A New Crossed Staircase Dipole Antenna for 915 MHz RFID Application

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Abstract
A crossed meander antenna and a crossed staircase antenna are studied for RFID based sensor networks. Both antennas are designed to operate in the unlicensed 915 MHz frequency band. Each antenna occupies a printed circuit board area of 152 by 102 sq. mm. It is demonstrated that the crossed staircase antenna has low mutual coupling (<-30 dB), overall good radiation pattern coverage, and high peak gain (2.1 dBi) suitable for RFID based sensor networks.

Introduction
Radio Frequency Identification Devices (RFIDs) are gaining popularity rapidly over similar other devices, such as, barcode modules, and optical character recognition (OCR) modules. An RFID module, consisting of an IC chip (called the tag) and an antenna, stores information for identification and uses radio frequency (RF) electromagnetic waves for data communication. Researchers have been working to design RFID antennas with miniature size, long read range, omnidirectional or directional radiation patterns, and relative insensitivity to nearby materials. Lu et al. [1] discussed an implantable MEMS based inductively coupled RFID transponder working at 13.56 MHz. Marrocco [2] developed an RFID transponder antenna which is small in size, works within 860-960 MHz band, and radiates low power compatible with the human body. Calabrese et al. [3] developed a miniaturized meandered slot antenna working at 870 MHz and 2.45 GHz using genetic algorithm for RFID sensors.
Nevertheless, to support the future development of robust sensor networks consisting of RFID modules operating in the unlicensed 915 MHz frequency band more work is needed to ensure that the tags can operate with longer read ranges and are generally not sensitive to the orientation of the object on which they will be placed on. These call for higher peak gain and very good radiation patterns coverage with as little of a pattern null as possible. Furthermore, in order to use commercially available RFID circuits the antenna and everything else must also fit within a specific surface area or volume [4]. To address these issues, we studied a crossed meander and a crossed staircase antenna in this paper. We found that the crossed staircase antenna has significantly lower mutual coupling than the crossed meander antenna. The radiation pattern coverage and the peak gain of the crossed staircase antenna are also significantly better than the crossed meander antenna.

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Figs. 1(a) and 1(b) show the geometries of the crossed meander and the crossed staircase antennas, respectively. Note that each antenna consists of two dipoles. For instance, the crossed meander dipole in Fig. 1(a) consists of two meander dipoles printed on the top and bottom surfaces of a 10 mil thick Duroid 5880 substrate ($\varepsilon_r=2.1$), respectively. The crossed staircase antenna is also printed the same way on a 10 mil thick Duroid 5880 substrate. The thin substrate will allow the RFID module to be easily placed on an object that needs to be monitored. Both antennas are designed to operate at 915 MHz. Each dipole in Fig. 1(a) consists of 14 equal arms with $m_1=n_1=13$ mm. The axial length, $L_1=99$ mm and the substrate size is $x_1=83$ mm, $y_1=82$ mm. Similarly, in Fig. 1(b) each dipole consists of 14 equal stairs with $m_2=n_2=11.7$ mm. The axial length, $L_2=117.5$ mm and the substrate size is $x_2=90$ mm, $y_2=93$ mm. Each substrate size is such that it fits within a standard area of 152×102 sq. mm. The width of the copper trace that was used to form the geometry of the antenna is 1 mm.

Results

Antenna performance was studied using Ansoft HFSS. The return loss ($S_{11}$, $S_{22}$) and mutual coupling ($S_{12}$, $S_{21}$) of the two antennas are shown in Figs. 2(a) and 2(b), respectively. The bandwidth of the crossed meander and the crossed staircase antennas are 10.9% and 8.4%, respectively with reference to a -10 dB upper limit. Both antennas have more than adequate bandwidths to support the 915 MHz RFID tags. Interestingly the mutual coupling of the crossed staircase antenna is significantly better than the crossed meander antenna. From Figs 2(a) and 2(b) it is clear that the mutual coupling between the two elements of the crossed meander antenna is worse than -10 dB while that between the two elements of the crossed staircase antenna is better than -30 dB in the frequency range around 915 MHz. In Figs. 3, 4, and 5, we show the radiation patterns (realized gain) of the antennas in the $\phi=0^\circ$, $\phi=90^\circ$, and the $\theta=90^\circ$ planes. Comparing Figs. 3(a) and 3(b) it is apparent that the patterns of both the crossed meander and the crossed staircase antennas look
Fig. 2. Input data of the (a) crossed meander and (b) crossed staircase antennas.

Fig. 3. Radiation patterns of the (a) crossed meander and the (b) crossed staircase antennas in the $\Phi=0^\circ$ plane.

Fig. 4. Radiation patterns of (a) the crossed meander and (b) the crossed staircase antennas in the $\Phi=90^\circ$ plane.
Fig. 5. Radiation patterns of (a) the crossed meander and (b) the crossed staircase antennas in the $\theta=90^\circ$ plane.

similar. The $E_{\phi}$ component of each antenna is nearly uniform with respect to the elevation angle $\theta$. However, the gain associated with the $E_{\phi}$ component of the crossed meander antenna is about 4 dB lower than that for the crossed staircase antenna. Due to the presence of the closely spaced conductors for the meander antenna the result is poor antenna gain. The behavior of the other field component is generally very similar for both antennas. In the $\phi=90^\circ$ plane (see Figs. 4(a) and 4(b)) nearly similar results are observed, except that the gain of the crossed meander antenna has improved slightly. Nevertheless, the gain of the crossed staircase antenna is still superior to that of the crossed meander antenna. Finally, comparing the patterns in the $\theta=90^\circ$ plane the peak gain of the crossed staircase antenna is significantly higher than the crossed meander antenna, 2.1 dBi as opposed to 0 dBi which will result in significant increase in tag read range.

References: