Abstract

A power transfer system is designed with wire antennas inside a metal case. There are two wire antennas namely transmitter and receiver. The metal case is connected to the ground and it serves as a third electrode between transmitter and receiver. The metal case also shields the radiation from antennas to outer space. The reflected impedance to the transmitter is reduced due to the interference with the metal case.

Description

By the end of 19th century, Nikola Tesla invented wireless power transfer system. As shown in Fig. 1, Tesla used two short monopole antennas, one is transmitter and the other one is receiver. However, Tesla’s system has lower transfer efficiency because the antennas radiate power to the space around. Although the reflected impedance is reduced due to the phase retardation [1, 2], the transfer efficiency cannot be improved significantly because the power loss to the space is overwhelmed.

In an early work [3], we designed a power transfer system with three wire antennas, which are transmitter, receiver, and counterpoise. The counterpoise is connected to the ground and it modifies the electric field between transmitter and receiver so that it reduces the transmitter current and increase the transfer efficiency.

In the recent work, we found that the metal case has the similar effect of counterpoise when the case is connected to the ground. So a modified designing is presented with two wire antennas enclosed in a metal case, as shown in figure 2. The metal case shields the radiation from antennas to outer space and it also modifies the electric field between the transmitter and receiver.
In general, the input impedance and current satisfy

\[ \vec{U}_0 = \vec{Z}_0 \cdot \vec{I}_0 \]

(1)

Where \( \vec{U}_0 \) is the source voltage, \( \vec{Z}_0 \) is the input impedance, and \( \vec{I}_0 \) is the input current. The input impedance include the transmitter impedance and the reflected impedance from the loading to the transmitter:

\[ \vec{Z}_0 = \vec{Z}_T + \vec{Z}_{\text{Reflect}} \]

\[ \vec{Z}_{\text{Reflect}} = \frac{\vec{M}^2}{R} \]

(2)

Where \( \vec{M} \) is the mutual inductance between transmitter and receiver,

\[ \vec{M} = \frac{U_R}{I_0} \]

(3)

The input power is

\[ P_{\text{input}} = Re(\vec{Z}_0) \cdot I_0^2 \]

(4)

The output power is

\[ P_{\text{output}} = \frac{|\vec{M}|^2}{R} \cdot I_0^2 \]

(5)
In order to calculate the power transfer efficiency, we need to measure the input impedance $\overline{Z_0}$ and the absolute value of reflected impedance $\frac{|\overline{M}|^2}{R}$.

Measurement

A measurement was performed for the input impedance and the absolute value of reflected impedance. The wires were replaced by narrow strips which were 1.0 meter long and 5.0 cm wide for each. The distance between the transmitter and receiver is 14.0 cm. The working frequency is 29.2 MHz and the loading $R$ is 50 ohm. The measured input impedance is 4.6 - 2.7j ohm. The absolute value of reflected impedance is 24.5 ohm.

Conclusion

The reflected impedance from the loading to the transmitter is reduced due to the interference with the metal case. This effect results in the input power less than the output power.

References:


Figure 1: Wireless power transfer by Nikola Tesla (copy from Wikimedia.org)
Figure 2: RF transformer composed of wire antennas of transmitter and receiver inside a metal case. The metal case is connected to ground.