Utilizing Millimeter Waves to Non-Invasively Measure Cranial Temperature in Traumatic Brain Injury (TBI)

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Motivation

- **TBIs are injuries that disrupt the normal function of the brain**[1]
- 2.5 million documented ED visits due to TBI in the US in 2010[1]
- Lifetime economic cost of TBI: approximately $76.5 billion[1]
- TBIs result in cellular/deep tissue injury, a marker of which is a brain fever[1],[2]
- **Detecting brain fevers is not part of the diagnostic process for hospitals**
- Current tools to measure brain fevers are **not accurate** and are **invasive**
- **There is a need for a non-invasive tool that can be used to measure brain fevers**

Limitations of Current Solutions

	CONSTRAINTS			
	Tissue Damage	Invasiveness	Integration Time	Accuracy
Infrared Thermography	5	5	3	4
Forehead Sensor	5	5	3	2
Millimeter Wave Sensor	5	5	4	5
Implantable Probbe	1	1	4	5

Constraints

C.P1. Time: 9 months
C.P2. Budget: $3500
C.P3. Resources: Lab/Materials

C.D1. First year of the project
C.D2. Minimal previous research
C.D3. Limited availability of models
C.D4. Attenuation/scattering of signal due to the phantom model

Requirements

R.1 Fundamental Operating Frequency - 80 GHz

R.2 Temperature Resolution - 2℃

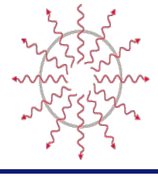
R.3 Signal Integration Time - 30 Seconds

R.4 Temperature Presented on Computer Display

R.5 Under 16 cm^3 for Final Volume

Planck's Blackbody Radiation Law

- Absorbs **all** incoming radiation at all frequencies equally[3]
- Re-admits radiation **with perfect efficiency**[3]
- Maintains Thermal Equilibrium[3]



$$B_f^p = \frac{2hf^3}{c^2}\left(e^{hf/kT} - 1\right)^{-1}$$

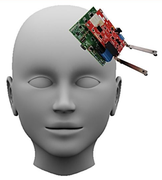
B_f^p – Spectral Brightness [$W \cdot m^{-2} \cdot sr^{-1} \cdot Hz^{-1}$]
h - Planck's Constant [$J \cdot s$]
f – Frequency [Hz]
k – Boltzmann's Constant [$J \cdot K^{-1}$]
T – Absolute Temperature [K]
c – Speed of Light [$m \cdot s^{-1}$]

Objective

Engineering a millimeter wave sensor to determine temperature of a phantom model non-invasively

Design Approach

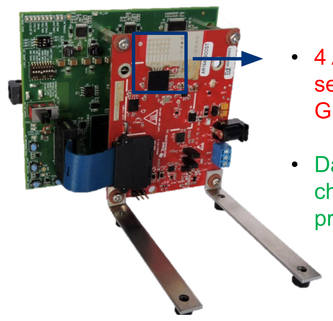
Receiving mm-waves from Phantom → Signal Processing → Temperature Display



38 ℃

Solution

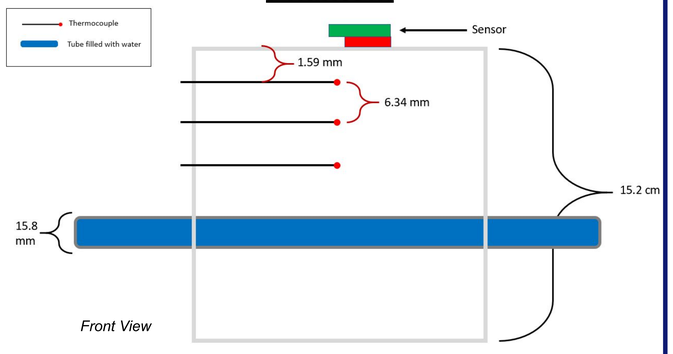
Millimeter Wave Sensor



Features

- 4 Antennas capable of sensing radiation in 76-81 GHz region
- Data transfer capabilities from chip to computer for signal processing to be done

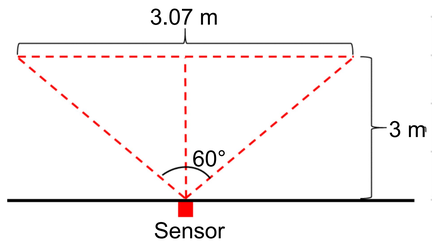
Phantom



- **Material:** Silicone Elastomer
- **Dimensions:** 15.2 cm^3 cube
- **Will be heated:** Thin-walled polycarbonate tubing will circulate heated water through
- **Thermocouples:** serve as verification of how sensing depth

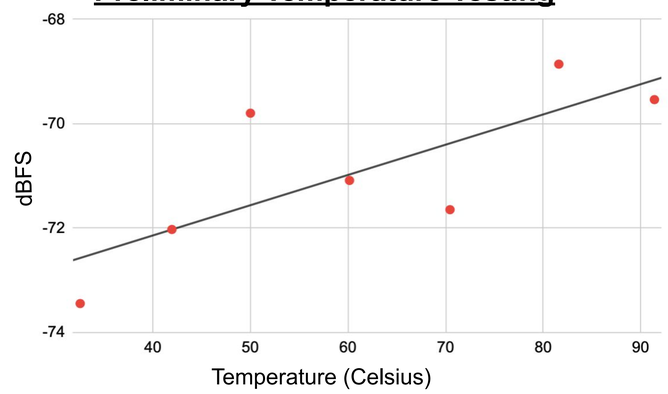
Verification

Radar Verification Testing



Object - Distance	dBFS Output
No Objects	-85.13
Reflector - 0.3 Meter	-45.1
Reflector - 2 Meter	-97.47

Preliminary Temperature Testing



Conclusion

- A Millimeter Wave device has been created to non-invasively detect temperature
- Verification tests prove that the device can differentiate between different temperatures
- Future work includes testing the temperature of the phantom and optimizing the software to give real-time temperature output

Impact

Quantitative Measurement of injury severity

Improve standard of care

Less undiagnosed injuries

Acknowledgements

Don Herzog, Dr. Michael Neirdauer, DrExcel Health, Dr. Paul Shore, and Drexel Biomedical Engineering Senior Design Faculty

References

[1] CDC, Report to Congress, 2015. [2] R. H. Sacco, Dissertation, 2009. [3] M.D. Grady, Dissertation, 2017.