Compact broadband circularly polarised slot antenna for universal UHF RFID readers

Bo Xu, Shuai Zhang, Yusha Liu, Jun Hu✉ and Sailing He

A compact broadband circularly polarised slot antenna is designed for universal ultra-high-frequency (UHF) radio-frequency identification (RFID) readers. The antenna consists of an L-shaped metal strip and a square-slot-loaded ground plane with four tuning stubs. The total size is 100 × 100 × 1.6 mm^3. The measured –10 dB impedance bandwidth is 40.7% (772–1166 MHz) and the measured 3 dB axial ratio (AR) bandwidth is 13.9% (840–965 MHz). Both the impedance and the AR bandwidth cover the worldwide UHF RFID band.

Introduction: Radio-frequency identification (RFID) in the ultra-high-frequency (UHF) band has been attracting increasing attention in many industry services such as supply chain management, goods tracking and logistics. A typical RFID system consists of a reader and a tag. Most commercial UHF RFID tags are linearly polarised. A circularly polarised (CP) antenna is preferred for the reader because the linearly polarised tag can be oriented arbitrarily. Moreover, it is useful for reduction of multipath effects.

The total frequency range of the UHF band for universal RFID systems is 840.5–955 MHz (e.g. 902–928 MHz in the North and South of America, 866–869 MHz in Europe, 952–955 MHz in Japan, 840.5–844.5 MHz and 920.5–924.5 MHz in China, 865–867 MHz in India, 908.5–914 MHz in Korea, 866–869 MHz and 923–925 MHz in Singapore, 865–868 MHz and 920–925 MHz in Hong Kong, 920–928 MHz in Taiwan and 920–926 MHz in Australia). A CP reader antenna needs to cover the entire UHF band (840.5–955 MHz) for worldwide RFID applications. However, traditional designs of universal CP RFID reader antennas are relatively bulky [1–3].

Using the CP slot antenna is a potential approach for universal UHF RFID application, since slot antennas usually have broader impedance and axial ratio (AR) bandwidths than other low-profile antennas, such as microstrip antennas and cross-dipole antennas [4, 5].

In this Letter, a compact bidirectional broadband CP slot antenna with four tuning stubs and an L-shaped metal strip is presented for universal UHF RFID applications. To reduce the number of unidirectional reader antennas, the bidirectional reader antenna can be used in the entry-way scanning systems, security systems and future supermarket checkout counters. The measured –10 dB impedance bandwidth of the proposed antenna is 40.7% (772–1166 MHz) and the measured 3 dB AR bandwidth is 13.9% (840–965 MHz). Meanwhile, the antenna configuration is simple and easy for fabrication.

Antenna design: Fig. 1 shows the geometry of the proposed CP antenna on an FR4 substrate with thickness of 1.6 mm and permittivity of 4.4. The proposed CP reader antenna mainly consists of a square-slot-loaded ground plane and an L-shaped metal strip. The dimensions of the proposed antenna are 100 × 100 × 1.6 mm^3. The geometric parameters are optimised through simulations with Ansoft HFSS 15.

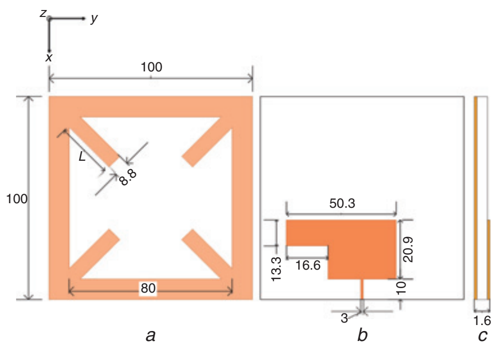

Fig. 1 *Configuration of proposed antenna*

a Top view
b Bottom view
c Side view

CP radiation is generated by the L-shaped strip fed by a 50 Ω microstrip feedline on the bottom. If the length and width of the L-shaped strip is properly selected, two orthogonal modes of the slot antenna would be excited with the same amplitude and 90° phase difference, which result in left-hand circular polarisation (LHCP) radiation in the +*z* direction and right-hand circular polarisation (RHCP) radiation in the –*z* direction. In addition, good impedance matching is also acquired by tuning the length and width of the L-shaped strip.

On the top of the substrate, four stubs in diagonal directions are extended from the ground plane into the square slot. Fig. 2 shows the effects of the stub lengths on the simulated reflection coefficient performance. It is observed that the operating band is shifted down as *L* increases. Increasing *L* makes the circumference of the slot longer, and thus lowers the operating band.

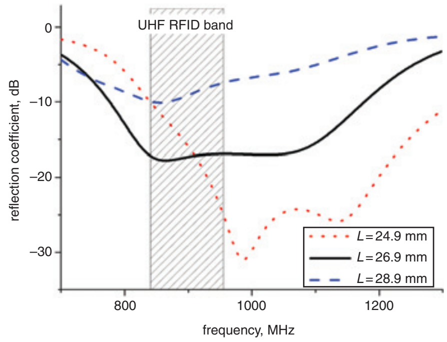

Fig. 2 *Simulated reflection coefficient characteristics of proposed antenna with L*

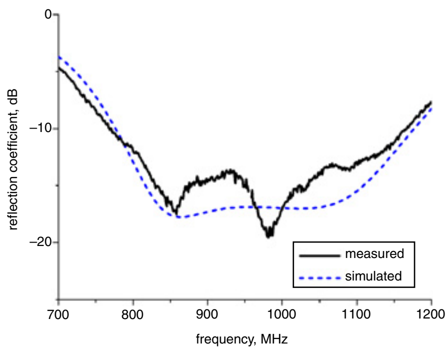

Fig. 3 *Simulated and measured reflection coefficients of proposed antenna*

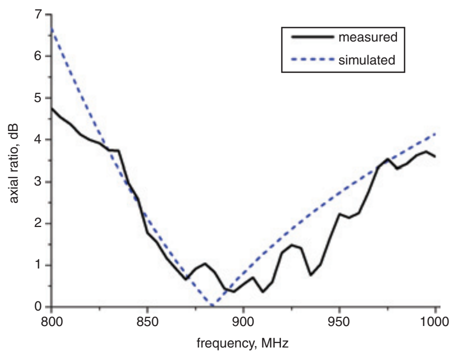

Fig. 4 *Simulated and measured ARs of proposed antenna*

Measured results: The antenna was measured in an anechoic chamber using the Satimo SG24 chamber and an Agilent E8358A vector network analyser.

Fig. 3 shows the simulated and measured reflection coefficients of the antenna. The measured –10 dB impedance bandwidth is from 772 to 1166 MHz. Fig. 4 shows the simulated and measured AR at the boresight. The measured 3 dB AR bandwidth is from 840 to 965 MHz. Both the measured impedance and the AR bandwidth cover the entire UHF RFID band. The simulated and measured gain in the +*z* direction is illustrated in Fig. 5. The antenna exhibits the measured LHCP gain of more than 2.2 dBic over the band of 840.5–955 MHz with a peak LHCP gain of 2.9 dBic at 913 MHz. The measured and simulated reflection coefficients, AR and gain show good agreement.

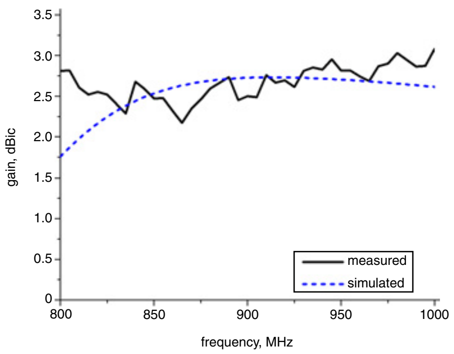

Fig. 5 *Simulated and measured LHCP gains of proposed antenna*

Figs. 6*a* and *b* show the simulated and measured normalised LHCP and RHCP radiation patterns at 900 MHz in the *x*–*z* and *y*–*z* planes, respectively. We observe that the CP antenna has LHCP in the +*z* direction and RHCP in the opposite direction.

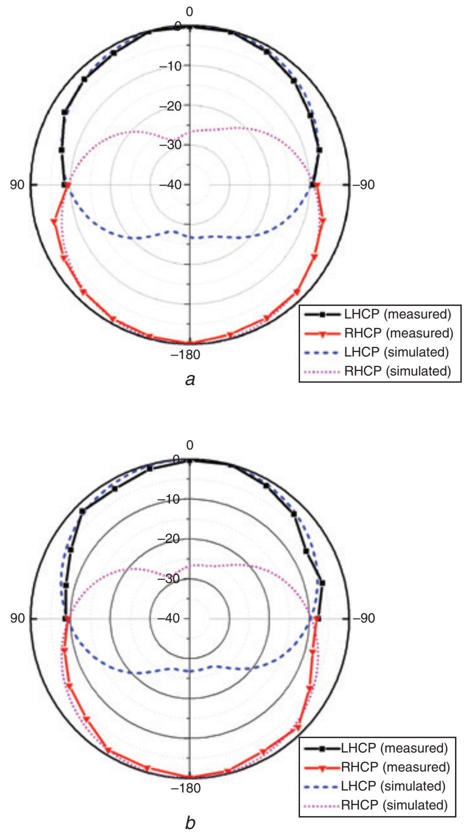

Fig. 6 *Simulated and measured normalised radiation patterns of proposed antenna at 900 MHz*

a x–*z* plane
b y–*z* plane

Conclusion: A broadband CP slot antenna has been designed, fabricated and tested. By using four stubs and an L-shaped metal strip, the optimised antenna has achieved the desired performance over the UHF band. The antenna demonstrates a measured –10 dB impedance bandwidth of 394 MHz and a 3 dB AR bandwidth of 125 MHz with a peak gain of 2.9 dBic. The measurements agree well with the simulated results. The antenna structure is simple and easy for fabrication.

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One or more of the Figures in this Letter are available in colour online.

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