ETTAC 2020

1st Workshop on Eye Tracking Techniques, Applications and Challenges

https://vision.unipv.it/ettac2020/

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In conjunction with

ICPR 2020

Ultrasound for Gaze Estimation

Andre Golard and Sachin S. Talathi

Facebook Reality Labs, Redmond WA 98052, USA

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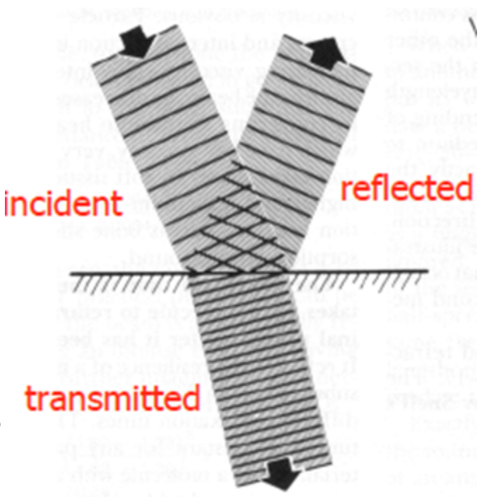
Background

Airborne ultrasound

- Wave intensity reflection coefficient is given as:

$$a = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$$



- Acoustic wave attenuation is given as: $A = A_0 e^{-\frac{a f}{8.7} z}$, where A_0 is the amplitude of the acoustic wave at some reference location, A is the amplitude of the wave at distance z from the reference location, a is attenuation coefficient in units of dB/cm/MHz

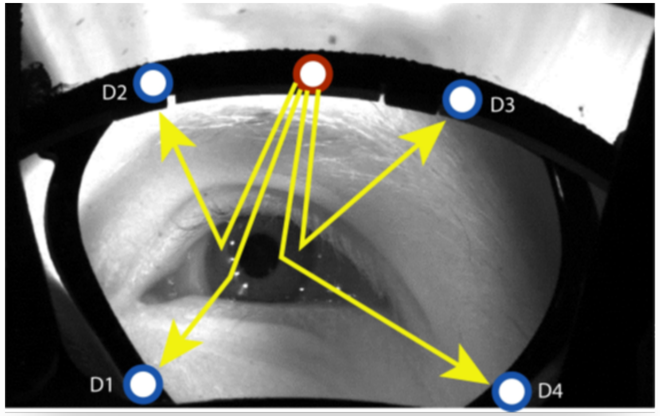
Attenuation of an ultrasound beam propagating in air:

- 100kHz: 0.03dB/cm
- 1MHz: 1.64dB/cm
- 2MHz 6.4dB/cm

Safety

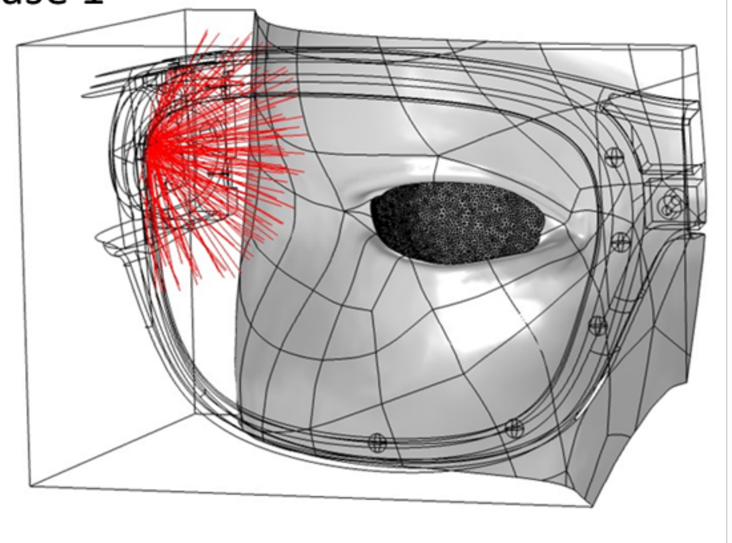
- The proposed SPLs (Sound Pressure Levels) to be delivered via this device (100 dB) are at least 40 dB below the expected limit for a frequency of 70 kHz – 4 MHz, using conservative assumptions.
- Adverse health effects on hearing of exposure to airborne acoustic energy at levels normally encountered have been reported only at frequencies below 100 kHz, and nearly all below 50 kHz.

Modeling

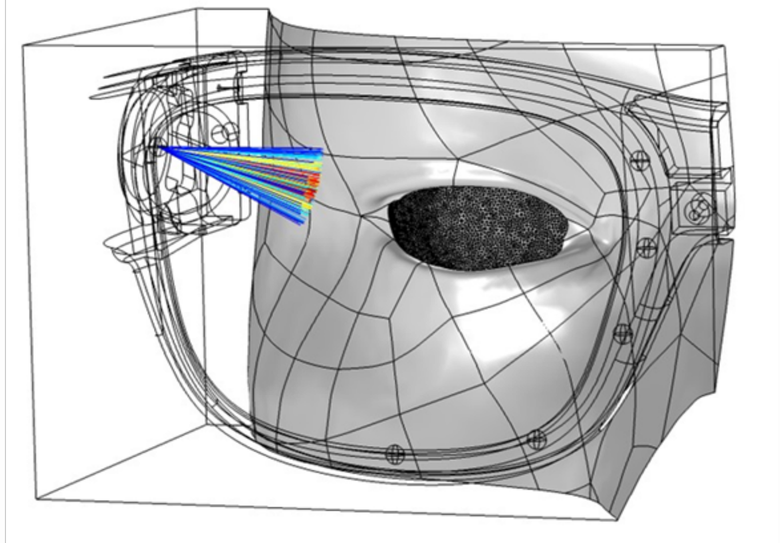


H = [(D3+D4)–(D1+D2)] /[D1+D2+D3+D4]
V = [(D2+D3)–(D1+D4)] /[D1+D2+D3+D4]

Case 1



Case 2



Methods

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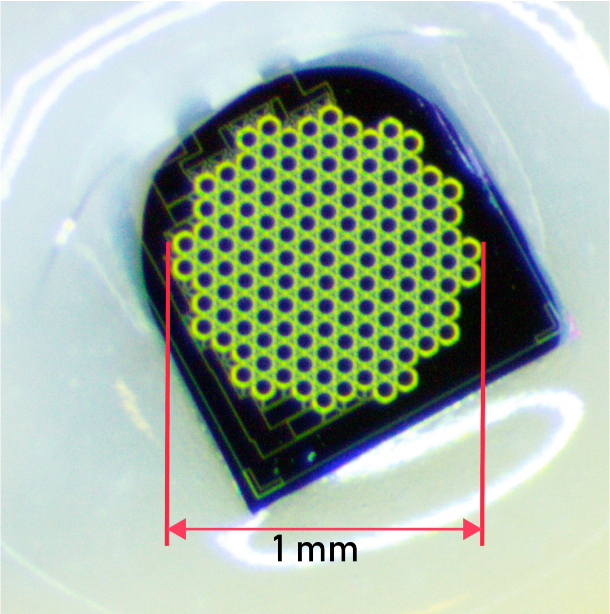

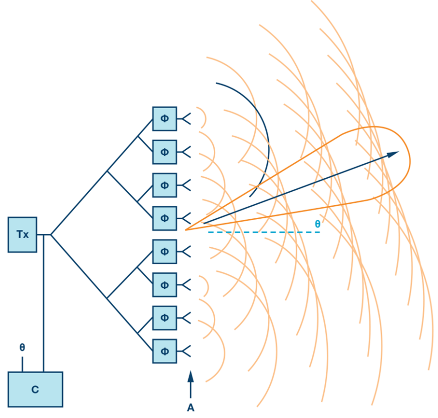

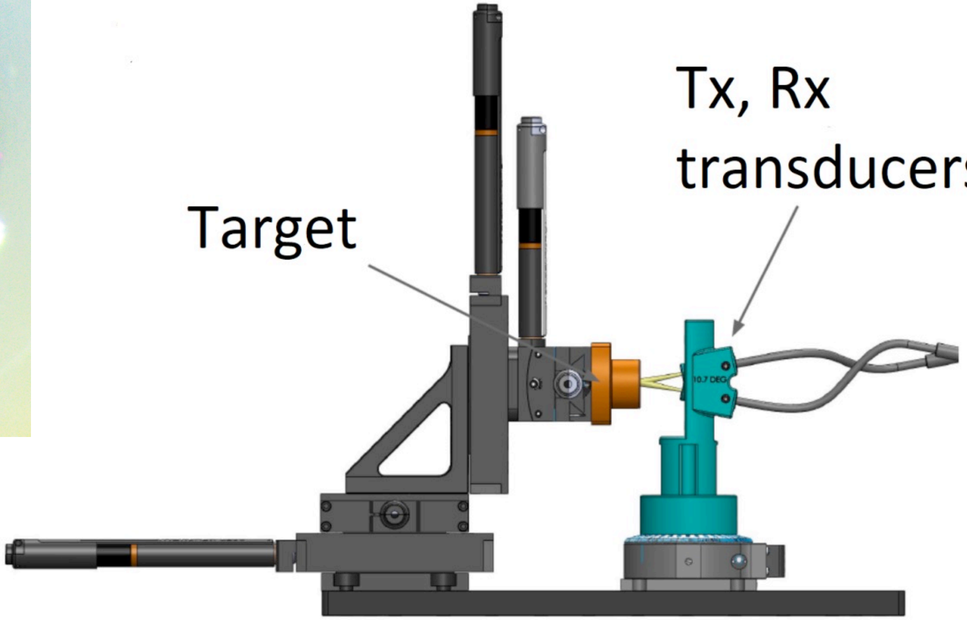

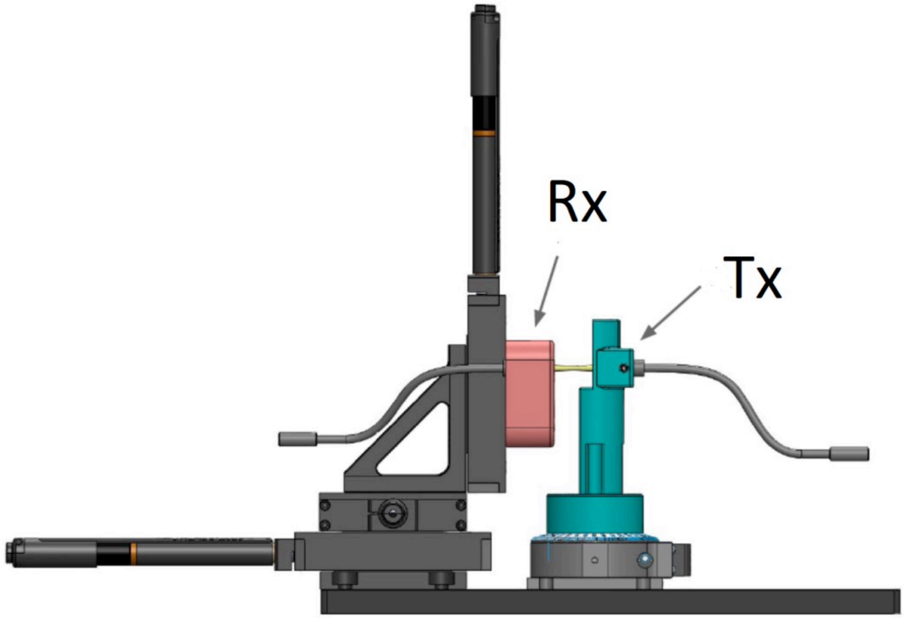

Methods

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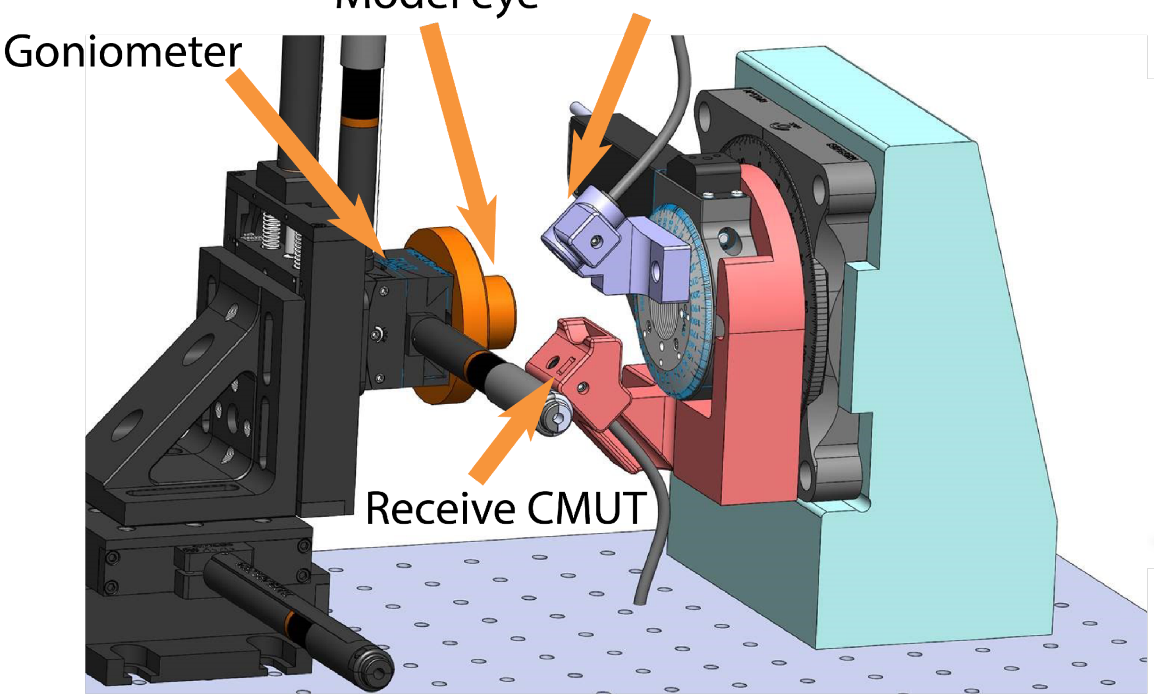
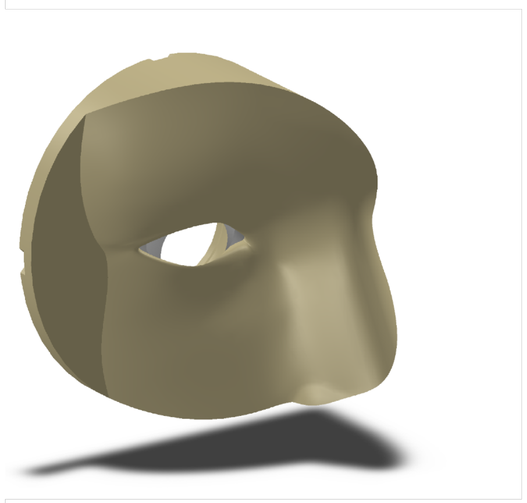
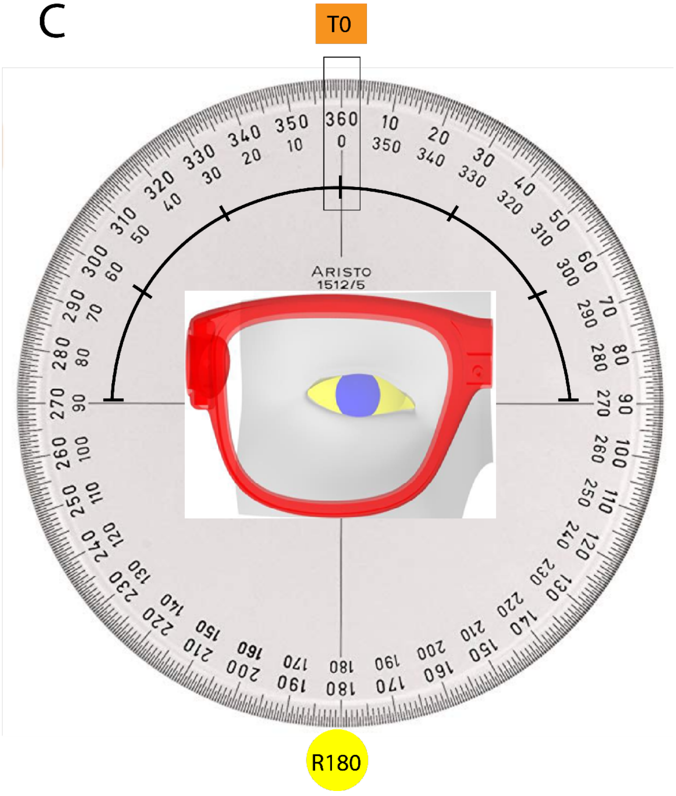
A


Goniometer
Model eye
Transmit CMUT
Receive CMUT

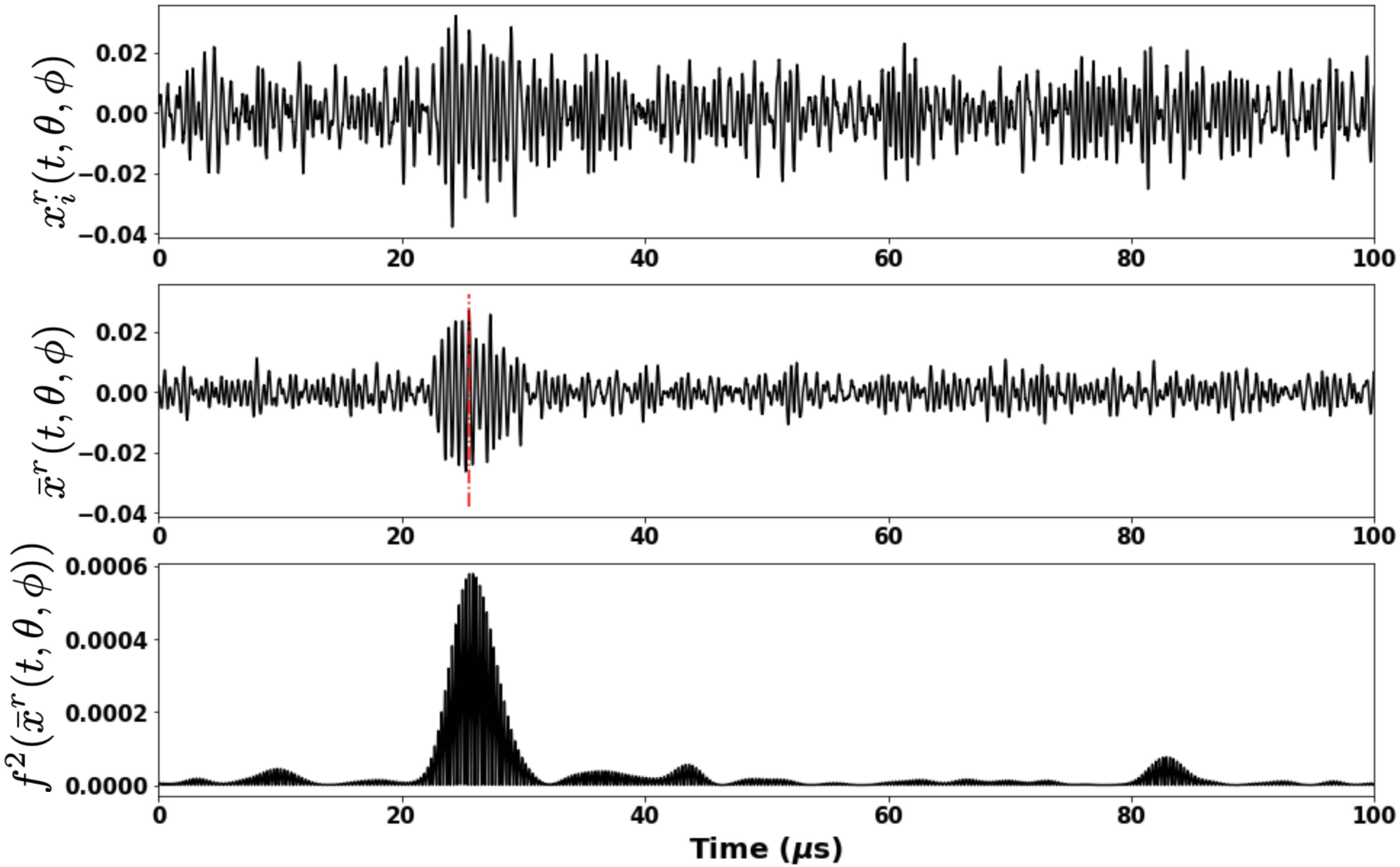
B



C


T0
ARISTO
1512/5
R180

Methods



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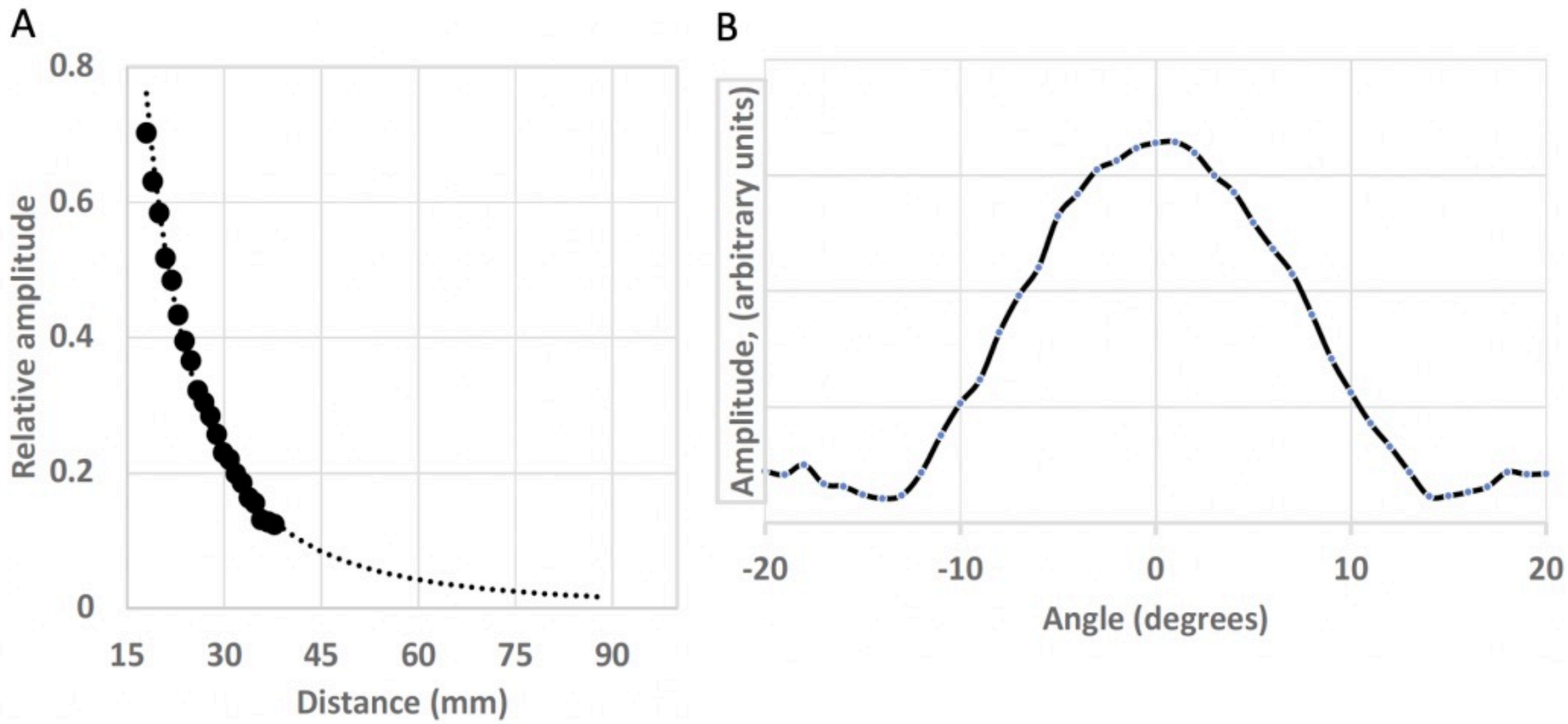
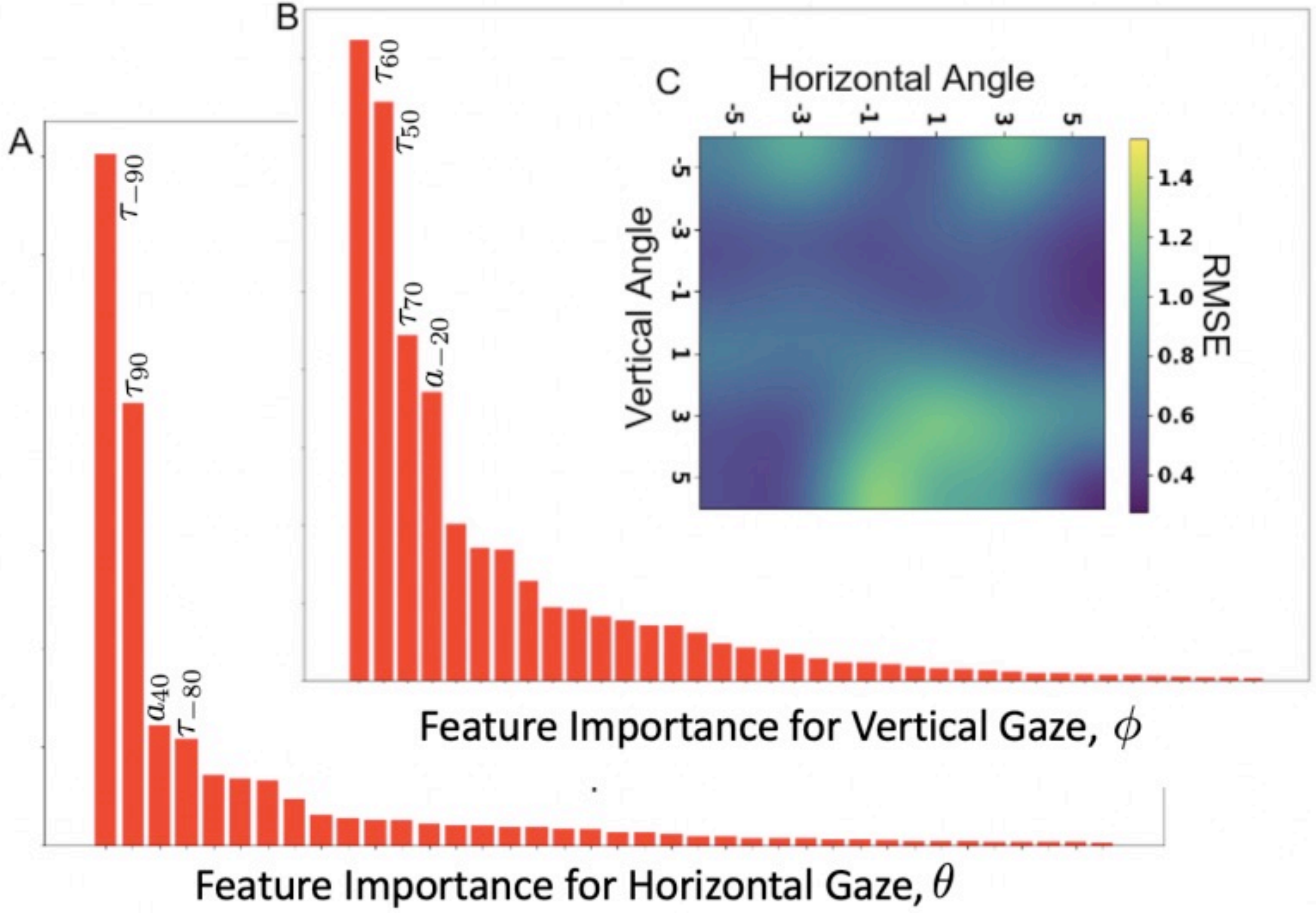
Results

Decay and directionality



Results



A
τ_{-90}
τ_{90}
a_{40}
τ_{-80}
Feature Importance for Horizontal Gaze, θ
B
τ_{60}
τ_{50}
τ_{70}
a_{-20}
Feature Importance for Vertical Gaze, ϕ
C
Horizontal Angle
-5
-3
-1
1
3
5
Vertical Angle
-5
-3
-1
1
3
5
RMSE
1.4
1.2
1.0
0.8
0.6
0.4

Conclusions

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- This study is the first experimental demonstration of ultrasound gaze estimation.
- We show that ultrasonic transducers produce signals that allow to resolve eye gaze within the range tested, ±5° in both up/down and left/right directions.
- Our GBRTs show that both amplitude and time of flight contribute to our ability to estimate gaze.
- We show that signal attenuation plays a role in our ability to estimate gaze, which would favor the use of high frequency transducers.

Future work

- Fast-moving model eye
- Multiple receivers operating at 2kHz.
- Adapt GBRT models and attempt to resolve saccades.