Charging without Wires

Convenience, but at what Price?

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Isidor Buchmann

CEO & founder of Cadex Electronics Inc.
www.BatteryUniversity.com; answers@cadex.com

Wireless charging may one day replace plugs and wires similar to how Wi-Fi and Bluetooth have modernized personal communication. Wireless charging with inductive coupling uses an electromagnetic field that transfers energy from the transmitter to the receiver, and this technology is also suitable to charge medical devices.

Wireless transfer of power is not new. In 1831, Michael Faraday discovered induction and stated that electromagnetic forces can travel through space. In the late 1800s and early 1900s, Nicola Tesla began demonstrating wireless broadcasting and power transmission. Early experiments in Colorado Springs in 1899 lead to the Wardenclyffe Tower in New York — Tesla was adamant to prove that electrical power could be transmitted without wires, but lack of funding halted the project.

It was not until the 1920s that public broadcasting began, and Europe built massive AM transmitters with signal strengths to penetrate many countries. The transmitter at Beromünster in Switzerland (Figure 1) could have transmitted at 600kW, but legislation on electro-smog and protests from the local population limited the power to 180kW. Smaller FM stations have since replaced these large national transmitters.

Figure 1: Switzerland's National AM Radio Station Beromünster

Constructed in 1931 as an independent voice against the Nazi propaganda of Germany to the displeasure of Adolf Hitler. The station broadcasted AM signals until 2008.

How does wireless charging relate to radio transmission? Both are similar in that they transmit power by *electro-magnetic waves*. Wireless charging operates in a *near field* condition in which the primary coil produces a magnetic field that is picked up by the secondary coil in close proximity. The radio transmitter works on the *far field* principle by sending waves that travel through space. While the receiving coil of the wireless charger captures most of the energy generated, the receiving antenna of the radio needs only a few microvolt (one millionth of a volt) to rise the signal above the noise level and receive clear intelligence when amplified.

Types of Wireless Charging

Wireless charging is classified into three categories: *Radio charging*, *inductive charging* and *resonance charging*. **Radio charging** will serve low-power devices operating within a 10-meter (30 feet) radius from the transmitter to charge batteries in medical implants, hearing aids, watches and entertainment devices. Radio charging can also activate advanced RFID (radio frequency identification) chips through resonantly enhanced induction. The transmitter sends a low-power radio wave at a frequency of 915MHz (frequency for microwave ovens) and the receiver converts the signal to energy. The radio charging method is closest to a regular radio transmitter; it offers high flexibility but has low power capture and exposes people to electro-smog.

Most of today's wireless chargers use **inductive charging** featuring a transmit and receive coil in close proximity. Electric toothbrushes were one of the first devices to use this charging method, and mobile phones are the largest growing sector to charge without wires. To retrofit an existing mobile phone for mobile charging, simply attach a "skin" that contains the receiver and provides interconnection to the charger socket. Many new devices will have this feature built in.

For larger batteries such as electric vehicles, **resonance charging,** or electro dynamic induction, is being developed. Resonance charging works by making a coil ring. The oscillating magnetic field works within a one meter (3 feet) radius; the distance between transmit and receive coil must be well within the 1/4 wavelength (915Mhz has a wavelength of 0.328 meters). Currently, resonance charging in trials can deliver roughly 3,000 watts at a transfer efficiency of 80–90 percent.

Standard

The success for wireless charging was subject to adapting a global standard and the WPC (Wireless Power Consortium) accomplished this in 2008. With the "Qi" norm, device manufacturers can now build charger platforms to serve a broad range of compatible Qi devices. The first release limits the power to 5 watts and works as follows:

While in ready mode, the charging mat sends signals that sense the placing of an object. Detection occurs by a change in capacitance or resonance. The mat validates the device for WPC compatibility by sending a packet of data by modulating the load with an 8-bit data string. The receiving device awakens and responds by providing the signal strength. The mat then sends multiple digital pings to identify the best positioning of the placed object. Only then will service begin. During charging, the receiver sends *control error packets* to adjust the power level. Figure 2 illustrates a Qi compatible charger mat.

Figure 2: Charging mat for a mobile phone

Wireless charging is most practical for mobile phones and accessories.

The charge mat only transmits power when a valid object is recognized. With no load, or when the battery is fully charged, the mat switches to standby mode. The transmit and receive coils are shielded to obtain good coupling and to reduce stray radiation. Some charge mats use a free moving transmit coil that seeks the object placed above for best coupling, others systems feature multiple transmit coils by engaging only those in close proximity with the object. Figure 3 shows a Qi kit representing the transmitter and receiver.

Figure 3: Wireless charging system by Texas Instrument

Qi-compatible transmitter module (left) and the receiver module. Commercial applications are currently limited to 5 watts.

Courtesy of Texas instruments

Drawbacks of Wireless Charging

Inductive charging is not without disadvantages. The *California Energy Commission* (CEC), Level V, mandates that AC adapters meet a minimum efficiency of 85 percent; *Energy Star*, Level V, requires 87 percent (European CE uses CEC as a base). Adding the losses of the charger circuit to the AC adapter brings the overall efficiency for a hardwired charger to about 70 percent. Wireless charging has a transfer efficiency of 70–80 percent; coupled with their own AC power conversion the overall charge efficiency hovers between 60 and70 percent. In addition to efficiency losses, the wireless charger includes the "readiness" mode to identify the placement of an object, a feature that adds to power consumption.

Charger manufacturers, including Cadex Electronics, make great efforts to meet regulatory requirements. Losses incurred through less efficient charge methods go against the government-backed *Energy Star* program, and exceptions may need to be made to allow more energy use to support convenience. With roughly one billion chargers on standby or in charge mode, the extra power consumed is significant. The number of mobile phones is estimated at over five billion in the world; in 2008, 3.2 billion power supplies were manufactured globally; most are plugged into the main drawing power.

Lost energy turns into heat and a wireless charger can get quite warm during charge. Any temperature increase to the battery causes undue stress, and batteries charged on wireless devices may not last as long on a mat as on the regular plug-in charger. It should be noted that the heat buildup only occurs during charging; the Qi wireless charger will cool down when the battery is fully charged.

WPC was very careful when releasing Qi; the first version has a power limit of 5 watts. A medium-power version of up to 120 watts is in the works but this norm must meet stringent radiation standards before release. There are health concerns because the devices operate in close proximity to human activity at a radio frequency ranging from 80–300kHz. Some stations transmit at 915MHz, the frequency used to heat food in microwave ovens.

Electromagnetic energy from radio towers, mobile phones, Wi-Fi, routers, and now wireless charging, are categorized as non-ionizing radiation and are believed to be harmless. Ionizing rays from x-rays, on the other hand, have been shown to cause cancer. As the number of non-ionizing devices increases, people begin to question safety. Regulatory authorities are waiting for evidence and will only impose restrictions if a health risk can be scientifically proven. Meanwhile, parents object to schools installing Wi-Fi, and homeowners protest about electric meters that communicate data without wires. Radiation from wireless chargers may be seen as harmless because they do not transmit intelligence. In most cases, the radiation in hospitals or care homes is low enough not to worry, but it is the field strength and close proximity to the source that could add to potential harm.

Charging EVs without plug and cable offers the ultimate in convenience as the driver simply parks the vehicle over a transmit coil. Engineers talk about embedding charging coils into highways for continuous charging while driving or when waiting at a traffic light. While this is technically feasible, cost, efficiency and radiation issues at these higher powers are insurmountable challenges.

At a transfer efficiency of 80–90 percent, 10–20 percent of the power is lost. This reflects in a substantial energy cost to the user and should be calculated as a decrease in drivable distance per watts. Applied to a large vehicle population, this goes against the efforts to conserve energy. Daimler's Head of Future Mobility, Professor Herbert Kohler, says that inductive charging for EVs is at least 15 years away and cautioned about safety. The potential radiation of EV charging is higher than Wi-Fi or talking on a mobile phone; it could also endanger people wearing a pacemaker.

Besides low efficiency and radiation concerns, wireless charging offers decisive advantages in industry. It allows safe charging in a hazardous environment where an electrical spark through charge contacts could cause an explosion, or where heavy grease, dust and corrosion would make electrical contacts impractical. Eliminating contacts also helps in sterilizing surgical tools, as well as preventing breakage of contacts on multiple insertions. There is, however, a cost premium and this is especially apparent in custom devices that cannot take advantage of cost reductions through mass production.

Currently, a wireless charging station will cost roughly 25 percent more than a regular charger. A 25 percent premium also applies to the receiver. If the portable device cannot be charged with the battery installed, as is possible with a mobile phone or wireless patient monitor, then each battery would need its own receiver and the battery pack would bear the added cost. Unless wireless charging is necessary for convenience or environmental reasons, charging through battery contact continues to be a practical alternative.

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About the Author

Isidor Buchmann is the founder and CEO of Cadex Electronics Inc. For three decades, Buchmann has studied the behavior of rechargeable batteries in practical, everyday applications, has written award-winning articles including the best-selling book "Batteries in a Portable World," now in its third edition. Cadex specializes in the design and manufacturing of battery chargers, analyzers and monitoring devices. For more information on batteries, visit www.batteryuniversity.com; product information is on www.cadex.com.