TRI-STEPPED RECTANGULAR ANTENNA FOR RF ENERGY HARVESTING

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ABSTRACT:

Electromagnetic energy harvesting holds a promising future for energizing low power electronic devices in wireless communication circuits. Solar energy, thermal energy and Radio frequency are the energy harvesting technologies but solar and thermal energy harvesting have low efficiency and not sufficient for practical applications. So this paper presents an RF Energy Harvesting system that can harvest energy from the ambient surroundings and converts into usable electrical energy.

An L-shaped antenna, ultra-wide band antenna and monopole antennas are designed and simulated but the gain is not sufficient for energy harvesting applications. Hence, a Tri-Stepped Rectangular antenna is presented for efficient radio frequency (RF) energy harvesting in between various frequency bands such as LTE B5(850), GSM 900, GSM 1800, 3G, 4G and ISM(2.4GHZ). The receiving antenna is the main element as it is used to capture the RF Energy. We give the coaxial feed to the designed antenna as it produces low radiation and can be fabricated easily.

KEYWORDS: RF Energy Harvesting, Tri-Stepped Rectangular antenna, Altair HyperWorks FEKO

1.INTRODUCTION:

Energy harvesting is the capture and conversion of small amounts of readily available energy in the environment into usable electrical energy. Energy harvesting is also known as energy scavenging or micro energy harvesting and power harvesting. A variety of sources and techniques are available in order to store or save energy like radiofrequency (RF) energy, solar energy, wind energy and thermal energy. In this paper we focus on RF Energy Harvesting, it holds a promise future for generating a small amount of electrical power for electronics device. This harvester enable a battery-less operation and extend significantly the operating lifetime of the Wireless Sensor Networks (WSNs).

For RF energy harvesting, rectenna is the critical element which consists of an antenna and a rectifier. Rectenna is a subsystem of a wireless power transfer system. Rectenna receives the electromagnetic power from corresponding frequencies. A typical rectenna contains a microstrip antenna to capture the energy and convert it to A.C power and high frequency rectifying circuitry, that converts the A.C power into D.C power. The frequency bands of ambient RF signals are different and distributed in a wide range. For this reason, there are a large number of rectennas operated at different communication frequency bands and some of them have been investigated for RF energy harvest at a single frequency band. Firstly Monopole antenna is designed and verified but the gain and efficiency obtained is less.

2.LITERATURE REVIEW:

The history of RF power scavenging in free space originated in the late 1950s by using a microwave-powered helicopter system. Later, the concept of power harvesting or energy scavenging was explained as a technique for reaping energy from the external environment using different methods including thermoelectric conversion, vibrational excitation, solar energy conversion, and pressure gradients. This technique promises tremendous scope for the replacement of small batteries in low power electrical devices and systems. RF power harvesting is used for replacing batteries or increasing their lifespans. Currently, batteries power a majority of low-power remote sensor devices and embedded equipment. In fact, batteries have finite lifespans and require periodic replacements.

3.BLOCK DIAGRAM:

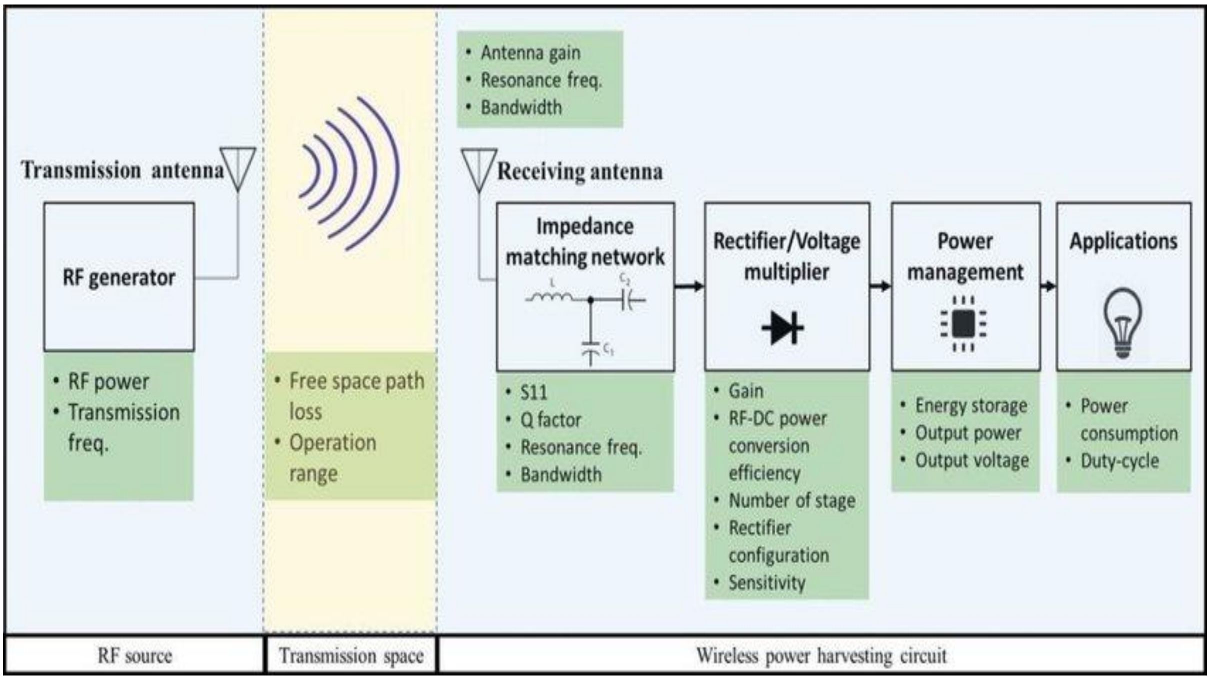

Fig-.1: Block Diagram of RF Energy Harvesting

The transmitter consists of transmitting antenna, RF generator which is used to transmit RF power. Receiver consists of Receiving antenna, Impedance matching network, Rectifier and power management. Impedance matching network task is to reduce the transmission loss from an antenna to a rectifier circuit and increase the input voltage of a rectifier circuit.

4.DESIGN EQUATIONS:

First we have to select the resonant frequency and a dielectric medium for which antenna is to be designed. The parameters to be calculated are width and length of the patch antenna.

Width of the patch is calculated using the below formula,

$W = (Co/2fr)*(2/\epsilon_r + 1)^{1/2}$

Where,

W = Width of the patch

Co= Speed of light

ϵ_r = value of the dielectric substrate

Length of the patch is calculated using the below formula,

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$L = Co/2fr*(\epsilon_r)^{1/2}$

By using above 2 formulas the dimensions of a patch are known. The length and width of a substrate is equal to that of the ground plane. Now the length of a ground plane (Lg) and the width of a ground plane (Wg) are calculated using the following formulas,

$Lg = 6h + L$

$Wg = 6h + W$

Where,

H=Height of the substrate

For feeding the patch antenna we have so many methods such as Line feed, Aperture feed, Coaxial feed and Proximity Coupled feed. Here we used Coaxial feed as it produces low radiation and efficient feeding and can be fabricated easily.

A simulation was performed by considering 1800 MHz as the center frequency and can be checked whether it is resonated or not by using the below formula,

$Fl = 7.2 /(L+0.159W + p)k$

Where,

Fl=lower band edge frequency

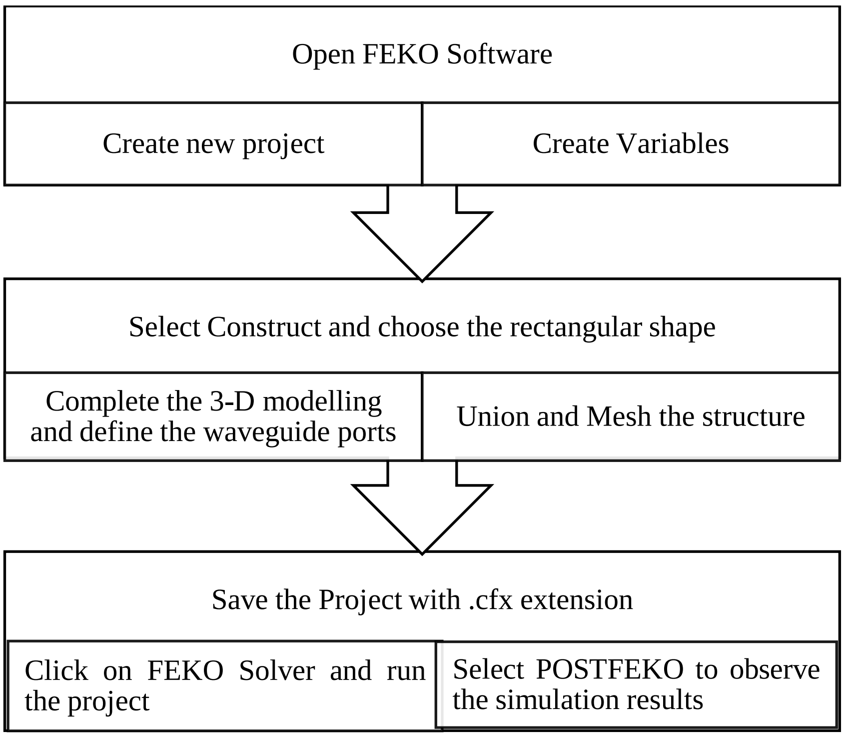
L = length of the antenna

W = width of the antenna

p = gap between the antenna and ground plane

k = correction factor (for FR4 substrate, Er = 4.4, h = 1.59 mm, $\tan\delta = 0.01$, then k = 1.15)

5.DESIGN METHODOLOGY:



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6.ANTENNA DESIGN:

Using the above mentioned formulas the Tri-Stepped Rectangular Antenna is designed at a multiband frequencies. The length and width of the patch antenna is found to be 60mm and 40mm and the height of the substrate is 1.6mm. The coaxial feed is provided at x = 7.5 and y = 8.5 from the centre of the ground plane of the antenna.

The antenna was designed on an FR4 substrate with a conducting patch on one side and a partial ground plane on the other side of the substrate. Changing the feed position, varying L and W, making the slots inside the patch, these modifications were performed in the basic rectangular shape. The below figure represents the CAD Geometry of Tri-Stepped Rectangular Antenna which was designed by using MOM(Method of Moment) method in Altair FEKO Software.

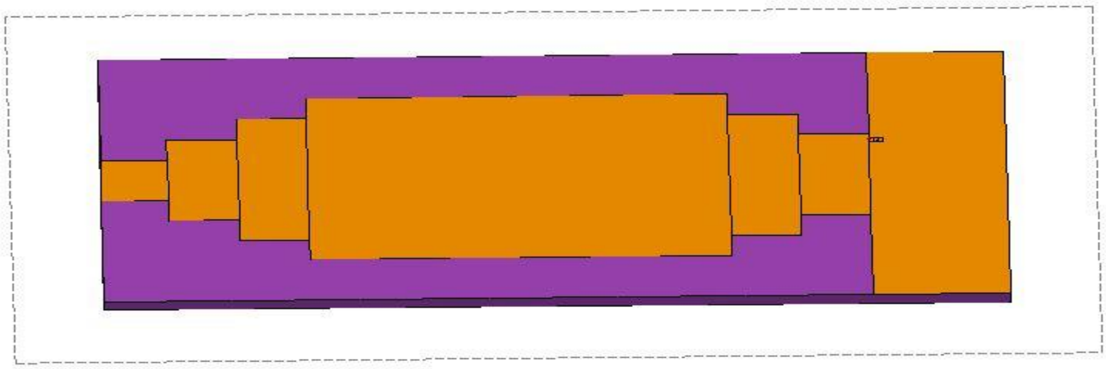

Fig.-2a: CAD Geometry of Front View of Tri-Stepped Rectangular Antenna

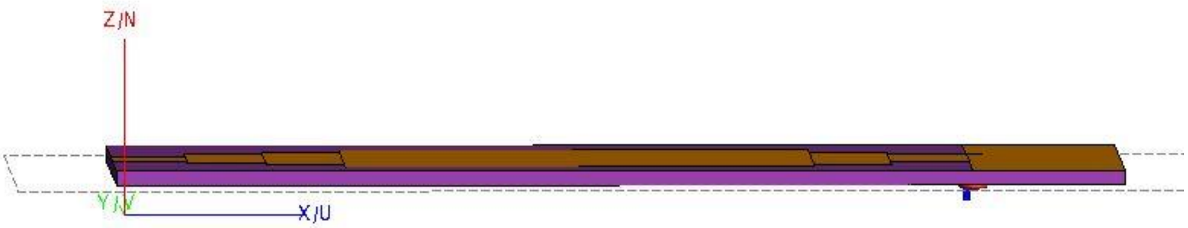

Fig.-2b: CAD Geometry of Side View of Tri-Stepped Rectangular Antenna

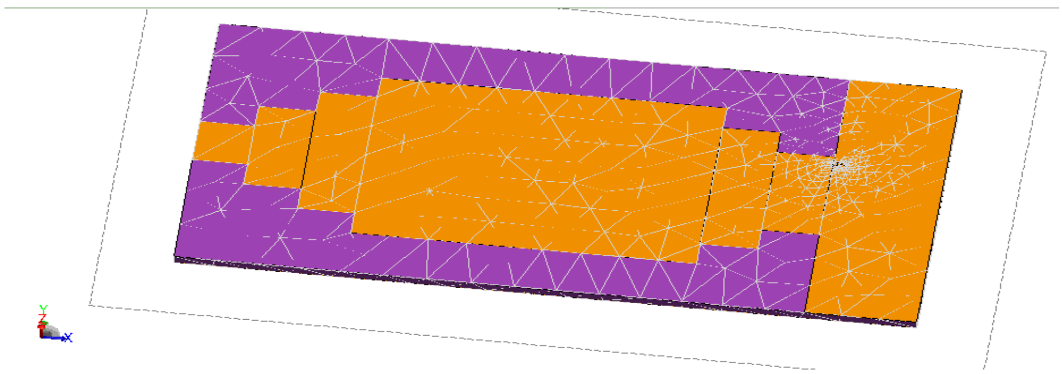

Fig.-2c: CAD Geometry of Mesh View of Tri-Stepped Rectangular Antenna

7.SIMULATION RESULTS AND DISCUSSIONS:

The below figure 2 represents the relation between Frequency on x-axis and Gain on y-axis. The gain obtained at 1GHZ,1.5GHZ, 2.0GHz, 2.5GHZ and 3GHZ is 85dB, 80dB, 65dB, 68dB and 60dB respectively.

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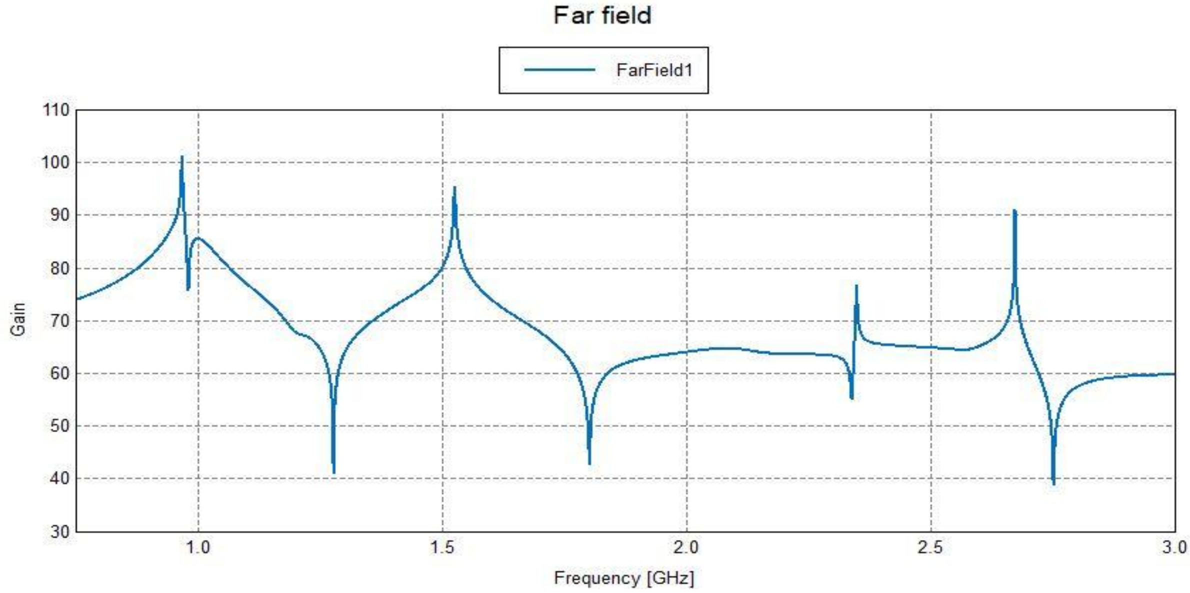

Fig.-3: Gain of Tri-Stepped Rectangular Antenna in dB

The below figure 3 represents the relation between Frequency and VSWR on x-axis and y-axis respectively. The obtained VSWR was less than 2 at all frequencies that is 1GHZ,1.5GHZ,2GHZ,2.5GHZ and 3GHZ that means it indicates that the antenna is suitable for all applications and has perfect match.

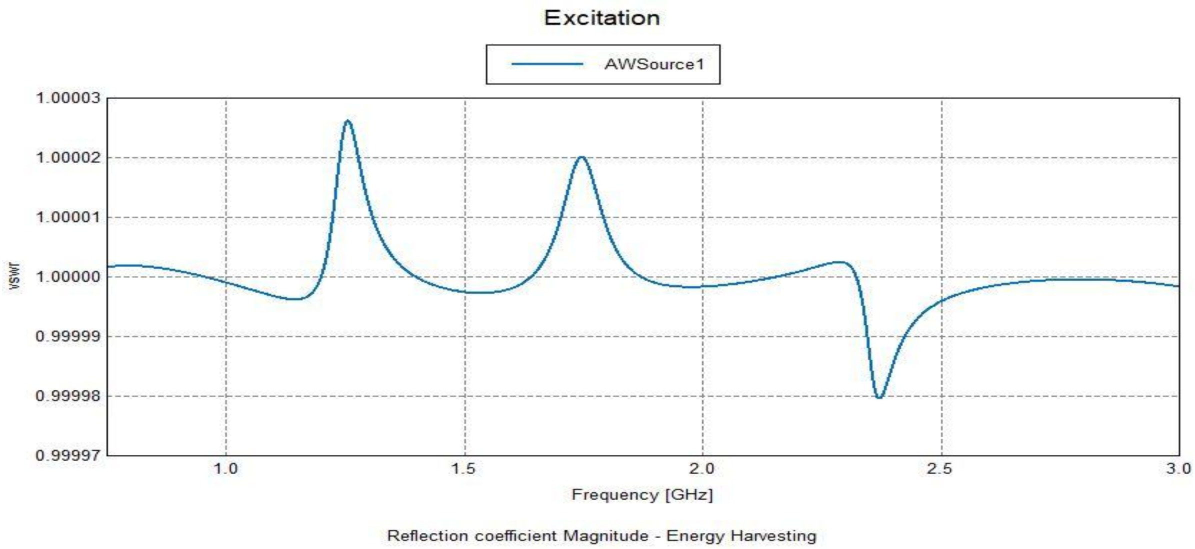

Fig.-4: VSWR of Tri-Stepped Rectangular Antenna

The below figure 4 represents the frequency on x-axis and reflection coefficient on y-axis.

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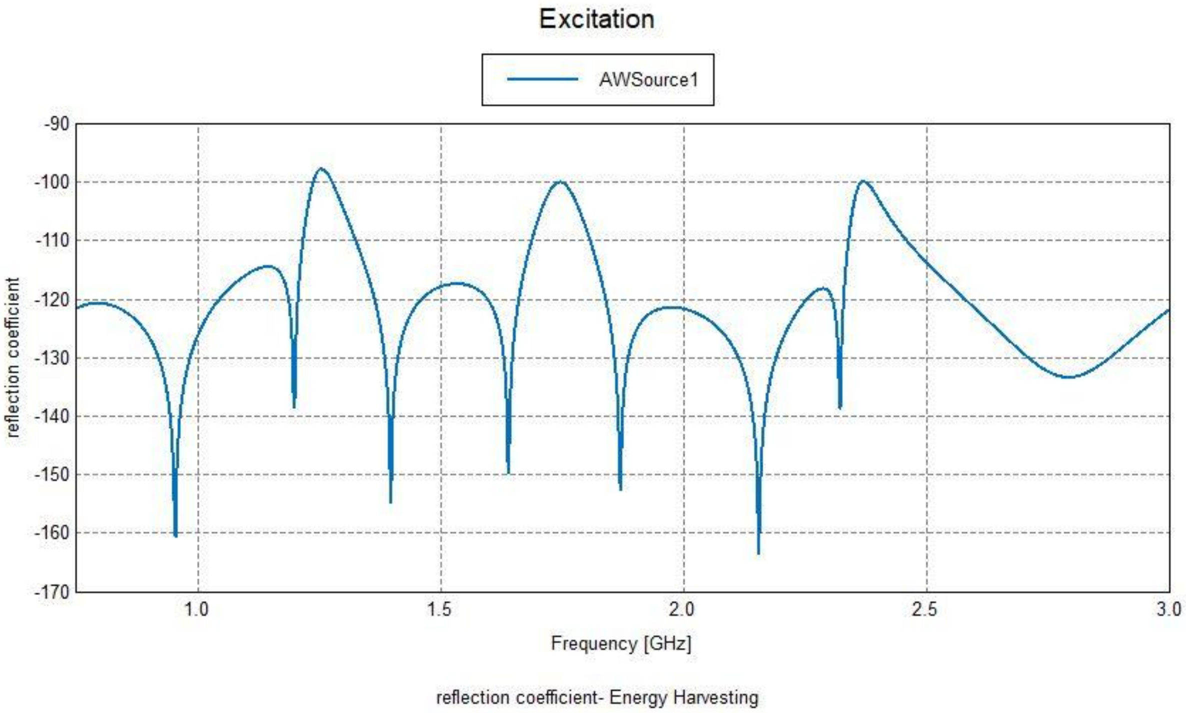

Fig.-5: Reflection Coefficient of Tri-Stepped Rectangular Antenna in dB

The below figure indicates the current flow of Tri-Stepped Rectangular Antenna. The red color indicates that the current flow is high and the blue color indicates that the current flow is low as it is covered by FR4 substrate.

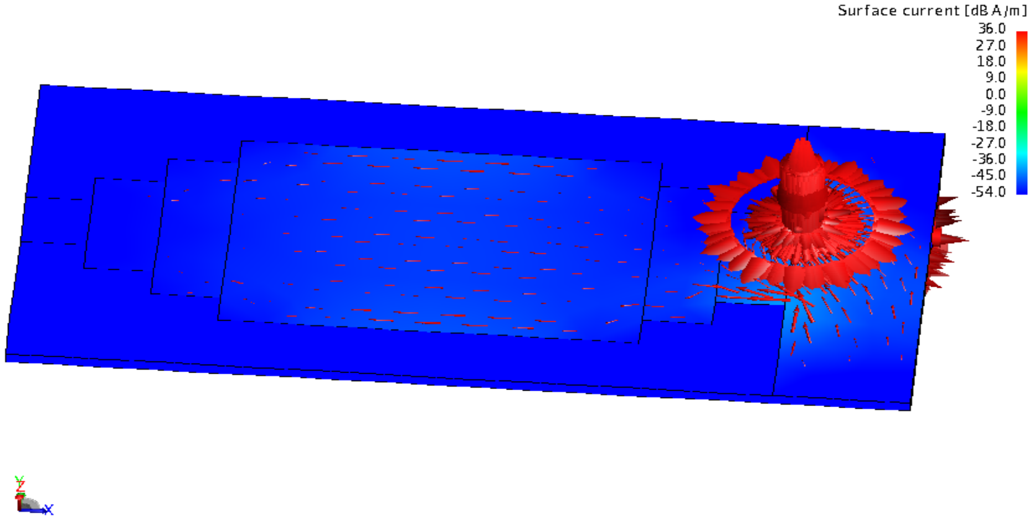

Fig.-6: Currents Flowing of Tri-Stepped Rectangular Antenna in DB A/m

COMPARISION TABLE-1:

The below table represents parameters of the designed antenna.

FREQUENCIES (GHZ)	VSWR	GAIN(dB)	RETURN LOSS (dB)
0.75	1.0000	80	-120
1	1.0000	85	-125
1.5	1.00002	80	-118
2	1.000025	65	-122
2.5	0.99999	65	-115

8.CONCLUSION:

This paper presents the design of Tri-Stepped Rectangular antenna with the dielectric substrate FR4(Flame Retardant) to harvest ambient RF Energy in between band of frequencies viz, LTE B5(850), GSM 900, GSM 1800, 3G, 4G and ISM(2.4GHZ).The designed antenna is very interesting for the RF harvesting energy system, meeting the desired criteria to maximize the captured RF energy. The simulated results indicates that the designed antenna provides excellent reflection coefficient and high gain nearly 80dB and the VSWR was also less than 2 for multi band frequencies.

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