EXTRACTION AND DENOISING OF HUMAN SIGNATURE ON RADIO FREQUENCY SPECTRA VIA CONDITIONAL GENERATIVE ADVERSARIAL NETWORK

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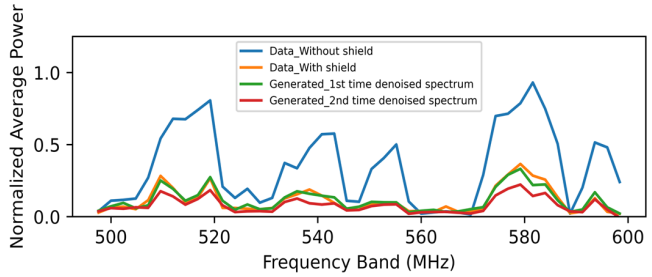
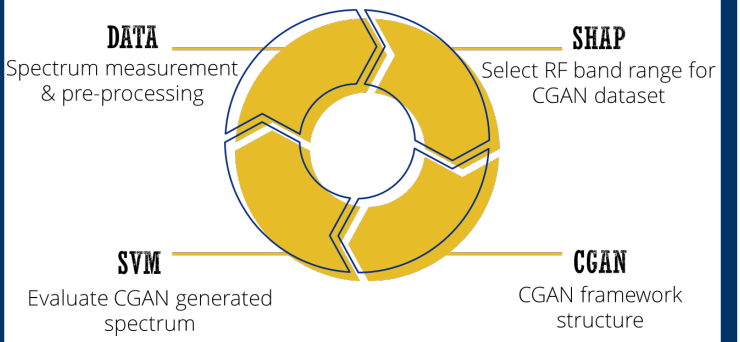
01 Problem Statement

Our goal in this paper:

- Capture the PRF spectrum contains human signature.
- Extract and denoise the human signature from the RF spectrum.
- Serve the purpose of human identification.



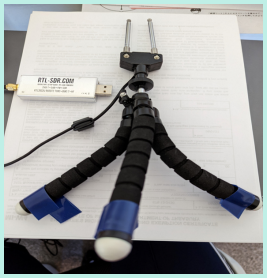
Framework 02



03 Proposed Method

01 HARDWARE

- Two cognitive radio devices (SDR)
- Physical shielded environment



02 DATASETS

Three phases of datasets are constructed:

- Phase 1 & 2: two rounds of SHAP analysis
- Phase 3: CGAN training and SVM

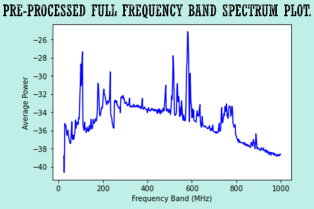
PHASE 1 & 2 DATASET PREPARED FOR SHAP:

	Phase 1	Phase 2
Frequency Band	24-1000MHz	200-800MHz
Sampling Step Size	2.4MHz	1.2MHz
Sampling Rate	2.4MHz	2.4MHz
Background Condition	With Shield Only	With Shield Only
Total Sample Quantity	600	400
Subjects	Human Subject 1-6, & Unoccupied	
Data Prepared For	SHAP	SHAP
Dataset Notation	D_{SHAP-1}	D_{SHAP-2}

PHASE 3 DATASET PREPARED FOR CGAN&SVM

	Phase 3	
Dataset Notation	D_W	D_{WO}
Frequency Band	500-600MHz	
Sampling Step Size	2.4MHz	
Sampling Rate	2.4MHz	
Background Condition	With Shield	Without Shield
Total Sample Quantity	800	800
Subjects	Human Subject 1 & 2, & Unoccupied	
Data Prepared For	CGAN & SVM	CGAN

PRE-PROCESSED FULL FREQUENCY BAND SPECTRUM PLOT.



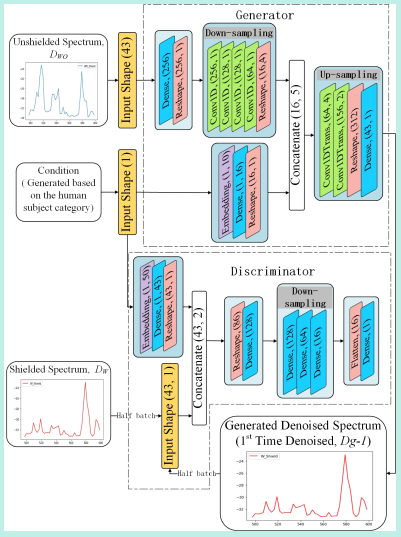
03 CGAN

Generator:

- Down-sampling for feature extraction
- Up-sampling for handling data imbalance
- All the Dense, Convolutional, and Convolutional Transpose layers are followed with a Leaky ReLU layer.
- Hyper parameters are tested to get better result.

Discriminator:

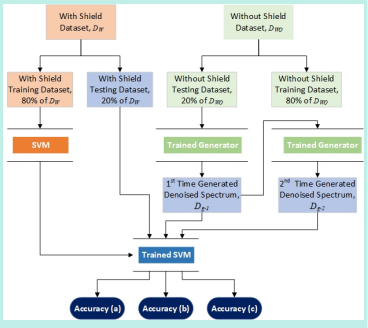
- Binary classifier.
- Dense layers outperform Convolutional layers due to data type and size.



04 SVM

SVM is used in this research to classify the human subjects in 3 datasets:

- The testing samples from D_W,
- The generated denoised spectrum D_(g-1),
- The generated additionally denoised spectrum D_(g-2).



04

Experiment & Results

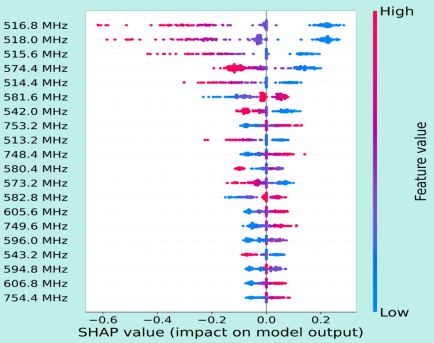
SHAP: Used on frequency band selection

Preliminary frequency band range selection:

- Spectrum initially captured in full frequency
- SHAP result shows top 20 frequencies fall within 100-850MHz.
- Phase 1 dataset frequency is set to 24-1000MHz

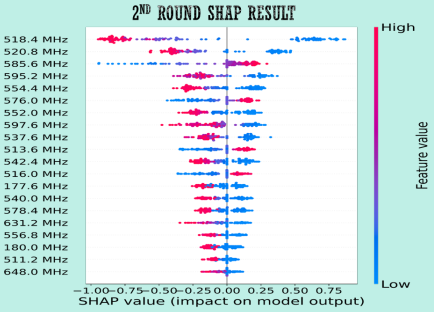
Phase 1 & 2: Two rounds of SHAP are performed respectively to narrow down the RF band range.

1ST ROUND SHAP RESULT



- The phase 1 dataset frequency range: 24-1000MHz.
- The top ten SHAP results all fall in 513-753MHz.

2ND ROUND SHAP RESULT



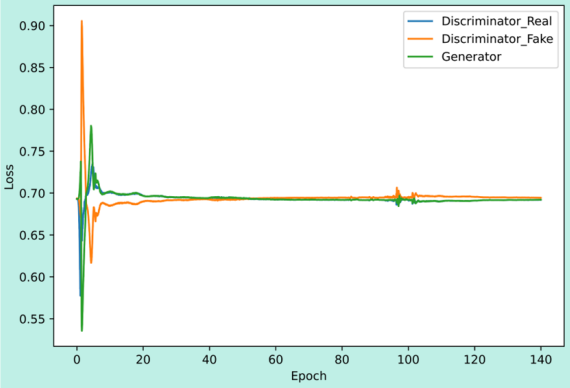
- The dataset frequency range: 200-800MHz.
- The top ten frequencies fall within 513.6-597.6MHz

The phase 3 dataset (CGAN training dataset) frequency range set to: 500-600MHz

CGAN: Training & synthesized spectrum

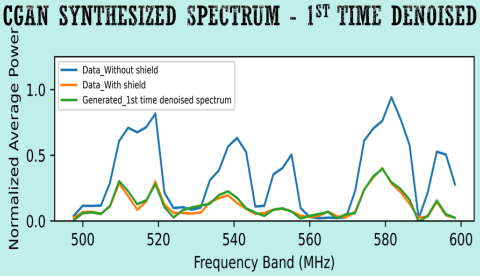
- CGAN model training dataset consist of 608 unshielded samples and 608 shielded samples.
- Discriminator input: shielded samples as target
- Generator training input: unshielded samples.

CGAN TRAINING LOSS CURVE



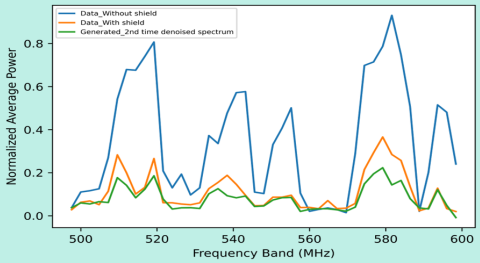
TRAINING PARAMETERS
EPOCHS: 220 N_BATCH: 20

CGAN SYNTHESIZED SPECTRUM - 1ST TIME DENOISED



- The synthesized VS shielded spectrum
- Small deviations

CGAN SYNTHESIZED SPECTRUM - 2ND TIME DENOISED

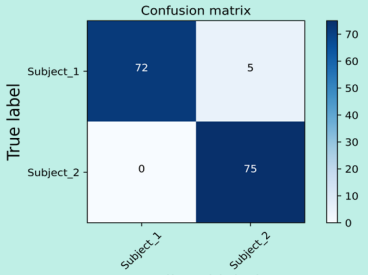


- Generator input: the synthesized 1st denoised spectrum.
- The same trained CGAN model is used.

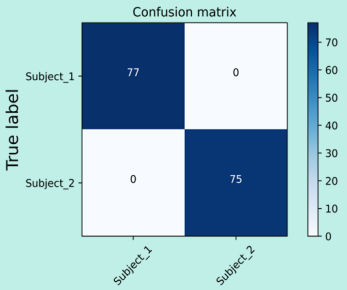
SVM: Evaluation of the synthesized spectrum

- SVM – Classify the synthesized spectra dataset.
- SVM is trained on the shielded training dataset.
- CGAN training target: obtain same F1 score as the shielded testing dataset.

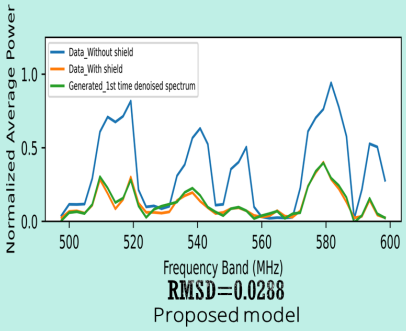
SVM CLASSIFICATION RESULTS



F1 SCORE=0.967
SHIELDED TESTING DATASET
20% of shielded spectrum dataset



F1 SCORE=1.0
SYNTHESIZED DATASET
Both 1st and 2nd time denoised synthesized dataset



RMSD=0.0288
Proposed model

05

Conclusion & Future works

CONCLUSION

- Synthesized spectrum exceeds the expectation, outperform the target spectrum.
- CGAN up-sampling achieved additional signature extraction function by altering data weight.
- The CGAN training strategy:

1. The CGAN structure down-sampling and up-sampling tunning.
2. The CGAN generator hyper parameters setting.
3. The CGAN discriminator Dense layer VS Convolutional layer.

FUTURE WORKS

Experiment setup:

- Increase human subject quantity and variety.
- Change of baseline condition.
- Upgrade shielding material.

Improvement on algorithm:

- Increase labelling dimensions.
- Adding baseline information into condition data.
- Investigate ResNet into CGAN.