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Coupling Factor

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If the receiver coil is at a certain distance to the transmitter coil, only a fraction of the magnetic flux, which is generated by the transmitter coil, penetrates the receiver coil and contributes to the power transmission. The more flux reaches the receiver, the better the coils are coupled. The grade of coupling is expressed by the coupling factor k.

The coupling factor is a value between 0 and 1. 1 expresses perfect coupling, i.e. all flux generated penetrates the receiver coil. 0 expresses a system, where transmitter and receiver coils are independent of each other.

The coupling factor is determined by the distance between the inductors and their relative size. It is further determined by the shape of the coils and the angle between them. If coils are axially aligned, a displacement causes a decrease of k. Figure 6 shows this effect for an exemplary arrangement of planar coils with 30 mm diameter. It shows the measured and calculated coupling factor for parallel coils at different misalignment distances at the horizontal axis. Coupling factors in the range of 0.3 to 0.6 are typical. Note that a negative coupling factor means that the receiver captures the magnetic flux "from behind.

The definition of the coupling factor is given by:

$$k = \frac{L_{12}}{\sqrt{L_{11} \cdot L_{22}}}$$

It results from the general equation system for coupled inductors:

$$\frac{U_1}{j \cdot \omega} = L_{11} \cdot I_1 + L_{12} \cdot I_2$$

$$\frac{U_2}{j \cdot \omega} = L_{12} \cdot I_1 + L_{22} \cdot I_2$$

where U_1 and U_2 are the voltages applied to the coils, I_1 and I_2 are the currents in the coils, L_1 and L_2 are the self inductances, L_{12} is the coupling inductance and ω = 2πf is the circular frequency.

The coupling factor can be measured at an existing system as relative open loop voltage u:

$$u = \frac{U_2}{U_1} = k \cdot \sqrt{\frac{L_2}{L_1}}$$

If the two coils have the same inductance value, the measured open loop voltage u equals k.