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Study on the Transmission of an RF Signal Through Phantom Muscle Tissue

Joel Flores[1], Jorge Becerra[2], Patricia Lorena Ramírez[3]
ICE, ESIME-ZACATENCO/IPN, México City, Mexico[1,2,3]

ABSTRACT: **The development of phantom materials provide an approximate simulation of the electromagnetic properties on human body over a determined frequency and temperature range. This material is important for understanding the interaction between implant medical devices and the electromagnetic fields. That is why, its importance in substitution of biological means on the development of transcutaneous energy links for implanted devices. This paper describes the effect of the biological environment, simulated by a substitute of tissue and silicon material on the transmission of the RF signal from a magnetic coupling between two coil system transcutaneous energy.**

Keywords: Phantom materials, Phantom muscle tissue, RF induction, Implanted devices.

I. INTRODUCTION

The phantom is defined as a material that provides a simulation of a biological body [1] or a physical model which simulates biological tissue [2]. The phantom material objectiveis to explore the interaction between the human body tissues and the electromagnetic field, to determine the electrical characteristics of the body, and these may be employed in the design of the power stage of communication devices placed within the humanbody[3].

It is known that the presence of an implant within a living system, because of its properties chemical, physical and electrical, affects the organization and processing of the elements of the tissue initsvicinity, particularly during the adaptation phase generating a complex médium for transmitting an electromagnetic signal. Sincean RF signal is attenuated depending on the dielectric constant of the propagation medium, it is expected that the signal sensed by the external receiver is modified in its magnitude [4].

The phantom materials in general can be classified from different points of view. A classification criterion is the frequency, as some materials work in the low frequency range, while others do so in the high frequency range. Another criterion is the type of biological tissue which represents material in tissues containing much wáter such as muscle, brain, internal organs etc., and in tissues that contain as little wateras bone and fat [5]. However the most common classification is based on the final state of the material: solid (dry), solid (gel) andliquid [6].

As the human body is electrically heterogeneous, several models have been proposed as phantom material for experimental use, reproducing physical characteristics such as body shape, electrical and magnetic constants, temperature [7], etc.

In developing of the phantom material should be a consideration in the foreground, the relative permittivity and the conductivity. In the case of muscle and brain, their phantome quivalents should have similar electrical characteristics in certain ranges of temperatura and frequency, as shown in Fig.1 and 2.

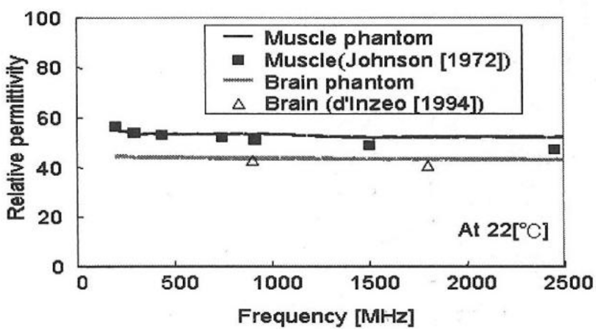

Fig. 1.RelativePermittivitymuscleandbrain, as well as their equivalentsphantom

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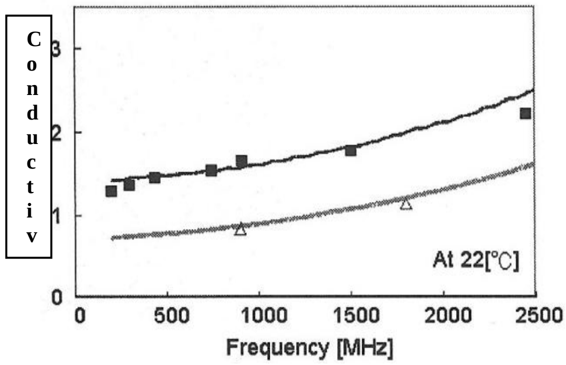

Fig. 2.Conductivity ofmuscle andbrain, and their equivalentphantom

Various materials are typically used to regulate the value of the relative permittivity and of the conductivity desired. The relative permittivity of dielectric materials is simulated with few ions; generally used PVC powder, aluminum powder, andTX-150 or super stuff (material composed of acrylamide and N, N'-methylene bisacrimalida). For a known and controlled conductivity, saline solution is performed; usually of sodium or potassium chloride in deionized wáter and that by varying the salt concentrationcan control the desired level of conductivity. See Table 1and 2.

TABLE 1.
Compositionofmuscleand brainphantom

Material	Muscle [3 g]	Brain [7 g]	Purpose
Deionizedwater	3375		Mainingredient
Polyethylenepowder	337.5	548.1	Relative permittivity control
Agar	104.6		Solidification
TX-150	84.4	57.1	Thickness
Sodiumchloride (base)	37.6	21.5	Conductivity control
Conservatives	SeeTable 2		Conservatives

TABLE 2.
Mass ofconservativesand sodium chloride

Material	Mass [g]	Sodiumchloride [g]	Lifetime
Sodiumacid	2.0	0	More thanone month
Potassiumsorbate	0.2	1.8	Two weeks
Dehydroaceticacidsodiumsalt	2.0	1.6	More thanonemonth
Boricacid	39.4	1.8	Three weeks

When using the phantom material in liquid state, is complicated the handling of this, so that a substance is added for to increase the solidity of the solution at room temperature without changing the linear relationship between the conductivity and concentration of salt. This is achieved with gelatinous elements, such as the agar, called chemical element, whose main advantage, is for provide on other gelatins greater stiffness and malleability, which allows to give the physical model.

The distribution of the agar in the phantom must be homogeneous for the same conductivity present at all points of its volume, since when the distribution of a substance is notuniform, there is a concentration gradient that produces a diffusion of such substance, which can be caused by two processes: molecular and turbulent diffusion. The agar in the phantom does not influence the electrical properties and has the same variation in temperatura with respect to the phantom without agar.

The phantom may be subject to different changes of temperature, achieving a variation in its conductivity, but this variation remains constant as in the frequency changes. As shown in Fig. 3.

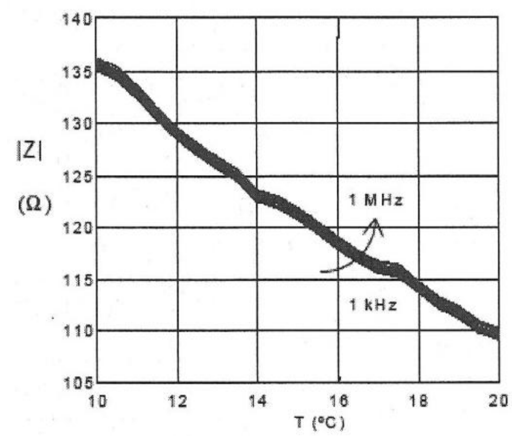

Fig. 3.Saline solution impedancewithrespect to temperatureand frequency

Furthermore, thanks to the technological advance that is has had both in the field of miniaturization and in the development of biocompatible materials, has been obtained telemetry systems bioimplantables, capable of sensing some physiological parameter and transmit in radio frequency (RF), information in a few inches out side the biological environment where it is received by an external receiver for analysis or diagnosis. However, there is still no exact knowledge of the effect of the transmitted signal (electromagnetic energy) on the tissue [8].

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Due to it is impractical and the risk represented to perform numerousim plants and determine the performance of biotelemetry systems in experimental stages, we resort to the use of materials capable of simulating the behavior of human tissues against as pecific type of energy. The material phantom is employed for this purpose. In general, it can be considered that the tissue substitute materials try to at tenuate electromagnetic energy in the same way that the different tissues of the human body. This paperuses a of muscle

Substitute for knowing the effect it will have on the transmission and reception of an RF signal of a magnetic coupling between two coils, as well as medical grade silicon material commonly used as implantable devices encapsulated in ageometric space [9].

II.DESCRIPTION

The induction system uses a Colpitts oscillator and a circuit LC(battery powered) stabilized with a crystal to generate and inducea sinusoidal signal of 20 MHz,via a transmitting coil(Tx) and a LCtank circuit of the parallel type, that through its receiver coil (Rx); receives the RF signal. Both circuits (the oscillator and tank) were placed in acrylic bases for displacement backwards and for Ward and lateral up wards and downwards, with respect to the placement of their respective coils, from a position compared between the two coils. The diameter of both coils is 1cm and was obtained according to the maximum radiation power (10mW/cm^2) [10]. The tank circuitis protected with medical grade silicone Type A.

The objective is to vary the distance between coils, in form of floor plans, for after having information for at hree dimensional plane. The distance that is interposed between the silicone is because the tank circuit is encapsulated with silicone, in order to observe the induction of an RF signal between two coils. Then the tank circuit is immersed inliquid (phantom) with the purpose of a muscle substitute, and to be implemented in a similar induction in an animal model, with two objectives: a) To ensure the bio compatibility) To analyze and avoid the risk to concentrations of electromagnetic radiation on healthy tissue.

For this, it builds a mounting system that allows moving the circuit without affecting the characteristics of the medium. The container for holding the phantom (e.g. Fig.4) and bases to support and give mobility to circuit (e.g. Fig.5), were made with acrylican dnylamid, respectively. It is known that the acrylic not affect the characteristics of the medium at the frequency of interest,and therefore,thetransmission-reception of the signal [11]. However, to ensure that the container made with nylamidhasn´t any adverse effect on the transmission-reception system, tests were performed.

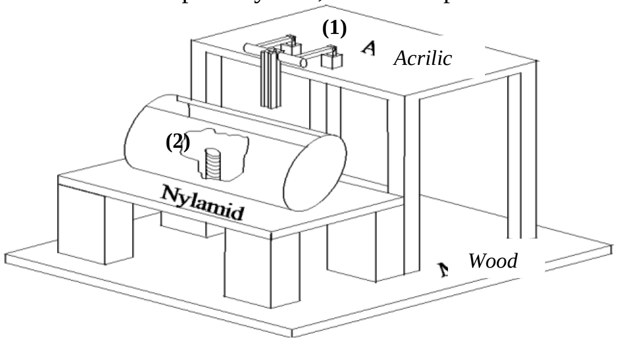

Fig. 4.Nylamid cylindrical container, to contain the phantom

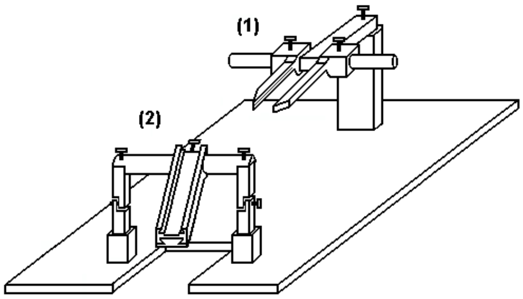

Fig. 5.Acrylic bases for the oscillator (Tx) and tank (Rx) circuits

The tissue substitute used is a mixture of wáter (85.5%), glycine (4.2%) and sodium chloride (0.54%); Hagmman proposed an substitute that is based on the dielectric properties of the muscle tissue in the frequency range from10 to 100MHz [12].

From Fig.5,at point(1) is placed the oscillator circuit and in the point(2) is placed the tank circuit to perform horizontal displacements backwards and forwards, and lateral displacements at a distance of 3 mm until 18 mm between both coils. For lateral horizontal displacements, the oscillator circuitis placed at the point (2) in order to move laterally and the tank circuit is placed at the point (1)to move backwards and forwards. The limitation of certain displacements, as in the case of top-down horizontally, is because only is interest movement top-down in vertical as displacements posible with phantom material.

From Fig.4, for the displacements with phantom material, it was designed an cylindrically shaped container (approximate volumen of 18 ×18 × 18mm 3) with an opening in its surface in order to introduce phantom material, and the encapsulated circuitis placed in tank

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point(2), having the advantage of being mounted on a vertically displacement up and down, the oscillator circuitis placed at the point (1) in order to move laterally and toward the bottom.

In all tests, was measured peak to peak voltaje produced in the tank circuit(receiver), every 3 mm. In all cases, the coils are not overlapping as shown in Fig 6.The measurements were performed under the following conditions:

a. The circuit (oscillator and tank) mounted on the acrylic base (e.g. Fig.5), the results of this test are compared with those obtained in test b) to ensure that the container of nylamidhasn´t influence in the behavior of the medium.
b. The empty container and the tank circuit without encapsulated(e.g. Fig.4),the values obtained in this test are considered for the test c).
c. The empty container and the tank circuit with encapsulated (layer about 1 mm) of silicone (e.g. Fig.6).
d. The phantom material container and the tank circuit with encapsulated of silicone (e.g. Fig.6).

These values are compared to obtain at tenuation of the peak-peak voltaje caused by each of the tests.

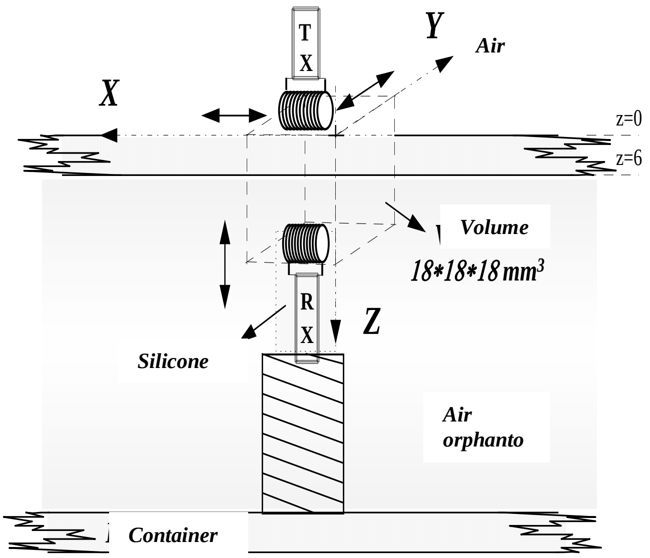

Fig. 6.Geometrical positionofthetransmitter-receivercoils within thecylindricalcontainer

III. RESULTS

There are nosignificant losses due to the use of the container made of nylamid. The average dispersión found was 5%, when comparing the test results: a)and b).

The average attenuation caused by the presence of the silicone\ covering the receiver circuit was 24.8%, with an average deviation of ±5%.

The attenuation caused by the effect of the presence phantom material depends largely on the geometric position between the coils. When comparing the test results: c) circuit with silic one-aircontainer, d) circuit with silicone-phantom material container, was reached with the following, as the coordinate axes that is showed in Fig. 6.

In the direction X, Y considering fixed, the attenuation decreases with increasing X. ForX≤ 12mm attenuation ranges from 0%toX= 12mm, up to 45% at X=0 mm, this range varies slightly depending on the value of Z.ForX> 12 mm no relationship was found(e.g. Fig.7).

In the directionY, X and Z considering fixed, the attenuation is variable, generally is within a range of 10 percentage points, for example if for any Y (X and Z fixed to) the minimum attenuation of 30% was found, the attenuation that is found in any other Y (for the same X and Z) is at most40%.

In the direction Z, Y considering fixed, for X≤ 12mm attenuation decreases with increasing of Z and goes from the 15% at Z= 18mm until 45% for Z= 6mm for X> 12 mm no relationship was found (e.g. Fig.8).

The graphs shown represent only the attenuation caused by each medium.

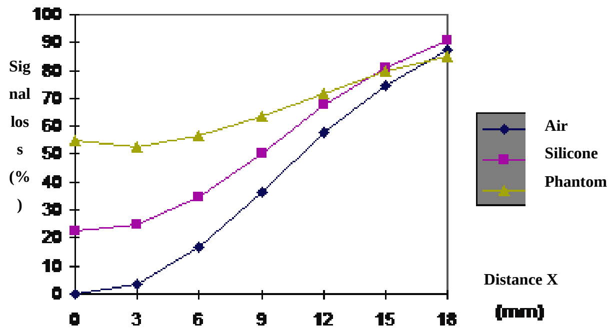

Fig. 7. BehaviordirectionX

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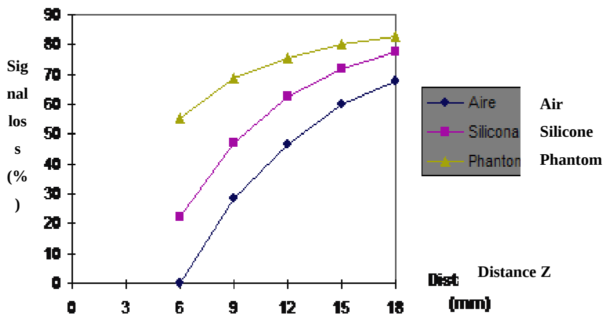

Fig. 8.Behaviour direction Z,for X≤ 12mm

IV.CONCLUSION

Tests showed the effect, the biological médium and the encapsulated material of the implant, on the RF signal transmitted via the powerstage of animplantable biotelemetry system can be considered that, in general, closer tan 12 mm has reliable behavior.

With the implementation and results of these experiments, it can be said that:

- In a system of implantable biotelemetry, the power should be regulated, this will ensure that the signal variations depend solely on the properties of the transceiver circuit and the médium through which it is broadcasting.
- It is not recommended for amplitude modulation. It is working with nearby fields, so that when there is a variation in the geometrical position on the transceiver,the reference is lostor the calibration.
- For the best results in a real implant, is must have "control" on the relative geometrical position between the coils.

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Biography

Joel Flores Martínez received his B.Sc. in electronics and communicationsengineering from ESIME Zacatenco IPN, Mexico, in 1997 and M.Sc. degree in Bioelectronics from CINVESTAV IPN, Mexico in 2000. Currently he is a Professor at the Department of Electronics and Communications engineering in ESIME Zacatenco. His research interests are in acoustics and biomedical engineering.

Jorge Becerra Garcíareceived his B.Sc. in electronics and communicationsengineering from ESIME Zacatenco IPN, Mexico and M.Sc. degree in Bioelectronics from CINVESTAV IPN, Mexico. Currently he is a Professor at the Department of Electronics and Communications engineering over 38 years’ experience in ESIME Zacatenco. His research interests are in acoustics and biomedical engineering.

Patricia Lorena Ramírez Rangel received her B.Sc. in electronics and communicationsengineering from ESIME Zacatenco IPN, Mexico, in 1997. Currently she is a Professor at the Department of Electronics and Communications engineering in ESIME Zacatenco. Her research interests are in acoustics.