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Research Article

Implantable Monopole Antenna for Bone Fracture Monitoring

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Abstract

A particular region of interest in the field of antenna is wearable antenna or implantable antenna. As the medical field is growing in the developing world the advancement of the devices in the medical field also grows, which increases the interest and opportunity for the implantable antennas. This type of antennas helps the physicians to diagnose and treat their patients in the most efficient manner. These antennas are light weight and easily wearable. The antenna designed here is implanted in the patient's body in the affected area. The antenna works at a frequency between 2.4 Ghz to 4Ghz range. The antenna uses two monopole antennas. The two monopoles are placed on either sides of the impaired area. The signal from the one monopole antenna reaches the other antenna. In the path between two poles the injury in the bone is present. As a matter of fact that each and every material have different dielectric constants, the system using these values to keep track on the healing process. As the antenna is designed for 2.4 Ghz, the monopole's length is about to be 3cm also the ground plane for the monopole antenna is designed for 4 x 3.4cm. So, this antenna will be more compatible to use. The S-parameter of the .port 1 and port 2 will help to keep track on the healing process of the bone.

1. Introduction

Bone fractures are grouped under the most common injuries in musculoskeletal injury. To diagnose bone fracture, there may be different techniques practiced across the world. The most widely used approach is the usage of x- radiation in which the exact whereabouts and seriousness of the fracture can be visualized for examining the image. Radiologists frequently facing the problem particularly in diagnosing, due to the poor image quality and other anatomical layers lying on above the other. In order to overcome this problem, many advanced computational perception and other modern day technologies like ML are established to enhance the obsolete method [1]. Moreover, applying xradition in bone breakage diagnosing isn't mostly probable. In previous decade, engrafted medical appliances have been improved developments in the experimentation branch of assessing human health. Medical works pictured in the publications predominantly works in the R_F bandwidth else at radio communication and medical-devices service (Med radio) aired at four hundred and one to four hundred and six MHz [2– 4] or can be at 2.4400 – 2.4600 MHz [5 - 7] within the I-S-M band. Generally the implanted ones are laid down beneath the skin layer otherwise within the muscle layered tissues. On account of body's sorely multiplexed design as well as lossy characteristics of the body's tissues, it is highly questionable in implanting devices; Additionally, bio-compatibility could also a problem [8].

In most of the cases non-invasive sensors comparatively more beneficial for continuous diagnosing purposes, as they render good comfort, robustness as well as a higher level protection from infection along with contamination [9, 10]. In inspite of so many advanced technologies in medical field, implantable device prosecution, especially on radiators it' been a tough thing. There can be many possibilities for performance deterioration which has been neutralized by di-electric coupling, and shock absorbing by physical body [11,12] and interlinings.

We can expect a slight constraints existed in Ultra-HF Radio-FID setup because of interference in contact with mobile frequency medium. The Ultra-HF Radio-frequency identification descriptions and values are explained[13] by EPC G-Class 01, And then the Generation-02 which specified many a things like ISO(29143) air divisions specifically in the case of Radio-FID mobile integrators, Finally the ISO (18,000-6C) along with ISO(18,000-6A) for direct method of execution [14]. Mobiles might one of the origins in case of an interference because of a double close waveband to Ultra-HF Radio-frequency identification system. The eight hundred Mega-Hz band of frequencies has been available in Spain plus some other European-Union countries for the use of 4th Gen LT-Evolution and nine hundred Mega-Hz band of frequencies for 3rd Gen GSMs particularly in remote places. The nearness of Ultra-HF Radio-frequency identification for brief scope of applications may generate few interferences, leading to deterioration of radio-signal behavior. This happened to be more true within the upper adjacent band because of out-of-band discretion created by wide band LT-Evolution systems [15].

This idea is establishing a good method for assessing the bone fracture non-invasively with the help of 50ohm UWB antennas. Two similar antennas are kept on either sides of the fractured portion as well as the s-parameters differences are depends on position of the breakage which benefitted in recruiting process. A basic cylinder-shaped pattern to recreate an human-arm kind of layout is taken into account for initial stage of investigation.

2. Models

The antenna system is built and then simulated with the use of CST Software (Computer Simulation Technology). The antenna used here is the Monopole antenna it is the class of radio antenna, we can simply say that it is λ/4 antenna. As the operating frequency is 2.4Ghz ,the length of each monopole is arrived as 3.125cm. The monopole's radius has simulated with 2mm radius as it will be more easy to use. The ground plane is 2cm x 2cm. The space between the ground plane and the monopole for inserting the port is calculated using the formula (lambda/100). By using this we get the port length as 1.25mm. With 50ohm impedance the system is simulated.

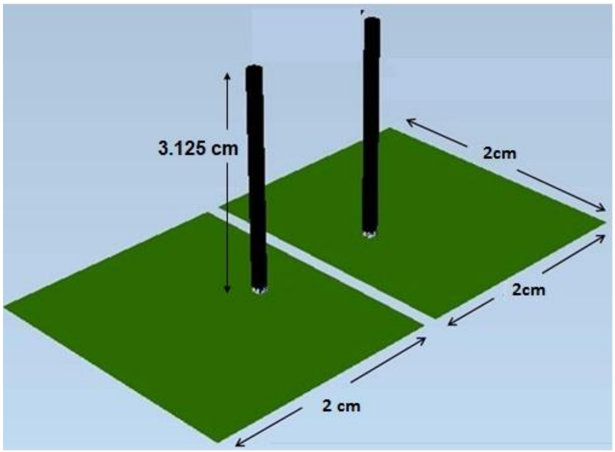

Figure 1: General representation of proposed antenna

A phanetom is designed to mimic the properties of human skeletal – muscular structure to witness the response of the antenna after implanting it in the injured area. The phantom is designed at 3Ghz of frequency to act similar t human body structure. Two monopoles are used to monitor the fracture. Two ports p1 and p2 are employed to excite both the monopoles.

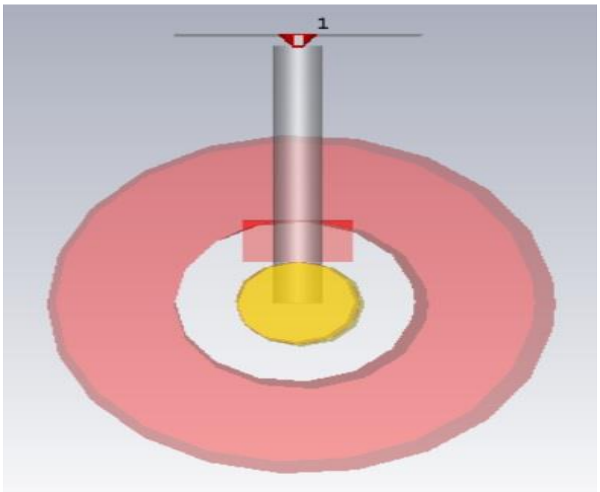

Figure 2: phantom with antenna side view.

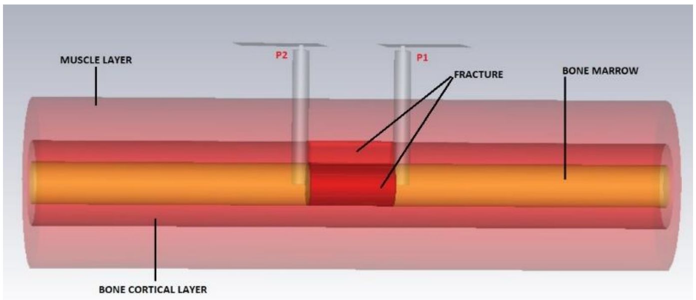

Figure 3: front view of the phantom with the fracture and antenna

The signal from the antenna has to pass through the injured areas as this area differs with dielectric constant values of bone-marrow, bone-cortical as well as muscle area which results in the frequency response variations of the two monopoles. The S21 parameter is used for monitoring purpose. The system is simulated between the range of 1Ghz to 10Ghz to obtain the S-parameter. As the phantom is designed at 3Ghz the frequency of resonance of the system is obtained at the 3.4Ghz as this frequency can penetrate the human body the system can work without any problem. The phantom model has the dimensions of 110mm x150 mm. The properties are given in the below table 1.

Table 1: Properties of Phantom

	Relative-permittivity (ϵ_r)	Conductivity (σ) (S/m)
Muscle	52.0500	3.0400
Bone- Marrow	5.2300	0.12
Bone- cortical	11.0600	0.50
Blood	57.350	3.040

The fracture region has varied values from the other parts of the phantom, it is represented in the below table 2.

Table 2: Properties of various stages of fracture

	Bone Marrow		Bone Cortical	
	($\in_r$)	σ (S/m)	($\in_r$)	σ (S/m)
100%	57.35	3.04	57.35	3.04
75%	44.32	2.31	45.77	2.40
50%	31.29	1.58	34.20	1.77
25%	18.26	0.85	22.63	1.13
0%	5.23	0.12	11.06	0.50

The simulated S21 results for the various stages of fracture is shown below figure.

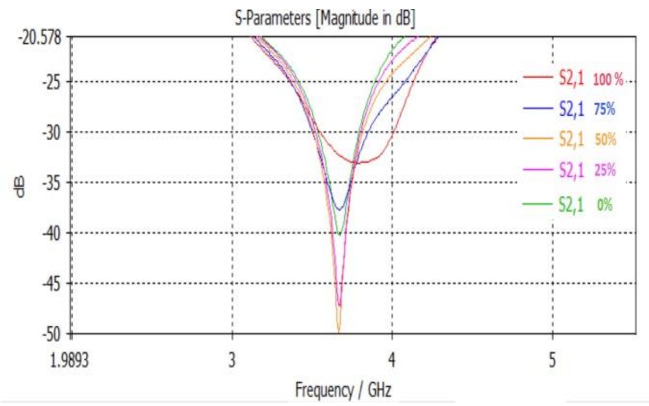

Figure 4: S21 parameter for various stages of fracture

In the above graph we can able to infer that the return loss for antenna is higher when the fracture 50% severe. This is because of the fact that as the injury heals the dielectric constant value changes due to the reason that calcium particles start to build inside the wound. But from the above graph we can say that when the injury is 100% the return loss is very low when compared to healed one.

We have also simulated the same system for the various length of gaps. This is because of the reason that all the fracture wounds do not have same amount gap between the particles and the obtained result is shown below.

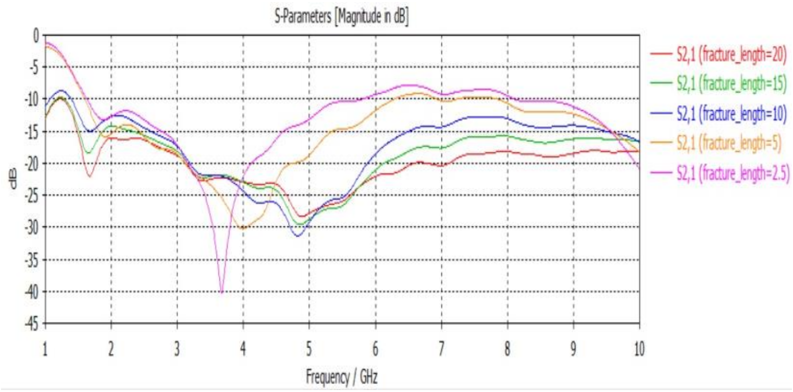

Figure 5: S21 parameter for the various fracture length

All the fracture lengths are simulated by considering the wound is 100% and the frequency response is obtained. From this graph we can infer that the antenna system works as expected as the space between the monopoles gets closer. So here we get the desired output at when the antenna is simulated with the gap of 0.25cm. And the radiation out graph has shown in the below diagram.

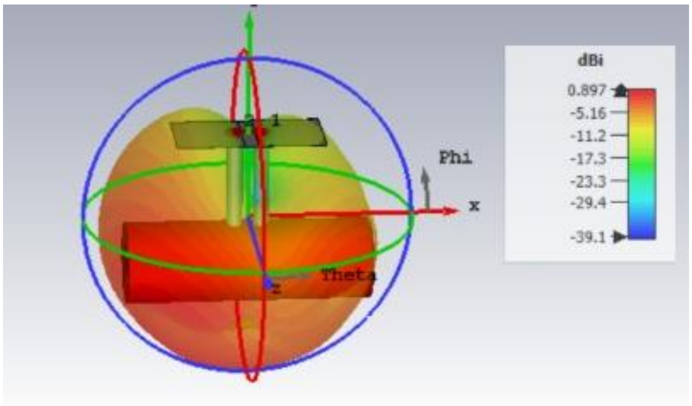

Figure 6: The Radiation pattern of suggested system

3. Conclusion

It can finally be pictured from the results that two similar Monopole antennas operating at the Ultra Wide Band (UWB) frequency will serve for the purpose of watching the bone wounds using S-Parameters. Reflection-coefficient and the tr-coefficients will be grouped into various stages of UWB f-band and these stages are useful for conducting bone fracture picturing. The suggested method can be very beneficial for bone-fracture diagnosing and analyzing.

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