Bidirectional radiated circularly polarised square-ring antenna for portable RFID reader

Y.-F. Lin, H.-M. Chen, F.-H. Chu and S.-C. Pan

A novel single-layer, dual-fed technique for a bidirectional radiated circularly polarised square-ring antenna operated in the UHF band is presented. The two feed ports of the square-ring radiating element are placed in orthogonal directions and connected to a feeding network with a Wilkinson power divider in the same plane. Properly adjusting the size of the capacitive coupling groundplane results in good impedance matching and circularly polarised radiation, and a broad impedance bandwidth ($S_{11} \leq -10$ dB) of about 45.2% and a 3 dB axial-ratio bandwidth of about 8.7% were obtained.

Introduction: Radio frequency identification (RFID) systems have gained much interest in several service industries: purchasing and distribution logistics, manufacturing companies and goods flow systems [1]. The RFID system generally consists of the reader and the tag. The reader can be a read device that uses an antenna which sends a radio frequency signal to a tag. The RFID reader antenna is one of the important components in RFID systems and has been designed with circularly polarised (CP) operation. CP antennas can reduce the loss caused by the multi-path effects between the reader and the tag antenna. A CP antenna with a low profile, small size, and that is lightweight is required in a portable RFID reader. A typical technique for producing circular polarisation is to excite two orthogonal linearly polarised modes with a 90° phase difference. Single-fed circularly polarised square, triangular, and circular patch antennas with perturbation elements are reported in [2–8]. Using perturbation cuts or strips to suitably differentiate the two orthogonal modes at resonant frequency, the antenna can easily radiate CP waves. However, these antennas provide a small impedance bandwidth and narrow axial ratio (AR) bandwidth. Recently, ring radiating elements, such as square and annular rings have been attracting more attention, because of their relatively small size when compare to patch antennas. The two near-degenerated resonant modes for circular polarisation of a single-fed ring antenna are generated by either cutting diagonal slits or inserting symmetrical perturbation strips in to the rings. However, impedance transformers are necessary to match the antennas to 50 Ω input ports [6–8]. In this Letter, a novel and simple square-ring antenna fed by a Wilkinson power divider is proposed to obtain circularly polarised radiation. The square-ring antenna is chosen for the design because of the simplicity in fabrication and small size compared to patch antennas. The antenna operates at its fundamental TM_{11} mode for the UHF band (860–960 MHz) and it does not need any transformer for impedance matching or extra slits and strips to generate the two orthogonal modes. Details of the antenna design and the obtained experimental results are presented and discussed.

Antenna design: Fig. 1 shows the proposed bidirectional radiated CP square-ring antenna using a Wilkinson power divider feeding for the RFID reader. The proposed simple antenna consists of the square-ring radiator and a Wilkinson power divider feeding structure in the same single-layer. A Wilkinson power divider, with its two output strips having a length difference of a quarter-wavelength to produce a 900° phase shift, is shown in Fig. 1. The square-ring and power divider are printed on the upper side of a single FR4 substrate with thickness $h =$ 1.6 mm and relative permittivity 4.4, and the square ground plane with a side length of 64 mm is on the rear side of the single substrate. The square ring radiator is fed by two strips which are connected to the end of the output strips of the power divider. A 100 Ω chip resistor is added in the power divider to achieve good isolation between the two output ports. The probe feed-point is positioned 14.5 mm away from the bottom edge of the groundplane. The size of the radiating square-ring has a side length of 95 mm and width of 9.5 mm, which operates at its fundamental TM_{11} mode and corresponds to about 0.9 free space wavelength of the centre frequency (915 MHz). In the power divider structure, the width (W_2) of the 50 Ω feed line is uniform and equals 3.0 mm, and the width (W_1) of the characteristic impedance 70.71 Ω is given by 1.6 mm. By selecting a proper groundplane size, this provides an effectively capacitive coupling between the groundplane and square-ring radiator and achieves good impedance matching of the proposed antenna. The proposed antenna with dimensions given in Fig. 1 has been fabricated and tested. Note that the antenna configuration shown in Fig. 1 will radiate a right-hand CP (RHCP) wave.

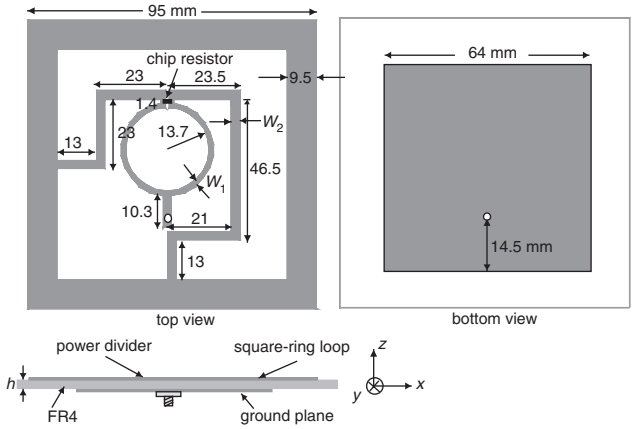

Fig. 1 *Geometry of single-layer, bidirectional radiated circularly polarised square-ring antenna*

Experimental results and discussion: The proposed CP antenna is designed to operate at the centre frequency of about 915 MHz in the UHF band for RFID readers. The return loss is measured using an Agilent N5230A vector network analyser, and axial ratio and radiation patterns are evaluated in an anechoic chamber with an NSI-800F10 antenna measurement system. Fig. 2 shows the simulated and measured return loss of the proposed antenna. The measured impedance bandwidth for 10 dB return loss is 45.2%, ranging from 725 to 1149 MHz, and agrees well with the HFSS simulated results. The measured axial ratio in the broadside direction against frequency is also presented in Fig. 3. The 3 dB axial-ratio CP bandwidth is about 80 MHz or 8.7% with respect to the centre frequency at 915 MHz. The RHCP radiation pattern measured at 915 MHz is plotted in Fig. 4, and good symmetry of bidirectional radiation has been observed. Also, it can be observed from the pattern that the 3 dB beam widths are about 70° (−35° ∼ 35°). The measured antenna gain over the whole CP bandwidth is presented in Fig. 5. The measured gain was obtained using the gain transfer method where standard gain horn antenna was used as a reference. The obtained peak antenna gain is from 1–4 dBic in the UHF band.

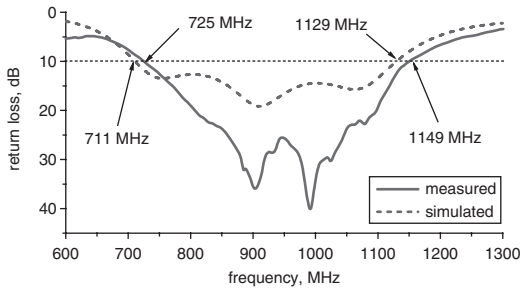

Fig. 2 *Measured and simulated return loss of proposed antenna*

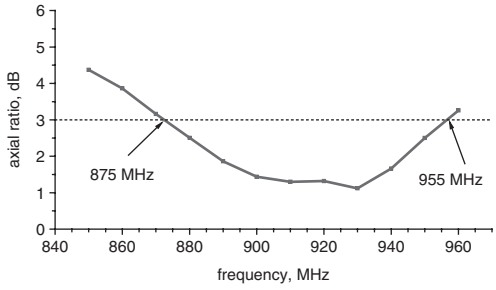

Fig. 3 *Measured axial ratio against frequency for proposed antenna*

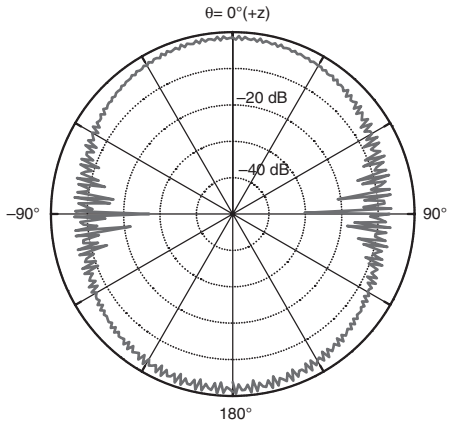

Fig. 4 *Measured normalised RHCP radiation pattern of proposed antenna in y-z plane at 915 MHz*

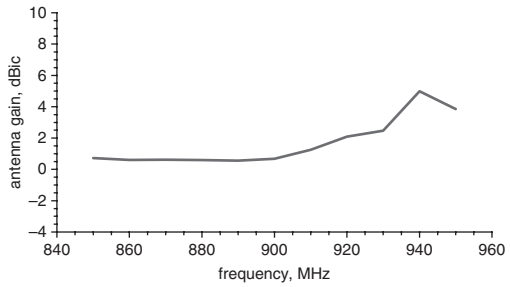

Fig. 5 *Measured antenna gain of proposed antenna*

Conclusions: A new bidirectional radiated CP square-ring antenna using a Wilkinson power divider feeding for RFID reader has been designed and measured. Experimental results show that the proposed antenna can have a 3 dB CP bandwidth of about 8.7% and an impedance bandwidth of about 45.2% (725 ~ 1149 MHz). In addition, the proposed antenna is compact and it is easy to find applications as a transmitting antenna in a portable RFID reader.

6 September 2008
Electronics Letters online no: 20082579
doi: 10.1049/el:20082579

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