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Absorption of Electromagnetic Radiation on Human Lower Back Region

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ABSTRACT

In this paper a simulation study is conducted on lower back region of human phantom to observe the absorption of electromagnetic (EM) radiation. To investigate the effectiveness, EM radiation with different frequencies (1-100 GHz) is administrated step by step in different tissue thickness (up to 25 mm) of lower back region of human phantom and using EM simulator HFSS, return loss (RL) is recorded at every stage. From the results, it is found that when radiation with frequency 0.899 GHz to 1. 089 GHz (~1 GHz) is applied return loss is varies from 0.413 dB to 1.022 dB in different thicknesses. This indicates that only 1.1 % of the incident power is absorbed maximally. When radiation of 9.899 GHz to 10.099 GHz (~10 GHz) frequency is applied, the return loss value obtained is 6.731 dB to 6.280 dB for different tissue thicknesses. This indicates that only 10.1 % power is absorbed maximally. Finally, when radiation with frequency 99.899 GHz to 100.1 GHz (~ 0.1 THz) is applied, the return loss value is found ranging from 26.902 dB to 26.429 dB in different thicknesses which indicates that almost 99.9% of the incident radiation is absorbed by the human tissue i.e. almost 100% of the incident radiation is absorbed in human lower back region in THz range. From therapeutic point of view, almost the entire incident radiation is attenuated to the lower back region with THz radiation which is clinically very useful in treating chronic low back pain.

Keywords: Back pain; infrared radiation; phantom; return loss; terahertz (THz); tissue

INTRODUCTION

Low backache is one of the most common medical disorders in industrialized societies (Koopman & Moreland 2005). Low back pain (LBP) has been estimated to afflict between 60% and 90% of individuals sometimes in their life, and is one of the leading causes of disability in people under the age of 45 years (Wilson et al. 1997). LBP is an uncomfortable sensation in the lumbar and buttock region originating from neurons near or around the spinal canal that are injured or irritated by one or more pathologic processes (Firestein et al. 2012). It is a common sickness which is related to of cause of inability to work in the western countries (Walker et al. 2014). Non-specific LBP of mechanical origin is the second common cause of self-limiting symptoms and the reflection of disability in the community (Ralston et al. 2018). Back symptom is also a common disability in patients under the age of 45 years (Jameson et al. 2018). Abnormalities in the lumbar spine are common, and degenerative changes virtually be found in all older people (Porter 1993). Management of LBP is not simple and may be refractory in many cases.

There are two main options for treatment- conservative (medicine, exercise and physical therapy) and surgery (Deyo 2007). Infrared radiation (IRR) that extends from the nominal red edge of the visible spectrum with wavelength 700 nanometers to 1 millimeter is used to reduce the pain. Radiation in the electromagnetic spectrum is absorbed by the human body as heat. Penetration of incident radiation takes place into 1 mm to 3 mm depth of the tissue and so used as a superficial heating agent. Different researchers have shown that infrared radiation with frequencies ranging from 3 GHz to about 400 THz can effectively be used in treating lower back pain. For example, Kahn (1994) described infrared radiation as modality for the treatment of pain at different sites of the human body. Kottke and Lahmann (1990) have described infrared radiation as modality for pain relief having penetrating power into the body tissue at specific depth (1 mm to 3 mm) and so can be used as a superficial heating agent (Kahn 1994; Kottke & Lehmann 1990). In a study, it was found that infrared radiation is helpful in Bell's palsy (Banu et al. 2017). Kahn (1994) gives a concept of producing heat within the deeper tissues by deep heating modalities like short wave diathermy (SWD), ultrasound therapy (UST) and microwave diathermy (MWD), beyond the reach of infrared, hot packs and other forms of superficial heat. Over the years the uses of SWD, UST and MWD have proven effective in reducing back pain and are also appreciated by clinicians and physicians (Deyo 2007). It is also thought that IRR can reach only to the superficial tissue that is up to 1 to 3 mm. On the other hand, Kahn (1994) and Carayannopoulos (2017) stated that IRR can raise the temperature by 1.3^0 C at a depth of 2 cm inside the tissue, which is very effective in reducing back pain. In a study, Shakoor et al. (2006) found that infrared radiation has beneficial effects on chronic neck pain. Actually, neck pain due to cervical spondylosis and chronic LBP because of lumber spondylosis occurs on account of same pathology. So, IRR may also be effective in chronic low back pain. But there are controversies about the absorption depth of IRR on human low back region.

In this paper, the result of a study that has been conducted to find out the absorption of electromagnetic radiation on low back region of human phantom in a specific frequency range is presented. To verify the penetration of the incident EM radiation, the thickness of the tissue layer has been varied from 0 to 25 mm and each step the return losses (reflection coefficients) have been recorded. From the observation, it is found that at the terahertz (THz) region almost the entire incident radiation is attenuated to the lower back region of the human phantom.

METHODOLOGY

The setup of the study is depicted in Figure 1. When a tranceiver (antenna) radiates an EM radiation towards a human phantom, it penetrates through the region of interest and produces scattering in different directions by the human tissues. The scattering level is proportional to the amount of mismatch in the dielectric properties of tissues during the wave propagation. This scattered signal can be received by the same tranceiver and be analyzed to capture the effective result of the incident radiation. The effectiveness of the wave in penetrating the human tissues depends upon how many percentage of the incident wave is reflected back to the transmitting tranceiver. Lower return losses (reflection coefficient) ensure the effectiveness of the incident EM radiation.

In this study, we used one tranceiver (antenna) for transmitting the wave and other one for the receiving of scatters as shown in Figure 1. A simple multi-layer human phantom is used which has the dielectric properties that are similar to the human lower back region. In human lower back region, the first layer is epidermis (averages thickness is 1 to 4 mm), second layer is dermis (average thickness is 2 mm), third layer that contain fat is subcutaneous (averages thickness is 1.65 mm to 18.20 mm) and the last layer is the muscle layer. The average thickness of human lower back region varies from 25 mm to 30 mm and that is why in this study we have varied the phantom thickness from 5 mm to 25 mm. High Frequency Simulation Software (HFSS) is used to perform the simulation.

STAGES AND PROCEDURE

As the frequencies of infrared radiation used in the treatment of chronic low back pain ranges from 3 GHz to about 400 THz, in this study electromagnetic radiation of frequencies ranging from 1-100 GHz is applied in different tissue thickness of lower back region of human phantom and return loss (RL) is measured in every stage.

At the very 1st stage, electromagnetic radiation of frequency 0.899 to 1.089 GHz is applied to the phantom and the phantom thickness varies from 5 to 25 mm. In the 2nd stage, we applied radiation of frequency 9.899 to 10.099 GHz to the human phantom. Finally radiation of frequency ranging from 99.899 to 100.1 GHz is applied to the phantom and in every case the return losses are recorded. In all cases the tissue thickness is same and varies in a step of 5 mm.

RESULTS AND DISCUSSION

Frequency of electromagnetic radiation and corresponding dielectric constant and conductivity of transverse muscles in the lower back region of human body are tabulated in Table 1 (Gabriel 1996). Dielectric constant is the ratio of permittivity of a substance to the permittivity of free space. In other words, it is the ratio of the amount of electrical energy stored in a material by an applied voltage, relative to that stored in a vacuum. Permittivity is a material property that affects the Coulomb force between two point charges in the material. Relative permittivity is the factor by which the electric field between the charges is decreased in comparison to vacuum. Relative permittivity as presented in Table-1 is also commonly known as dielectric constant, a conventional term in physics and engineering as well as in chemistry and is used as input during the simulation of this study.

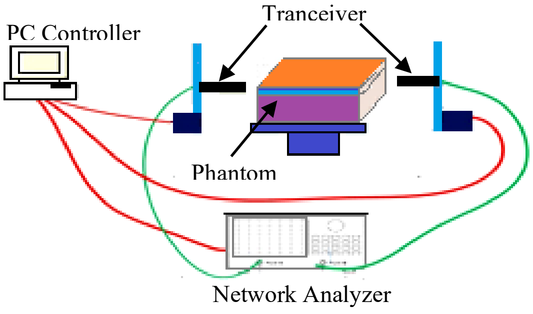

FIGURE 1. Setup for simulation

Return loss for different thickness at a frequency around 1 GHz: It is found that when EM radiation with frequency 0.899 GHz to 1. 089 GHz is applied; the return loss varies from 0.413 dB to 1.022 dB for different tissue thickness as shown in Figure 2. This indicates that only a fraction of incident radiation is absorbed maximally that means in this frequency, radiation is not at all clinically important for reducing sign and symptom of lower back pain.

Return loss for different thickness at around 10 GHz: When radiation with frequency 9.899 GHz to 10.099 GHz is applied the return loss value lies between 6.731 dB to 6.280 dB for different tissue thickness as displayed in Figure 3. This indicates that about 60 - 70 % incident radiation is absorbed maximally that is in this frequency radiation is to some extent clinically important for reducing sign and symptom of low back pain.

Return loss for different thickness at around 100 GHz: When radiation with frequency 99.899 GHz to 100.1 GHz is applied step by step, it is found that the return loss value is ranging from 26.901 dB to 26.429 dB in different tissue thicknesses as depicted in Figure 4. This indicates that about 99 % of the incident radiation is absorbed. This is an indication that when electromagnetic radiation having Terahertz frequency (Infrared radiation) is applied, the return loss will be less than 26.43 dB and it will be increased with the frequency. That means the power will be absorbed ~100% in human lower back region in THz range and in this frequency radiation is clinically very important for reducing sign and symptom of chronic low back pain.

The return loss of EM waves in GHz range for different tissue thickness of lower back region shows that the return loss decreases i.e. absorption increases with the increase in frequency and reaches the maximum at around 100 GHz for all thicknesses of tissues of human lower back region as observed from Figure 5. If the frequency of electromagnetic wave increased beyond 100 GHz i.e. to THz region, similar results will be obtained.

In this study, it is observed that absorption of EM radiation increases with the rises in frequency and reaches the maximum at around 100 GHz for all thicknesses of tissues of human lower back region. That means almost 99.9% of the incident radiation is absorbed by the human tissue when radiation is applied at the frequency of 100 GHz. In therapeutic point of view, it can be pointed out that as the entire incident radiation is attenuated to the lower back region, this radiation is clinically useful in treating chronic low back pain. In an experimental study, Shakoor et al. (2006) showed that both infrared radiation (IRR) and cervical traction have useful effect on Cervical Spondylosis. In this study, it is found that radiation is well absorbed in 25 mm thickness and hence be helpful for the patients with LBP. It is also found in this study that absorption is about 100 % when frequency of the applied EM radiation varies from 99.89 GHz to 100.1 GHz i.e. in THz region. This also supports that the IRR administrated to lower back region of the patients is absorbed maximally and give good clinical results in reducing low back pain (Rao 2014). In an another study, Gale et al. (2006) performed a double-blind placebo control trial by using infrared radiation on the patients with chronic low back pain and found that there was a 50% reduction of back pain. This is also support that radiation in the terahertz region like IRR can be effectively used to reduce chronic low back pain (Wilmink & Grundt 2011).

TABLE 1. Dielectric constant and conductivity for different frequencies of transverse muscles in the LBR of human body (Gabriel, 1996).

Frequency (Hz)	Dielectric Constant	Conductivity (Siemens/m)
1.00×10^{1}	3.00×10^{7}	2.00×10^{-1}
1.00×10^{2}	1.24×10^{7}	2.50×10^{-1}
1.00×10^{3}	5.00×10^{5}	2.80×10^{-1}
1.00×10^{4}	2.00×10^{4}	3.20×10^{-1}
1.00×10^{5}	1.00×10^{4}	4.00×10^{-1}
1.00×10^{6}	1.80×10^{3}	5.00×10^{-1}
1.00×10^{7}	1.60×10^{2}	6.00×10^{-1}
1.00×10^{8}	8.00×10^{1}	8.00×10^{-1}
1.00×10^{9}	5.00×10^{1}	1.20×10^{0}
1.00×10^{10}	3.00×10^{1}	1.20×10^{1}
1.00×10^{11}	9.66×10^{-1}	1.59×10^{1}
1.00×10^{12}	1.87×10^{-1}	2.15×10^{1}
1.00×10^{13}	3.61×10^{-2}	2.71×10^{1}
1.00×10^{14}	6.98×10^{-3}	3.27×10^{1}

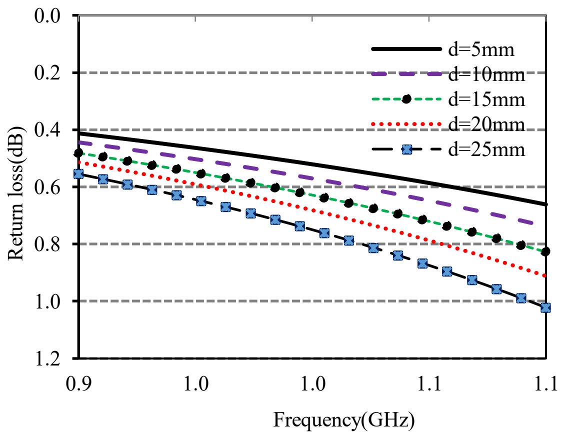

FIGURE 2. Return loss for different thickness at around 1 GHz

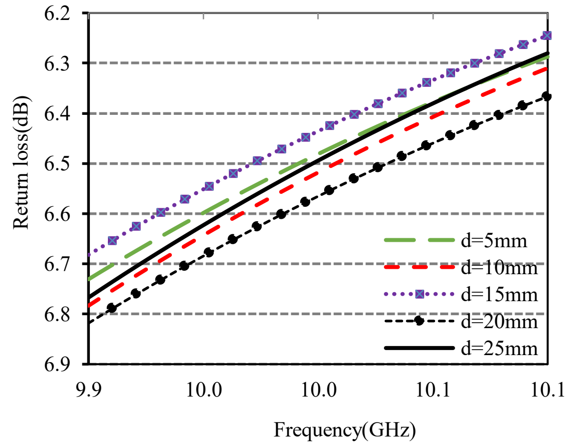

FIGURE 3. Return loss for different thickness at around 10 GHz

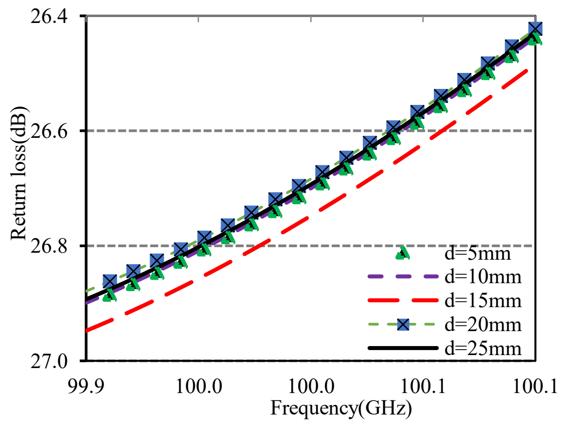

FIGURE 4. Return loss for different thickness at around 100 GHz

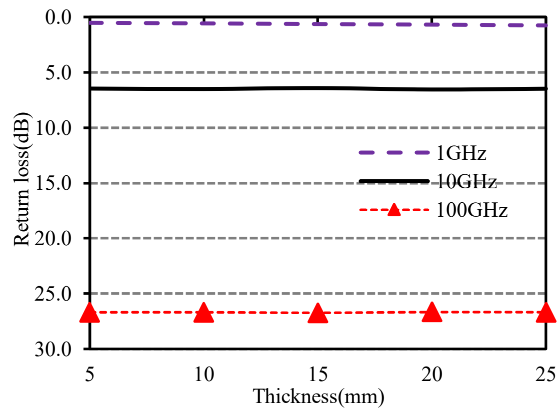

FIGURE 5. Return loss curves in GHz range for different tissue thickness of lower back region

CONCLUSION

The absorption of electromagnetic radiation into lower back region of human phantom has been observed in this paper. To see the effectiveness, radiation with different frequencies (1-100 GHz) is directed in different tissue thickness (up to 25 mm) of lower back region of human phantom. From the study, it is observed that the absorption increases with the increment of frequency and reaches the maximum at around 100 GHz for all thicknesses of tissues which indicates that almost 99.9% of the incident radiation is absorbed by the human tissue when the frequency of the radiation is in the vicinity of 100 GHz (0.1 THz). Therefore, it can be concluded that at GHz and THz region almost the entire incident radiation is attenuated to the lower back region and hence radiation like IRR is very useful in treating chronic low back pain.

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DECLARATION OF COMPETING INTEREST

None.

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