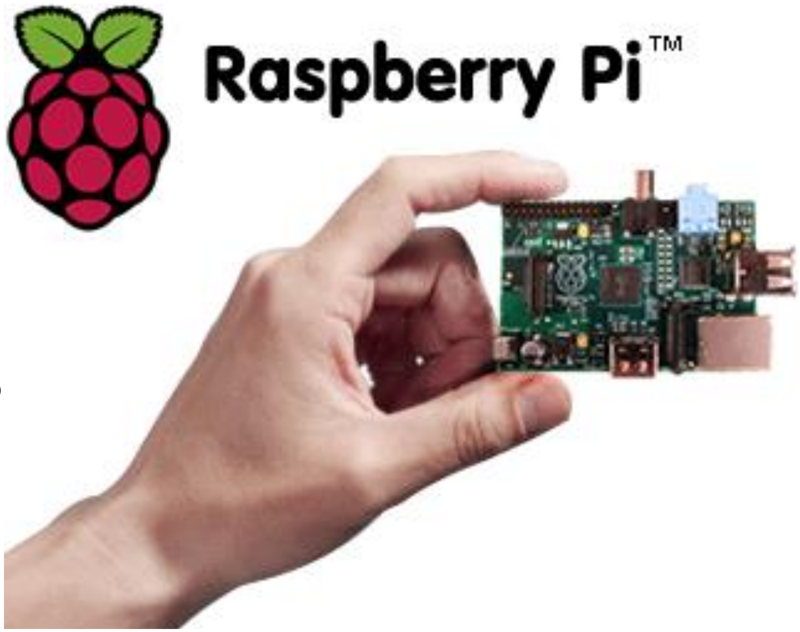
Dynamic Spectrum Sensing using Software Defined Radio on Raspberry Pi with RTL-SDR

Presenter: *Renato Iide, Le Wang*

Presentation Date: *12/16/2015*

Project Overview

- Introduction
  - Motivation
  - Cognitive Radio
  - TV White Space
- Dynamic Spectrum Access
  - Spectrum Sensing
  - Spectrum Analysis
  - Spectrum Decision
- Implementation
  - Hardware
  - Software



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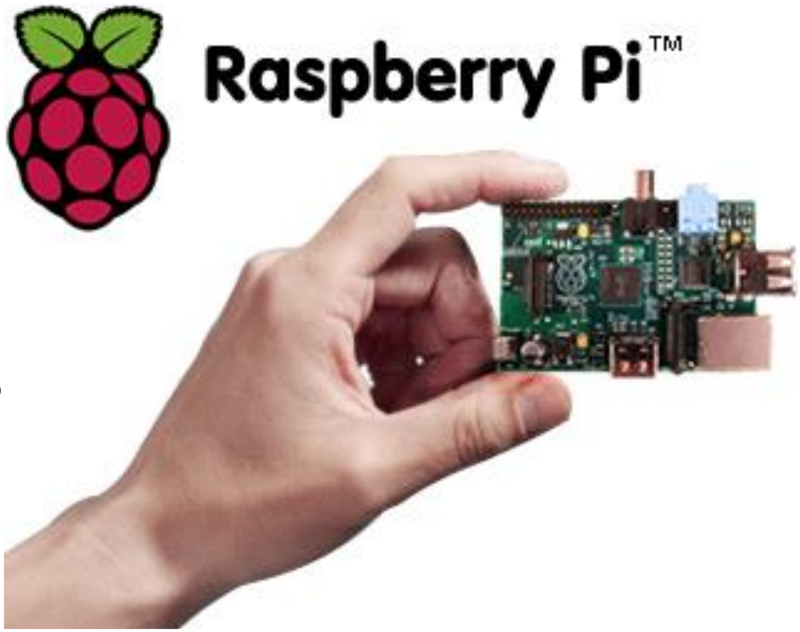
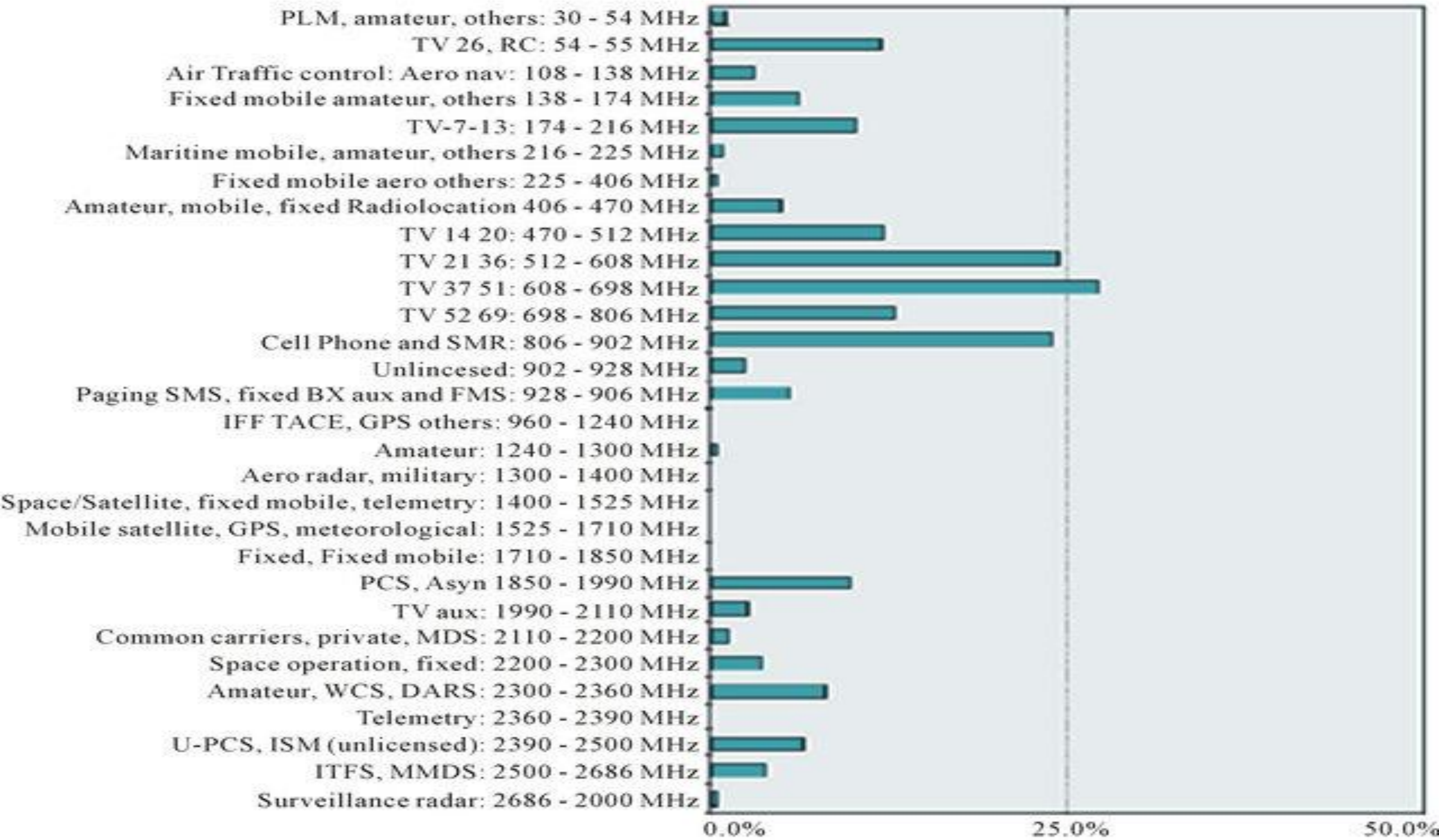


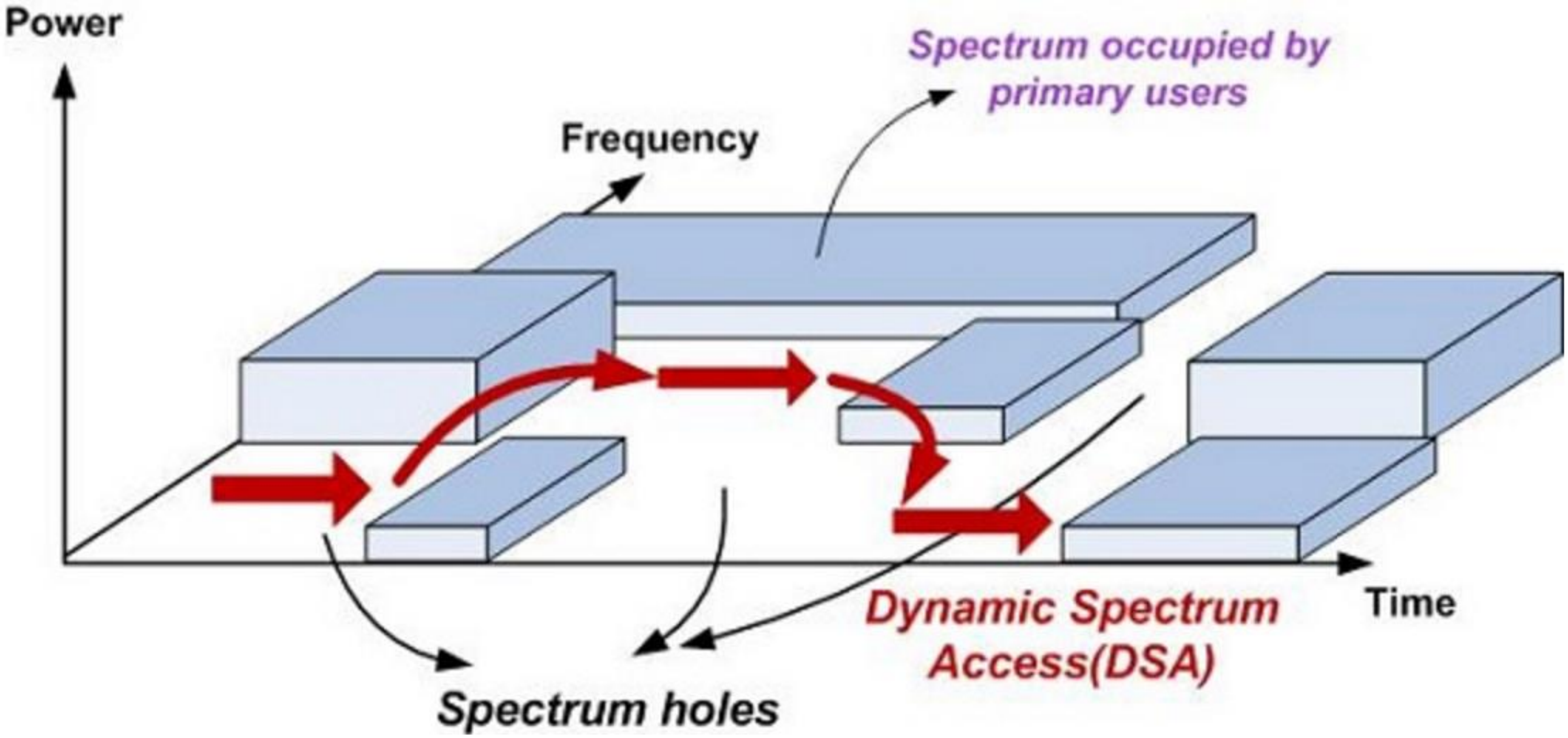
Motivation


PLM, amateur, others: 30 - 54 MHz
TV 26, RC: 54 - 55 MHz
Air Traffic control: Aero nav: 108 - 138 MHz
Fixed mobile amateur, others 138 - 174 MHz
TV-7-13: 174 - 216 MHz
Maritine mobile, amateur, others 216 - 225 MHz
Fixed mobile aero others: 225 - 406 MHz
Amateur, mobile, fixed Radiolocation 406 - 470 MHz
TV 14 20: 470 - 512 MHz
TV 21 36: 512 - 608 MHz
TV 37 51: 608 - 698 MHz
TV 52 69: 698 - 806 MHz
Cell Phone and SMR: 806 - 902 MHz
Unlincesed: 902 - 928 MHz
Paging SMS, fixed BX aux and FMS: 928 - 906 MHz
IFF TACE, GPS others: 960 - 1240 MHz
Amateur: 1240 - 1300 MHz
Aero radar, military: 1300 - 1400 MHz
Space/Satellite, fixed mobile, telemetry: 1400 - 1525 MHz
Mobile satellite, GPS, meteorological: 1525 - 1710 MHz
Fixed, Fixed mobile: 1710 - 1850 MHz
PCS, Asyn 1850 - 1990 MHz
TV aux: 1990 - 2110 MHz
Common carriers, private, MDS: 2110 - 2200 MHz
Space operation, fixed: 2200 - 2300 MHz
Amateur, WCS, DARS: 2300 - 2360 MHz
Telemetry: 2360 - 2390 MHz
U-PCS, ISM (unlicensed): 2390 - 2500 MHz
ITFS, MMDS: 2500 - 2686 MHz
Surveillance radar: 2686 - 2000 MHz
0.0%
25.0%
50.0%

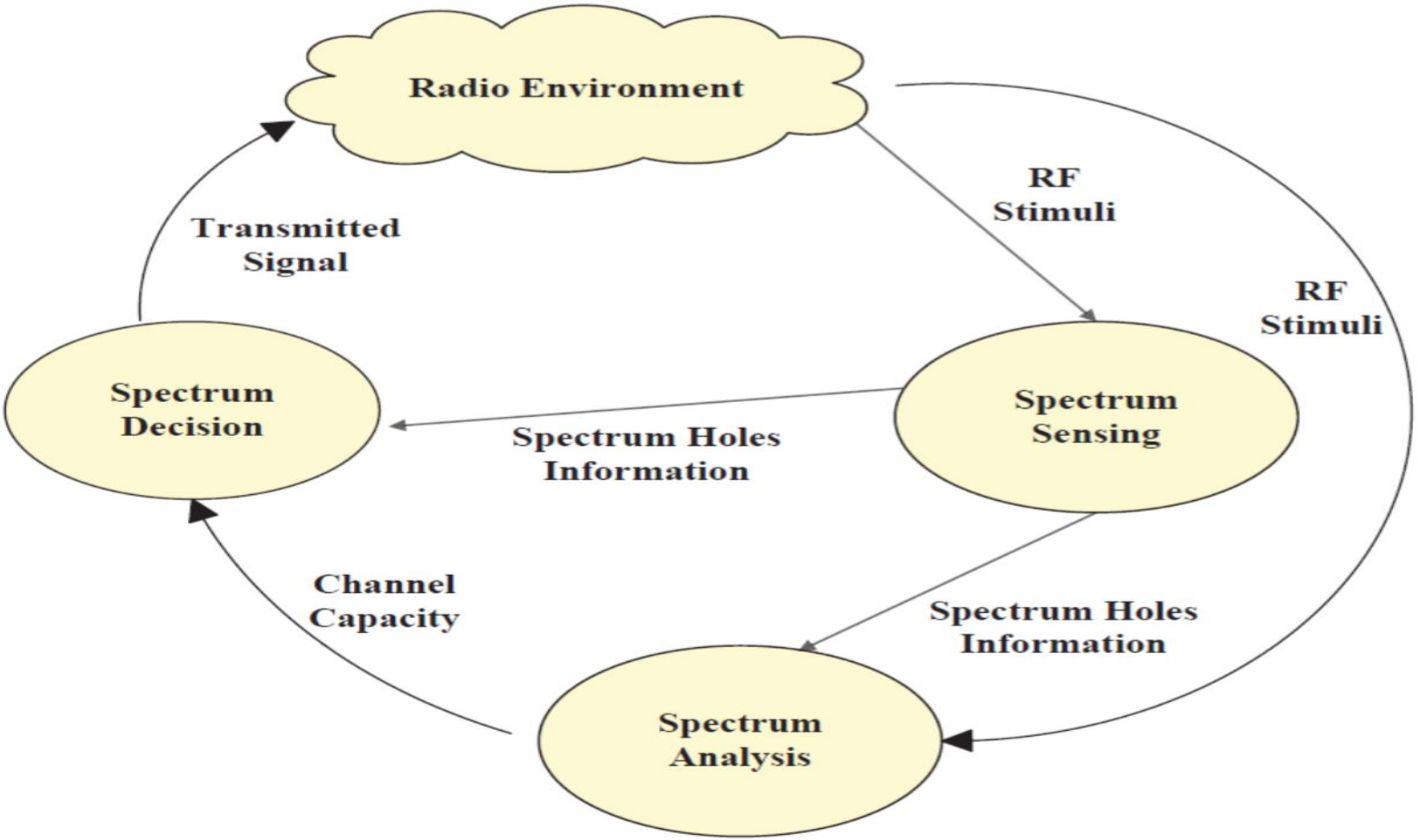
Motivation

- Low utilization
  - Caused by inefficient fixed frequency allocations instead of physical shortage of spectrum.
- Dynamic Spectrum Access (DSA):
  - To increase spectrum efficiency via spectrum sensing, probing and connectivity in cognitive radio networks.
- Cognitive Radio (CR) networks:
  - Primary User (PU) and Secondary User (SU)
  - PUs (licensed) have priority over SUs (Secondary) when accessing the wireless channel.

Cognitive Radio Networks

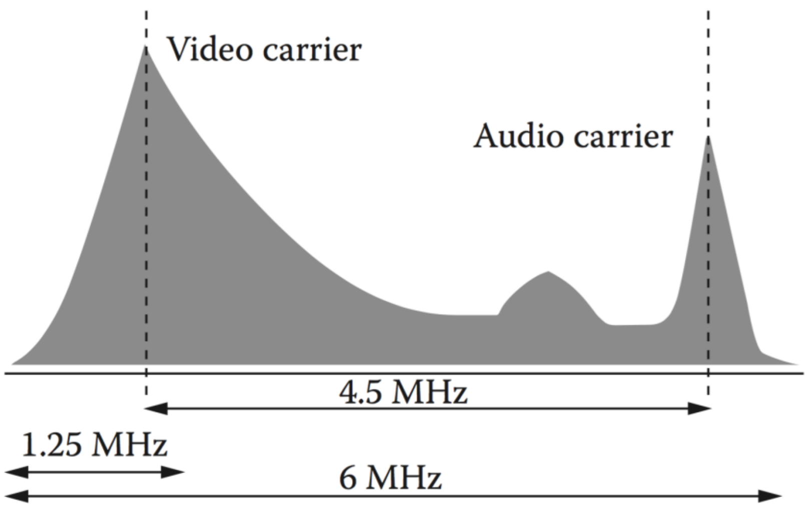


Cognitive Radio Networks



TV White Space (TVWS)

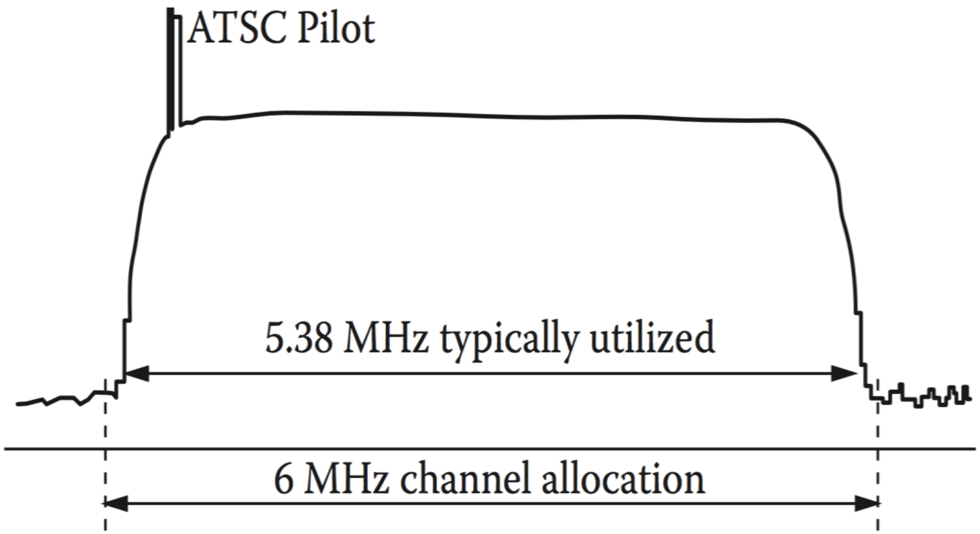
- TVWS, defined by FCC, means unused TV spectrum



NTSC Channel Spectrum

National Television System Committee (NTSC)

An analogy television system

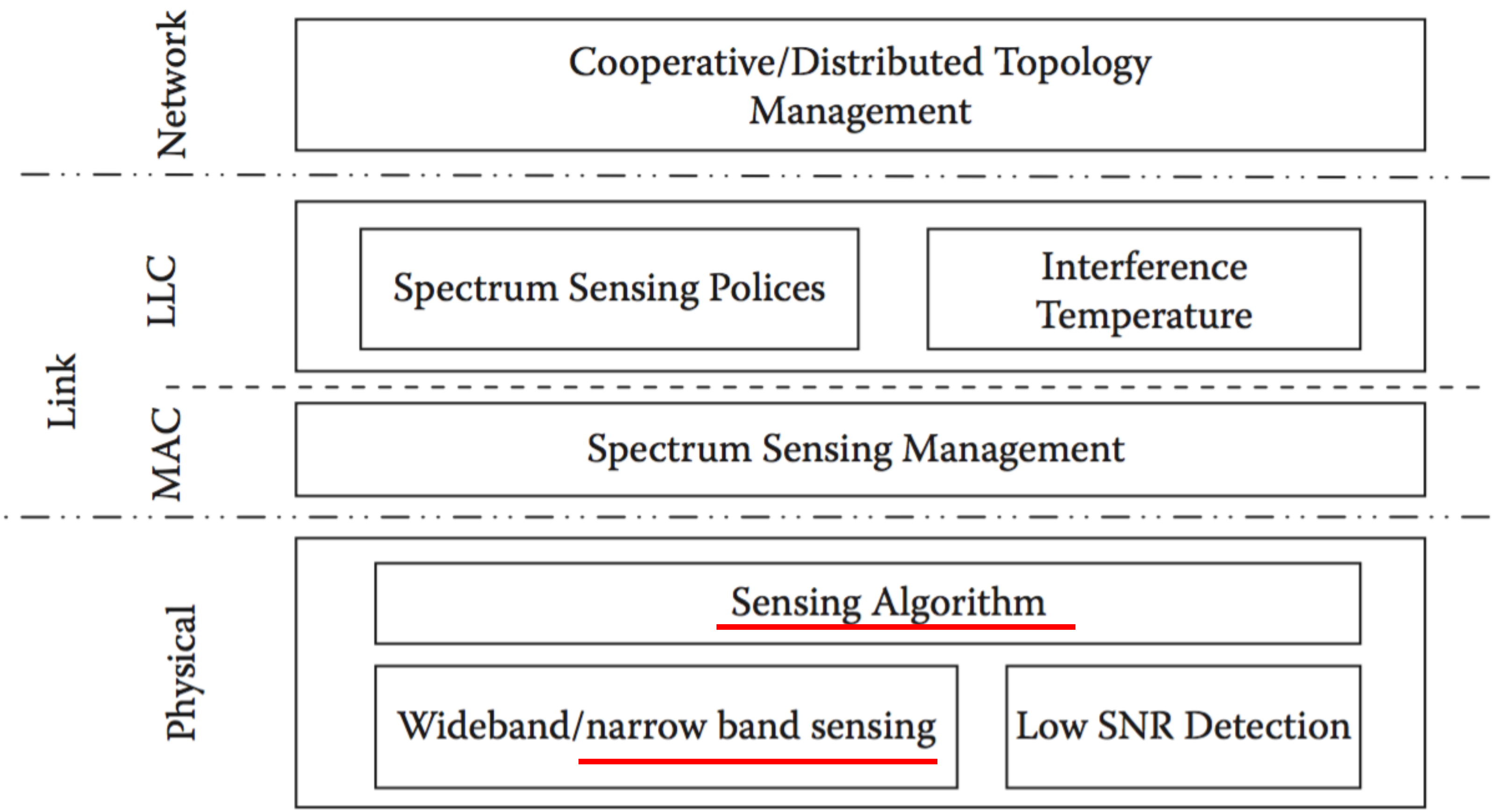


DTV-ATSC Spectrum

Advanced Television System Committee (ATSC)

A digital television system

Spectrum Sensing Function Stack



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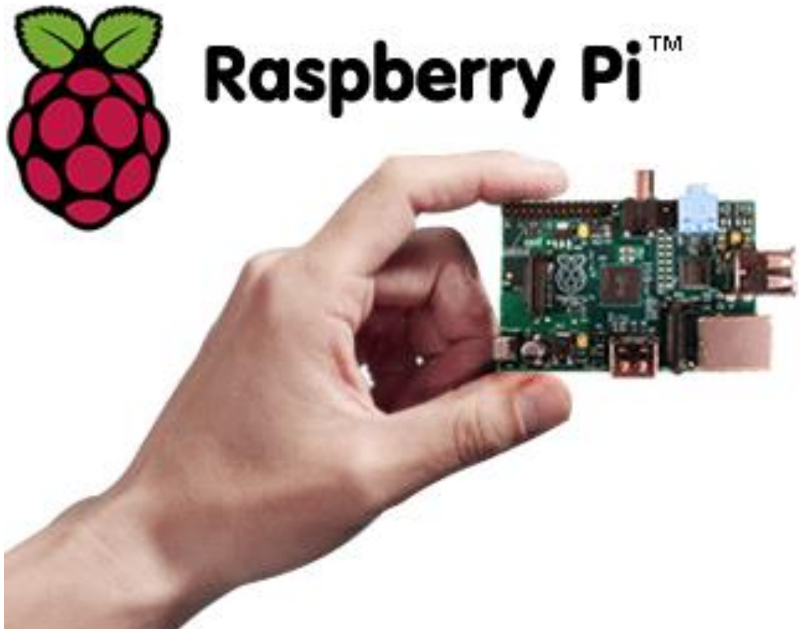
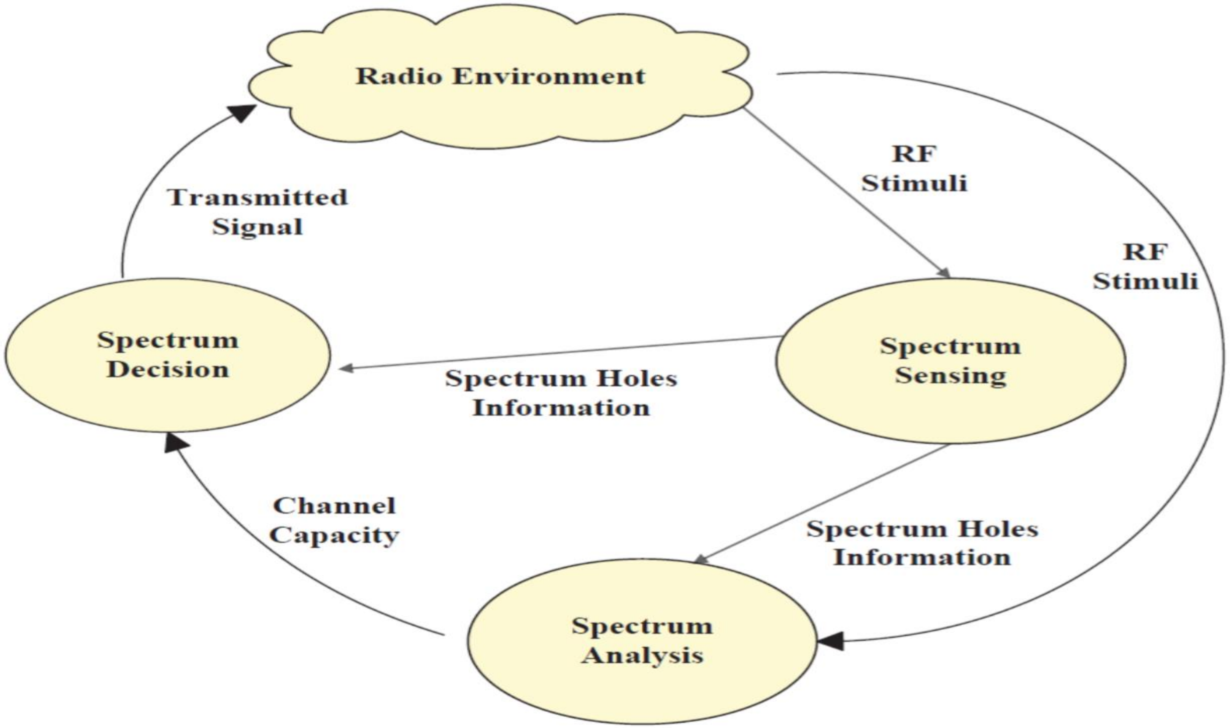


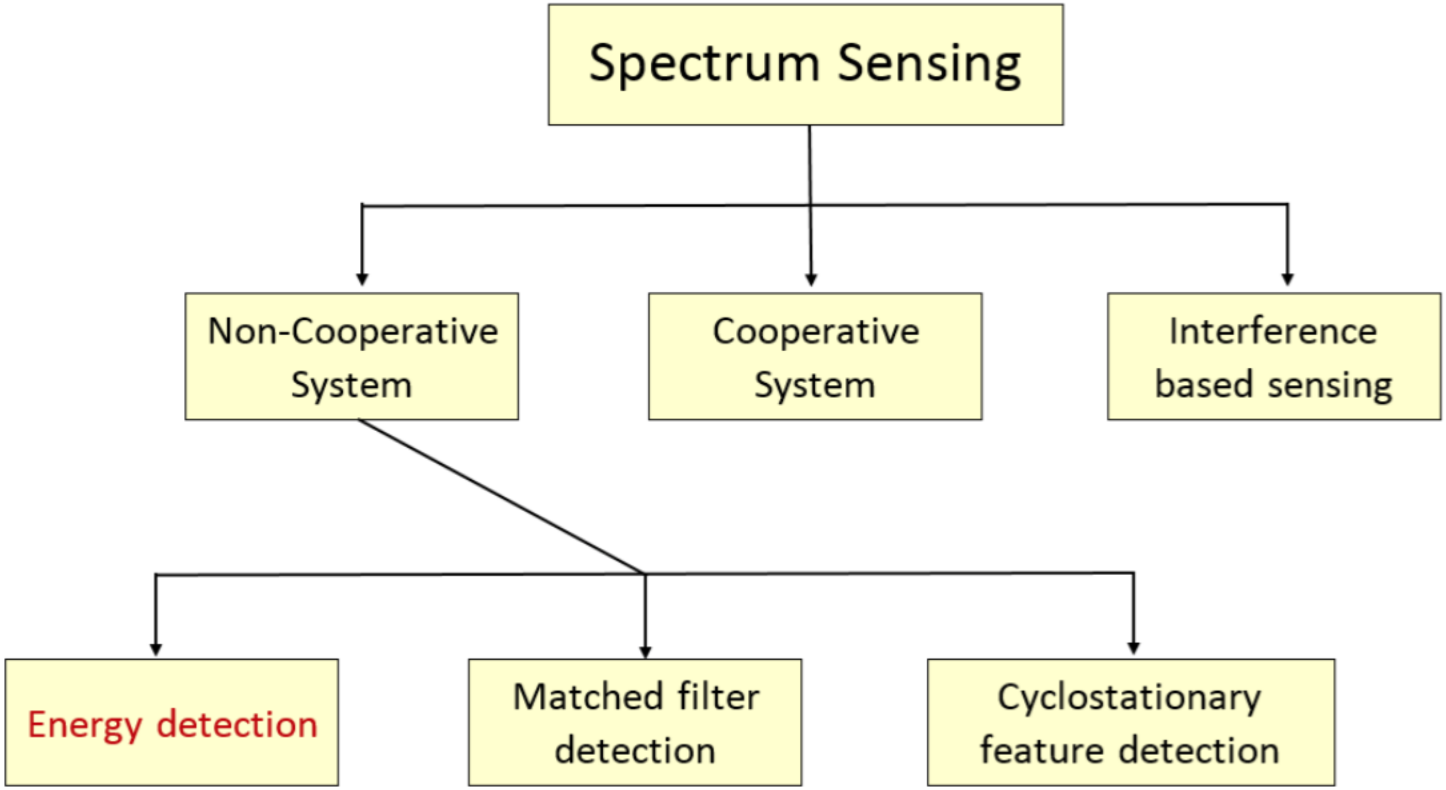
Dynamic Spectrum Access (DSA)

- Step 1. Spectrum Sensing
- Step 2. Spectrum Analysis
- Step 3. Spectrum Decision



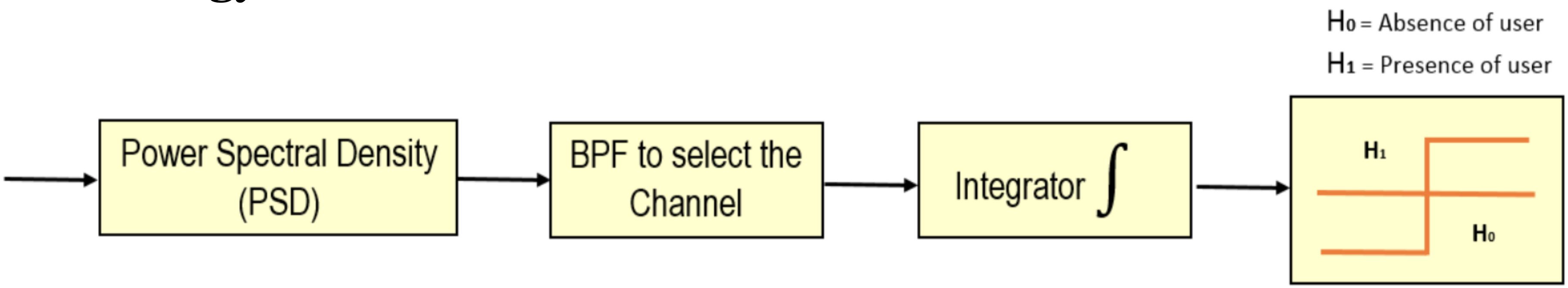
DSA – Spectrum Sensing

- The secondary users (SU) need to detect the presence of primary users (PU) in a licensed spectrum.
- If a PU emerges, the SU should quit ASAP in order to avoid interference to PUs.



DSA – Spectrum Sensing

- Energy Detection (ED):



  - The PSD of the signal is passed through a Band Pass Filter to select the channel.
  - Then integrated over time interval, i.e., the observation interval.
  - The output of the integrator is compared to a predefined threshold (H0/H1)

Comments on Energy Detection (ED)

- Advantages:
  - Simple
  - Is not required to know the primary user signal in advance.

- Disadvantages:
  - A pure energy detection scheme is confounded by the in-band interference because it is not robust against spread spectrum signals
  - Its performance severely suffers under fading conditions

DSA – Spectrum Analysis

- *S_0: Scenario when only noise exists* $S_0 : y(n) = w(n)$

- *S_1: Scenario when both noise and signal exist.* $S_1 : y(n) = s(n) + w(n)$

- The decision metric for the energy detector: $$M = \sum_{n=0}^{N} |y(n)|^2$$

  M is used in Spectrum decision step by comparing M with the threshold λ_E

DSA – Spectrum Decision

- Spectrum Decision is implemented by comparing M with λ_E
- Probability of detection: $P_D = P_r(M > \lambda_E | S_1)$
- Probability of false alarm: $P_F = P_r(M > \lambda_E | S_0)$

S_0: Scenario when only noise exists

S1: Scenario when both noise and signal exist.

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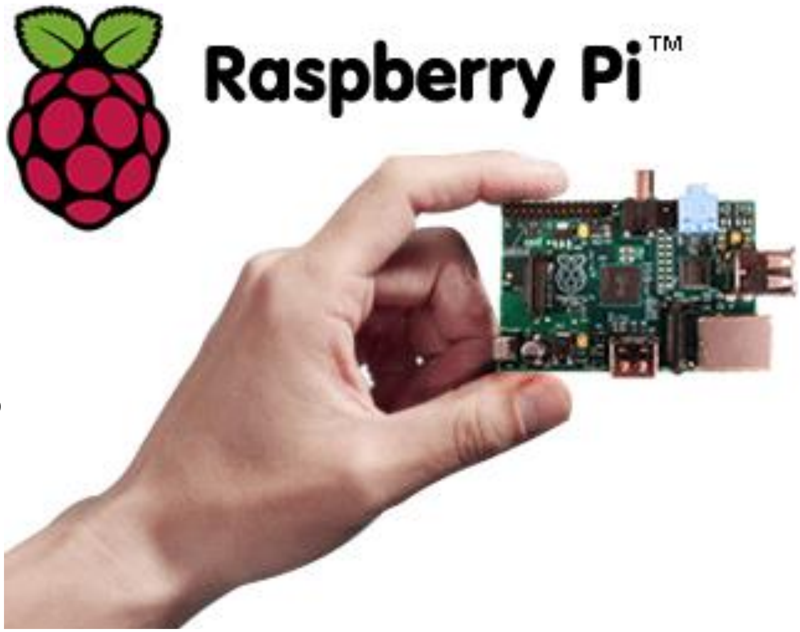
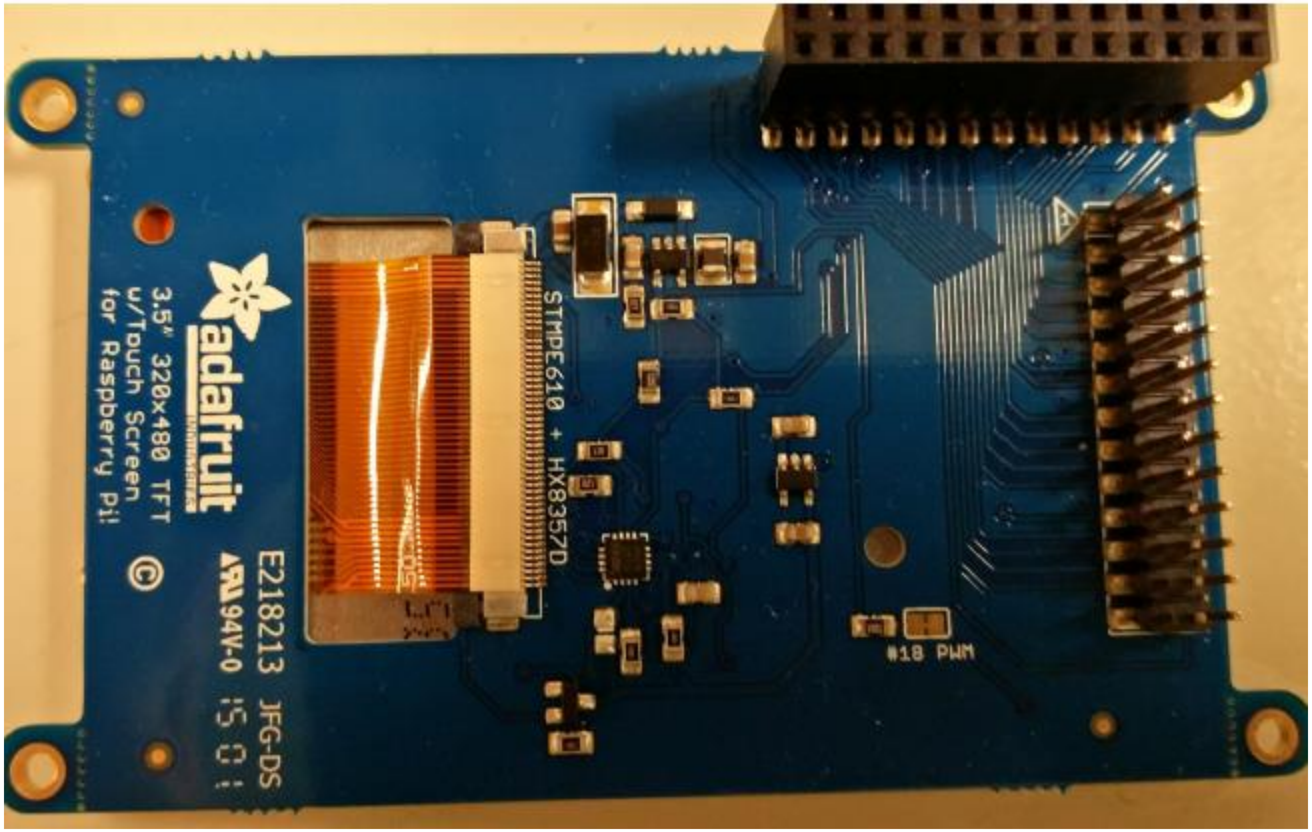


Hardware – Raspberry Pi B 2

Model	Raspberry Pi 2 Model B
CPU	900 MHz quad-core ARM Cortex-A7
Memory (SDRAM)	1 GB (Shared with GPU)
GPU	Broadcom Video Core IV @ 250 MHz

Hardware – 3.5” PiTFT Display



480 x 320 resolution; Touch screen;
Use SPI and GPIO pins.

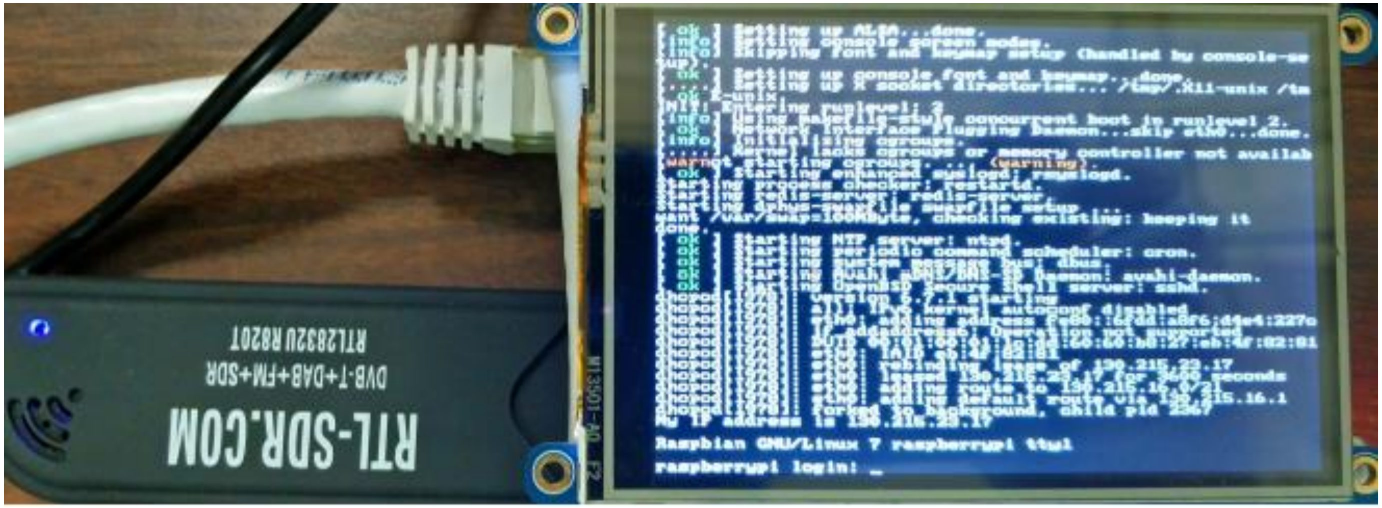
Hardware – RTL-SDR

RTL2832u REALTEK ;
R820T Tuner: 24 - 1766 MHz;
Sample Rate: 2.56 MSamples/s.

Software

- Linux Modified Kernel
- FreqShow
- Scan Function
- Report

Software – Linux Modified Kernel

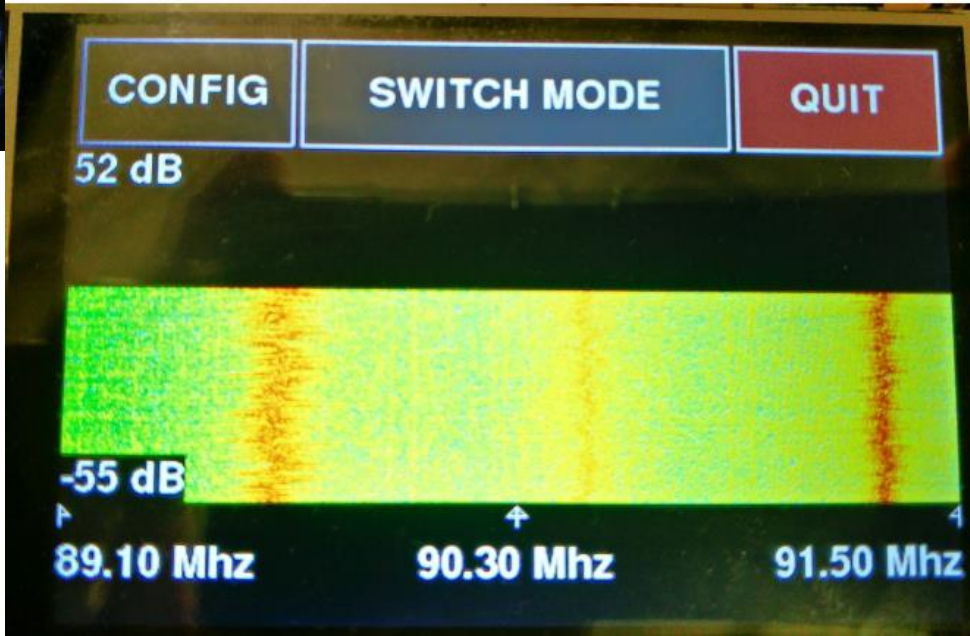


Distribution	Rasbian Wheezy (Debian 7.0)
Kernel	Linux 4.1.6
GCC	4.6.3
CMAKE	2.8.9
Python	2.7.3

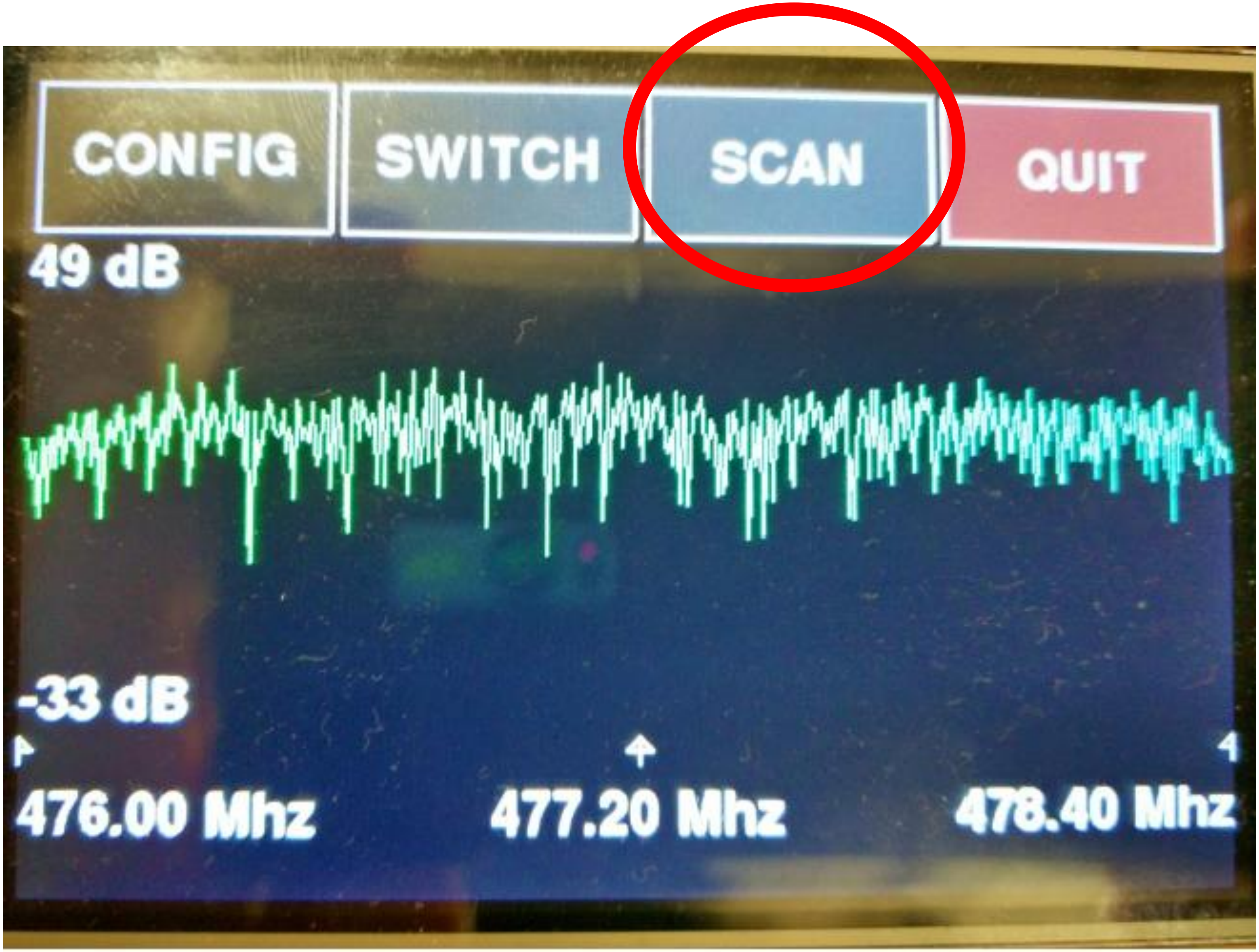
Software – FreqShow

Spectrum from 89.1 MHz to 91.5

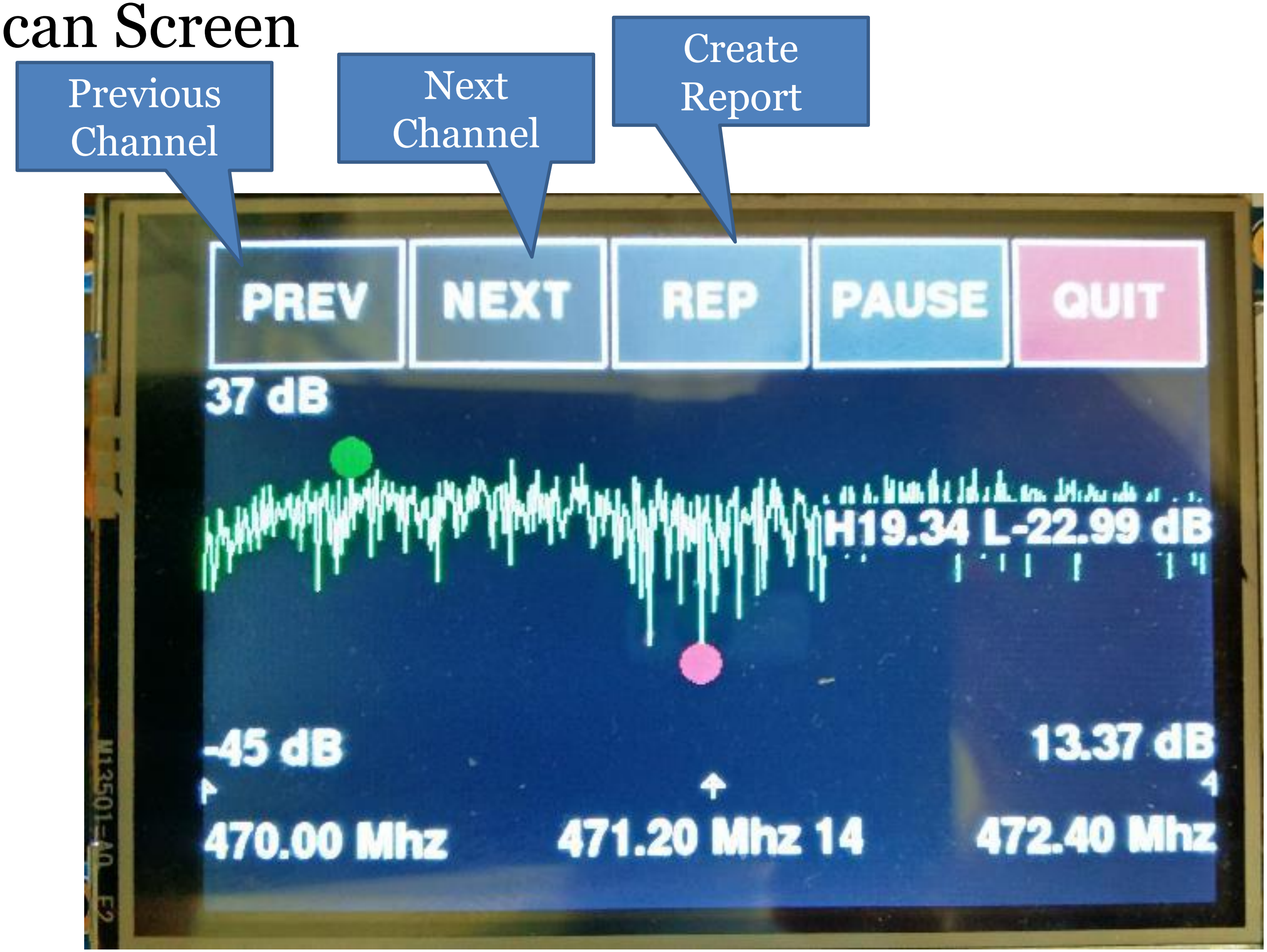
Waterfall Spectrum from 89.1 MHz to 91.5 MHz



Software – Add New Function : Scan



Scan Screen



Previous Channel
Next Channel
Create Report
PREV
NEXT
REP
PAUSE
QUIT
37 dB
H19.34 L-22.99 dB
-45 dB
13.37 dB
470.00 Mhz
471.20 Mhz 14
472.40 Mhz

Scan Screen

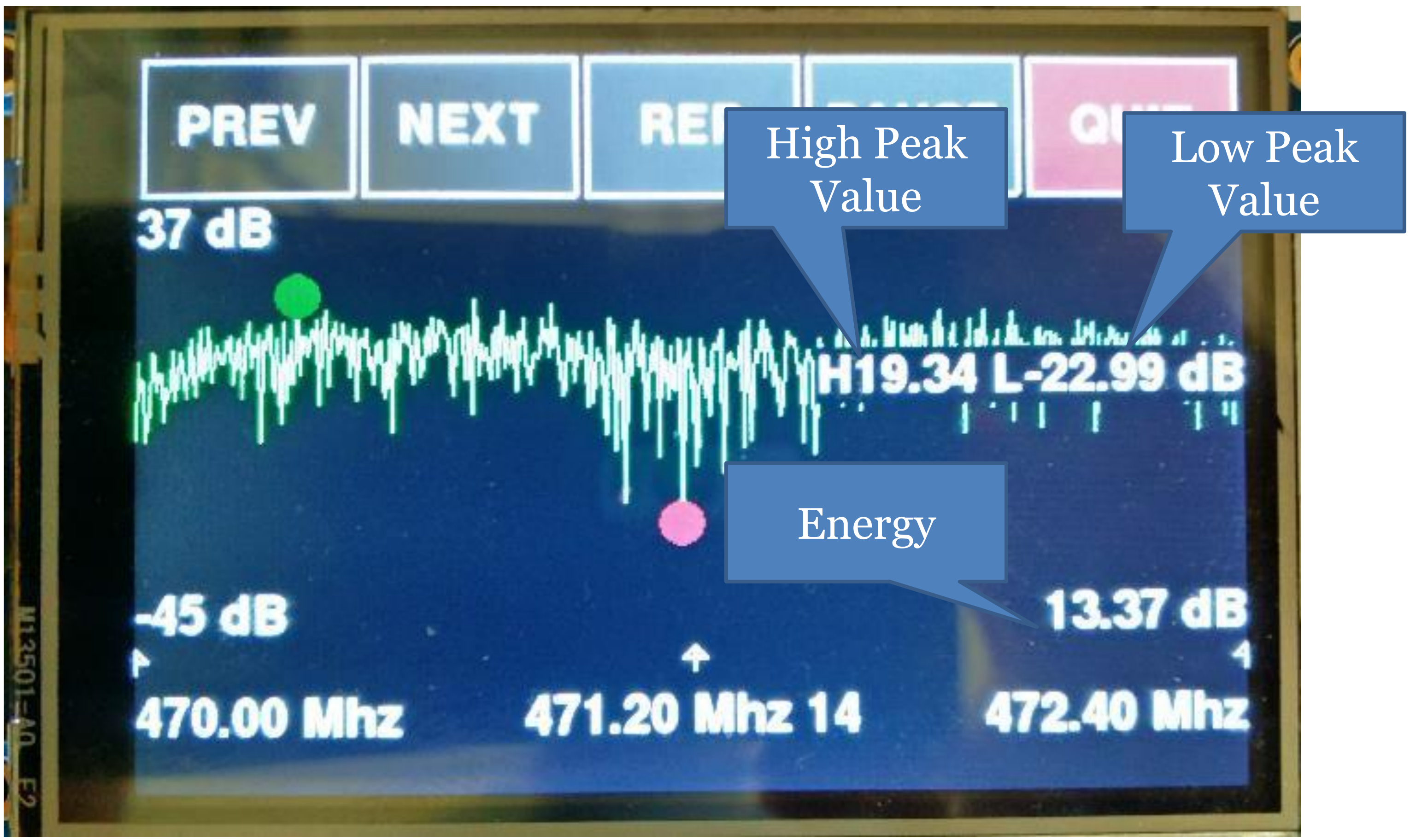
Pause the data

Quit the program

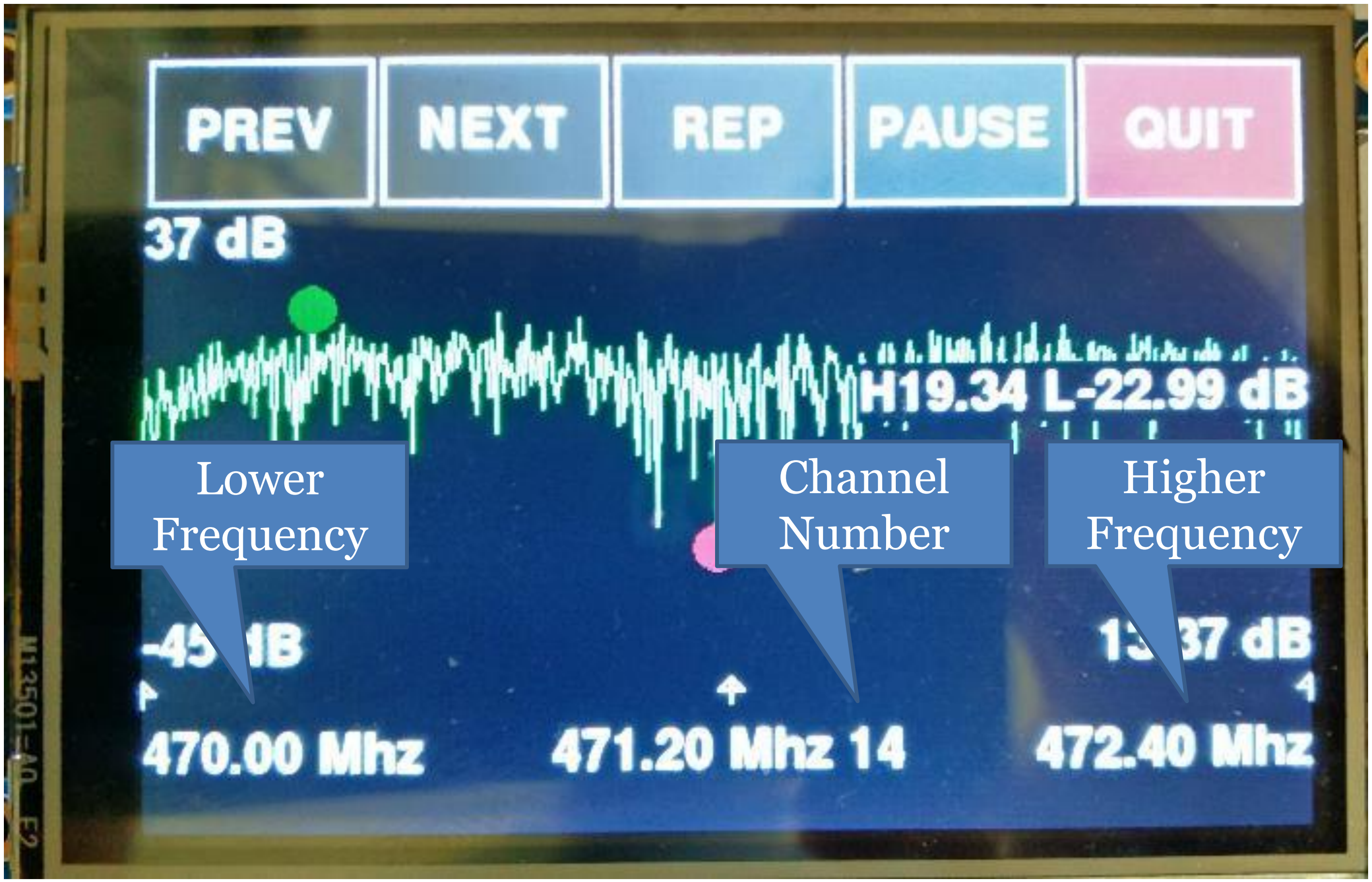
Scan Screen

High Peak
Low Peak
EXT
REP
PAUSE
QUIT
L-22.99 dB
-45 dB
13.37 dB
470.00 Mhz
471.20 Mhz 14
472.40 Mhz

Scan Screen


PREV
NEXT
High Peak Value
Low Peak Value
37 dB
H19.34 L-22.99 dB
Energy
-45 dB
13.37 dB
470.00 Mhz
471.20 Mhz 14
472.40 Mhz

Scan Screen


PREV
NEXT
REP
PAUSE
QUIT
37 dB
H19.34 L-22.99 dB
Lower Frequency
Channel Number
Higher Frequency
470.00 Mhz
471.20 Mhz 14
472.40 Mhz

Report Formatted

Channel Number	Energy in dB	Average Power in dB	Peak Value in dB	Frequency of peak in Mhz
14	13.68	6.94	19.2	470.95
15	14.27	8.48	20.74	476.68
16	12.33	6.63	19.19	482.94
17	14.24	8.4	20.1	488.95
18	16.23	10.17	22.53	494.63
19	16.44	9.88	21.49	500.47

Contribution

1. Learned:

   Dynamic Spectrum Control, Cognitive Radio, TV White Space, etc.

2. Configured:

   Raspberry Pi 2 with 3.5” TFT touch screen and RTL-SDR

3. Implemented:

   Energy Detection function in Python

Live Demonstration

Show the sensor working