Multi-frequency Microwave Radiometry for Non-invasive Temperature Measurement

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Desirability for noninvasive measurement of temperature distributions in a human body has been advanded in the field of hyperthermic cancer treatments for the last ten years. However, no methods have been developed to a level sufficient for clinical use.

In this thesis, multi-frequency microwave radiometry is studied to develop a non-invaseve method of measuring temperature-versus-depth profiles in a human body. An expression for the relationship between temperature distribution in a tissue and brighness temperature observed at the body surface by a milti-frequency microwave radiometer is derived using a plane-parallel three-layer tissue model consisting of the skin, fat, and muscle. A temperature-versus-depth profile is to be retrieved from a set of the brightness temperatures. This temperature retrieval process constitutes a typical ill-conditioned inverse problem. In order to obtain stable solutions to the inverse problem, a temperature distribution model function is introduced, which is characterized by five (or three) unknow model parameters. The temperature distribution model function is then fitted to unknow actual distribution by applying the least-square method to brightess temperatures predicted by the model and those obtained by the measurements. Since the brigtness temperature measurements suffer from relatively large measurement errors, effect of the meassurement errors on the estimated temperature profiles are evaluated through a statistical consideeration of the measurement errors. The final form of the solution is a temperatuve-versus-depth profile with a confidence interval at a depth at a specified confidence level. This method of data analysis permits a comparison between the systamatic errors in model-fitting and the radom errors in measurements which, in turn, gives a measure of the degree of fit of a particular model function employed in the analysis.

To test the capability of radiometry, an experimental 3- or 5-band radiometer system operating over a 1-4GHz range has been developed.

Using this microwave radiometer system and the data analysis procedure described above, temperature measurement experiments were performed on phantoms and anesthetized animals (rabbits). Results of the experiments showed that radiometric measurements agreed well with thermocouple or fiber optic thermometer readings. The results obtained in this thesis work warrant further investigations on the multi-frequency microwave rediometry to develop a method of non-invasive temperature measurement.