New Radar System In Medicine

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***Abstract*— UWB Radar system helps us to capture image of human biological structure. In this paper, we propose medical system Radar that can explore human body layer by an oblique incident UWB pulse. This system can capture human tissue image by analyzing the echo of each layer. In attempt to distinguish reflected echo, our system exploit the diversity of electromagnetic direction propagation and the variety of travel time of each echo. Our solution consists on recursion expressions that estimate the position of the network antenna and the travel time on each echo layer.**

I. INTRODUCTION

Whole systems of UWB comprised in sending out an ultra wide band impulsion and examining the received echo like the Magnetic Resonance Image (MRI) and ultrasonic system. This kind of system is used nowadays in several applications such as medical applications.

An UWB radar system offers many reimbursements over continuous wave radars [1]:

- Due to a very lofty down-range resolution, a target can be precisely located;
- Outsized bandwidth allows better severance between targets and clutter;
- It possesses good resistance in opposition to multipath interference, which is very burly within buildings and distorted buildings;
- Various targets can be resolved.

Electromagnetic wave impulses are able to explore the human body. This is because there are differences in reflection magnitude between several layers of the human tissue. There are several works in the literature which are interested in estimating the echo of electromagnetic wave by the human body[6][7][8][9]. In this paper we study a electric property of human body. First, we modeled the human body by a plane multilayer. Then, we proposed a new radar system able to capture all echo reflected by human body of an oblique incident wave in the second part. In a same manner, we calculate the travel time and the distance covered by each layer echo. By exploiting these results our system has become ready to take an image of interior human body layers. Through this manner the doctors will be allowed to detect an anomaly in human body like tumors. Finally results are resume in a conclusion.

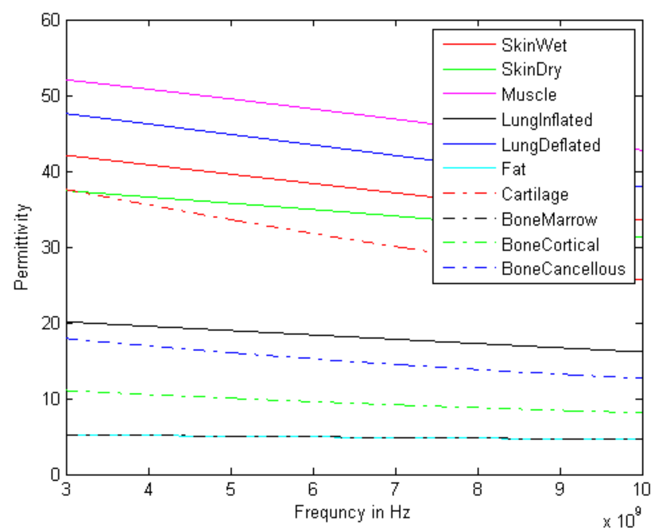

Fig. 1. Relative permittivity as a function of frequency for normal tissue as measured by Gabriel in [2][3][4][5]

II. ELECTRICS CHARACTERISTICS OF HUMAN BODY LAYERS

Each layer of human body can be represented by a dielectric in which properties vary with the frequency of incident pulse. The dielectric characteristics of tissues are not only frequency dependent but also temperature dependent [2][3][4][5].

Fat and Bone have a very law water content and therefore significantly a high permittivity. Most other body tissues have very high water content, for this reason they has a less permittivity. The permittivity increases with frequency in all layers of the human body. This result is demonstrated by Gabriel as shown in Fig1.

The same, conductivity is very less for a layer that has very high water content and it is very important for a layer that has a less water content. But conductivity decreases with frequency in all layers of the human body. This outcome is established by Gabriel as shown in Fig2.

We can model any layer of biological structure by a good electric. Fig3 illustrates that the condition for good dielectric $(\sigma/\varepsilon\omega)^2 \ll 1$ is satisfied for all layers of biological tissue [10].

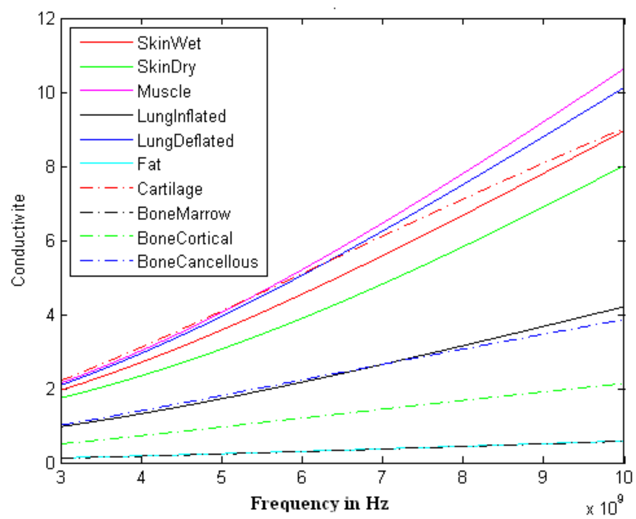

Fig. 2. Conductivity as a function of frequency for normal tissue as measured by Gabriel in [2]

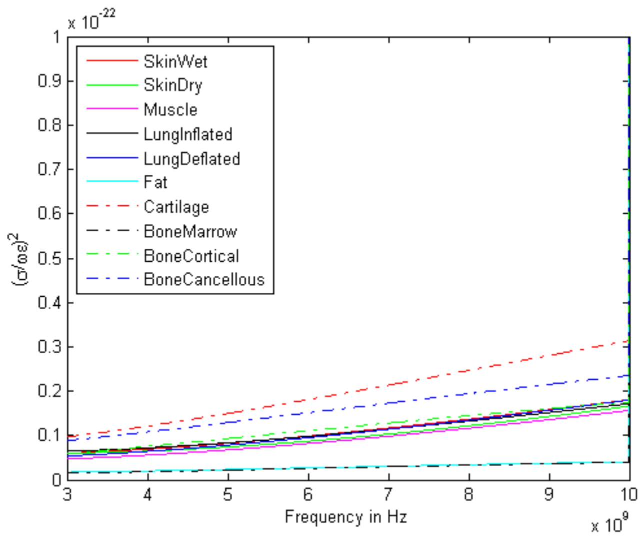

Fig. 3. $(\sigma/\varepsilon\omega)^2$ as a function of frequency for normal tissue

Where:
ω : wave pulsation
ε : relative permittivity.
σ : relative conductivity.
At this statement, we can model human body by a multilayer good dielectric that is composed of planar layers skin, fat, muscle, bone and lung tissue. The human body model is shown in Fig4.

III. Proposed Radar System

In attempt to propose a new Radar system, we study interaction between an oblique incident wave and a human biological structure.

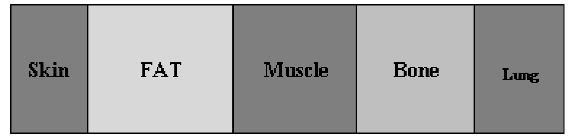

Fig. 4. Layered flat tissue model.

Let us now presume the electric field of the uniform plane wave incident on a planar interface at on oblique angle.

In this section, we started by a single layer of human body in free space.

When the incident wave run into the interface, a part of the wave intensity will be reflected into layer one and fraction will be transmitted into layer two. In addition to the two Snell's low of reflection we can lead to the following two relations.

$$\theta_{in} = \theta_r \tag{1}$$

$$\eta_1 \sin(\theta_{in}) = \eta_2 \sin(\theta_t) \tag{2}$$

Where θ_{in}, θ_r and θ_t are, respectively, the incident angle, reflected angle and the transmitted angle; η_1 and η_2 are respectively, the intrinsic impedance of medium one and the intrinsic impedance of medium two.

We use a pulse emitter UWB in the position P_0 that transmits an electromagnetic wave with oblique incident angle upon a human tissue layer surface, in attempt to capture the echo of the layer of the biological structure so, we should place the receiver antenna in the position P_1 shown in the Fig 2. P_1 that can be expressed by:

$$P_1 = 2l_1 \tag{3}$$

Where :

$$l_1 = w_0 \tan(\theta_{in}) \tag{4}$$

The transmitted part by the first layer became an incident wave compared to the second layer with an incident angle explained by

$$\theta_{t,1} = \sin^{-1}(\frac{\eta_0}{\eta_2}\sin(\theta_{in})) \tag{5}$$

The later is reflected by layer two and crosses layer one as shown in the direction in Fig . To capture this echo, we must place the receiver antenna in P_2 or move it to the same position which is expressed by

$$P_2 = 2(l_1 + l_2) \tag{6}$$

where

$$l_2 = w_1 \tan(\theta_{t,1}) \tag{7}$$

The same is true for layer three. The position P_3 is calculated by:

$$P_3 = 2(l_1 + l_2 + l_3) \tag{8}$$

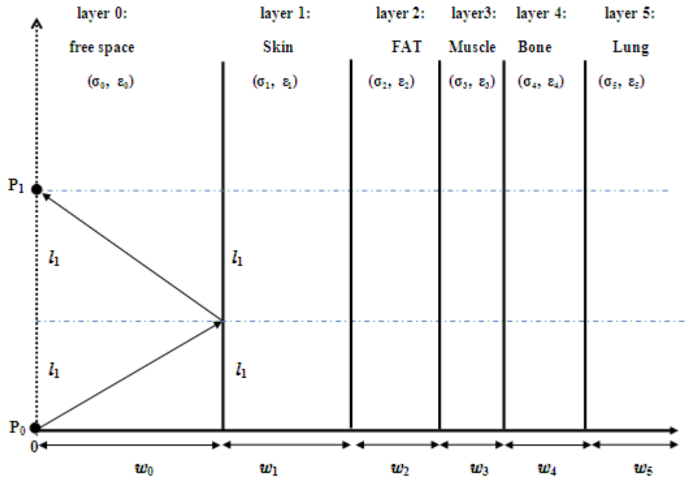

Fig. 5. Receiver antenna position P in order to capture layer one echo

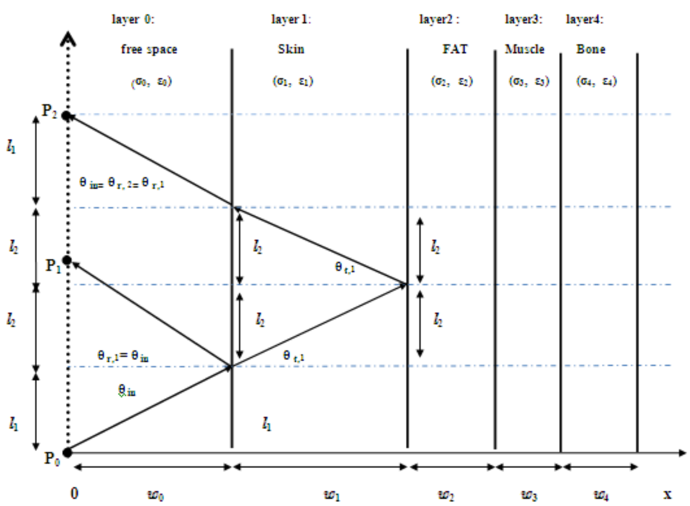

Fig. 6. Receiver antenna position P in order to capture layer two echo

$$l_3 = w_3 \tan(\theta_{t,2}) \tag{9}$$

$$\theta_{t,2} = \sin^{-1}(\frac{\eta_0}{\eta_3} \sin(\theta_{in})) \tag{10}$$

At this stage, we can generalize this finding which is placing receiver antenna in P$_i$ to capture the ith echo layer where P$_i$ is expressed by:

$$P_i = 2(l_1 + l_2 + l_3 + ...l_i) \tag{11}$$

In expression (11) l_i is:

$$l_i = w_i \tan(\theta_{t,i-1}) \tag{12}$$

and

$$\theta_{t,i-1} = \sin^{-1}(\frac{\eta_0}{\eta_i} \sin(\theta_{in})) \tag{13}$$

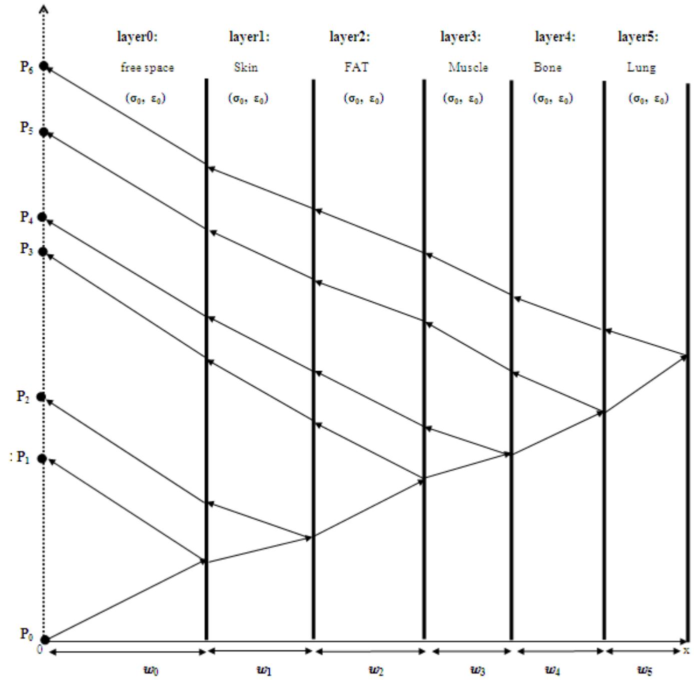

Fig. 7. Receiver antenna position P$_i$ in order to capture layer ith echo

In order to compute P, we can define a recurrence expression:

$$P_i = P_{i-1} + 2l_i \tag{14}$$

IV. OUTDISTANCE CROSSED BY THE ECHO OF EACH LAYER OF HUMAN TISSUE

In this part, we will try to determine the travel distance crossed by each echo layer of human body tissue. Let us start by the distance traveled by the echo reflected by layer one that can be expressed by:

$$d_1 = 2\frac{l_1}{\sin(\theta_{in})} \tag{15}$$

His expression can be written for second layer as:

$$d_2 = d_1 + 2\frac{l_2}{\sin(\theta_{t,1})} \tag{16}$$

And three layer:

$$d_3 = d_2 + 2\frac{l_3}{\sin(\theta_{t,2})} \tag{17}$$

To calculate the other distances traveled by the echo reflected by each layer we use the same method. This result can be generalized by a recurrence expression:

$$d_i = d_{i-1} + 2\frac{l_i}{\sin(\theta_{t,2})} \tag{18}$$

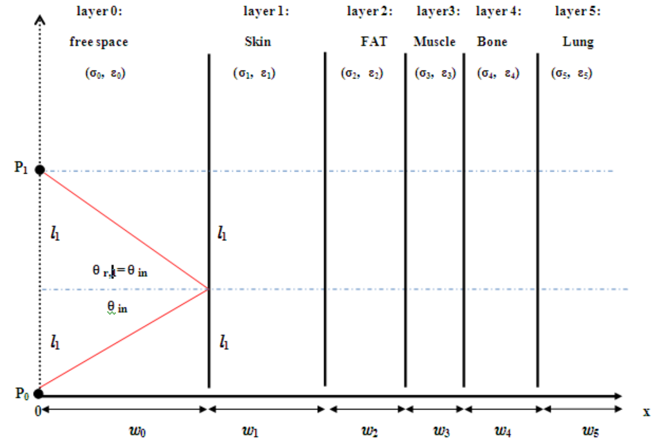

Fig. 8. Outside distance d_1 crossed by the echo through one layer

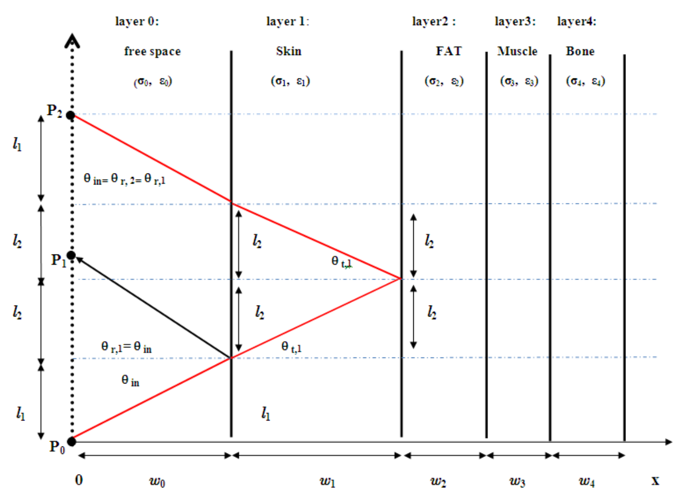

Fig. 9. Outside distance d_2 crossed by layer one echo

V. RETURN ECHO DAILY OF HUMAN BODY LAYERS

In the previous section, we have calculated the distances traveled by echo layer. Now we can determine the travel time echo layer.

The echo reflected by the first layer crossed twice free space, for this reason the echo time travel t_1 can be expressed by:

$$t_1 = \frac{d_1}{c} \tag{19}$$

Where C is the speed of light in free space .

On the other hand, for the second layer, the echo twice crosses the layer of free space as well as the second layer with this intention the time put by this echo can be expressed by:

$$t_2 = t_1 + \frac{d_2 - d_1}{v_1} \tag{20}$$

where

In the same way for layer three t that can be written by:

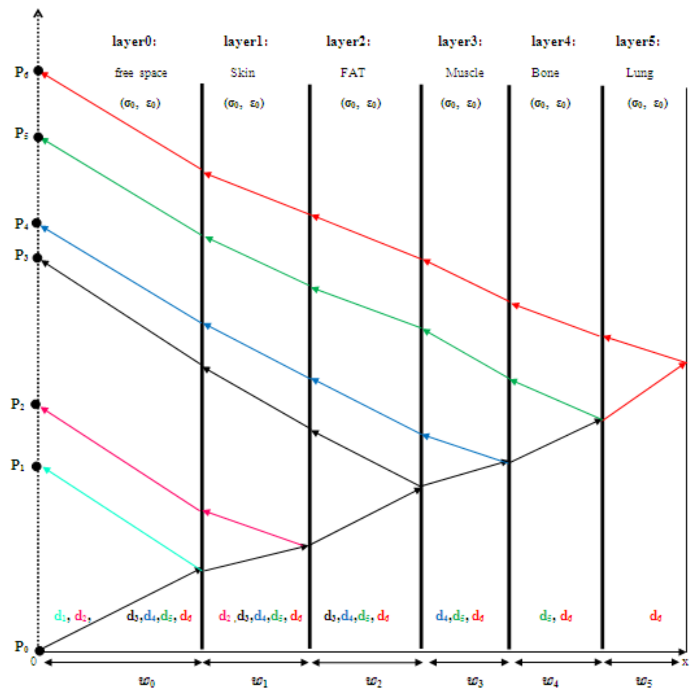

Fig. 10. Outside distance d_i crossed by layer i^{th} echo

$$t_3 = t_2 + \frac{d_3 - d_2}{v_2} \tag{21}$$

which can generalized by :

$$t_i = t_{i-1} + \frac{d_i - d_{i-1}}{v_{i-1}} \tag{22}$$

VI. APPLICATION

Our goal is to carry out a radar system of medical imagery which will enable us to take images of the various layers of human tissue.

This system consists on sending an impulse with an oblique incidence in UWB frequency range. At the time of each meeting with the various layers of biological structure, a part will be reflected by the layer one, giving place to a first echo, and another part will be transmitted towards the layer two, and which will be divided in the same way in two considered and transmitted parts: the considered part will cross layer one in order to make the echo of the second layer. This principle will be applied for the other layers.

To distinguish the various echoes, we can propose several methods; we can enumerate: direction of propagation of each echo, the time put by each echo and the polarization of the wave reflected by each layer.

In this paper we stressed the first and the second method. In fact, for an oblique incidence, each echo has its own direction which is always paralleled to the direction of incidence, as we have explained in the preceding section. With this intention, we thought of a strategic emplacement of the reception antennas. Moreover, each echo has its own way on the one hand, and its speed changes a layer with another. Of another share, this makes it possible to have a time of arrived single for each echo.

Table Tab I illustrates the emplacement of receiver's antenna and the travel time of each echo layers for an oblique incident impulsion $\theta_{in} = 45°$ at frequency 5 Ghz.

In order to compute P and t we use conductivity and permittivity of human body layer that is estimated by Gabriel. The tissue thickness of the different human body region used in this section is represented in [6].

Layer	Skin	FAT	Muscle	Bone	Lung
Thickness (mm)	1.3	9.5	13.5	6.6	5.7
Permittivity (S/m)	35.774	5.0291	49.54	16.05	44.859
Intrinsic impedance	5.9811	2.2426	7.0385	4.0062	6.6977
Antenna position (mm)	40	40.3096	46.6225	49.3488	51.715
Echo distance crossed(mm)	56.5685	59.1869	79.2082	106.3455	119.756
Echo travel time (ps)	188.5618	240.7644	390.4282	752.8237	931.91

Table I
Antenna position, distance crossed and travel time of each echo layer

VII. CONCLUSION

A new UWB Radar system for medicine application was investigated. In this work we have proposed a new Radar system that consists of sending an UWB pulse with an oblique incident. This type of incidence can make a variety of direction's echo propagation that facilitates capture each echo by a strategic emplacement receiver's antenna. Furthermore, we can discern each echo by using a travel time because each echo has its appropriate way. In fact, this system can make image of human body structure by analyzing the echo reflected by each layer after making database learning phase.

REFERENCES

[1] A.G. Yarovoy, X. Zhuge, T.G. Savelyev, L.P. Ligthart "Comparison of UWB Technologies for Human Being Detection with Radar" Proceedings of the 37th European Microwave Conference, October 2007, Munich Germany

[2] C. Gabriel, "A compilation of the dielectric properties of body tissues at RF and microwave frequencies," Radiofrequency Radiation Division, Brooks AFB, San Antonio, TX, Contract AL/OE-TR-1996-0037, 1996.

[3] C. Gabriel, S. Gabriel, and E. Corthout, "The dielectric properties of biological tissues: I. Literature survey," Phys. Med., Biol., vol. 41, no.11, pp. 2231–2249, Nov. 1996.

[4] S. Gabriel, R. W. Lau, and C. Gabriel, "The dielectric properties of biological tissues: II. Measurements on the frequency range 10 Hz to 20 GHz," Phys. Med., Biol., vol. 41, no. 11, pp. 2251–2269, Nov. 1996.

[5] S. Gabriel, R. W. Lau, and C. Gabriel, "The dielectric properties of biological tissues: III. Parametric models for the dielectric spectrum of tissues," Phys. Med., Biol., vol. 41, no. 11, pp. 2271–2293, Nov. 1996.

[6] Andreas Christ, Anja Klingenböck, Theodoros Samaras, Cristian Goiceanu, and Niels Kuster, "The Dependence of Electromagnetic Far-Field Absorption on Body Tissue Composition in the Frequency Range From 300 MHz to 6 GHz", IEEE transactions on microwave theory and techniques, VOL. 54, NO. 5, MAY 2006

[7] EVERET"I'E C. BURDETTE, FRED L. CAIN AND JOSEPH SEALS "In vivo Probe Measurement Technique for Determining Dielectric Properties at VHF Through Microwave Frequencies ", IEEE transactions on microwave theory and techniques, VOL. MTr-28, NO. 4, APRIL 1980.

[8] Gang Kang, and Om P. Gandh, "Effect of Dielectric Properties on the Peak 1- and 10-g SAR for 802.11 a/b/g Frequencies 2.45 and 5.15 to 5.85 GHz",IEEE transactions on electromagnetic compatibility, vol. 46, NO. 2, MAY 2004

[9] G. Varotto and E. M. Staderini, "A 2D Simple Attenuation Model for EM Waves in Human Tissues: Comparison with a FDTD 3D Simulator for UWB Medical Radar", Proceedings of 2008 IEEE international conference on ultra-widebanb (ICUWB2008), vol. 3

[10] Balanis, C.,"Advanced Engineering Electromagnetics". John Wiley & Sons; USA, 1989; ch. 5.