Harmonic Suppression Technique of Magnetic Field Coupling Type Wireless Power Transmission System Using ATAC Circuit

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Research Objectives

**Objective**

Magnetic field coupling type wireless power transmission system
- Resonance frequency matching
- Magnetic field harmonic suppression

**Approach**

ATAC & harmonic suppression switching pattern

ATAC: Automatic Tuning Assist Circuit
Outline

• Research Background
• ATAC Circuit
• Harmonic Suppression Pattern
• Simulation
• Conclusion
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• Research Background
  • ATAC Circuit
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  • Conclusion
## Wireless Power Transmission

Wireless power transmission

Electric car & mobile electronics etc.

### Method & Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Electromagnetic induction</th>
<th>Magnetic field coupling</th>
<th>Electric field resonance</th>
<th>Radio wave</th>
<th>Laser</th>
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</thead>
<tbody>
<tr>
<td>Transmission medium</td>
<td>Magnetic field</td>
<td>Magnetic field</td>
<td>Electric field</td>
<td>Micro wave</td>
<td>Light</td>
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<tr>
<td>distance</td>
<td>2-3 [cm]</td>
<td>2-3 [m]</td>
<td>2-3 [mm]</td>
<td>2-3 [m]~</td>
<td>2-3 [m]~</td>
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<tr>
<td>Degree freedom</td>
<td>Fixed</td>
<td>3 dimensions</td>
<td>plane</td>
<td>3 dimensions</td>
<td>3 dimensions</td>
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<tr>
<td>Distance freedom</td>
<td>impossible</td>
<td>possible</td>
<td>possible</td>
<td>possible</td>
<td>possible</td>
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<tr>
<td>efficiency</td>
<td>~90%</td>
<td>~90%</td>
<td>~90%</td>
<td>~40%</td>
<td>~30%</td>
</tr>
</tbody>
</table>

Magnetic field coupling has good potential
Magnetic Field Coupling Problem

Problem

- High Q value, and L & C with low resistance
- High precision resonance frequency adjustment
  - Power supply & transmitter, transceiver
- Class D amplifier configuration
  - harmonic distortion generation

Proposed Method

Automatic adjustment of resonance frequency
Magnetic field harmonics suppression system
Outline

• Research Background
• **ATAC Circuit**
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Equivalent Circuit of Magnetic Field Coupling

\[ Q_{TX} = \frac{\omega_o L_{TX}}{R_{TX}}, \quad Q_{RX} = \frac{\omega_o L_{RX}}{R_{RX}} \]

Power supply efficiency \[ \eta = \frac{1}{\left( \kappa^2 Q_{TX} Q_{RX} \left( \frac{R_L}{R_{RX}} + 1 \right) + 1 \right) \left( 1 + \frac{R_{RX}}{R_L} \right)} \]
Proposed Circuit: ATAC

**ATAC (Automatic Tuning Assist Circuit)**

Automatic correction of phase shift between current & voltage

Main power supply & ATAC section shift switching phase by 90°
ATAC Principle

Main power supply

\[ \begin{align*}
V_S & \quad \text{Phase: 90[Deg]} \\
\end{align*} \]

Auxiliary power supply having phase 90\(^\circ\)

\[ \begin{align*}
V_A & \quad \text{Phase: 90[Deg]} \\
\end{align*} \]

Add together

\[ \begin{align*}
V_S & \quad V_A \\
\text{Phase: 90[Deg]} \\
\end{align*} \]
Conventional Circuit

Error of resonance frequency 0.80%~3.78%
Error of output current 60%~80%
ATAC Circuit

Error of resonance frequency 0.80%~3.78%
Error of output current 0%~20%
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• Research Background
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Harmonic Suppression Switching Pattern

Harmonic Suppression Algorithm

Switching output pattern

Harmonic suppression

Duty50%

Fourier transformation

Harmonic Distortion

\[ f(t) = \sum_{k=1}^{\infty} \frac{1}{k\pi} \sin(2kf\pi t) \quad (k = 1, 3, 5, \ldots) \]
Harmonic Suppression Switching Pattern

\[ f(t) - f(t - \tau) - f(t + \tau) = \sum_{k=1}^{\infty} \frac{1}{k\pi} \{1 - 2\cos(2kf_{in}\pi\tau)\} \sin(2kf_{in}\pi t) \]

In case HD3 suppression \( f_{in}\tau = \frac{1}{18} \)

Specific frequency suppression switching pattern

Time waveform

Spectrum
Outline

• Research Background
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• Simulation
• Conclusion
Apply HD3 Suppression Pattern

**Objective**

- Harmonics suppression
- Operation of ATAC not Duty 50%
Spectrum of Inductor Current

Duty 50% switching

HD3 suppression switching

-20dB suppression
Output Current of HD3 Suppression

Error of resonance frequency 0.80%~3.78%
Error of output current 0%~20%
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• Research Background
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Conclusion

- Wireless power supply system
  
  Automatically adjust resonance frequency

- ATAC circuit can operate without duty 50% switching.

- Harmonic suppression pattern switching
  
  HD3 suppression