Analytic Study on the Antenna Insulating Layers for Highly Reliable Wireless Biotelemetry

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Recently, the interest in the wireless biotelemetry technology for the implants grows explosively along with the increased human life expectancy. Especially, the study and treatment of the brain diseases through analysis of the brain signal gain the greatest attention. However, it is very challenging to implement reliable wireless interface for the brain implants. It is because the signal level is very low of just a few microvolts or millivolts, the surrounding environment is very noisy, the battery life is limited, and the size of the implanted device is restricted. Each part of the platform should be studied thoroughly for this reason, and the optimal radiating mechanism is worth to study from the antenna point of view. The effect of the essential biocompatible insulating layer was analyzed using the mode matching technique for the MedRadio band of 403.5 MHz (F. Merli, et al., *IEEE Trans. Antennas Propagat.*, 59, 21-31, 2011). In our work, we investigate the influence of the insulating layer of the implanted antenna in the human brain for the MedRadio and ISM bands and search for its optimal values for the reliable wireless transmission using the spherical wave theory.

We first model the insulated antenna immersed human head as the multi-layer spherical shell problem. Using the spherical wave expansion for the small antennas, the closed form expressions are derived for the power transmission efficiency (PTE, or $|S_{21}|^2$) between the two antennas separated by the lossy mediums of the human head and the insulator. The derived expressions for the TM_{10} mode and the TE_{10} mode radiations are verified using the numerical EM simulator FEKO.

Using the derived expression, it is found that the thickness of the insulating layer has a greater influence on PTE than the type of the biocompatible material at 5.8 GHz. Moreover, being different from the MedRadio band case, the TM_{10} mode shows superior PTE value to the TE_{10} mode. At 2.4 GHz, it is observed that the best radiation mode is dependent on the thickness of the insulating layer. We also search for the optimum thickness and permittivity of the insulator at 5.8 GHz with the constraint of the maximum size of the antenna. The antenna position is fixed for this search. The TM_{10} mode dipole having an antenna size of 13 mm (insulator thickness: 4.5 mm, permittivity: 12.5) achieves the highest PTE. As is well known, the magnetic dipole or the TE mode radiator is advantageous for the implanted antennas, but it only holds true under certain conditions. Therefore, depending on the target frequency, antenna radiation mode and the optimum insulator design are better to study as a means of increasing the reliability in the wireless biotelemetry implementation.