Comparison between IPT & CPT

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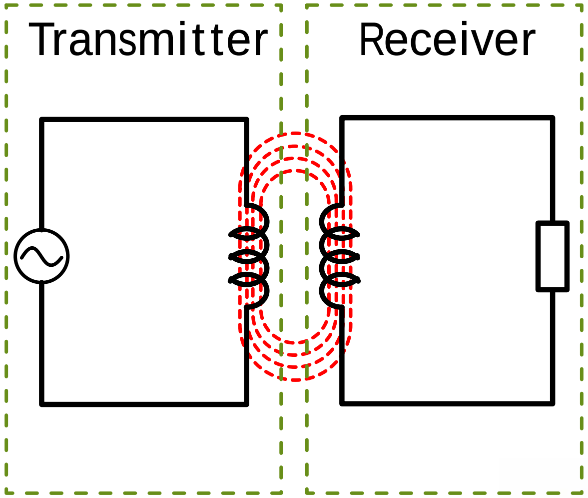
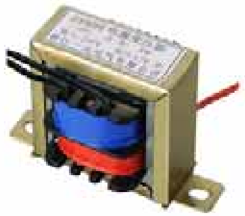
Near-field wireless power transfer

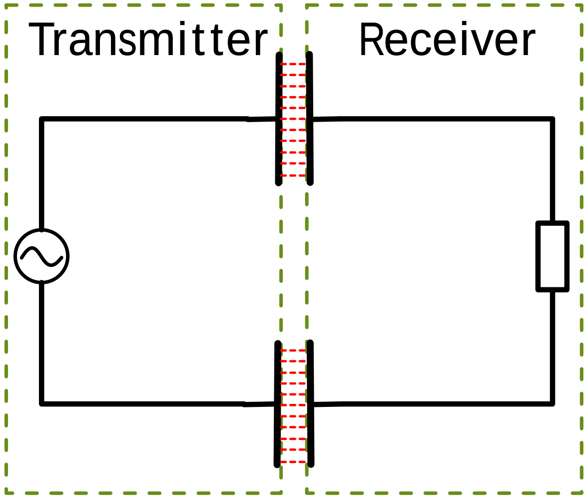
Inductive coupling Power Transfer (IPT)



Transformer

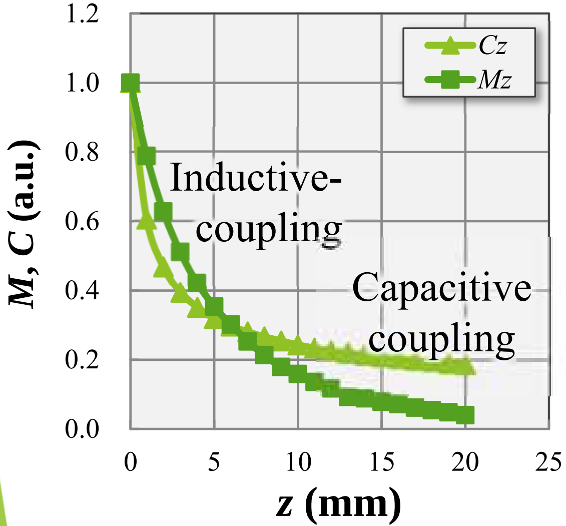


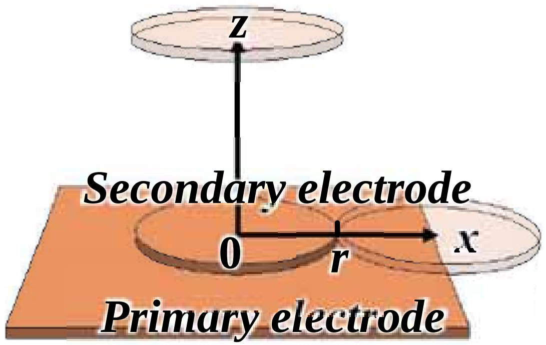
Capacitive coupling Power Transfer (CPT)



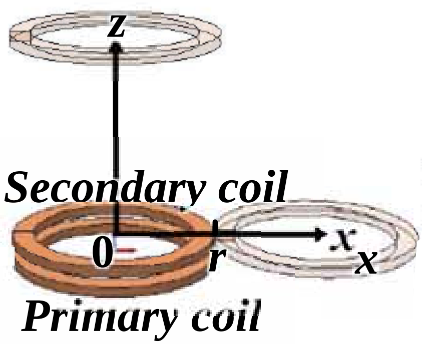
Capacitor

Displacement changes of M & C

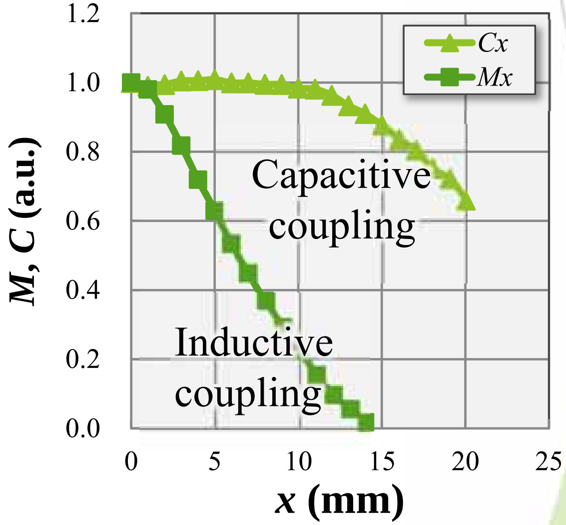




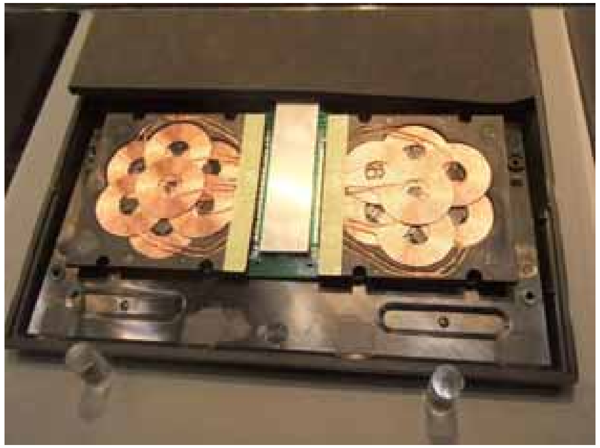
$$C = \frac{\varepsilon S}{d}$$



$$M = k\sqrt{L_1 L_2}$$



Technologies for free positioning



Coil-array

Moving coil

Magnet attracting

Source : NIKKEI ELECTRONICS 2011

Freedom of setting position is critical.
This can be obtain more easily using capacitive coupling!

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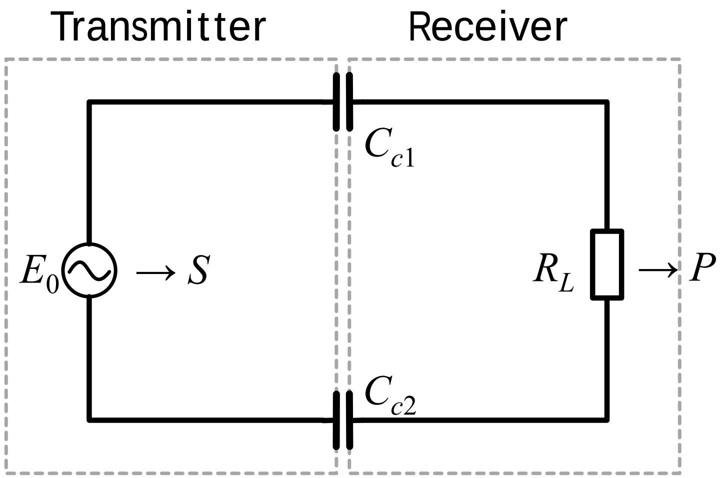
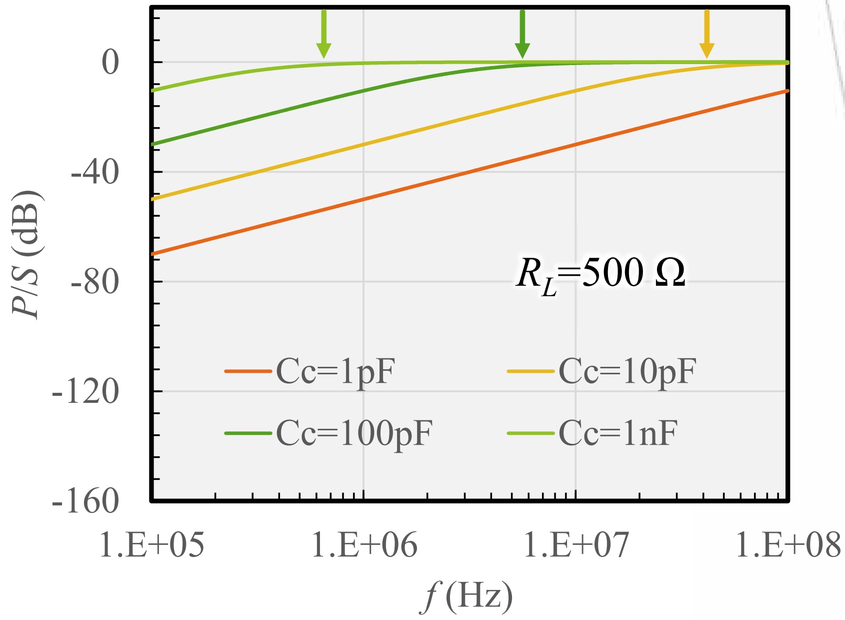
Fundamentals of capacitive coupling



Basic equivalent circuit of C-coupling

S(Apparent power) =
Q(Reactant power + P(Effective power)

$$f_C = \frac{1}{2\pi C_c R_L}$$



Spectrum of output power gain

$$\boxed{P/S = \frac{\omega C_c R_L}{\sqrt{1+\omega^2 C_c{}^2 R_L{}^2}}}$$

$$\frac{1}{C_c} = \frac{1}{C_{c1}} + \frac{1}{C_{c2}}$$

To transfer large power, we need Higher f, Larger C_c, Larger R_L

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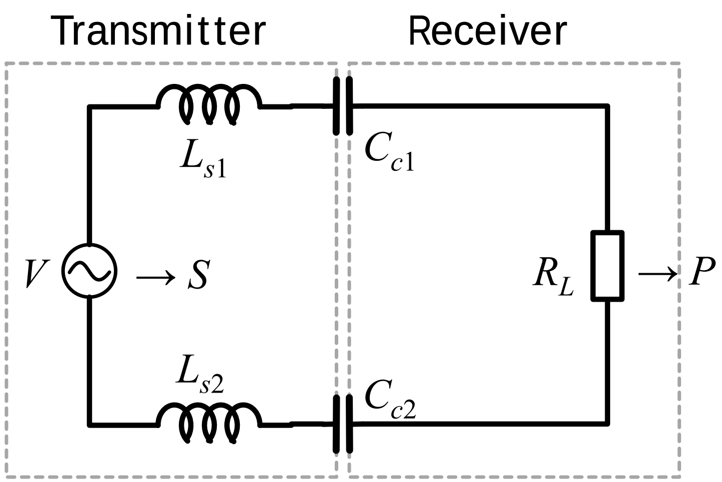
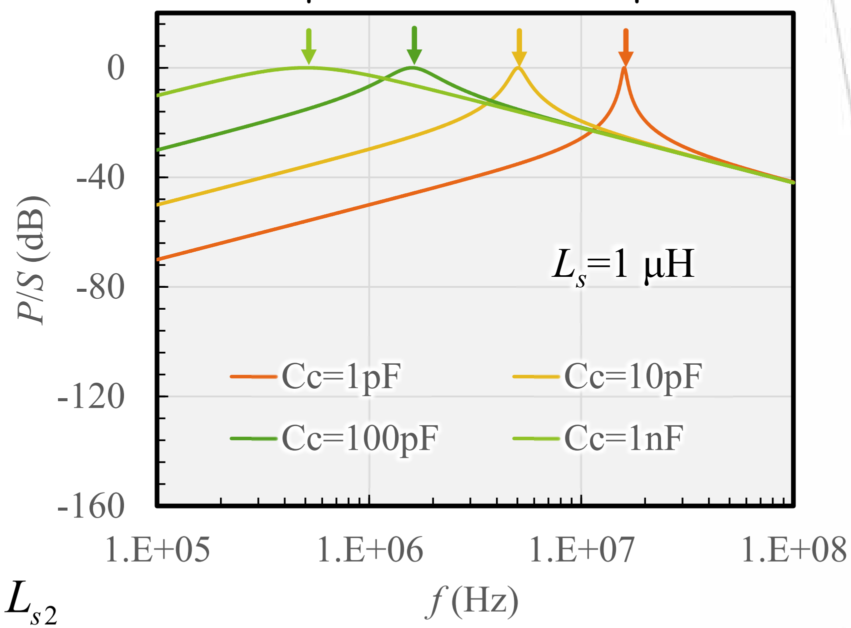
Resonant circuit



Equivalent circuit of resonant C-coupling

$$f_r = \frac{1}{2\pi\sqrt{L_s C_c}}$$



Spectrum of output power gain

$$P/S = \frac{\omega C_c R_L}{\sqrt{\left(1-\omega^2 C_c L_s\right)^2 + \omega^2 C_c{}^2 R_L{}^2}} \qquad L_s = L_{s1} + L_{s2}$$

- For instability of C_c, resonant condition is hard to keep.
- To obtain resonant conditions, we must tune f or L_s.

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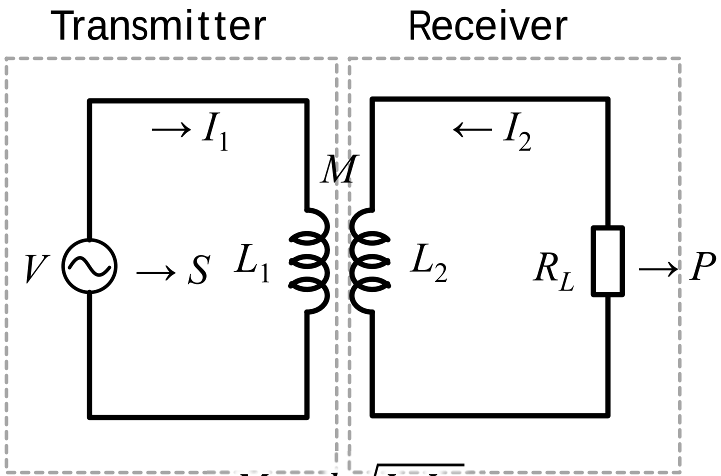
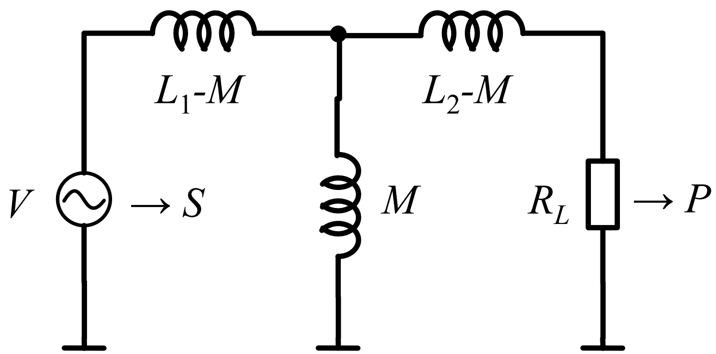
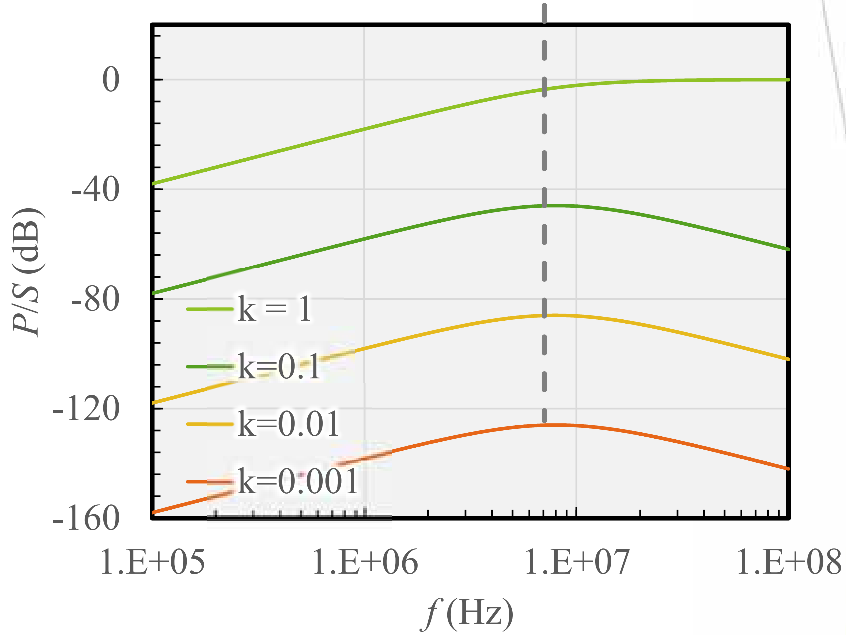
Fundamentals of inductive coupling



$$M = k\sqrt{L_1 L_2}$$



$$f_c = \frac{R_L}{2\pi L_2}$$



$$P/S = \frac{\omega k\sqrt{L_1 L_2}}{\sqrt{\omega^2 L_2{}^2 + R_L{}^2}} \frac{kR_L}{\sqrt{\omega^2\left(k^2-1\right)^2 L_1 L_2 + \frac{L_1}{L_2} R_L{}^2}}$$

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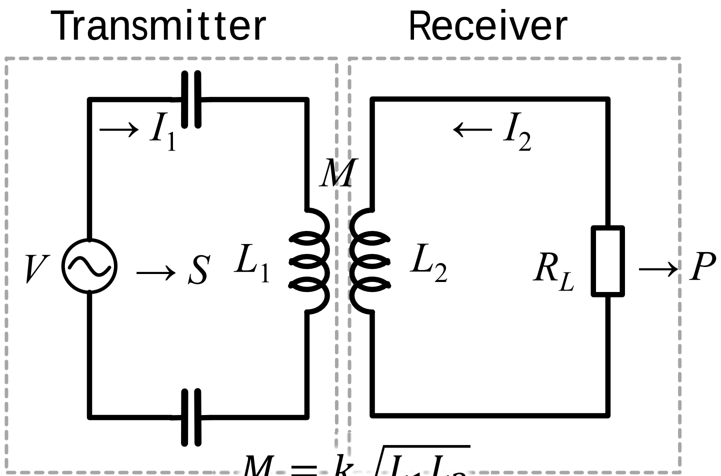
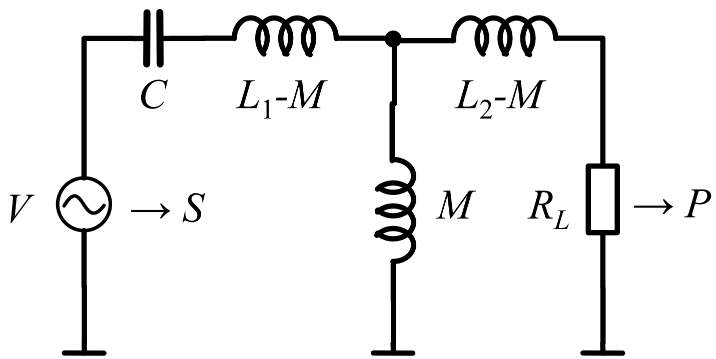
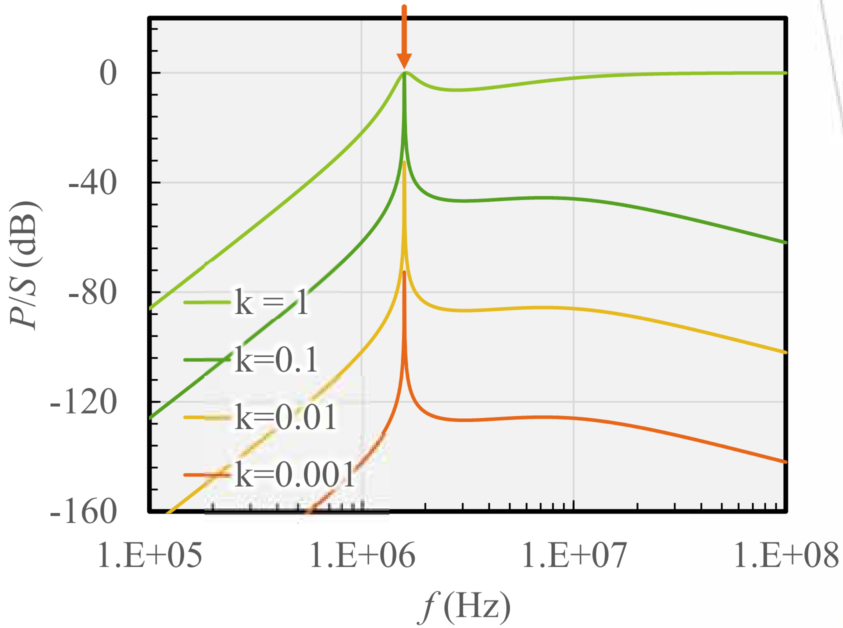
Resonant circuit



$M = k\sqrt{L_1 L_2}$



$$f_r = \frac{1}{2\pi\sqrt{CL_1}} \qquad P/S\big|_{f=f_r} \approx 1$$



$$P/S = \frac{k^2\omega^3 CL_1L_2R_L}{\sqrt{R_L{}^2+\omega^2L_2{}^2}}\frac{1}{\sqrt{\omega^2L_2{}^2\left\{\omega^2CL_1\left(k^2-1\right)+1\right\}^2+\left(\omega^2CL_1-1\right)^2R_L{}^2}}$$

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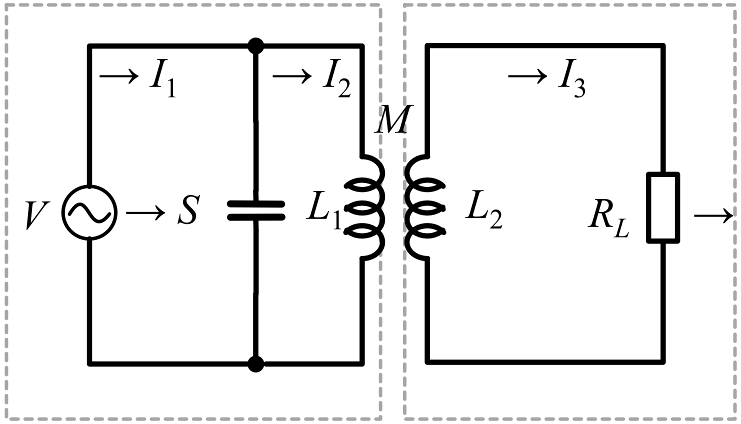
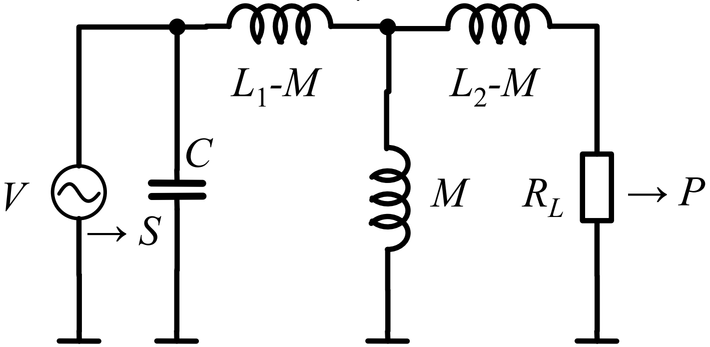
Resonant circuit



$$M = k\sqrt{L_1 L_2}$$



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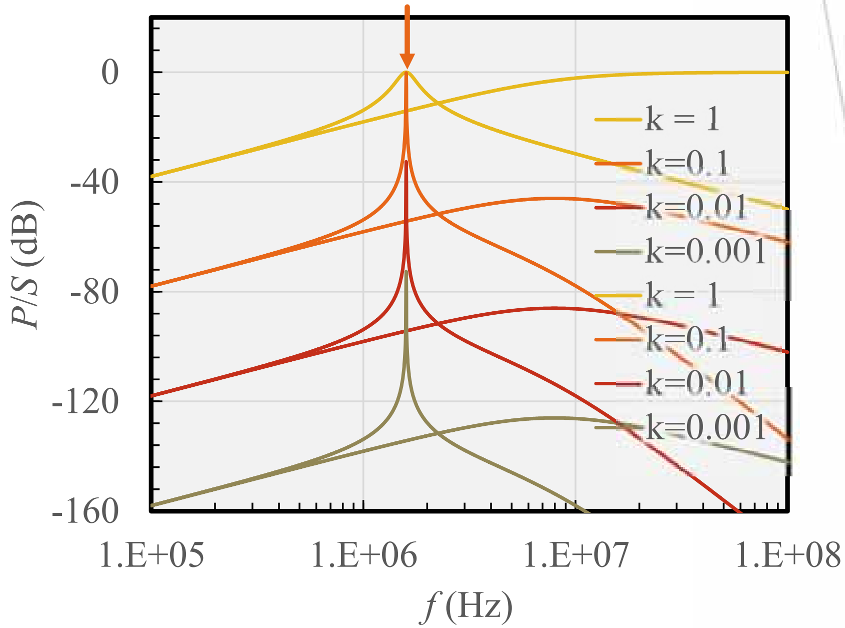
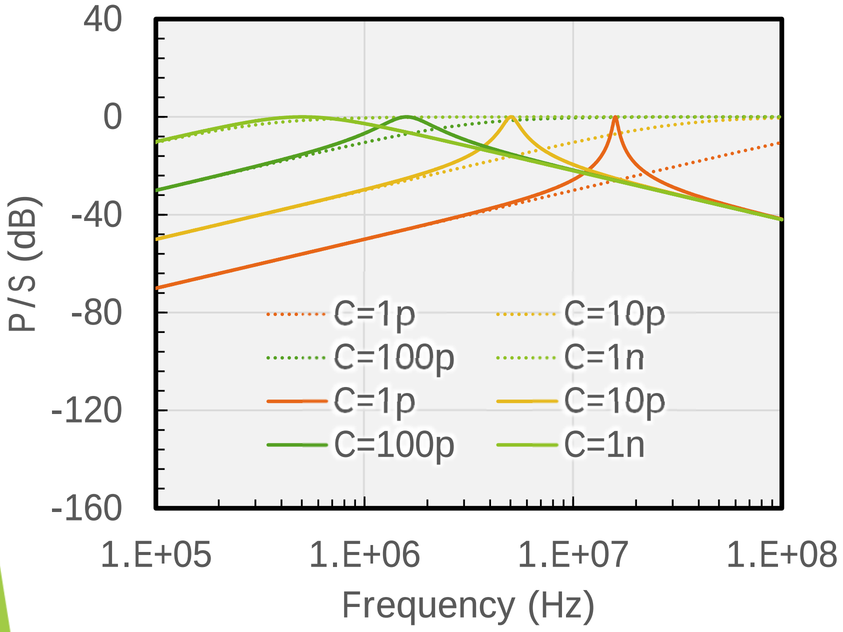
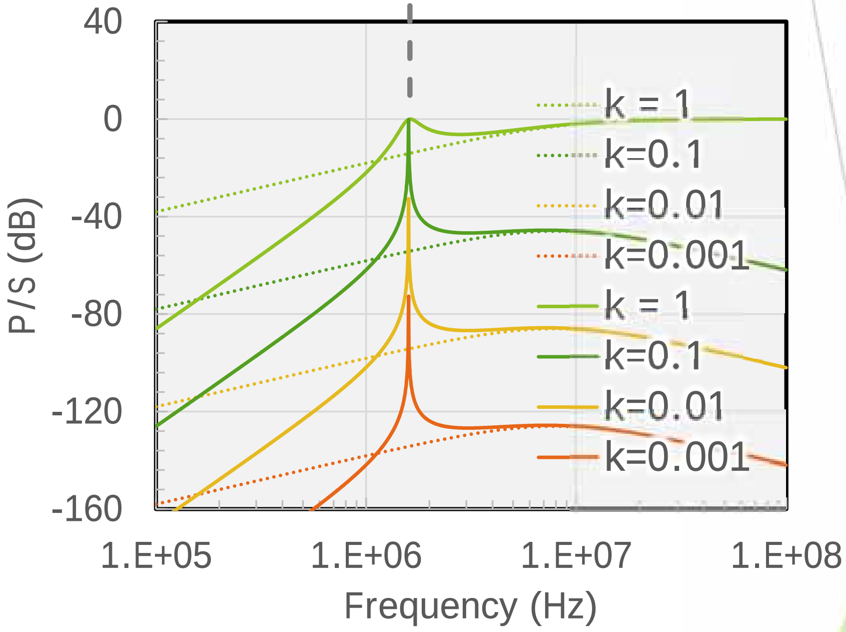


IPT & CPT Comparison





$$P/S = \frac{R_L}{\sqrt{R_L{}^2 + n\frac{L_2}{C_c}}}$$

Summary

- Higher frequency is required in both of IPT and CPT.
- Lower and higher load resistances are required for IPT and CPT, respectively.
- Larger inductive coupling factor, k, and coupling capacitance, C_c, are required for IPT and CPT, respectively.
- These requirements can be avoided by resonant phenomena.
- In IPT, the resonant frequency is stable against the change of k, but ideal factor, Q, is extremely high.
- In CPT, the resonant frequency changes dependent of C_c, but Q is relatively small comparing with IPT.