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Qualcomm Technologies, Inc.

Wireless Charging by Magnetic Resonance

ECTC 2014
Wireless Power Transfer Systems
Wireless Charging Landscape

- **Long Range**: Far-field RF
  - Coupling of RF energy to a device with a small receiver antenna with device in the RF far field

- **Short to Medium Range**: Magnetic Resonance
  - Device is brought within near field of a low frequency TX antenna. RF energy couples to device with small receive antenna where it is rectified for device charging

- **Short Range**: Magnetic Induction
  - Coupling of RF energy when a device with a small receive antenna is placed on a “charging surface” containing the transmit elements

- **Zero Range**: Conductive Mat
  - Current flows through the pad to a conductive adapter in the device
Magnetic Resonance vs. Inductive Solutions

Key Distinctions – Size, Separation and Orientation

Magnetic Induction (MI)
- 1:1 ratio of Tx to Rx coil
- Tx and Rx coils:
  - Are generally closely matched in size and shape
  - Are generally in close proximity to each other
  - Generally utilize magnets or other mechanism to maintain precise alignment

Magnetic Resonance (MR)
- Tx antennas are designed to create a CHARGING AREA or FIELD
- Allows devices to charge effectively even when Tx & Rx is separated by 10's mm
- Not impacted by coins, pens, and other metal objects
- Doesn't affect magnetic strip credit cards
- No precise alignment required of Rx to Tx
- Not just limited to desktop solutions
Freedom of Placement

Magnetic Induction (MI)

- MI solutions utilize positioning devices, such as magnets or physical constraints such as blocks or ‘posts’ to insure alignment.

- You cannot place the BT device on the tablet charging spot, and you can’t place the tablet on the smart phone spot and expect them to charge.
Freedom of Placement

Magnetic Resonance (MR)

- Flexible coupled solutions do NOT require any alignment devices
- One transmitter ‘field’ can charge BT, smart phones, and tablets.
Freedom of Design

MI Systems
Each device requires a dedicated transmitter location where the coil size is reasonably matched in size or a multi-coil Transmitter is required.

Must have Tx and Rx coils of comparable size and dedicated area for each device form factor.

MR Systems
Each device can be placed anywhere on the transmitter.

Can have a range of antennas for Tx and Rx therefore supporting form factors as small as Bluetooth headsets while still supporting smartphones, netbooks, etc.
Ensuring Metal Objects in or Near the Field Do Not Have a Significant Temperature Rise

Expected Variation in Induced Power Losses Across Frequency

Wireless Charging Solutions Operating in the 100s of KHz Range Generate ~10x the Amount of Induced Power in Foreign Objects as That of 6.78 MHz Systems
Total Market (Rx and Tx)
Variance From Previous Edition - Revenue

Market begins to accelerate in 2015.

Transition To Loosely Coupled Begins in 2015

Loosely Coupled overtakes tightly coupled as dominant technology

>5W is ~30% of market

Wireless Power Receivers

Volumes by Application
Quick comparison of the Alliances

<table>
<thead>
<tr>
<th>Consumer Brand</th>
<th>A4WP</th>
<th>PMA</th>
<th>WPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>When Established</td>
<td>5/2012</td>
<td>2012</td>
<td>12/2008</td>
</tr>
<tr>
<td>Number of Members</td>
<td>101</td>
<td>~70</td>
<td>~210</td>
</tr>
<tr>
<td>Technology Type Promoted</td>
<td>Resonant (MR)</td>
<td>Magnetic Induction (MI)</td>
<td>Magnetic Induction(MI)</td>
</tr>
<tr>
<td>Specification Release</td>
<td>2012</td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td>First Product Launch</td>
<td>NA</td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td>Frequency of power transfer</td>
<td>6.78MHz</td>
<td>Variable 80~300KHz</td>
<td>~205KHz</td>
</tr>
<tr>
<td># of devices charged simultaneously</td>
<td>2, 3, more</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Type of devices supported</td>
<td>Currently up to 22W</td>
<td>Limited to 5W or less</td>
<td>Limited to 5W or less</td>
</tr>
<tr>
<td>Signaling method</td>
<td>OOB – BLE 2.4GHz</td>
<td>IB</td>
<td>IB</td>
</tr>
<tr>
<td>System Efficiency</td>
<td>50-65%</td>
<td>70+% 1:1</td>
<td>~70% - 1:1 designs, ~60% - coil arrays</td>
</tr>
<tr>
<td>Specification Requires EMI/EMC Compliance</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td># of potential generated network harmonics</td>
<td>&lt;9</td>
<td>100’s</td>
<td>100’s</td>
</tr>
<tr>
<td>Device heating or Foreign Object Concerns</td>
<td>No</td>
<td>Yes, deploys FOD</td>
<td>Yes, deploys FOD</td>
</tr>
</tbody>
</table>
A4WP Latest Developments

Alliance for Wireless Power Unveils Rezence™ Brand

Rezence Named Digital Trends Best of CES 2014 Award Finalist (Top 5!)

A4WP Announces First Rezence Products Following Launch of Global Certification Program

- 4 companies have certified product:
  - Samsung
  - Qualcomm
  - Gill Electronics
  - Samsung Electro-Mechanics

Alliance for Wireless Power and Power Matters Alliance Join Forces
Overcoming the Hurdles to Drive Wireless Power into the Mainstream

| Meets User Case Requirements | Delivers Spatial Freedom (Simultaneously meeting X/Y and Z) ✓ |
|                             | Simultaneous charging of multiple devices from a single specification ✓ |
|                             | Simultaneous charging of multiple device types from a single specification ✓ |

| Meets Regulatory Requirements | ICNIRP ✓ |
|                              | FCC Part 15/18 ✓ |
|                              | CISPR 11 ✓ |

| Meets Standardization Requirements | Rezence brand launch by A4WP provides certification of products for interoperability and safety ✓ |

| Meets Commercial Readiness Requirements | Charge Time, Touch and Battery Temperature Requirements ✓ |
|                                         | Mobile Phone Coexistence ✓ |
|                                         | Minimal temperature rise in foreign objects in or near the field ✓ |
Technology challenges

What it takes to operate at 6.78MHz

- Ferrite and antenna structures trade-off: thickness vs. permeability
  - Magnetic reluctance is given by $R = \frac{l}{\mu w t}$, where $\mu$ is the permeability of the material
  - Hysteresis losses (given by $\mu''$), which contribute to heating of the assembly
  - Complex permeability: $\mu = \mu' - j \mu''$
  - Magnetic loss tangent $\tan \delta = \frac{\mu''}{\mu'}$

<table>
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<tr>
<th>Quantity</th>
<th>Existing</th>
<th>Desirable</th>
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<tbody>
<tr>
<td>$\mu'_r$</td>
<td>100-200</td>
<td>&gt;200</td>
</tr>
<tr>
<td>$\mu''_r$</td>
<td>1-5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>t (mm)</td>
<td>0.4-0.75</td>
<td>≤0.3</td>
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</tbody>
</table>
Electronic components’ challenges

- **Transmitter: High efficiency, resonant Power Amplifiers from 10 to 50+ Watts**
  - Low average dissipation, but large instantaneous power loss when off-resonance
  - GaN shows some advantage, but dynamic conditions and thermal capacitance are a challenge

- **Receiver: Rectification at 6.78MHz**
  - Challenges: high efficiency, low EMI generation
  - Synchronous rectification presents some advantages but high voltage required and power dissipation challenge integration

- **EMI filters:**
  - Low losses at 6.78MHz and high rejection at the harmonics and all the way to LTE and WWAN bands
Wireless Power Integration opportunities

- Integration of Wireless Power and NFC antennas
- Integration of antenna structure in Wearables
- Integration in SiP
Thank you