Solar-Powered RF Signal Generation for Energy Harvester Applications

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Table of Contents

Abstract

Solar-powered RF signal generation for energy harvester applications is a senior project that will be completed during the 2017-2018 school year. This project will use a Photovoltaic panel to harness solar energy and convert it into electrical energy. That electrical energy will be used to transmit a 915 MHz EM wave which will be used in a wireless power transfer system. The project is to be designed for 24/7 operation, even in times of low insolation.

I. Introduction

The goal of this project is to design a 915 MHz RF transmitter powered by solar energy, instead of utility power. The system will have the capacity to store backup power for times with low levels of insolation. It will be built for 24/7 operation.

The RF transmitter frequency of 915 MHz was chosen since it was used in the Panduit wireless power transfer project completed in 2016-2017**.** In addition, the transmitter may be used as a source of RF power for charge pumps designed for 915 MHz operation in a concurrent senior project. This wireless powering system has potential applications for powering remote sensors and controllers. The output power of the transmitter will be limited to 1 Watt per Federal Communications Commission (FCC) regulation. The system will run with a variable duty cycle operation as opposed to continuous operation.

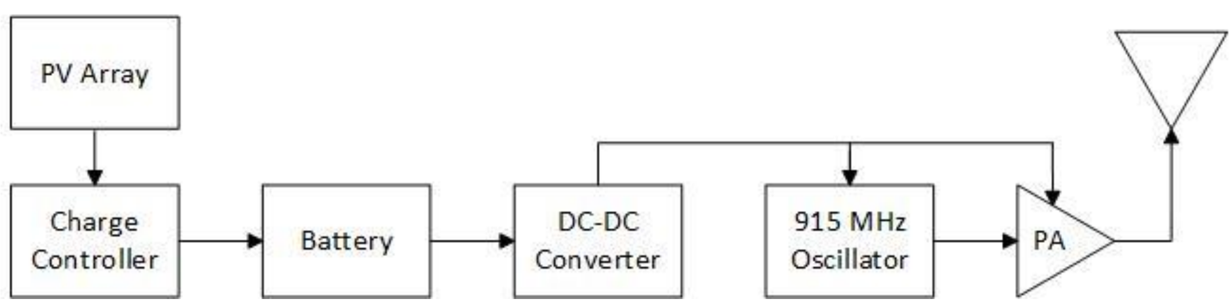

Fig. 1 Block Diagram of Solar-Powered Signal Generation for Energy Harvester Applications

The block diagram of the system is shown in Fig. 1. Incident solar radiation is converted to DC power by the Photovoltaic (PV) array. The important parameters for the PV array are voltage, current, and power outputs as a function of insolation. The array connects to the charge controller which interfaces to the battery. The important parameters for the charge controller are input and output voltage, current, efficiency, power, and how well it can regulate these parameters.

The battery specifications are capacity, voltage, current, and power (steady state and peak). The values of the parameters for these 3 subsystems (see Fig. 2 and 3) will be determined in consideration of the RF subsystem requirements. These include supply voltage and current for both the oscillator and power amplifier (PA) as well as the duty cycle of the RF transmission.

The PV subsystem and RF subsystem will be connected by a DC-DC converter. The DC-DC converter will be used to change the voltage level of the battery to the voltage levels required by the oscillator and power amplifier. There are two methods being considered that can be used to get the two voltage levels required by the two components. The first method is using two separate DC-DC converters– one for each component. The second method would be to use a single DC-DC converter and place a resistor in series with the power amplifier to lower the Vcc. The second method will be cheaper, but will incur more loss and therefore less efficiency in the system, while the first method will be more expensive, but also more efficient.

II. Specifications

As stated earlier, the oscillator will generate a 915 MHz signal. The signal will be amplified by a power amplifier. The output power will not exceed 1 Watt in accordance to FCC regulation. The system will run as a variable duty cycle system. It will also be built for 24/7 operation. The specs of each part are listed below:

Table 1 Specifications of RF Subsystem Parts

Part Name	Part Number	Vcc	Current	Power Output	Gain	Frequency	Impedance
Voltage Controlled Oscillator	ZOS-1025+	12V	140mA	8dBm		685MHz-1025MHz	50Ω
Power Amplifier	ZX60-V63+	5.0V	69mA	18.5dBm	21dB	0.05-6GHz	50Ω

Table 2 Specifications of PV Subsystem Parts

Part	Part Name	Type	Rated Panel Power	Nominal Battery Voltage	Max Voltage	Panel Short-Circuit Current
PV Panel	BP 350		50W	12V	17.5V	3.2A
Charge Controller	Genasun GV-4	MPPT	50W	12V	27V	4A

The battery will need to be a deep-cycle flooded battery or an AGM battery, which are types of lead-acid batteries. The charge controller is only compatible with lead-acid batteries. Deep-cycle batteries are cheap, efficient, but hazardous so they cannot be used on campus, while AGM batteries are a bit more expensive but safe to use. On average for the worst month of the year, December, there will be about 2-2.9 hours of useable solar energy collected by the PV array. That means that about 100-145 Watt-hours is the maximum potential power output from the solar panel into the battery. By doing some calculations, it was found that the RF subsystem consumes about 0.076 Watt-hours of energy. In a 24 hour period, it consumes 1.824 Watt-hours of energy. The worst-case efficiency of the charge controller is 96%, according to its data sheet. This would mean that a range of 96-139.2 Watt-hours would be available for the battery. This amount of stored energy would be enough to run our system for a few days, during a string of worst-case scenario days. After looking into several battery options, the current best choice would be the Concorde Sun Xtender PVX-340 which is an AGM 12 Volt battery with a capacity of 408 Watt-hours.

III. Parts

The 915 MHz oscillator and power amplifier are currently being researched and will most likely be chosen from Mini-Circuits or Hittite. The solar panel that will most likely be chosen is the BP 350 that the department already owns. Along with this, the charge controller that is currently being researched is the Genasun GV-4. Once these parts are chosen, a battery with enough capacity will be picked out, along with a DC-DC converter. Below are the current parts to be ordered:

- ZOS-1025+: 915 MHz Oscillator (Mini Circuits)
  - 12V max operating voltage, 8dBm power output, 50Ω output impedance, 140mA operating current
- ZX60-V63+: Power Amplifier (Mini Circuits)
  - 0.05 to 6 GHz (wideband), 21 dB gain, 5.0V, 69mA DC Current, 18.5dBm power output
- BP 350: Photovoltaic Panel (BP Solar)
  - Max power (50 W), Short Circuit Current (3.2 A)
- Genasun GV-4: MPPT Charge Controller (Genasun)
  - Max Panel Power (50 W), Rated battery (output) current (4 A), Electrical Efficiency (96% - 99.85% typical)

IV. Tests and Measurements

Individual components will be tested in order to verify their critical specs on the data sheets. Then the sub systems will be put together and tested throughout assembly. All of the tests will be done in the RF laboratory located in Jobst 325 and will require the Network Analyzer, Spectrum Analyzer, Oscilloscopes, and signal generators.

The system will be broken down into two subsystems to be tested before assembling and testing the final system. The first subsystem seen in Figure 2will include the PV panel, charge controller, and battery. This subsystem will be tested to verify that the battery can be properly charged from the PV panel and charge controller.

The second subsystem seen in Figure 3 will consist of a DC power supply, the 915 MHz oscillator, the power amplifier, the transmitting antenna, and a test circuit consisting of a receiving antenna, energy harvester, and load. This second subsystem will be tested to verify that we can properly transmit and receive power wirelessly. After both subsystems have been verified, they will be combined into one system and tested to verify function and efficiency.

Fig. 2 PV Array Subsystem

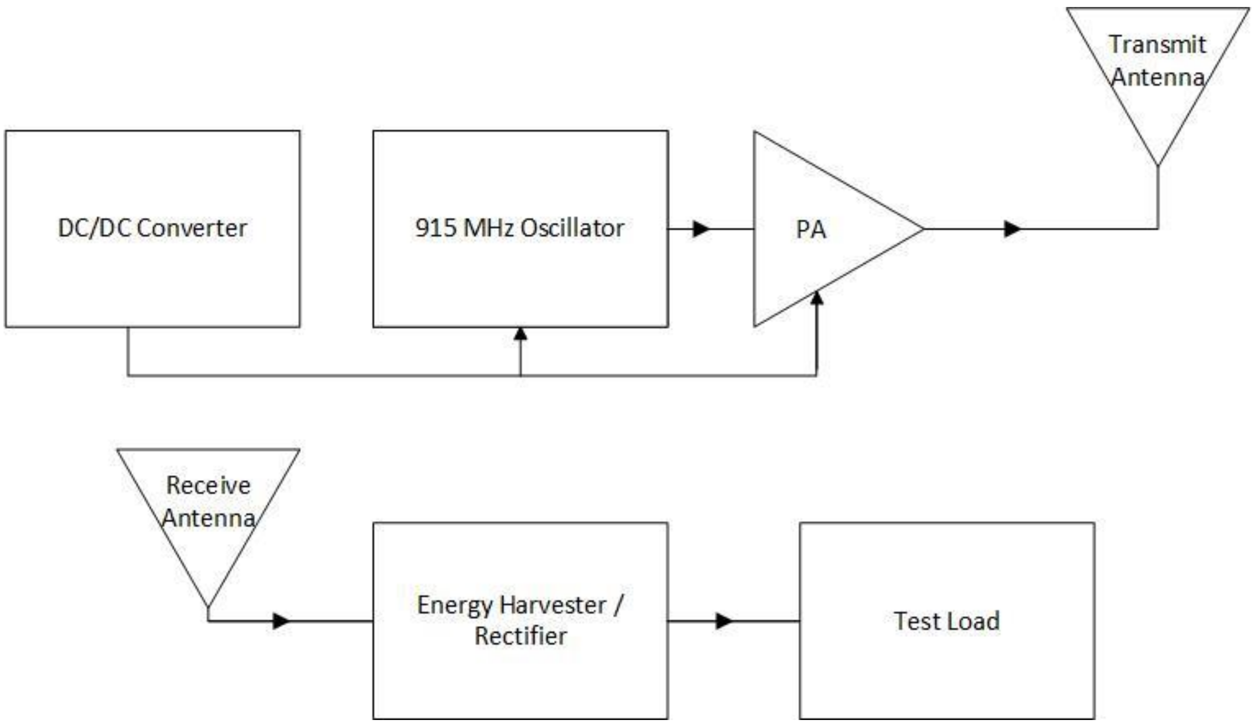

Fig. 3 Wireless Power Transfer Subsystem

V. Tasks and Schedule

Parts will be ordered by the middle of December. Parts will then be tested. The draft proposal presentation will be on November 28th, and by the end of the month the proposal presentation will be given. The final proposal report will be completed by November 30th. The spring semester will consist of building and testing the system and writing the final reports. The final report and presentation will be finished and given at the end of the spring semester of 2018.

Table 3 Tasks and Schedule

Task	**Date (2017-2018)**	**Team Lead**
Proposal Presentation	November 28th	MS & SC
Final Proposal	November 30th	MS & SC

Website Update	December 7th	MS
Order Parts	December 13th	SC
RF Parts Tested	4th Week of January	MS
PV Parts Tested	4th Week of January	SC
Assemble PV Subsystem (and test)	1st Week of February	SC
Assemble RF Subsystem (and test output power)	1st Week of February	MS
Test Wireless Power Transfer System	2nd Week of February	MS
Midpoint Progress Self-Check	February 15th	MS & SC
Assemble Full System	3rd Week of February	MS & SC
Test Full System for Functionality	4th Week of February	SC
Test Efficiency of System	1st Week of March	MS
Begin Collecting Data of System Performance	2nd Week of March	SC
Final Report Draft	March 29th	MS
Poster Print	April 5th	SC
Student Expo	April 10th -13th	MS
Final Presentation Draft	April 17th	MS & SC
Senior Project Conference and Reception	April 28th	MS & SC
Final Report and All Deliverables	May 1st	MS & SC
Final Presentation	End of Spring Semester	MS & SC

VI. Concluding Remarks

The project will be completed following the tasks and schedule by the end of the 2018 spring semester.

References

[1] Guoen Cao, Zhicheng Guo, Yibo Wang, Kai Sun, Hee-Jun Kim, "A DC-DC conversion system for high power HVDC-connected photovoltaic power system", *Electrical Machines and Systems (ICEMS) 2017 20th International Conference on*, pp. 1-6, 2017.

[2] Li, Kai, et al. “Wireless Power Transfer and Data Collection in Wireless Sensor Networks.” *IEEE Transactions on Vehicular Technology*, PP, no. 99, 13 Nov. 2017, pp. 1–1. *IEEE Xplore*

[3] U. Jadli, P. Thakur, and R. D. Shukla, “A New Parameter Estimation Method of Solar Photovoltaic,” *IEEE Journal of Photovoltaics,* vol. PP, no. 99, pp.1-9, Nov. 2017. *IEEE Xplore*