Influence of the Non-Linear UHF-RFID IC Impedance on the Backscatter Abilities of a T-Match Tag Antenna Design

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Abstract — **In ultra-high-frequency radio-frequency-identification (UHF-RFID) the conjugate complex matching of the packaged UHF-RFID transponder IC and the tag antenna structure is important to increase the reading range of the transponder tag. Quite often half-wavelength dipole-like antenna structures are used. Due to the fact that the impedances of the packaged IC and of the dipole antenna structure are in different domains, a matching structure is needed to accomplish the conjugate complex matching. A common technique to carry out the matching is the so called T-match where a short-circuit stub is introduced to change the dipole antenna's input impedance to the desired value. In passive UHF-RFID systems, the data flow from the transponder tag to the reader is established by modulating the radar cross section (RCS) of the tag. The modulation is set up by changing the input impedance of the transponder IC corresponding to the data stream. Since the nominal input impedance of the IC depends on the applied power (and in a strongly non-linear way), the backscatter abilities of the tag are also functions of the applied power. In the present work those power dependencies are investigated in terms of full wave finite element simulations and measurements for a T-matched tag antenna design.**

I. T-MATCH TAG ANTENNA

In principle, the T-match is the general case of the commonly known folded dipole antenna [1] which allows a conjugate complex matching of a given antenna design without an external matching network of additional lumped elements. This matching technique utilizes the impedance transformation behavior of a short-circuit stub. In [2] the T-matching method is described in detail leading to the total input impedance Z_{in} of the tag antenna design given by

$$Z_{in} = \frac{2Z_T\left(1+\alpha\right)^2 Z_{Dipole}}{2Z_T + \left(1+\alpha\right)^2 Z_{Dipole}} \tag{1}$$

where Z_T is the input impedance of the short-circuit stub formed by the T-match structure and part of the dipole antenna structure; Z_{Dipole} is the input impedance of the dipole antenna without the T-match; α is the current division factor which describes the division of the current at the input terminals to the two conductors and is given as [2]

$$\alpha = \frac{\cosh^{-1}\left(\dfrac{v^2-u^2+1}{2v}\right)}{\cosh^{-1}\left(\dfrac{v^2+u^2-1}{2vu}\right)} \simeq \frac{\ln(v)}{\ln(v)-\ln(u)} \tag{2}$$

with

$$u = \frac{a}{a'} \quad \text{and} \quad v = \frac{s}{a'} \ . \tag{3}$$

In (3) a and a' describe the equivalent radii of the dipole antenna and the T-match structure, respectively forming the short-circuit stub and s the distance between the conductors as shown in Fig. 1. The transformation behavior can be interpreted as an impedance transformer as reported e.g. in [2] and [3].

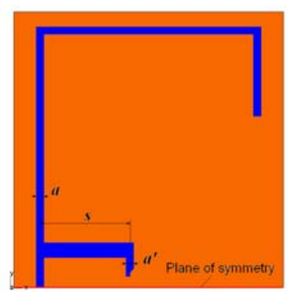

Fig. 1. Half model of the T-match tag antenna design

The design of the present T-match tag antenna is tailored to the nominally IC input impedance of the NXP UCODE G2 given as $Z_{chip} = 24 - j153\ \Omega$ at a frequency of 865 MHz. In Fig. 2, the input impedance of the antenna design is plotted as a function of the frequency. The electromagnetic field problem has been solved with an in-house FE-code based on the standard **A**,v-formulation [4]. Applying the potentials **A** and v the field intensities in the time harmonic case are

$$\mathbf{E} = -j\omega\mathbf{A} - j\omega\nabla v \tag{4}$$

$$\mathbf{H} = \left[\frac{1}{\mu}\right]\nabla\times\mathbf{A} \ . \tag{5}$$

The problem has been excitated by impressing a voltage U_0 by prescribing a constant vector potential **A** in the antenna gap with the length Δy satisfying

$$\mathbf{E}\cdot\mathbf{e}_y\Delta y = -j\omega A_y\Delta y = U_0 \,. \qquad (6)$$

as suggested in [5]. The truncation of the FE-mesh has been realized by applying perfectly matched layers (PMLs) [6]. A good agreement between the results obtained by the commercial software Ansoft HFSS and the in-house code has been found.

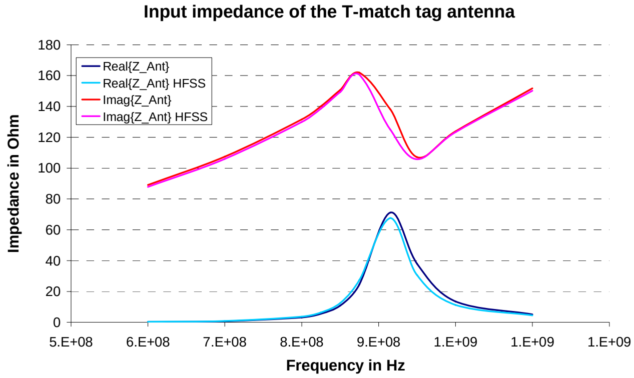

Fig. 2. Comparison of the T-match tag antenna input impedances

II. POWER DEPENDENT IC IMPEDANCE

Quite often the input impedance of the transponder IC is given as a function of the power available from the source P_a, as shown in Fig. 3.

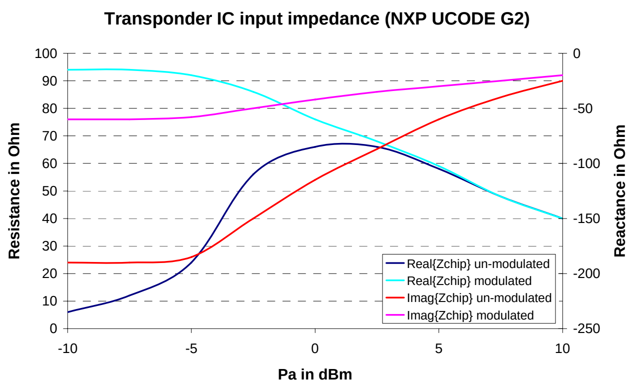

Fig. 3. Measured power dependent input impedance of the transponder IC

P_a is the power which the source, in this case a vector network analyzer (VNA), is able to deliver to a conjugate complex matched load impedance. To get P_L, the power delivered to the IC,

$$P_L = \left|\frac{V_{S@Z_0}\sqrt{Z_0}}{Z_0 + Z_0}\right|^2 \left(1-\left|\Gamma_L\right|^2\right) \qquad (7)$$

holds where $V_{S@Z0}$ is the internal source voltage of the VNA. Since the receiving antenna is usually described as a Thevenin equivalent circuit [2] with an internal voltage V_{Ant} and a Thevenin resistance Z_{in}, P_L should be converted to the Thevenin equivalent voltage given by

$$V_{Ant} = \frac{Z_{in} + Z_0}{\sqrt{Z_0}} \sqrt{P_L \frac{\left|1-\Gamma_L\Gamma_S\right|^2}{1-\left|\Gamma_S\right|^2}} \qquad (8)$$

where Z_0 is the reference impedance stated as $Z_0 = 50\,\Omega$ and Γ_S and Γ_L are the source and load reflection coefficients, respectively defined by

$$\Gamma_S = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \text{ and } \Gamma_L = \frac{Z_{chip} - Z_0}{Z_{chip} + Z_0} \,. \qquad (9)$$

For the FEM-model, this means that it is necessary to find the distances between the reader antenna and the tag antenna leading to the corresponding antenna voltage V_{Ant}.

III. MODULATION OF THE RCS

In order to reduce the computational effort, the reader antenna is modeled by a Hertz dipole producing an effective isotropic radiated power (EIRP) of 1 W. To get the backscattered field from the passive tag, the field of the Hertz dipole in the absence of the tag is subtracted from the solution as described in [7]. To enable the investigation of the power dependent backscattering signal due to the alteration of the IC impedance, the change of the complex scattered power $\underline{S}$ from the un-modulated to the modulated IC state is evaluated and will be given in the full paper.

IV. CONCLUSION

The power dependent backscatter ability of a T-match tag antenna design has been investigated. First preliminary results have shown that solely focusing on the conjugate complex matching of the tag antenna to the nominal IC impedance does not in general lead to an optimum tag design. To find an optimum tag antenna design the non-linear and power dependent characteristics of the given transponder IC have also to be taken into account. Comparison to measurements will be given in the full paper.

V. ACKNOWLEDGEMENT

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VI. REFERENCES

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