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Magnetic induction-based communication through underground

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Abstract

The Wireless Underground Sensors Network is a promising alternative method for the data transmission through the underground soil. The method uses various sensors to record the data and transmit them through a distance wirelessly and thus called Wireless Underground Sensors Network. The system uses the Magnetic fields generated due to the Magnetic Induction produced in the induction coils present in the transmitter and receiver. From this method there is accuracy in the data transmitted through the soil. Also the data transmitted at the transmitter are well correlated with the values received at the receiver end. The paper investigates a method to transfer signals underground more efficiently than transferring them through the atmosphere. The ultimate aim of this work is to transfer the signals through the soil efficiently than transferring them through the atmosphere.

Keywords: Wireless Underground Sensor Networks, Magnetic Induction, Data Transmission.

INTRODUCTION:

The WUSN technique is a developing technology to transfer the data signals underground wirelessly. It is the method of transmitting the data signals from transmitter to the receiver through a medium without transferring them through the wires. In WUSN method the medium used for transmission is soil. In this method, the transmitter transfers the data signals to the receiver side through the soil and the data signals are received at the receiver's end. In this process the transmitter antenna and the receiver antenna is placed deep underground the soil where the factors affecting the transmission are minimum. The process can be carried out by either placing the node in an open place or in a closed place like the cave or soil or rock which has many applications in the data transmission in places such as in office building, security purposes, environmental monitoring, etc. There are many sensors used to record the data and then it may be processed. Also, this method of using multiple sensors in a sensor network which lowers energy consumption and the reliability of measurements of the data are increased [1].This method is advantageous where the collisions between the sensors can be avoided with retrieval of original data in real-time can be seen [2]. Magnetic Induction (MI) is an alternative method compared to the EM technique for the Underground wireless communication. Some of the disadvantages like dynamic channel condition and the large antenna size of the EM waves technique can be solved in efficient manner. In air, the attenuation rate of the magnetic field may have a little variation when using the soil and water medium but the permeability conditions of the magnetic materials is similar. Thus, this paper explains the experiment carried out in the testing the efficiency of the transmission of the data signals through underground.

FIELDS OF APPLICATIONS:

- **Environmental monitoring**:

WUSNs are mostly carried out with the usage of soil sensors for obtaining the soil properties. The most important application of this method is the irrigation system where the data can be generated and transmitted for the efficient irrigation system. The imbalance in glacier and volcanic eruptions movements is monitored [3]. The application of the WUSN technique is in the prediction of the occurrence of the natural disasters such as landslides, earthquakes, etc. These disasters occur due to the

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changes in the materials such as the soil, water, etc. which can be monitored by the sensors buried deep under the soil.

- **Infrastructure monitoring:**

The wireless monitoring is used to monitor the internal structure of the tunnels, dams, liquid reservoirs, buildings etc. MI technology serves this purpose. The need for monitoring the infrastructure is to know the factors affecting the durability of the infrastructure. This can be done by keeping a track record of the stress and strain induced in the materials used for their construction such as the water, sand, concrete, etc., using the MI technology.

- **Location determination:**

The location determination is done by using the WUSN method to transfer the data from a node underground to the node above the ground through a medium. The WUSN method can be used for the visually impaired for better understandings of their surroundings. The WUSNs are primarily used for the determination of the occurrence of the natural disasters such as earthquakes, landslides, floods, etc. and also in which the sensors were found to be working even after the disaster [4].

Security monitoring:

Underground Sensor Networks have higher degree of concealment compared to the other Aboveground Sensor Networks. Since their presence is hidden, the possibility of knowing its presence and disabling it is very less. For Real-Time Application, this can be used in Border Patrol, these pressure sensors can be deployed along the borders at shallow depth, if in case of illegal entry, the authorities can be informed. So by this method, the security system can be maintained without fail[10]**.**

CHANNEL MODELLING:

The induction coil present in the MI transceiver plays the key role in the data transmission. The coil in the transmitter generates magnetic fields which are received by the coil in the receiver's end. A capacitor is also connected in the circuit which makes it resonant and the high path loss at the selected resonant frequency is reduced. For a large distance of transmission, coils of moderate size are used. On compared with the traditional EM waves, this kind of communication has a much high path loss. Due to eddy current effect, the magnetic field and the electrical conductivity of the soil are additionally attenuated. The transmitter coil generates minimum current in the primary magnetic field which in turn produces a secondary magnetic field in a direction opposing as it is shown in Figure 1. On using a heterogeneous medium, there will be different conductivity assumed for different layers of propagation medium. The attenuation of the magnetic fields is different in several ways that depends upon the layers of medium with respect to the placement of coil. The scaling factor for a transmitter coil placed in the ground is calculated in [5]. The signal propagation through the soil medium which has a changing environment has been analyzed and an equivalent skin depth of the soil heterogeneous medium is determined. For a transmission distance over 10 m, due to some path loss in soil, resonance frequencies which has lower range of 100 he and 1Mhz are mostly preferable. If the transceivers having squared distance between them, the optimal resonance frequency decreases. J. Wait has investigated the basic characterizations of the propagation of the magnetic fields in the underground medium [5, 7]. The design of the channel modeling between the MI transceivers for the MI-WUSNs is discussed in [8]. In a recent time, some MI asymmetric transceivers has been discovered which can be used for data transmission in soil over long distance in order to transmit signals even in case of unpredictable environment conditions [9].

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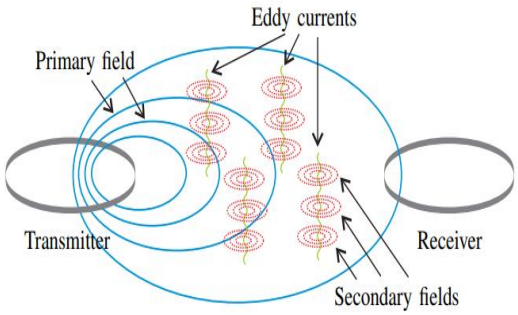

Figure 1. Propagation of magnetic field in conductive medium.

SENSORS USED:

Soil moisture sensor:
It is used to measure and monitor the moisture content present in the soil

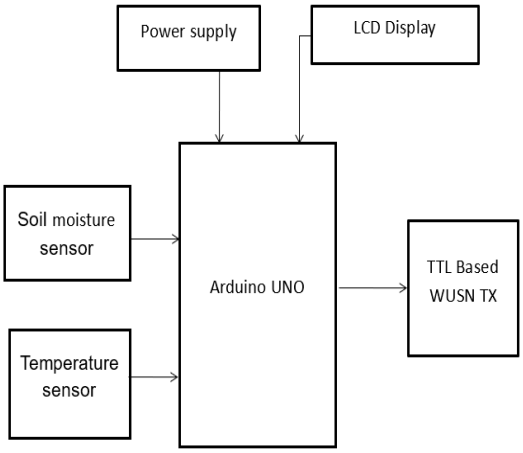

Figure 2. Block diagram of transmitter circuit

Temperature sensor:
Temperature sensors are used to sense and measure the amount of heat energy or the temperature at a place and that can be used for understanding the soil. These sensors provide digital output of the recorded temperatures.

SYSTEM DESIGN:
The WUSNs is the technique that uses sensors to record data and transfer them through a distance. The sensors re buried underground and the data transfer occur through the soil. The major application of the WUSNs occurs in the intelligent agriculture, environmental monitoring, security applications.

EXPERIMENTAL PROCEDURE:
The WUSN technology is used for the transferring data through the soil. The components used for the experiment are Peripheral Interface controller, Arduino UNO, Variable Voltage Power Supply.

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The WUSN is a promising technology in the developing stage which would be implemented in every aspects of data transmission. The experiment is carried out by connecting the transmitter, receiver as such in the block diagram. In the transmitter circuit, various sensors are used for recording the data. Here, the soil moisture sensor and temperature sensors are used to record the moisture content and the temperature of the soil at that particular place and it is then send to the Arduino UNO. In the receiver side, the Arduino UNO receives power from the power supply and also displays the recorded data values in the LCD displays. The magnetic induction process is carried out by which magnetic fields are generated by which data is transmitted through the soil. Then it is sent to the TTL Based WUSN TX which is buried underground, then which the data are transmitted through the soil. . Then it is sent to the TTL Based WUSN TX which is buried underground, then which the data are transmitted through the soil.

The TTL based WUSN TX consist of Encoding circuit, impedance matching circuit and amplifier. Both the transmitter and the receiver circuit are matched by the impedance matching circuit.

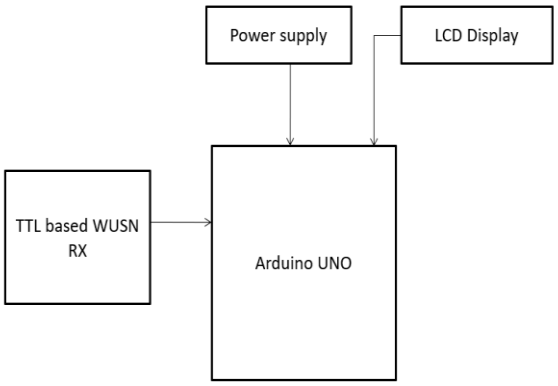

Figure 3. Block diagram of receiver circuit.

The transmitted data signals are passed through the soil medium and then it is received at the receiving end by the receiver. The data signals are received by the TTL Based WUSN RX at the receiver end and the data are sent to the Arduino UNO where it is decoded. Then the values are displayed in the LCD display monitor.

RESULTS AND DISCUSSION:

The WUSN technique is used to transfer data through the soil medium and the results obtained shows an accuracy in the values transmitted. The data received at the receiver's end well matched with the data values transmitted at the transmitter's end. The images of the data transmitted at the transmitter's end and the receiver's are shown in Figure 4 and Figure 5.

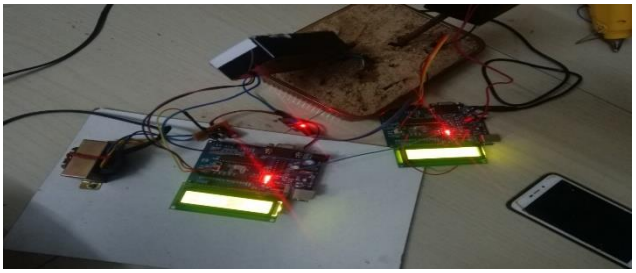

Figure 4. Data transmission between both the ends.

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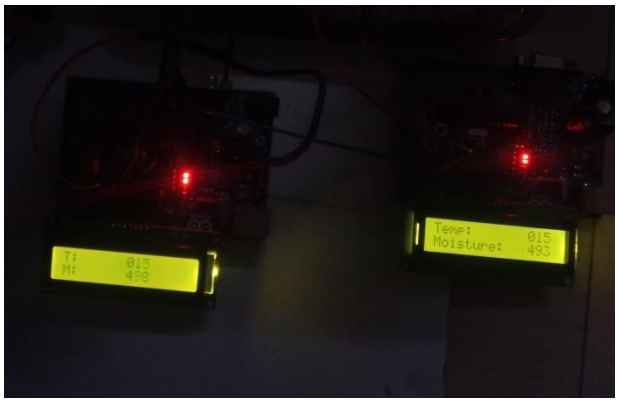

Figure 5. Final results.

CONCLUSION:

The WUSN technique using the MI method is found to be promising technology to be developed to a greater extent in the near future. From the experiments the conclusions are made as the values detected by the sensors are transmitted as Transistor –Transistor Logic (TTL) output through the soil and the data values are received and displayed by the LCD unit. It senses the moisture of the soil and sends the output through the existing soil. The technique can be implemented in various fields of applications such as security purposes, agriculture, border patrol etc.

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