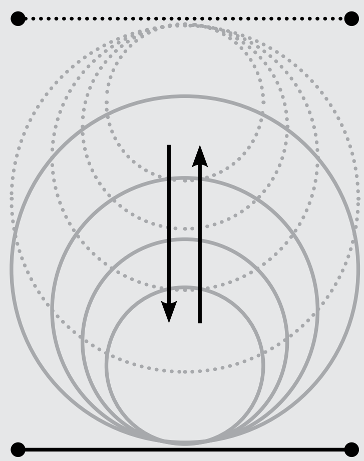

UNDERSTANDING WIRELESS POWER

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ABSTRACT

Wireless power is transitioning from a technology to an industry, and many questions ranging from what consumers really expect to which technology is the safest and most efficient solution are generating an increasing amount of debate as proprietary products come to market and a wireless power standard is introduced. As wireless power reaches a tipping point, it is important that developers and consumers alike understand the realities of the different technological approaches, especially the safety and efficiency concerns surrounding them, and the current and future states of the technology as it gains momentum.

EXECUTIVE SUMMARY

Research has shown that wireless power is one of the most attractive new technologies with consumers. However, there are misconceptions in the media and the marketplace around what consumers really expect from the technology. In order for the industry to fully develop and reach mass adoption, there needs to be a fuller understanding of the different embodiments of wireless power technology, as well as clearer definitions around efficiency (in particular, how efficiency is measured), safety and the different consumer embodiments of the technology, including pad and adapter solutions and a wireless power specification.

Given these considerations, the viability of the technology and the growing wireless power industry, it has become necessary to collectively understand and educate developers and consumers and to collaborate to create the best available solution for today to position wireless power for its future.

UNDERSTANDING WHAT CONSUMERS REALLY EXPECT

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Research has shown that a desire to simplify powering and charging experiences and add a new level of convenience to everyday life are driving the consumer expectation for wireless power. And, as the latest wave of wireless power products enter the marketplace and the viability of the technology expands into industry, a need to address the understanding of wireless power and how it will be incorporated into everyday life has also arisen.

There has been a level of misunderstanding about what the consumer really wants and needs. Research has shown that, if consumers knew that an integrated wireless power solution was going to be offered in the future, they would support a pad and adapter solution today. Nearly half of consumers (surveyed) indicate that they would wait for two years for (the) product if they could have the technology built into electronic devices. Still, about one-third would be willing to buy adapters, and about one-quarter would buy the stand alone charger (pad) and use them until they replace their devices with ones with embedded technology[1].

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However, this research also indicates that there is a specific price point that, once exceeded, no longer makes the adaptive solution attractive - even to early adopters. Also, given the size of the adapter market in light of the larger picture of all consumer electronics and infrastructure, it is not reasonable to think that proprietary charging pads and adapters are anything more than short-term options that will help prepare consumers for the universal, integrated, globally-available solution they are expecting.

Given this understanding of the marketplace, many underdeveloped and divergent thoughts have been introduced from both the developmental and perceived consumer points of view. These range from broadcasting power and charging any device, in any position, anywhere in a room, to leveraging near-field solutions where devices interact with charging hot spots built into the surrounding infrastructure.

As the industry matures and more specific questions and concerns around wireless power technology develop along with it, there is a necessary sequence of events that is required for mass adoption of the technology worldwide. The first of these is a deeper understanding of the available technologies, their strengths and limitations and the importance of creating a global standard to serve as the most effective vehicle for the evolution of the universal wireless power solutions that is capable of answering the consumer demand for a universal, integrated solution.

A simple assumption would be that consumers want wireless power in the same vein as Wi-Fi™ solutions where power would be available anywhere. Initially, this holds true until the aspects of efficiency, safety, cost and interoperability weigh into the equation. This then becomes a complex consideration of solutions. This is the underlying reason to discuss these considerations, compromises and available solutions further.

THE PRIMARY EMBODIMENTS OF CONSUMER-READY WIRELESS POWER

Wireless power can be transferred a number of ways. From microwaves and lasers, to the way Tesla did it, to simple embodiments like rechargeable toothbrushes, all these methodologies have limitations that potentially undermine mass adoption and commercialization. As an opening caveat, microwave and laser type wireless power systems that are typically point-to-point sources have been excluded from this discussion. That said, development teams are stretching the boundaries of physics using available components to create systems that are able to compete with the efficiencies of wired solutions while offering the conveniences of wire-free connections. The solutions being offered currently are based on high frequency broadcast, mid-range inductive coupling or near-field inductive coupling technologies. Other terms like "magnetic resonance" may be used, but think of this in terms of a very well-tuned and possibly larger inductively coupled transmitter and receiver system that can be configured and enabled in various ways.

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In defining inductive wireless power transfer several terms are used, including magnetic coupling, where wireless power transfer is typically near-field inductive coupling. When discussing terms like non-radiated energy, this would assume magnetic coupling or, more specifically, inductive coupling. This can refer to both near-field and mid-range inductive coupling. This discussion defines these systems as near-field and those that use a larger primary coil for mid-range distances as near-field, far-edge. In addition, mid-range is defined as somewhere between one and ten times the diameter of the transmitting coil.

Far-field is typically radio frequency (RF) and has a lower wave length with a smaller antenna and propagates effectively. This discussion also reviews the considerations of these systems for use and integration. As a general term, both RF and mid-range wireless power are defined here as broadcast power systems, where the range invokes additional considerations in field, susceptibility and coverage in both radiated and non-radiated terms. The basic term "broadcast" for discussion is in a one-to-many relationship – that is to say, one transmitter coil providing power to many receiver coils. In these broadcast relationships the design requires every receiver in the system to suffer the difference from the most demanding requirement on the system. This will typically be expressed as losses in the transmitter and receiver. In broadcast systems the consideration of the one-to-many relationship is very interesting; however, it brings many additional demands on both sides of the power system. On the receiver side, it demands that any device has the protection and limiting of the largest device. This places very interesting and challenging requirements on the receivers to manage these voltages and power transactions. Although technology has advanced in DC-to-DC conversion, the efficiency of such systems will be challenged. Other factors include extraneous losses in the field and other parasitic elements. With close proximity systems these can be easily managed. Each power channel delivers only what is requested for peak efficiency which, in turn, limits losses.

Another key challenge is controlling in various modes with broadcast power. Consider the option to run as a battery charger, power supply or fast rate charger. A difficult problem for the one-to-many broadcast power system is managing power supply interactions, as seen in Figure One, along with meeting the time dependant requirements of a demanding power system.

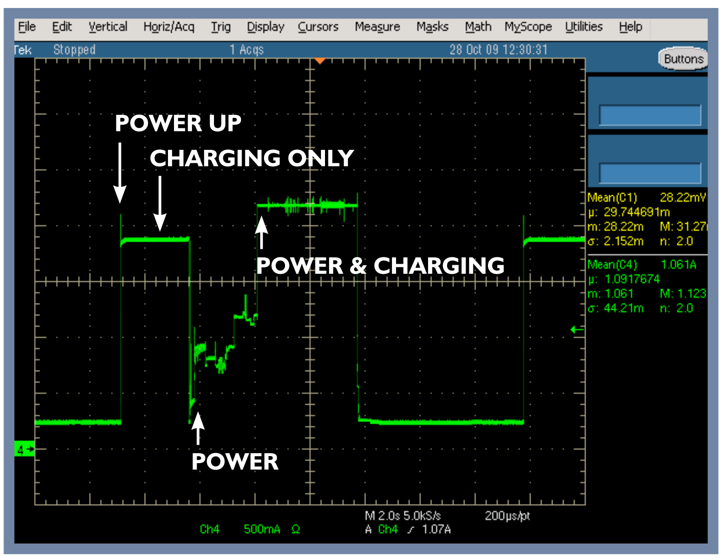

Figure 1: The power supply management demands of a basic 45 watt laptop power supply from start up charging only, power, power and charging.

It would be reasonable to think that for most broadcast systems the solution is one output and one charging solution, resulting in more waste. It is also important to point out that batteries are typically more forgiving than power systems. With closer proximity systems, scalable power from one transmitter over many control modes has been more easily demonstrated. This problem appears to be very challenging in broadcast power and may limit applications and interoperability.

MID-RANGE WIRELESS POWER

Mid-range wireless power, as defined here, is wireless power that extends to larger areas of influence. Mid-range wireless power is built around the idea of using resonant magnetic induction or near-field, far-edge to send power between coils across distances from several inches to several feet. The limitations of this concept start with the diameter of the transmitter. Typically, an inductive coupled system can transmit roughly the diameter of the transmitter. With additional tuning of the primary and secondary Q along with impedance matching capacitance or inductance to achieve a matched magnetic resonance, these distances can be extended. To date, the publications and experimentation show highly tuned systems that can transmit power over substantial distances with transmitter and receiver diameters that are larger than many consumer electronic devices. This tuning and the use of well engineered low loss coils in turn allow these distances to be extended. It should be noted that the discussion to date has been about extending distance and efficiency to ratios greater than 4x the diameter of the transmitter. This is not to say that 4x will produce high efficiency, but rather that power can be transferred at this distance. For many, this will be more interesting at shorter distances where efficiencies are higher and suitable distances for specific applications are gained. This allows gains that create exciting opportunities but again benefit the closer proximity applications the most by extending distances while maintaining the highest efficiencies. The opportunities in this range are exciting but require additional considerations.

In reviewing the case of early RF wireless home control technologies which attempted to leverage the same thinking, these systems were tested in situations where significant gaps in coverage and limiting factors like aluminum siding were discovered that created additional consumer confusion and cost. Imagine these power transfer coils on the inside wall of a house with aluminum siding. This places a large coil within 6” of a metal surface. This is not an easy solution as the screen that holds plaster or stucco would present the same challenges to an RF-based power solution. Broadcast wireless power faces the same probable set of challenges, the most significant of which is consumer education. Today, this technology has been presented in a way that appears to be magic while the real comparisons will be made by the designers of future products.

Wirelessly powered devices can be very finely tuned and operate at specific frequencies. If a device, printed circuit, semiconductor or wire circuit happen to be tuned to these frequencies, they will suddenly develop a potential from the power being broadcasted. This opens up channels of interference that threaten efficiencies as well as functionality, creating usage issues for consumers. And, as distances between power sources and devices increase, these issues are amplified beyond simple shielding solutions. Additionally, wireless power in larger areas may present susceptibility and compatibility issues with devices. This may create a need for regulation and standardization that would require new levels of testing and design for devices to prevent additional reliability and warranty failures. Potential susceptibility failures can be immediate or latent failure modes.

In reviewing the claims of non-radiated energy by some, one could see how it is more directed as in magnetic fields, but a specific energy is still present at the transmit frequency within that field. This is typically strongest between these coils. It should be noted that this can be minimized but a component of radiated and non-radiated energy will be present.

Orientation provides yet another challenging factor for broadcast power as distance increases. In this, consideration must be given to not only the physical orientation and alignment between the specific transmitter and receiver, but also orientation and alignment in conjunction with other bodies of various materials that fall within the broadcast field. If this condition happens to restrict the field completely the consumer is left with a dead spot. These circumstances will change performance and operation unless the system can adjust and respond accordingly. This becomes even more important when considering efficiencies in a highly tuned system. Adaptive intelligent solutions can provide gains in performance when facing these issues. However, if adaptive intelligence is not built into systems at the outset, the system risks potential technology failures and reduced consumer confidence.

In addition to tuning and orientation challenges, mid-range wireless power solutions face coil geometry factors that should also be considered. The laws of physics have proven that well-matched coils provide the best power transfer. Referencing a recent paper by researchers at Koninklijke Philips Electronics N.V., one can see the possible practical applications using these methods[2]. All efficiencies referenced in the following efficiencies section of this paper also consider tightly matched transmitter and receiver coils. Subsequent demonstrations have been realized with vastly different ratios from the transmitter diameter to receiver diameter. It should be pointed out that these efficiencies may follow some portion of these ratios. This may further degrade the efficiency references provided below for these systems as these ratios are changed from the mentioned efficiency. The example that follows uses a transmitter and receiver each with a 25cm coil, and this system demonstrates an AC system efficiency of 15 percent. By changing the receiver coil from 25cm to 25mm (a typical size needed for a handheld device) there should be a negative impact in efficiency. It would also be expected that any change in coil size would negatively impact tuning, so this system would need to be highly tuned as the system changes. Given these variables, there is opportunity for more system inefficiency at the system level when considering interoperability than has been communicated previously.

Another consideration with mid-range wireless power systems is power control. When powering a laptop, a headset and cell phone, the power transmitted must be tailored to the highest demand. The other devices must be designed to either accommodate this input amplitude or other tradeoffs must be made. This represents yet another opportunity for losses, leading to overall lower efficiency and potentially greater thermal dissipation in the device. This also represents additional design considerations and protections for smaller devices that already struggle to reach their high level of integration.

ADAPTIVE INDUCTIVE COUPLING

Adaptive inductive coupling leverages the physics of magnetic induction. However, the technology is presently applied in near-field and mid-range configurations at the highest design efficiency in applications of less than several inches, tuning the power and coils closely to realize performance levels comparable to present wired power usage while charging or powering devices at the present wired rates. Near-field adaptive inductive coupling has proven that tuning improves system Q dramatically which, in turn, maximizes the system efficiency. This is also understood as a critical factor for maximizing the magnetic field and therefore power transfer as discussed above. If systems are NOT being tuned to account for almost every situation, the physics behind wireless power are NOT being maximized. This is the primary issue that prevented Tesla and other early pursuers of the technology from succeeding. The difficulty of realizing the influencing factors in highly resonant systems can be very subtle. This same methodology can be applied when the transmitter and receiver are highly tuned as in mid-range wireless power systems. Adaptive inductive coupled mid-range systems allow the flexibility needed for such a dynamic system.

Another value of adaptive coupling systems is that they can provide power more efficiently at any distance. Tuning any of these systems for maximum performance in a given operating environment will improve performance. Without this capability, the depth and breadth of applications becomes limited, because the cost of efficiency is not only measured in additional parts cost but also in the cost to operate. Social pressures amplify this as the sheer number of devices could have a significant impact globally if this is not taken into consideration.

One of many consumer expectations for wireless power is that wireless power transmitters for laptops will also power cell phones, headsets, MP3 players, toys, and many other devices. This also becomes a tuning and power control issue allowing devices to receive the necessary power required by each device. When this is considered in terms of broadcast power, the maximum power needs to be available while the other devices then become less efficient. The same is true with closer proximity with the exception that power for greatest efficiency with each device can be managed independently. Think of this as a power control and communications channel.

As with broadcast power, orientation can be an issue for adaptive inductive coupling. And as with broadcast power, using multi-axis coils or arrays to maximize coupling in any direction can minimize gaps. Position within the field and high Q can minimize some of these effects. However, with adaptive inductive coupling, some of these challenges become significantly easier. To illustrate the complexity of the challenge when considering broadcast solutions, consider current cellular reception and other RF communications. This becomes even more complicated when placing coils or arrays in a device. Device shielding used to meet other regulatory requirements starts to become effective in limiting wireless power performance. Placement and proximity to other materials and devices again can limit the performance and alter coupling to the source. Using near-field or mid-range configurations can offer many implementation solutions while securing a surface for transmission and reception of power in a known configuration with which both manufacturers and consumers are familiar. This is to say that when this is expanded over distance, the difficulty of guaranteeing power is compounded by these complications and therefore burdens device manufacturers with an additional layer of design considerations. The future will most likely offer additional solutions, but the eminent solution is to control some of these variables as we simplify the implementation. Meanwhile, these additional considerations are just being realized and may impose additional limitations to the design requirements.

THE HIDDEN CONCERNS WITH WIRELESS POWER

Efficiency

Citing the most influential published resources available today, ongoing work is seeking to improve and innovate solutions. The following is a very basic summary of some of this work.

- RF Harvesting
    - 50-70% at <100mw (conversion eff.) [3]
- Near Field (far edge) eff. between source coil and load [4]
    - 50% at 60 Watts at 2m (coil to coil eff.) [5, 6, 7]
        - – 15% (AC to AC load system eff.) [8]
    - 75% at 60 Watts at 1m (coil to coil eff.) [9, 10]
- Near Field – AC to AC
    - 94+% at 1.4KW at 8mm (AC to AC load system eff.) [11, 12]

MEASUREMENT AND UNDERSTANDING

Figure Two below at low voltages represents one of the most challenging aspects of wireless power. In the AC-to-DC power supply or charger, low voltage along with typical semiconductor losses are some of the most significant losses. Notice this is measured from the wall to the battery or load for a complete picture. Losses occur at each of these junctures A1, A2 and A3 respectively.

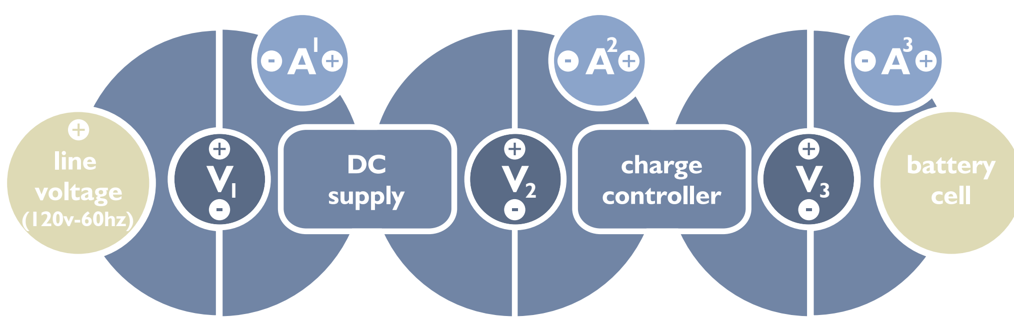

Figure 2: Measuring a traditional low voltage system and contributing losses.

There has been a lack of understanding regarding the efficiency of systems, most especially near-field, far-edge or mid-range and RF wireless power systems. Current measurements are being based on conversions and/or coil-to-coil efficiency, which would exclude other key system factors that greatly impact the true efficiency of a total solution. The full system must be considered to give a clear picture of actual efficiency to consumers (see Figures Three, Four and Five below). These measurements are a key factor on which type of wireless power is being judged in terms of global feasibility and mass adoption.

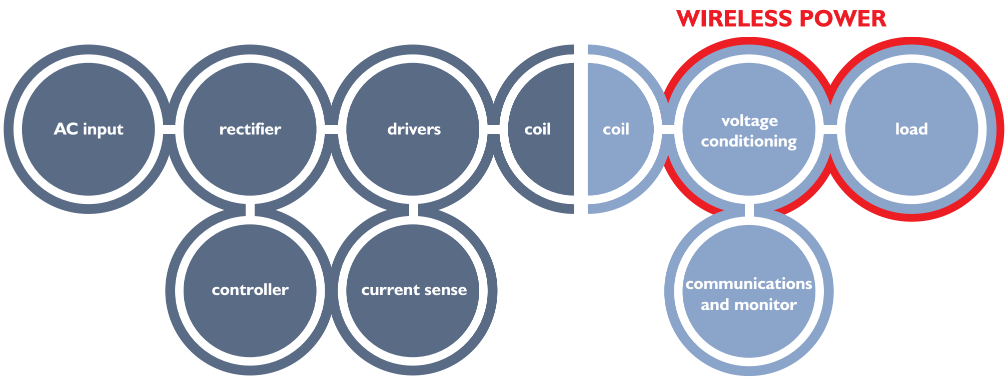

Figure 3: Conversion is important but only one part of the system. Typically a measurement referred to in RF systems.

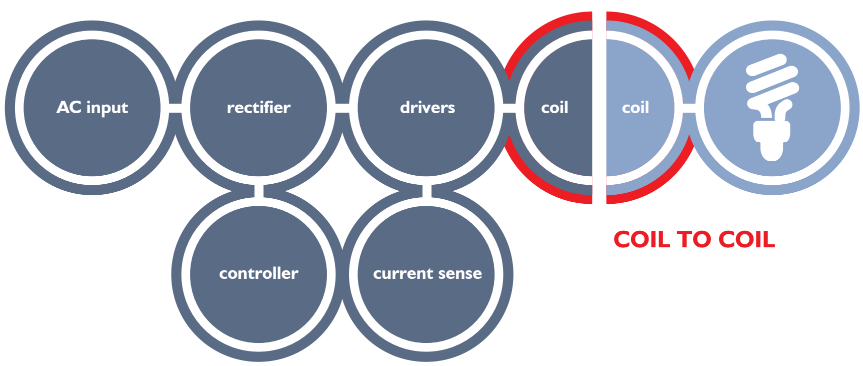

Figure 4: Coil-to-coil efficiency or coupling factor is very important but is only one part of the system.

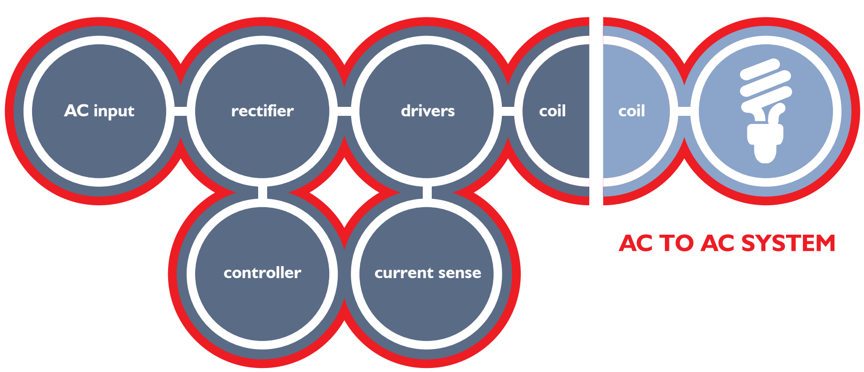

Figure 5: System efficiency has many elements that directly effect overall efficiency numbers, and the full system must be considered to give a clear picture of capabilities.

PERFORMANCE

Along with efficiency, this issue is arguably the most important factor in bringing wireless power to a mass market. The consumer solution is the greatest challenge wireless power faces. Providing a "wow" factor while keeping a solution safe, affordable, easy to use and understood can be a barrier to complex technology solutions. The variability of consumer use cases, environments and user habits form yet another layer to the challenge. Regardless of whether broadcast or adaptive coupling systems are leveraged, the solutions will need the ability to adapt and respond to the myriad of variables associated with performance which will be generated at the consumer level. If the technology does not have this capability to adapt, the technology and, ipso facto, the industry will be limited in its ability to meet demand and provide value.

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THE IMPORTANCE OF A STANDARD IN UNDERSTANDING WIRELESS POWER

Given the unique features and benefits of both broadcast and adaptive inductive coupling solutions, as well as the recent case studies surrounding other globally accepted technologies like Bluetooth™ and Wi-Fi™, the logical course of action, which is already in motion through the efforts of the members of the Wireless Power Consortium[13], is to evaluate and agree on the most effective wireless power solution(s) to ensure rapid, mass adoption.

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THE MANUFACTURERS POINT OF VIEW

There must necessarily be an engagement of equipment companies to understand and integrate wireless power worldwide. This is an essential step, but it is time consuming. Each manufacturer has stringent requirements that forge new technologies into real solutions for industry. A technology that appears to be a solution in the lab may have significant issues integrating into product, coexisting with other technologies and meeting regulatory or company-specific standards. Without this step, a technology can only advance if viable solutions can be realized. It can take years to fulfill these requirements as each respective company has much to lose if these efforts go unfulfilled. Consider the technology readiness level as an enabling or limiting trigger. This process is amplified as multiple companies introduce overlapping and extended expectations further refining the end solution. The ability of a technology to survive this gauntlet is the very essence of enabling adoption. The lessons learned then fold back into the standard—teaching others to execute while allowing invention.

In an effort to position in the marketplace, some technology companies will attempt to forgo this process as it is expensive and time-consuming. This can position a technology well within consumers' eyes yet fall short of the need or expectation by consumers and manufacturers. We have all seen the immature technology that fails to deliver or meet the unspoken expectation. Only a few technologies are so successful that they dictate the market and this is usually company-specific and does not require collaboration from other companies. Seeking to have the highest integrity in a technology solution, embracing this gauntlet and knowing these are requirements for success is imperative. Attempting to circumvent this process does little more than delay scrutiny and limits the market at the same time.

This is not to say that other technologies and methods will not evolve in this very same way. However, the surest approach to increase the likelihood for mass adoption involves engaging key influencers with the highest technology readiness.

ADAPTIVE SOLUTIONS

Adapters must be viewed as bridging solutions for legacy products and development of supporting infrastructure. This has a specific market size and function for people to test and experiment. This market represents a very small portion of the device market, yet it serves a very important role. It provides an arena for additional functions and designs to educate and delight consumers. However, if these solutions are NOT interoperable with a standard, they will limit their own ability to penetrate the market and will ultimately frustrate consumers who are looking for a universal, interoperable solution.

INFRASTRUCTURE

These market segments require a key component to drive adoption and one overarching unspoken trigger. The key component is a standard. As each manufacturer starts down the development road, they commit design, intellectual property and resources to momentum in a specific direction. This adds to the previously discussed device manufacturer's gauntlet as these infrastructure manufacturers add additional consumer need, regulatory requirements and company-specific requirements. The technology must hold up to these consumer and manufacturing needs to be validated for product viability in infrastructure. This creates a convergence of requirements that should be introduced as important elements to further refine a standard. If independent developers and proprietary device manufacturers overlook this very important consideration, the rate of mass adoption for wireless power may be severely limited.

The overarching unspoken trigger is the momentum of solutions within the massive space of device and infrastructure manufacturers. At some point, progress or number of adopters moving forward will drive the tipping point. When this happens, adopters will be looking for stability in the technology and solution offerings. A global standard with major manufacturer participation delivers the message that a large number of challenges have been overcome and that there is an organization in place to address future challenges and the evolution of the technology. This clarity will give infrastructure manufacturers confidence in investing in a viable solution and this confidence will translate to adoption.

CONCLUSIONS

Wireless power solutions today provide hope for additional freedoms in the future, but many hurdles still stand in the way. Some of these hurdles will be adjusting to the wide range of expected operating requirements yet undefined by consumer use. Meanwhile, consumers are looking for simple comparisons within the advancements of wireless power technologies, while a steady stream of media confuses coil-to-coil efficiency or conversion efficiency with system efficiency, which is a dramatic misconception.

It must be recognized that wireless power is making the transition from a technology to an industry – products are commercially available, and a wireless power standard is evolving. In the near term, more products will be adopted and accepted by consumers. And, though the real stability of any one technology can be defined as a solution that allows the most flexibility through multiple commercial applications while meeting consumer expectations, the ultimate scenario is for the best solutions to meld together as wireless power as a whole evolves. As scenarios continue to play out and the industry continues to be defined, there are several key considerations that need to be fully explored:

- The safety of broadcasted power remains unknown. Research and additional studies continue to pour in with oftentimes confusing or conflicting results that appear to be inconclusive. Close proximity wireless power can be designed to be as safe as existing power supplies allowing a conservative first step in the evolution of wireless power.

- Range of power or scalability can be addressed with near-field technologies, but broadcast power harvesting is somewhat limited by regulatory standards as a supplemental and secondary source of energy requiring the device to be very low in power or tightly shielded to the surface. Regulatory issues may also play a significant role in broadcasting power. Present rules may not be the long-term regulations as these technologies get tested but they are the rule today. Wireless power device compatibility compliance will also impact these considerations. Many manufacturers will ask new electromagnetic compatibility questions when 210V/m fields interact with products[14]. In any interoperable wireless power system, the range of scalability and power will be needed to adjust various elements of the system dynamically to maximize efficiency as operating parameters change.

- Efficiency is a crucial aspect of almost any wireless power system. It will define usage, reliability, cost, integration size and mass adoption appeal. Efficiency is being compared in many ways and, not in an attempt to confuse or diffuse, but in an attempt to understand the wireless power opportunity. It is important to understand this matrix of offerings within the limits, capabilities, complicating factors and range of use. With that said, today it is apparent that the highest efficiency possible is desirable. It seems logical to assume that the highest efficiency will not be achieved without intelligence and adjustability in any case or technology mentioned. Performance versus impact will always be a commercial decision within this realm. It is important to understand that efficiencies powering actual product account for additional systems and losses that are typically not represented in laboratory or advertised numbers. This can lead to misleading assumptions and comparisons. It is important to understand these predictably elusive aspects of wireless power.

- The system coil geometries discussed earlier show that anything not matched very well will have additional system losses. These ratios determine part of the final system efficiency. The ability of a system to tune the needed elements will be a critical aspect of future designs to maximize system efficiency.

- Although many exciting applications are imminent, the most practical implementation of mid-range inductive power technologies appears to be moving closer in proximity for stability in the system, installation, use case and environment. This is also where we see peak efficiency as shown in Figure Six.

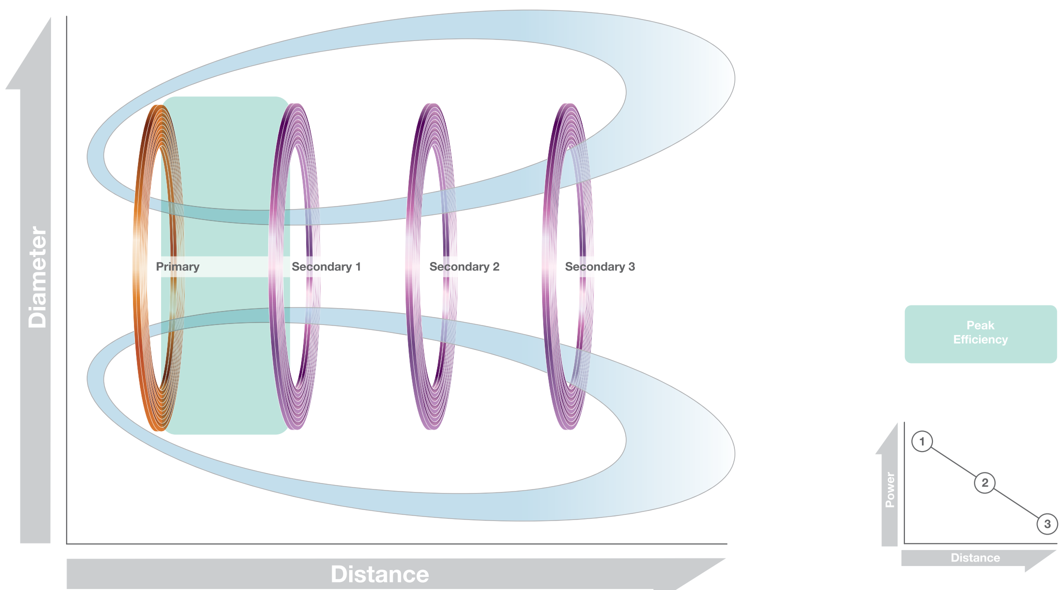

Figure 6: Shows that distance impacts coil to coil efficiency. This also shows that for all near-field or mid-range systems a peak efficiency range is fairly close proximity although the range is extended. This figure is not drawn to scale.

Although mid-range solutions can extend power transfer the peak efficiency range is extended in a much smaller range. This will be pragmatic for the initial commercialization while the technology evolves. Higher frequencies and larger fields provide specific benefits and also bring additional regulatory and susceptibility issues that require further investigation and consideration. In Figure Seven you can also see that the diameter of the coils associated with the primary over distance have a specific efficiency relationship.

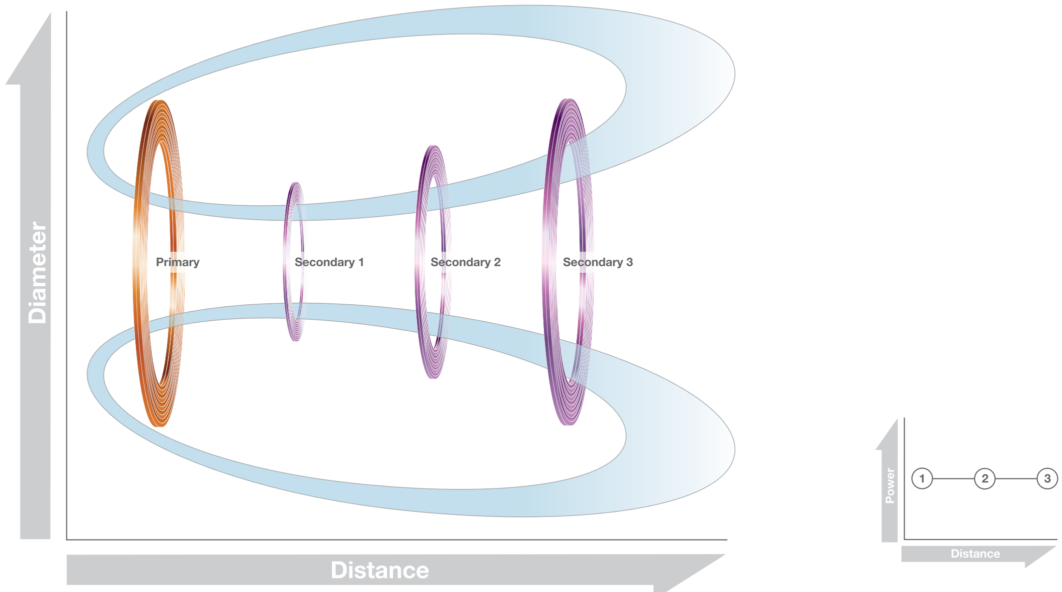

Figure 7: Shows a simple example of maintaining efficiency by comparing several progressively larger coils to achieve the same level. This figure is not drawn to scale.

- Solutions to real world problems are important. For example, overcoming industrial design challenges like the misconception that metal industrial camera cases cannot be wirelessly charged will need to be addressed by innovative solutions such as charging through the display. These creative results should be shared with the wireless power community to advance the development of the technology and encourage newer, more efficient user-friendly solutions to reach the global marketplace. The best solution will have the capability of interfacing and controlling power using any or all of these technologies.

Appendix

Page 1

[1] AcuPOLL® Research, Inc., August 2008 "Project Alamo River"

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[2]Eberhard Waffenschmidt and Toine Staring, "Limitation of inductive power transfer for consumer applications", Submitted as synopsis to European Power Electronics (EPE) Conference 2009, Barcelona, Spain, 8-10 September, 2009.

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[13] www.wirelesspowerconsortium.com

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[14] Aristeidis Karalis, J.D.Joannopoulos, and Marin Soljacic (2006). "Wireless Non-Radiative Energy Transfer."

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Mr. Baarman joined Amway in 1997, where he first pioneered the use of intelligent inductive coupling in the eSpring™ Water Purifier. With over 20 years of leadership experience in the development of consumer and industrial products, Mr. Baarman took the technology behind eSpring and developed it to power everyday technologies, including consumer electronics, with a diverse range of power needs.

Mr. Baarman's efforts have led to national and global recognition of eCoupled technology and the acquisition of former competitor, Splashpower, in May 2008. Mr. Baarman has more than 350 U.S. and foreign patents that are granted or pending.

JOSHUA SCHWANNECKE
RESEARCH SCIENTIST

Joshua Schwannecke is a Research Scientist with the Advanced Technologies Group at Fulton Innovation. Josh has more than five years of experience with wireless power and developing solutions using eCoupled technology. He has developed wireless power solutions for the Amway eSpring Water Purifier and other devices including hearing aids, phones, headsets, laptops, and power tools. He also works closely with Fulton's partner companies to research wireless power solutions for prototype products.

Mr. Schwannecke holds a Masters in Electrical Engineering from Michigan State University and has received an excellence award for coil design and optimization. He holds one granted patent and has eight published patent applications.