Synthesis of NFC Antenna Structure under Multi-Card Condition

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Abstract **—** Wireless communication technologies such as Near Field Communication (NFC) found its way into our everyday life. The antenna structures used in such systems have to comply with several standards to achieve all requirements defined for the specific application. However, in practice there are scenarios for such antennas which are not considered in standards or design guides, but mainly influence the antenna behavior. In the present paper the synthesis of an antenna used for NFC-cards in a contactless payment system under multi-card condition is presented. The optimization relies on the differential evolution (DE) strategy. The computation of the forward problem is based on the partial element equivalent circuit (PEEC) method.

Index Terms **—** Near field communication, numerical optimization, partial element equivalent circuit method.

I. INTRODUCTION

NFC applications, which belong to the contactless communication technologies, have become popular within the last decade. Especially for the usage of contactless payment systems a big increase is recognized. Although there are design guides and standards which describe the requirements and limits of the antennas used in such systems, there are applications and use cases which are not covered by the standards but have significant impact on the overall system behavior.

One of those use cases for contactless payment is a wallet loaded with credit cards or cash cards of different providers, which should operate under those conditions. The standard for contactless payment EMVCo [1] only defines parameters for a system consisting of a Proximity Coupling Device (PCD), which provides the power to one Proximity IC Card (PICC). There are specific tests for the power and data transfer defined in a given three dimensional operating volume, as shown in Fig. 1. The antenna design under these standardized tests have been done by [2], but without considering, e.g., multi-card condition.

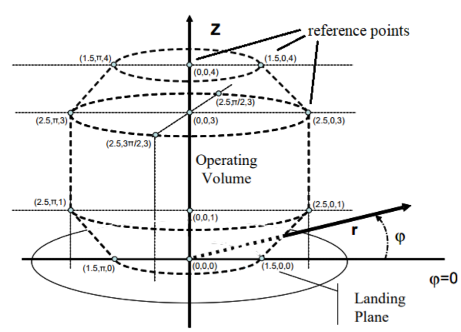

Fig. 1. The Operating Volume defined by EMVCo [1]. Tests have to be carried out in different defined points of this volume.

The communication of a NFC device is established at an operating frequency of 13.56 MHz in the near field surrounding the antennas, consequently loop antennas are utilized. For achieving optimal power transfer, the system consisting of the PCD and the PICC should result in a resonance frequency at 13.56 MHz.

In this paper the synthesis of a PICC-antenna with its corresponding matching network under the effect of multiple stacked PICC-cards is proposed. Aspects for conformance to the ISO/IEC14443 [3] as well as the EMVCo standard are considered.

II. NFC REQUIREMENTS

The tests for designing a PICC-antenna, with respect to the power transfer (defined in the EMVCo standard), forces to place the defined Poller-0 antenna [1] in the landing plane of the operating volume, as shown in Fig.

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1. The PCD should be matched to an input impedance of Z = 50 $\boldsymbol{\Omega}$ at the operating frequency. To fulfill the resonance requirements, the PICC antenna is connected to a matching circuit, as shown in Fig. 2. To model the behavior of the card-IC, an input impedance is connected, which values were taken from [4]. The standardization test demands to place the PICC at given reference points in the operating volume as shown in Fig. 1. The measured voltage at R_{IC} have to exceed a voltage level higher than 100mV to guarantee the power supply of the reader-IC [4].

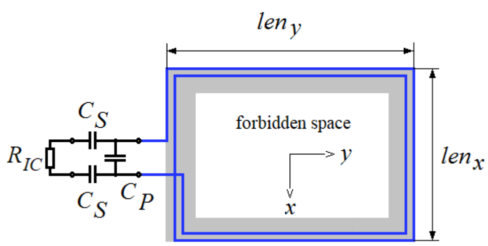

Fig. 2. Typical PICC-antenna design enclosed in an ID card.

III. ANTENNA OPTIMIZATION

Figure 2 shows the geometry and matching circuit of the antenna design to be optimized. The antenna have to be placed in an area defined for ID1 cards [3], considering a forbidden space. The parameter vector $\boldsymbol{x}$ to be optimized consists of the lengths len_x and len_y for the antenna size and the capacitors C_s and C_p of the matching circuit. The whole problem has been computed in the presence of one to five PICCs. The optimization of the antenna design is done by a standard DE [5]. For solving the forward problem a one dimensional type of the PEEC method [6] is used. Due to the fact, that within this method the antenna structure is described in terms of lumped elements the matching circuit can easily be added to the system. Consequently, the combined system, consisting of the antenna structure and the matching circuit can be solved within one step.

In this work the power requirements for the PICC, in this case the voltage conditions U_{IC} defined in chapter II, in all fourteen positions and in the presence of one to five antennas were used for the quality function. Additionally, the area A_{ant} of the antenna was minimized.

Introducing sigmoidal membership functions μ for these parameters, a scalar quality function can be defined:

$$q = \sum_{N_{card}=1}^{5} \sum_{pos=1}^{14} \mu(U_{IC}) + \mu(A_{ant}). \qquad (1)$$

In Fig. 3 the input impedances of the PCD antenna with the optimized antenna design and different numbers of PICC antennas are shown. The detuning effect of the additional antennas can clearly be seen. This effect results in a deterioration of the power transfer to the card system.

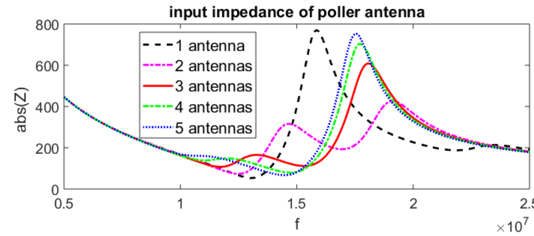

Fig. 3. Input impedance at the matching circuit of the PCD antenna for different numbers of PICC-antennas.

In Table 1 the voltages at the reader-IC's input resistance R_{IC} of the optimized and of the reference antenna design [1] are compared. As can be seen for a one antenna system the reference design delivers a higher voltage, which results in a better power transfer to the PICC. In contrast, for the three and five antenna system, the optimized design outperforms the reference design. Especially for the system consisting of five PICC's, the voltages of the reference design does not comply with the voltage level defined in the datasheet of the supplier [4]. It can also be observed, that the optimized design has a higher voltage with the three card system than with the single card system. This effect can be described with a better tuning of this system.

Table 1: Voltage at IC-terminal of card

	U_{IC} of	Position (0,0,0)	Position (2.5,0,3)	Position (1.5,π,3)
1 Card	Reference design	12.29 V	5.82 V	5.32 V
	Optimized design	7.18 V	1.32 V	1.18 V
3 Cards	Reference design	1.84 V	0.42 V	0.38 V
	Optimized design	14.87 V	3.52 V	3.15 V
5 Cards	Reference design	1.60 V	0.07 V	0.08 V
	Optimized design	5.12 V	1.07 V	0.95 V

Voltages at IC-terminal for different antenna designs and with different numbers of cards at specific positions as shown in Fig. 1.

IV. CONCLUSION

In this paper an approach for a design optimization of an antenna system, compliable to the EMVCo-standard and considering multi-card conditions has been presented. Since the PEEC method offers the possibility to directly connect lumped circuit elements, the integration of the matching circuit within the optimization process is enabled. Since a typical use case with several cards in the wallet was considered, a more robust antenna design could be achieved.

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