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Domino Resonators for Enabling Energy Harvesting at a Distance in RFID Cards

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ABSTRACT: With requirements for increased security in access control, there are ongoing developments to integrate additional electronic security features within RFID cards; e.g. LEDs. The aim of this work is to present a design procedure for domino resonator coils that can extend the operating distance between an RFID reader and card, while also increasing the level of power transmitted so that additional electronic features such as sensors can be powered.

Background and objectives

While the application of resonator/repeater coils to increase power transfer between wireless coils at a distance is well known, a new design procedure is presented here to address the following issues for systems that include combined power and data transfer:

- Complex circuit analysis is required for more than 2 resonator coils
- The size of resonator coils increases with increasing distance
- Varying loads and/or voltage clamped loads are not considered

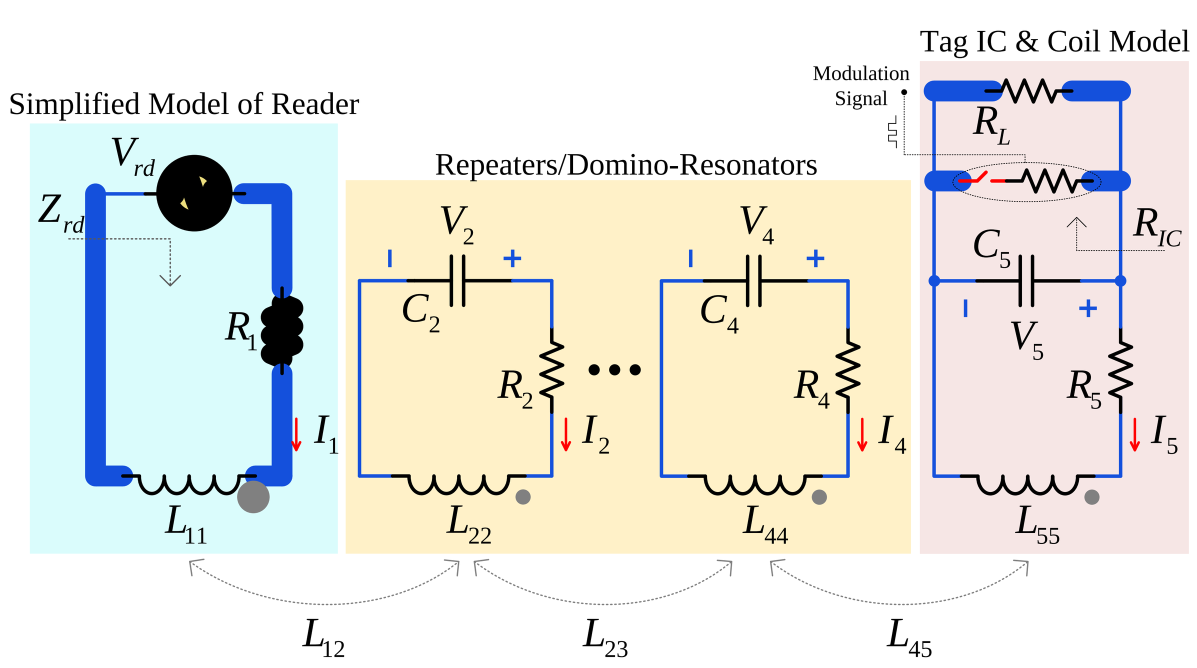

Figure 1 – Circuit model of domino resonator coil system

Voltage clamped load model

As shown in Figure 1, the load consists of two resistors which, depending on whether or not both are connected, result in two different output voltages for the same other system conditions. This represents the operation of an RFID tag in which the output voltage alternates between two clamped levels during data modulation.

Using measurements at the maximum operational distance the following system characteristics may be determined:

- Minimum and maximum tag load resistances
- Minimum power required for RFID operation

Formulation of multiple resonator coil system

Within a multiple coil system, circuit analysis is complicated by the interdependence of resonator coil impedances and the effective load resistance.

The proposed method is based on a simple circuit model and involves the following steps for determining the maximum operational distance for a defined set of resonator coil structures and an initial coil distance:

1. Calculate the impedance matrix and resonant capacitors for all coils
2. Apply the system impedance model to determine the minimum and maximum effective load resistances using iterative estimation
3. Determine the load power and if it is higher than the minimum required for operation, increase the gap and repeat steps 1 – 3.

Results for a 5-coil system (3 resonator coils)

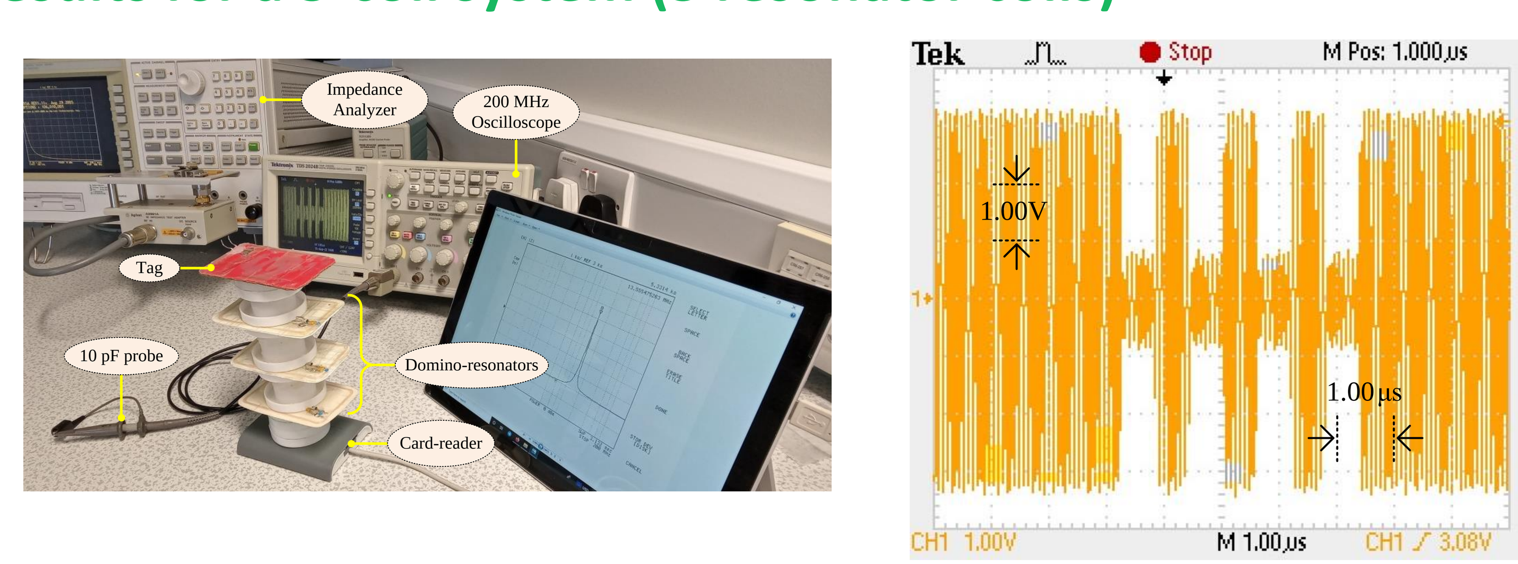

Figure 2– (a) Experimental set-up of 5-coil system,
(b) Tag output voltage at a maximum distance of 160 mm

The method is demonstrated for a 5-coil system, including reader, tag and 3 resonator coils. The load and resonator coils all have the same 3-turn structure within a standard RFID card size.

- The maximum distance achieved for RFID operation is 160 mm vs. 72 mm with no resonator coils
- Power transfer at the maximum distance is 11.5 mW of which 6.4 mW is available for additional functionality (over RFID)

Summary

- To address limited power transfer at a distance in wireless power transfer systems, resonator coils have shown good promise, but design and analysis tools for systems that include data transmission are limited
- The proposed method is based on (i) a simple equivalent circuit model of multiple coupled coils and (ii) measured reader and tag coil voltages for a 2-coil RFID system at the maximum operational distance
- The method is successfully demonstrated for a given 5-coil system (3 resonator coils), but can be applied for other system configurations and loads

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