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RESEARCH ARTICLE

DESIGN OF CHANNEL MODEL FOR WIRELESS UNDERGROUND SENSOR NETWORK USING ZIGBEE

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ABSTRACT

In this paper an attempt is made to find the sand and clay percentage of the selected region by performing various tests like: sieve method and hydrometer. The readings of the sand, clay and silt present in the soil sample are calculated. The water content of the soil for different layers of the soil samplesis identified and the density of soil for the region selected is calibrated. The zigbee s2 (mesh) is used as the mote; the sensor has a good receiving capability upto -98dB, an Arduino is used at the receiving end. There are 3 motes used, one of them at the above ground, which was configured as the coordinator, and the other two underground sensors were made as the router, this was able to communicate in a mesh network. Then the motes were connected to the moisture sensor and temperature sensor, and the reading was taken wirelessly by burying inside the ground upto 40cm from the ground surface.

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INTRODUCTION

Underground Sensor Networks (USNs) are characteristic augmentations of the secured Wireless Sensor Network (WSN) sensation which comprise of sensors buried underground which impart through soil. And WUSNs can possibly affect a wide assortment of uses like environmental sensing, agriculture, border patrol, and infrastructure detection. The principle distinction in the middle of WUSNs and conventional systems is the communication medium. The main contrast in the middle of terrestrial wireless sensor networks and the WUSNs is the communication channel. The direct characterization of the underground wireless channel is highly difficult. Since, there are huge contrasts between the propagation characteristics of electromagnetic (EM) waves passing through the air in the soil gap. To this end, propelled channel models are inferred to portray the WUSN channel considering propagation of EM waves propagating soil, soil moisture, soil composition and so forth. One of the most promising application areas of the late created wireless networking techniques are the WUSNs. The WUSNs are having wireless devices that work beneath the underground surface. These devices are either (i) set within an open bounded underground space, (ii) buried totally under thick soil or for example, road/subway, underground mines and tunnels.

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In the previous case, wireless nodes and their networks are buried underground and impart through soil. For this situation, the WUSNs guarantee a wide assortment of different applications, which include environmental monitoring, border patrol, irrigation, localization and infrastructure monitoring (Akyildiz and Stuntebeck, 2006). In the recent case, despite the fact that the system is found underground, where communication happens through the air, i.e., through the air gaps that are there underground. For this situation, the WUSNs are important to enhance the wellbeing in mines which are the ground, to acknowledge helpful communication in drivers and travelers in subway, road tunnels, and to dodge assaults by ceaselessly monitoring for these vulnerable territories. The main objective of the paper is to design an underground channel model to obtain the VWC of the mud and to calculate the path loss through soil. The software used is: MATLAB/Simulink for channel analysis, Arduino software and Xctu software for Zigbee s2 sensors configuration.

Relatedwork

Ian F. Akyildiz *et al.* (2006). WUSNs comprise of wireless systems. These devices are either buried totally under thick soil, or put inside a limited open underground space.WSN work underneath the ground, for example, mines and subway road tunnels. The WUSNs guarantee to empower a wide mixed bag of good applications that were impractical with the monitoring techniques used currently for underground devices. Contrasted with the current WUSNs, which utilize wired communication techniques for system deployment, The WUSNs have a few momentous benefits, for example, concealment, timeliness of data, ease of deployment, coverage density, and reliability.

Akyildiz *et al.* (2009). Conventional sign engendering methods utilizing Electromagnetic waves experience three types of issues in the soil medium: with path loss, large antenna size, and dynamic channel condition. Firstly, the EM waves encounter huge attenuation because of absorption by the soil, shake, and the water. Also, the loss is hugely reliant on various soil properties, for example, water content, soil cosmetics (sand, clay or silt), and the density. What's more, the loss is able to change drastically with time and space. As a sample, the water content in the soil, increments after precipitation and theproperties of soil might fundamentally change over small separations. Accordingly, the BER for the communication system additionally shifts as a function of location and time. Thirdly, the operating frequencies in the MHz or the lower ranges are important to attain to practical range of transmission.

Bogena *et al.* (2009). In this paper they discuss the Magnetic Induction communication, transmission and reception is expert along the utilization of little coil. Subsequently, the antenna's size is not significant constraint for Magnetic Induction techniques. Nonetheless, the primary tests of Magnetic Induction based communication are attenuation: the EM waves decreases much slower than the magnetic field's strength.

Li Liyz Mehmet *et al.* (2007), In this, The propelled communication models were proposed to totally characterize the WUSNs and establish the frameworks for effective communication for this situation. Specifically, the USN channel is modeled considering the propagation of EM waves in soil, and other influences, for example, composition of soil, multipath, VWC, and also depth of burial. In addition, based on this model, the ensuing bit error rate will be investigated for soil parameter and the diverse network. The simulation results and theoretical analysis demonstrate the possibility of WUSN environment and also highlight a few imperative angles in this field.

Dong, Xin and Vuran, Mehmet (2011), in this paper its given that, So far, for none of these current models completely catch all the parts of EM signal propagation in the mud medium. In this reference paper, a shut structure channel model is produced focused around electromagnetic propagation of signals through the soil. Likewise, three noteworthy segments that impact soil communication are distinguished: lateral, reflected, and direct waves, where the first has not been dissected for WSNs as such. The closed-form channel models are demonstrated to concur with both the underground test bed trials and electromagnetic analysis focused around Maxwell's equations, that can't be spoken to in closed form.

Silva and Vuran *et al.* (2009), In this paper, Numerous applications for environment monitoring and irrigation management adventure buried sensors that are wire joined with the mud surface for the information recovery. WUSNs are a developing territory for research which guarantees to give communication abilities for those sensors. For performing this, a dependable WUSN channel is essential, permitting the immediate communication for the buried wireless sensors without assistance of aboveground system. Notwithstanding, the fundamentally high attenuation brought about by soil is the fundamental test for the achievability of WUSNs. Results demonstrate the potential possibility of the WUSNs with the utilization of effective RF sensors at lower frequencies (e.g., 300 to 500MHz range).

Applications

The underground applications can be classified based on four types: infrastructure analysis, environmental analysis, border patrol, location sensors, and security analysis (Akyildiz and Stuntebeck, 2006).

A. Environmental monitoring:

The covering offered by the WUSN additionally makes it more appealing and extensively feasible arrangement than the agricultural terrestrial WSNs. Unmistakable and physically conspicuous gear, for example, surface WSN gadgets or the data loggers could undoubtedly be unsatisfactory for the applications, and for example, garden and lawnor field analysis. WUSNs are especially appropriate to sports ground monitoring, in which they can be utilized to monitor the soil properties of golf field (see Fig. 1), tennis courts, baseball fields, and soccer fields. For these games, bad turf conditions for the most part make an unfavorable experience of playing, so soil support is particularly imperative to guarantee healthy grass. Extra pragmatic gimmick of these underground sensors are that, they are shielded from supplies, for example, lawnmowers and tractors (Akyildiz and Stuntebeck, 2006).

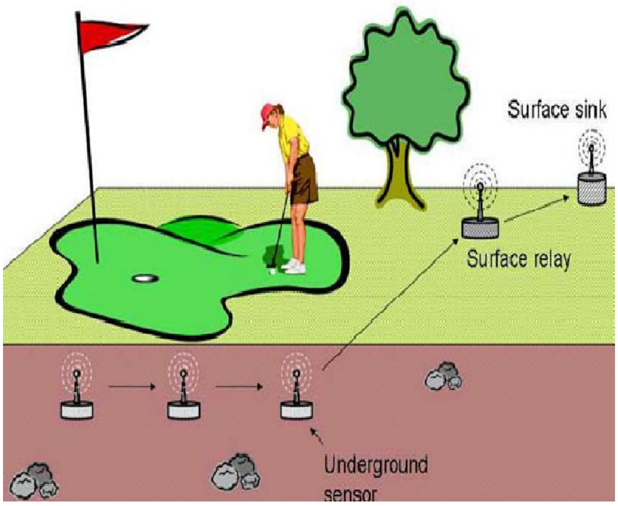

Fig. 1. A WUSN deployed for monitoring a golf course (Akyildiz and Stuntebeck, 2006)

B. Infrastructure analysis

A lot of underground topologies exist, for example, liquid storage tanks, electrical wiring, and pipes. WUSNs could be utilized to screen them. For instance, underground tanks can store fuel in fuel stations, which could be precisely checked to guarantee that no breaks are available and to constantly focus the measure of the fuel. Homes in areas without a seuwiere normally have an underground sewer tank, and that must be observed to anticipate flood. WUSNs will likewise be helpful in checking underground pipe works, where sensors could be placed along the path of the pipes, so that the leakages can be located quickly and can be repaired (Akyildiz and Stuntebeck, 2006).

C. Location identification for objects

WUSN devices which are known for their location based work sare used for location based services. Even one can envision gadgets placement beneath the road surface that speaks with a car as it moves. A conceivable administration would be to caution the driver for an upcoming sign for stop or activity signal. The car will get the information about the upcoming stop signal and send it to the driver. Location information will likewise serve as a navigational help for the autonomous frameworks, e.g. an autonomous fertilizers unit, which travels around the place to be fertilized, focused around the underground beacons and the soil condition information from the underground sensors (Akyildiz and Stuntebeck, 2006).

D. Security analysis and Border patrol

WUSNs could be used for monitor the AG presence and development of individuals or articles. Like location survey, employed devices should be stationary and mindful of the location. Dissimilar to determination of location, in any case, where devices report their presence by means of immediate correspondence with the device, to monitoring the presence requires the sensors, for example, magnetic, or pressure, to focus the individuals or objects presence. Since their presence could be hidden, the intruders can not know about the action taken to off the security system (Akyildiz and Stuntebeck, 2006).

Experimental setup

WUCNs have got explored in numerous contexts recently. In spite of the fact that in novel areas, a point by point classification of the systems is vital since a few different situations, with distinct difficulties and characteristics are exhibited under the title WUSN communication. In (Akyildiz and Stuntebeck, 2006), two conceivable methodologies for WUCNs are displayed: the underground method, where most of the nodes will be buried underground, and the hybrid method, where the buried sensors exist together with some sensors which are kept above ground. In light of this classification, an expanded classification of WUCNs is recommended, as delineated in Figure 2.

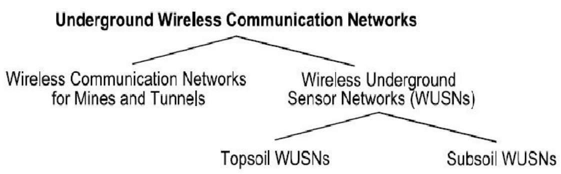

Fig. 2. Classification of WUCNs (Silva and Agnelo, 2013)

The soil is a dielectric substance, and is characterized by some particular relative permittivity or dielectric constant. The proliferations of electromagnetic waves are straightforwardly influenced by the permittivity of the materials. All the more particularly, a littler quality for the relative permittivity fundamentally suggests better situations for the engendering of the EM waves. And the soil mediums carries on as dielectric mixed material made out of bulk soil, free water, bound water, and air. On the off chance that the soil shows high porosity and little density, the conditions for the spread of electromagnetic waves are better because of the high amount of air in the medium. However, the waters presence in soil has an adverse effect on communication.

The soil permittivity varies, other than other factors, as function of the soil composition. The soil textures are generally distinguished as far as fractions of silt, clay, and sandparticles, as demonstrated in Figure 3. Dependenton the content of silt, clay, and sand, the soil type receives a particular name or classification (Xiaoqing Yu *et al.,* 2013). For example, the point P as shown Figure3is representing a soil content with a homogeneous mixture of silt, clay, and sand, and it is found as clay loam.

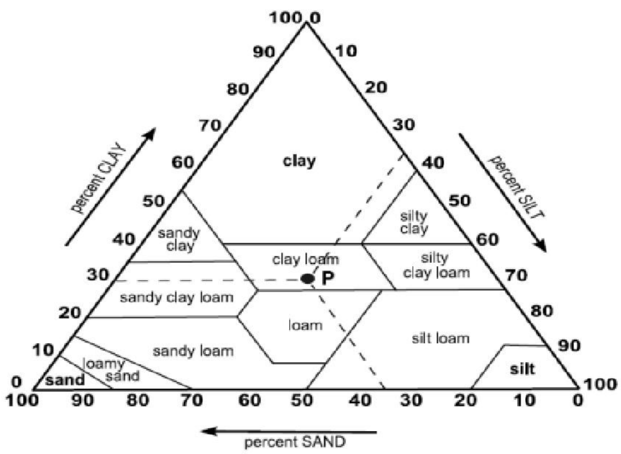

Fig.3. Soil types triangle showing the (USDA) grain size classification system (Silva and Agnelo, 2013)

Physical commodity sensors zig bee motes, operating at 2.4 GHz and 0dbm of transmit power level, are tried for UG2AG and the empirical results are accounted for in. Two sets of tests are understood: one considering that the receiver node is located at the soil surface and the other one with the receiver elevated 1m above the soil surface. For these tests, three burial depths for the sender node are utilized: 0, 15, and 30 cm. The 0-cm burial depth case is used to establish a baseline for comparisons. The maximum horizontal inter-node distances achieved, with PER <10%, are 2.5 and 7m for 13 and 6cm-burial depths, respectively. These results explain the criticality of the soil path attenuation. In the same empirical work, UG2UG experiments are realized. However, such communication link is reported as not feasible for that some of the test bed scenarios.

For this paper firstly the sand and clay% of the place had to found out, so soil sample were taken and many tests were done like: sieve method, hydrometer method and many other methods as shown in Fig.4 to Fig.9. From which the reading of the sand, clay and silt which was present in the soil sample was calculated. Also the water content of the soil for different layers of the soil samples was found. And the density of soil for the region selected was calibrated.

Fig. 4. Soil Unearthed for sensor placement

Fig. 5. Soil samples being weighed

Fig.6. Soil samples being kept in the oven for VWC calculation

Fig.7. Soil samples being powdered for hydrometric test

Fig.8. Hydrometric test for silt and clay % calculation

Fig.9. SIEVE method foe calculation of the size of different partials in the soil sample

A. Sensor design

The underground channel is crucial for the designing a communication protocols for WUSNs.

The underground channel altogether not quite the same as the air channel. The underground communication where nature has a noteworthy and immediate effect on the communication performance. Ecological perspectives, for example, soil moisture and texture, possibly change the dielectric properties of the soil and influence the wireless communication. Moreover, deployment parameters, such as the burial depth and the frequency, also have strong impact on the communication. Therefore, an underground communication channel must capture these aspects related to the environment and nodes deployment architecture.

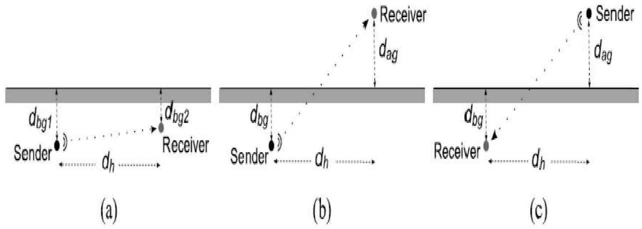

Fig.10. The three communication scenarios Used for the WUSN Setup: (a) UG2UG link, (b) UG2AG link, and (c) AG2UG link

B. Zigbee node setup and Block diagram

The complete setup is simulated in the Simulink and then the results are verified by theoretical calculation. The block diagram is as shown in Figure 11.

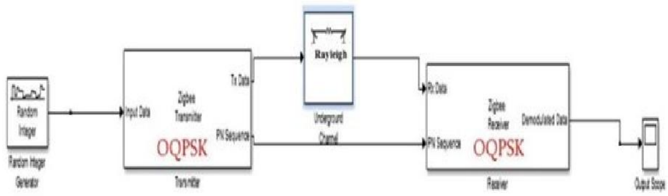

Fig. 11. Block diagram of the complete setup

The zigbee s2 (mesh) is used as the mote; the sensor had a good receiving capability up to -98dB as shown in the Fig 12 to Fig 15. An Arduino platform is used in the project at the receiving end which consists of three motes: one of them is configured as the coordinator, which is above the ground, the second is the underground sensor configured as the router to enable the communication in the mesh network.

Then the motes are connected to the moisture sensor and temperature sensor. The reading is recorded wirelessly inside the ground, burying at the distance of 40cm from the ground surface.

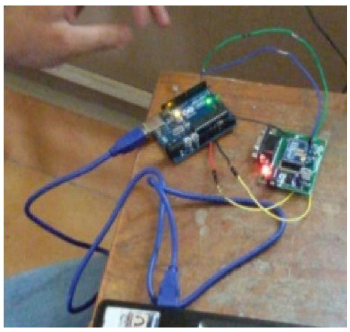

Fig. 12. Zigbee coordinator hardware setup with Arduino connected to laptop

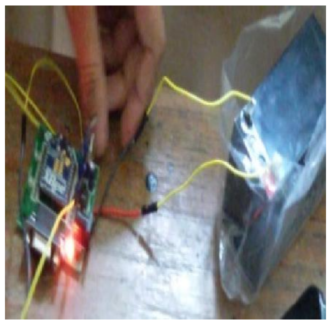

Fig. 13. Zigbee router mote setup with the battery

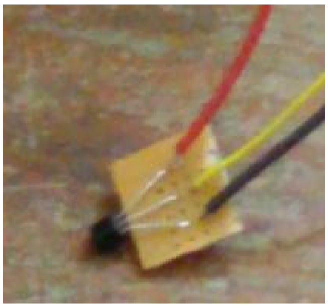

Fig. 14. Temperature sensor

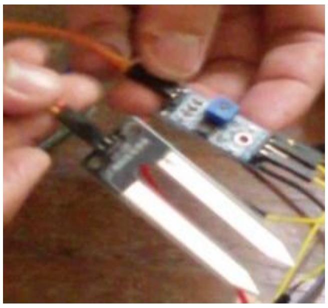

Fig. 15. Soil moisture sensor

The zigbee was setup as coordinator and router using XCTU software. The setup screen shots are as follows:

The dielectric properties of soil can be derived using Peplinski model (NchimunyaChaamwe *et al.,* 2010), as follows:

$$\varepsilon = \varepsilon' - j\epsilon'' \qquad \text{...........(1)}$$

$$\varepsilon' = 1.15\left[1 + \frac{\rho_b}{\rho_s}\left(\varepsilon_s^{\alpha'}\right) + m_v^{\beta'}\varepsilon_{fw}^{'\alpha'} - m_v\right]^{\frac{1}{\alpha'}} \qquad \text{................(2)}$$

$$\epsilon'' = \left[m_v^{\beta''}\varepsilon_{fw}^{''\alpha'}\right]^{\frac{1}{\alpha'}} \qquad \text{...............(3)}$$

Where mv =volumetric water content (VWC) of the mixture, ρ_s= $2.66g/cm^3$ density of the solid soil particles,

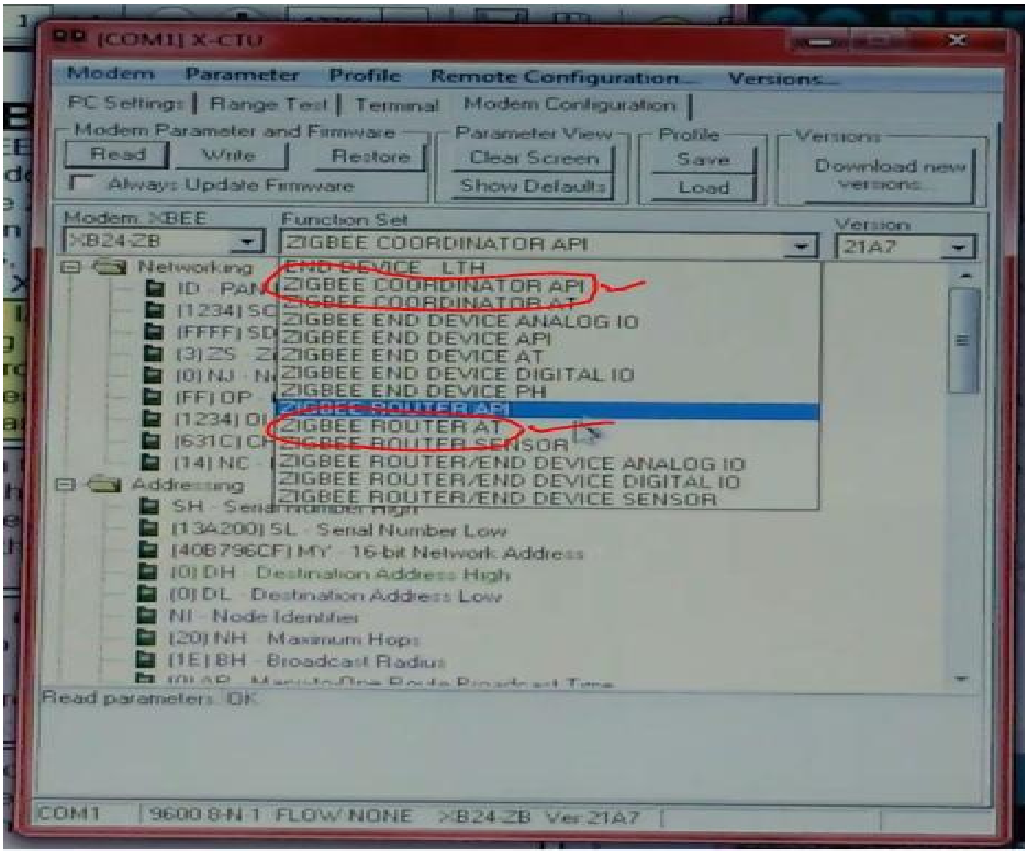

Fig. 16. Zigbee setup using XCTU software

This is the methodology and design procedure of experimental setup for conducting this paper.

Soil dielectric constant calculation

The soil dielectric constant is the factor that impact on the attenuation of the underground wave. The major challenge for attenuation in the underground process is the dielectric constant for a homogeneous soil sample.

Parameter	Change	Effect on signal attenuation
Water content	↑	↑
Temperature	↑	↑
Soil bulk density	↑	↑
% Sand	↑	↓
% Clay	↑	↑

Fig. 17. Soil parameter change on signal attenuation

ϵ = dielectric constant of the soil-water mixture ρ_b= bulk density in grams/cubic centimetre, α'=0.65, $\beta'$and β'' empirically determined constant, dependent on soil type and given by,

$$\beta' = 1.2748 - 0.519S - 0.152C \qquad \text{…………(4a)}$$

$$\beta'' = 1.33797 - 0.603S - 0.166C \qquad \text{…………(4b)}$$

S and C represent the sand and clay mass fraction. The real and imaginary parts ε'_{fw} and ε''_{fw} are the dielectric constant of water.α *and* β *is* the attenuation and phase shifting constant is given as,

$$\alpha = \omega\sqrt{\frac{\mu\varepsilon'}{2}\left[\sqrt{1 + \left(\frac{\varepsilon''}{\varepsilon'}\right)^2} - 1\right]} \qquad \text{............(5a)}$$

$$\beta = \omega \sqrt{\frac{\mu\varepsilon'}{2}\left[\sqrt{1+\left(\frac{\varepsilon''}{\varepsilon'}\right)^2}+1\right]} \qquad ....(5b)$$

Thefriss equation for free space, the received signal power is the distance r from the transmitter is:

$$P_r = P_t + G_r + G_t - L_p \qquad ....(6)$$

Where,

$$L_p = L_0 + L_s \qquad ....(7)$$

The free space path loss $L_0 = 20\log(4\pi d/\lambda_0)$, EM wave soil of the path loss is found by combining L_0, (5), and (6) as follows:

$$L_p = 6.4 + 20\log(d) + 20\log(\beta) + 8.69\alpha d \qquad ……….(8)$$

d is the distance, in meters, α *and* β *is* the attenuation and phase shifting constant (Mehmet *et al.,* 2010).

RESULTS

In this project three sensors are used for three different configurations. The MATLAB Simulations for different configurations are:

A. Underground to underground

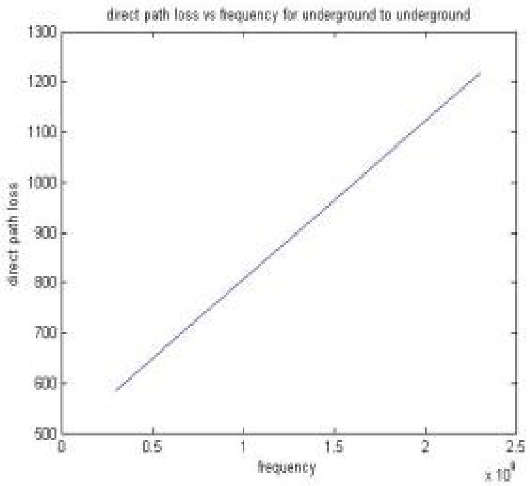

Fig. 18. Path loss V/S Frequency

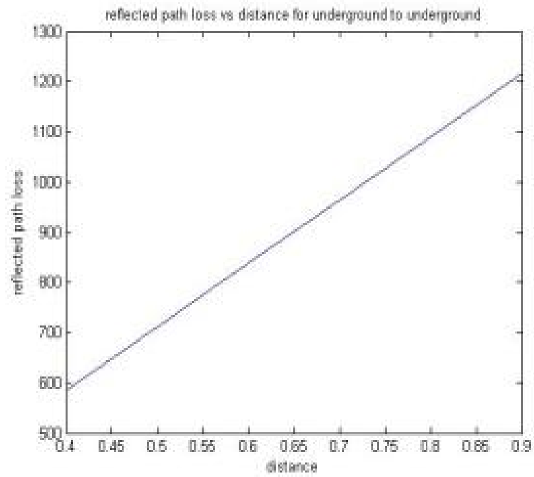

Fig. 19. Path loss V/S Distance

B. Underground to aboveground

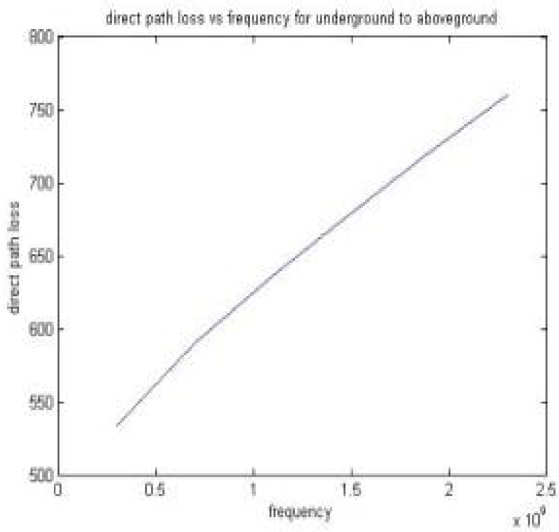

Fig. 20. Path loss V/S Frequency

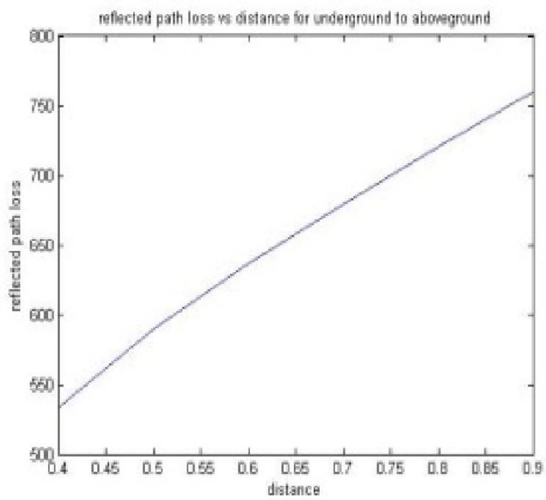

Fig. 21. Path loss V/S Distance

C. Aboveground to underground

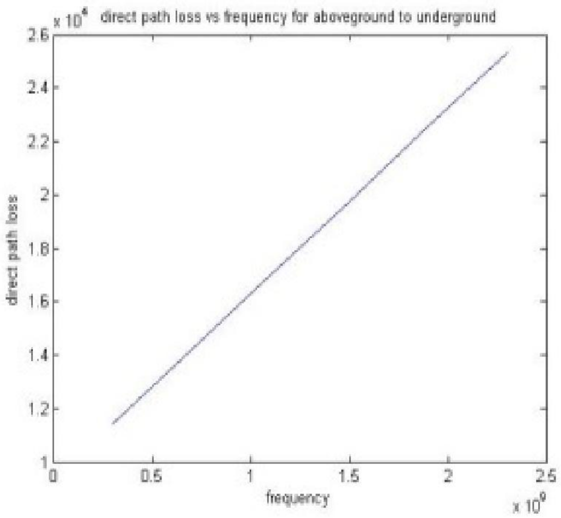

Fig. 22. Path loss V/S Frequency

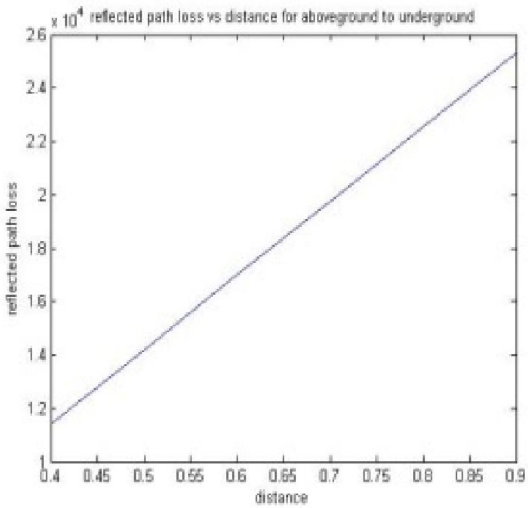

Fig. 23. Path loss V/S Distance

Conclusion

The underground channel characterization is one of the most important aspects for calculating the path loss in the channel. The Zigbee provides a good result. It works at higher frequency and hence there is less attenuation or path loss compared to other motes. The project work can be extended further to implement the setup on a zinc board. It can be practically demonstrated in the border areas with a vibration sensor attached to the node which can be used in the irrigation fields.

REFERENCES

Akyildiz and Vuran, 2010. "Wireless Sensor Networks", Wiley publication, ch 17, August 2010.

Akyildiz I.F. and E. P. Stuntebeck, 2006. “Wireless underground sensor networks: Research challenges,” *Ad Hoc Networks Journal (Elsevier),* vol. 4, pp. 669-686, July 2006.

Akyildiz I.F., Z. Sun and M. C. Vuran, 2009. “Signal Propagation Techniques for Wireless Underground Communication Networks,” *Physical Communication Journal (Elsevier),* Vol. 2, No. 3, pp.167-183, September 2009.

Bogena H. R., J. A. Huisman, H. Meier, U. Rosenbaum, and A. Weuthen, 2009. “Hybrid Wireless Underground Sensor Networks: Quantification of Signal Attenuation in Soil,” *Vadose Zone J.,* vol. 8, no. 3, pp. 755- 61, August 2009.

Can Vuran M. and Agnelo R. Silva, 2010. "Communication Through Soil in Wireless Underground Sensor Networks – Theory and Practice", Signals and Communication Technology, DOI 10.1007/978-3-642-01341-6 12, Springer-Verlag Berlin Heidelberg.

David Bastos Silva Lino, 2014. "A New MAC forWi-Fi based Underground Networks", Faculdade de engenharia da universidade do porto, A master thesis February 14, 2014.

Dong, Xin and Vuran, Mehmet C., 2011. "A Channel Model for Wireless Underground Sensor Networks Using Lateral Waves" 2011. IEEE Communications Society Subject matter experts for publication in the IEEE Globecom 2011.

I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, 2002. "Wireless sensor networks: a survey", Computer Networks 38 (2002) 393–422.

Jing Huang, Ratnesh Kumar *et al*. 2008. "Development of a Wireless Soil Sensor Network", Iowa State University, Ames, IA 50011, July 2, 2008.

John Tooker, Xin Dong and Mehmet C. Vuran, 2012. "Connecting Soil to the Cloud: A Wireless Underground Sensor Network Testbed", Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks, Annual IEEE.

Li Liyz Mehmet C. Vurany Ian F. Akyildizy, 2007. "Characteristics of Underground Channel for Wireless Underground Sensor Networks", The Sixth Annual Mediterranean Ad Hoc Networking WorkShop, Corfu, Greece, June 12-15, 2007.

Lu De Yang, 2011. "Implementation of a wireless sensor network with ez430-rf2500 development tools and msp430fg4618/f2013 experimenter boards from texasinstruments",A Thesis for Master of Science in Electrical Engineering, Jilin University, China, August 2011.

Mehmet C. Vurana, Ian F. Akyildiz, 2010. "Channel model and analysis for wireless underground sensor networks in soil medium", Contents lists available at ScienceDirect, Physical Communication 3, 2010.

Mohammad Riahi, AmirhosseinTavangar, 2008. "Prognosis of the Effects of Soil Characteristics on the Performance of Landmine Detection in Ground-Penetrating Radar System - A Case Study", The 2nd International Conference on Technical Inspection and NDT (TINDT2008)- October 2008.

NchimunyaChaamwe, Wenyu Liu, and HongboJiang, 2010. "Wave Propagation Communication Models for Wireless Underground Sensor Networks", Huazhong University of Science and Technology, Wuhan, China.

SérgioDavide Lopes Conceição, 2014. "Ns-3 Simulation Model for Underground Networks",Faculdade de engenharia da universidade do porto, Master THESIS in Electrical and Computers Engineering, February, 2014.

Silva A.R. and M.C. Vuran, 2009. "Empirical evaluation of wireless undergroundto- underground communication in wireless underground sensor networks", in: Proc. IEEE DCOSS'09, Marina Del Rey, CA, June 2009.

Silva, Agnelo R. 2013. "Channel Characterization for Wireless Underground Sensor Networks", *Computer Science and Engineering: Theses, Dissertations, and Student Research*.

Xiaoqing Yu, PuteWu, Zenglin Zhang 1, NingWang, and Wenting Han, 2013 "Electromagnetic wave propagation in soil for wireless underground sensor networks", *Progress In Electromagnetics Research M*, Vol. 30,11, 2013.

Zhi Sun, 2011. "Reliable and efficient communication in wireless underground sensor networks", A Thesis Presented to Georgia Institute of Technology, August 2011.

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