UHF Wave Attenuation throughout the Cow Body

Habib Dogan[1], I. Bahadir Basyigit[2], Musa Yavuz[3] and Selcuk HELHEL[4]

[1]SüleymanDemirel University, Department of Electronics and Communication Engineering, Isparta, Turkey
habibdogan@gmail.com
[2]Süleyman Demirel University, Distance Learning Vocational School, Isparta, Turkey
bahadirbasyigit@sdu.edu.tr
[3]Süleyman Demirel University, Faculty of Agriculture, Animal Science Department, Isparta, Turkey
musayavuz@sdu.edu.tr
[4]Akdeniz University, Department of Electrical and Electronics Engineering, Antalya, Turkey
selcukhelhel@akdeniz.edu.tr

Abstract

RFID is at the forefront of technologies that have found widespread use in recent years. The diversity of fields of 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. The pH values in the rumen from a certain distance from the outside can be continuously and instantly monitored with the active RFID tags used for the follow-up of the pH data. 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. Simulation results in CST are verified with measurement results.

1. Introduction

RFID is a system of identifying objects using waves of radio frequencies. This technology firstly, based on the work done to distinguish friendly and enemy planes of World War II, has gained widespread use due to the rapid development of electronic circuit technology and the increase of miniaturization. RFID technologies are used from 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 an RFID systems are using, 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).

The first use of these systems in animals is found in 1970s and the first applications are seen as a label attached to the animal's neck. 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, as the possibility of subcutaneous labels sticking to carcass meat products is high. Although most of the ear type labels are preferred for animal identification, these labels have been worked on a more secure identification system by being ineffective against alteration, cheating and theft events like the classic plastic type labels.

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[1].

Highly comprehensive projects such as the IDEA in the European Union [2,3] the selection and effects of RFID tag types to be 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 [4].

Studies at different times and places [5-8] 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 using passive tags, remote data acquisition studies are also performed by adding sensors to active tags. For this purpose, it is important to follow the animal health in order to follow the instantaneous follow-up of animal body data by adding temperature and pH sensor to active RFID tags [9].In particular, continuous monitoring of ruminal pH data is thought to be helpful in predicting SARA-type disorders, which are the most economical source of livestock in animals, and to enable rapid and effective treatment of these diseases [10].

In the applications seen in the market [11, 12], it is seen that the signals received from outside animals can be taken from very short distances. The reason for this is thought to be the fact that the frequency radio waves being worked on are extremely weakened by the animal's body and that the long distance accesses cannot be made.

A practical study has been carried out to show how and to what extent the signals from the labels used in this study are attenuated in which region of the animal's body. Preferred RFID tags are operating at 433MHz (UHF), and CST simulations are verified by real measurements.

2. Material and Method

In this study, cattles with a cannulated age were used and activated by adding Hanna1270 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. 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

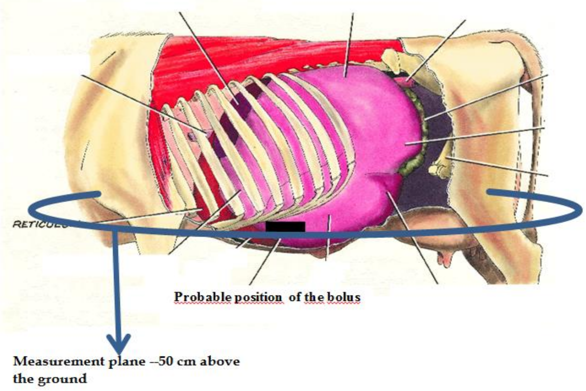

Fig. 2. Measurement plane

For CST simulation, a multilayer structure model in Figure 3 is used. Dielectric properties of animal tissues were obtained from the literature [13, 14]. 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 Figure 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.

Table 1. Tissue thickness between Tx and Rx antennas

Tissue	Tissuethickness (cm)							
	0 °	45 °	90 °	135 °	180 °	225 °	270 °	315 °
RumenLumen	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

Table 2. Dielectric properties of tissues [13,14]

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

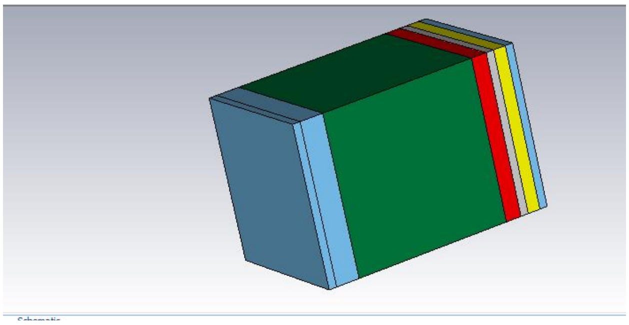

Fig. 3. CST Modelling for 0° in the Table 1.

Table 3. Measurement results (with animal and without animal—units are dBm)

		0 °	45 °	90 °	135 °	180 °	225 °	270 °	315 °
Body Embeded RFID	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

		0 °	45 °	90 °	135 °	180 °	225 °	270 °	315 °
Non Obstacle	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 Table 2. After reflection and transition coefficients have been determined by using the following equations using intrinsic-impedance.

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

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

An attenuation constant in terms of permittivity and conductivity can be written as in Eq.3 [15].

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

where α in Np/m is an 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.

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

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.

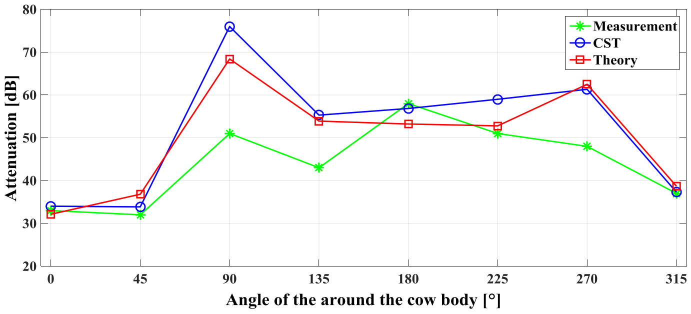

Fig. 4. Comparisons of the attenuations at the 50 cm height

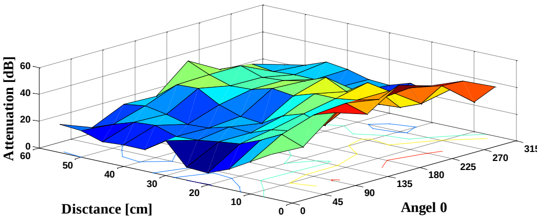

Fig. 5. Attenuations around the cow body

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 is not too 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

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4. References

[1] FallonR.J.. “The development and use of electronic ruminal boluses as a vehicle for bovine identification”, Revue Scientifique et Technique Office International, 20(2), 480-490, 2001

[2] Voulodimos, A. S. “A Complete Farm Management System Based on Animal Identification Using RFID Technology”, Computers and Electronics in Agriculture70 , 380–388., 2010.

[3] Wismans W.M., “Identification and registration of animal in the European Union”, Computers and Electronics in Agriculture, 24:99-108, 1999.

[4] Ghirardi, J.,Caja G., Flores C., Garı´n D.,Herna´ndez-Jover M., Bocqui F., “Suitability of electronic mini-boluses for early identification of lambs”, J ANIM SCI 85:248-257,2006.

[5] W.Pinna et al., “Electronic Identification of SARDA goats under extensive conditions in the Island of Sardinia”, Small Ruminant Research 66, 286–290,2006.

[6] D.Garinet al., “Performance and effects of small ruminal boluses fort the Electronic Identification of fattening lambs”, Livestock Production Science 92, 47 – 58, 2005.

[7] A.H.Ipema et al., “2008-Pilot study to monitor body temperature of dairy cows with a rumen bolus”, Computers and Electronics in Agriculture archive, Volume 64 Issue 1, November,Pages 49-52, 2008.

[8] Edouard Timsit et. al., “Early detection of bovine respiratory disease in young bulls using reticulo-rumen temperature boluses”, The Veterinary Journal 190, 136-142, 2011

[9] A.Castro-Costa et al., “Using wireless rumen sensors for evaluating the effects of diet and ambient temperature in nonlactiating dairy goats” DairySci. Jul;98(7):4646-58.2015.

[10] Jörg M.D. Enemark, “The monitoring, prevention and treatment of sub-acute ruminal acidosis (SARA). A review.”,Veterinary Journal., 176(1):32-43, 2008.

[11] J.Gasteiner, “Continous and long-term measurement of reticuloruminal pH in Grazing Dairy Cows by an Indwelling and Wirless Data Transmitting Unit”, Veterinary Medicine International Volume 2012.

[12] Tobby Mottram, “Technical Note: A wireless telemetric method of monitoring clinical acidosiz in dairy cows. Computers and electronics in agriculture 64 45–48, 2008.

[13] S. Gabriel, et al.,“The dielectric properties of biological tissues: II. Measurements in the frequency range 10 Hz to 20 GHz”, Phys. Med. Biol. 4, 2251–2269, 1996.

[14] Azadeh Peyman, Dielectric properties of tissues; variation with age and their relevance in exposure of children to electromagnetic fields; state of knowledge, Progress in Biophysics and Molecular Biology 107, 434-438, 2011

[15]Sukru Ozen, Selcuk Helhel and O. Halil Colak, Electromagnetic field measurements of radio transmitters in urban area and exposure analysis, Microwave And Optical Technology Letters, 49(7), 1572-1578, 2007