

Microwave Characterization of Human Blood using Dielectric Waveguide Measurement System

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ABSTRACT

This paper gives the design and development of a nondestructive method for measuring the complex permittivity of human blood from healthy volunteers using rectangular dielectric waveguide (RDWG) measurement system in the frequency range of 9 – 12 GHz. The human blood is placed in a Plexiglas sample holder and values of the complex permittivity of samples were computed from measured reflection (S_{11}) and transmission (S_{21}) coefficients. TRL calibration technique and time-domain gating feature in the vector network analyzer were used to eliminate errors due to multiple reflections in the RDWG measurement system.

INTRODUCTION

The use of microwave is increasing and prevalent in various applications [1] and there is a growing concern about the possible health hazards and the possibility of non-thermal effects to the users and environment. Thus, there is a need to study the interaction of microwave with living organisms, especially, its effect on biological materials.

An essential element in the study of possible health hazards caused by microwave is the calculation of the absorbed energy by humans and animals. The amount of energy absorbed is a function of the complex permittivity of a material [2]. Hence, it is crucial to know the dielectric properties of biological materials and the various constituents thereof.

Various measurement techniques [3] – [9] can be adopted to measure the complex permittivity of a material and the chosen technique depends on various factors such as the nature of the sample and the frequency range used. In this study, rectangular dielectric waveguide was used for dielectric measurements because this measurement technique requires minimum amount of sample. Using this approach, the sample is placed inside the Plexiglas sample holder and the measurement could be done in a fast and efficient manner, as cited by Abbas et al [7 - 8]. This measurement technique is nondestructive in nature.

In the past, dielectric properties of human blood were reported by several researchers [10 - 12] at microwave and millimeter wave frequencies. In this paper, dielectric properties of human blood are measured by the RDWG measurement system in the frequency range of 9 to 12 GHz.

MEASUREMENT SYSTEM

The rectangular dielectric waveguide (RDWG) measurement system for transmission and reflection measurements is as shown in Figure 1. This measurement system consists of RDWGs, standard-gain horn antennas, coaxial cables and WILTRON 37269B vector network analyzer (VNA) [8]. The sample holder is placed in direct mechanical contact between two RDWGs. The standard metallic waveguide (WR-90) carrying TE_{10} mode is used as a launcher for the RDWG. For launching electromagnetic waves in RDWG, it is double-tapered at one end and inserted into the WR-90 waveguide through standard-gain horn antennas. The length of RDWG beyond the horn antenna is 5.6 cm and tapering of RDWG in the feed section reduces reflections. The dielectric material used for RDWG is made of poly-tetra-fluoro-ethylene (PTFE). Its cross sectional area is

22.86 mm x 10.16 mm which is same as the standard metallic rectangular waveguide (WR-90). PTFE material is chosen because it has low dielectric constant (2.08) and very low loss.

The internal TRL (through, reflect, line) calibration model of VNA is used for calibration of RDWG measurement system. The *through* standard is realized by keeping the distance between two RDWGs equal to zero. Reflect standards for port 1 and port 2 are obtained by mounting a metal plate between transmit and receive RDWGs. The line standard is achieved by separating two RDWGs by a distance which is approximately equal to quarter wavelength at the mid-band frequency. After TRL calibration, the through standard was measured. The amplitude and phase of S_{21} (or S_{12}) was within 0.00 ± 0.06 dB and $0.0 \pm 0.8^\circ$, respectively. For the metal plate, the amplitude and phase of S_{11} (or S_{22}) were 0.00 ± 0.06 dB and $180.0 \pm 1.9^\circ$, respectively.

Accuracy of the RDWG measurement system was verified by measuring complex permittivities of samples of known dielectric properties such as ethanol, methanol and deionized water.

SAMPLE PREPARATION

The blood samples were extracted from members of research group at the Institute of Biotechnology, UiTM, Shah Alam, Selangor, Malaysia using syringes and stored in EDTA-treated sealed test tubes at 4°C in order to prevent coagulation. Fig. 2 shows the Plexiglas sample holder. It consists of two Plexiglas plates of 4.6 mm thickness which is quarter wavelength at 10.0 GHz. The dielectric constant of Plexiglas material is measured by a free-space method [4] and its value is 2.65 at 10 GHz.

For measurement purposes, the blood is placed in the Plexiglas sample holder. The thickness of the human blood sample is 1.85 mm.

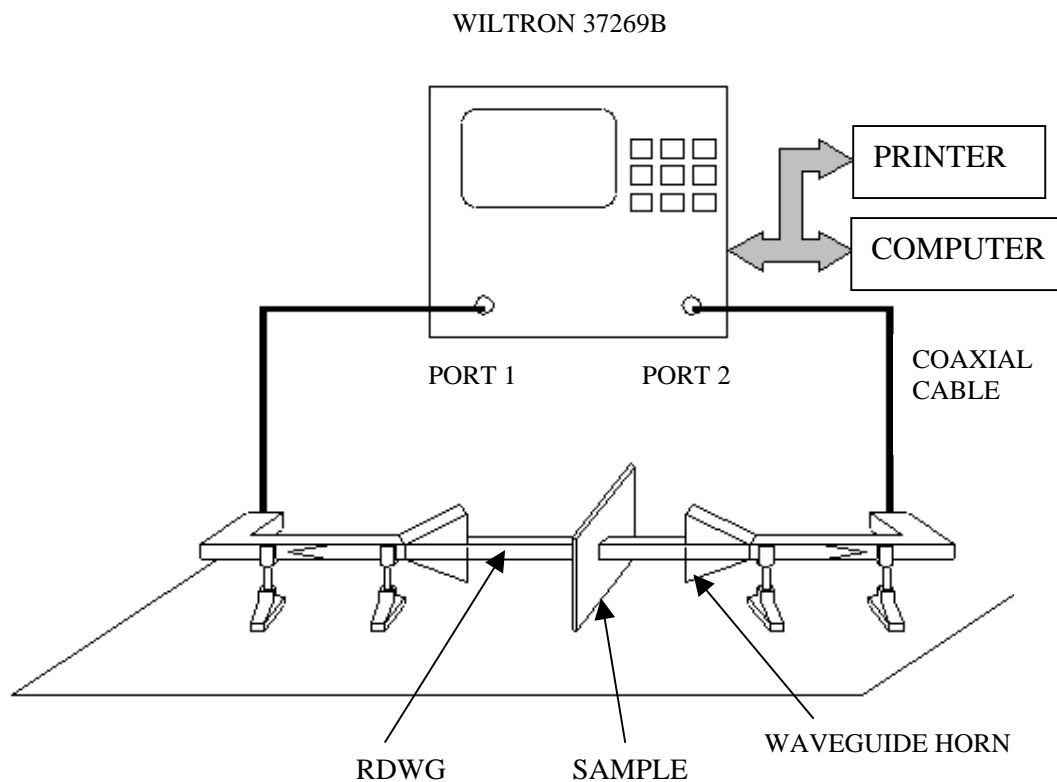


Figure 1: Rectangular dielectric waveguide (RDWG) measurement system

EXPERIMENTAL RESULTS

After performing TRL calibration for the RDWG measurement system, S_{11} and S_{21} parameters were measured for the Plexiglas sample holder containing human blood. In this research, it was assumed that the complex permeability of the sample is $\mu_r = 1 + j0$. After removing the effect of Plexiglas plates [3], S_{11} and S_{21} are calculated for the human blood sample. Then, transmission (S_{21}) only method [9] is used to calculate complex permittivity of human blood. Figure 3 illustrates the measured and calculated complex permittivity results at 25°C. Debye parameters reported by Ghodgaonkar [10] were used to obtain calculated values of complex permittivities of human blood. The single Debye equation was implemented by a program written in MATLAB.

CONCLUSIONS

From experimental results, it was found that measured and calculated results for human blood are in good agreement. So, RDWG measurement system can be used to measure complex permittivity of biological materials such as human DNA. Also, RDWG measurement system can be use in other frequency ranges.

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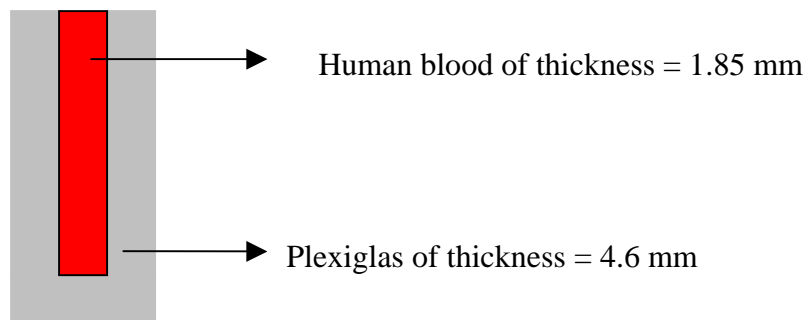


Figure 2: Plexiglas Sample Holder

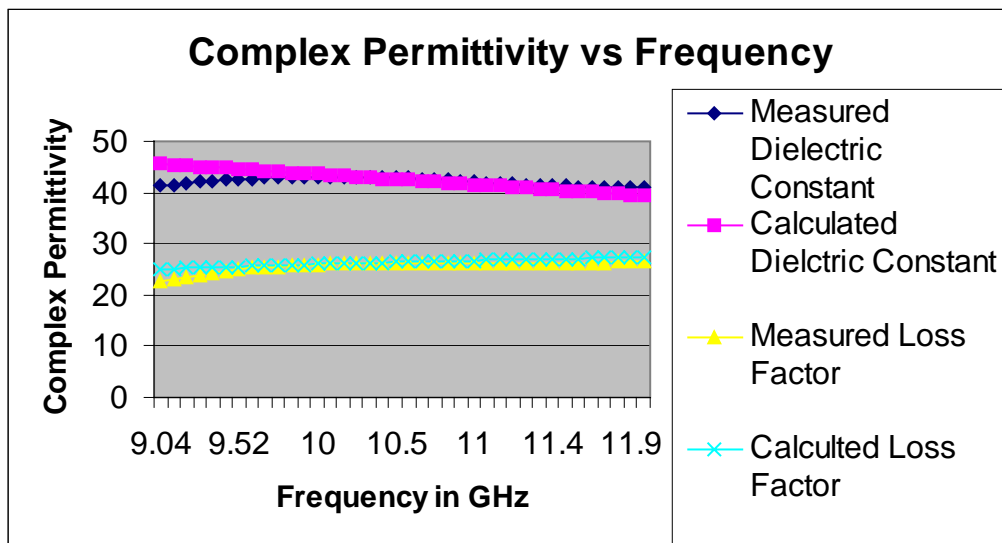


Figure 3: Measured and calculated complex permittivity of human blood.