Triple Loop Antennas with Shifted Gate Arrangement for LF-RFID Systems Optimized by Evolution Strategies

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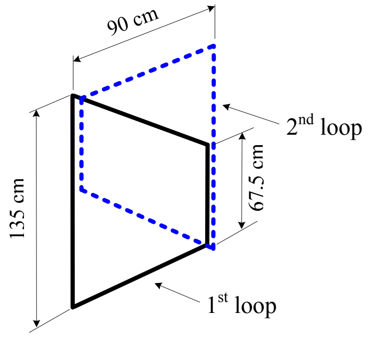
1. Introduction

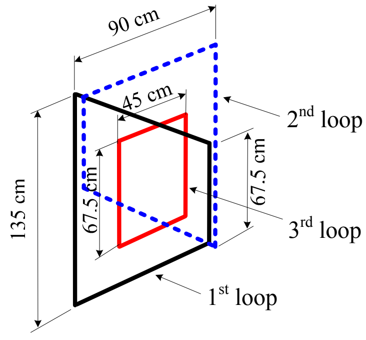
The animal identification in farm is one of the most promising applications of Radio Frequency Identification (RFID) system at the low frequency (LF) band (134.2 kHz). Conventionally, the rectangular and the circular loops are used as the reader antennas. However, these antennas cannot communicate with tags for some tag orientations [1],[2]. For the antenna in walk-through with shifted gate arrangement, the cancellation of magnetic field distribution in the middle region of the antenna gates can be mitigated[3]. In this paper, triple loop antennas arranged as a shifted gate are proposed to improve magnetic field distribution in the region occupied by two shifted gates. The enhanced communication performance is due to the increase of numbers of loop antennas (from two to three) with appropriate shifted gate arrangement. Optimum parameters of the proposed triple loop antenna are obtained using evolution strategies (ES) [4] and the Numerical Electromagnetic Code (NEC) [5]. The evolution strategy is an optimization tool of evolution in nature which is one of family of evolutionary algorithm processes. The optimized antenna is fabricated and measured its performance. Simulated and measured results are-in good agreement.

2. Gate Antennas Structure

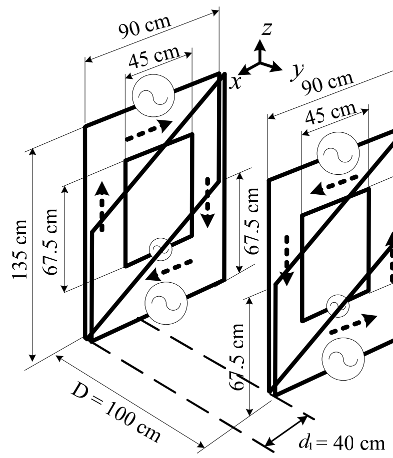
Reader antenna of the LF-RFID system for cattle identification are usually gate antennas arranged in a walk-through configuration. For the cattle identification, the suitable dimension of each gate antenna is 135 cm of height and 90 cm of width. The antenna structure consists of three loops for each gate. The first and second loops of each gate antenna are trapezoidal in shape confined in a rectangular loop as shown in Fig. 1(a). In addition, the third loop is in a rectangular shape initially employed to improve the distribution of magnetic fields in the *y*-direction as shown in Fig. 1(b). Triple loop antennas for each gate are excited in-phase. The distance between each gate antenna (*D*) in *y*-direction is 100 cm, and the shifted distance (d_1) between each gate in *x*-direction is 40 cm. Note that the gate antennas in a walk-through shifted arrangement are excited with 180 degree out-of-phase currents as shown in Fig. 1(c).



(a) Double trapezoidal loops.



(b) Double trapezoidal loops with an initial rectangular loop.



(c) The 180 degree out-of-phase current excitation of triple loop gate antennas in a walk-through shifted-gate arrangement.

Figure 1: Structure of triple loop antennas.

3. Optimizations of Antenna Structure

In this section, the simple ES is used to optimize antenna parameters with the process selection (1+1)-ES [4]. The mutation employs the normal distribution. Note that the mutation of ES can be an adaptive mechanism in process or self-adaptive mutation with 1/5-success rule. The NEC is employed to simulate antenna characteristics. In this study, the percentage of volume is used as a figure of merit [3] to express the communication ability of the antenna. The objective percentage of volume of each principal axis is

$$\text{Objective function } (F) = [\, P_{v,H_x} ,\ P_{v,H_y} ,\ P_{v,H_z} \,], \tag{1}$$

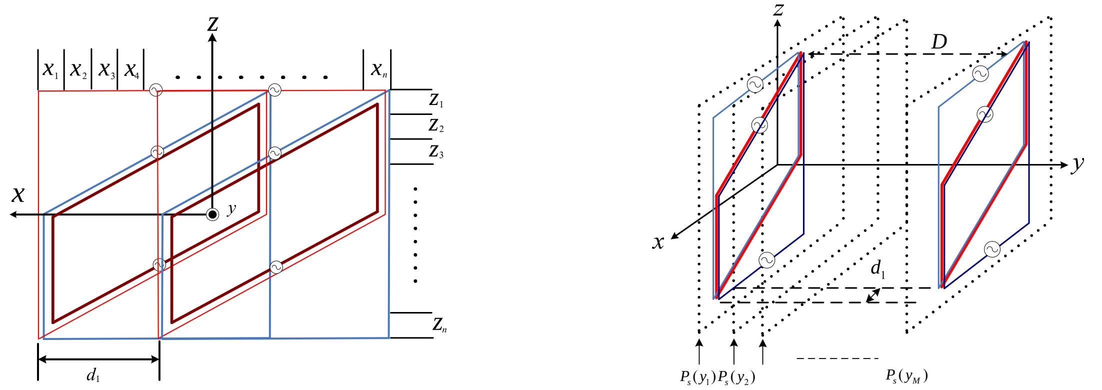
where P_{v,H_x}, P_{v,H_y} and P_{v,H_z} are the percentage of volume in *x*, *y* and *z*-directions, respectively. To determine the percentage of volume, the percentage of line (P_l) is the computed first by considering the tag movement through the gate antenna along a line (parallel to the *x*-axis in the *x*-*y* plane in Fig. 2(a) from entrance to exit. If some points along the line posses the magnetic field intensity $H(x,y,z) \geq H_t$, the percentage of line is equal 100, where H_t is the activated magnetic field strength of tag. However, if every point along the line has $H(x,y,z) < H_t$, the percentage of line is equal 0. In the simulation, it is assumed that H_t is equal to 3A/m for the bolus tag of cattle. Furthermore, the percentage of surface $P_s(y_m)$ at the distance y_m can be calculated as

$$P_s(y_m) = \frac{1}{N}\sum_{n=1}^{N} P_l(z_n), \tag{2}$$

where $P_l(z_n)$ is equal to the percentage of line at distance z_n, and *N* is total number of lines along the *z*-axis as shown in Fig.2(a). The percentage of volume P_v can be calculated from $P_s(y_m)$ by

$$P_v = \frac{1}{M}\sum_{m=1}^{M} P_s(y_m), \tag{3}$$

where *M* is the total number of planar surfaces parallel to the *x*-*z* plane between two shifted-gate antennas as shown in Fig. 2(b). Note that the considered volume is occupied by two gate antennas; i.e., -45 cm to 45+ d_1 cm along the *x*-axis, 0 cm to 100 cm along the *y*-axis and -67.5 cm to 67.5 cm along the *z*-axis.



(a) Consideration of the percentage of line. (b) Calculation of the percentage of volume.
Figure 2: Percentage of volume.

The optimum gate antenna structures are obtained using the ES as shown in Fig. 3. Note that the third loops of each gate antenna in Fig.3 are not rectangular shape. The distance of shifted gate calculated from ES is 45 cm. It is found that the simulated percentages of volume in the *x*-, *y*- and *z*-directions are equal to 100%, 98.36% and 93.43%, respectively for distance between two antenna gates of 100 cm. Furthermore, Fig.4 illustrates the plots of simulated magnetic field intensities in each principal direction of the proposed gate antenna on the *x*-*z* plane at the middle region of the gate antenna (the distance in *y*-direction is equal 50 cm).

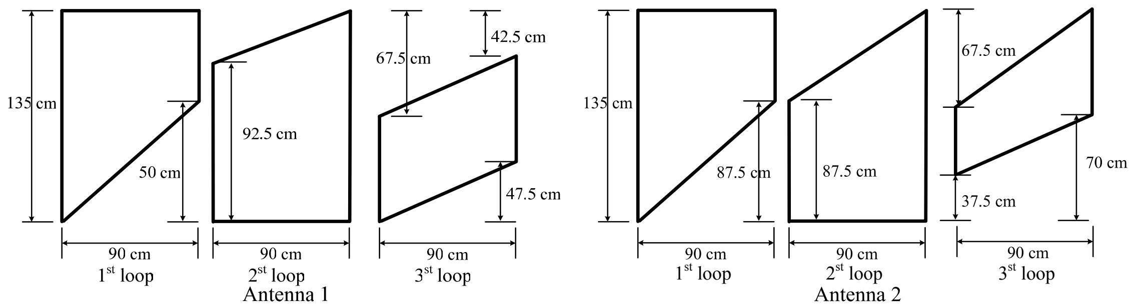
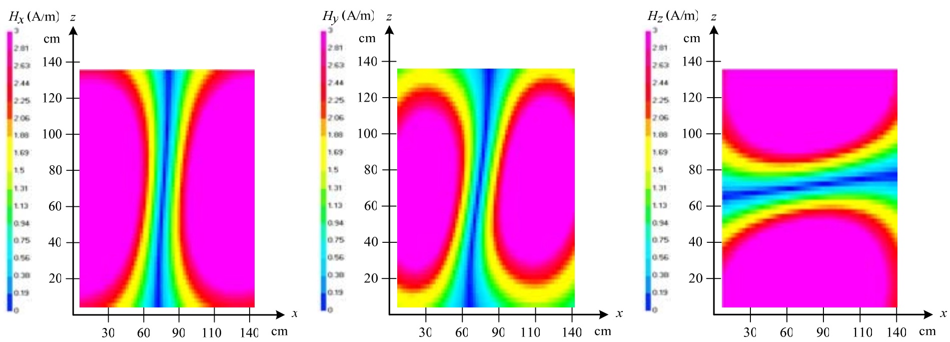


Figure 3: Optimum structures of two triple loop gate antennas.



(a) H_x (b) H_y (c) H_z
Figure 4: Plots of simulated magnetic field intensities in three principal directions.

4. Measured Results

The prototype antenna is fabricated on the wood structure as shown in Fig. 5. The total inductance of the gate antennas is equal to 250–270 μH suitable for the RFID reader (SIC-Pi80-05). The tag under test is the bolus tag operating at 134.2 kHz. After measurement, it is found that the percentages of volume in all principal axes are equal to 100%.

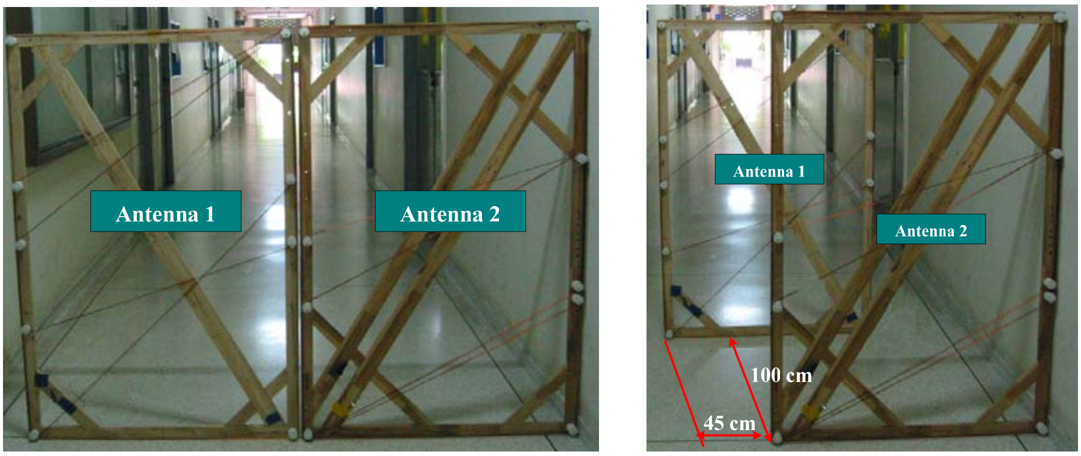


Figure 5: Prototype antenna.

5. Conclusions

An efficient antenna for LF–RFID systems in animal identification is proposed. The design of triple loop antennas with shifted gate arrangement is optimized via evolution strategies in conjunction with the NEC. For the distance between each gate of the proposed antenna of 100 cm, the distance of the shifted gate arrangement calculated from ES is equal to 45 cm. The simulated percentages of volume in each principal direction are equal to 100%, 98.36% and 93.43%, respectively. The antenna prototype is fabricated to test the performance. It is found that the percentages of volume in all principal axes are equal to 100%.

References

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