Microwave Microsystems Lab

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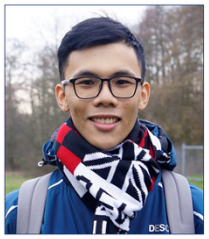
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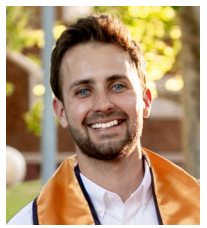
Tyler Kelley

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Motivation

- Communication with enclosed sensors inside metal requires drilling holes.
  - Other highly lossy mediums are concrete or composite materials.
- Battery is not allowed inside for safety or long-term applications.
- Inductive power coupling can transfer power through common metals:
  - Wireless Power Transfer (WPT) through metal.

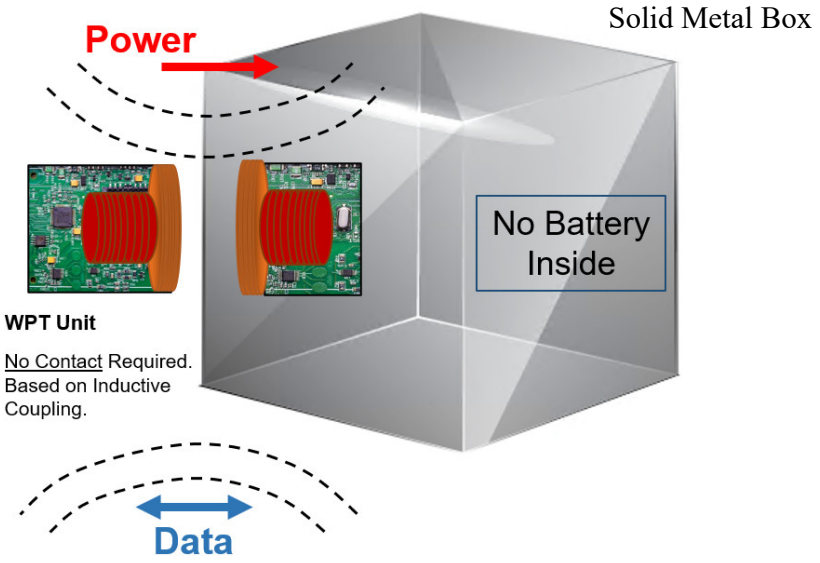


Fig. 1. Proposed inductive power transfer solution.

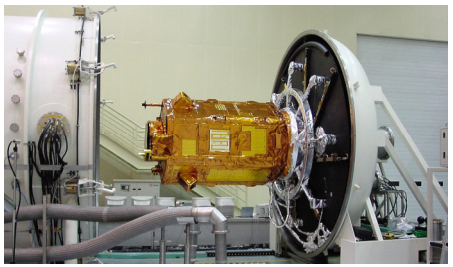
WPT Challenges:

- Low transfer efficiencies due to lossy materials.
- Only very low data rate communication is possible.
- Low frequency operation due to skin effect of the metal.

Potential applications

External Aerospace Sensors

High Temperature & Pressure Chambers



Sealed Containers

Embedded Sensors

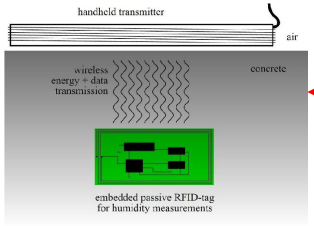


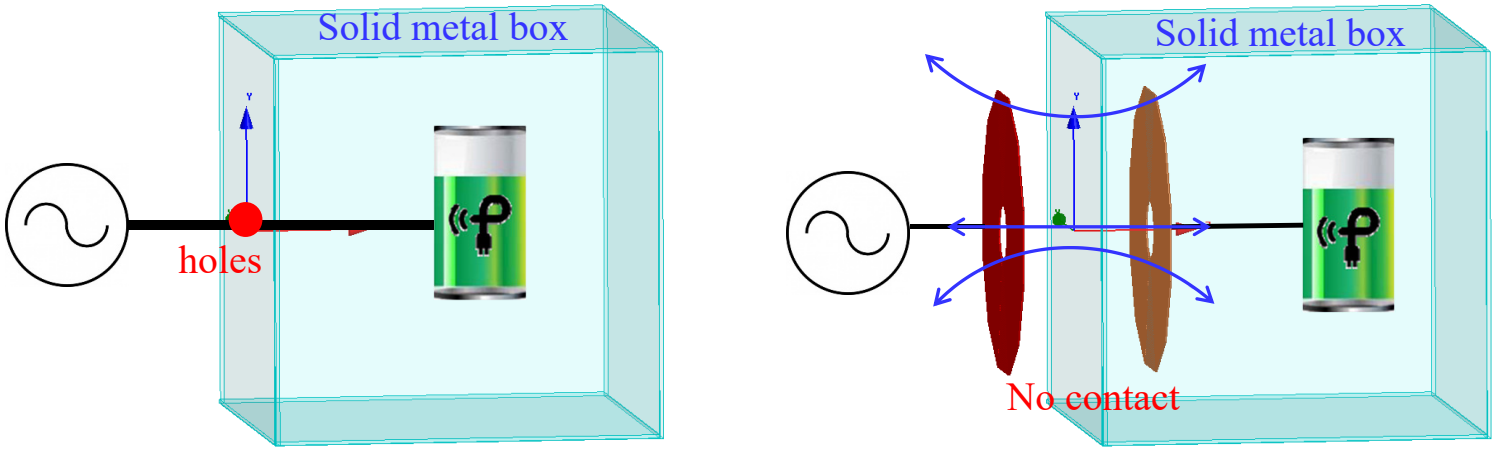
Fig. 2. Potential Applications of Wireless Power Transfer through metal and high loss medium.

Research Topic 1

High efficiency through metal power and data transfer

Through metal energy harvesting

- Drilling holes cause leakage and reduce structural integrity
- Inductive power coupling can transfer power through common metals
- Low efficiency power and data transfer due to skin-depth effect of metal

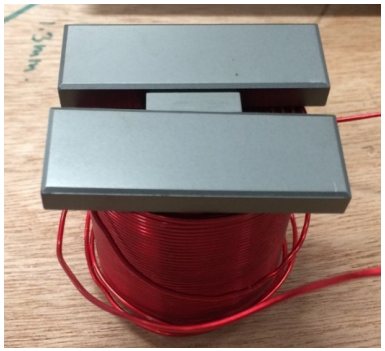


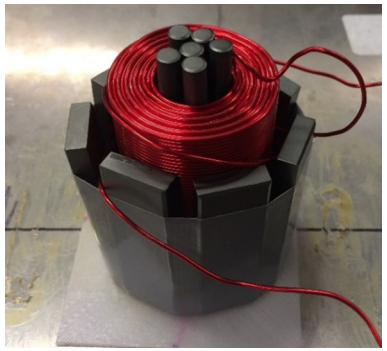
Conventional through-wire solutions

Proposed inductive power transfer

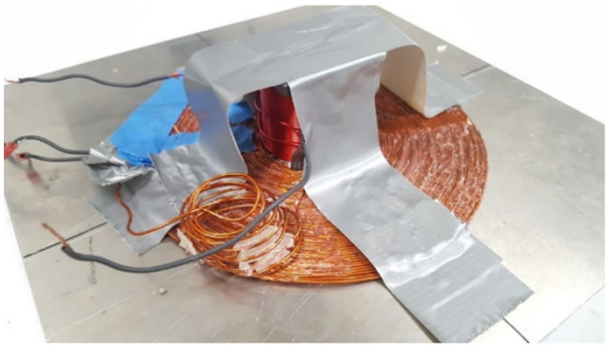
Fig. 3. Traditional vs inductive power transfer approach.

Helical coils for wireless power and data transfer



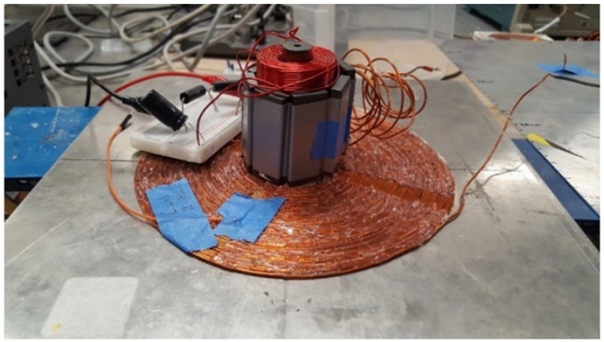


Helical stacked coils used for power transfer



Hybrid transmitting coil

Helical flat coils used for data transfer



Hybrid receiving coil

Fig. 4. Custom designed coils for wireless power and data transfer.

Through metal power transfer performance

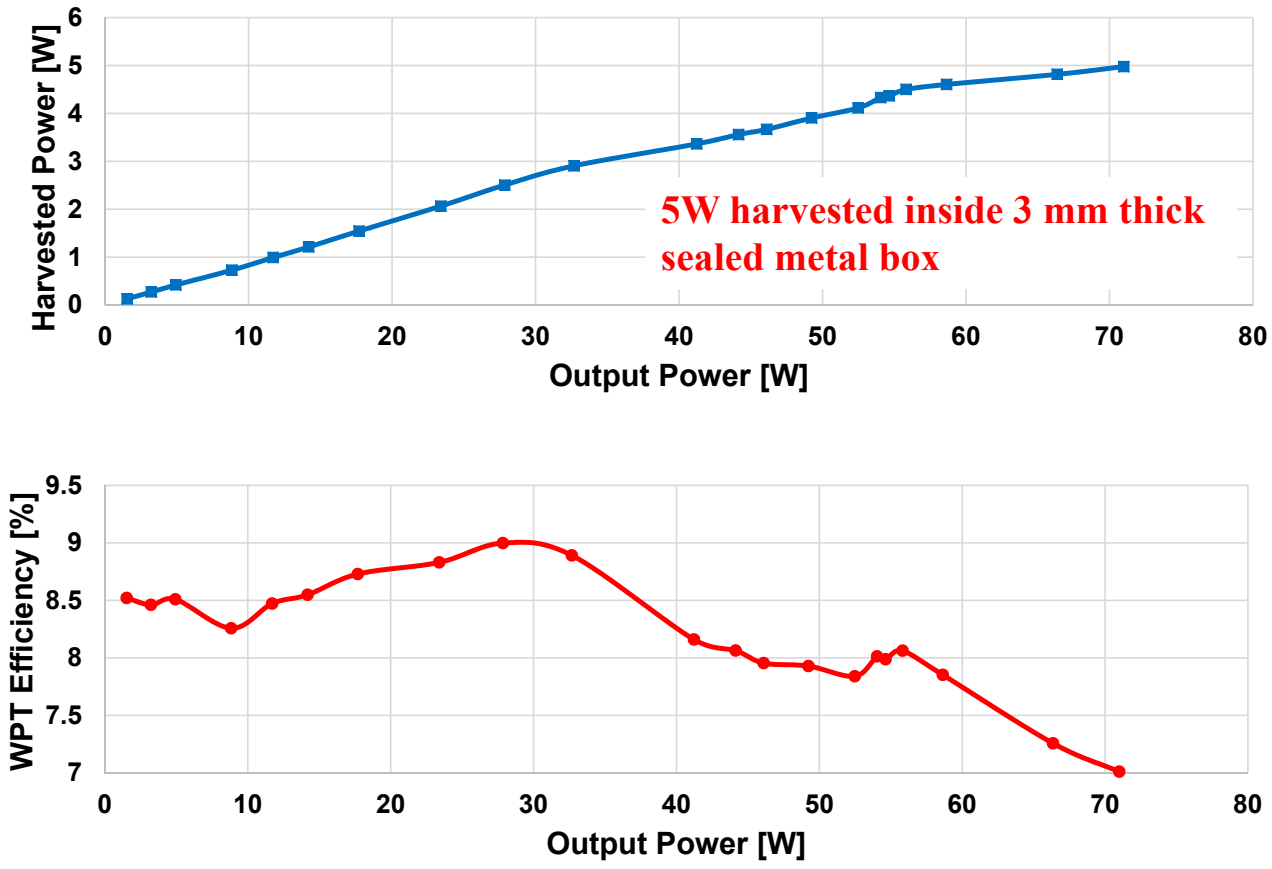


Fig. 5. Harvested power and power transfer efficiency versus transmitter output power.

Through metal power and data transfer system

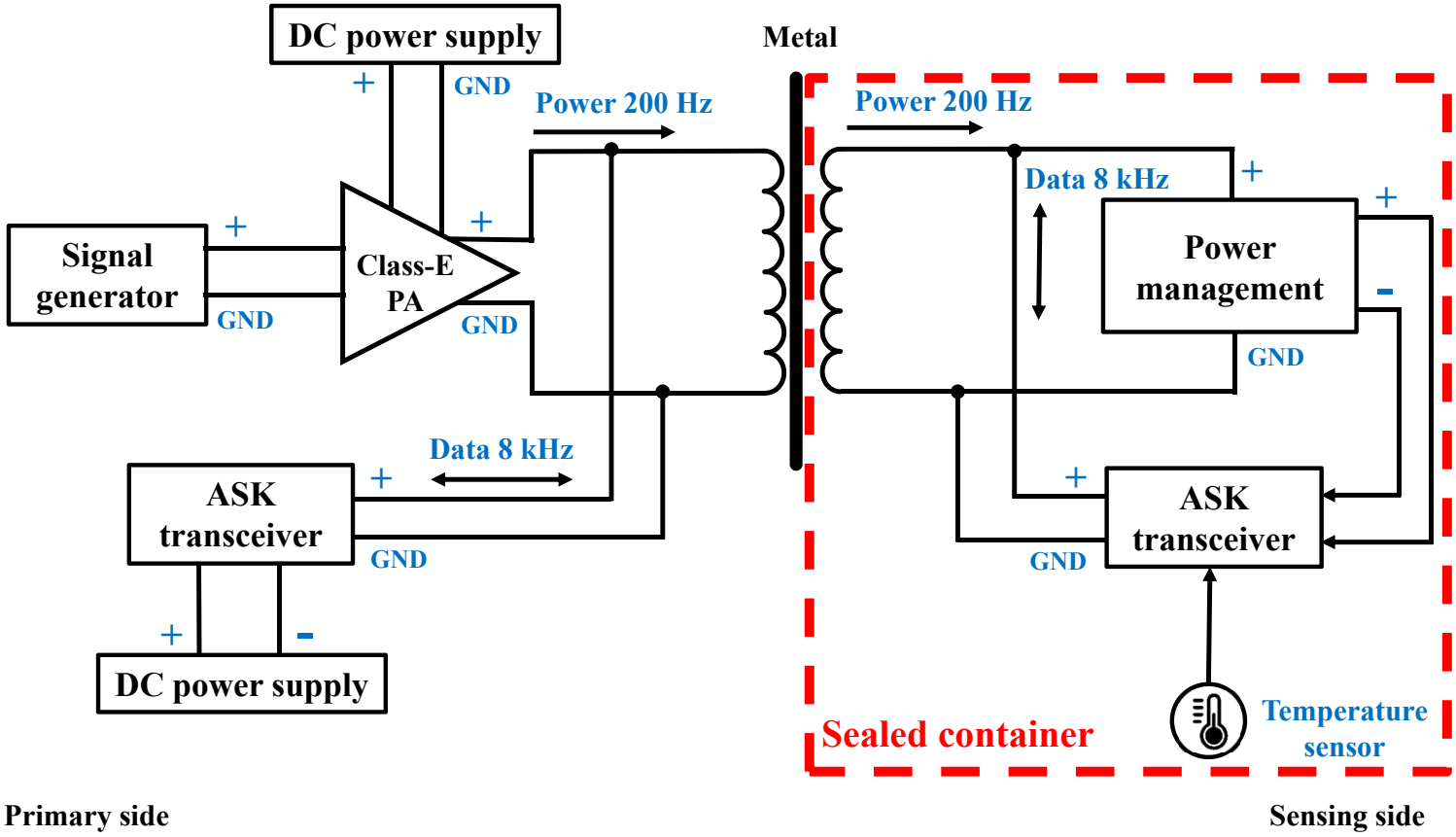


Fig. 6. Block diagram of through metal power and data transfer system.

Data transfer: ASK transceiver

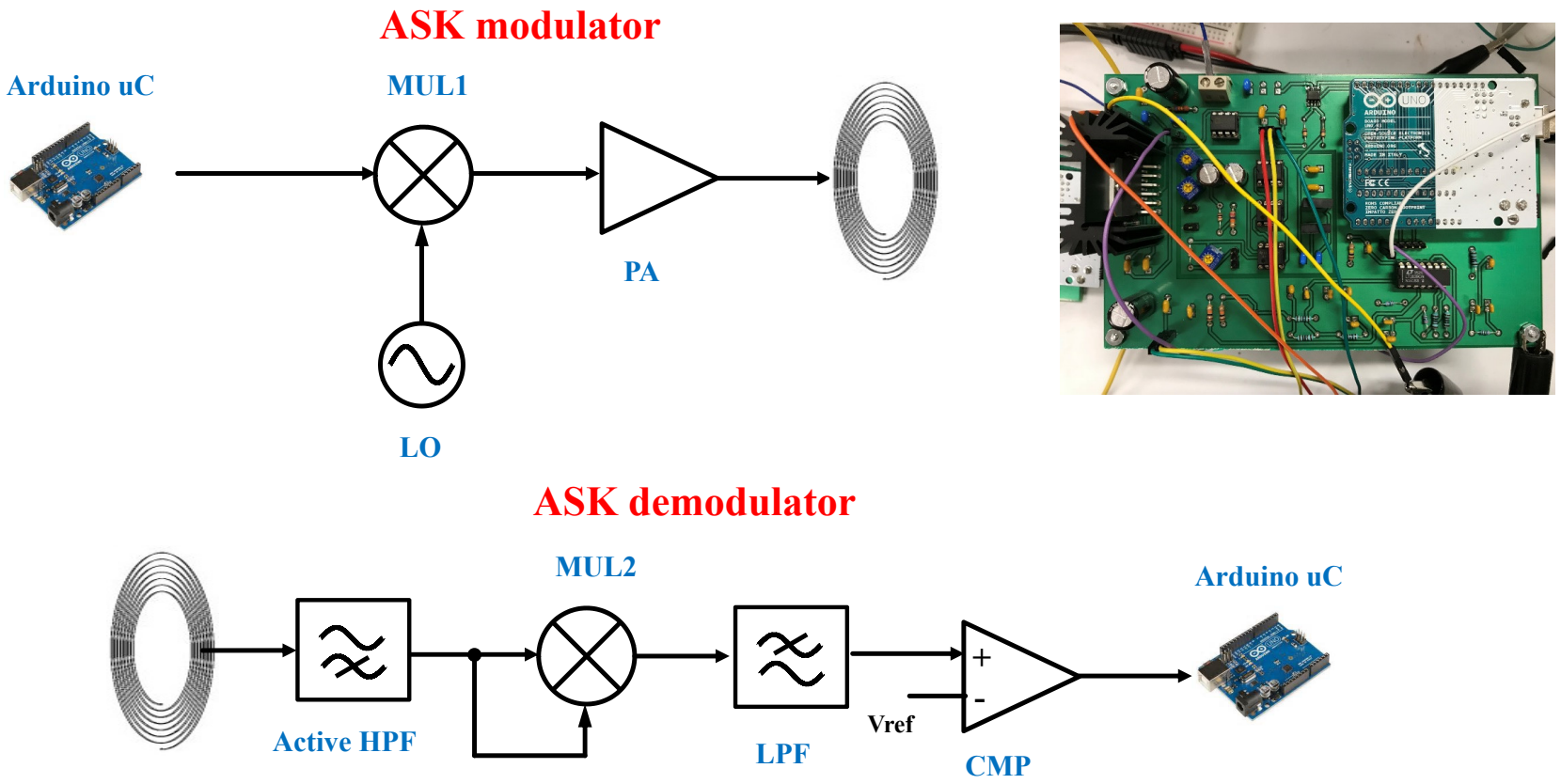


Fig. 7. Overview of data transfer block for data transmission and reception.

Transmitted data at 2.4 Kbps

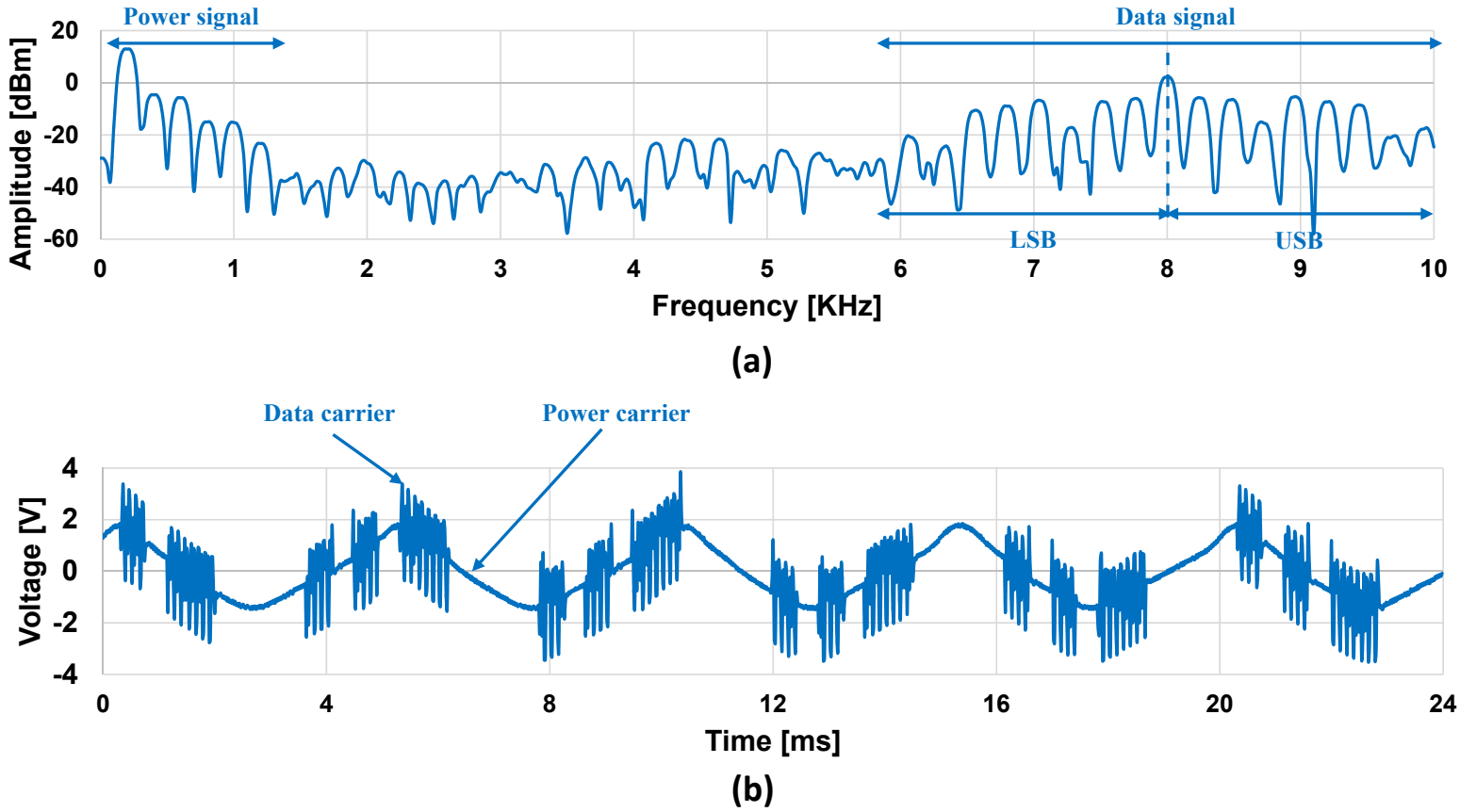


Fig. 8. Measured transmitting signals across the flat coil in (a) frequency domain and (b) time domain.

Received data at 2.4 Kbps

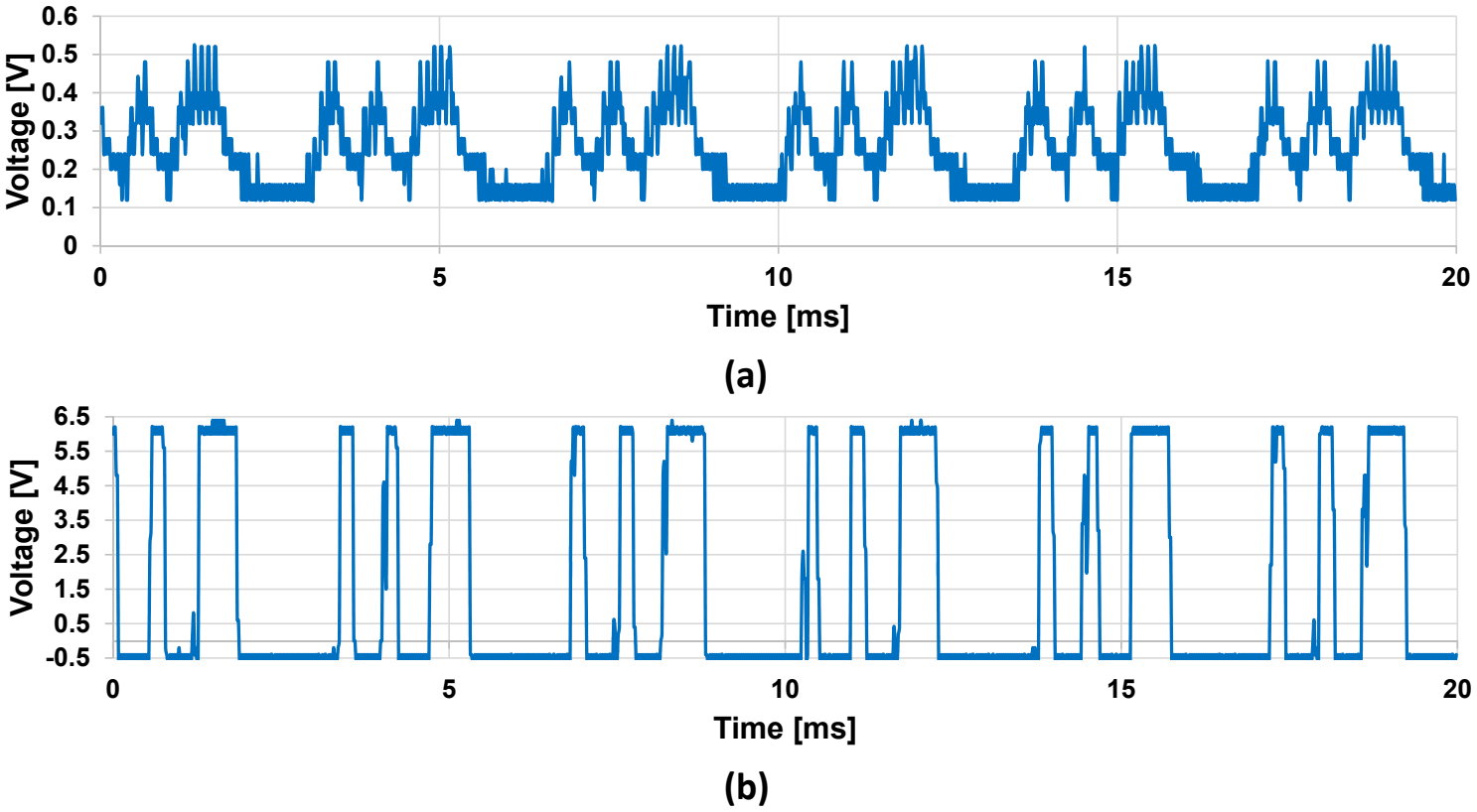
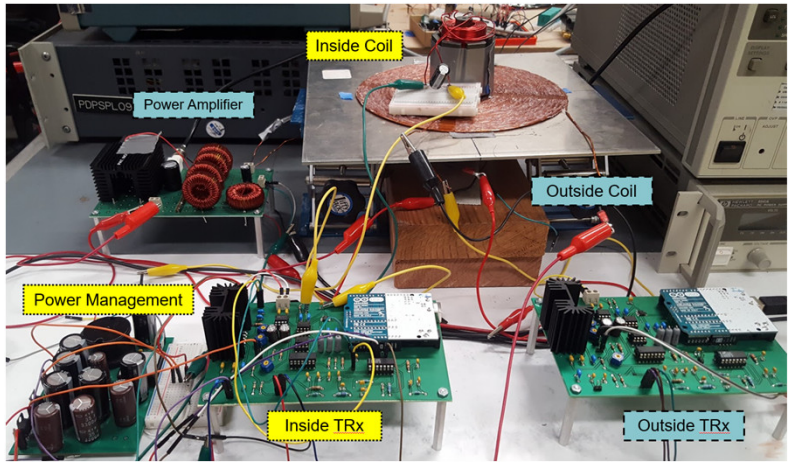
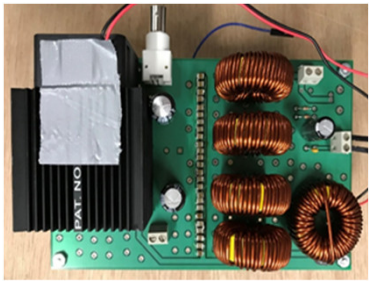


Fig. 9. (a) Received signal after low-pass filtering; (b) Received digital data after thresholding.

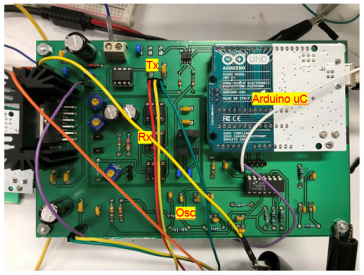
Power and data transfer through 3-mm thick aluminum



Test setup showing integrated system



Class-E power amplifier



ASK data transfer circuit

- More than 9% Power Transfer Efficiency (PTE) is achieved through 3mm thick aluminum plate.
- Harvested power on the inside of the metal barrier is larger than 5W.
- Data transfer rate is more than 4800 bps free of errors.

Demodulated data signal.

Fig.10. Complete system and custom designed circuits for high power through metal application. 3mm thick Aluminium.

Research Topic 2

Miniature coil for through metal power and data transfer

Ultra-small coil for wireless power transfer

- A miniature coil of only 2 mm × Ø15 mm can be used to transfer up to **100 mW** through a 1-mm thick aluminum.

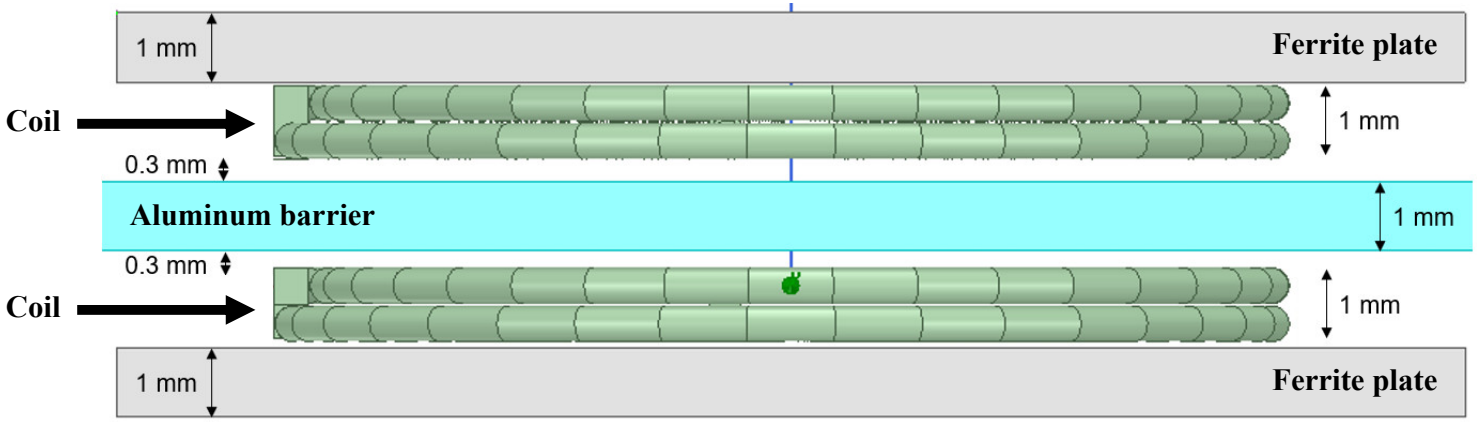
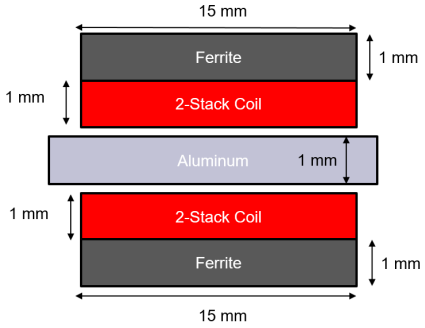


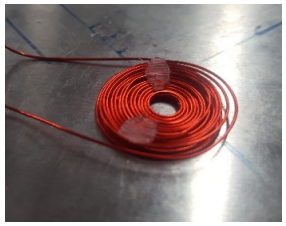
Fig. 11. Measurement setup for though metal power transfer

Ultra-small coil for wireless power transfer through aluminum

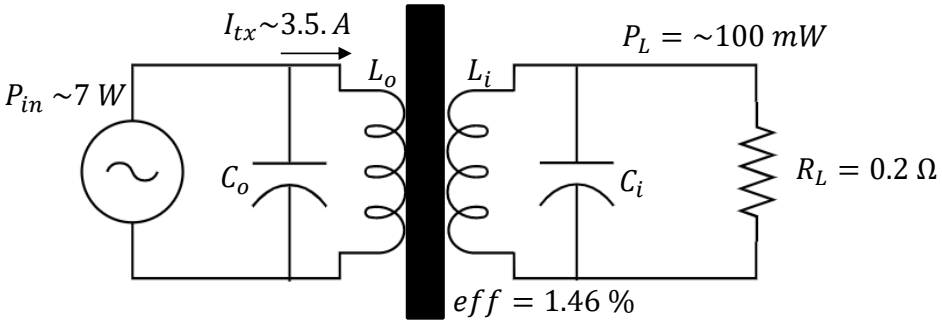
- Coil size: 2 mm × Ø15 mm



(a)



(b)



(c)

Fig. 12. Designed WPT coils: (a) structure (b) fabricated, (c) test setup.

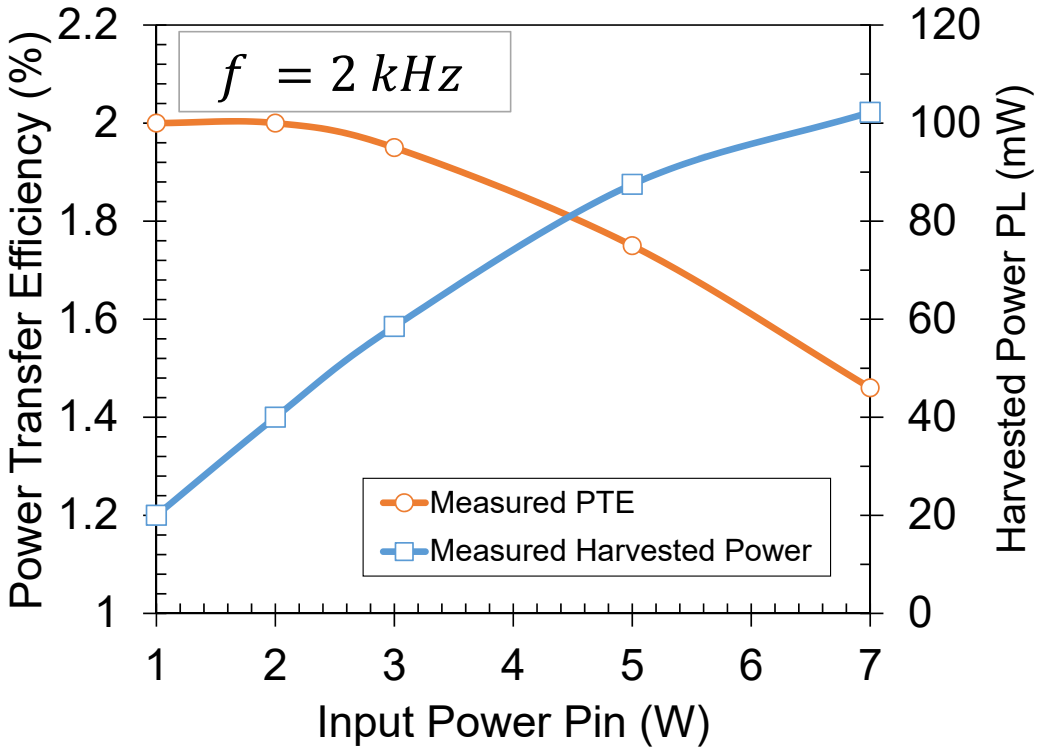


Fig. 13. Coil to coil efficiency and output power versus varying input power at f=2 kHz, R_L = 0.2Ω.

Miniature coil for through-metal communication

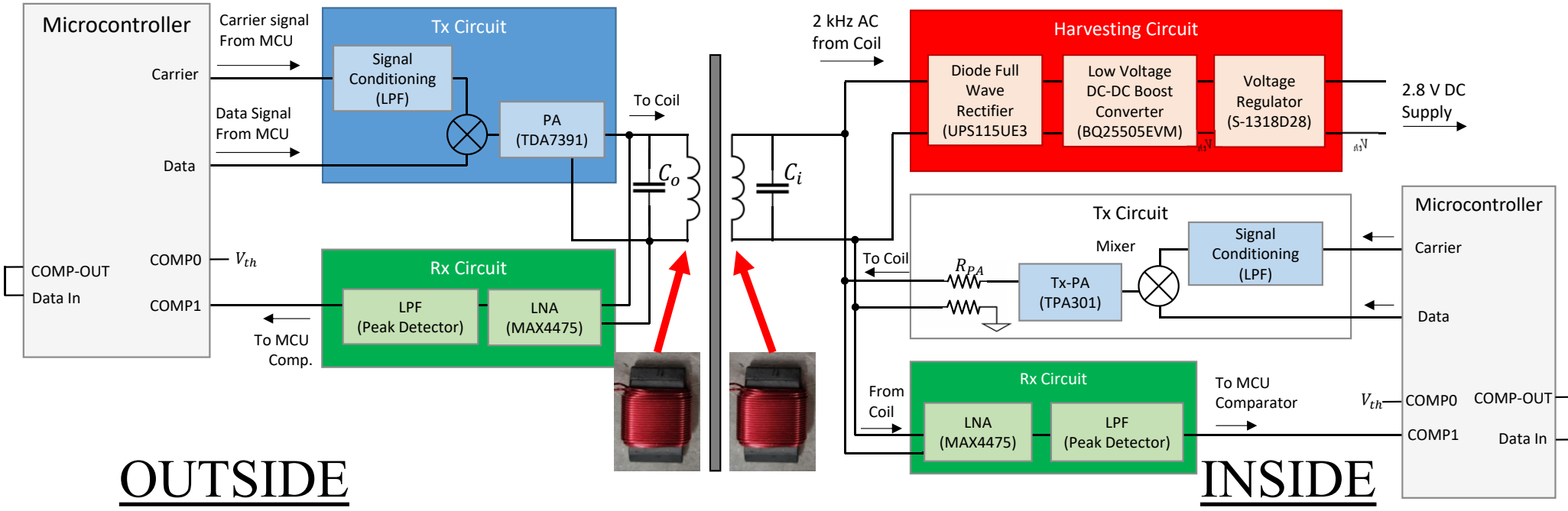


Fig. 14. Fully integrated communication system.

- Coil redesign allows **power** and **data** transfer. Size: 15 x 3 x 6 mm
- System operated using only WPT energy and no battery.
- Successful bidirectional (half-duplex) communications through metal.

Miniature coil for through-metal communication

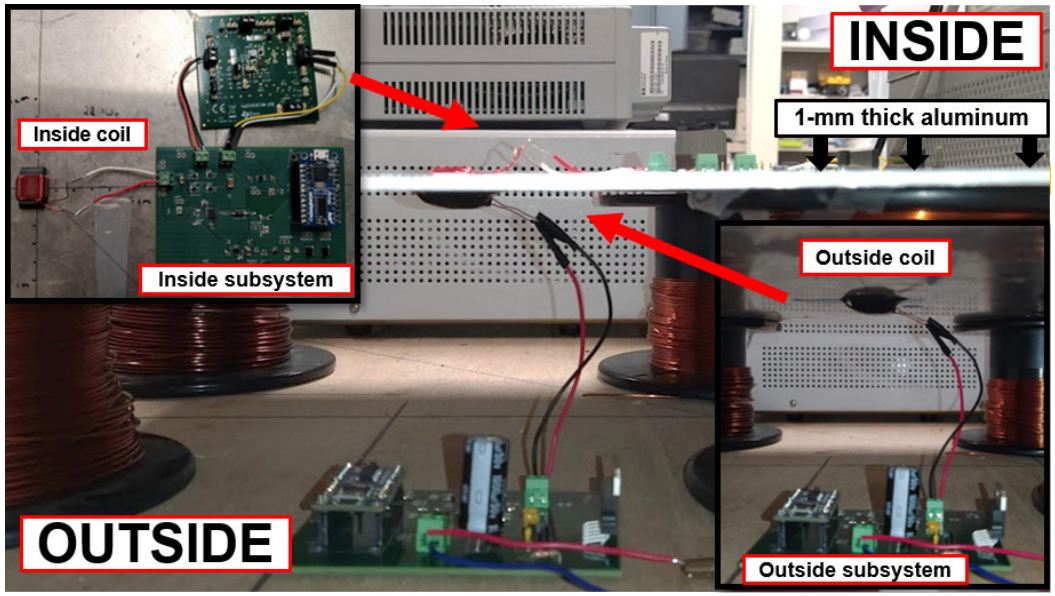


Fig. 15. Fully integrated communication system. Each coil is located at the center of the 1 mm-thick aluminum plate and separated 0.5 mm away from the metal plate.

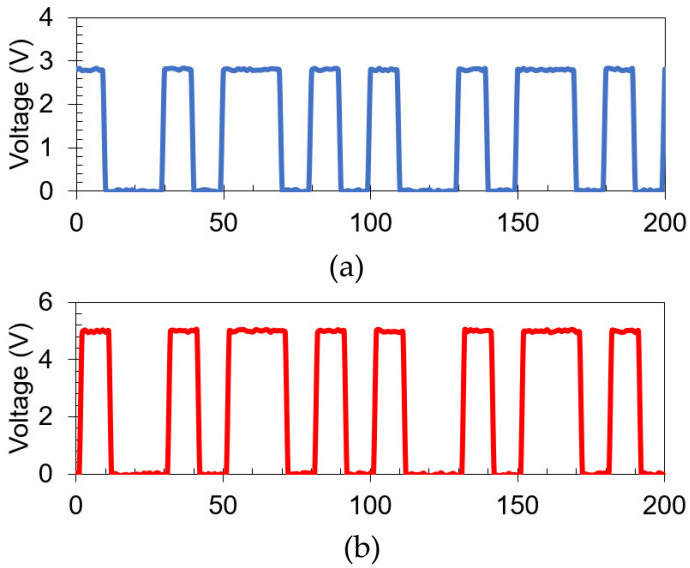


Figure 16. Transmit (**a**) and receive (**b**) data signal at 100 bps using a 2 kHz carrier.

- System operates using only WPT energy and no battery.
- Successful bidirectional communications through metal.

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Research Topic 3

Long range through metal power and data transfer

Potential applications

- Long distance energy harvesting.
- Low power –battery less- communication system.
- Custom application: container monitor (material, thickness).

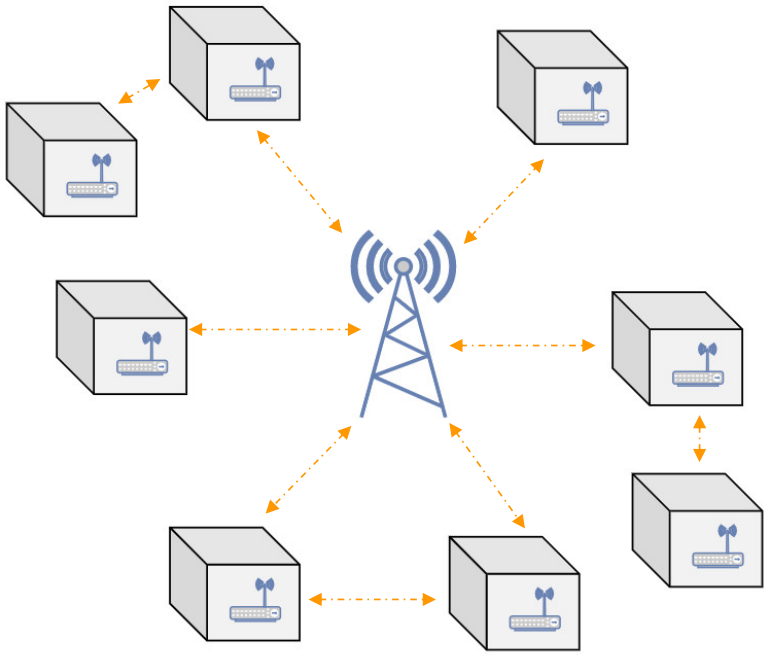


Fig. 17. Wireless powered sensor network.

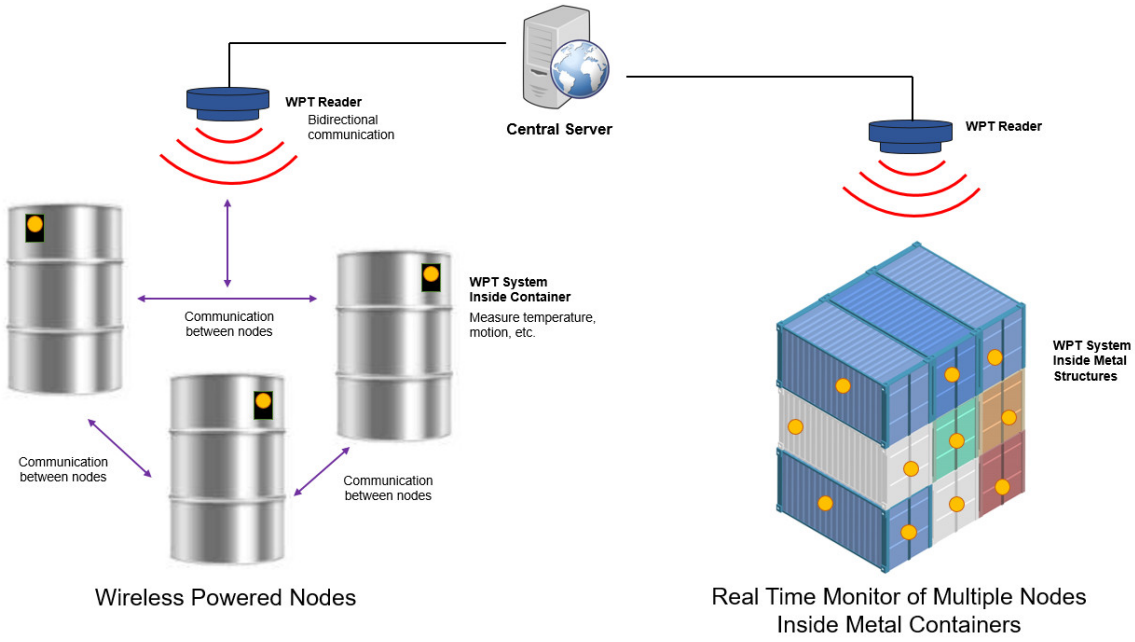


Fig. 18. IoT Network of Wireless Powered Nodes Through Metal.

Long distance through metal communication system

- Power and data is wirelessly transferred even through metal.
- Multiple containers can communicate simultaneously
- Maximum harvested DC power: 38 uW

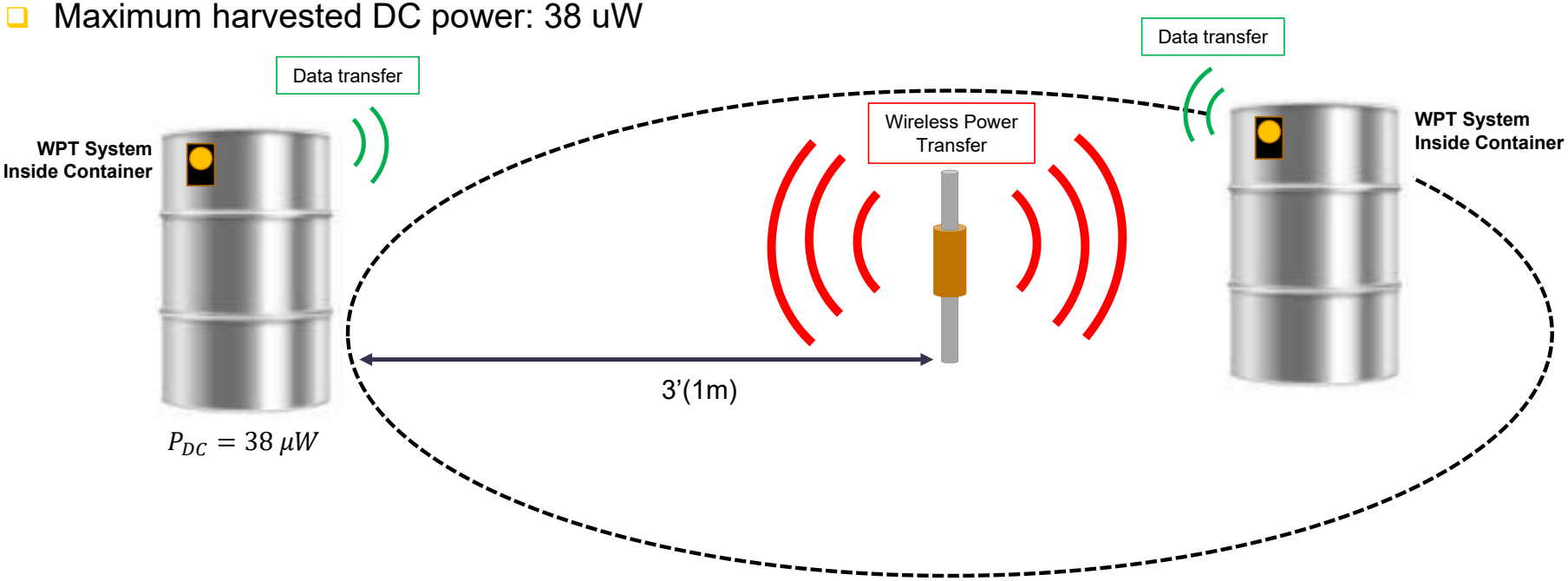
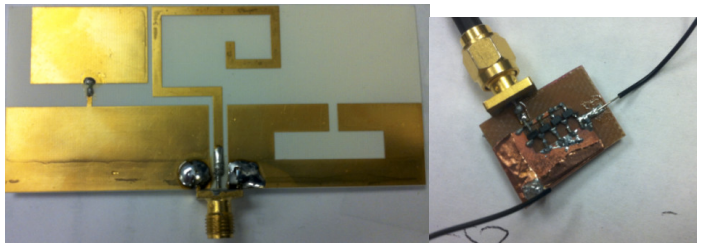


Fig. 19. Application scenario for long range wireless power transfer.

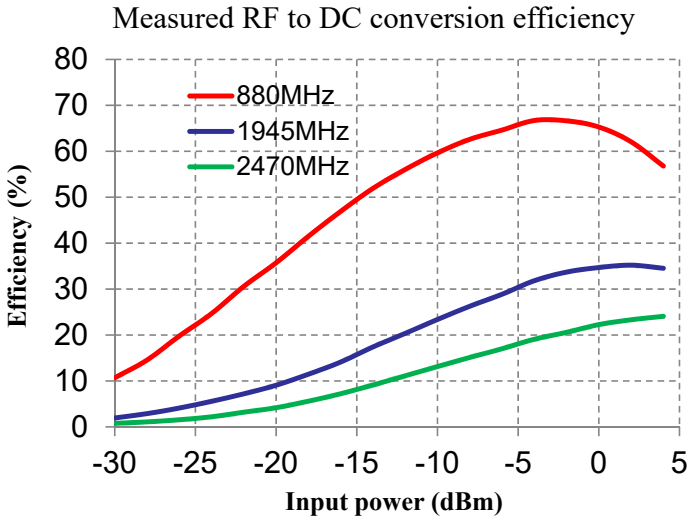
Research Topic 4

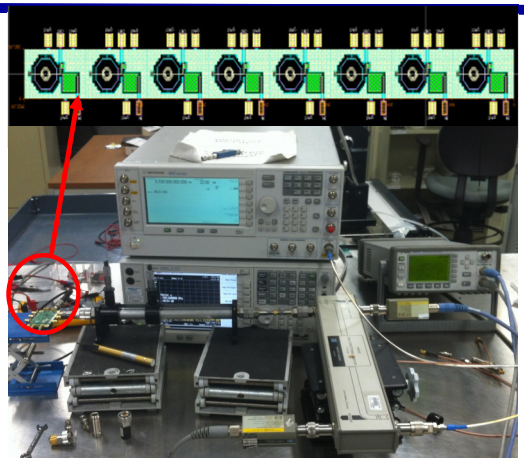
RF to millimeter-wave energy harvesting

RF to millimeter-wave energy harvesting



Triple-band (0.9, 1.9 and 2.4 GHz) energy harvesting circuits





5.8 GHz

Array of CMOS rectifiers


a)


b)


c)

Antennas

Number of Cells	Simulated gain (dBi)	Measured gain at 900 MHz (dBi)	Bandwidth (MHz)	Size (mm)
2 cells	2.17	1.98	760 - 1180	38 x 121
3 cells	3.28	3.13	720 - 1050	37 x 164
5 cells	5.12	5.17	870 - 1170	43 x 280

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