SURVEY ON KITE TAIL FED SQUARE MICROSTRIP ANTENNAE FOR RF ENERGY HARVESTING APPLICATION

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***Abstract*— This article presents the design, comparison and performance of three antennae which captures electromagnetic energy from free space. Each antenna is designed to resonate at multiple frequencies, so as to accumulate more energy. The design was performed using HFSS software, after fabrication the results were verified using Network Analyzer. Simulated and practical values of return loss are less than -10dB, Voltage Standing Wave Ratio (VSWR) is less than or equal to 2 at multiple frequencies between 3GHz and 10GHz. These antennae in association with other circuits can be used to capture power from free space. The obtained energy can be used to power low power electronic devices.**

***Index Terms*— Rectifying antenna, electromagnetic energy, energy recycling.**

I. INTRODUCTION

Energy harvesting or energy scavenging is a process in which energy from external sources such as solar energy; thermal energy, wind energy etc. are converted into required form of energy. Energy harvesting had its foundation stone long back with the construction of wind mill. The motivation behind this concept is to power devices without batteries or to assist the battery when it is low [1]. The conversion of radio frequency energy into electrical energy which is available in free space due to various sources became an alternative to natural sources. In present days electromagnetic environment is available round the clock and 365 days, which can be used as a source of energy harvesting.

Figure 1. Energy Harvesting Module

In the area of rectifying antennas active research is going on, as the electromagnetic energy is available for free in free space and the system is environmental friendly. Differential antenna, Folded dipole antenna, Ultra Wide Band antenna and E Shaped antenna are designed at a frequency range of GSM 900 band for the purpose of recycling [2-6]. A bow shaped antenna is designed to resonate at two frequencies at 900MHz and 2.4 GHz, the other antenna resonates at 433MHz and 900MHz [7], Yagi antenna, a dual band antenna and an array are designed for harvesting electromagnetic energy[8-11]. In this paper, design of an antenna to resonate at multiple frequencies is presented so as to gather more energy between 3GHz and 10GHz using energy harvesting module shown in Figure 1.

In section 2, design equations for a square Microstrip antenna are mentioned [12-14]. A micro strip feed is given to the square patch at one of the truncated corners. Second and third antennae are modifications of the square Microstrip antenna with two perpendicular and parallel slots with respect to Microstrip feed.

In section 3, Practical implementation of the antennae is given. The fabricated structures along with simulated structures were shown in Table 1.

In section 4, the response of each antenna is shown, compared with the simulated responses from Figures 4 to 15 and the conclusions regarding each antenna are mentioned.

II. DESIGN USING HFSS SOFTWARE

In this article three antennae were designed and simulated using HFSS software, on FR4 epoxy substrate of height h=1.6mm and ε_r=4.4. In the design of square Microstrip antenna, a rectangular Microstrip antenna along with its design equations is considered as a special case of rectangular patch by assuming identical width and length. Width of the patch antenna is chosen using the following equation [12].

$$W = \frac{1}{2 f_r \sqrt{\mu_o \varepsilon_o}} \sqrt{\frac{2}{\varepsilon_r + 1}}$$

Calculation of effective dielectric constant is given by equation 2.

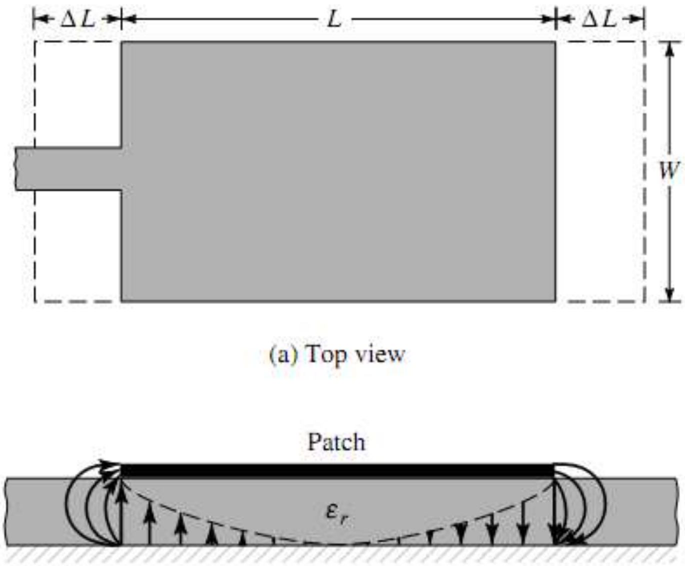
$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + \frac{12h}{W}}} \right)$$

$$v = \frac{C}{\sqrt{\varepsilon_{reff}}}$$

$$\lambda = \frac{v}{f}$$

Effective length is calculated using equation 5, as shown in Figure 2[12].

$$L_{eff} = \frac{\lambda}{2}$$



(b) Side view

Figure 2. Physical and effective lengths of a Microstrip antenna.

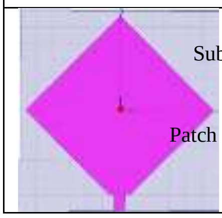
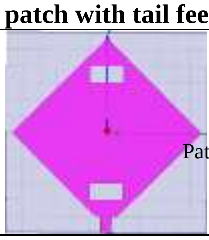
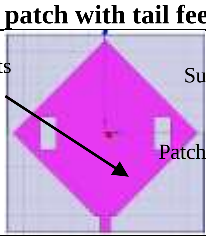
$$\frac{\Delta L}{h} = 0.412 \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)}$$

Actual length of antenna is obtained using equation 7.

$$L = L_{eff} - 2\Delta L$$

The design procedure is same for all the three antennae. First a square Microstrip antenna is designed with W = L and constructed on FR4 epoxy substrate. The constructed square patch is rotated by 45^0 with respect to the substrate (kite). One of the corners is truncated and then a Microstrip feed is given (kite tail feed). In the construction of the second antenna, feed is given at one of the truncated corners and two slots were made perpendicular to the feed on the square patch. For the third antenna the feed is given at one of the truncated corners and two slots were made parallel to the feed as shown in Table 1.These three antennae were fabricated on FR4 epoxy substrate and the practical antennae are also shown in Table1.

Table 1 Simulated antenna structures and fabricated antenna structures.

1. Square patch with tail feed	**2. Perpendicular slotted square patch with tail feed**	**3.Parallel slotted square patch with tail feed**
		

III. PRACTICAL IMPLEMENTATION OF ANTENNAE

Simulated three antennae are fabricated on FR4 epoxy substrate. Photo-lithographic method enables to remove unwanted copper layers on the patch antenna. Proper care has taken in the etching process to reduce fabrication errors. The fabricated antennae are tested for return loss and VSWR using Agilent technologies E5071C Network Analyzer. The measurement setup was shown in Figure 3.

Figure 3. Setup for the measurement of return loss and VSWR.

IV. RESULTS

In the measurement of return loss and VSWR for square patch antenna with tail feed, it is observed from Figures 4 to 7 that their values are less than -10dB and 2 respectively at two frequencies.

In the measurement of return loss and VSWR for perpendicular slotted square patch antenna with tail feed, it is observed from Figures 8 to 11 that their values are less than -10dB and 2 respectively at five frequencies.

In the measurement of return loss and VSWR for parallel slotted square patch antenna with tail feed, it is observed from Figures 12 to 15 that their values are less than -10dB and 2 respectively at four frequencies.

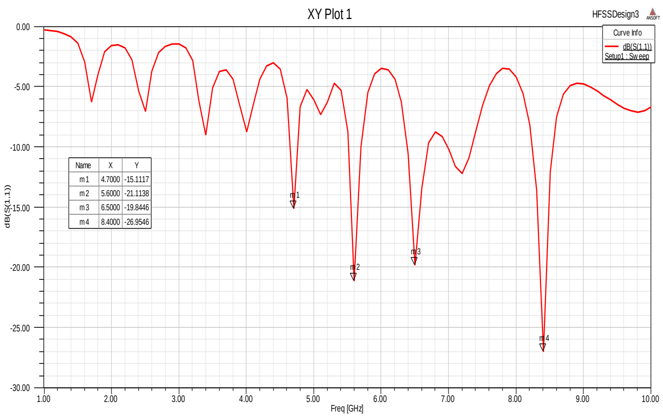


Figure 4. Simulated Return loss for square patch with tail feed.

Figure 5. Practical Return loss for square patch with tail feed.

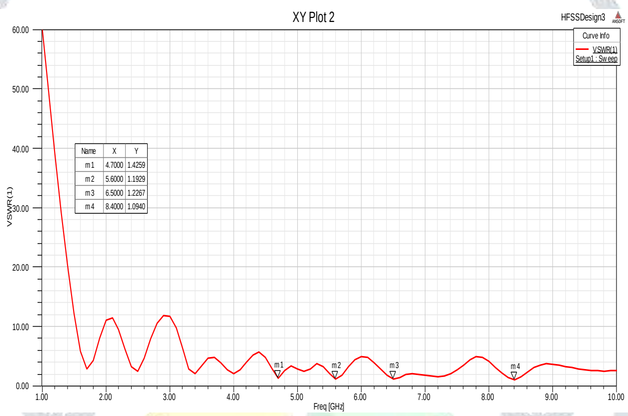


Figure 6. Simulated VSWR for square patch with tail feed.

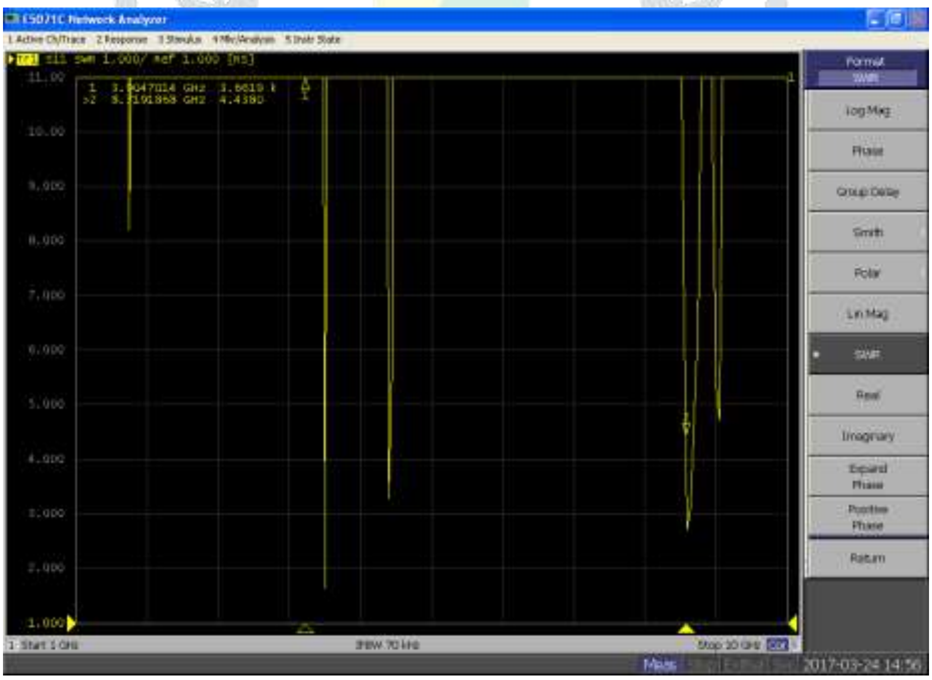


Figure 7. Practical VSWR for square patch with tail feed.

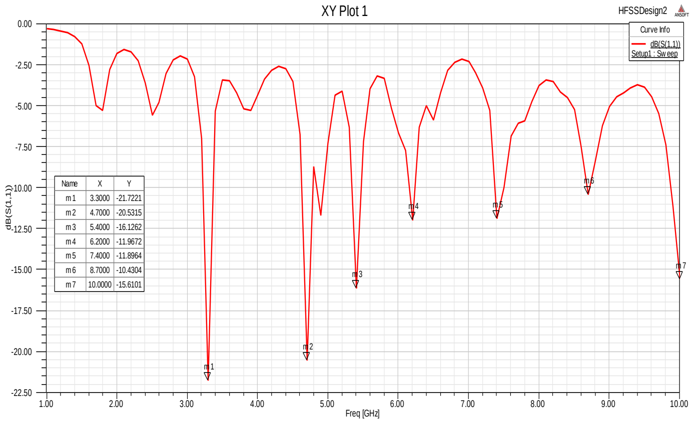


Figure 8. Simulated Return loss for Perpendicular slotted square patch with tail feed.

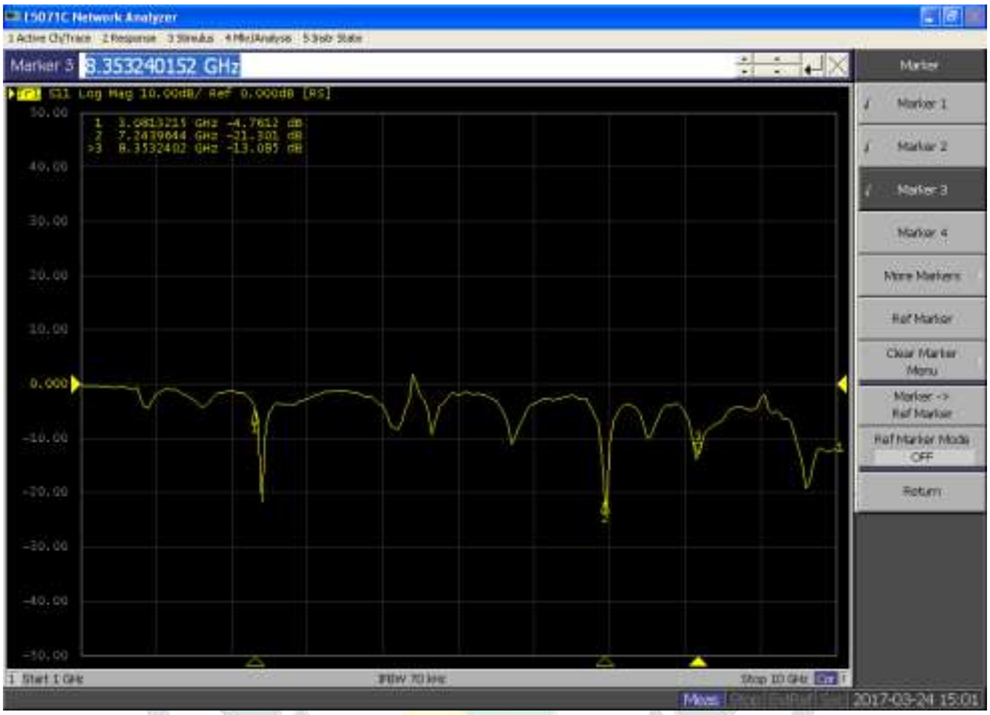


Figure 9. Practical Return loss for Perpendicular slotted square patch with tail feed.

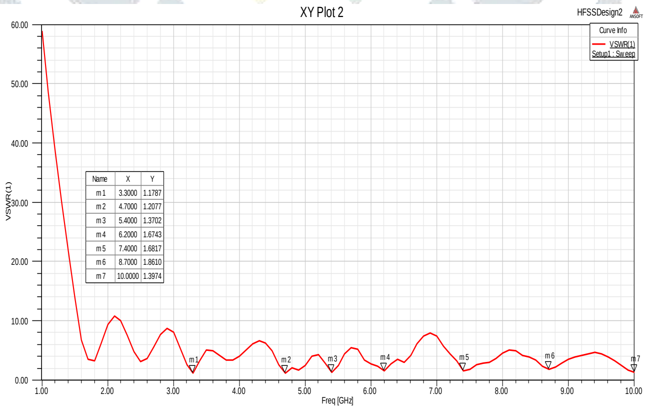


Figure 10. Simulated VSWR for Perpendicular slotted square patch with tail feed.

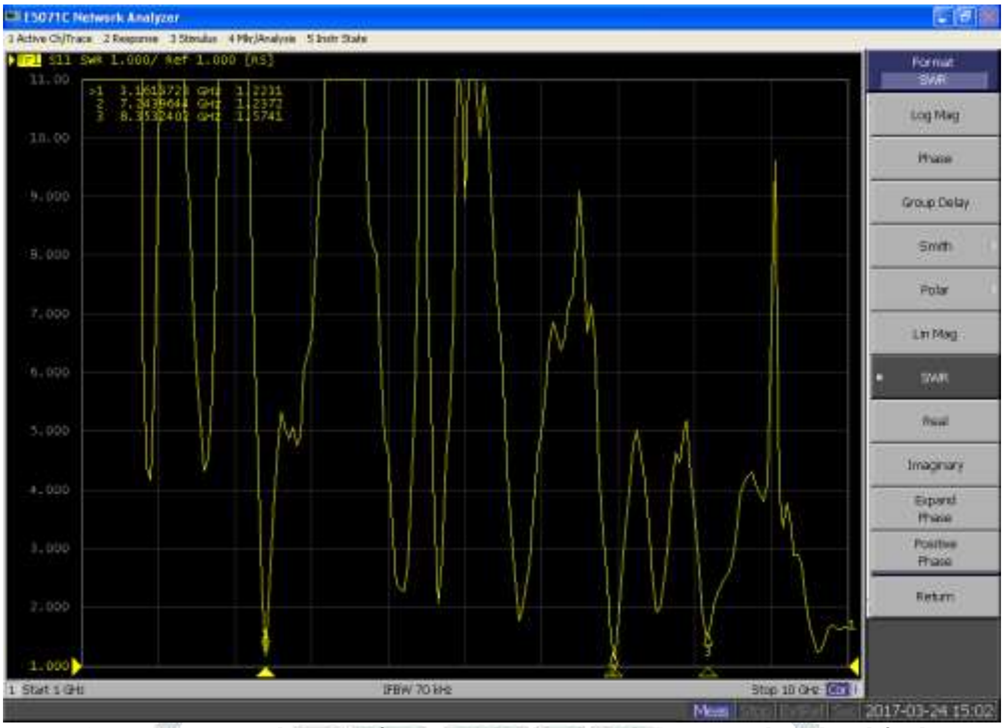


Figure 11. Practical VSWR for Perpendicular slotted square patch with tail feed.

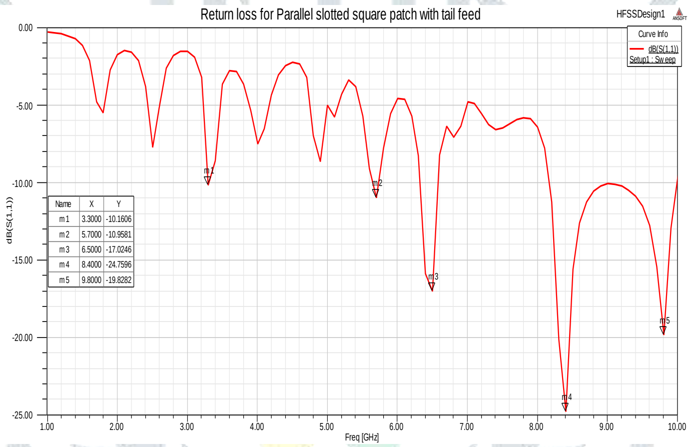


Figure 12. Simulated Return loss for Parallel slotted square patch with tail feed.

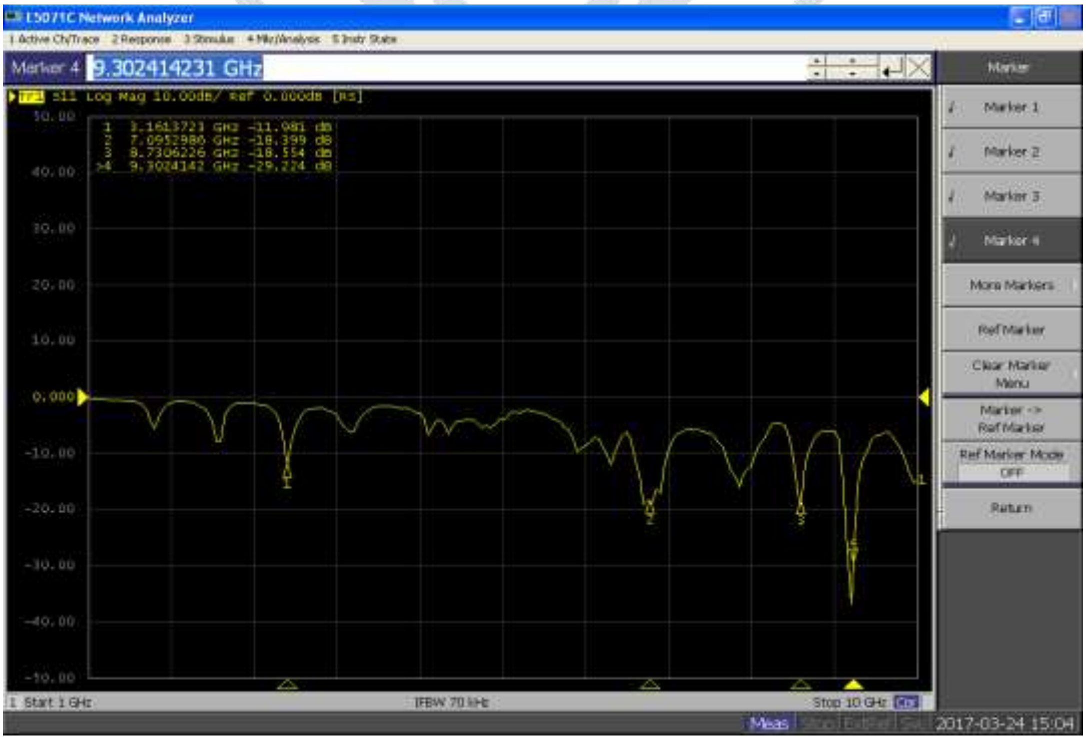


Figure 13. Practical Return loss for Parallel slotted square patch with tail feed.

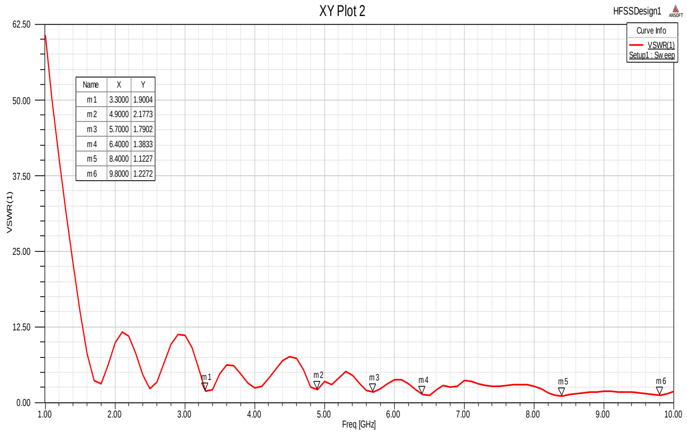


Figure 14. Simulated VSWR for Parallel slotted square patch with tail feed.

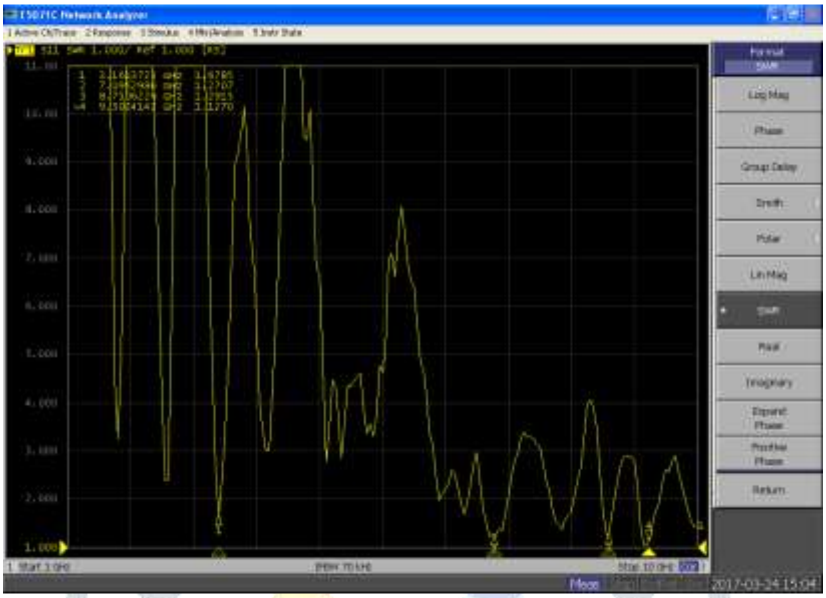


Figure 15. Practical VSWR for Parallel slotted square patch with tail feed.

V. CONCLUSION

From Figures 4 to 15 it is observed that these antennae resonate at multiple frequencies. At these frequencies maximum energy is captured by the antennae. Antenna along with matching circuit and a rectifier can be used for energy harvesting application as shown in Figure 1. The deviation of practical responses from simulated responses is due to effective length of practical Microstrip antenna.

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