MMWAVE ECG

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CSCE 790

UNIVERSITY OF
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College of Engineering and Computing

OBJECTIVE

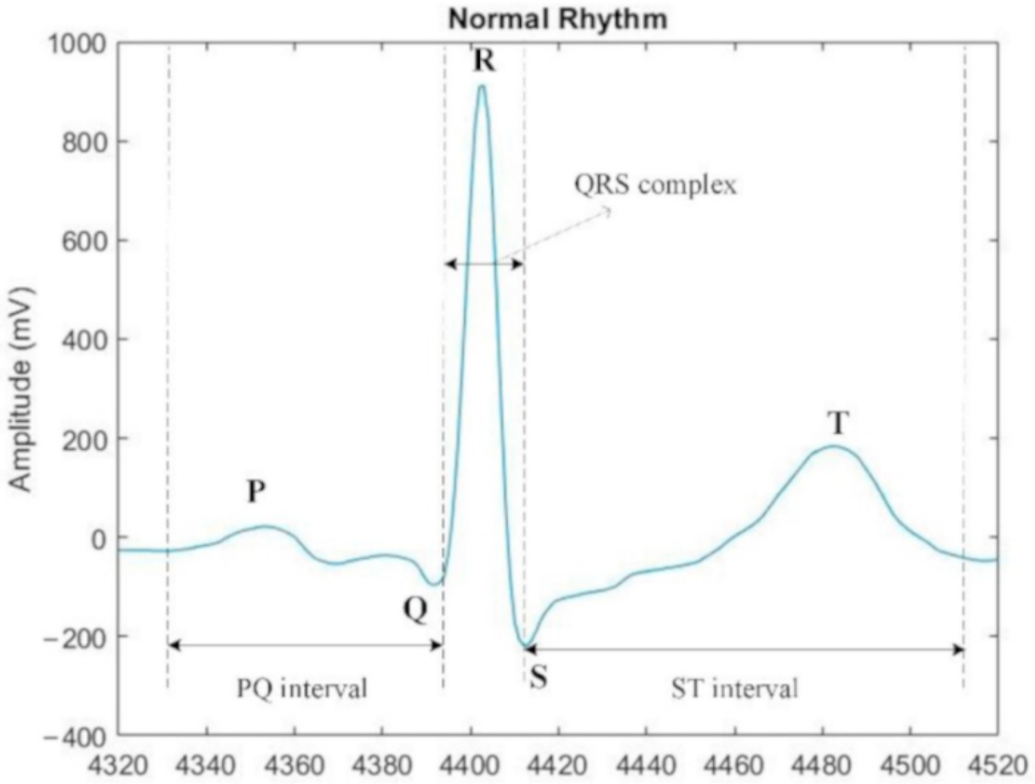
- Use mmWave radar to generate non-contact Electrocardiograms (ECG) with off-the-shelf devices

BACKGROUND

- Cardiovascular disease is a leading killer in the US
- ECG is important heart health diagnostic
- Traditional ECGs are invasive

BACKGROUND

- **P Wave**: Atrial depolarization, atria contract to push blood into ventricles.
- **QRS Complex**: Ventricular depolarization, triggers ventricles to pump blood to lungs and body.
- **T Wave**: Ventricular repolarization, indicates ventricles' resting phase before next beat.

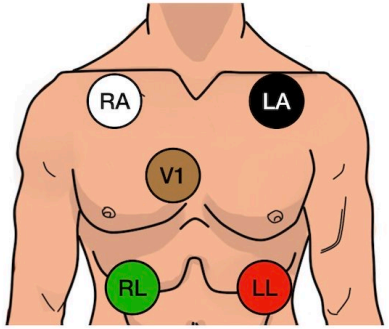


BACKGROUND

- **Electrode Placement**: Adhesive electrode patches are attached to the skin over the heart.
- **Lead Configuration**: Typically uses 4, 6, or 12 leads to capture detailed electrical activity.
- **Voltage Detection**: Leads detect tiny voltage changes from heart's electrical activity.
- **Invasive Nature**: Can be uncomfortable due to wires and placement of electrodes.

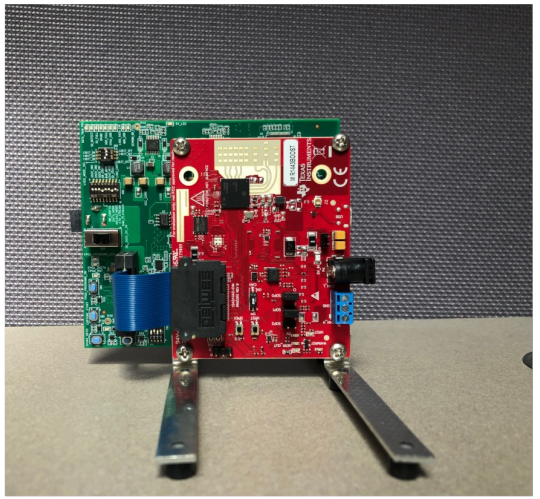
5 Lead ECG Placement

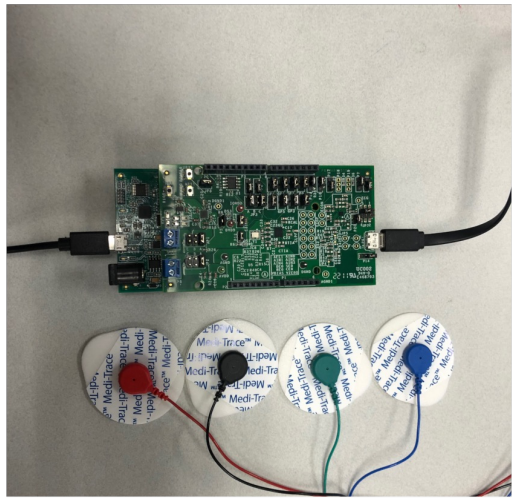
Electrode/ Lead Wire	Position	Color
RA	Right Arm	White (clouds)
RL	Right Leg	Green (grass)
LA	Left Arm	Black (smoke)
LL	Left Leg	Red (fire)
V1 or C	Center of Chest	Brown (chocolate)



SYSTEM DESIGN

- Setup components:
  - TI IWR1443BOOST mmWave Radar
  - TI DCA1000EVM Data Capture Adapter
  - Analog Devices AD5940BIOZ BioElectric Frontend
  - Analog Devices ADICUP3029 Microcontroller
  - Arduino NANO 33BLE Microcontroller





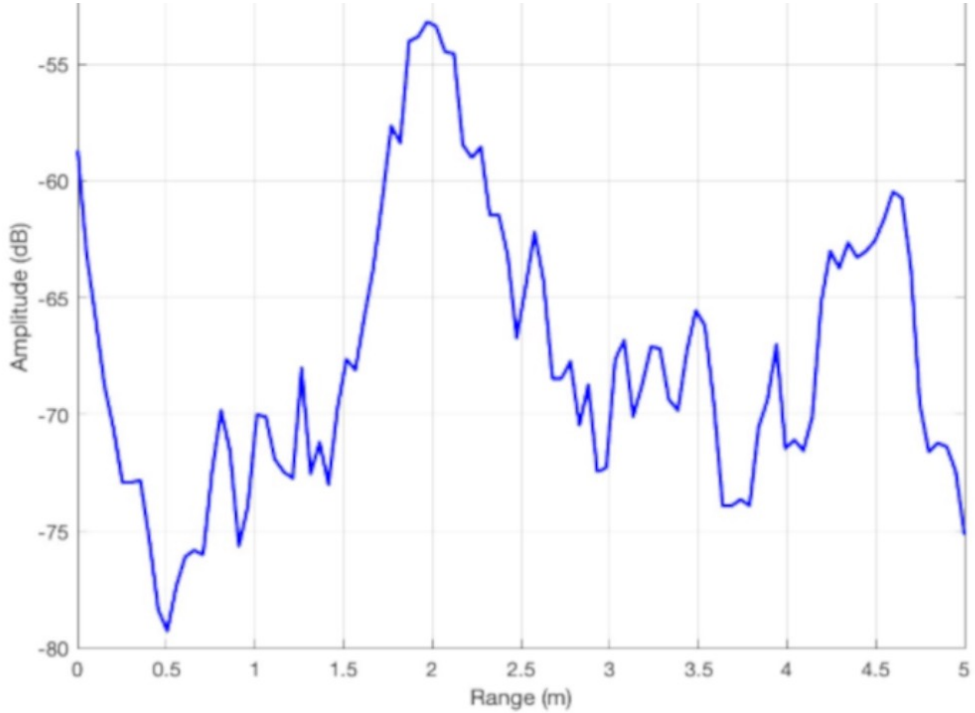
SYSTEM SYNCHRONIZATION

- Heart movement has minimal effect on mmWave signal
  - Not obvious without computational techniques
- Need to ensure direct correlation
  - Hard to visually sync

SYSTEM SYNCHRONIZATION

ECG

mmWave



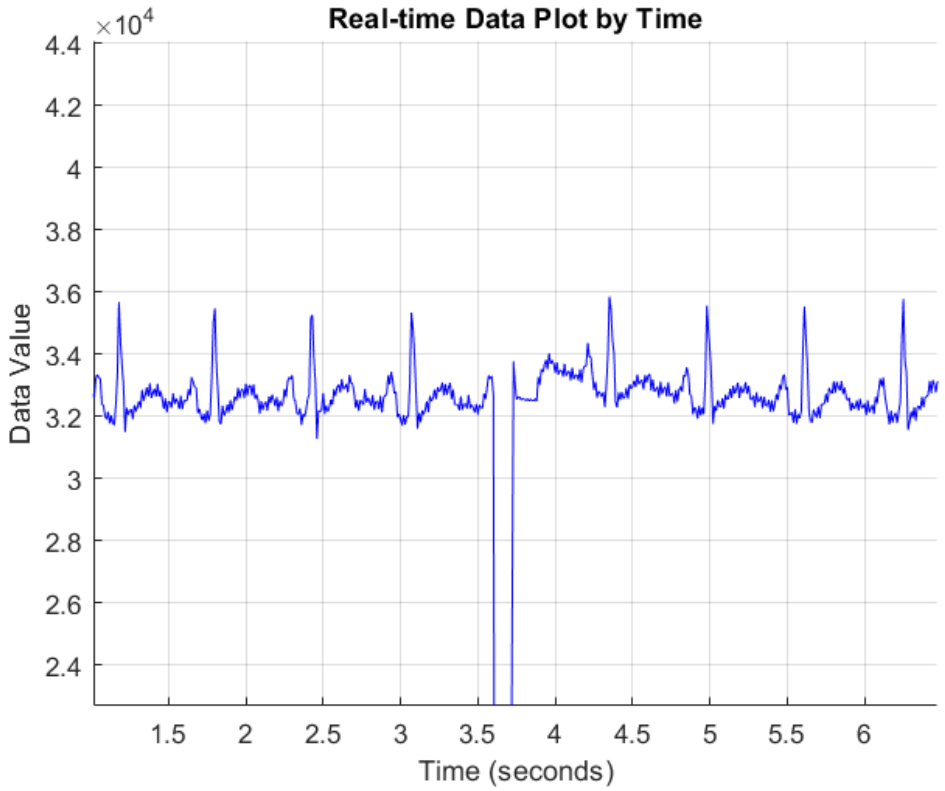
SYSTEM SYNCHRONIZATION

- Devices operate different sample rates
  - IWR1443: 625KSps
  - AD5490: 400KSps
- Hardware setup/start times different
- AD5940 for BIOZ ECG operates at 250Sps due to UART throughput limitations

- ECG waveform is relatively low-frequency
  - <100Hz vs 77-81GHz
- mmWave needs to capture more fine-grained movements in general environment
- ECG captures significant electrical signals in small location

ECG SYNCHRONIZATION

- Introduce significant disturbance
  - Pull RA ECG line low
  - Ignore all data before, and briefly after
- This signal can be seen very easily



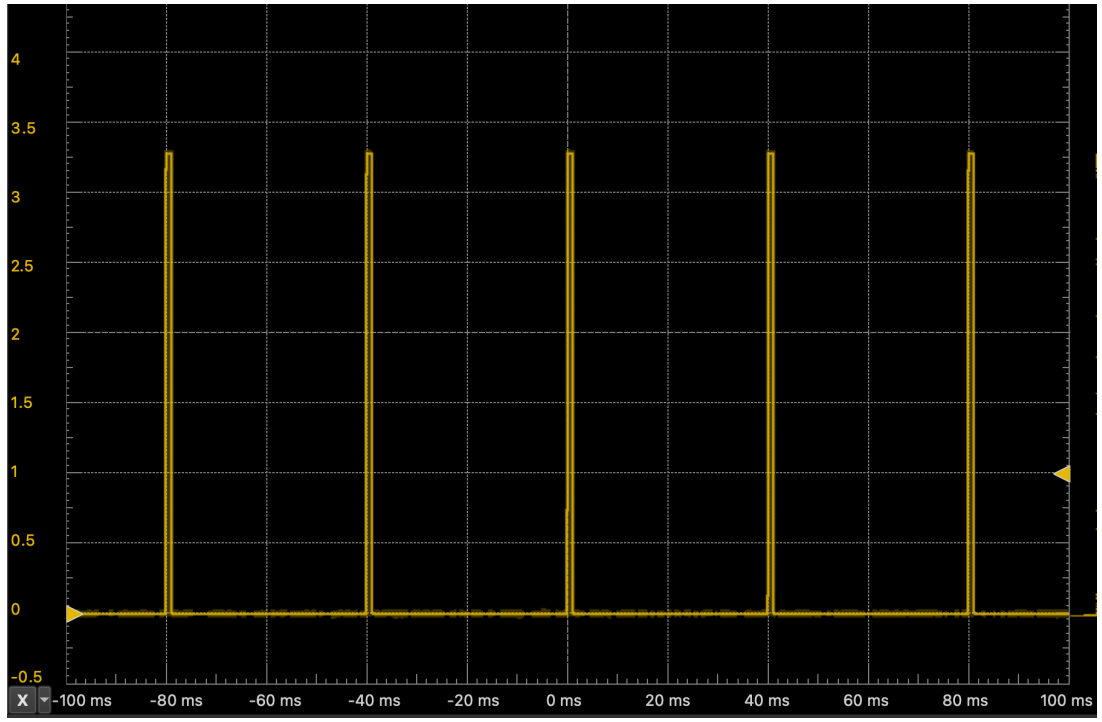
MMWAVE SYNCHRONIZATION

- 40ms in between pulses
  - Frame time
- 1ms pulse width
  - Indicates frame start
- Implemented with hardware timer on the Arduino MCU
- Serial command to start
- ICSP reset to stop
  - Checking serial for stop command increases loop time

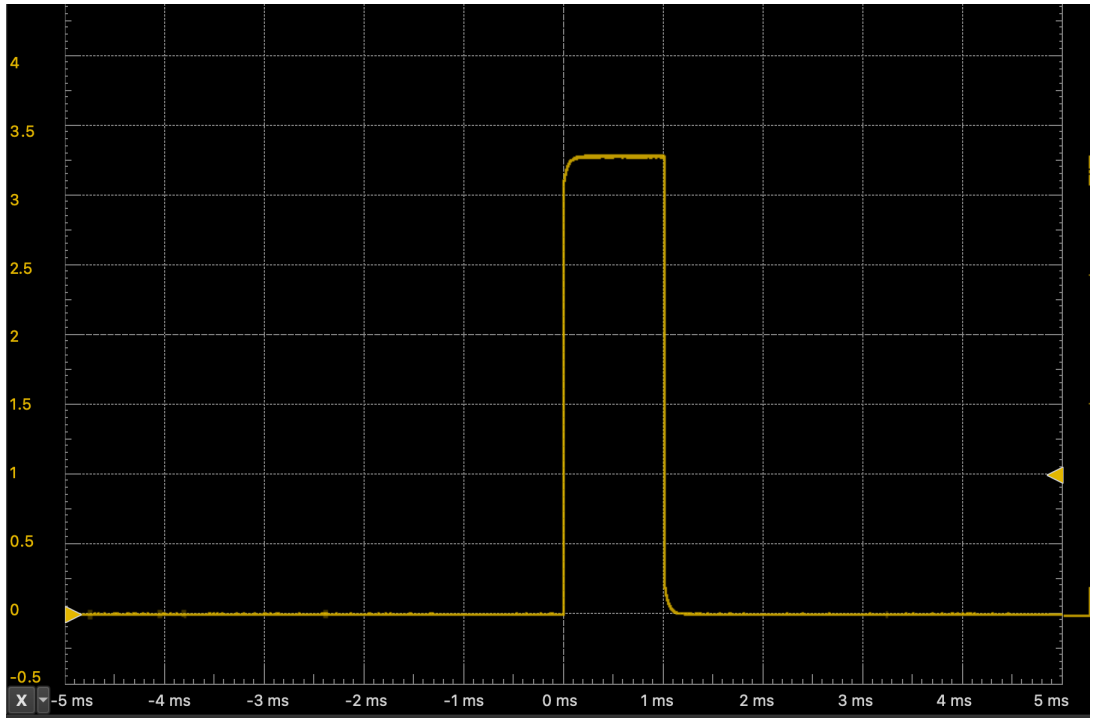
- Can divide up ECG into ~40ms frames for future analysis and correlation

MMWAVE SYNCHRONIZATION

Zoom-Out View



Closeup



PROCEDURE

1. Flash ECG and Arduino
2. Enable ECG
3. Configure mmWave
4. Enable Arduino synchronizer
5. Data Collection Period
6. Reset synchronizer
7. Postprocessing/trimming
8. Feature Extraction
9. Correlation

POST-PROCESSING

- Split data into frames synced with mmWave
- Filter out static scene elements
- Range-FFT to extract frequency components of movement
  - We want to look at >100Hz movements near wear patient is sitting

RESULTS

- Remote mmWave timing required many modifications
  - Hardware and software
- Getting accurate timing was challenging
  - Required functions to be stripped
  - Has to be reset via ICSP debugger and reflashed before use
- Getting ECG to connect with MATLAB was not trivial
  - SensorPal not an open protocol
  - Has to be “tricked” into a debug state
- Also required custom scripts to handle flashing each MCU
  - Complex compiler directives

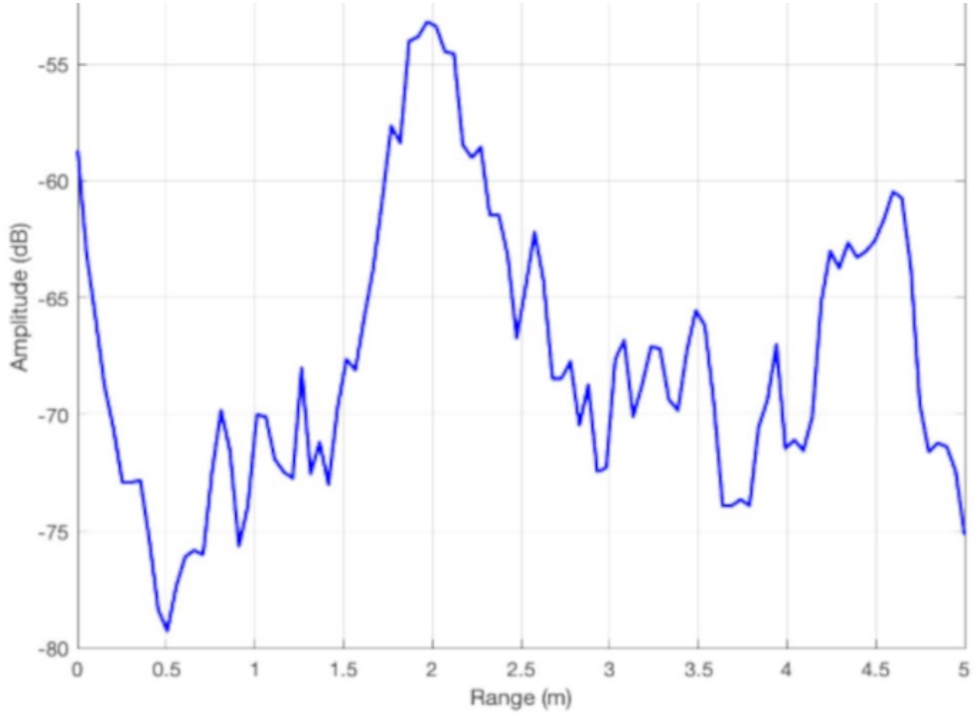
RESULTS

- Some work done on correlation
  - LSTM and CNN
- Data was collected with synchronization method
- Throughput issues for real-time ECG data visualization

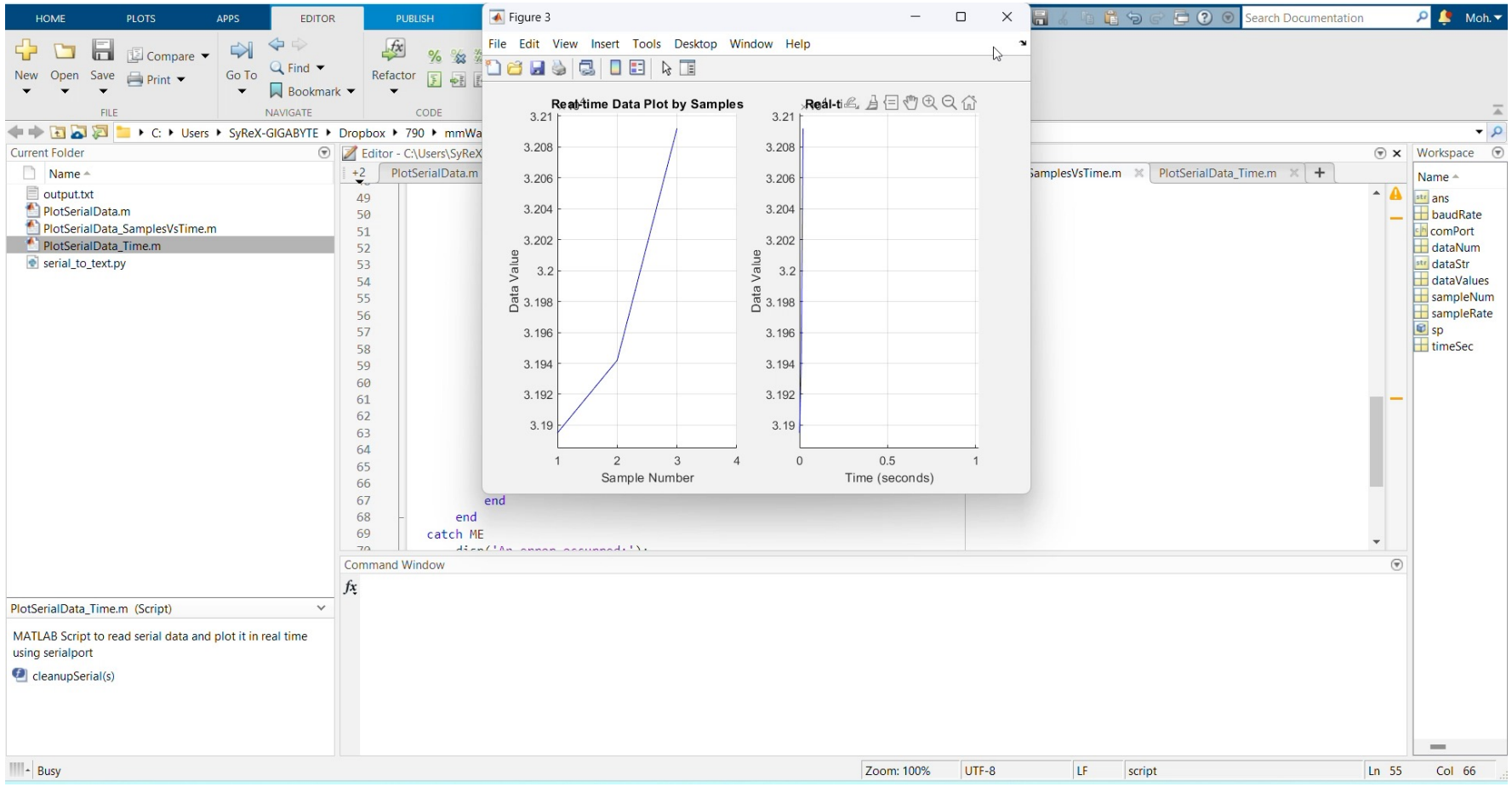
DATA EXAMPLE

ECG

mmWave



REALTIME ECG



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CONCLUSION AND FUTURE WORKS

- Developed data collection setup for contactless ECG
- Collect more data
- Complete correlation model

RELATED WORKS

- U. Ha, S. Assana and F. Adib, "Contactless seismocardiography via deep learning radars", Proc. 26th Annu. Int. Conf. Mobile Comput. Netw. (MobiCom), pp. 1-14, Sep. 2020.
- Mélanie Brulc, Thibaut Deleruyelle, Alain Loussert, Pierre Laurent, Rémi Grisot, Jean-Paul Caruana, "Cardiac Signature Detection and Study Using Contactless Technology: Millimeter-Wave FMCW Radar", IEEE Open Journal of Instrumentation and Measurement, vol.2, pp.1-8, 2023.
- Rémi Grisot, Pierre Laurent, Claire Migliaccio, Jean-Yves Dauvignac, Mélanie Brulc, Camille Chiquet, Jean-Paul Caruana, "Monitoring of Heart Movements Using an FMCW Radar and Correlation With an ECG", IEEE Transactions on Radar Systems, vol.1, pp.423-434, 2023

THANKS!

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