Quality Factor Measurement and Coupling Measurement

◆Helical coils
  ➢Coil radius r=2.5 cm
  ➢Wire diameter d=1.6 mm
◆By network analyzer
◆Quality factor
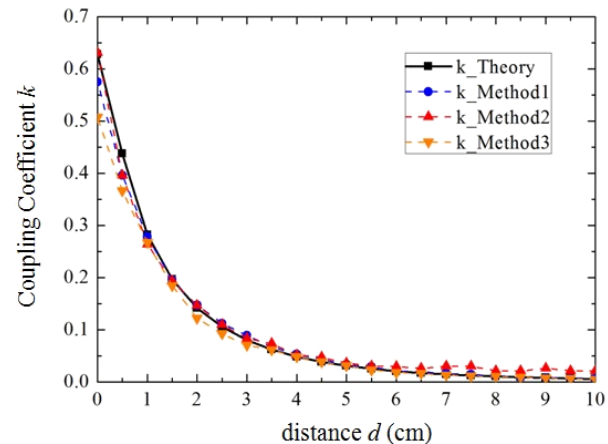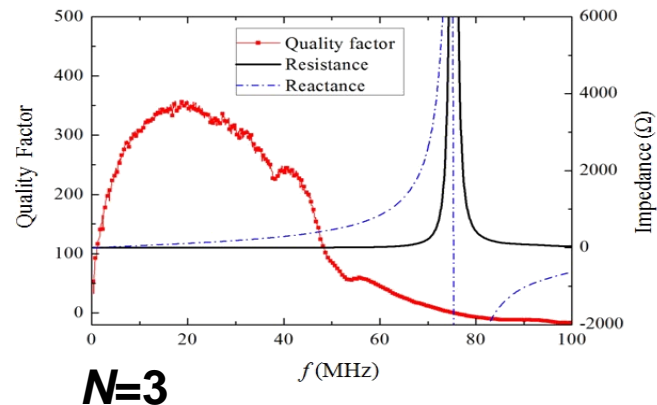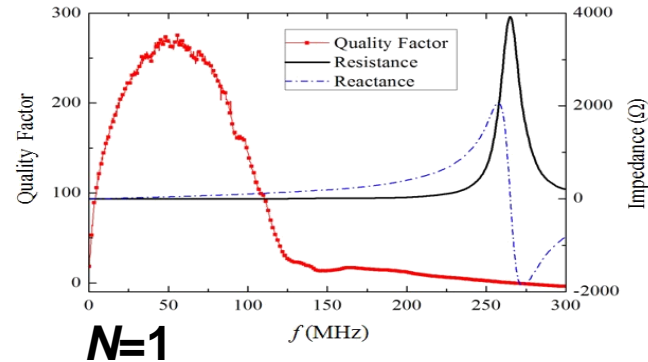 ➢172 (**N=1**)
  ➢340 (**N=3**)
◆Self resonant frequency
  ➢270 MHz (**N=1**)
  ➢75 MHz   (**N=3**)

N=1

N=3

◆Coils used: r=2.5 (cm), a=0.8 (mm), N=1 (turn)

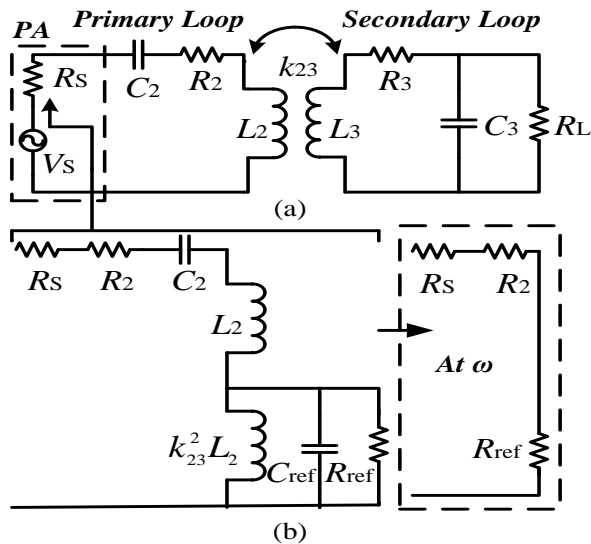$$k_{12} = \sqrt{\frac{\text{Im}(Z_{12})\,\text{Im}(Z_{21})}{\text{Im}(Z_{11})\,\text{Im}(Z_{22})}}$$

$$k_{12} = \sqrt{\frac{V_{OC2}}{V_{d1}}\frac{V_{OC1}}{V_{d2}}}$$

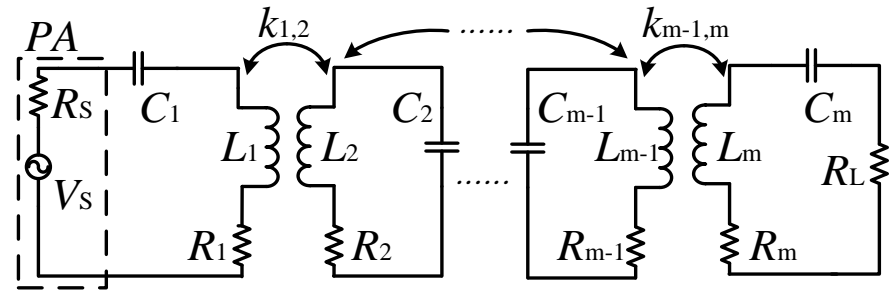$$k_{12} = \sqrt{1 - \frac{L_{leak12}}{L_{11}}}$$

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Reflected Load Theory

◆ Coupling is simplified into an impedance and only pure resistance is left at ω_0.

◆ Only adjacent coupling is considered.

◆ Reflection is from the latter stages to the former ones.

$$\eta_{i,i+1} = \frac{R_{ref,i,i+1}}{R_i + R_{ref,i,i+1}}$$

$$\eta_{m-coil} = \prod_{i=1}^{m-1} \eta_{i,i+1} \frac{Q_{mL}}{Q_L}$$

$$R_{ref,i,i+1} = k_{i,i+1}^2 \omega_0 L_i Q_{(i+1)L}$$

$$Q_{iL} = \frac{\omega_0 L_i}{R_i + R_{ref,i,i+1}}$$

$$P_{m-coil} = \frac{V_s^2}{2(R_s + R_1 + R_{ref,1,2})} \eta_{m-coil}$$

Adjustable Couplings for Optimization

◆Efficiency of the 4-coil system is simulated with k_{12} and k_{23} by Agilent ADS®.

◆The reflected resistance $R_{\text{ref},1,2}$ is analyzed with efficiency.

$$P_{4-coil} = \frac{V_S^2}{2R_S} \frac{(k_{12}^2 Q_1 Q_2)(k_{23}^2 Q_2 Q_3)(k_{34}^2 Q_3 Q_{4L})}{[(1+k_{12}^2 Q_1 Q_2)(1+k_{34}^2 Q_3 Q_{4L})+k_{23}^2 Q_2 Q_3]^2} \frac{Q_{4L}}{Q_L}$$

$$k_{23,PDL} = (\frac{(1+k_{12}^2 Q_1 Q_2)(1+k_{12}^2 Q_3 Q_{4L})}{Q_2 Q_3})^{\frac{1}{2}}$$

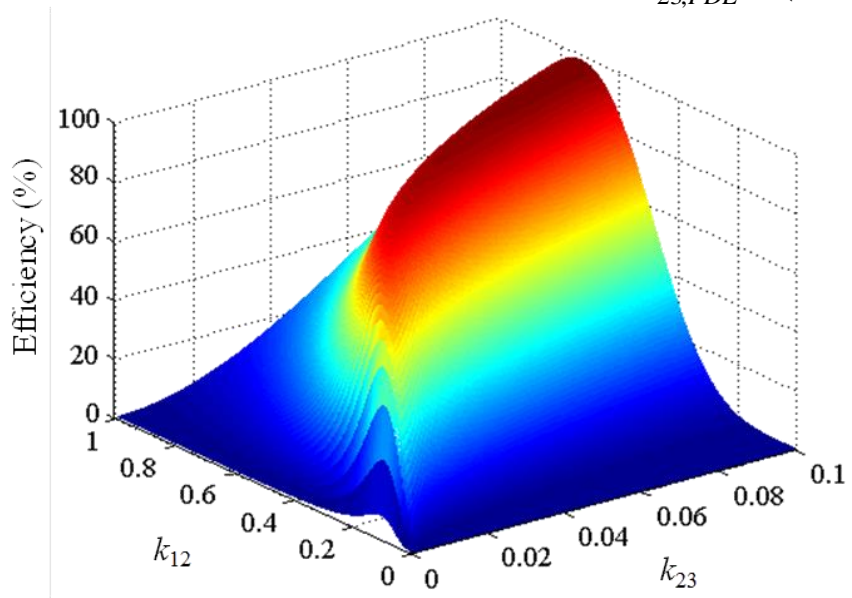Figure : Simulated efficiency versus k_{23} and k_{12}

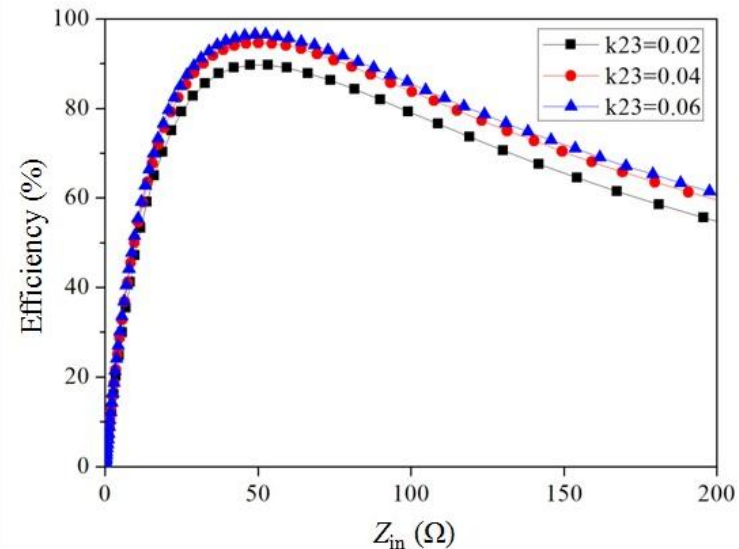Figure : Simulated efficiency with input resistance R_{in} of the 4-coil system

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Intermediate Transmission Coils

◆**Contribution**
  ➢Ranging 5 % to 50 % of efficiency is enhanced by adjustable couplings in aligned and misaligned conditions.
  ➢There is 85 % of efficiency achieved in the proposed 4-coil system.
  ➢With output 31.8 dBm and 73 % of PAE for power amplifier, approximately 30 % of overall efficiency is achieved in wireless charging system.
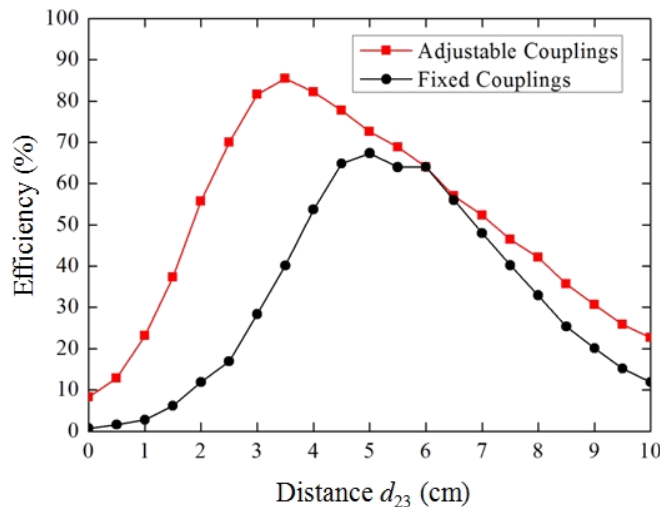
Figure : Measured efficiency versus aligned distance d_{23} by methods of fixed coupling and varying coupling.
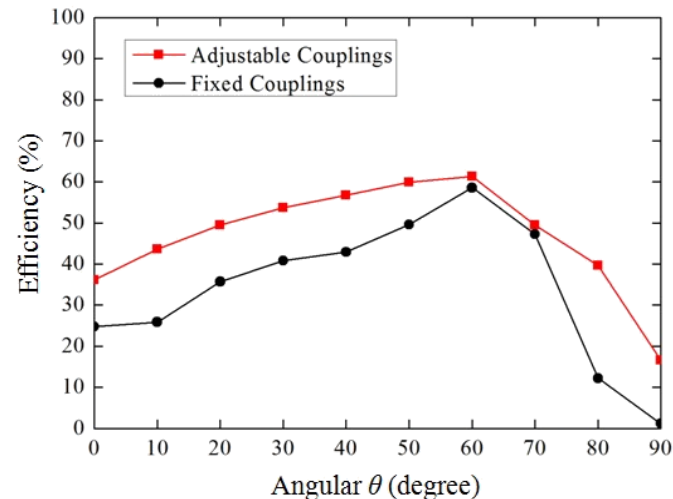
Figure : Measured efficiency versus misaligned angular theta θ by methods of fixed coupling and varying coupling.