OPTIMIZATION OF SELECTED RFID SYSTEM PARAMETERS

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Summary This paper describes procedure for maximization of RFID transponder read range. This is done by optimization of magnetic field intensity at transponder place and by optimization of antenna and transponder coils coupling factor. Results of this paper can be used for RFID with inductive loop, i.e. system working in near electromagnetic field.

1. INTRODUCTION

Basic RFID (Radio Frequency Identification) system consists of three parts:

- One or more identification transponders
- Reading device (reader), which enables communication between transponder and host system
- Data processing unit (microprocessor).

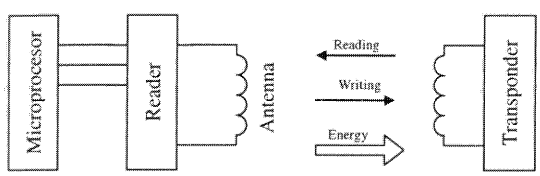

Fig. 1. Basic principle of RFID system with inductive loop.

Basic electromagnetic field parameters of RFID systems are in Fig. 2, where

- R_R is loss resistance of transmitter's antenna coil
- L_R is transmitter's antenna coil inductance
- C_R is serial resonant capacitance of transmitter's antenna coil
- U_R is voltage on transmitter's antenna coil
- I_R is transmitter's antenna coil current
- R_T is loss resistance of transponder coil
- L_T is transponder coil inductance
- C_T is parallel resonant capacitance of transponder coil
- U_T is voltage on transponder coil
- I_T is transponder coil current
- R_P is parallel loss resistance of RFID chip
- k(x) is coupling factor between transponder and antenna coil

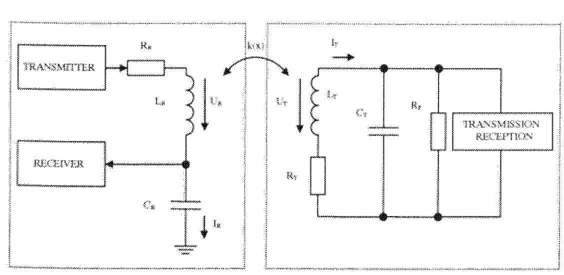

Fig. 2. Parameters of inductive loop RFID system.

Next analysis deals with maximization of read range, i.e. how

- to determine conditions under which the reader antenna radiated energy is maximum
- to determine conditions under which the voltage induced from reader antenna coil to transponder coil is maximum, or, when the coupling factor k(x) is maximum.

2. MAGNETIC FIELD INTENSITY OF READER ANTENNA COIL

If the energy and data transfer proceeds in frequency range up to 30 MHz (wavelength more than 10 m), the RFID system works with inductive coupling in near electromagnetic field. Near electromagnetic field lies at distance up to $\lambda/2\pi$ from its source (where $\lambda=c/f$ is wavelength). Usually, the near field is being created by circular loop antenna with winding several numbers of turns with radius r_R. The reader's antenna arranged according to Fig. 3. creates magnetic field with intensity

$$H(x)=\frac{I_R.N_R.r_R^{\,2}}{2.(r_R^{\,2}+x^2)^{3/2}}, \qquad \text{[A/m]} \qquad (1)$$

where I_R is antenna current, N_R is number of turns and x is distance from antenna in its axis direction.

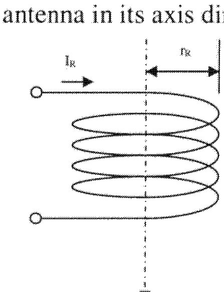

Fig. 3. Arrangement of circular loop antenna.

Solving the equation (2), which is derivative of (1)

$$\frac{dH(x)}{dr_R}=\frac{2r_R.(r_R^{\,2}+x^2)^{\frac{3}{2}}-3r_R^{\,3}.(r_R^{\,2}+x^2)^{\frac{1}{2}}}{(r_R^{\,2}+x^2)^3}=0, \qquad (2)$$

we can compute that the maximum magnetic field intensity is reached when $\mathbf{r_R=\sqrt{2}.x}$, i.e. when the radius of reader's antenna is approximately by 41 % larger than required reading distance (Figs. 4 and 5).

Magnetic field intensity can be increased by increasing of number of turns N_R and by increasing of current I_R. Fig. 2 shows that the reader's antenna is serial resonant LC circuit with loss resistance, i.e. the current I_R reaches maximum on resonant frequency

$$f=\frac{1}{2\pi\sqrt{L_R.C_R}} \qquad \text{[Hz].} \qquad (3)$$

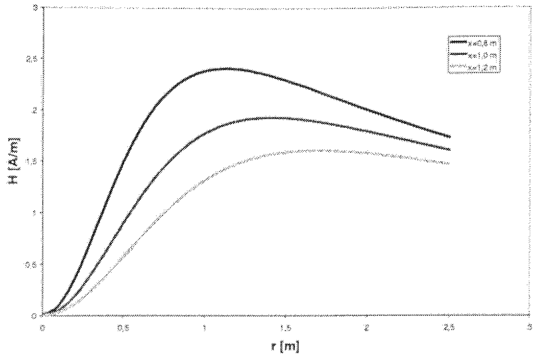

Fig. 4. Dependence of magnetic field intensity H on coil radius r. Current I_R=0.5 A, number of turns N_R=20.

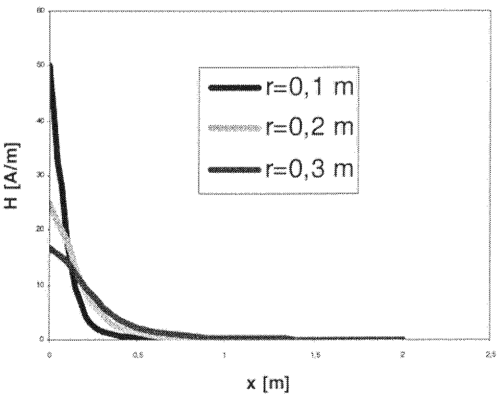

Fig. 5. Dependence of magnetic field intensity H on distance from coil x. Current I_R=0.5 A, number of turns N_R=20.

3. COUPLING FACTOR BETWEEN COILS

We assume that the coils are arranged according to Fig. 6, where

- r_R is radius of reader's antenna coil
- r_T is radius of transponder coil
- θ is angle between coils (0°... parallel)
- x is distance between coils.

In transponder coil place the magnetic induction B(x) and magnetic flux Φ(x) are given by equations

$$B(x) = \mu . H(x) \qquad [\mathrm{T}] \qquad (4)$$

$$\Phi(x) = \pi . r_T^2 . \mathrm{B(x)} \qquad [\mathrm{Wb}]. \qquad (5)$$

In transponder coil there is induced voltage U given by

$$U = N_T . \frac{d\Phi(x)}{dt} = -N_T . B(x) . \pi . r_T^2 . \omega \qquad [\mathrm{V}]. \qquad (6)$$

The coils create a loss transformer, coils of whose are coupled by mutual inductance

$$M = k(x) . \sqrt{L_R . L_T} \qquad [\mathrm{H}] . \qquad (7)$$

Coupling factor k(x) is parameter which depends on geometrical dimensions of coils (Fig. 6.) and is given by

$$k(x) = \frac{r_R^2 . r_T^2 . \cos\theta}{\sqrt{r_R . r_T} . (r_R^2 + x^2)^{\frac{3}{2}}} \qquad [-]. \qquad (8)$$

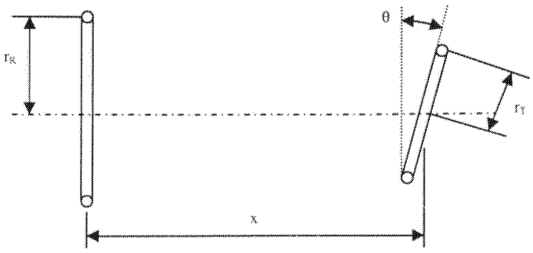

Fig. 6. Arrangement of transponder and reader coils.

The coupling factor is basic parameter needed for correct RFID system operation. Theoretically, the system will be operate very well if k(x)=1, however it is unreachable in practice. For good system performance the sufficient value of k(x) is 0.01 (1 %), in special cases the transponder is readable even if k(x)<0.001 (0.1 %). Detailed analysis of (8) shows, that

- the angle between coils has to be 0°
- the radiuses of coils have to be equal, in practice, the areas has to be equal
- distance x must be as minimum as possible.

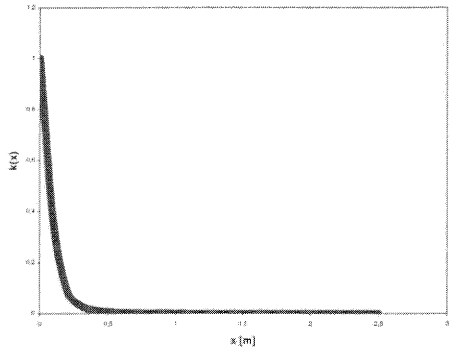

Fig. 7. Dependence of coupling factor k(x) on distance x. Radius r_R=0,1 m, r_T=0,1 m, angle θ=0 °.

4. CONCLUSION

In this paper mathematical analysis of some of RFID system parameters is described. Results of analysis are valid only for RFID with inductive loop, i.e. when energy and data are transferred by magnetic field. In practice the working frequencies of such systems are 125 kHz (λ= 2400 m) and 13.56 MHz (λ=22.12 m). If RFID system works on higher frequencies the electric field becomes dominant and theory described in this paper cannot be used. Moreover, results of analysis are not always practically usable. For example, if we require read range of transponder to be equal 1 m, diameter of antenna and transponder coils should be 2.8 m. Such coils are very hard to realize, so only way to maximize the read range in such case is maximization of couple factor.

REFERENCES

[1] Research report of project no. 472 VÚD/2002-1 "Intelligent Transport Systems in Conditions of Slovak Republic", Žilina, 2003

[2] Finkenzeller, K.: RFID Handbook. Radio-frequency Identification Fundamentals and Applications. John Wiley & Son, Ltd. Chichester, England 1999

[3] Gehring, U., Roz, Th.: RFID made easy. EM Microelectronic-Marin SA. Marin, Switzerland, 2000