The Effect of Lossy Dielectric Objects On A UHF RFID Meander Line Antenna

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Abstract—Meander line antennas placed on various objects suffer a shift in resonant frequency. Numerical modeling demonstrated that the frequency increases with wire diameter and object conductivity, and decreases with increasing permittivity. This contrasts with a linear dipole where an increase in wire diameter results in a decrease in resonant frequency. A 4% bandwidth is sufficient for conductivity (σ) values up to 0.01 S/m and small changes in permittivity. This has implications for RFID antennas designed for placement on a wide variety of materials.

I. INTRODUCTION

The first paper on modulated backscatter (the basic principle of passive RFID) was published in 1948 [1] and recent development of RFID technologies needs the antenna to be placed on variety of goods. Commonly the printed antennas are placed on adhesive, thin, plastic sheet [2]. The tag performance is governed by the wire radius and the material used to fabricate the antenna [3]. Problems arise when an antenna tuned for free space experiences a change in impedance when attached to objects with unknown electrical properties. The shift in resonance frequency (f_c) results in a decrease in read range.

The RFID tag antennas with different conductor line widths printed on different substrates has been reported [3, 4]. These investigations did not report the effect of the electrical properties on the f_c . Meander line antennas are common in RFID applications [3-6], with the antenna performance optimized for different substrates by changing the thickness of the meander line antenna. Larger antenna bandwidth may solve this problem [7 - 9]. To reduce cost, the size of the tag is minimized, however the amount of conducting material (silver) is larger than in standard meander line antennas [10]. The introduction of a conductive ground plane further increases cost of a tag [8].

This paper reports the change in f_c for meander line antennas with different wire radius located close to objects with different electrical properties. The effective σ and permittivity (ϵ_r) will vary significantly should the RFID tag be placed on such objects as glass and plastic containers containing liquids.

II. MODELLING METHOD

A linear dipole and a meander line antenna were modeled using the Numerical Electromagnetic Code (NEC) [11]. The NEC guidelines limit some aspects of the antenna design including wire radius and intersecting segment angle [12]. A centre-fed half wave linear dipole antenna at 850 MHz was

modeled in free space. The meander antenna structure [4] (see Fig. 1) was located 1 mm (centre to top surface) above a lossy object. The radius range valid for NEC models was 0.01mm to 0.29mm. Both antennas were modeled using silver ink with conductivity 2×10^6 S/m [3]. The first series resonance frequency was recorded in all cases reported here. In free space, $f_c = 922$ MHz.

Figure 1. Meander line antenna model with dimensions. The antenna was fed at the centre of the 3mm section.

III. RESULTS

The meander line antenna f_c was determined for different wire radius and different object conductivities ($\sigma = 10^{-7}$ S/m to 4×10^{-2} S/m). The result for $\sigma = 10^{-7}$ S/m was identical to the result in air. The impedance bandwidth was 4%. Fig. 2 shows a 1.4% decrease in f_c for $\sigma < 4 \times 10^{-2}$ S/m for all radii values when $\epsilon_r = 1$. For larger σ values, f_c decreases significantly.

Figure 2. Meander line antenna f_c with different radii located 1 mm above a lossy object with various σ values.

The variation in f_c with radius is given in Fig. 3 for various σ values. The half wave dipole in free space shows a 1.3% decrease in frequency across the radius range. The meander line antenna shows f_c increasing with radius, but independent of σ for $\sigma < 10^{-2}$ S/m.

A meander line antenna with wire radius 0.2mm in free space has a complex input impedance of $9 - 0.2j$ ohms. When the RFID chip has complex impedance, the resonance condition is changed and an alternative matching technique is required. One common option is the “T match” [3], [5- 6].

A change in ϵ_r has a significant effect on the resonant frequency. The meander line antenna radius was fixed at 0.2mm. An increase in ϵ_r greatly decreases f_c (see Fig 4) but was independent of σ (all lines are superimposed). The antenna resonance frequency shifted significantly when ϵ_r was changed from 1 to 4, but the rate of change decreased when ϵ_r was changed from 4 to 8.

Figure 3. Variation in f_c with radius for a linear half wave dipole in free space (broken line), the meander line dipole in free space (solid line superimposed), and on objects with various σ values.

IV. CONCLUSION

A 1.4% variation in f_c when $\sigma < 4 \times 10^{-2}$ S/m is accommodated within the 4% impedance bandwidth of the meander line antenna. If the object is more conductive, then a much larger shift results and alternative, broadband antenna designs must be used. While an increase in the wire radius for the straight wire dipole shifts f_c and increases the impedance bandwidth significantly, this is not the case for meander line antenna. Increasing ϵ_r and σ both resulted in a decrease in f_c . This effect was less than 4% over the relative permittivity range of 5 - 8.

Common materials such as glass, wood and paper, cannot be completely accommodated by a single, simple meander line antenna, however this is possible if bandwidth is greater than 28.5%. Several antennas suggested for RFID applications

achieve a bandwidth of 10% [8, 9]. The antenna design by Okano [7] almost satisfies this requirement, the performance of this antenna has not been assessed under the same conditions.

Figure 4. Variation in f_c with ϵ_r with fixed antenna radius of 0.2mm and various σ values (all lines are superimposed).

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