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INVESTIGATION OF THE DISTRIBUTIONS OF THE HARVESTING POWER USING SENSOR NETWORK

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Abstract:-*This paper formulates the location-dependent power harvesting rates in generalized 2D placement of multiple Radio Frequency (RF) Energy Transmitters (ETs) for recharging the nodes of a wireless sensor network (WSN). In this paper, a new design has been proposed for the energy harvesting device, which could enable radio frequency (RF) to remove energy from electromagnetic waveIn particular, we study the distribution of total available and harvesting powers on the entire WSNWe also analyze the performance of energy transfer in WSN through electrical outage probability and harvested voltage as a function of wireless power obtained from ETS.Our results reveal that the network wide received power and the harvested voltage over the network follows a Linear distribution.*

Keywords: *- RF energy harvesting circuit, voltage multiplier*

1. Introduction:

The rectification of microwave signals to DC power has been proposed and researched in the context of high-power beaming since the 1950s [8]. It has been proposed for helicopter powering [9], solar power satellite (SPS) [10], the SHARP System [11], and recently for RFID system. The principle of this kind of power transfer is presented in the Figure 1.

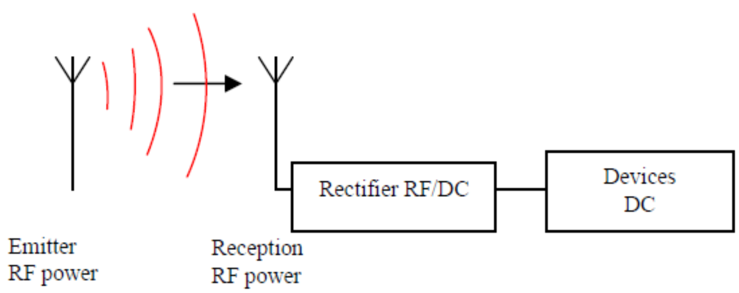

Fig. 1. Conceptual view of the WPT system.

In this paper we focus on ambient RF energy. We propose to use the energy from commercial RF broadcasting stations like GSM, TV, WIFI or Radar to supply energy for wireless sensor nodes or other applications. This powering method can be especially interesting for sensor nodes located in remote places, where other energy sources like solar or wind energies are not feasible.

The DC power depends on the available RF power and conversion efficiency RF/DC.

$$P_{dc} = \eta_{RF/DC} . P_{RF}$$

The rest of paper is organized as follows. In section 2 we discribed Wireless Sensor Network and Energy Harvesting. In section 3 we detrmine the harvestable energy in the plain. In section 4 we deployed rand node and their uses. Finally, Section 5 concludes the paper.

2. RELETED WORK

Recently many approaches and optimization techniques have been proposed to maintain the energy of the sensor device and extend the lifetime of the sensor network.

In [1] authors presented to recharge the wireless sensor network (WSN) nodes, the location-based power harvesting rate in 3D placement of 2D and multiple radio frequency (RF) energy transmitters (ETs).

In [2] authors presentedan overview of principles and requirements for powering wireless sensors by radio-frequency (RF) energy harvesting or transportation.The feasibility of harvesting is discussed, from which conclusions arise that RF energy transport is preferred for giving power to small size sensors.

In [3] authors consider the wireless power communication network which can work continuously, because the base station (BS) transmits energy for many energy harvesting (EH) information transmitters.These employ "harvest then transmit" mechanism, since they harvested all their energy during the last BS air transit to broadcast information to BS.

In paper [4], a new design has been proposed for an energy harvesting device, which is capable of removing energy from radiofrequency (RF) electromagnetic waves.Compared to general alternative energy sources such as solar and wind, there is minimal energy density in RF storage.

In [5] authors Autonomous sensor networks require energy harvesting techniques, for which it is not possible to use a power source from recharging a certain utility or manual battery.An energy storage device (for example, a solar cell) changes the energy of different types of electricity to supply for a sensor node.However, since it can produce energy only at a limited rate, the energy saving mechanism plays an important role in reducing the energy consumption in the sensor node.

3. 2D ENERGY MODEL: In this section we generate expressions for the total harvested energy from two ET on any place in the plane. We then expand these expression in the case of N ET in the plane. ET and sensor are considered to be equipped with omnidirectional dipole antennas, and ET transfers

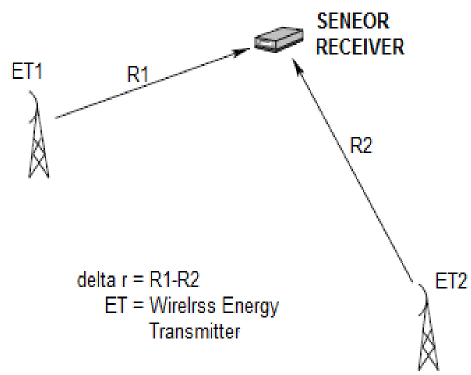

fig .2. Transfer the distance to R1 and R2 for a receiver node at two ET at the same frequency

RF waves with the same initial stage. RF waves carry energy in the the form of electric field. Distance range (R) is measured by a receiver device from the electric field (E):

$$E = \sqrt{Z_0 S} e^{-jkR} = \sqrt{Z_0 S} e^{-j(\frac{2\pi}{\lambda})} R$$

Where Z_0 = constant indicates that there is impedance of plane wave in free space [6].

S = power spatial density at distance R and k is the wave number of the energy wave.

Here $S = \frac{P_t G_t}{4\pi R^2}$, where P_t is output power and G_t is transmitter gain of the ET.

Total electric field E_T at receive both Ets transmitting energy:

$$E_T = E_1 + E_2 = \sqrt{Z_0 S} e^{-jkR1} + \sqrt{Z_0 S} e^{-jkR2}$$

Where ET_1 and ET_2 is the magnitude of the field can be expressed as:

$$|E_T| = \sqrt{|E_1|^2 + |E_2|^2 + 2|E_1||E_2|\cos(k(R_1 - R_2))}$$

Therefore, density of the total transferred power at the receiver is:

$$S_T = \frac{|E_T|}{Z_0} = S_1 + S_2 + 2\sqrt{S_1 S_2}\cos(k\Delta r),$$

Where $\Delta r = |R_1 - R_2|$ i.e. difference of the distances between the two Ets and the receiver.

$$S_T = \frac{G_1 P_1}{4\pi R_1^2} + \frac{G_2 P_2}{4\pi R_2^2} + \sqrt{\frac{P_1 P_2 G_1 G_2}{R_1^2 R_2^2}}\cos(k\Delta r),$$

Where P_1 and P_2 are transmission powers and G_1 and G_2 are the transmission gain of ET_1 and ET_2 respectively.

$$P_T^r = S_T A = S_T G_R (\frac{\lambda^2}{4\pi}),$$

Where G_R = gain of RF harvester antenna.

The total received power from two ET_S would be as follows:

$$P_T^r = P_1 G_1 G_r (\frac{\lambda}{4\pi R_1})^2 + P_2 G_2 G_r (\frac{\lambda}{4\pi R_2})^2$$
$$+2(\frac{\lambda}{4\pi\sqrt{R_1 R_2}})^2 G_r \sqrt{G_1 G_2}\sqrt{P_1 P_2}\cos(k\Delta r).$$

If two energy transmitters have same gain G_t and transmission power P_t ,then total received energy at the receiver node simplifies to:

$$P_T^r = P_t G_t G_r (\frac{\lambda}{4\pi})^2 (\frac{1}{R_1^2} + \frac{1}{R_2^2} + \frac{2\cos(k\Delta r)}{R_1 R_2}).$$

According to the RF wireless charging model, the amount of harvested power would be

$$P_H = \eta P_T^r$$

Where η =RF-to-DC conversion efficiency

The harvested voltage could be found by

$$V_H = F(P_T^r)$$

where the function F relates input power to the harvested voltage and depends on the energy harvesting circuit[7].

Similarly, we can get total received power from N Ets as follows.

$$P_T^r = G_r (\frac{\lambda}{4\pi})^2 \left[\sum_{i=1}^{N} \frac{P_i G_i}{R_i^2} + \sum_{\substack{i=1 \\ i \neq j}}^{N} \sum_{j=1}^{N} \frac{\sqrt{G_i G_j P_i P_j}}{R_i R_j} \cos(k(\Delta r_{ij})) \right]$$

Where P_i and G_i are the transmission power and transmission gain of ET_i respectively.

If all ET_s have same antenna gain and transmission powers then the total received energy on the receiver node simplifies the following: $P_T^{\ r} = P_t G_t G_r (\frac{\lambda}{4\pi})^2 \left[\sum_{i=1}^{N} \frac{1}{R_i^{\ 2}} + \sum_{\substack{i=1 \\ i \neq j}}^{N} \sum_{j=1}^{N} \frac{\cos(k(\Delta r_{ij}))}{R_i R_j} \right]$

4. ANALYSIS AND SIMULATION RESULT:

In this section, we analyze the performance of Wireless Energy Transfer on Sensor Network with more than one ET. A variable number of ETs is linearly deployed in a $20 \times 20\ m^2$ grid. Each ET transfers RF energy at center frequency 915 MHz with Effective Isotropic Radiated Power (EIRP) equal to 4 W, which is the maximum transmission power allowed by the Federal Communications Commission (FCC) for omni-directional energy transfer.All ET Transmission parameters of the same are considered identical.The parameters of the energy harvesting receiver have been determined with the linear antenna benefit of 6 dBi, according to dual-stage phase energy harvesters [6].Energy transfer of many ETSs across the entire WSN has been analyzed. At the end, the selection of all sample points from the Mesh Grid range [0,20] has been done with interval 0.5. If 8all ETs transmit omni-directional RF power at the same frequency, while in the second scenario (i.e., FDMA like) each ET transmits power at a different frequency.We focus on our analysis on the study of network-wide performance of two energy-efficient electrical outage probability and concurrent wireless energy transfer in the case of harvested power and voltage.

A.Power Outage Probability:

Figures 3 show that PDF distribution of power received for different numbers of ET, i.e. 10, 20, 30 and 40. This figure shows that the received power over the network has Log-Normal distribution (Gaussian distribution in a logarithmic scale such as dBm).

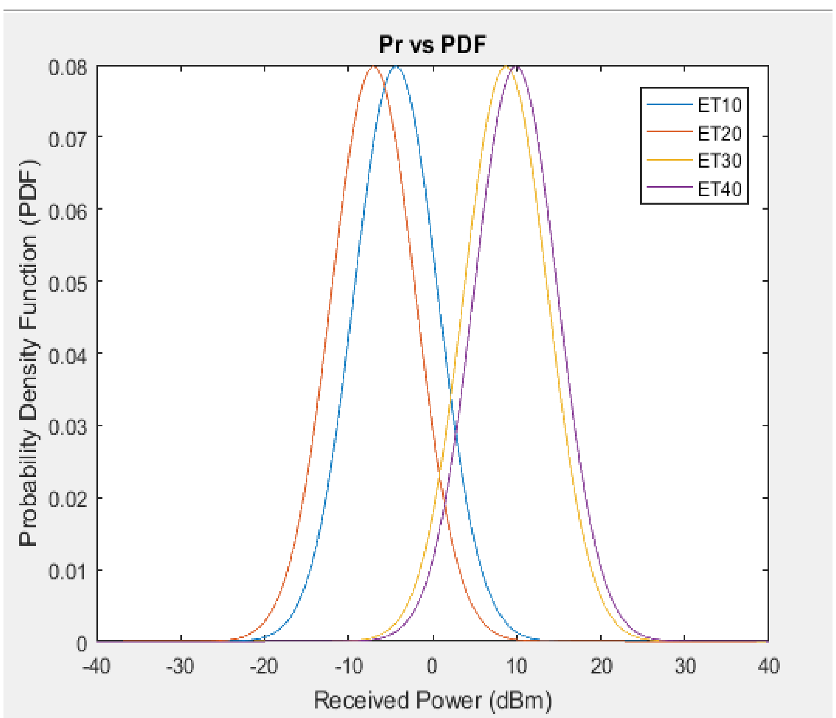

Fig.3. Log-Normal distributions of the network widereceived power from multiple ETs

B.Plotting of CDF distributions of Received Power for different of ETs: Figure 4 shows the increased effect of ET on the power received on the network. . Interestingly, the probability that the received power from multiple ETs becomes larger than 0 dBm is 10% for 10 ETs, 20% for 20 ETs, 94% for 30 ETs, and 97% for 40 ETs.

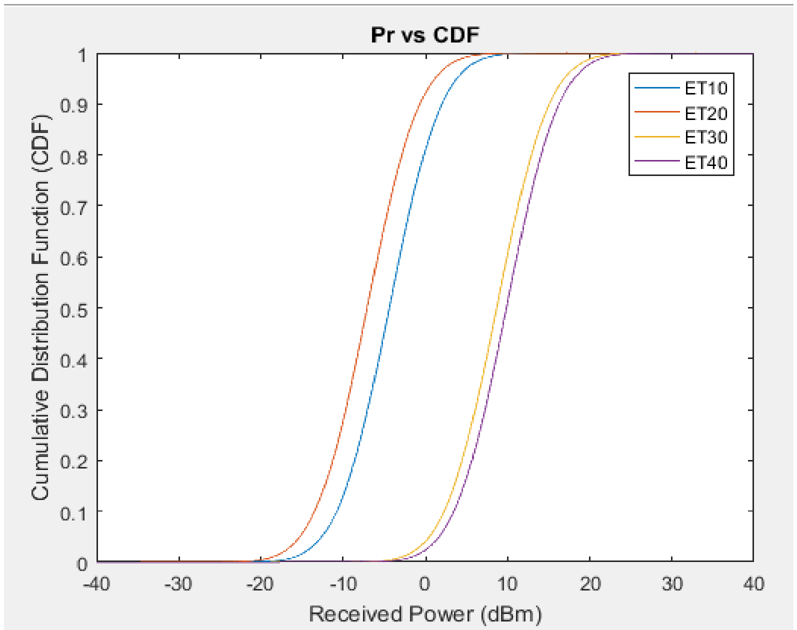

Fig. 4: Power outage probability based on CDF of the received power from multiple Ets

4.2.Harvested voltage and power: We next investigate the distributions of the harvested power and voltage over the sensor network.

A. Plotting of CDF of the Harvested Voltage over the whole sensor network: Fig. 5 shows the CDF of harvested voltage in the network. We see that the probability that the harvested voltage is less than 5V is 85% for 10 ETs, 80% for 20 ETs, 75% for 30 ETs, and 70% for 40 ETs.

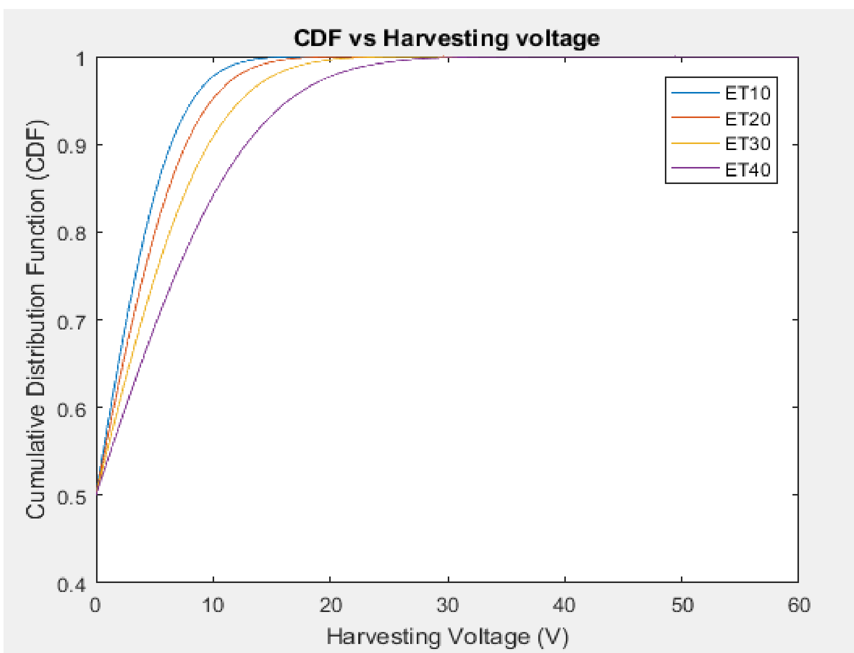

Fig. 5: CDFs of the harvested voltage over the network

B. Plotting of PDF of the Harvested Power over the whole sensor network: Figures 6 shows PDF of the harvested power and harvested voltage over the whole sensor network for 10, 20, 30 and 40 ETs. Importantly, it is shown that harvested voltage over network has Rayleigh distribution, and harvested power clearly shows a dual-stage behaviour in its distribution.

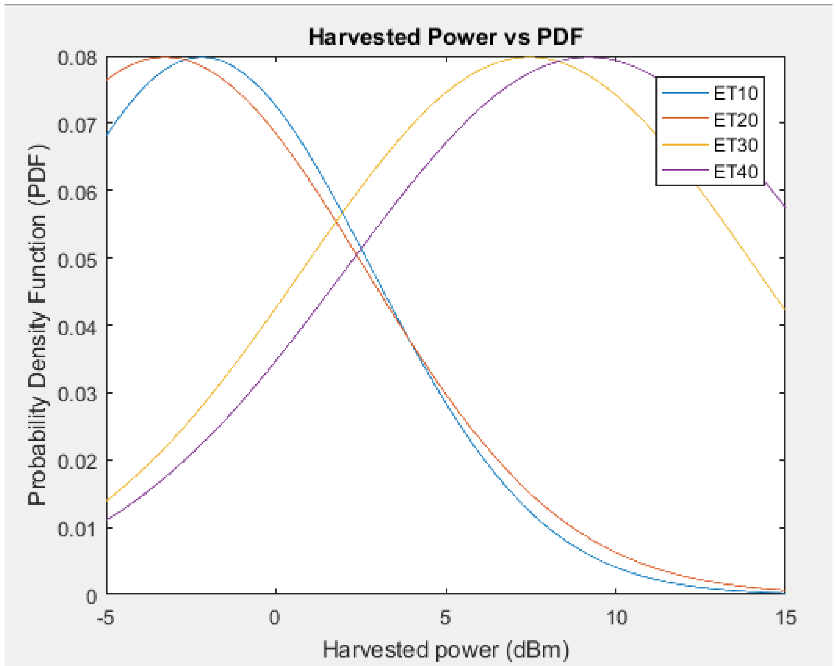

Fig. 6: Dual-stage distributions of the harvested power (dBm) over the sensor network with different number of ETs.

5. CONCLUSION: In this paper we acquired expression for the total harvested production at any place in WSN at any place, with many ET, while capturing spatial correlation between ET and their constructive and destructive energy transfers. We provide formulas for plane and 2D WSN deployments. In this paper we also deployed linear node on x and y axis respectively. Which will help us to calculate the distance between two nodes. Our results show that in Linear distribution received power from multiple ETs over the network and the network energy interference have Log-Normal distributions. We further observed that the harvested voltage over the network has a Rayleigh distribution.In the future, the linear distribution energy transmitter can be used to use the RF energy of the sensor network, along the linear road side.

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