Transmit/Receive Isolator for UHF RFID Reader with Wideband Balanced Directional Coupler

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Abstract— A wideband balanced directional coupler for UHF RFID reader is proposed. The wideband balanced coupler has a high isolation feature insensitive to load variations. The transmit and receive isolation characteristic is achieved for UHF RFID band (860~960 MHz). The proposed structure has an isolation of more than 45dB in the UHF RFID band according to the variations in matching.

Index Terms — Antenna isolation, wideband, directional coupler, UHF RFID, front-end

I. INTRODUCTION

RFID (Radio Frequency Identification) technology that contactlessly recognizes data has become the mainstream in current IT area. RFID continuously extends its application fields such as distribution, regulation and security. However, RFID has a critical problem that CW (continuous wave) transmit signal leaks to a receiver when receiving a signal from a tag. Thus, UHF RFID front-end requires a high isolation between Tx and Rx other than using the duplexer or switch used for a regular communication system.

RFID readers have previously been designed to use a circulator, a directional coupler, or a quadrature hybrid to minimize a leakage ([1]-[3]). However, these structures cannot efficiently resolve the leakage due to antenna reflection and inherent isolation characteristic of components. Commercial circulator, directional coupler or hybrid coupler has about 25dB isolation between ports in general, which implies that the leakage signal as much attenuated as 25dB in the transmitter flows into the receiver. Moreover, if an antenna is not matched to 50Ω , the isolation gets worse. Previously studies have mostly focused on only isolator characteristic without considering antenna reflection and there has been no studies to remove the antenna reflection in the UHF RFID band (860~960 MHz).

In previous study, we proposed the structure (Fig. 1(a)) effectively removing the transmit leakage signal caused by the variations in antenna matching ([6]-[7]). In this paper, a wide band balanced directional coupler to remove transmit leakage signal is proposed (Fig. 1(b)). The proposed structure has a Tx/Rx isolation characteristic in the whole UHF RFID band (860~960 MHz)



Fig. 1. (a) Previous Tx leakage canceller with balanced directional coupler, (b) proposed scheme for Tx/Rx isolation with wideband balanced directional coupler.



Fig. 2. (a) Conventional wideband quadrature hybrid, (b) proposed minimized wideband quadrature hybrid.

II. WIDE-BAND QUADRATURE HYBRID

The quadrature hybrid in the proposed structure as shown in Fig. 2 decides bandwidth. Since wideband quadrature hybrid using microstrip line has been previously studied in many papers ([4]-[5]), miniaturization of the previously studied quadrature hybrid is focused to fit into the proposed front-end structure. The structure in Fig. 2(a) uses two pairs of series transformer and parallel stub. Its magnitude and phase characteristic is shown in Fig. 3 The outputs from port2 and port3 of the proposed structure are generally balanced in the whole band comparing to existing structures. For the implementation in realty, series transformer and parallel stub are replaced with lumped elements: $L_1 = 10$ nH, $L_2 = 18$ nH, $C_1 = 3$ pF and $C_2 = 1.7$ pF.



Fig. 3. Simulated magnitude and phase characteristic for the proposed wideband quadrature hybrid. (a) Magnitude response. (b) relative phase response.

III. BALANCED DIRECTIONAL COUPLER

Fig. 4 shows the proposed wideband balanced directional coupler to improve the Tx/Rx isolation characteristic of a single directional coupler. The proposed structure consists of two wideband quadrature hybrid couplers and the equivalent circuit of two directional couplers connected with load impedances. Here, I_A and I_B denote the isolations of the directional coupler. Γ_A and Γ_B indicate the reflection coefficients of the antenna connected to the directional coupler.

In the equation of Fig. 5, x(f) and y(f) are the wideband quadrature hybrid outputs calculated from a former stage.

If $x(f)^2 + y(f)^2 = 0$, S_{21} corresponding to Tx leakage can be removed as follows.

$$Tx \ leakage = \frac{b_2}{a_1} = [I_A - I_B] + TC[\Gamma_A - \Gamma_B] = 0,$$

for $I_A = I_B$ and $\Gamma_A = \Gamma_B$ (1)



Fig. 4. Equivalent circuits of the conventional directional coupler with mismatched load.



Fig. 5. Bandwidth of the proposed structure with and without wideband quadrature hybrid.



Fig. 6. Isolations for the variation in reflection coefficients of the antenna ports.

Based on the equation (1), the isolation of the wideband balanced directional coupler is improved because the isolation characteristic of two directional couplers and the reflection coefficient of the antenna ports are lowered by subtraction. Since the proposed structure has the reflection coefficients of two antennas expressed as a difference, the antenna reflection can be removed even if the antenna reflection coefficient is not 0. That is, Tx leakage can be removed regarding the arbitrary variations of antenna impedance by circumstances.

Using the calculation discussed above, characteristic of the Tx leakage elimination is observed. As shown in Fig. 5, the bandwidth gets wider with a wideband quadrature hybrid comparing to the bandwidth without a wideband quadrature hybrid.

When the antenna reflection coefficients, Γ_A and Γ_B , are different, elimination of Tx leakage is shown in Fig. 7. Here, Γ_B is fixed to -20dB and Γ_A varies to -15dB, -20dB and -25dB. From Fig. 7, the proposed structure has a high elimination of Tx leakage even if two antennas are mismatched.

IV. MEASUREMENT

The proposed UHF RFID front-end structure is designed to have a wide bandwidth and be insensitive to the variation of antenna matching. In order to verify its performance, wideband characteristic and Tx/Rx isolation characteristic with respect to load variations are measured when a wideband quadrature hybrid is combined with a balanced directional coupler.

The Wideband quadrature hybrid and the balanced directional coupler are implemented with a Taconic board (RF-35, $\varepsilon_r = 3.5$) of 0.5 mm thickness. The 90° hybrid branch line coupler and the 10-dB directional coupler are implemented with RCP890A03 and RCP890A10.

The proposed wideband quadrature hybrid is also implemented with lumped elements: $L_1 = 10$ nH, $L_2 = 18$ nH, $C_1 = 3$ pF, $C_2 = 1.7$ pF.

Fig. 7 shows the measured results for the bandwidth of Tx/Rx isolation regarding the use of wideband quadrature hybrid. The structure with the wideband quadrature hybrid shows more than 55dB isolation in the UHF RFID.

The isolation characteristic regarding various load impedances (25 Ω , 50 Ω , 75 Ω and 100 Ω) is shown in Fig. 8.

When there is no reflection from the load impedance (i.e. perfect antenna matching and load impedance of 50Ω), the isolation is measured 62.1dB at 910MHz. When 100 Ω impedance is connected, the isolation is 45.4dB which is 23dB better than existing directional couplers. Thus, the proposed balanced structure has an excellent Tx/Rx isolation characteristic regarding the variations of load impedance.

V. CONCLUSIONS

In this paper, a Tx/Rx isolation problem of RFID front-end in the UHF band has been studied. The proposed structure has a wideband characteristic and an isolation characteristic insensitive to an antenna matching affected by circumstances. The proposed circuit consists of wideband quadrature hybrids and balanced directional couplers. The wideband quadrature hybrid is designed to be applied in the UHF RFID band (860~960 MHz) and then replaced with lumped elements for



Fig. 7. Measured isolation characteristic of proposed structure with and without wideband quadrature hybrid.



Fig. 8. Measured isolation characteristics of the proposed structure with mismatched load.

a miniaturization. The Tx/Rx isolation characteristic of the balanced directional coupler is theoretically analyzed and verified that it is not affected by an arbitrarily matched antenna. The balanced directional coupler combined with the wideband quadrature hybrid is fabricated and shows more than 45dB isolation regarding the variations of load impedance.

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