RF to Microwave Measurements and Methods on Several Tissue-Equivalent Materials

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For a variety of applications it is useful to have synthetic materials that match the effective electrical properties of the human body. Applications of tissue-equivalent materials are important in such areas as cancer research, implantable device modeling, cell phone studies, through the wall imaging, and inverse scattering studies. In this paper we discuss both permittivity measurement methods and measurements on a number of materials that could be used for this research. Over the years there have been many measurement methods used to characterize the electrical properties of tissue-equivalent materials. In this study we used a suite of open-ended coaxial probes of varying diameters and coaxial lines to measure the candidate materials from rf to microwave frequencies. Over the years there have also been many materials used to simulate the electrical properties of the human body. In this study we concentrated on agarose-based and carbon-black materials. The loss mechanisms in these materials are fundamentally different. The agarose materials contain water, salts, and a polymer to achieve the required properties. In agarose materials the electrical loss is due to ionic conduction. In carbon-black materials the conductivity is due to a percolation phenomena. As a result, near the percolation threshold the conductivity can change abruptly as a function of the carbon black added to the polymer. We found that carbon black materials could be engineered to simulate tissue, but the manufacturing process is time consuming. In some applications the measurement of the real part of the permittivity is the most important, in other applications the lossy or imaginary part is of primary significance. We found that we could vary both the loss and the real part of the permittivity easily with the agarose-based materials.