DESIGN OF NEAR FIELD COMMUNICATION PASSIVE ANTENNA FOR CIRCULAR SHAPED WEARABLE ITEMS

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ABSTRACT: The paper discusses proposed Near Field Communication (NFC) passive antenna design for circular and round shaped wearable items like rings, watches and wristbands. Several NFC passive tags were available in the market, which had different shaped antennas, incorporated into them. However, these tags were designed with specific shape and diameter and could not fit for most of the wearable items like rings, watches and wristbands etc. In order to overcome this problem, a customized NFC antenna for passive tags was designed, which could be suitable for circular shaped wearable items. Moreover, comparative analysis of proposed antenna with vendor made antenna had been performed to show how proposed customized antenna was much more efficient in performance.

Keywords: Near Field Communication, Mobile Communication, Antenna Design, Wearable Computing, Passive Tags, Radio Frequency Identification.

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INTRODUCTION

Wireless technologies have been playing an important role in communication between devices. Near Field Communication (NFC) is an emerging short-range wireless technology, which is known for its efficient two-way communication and high security (Fischer, 2009). Due to its reliable communication, NFC is gaining popularity at rapid pace and hence capturing markets of various domains like HealthCare, Education, Transportation, Enterprise and Entertainment (Brown and Diskos, 2011).

The work presented in this paper is an extension of previous work on the design of NFC passive antenna and exclusively discussed the simulation results for h-field, gain and directivity to show that customized antenna is efficient enough to communicate with any active NFC device (Razi and Awais, 2014).

NFC works on the principle of Radio Frequency Identification (RFID) in which there are two components; a reader and a tag (Schamberger *et. al.*, 2013). The tag contains the information and reader reads this information and performs tasks based on this information. There are two types of tags available for NFC, an active and a passive tag. An active tag is the one that needs power to operate (Mika *et. al.*, 2009). Such tags are available in NFC which enabled mobile phones and NFC reader and writer devices. A passive tag is the one that does not require its own power to operate; instead, it operates on the power of electromotive force (emf) produced by the magnetic field of active NFC devices like NFC enabled mobile phone or NFC reader writer devices (Fischer, 2009). Such tags are available in the market in the form of stickers or key chains etc.

NFC is currently being widely used in mobile phones for contact sharing, ticketing in transportation, ticketing in cinemas and for tourists in museums etc (Schamberger *et. al.*, 2013 and Fischer, 2009). However, most of the passive tags used for above mentioned applications have fixed sizes and shapes and cannot be folded to fit to circular shapes. If these tags are forced to fit on circular or rounded shapes, chances are that the antenna breaks and the tags become useless (Razi and Awais, 2014). The study is based on the design of a customized passive antenna for NFC so that it can fit well for circular and rounded shapes like wristbands, watches and rings etc. Various real time experiments and simulations have been performed to prove that proposed design is efficient and reliable for circular shapes. However, the results have also shown that the antenna designed with the parameters used in this paper can also help in designing antennas of various other shapes like square, rectangular and oval. The efficiency of Near Field Communication also depends upon the material used for creating antennas.

Related work: Some studies have already been done in the field of Near Field Communication that show how NFC is efficient enough to perform some daily life activities. In this section, literature related to NFC and specifically for antenna designed has been reviewed.

A study conducted by (Fischer, 2009) introduces the NFC, and describes its applications and explains how it works and how it can affect the modern technology based human life. It also performs a comparison of specifications between the active and passive sides of NFC technology.

Scenario in which a large metallic object can be a rogue antenna to sniff the wireless communication happening within the range is also discussed by (Brown and Diakos, 2011). Who reported that the eavesdropping can be done if the criminal attaches a transceiver that can demodulate the signals received by an antenna from a nearby electronics contactless payment machine. For this purpose the shopping mall trolley can be used as antenna. The matching circuit can be used to match the other parameters for the system to be working. They have also given a comparison of inductance and resistance of the trolley with different distance scenarios eventually proving that eavesdrop is possible. The biggest challenge to coop with is the background noise that is making it very difficult for a successful eavesdrops.

A system for interoperable NFC mobile payment ecosystem and its benefits for the existing banks and other payment services providing companies has been presented by (Schamberger *et. al.*, 2013). They describe the simplicity and cost of integration of this system. Their system introduces this NFC based system by minimally changing the existing system that makes it cheap and easy to implement.

The concepts of NFC to the sensors has been introduced by (Mika *et. al.*, 2009). That makes them the contactless sensors. They propose that a temperature sensor can be applied with some NFC chip and antenna and over time it notes the values and whenever the user needs, he reads the temperature value through NFC enabled reader. Their idea also takes the sensors to the higher level by introducing contactless battery less sensors.

NFC antennas can be printed by using inkjet printer. The implementation and a thorough study has been done by (Mujal *et. al.*, 2010). Different testing and simulation results are analysed to show different results in the study. The quality factor of 5 was achieved at 8 layers of conductive ink, and it is highest within the range of 13.5MHz. Inkjet printed antennas do not have range issues but the bandwidth issues because their conductivity is somehow less than a copper antenna. The bandwidth issue can be resolved if the conductivity can be increased.

Introduction to inductive powered NFC antennas is also presented in a study performed by (Cho *et. al.*, 2009). The speciality of using this type of system is that they can communicate over RFID mode. In this way they were able to achieve the low power consumption on the receiver side. This has been achieved due to the inductive power structure. Currently the performance and the power are not very good. But further work can increase both of them.

Majority of inventory control systems throughout the world use barcode or RFID or NFC (Razi *et. al.*, 2014). This research performed a detailed comparison between the Barcode and NFC. Barcode is an old technology with some glitches e.g. barcode cannot be read if the orientation is not correct. It is also surface dependent and it can be long up to a specific length but NFC overcomes all the issues. It consumes the same space even for very large amount of data, it is also not dependent to orientation also it does not depends upon the surface shine which highly affects the barcode reading.

A passive NFC tag antenna for circular shaped wristband has been designed by (Iqbal *et. al.*, 2014), who designed their antenna keeping in mind the size, shape and form. A comparison of vendor made and custom made antenna is performed to show that custom made antenna is far more efficient for circular shaped wristbands than the vendor made passive tags. The design of antenna is minimized which actually made circular antenna possible. Several experiments were performed to show how custom made antenna for various shapes like square, circular and rectangular is much more efficient than vendor made antenna. However, the study lacked major design parameters like gain, directivity and h-field which are required to claim a better antenna design.

MATERIALS AND METHODS

The proposed system model for this study was prepared. A wristband (circular in shape) and embossed the customized NFC passive antenna as is depicted in Fig. 1. Developed a smart phone application for NFC enabled Android powered smart phone, which can read the information from the tag on wristband when phone was brought closer to the tag. After reading the information, the application could perform several tasks depending upon the scenario. The application simply read the information from the tag and displayed it on the mobile phone screen. The tag in Fig. 1 was small enough to fit on to the wrist band. Furthermore, the tag was designed in such a way that it could fit well on circular shaped wristbands, watches and rings. This study was done using the antenna made of copper; however, results could further improved by using Aluminium.

Mutual inductance in NFC: Detailed study on antenna design showed that one of the most influential factors on efficiency and reliability of transmission using NFC was the size or area of the coil used for antenna design. Various other factors like matching circuitry of NFC chip, etching material, coil material and specifications of active antenna powering the passive antenna could affect the communication in NFC (Mujal *et. al.*, 2010), however, for the purpose of this paper the focus is only on coil size and its effect on transmission.

Mutual induction had been the basic principle of NFC working. Whenever current passed through the coil, a magnetic field was generated around the coil. The strength of magnetic field changed with the changing values of the current (Schantz, 2005). According to Faraday's law, when active module was brought closer to the passive antenna in NFC, the changing magnetic field induced an electromotive force (emf) in the passive antenna as represented by the equation below:

$$\in = -N\frac{d\phi}{dt} \qquad (1)$$

In the equation, ∈ was the electromotive force produced in the coil of the passive antenna, N was the number of turns of the coil and ϕ was the magnetic flux passing through the coil.

Furthermore, the power generated in the passive antenna through the magnetic flux generated in the active antenna depended upon the area of the coil (active or passive) and the angle at which these two coils communicated with each other. Fig. 2 was drawn to further explain the concept.

Proposed antenna design: The aim of the study was to design a custom made antenna for circular and rounded shapes so that it could fit on wearable items like wristbands, watches and rings. The size of ring was very small, so for the purpose of this paper the focus was on designing the antenna for wristbands that could also fit in for watches. In order to design an antenna for circular items, MIFARE MF0ULx1 NFC chip was used. Copper wire was used to solder the chip to the proposed antenna (coil) and all the components were stuck on an electrical tape (Lee *et. al*., 2014). Fig. 3 represented the design of proposed antenna.

The aim was to design an antenna that fit well for circular and rounded shapes, so antennas of various shapes, e.g., circular, rectangular, oval and square were prepared; however, the best design appeared to be rectangular, since it can cover the maximum space of the rounded shapes without compromising the width.

RESULTS AND DISCUSSIONS

In order to claim that proposed antenna design was suitable for communication with any active NFC antenna, various simulations were performed to measure H-field, Directivity and Gain for the proposed antenna. The software used for those simulations was CST Microwave Studio. In this study simulations were performed without wrapping the antennas around the rounded surface to measure various parameters. Vendor made antenna performed very well when not wrapped around any rounded surface and hence could be used as a standard for measuring the H-field, Directivity and Gain, which means if the values of proposed antenna were close to vendor made antenna; the proposed antenna was expected to communicate well with any active antenna.

H-Field: Several simulations were performed for both vendor made and proposed custom made antenna for NFC passive tag to compare the performance of tags. The results for H-field for vendor made and proposed custom made antenna were achieved and shown respectively in the Fig. 4.

It was clear from Fig. 4 that field was maximum at the edges for both the antennas. The magnitude of magnetic field strength for vendor made and proposed custom made antenna was -56.6 dB A/M and -57.9 dB A/M respectively. The results of proposed antenna were very close to the vendor made antenna which confirmed a reliable communication.

Directivity: Directivity is the intensity of field of antenna in a given direction. It is actually the ratio of the radiation intensity from antenna to the intensity averaging in overall directions (Constantine, 2012). Better the directivity of antenna, the better the communication which means that energy will be maximized around the target area (Joseph and George, 2012). Directivity could be calculated by the formula below:

$$D = \frac{U}{Uo} = \frac{4\pi U}{P} \qquad (2)$$

The directivity of an isotropic antenna was 1 since U and U_0 were same. In the equation (2) U was radiation intensity (power per unit solid angle) and U_0 represented the average power per unit solid angle. The directivity of vendor and custom made antenna were shown in the Fig. 5.

The achieved simulation results showed that directivity of vendor made and custom made antenna was 1.41 and 1.35 respectively. Although the directivity of custom made antenna was little less than the vendor made antenna but it could still be affordable since the size of the antenna was reduced and the shape was customized. The proposed custom made antenna was still communicating at a reasonable distance with active antenna which made this little difference in directivity negligible.

Gain: Gain is the ratio of radiating energy in a given direction to radiation intensity of isotropic radiating antenna directions (Constantine and Balanis, 2012). Gain is usually considered as a relative to lossless isotropic reference antenna (Joseph and George, 2012). Normally, gain was represented by the following mathematical equation:

$$G = \frac{4\pi U(\theta,\phi)}{P\,(lossless\ isotropic\ source)} \qquad (3)$$

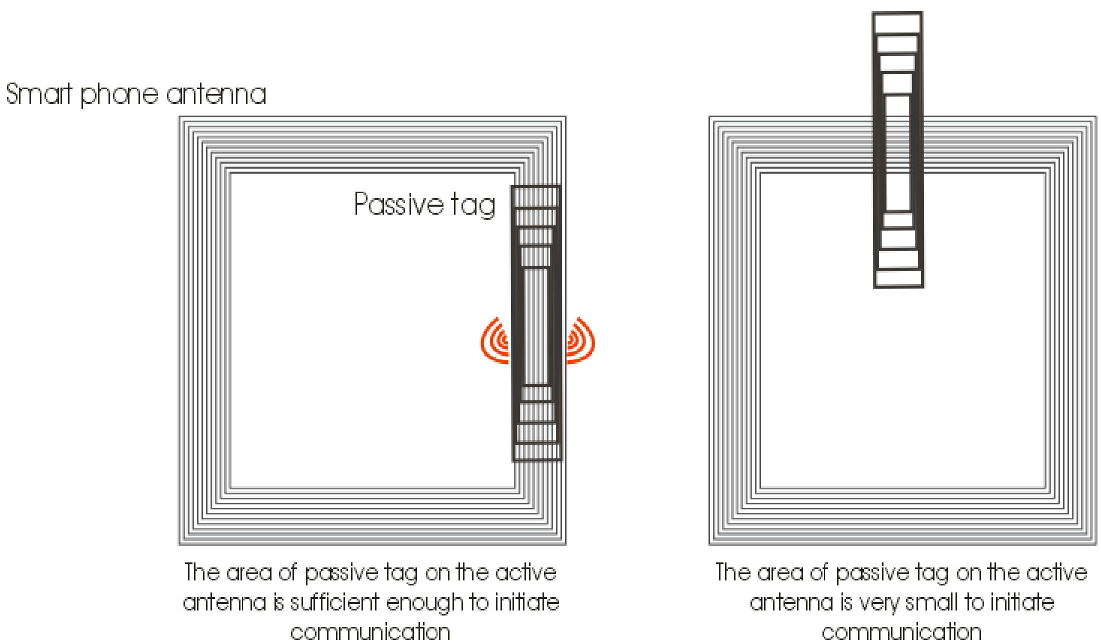
Where P was the total radiated power for lossless isotropic source. Several simulations were performed to calculate the gain of vendor made and custom made antenna. The gain of vendor made and custom made antenna were represented by the Fig. 6.

The achieved simulation results showed that gain for vendor made and custom made antenna is 1.57 dB and 1.36 dB respectively. The results were very close, which means proposed custom made antenna design was close to the industry design and the experiments already showed that proposed custom antenna performs better than vendor made antenna when wrapped on rounded surfaces.

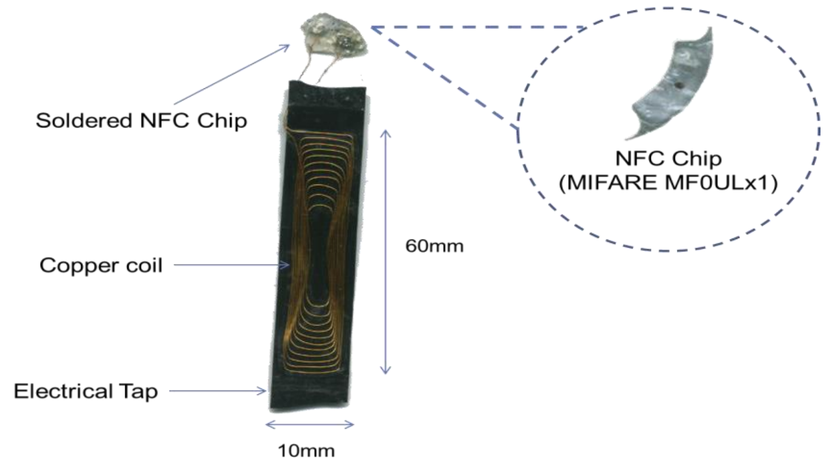
Using NFC for wearable items can significantly increase its usage. Below were some expected applications of NFC wearable items where the custom made tags could be handy:

- For newly born babies at the hospital
- For patient monitoring system at clinics and hospital
- For Pets identification
- For contact sharing
- For payments at GYM
- For event passes at sports complexes

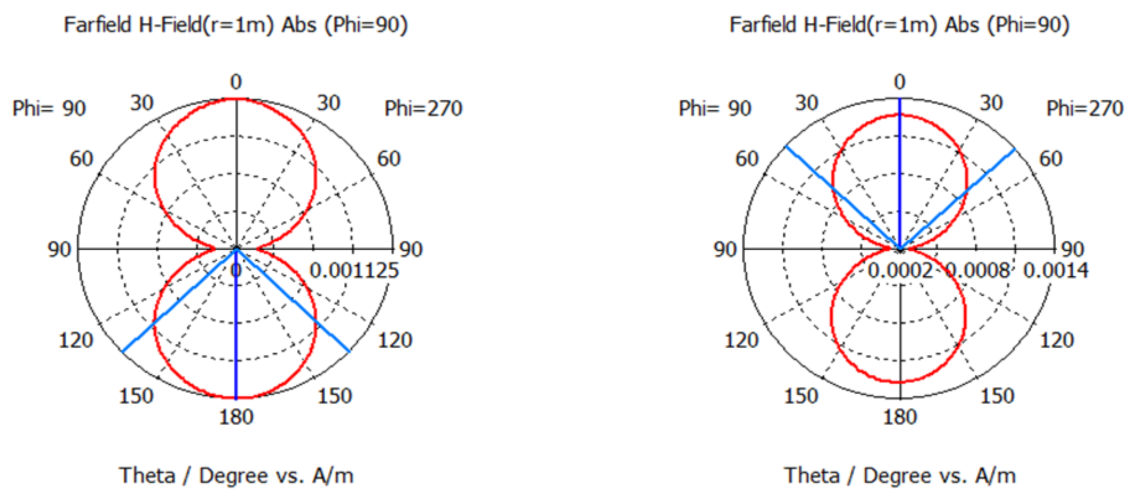
- **Fig-1: Proposed System model**



- **Fig-2: Active and Passive antenna communication**

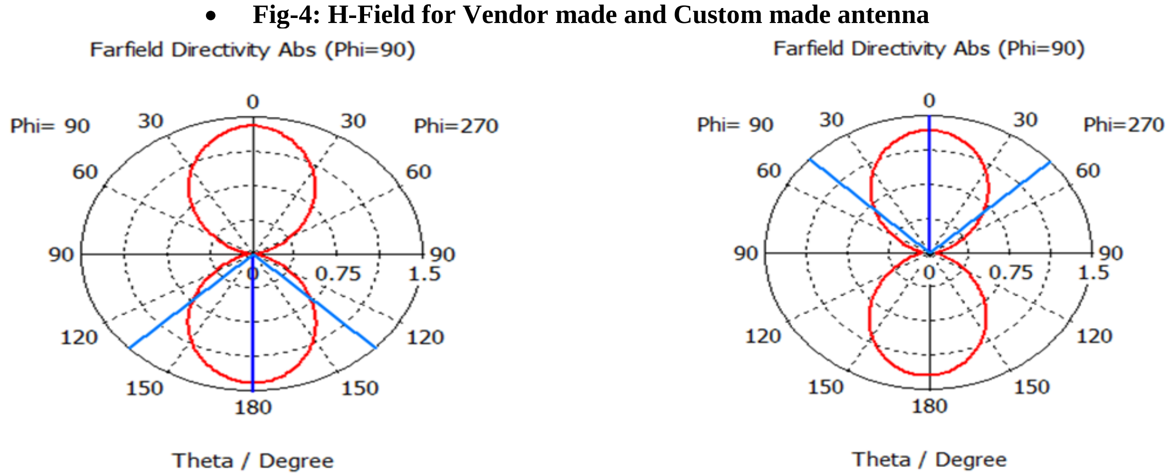


- **Fig-3: Design of proposed antenna for passive NFC tags**



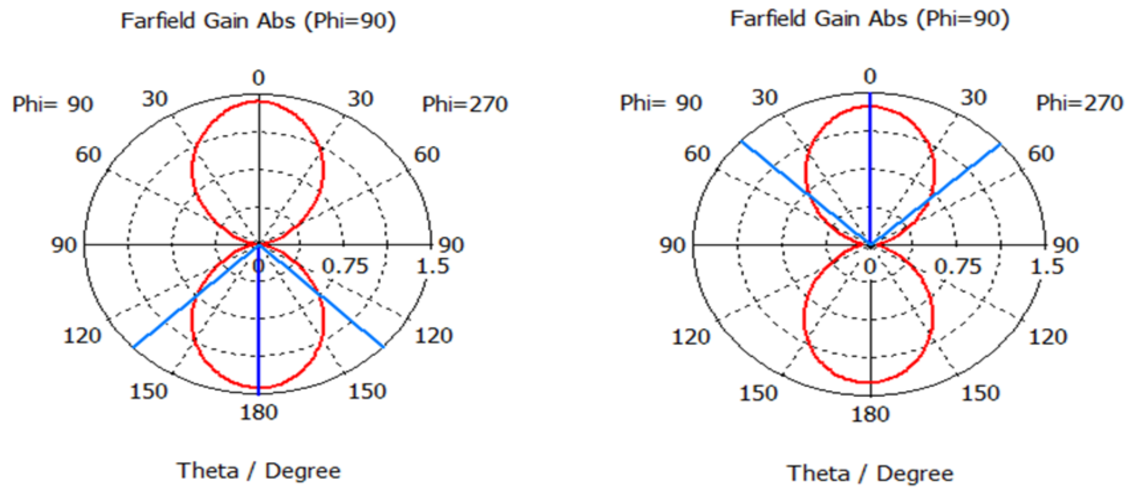
Vendor made antenna **Our custom made antenna**

- **Fig-4: H-Field for Vendor made and Custom made antenna**



Vendor made antenna **Our custom made antenna**

- **Fig-5: Directivity for Vendor made and Custom made antenna**



Vendor made antenna **Our custom made antenna**

Fig-6: Gain for Vendor made and Custom made antenna

Conclusion: This paper discussed the design of proposed custom made antenna for small wearable items like wristbands and watches. While designing antenna it was observed that several parameters could affect the overall performance of antenna communication. In this paper, various experiments where performed to measure the efficiency and accuracy of proposed antenna and comparative analysis of the antenna design was performed against vendor made antennas available in the market. Different simulations were performed in different scenarios to gauge the overall efficiency of proposed antenna design. Although the antenna was designed for rounded wearable items, however, simulation results showed that proposed antenna design is reliable even for non-rounded surfaces. H-field, Directivity and Gain values were compared with vendor made antennas which appeared to be very close to industry standards. The overall analysis of simulation and experimental results showed that the proposed antenna design was efficient enough to communicate with any active NFC reader.

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