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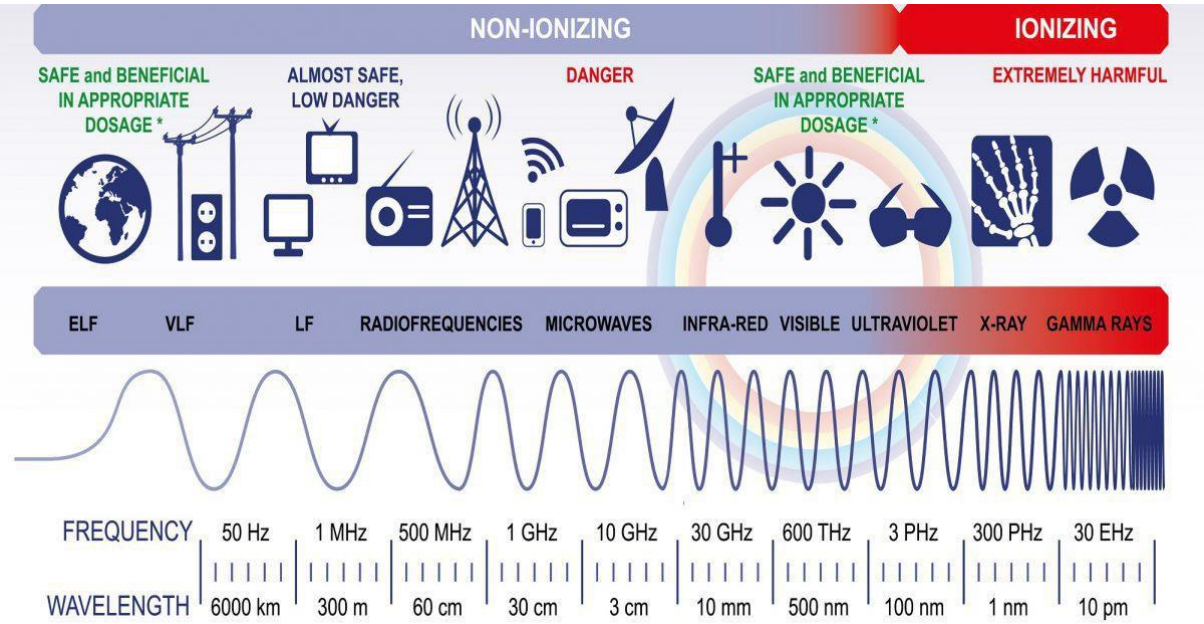
Harvesting energy from Electromagnetic radiation

Abstract

Electricity!! Something which is very important nowadays. There are many ways to extract energy from renewable and non-renewable sources. But there are some sources called as artificial sources which have been materialized by the technologism and human development. One such source is electromagnetic radiations. EM energy can be harvested not only from natural sun radiation, but also from all the artificial RF sources. Though EM radiations are superabundant and avowed, the energy is being wasted and not harvested suitably. In this we are going to build a module using latest technologies that pull out the energy from the radiations that are being wasted. Previous studies have done this using a normal *rectenna* (which responds only to certain frequencies). Our goal is to build an integrated *optical rectenna (OR)* that extracts energy even from the radiations that belongs to visible spectrum. Though the efficiency is less than the normal rectenna but the impact on the power engineering is huge and will dominate today's best solar cells {like efficiency (2x)}. The power transfer is based on far field ambient wireless energy harvesting and we are intent to increase the probability of reception by designing rectennas with wide beam width and multiple/wideband resonance frequencies. From this we can implicate that if we replace solar cells by OR (point detectors; very fast; broad tuneability; robust; remarkable selectivity; polarization) we can create a very sustainable; efficient way of extracting energy and the applications are in ample. But impedance matching between OR and source is an issue and an experimental process.

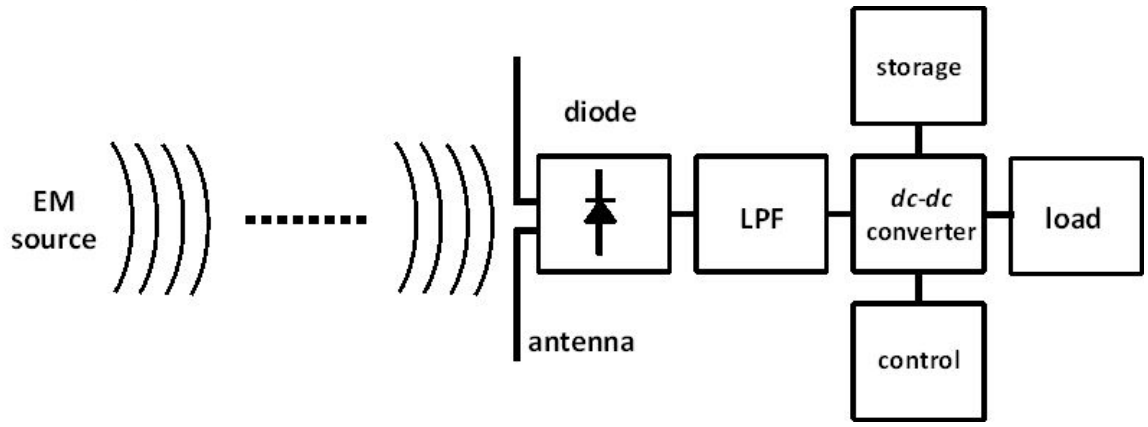
Introduction

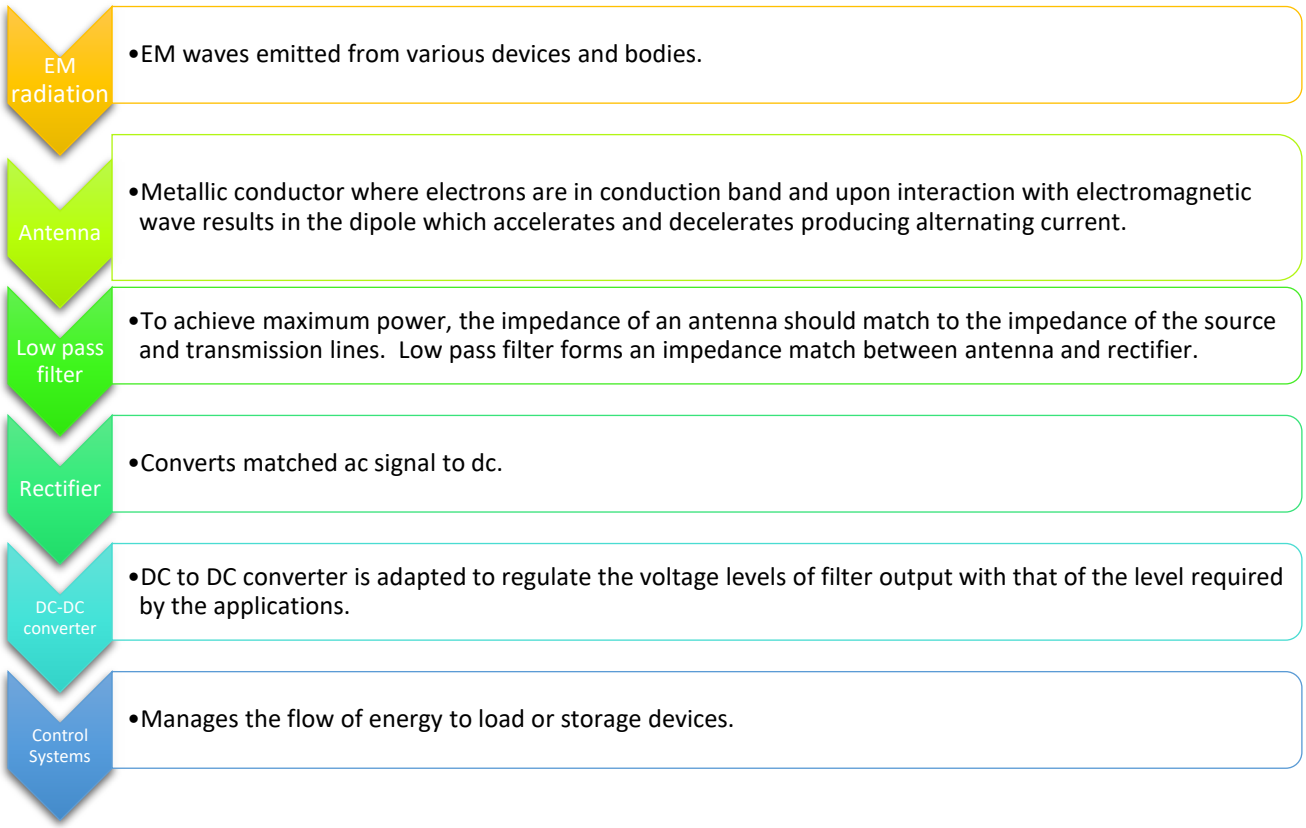
Electromagnetic radiation is a form of energy which is a result of oscillation of electric field and magnetic field perpendicular to each other.



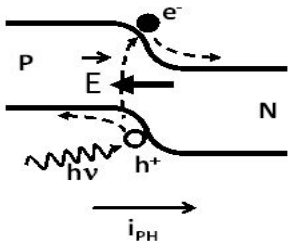
Electromagnetic radiation energy propagates in such a way where photon with a particle and wave like properties travel at the speed of light and carry energy which can be transferred upon interaction with matter. This energy can be converted into electrical power using a device called Rectenna (RECtifying antENNA) basically a receiving rectenna which mainly consists of a dipole antenna, low pass filter circuit, rectifying circuit, DC to DC converter/filter, storage and control systems.

Block diagram

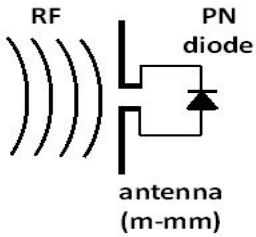




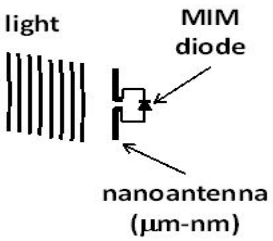
This conversion process can be divided into 2 parts where each part works for a different range of frequencies. Just like a PV cell, normal Radiofrequency rectenna (RFR) produces electric power and works in low frequency range (RF range), whereas Optical rectenna works in the optical range.



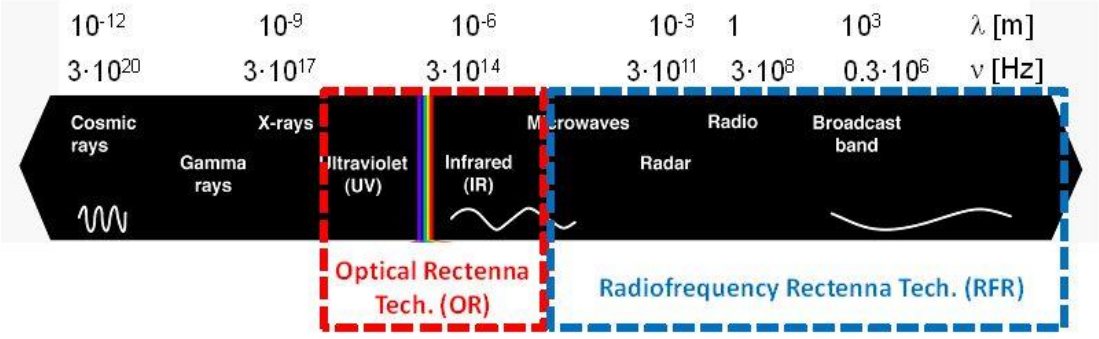
PV cell



RFR



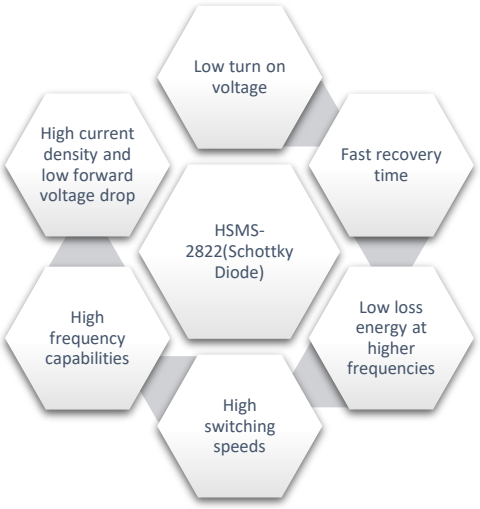
OR



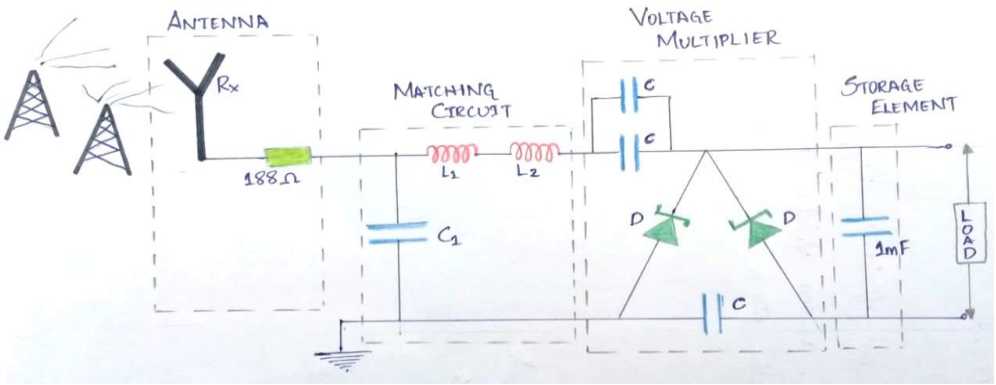
Methodology

Antenna length should be comparable to the size of wavelength of the considered spectrum and the equation is given by, 2L=λ. A low-pass filter is a filter that passes signals with a frequency lower than a selected cut-off frequency and attenuates signals with frequencies higher than the cut-off frequency. Rectifier circuit usually uses Schottky diode as it has lowest voltage drop and high speed which results in low power loss due to conduction and switching. DC-DC filter provide voltage at the desired magnitude which is either stored or used up by the load.

ADVANTAGES OF USING SCHOTTKY DIODE:



CIRCUIT DIAGRAM :



- D = HSMS-2822 (Schottky Diode)
- C1= 4.7Pf
- Rx = Receiving antenna
- L1 = 8.2nH
- L2 = 4.3nH
- C = 33pF

Motivation

Since EM waves are omni-present and abundant just like solar and wind, we thought to harness energy out of it so that the obtained electrical energy can be used for domestic purpose (from powering a small sensor or electronic circuit to powering a bulb or a fan). In EM spectrum, energy can not only be harvested from natural sun's radiation but also from all artificial radio frequencies sources that are increasing in number.

Our motto is to bring up the idea of "Optical Rectenna" instead of old fashioned rectenna because this device would lead us to a new generation of highly efficient solar cells producing twice the efficiency compared to today's best solar cells. As it deals with visible spectrum, the antenna used will be of smaller size, low-cost and with minimum losses. The optical rectenna can also harness UV rays unlike other rectenna, which is not able to operate at optical wavelengths and requires different sizes of antenna which will not be stable or rigid at higher frequencies (visible spectrum).

Frequency	Input	Efficiency
2.45GHz	5dBm -10dBm -20dBm -9dBm **2.2kΩ**	68% 48% 19% 30%
915MHz	-9dBm **2.2kΩ**	37%
>2.4GHz	-16dBm **0.5MΩ**	42.8%
5.2-5.8GHz	-11dBm **5kΩ**	86%
400-789THz (Visible rays)	-	-

Statistical analysis for a normal rectenna

From the above analysis considering the limitations of a normal rectenna, we are trying to bring a robust antenna that extracts energy irrespective of frequencies and type of EM waves used. To overcome this, studies/researchers have come up with the idea of using "carbon nanotubes" as an antenna which works for visible spectrum too. But, to extract energy out of signals carrying information is challenging and we need collaboration to design new devices and circuits.

Social Impact

Nowadays, space in urban areas, including work and home environment is strongly packed with EM radiations at various bands and spectral regions, some being very harmful and some barely effecting. We mainly focus on harvesting energy from spill-over losses of antenna placed everywhere. For instance, from a microwave antenna placed on board of a geostationary satellites, we can harvest the energy using rectenna and the energy so obtained can be used for powering wireless sensors for satellite health monitoring and many more wireless electronics.

Optical rectennas as mentioned earlier, is quite promising for improving the performance of traditional PV cells. Though the efficiencies observed of an OR is less, the impact so obtained by using an array of rectenna modules would give a significantly increased output. The Array we use should work for a wide range of frequencies which results in higher efficiency which could open the door to "Photodetectors" that would operate without the need for cooling and energy harvesters that would convert waste heat to electricity.

Market survey (Future Scope)

Dr.Novack in an interview claimed that "OR could one day be used to power cars, charge cell phones and even cool homes". He also said that this work by both absorbing and IR heat available in the room and producing electricity which could be used to further cool the room. Integration of nanotechnology for the production of rectennas using carbon nanotubes which works ultimately for visible spectrum would result in cells outstanding the PV cell and being 10 times better than them. Building walls and roof covered with certain material able to capture both heat and EM radiation and finally converting them to electric power using rectennas. This would result in power the whole building. Black body (Vantablack) can be used as an absorber to absorb heat produced by RF radiation (which in large amount damages tissues) and ultimately extracting that heat energy from it and converting it into electric power.