International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 11, November-2020

Analysis of Wireless Channel Parameters for Near Field Communication

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***Abstract*— Near field magnetic induction is a short range communication and this technology achieves less inference and low power consumption for processing. Analysis of wireless channel parameters for short range communication is considered in this paper. The channel parameters are analyzed by considering channel path loss model depending on distance (in the range of few cm) between transmitter and receiver, frequencies, number of turns and radius of the transceiver coils. The aim of this paper is to analyze the near field channel models, and then with the help of MATLAB the channel path loss models are simulated. For practical analysis, the inductive coupling experiment setup with primary and secondary coils of copper wire is used. Practical analysis and performance evaluation is done with respect to distance between the transceivers, frequency and number of turns in transmitter and receiver coils.**

Keywords*— *Near field magnetic induction, coupling, channel parameters

I. INTRODUCTION

The modern wireless technologies are boosting economic sectors to develop smarter devices enabling a massive connectivity to internet thus creating new business models and services for wireless power transmission application for many applications. Beyond this fact, the technology of the short range communication systems has some special characteristics physical security provided by the low range coverage area of induction and its non-propagating nature, low consumption devices, low manufacturing costs, simplicity of use, and the possibility of embedded solutions in other devices, such as smartphones.

In the radioactive field, the electromagnetic (EM) wave propagates as described by Maxwell's equations, unfortunately the description of the near field like short range is a complex issue and the fundamental transmission parameters of the equivalent channel are difficult to establish for the magnetic induction. The RF based near field communication have many mathematical models but for the near field magnetic induction there is no particular mathematical channel models applicable because it's difficult to describe the equivalent circuit of magnetic induction. The great advantage of near field magnetic induction communication is not much affected by environment and also from other dielectric material like wood, glass and fiber etc.

II. NEAR FIELD MAGNETIC INDUCTION COMMUNICATION

In wireless power transmission system there are many technologies used to transmit power from transmitter to receiver in a close proximity of distance. In near field, the transceiver coils are in few cm distances from each other. The transmission of the power from transmitter to receiver coils by inductive coupling without contact to each other and this technique is called as near field magnetic induction.

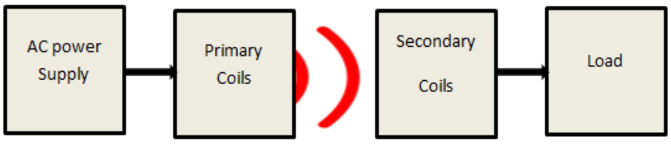

Fig.1. Block Diagram of Magnetic Induction

In near field, magnetic induction works by inductive coupling that is through natural movement of current through coils. In this block diagram an alternating current is fed to primary coil that produces the magnetic field in the coil by the input Ac source, then magnetic field induces the voltage to the secondary coil. The distance and frequencies are the major constraint in magnetic induction, if the primary coil is too far from secondary then mutual coupling will be less. There are many devices implemented on this technology to transmit power wirelessly to the secondary. These coils are made of copper wires or coils with different standard wire gauge. These coils contains internal linear resistance which varies depends on the number turns in length of the coils, and coil gauge.

III. PROPOSED METHODOLOGY

The proposed method is represented in blocks which gives the brief idea to understand the overview of the paper.

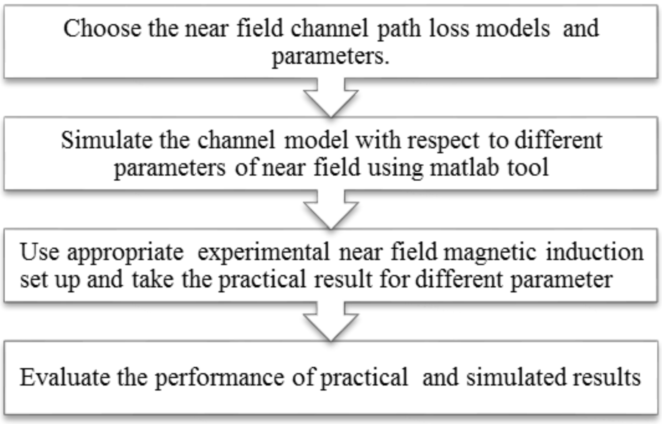

Fig.2. Flow Diagram of Proposed Methodology

IV. CHANNEL MODELS OF NEAR FIELD COMMUNICATION

Near field short range communication is an application of magnetic induction. In this system information is transferred through the coupling of magnetic flux. Near field magnetic induction uses the transmitting and receiving coils, N_t and N_r are number of turns in transceiver coil with linear resistance R_0, d is the distance separation of transmitter and receiver and a_(t) and a_(r) are radius of coils, both the coils are axially aligned in the proper plane [4].

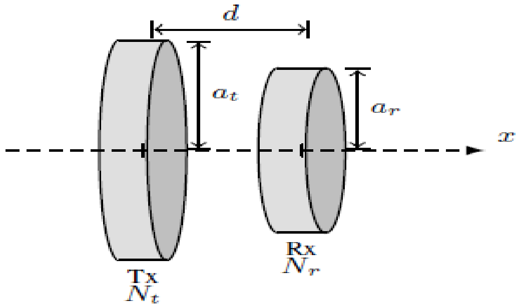

Fig.3. Geometry of Transmitting and Receiving NFC

As shown in Fig. 3, the transmitter and receiver coils should be aligned in the x-plane to achieve the higher magnetic induction in the near field, if in the case both coils are mis-aligned then it results lower induction coupling in the field. The range of communication is mainly depends on the number of turns of the coils, coils radius and also depends on core of the coupling devices. In the near field primary and secondary coils are made of air or ferrite core to extend the range of communication, if it uses the air core copper wire should be tightly bounded to avoid skin effect and air core coils are used at high frequency to avoid core losses. Channel path loss models are derived from mutual coupling and coupling coefficient equations, by using RLC equivalent circuits and two port network terms [4]. Those derived models are as follows: i). Path loss model-1(PL1), ii). Path loss model-2 (PL2), iii). Path loss model-3(PL3), iv). Path loss model-4 (PL4), v). Agbinya mashipour model [2].

The wireless near field channel is affected from any parameters when input power coupled to the secondary coil because of larger distance between transmitter to the receiver or it from frequency and also from other parameter of inductive coupling coils. The amount of the power which is reduced while coupling from transmitter to secondary coil because the input power may effect from copper wires skin effect or from other parameters between coils are analyzed by these following models.

The path loss (PL) is defined as ratio of received power to transmitted power, is expressed as

$$\text{Path loss (PL)} = \frac{P_r}{P_t} \qquad (1)$$

$$\text{Path loss in db} = -10log_{10}\left(\frac{P_r}{P_t}\right) \qquad (2)$$

Path loss model-1 (PL1): Path loss model-1 of magnetic induction is modeled using RLC lumped parameters, in this model intrinsic complex impedances are used to develop the path loss model-1 which is derived from equivalent RLC circuit of magnetic coils [4].

$$\text{PL1} = \frac{P_r}{P_t} \cong \frac{\omega\mu N_r a_t^3 a_r^3}{16 R_0 d^6} \qquad (3)$$

Where $\omega = \text{angular frequency in rad s}^{-1}$, R_0=linear resistance in ohm.

Path loss model-2 (PL2): This model uses two-port network representation of an inductive system [4] is described by its impedance matrix. A path loss, considering a small distance (d_0) between the coils is given as,

$$\text{PL2} = \frac{P_r}{P_t(d_0)} = \frac{R_L\omega^2M^2}{R_t(R_L+R_r)^2+R_t(X_L+\omega L_r)^2} \qquad (4)$$

V. RESULTS AND DISCUSSIONS

In this section the near field magnetic induction channel parameters are considered. The channel models of path loss and agbinya mashipour models are executed in MATLAB tool and simulation results are discussed depending on various parameters and compared with practical results.

A. *Simulation results for parameter analysis*

The channel behavior of near field depends on various parameters like distance, frequency, number of coil turns, coil radius, and also depends on the core of primary and secondary coils of inductive coupling. Core of the coil may be air core or ferrite core, if the magnetic core material like iron or ferrite is used as a core of the coil then it increases the range of communication and coupling between the coils.

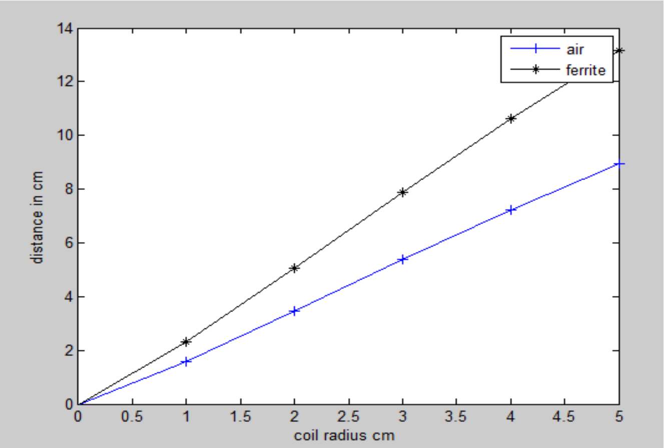

Fig.4. Coil Radius versus Distance

As shown in the Fig. 4 that the air core will support up to 8.4cm with large radius than ferrite core, but ferrite core will extend the range of communication of the transceiver coil up to 13.1cm with smaller radius of transmitter coil than air core transmitter coil.

B. Experimental results

To evaluate the performance of the near field magnetic induction, three channel path loss models are considered and simulated results are compared with practical results. For the practical result we have used copper coils of 26 and 23 standard wire gauge wires and the resistance calculation of R0 done through standard wire gauges table specification [9]. Different radius, frequency, and number of coil turns in transmitter and receiver coils are tried along with varying distance and its output voltage. The practical setup is shown in Fig. 5. The frequency range used is in between 100 kHz to 3MHz, number of turns in transmitter and receiver coils are 5 to 25 coil turns with different radius. The primary and secondary coil is made of copper with different standard wire gauge. The input resistance of the primary coil at one end is of 10Ω resistor and 1kΩ resistor is used as load at the secondary coil. The transmitted and received power is calculated with the help of basic ohms law and power equations.

Fig.5. Experimental Setup of Inductive Coupling

As shown in Fig. 6, considering PL1, the path loss is decreasing as frequency increases. Practically, better results are seen in MHz range frequency from 1MHz to 3MHz.

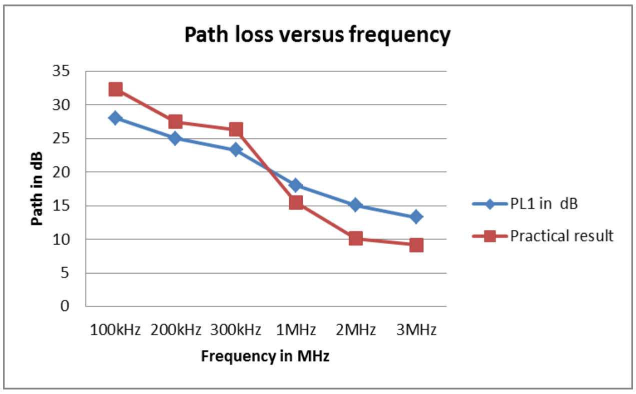

Fig.6. Path Loss versus Frequency, d=0.1cm, Vrms=7.84v, Irms=0.02, nt = nr =10, at=3.5cm, ar=2.75cm

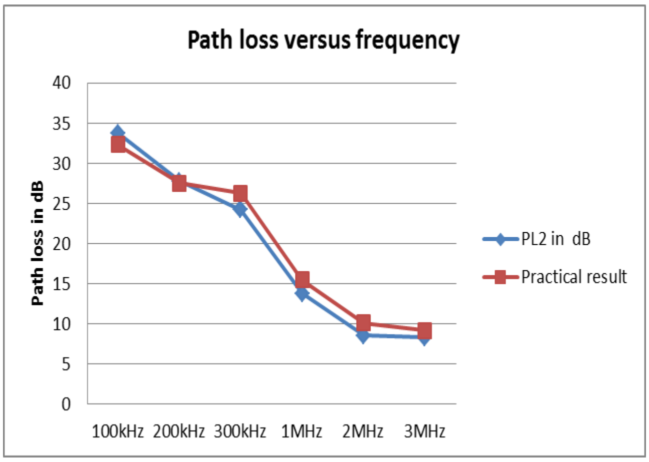

Fig.7. Path Loss versus Frequency, d=0.1cm, Vrms=7.84v, Irms=0.02, nt = nr =10, at=3.5cm, ar=2.75cm

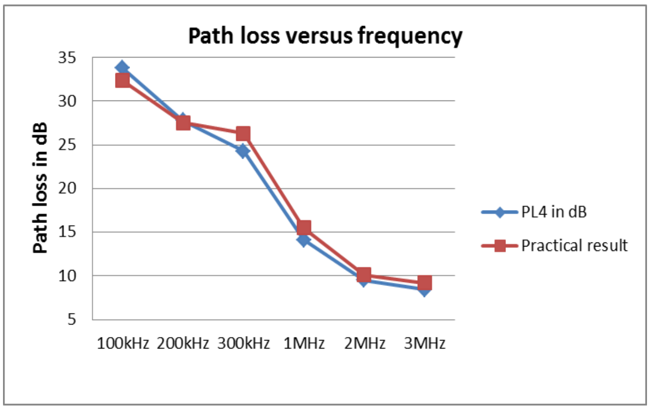

Fig.8. Path Loss versus Frequency, d=0.1cm, Vrms=7.84v, Irms=0.02, nt = nr =10, at=3.5cm, ar=2.75cm

The simulated and obtained results are almost matched in PL2 and PL4 analysis as shown in Fig. 7 and Fig. 8. In Fig. 9, PL1, PL2 and PL4 are compared with the practical results. The overall result of the path loss varies from 0 to 33.98 dB and frequency ranging between 1 kHz to 3 MHz.

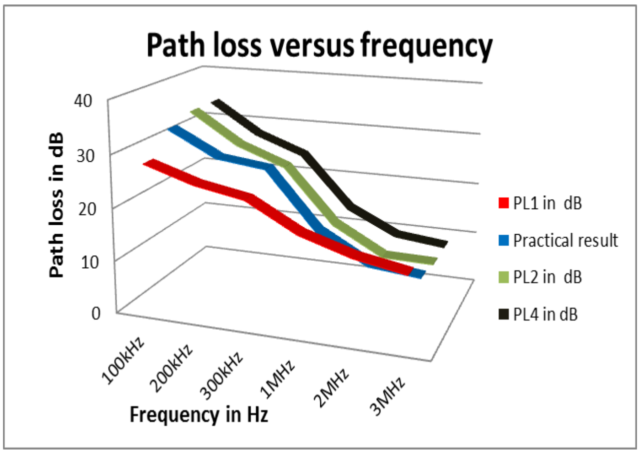

Fig.9. Path Loss versus Frequency, d=0.1cm, Vrms=7.84v, Irms=0.02, nt = nr =10, at=3.5cm, ar=2.75cm

Received power obtained across the load of secondary coil, increases as its frequency increases. As shown in Fig. 10, at 100 kHz frequency the received is less than 0.5mw, as its frequency increases to 3MHz then resultant received power is 9mw. The variations of Path loss obtained with respect to distance is shown in the Fig. 11, at the closer distance of 0.1 cm between the transceiver coils results 5.51dB of path loss. As the distance increases to 10 cm between the coils, path loss increased up to 33.45 dB. Received power versus distance shown in Fig. 12, as the distance between the primary and secondary coil increases it results the lower received power at the secondary coil. Power of 5.28mw results at 0.1cm, as its distance increase to 10cm, the received power is less than 0.25mw.

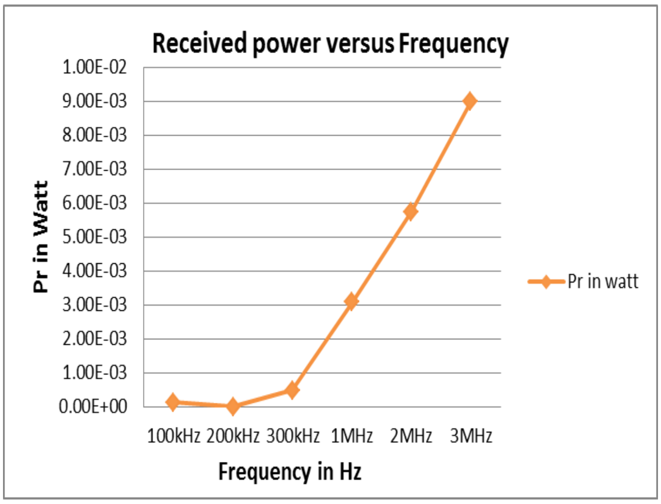

Fig.10. Path Loss versus Frequency, d=0.1cm, Vrms=7.84v, Irms=0.02, nt = nr =10, at=3.5cm, ar=2.75cm

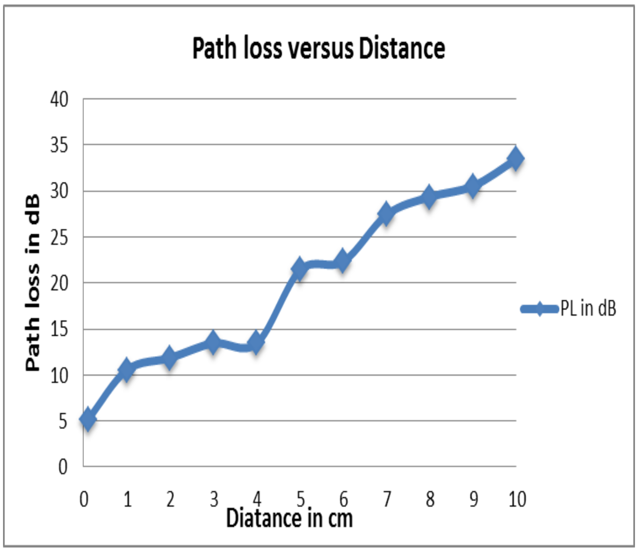

Fig.11. Path loss versus Distance, f=3MHz, Nt,Nr=10, at=3.5cm, ar=2.75cm, Pt=17.29mw, Vin=7v,Vrms=2.47v, Irms=0.247A

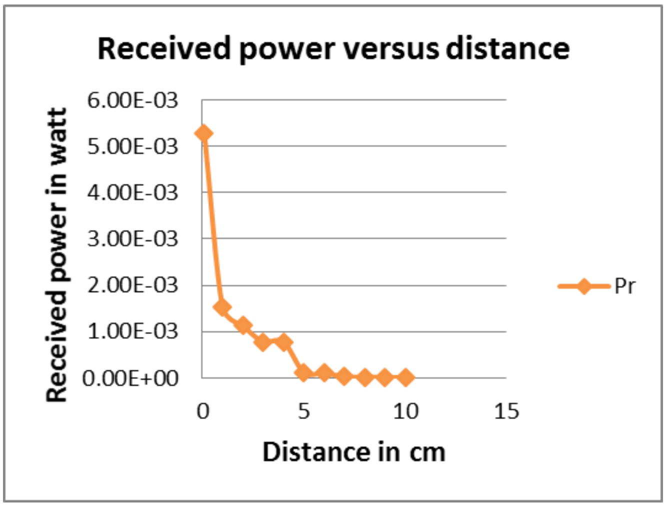

Fig.12. Received power versus Distance f=3MHz, Nt,Nr=10, at=3.5cm, ar=2.75cm,Pt=17.29mw, Vin=7v,Vrms=2.47v, Irms=0.247A

Considering lesser input voltage of 4.8v, the path loss between the transceivers is around 38.27dB at 10cm and at 0.1cm distance path loss is 4.73dB for the received power of 450μw across 1kΩ load resistor. Considering the number of turns in transceivers coils, the path loss decreases as the number of turns in transmitter coil increases as shown in Fig. 13. The number of receiver coil is 5 turns it results path loss of 10.2dB, if the turn's increases to 25 it gives a path loss of 6.39dB. The received power of the secondary coil increases as the number of receiver coil turns increases. The received power of secondary coil is 40μw at 5 turns, if number of turn's increases to 25 in receiver coil then output power of secondary coil is 1.2mw shown in Fig. 14.

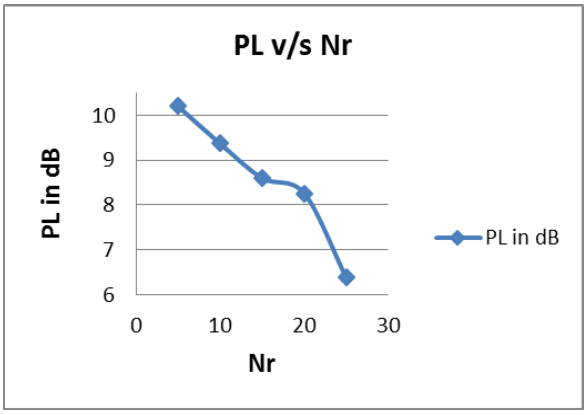

Fig.13. Path Loss Versus Number of Receiver Coil Turns, Nt=5,f=3MHz, at=4.25cm,ar=3.25cm,Vrms=1.56v, Irms=13.43mA,0.25,pt=5.23mw

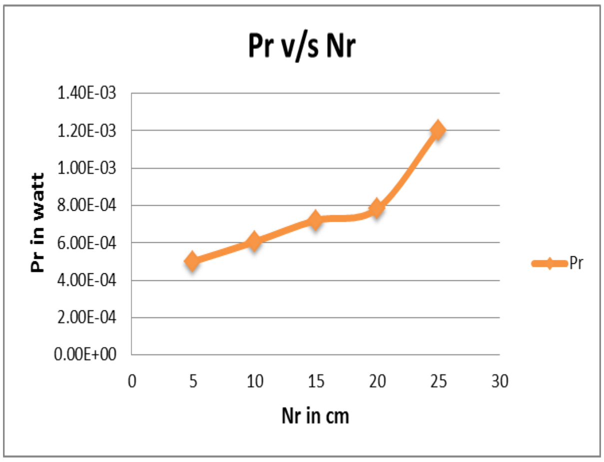

Fig.14. Received Power Versus Number of Receiver Coil Turns, Nt=5, f=3MHz, at=4.25cm,ar=3.25cm,Vrms=1.56v, Irms=13.43mA,0.25, pt=5.23mw.

Path loss versus receiver coil radius is shown in Fig. 15, the receiver coil radius of 2.25cm results in the path loss of 6dB. As radius increases to 3.75cm gives the path loss of -3.83dB.

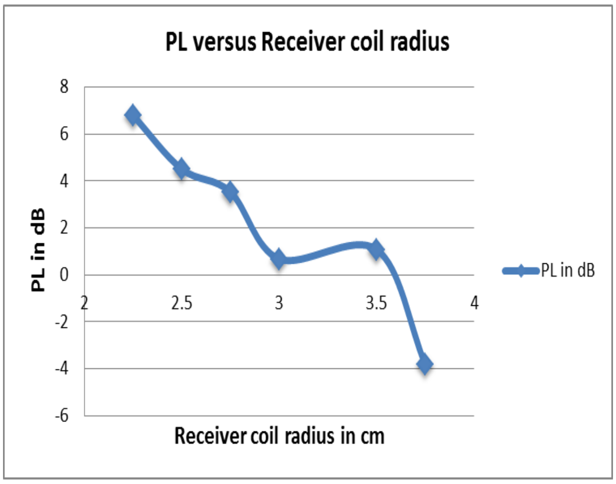

Fig.15. Path Loss versus Receiver Coil Radius, f=3MHz, d=0.5cm, nt=nr=10, at=4.25cm, Vrms=1.69, Irms=3.18mA, Pt=1.39mw.

VI. CONCLUSION AND FUTURE SCOPE

This paper deals with channel parameter analysis of near field communication considering magnetic induction. Here different channel path loss models, agbinya mashipour models are considered for the analysis and simulated results are compared with practical results. The analysis and performance evaluation is done considering the distance up to 10cm between the transceivers, frequency ranging from 100 kHz to 3MHz and number of turns in transmitter and receiver coils.

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