IJERMT
International Journal of Engineering Research & Management Technology
ISSN: 2348-4039
May- 2015 Volume 2, Issue-3
Email: editor@ijermt.org
www.ijermt.org

Wireless Powering S of Multiple Electronic Device in Over Moded Cavity

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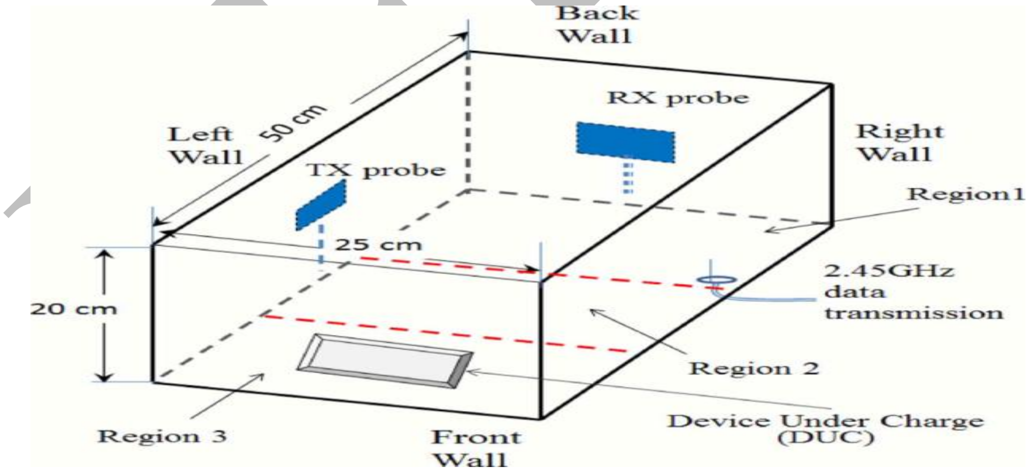
ABSTRACT:

This project discusses about wireless powering of multiple electronic devices simultaneously in shielded over moded conductive cavity using a sub watt transmitter which provides 10GHz powering. This method is to increase the uniform power density within the cavity using frequency modulation. It is noted that a frequency modulation of 0.1% is sufficient to provide power density in an uniform manner. A device under charge (DUC) with rectenna, power management circuit, storage, solid state battery and an ISM band wireless transceiver is considered for monitoring of battery charge at various locations of the cavity. Microcontroller performs power management and the available power is monitored using a 900MHz transceiver. The shielded cavity powering method is scalable in volume, frequency, power and the number of devices that is to be powered.

Keywords:- wireless powering, over moded cavity, frequency modulation, rectenna device under charge(DUC).

I.INTRODUCTION

Research and development in wireless powering devices has grown rapidly in popularity over the past decade. Methods of wireless power transfer include near field coupling for high power vehicle applications, lower power inductive charging far field power beaming for powering aircraft or beaming power though the atmosphere and far field scavenging/harvesting to power embedded or hard to reach sensors that cannot easily have a battery changed. An alternative approach is investigated using a metal enclosure at 2.2 GHz with the goal of watt level shielded wireless powering of multiple electronic devices in a three dimensional (3D) arrangement. A closed metallic cavity resonator is a major component of modern microwave communication systems.



10 GHz Transmit and receive probes are located on two walls of the cavity which relaxes the design constraints imposed by the Face Centric Cube / Institute of Electrical and Electronics Engineers health and safety emission guideline differing for various frequencies. The fully shielded metal box allows more freedom in choice of frequency, as well as selection of power level for wireless power transfer. A similar approach was used, where frequency dependent meta material cavity walls were implemented in order to control magnetic field leakage. This project presents characterization of an over moded metal waveguide cavity that operates at 10 GHz. The cavity resonator creates a shielded scalable environment for efficient power delivery using electromagnetic waves. The cavity is analyzed using the models applied to reverberation chambers. Multiple Devices Under charge (DUCs) can be placed anywhere within the cavity for power collection. Each DUC consists of an antenna integrated with a rectifier, also known as a rectenna, power management circuitry, and a storage device in the form of a solid state battery on a chip. The goal is to create a power density distribution in the cavity that is as uniform as possible as more DUCs are added. The cavity resonator creates a shielded scalable environment for efficient power delivery using electromagnetic waves. The cavity is analyzed using the models applied to reverberation chambers. The approach is designed to deliver power to multiple devices simultaneously with low sensitivity to device orientation. Additionally, legal and health considerations are not an issue because the electromagnetic energy is contained within the cavity.

II.CAVITY CHARACTERIZATION

The mode distribution is sensitive to the location and size of objects inside, as well as the dimensions of the cavity. The average power density distribution can be modeled in analogy to statistical analysis of reverberation chambers. EMI/EMC testing often requires the use of such a chamber which, ideally, has a completely uniform distribution of power in the volume. In the case of powering applications, this goal is relaxed; it requires sufficient power to allow charging irrespective of the orientation and location of the DUC. The inside dimensions of the cavity in Figure 1 are 24.7 cm 18.7 cm 49.7 cm, which is considered to be electrically large when using the excitation frequency of 10 GHz.The overall sensitivity to outside perturbation, be it frequency or volume change, drives the reasoning for moving to a statistical approach to solving Maxwell's equations for the fields in the cavity is presented. In order to measure the effects of frequency and volume shift in the cavity for a statistical analysis, a static probe is placed inside the cavity. The probe response in the cavity can also be modeled statistically.

A powering frequency of 2.2 GHz was chosen, first prototype size of 20cm x 25cm x 50cm will support a number of modes at this frequency and thus have a very incoherent field profile, suitable for powering. This 2.2 GHz frequency is chosen to avoid interference with military and commercial GPS devices, mobile phone frequency allocations, and Bluetooth and Wi-Fi enabled devices that may be placed within the cavity.

Cavity modes

The waves propagating inside the metal waveguide may be characterized by reflections from the conducting walls.

If the single non zero longitudinal field component associated with a given waveguide mode can be determined (E_Z for a TM mode, H_Z for a TE mode), the remaining transverse field components can be found using the general wave equations for the transverse fields in terms of the longitudinal fields. A Transverse electric wave has E_z=0 and $H_z \neq 0$. consequently,all E components transverse to the direction of propogation.conversely to TE Modes, Transverse magnetic mode have H_Z=0 and E_Z =0. The size of the rectangular powering box is well above cutoff for a number of rectangular waveguide resonator modes. Expressions for the TE mnp and TM mnp modes can be found in various electromagnetic texts and the cutoff frequencies calculated for the dimensions at 2.2 GHz this resonator supports 61 modes with varying field profiles and polarizations allowing for more uniform power density throughout the cavity.

Excitation probe

To excite the cavity, patch probes were designed and included in a full wave simulation (HFSS) to find the fields in the unloaded resonator. The patch dimensions are obtained by simulation inside the cavity for 2.2 GHz input match, since it will not behave the same as a patch antenna in free space.

Simulations were performed for the electric field distribution in the cavity with the two probes fed with 1W of power with varying relative phase. The electric field magnitude is about 1V/m, and the relative phase did not seem to have a large effect. For example, with the two sources in quadrature, the average electric field magnitude within the volume is 0.08 V/m less than with the sources in phase. The case in which the probes are fed 135 degrees out of phase yields the highest average electric field magnitude of 1.21 V/m, which is 0.28 V/m greater than the sources in phase.

III.CAVITY STIRRING

Most reverberation chambers use mechanical stirrers to mix the fields inside the camber in a controlled way. The mixer is an electrically large metal object controlled with a stepper motor. The power radiated into the chamber is directed at the stirring mechanism and mixed within the cavity. The power radiated into the cavity is 0.25W, and the power is measured by the static receive probe located inside the cavity at the back side.

The metal scatterer are placed at numerous positions and configurations within the cavity. The stirring takes place 500 times, where a measurement is taken after each pulse, as in the previous test of an empty cavity When the 500 counts are recorded, the absorbers are moved and the measurements taken again. The mechanical stirring and pseudorandom placement of scatterers are both mechanical methods of stirring the cavity. It is of interest to use electronic methods of stirring to allow for fewer moving parts, which would help keep cost and variability low. The power radiated into the cavity is 0.25W, and the power is measured by the static receive probe located inside the cavity at the back side.

It was observed that even a small change in location of the small metal object had an effect on the power incident on the static receive probe. The test for frequency modulation is done with a single small brass scatterer measuring 2 cm placed in region 1 and the frequency was swept from 9.990 to 10.001 GHz in 1MHz increments. A measurement is taken at each increment in frequency, and this is repeated for the scattering object in all three regions and facing each wall. From these data, that the static receive probe is reading a large variation in power, which would assume that the excited modes are stirred. Now that a method is shown to stir the modes with a change in frequency, this can be used to test the power received from a DUC model. the static receive probe is reading large variation in power, which would assume that the excited mode.

IV.POWER MANAGEMENT CIRCUIT

A single MSP430 microcontroller processes for power management and the power converter, which actively adjusts the rectenna output impedance. The power converter implements an asynchronous DCM boost converter controlled by the MSP430 via a gate drive signal of adjustable period and duty cycle.

Even with the low RF–dc conversion efficiency at this high power level, the development board was able to run a MPPT algorithm, charge the on board solid-state battery, and communicate to the outside computer in many different orientations and regions. It shows the rectified DC voltage vs probe placement with identical probe orientation but with an active load utilizing a maximum power point tracking (MPPT) algorithm that dynamically adjusts its input resistance to achieve maximum power. The fields within the cavity are not actively altered with frequency modulation or mechanical stirring, yet the rectified voltage as a function of location remained relatively constant. Probe orientation the modes aligned such that there exists a constructive superposition of fields near the cavity side walls Similar observations were noted with different probe orientations and placements. The RF–dc conversion efficiency of the rectenna was measured to be in the range of 8%–15%, depending on the dc load. The power level for the efficiency test was 228 W/cm.yet the rectified voltage as a function of location remained relatively constant.

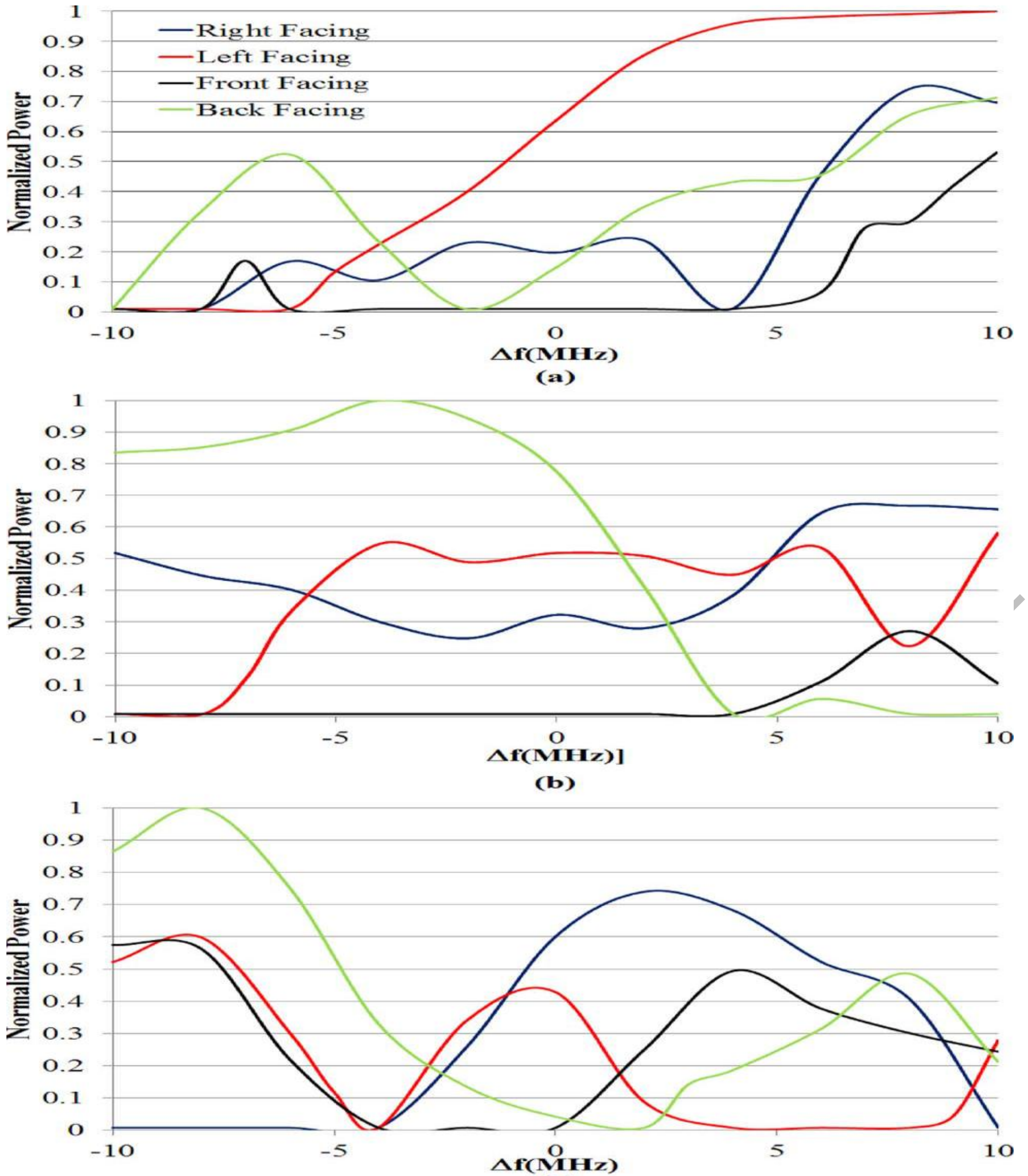


Figure Normalized measured dc power collected by battery in (a) region 1,(b) region 2, and (c) region 3 when the rectenna facing different walls of the cavity, where is the frequency shift in megahertz from the center frequency of 10 GHz.

V.CONCLUSION

A shielded over moded resonator powering cavity which includes Cavity with four small pieces of absorbing surfaces that mimic multiple DUCs is presented. The approach is scalable in terms of volume and frequency. Other wireless powering approaches use different field distributions: inductive and resonant coupling uses the near field, and beaming and scavenging receive power in the form of one or more plane waves. The approach is scales, and applications include charging personal electronic devices, while a scaled version can be used to powering toys in an “electromagnetic” toy box. The MPPT on the board, charge a solid state battery, and communicate that data to the outside of the cavity.Stirring the cavity by the methods or a combination of them described are practical operational scenarios. The new wireless charging standard A4WP (alliance for wireless power) is the changing the concept of inductive charging from magnetic induction to resonance. magnetic induction requires the two coils to be placed very closely,whereas in this technique a large area is covered so the device's position is not very critical. In fact multiple devices can be charged wirelesssly with this technique by placing them all within the wide resonant field. Also, charging is not affected by the position of the device being charged pad, maximum amount of power gets transferred to the device to charge it easily fast.

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