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Wireless Power Transfer System

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INTRODUCTION

- This work proposes a Wireless Power Transfer (WPT) technology that would power a sea of sensor nodes wirelessly over a large area without the need for batteries.
- Effective coupling range is increased by using a resonantly coupled wireless power transfer system.
- The final goal is to field a WPT system capable of efficiently powering a sea of sensors spread over a large area.

INDUSTRY IMPACT

- The sensor nodes would be reliable for purposes such as perimeter, border, transmission line, and pipeline security.
- Future applications could also apply to the Internet of Things (IoT).

OBJECTIVES

- Determine the most optimal configuration for efficient wireless power transfer.
- Create a WPT system that will have a lifetime of over 50 years.
- Demonstrate increased coupling efficiency using tightly spaced sensor nodes with an overall coupling efficiency of over 50%.
- Provide intrusion detection with high detection rates and low false alarm rates.

PROPOSED APPROACH

- Test three configurations for the sensor nodes:
  - Inductive Coupling
  - Series-Resonant Coupling
  - Parallel-Resonant Coupling
- Test and model the coupling efficiency among the receiver nodes placed inside the transmit loop.
- Evaluate the sensing abilities of sensor nodes powered by the wireless power transfer system.

Sensor Node Configurations

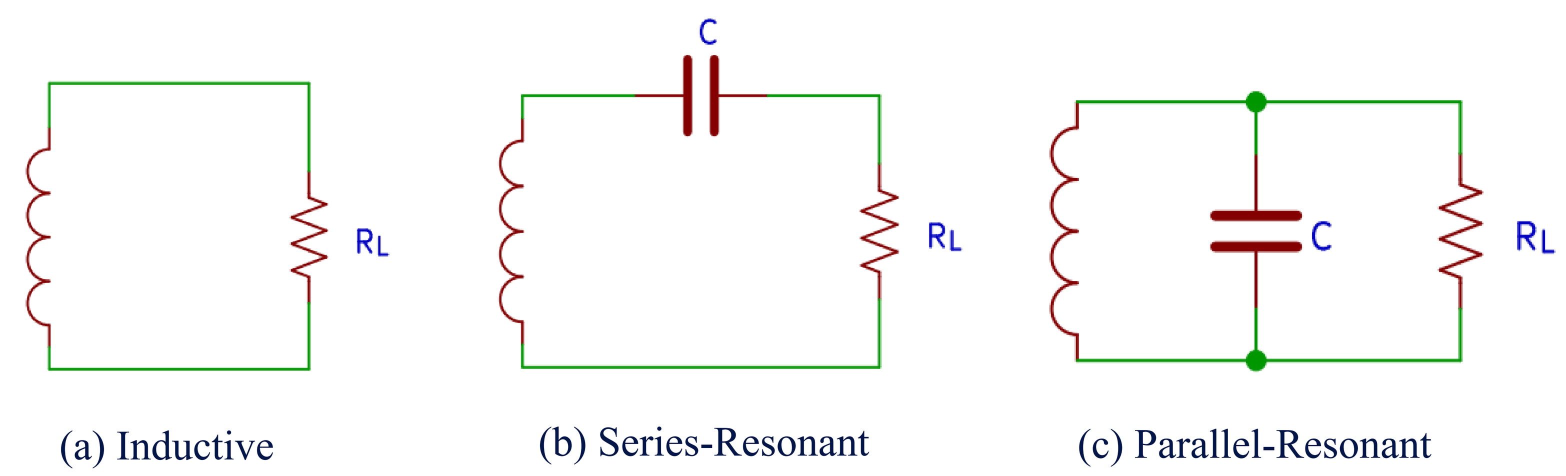

Fig. 1. Configurations for the Transmit Loop & Receiver Nodes

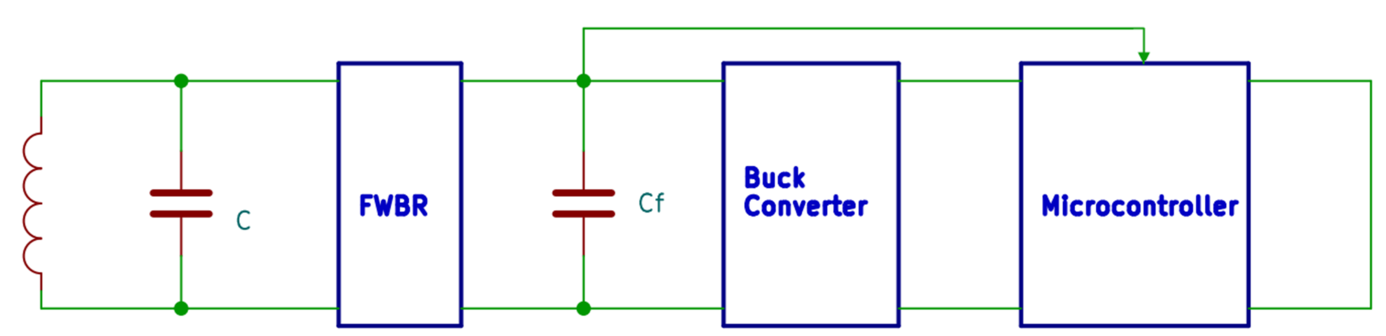

Fig. 2. Circuit for the Sensor Nodes

- This circuit includes the use of a full wave bridge rectifier, filtering capacitor, buck converter, and microcontroller. This configuration will convert AC to DC and lower the voltage so it can power a low-power microcontroller. Different sensing capabilities can be easily added to this configuration.

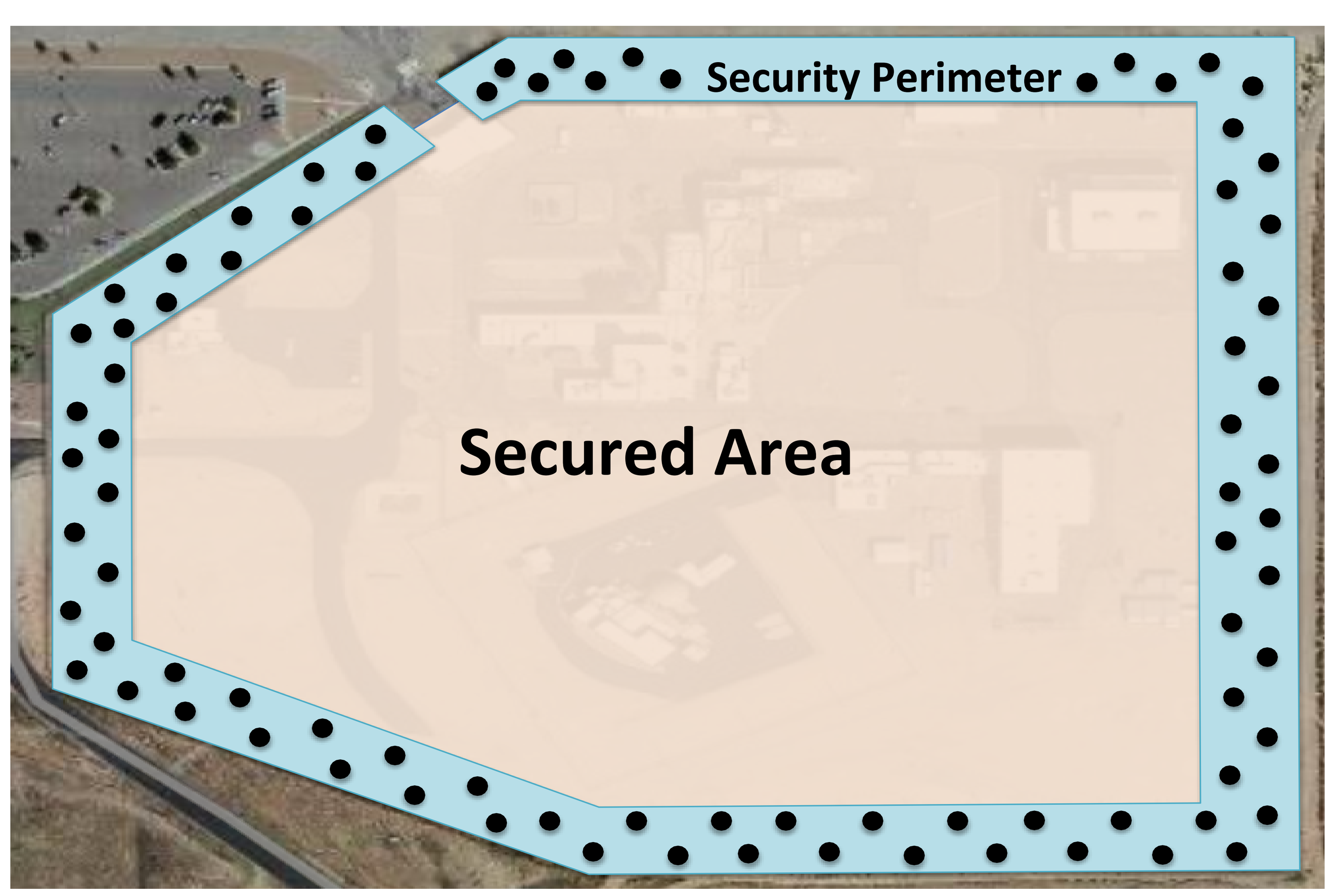

Fig. 3. Security Perimeter with Wireless Sensor Nodes

- The intended purpose of the WPT system is to enhance physical security by deploying wireless sensor nodes within the perimeter surrounding a secured area. Sensor nodes, represented as black dots in the image, use their sensing capabilities to detect intruders.

$$V_{out} = \frac{R(V_p*V_s+Zm^2)}{(2*V_s*V_z)}*I \quad (1)$$

(1) is the modeled voltage obtained from the induced current and respective load resistance, shown in Fig 4.

$$V_{out} = \frac{R}{(1+j*R*C*w)}*I \quad (2)$$

(2) is the modeled voltage for the parallel-resonant configuration, shown in Fig. 5

SIMULATION RESULTS

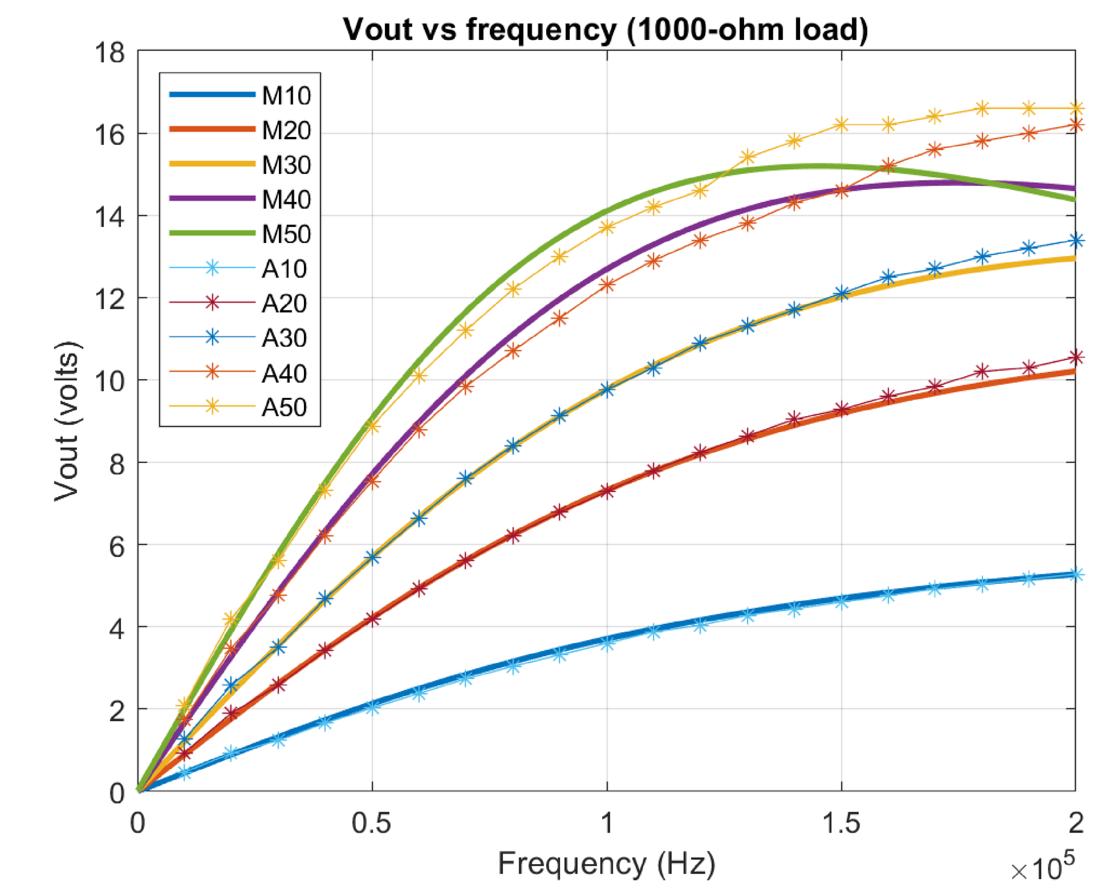

Fig. 4. Modeling Results for Inductive Coupling using 1kΩ load

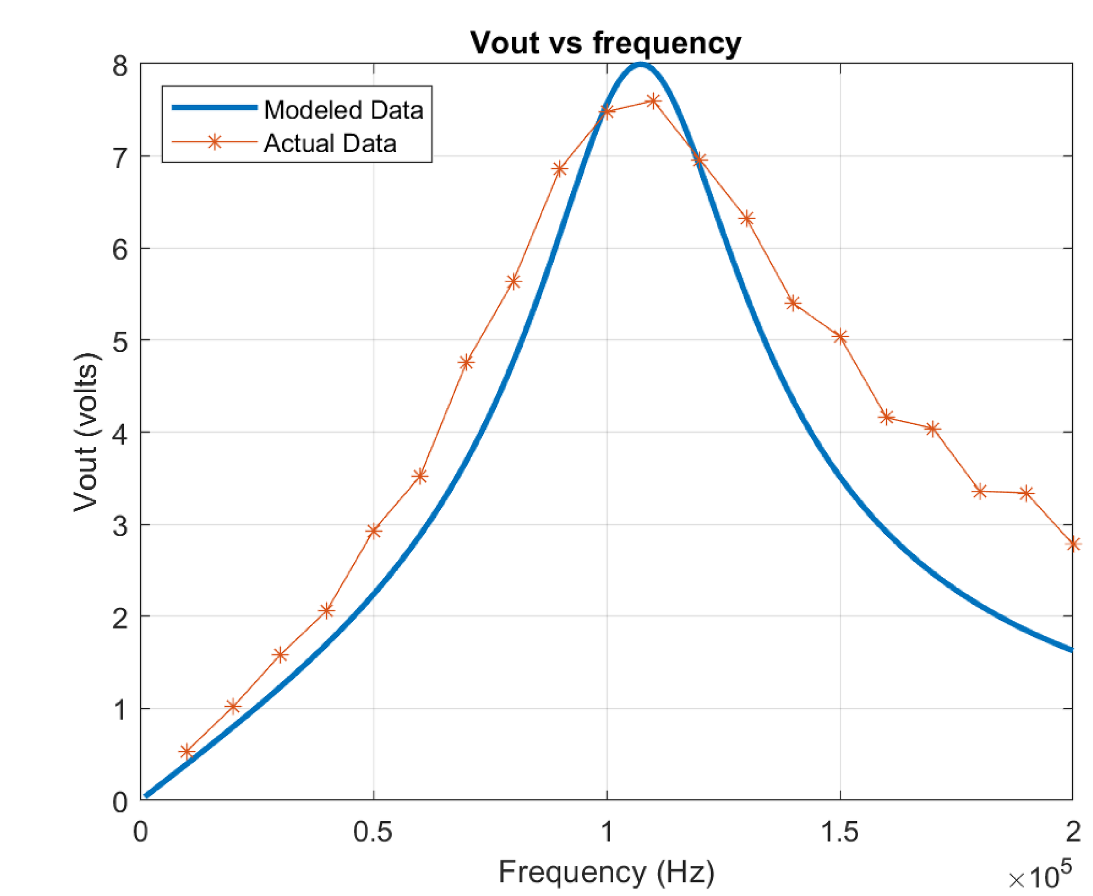

Fig. 5. Modeling Results for Parallel-Resonant Coupling for 150Ω load

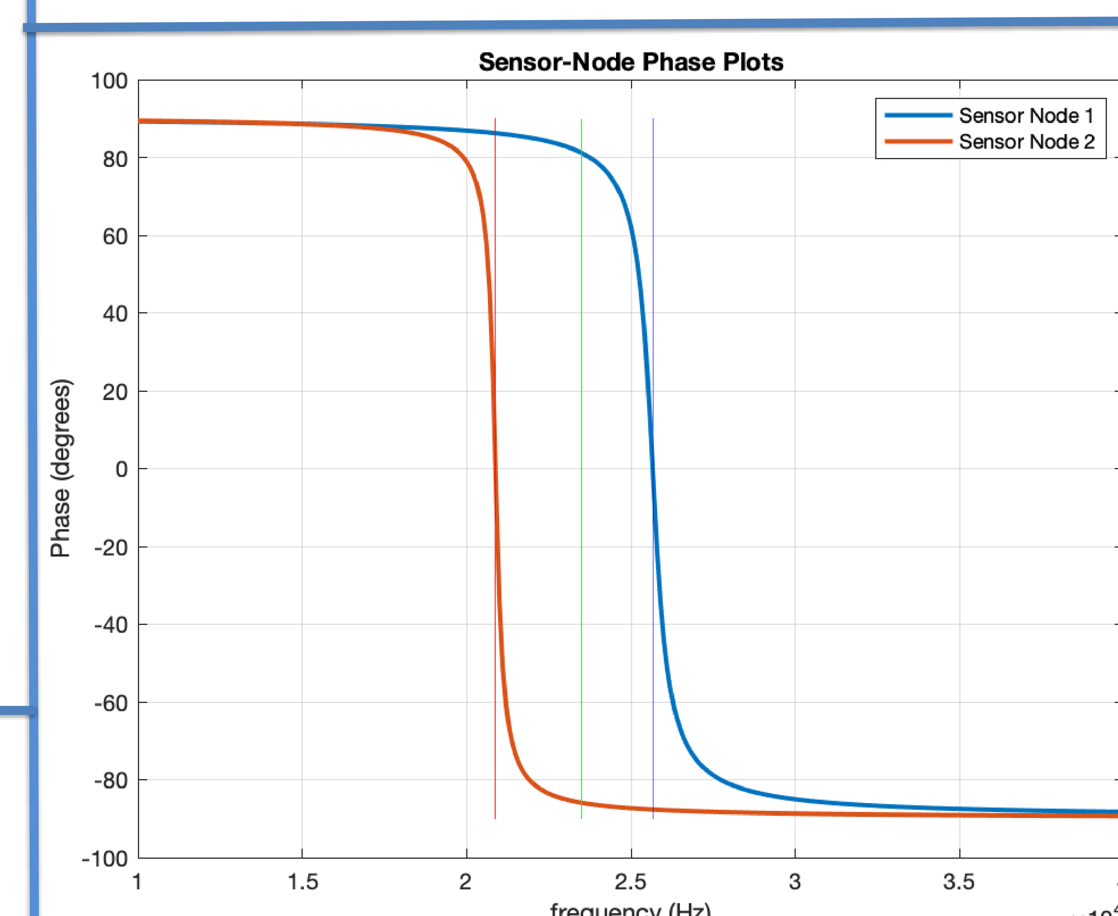

Fig. 6. Condition for Additive Coupling Between Sensor Nodes

- In Fig. 6, the currents in adjacent sensor nodes must be in phase for additive coupling to occur. Otherwise, the nodes will cancel each other out.

$$\theta_L = -\tan^{-1}\left(\frac{\omega L - \frac{1}{\omega C}}{R}\right) \quad (3)$$

(3) is the phase of the sensor node current shown in Fig. 6

CONCLUSIONS

- The proposed WPT system is feasible based on our experimental outcomes and the sensor nodes can detect intrusions based on changes in the induced voltage in the sensor node coils.
- The parallel resonant configuration was found to be the optimal configuration for sensor nodes.
- Power transfer efficiency was shown to increase with multiple tightly spaced sensor nodes.
- Battery-less operation will enable extremely long sensor lifetimes greater than 50 years.

FUTURE WORK

- Assess the impact of various transmit loop configurations.
- Add a communications capability to exchange information between sensor nodes.
- Incorporate capacitive touch sensing and other sensing capabilities into the sensor nodes with the use of a microcontroller.
- Test the system at a larger scale (e.g., 10m x 100m).

REFERENCES

[1] A. Kurs, A. Karalis, R. Moffatt, J. Joannopoulos, P. Fisher, M. Soljacic, “Wireless Power Transfer via Strongly Coupled Magnetic Resonances”, Science, Vol 317, Issue 5834, 06 July 2007

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