Hybrid Solar-RF Energy Harvesting using Relaying Protocols

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***Abstract*—RF Harvesting is one of the new methods of Energy Harvesting which has received a lot of attention in the current days . From charging small sensors to charging of laptops etc., RF Harvesting is very much efficient . RF Harvesting has also being proven very useful for energy harvesting in UAVs [14] where hybrid models of Solar and RF Harvesting are employed [4] . Now if we want to extract information as well as harvest energy from RF signals we have to follow relaying protocols . There are two relaying techniques based on the time switching and power splitting receiver architectures . One is time switching-based relaying (TSR) protocol[1] and other one is power splitting-based relaying (PSR) protocol[2] are proposed to enable energy harvesting and information processing at the relay. This paper mainly focuses on how we can model a Hybrid Solar-RF Energy Harvesting System using Relaying Protocols .**

***Index Terms*—Hybrid energy harvesting , communication protocols, simultaneous wireless information and power transfer , wireless power transfer, amplify-and-forward, receiver operation policy , solar cells, astable multivibrator , 555 Timer**

I. Introduction and Motivation

A general architecture of RF Energy Harvesting is given below . The Information gateways as in Fig 1. are the relays or the base-stations.

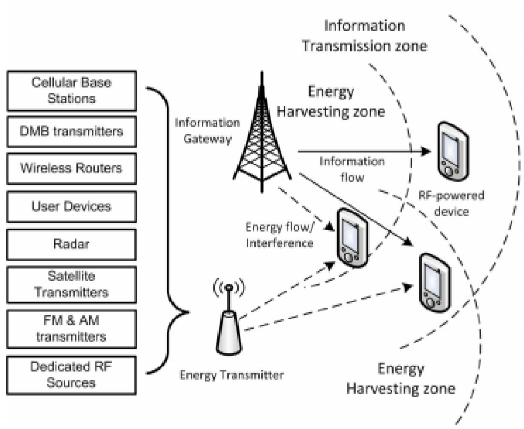

Fig. 1. Architecture of a RF Harvesting System with separate information gateways and RF Energy Source [1]

The network nodes are the user devices which are communicating with the relays . In certain model designs the Information gateway and RF energy source can be the same as shown in the Fig 2 . The RF energy flow is represented by the dotted lines while the solid lines represent the flow of information [15]

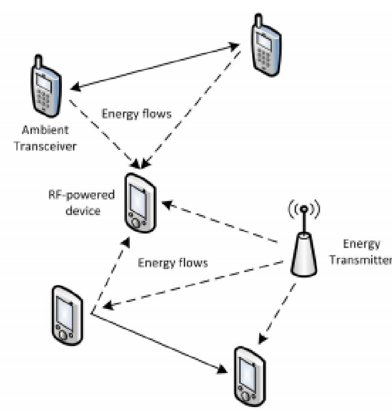

Fig. 2. Architecture of a RF Harvesting System without separate information gateways and RF Energy Source [1]

Now in the Relay or the nodes of such RF Harvesting systems we would like to apply the RF Harvesting Protocols . A basic system model is given below :

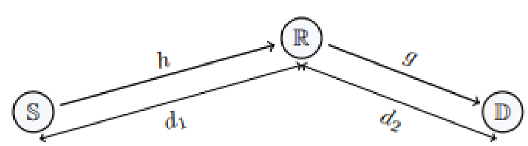

Fig. 3. System Model for TSR PSR Protocol [2]

We will be applying our Relaying protocol at node R or the Relay as in Fig 3.

The block diagrams of TSR and PSR protocols [2] are given in Fig 4 and Fig 5 .

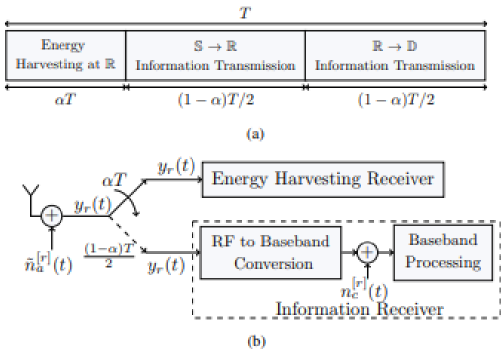

Fig. 4. (a) Demonstration of the key parameters in the TSR protocol for energy harvesting and information processing at the relay. (b) Block diagram of the relay receiver in the TSR protocol.[2]

$y_r(t)$ is the received signal at the relay node . α is the a constant which governs the equations of the time of switching of relays . The Total time is T and how the time is splitted up is shown in Fig. 4(a) . The term $n_a(t)$ is the narrow band Gaussian noise

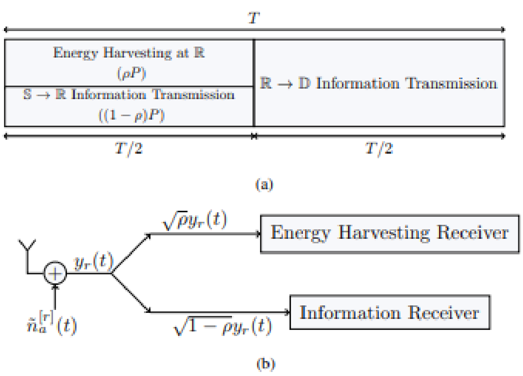

Fig. 5. (a) Demonstration of the key parameters in the PSR protocol for energy harvesting and information processing at the relay. (b) Block diagram of the relay receiver in the PSR protocol.[2]

$y_r(t)$ is the received signal at the relay node . The term $n_a(t)$ is the narrow band Gaussian noise . ρ is a constant (called as power fraction) which governs the equations of the power division . ρP power is used for the task of Energy Harvesting and $(1 - \rho)$P power is used for the task of source to relay information transmission . This can be clearly understood from the Fig 5. (a)

In both of these figures , we can clearly see that there is a Energy Harvesting Block which harvests the RF Energy. **Our main contribution is that we are replacing the RF Energy Harvesting region of both protocols with a Hybrid Solar-RF Hybrid model to harvest more amount of energy and also to increase the efficiency of harvesting**

We have shown our proposed model in the form of block diagrams in Fig 6. and Fig 7.

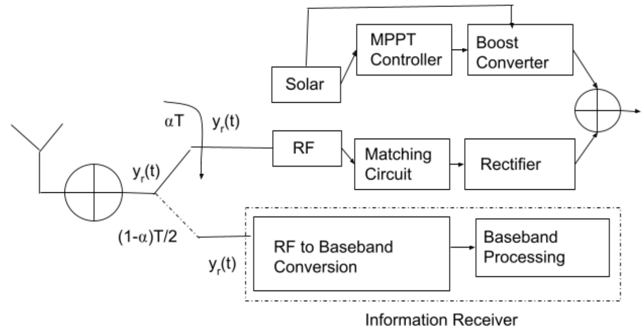

Fig. 6. Block diagram of the relay receiver in the TSR protocol using proposed Hybrid Solar-RF technique

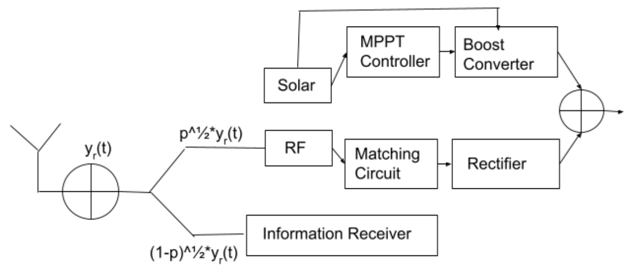

Fig. 7. Block diagram of the relay receiver in the PSR protocol using proposed Hybrid Solar-RF technique

II. Previous Works

Our current work is based on relaying protocols which involves part energy harvesting [18] and part information processing. Observing the paper done by the authors in [2] ,we came across two important protocols namely time switching-based relaying (TSR) and power splitting based relaying (PSR). The TSR protocol as discussed is implemented by dividing the time by an optimal fraction so that a part of the received energy at the relay is used for harvesting energy [20] and the other part for information processing. For PSR,the time was kept half for both the mechanisms but the total supplied power was divided in an optimal fraction.This paper mathematically compared the amount of throughput and net power harvested by calculating them in terms of outage probability and ergodic capacity.Which brings us to different cases,i.e, Delay tolerant transmission and delay limited transmission.

Delay Limited Transmission-In this mode,the maximum amount data that can be decoded is limited as the receiver has to decode it block by block thus mathematically this mode was implemented by considering the factor of outage probability which is when the information transfer rate is below the threshold rate.

Delay Tolerant Transmission-This model [19] as seen in the paper was mathematically modeled by taking the ergodic capacity as a determining factor.

This paper focused on finding an optimal value of α for which we could get maximum throughput. On studying further it was found that the value α has maximum peak value for which we are able to get maximum throughput.For lowerα values,throughput was low as less time was there for energy harvesting but for higher αvalues(all this considered against the peak α values) the amount time used for energy harvesting though increased ultimately decreased signal processing time,consequently it decreased the total throughput.

The authors in [3], proposed a hybrid system consisting of solar energy and RF energy harvesting system.This system was proposed to apply to any system which could be used simultaneously during day time through solar energy and during night via RF harvester.More detailed work was observed in [4] ,where the solar harvesting part was implemented by using MPPT.The Maximum Power Point Tracking algorithm(MPPT) is a technique wherein we try to extract the maximum power obtainable through any PV module.A boost converter was also included so that output power could be maximised while keeping the net weight of the system optimized. The RF harvester involved a voltage multiplier which converted AC to DC power and it also stepped up the net output voltage.Therefore,to complete the overall system of charging UAV models in this case,via hybrid solar and RF system,the system of UAV was charged using a stabiliser and a booster which got it's power from the summing up of both the RF and solar energy harvester.

III. Relaying Protocols

According to the paper "Relaying Protocols for Wireless Energy Harvesting and Information Processing" [2] TSR Protocol is considered better than PSR protocol in terms of throughput [17]

So we will be focusing on using the TSR protocol for our model in this paper for illustration and simulation purposes . The Monte Carlo based MATLAB simulation for TSR Protocol given in Fig 8.

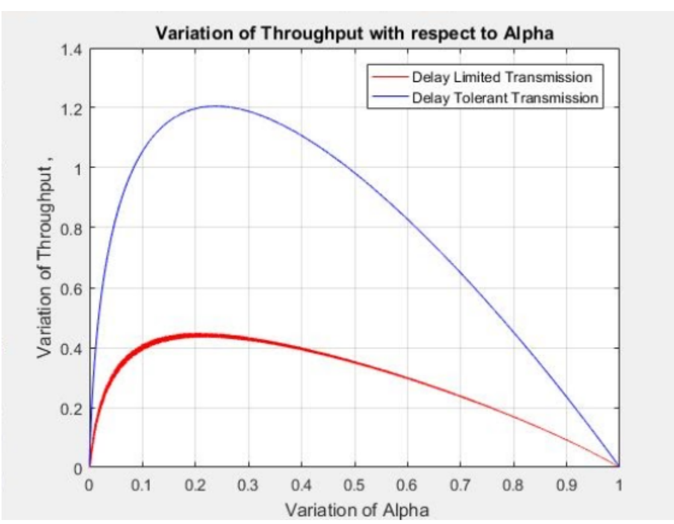

Fig. 8. Throughout variation at destination node for TSR Protocol

IV. Hybrid Solar and RF

Now-a-days hybrid solar and RF energy sources are used a lot for getting high output power even at night when the sun is not present.

A. Solar Energy Source

Solar energy is a very common source of energy used since a long time. We try to simulate the solar energy source by using a 5V solar panel in Proteus.With the weather condition,sunlight varies so efficiency also varies and so on an average we can get this amount of value in our output from a solar panel. But main disadvantage of solar energy is that at night we cannot get sunlight so the relay system has to depend on the stored energy in the battery.From the paper [4] we use DC-DC boost converter to boost the voltage output of the solar output voltage which maximises the efficiency of stand alone solar power.

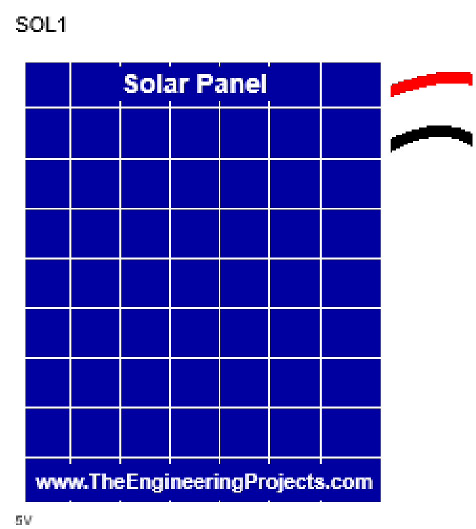

Fig. 9. 5V solar panel in Proteus

B. Boost Converter

It is a device [12] which boosts the output voltage of a solar panel by using an inductor and a switching MOSFET.The duty cycle of the control voltage of the MOSFET can be controlled by a Maximum Power point tracking controller(MPPT) [8].Further details of boost controller circuit can be found in paper [7][10] .Our Proteus simulation of solar panel and boost converter is given in the Fig 10.

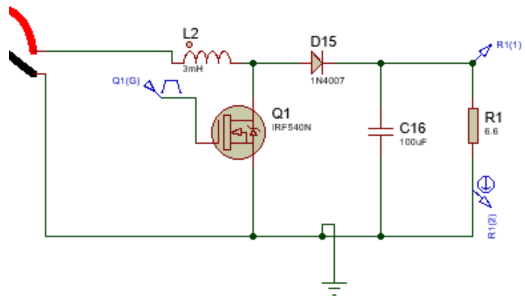

Fig. 10. Boost Converter

C. *Seven Stage Multiplier*

A major disadvantage of solar power is that it is not available at the time of night.But ambient RF signals are always available so if RF energy harvesting is used then it can charge the battery at night also.But the voltage comes from RF is very small.That is why we use a seven stage voltage multiplier circuit [5][6][7] to increase the voltage level. The schematic of the circuit is given in Fig. 11

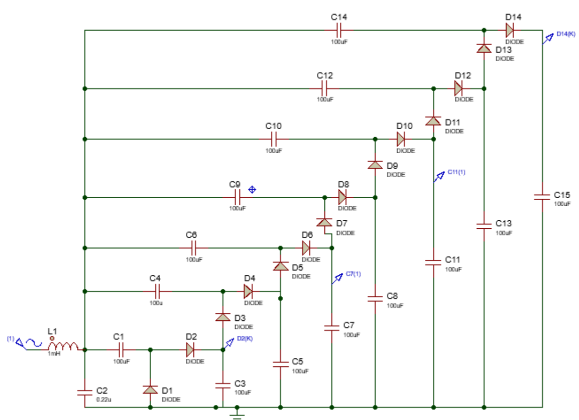

Fig. 11. Seven Stage Voltage Multiplier to Enhance the Voltage Output of RF Section

D. *Hybrid Energy Harvesting System*

This solar and RF energy is sufficient for giving input to charging system of the relays. But the voltage is fluctuating rapidly so we need a charging system which sum-up the two voltage sources and gives a high and stable output voltage [13]. The schematic is given in Fig 12.

E. *Block diagram for Hybrid Solar-RF Energy Harvesting*

The complete Block Diagram for the Hybrid Solar-RF Energy [11] Harvesting is given in Fig 13.

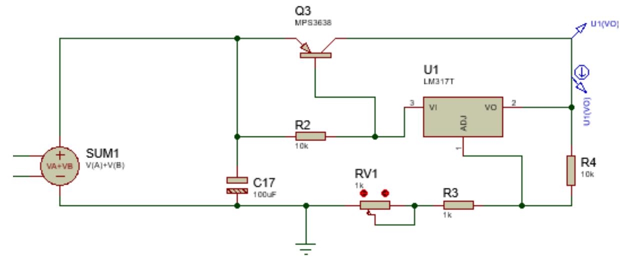

Fig. 12. Charging system to sum up the voltage of solar and RF section and produce a stable output

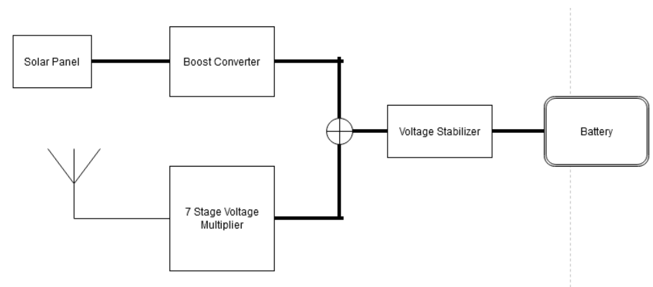

Fig. 13. Block Diagram of a Hybrid Solar and RF Energy system

V. Our Proposed System

Our paper is focused on the implementation of the TSR protocol in the hybrid Solar-RF harvesting system.We have tried to implement the TSR protocol based on the previous works and tried to incorporate it in the existing hybrid solar-Rf harvesting system.As we have discussed that the TSR protocol is way better than PSR [2] so we try to implement the TSR protocol in hybrid-RF energy harvesting system.

The TSR protocol is solely based on the value of α which determines the net throughput,i.e,rate of transfer of information.Thus,our ultimate goal lies in the fact that inorder to have a maximum signal transfer from a relay,we must set the value of α according to our needs.Our main motive in this paper is to somehow implement this variation of α in the above hybrid system so that we could determine the maximum amount of energy that we could get from RF energy harvester while maintaining just ample power for information processing. The TSR protocol's throughput is dependent on α so we try to intiate the switching feature of α by an IC called 555 timer.Using 555 timer IC we try to design the astable multivibrator.The use of multivibrator at this juncture is used to incorporate the relaying protocol in our hybrid system.The astable multivibrator is used to generate a pulse which on it's application to the gate of MOSFET would behave as switch.The switch's position would dictate the value of α for the harvesting or the information processing time .This position in turn would be controlled by the ON time and OFF time of the astable multivibrator,i.e,it's duty cycle.Thus,inorder to choose our desired α on the basis of the above discussed graphs for optimal throughput we would have to design our astable circuit in such a way that the duty cycle of the circuit becomes the deciding factor for the value of α.

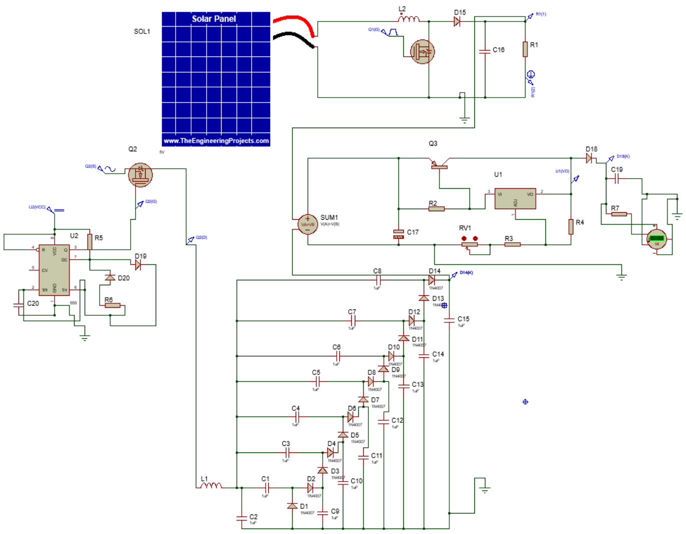

Fig. 14. Our proposed hybrid system with IC 555 as astable multivibrator.

From Fig. 8 the optimum throughput is obtained at the value of 0.25. So we have designed our astable multivibrator such that it can generate a pulse with 25 percent duty cycle.Now we have measure the voltage and power across a restive load.On increasing duty cycle, the amount of harvested power also increases but in general as discussed previously [2] on using increased α value the net throughput would not increase unlike the harvested power.

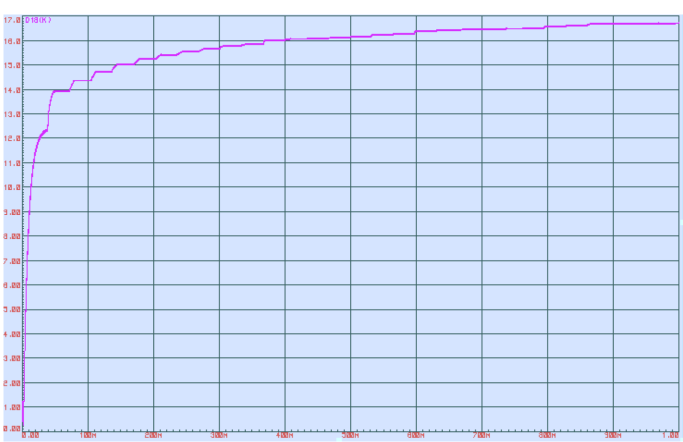

Fig. 15. Voltage Output of Our Entire Hybrid System System

Maximum stable output voltage obtained form the circuit is 16.5V.Maximum power obtained form the circuit is 0.27VA after stabilization, which is sufficient to charge a battery of relay so that it can process the information during (1-α)*T time.

VI. Future Works

We plan on improving our proposed model by :

1. Increasing SNR Ratio

2. Increasing the output voltage which is supplied by the hybrid Solar-RF Model

3. Trying to power electronics which require moderate to high voltage .

4. Modify our model to utilise both Ground based and Space Based Solar Powers . The main idea is that SBSP [9]can be harvested in space in satellites and then they can beamed down to earth in the form of RF Signals which then can be utilised for energy generation . Our goal is to create a model which will be able to outperform the conventional energy generation or harvesting techniques . The Space Based Solar Power Concept is shown in Fig. 16

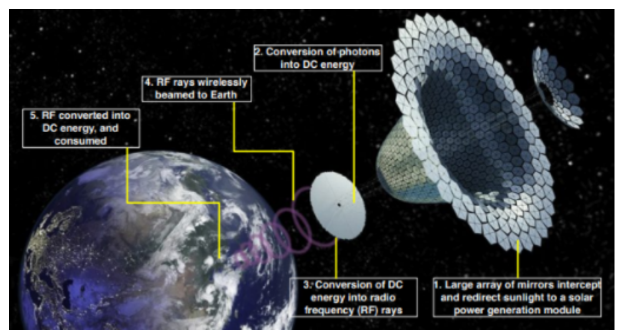

Fig. 16. Space based solar power concept

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