High Gain Wireless Power Transfer Using 60GHz Antenna Array

Hugo Flores-García
Department of Electrical and Computer Engineering
Georgia Southern University
Statesboro, GA
hf01049@georgiasouthern.edu

Deon Lucien
Department of Electrical and Computer Engineering
Georgia Southern University
Statesboro, GA
dl02399@georgiasouthern.edu

Tyler McPherson
Department of Electrical and Computer Engineering
Georgia Southern University
Statesboro, GA
tm05259@georgiasouthern.edu

Sungkyun Lim
Department of Electrical and Computer Engineering
Georgia Southern University
Statesboro, GA
sklim@georgiasouthern.edu

***Abstract*—An indoor, high gain 60-GHz wireless power transfer system is proposed in a residential house filled with furniture and home appliances. A single transmitter composed of a 32 by 32 patch antenna array transfers power wirelessly to 5 different security cameras equipped with 32 by 32 patch array receivers located at 5 different positions around the house. The array exhibits a realized gain of 34.42 dB. The minimum required power to feed a prototype ultra-low power camera is 4.6 dBm (2.36 mW). In order to deliver the required amount of power to each receiver, an exhaustive search is conducted to find the best transmitter position in which the maximum amount of power is fed to all receivers. Overall, the necessary amount of power required to feed the ultra-low power camera is met, with an average power transfer of 22.03 dBm (0.16 W) at the best transmitter position.**

Keywords—Wireless power transfer, patch antenna array, 60-GHz frequency band.

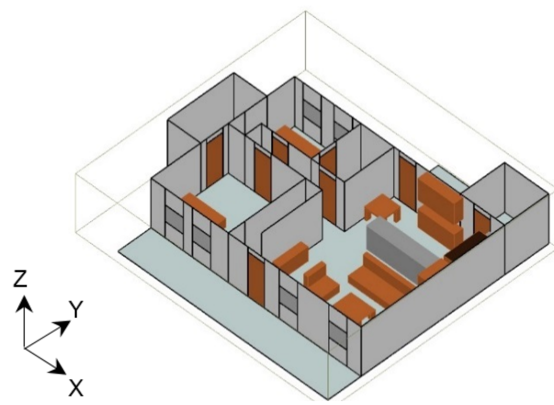
I. Introduction

"Smart" home appliances have become more and more common around the world. Devices such as smart thermostats, smart LED lightbulbs, smart cameras and sensors are popular to everyday consumers. These devices introduce the idea of a connected home and the option to control various aspects of a home environment from a smartphone. The communication between most of these devices is already wireless, either through Bluetooth or Wi-Fi technology. However, these devices need to be powered. Most current appliances are powered using a standard wall plug AC adaptor. Some of the disadvantages to these appliances include the requirement of installation for in-the-wall wired systems, such as security cameras and sensors placed near the roof of an indoor environment.

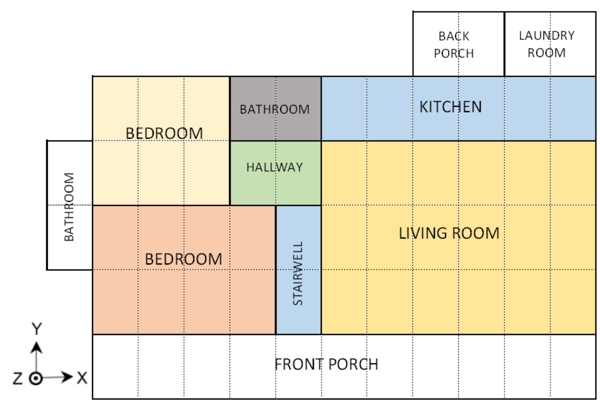
In this paper, a novel, 60-GHz, wireless power transfer system using high gain arrays is proposed to power several security cameras wirelessly. A single transmitter is used to deliver power to multiple receivers with cameras. Multiple-element, highly directive array antennas usually have a large footprint. However, the use of the 60GHz band increases the directivity of the antenna with small physical volume of the array due to a short wavelength. Small cameras with an ultra-low power device are used for optimal functionality. The ultra-low power streaming camera presented in [1] uses a novel technique that eliminates the high power consuming hardware involved in a camera, such as ADCs and amplifiers with the power input of 4.6 dBm (2.36 mW).

II. Simulation Setup

A. Simulation Environment



(a)



(b)

Fig. 1. Simulated model of a residential house, (a) 3D view, (b) 2D floor plan.

The wireless power transfer system is simulated using ray tracing software. A real residential house is modeled for simulation (Fig. 1(a)). Five receivers to power cameras are placed at an altitude of 2.6 m (just below the ceiling) on different corners of the living room, kitchen, and bedroom areas to model tentative positions for security cameras within the house. An arbitrarily located transmitter is placed at a similar height and points towards each of the receivers for maximum power transfer to the receivers. The cameras are placed outside the house, are wired through the wall, and connected with their respective receivers inside.

Fig. 1(b) shows the top view of the floor plan in simulation. Furniture and kitchen appliances of different materials (such as metal and wood) are placed within the simulated residential house to accurately approximate the reflections and diffractions of the electromagnetic rays on these household appliances. Ray interactions in the simulation model include reflections from feature faces, diffractions around feature edges, as well as transmissions through features faces.

B. *Exhaustive Search*

The best position for the transmitter is calculated using an exhaustive simulation process. A set of 44 equally spaced points are created and spread throughout the residential house. The angle between each transmitter and receiver is calculated and are applied to the ray tracing software. The simulation then calculates received power for each receiver. The results of the simulation are then evaluated to find the transmitter location with best power transmission to each receiver.

C. *Antenna Design*

Grid array antennas such as the ones in [2] and [3] are used for high frequency applications due to their small size and high gain. In this study, a 60-GHz, 32 by 32 patch antenna array is chosen as both the transmitter and receivers for the wireless power transfer system. The use of the 60 GHz band allows the easy use of a multiple element array to maximize directivity while preserving physically small antenna dimensions. The total surface area of the 32 by 32 patch array is under 8 cm by 8 cm. The main beam of the antenna has a realized gain of 34.42 dB. The side lobe effect of the array is negligible (power transfer < -30 dBm or 1 µW).

III. Simulation Results

Fig. 2 shows all of the 44 transmitter positions within the house. Out of the 44 points, only 10 points are able to meet the minimum 4.6 dBm power transfer requirement for all receivers. The positions highlighted in red meet the minimum power transfer requirement, while the positions highlighted in blue have at least one receiver that does not meet the minimum requirement. Each position is evaluated based on two criteria; The lowest received power from all 5 receivers, and their average power. After the exhaustive search, as shown in Fig. 3, position 16 is found as the best position with the highest average power at 22.03 dBm (0.16 W), and with the highest minimum 18.9 dBm (0.08 W).

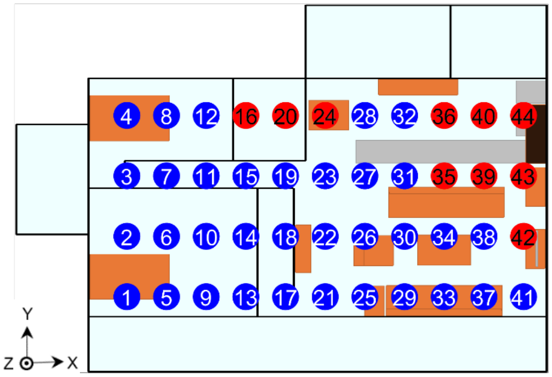
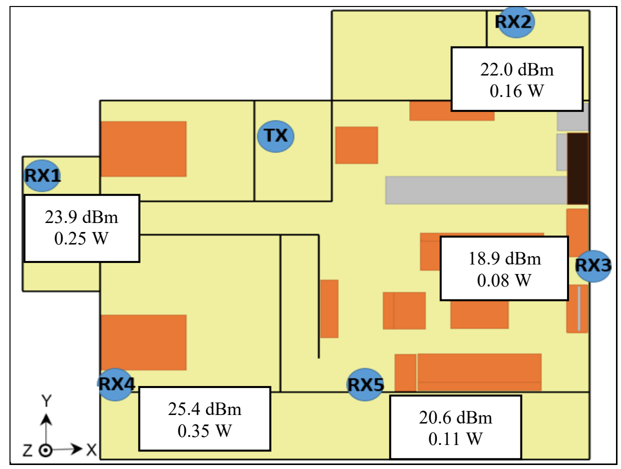


Fig 2. Transmitter positions.



TX: Transmitter, RX: Receiver

Fig 3. Receiver antenna positions along with received power at the best transmitter position (position 16).

IV. Conclusion

A high gain wireless power transfer system using 60-GHz array is proposed. After the exhaustive search, a total of 10 transmitter positions out of 44 positions is found as possible positions to wirelessly power all 5 receivers for cameras. The minimum received power in the optimal transmitter position (Position 16) is shown to be 18.9 dBm (80 mW), which is far greater than 4.6 dBm (2.36 mW) required.

References

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