Thermal Effects of Terahertz-Band Radiation on Heart Tissue

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Abstract

The terahertz (THz) frequency band has shown exceptional promise in wireless communication. Its superior data transfer speeds and non-invasive nature, among other advantages, have the potential to unlock vast possibilities in 6G and 7G technologies, including mobile devices, environmental monitoring, and healthcare. One particular application in the medical field is biomonitoring devices for the heart. We explore this application in our project, which aims to ensure the safety of THz radiation when interacting with human cardiac tissue. To do this, we extended an existing computational model in COMSOL Multiphysics© by developing both 2D and 3D models of the human heart to simulate the wave propagation and thermal effects of THz waves in cardiac tissue. These models help define safe limits for THz radiation in next-generation biomedical devices, accelerating the advancement of wireless networks.

Background

- Next-generation wireless communication (6G and 7G) will use terahertz-band radiation
    - Non-ionizing (doesn't break molecules)
- Goal: ensuring THz waves are safe in human body before implementation → our focus is the heart

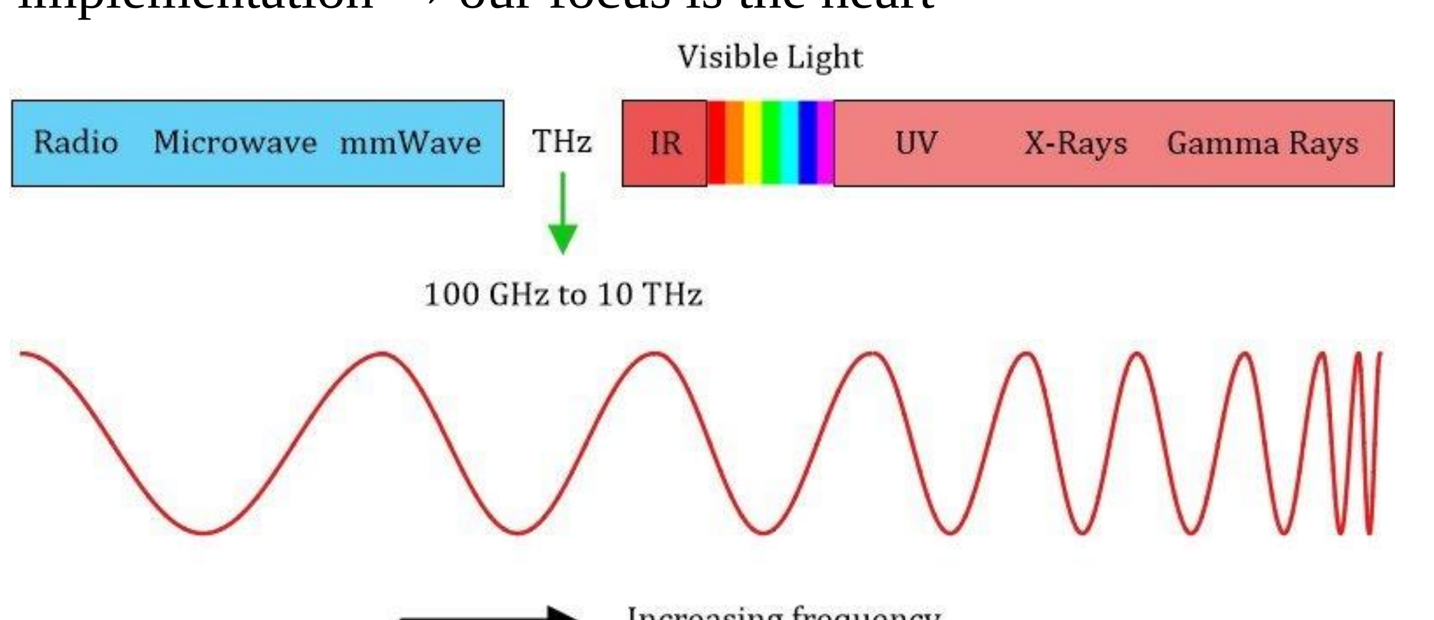

Figure 1: The THz band in the electromagnetic spectrum.

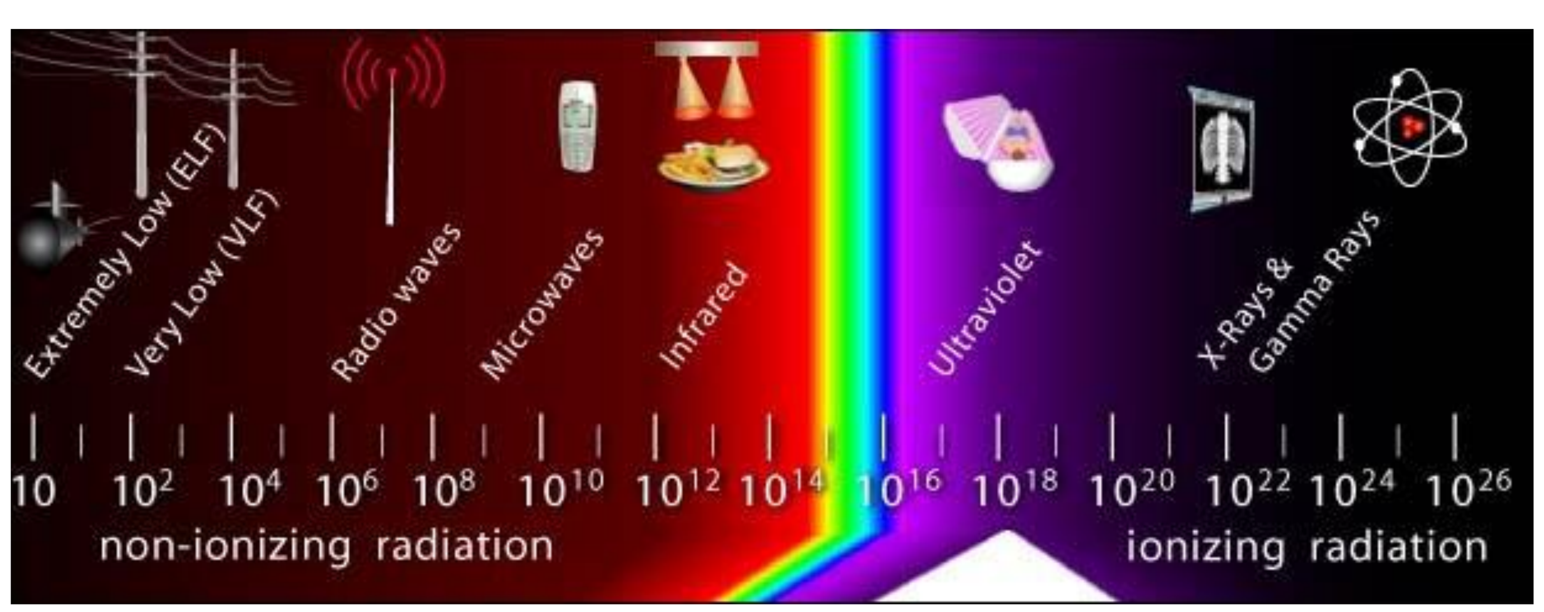

Figure 2: The non-ionizing and ionizing ranges of radiation.

Experimental Methods

Specific values of electrical and thermal parameters are required to used to use the COMSOL Multiphysics© modeling software to create our models.

Parameters

Name	Expression	Value
f0	1 [THz]	1E12 Hz
mua	150 [1/cm]	15000 1/m
n	2.1	2.1
dens	1050 [kg/m^3]	1050 kg/m³
heat_cap	3.72 [kJ/(kg * K)]	3720 J/(kg·K)
therm_cond	0.550 [W/(m * K)]	0.55 W/(m·K)
Pav	1000 [W/m^2]	1000 W/m²
w_tx	sqrt(0.6^2+0.4^2)	7.2111E-4 m
x_tx	0 [mm]	0 m
y_tx	0 [mm]	0 m
mua_blood	205 [1/cm]	20500 1/m
n_blood	2.145	2.145
dens_blood	1.06 [g/cm^3]	1060 kg/m³
heat_cap_blo	4.0 [kJ/(kg * K)]	4000 J/(kg·K)
therm_cond_	0.52 [W/(m * K)]	0.52 W/(m·K)

Figure 3: The parameters used.

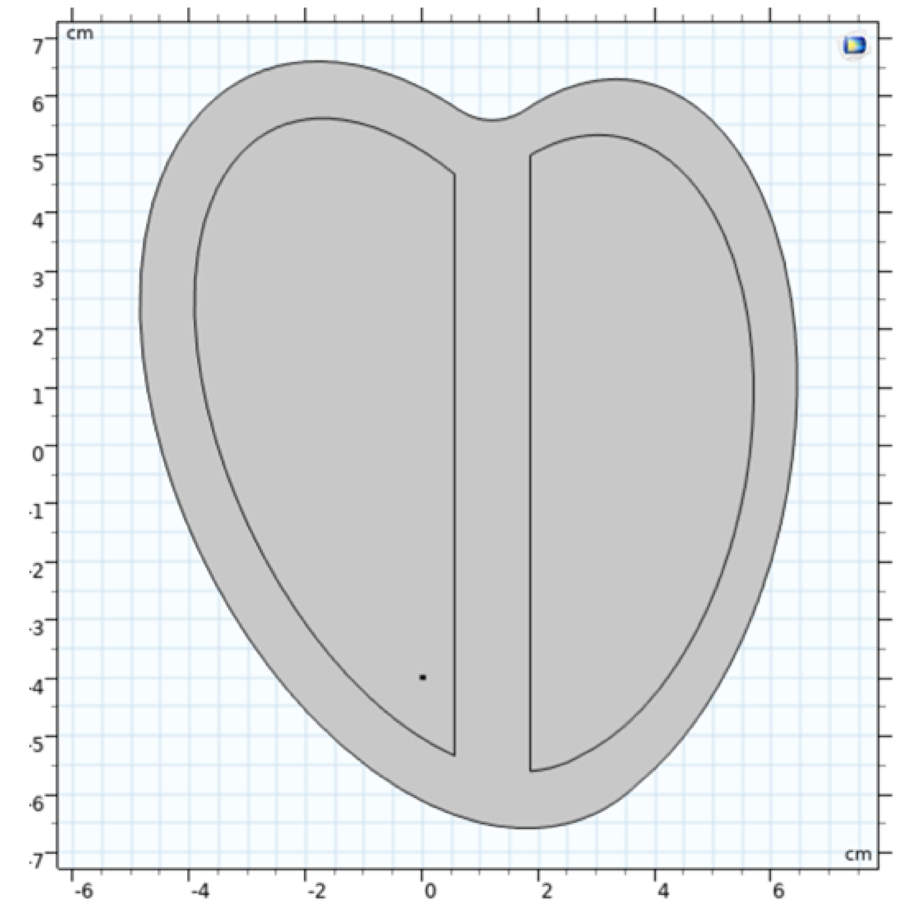

Figure 4: The 2D model's shape.

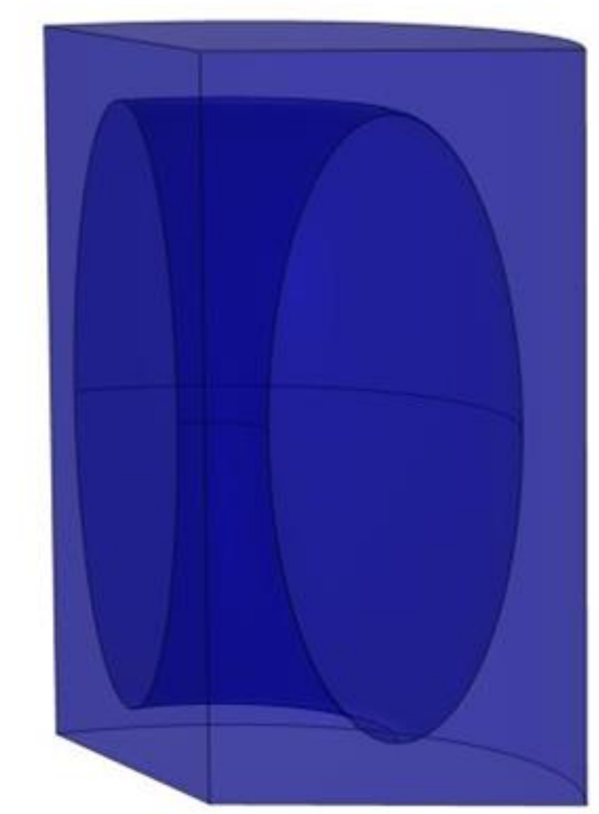

Figure 5: The 3D model's shape.

Results

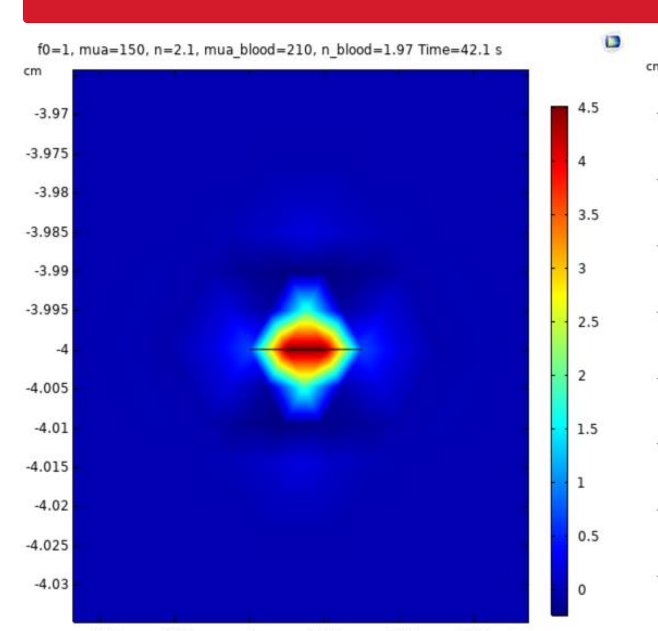

Figure 6: An example of a power density output in the 2D model.

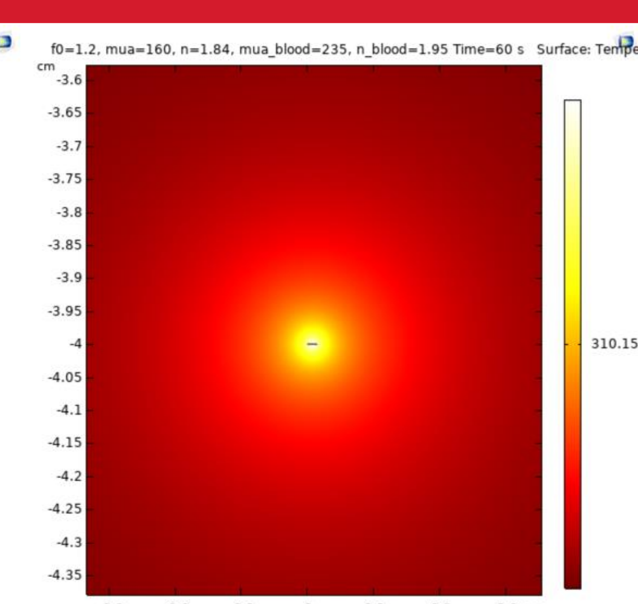

Figure 7: An example of a temperature output in the 2D model.

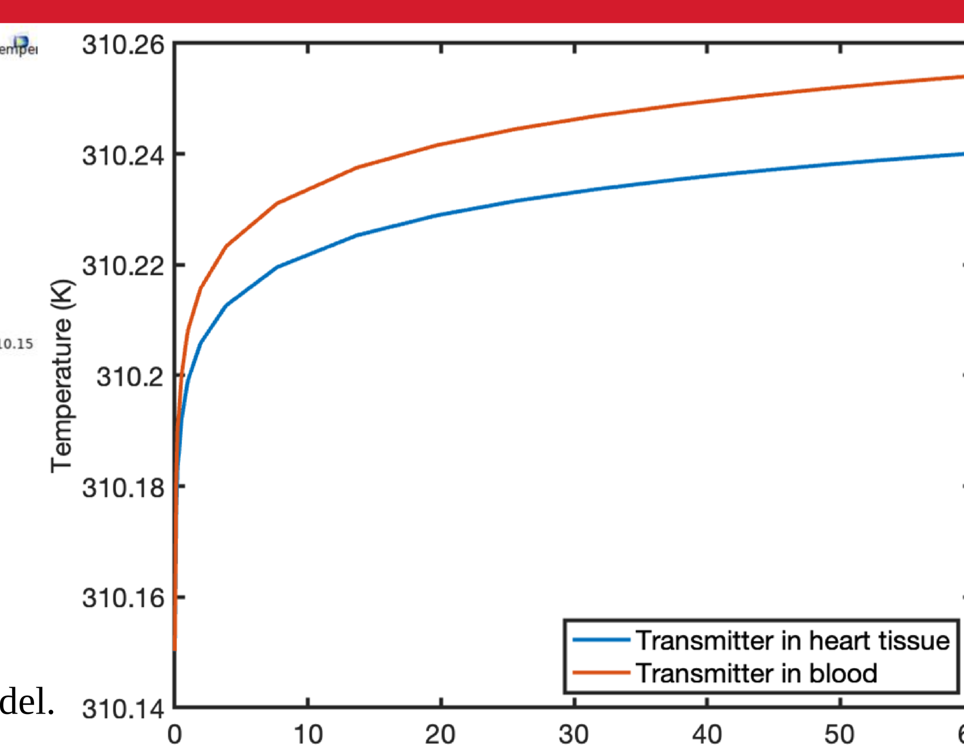

Figure 8: Temperature vs. time in the 2D model with transmitter in heart and in blood at 1 THz and 0.5 mW/mm^2.

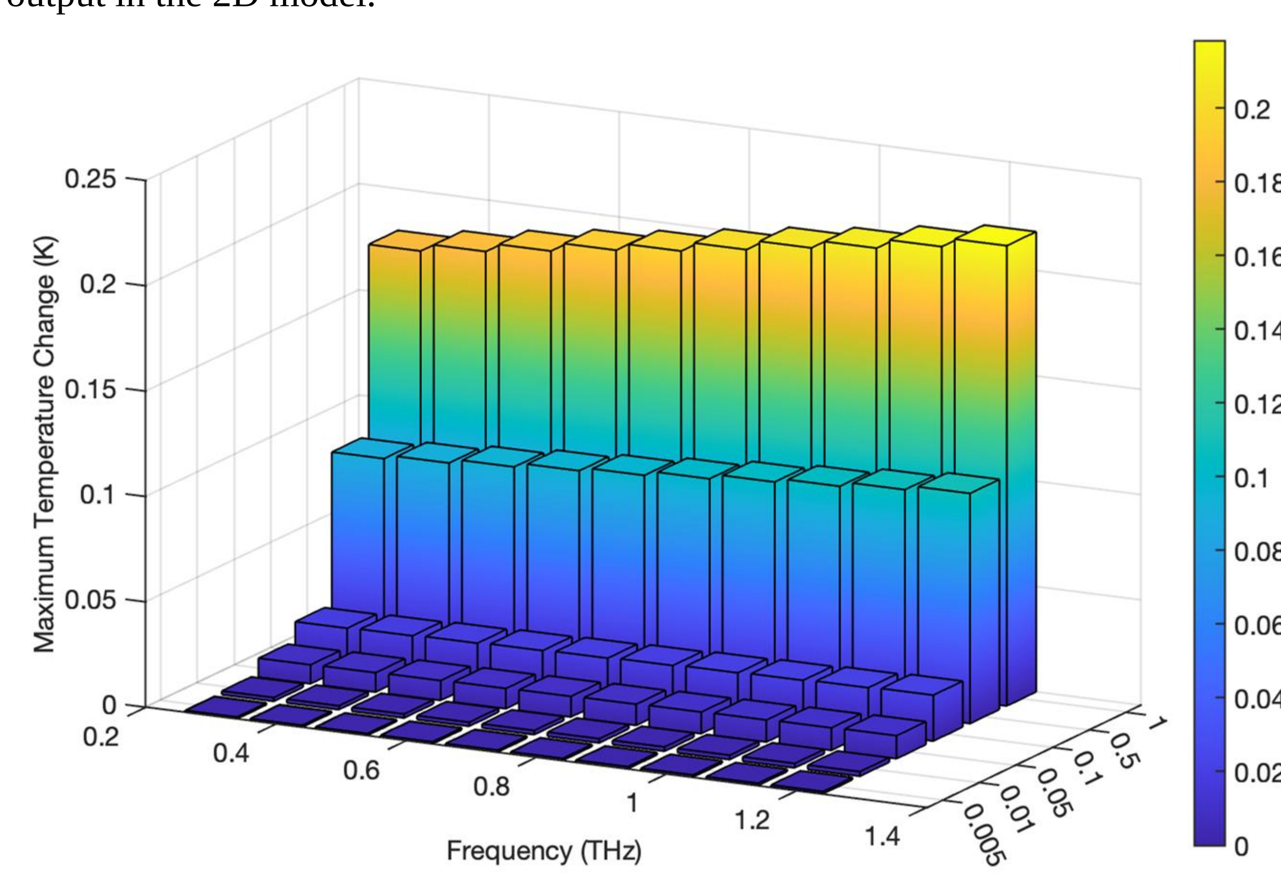

Figure 9: Frequency vs. power vs. temperature change in the 2D model.

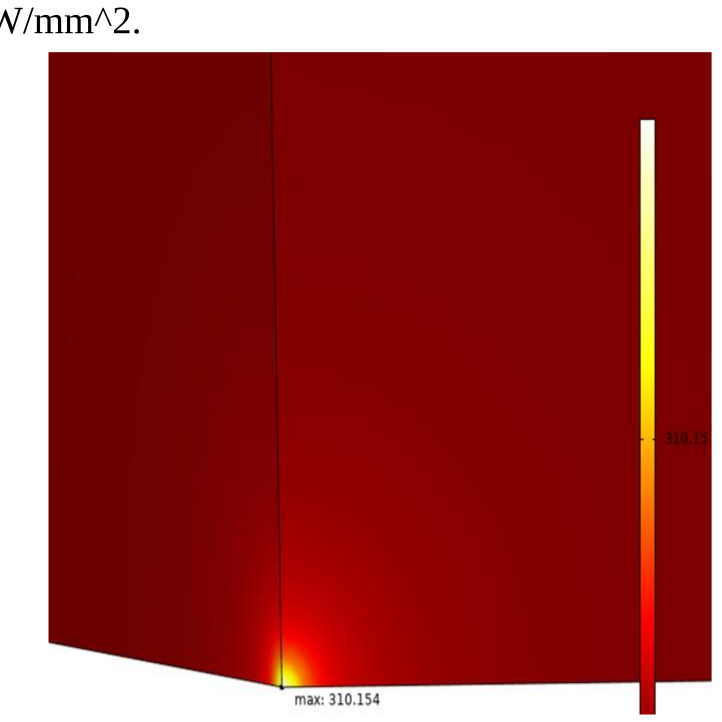

Figure 10: An example of a temperature output in the 3D model.

Conclusion and Future Steps

- Maximum temperature shares positive relationship with both power and frequency
- Temperature change seems directly proportional to power level
- Each power-frequency combination = a different temperature change → must consider both factors when defining safe limits for specific devices
- Temperature raised higher in blood than in heart tissue → advise particular caution for in-blood technologies like pacemakers and blood monitors
- Hope to compare our results to radiation of higher and lower frequencies as well as 3D model results
- The model/findings will deepen our understanding of terahertz biosafety, helping to harness the band's great potential while protecting human life

References

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