + j\frac{1}{2}(S_{ca} + S_{db}) \quad (3)$$

$$S_{R_2T_1} = -\frac{1}{2}(S_{ca} - S_{db}) + j\frac{1}{2}(S_{da} + S_{cb})$$

In the proposed antenna, its geometry and feed point locations are symmetric to xz -plane, and, hence, $S_{da} = S_{cb}$ and $S_{ca} = S_{db}$. Thus, the first term in the right side of Eqs. 3 and 4 becomes zero. This means that the directly-coupled signal

from the feed point a to d cancels out that from the feed point b to c , and the directly-coupled signal from the feed point a to c cancels out that from the feed point b to d .

According to this cancellation, the isolation from the Tx port T_1 to the Rx port R_1 (or R_2) may be better improved. The same canceling effect can be achieved with the arrangement of the feed points such as *type B* and *C* in Fig. 3 as well as *type A* in Fig. 1.

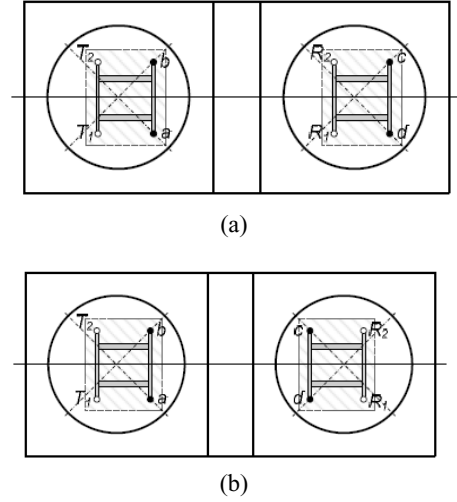


Fig. 3 Other arrangements of feed points; (a) *Type B* (b) *Type C*

Using $S_{da} = S_{cb}$ and $S_{ca} = S_{db}$ in Eqs. 3 and 4, the magnitude of $S_{R_1T_1}$ and $S_{R_2T_1}$ are given by:

$$|S_{R_1T_1}| = |S_{ca}| \quad (5)$$

$$|S_{R_2T_1}| = |S_{da}| \quad (6)$$

Eq. 5 (6) shows that the isolation between ports T_1 and R_1 (R_2) is the same as that between feed points a and c (d). Thus, in order to design a compact antenna with high isolation, we should find out the optimum arrangement of the feed points to minimize the value of $\min[|S_{da}|, |S_{ca}|]$ among *type A, B* and *C*. And then, if $|S_{da}| < |S_{ca}|$, the port R_2 should be used as an Rx port corresponding to the Tx port T_1 ; otherwise, the port R_1 should be used as an Rx port.

Fig. 4 shows the simulated results of $|S_{da}|$ and $|S_{ca}|$ for the feed point arrangements of *type A, B* and *C*. The other parameters except the feed point locations are the same as in Fig. 1. The simulations were performed using CST MW Studio. Fig. 4 shows the value of $\min[|S_{da}|, |S_{ca}|]$ is the smallest for *type A*. In case of *type A*, $|S_{da}| > |S_{ca}|$ and, therefore, the port R_1 should be used as an Rx port corresponding to the Tx port T_1 .

3. RESULTS

Fig. 5 shows the measured isolation between the Tx port T_1 and the Rx port R_1 in the proposed reader antenna. The

antenna has high Tx/Rx isolation of more than 36dB in the 902-928MHz RFID frequency band in North America. The isolation between the ports T_1 and R_2 is also presented in Fig. 5 and it is about 10dB less than that between the ports T_1 and R_1 as predicted in Fig. 4. The measured antenna gain and axial ratio of the prototype antenna are 7.5-8.0dBic and 0.6-1.1dB in the 902-928MHz band, respectively.

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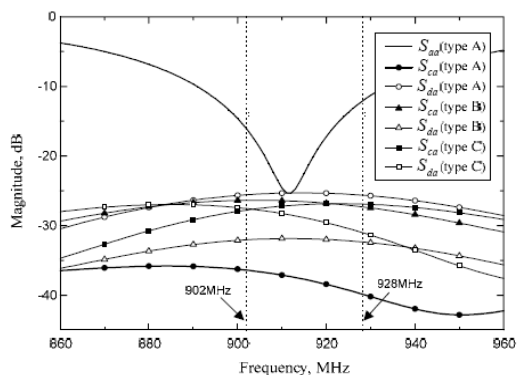


Fig. 4 Simulated results of mutual coupling between feed points

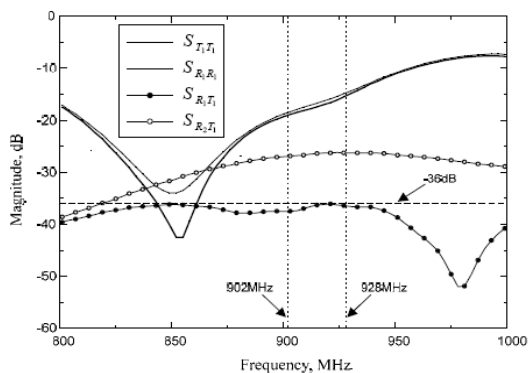


Fig. 5 Measured return loss and Tx/Rx isolation

4. CONCLUSION

A novel design of a backscatter reader antenna with circular polarization and high transmit/receive isolation has been presented. By using the feed networks based on branch-line couplers, the overall size of the antenna can be much reduced by shrinking the separation distance between two radiating patches while keeping the required isolation. The prototype antenna has a small size of 20×45×3cm, and the Tx/Rx isolation over 36dB has been experimentally demonstrated in the 902-928MHz band.

REFERENCES

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