S-BAND ANTENNA CANDIDATE FOR THE FRONT-END RECTENNA OF THE WPT PROTOTYPE RECEPTION

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ABSTRACT

The sun is the most abundant energy and sustainable source of energy for mankind. The energy from the sun can be tapped by converting it into electricity, then into microwave and beamed to ground-based receiving stations. This is the Solar Power Satellite (SPS) concept. Solar power plants are placed in the geostationary orbit above the earth. In the ground-based station, the receiving antenna called the rectenna or rectifying antenna receives the microwave power, rectifies it into electricity and transforms it into utility power for public use through connections to the available terrestrial electrical power lines. The key for delivering the power to earth in this system is microwave power transmission. This paper presents the design of a receiving antenna single element candidate operating at 2.45 GHz. The specifications are low gain, narrowband and low return loss. The basis of the design is the microstrip patch antenna. The patch antenna has been successfully modified to fulfill the desired specifications with reduced size. Low return loss of better than -20 dB has been achieved. Furthermore, the inserted slits allow the antenna to operate at a lower frequency, hence corresponds to a reduced size at 2.45 GHz.

KEYWORDS
Front-end rectenna, compact antenna, wireless power transmission (WPT) prototype, solar power satellite (SPS) reception.

1.0 INTRODUCTION

Wireless power transmission (WPT) is one of the most useful applications of radio waves. In this system, microwave signal is beamed to a receiver where the received signal can be converted to electricity. The source of the microwave beamed signal may come from a microwave source or microwave energy converted from an electricity generated source. One of the keys in a WPT system is the circuit known as the rectenna at the receiving end. This is shown in Figure 1. The rectenna circuit consists of the receiving antenna, low-pass filter (LPF) and rectifying circuits. Single rectenna elements can be The antenna can be designed with planar configuration having transmission line structure such as the microstrip. The chosen operating frequency is 2.45 GHz due to its location in the industrial, scientific, and medical (ISM) band [1]. A number of antennas have been studied and proposed for WPT [2]-[4].

This paper details the design of an antenna candidate having the basic structure of a microstrip patch, modified with truncations and embedded slits. The truncation is aimed to change the linearly polarised characteristic to the circularly polarised characteristic. Circular polarisation allows the receiving antenna to be aligned in any position. Slits are introduced to reduce the size of the antenna, hence a more compact single element can be produced. This will allow the overall size of the receiving antenna array configuration to be further reduced.

2.0 ANTENNA DESIGN CONSIDERATIONS AND SIMULATIONS

The chosen basic shape of the antenna is a square patch as shown in Figure 2(a). Side feeding technique is considered since integration with other circuitry can be done on the same layer. The dimensions of the square patch antenna operating at 2.45 GHz can be obtained from the formulation available in the literature [5]. The microwave board parameters chosen are relative permittivity = 2.33, loss tangent = 0.0012, thickness of substrate = 3.175 mm, copper thickness = 0.035 mm and conductivity of copper = 5.882 x 10^7 S/m. Other board parameters may be used, for example, thinner substrates. The antenna layout is then drawn in Sonnet Suites v.9 environment [6] and simulated. The software provides electromagnetic solution using modified method of moments analysis based on the Maxwell's equations.

In order to radiate with circular polarization with no external network and only one feed, the patch is perturbed at two diagonally opposite corners. The size of the truncation is related to the *Q* (quality factor) of the antenna and can be obtained as follows [5]:

$$\frac{\Delta s}{S} = \frac{1}{2Q} \qquad (1)$$

$$S \quad L^2 \qquad (2)$$

$$c \quad \sqrt{\quad s} \qquad (3)$$

where Δs is the total area of perturbation segment, *S* is the total area of the patch before truncation and *Q* is the patch quality factor. The layout of the truncated-square patch antenna is shown in Figure 2 (b).

Four inserted slits with equal widths and lengths are then introduced to the corner-truncated square patch. These inserted slits can lower the resonant frequency of the corner-truncated square patch due to the meandering of the excited fundamental-mode patch surface current path by the slits [7]. Hence, a size reduction is expected since the embedded slits will allow the antenna to resonate at a lower frequency. The size is known to be inversely proportional to the frequency of operation of the antenna.

3.0 ELECTROMAGNETIC SIMULATION RESULTS AND DISCUSSIONS

The square patch antenna resonates at 2.438 GHz with the dimensions of 37.5 x 37.5 mm and the corresponding reflection bandwidth is 1.4 % at VSWR = 2:1 as shown in Figure 3 (a). The feed line is placed at *L*/2. The antenna is well matched to the 50 Ohm input.

The return loss response of the truncated-square patch antenna is shown in Figure 3 (b). Because of the perturbations, the impedance of the feed point at *L*/2 changed. The feed line may be embedded below the patch to produce a right-hand circular polarisation. A quarter wavelength transformer of 22.24 mm x 4.25 mm is used to match the antenna to the 50 Ohm input. The antenna is well matched at 2.45 GHz and the reflection bandwidth is 2.2 % at VSWR = 2:1.

The width and length of each inserted slit is found to be 1 mm and 18 mm, respectively. The layout of the corner-truncated square patch with four inserted slits is shown in Figure 2(c). Because of the inserted slits, the modified antenna is fed by a 0.75 mm x 29.75 mm line to match to the 50 Ohm input. It is found that the resonant frequency decreased to 2.18 GHz as shown in Figure 4. The return loss is better than -30 dB with VSWR of 1.06. The reflection bandwidth is narrower, i.e. 1.8 % at VSWR 2:1.

A good right-hand circular polarization is obtained from the simulation result as shown in Figure 5. It shows that the right hand circular polarization performs well with this design. The antenna size is decreased by ~12 %. This corresponds to the lowering of the resonant frequency by ~ 11 %.

4.0 CONCLUSION AND RECOMMENDATIONS

A single microstrip side-feed corner-truncated patch with four inserted slits has been successfully simulated. The antenna resonates well at the corresponding frequency of operation. The resonant frequency decreased by ~ 12 % compared to the corner-truncated square patch. This corresponds to a decrease in size of ~ 11 %. In addition, it is observed that the reflection bandwidth also decreased compared to the corner-truncated square patch. However, the bandwidth can be increased by employing bandwidth enhancement techniques. Good radiation characteristics are obtained from the simulation results. Work is currently under way to resize the proposed antenna to resonate at the desired 2.45 GHz. An electromagnetic coupling feed may be considered for compactness in size. Fabrication and experimental measurements will then be carried out.

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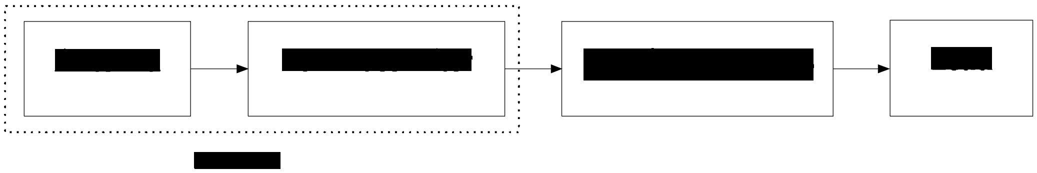
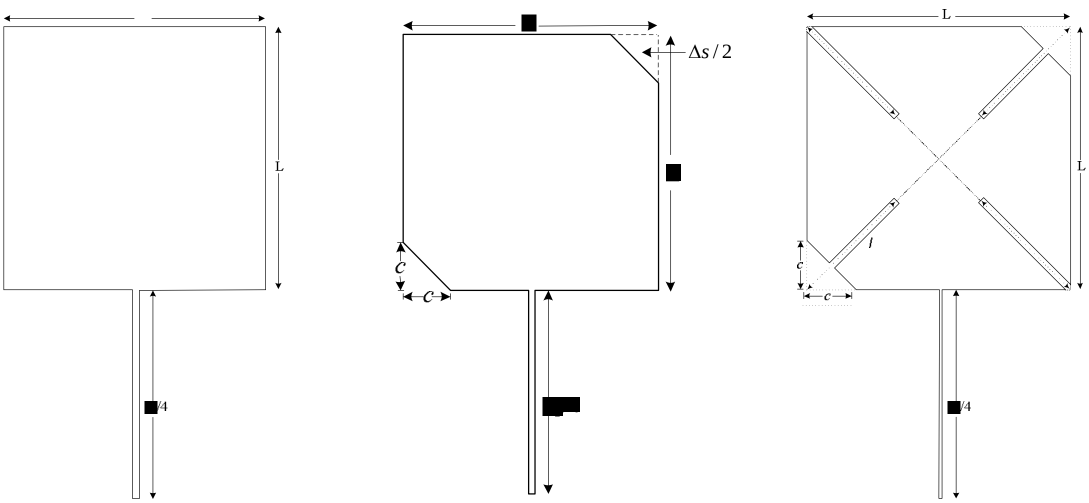
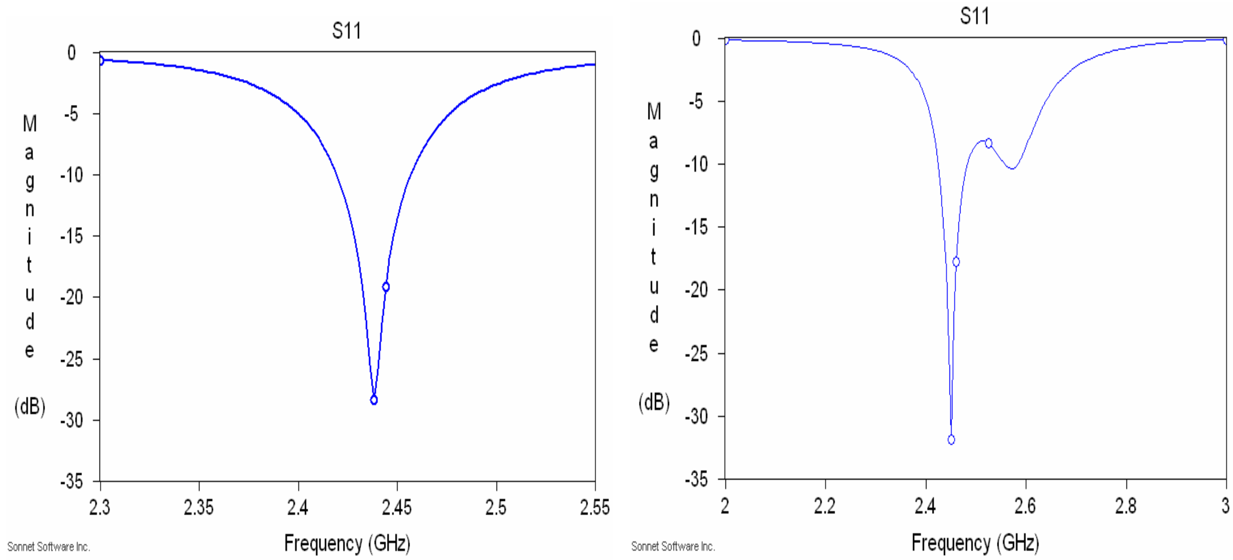


FIGURE 1: Block diagram of a rectenna circuit and load.



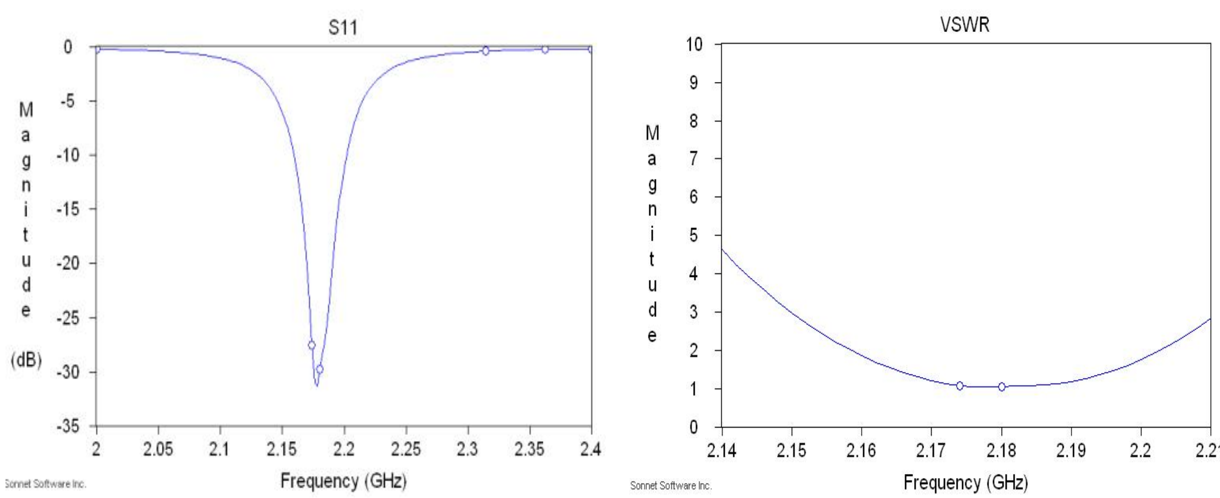
(a) (b) (c)

FIGURE 2: Geometry of the antenna
(a) Square patch
(b) Corner-truncated square patch
(c) Corner-truncated square patch with four inserted slits.



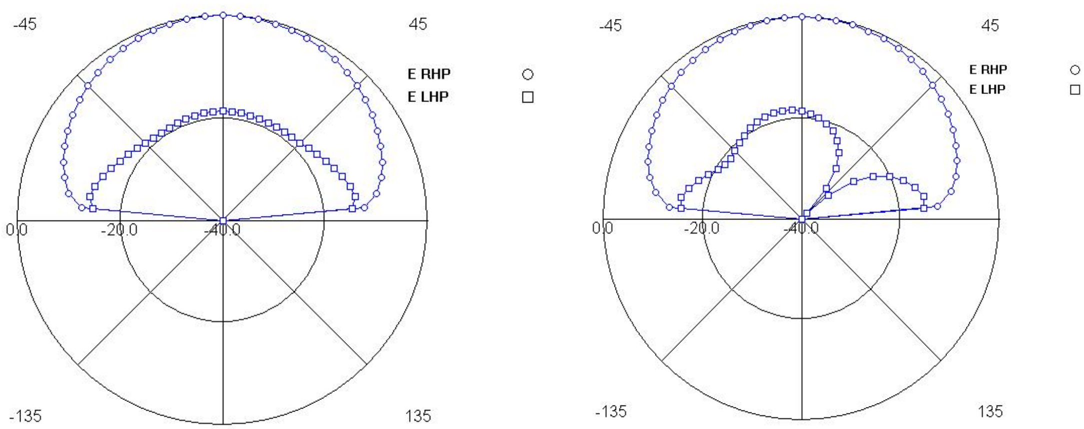
(a) **(b)**

FIGURE 3: Return losses of
(a) Square patch antenna
(b) Corner-truncated Square patch antenna.



(a) **(b)**

FIGURE 4: The response of the corner-truncated square patch with four inserted slits
(a) Return loss (b) VSWR



(a) **(b)**

FIGURE 5: The simulated response of the circular polarisation radiation (a) x-z plane (b) y-z plane.