High-Gain Microstrip Antenna for Microwave Power Transmission

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***Abstract* – A high-gain and high-efficiency microstrip antenna is proposed and developed for microwave power transmission. Air substrate design is utilized to maximize the total efficiency of the circular patch operating in the fundamental TM110 mode. Low-cost PCBs have been used to form the ground plane and patch element. The measured -10 dB return loss bandwidth is 350 MHz (5.67 – 6.02 GHz). Maximum measured antenna gain is 8.4 dB while the measured total efficiency is 96.4% at the operating frequency of 5.8 GHz. Measurement data shows good agreement with the simulation results. The proposed antenna is being used in the microwave power transmission system with both transmitter and receiver RF circuits.**

***Index Terms* — Microstrip antennas, high antenna gain, total efficiency, microwave power transmission.**

1. Introduction

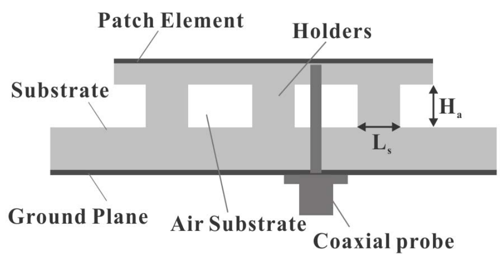
Microwave power transmission (MPT) is a promising technology to transmit radio frequency (RF) power into free space over a long distance and be received by an antenna with a RF to DC rectifying circuit. As the key technology of wireless power transmission (WPT), MPT has been an area of intensive research interest over a long time. MPT research has been driven primarily by the desire to remotely power unmanned aerial vehicles and by the concept of space solar power (SSP) first conceived by Dr. Peter Glaser of the Arthur D. Little Company in 1968 [1].

Among all the components of a MPT system, transmitting/ receiving antenna plays an important role as an energy transceiver. In order to satisfy the requirements of MPT performance, antenna should have high total efficiency, high antenna gain and compact size. Many researchers have contributed to improving these key points and developing multi-function rectennas and antenna arrays [2]-[6].

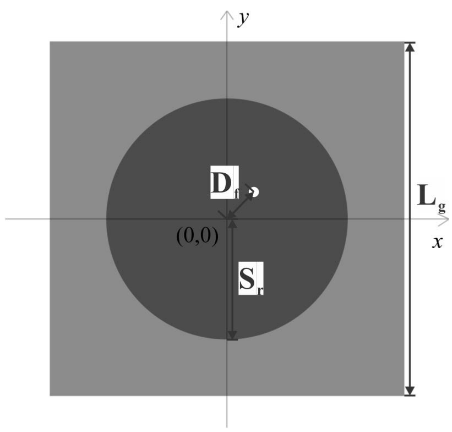
In this paper, a high-gain and high-efficiency microstrip antenna is proposed for microwave power transmission. Air-filled substrate between two PCBs is used to maximize the total efficiency while providing low-cost design solution.

2. Antenna Design

The configuration of the proposed antenna is shown in Fig. 1. The antenna consists of a circular patch printed on top of Duroid substrate, four cubic holders, and a square ground plane at the bottom of the same Duroid PCB being used to provide the rigidity of antenna structure. S_r is the radius of circular patch; D_f is the feed location, while L_g denotes the length of a ground plane. Air-filled substrate utilized in this design contributes to increasing the antenna gain and total efficiency. The directional performance of this antenna in XZ-and YZ-planes fits well the requirements of the MPT system. In order to further improve front-to-back ratio, ground plane dimension should be at least 20% larger than the size of a patch radiator. Four cube holders with length L_s are placed symmetrically near the edge of the radiator element to support to top patch, while a coaxial feed line goes through three medium layers as shown in Fig. 1a.



(a)



(b)

Fig. 1. Antenna layout: (a) cross-sectional view (b) top view.

EM simulation is carried out with HFSS 15.0. First we calculate the size of circular patch then optimize the performance by tuning the design parameters. Patch element radius defines the resonant frequency, while the ground plane size affects the front-to-back ratio and radiating pattern. D_f is mainly tuned to improve input impedance matching, and H_a tuning affects matching performance and resonant frequency as well.

After optimization, the proposed antenna design parameters at the operating frequency of 5.8 GHz are as follows: air substrate height H_a= 0.25 mm; cubic holder length L_s= 2 mm; ground plane superstrate thickness T_g= 0.8 mm, patch substrate thickness T_p=0.25mm, coaxial feed location D_f = 3.7 mm, circular patch radius S_r=12.1 mm, and dimension of the ground plane L_g=37 mm.

3. Measured Results and Discussions

The proposed antenna has been fabricated and measured to validate the design. The antenna prototype is realized on Roger Duroid RT 5880 substrate (dielectric constant = 2.28, and loss tangent = 0.001). The antenna prototype is shown in Fig. 3 and compared to the 1-Yuan coin.

The simulated and measured results of the return loss are plotted in Fig. 2. Measured -10 dB return loss bandwidth is 350 MHz (5.67 GHz to 6.02 GHz). Fig. 4 indicates that the measured maximum boresight gain is 8.4 dB and the measured total efficiency is 96.4% at 5.8 GHz. Measurement shows good agreement with the simulation results. Measured antenna radiation pattern has the 3D shape that is typical for the TM110 fundamental mode of a circular patch.

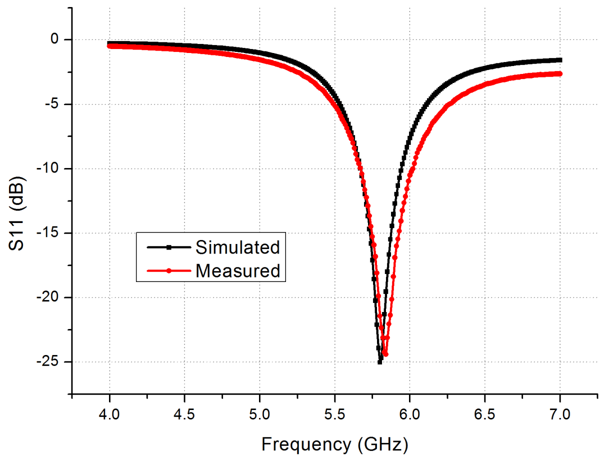


Fig. 2. Simulated and measured S-11 parameter.

4. Conclusion

A high-gain and high-efficient microstrip antenna is proposed for microwave power transmission. The operating frequency can be tuned by varying the radius of the patch element. Air-filled substrate design results in the measured top antenna gain of 8.4 dB and total antenna efficiency of 96.4%. The -10 dB return loss bandwidth is obtained as 350 MHz at 5.67 to 6.02 GHz band. Considering the excellent radiation performance of this design together with the low-cost production, the proposed antenna is currently being used for the directional applications of long-distance microwave power transmission as well as for the efficient wireless RF energy harvesting.

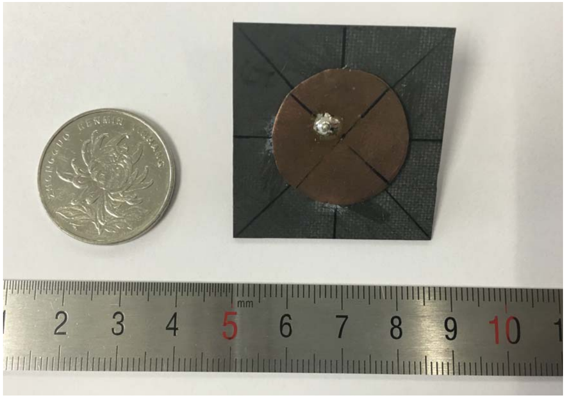


Fig. 3. Antenna prototype as compared to a coin.

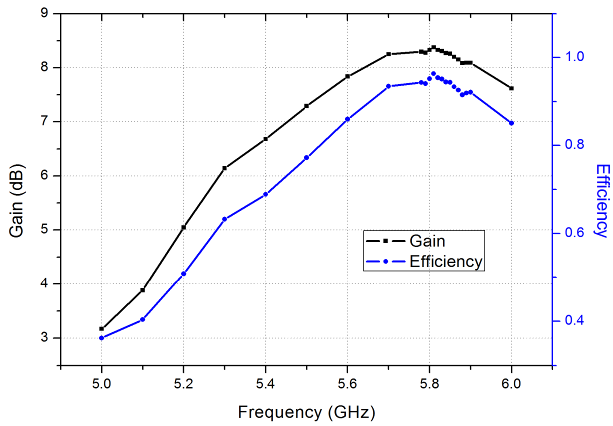


Fig. 4. Measured antenna gain and total efficiency.

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