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EMF Exposure and SAR Analysis in the Cow Tissues

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Abstract— *There is a tremendous increase in use of RF electronics in veterinary for tracking and health check of animals. The mechanisms of magnetic and electromagnetic effects in biological systems are known, effect of electromagnetics in biological tissues are generally studied in human tissues in the literature, and the mechanism was convincingly established for enzymatic adenosine triphosphate (ATP) and desoxynucleic acid (DNA) synthesis. In this study, the SAR effect of pH boluses used to monitor the rumen pH value of animals has been tried to be revealed. For this purpose, active RFID tags operating at 434 MHz have been placed in the rumen zone by adding a pH sensor and the rumen pH values have been monitored dynamically for two months. The SAR value generated by active RFID tag antennas with 1 mW output power has been modeled with the help of a simulation program. The resulting SAR effect appears to be well below the legal limit.*

Keywords— *SAR, Active RFID Tags, pH bolus.*

I. INTRODUCTION

The use of RFID tags for animal identification dates back to the 1970s [1]. In the first place, the applications seen as RFID tags attached to the belts attached to the neck of the animals have gradually turned into ear cuffs and subcutaneous types. The use of "bolus" type labels, which are placed in rumen for animal identification, has led to the use of labels that can easily be lost, exchanged, and that the subcutaneous varieties have a high likelihood of interference with the carcass during cutting [2].The labels on all these first applications are passive type and do not have their own power sources. Therefore, when they are not used intensively, a negative situation is not expected in terms of electromagnetic effect [3].

In animal health, key roles played by body temperature and rumen pH [4] led researchers to work in a way that would enable researchers to dynamically monitor characteristic values (such as temperature and pH) from animal rumen. Especially SARA disease has reached an economic loss of 1 billion dollars annually in North America. For this reason, acceleration of the early detection of low pH value of the rumen, which is the main cause of this disease, has been accelerated. SARA occurs when the pH value of the rumen falls below 5.5 for a long time and monitoring of it is only through the long-term monitoring of the pH value. [13]. For the purpose of this aim, studies have been carried out to monitor the temperature and pH values of rumen in the literature [5-8]. The studies are usually in the form of analysis of situations that will ensure a accurate measurement of pH or temperature values, and the electromagnetic effects of such measuring devices in animal tissues have not been studied as far as we know. For this purpose, in this study, it was attempted to interpret what kind of SAR effect of pH groups would occur in animal tissues.

The second part of the study includes material and method, and the third part contained SAR simulation studies. Finally, the results obtained in the fourth part are interpreted.

II. MATERIAL AND METHOD

In this study, 3 native race cattle animals that are 16 months old have been used. The animals have been surgically implanted with cannula and pH measurement studies have been conducted over a period of two months through the placement of the designed bolus rumen. All these studies were carried out within the context of the ethics committee decision of Süleyman Demirel University Ethics Committee dated 21.05.2015 and numbered 05.

Signals from active RFID tags that measure the rumen pH value pass through the animal's body tissues to reach the RFID reader. Measurements have been made in these tissues to determine how weak the signals are. Measurements have been repeated at heights of 25cm, 50cm, 75cm and 100 cm, turning around the animal every 45º. The left side of the animal has been assumed to be 0º and moved counter-clockwise. The measurement setup is shown in Fig. 1.

Fig. 1. Measurement environment.

In addition, the attenuation of the electromagnetic signals from the label and the reflection coefficient can be seen in (1) and (2), respectively.

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

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

These values have been calculated analytically using transmission coefficients. By CST MWS 2015 simulation

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program, the tissues between transmitter and receiver antennas have been modelled and attempted to determine attenuation. The simulations were done on a computer with 4GB RAM memory with i5 processor. Fig. 2 shows the attenuation values of the simulation, analytical and measurement results at a height of 75cm. From Fig. 2, it is seen that the results of simulation and analytical model are consistent with the measurement results.

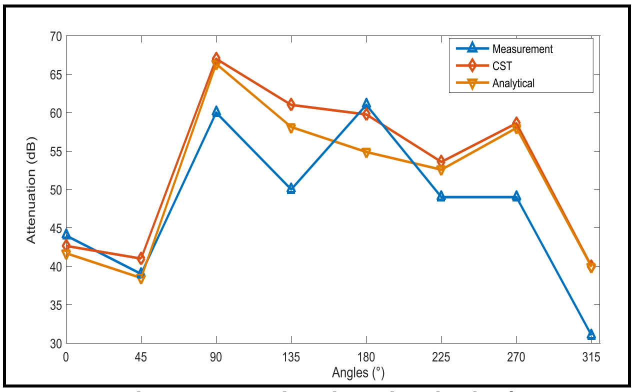

Fig. 2. The attenuation values obtained at a height of 75cm.

Moreover, observing from these results, it has been observed that the angles that see the left side of the animal are more advantageous in terms of signal acquisition. This is because the left side of the animal's body is less dense than the other, in terms of tissue. In regions where the tissues are dense, the electromagnetic signals are attenuated and come out.

III. SAR Simulations

Absorption, reflection and transmission losses occur in animal tissues as in all lossy dielectric environments [9,10]. The SAR value is a measure of how absorptive the electromagnetic signal from the transmitter is in the biological tissues and it is widely used in evaluating the electromagnetic effect. The power absorbed by biological tissues turns into heat by increasing cell temperature, it has potential to change enzymatic adenosine triphosphate (ATP) and desoxynucleic acid (DNA) synthesis, and the potential increase in heat may result in damaged cell structure of the tissue.

The high water content in biological tissues increases the amount of absorbed energy. The study shows that it is possible to distinguish two fabrics with high water content and low water content. Water content in body fluids is 90%, while in cortical bone this ratio drops to 20% [11].

How and how biological tissues are affected by electromagnetic fields has been and continues to be a matter of research. Many organizations (ICNIRP, IEC, FCC, etc.) have worked on this area and have set standards for what the SAR limits of the tissues will be. The average SAR value is 4W / kg threshold for the whole body. In RF safety standards, 1/10 of this value for controlled exposure and 1/50 for uncontrolled exposure are acceptable limits. These values are 0.4 W / kg and 0.08 W / kg respectively. New SAR limits have been defined for small tissue densities (1 gr and 10 gr) since SAR values are considered to be higher in local applications such as mobile phones. The upper limit for 1 gr tissue density was 1.6 W / kg, and for 10 gr tissue density was 2 W / kg [13, 14, 15, 16].

For controlled and uncontrolled exposures, a power rating on these legal limits is considered exposure to biological tissues. The SAR value as shown in (3) is calculated for small grids of 10 gr and 1 gr [10].

$$SAR = \frac{\sigma |E|^2}{2\rho} \quad (3)$$

The active RFID tag we have used operating at a frequency of 434 MHz and have a quarter wave monopole antenna. The pH probe has been insulated with epoxy material of 3 cm in diameter so that the added RFID tag is not affected by the liquid in the rumen environment. In addition, a steel cylinder structure with a weight of 40 gr and a diameter of 2.5 cm has been added to the back of the bolus for less movement of the bolus in the rumen environment and collapse into the rumen. Since it is known that the pH value is different in the regions within the rumen, little movement of the bolus will increase the compatibility between the received data.

The S_{11}values of the used antenna are shown in Fig. 3 and the structure of the bolus can be seen in Fig. 4.

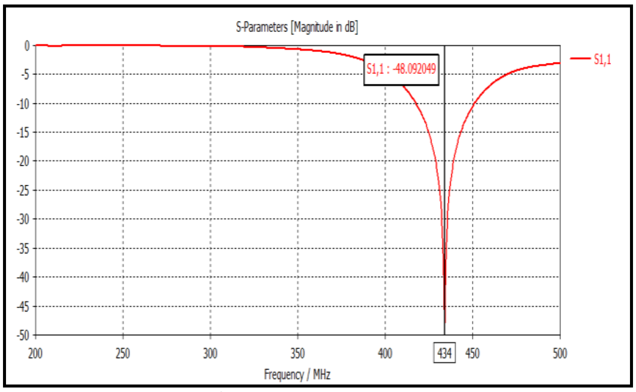

Fig. 3. The S11values for the monopole antenna structure used in the simulation results.

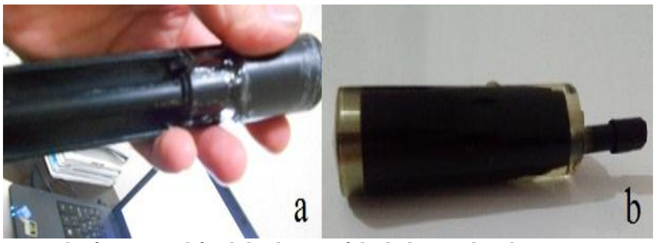

Fig. 4. The first (a) and final (b) design of the bolus used in the measurements.

In the experimental studies performed, the bolus is located in the reticular region at the bottom of the rumen in the rumen, and the rumen is at a distance of usually 5-10 cm from the rumen wall. By using these physical dimensions, the SAR structure has been modeled as a sphere and SAR simulations have been calculated. The results of the simulations are given in Fig. 5-9.

When Fig. 6 and Fig. 7 are examined, it is seen that the electromagnetic waves emitted from the antenna belonging to the pH bolus placed in the rumen are absorbed within a short distance. Also these electromagnetic waves appear to have become very low outside animal tissues. In this case, the amount of power absorbed in the rumen becomes important. There are two reasons why the content of the rumen reduces the duration of the exposure caused by the applied source: 1) Rumen content is heterogeneous in animal tissues. 2) Rumen content is constantly changing.

The designed pH is very low power level of the electromagnetic waves coming out of the bolus out of the rumen. That's why the tissues outside of the rumen will be more protective of the electromagnetic effect.

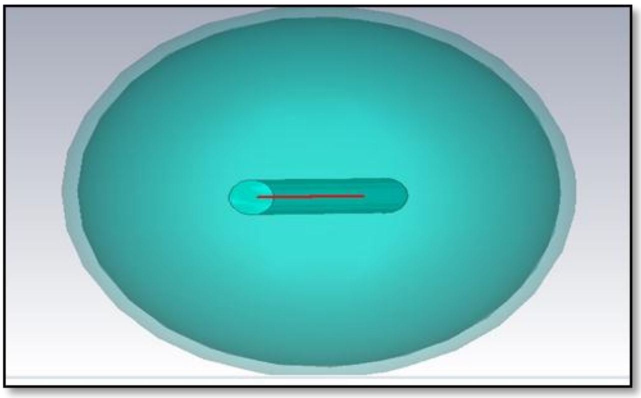

Fig. 5. Model used for SAR analysis (Monopole antenna insulated with epoxy material).

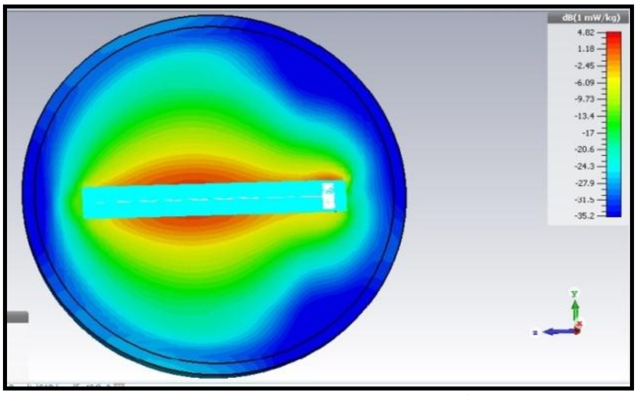

Fig. 6. 2-D SAR graph (antenna in the center of the sphere).

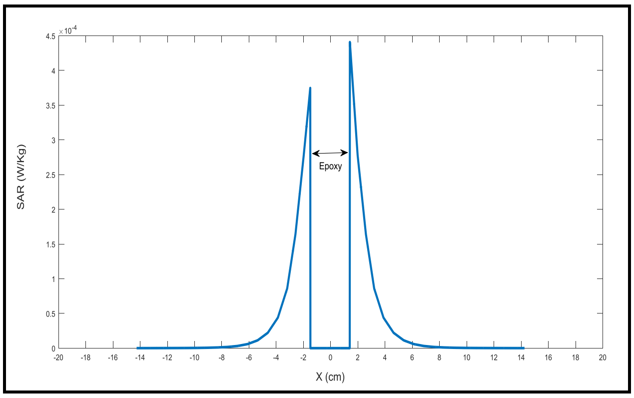

Fig. 7. 1-D SAR graph.

In Fig. 8 and Fig. 9, it is analyzed how SAR effects will be produced in tissues outside the rumen, considering the possibility that the designed bolus is close to the rumen wall. As can be seen from the graphs, the SAR value of the electromagnetic waves emitted from the bolus approaching the rumen wall is very much in excess of the limit values in the tissues outside the rumen.

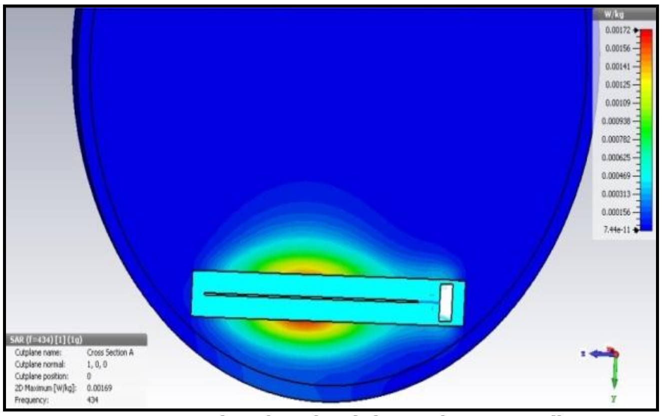

Fig. 8. SAR value when placed close to the rumen wall.

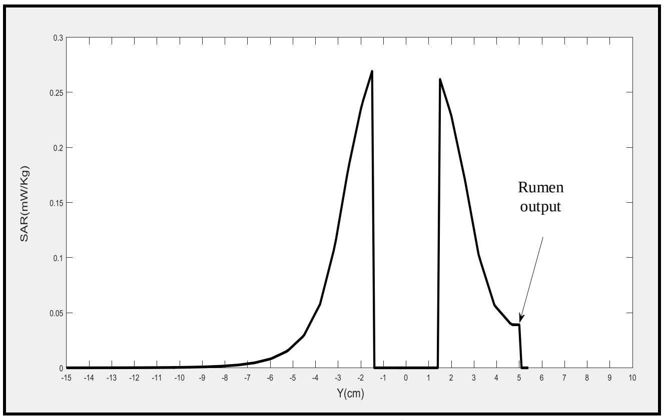

Fig. 9. 1-D SAR graph (for Fig. 8).

IV. CONCLUSION

Since RFID tags we use are active, their power consumption will be much higher than passive tags. The rumen and the rumen wall are modeled as spheres to interpret the SAR effect created by the animal source in the power source to be used during the simulation process and this is shown in the graphs of Fig. 5-9. Observing all these graphs, it is possible to get the following results:

- Used RFID tags in this study do not pose any danger to animal tissues.
- The resulting SAR value is well below the limit values.
- Since the bolus is moving within the rumen, it is hard to model how much SAR is observed on which tissue. However, SAR values can be interpreted for certain locations with some assumptions.
- Even if we use a maximum power of 10 mW, which is the legal limit for the 434 MHz band, the SAR effect is still below the limit values. Additionally, bolus applications that meet a power consumption of this magnitude will not be economical and useful. It is desired

to extend the life of the bolus placed in the rumen by reducing the power consumption in the boluses.

- In the literature, studies have been done to determine how base stations affect stress enzymes in animals [12]. In this study, an exposure time of 6 hours and 36 minutes a day for 30 days has been applied and the applied electric field values have been kept between 3,4-29 V/m. Negative effects have not clearly been detected even at these higher values compared to the values we worked with. The field value is much smaller and the amount of exposure is small at the point of no comparison on the labels we use. Therefore, it is not anticipated that any negative events will occur in the boluses by comments of short term applications.

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