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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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Wireless Power Transmission

Wireless power transmission

➡️ Electric car & mobile electronics   etc….

Method & Characteristics

	Electromagnetic induction	Magnetic field coupling	Electric field resonance	Radio wave	laser
Transmission medium	Magnetic field	Magnetic field	Electric field	Micro wave	Light
distance	2-3 [cm]	2-3 [m]	2-3 [mm]	2-3 [m]〜	2-3 [m]〜
Degree freedom	Fixed	3 dimensions	plane	3 dimensions	3 dimensions
Distance freedom	impossible	possible	possible	possible	possible
efficiency	〜90%	〜90%	〜90%	〜40%	〜30%

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
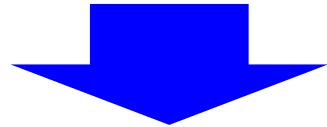
**Automatic adjustment of resonance frequency
Magnetic field harmonics suppression system**

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Equivalent Circuit of Magnetic Field Coupling

Transmitter Side

Receiver Side
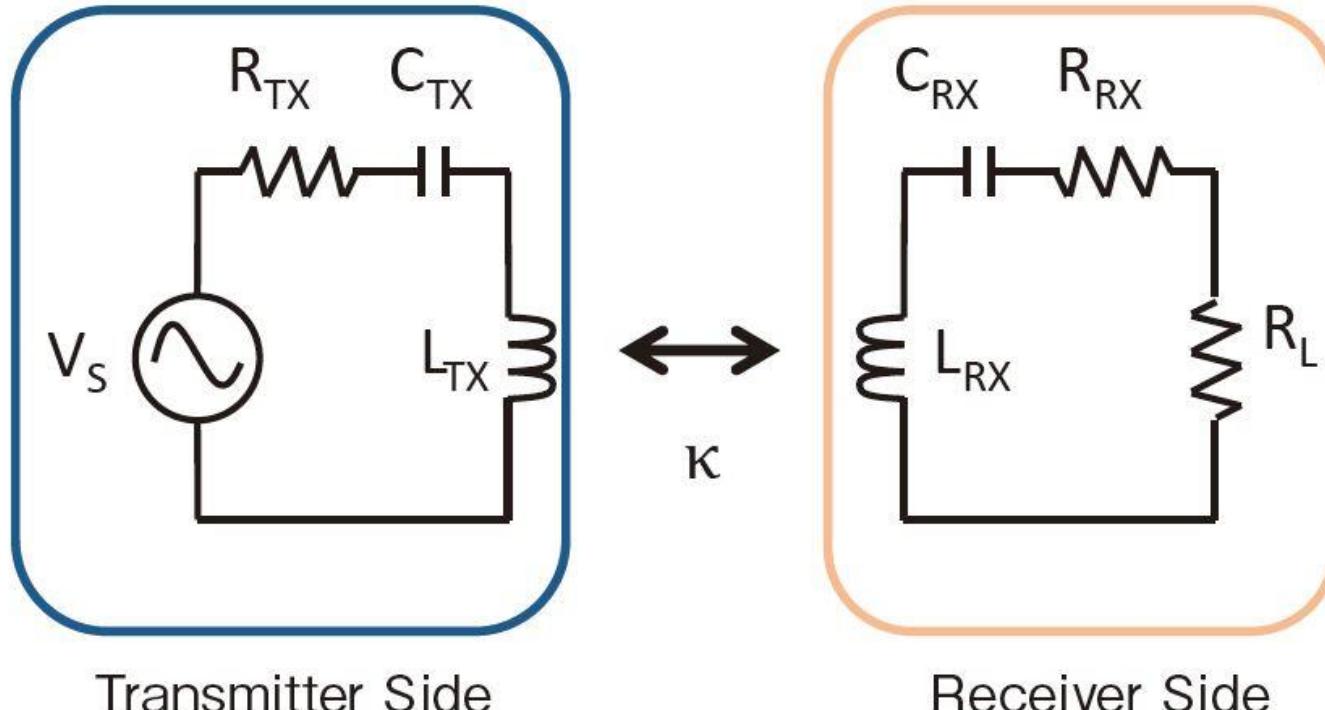
$$Q_{TX} = \frac{\omega_o L_{TX}}{R_{TX}}, Q_{RX} = \frac{\omega_o L_{RX}}{R_{RX}}$$

$$\omega_o = \frac{1}{\sqrt{L_{TX}C_{TX}}} = \frac{1}{\sqrt{L_{RX}C_{RX}}}$$

Power supply efficiency $\quad \eta = \dfrac{1}{\left\{\dfrac{1}{\kappa^2 Q_{TX} Q_{RX}}\left(\dfrac{R_L}{R_{RX}} + 1\right) + 1\right\}\left(1 + \dfrac{R_{RX}}{R_L}\right)}$

Proposed Circuit: ATAC
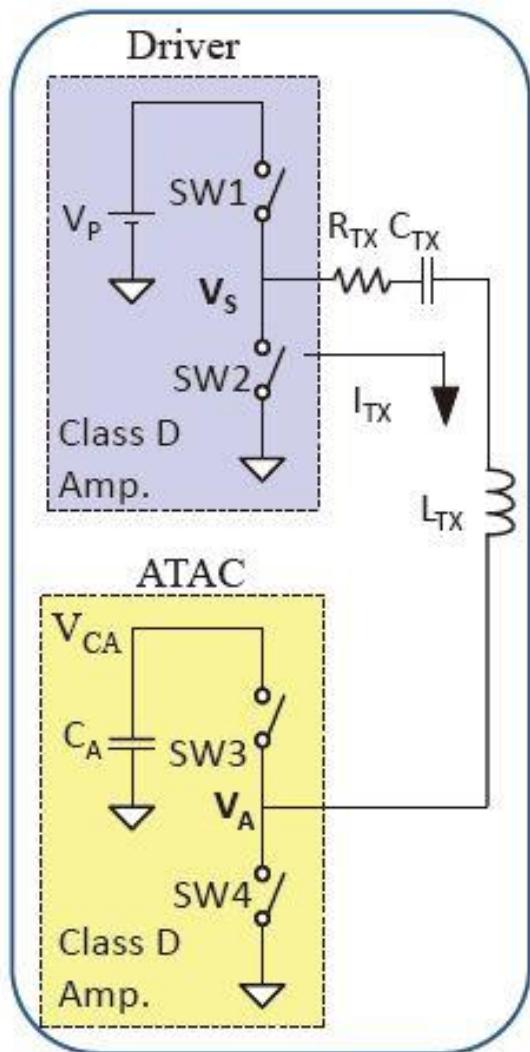
ATAC (Automatic Tuning Assist Circuit)

Automatic correction of phase shift between current & voltage

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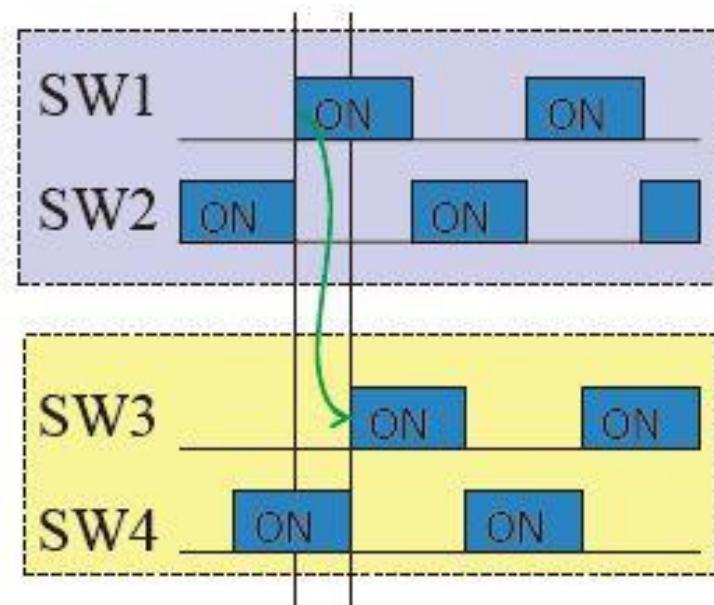
ATAC Principle

**Main power supply**
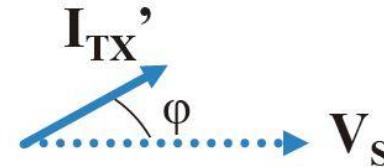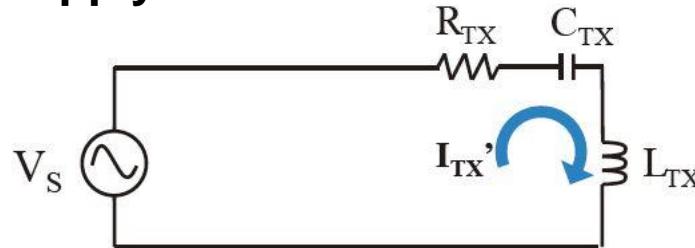
Auxiliary power supply having phase 90°
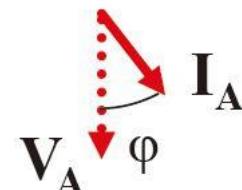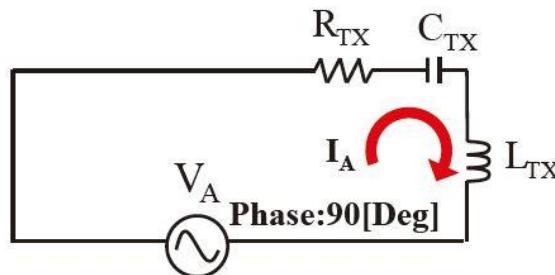
Add together
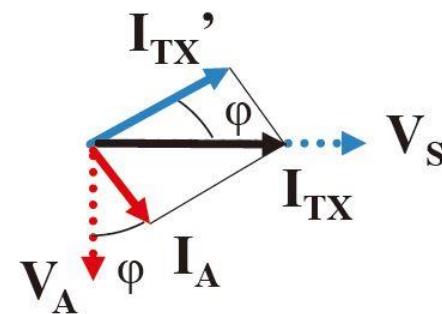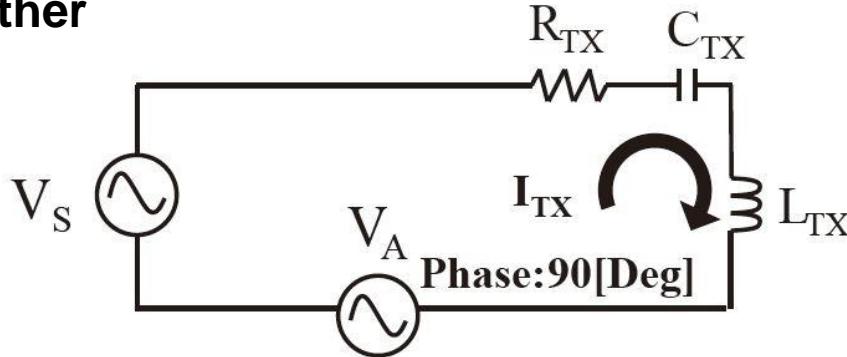
Conventional Circuit
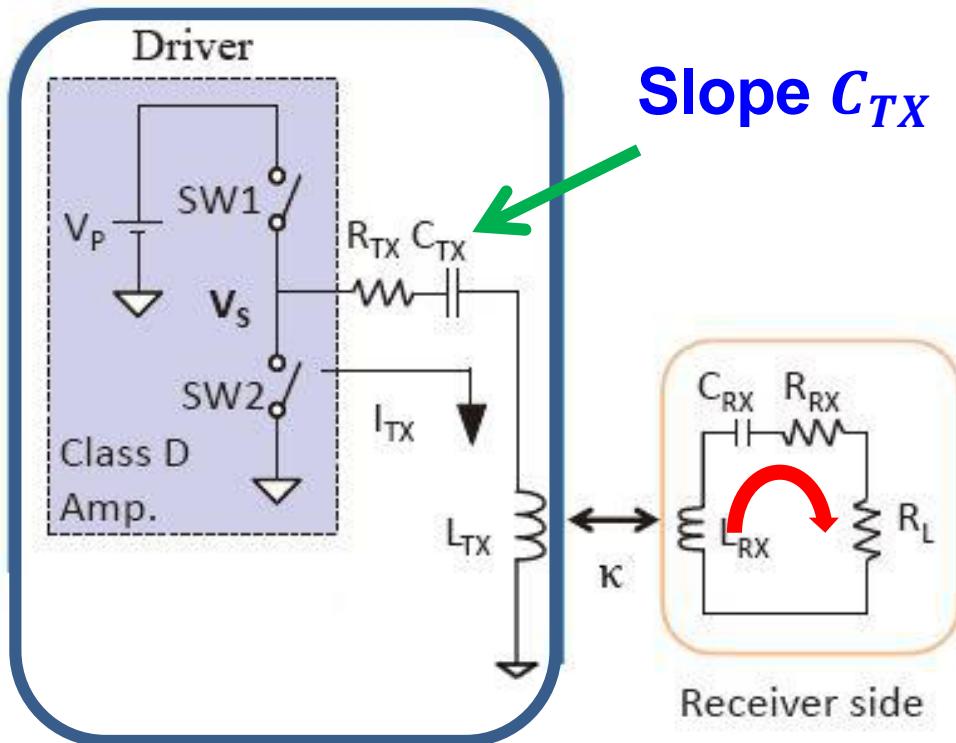
Slope C_{TX}

Output current

126pF 124pF 122pF 120pF 117pF
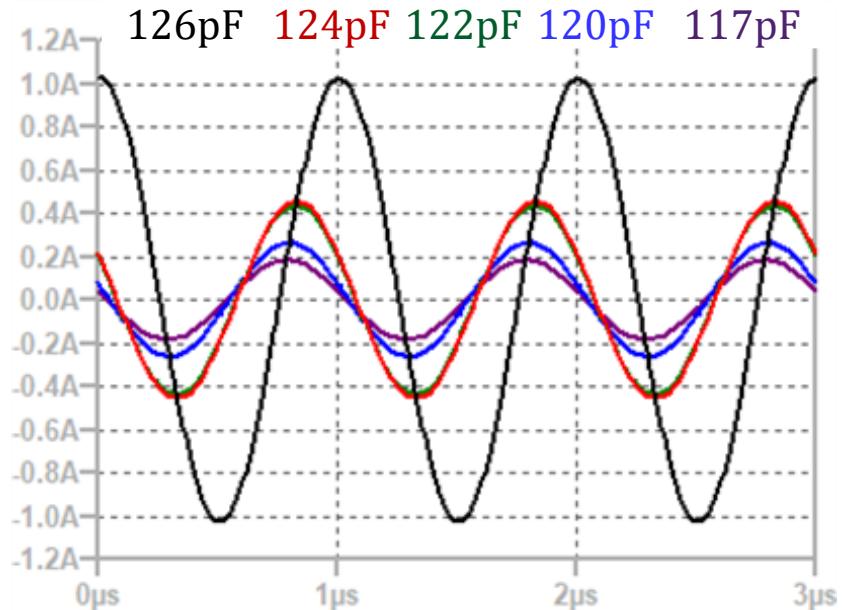
Error of resonance frequency 0.80%~3.78%
Error of output current 60%～80%

ATAC Circuit
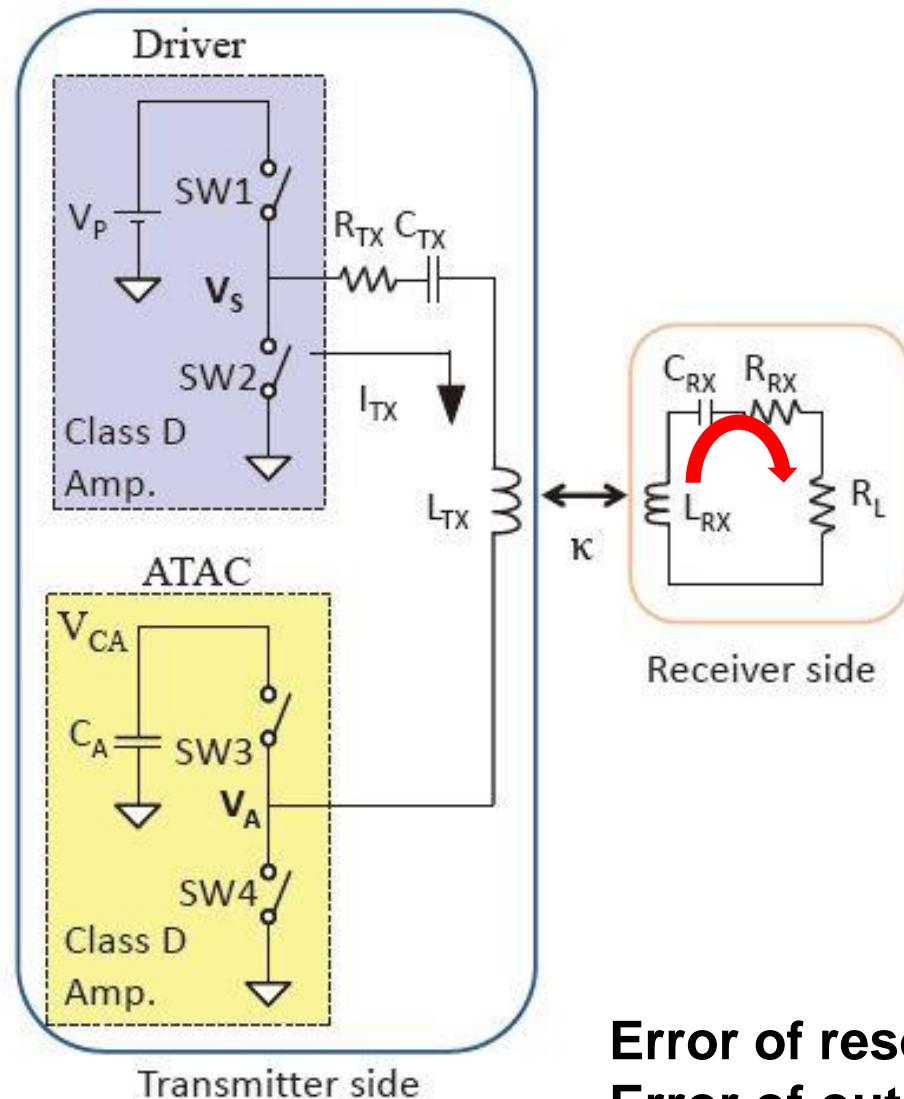
Output current
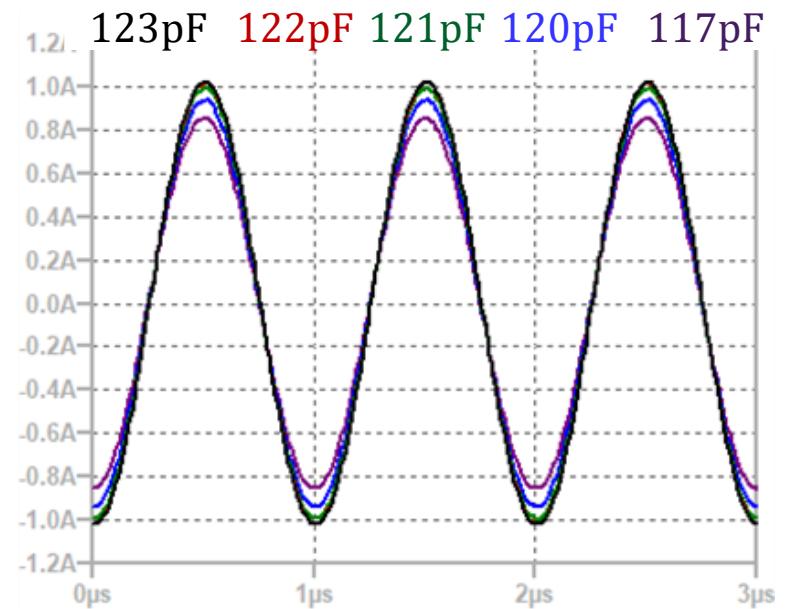
123pF 122pF 121pF 120pF 117pF

Error of resonance frequency   0.80%~3.78%
**Error of output current   0%～20%**

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Harmonic Suppression Switching Pattern

Time

Fourier transformation

Frequency

HD : Harmonic Distortion

1

0   1/2f   1/f

t

f   3f   5f   7f   f

$$f(t) = \sum_{k=1}^{\infty} \frac{1}{k\pi} \sin(2kf\pi t) \qquad (k = 1, 3, 5, \cdots)$$

Harmonic suppression Algorithm

Switching output pattern

Duty50%

τ_1

1
0   τ_1 1/f_{in}

$-\tau_1$

1
0              $-\tau_1$ 1/f_{in}

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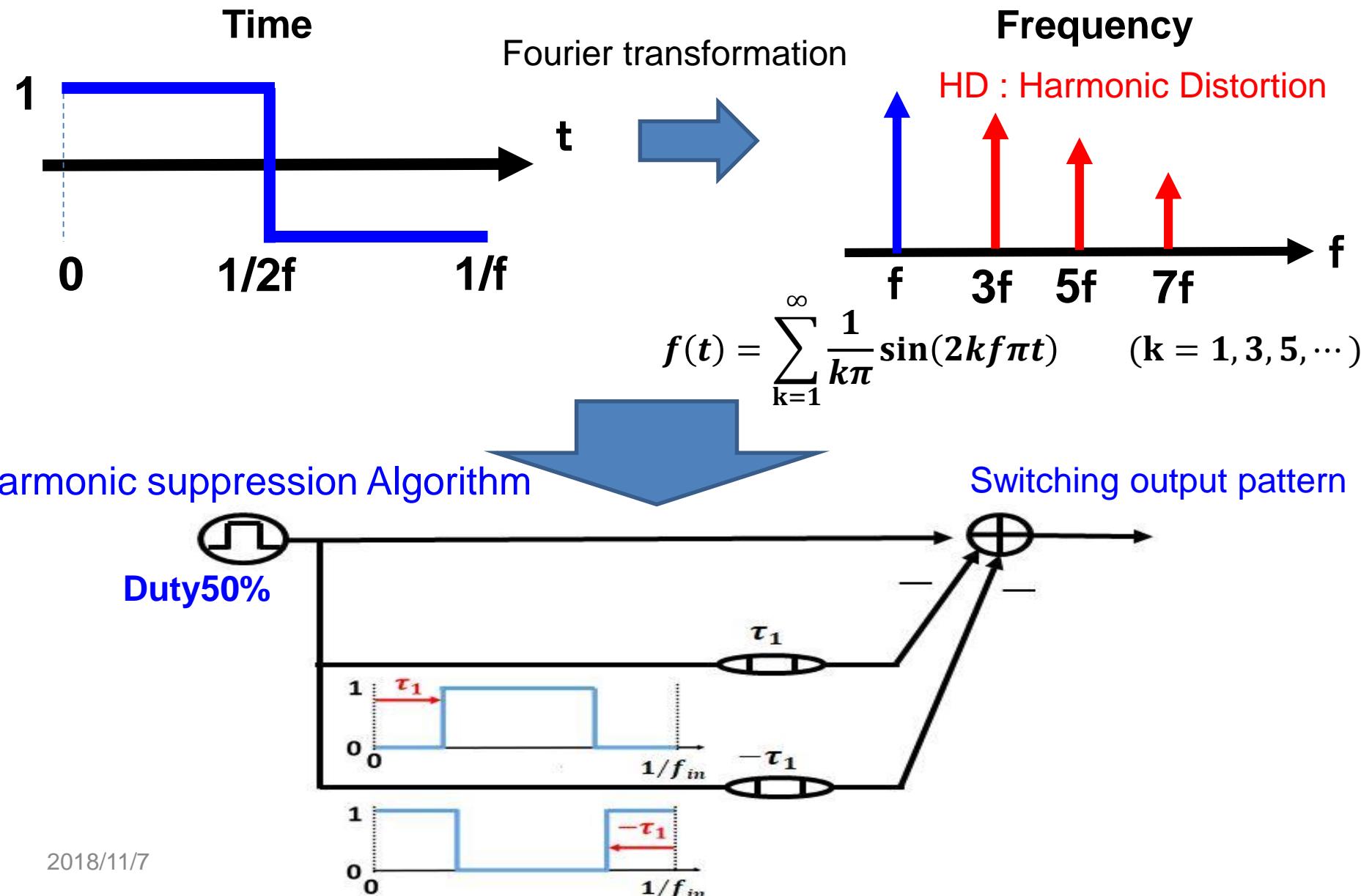
Harmonic Suppression Switching Pattern
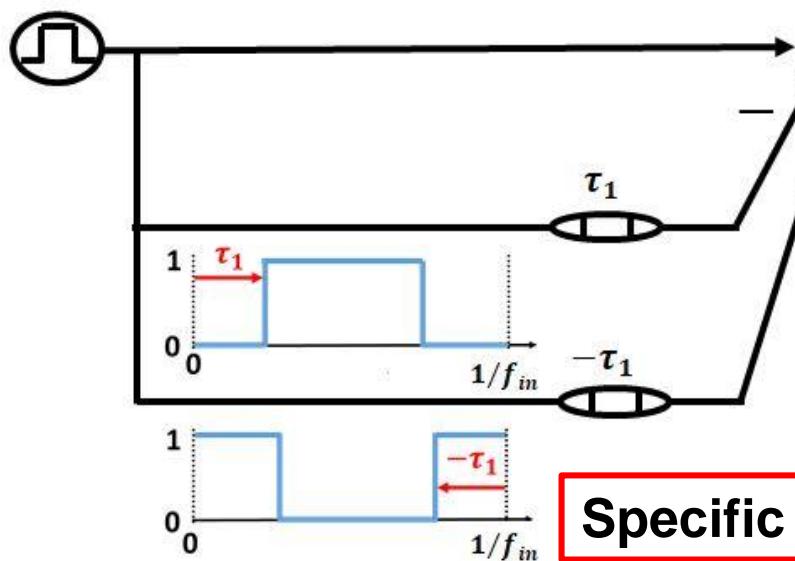
$$f(t) - f(t - \tau) - f(t + \tau)$$

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

In case HD3 suppression $\quad f_{in}\tau = \dfrac{1}{18}$

Specific frequency suppression switching pattern

Time waveform

Spectrum

Outline

Apply HD3 Suppression Pattern

SW1

SW3

90° phase difference
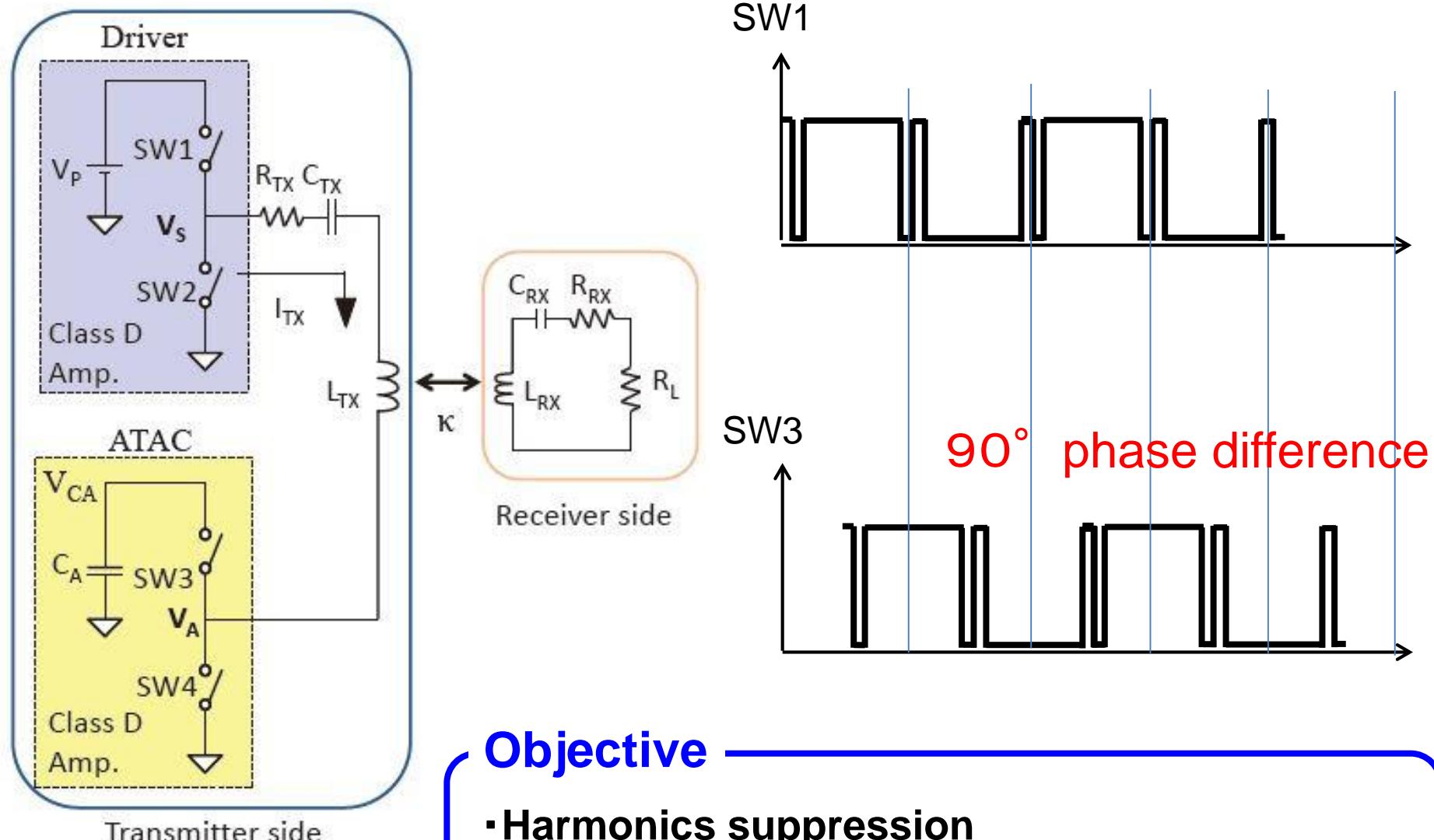
Objective

· **Harmonics suppression**
· **Operation of ATAC not Duty50%**

Spectrum of Inductor Current

Duty 50% switching
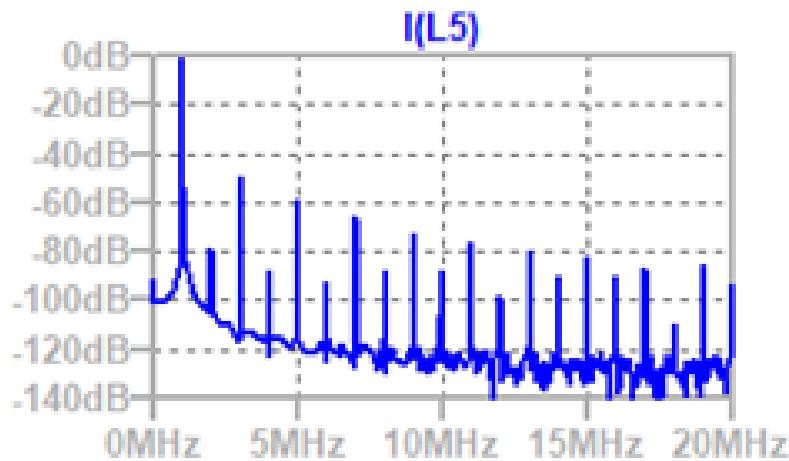
**HD3 suppression switching**

-20dB suppression
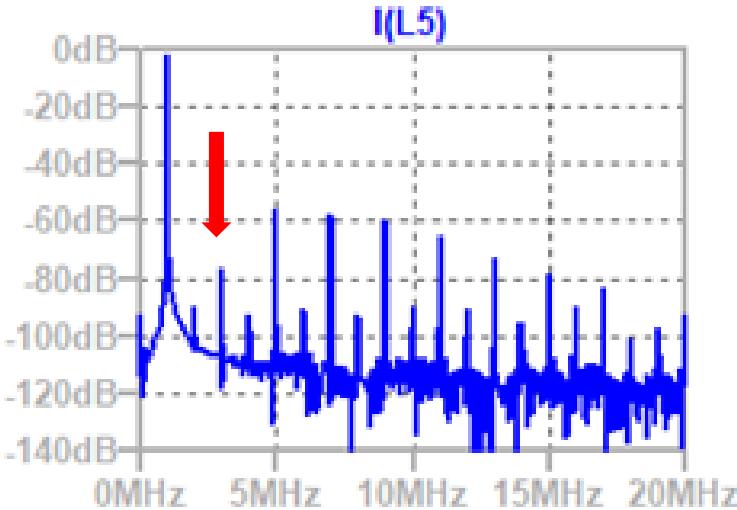
Output Current of HD3 Suppression
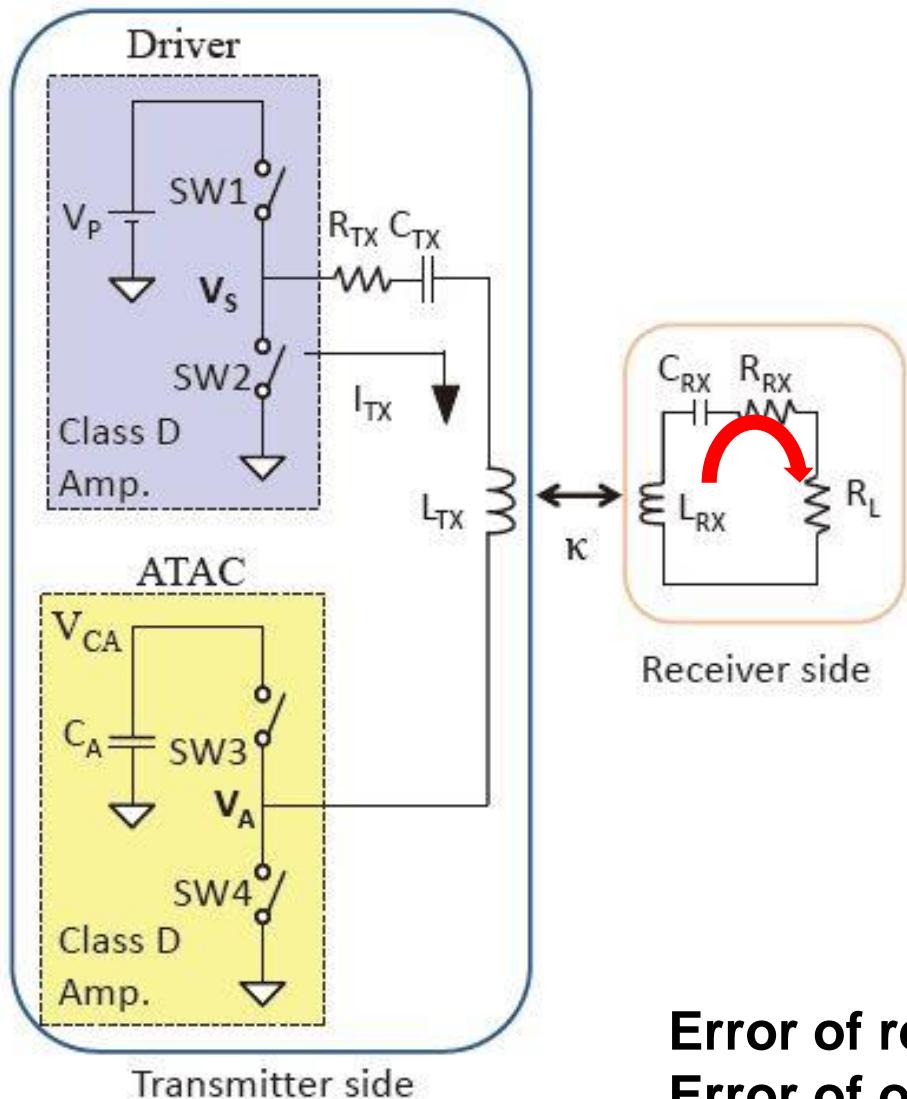
Output current
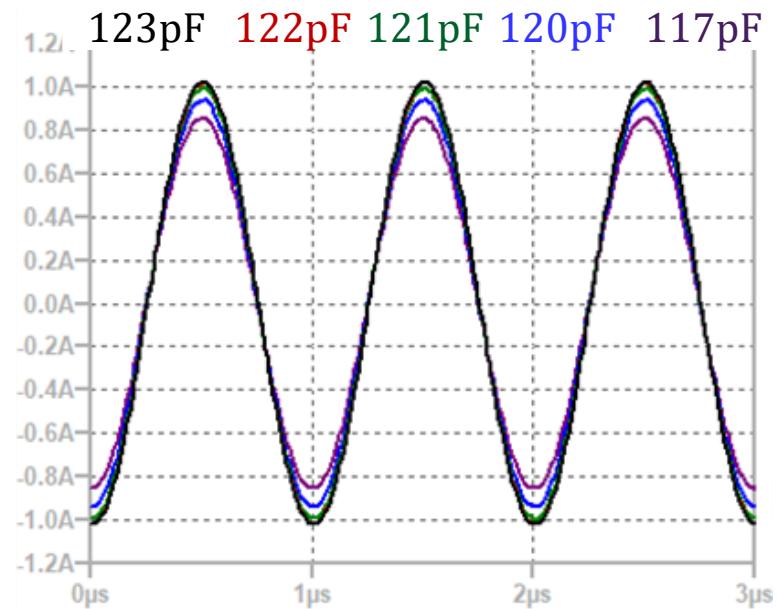
123pF 122pF 121pF 120pF 117pF

Error of resonance frequency   0.80%~3.78%
Error of output current   0%～20%

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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