A MOBILE RADAR SYSTEM

TO DETECT AND TRACK A SMALL MOVING OBJECT

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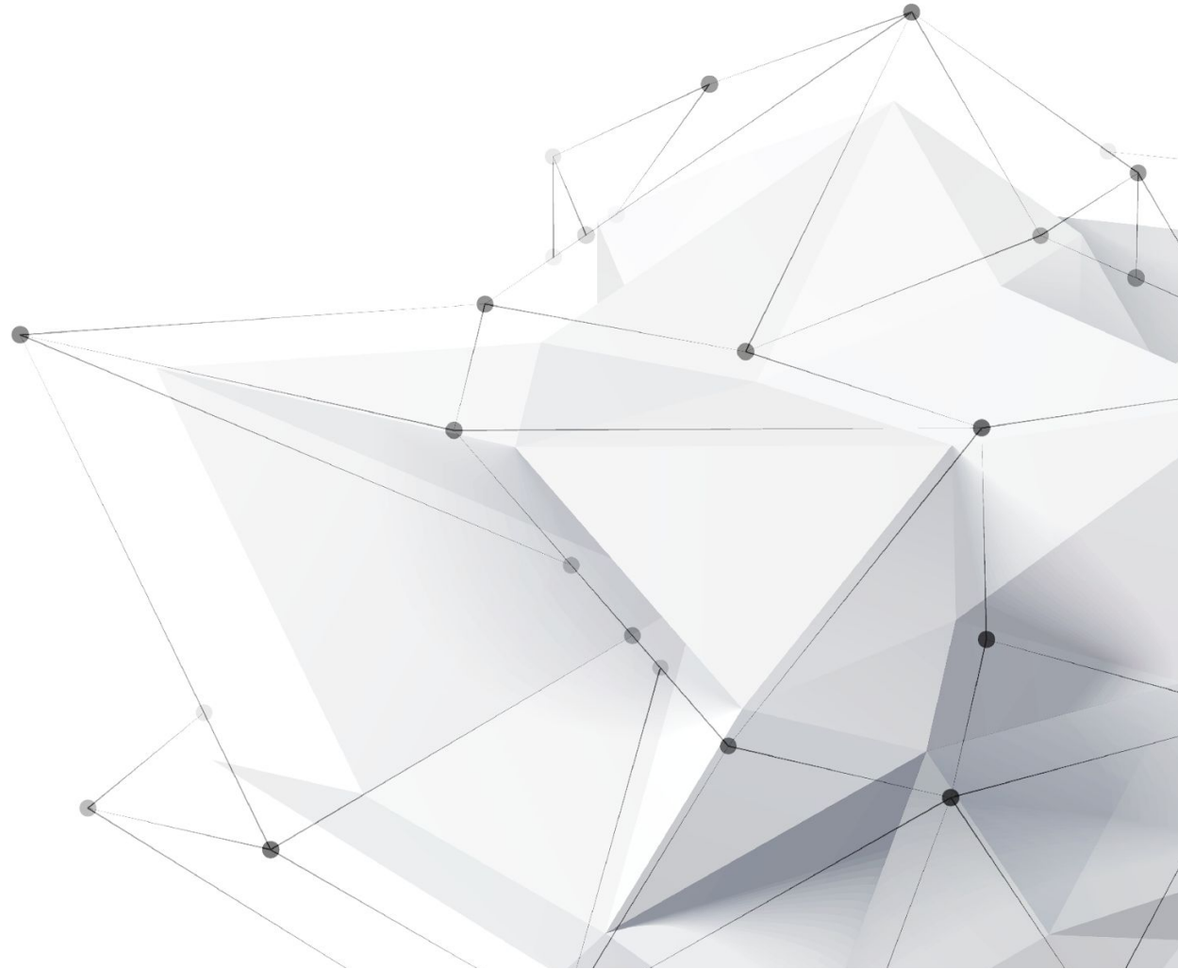

MOTIVATION

Sudden landing of a drone on the White House lawn

- A drone landing on the last of the White House on Jan 26th, 2015
- What if the purpose of the drone was to throw an explosive?
- What is a method to detect those kind of unmanned vehicle?

https://scottschober.com/downed-drone-raises-white-house-security-concerns/

MOTIVATION

What if it is happened in the middle of a big festival?

- What if a threatening drone appears at a public place such as the Purdue football stadium or a festival at a University?
- What kind of sensor can catch the drone and report in real-time?

http://www.jconline.com/story/news/crime/2016/11/18/plainclothes-police-patrol-purdue-home-games/93296122/

http://blog.daum.net/_blog/BlogTypeView.do?blogid=0fGWm&articleno=27&categoryId=0

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PROBLEM STATEMENT

A radar to detect and track a moving target

- Requirements for a sensor to detect a drone in a public place:
  - Safe for human health
  - Robust to sound noise, weather, and light condition
  - Real-time detection
  - Low power and maintenance cost
  - Ability to monitor high altitude where drones fly
- Military, weather, maritime or air traffic monitoring:
  - High power, large volume, high cost, low accessibility

https://en.wikipedia.org/wiki/Radar

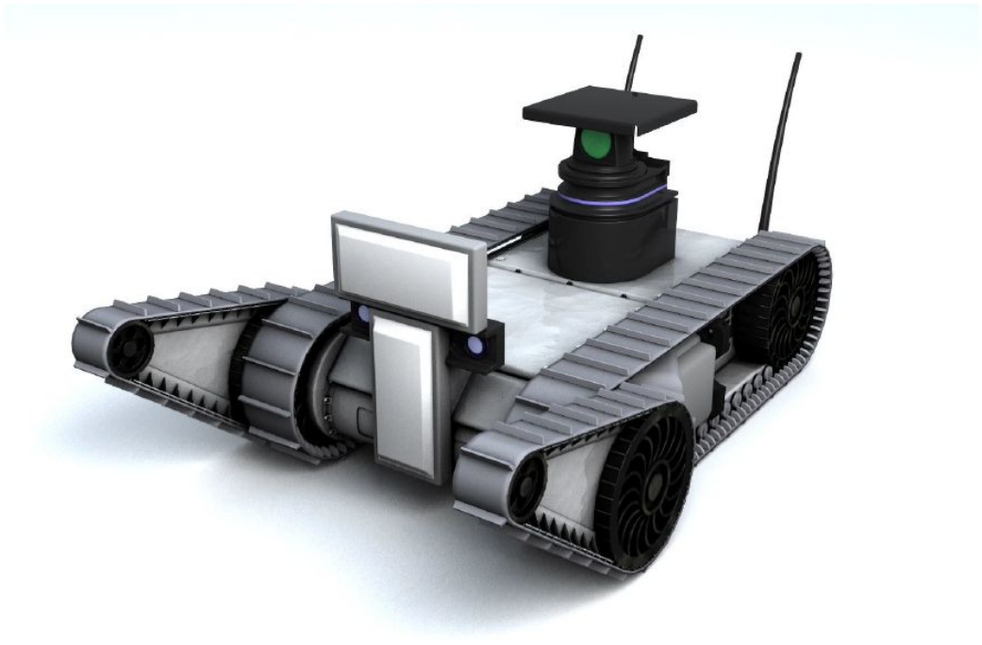
http://www.raymarine.com/view/?id=243

http://www.coherentchronicle.com/weather-radar-market-trends-analysis-growth-industry-outlook-and-overview-by-million-insights/

SURVEILLANCE RADAR

A solution for surveillance a public place

- Develop a radar system that is portable, safe to operate in public places:
  - The size of the radar system is small enough to load on an unmanned vehicle
  - The radar will provide monitoring data in real-time
  - Fundamental technology applicable to sensing and remote surveillance



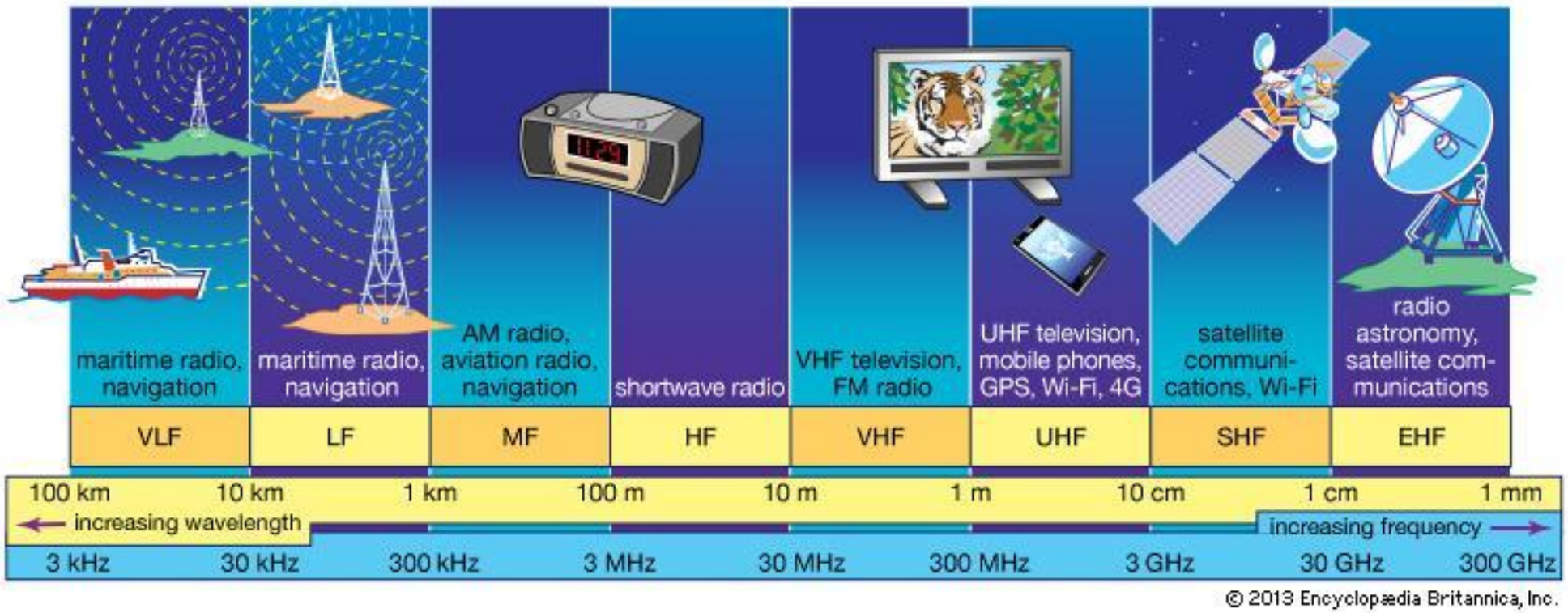
Yamauchi, B. (2007, May). Daredevil: ultra-wideband radar sensing for small UGVs. In *Unmanned Systems Technology IX* (Vol. 6561, p. 65610B). International Society for Optics and Photonics.

Moses, A. A., Rutherford, M. J., Kontitsis, M., & Valavanis, K. P. (2011, May). UAV-borne X-band radar for MAV collision avoidance. In *Unmanned Systems Technology XIII* (Vol. 8045, p. 80450U). International Society for Optics and Photonics.

RADAR

What is radar?

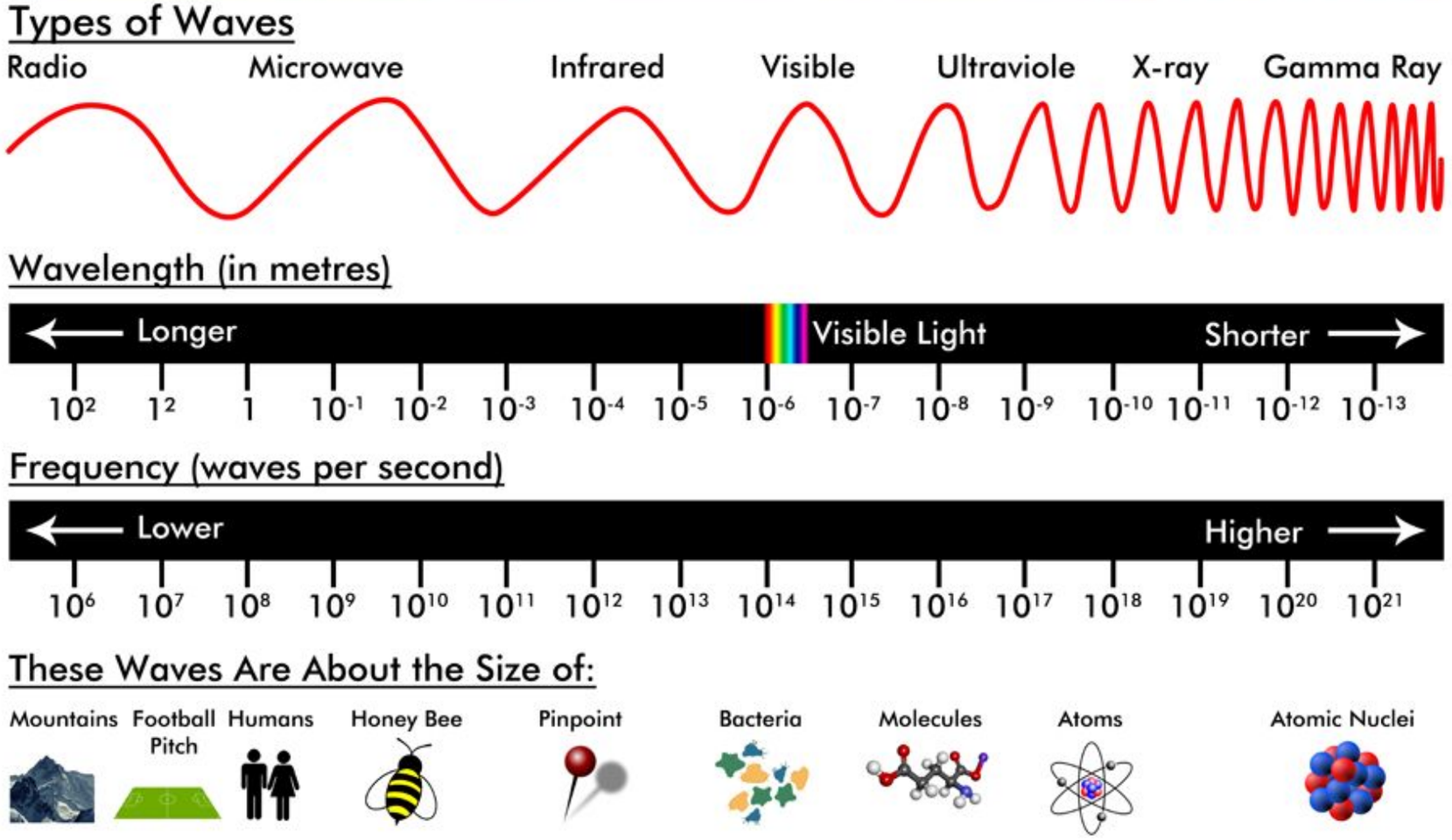
- **Radar**: **RA**dio **D**etection **A**nd **R**anging
- **Radio frequency** (**RF**): Any of the **electromagnetic** (**EM**) **wave frequencies** that lie in the range from 3 kHz to 300 GHz



ELECTROMAGNETIC WAVE

What is electromagnetic wave?

- Visible light and radio frequencies are parts of EM wave
- Radio: Broadcasting band 87.5 ~ 108.0 MHz
- WiFi (wireless local area networking): 2.4 GHz, 5.8 GHz
- Radar we are using: 2.4 ~ 2.5 GHz



https://www.tigermoon.co.uk/products/the-electromagnetic-spectrum-posterd

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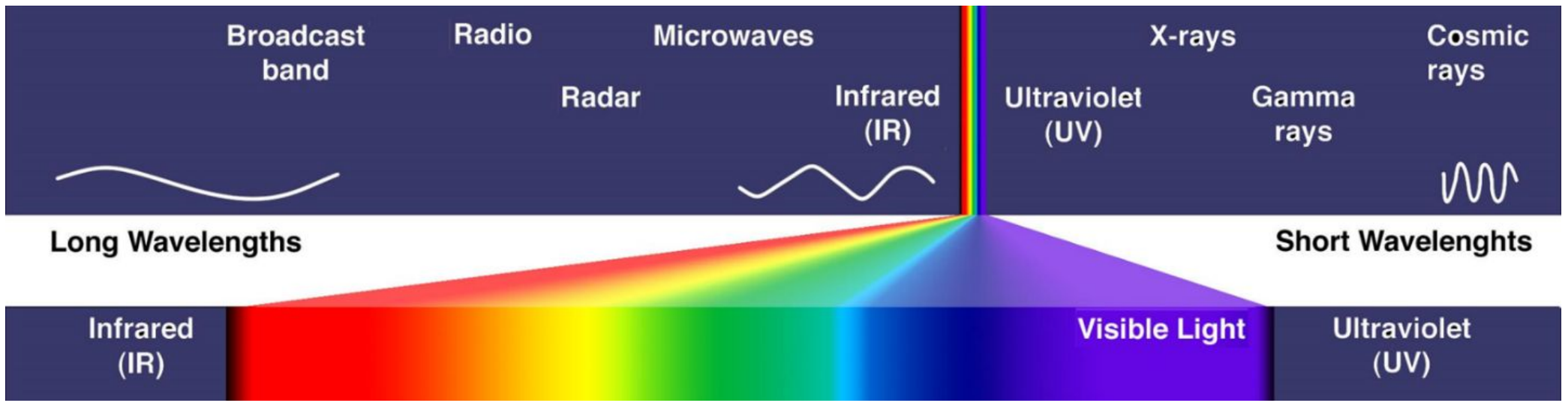
DOPPLER SHIEFT

How to measure range or velocity using the EM wave?

- **Doppler Effect** (or **Doppler shift**)**:** The change in frequency or wavelength of a wave for an observer moving relative to its source (also called as Red shift / Blue shift)
- https://en.wikipedia.org/wiki/Doppler_effect#/media/File:Dopplerfrequenz.gif
- The wave is extended or compressed
- In other words, the frequency is decreased or increased

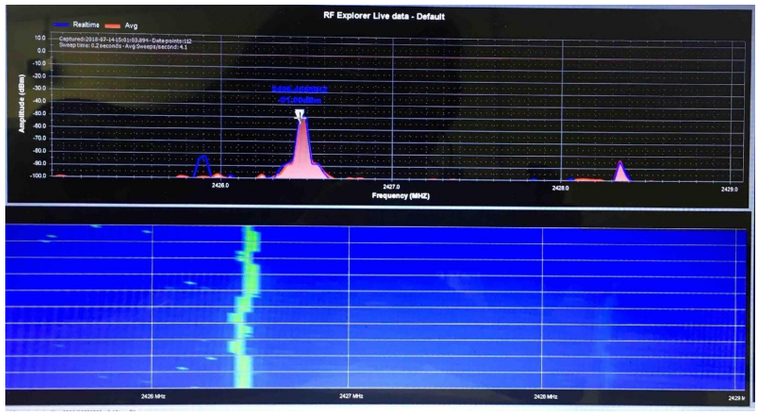


http://www.dailyoptician.com/andrew-bruce/2015/9/23/the-electromagnetic-spectrum-uv-rays-andrew-bruce

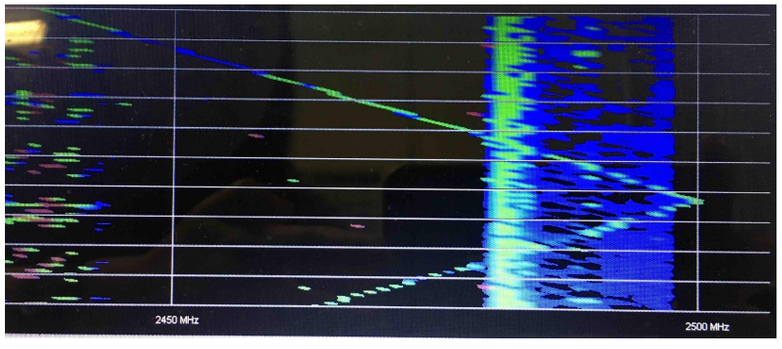
TYPES OF RADAR

Pulse-Doppler radar and Frequency Modulated radar

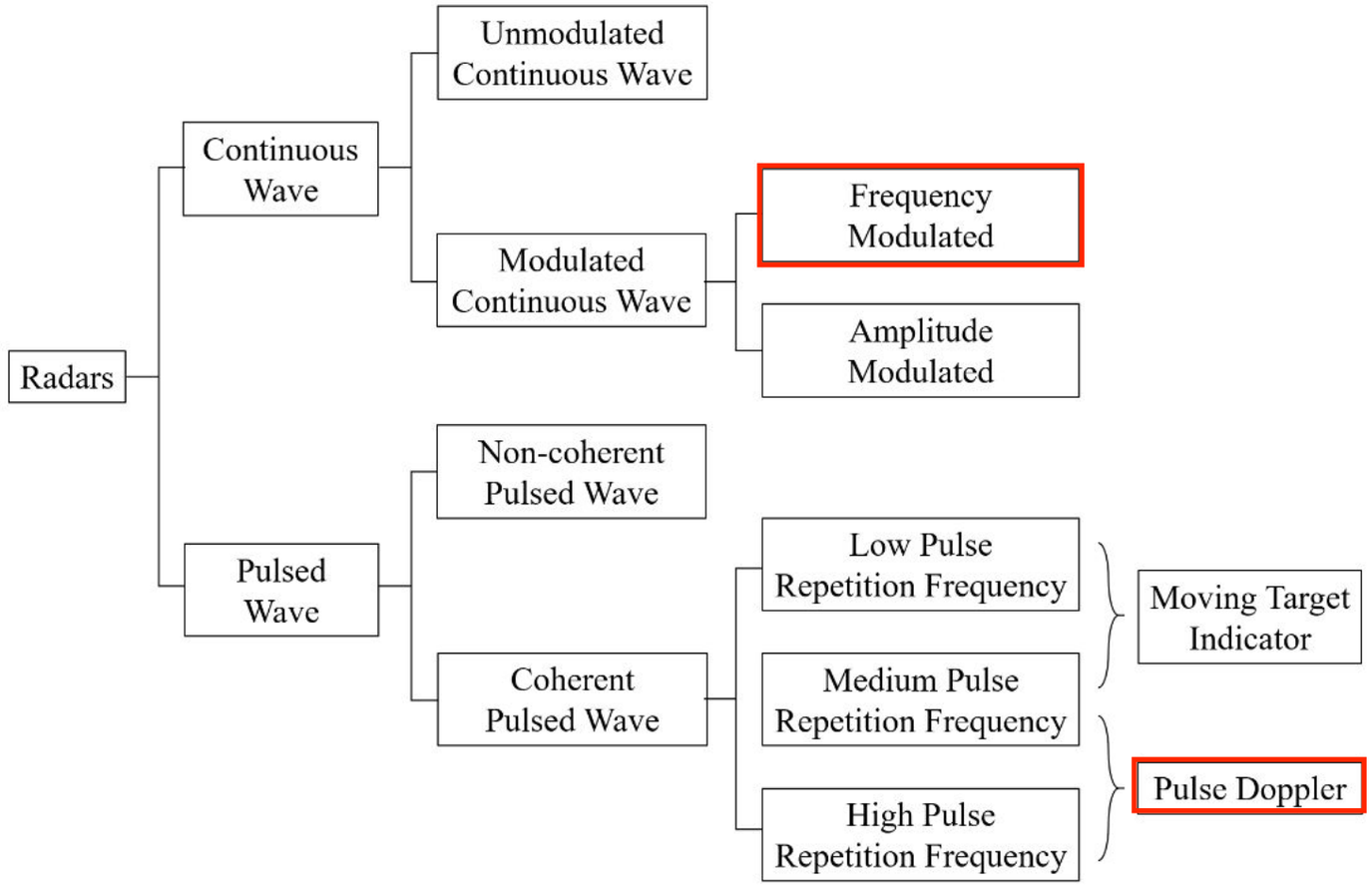
- **Pulse-Doppler Radar:** A radar system utilizes pulse-timing techniques to determine the range to a target, and uses the Doppler Effect to measure velocity of target objects
- **Frequency-Modulated Continuous-wave (FMCW) Doppler radar:** A radar system utilizes a range of frequency, usually uses the Doppler effect of the returned signal to determine the velocity of target objects



Continuous Wave (CW)



Frequency Modulated Continuous Wave (FMCW)



Jenn, D. (2008) Radar Fundamentals, Presentation

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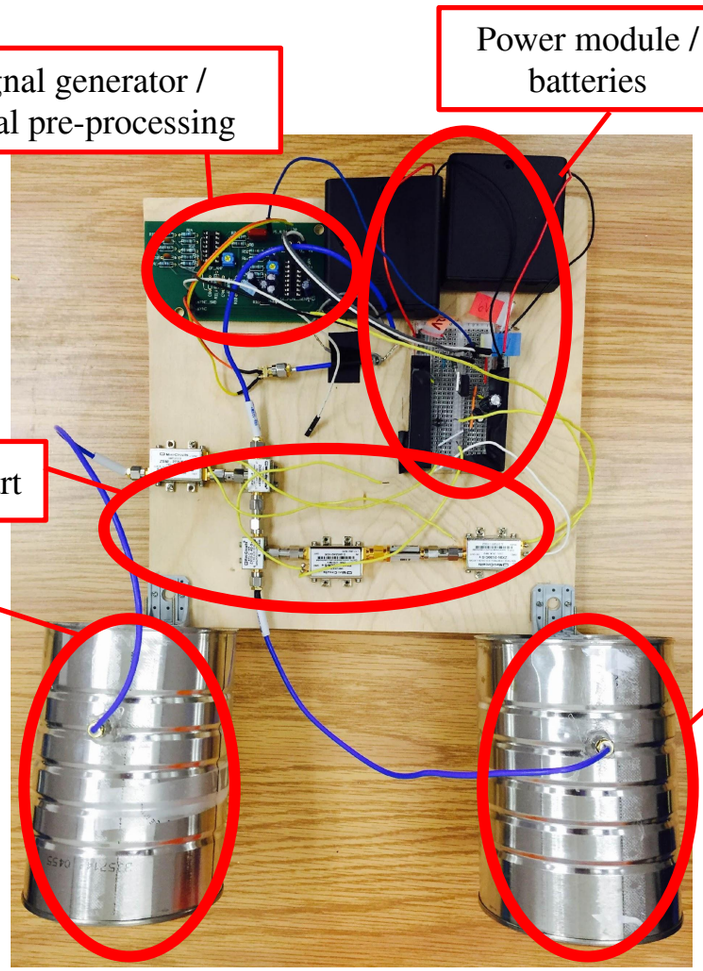
A LOW COST DETECTOR

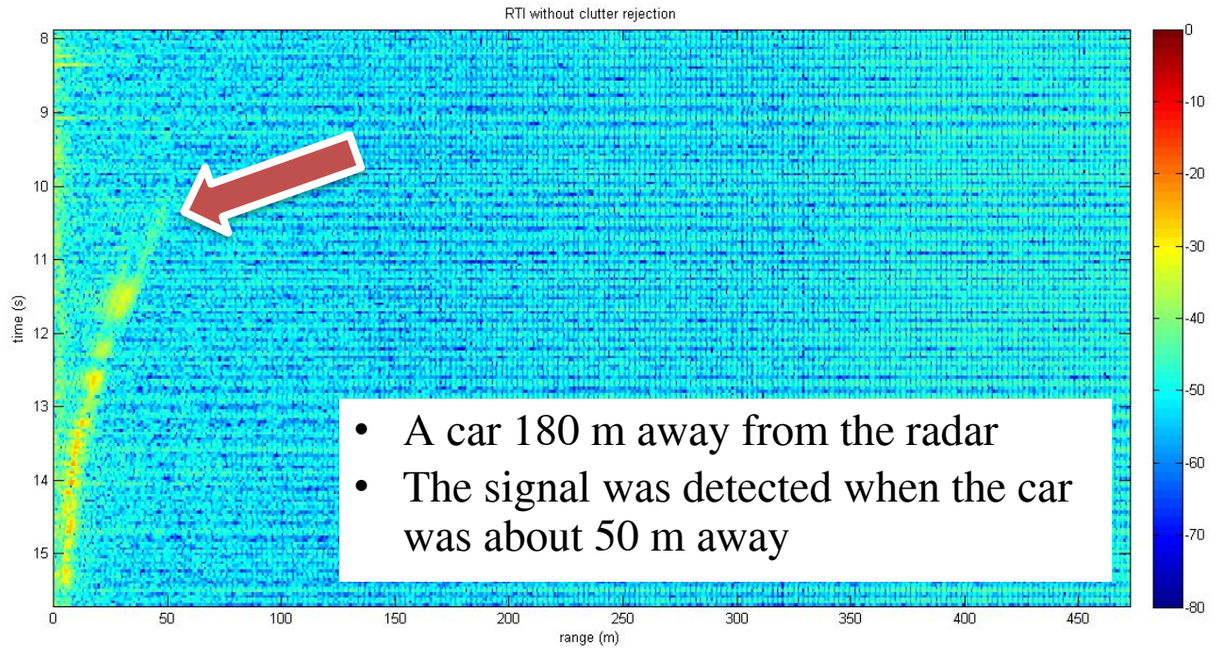
Detection system



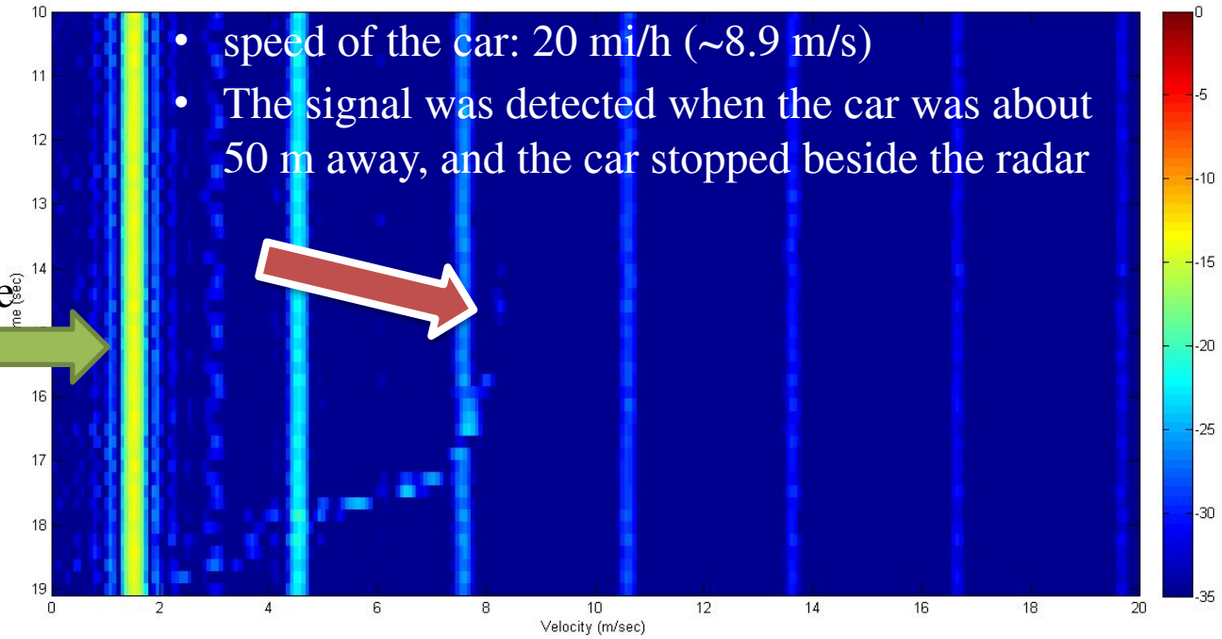
- MIT cantenna based system
- Need to be attached to a laptop to collect and process data

➤➤➤ Basic EE radar

Preliminary Experiment with a Car



Strong Harmonic Noise



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CHALLENGES

Detection range

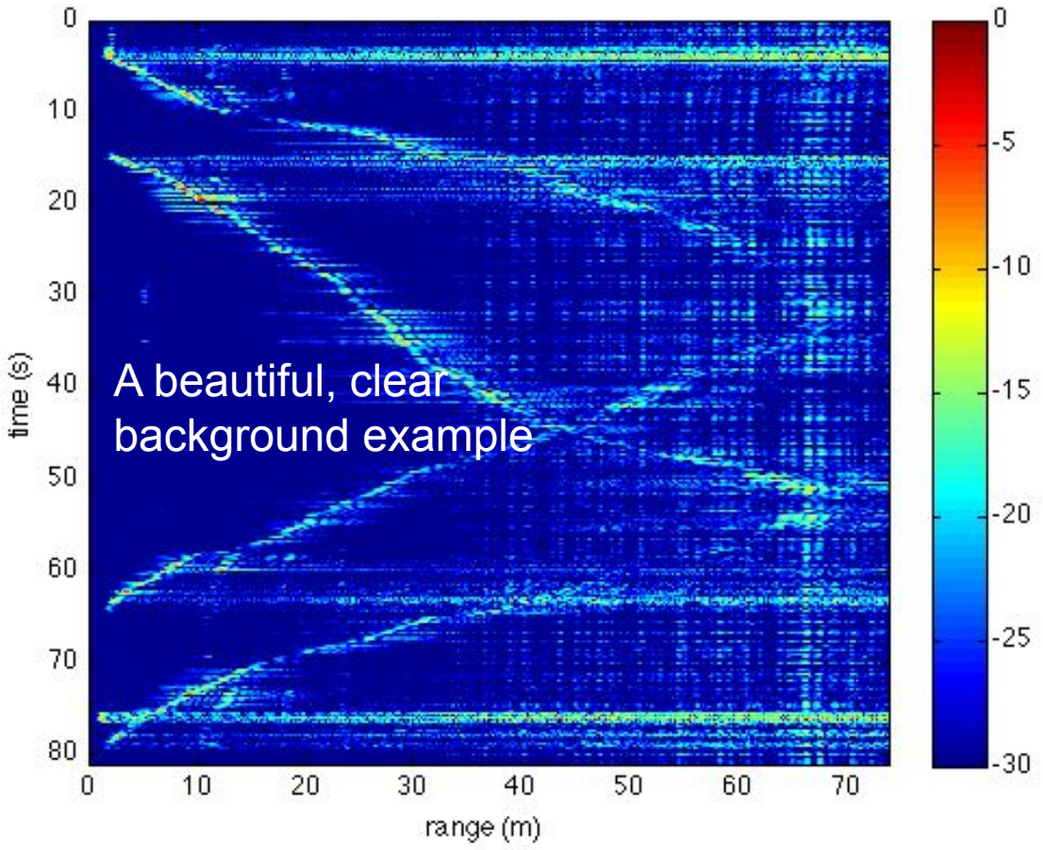
- Detection range from the experiment with a car: about < 50 m
- To extend detection range for UAVs:
  - Increase transmission power (for now 10 mW)
  - Use higher gain antenna
  - Load the system on mobile platform to follow target

Background noise

- Noise generated from hardware
- Add post-processing for noise reduction

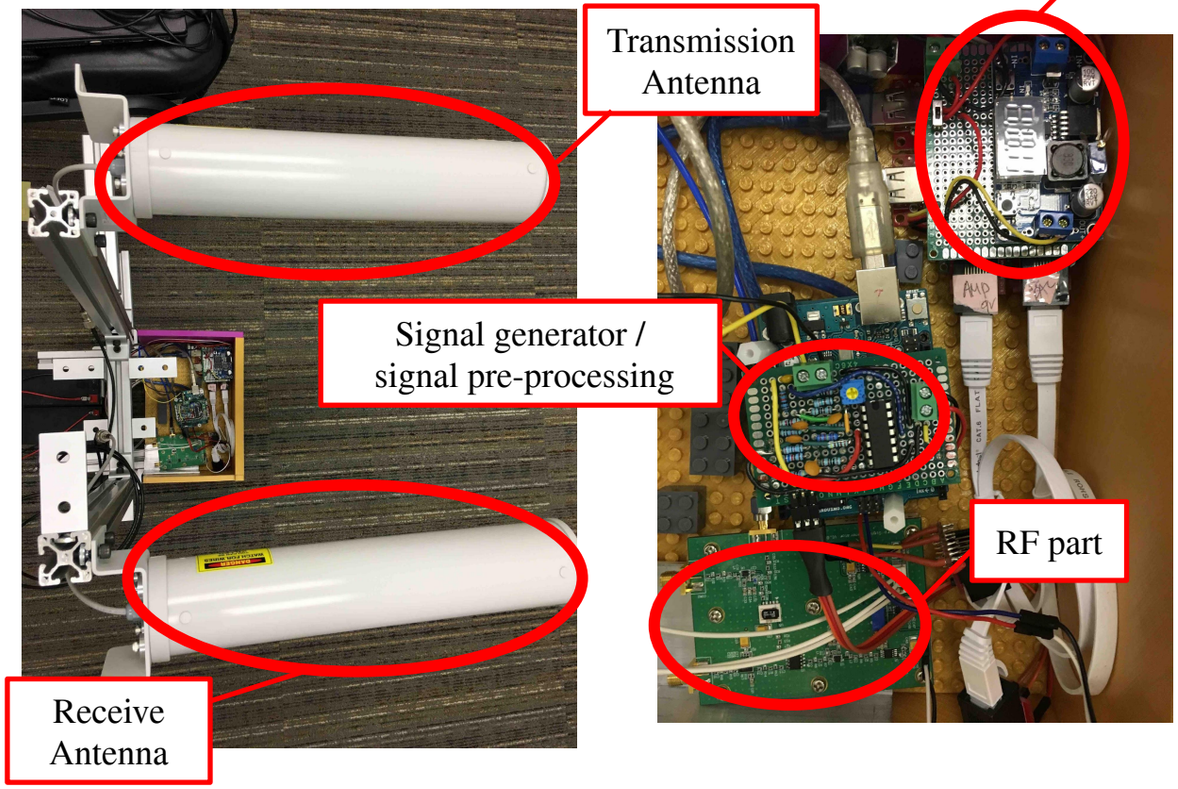
Realtime operation

- Accomplish data processing in real-time
- Portable monitoring system that detached from radar



A NEW LOW COST DETECTOR

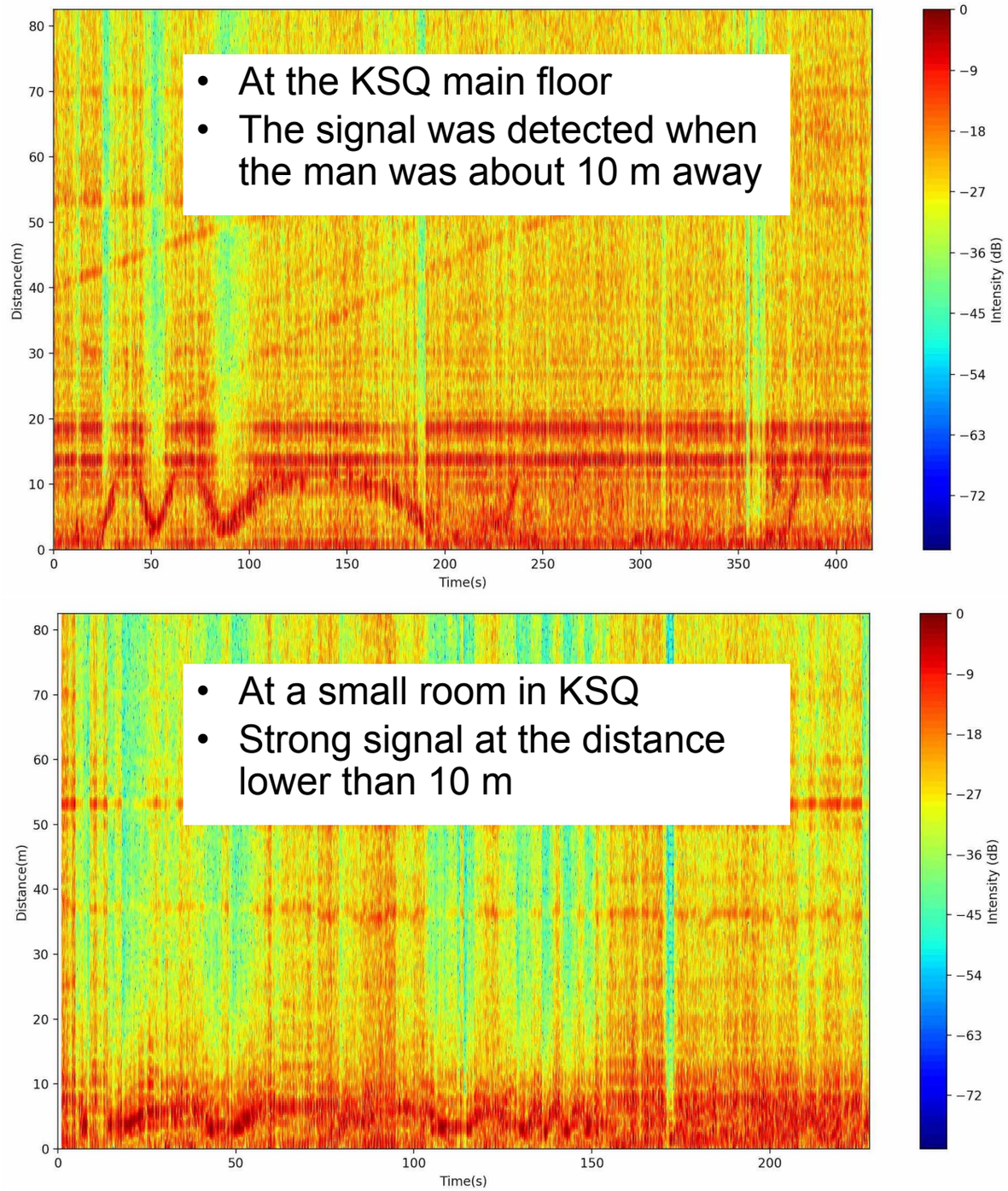
Detection system



- Increased transmission power to 1 W (100 times greater)
- Use powerful commercial antennas
- Use an Arduino for a modulator (ramp generator)
- Use another Arduino as an ADC to detach the data collection part from radar

➤➤➤ More powerful and CS friendly system

Preliminary Experiment with a Man



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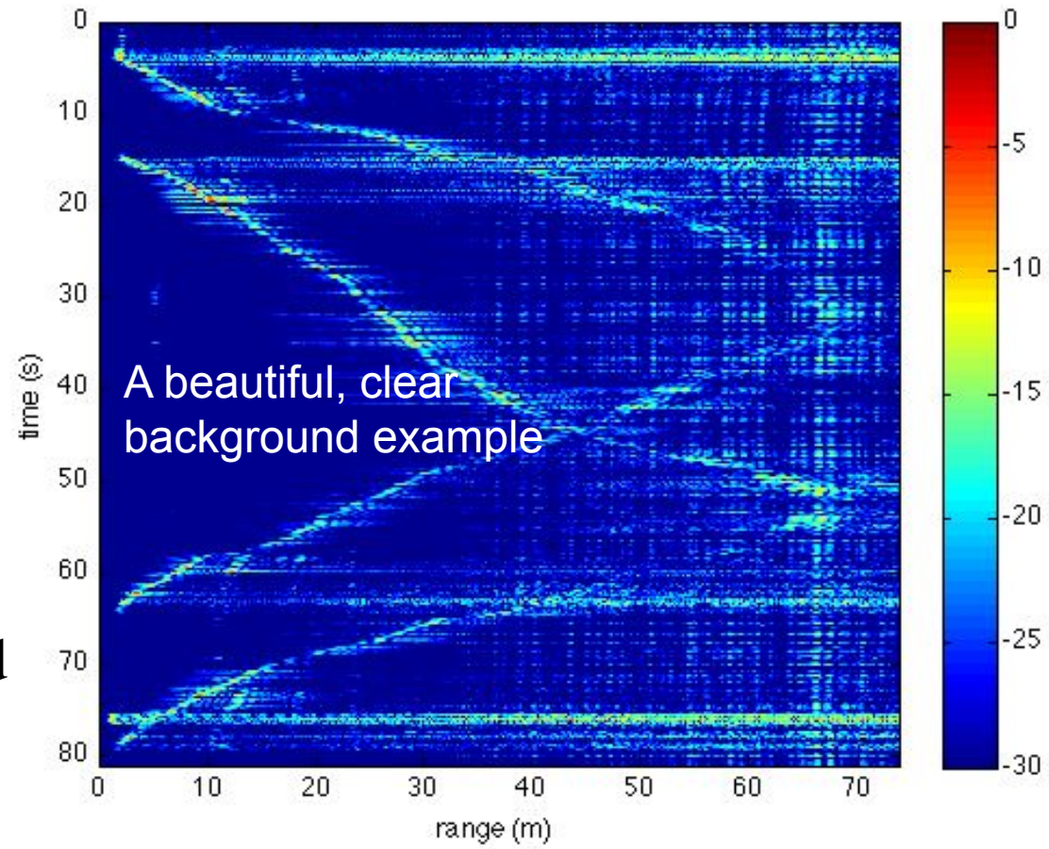
CHALLENGES

Detection range

- Detection range from the experiment with a man: about < 10 m
- With current noisy data, detection range cannot be affirmed

Background noise

- Noise generated from hardware
- Find noise source by experiments, part by part
- Add post-processing for noise reduction



Realtime operation

- Realtime data processing is accomplished
- Any sort of portable monitoring system can be added

Target tracking and classification

- Add filters and algorithms to confirm detection of target and track it (KF, EKF, PF)
- Classify targets through machine learning (drone, human, or others)

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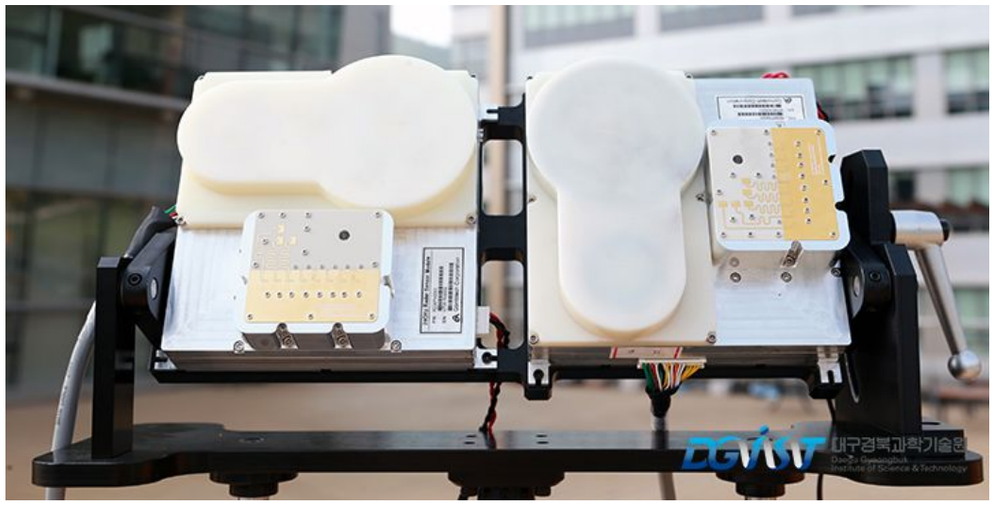
FUTURE WORKS

Compact radar and Mobility using unmanned vehicles

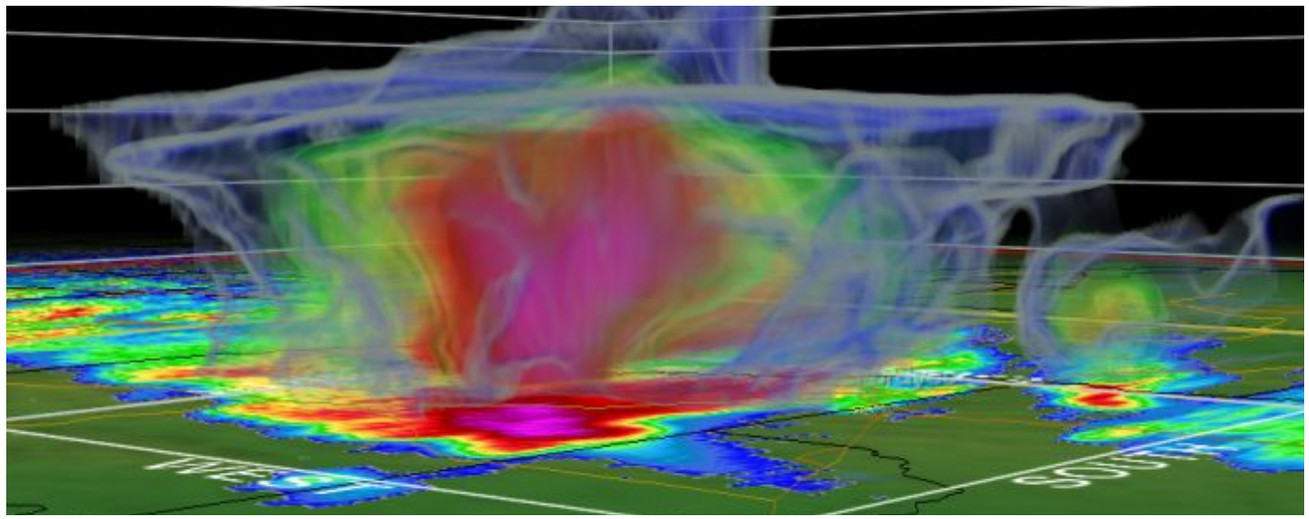
Still the radar can be more compact in many ways



https://www.dgist.ac.kr/site/dgist/menu/37.do?configNo=30&cmd=read&contentNo=32043&pageIndex=7&recordPerPage=10&month=0&condition=&keyword=

Two or Three dimensional detection and tracking system

To localize the target to follow its track more precisely, 2D or 3D detection and tracking will be needed



http://thevane.gawker.com/towering-supercells-in-arkansas-produce-golf-ball-size-1554006741

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Thank you

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