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# Analysis of Wireless Sensor Networks with Energy Harvesting Capabilities of Transmitter and Receiver Antenna

Rajiv Dahiya, A. K. Arora and V. R. Singh
Research Scholar, Manav Rachna International University, Faridabad
Professor, Manav Rachna International University, Faridabad
Professor, PDM College of Engineering, Bahadurgarh

***Abstract: - In this paper, we analyse the energy harvesting capabilities of wireless sensor nodes with the transmitter and receiver antenna power. Simulations shows that received power and $V_{rms}$ (induced voltage) are inversely proportional to the distance. Finally some examples are presented with different numbers of wireless sensor nodes to show the location of nodes in the transmission field and the approximated RF power received.***

***Keywords:-*****Wireless sensor Network (WSN), half dipole antenna, patch antenna.**

## I. INTRODUCTION

Energy-constrained wireless sensor networks have gained considerable research attention in recent years [1][2]. In such sensor networks, battery-operated sensors are expected to work for months, or even years, without replacement or renewing its energy rendering energy optimization a critical issue in system design. The sensor nodes are typically battery powered, energy optimization and efficiency is extremely important in WSNs. Wireless systems the main power consumption is due to the actual transmissions power. However, this may not be the case in a wireless sensor network. In some cases it is the circuit energy needed for receiver and transmitter processing that is dominant. Thus energy optimization techniques that minimize the required transmission energy may be effective in wireless sensor networks. Wireless sensor networks have application to the most diverse fields such as Environmental monitoring, warfare, child education, surveillance, micro-surgery, and agriculture [7]-[14]. Commercial applications of wireless sensor networks include industrial monitoring, building controls, security, traffic management, weather, wildlife tracking, and agricultural field temperature-sensing networks [4][16]. Wireless sensor networks provide many opportunities, but also pose many challenges, such as the fact that energy is a scarce and usually non-renewable resource. This paper analyse the energy harvesting capabilities of wireless sensor nodes with the transmitter and receiver antenna power. Simulations shows that received power and $V_{rms}$ (induced voltage) are inversely proportional to the distance. The rest of the paper is organized as follows. In section II, basic of wireless sensor network is explained. In Section III, explain the effect of transmitting antenna on the energy harvesting capability of wireless sensor network using patch antenna. In Section IV, explain the effect of receiver antenna on the energy harvesting capability of wireless sensor network using Omni directional antenna. In Section V, simulation results are explained. Finally, conclusions are drawn in Section VI.

## II. WIRELESS SENSOR NETWORKS (WSN)

Wireless Sensor Network is a network, which consists of spatially distributed sensor nodes to monitor physical or environmental conditions, such as temperature, light, vibration, motion or pollutants [3]. A node contains a processor and multiple types of memory, may have a transceiver, include a power source, and accommodate various sensors. A wireless sensor node is a low cost, small, battery powered electronic device designed to monitor or measure a physical phenomenon of the environment around it, such as temperature, pressure, humidity, soil pH, vibration, motion, light, sound, radiation, and chemical presence. These components are integrated on a single or multiple boards, and packaged in a small box. A WSN usually consists of tens to thousands of such nodes that communicate through wireless channels for information routing and processing [15]. Each node collects information about its environment and cooperatively transfers data through the wireless network to a sink node. The collected information is processed either at the node, or at the base station, or in any combination of these. Sensor nodes of energy-efficient WSNs are usually battery-driven, and hence work on an extremely frugal energy budget [3].

## III. TRANSMITTING ANTENNA

Selection of a proper operating frequency band for the proposed RF energy harvesting system is crucial since it will affect the overall size of the receiving antenna and operating range of the system. Two unlicensed UHF bands 867MHz and 2.45 GHz were evaluated. 867MHz was chosen due to its lower free space attenuation. We can consider some commercially available antennas and also some of the transmitting antenna which is mainly designed for energy harvesting. The main challenge faced

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in harvesting RF energy is the free space path loss of the transmitted signal with distance. The Friis transmission equation relates the received ($P_r$) and transmitted ($P_T$) powers with the distance R as

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\Pi R^2}\right) \dots \dots (1)$$

Where, $G_t$ and $G_r$ are antenna gains, and $\lambda$ is the wavelength of the transmitted signal. The received signal strength, diminishes with the square of the distance, requires special sensitivity considerations in the circuit design. Moreover, FCC regulations limit the maximum transmission power in specific frequency bands.

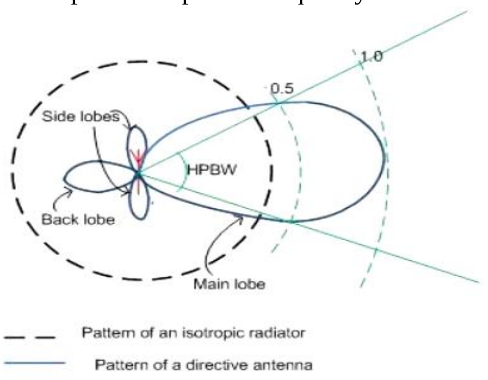


**Fig: 1 Radiation Pattern of Patch Antenna**

We use Patch antenna as transmitting antenna and Half-wave Dipole antenna as receiving antenna. We have chosen these standards because of the following facts: In RF energy harvesting: power transmission and reception all the nodes are arranged in such a manner that Transmitting antenna needs to transmit in a single direction. Isotropic antenna will be a total power waste here, we need a directional one. In fig. 1 Patch antenna is a Directive antenna thus its most of the power is concentrated in only one direction as compared to isotropic antenna. As receiving system i.e. Node must have an omni-directional antenna in order to catch maximum possible signal power from each and every direction. Half-wave dipole antenna, being an Omni directional one, works perfectly for this application.

## IV. RECEIVING ANTENNA

Antennas are dual, metallic devices which are designed for radiating and receiving electromagnetic energy. An antenna acts as a transitional structure between the guiding device (e.g. waveguide, transmission line) and free space. An Omni-directional antenna is an antenna which radiates radio wave power uniformly in all directions in one plane, with the radiated power decreasing with elevation angle above or below the plane, dropping to zero on the antenna's axis. A dipole antenna is a very basic type of radio antenna. It comes in various geometries with different feeding mechanisms and radiating elements. This antenna is the simplest practical antenna from a theoretical point of view Hertzian dipole is a small length of conductor δℓ (small compared to the wavelength λ) carrying an alternating current:

$$I = I_0 e^{j\omega t} \dots \dots \dots (2)$$

The antenna produces a truly Omni directional pattern in both E-plane and H-plane, which allows for non-intermittent communication that is orientation independent. The frequency of operation lies in the UHF RFID band, 902 MHz–928 MHz (centred at 915 MHz). A radio receiver may be a separate piece of electronic equipment, or an electronic circuit within another device. Devices that contain radio receivers include television sets, radar equipment, two-way radios, cell phones, wireless computer networks, GPS navigation devices, satellite dishes, radio telescopes, Bluetooth enabled devices, garage door openers, and baby monitors. In consumer electronics, the terms radio and radio receiver are often used specifically for receivers designed to reproduce the audio (sound) signals transmitted by radio broadcasting stations historically the first mass-market commercial radio application.

In WSN systems, we need to receive signals for a particular node [7]. Each node has its own Receiving antenna with proprietary circuitry. As stated earlier, receiving antenna must be an Omni directional one, best of them is Half-wave dipole antenna.

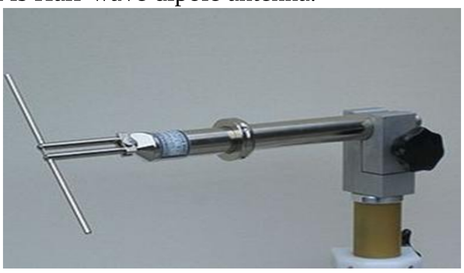

**Fig 3: Instantaneous voltage distribution Half-wave dipole antenna**

A cross a dipole antenna of total length λ/2. Typically a dipole antenna is formed by two quarter-wavelength conductors or elements placed back to back for a total length of *L* = λ/2.

## V. SIMULATION RESULTS

Simulation results show that how much Power is received at the Half-wave dipole antenna in the Node which is at a random location in the FOV of patch antenna. We can calculate RF Power received at a particular Node and accommodate the 2D as well as 3D orientation of the node in the field. First plot is a 3D revolving Plot showing you the exact location of the Node (N). Next Plot gives the approximate RF Power received (in dB) at a particular node. This simulation can only accommodate maximum of 10 Nodes, so to get better graphics and error-less calculations. Fig: 4 shows the 3D plot for exact location of the Node (N=1) and

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approximated RF power received. Fig: 5 shows the 3D plot for exact location of the Node (N=2) and approximated RF power received. Fig: 6 shows the 3D plot for exact location of the Node (N=5) and approximated RF power received. Fig: 7 shows the 3D plot for exact location of the Node (N=10) and approximated RF power received.

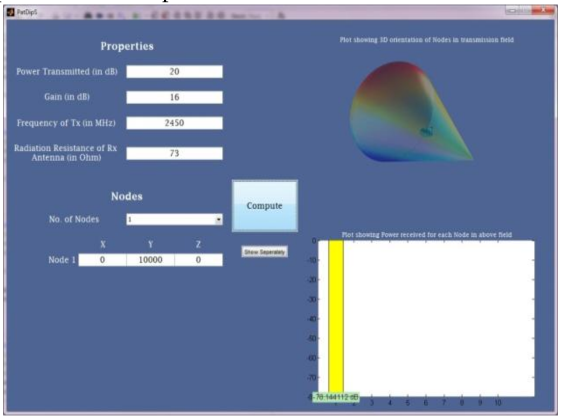


**Fig: 4: 3D plot for exact location of the Node (N=1) and approximated RF power received.**

Table: 1 shows the Distance of Omni Directional Antennas from Patch Antennas, Power transmitted to load, Voltage induced for the Detector Circuit and Current induced for the Detector Circuit. Fig 8 shows the variation of power received with the distance between Omni Directional Antennas and Patch Antennas. Fig 9 shows the variation of voltage induced in the detection circuit with the distance between Omni Directional Antennas and Patch Antennas. RX power and Vrms are inversely proportional to the distance.

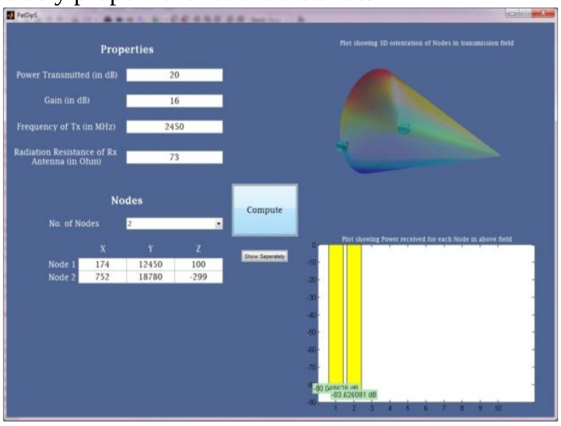


**Fig: 5: 3D plot for exact location of the Node (N=2) and approximated RF power received.**

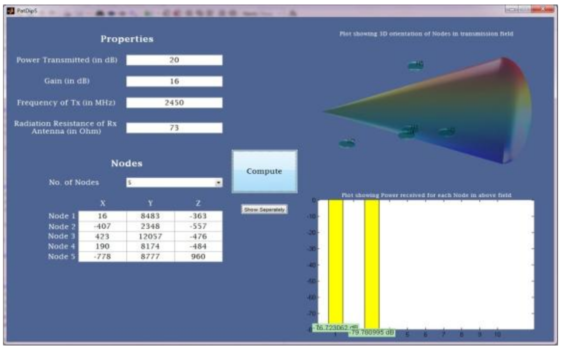


**Fig: 6: 3D plot for exact location of the Node (N=5) and approximated RF power received.**

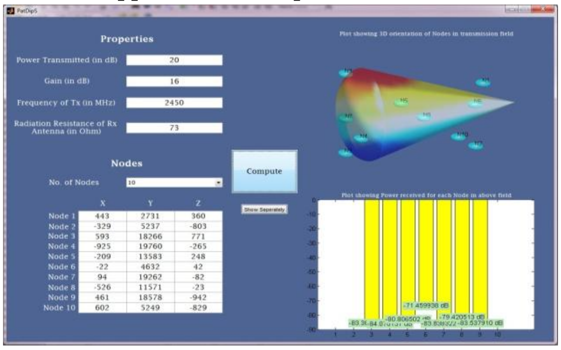


**Fig: 7: 3D plot for exact location of the Node (N=10) and approximated RF power received.**

| Distance of Omni D. Ant. (or NODE) from Patch Ant. (in m) | 392 | 220 | 124 | 70 | 39 | 22 | 12 | 6.97 | 3.92 |
|---|---|---|---|---|---|---|---|---|---|
| Power transmitted to load in NODE, P(load) (in dB) | -50 | -45 | -40 | -35 | -30 | -25 | -20 | -15 | -10 |
| Power transmitted, P(load) (in dBm) | -20 | -15 | -10 | -5 | 0 | 5 | 10 | 15 | 20 |
| Voltage induced for the Detector Circuit (Vrms) (in V) | 0.053975 | 0.096092 | 0.170867 | 0.303565 | 0.5397 | 0.95 | 1.707711 | 3.0365 | 5.397588 |
| Current induced for the Detector Circuit (Irms) (in A) | 0.000369 | 0.000658 | 0.001170 | 0.002079 | 0.003696 | 0.0065 | 0.011696 | 0.020798 | 0.036969 |

**Table 1: Power Received**

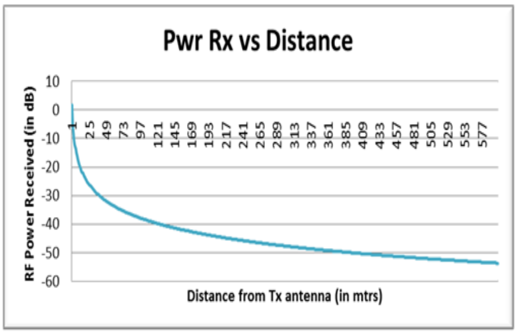


**Fig 8 Variation of power received with distance**

Fig 10 shows the variation of current induced in the detection circuit with RF power. This current value is not the actual value that we are going to use in further calculations as it depends over the Load connected at the output.

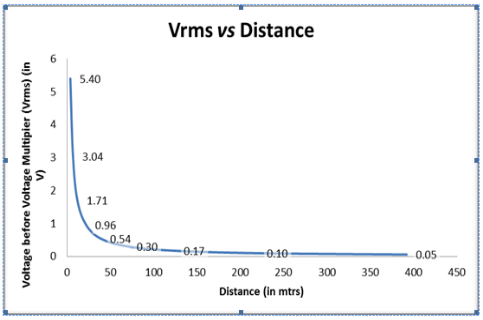


**Fig: 9 Variation of voltage induced with the distance**

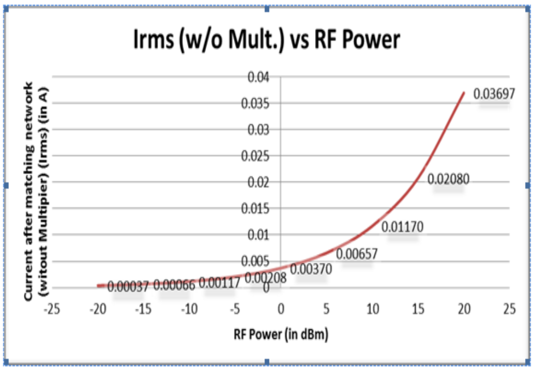


**Fig 10 shows the variation of current induced in the detection circuit with RF power**

## VI. CONCLUSIONS

In this paper, the performance of the transmitter and receiver antenna on the energy harvesting capability of wireless sensor network is presented. Wireless sensor nodes are place in the transmission field and the power received for each node is calculated with different number of nodes varied from 1 to 10. Simulation results shows that received power and Vrms (induced voltage) are inversely proportional to the distance. The received power or the Voltage induced after matching network decreases much rapidly.

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