Logo-Antenna Based RFID Tags for Advertising Application

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***Abstract*—** In this paper we provide the basis of using radio frequency identification (RFID) tags for advertisement. Two RFID tags that apply to the 866 MHz and 915 MHz operating frequencies, respectively, were designed based on the logos of two universities participating in this project. Several fabrication methods were used to build the RFID tags on different substrates. The experimental results exhibited favorable read ranges and radiation patterns. This work demonstrates the applicapability and design flexibility of RFID tags for many advertising applications.

***Index Terms*—** Radio Frequency Identification (RFID), advertising applications, active radiation pattern measurements, tag read range.

I. INTRODUCTION

The sales of company products thrive off innovative advertising propagation. Thus, the purpose of Logo-RFID tags is to stimulate an emotional reaction and generate a favorable response towards a company by representing their advanced capabilities. Therefore, Logo-RFID tags are an immense asset for companies because of their new perspective for advertising that has never been used in marketing.

Radio Frequency Identification (RFID) is a technology which uses RF signals for automatic identification of objects. RFID tags are used for many applications in various areas such as electronic toll collection, asset identification, retail item management, access tracking systems and many others. An RFID system consists of two basic parts: a reader (interrogator) and a tag (transponder). An RFID tag can either be an active tag which has a battery or a passive tag which is battery-less. A passive tag consists of an antenna and an application specific integrated circuit (ASIC) known as a chip. A passive back-scattered RFID system operates as follows: the reader transmits modulated signal with periods of un-modulated radio frequency (RF) carrier, which is received by the tag antenna. The RF voltage developed on the antenna terminal during un-modulated period is converted to DC. This voltage powers up the chip, which sends back the information by varying its complex RF input impedance. The impedance typically changes between two different states, a conjugate match impedance and a mismatched impedance, effectively modulating the back-scattered signal [1].

The idea of using text as a meander line antenna in RFID tags has been discussed before in [2]. In this paper the idea of using logo-antenna based passive RFID tags for both identification and advertising purposes is investigated. RFID tags consisting of logos from two universities were designed, simulated, fabricated on different substrates, and measured. The implemented substrates included paper, thin transparent film, polyethylene terephtalate (PET) and fabrics which are popularly used in the advertising industry. The measured tags gave desirable performance and read a range of nearly 12m at both 866MHz and 915MHz, the European and US frequencies. While the RFID tags were activated, their radiation patterns were measured for both bandwidths.

II. LOGO ANTENNA DESIGN

An RFID tag consists of two parts, an antenna and a chip. For maximum performance the antenna input impedance must be the conjugate match of the chip's impedance [3] which is usually capacitive impedance and depends on both the operation frequency and received power level [4]. To compensate for the capacitive part of the chip's impedance, a matching loop is needed in tag antenna designs [5].

Generally, during the design of an efficient RFID tag several parameters must be determined, (1) the operation frequency and required bandwidth [6], (2) the type of chip and its impedance, (3) the chip's minimum operating power, (4) the substrate parameters according to the fabrication process [7]. These issues will be presented in the following design procedure.

A. The Logo Tag Design

Our design process started by combining the logos of two universities, The University of Mississippi (UM) and Tampere University of Technology (TUT) . To design a symmetric antenna, "TUT" was aligned horizontally and "UM" was positioned vertically, as shown in Fig. 1. The main controlling parameter in our RFID tag was the letter 'M' which had an inductive loop for the tag design. By controlling the shape of 'M' the input impedance of the antenna could be matched to the conjugate of the chip's impedance.

The design was simulated using Ansoft HFSS (**h**igh **f**requency **s**tructural **s**imulator) [8]. The tag was designed on a substrate with ε_r = 2.33, thickness 0.1 mm, copper with σ=5.8 MS/m and thickness 17µm. The type of chip used for our RFID tag was the Alien gen2 and the chip impedance is 17-135jΩ at 866MHz and -11dBm power level. Two final designs corresponding to the US and European frequencies were developed and their dimensions are shown in Fig. 2.

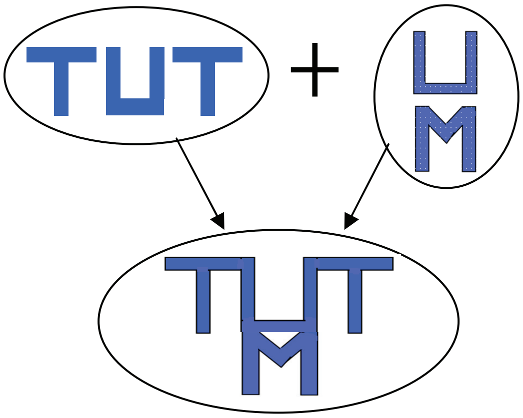
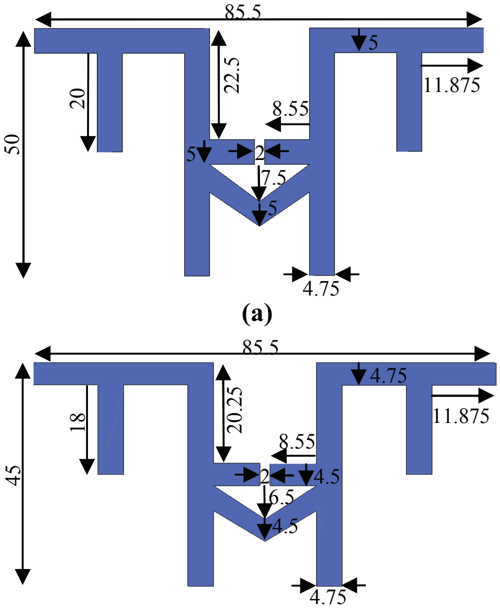


Fig. 1. The logo-RFID tag for the University of Mississippi (UM) and Tampere University of Technology.



(a)

(b)

Fig. 2. The final designs for (a) 866MHz and (b) 915MHz, respectively all dimensions are in (mm).

These designs were achieved by conducting parametric studies to determine good initial values for optimization. Quasi Newton optimization was used to determine the final values.

To match the input impedance of the antenna to the conjugate of the chip's impedance, the size of the letter 'M' was decreased to get the needed induction. Design

(b) is obtained from shrinking design (a) and modifying the letter ‘M’ to operate at a higher frequency.

B. Simulated Results of Power Reflection Coefficient and Input Impedance

The power reflection coefficient and the input impedance of the antenna were calculated, as shown in Fig. 3 and Fig. 4. The power reflection coefficient was calculated using the following equation:

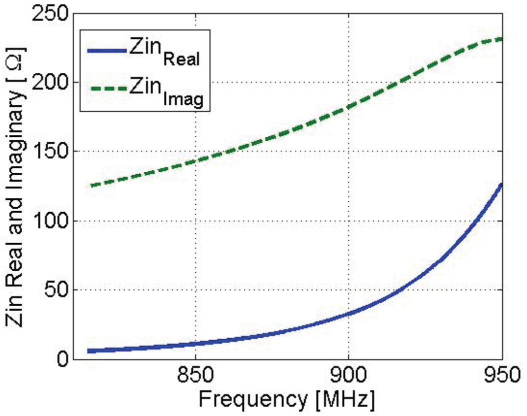
$$|\Gamma|^2 = \left|\frac{Z_c - Z_a^*}{Z_c + Z_a}\right|^2 \qquad (1)$$

where Z_c is the chip impedance and Z_a is the antenna impendence. This is a general formula used for complex nominal impedance; the scattering parameters for complex nominal impedance were proved in [9] to be as follows:

$$a = \frac{1}{2\sqrt{R_a}}\left(V + Z_a I\right), b = \frac{1}{2\sqrt{R_a}}\left(V - Z_a^* I\right) \qquad (2)$$

The normal power reflection coefficient formula can’t be used while the nominal impedance is complex, because this might lead to having the magnitude of the reflection coefficient greater than 1.

The center frequency for design (a) was 857MHz and for design (b) was 898 MHz while the -10dB bandwidth for design (a) was 2.89% and for design (b) was 3.37%.



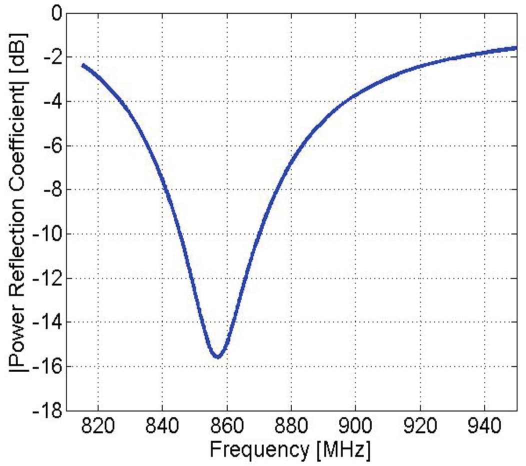
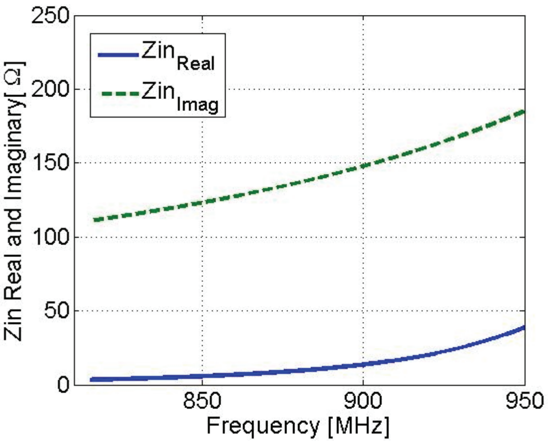


Fig. 3. The input impedance and power reflection coefficient for design 1 shown in Fig. 2(a).



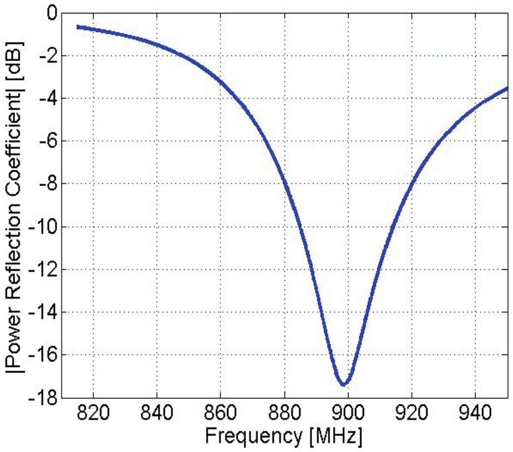


Fig. 4. The input impedance and power reflection coefficient for design 2 shown in Fig.2 (b).

C. Measurements Results

All measurements were conducted using the Tagformance device [10]. The measurements were based on an electromagnetic threshold technique, in which the frequency was changed from 830 MHz to 990 MHz in a step of 1 MHz. At each frequency the transmitted power was increased by 0.1dB until the tag was activated and properly responded. The minimum transmitted power to activate the tag was measured at each frequency. The device can calculate the read range by using free space Friis formula [11] and taking into account the path and cable losses and also the antenna gains. The read range is calculated using the following equation:

$$r_{\max}(f) = \sqrt{\frac{EIRP}{P_{t\min} L G_t}} \qquad (3)$$

Where $EIRP$ is the effective isotropic radiated power, P_{tmin} is the minimum transmitted power to activate the tag and it is measured by the device, L is a factor taking in consideration the cable and path loss, and G_t is the transmitting antenna gain [4].

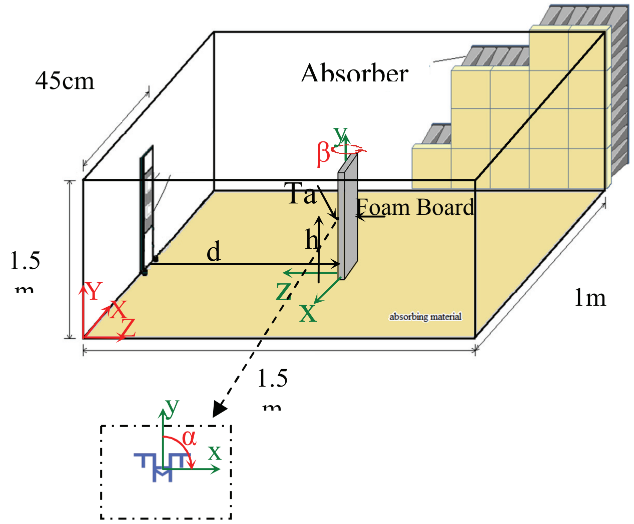


Fig. 5. The measurement setup for RFID tags.

Figure 5 shows the measurement setup. The tag was mounted over a foam board at height h = 1m and at distance d = 1m from the Tagformance antennas the ground and side wall were covered by absorbers. To measure the radiation patterns for the tag while it is operating the following procedures were used: For the x-z plane, horizontal polarized reader antennas were used and the foam board was rotated around the y-axis in x-z plane by changing the ‘β’ angle by a step of 15 degrees as shown in Fig. 5. For the y-z plane, vertical polarized reader antennas were used and the tag was rotated so that its x-axis became the vertical axis. The board was rotated along the x-axis, by changing the ‘β’ angle by a step of 15 degrees.

The Tagformance measured the minimum transmitted power to activate the tag. These values were used at each angle to plot the measured radiation pattern in each plane.

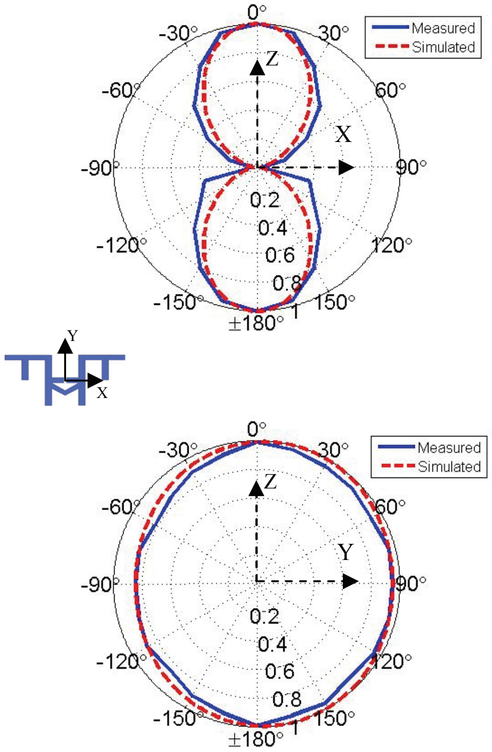


Fig. 6. The measured and simulated radiation pattern for different plane cuts at 866 MHz.

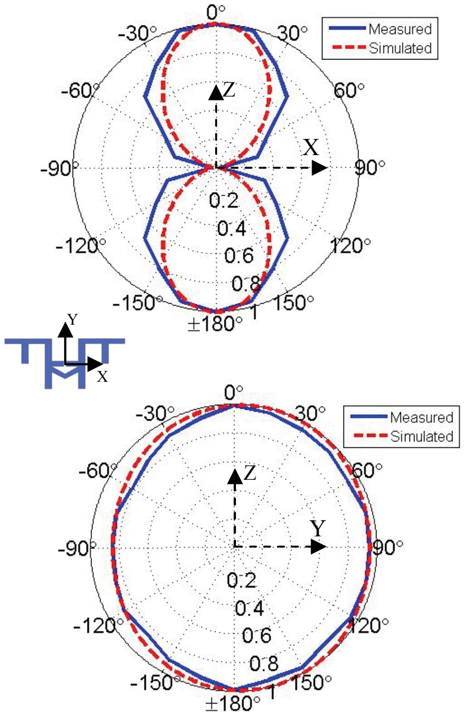


Fig. 7. The measured and simulated radiation pattern for different plane cuts at 915 MHz.

Figs. 6 and 7 compare the measured data to the simulated radiation patterns based on HFSS simulation in both frequencies, and it can be noticed that the measured and the simulated data are in good agreement. Differences could have occurred due to the resolution of the measurement device by increasing the transmitted power (0.1dB), and the 15 degree increment tag rotation.

D. Using Different Substrates in Fabrication Process

The RFID tags were fabricated using three different techniques: manual cutting using copper tape, etching using aluminum and copper, and screen printing using silver conductive ink. Each method was used on four different substrates: paper thin transparent film, PET and fabric. The components of the fabricated tags are shown in Table 1. The multiple substrates and conducting materials were used to prove the flexibility of the logo design for advertising applications. More than 40 tags were fabricated and measured. The best tags for each substrate and conductive material were chosen as prototypes if mass production is needed. Their read ranges are recorded and compared in Table 1.

Table 1. Tags with different substrates and conductive materials.

Tag No.	Substrate	Conductive Material	Fabrication process	Read Range[m]	Frequency of operation[MHz]
1	PET	Copper	Etching	12	866
2	Thin film	Sliver Ink	Screen Printing	9.5	866
3	Thin film	Sliver Ink	Screen Printing	6	915
4	Thin film	Copper	Manual cutting	10	866
5	Thin film	Copper	Manual cutting	9.5	915
6	Thin film	Aluminum	Etching	9	866
7	Paper	Sliver Ink	Screen Printing	9	866
8	Fabric	Sliver Ink	Screen Printing	11.2	866
9	Fabric	Sliver Ink	Screen Printing	7	915

III. CONCLUSION

In this paper the technique of using the RFID tags for advertising application was confirmed. An example of this application was implemented by a sample logo tag. The tags were simulated and fabricated using different substrates such as fabric and printing paper and different conducting materials which are widely used in advertising applications. The performance of these tags were measured and compared well with simulation results. The tag was originally designed using PET and copper as conducting material which is the reason for producing the highest performance (longest read range). Future designs can be modified for different substrates and conducting materials to obtain better results. This paper provides substantial proof that RFID logo tags could be used for both identification and advertising applications.

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