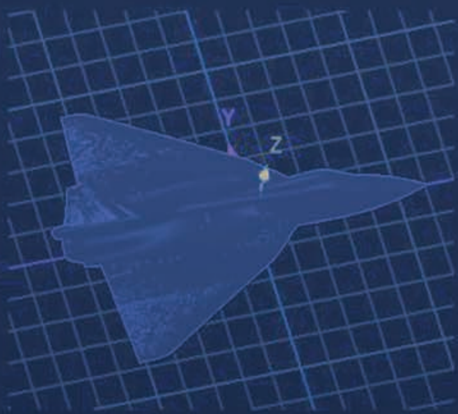
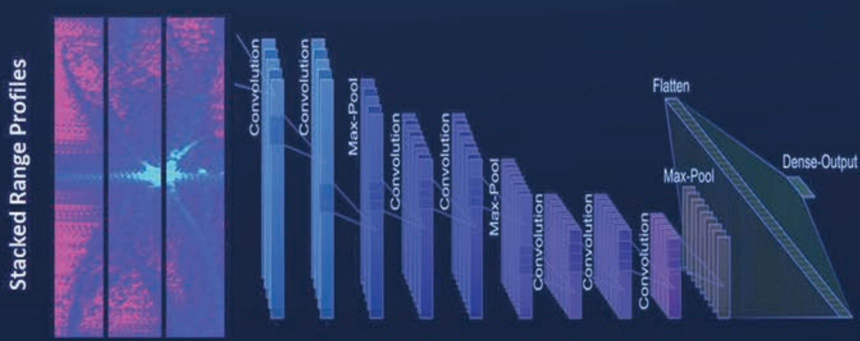
DRDO Young Scientist Laboratory
Cognitive Technologies

DYSL CT





About the Lab

DYSL-CT with emphasis on Cognitive technologies, works in the area of design and development of Cognitive Radar, Cognitive Radio and Edge AI Systems, realizing through Deep Neural Networks and Reinforcement learning algorithms.

DYSL (CT) lab was formed for providing cutting edge technology to DRDO in the cognitive field. The lab is constituted of young scientists to do extensive research and development in the cognitive radar, cognitive radio, Edge AI and cognitive Surveillance fields.

DYSL-CT will be the epicenter for Deep Learning and Reinforcement algorithmic solutions to many classical problems in military applications, in specific radar, radio ,Edge Computing and surveillance systems.

Historical Background

DYSL-Cognitive Technologies (CT) is one amongst the five DRDO young scientist laboratories dedicated to the Nation by Prime Minister of India Shri Narendra Modi on 2nd Jan 2020. The inspiration to start these laboratories came from the Prime Minister Shri Narendra Modi to empower the youth, by giving them decision making powers and challenging research opportunities.

COGNITIVE RADAR

List of Products

- Congnitive Radar Prototype
  - Radar Prototyping System
  - Radar Target Simulator

Technology Achievements

- Deep Neural Network based Automatic Target Recognition using High Resolution Range Profiling.
- DNN based Signal Processing Algorithms for Target Detection and Angle Estimation.
- Improved Algorithm for Ambiguity Resolution & Range Migration Correction.
- Reinforcement Learning Based optimal waveform bandwidth selection at transmitter.

COGNITIVE RADIO

List of Products

Covert Hand-held Radio With Cognitive Features

Technology Achievements

- FFT Based Spectrum Sensor
- Deep Neural Network based modulation identification and Spectrum Sensing
- Dynamic Frequency Hopping @ 12500 hops per second
- Edge A.I. for low power autonomous applications

COGNITIVE RADAR

Cognitive radars are systems that sense the environment, learns from the environment and adapt waveform parameter to improve detection performance, track accuracy, and optimize the radar resource effectively.

Algorithms Developed

01 **Reinforcement Learning Based Waveform Selection**

02 **DNN based Target Discrimination**

03 **DNN based CFAR**

04 **DNN based Angle Estimation**

05 **Improved Algorithm for Ambiguity Resolution & Range Migration Correction**

01 Reinforcement Learning Based Waveform Selection

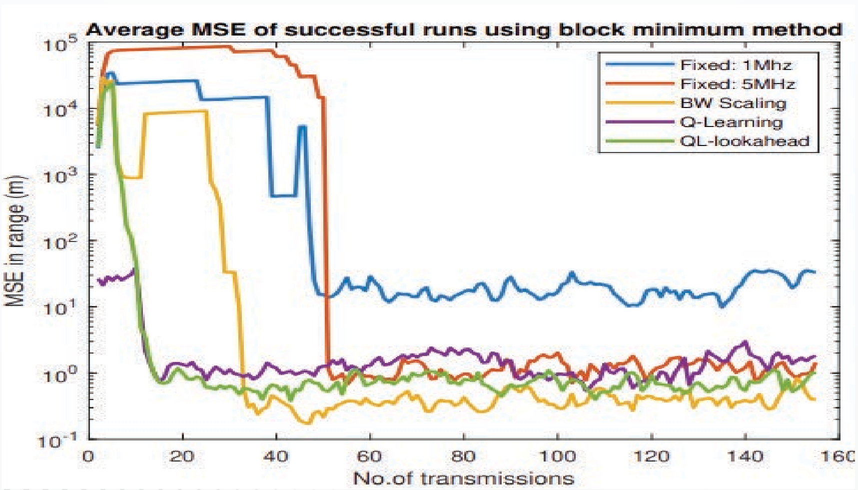
- Adaptive waveform parameter selection to reduce tracking error and loss of track
- Waveform parameter, Bandwidth, selection based on Q Learning (RL Method)
- States : Measurement and Prediction covariance matrices of range
- Actions: Values that Bandwidth can take
- Reward: Function of Error in range and whether track is lost
- Q Table Update

$$Q[s_{t-1}, a_{t-1}] = Q[s_{t-1}, a_{t-1}] + \alpha * (reward_t + \gamma * \max(Q[s_t, :]) - Q[s_{t-1}, a_{t-1}])$$

St is State, at is Action, α is Learning Rate, and γ is Discount Factor

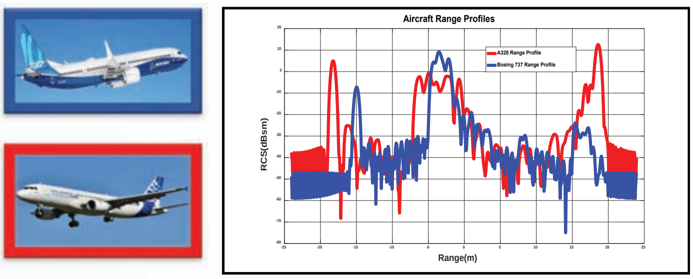
		Measurement error variance							
		<20	20-40	40-60	60-80	80-100	100-150	150-200	>200
Prediction error variance	<20	10	1	2.5	5	0.5	7.5	0.5	7.5
	20-40	2.5	7.5	2.5	2.5	10	0.5	7.5	5
	40-60	10	5	7.5	7.5	2.5	10	2.5	5
	60-80	5	10	2.5	5	1	10	10	10
	80-100	10	1	0.5	5	0.5	7.5	0.5	10
	100-150	7.5	0.5	10	7.5	10	1	1	10
	150-200	7.5	2.5	7.5	2.5	1	5	7.5	2.5
	200-300	5	10	5	7.5	10	5	10	7.5
	300-500	2.5	5	5	5	5	7.5	5	2.5
	> 500	5	10	10	5	5	7.5	1	7.5

Table 1: Best BW (in MHz) learnt by Q-Learning lookahead

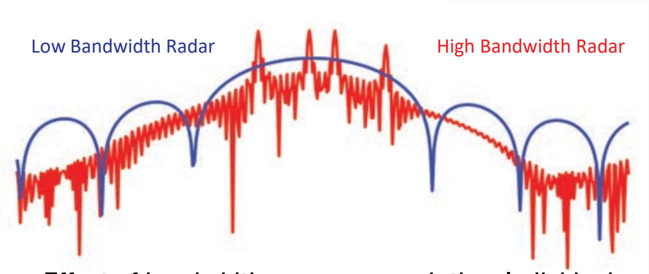


02 Target Discrimination using HRRP

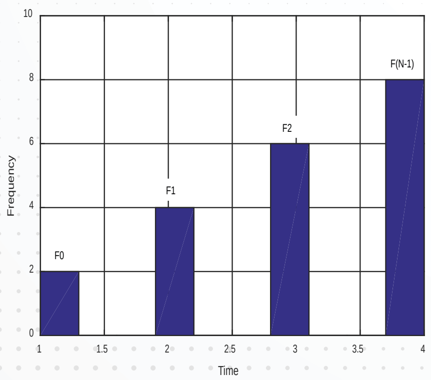
- Range Profile is a one-dimensional signature of an object
- Wide Bandwidth signal is used to produce High Resolution Range Profile of Target
- Stepped Frequency Mode (SFM) is used to achieve desired wide bandwidth from a series of pulses
- Deep Neural Network based Classifier (ex. CNN, SAE, RBM) is used to determine target type
- Aircraft Range Profile data simulated using Electromagnetic Simulation Software is used to train Neural Networks



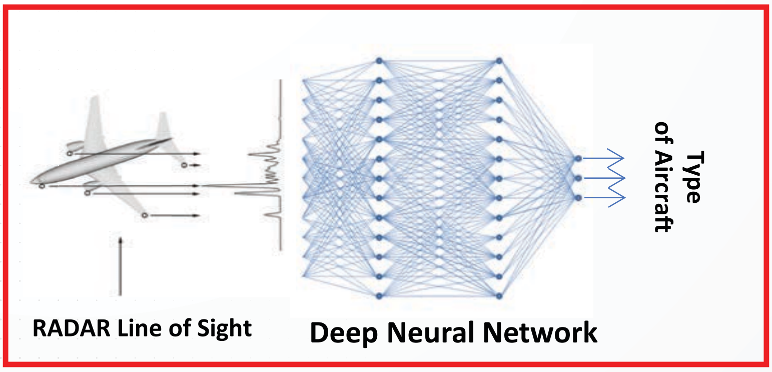
Range Profiles of Civilian Aircraft

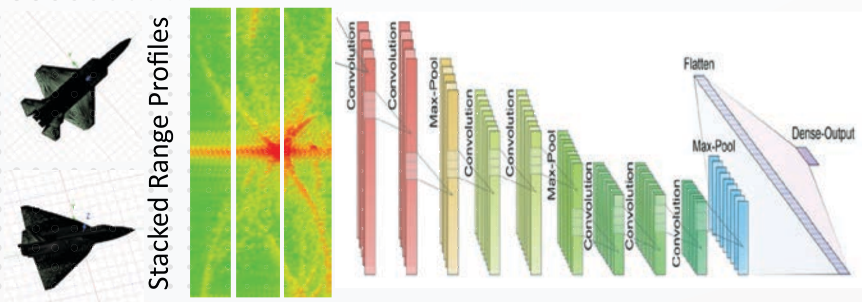


Effect of bandwidth on range resolution, Individual scatterers are visible in higher bandwidth



Stepped Frequency

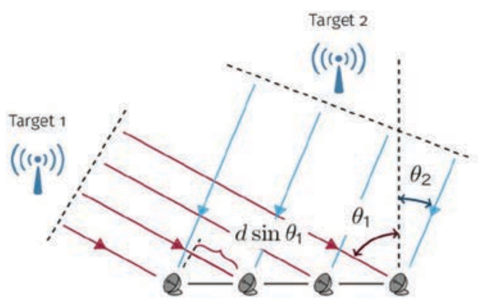




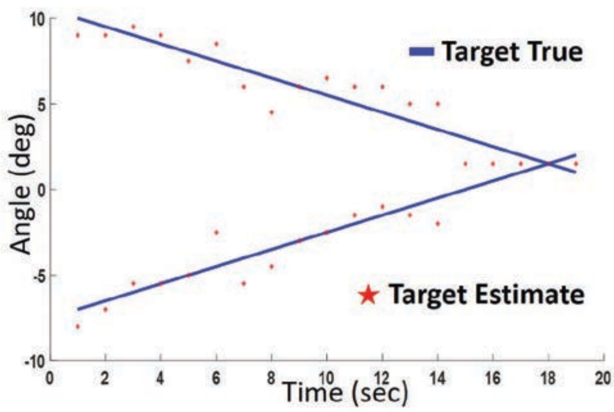
Range Profiles of Military Aircraft

03 Neural Network based Angle Estimation

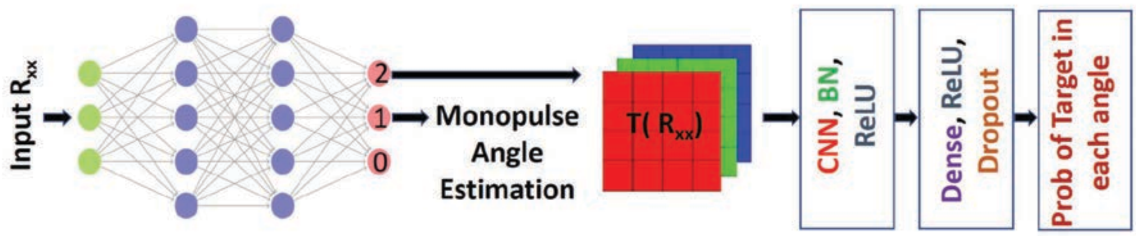
- Conventional Angle of Arrival algorithms like Monopulse cannot discriminate targets within beamwidth, if targets cannot be discriminated in range & range rate
- Classical algorithms for multiple source's angle estimation are MUSIC, R-MUSIC, and ESPIRIT , which needs prior information of number of targets, for better accuracy at lower SNR
- Neural network based two stage multiple source's angle estimation
  - First stage neural network estimates the number of targets / sources in the signal
  - If the number of targets are more than one, second stage neural network will estimate the corresponding angle of arrivals.



Signal X Size: 4 x T
T is number of snapshots



Results of two Targets Angles of Arrival Estimation

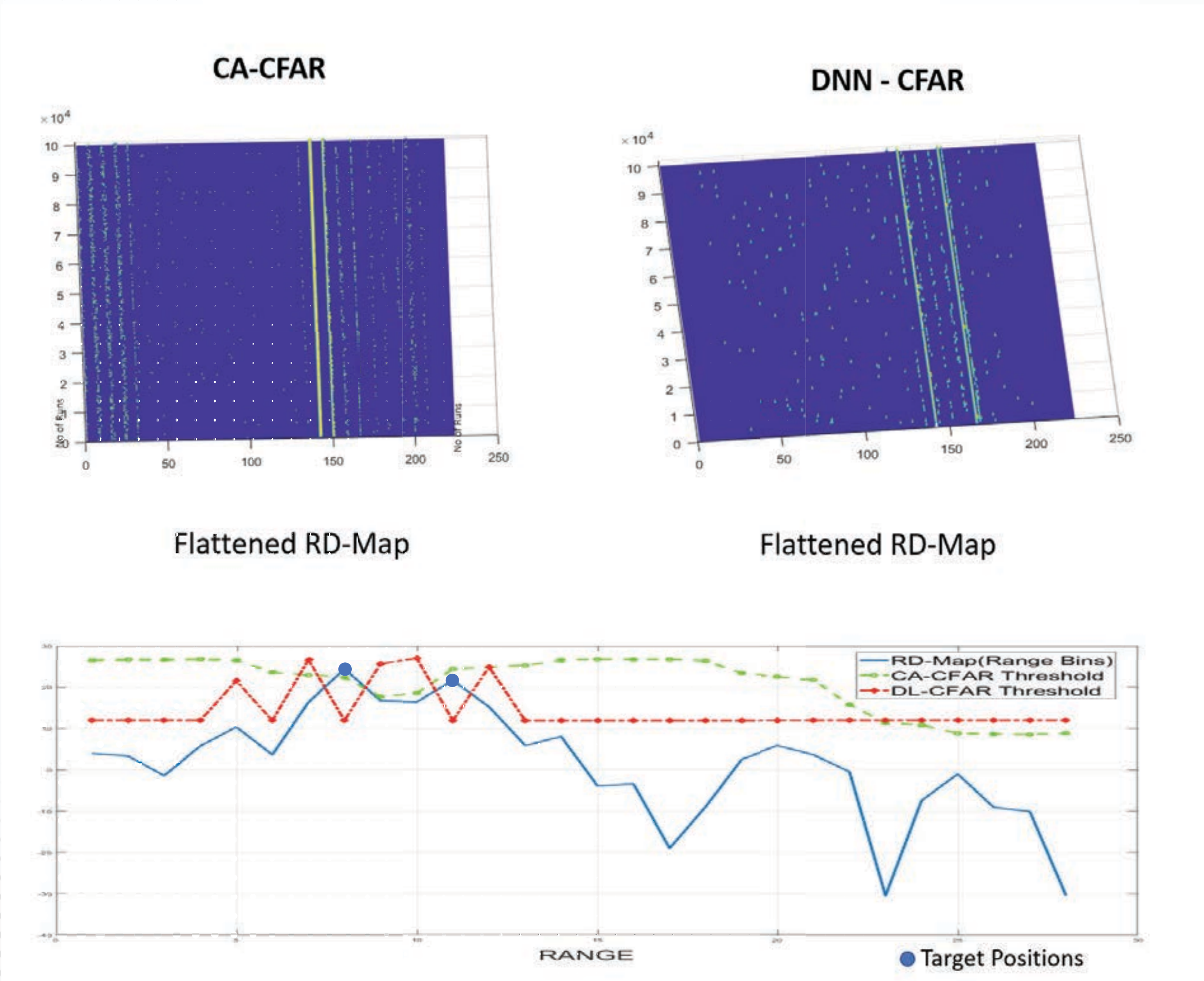


Estimate Number of Targets

Neural Network Angle Estimation

04 Neural Network based CFAR

- **Classical : Cell Averaging – Constant False Alarm Rate**
  - Utilizes the arithmetic mean of power of reference cells as noise cell estimate
  - Performance degrades in multi-target scenario because of erroneous noise estimate
  - Result is influenced by parameter setting (Guard Cell Size)
  - Ordered Statistic - CFAR solves the problem but bottleneck is sorting problem that increases computational complexity
- **Improved : Deep Neural Network – Constant False Alarm Rate**
  - Learns the structure of targets in RD map and eliminates those structures to acquire RD map with pure noise.



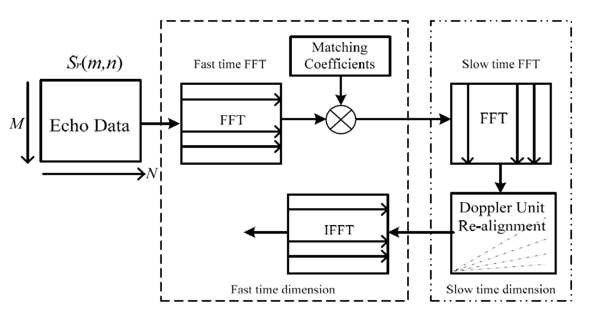
05

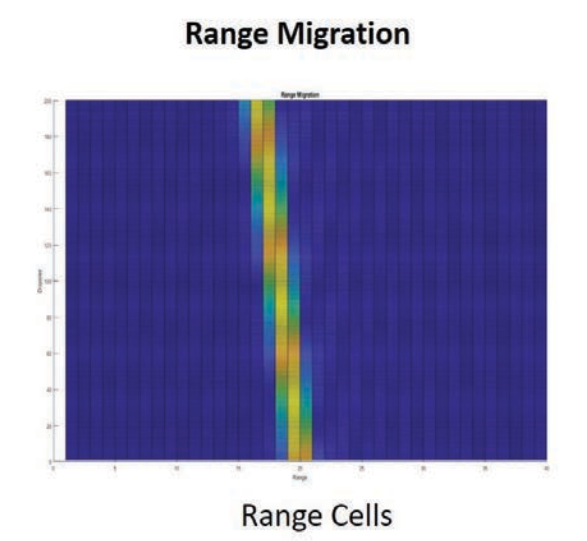
Range & Doppler Correction for Wide Bandwidth

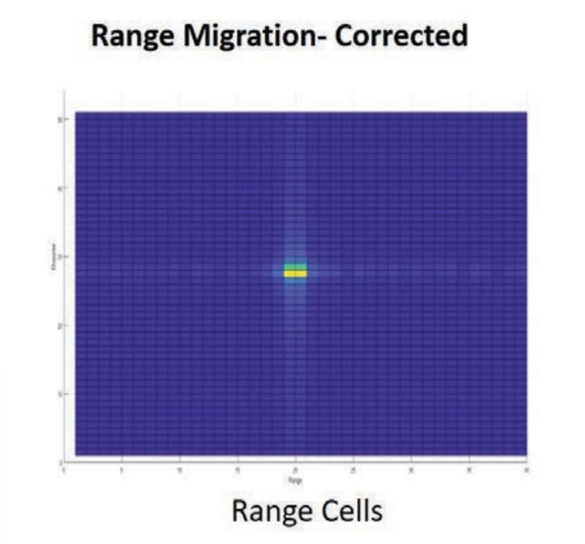
- The motion of Target in the coherent integration interval will severely affect the coherent integration performance of target echo
- Conventional Range Migration Correction
  - Hough Transform – Target Detection is transformed into the line detection in image processing, and the HT method of detecting straight lines in images is used for target detection.
  - Keystone Transformation fails when the doppler is ambiguous. KT method with simultaneous search for doppler ambiguity integer and frequency solves the issue. But, Complexity is high

Range Migration Correction based on 2D Frequency Correction

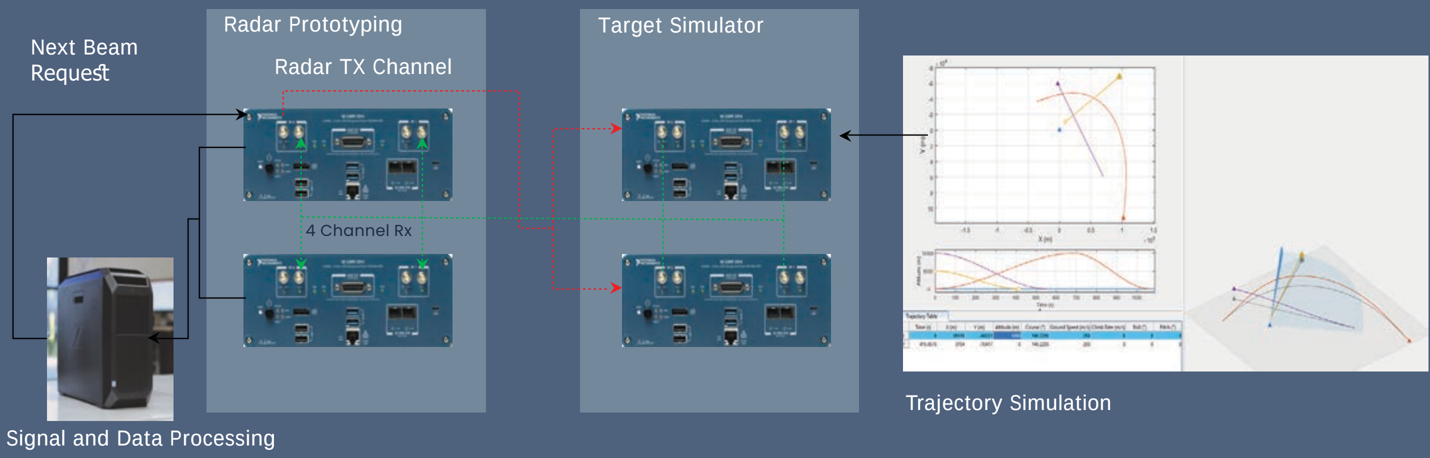
  - The algorithm realizes the motion compensation of the target by re-aligning the echo data in fast time frequency doppler domain, and achieves intra pulse accumulation and inter-pulse integration in transform domain







06 Lab Prototype System



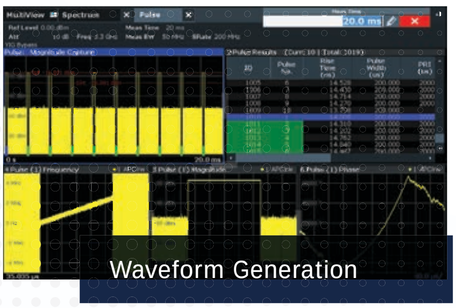
Block Diagram of Cognitive Radar – Prototype project

Radar Prototyping system

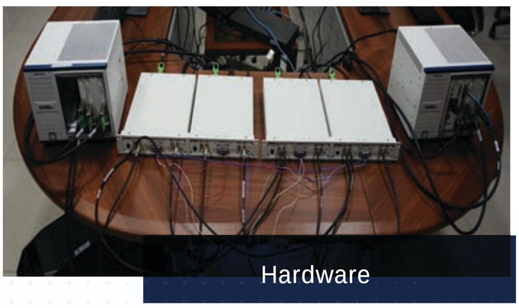
- USRP (Software Defined Radio) based 4 channel Radar Prototype
- Generates waveform (LFM) with various bandwidth (few KHz to 100 MHz) based on request from Radar Controller
- Receives the 4 channel target information from Radar Target Simulator, decimates and sends IQ data to Signal Processor implemented in a Workstation

Radar Target Simulator

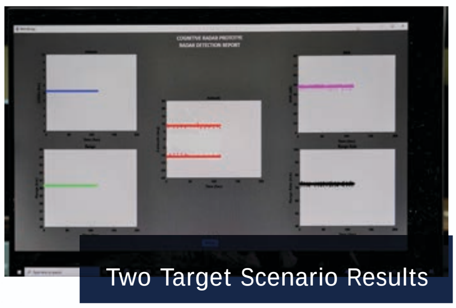
- Simulates target information (range, range rate, & Angle) based on the trajectory
- Modulates the Tx signal Prototype System as per target parameters & Transmits back to the prototype



Waveform Generation



Hardware

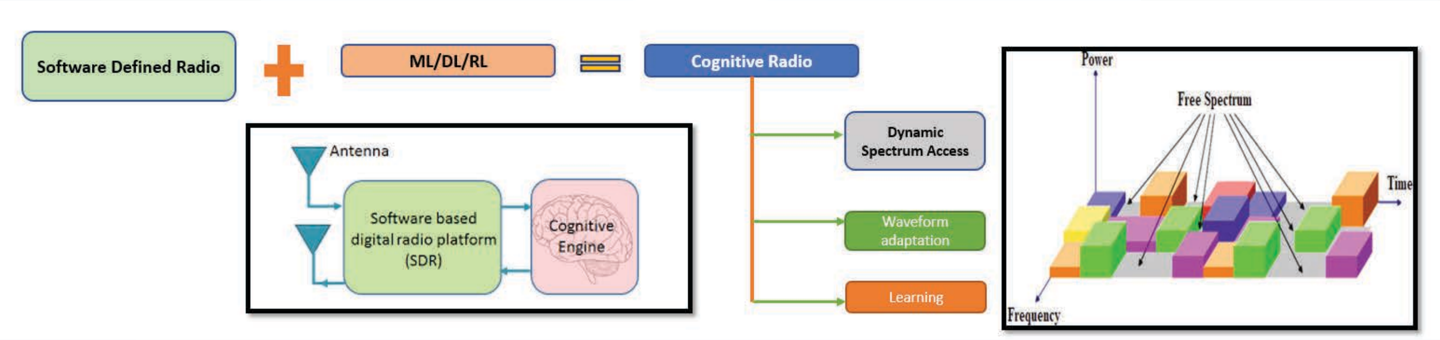


Two Target Scenario Results

COGNITIVE RADIO

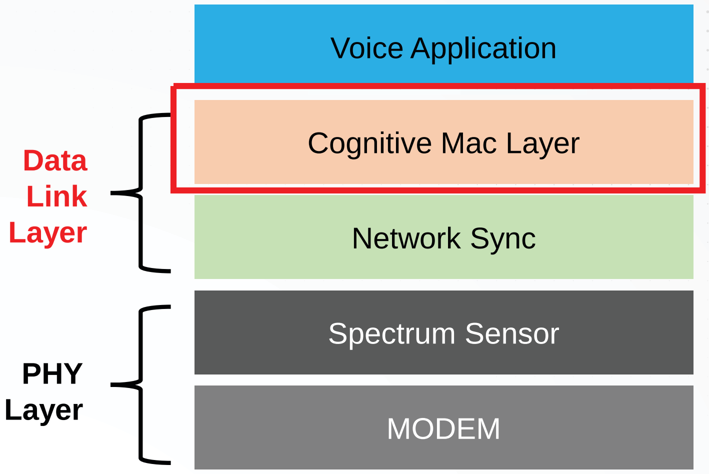
Covert Hand-held Radio With Cognitive Features

- An intelligent radio, aware of its spectrum and reconfigures its transmission parameters (Frequency, waveform, modulation, protocols) dynamically by exploiting the learning acquired through exploring.
- A Promising technology for providing the mechanisms to mitigate interference, and allow more flexible and dynamic radio resource utilization.
- The adjustability function is achieved by software controlled signal processing algorithms.
- The product promises improvement in frequency spectrum utilization and also interference mitigation by implementing highly reliable and efficient wireless communications.



Features of Cognitive Waveform Developed

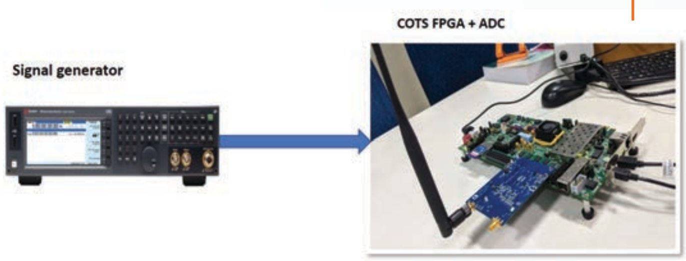
- Network Degree: 15
- Frequency Hopping @ 12500 hops per second
- Dynamic Frequency Hopping
- Spectrum Sensing
- Cognitive Cycle Duration : 30 ms



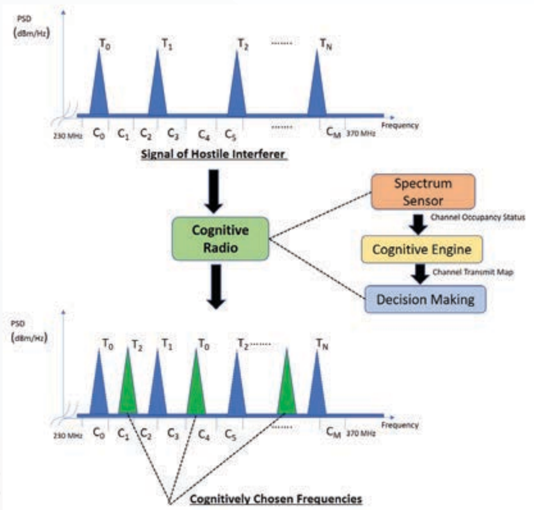
WAVEFORM STACK

Development of FFT based Spectrum Sensor

Hardware Implementation of the FFT based Spectrum Sensor



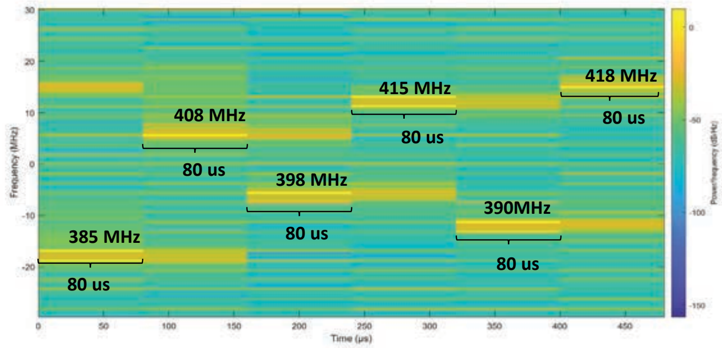
- Cognitive Waveform has spectrum sensing capabilities by performing real time analysis (every 80 us) of the operational spectrum.
- Cooperative Sensing is carried out where individual receivers share the local sensing information with the call initiator to resolve interference.



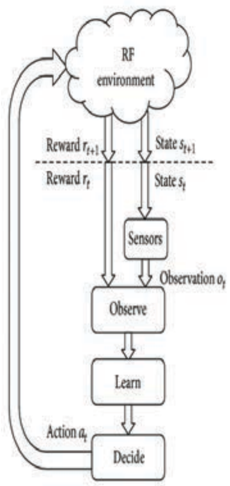
Dynamic Frequency Hopping

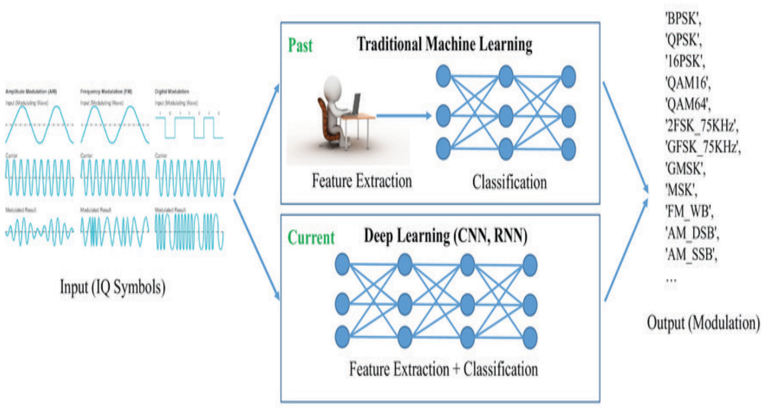
Frequency hopping
@12500 hops per second

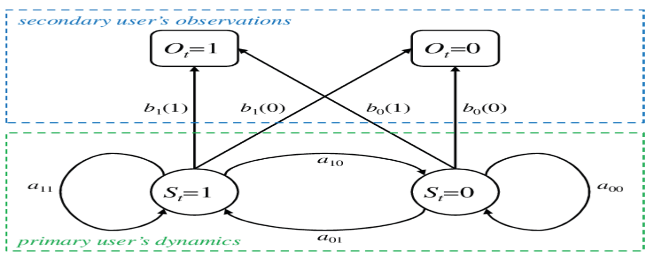
- Research and Development on spectrum sensing, modulation identification, fast hopping for anti-jamming hand held cognitive radio designed and developed at DYSL-CT, Chennai.



- Design and development of Spectrum sensing methods using Reinforcement learning and Deep Learning techniques to improve Detection Probability at low SNR.
- Design and implementation of Deep learning based modulation identification.
- Design and development of Cognitive MAC using Deep Reinforcement







EDGE A.I.

Edge A.I. = Edge Computing + Artificial Intelligence

Edge Computing: distributed computing paradigm that brings computation and data storage closer to the location of the device.

Artificial Intelligence: Autonomous data and experience driven decisions

Starting with sensors and ending with actions

DATA CENTER-GRADE NETWORK, COMPUTE & STORAGE

Closer to

ENDPOINT DEVICES

5G

TO IMPROVE SERVICE CAPABILITIES

Optimize Cost

Reduce Application Latency

Comply with Data Locality

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