This is Your Brain on 5G

Peter H. Siegel[1], David H. Gultekin[2]
[1]THz Global, La Canada, CA, USA 91011
[2]Columbia University, New York, NY, USA 10027

***Abstract*— The rapid expansion of 5G wireless communication networks has spurred renewed concerns regarding the interactions of these higher radio frequencies (RF) with living species. In this study we examine in detail the relationship between RF exposure levels, absorption and diffusion in ex vivo bovine brain tissue and a brain simulating gel at 1.9 GHz, 4 GHz and 39 GHz as relevant to the current (4G) and upcoming (5G) spectra.**

I. Introduction

UPCOMING implementation of fifth generation (5G) wireless communication systems will greatly expand the available radiofrequency (RF) spectra and bandwidth, and correspondingly, the number of RF devices connected and in use. By necessity, this will greatly increase the already ubiquitous RF exposure that is now present on all living species, wherever wireless technology is employed. The fact that 5G is based around new and significantly higher frequency sources with dramatically different focusing and penetration properties in tissues makes it essential to understand and quantify the absorption, reflection and scattering properties of such radiation in and on biological tissues as a function of frequency, power and exposure time in order to provide fundamental guidelines for release of the technology, setting public safety standards and national and international standards and policies.

II. Results

In this presentation we employ standard RF waveguides with well-defined field and power patterns for coupling calibrated RF power at each of three representative 4G and 5G frequencies (1.9, 4 and 39 GHz) into fresh ex vivo bovine brain tissue and a tissue simulating gel. We derive accurate incident power dependent temperature coefficients (*dT/dP*) as a measure of exposure applicable to all of these wavelengths. We also compare the heating characteristics of brain tissue with the gel and show that there is a very strong deviation in the response of the gel and the brain tissue at the higher 5G frequencies. We observe that brain tissue has a much broader linear range of radiation absorption and subsequent temperature rise (Fig.1). This finding negates some of the advantages of using such tissue simulating gels when evaluating thermal transport effects in the millimeter-wave bands. The high precision experimental *dT/dP* data tabulated from the brain tissue and gel measurements at frequencies of 1.9, 4, and 39 GHz, over exposure times up to 30 minutes and depths of 1 to 21 millimeters can be used to accurately predict the magnitude of heating over a wide range of power levels and help to elucidate, and extend downwards, the boundaries between designated thermal and nonthermal regimes. Our simple, but highly accurate thermal measurement method is believed to be one of the most sensitive experimental demonstrations for ex vivo brain tissue and has a detection threshold of 1 mW at 39 GHz and can record a temperature change of less than 0.1ºC [1]. We examine the RF beam penetration, absorption and diffusion at our three representative 4G and 5G frequencies, and show that the impact of RF heating increases rapidly with increasing frequency at every depth studied and raises the temperature of the hotspots by 0.5, 3 and 60ºC in the brain tissue at 1.9, 4 and 39 GHz respectively, with only 1W of incident power and an exposure time of only a few minutes. Our measurements are supported by finite difference time domain (FDTD) simulations showing in detail, the distribution of RF source power with depth and surface area in the brain tissue. We also show experimentally the effects of rapid pulsing of the RF power at different frequencies (pulse lengths of 1 µs, 1 ms and 1 s at 50% duty cycle) and single pulses with short (1 s) and long (30 s) pulse duration with on/off RF cycles in both brain tissue and gel.

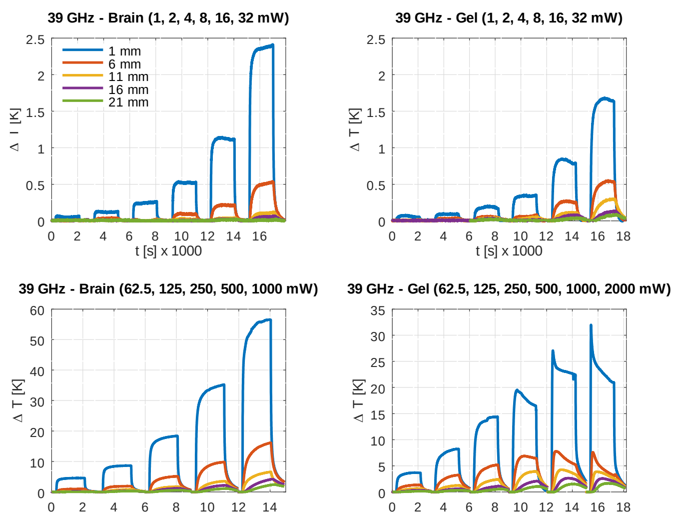

Fig. 1: The experimental temperature rise (dT) vs. time (t) and power (P) for brain (left) and gel (right) at 39 GHz. The curves correspond to temperature measurements at the power levels of 1, 2, 4, 8, 16, 32, 62.5, 125, 250, 500, 1000 and 2000 mW and depth of 1, 6, 11, 16 and 21 mm, respectively.

III. Summary

The talk will cover very extensive RF exposure measurements on brain and gel samples at 4G and 5G frequency bands (including CW and pulsed exposures with varying duty cycles, pulse lengths and power levels from 1 mW to 2 W, and exposure time), FDTD simulations of the incident power and field distribution in the samples, and derivations of the linear thermal coefficients (*dT/dP*) for the brain tissue and gel samples. The conclusions are surprising and will help set the groundwork for future 5G exposure studies in tissues.

References

[1] David H. Gultekin and Peter H. Siegel, “Absorption of 5G Radiation in Brain Tissue as a Function of Frequency, Power and Time,” IEEE Access, vol. 8, pp. 115593-115612, 2020.