CPW Fed HMSIW Slot Antenna for Wireless Power Transmission

S. Revathy[1], H. Umma Habiba[2], A. E. Ramanujan[3]
[1],[3] Student, M.E, Communication Systems,
[2]Professor, Department of Electronics and Communication,
Sri Venkateswara College Of Engineering
Chennai, India

***Abstract*— The electricity requirements of the world including India are increasing at an alarming rate and the power demand has been running ahead of supply. One of the major motivations for rectenna research is to design a receiving antenna for proposed wireless power transmission (WPT), which would harvest energy from sunlight in space with solar cells and beam it down to Earth as microwaves to huge rectenna arrays. In this paper a half mode substrate integrated waveguide (HMSIW) slot antenna is designed for the wireless power transmission at 5.8 GHz (industrial-scientific-medical band) which is capable of achieving a size reduction of nearly 50% in comparison to conventional SIWs. The substrate integrated waveguide (SIW) is a low cost realization of the traditional waveguide. The rectenna design consist of antenna combined with rectifier. The design of antenna involves dumb-bell stub embedded open loop resonator integrated with one side vias. Then the rectifier is to be designed for the same frequency using silicon schottky diode and matching network. The model of the antenna is built and simulated using ADS software. The designed slot antenna having the good return loss of -16 dB for 5.8 GHz and the size of 11 mm x 15 mm is achieved, which is very compact compared to other design.**

Keywords*— Substrate integrated waveguide; rectenna; wireless power transmission; Schottky diode.

I. INTRODUCTION

It is understandable that the whole world is in pursuit of developing ways to meet their energy needs, this particular issue is more relevant and challenging for emerging economies such as India, China, South Africa etc. because of the fact that the scale of interventions needed are of higher order.

Since then, considerable research has been conducted on rectennas for WPT applications. In the 1970s, P. E. Glaser proposed the idea of wireless power transmission (WPT) [1]. During 2001- 2002, NASA has been pursuing an SSP Concept and Technology Maturation (SCTM) [2] program follow-up to the SERT, with special emphasis on identifying new, high-leverage technologies that might advance the feasibility of future SSP systems [3]. Then in the year of 2002 a dual-frequency printed dipole rectenna has been developed for the wireless power transmission at 2.45 GHz and 5.8 GHz (industrial, scientific and medical bands) using coupling method [4]. In the year of 2011 the development of rectenna in terms of its applications in Microwave Power Transmission, Harmonic Rejection, CP radiation and ISM band is described [5]. These rectennas consist of several antennas such as dipole, antenna arrays, slot meander line and rhombic loop antennas along with the rectifying diodes. In some cases, more than one rectifying devices have also been used and antenna is found to be act at dual bands. Then in the year of 2012 the use of Geosynchronous satellites for collecting sunlight, harnessing it to produce solar power and transmitting the generated power back to Earth using Wireless power transmission (WPT), safely and reliably was studied [6]. The advantage of placing solar cells in space is the 24-hour availability of sunlight. Also the urgency of finding an alternative energy source due to the depleting energy resources on earth calls for Space Based Solar Power. In the year of 2014 the review of energy harvesting contained in electromagnetic waves was studied [7].

In this paper the slot antenna is designed by incorporating the HMSIW technology for 5.8GHz frequency having very good return loss of -16 dB with real value of 4.6 and loss tangent of 0.01 using ADS software which brings in compactness compared to other earlier designs.

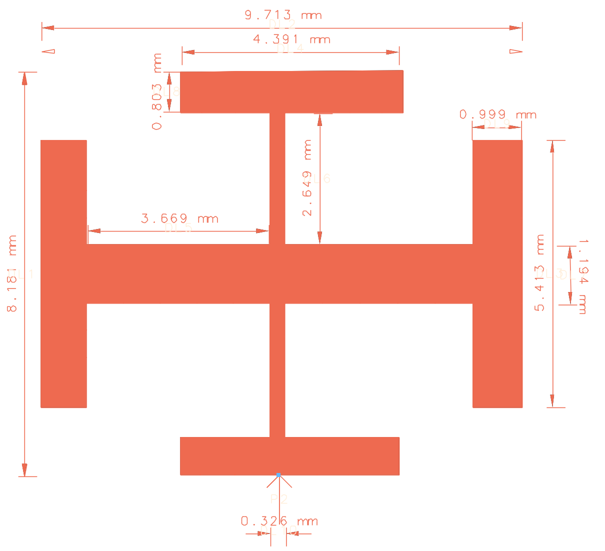
The structure of the half-mode substrate integrated waveguide (HMSIW) is similar to that of the SIW, but with the waveguide width half of conventional SIWs. The narrow band operating frequencies of the antenna is achieved by proper matching. Wireless power transmission was proposed early on as a means to transfer energy from collection to the Earth's surface, using either microwave or laser radiation at 5.8 GHz frequency. This frequency is selected because it is in the industrial, scientific and medical (ISM) band and therefore should have minimal problems with respect to allocation and radio frequency interference, results in near-optimum efficiency, and avoids brown-outs in rain.

II. DESIGN OF HMSIW ANTENNA

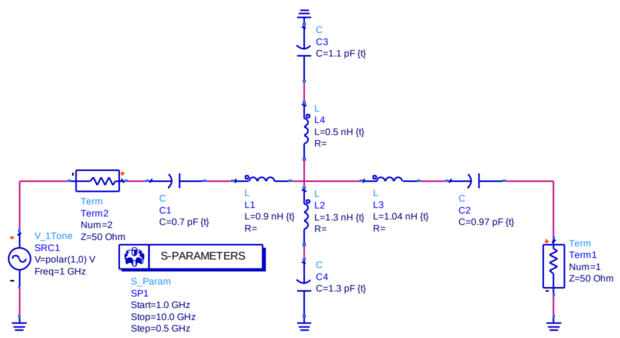
A. Design of Dumbbell Shape Resonator

The design of HMSIW slot antenna consists of open loop resonator embedded with dumbbell shape resonator. The dumbbell shape resonator is initially designed. Due to its resonant behavior it may be compared to the series resonators (LC circuit). The equivalent circuit of the dumbbell shape resonator is shown in Fig. 1(b). The length and width of the resonator plays a very important role to find the resonant behavior of the dumbbell shape resonator.

The layout of the dumbbell shape resonator and its equivalent circuit is shown below



(a)



(b)

Fig. 1. Layout of dumbbell shape resonator (a) and its equivalent circuit (b).

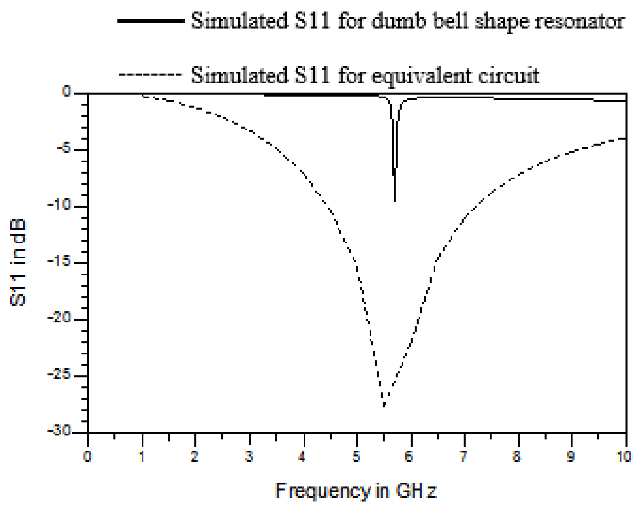
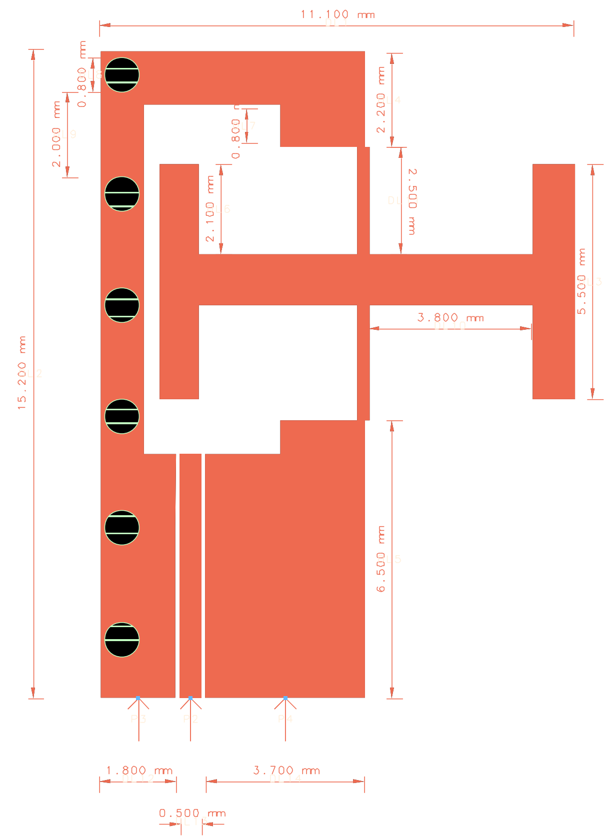


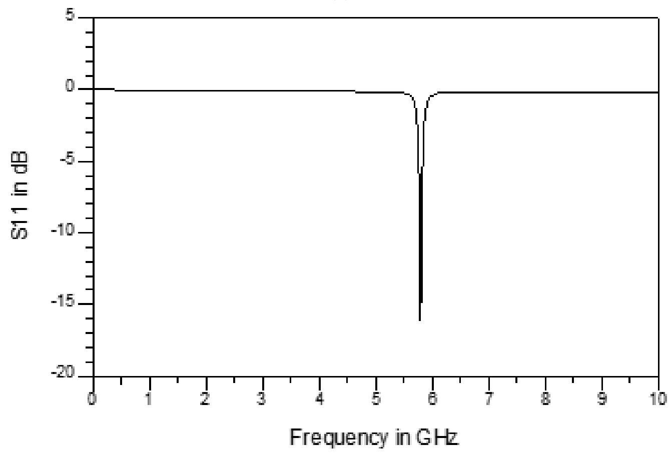
Fig. 2. Simulated S11 results of dumbbell shape resonator and equivalent circuit.

B. Design of HMSIW antenna

Then the dumb-bell shape resonator is embedded with open loop resonator integrated with one side vias attached to a coplanar waveguide(CPW) feeding line which is nothing but HMSIW. The half mode (a row of vias) SIW slot antenna for 5.75 GHz is initially designed. Then it is made to resonate at 5.8 GHz band by varying dimensions of the feeding structure.



(a)



(b)

Fig. 3. Layout of HMSIW antenna (a) and its simulated S11 result (b).

The return loss is improved by varying dimensions of dumbbell structure and feeding structure. The curve is

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smoothened by varying the feeding structure and truncation is made at the open loop resonator near the feeding structure to optimize the output. The proposed HMSIW slot antenna is fed by a CPW feed.

A comparison of various papers on the WPT application is shown below in a tabulation. Where the overall dimension of the antennas is large when compared to the proposed HMSIW antenna. Therefore, the proposed HMSIW slot antenna is very compact when compared to other antenna designs. A size reduction of greater than 50% is achieved by using the HMSIW technology.

Title	Frequency with return loss	Size
Proposed CPW fed HMSIW slot antenna for Wireless Power Transmission	5.8 GHz with return loss of -16dB	11 x 15 mm
Design of Stacked Microstrip Dual-band Circular Polarized Antenna, 2012	2.45 GHz and 5.8 GHz with return loss >-10dB	60 x 60 mm
Dual-band Transparent Antenna for ISM Band Applications, 2013	2.45 GHz and 5.8 GHz with return loss >-10dB	60 x 60 x 2.075 mm

Table 1. Comparison of overall dimension of the proposed antenna and other antenna types.

III. RESULTS AND DISCUSSIONS

The 3D radiation pattern of the HMSIW slot antenna shows that the antenna is directional 5.8GHz frequency is shown in Fig. 4.

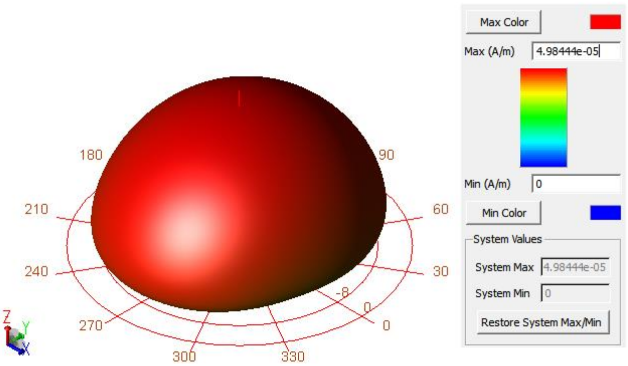
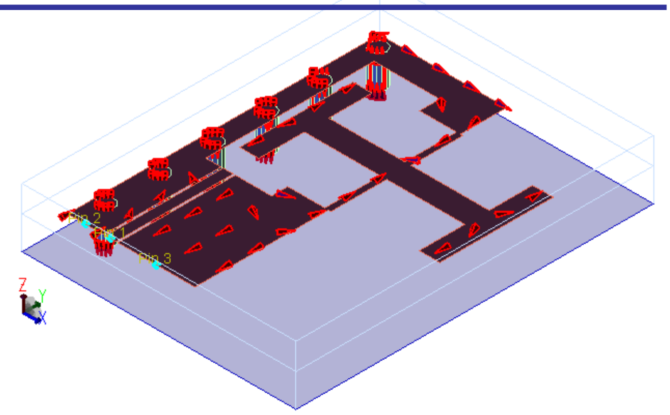
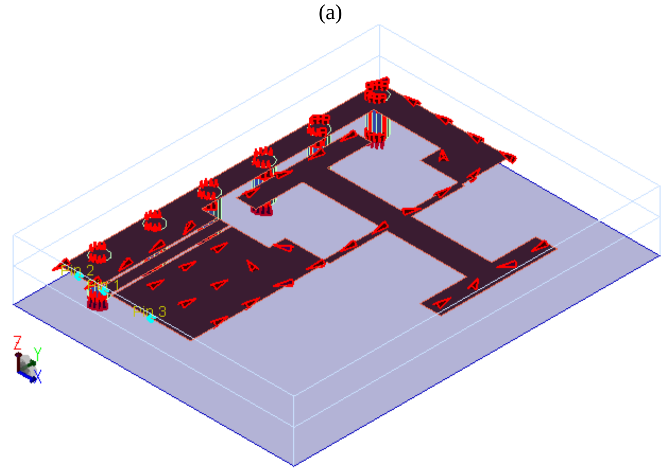
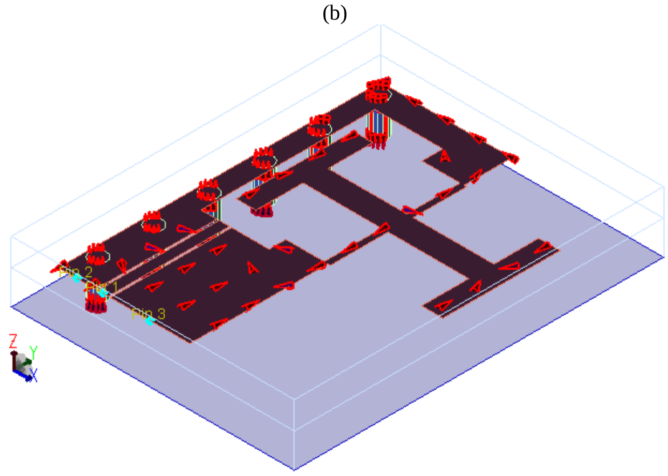


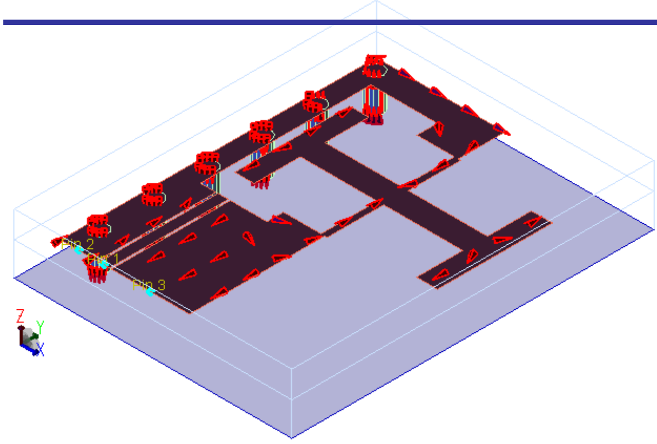
Fig. 4. 3D radiation pattern of the HMSIW slot antenna at 5.8GHz frequency.

The current distribution for 5.8GHz frequency from 0-degree to 360-degree phase are obtained from the ADS software after simulation is given in the Fig. 5.

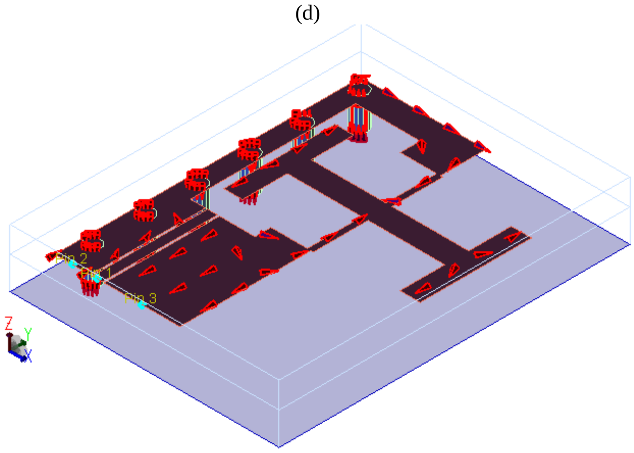

(a)


(b)


(c)



(d)



(e)

Fig. 5. Current distribution of the HMSIW slot antenna at 5.8GHz frequency for various phase from 0 – 360 degree like 72 (a), 144 (b), 216 (c), 188 (d) and 360 (e) degree phase .

IV. CONCLUSION

In this paper, the performance of a HMSIW slot antenna has been presented. The antenna operates well at return loss of -16 dB for 5.8 GHz and the size of 11 mm x 15 mm which is very compact compared to other design. The narrow band operating frequency of the antenna is achieved by proper matching. This work is extended for rectenna and array with proper matching network for wireless power transmission application.

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