# Dual-band circularly polarized RFID reader antenna employing metamaterial quadrature hybrid coupler

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**Abstract**

A dual-band circularly polarized aperture coupled microstrip RFID reader antenna using a metamaterial (MTM) quadrature hybrid coupler has been designed, fabricated, and measured. The proposed antenna is fabricated on an FR-4 substrate with relative permittivity of 4.6 and thickness of 1.6 mm. A dual-band (UHF and ISM) circularly-polarized RFID planar reader antenna with separate TX and RX ports is incorporated connected to the designed metamaterial (MTM) quadrature hybrid coupler. The measured 10dB bandwidth of the proposed antenna is 908 to 939 MHz (3.4%) and 2370 to 2540 MHz (7.0%). The maximum measured CP gain is 6.6 dBc at 920MHz (UHF) and 7.9dBc at 2.45GHz (ISM). The cross-polar gains near broadside of the RFID reader antenna are approximately less than -20dB compared with the co-polar gains in both bands. The proposed antenna presents isolation of 25dB and 38dB at each band.

## 1. Introduction

The Radio-frequency identification (RFID) is a technology that uses communication via radio waves to exchange data between a reader and an electronic tag attached to an object, for the purpose of identification and tracking. There is an increasing need to develop a dual-band RFID reader antenna to accommodate two frequency bands in one structure. Circular polarization (CP) is also an important aspect of the RFID reader antenna. It is for signal reception regardless of the physical orientation of the tag. One more requirement for the RFID reader antenna is sufficient isolation between the TX and RX ports. A two-port TX/RX one-body reader antenna is certainly a favourite. In [1], a linearly-polarized aperture-coupled two-layered dual-band RFID reader antenna was designed with a 2:1 VSWR bandwidth of 17% at the UHF band 31% at the ISM band. Circularly-polarized RFID reader antennas for the single UHF band have been extensively studied [2] and there are already some commercial products from various manufacturers. In this paper, a dual-band (UHF: 917-923MHz, ISM: 2.4-2.48GHz, in Korea) CP RFID planar reader antenna with separate TX and RX ports is proposed using the metamaterial (MTM) quadrature hybrid coupler. A single rectangular patch is fed by the two output line of the designed the MTM coupler through the near orthogonally positioned slots.

## 2. Metamaterial dual-band quadrature hybrid coupler

The required characteristic impedances and phase shifts of a dual-band quadrature hybrid coupler are shown in Fig. 1(a) and (b). A conventional quadrature hybrid coupler with four quarter-wavelength segments is well known to show the phase shifts of $-90^{o}$ and $-270^{o}$ at fundamental and third harmonic frequencies, respectively, as seen in Fig. 1. Thus, it is basically a dual-band device. The phase shifts of $-90^{o}$ and $-270^{o}$ of the segment at arbitrarily chosen two frequencies (f1 and f2) can be realized using the metamaterial techniques in [3], [4]. Fig. 1 (c) shows the geometry of the metamaterial dual-band coupler. The total size of the coupler is approximately 50 mm×55 mm. The calculated values are for $Z_c=50/\sqrt{2}\Omega$, $d_1$=49.3mm, L=223.7nH/m, C=179pF/m, $L_1$=26.4nH, and $2C_1$=42.3pF and, for $Z_c=50\Omega$, $d_2$=50.4mm, L=309.2nH/m, C=123.7pF/m, $L_2$=37.5nH, $2C_2$=29.9pF.

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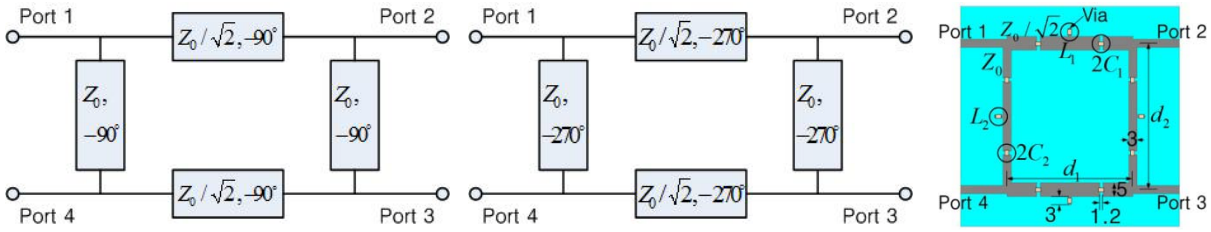
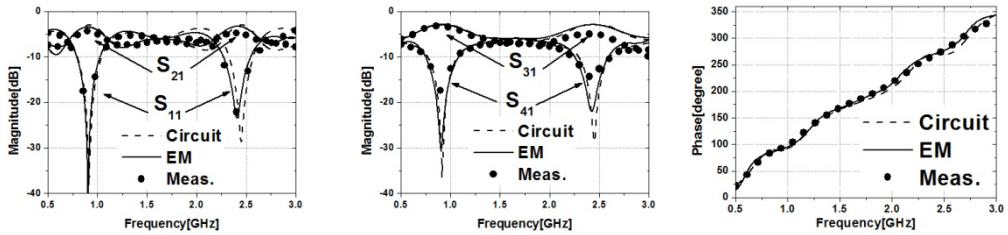



(a) (b) (c)

Fig. 1: Conceptual schematics of dual-band quadrature hybrid coupler (a) UHF band (b) ISM band.

Fig. 2 shows the S-parameters of the proposed coupler. The S-parameters are compared among the circuit, EM, and measured results; the magnitudes of the S-parameters are provided in (a) and (b), and the phase balance |phase($S_{21}$)-phase($S_{31}$)| as a function of frequency is provided in (c). Based on the phase difference of ±5° and magnitude difference of ±1.2 dB, the bandwidth of the coupler is 896 to 934 MHz (4.1%) and 2380 to 2480 MHz (4.1%).

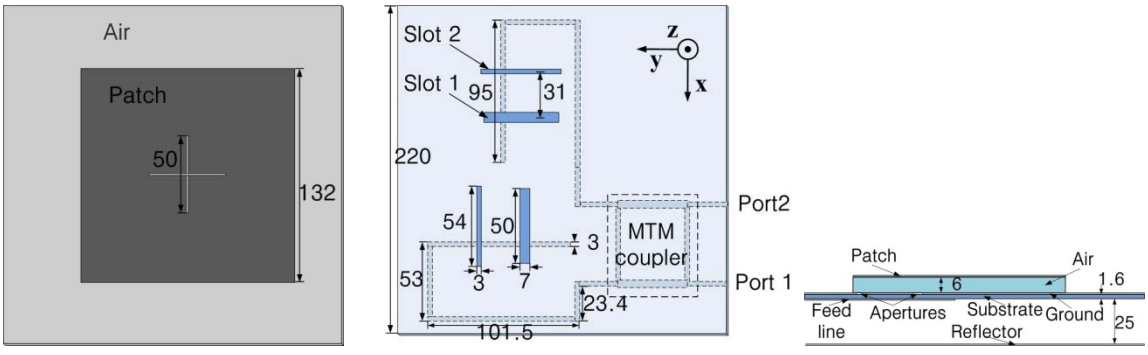



(a) (b) (c)

Fig. 2: S-parameters of dual-band quadrature hybrid coupler (a) Magnitudes of $S_{11}$ and $S_{21}$ (b) Magnitudes of $S_{31}$ and $S_{41}$ (c) |phase ($S_{21}$)-phase ($S_{31}$)|.

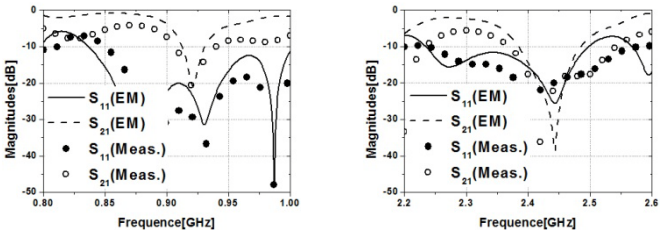
## 3. Dual-band aperture coupled circularly polarized antenna

Fig. 3 shows the schematics of the proposed dual-band (UHF and ISM) circularly polarized aperture-coupled RFID microstrip patch antenna. The radiating patch antenna (a) is fed by the two outputs of the designed dual-band MTM quadrature hybrid coupler through two slots (b). The S-parameters of the antenna are shown in Fig. 4. The S-parameters are compared between the results of EM-simulation and actual measurements. The magnitudes of $S_{11}$ and $S_{21}$ are presented in UHF band (a) and in ISM band (b).The results are shown to be fairly consistent. The measured 10dB bandwidth of the antenna is 908 to 939 MHz (3.4%) and 2370 to 2540 MHz (7.0%).




(a) (b) (c)

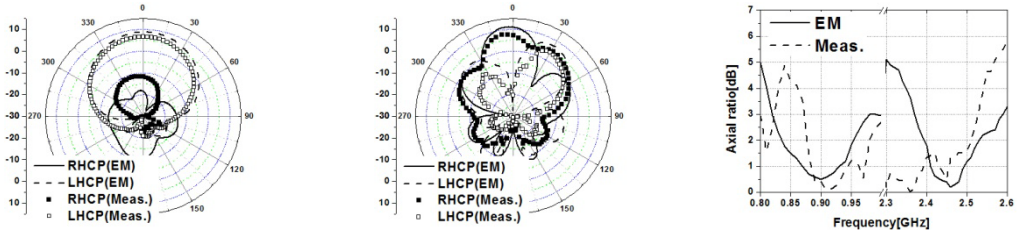
Fig. 3: Schematics of proposed antenna (a) Radiating patch (b) Feeding circuit (c) Side view.(unit : mm)




(a) (b)

Fig. 4: -parameters of proposed antenna (a) UHF band (b) ISM band.

Fig. 5 (a) and (b) show the CP gain patterns of the proposed antenna in the XZ plane at 920MHz and 2.45GHz, respectively, based on EM simulations and measurements when the port 1 is excited. The proposed antenna is shown to generate a LHCP at 920MHz and RHCP at 2.45GHz. The maximum measured CP gain is 6.6 dBc at 920MHz (UHF) and 7.9dBc at 2.45GHz (ISM). Fig. 5 (c) shows the axial ratios (AR) of the antenna in the UHF and ISM bands




(a) (b) (c)

Fig. 5: CP gain pattern of proposed antenna in XZ plane (a) at 920MHz (UHF band) (b) at 2.45GHz (ISM band) (c) Axial ratios of proposed antenna at UHF and ISM bands.

## 4. Conclusion

A dual-band aperture coupled, circularly polarized, RFID reader antenna has been proposed using a dual-band metamaterial quadrature hybrid coupler. Both the EM simulation and actual measurement results of the antenna have been provided. The proposed antenna presents isolation of 25dB at UHF band and isolation of 38dB at ISM band. The maximum measured CP gain is 6.6dBc at 920MHz (UHF) and 7.9dBc at 2.45GHz (ISM). Besides, the measured AR's are less than 0.7dB at UHF band (917-923MHz) and 1.5dB at ISM band (2.4-2.48GHz). The proposed antenna is a good candidate for a dual-band RFID reader for both UHF and ISM band applications.

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