A system for robust and efficient wireless power transfer

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The equipment used by the researchers to build their system. Credit: Assawaworrarit & Fan.

Current methods for charging electronic devices via wireless technology only work if the overall system parameters are set up to match a specific transfer distance. As a result, these methods are limited to stationary power transfer applications, which means that a device that is receiving power needs to maintain a specific distance from the source supplying it in order for the power transfer to be successful.

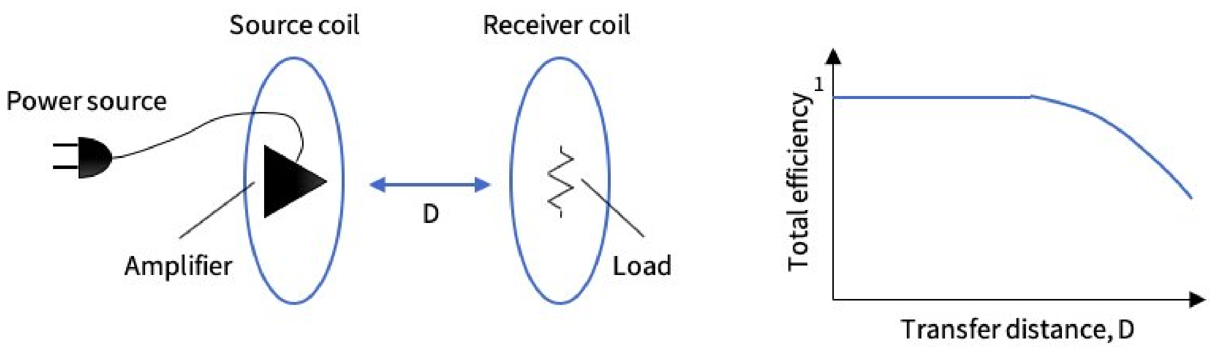
Researchers at Stanford University have recently developed a new technique that could enable more efficient wireless power transfer regardless of the distance between a device and its power source. Their paper, published in *Nature Electronics*, could help to overcome some of the current limitations of existing tools for the wireless charging of elecronic devices.

"The main purpose of our study was to overcome the barrier to dynamic wireless charging," Sid Assawaworrarit, one of the researchers who carried out the study, told Phys.org. "Our idea is based on parity-time symmetry (PT symmetry), which concerns systems with balanced gain and loss."

In one of their previous studies, Assawaworrarit and his colleague Shanhui Fan introduced a nonlinear PT-symmetric circuit setup that could deliver robust wireless power transfer, maintaining this capability even when a device was rapidly moving around in a given space. While their system achieved promising results, its overall efficiency was far from satisfactory. In their new study, the researchers introduced a design strategy that makes their previously developed system more robust and efficient.

"The robustness of our system was achieved by incorporating an amplifier as a gain element into the source side of our proposed wireless power transfer system," Assawaworrarit explained. "The gain allows oscillations to build up in the system over time with the oscillation frequency being the one that grows the fastest. This is similar to what happens in an oscillator except that the power source and load are separated in space."

The system eigenfrequency is the frequency at which a system operates well and that facilitates efficient transfer of power to a device. In the system devised by the researchers, this oscillation frequency self-adapts to the changing conditions, which could be the movement of the device receiving power in sub-millisecond timescale, thus maintaining an efficient transfer point, even when device is under rapid movement.



A conceptual drawing of the wireless power transfer system developed by the researchers. Credit: Assawaworrarit & Fan.

"Our system's high efficiency was achieved by carefully designing its gain element," Assawaworrarit said. "An off-the-shelf amplifier, which was used in our earlier work, generates an amplified version of an input signal by carving out part of its DC power supply that does not go out as oscillations at output, and thus has low efficiency typically on the order of 50% or lower."

Using switch-mode amplifiers, Assawaworrarit and Fan were able to prevent the efficiency loss that hindered the overall performance of the circuit setup they developed in their previous research. The amplifiers they used prevented this loss in efficiency by operating a transistor as a controlled switch, which consumes no power both when the system is on or off.

"Switch-mode amplifiers, however, are usually designed for a narrow operating frequency band, due to the need to satisfy an efficient switching condition and output power, which are typically sensitive to frequency," Assawaworrarit said. "With the right circuit design, contributions from coupling and eigenfrequency variations in the transfer distance cancel, and therefore, the efficient switching condition can be maintained for a wide range of transfer distance."

The key advantage of the new system for wireless charging devised by the researchers is its robustness, regardless of how far a device is from the power source. The system can rapidly adapt at a sub-millisecond timescale, which means that it could enable remote wireless charging even when a device is moving at very high speeds, for instance, if the device in question is a car speeding on a motorway.

"This study represents substantial contributions both in theory and practice," Fan, the other researcher involved in the study, told Phys.org. "In terms of theoretical contributions, our work points to the importance of nonlinearity on the dynamics of PT-symmetric systems. On the practical side, our work represents a major step toward dynamic wireless power transfer by showing that such a transfer can be done both robustly and efficiently."

In a series of initial tests, the new system achieved remarkable results, as it was able to effectively transfer around 10W of power via wireless technology to a moving device that was at distances ranging between 0 and 65 cm from the source, with an almost constant total efficiency of 92%. In the future, the system could be improved further to enable the transfer of greater amounts of energy from an even broader range of distances.

"There are a few avenues worth exploring in our next studies," Assawaworrarit said. "For some applications, such as charging a moving car, it is beneficial to have an array of source coils embedded under the roadway. In such a case, studies of their optimal placement and interaction should be useful. Further increasing the amount of power that is transferred is also important, especially for vehicle applications."

More information: Sid Assawaworrarit et al. Robust and efficient wireless power transfer using a switch-mode implementation of a nonlinear parity–time symmetric circuit, *Nature Electronics* (2020). DOI: 10.1038/s41928-020-0399-7