European Conference on Antennas and Propagation 2011, 11-15 April 2011, Rome

ON THE DESIGN OF NFC ANTENNAS FOR CONTACTLESS PAYMENT APPLICATIONS

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Introduction: The increasing interest in using the Near Field Communications (NFC) technology [1] at 13.5MHz is growing rapidly in the area of contactless payments, as well as numerous other applications, between devices that are within 10cm distance apart. However, there is growing concern that the use of such devices for contactless payments invites problems with regards to using metallic objects in the vicinity of the two devices to act as "rogue" antennas and eavesdrop information whilst a financial transaction is taking place. This paper will present aspects of designing H-antennas both for the two devices while also identifying the means by which rogue antennas can be designed from real life metallic structures such as a trolley.

NFC Antenna Design Theory: The design of magnetic coupling loop antennas, otherwise known as "H-antennas" for NFC applications, is presented here built upon existing models used for radio frequency identification antennas [2] illustrated in figure 1. The antenna loop, or coil, is modeled as an inductor, which is in fact frequency dependent. Measured data as illustrated in figure 2 verifies the DC inductance and below 1MHz is comparably higher than that of the "settled" inductance that is reached by the time the inductor reaches the desired frequency of 13.5MHz. Therefore in the strictest sense, the inductance of the coil should be considered at the frequency of operation and the resonant capacitance can be derived as:

$$C = \frac{1}{(2\pi f_0)^2 L(f_0)} \qquad (1)$$

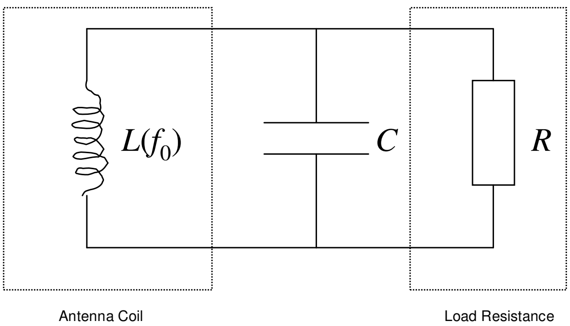

Fig.1: Circuit model of a H-antenna

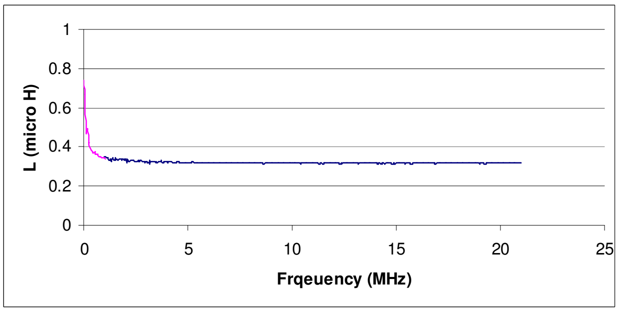

Fig.2: Measured values of inductance over frequency

At the resonant frequency, the transceiver connected to the antenna is assumed to have a source/load resistance, *R*. In the case of receive mode, the system frequency response, based on the load voltage, V_L, compared to the input voltage induced in the antenna, V_{in}, is defined as follows:

$$\frac{V_L}{V_{in}} = \frac{1}{1 + \frac{j\omega L(\omega)}{R} - \omega^2 LC} \qquad (2)$$

One important point to realise from this is that maximum power transfer at the resonant frequency, ω_0, will reduce to:

$$\frac{V_L}{V_{in}} = \frac{R\sqrt{C}}{j\sqrt{L(\omega_0)}} \qquad (3)$$

thus requiring a low inductance in order to maximize gain with as high load resistance as possible. The magnitude of this equation is also equal to the Q factor of the system, that will depend on a low value of *L* and a high value of *R*.

For transmit mode, the transfer function relating the voltage induced in the antenna, V_A, to the source voltage, V_S, is as follows:

$$\frac{V_A}{V_S} = \frac{1}{jR\left(\omega C - \frac{1}{\omega L(\omega)}\right) + 1} \qquad (4)$$

which by inspection shows that it will always have a value of 1 at the resonant frequency. The Q factor is derived in the same way, thus emphasising the need to design quality NFC antennas with low inductance and a high load resistance.

Measurement setup and coupling: To verify the expected resonance between two NFC antennas touching each other, a measurement was carried out at 13.5MHz using the two NFC antennas illustrated in figure 3, that would typically be used in a wireless payment application. Capacitors were placed in parallel with the loop source as shown and then the antennas were attached to each other for measurement while ensuring that the two conducting printed loops did not come into contact, thus maintaining the same inductance in each antenna.

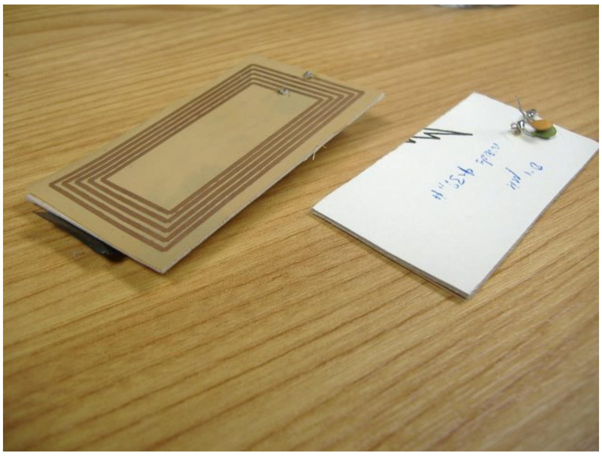

Fig.3: Illustration of tuned NFC antennas used in a contactless transaction

A suitably low inductance around 0.4µH was found in each antenna as shown in figure 2, which allowed realisable capacitors around 400pF to be used to make the resonance. With a source and load resistance of 50Ω, the results obtained in figure 4 show an expected frequency response, though in practice there is an insertion loss at the desired frequency that is not accounted for in the theory. This loss is approximately 6dB at 13.5MHz with the resonance slightly offset due to availability of preferred capacitor values being offset from the resonant point.

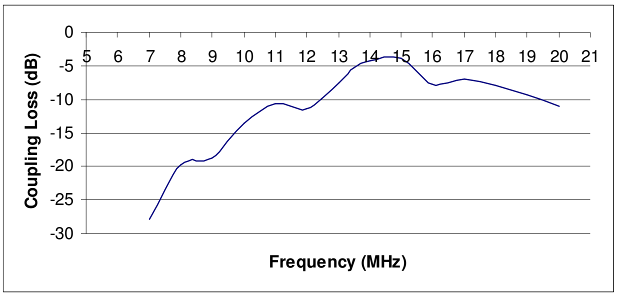

Fig.4: Measured values of cross coupling over frequency between two NFC antennas.

Further work: So far the design aspects of NFC antennas that are used on a mobile terminal and payment device have been analysed and tested. The next stage of this work, where results will be available by the time of writing the full paper, is to analyse the inductance properties of large metallic structures such as shopping/luggage trolleys, metallic ticket machines and metallic shelving in the vicinity of a contactless payment device. Such objects also have the added advantage of being connected to a high frequency operational amplifier, which will have the desired high input resistance for the necessary Q factor in receive mode. All of these factors will be measured and analysed in the full paper to provide new results on the potential threat of existing objects to be used in eavesdropping financial transactions.

REFERENCES

[1] NFC Forum, http://www.nfc-forum.org/aboutnfc/

[2] Z.N. Chen et al. "Antennas for Portable Devices", 2007, *Wiley*, UK.