UHF Wave Attenuation throughout the Cow Body

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Abstract

Radio frequency identification (RFID) is one of the forefronts of technologies that have found widespread use and the ability to track objects easily from a distance, make it advantageous within other automatic identification systems. RFID systems, which have been used for many years in animal identification and follow-up, have recently been used to track the data (such as pH and temperature) in the rumen. One of the problem is body tissues weakens the signal when the device is used inside the rumen. In this study, we tried to model how UHF signals of RFID tags used as pH bolus weaken after it comes out of the inner body of animal. Preferred RFID tags are operating at 434 MHz (UHF) and CST simulations are verified by real measurements. The signal is taken stronger at the left side of the animal because the amount of tissue on the left side of the animal is less than other sides. The weakest signals are taken at right side with dense organs.

1. Introduction

RFID is a system of identifying objects using waves of radio frequencies. This technology was first used to distinguish friendly and enemy planes of World War II. It has gained widespread use due to the rapid development of electronic circuit technology and the increase of miniaturization. RFID technologies are used in wide range of areas such as; library systems to product follow-up, as well as parking control to electronic passages on the highway and the animal identification and monitoring. There are different frequencies of RFID systems are in use, and the most commonly used frequencies are low frequencies (LF: 125-134 kHz), high frequencies (HF: 13.56 MHz) and ultra-high frequencies (UHF, 433MHz, and 860-960 MHz) [1].

The first use of these systems in animals was found in 1970s and the first applications were seen as a label attached to the animal's neck [2]. In the following years, the use of ear-type labels and injectable labels on the market restricts the use of such labels in meat-prone animals, because of the high the possibility of subcutaneous labels sticking to carcass meat [3] .Most of the ear type labels preferred for animal identification, ineffective against alteration, cheating and theft events like the classic plastic type labels [4].

The bolus type labels placed inside the rumen are the RFID tag type which is both safer in terms of animal identification and more reliable than other types in follow-up and has the highest recovery rate [5].

Highly comprehensive projects such as the IDEA in the European Union [6, 7] the selection and effects of RFID tag types used in electronic identification have been investigated. According to the results of the project on one million animals, the rumen bolus type identification tag is proved to be the safest label [8].

Studies at different times and places [9-12] have proven that such labels do not lead to any negative effects on animal health, meat and milk production. In addition to animal identification processes by using passive tags, remote data acquisition studies are also performed by adding sensors to active tags. it is important to maintain the animal health in order to ensure the instantaneous follow-up of animal body data by adding temperature and pH sensor to active RFID tags [13].In particular, continuous monitoring of ruminal pH data is thought to be helpful in predicting SARA-type disorders, which are the most economical decrement of livestocks, and to enable rapid and effective treatment of these diseases [14].

In the applications seen in the market [15, 16], the signals received from outside animals can be taken from very short distances. The reason is thought to be the fact that the frequencies radio waves being worked on are extremely weakened by the animal's body hence the long distance accesses cannot be made. In this study, we tried to model how UHF signals of RFID tags used as pH bolus weaken after it comes out of the inner body of animal.

2. Material and Method

In this study, cannulated heifers age were used and activated by adding Hanna 1270 pH sensor to active RFID tags operating at 434MHz. Since the antennas on the existing PCB helical structure of RFID 11-TWD tags sold by UDEA can give a very weak signal outside the animal's body, this type of antenna is replaced by a quarter wave monopole antenna. With monopole antennas, 100% reading success was achieved at a distance of 10 meters, which decreased to 80% at 20 meters. The maximum signal reception distance is measured as 30 meters.

The measurement plane is seen in Fig. 1 and Fig. 2 [17]. Measurements have been conducted at a height of 50 cm considered as the best signal transducer plane (only for the

animal under in this measurement test). Because the signal coming from the bolus in this plane passes through the minimum tissue layer and reaches the reader antenna. The measurement results were taken in dBm. In parallel to measurements, a cow body was modeled in CST in order to simulate this scenario. Through the modeling, literature data were used for fat, muscle and so on. Finally, CST simulation results combined with analytical calculations have been verified by field measurements. Non-obstacle measurements (RFID were out of cow body and it is in the air) as background data were followed by body embedded RFID measurements. Subtraction of those two categories of measurements gives us real attenuation through that section of the body of cow.



Fig. 1. Measurement and test set up

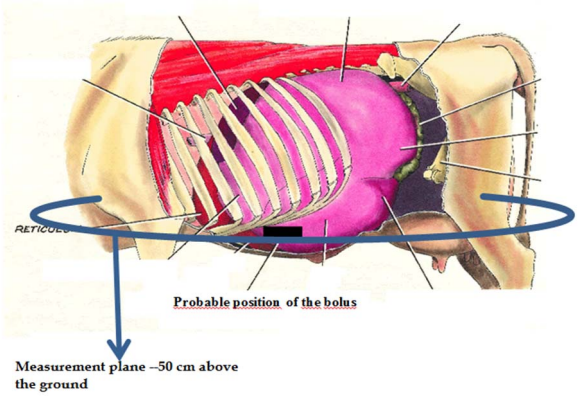


Fig. 2. Measurement plane

For CST simulation, a multilayer structure model in Figure 3. is used. Dielectric properties of animal tissues were obtained from the literature [18, 19]. The dimensions of the tissues were obtained from the measurements of the animal that we used in the simulations. It was also benefited from the scale cow model in the anatomy laboratory of the Burdur Mehmet Akif Ersoy University Veterinary Faculty. In this setup, the tissue layers in the angled plane where the reader and the label in the animal are directly facing each other are taken as a layer. The dielectric properties of the tissue layers used for the CST simulation are given in Table 2. In addition, the layers between the transmitter and receiver antennas and approximate the thickness of tissues are given in Table 1. The simulations have been carried out in frequency domain solver and attenuations of the signals between transmitter and receiver antennas have been obtained in terms of dB. The measurement and simulation results have been seen in Fig. 4. Layered structures of body tissues were extracted from 8 different angles (0: 45: 360) and all of the points of view have been compared with analytical results and CST simulations.

Table1. Tissue thickness between Tx and Rx antennas

Tissue	**Tissue thickness (cm)**							
	0 °	45 °	90 °	135 °	180 °	225 °	270 °	315 °
Rumen Lumen	10	15	25	15	15	20	10	10
Rumen Muscle	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Muscle	1	1	10	-	1	2	10	2
Bone	-	-	5	-	-	-	5	-
Intestine	-	-	-	5	-	-	-	-
Colon	-	-	-	-	5	-	-	-
Hearth	-	-	-	-	-	-	10	-
Liver	-	-	-	-	-	5	-	5
Fat	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Skin	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Table2. Dielectric properties of tissues

Tissue	**DielectricProperties**	
	Permittivity ε	**Conductivity σ**
RumenLumen	67	1
Rumen Muscle	57	0.8
Muscle	80	0.7
Bone	18	0.1
Intestine	65	1.92
Colon	40	0.7
Liver	45	0.7
Hearth	75	0.95
Fat	8	0.05
Skin	45	0.5

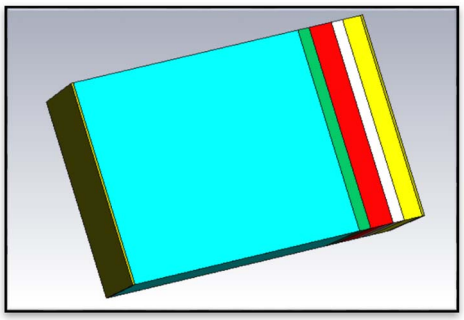


Fig. 3. CST Modeling for 0° in the Table 1.

Table3. Measurement results (With animal and without animal—units are dBm)

Body Embedded RFID	0 °	45 °	90 °	135 °	180 °	225 °	270 °	315 °
0 cm	-47	-58	-73	-72	-75	-77	-71	-68
10 cm	-55	-67	-73	-82	-74	-76	-71	-67
20 cm	-60	-70	-78	-75	-76	-78	-68	-75
30 cm	-56	-70	-80	-79	-77	-86	-71	-68
40 cm	-64	-70	-78	-79	-78	-86	-75	-72
50 cm	-76	-72	-76	-75	-74	-89	-75	-71
60 cm	-64	-68	-72	-75	-79	-82	-74	-72
70 cm	-66	-70	-73	-79	-78	-79	-74	-75
80 cm	-65	-70	-88	-89	-79	-80	-76	-75
90 cm	-69	-73	-89	-88	-79	-89	-77	-72
100 cm	-68	-72	-78	-79	-87	-88	-82	-71

Non Obstacle	0 °	45 °	90 °	135 °	180 °	225 °	270 °	315 °
0 cm	-14	-26	-22	-29	-17	-26	-23	-31
10 cm	-31	-29	-27	-34	-30	-30	-30	-45
20 cm	-45	-40	-48	-47	-36	-38	-44	-46
30 cm	-47	-46	-52	-46	-39	-43	-53	-46
40 cm	-54	-48	-56	-51	-40	-53	-58	-46
50 cm	-50	-52	-53	-56	-41	-49	-52	-50
60 cm	-48	-49	-53	-54	-44	-48	-52	-50
70 cm	-50	-46	-55	-53	-47	-48	-49	-49
80 cm	-50	-47	-66	-54	-49	-50	-51	-47
90 cm	-49	-55	-64	-54	-44	-54	-53	-50
100 cm	-47	-60	-55	-57	-45	-59	-56	-52

In multi-layer structures, the intrinsic-impedance of the medium has been calculated by using the dielectric properties given in Table 2. After reflection and transition coefficients have been determined by using the following Eq. (1, 2) using intrinsic-impedance.

$$\Gamma_i = \frac{E_{r_i}}{E_{t_i}} = \frac{\rho_i + \Gamma_{i+1} e^{-2\gamma_i d_i}}{1 + \rho_i . \Gamma_{i+1} e^{-2\gamma_i d_i}} \quad (1)$$

$$\tau_i = \frac{1-\rho_i \Gamma_i}{1-\rho_i} \left(e^{-\gamma_i d_i}\right) \quad (2)$$

An attenuation constant in terms of permittivity and conductivity can be written as in Eq.3 [20].

$$\alpha = \omega \left[\sqrt{\frac{\mu\varepsilon}{2} \left(\sqrt{\frac{\sigma^2}{\varepsilon^2 \omega^2}} - 1 \right)} \right] \text{Np/m} \quad (3)$$

Where α in Np/m is attenuation in lossy medium, σ in S/m is conductivity of medium, ε in F/m dielectric permittivity of the medium and μ in H/m is the magnetic permeability of the medium.

3. Results

Attenuation calculation can be done by using Eq.4.

$$A(dB) = SS_{Non-Obs} - SS_{body-embeded} \quad \text{(dB)} \quad (4)$$

Where A in dB is the total attenuation, $SS_{Non-Obs}$ in dBmW is the background measurement held in the air as a reference and $S_{body-embeded}$ in dBmW is the signal strength measured in case of cow embedded RFID tag case.

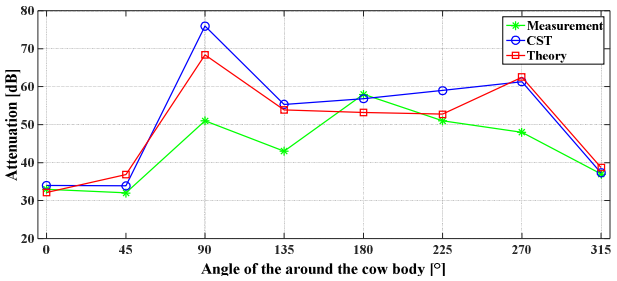


Fig. 4. Comparisons of the attenuations at the 50 cm height

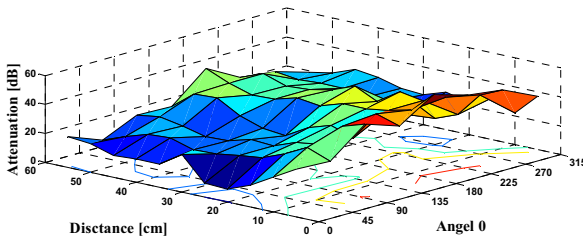


Fig. 5. Attenuations around the cow body

4. Conclusions

Comparing analytical results and CST simulations with real-time measurements reveals how the animal's body weakens the radio waves at 434MHz. According to this, it is understood that the signal is taken stronger at the sides that the left side of the animal (0, 45 and 315 in this study), because the amount of tissue on the left side of the animal is less than other sides and the signal weakened. The weakest signals are taken at between 90-270 degrees. These regions are regions where muscle and other tissues are dense.

It has been observed that measurement results at 90^o and 270^o with respect to zero axis (Zero degree has been considered to be left side of animal and measurement were made by moving counter clockwise direction.) are far from both CST simulation and analytical calculation. It is assumed that this difference is due to penetration of wave through the animal legs that this phenomena has not been included in the simulation.

Acknowledgement

This study was conducted in accordance with the legal frameworks and code of ethics of the SDU Ethics Committee, dated 21.05.2015 and numbered 05.

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