Power Equations and Capacity Performance of Magnetic Induction Communication Systems

Johnson I. Agbinya · Mehrnoush Masihpour

Abstract  Although a number of studies have been done on the traditional Radio Frequency (RF) terrestrial communication system, the potential applications and the advantages of Near-Field magnetically coupled coils in wireless short range communications is just emerging and is yet to be explored. This paper investigates the impacts of magnetically coupled transceiver antenna coil on the received signal power and the communication link capacity. Based on the equivalent circuit model in free space, theoretical foundations are laid with observed simulation results. The simulation result benefits the antenna designers and the network planning engineers to estimate the power at the receiver and a near field magnetic communication system capacity for different antenna coil characteristics and different communication ranges.

Keywords  Antenna coil characteristic · Capacity · NFMIC · Power equation · Received power

1 Introduction

Traditionally, the emphasis in telecommunications has been to reach long distances (far field). Even though the first telephone call on March 10 1876 by Alexander Graham Bell and his assistant Thomas A Watson was a short distance call in nearly by offices, the emphasis has been long distance communications. Thirty nine years after the first short range telephone call was made, on the 25th of January 1915, Alexander Graham Bell and Thomas Watson also made the first long distance voice call between New York and
San Francisco. Recently new focus has been placed on short range communications due to its apparent advantages of easier achievement of wireless large capacity. The most commercially prevalent communication systems have therefore been those which operate in the higher microwave frequencies and they include mobile telephones and short range data communication systems. The shift in increasing capacity is also directly related to the shift to higher and higher frequencies where large spectrums exist to be dedicated to capacity hungry applications such as imaging and multimedia. These higher frequency ranges also mean shorter wavelengths which further facilitate the design of more efficient and small sized antennas. Of course there are applications which do not need large spectrum outlays such as hands free wireless communication, real time location systems, low data rate voice communications and low data rate communication systems. Practically, low frequencies (long wavelengths) penetrate objects more and are subject to diffraction around objects which would normally have blocked high frequency transmissions. Low frequencies are also known to be less susceptible to multipath effects. Hence low frequency systems have for a long time enjoyed commercial patronage.

Short range communications (a.k.a near field communications) have for long been neglected by engineers and most researchers in the field. This focus is intentional to take advantage of far field communications where near field negative effects are less pronounced. Recently the study of magnetic induction communication is emerging as a new form of physical layer access and most of the interests lie in the near field region where energy is coupled between antennas instead of being radiated as in traditional electromagnetic wave communications. Near Field Magnetic Induction Communication (NFMIC) is a wireless form of short range communication, up to 5 m, that uses near field magnetic flux for the data transmission [1–3]. In NFMIC systems, information is transferred through the coupling of the magnetic field rather than the radiation of the electromagnetic waves [4]. NFMIC has applications in Personal Area Networks, payment cards, biomedical monitoring, mobile phones, MP3 players, body implants and many more [1,2,4]. NFMIC is gaining grounds as a means of providing secure short range air interface of a few meters in range. It targets medium capacity personal area networks [2,3] and close proximity condition monitoring. Since the great interest in short range NFMIC is up to 5 m, lower transmission power is required. However, compared to other short range communication technologies such as Bluetooth, it is more efficient. As sited in [3], it can be up to 6 times more efficient than the Bluetooth-type devices in terms of required transmission power. Moreover it promotes the frequency reuse, because it does not operate in busy 2.45 GHz bandwidth and the data needs to be communicated within a person’s NFMIC ‘bubble’ [1]. It also results in less interference with other Radio Frequency-based electromagnetic (EM) communication systems and consequently robustness and reliability in terms of QoS (Quality of Service) in the network [3]. Regarding to the antenna design, NFMIC has another advantage, which is smaller size antennas, since this technology operates at higher frequency, it has shorter wavelength which results in smaller antennas [5]. Although NFMIC can highly benefit short range communications, there has been less contribution in the literatures so far. From the antenna designer’s perspective, it is crucial to identify how each antenna parameter, impacts the link performance. This paper, based on the circuit model in free space at frequency band 13.56 MHz, analyses the effect of antenna coil characteristics on the link performance and the system capacity to distinguish how each parameter contributes to the received signal power. Therefore it could be a guideline for antenna designers and the power estimation at the receiver and consequently for capacity estimation in regard to delivering different application types. From our simulation, the optimum value for Quality-Factor, efficiency and permeability of the antenna coils, also transmitter and receiver coil radius can be derived for a desirable communication range or