Dielectric properties of human skin at an acupuncture point on 50-75 GHz

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INTRODUCTION

Millimeter wave therapy (mmWT) commonly applies 42.2 GHz, 53.6 GHz and 61.2 GHz waves in the treatment of a large variety of diseases. The reason for using acupuncture points as exposure sites in mmWT has been unclear. Some studies carried out at DC or at low frequencies suggested an association between acupuncture points and reduced electrical impedance, yet with insufficient evidence, according to [1]. A difference in optical properties between acupuncture points or meridians compared to surrounding skin has also been reported: increased light absorption [2] and different light propagation and reflectance [3].

The aim of this human pilot study was to test whether an acupuncture point could exhibit different dielectric properties (DP) than surrounding skin in the frequency range from 50 to 75 GHz, by measuring complex reflection coefficients and applying appropriate analyses.

MATERIALS AND METHODS

Measurement of the reflection coefficient Γ: Γ was measured at the skin surface using an open-ended rectangular waveguide technique. A Rohde & Schwarz ZVA50 vector network analyzer equipped with a ZVA Z75 millimeter wave extender comprising a standard flanged V-band waveguide was utilized. A standard calibration was performed at the waveguide aperture. We used a quarter-wavelength (at mid-band) Teflon plug (impedance transformer) to get good measurement stability and sensitivity of Γ in phase and magnitude, as explained in [4]. The pressure of the Teflon-filled aperture on the skin had no detectable influence on Γ.

Probe model and calculation of DP: The real ε_r' and imaginary ε_r'' parts of the complex permittivity were reconstructed from Γ at the aperture of an open-ended rectangular waveguide radiating into a lossy dielectric half-space, as modeled in [5] and adapted to take into account the Teflon plug. A solving procedure was implemented using Matlab.

Experimental procedure: Ten healthy volunteers participated in the study. We chose the so-called PC4 acupuncture point (Pericardium Meridian of Hand) on the forearm. Because the location of acupuncture points is not anatomically defined with a high precision, we measured and averaged 9 spots: one at the alleged acupuncture point and 8 spots immediately around it in a rectangular area of about 6 mm × 12 mm made of 3×3 aperture-sized rectangles. Choosing only one control site could create differences not necessarily due to the presence of an acupuncture point. Therefore two comparable control sites were chosen, *a priori* expected to have similar properties: one 2.5 cm away from the acupuncture point on the same forearm, and the second one on the other forearm, symmetric from the first control. The arm at which the acupuncture point was measured, as well as the order of the measurements, were randomized.

Statistical analyses: Due to the uncertainty in the location of the acupuncture point and because 9 spots were averaged, significance levels of statistical tests were set at 0.1. Firstly, a one-way within-subject analysis of variance (repeated measures ANOVA) was carried out to compare the three sites among all subjects, for both ε_r' and ε_r''. Further, the Bonferroni t-test was used for multiple comparisons (which set the significance level at 0.033). Secondly, we compared the sites two by two, calculating for each subject, pair-wise percentage variations of ε_r' and ε_r''. The statistical significance of each percentage variation considered across the 10 subjects was evaluated by performing a two-sided single-sample t-test.

RESULTS

On average, ε_r' of the acupuncture site was found to be lower by 5% and ε_r'' to be higher by 2.5% when compared to the two controls. The repeated measures ANOVA revealed a statistically significant difference amongst the means of the three groups for ε_r' ($p < 0.1$) at frequencies below 61 GHz, but not for ε_r'' ($0.1 < p < 0.3$). Further multiple comparisons for ε_r' showed that the two control sites were not statistically different ($p > 0.6$), as well as the acupuncture site and the control on the other arm ($0.1 < p < 0.2$). But the acupuncture site and the control site on the same arm were statistically different up to about 60 GHz ($p < 0.033$).

The t-tests relative to percentage variations of ε_r' and ε_r'' showed no statistically significant difference between the two control sites. However, a statistically significant difference regarding both ε_r' and ε_r'' was found between the acupuncture site and the control site on the same arm up to around 65 GHz ($p < 0.1$). The difference between the acupuncture site and the control on the other arm were not statistically significant (yet $0.1 < p < 0.2$).

In all cases, the p-values relative to the comparison of both controls were mostly much higher than the ones relative to the comparison of the acupuncture site and either control site.

CONCLUSIONS

This study showed that the DP (notably ε_r') of the PC4 acupuncture site may be different from those of surrounding non-acupuncture sites at frequencies from 50 to about 65 GHz. The distinctive characteristic of this study is that it involved two control sites, and they were found to be statistically indistinguishable. The possible benefit of using acupuncture points in mmWT, if any, is consistent with our observation of a possible difference in skin DP at these points at frequencies used in mmWT. Our data justify more investigations with more subjects, more acupuncture points and an extension towards lower GHz frequencies.

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REFERENCES

[1] A.C. Ahn, A.P. Colbert, B.J. Anderson, O.G. Martinsen, R. Hammerschlag, S. Cina, P.M. Wayne, H. Langevin. Electrical properties of acupuncture points and meridians: a systematic review. *Bioelectromagnetics*, 29: 245-56, 2008.

[2] H. Lazoura, M. Cohen, E. Lazoura, I. Cosic. Do acupuncture points have different absorption properties to laser light than surrounding skin? *2nd Intern Conf on Bioelectromagnetism*, Melbourne, Australia, 1998.

[3] C. Choi, K.S. Soh, S.M. Lee, G. Yoon. Study of propagation of light along an acupuncture meridian. *J of the Optical Society of Korea* 7(4): 244-7, 2003.

[4] D.K. Ghodgaonkar. Measurement of complex permittivities of biological materials and human skin in vivo in the frequency band 26.5 – 60 GHz. *PhD dissertation, Dept. of Elec. Eng., University of Utah*, 1987.

[5] S.I. Ganchev, S. Bakhtiari, R. Zoughi. A novel numerical technique for dielectric measurement of generally lossy dielectrics. *IEEE Trans Instrum Meas* 41(3): 361-65. 1992