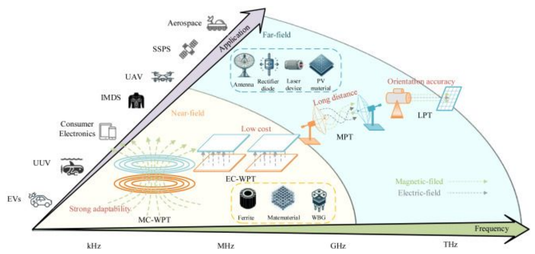
Multi-Frequency Multi-Receiver MHz Wireless Power Transfer using an Impedance-Shaped Class-Φ2 Inverter

STUDENT(S): JUSTIN SUN

MOTIVATION & INTRODUCTION

- Charge multiple everyday devices at the same time with one transmitter (TX)
- Use **multi-frequency channels** so receivers (RX) tune to different frequencies → less interference, more predictable power transmission
- **MHz operation** remains challenging

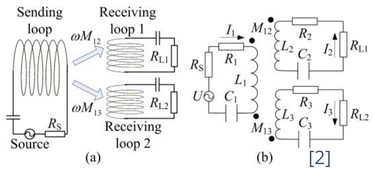


[1]

- We reshaped **single-switch Class-Φ2 inverter** drain impedance to strengthen usable harmonics and pass higher-order content

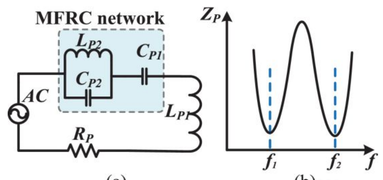
BACKGROUND WORKS

- Each load is strongest at its own resonance, and close resonances reduce system performance.



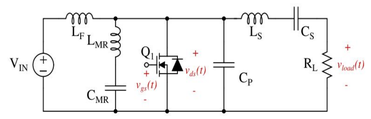
[2]

- Multi-frequency resonating compensation (MFRC) network enables multi-channel transfer with one TX coil.



[3]

- Class-Φ2 is efficient at MHz frequencies, and naturally supports strong ω and 3ω content.

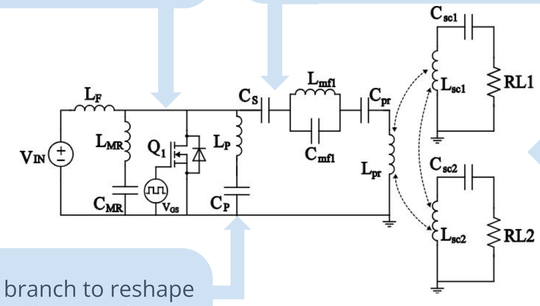


[4,5]

PROPOSED SYSTEM DESIGN

A single-switch Class-Φ2 inverter for high-frequency operation.

- A DC-blocking capacitor passes the AC harmonic content.
- LS omitted to avoid cutting off higher-order harmonics
- MFRC network tuned to near-resistive at the selected frequencies.

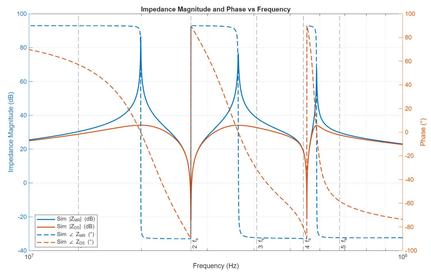


Series LP-CP branch to reshape the drain impedance and strengthen the 3rd-harmonic while clamping unwanted harmonic components.

A single TX coil couples to two RXs coils with distinct loads

WAVE-SHAPING NETWORK ZMR(ω) & ZDS(ω)

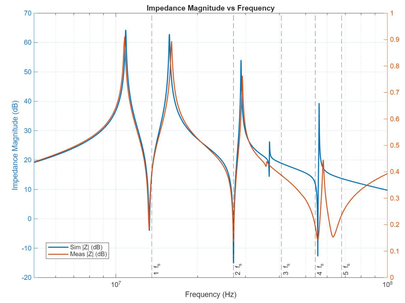
$$Z_{MR}(\omega) = (j\omega L_F) \parallel \left(j\omega L_{MR} + \frac{1}{j\omega C_{MR}}\right) \parallel \left(\frac{1}{j\omega C_{OSS}} \parallel \left(j\omega L_P + \frac{1}{j\omega C_P}\right)\right)$$



Parameter	Value	Parameter	Value
f_s	13.56 MHz	V_{in}	170 V
D	0.3	R_L	50 Ω
Q	GS66508T	L_{pr}	950 nH
L_F	240 nH	C_{pr}	98 pF
L_{MR}	612.3 nH	L_{mf1}	373 nH
C_{MR}	56.25 pF	C_{mf1}	60 pF
L_P	750 nH		
C_P	11 pF		
C_S	0.1 μF		

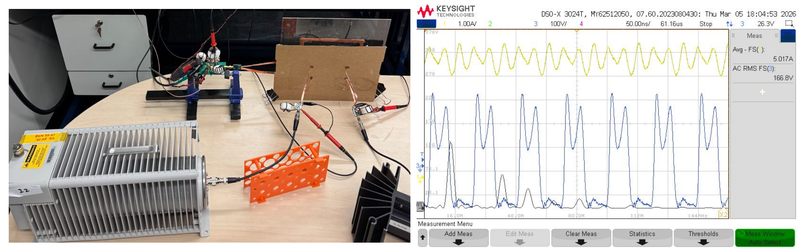
$$Z_{DS}(\omega) = Z_{MR}(\omega) \parallel Z_L(\omega)$$

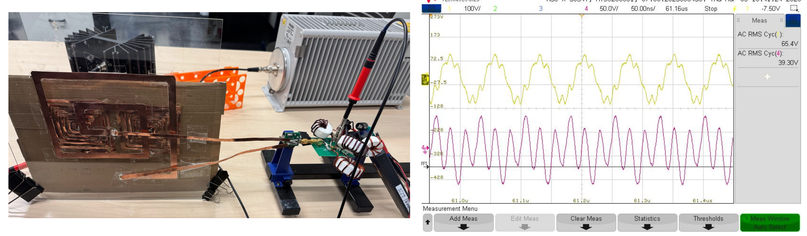
$$Z_L(\omega) = Z_{CS}(\omega) + Z_{CN}(\omega) + Z_{RL}(\omega)$$



EXPERIMENTAL RESULTS

- Built and tested a single-switch Class-Φ2 inverter with MFRC network and a coupled TX/RX coil link, confirming drain-voltage shaping and concurrent 13.56MHz load and 40.68MHz load operation.





- At 15 mm separation, delivered 660 W (13.56MHz) and 14.6 W (40.68MHz) with 79.1% DC-to-load efficiency (power ratio 1st/3rd ~45); the 5th harmonic was not demonstrated due to PCB parasitic attenuation above ~50 MHz.

Future Work, References, and Acknowledgments

- Reduce PCB parasitics/EMI to preserve higher-order harmonics.
- Improve the TX coil to reduce self-capacitance and raise SRF for wider-band harmonic operation.
- Extend to ω/3ω/5ω co-design and investigate load and input voltage variations.

[1] Liu, Z., Li, T., Li, S., & Mi, C. C. (2024). Advancements and challenges in wireless power transfer: A comprehensive review. Nexus, 1(2).
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[4] J. M. Rivas, Y. Han, O. Leitermann, A. Sagneri, and D. J. Perreault, "A high-frequency resonant inverter topology with low voltage stress," in 2007 IEEE Power Electronics Specialists Conference, 2007, pp. 2705–2717.
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