Cardinal Radio Frequency (CARDRF) Dataset

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***Abstract*—This article presents the details of the Cardinal RF (CardRF) dataset. CardRF is acquired to foster research in RF-based UAV detection and identification or RF fingerprinting. RF signals were collected from UAV controllers, UAV, Bluetooth, and Wi-Fi devices. Signals are collected at both visual line-of-sight and beyond-line-of-sight. The assumptions and procedure for the data acquisition are presented. A detailed explanation of how the data can be utilized is discussed. CardRF is over 65 GB in storage memory.**

***Index Terms*—RF fingerprinting, unmanned aerial system.**

I. Introduction

In this work, we curated an open-source dataset called the Cardinal RF dataset, abbreviated as the CardRF dataset. Here, both the UAV and UAV flight controller signals from six UAS (unmanned aerial systems), WiFi signals from two WiFi devices, and Bluetooth signals from five devices are used to acquire the CardRF dataset in an outdoor environment.

The device catalogue (UAS, Bluetooth, and WiFi) is listed in Table I. The Bluetooth and WiFi devices are used to acquire Bluetooth and WiFi signals, respectively. Similarly, two components (i.e., UAV and its flight controller) of a UAS are utilized in collecting the UAS signals.

TABLE I
Catalog of RF devices used in the experiment for 2.4 GHz RF fingerprint acquisition.

Device	Make	Model
UAV	DJI	Phantom 4
		Inspire
		Matrice 600
		Mavic Pro 1
	Beebeerun	FPV RC drone mini quadcopter
	3DR	Iris FS-TH9x
Bluetooth	Apple	iPhone 6S
		iPhone 7
		iPad 3
	FitBit	Charge3 smartwatch
	Motorola	E5 Cruise
WiFI	Cisco	Linksys E3200
	TP-link	TL-WR940N

The experiment was conducted during the Summer of 2020 (August 2020) using the AERPAW (Aerial Experimentation Research Platform for Advanced Wireless) facility [1] which is called the Lake Wheeler site. The site is located at 4191 Mid Pines Road, Raleigh, North Carolina, USA.

II. Experimental Model and Design

The experimental model and design have been discussed in [2]. Please refer to [2] for how we deal with the absence of RF signals in an environment.

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III. Data Acquisition

The data acquisition is categorized into visual line-of-sight (VLOS) and beyond-visual-line-of-sight (BVLOS) data collection.

1) Visual line of sight data: The VLOS is synonymous to light-of-sight (LOS). During the VLOS signal capturing, there is no obstruction between the RFSSCS (RF signal sensing and capturing system) and the device (i.e., UAV, UAV controller, or other devices). Fig 1(a) and Fig 1(b) show the VLOS capturing of a UAV controller and UAV (DJI Matrice 600), respectively. Signals are captured at a distance range of 8 - 12 meters between the devices and RFSSCS.

2) Beyond-visual-line-of-sight: BVLOS is synonymous with non-line-of-sight (NLOS). In BVLOS data capturing, there is an obstruction between the RFSSCS and the devices. This is to analyze the impact of multi-path fading or other channel effects on the RF signature. Fig 2 shows the BVLOS UAV signal capturing where the UAV is flying adjacent to a building. Only three UAVs' signals (i.e., DJI Inspire, DJI Matrice 600, and DJI Phantom) are captured for this collection.

IV. Data Description and Utilization

The data labeling is done by a manual process using a directory and sub-directories. Fig. 3 shows the directory tree for the labeling of the RF dataset. The root directory is the name of the dataset repository, which is called CardRF. Because signals are captured at LOS and NLOS, two sub-directories are created for LOS and NLOS. Four categories of signals (i.e., UAV, UAV controller, Bluetooth, and WiFi) are collected for the LOS data collection. So for each category of signals, a sub-directory is created under the LOS directory to store the signals. Similarly, only UAV signals are captured at NLOS. So the NLOS directory only contains the UAV sub-directory.

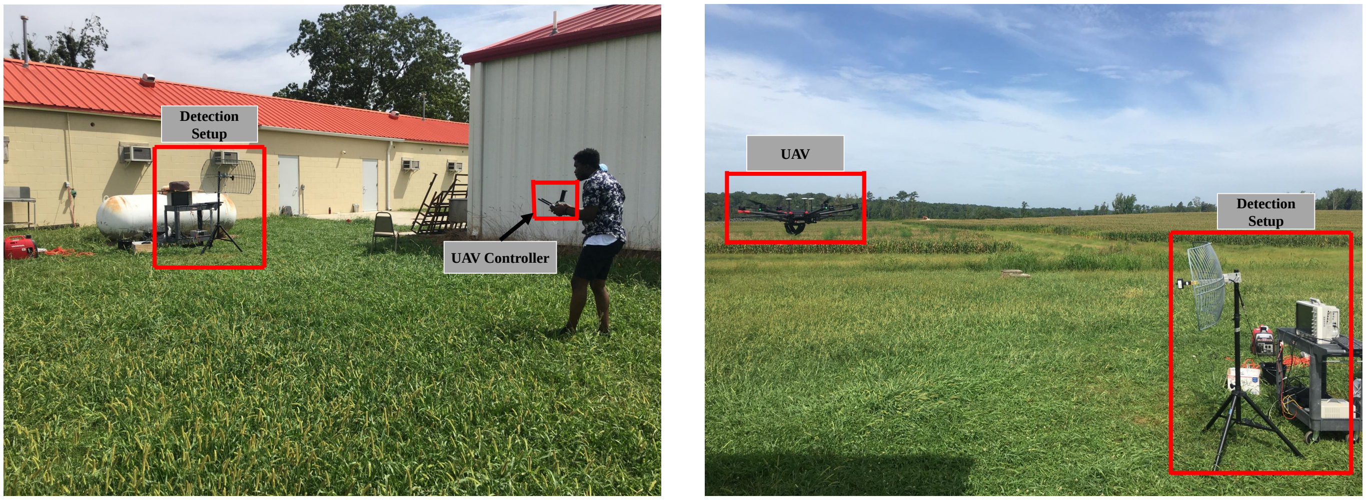
Please refer to [2], [3] for the detailed data description. Fig. 6 shows a signal captured from DJI Phantom 4 flight controller where the transient and steady state of the signal are labeled.

V. MATLAB Code for Labeling and Preprocessing

When the mat file is loaded in MATLAB, it gives two struts (i.e., Channel_1 and Frame). The Frame consists of other metadata. The Channel_1 has over 15 fields. Fig. 7 shows the list of fields in the Channel_1 struct. The captured signal (signal sampled) is exposed by the Data field.

Listing 1. Loading signal in MATLAB

```
x=load(file_path); %Loading a MAT file
signal=double(x.Channel_1.Data);
```



(a) (b)

Fig. 1. The RFSSCS setup for visual line of sight capturing of signals from : (a) a UAV controller, (b) a UAV (DJI Matrice 600).

Fig. 2. The RFSSCS setup for beyond-visual-line-of-sight capturing of signals from UAV.

CARDRF directory has the raw signals and it is split to train and test set already. The Processed CardRF directory has the sliced steady signals from LOS with respective class or label. Each signal in the processed CardRF directory has 1024 sampling points. MATLAB code used for processed CardRF is in code directory.

In the code folder, there is a MATLAB file ($SIGNALPLOT.mlx$) for plotting the signals. However, the raw signals need to be scaled by using a scale factor of $6.581e-06$ for the voltage. The detail of the scaling is in the file.

More information about the code used for [2], [3] can be found https://github.com/medosh09/Cardinal-RF

VI. Conclusion

This data can be used to foster research in RF fingerprint and UAV detection.

VII. Acknowledgment

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References

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[3] O. Medaiyese, M. Ezuma, A. P. Lauf, and I. Guvenc, "Wavelet transform analytics for RF-based UAV detection and identification system using machine learning," *arXiv preprint arXiv:2102.11894*, 2021.

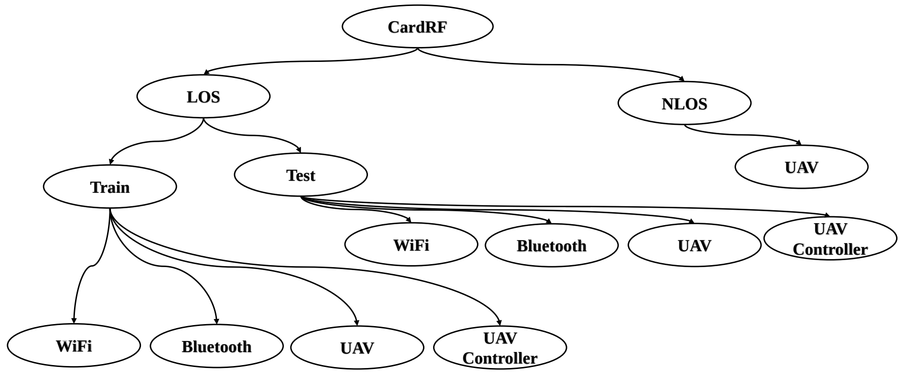

Fig. 3. Directory tree for data label of the Cardinal RF dataset.

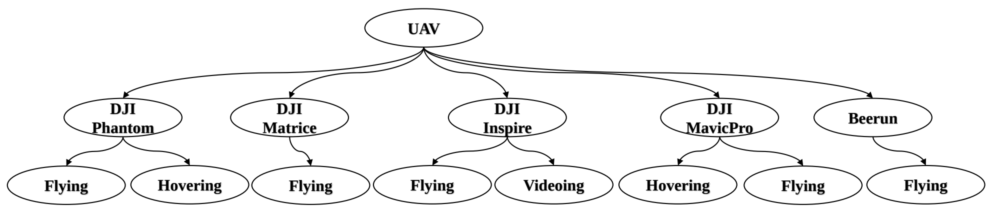

Fig. 4. Directory tree for the LOS UAV signal labels showing the UAV models and UAV flight modes as sub-directories and sub-directories of sub-directories, respectively.

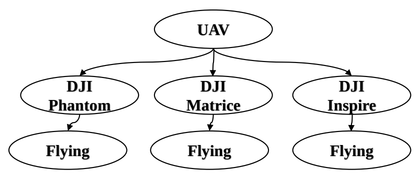

Fig. 5. Directory tree for the NLOS UAV signal labels showing the UAV models and UAV flight modes as sub-directories and sub-directories of sub-directories, respectively.

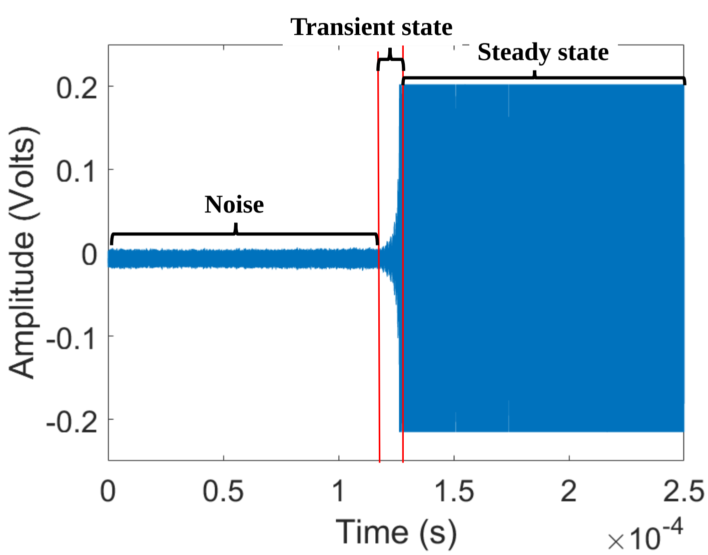

Fig. 6. A typical example of a signal captured from DJi Phantom 4 flight controller (adopted from [2])

```
Channel_1 =

  struct with fields:

       NumPoints: 5000000
     NumSegments: 0
    WaveformType: 'NORMAL'
     XDispOrigin: -5.0000e-04
      XDispRange: 0.0010
            XInc: 5.0000e-11
            XOrg: -1.2500e-04
          XUnits: 'Second'
     YDispOrigin: 0
      YDispRange: 0.4000
            YInc: 6.5841e-06
            YOrg: 0.0066
          YUnits: 'Volt'
            Data: [5000000×1 int16]
           XData: []
```

Fig. 7.