Maximum Wireless Power Extraction: Some Antennas in the Receive Array May Have to Transmit Power

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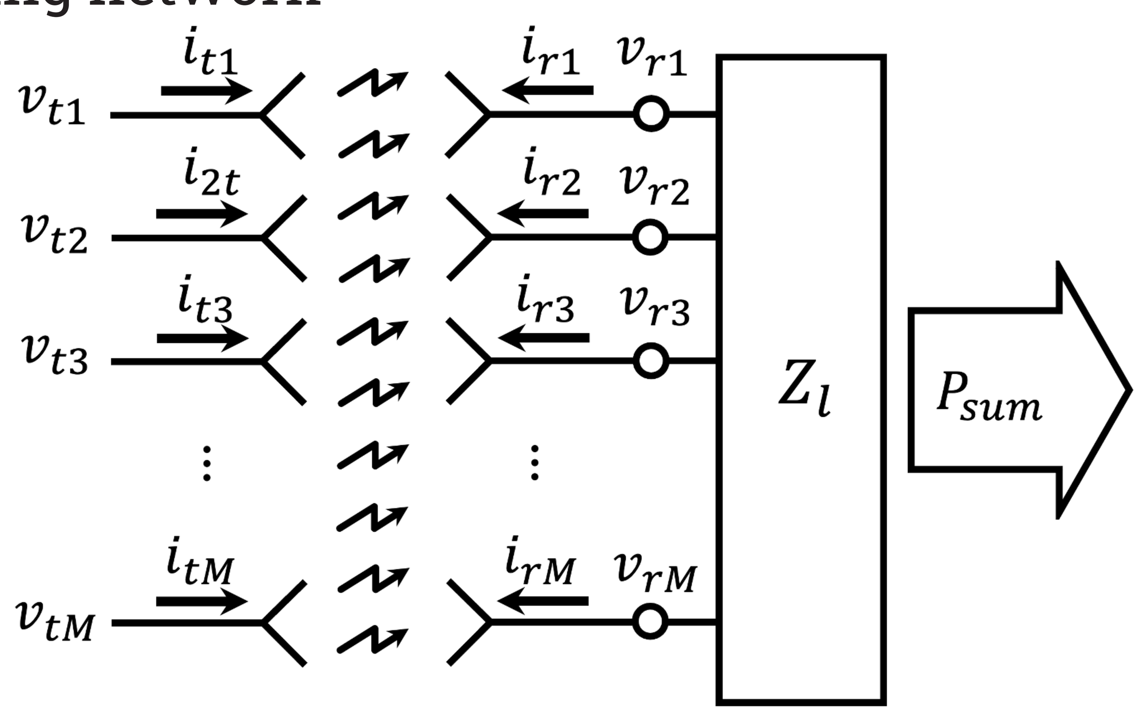
BACKGROUND

Current wireless power transfer technology is relegated to short range and low power. Super-directivity hold out hope for powering a drone 100 meters away, with a physically small transmit array, but the concept has never been reduced to practice [3]

- Portable electronics provide substantial demand
- New wireless power infrastructure must consider spectrum usage
- The physics is old, but still not completely understood

MAXIMUM WIRELESS POWER TRANSFER

A wireless power transfer system is usually defined with a transmit and receive array, each with a matching network



We can treat each array as a ported network [2]:

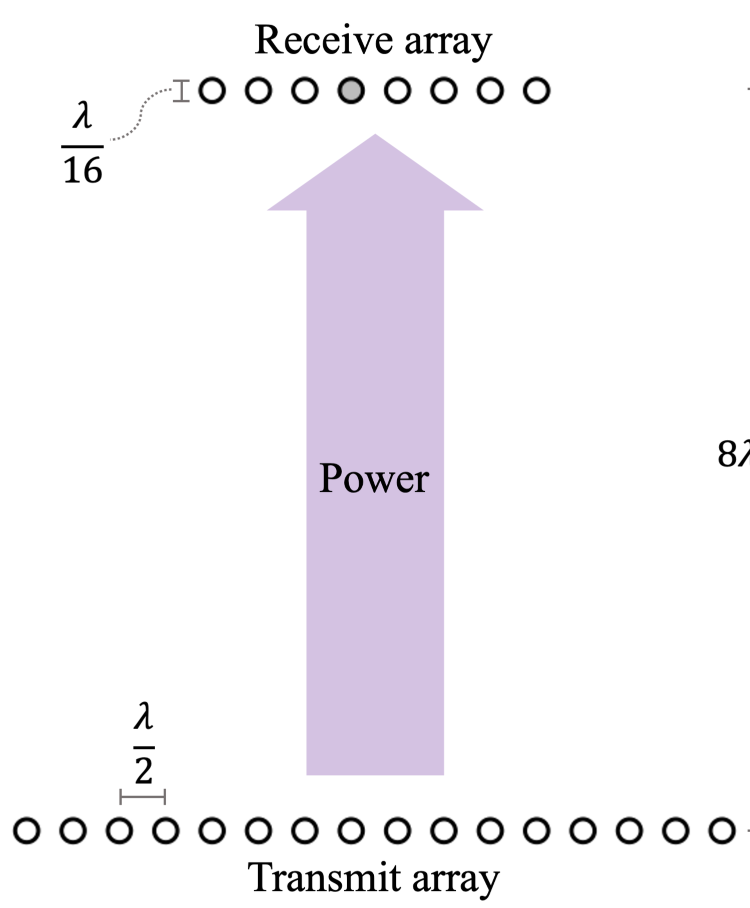
$$\begin{bmatrix} \mathbf{v_T} \\ \mathbf{v_R} \end{bmatrix} = \begin{bmatrix} \mathbf{Z_T} & \mathbf{Z_{TR}^T} \\ \mathbf{Z_{TR}} & \mathbf{Z_R} \end{bmatrix} \begin{bmatrix} \mathbf{i_T} \\ \mathbf{i_R} \end{bmatrix}$$

We pull maximum sum-power out of the receive array. We show that, in so doing, one of the antennas may radiate positive power.

$$\min_{\mathbf{i_T}} \frac{P_{R1}}{P_{sum}} = \min_{\mathbf{v_{OC}}} \frac{0.5Re[\mathbf{i_{R1}}^* \mathbf{v_{R1}}]}{.125\mathbf{v_{OC}}^H Re[\mathbf{Z_R}]^{-1}\mathbf{v_{OC}}}$$

And we solve the resulting eigenvector/eigenvalue problem.

NUMERICAL SIMULATION OF SYSTEM



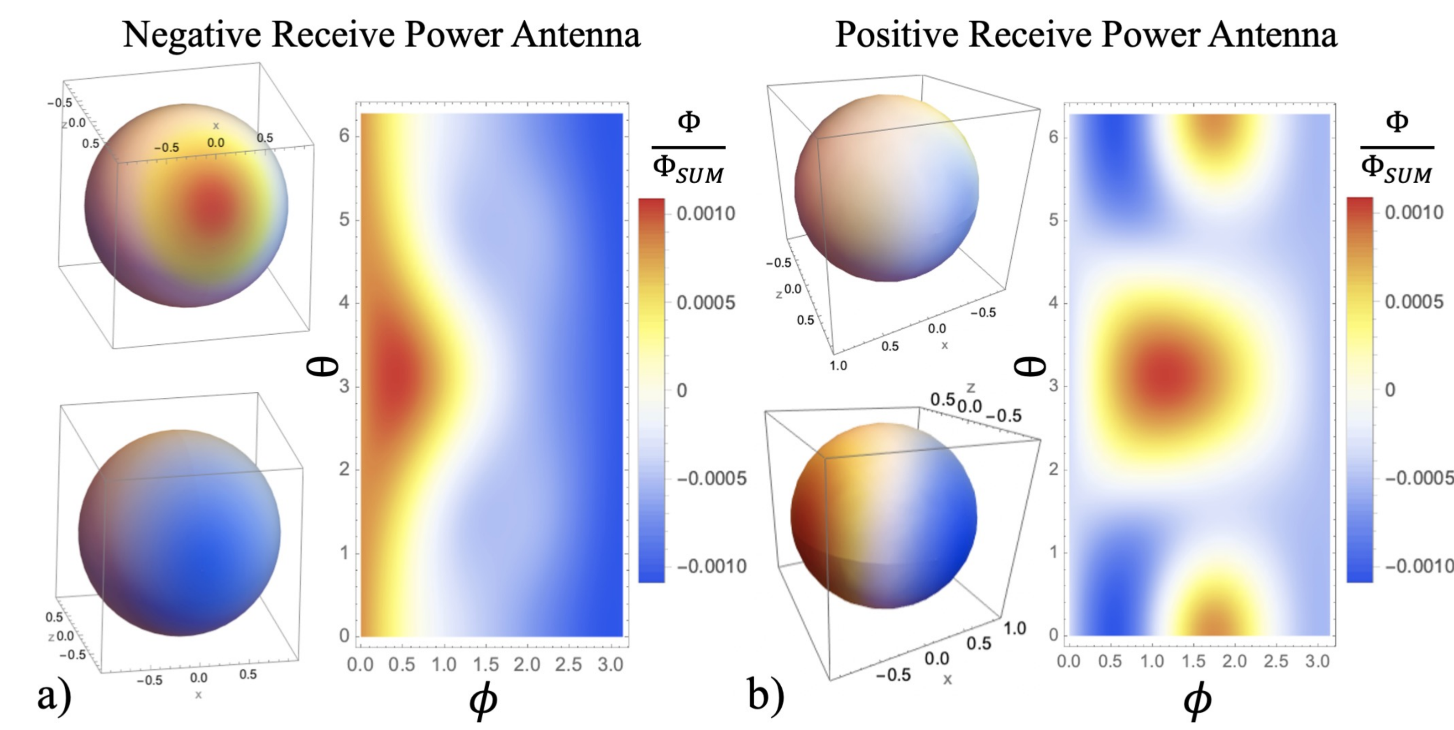
- We perform simulations using $\frac{\lambda}{2}$-spaced antenna arrays
- The antenna radiating positive power is marked in grey
- Using an LTI acoustic model, we populate the impedance matrix [3]:

$$Z_{self} = 1 - i\frac{cos(kR_0)}{sin(kR_0}$$

$$Z_{mut}(R) = \frac{sin(kR)}{kR} - i\frac{cos(kR)}{kR}$$

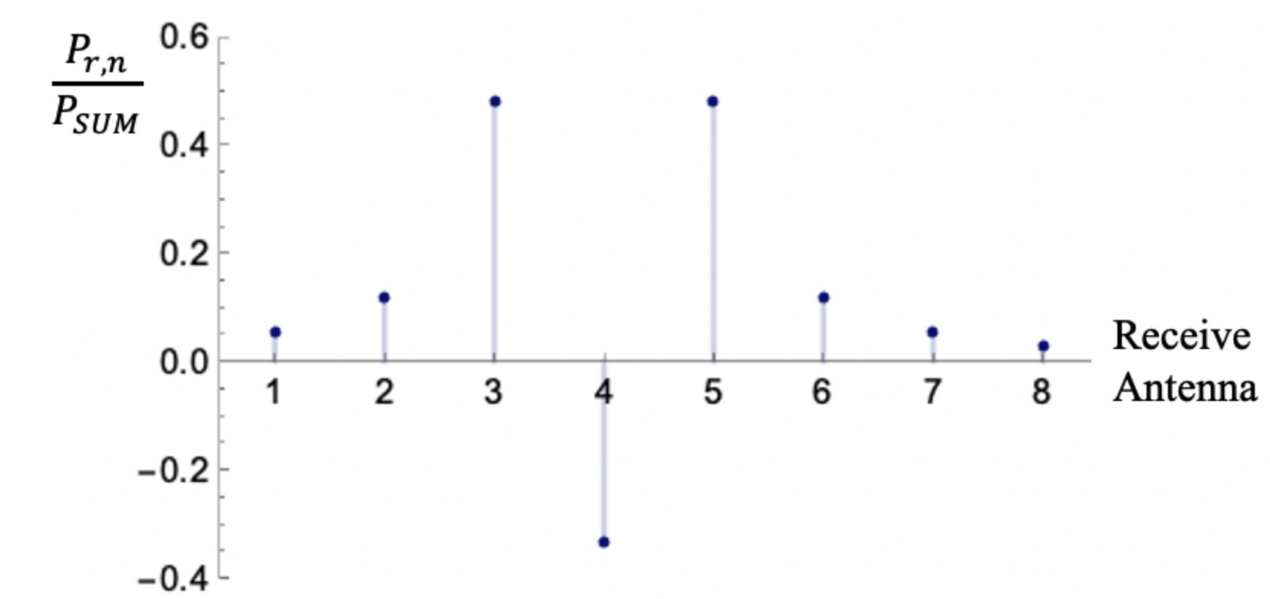
RESULT: ANTENNA COUPLING EFFECTS

We can simulate the surface flux on each of the antennas using our acoustic model:



- The radiating receive antenna (a) mostly receives power from the transmit array direction
- An adjacent antenna that absorbs power (b) can be seen receiving power in the direction of the radiating antenna
- This implies the radiating antenna is actively assisting other antennas in the array

RESULT: POWER ON EACH ANTENNA



- Here a plot of the power received by each antenna is normalized by the sum-power
- The sum power diminishes as distance from the radiating antenna increases, showing the role the radiating antenna plays in max power transfer

ACKNOWLEDGEMENTS

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REFERENCES

[1] Karalis, Aristeidis, et al. "Efficient Wireless non-radiative mid-range energy transfer." Annals of Physics, vol. 323, no. 1, Jan. 2008.
[2] M.T. Ivrlac and J.A. Nossek, "Toward a circuit theory of communication", IEEE Transactions on Circuits and Systems, July 2010
[3] T.L. Marzetta, "Super-directive antenna arrays: Fundamentals and new perspectives", Proc. 53nd Asilomar Conference on Signals, Systems, and Computers, 2019.
[4] M.N. Abdallah, T.K. Sarkar, M. Salazar-Palma, "Maximum power transfer versus efficiency", IEEE
Antennas and Propagation Society International Symposium, 2016.
[5] T. L. Marzetta, E. G. Larsson, T. B. Hansen, "Massive MIMO and Beyond", in Information Theoretic Perspectives on 5G Systems and Beyond (I. Maric, S. Shamai (Shitz), and O. Simeone, eds.), Cambridge University Press, 2020.
[6] T.B. Hansen, "Inverse Source Problem for Determining a Surface Impedance: Generating the Field of a Complex Point Source", IEEE Transactions on Antennas and Propagation, June 2018.