Design and Implementation of Power Detector and UHF Converter for TVWS Application

Nordin Ramli*, Tengku Azhar Long Sulaiman*, Hafizal Mohamad*,
Takeshi Matsumura**, Kentaro Ishizu**
*MIMOS, Malaysia, **NICT, Japan
Email: nordin.ramli@mimos.my

26 November 2015

Innovation for Life

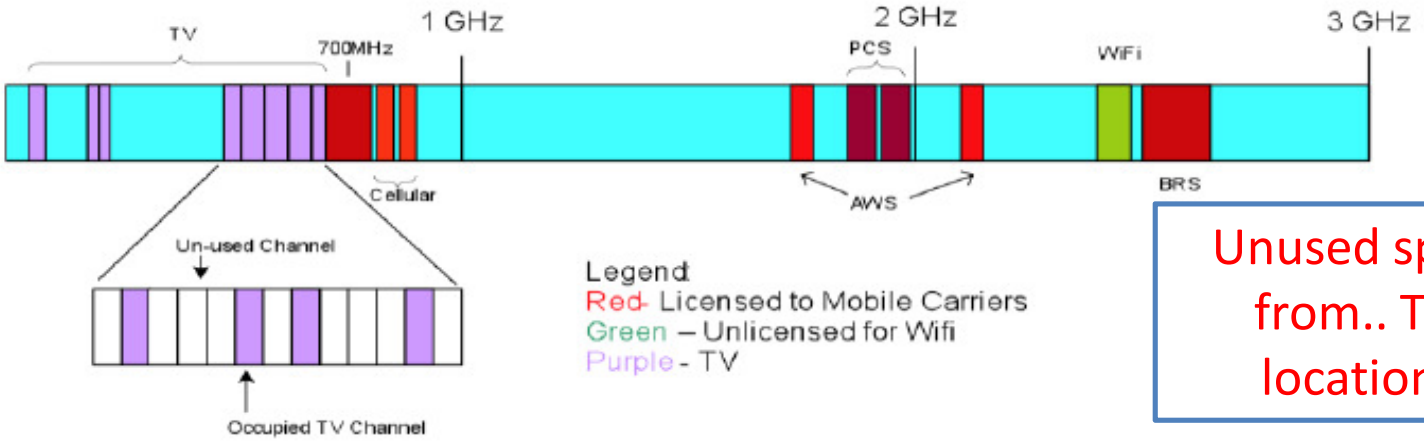
Outline

- Introduction
  - TV White Space
- Spectrum Measurement
  - VHF and UHF Band Utilization
- Downconverter Implementation
- Integration Work and TVWS Prototype
  - Power Detector
  - Lab Experimental and Results
- Moving Forward
- Conclusion

Outline

- **Introduction**
  - **TV White Space (TVWS)**
- Spectrum Measurement
  - VHF and UHF Band Utilization
- Downconverter Implementation
- Integration Work and TVWS Prototype
  - Power Detector
  - Lab Experimental and Results
- Moving Forward
- Conclusion

What is TV White Space?



Unused spectrum exists from.. Time to time, location to location

- TV band white spaces are gaps left between broadcast channels. They occur in different places on different channels.
- Key enabling technologies that allow utilization of white spaces include Cognitive Radio and Geo-location Database.

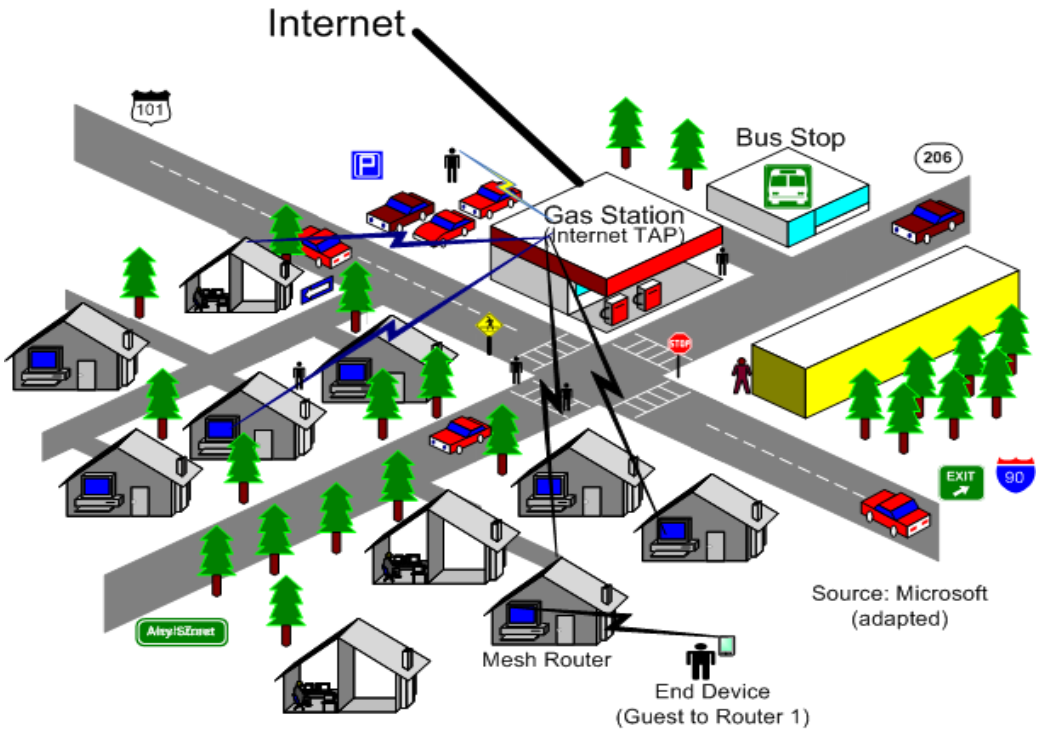
Source: Jeffrey Yan, Microsoft, TVWS Industry Forum, SKMM Cyberjaya, Jun 2012

TVWS & Rural Communications

- What is it?
  - Using TV white spaces to provide a wireless connection to rural areas
- Why is TV white space spectrum attractive?
  - A cost-effective means to provide communications to rural areas that would be too expensive to serve by other means
- Benefits of VHF/UHF;
  - ✓ **Long distance propagation → Good for rural areas**
  - ✓ **Larger cell radius → Smaller number of towers**

Rural Internet Access

- TV white spaces will provide more widely available and cost effective access to the internet in underserved markets.
- The superior propagation characteristics provide much greater coverage range than existing unlicensed technologies.



TVWS Economic Potential

- A range of studies have looked at the potential value of licence-exempt use of spectrum. These include studies commissioned by:
  1. Ofcom (2006), by Indepen, Aegis and Ovum
  2. Microsoft (2009), by Richard Thanki (Ingenious Media)
  3. Google (2011), by respected US economists (Stanford Report)
  4. The Consumer Federation of America (2011)
- The last three have included estimates of the economic potential from the TV white spaces. Although they were focused on the US, with FCC proceedings in mind, the applications they identify are just as relevant in the UK and the rest of Europe, as they are in other parts of the world.

- References:

1. Ofcom, The economic value of licence exempt spectrum, December 2006: http://stakeholders.ofcom.org.uk/binaries/research/technology-research/value.pdf
2. R. Thanki, The economic value generated by current and future allocations of unlicensed spectrum, 8 September 2009, http://fjallfoss.fcc.gov/ecfs/document/view?id=7020039036
3. Stanford Report: Milgrom, Paul R., Levin, Jonathan D. and Eilat, Assaf, The Case for Unlicensed Spectrum (October, 23 2011). Available at SSRN: http://ssrn.com/abstract=1948257
4. Consumer Federation of America, The Consumer Benefits of Expanding Shared Used of Unlicensed Radio Spectrum, Mark Cooper, 29th November 2011

Collaborative Project on TV White Space for Rural Communications

- From July 2014 – June 2015 (one year)
- Collaborative Project between MIMOS and NICT
- Main Members:
  - MIMOS, Malaysia
  - NICT, Japan
- Associate Members
  - Universiti Teknologi Malaysia, Japan
  - Multimedia University, Japan
- Objectives:
  - To measure the of spectrum utilization and occupancy in Malaysia
  - To develop the TVWS transceiver prototype
  - To conduct the experimental on TVWS transmission

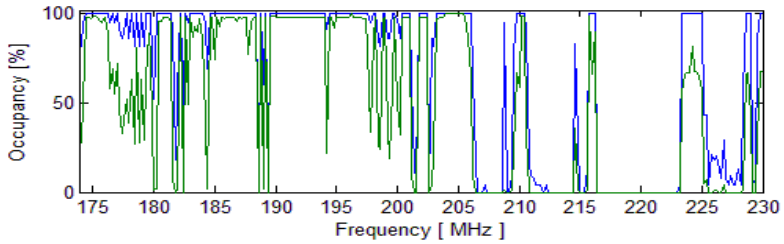
Outline

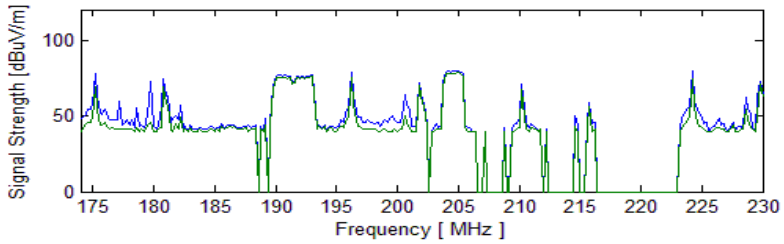
- Introduction
  - TV White Space
- **Spectrum Measurement**
  - **VHF and UHF Band Utilization**
- Downconverter Implementation
- Integration Work and TVWS Prototype
  - Power Detector
  - Lab Experimental and Results
- Moving Forward
- Conclusion

Frequency Allocation Table Malaysia

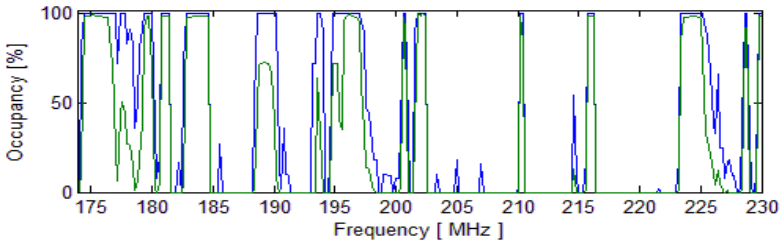
Band (MHz)	Bandwidth (MHz)	Service Allocations
30 – 174	144	FM Radio, Maritime VHF, Amateur Radio, Radio Paging, Aeronautical Radionavigation, Space Research, Space Op.
174 – 230	**56**	**VHF TV**
230 – 470	240	Digital Trunk Radio Service, UHF Mobile Radio, Maritime UHF, Amateur Radio, CDMA 450, Aero
470 – 798	**328**	**UHF TV**
798 – 880	82	Analogue Trunk Radio Service, BWA, FWA,
880 – 960	80	GSM 900, RFID
960 – 1429	469	Galileo, COSPA-SARSAT, Radiolocation, Space Operation
1429 – 1710	281	Radionavigation Satellite Service, L-band Digital Broadcasting
1710 – 1880	170	BWA, GSM 1800
1880 – 2200	320	TDD, MSS, FDD, FWA
2200 – 2400	200	WiMAX, BWA
2400 – 2500	100	ISM
2500 – 2700	200	BWA
2700 – 3000	300	Aeronautical Radionavigation, Radionavigation

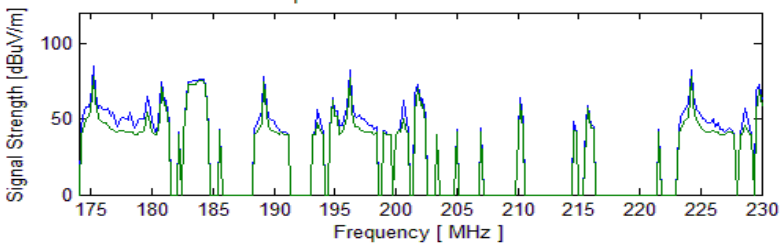
High Utilization for VHF TV Band



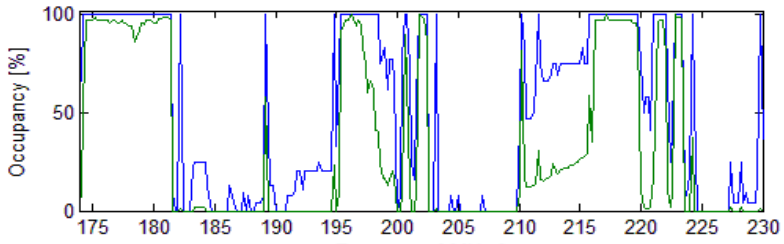


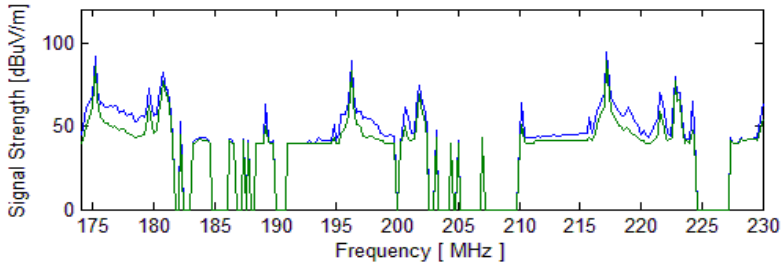
Johor Bahru VHF TV Band 174 MHz - 230 MHz



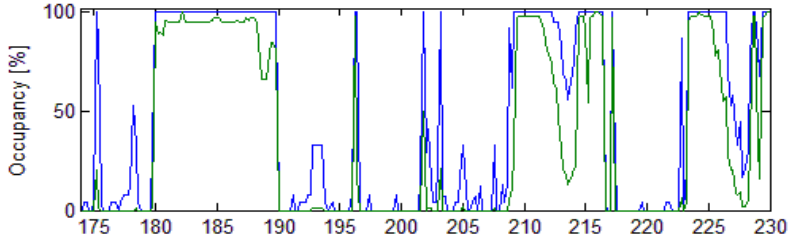


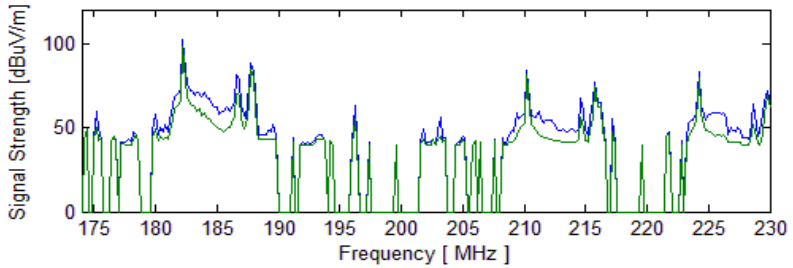
Kuala Lumpur VHF TV Band 174 MHz - 230 MHz



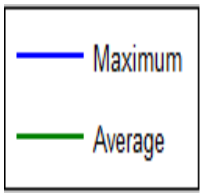


Sibu VHF TV Band 174 MHz - 230 MHz

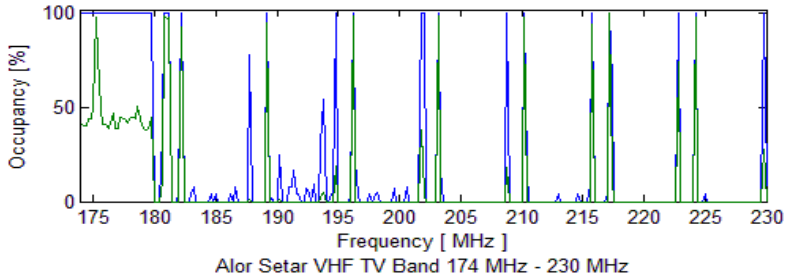




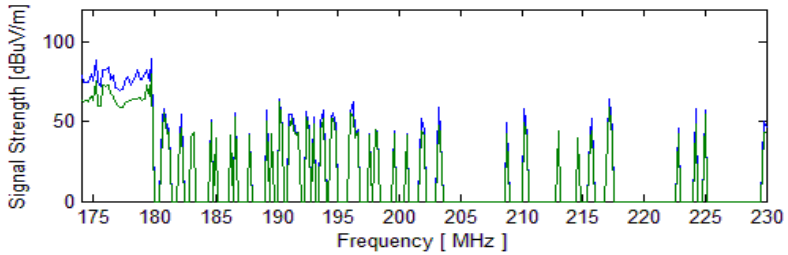
Miri VHF TV Band 174 MHz - 230 MHz

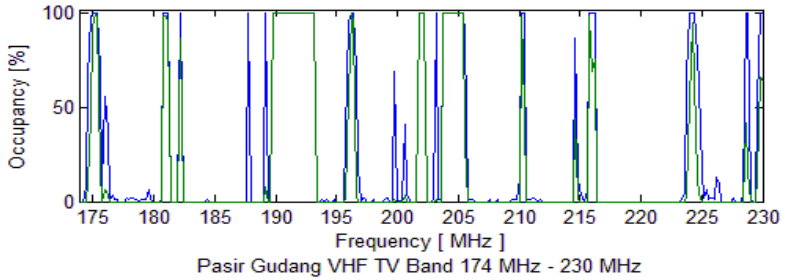


Medium Utilization for VHF TV Band

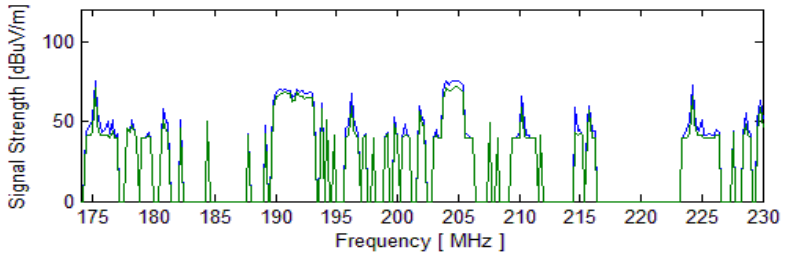


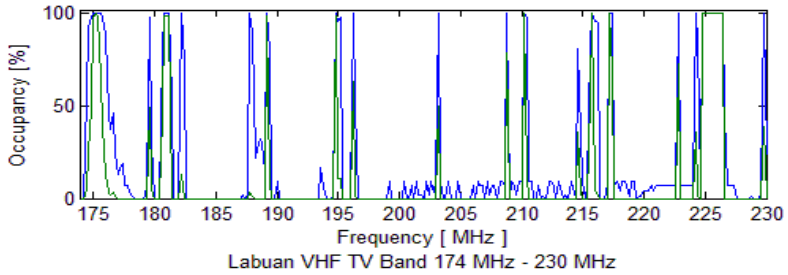
Alor Setar VHF TV Band 174 MHz - 230 MHz



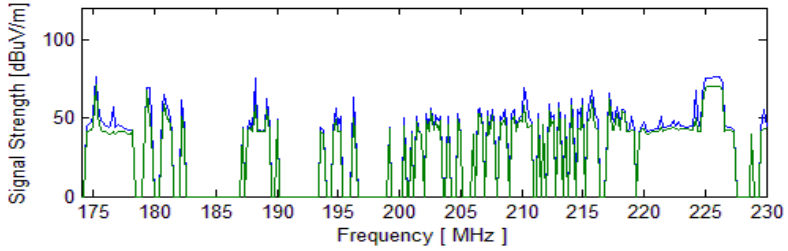


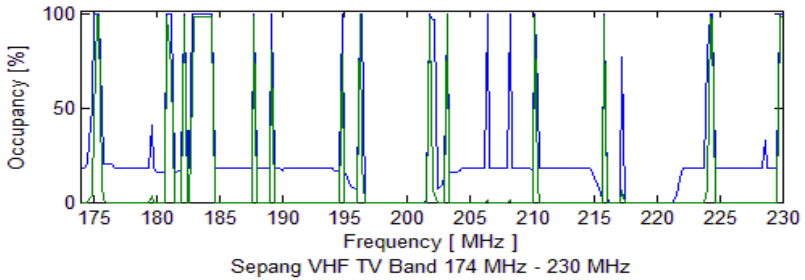
Pasir Gudang VHF TV Band 174 MHz - 230 MHz



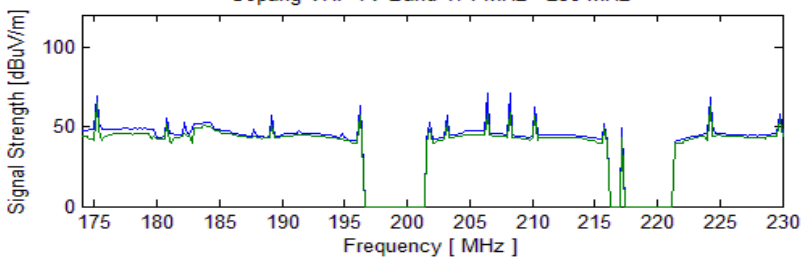


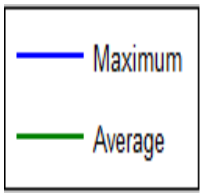
Labuan VHF TV Band 174 MHz - 230 MHz



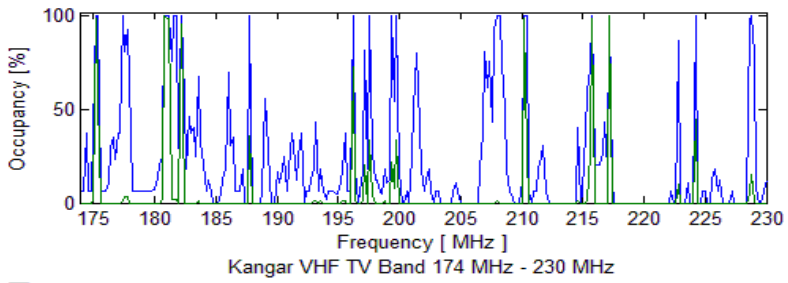


Sepang VHF TV Band 174 MHz - 230 MHz

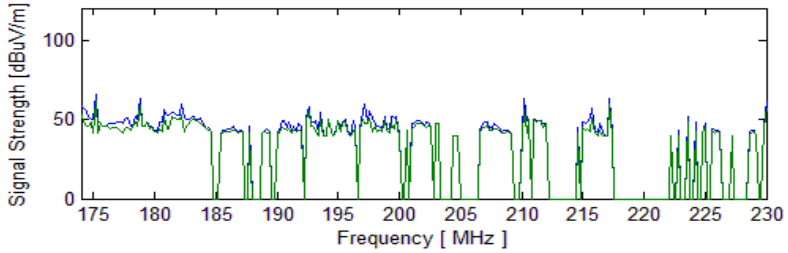


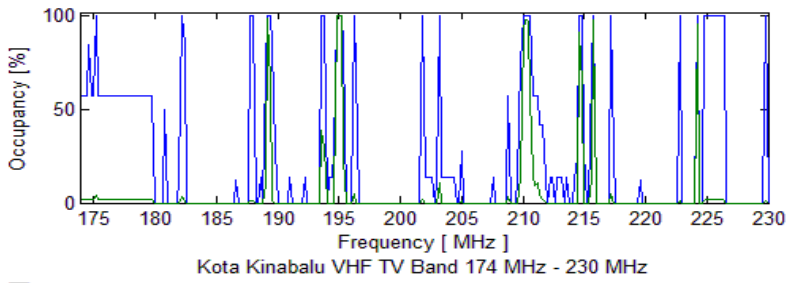


Low Utilization for VHF TV Band

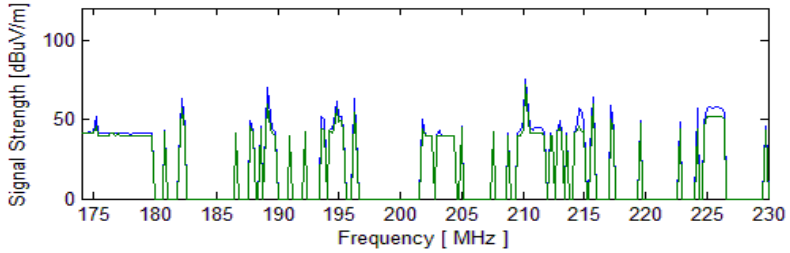


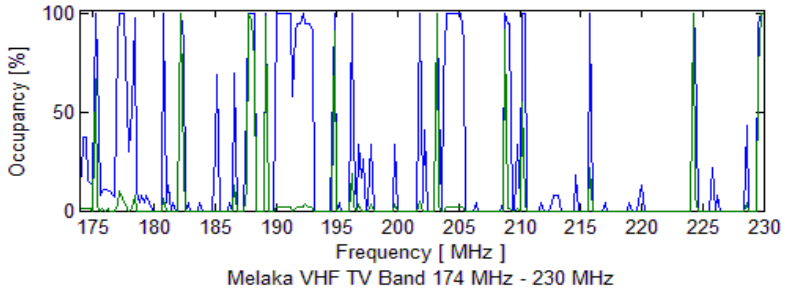
Kangar VHF TV Band 174 MHz - 230 MHz



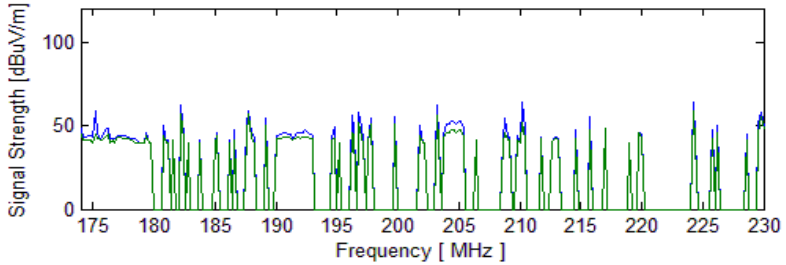


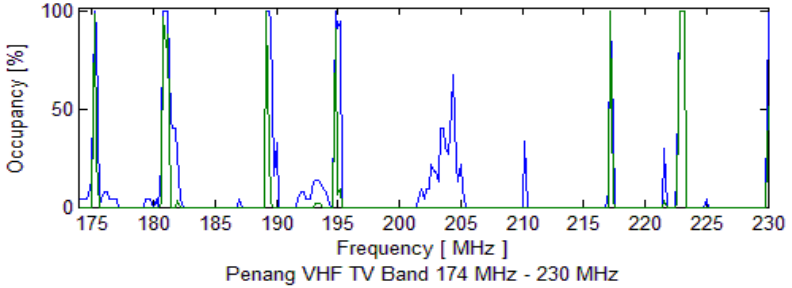
Kota Kinabalu VHF TV Band 174 MHz - 230 MHz



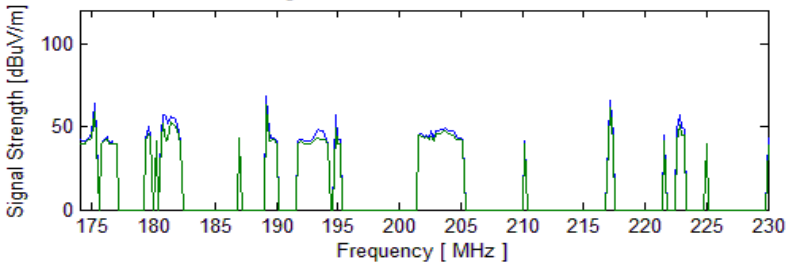


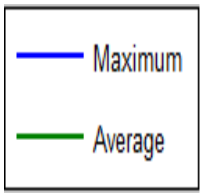
Melaka VHF TV Band 174 MHz - 230 MHz



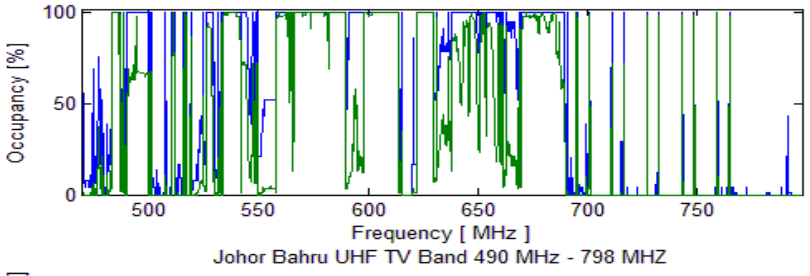


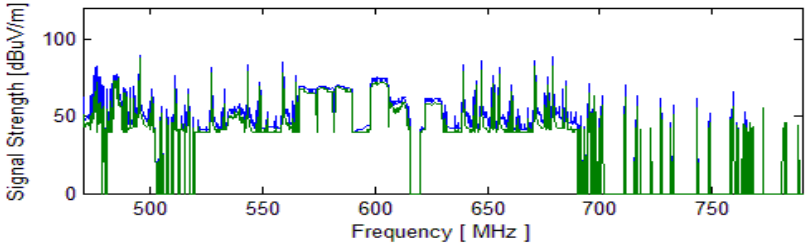
Penang VHF TV Band 174 MHz - 230 MHz

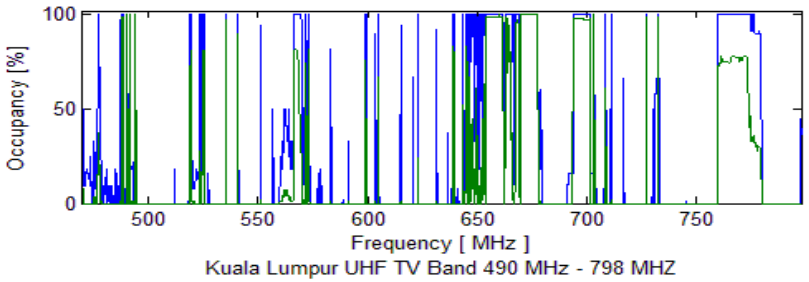


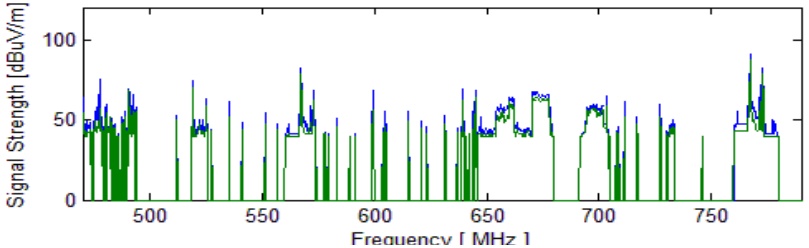


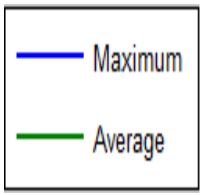
High Utilization for UHF TV Band

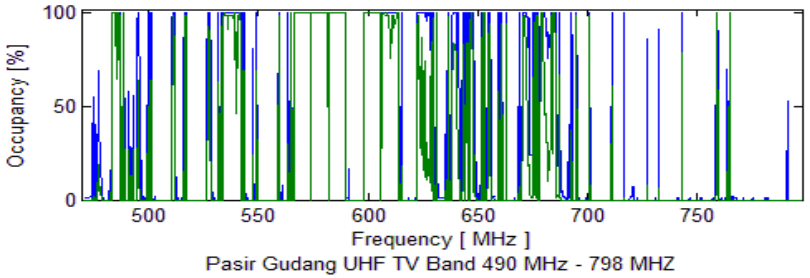


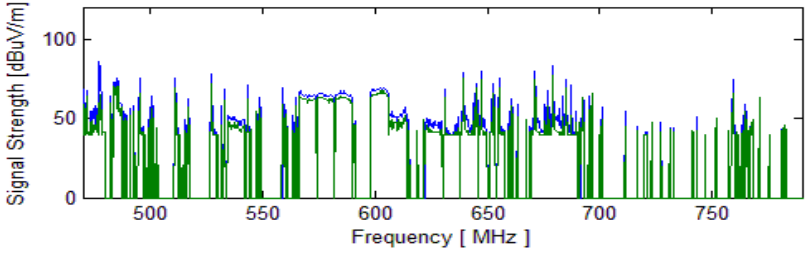


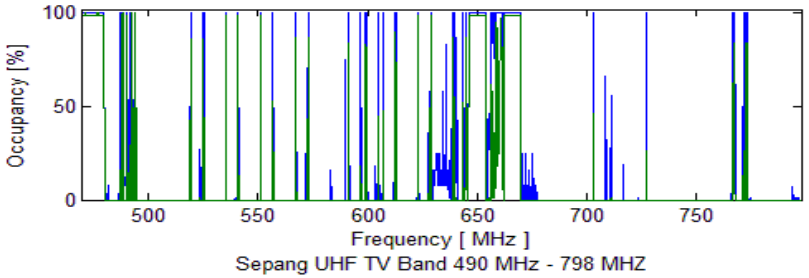


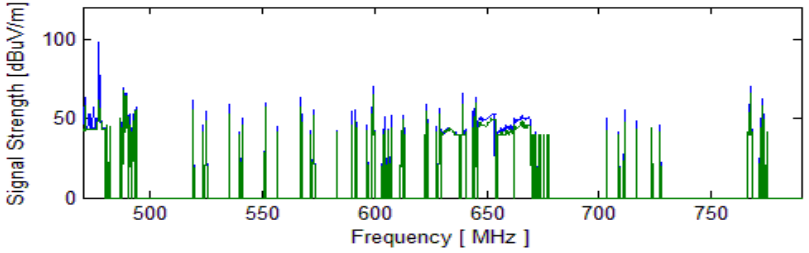




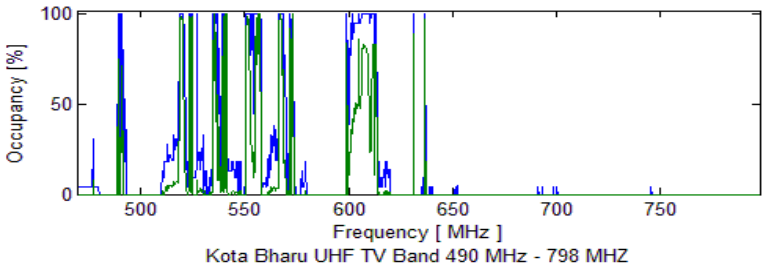




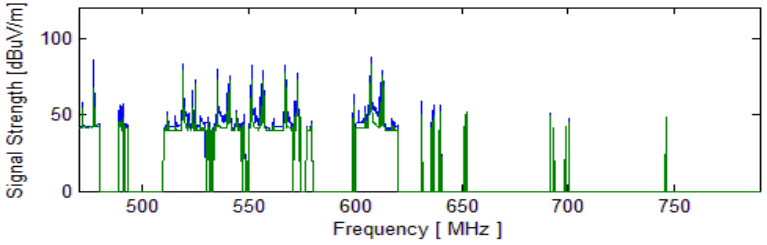


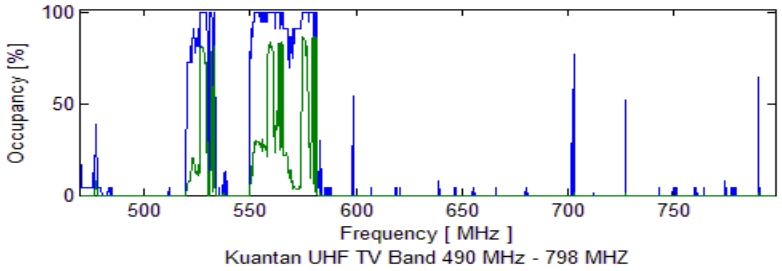


Medium Utilization for UHF TV Band

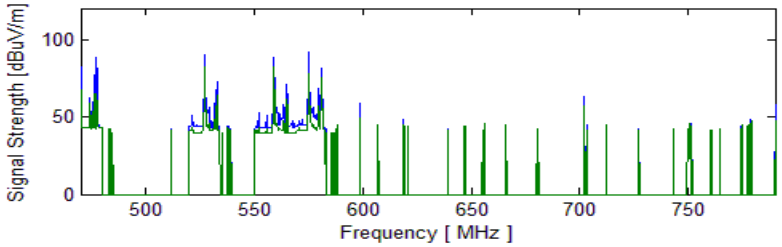


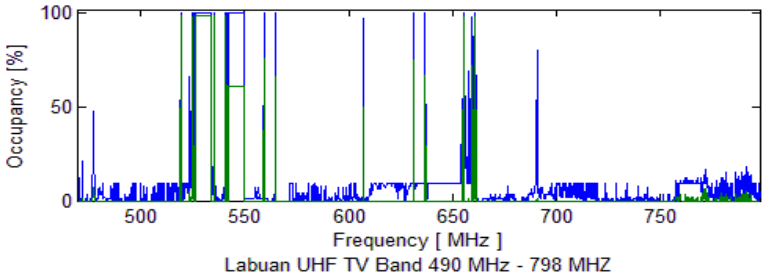
Kota Bharu UHF TV Band 490 MHz - 798 MHZ



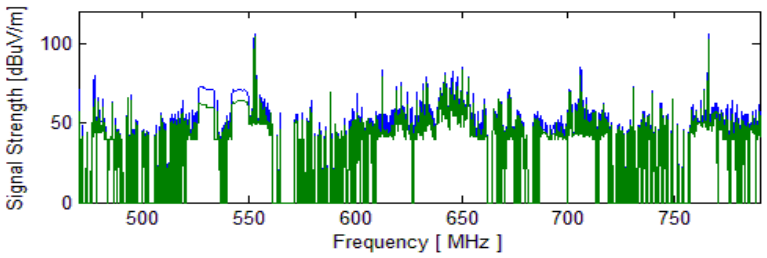


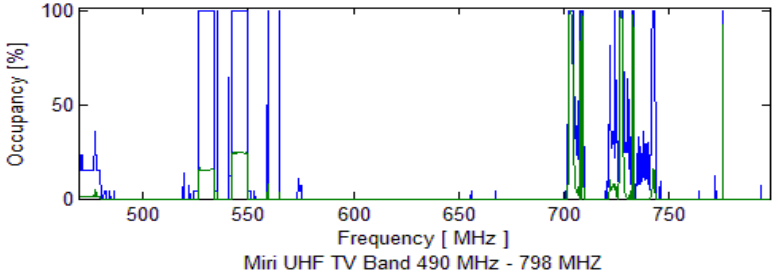
Kuantan UHF TV Band 490 MHz - 798 MHZ



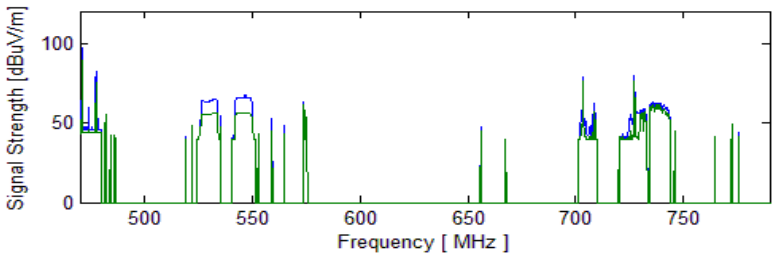


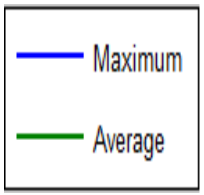
Labuan UHF TV Band 490 MHz - 798 MHZ



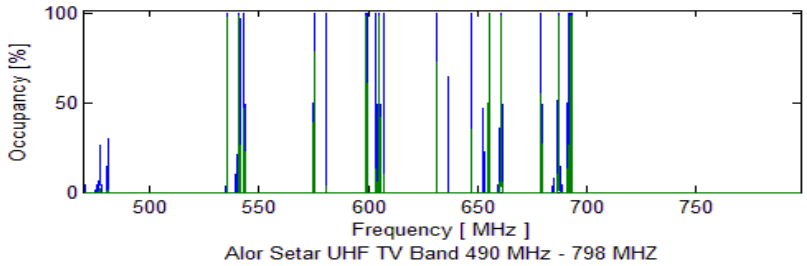


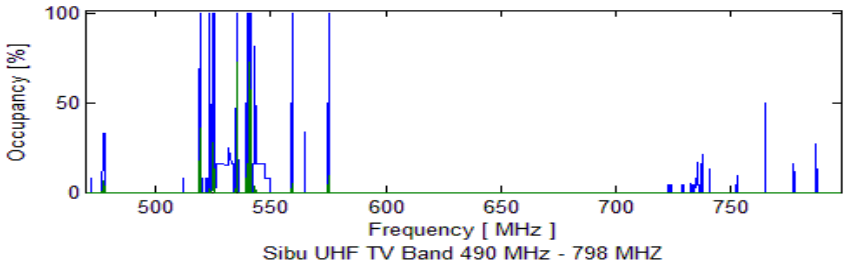
Miri UHF TV Band 490 MHz - 798 MHZ

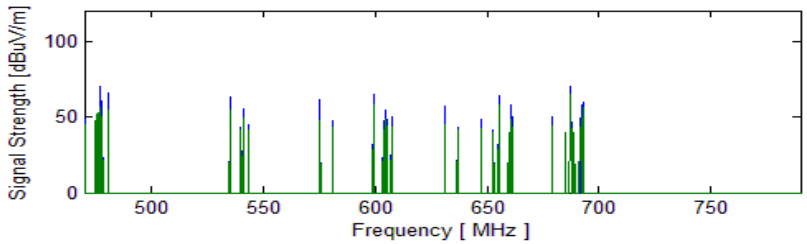


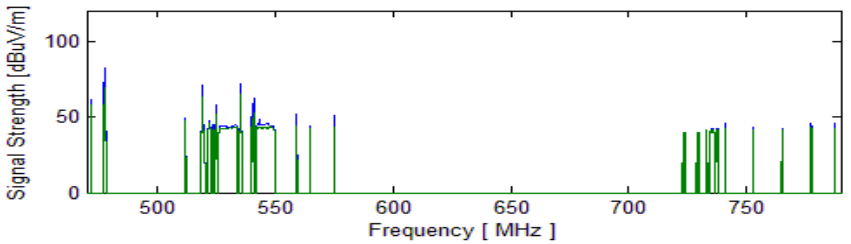


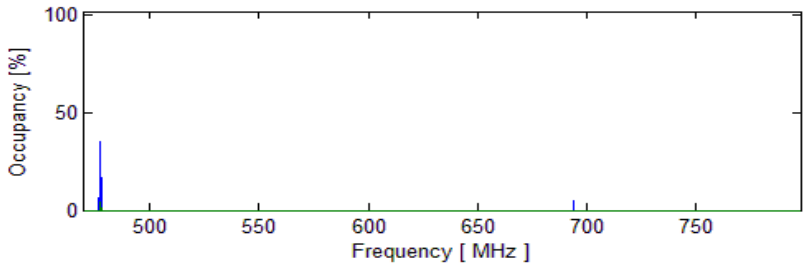
Low Utilization for UHF TV Band

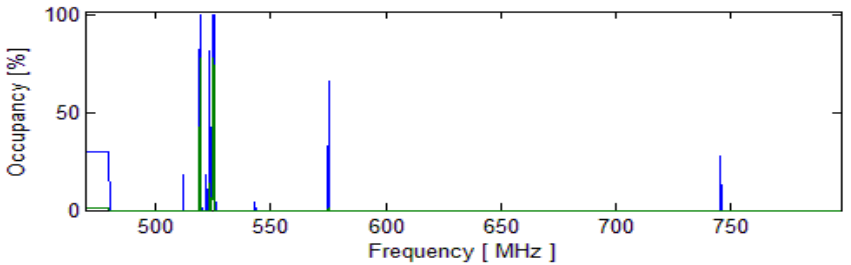


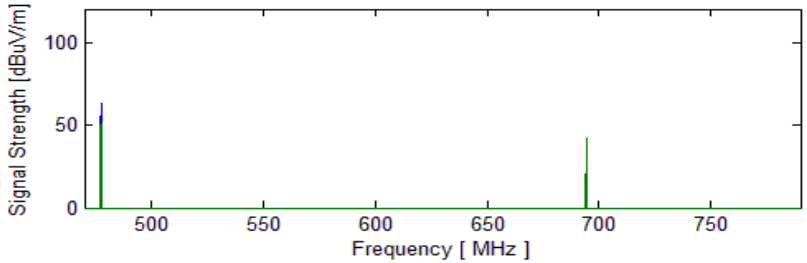


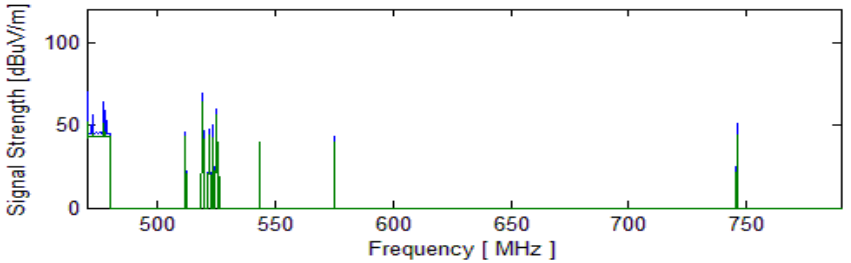


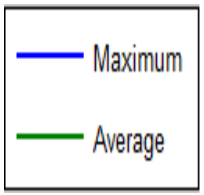




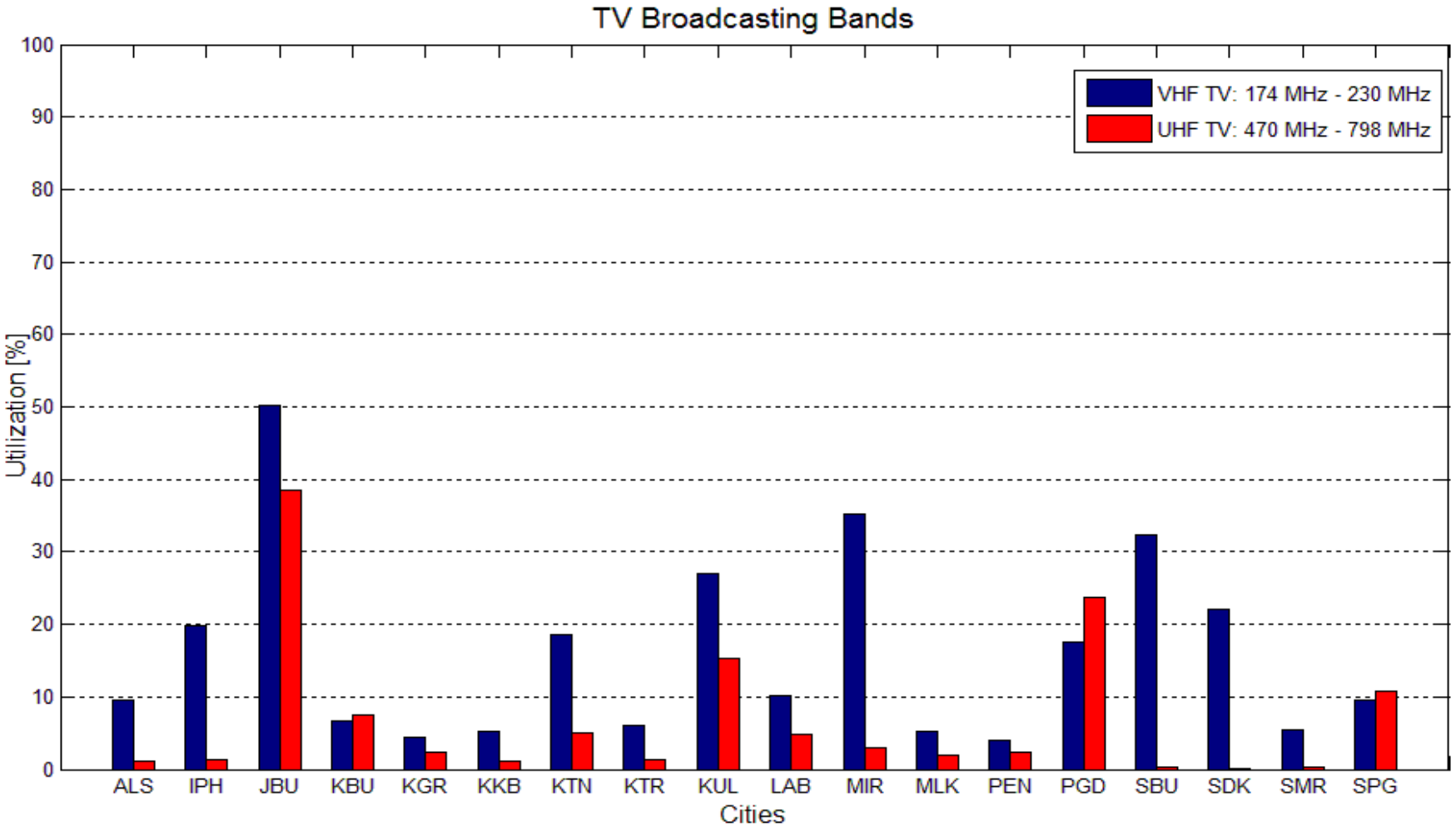








Summary: Spectrum Utilization



Summary: Spectrum Utilization

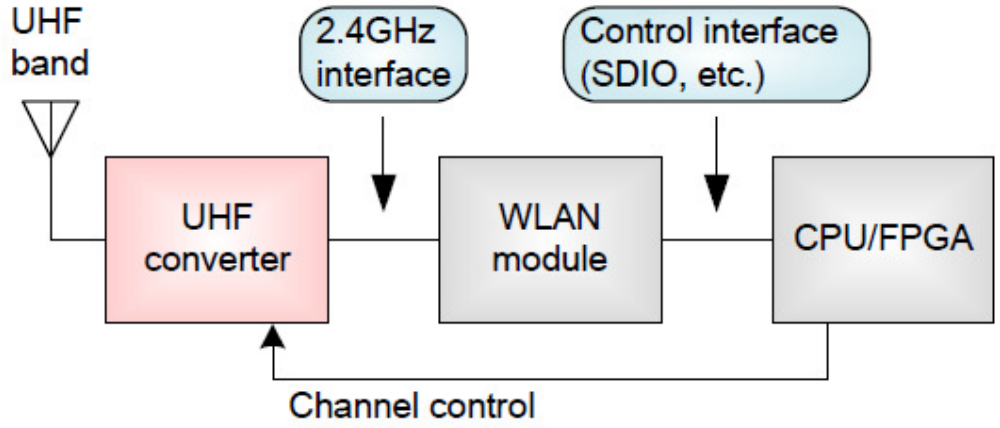
- Most of the cities show low utilization for UHF TV band (less than 20% utilization)
- High chances for deployment of dynamic spectrum access in TV band as the average usage in UHF TV band is only 6.7%

- Notes:
  - Medium Utilization (9 – 20%), 6 cities:
    - Alor Setar, Pasir Gudang, Labuan, Sepang, Ipoh, and Kuantan
  - Low Utilization (0 – 9%) 7 cities:
    - Kota Kinabalu, Kangar, Melaka, Penang, Kota Kinabalu, Kuala Terengganu and Samarahan

Outline

- Introduction
  - TV White Space
- Spectrum Measurement
  - VHF and UHF Band Utilization
- **Downconverter Implementation**
- Integration Work and TVWS Prototype
  - Power Detector
  - Lab Experimental and Results
- Moving Forward
- Conclusion

Downconverter Features & Design

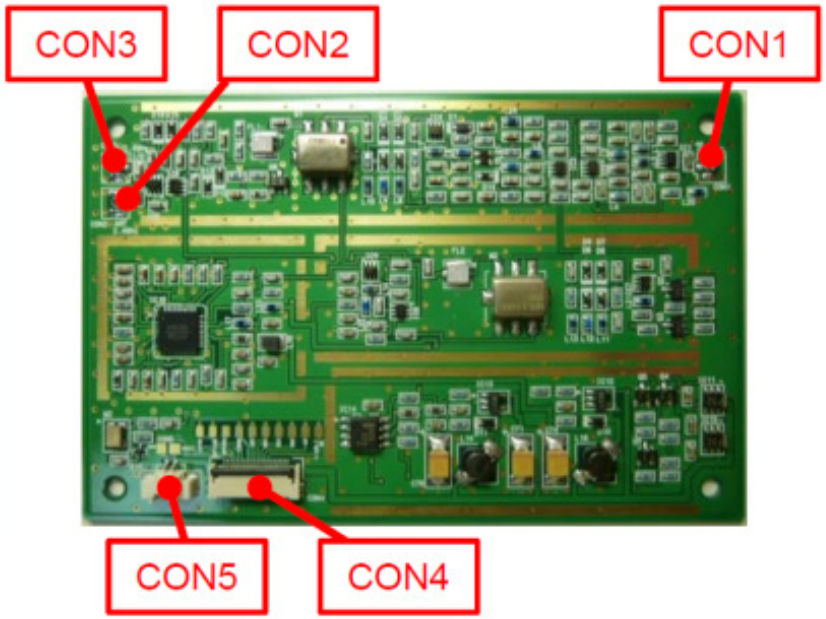


- Frequency conversion from up to 3 GHz to UHF
- Support TV white-spaces from 470 to 770 MHz
- High power handling up to 20 dBm (peak)
- Battery operation, 3.7 V and 500 mA max
- Simple interface for UHF CH control
- RF receptacles are mounted for all RF interface

Matsumura, T, & Harada, H, "Prototype of UHF Converter for TV White-space Utilization," WPMC 2012, pp. 24-27.

Downconverter Specification & Fabrication

Contents	Specification
Native frequency	up to 3 GHz
UHF	470 ~ 770 MHz
Bandwidth	< 20 MHz
Tx power	< 20 dBm (peak)
Rx gain	0 dB
Rx NF	7 dB
Vcc	3.7 V
Current consumption	450 mA (Tx) / 350 mA (Rx)
Size	100 × 65 mm^2
Weight	24 g

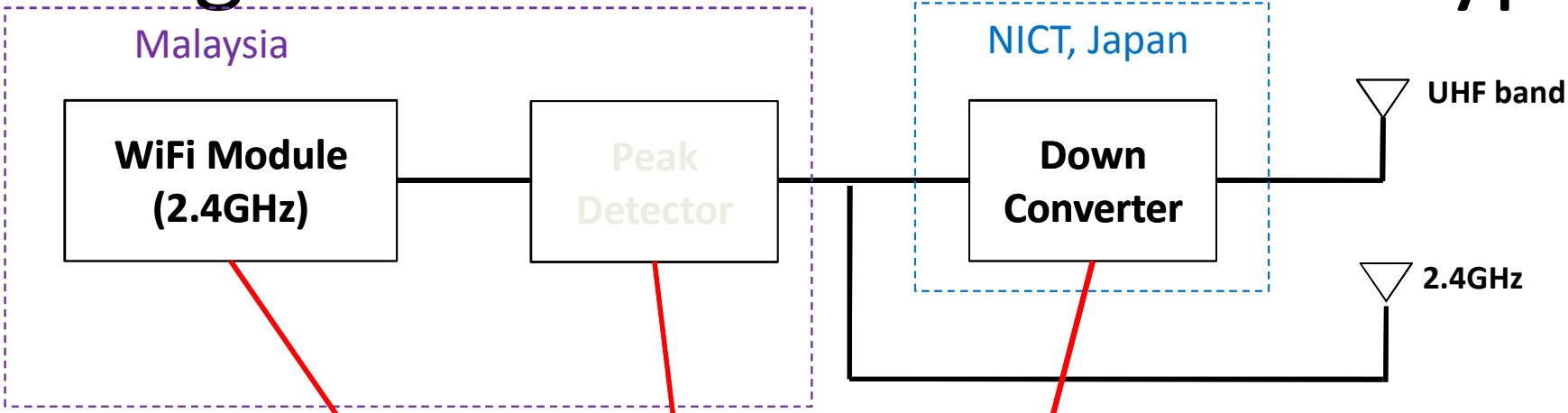


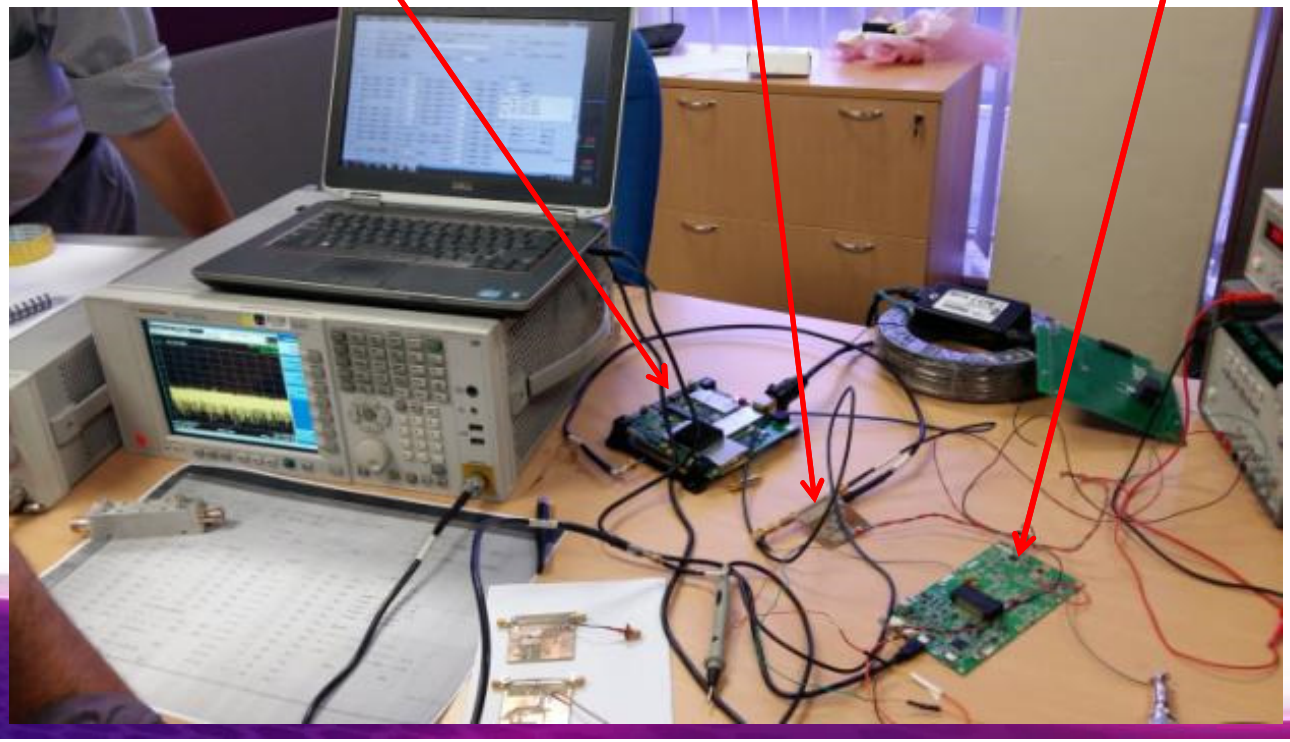
Matsumura, T, & Harada, H, "Prototype of UHF Converter for TV White-space Utilization," WPMC 2012, pp. 24-27.

Outline

- Introduction
  - TV White Space
- Spectrum Measurement
  - VHF and UHF Band Utilization
- Downconverter Implementation
- **Integration Work and TVWS Prototype**
  - **Power Detector**
  - **Lab Experimental and Results**
- Moving Forward
- Conclusion

Integration Work & TVWS Prototype



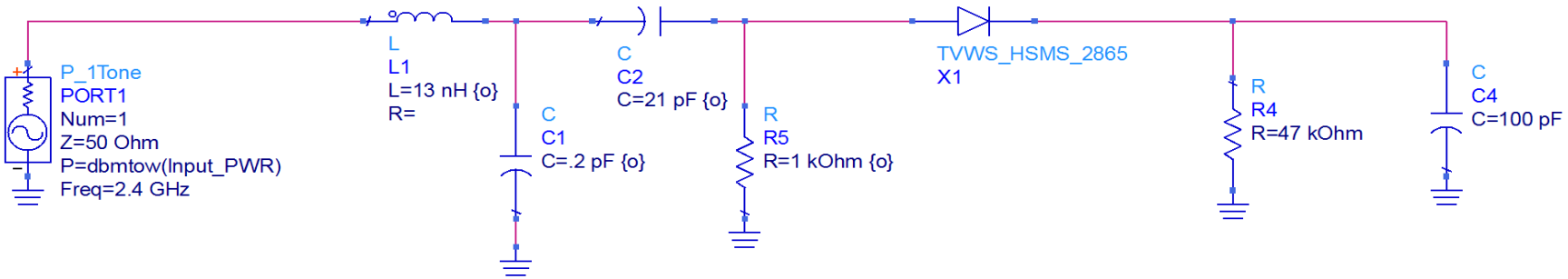


Development of Power Detector

- Integrating the WLAN Router Board with TVWS Down converter requires the knowledge of the radio transmission (transmit or receive).
- Since the WLAN Router Board and TVWS Converter are independent
  - **Power detector** is proposed to determine the timing sequence of radio transmission.

Power Detector

Simulation was performed using ADS circuit and layout simulation



HARMONIC BALANCE

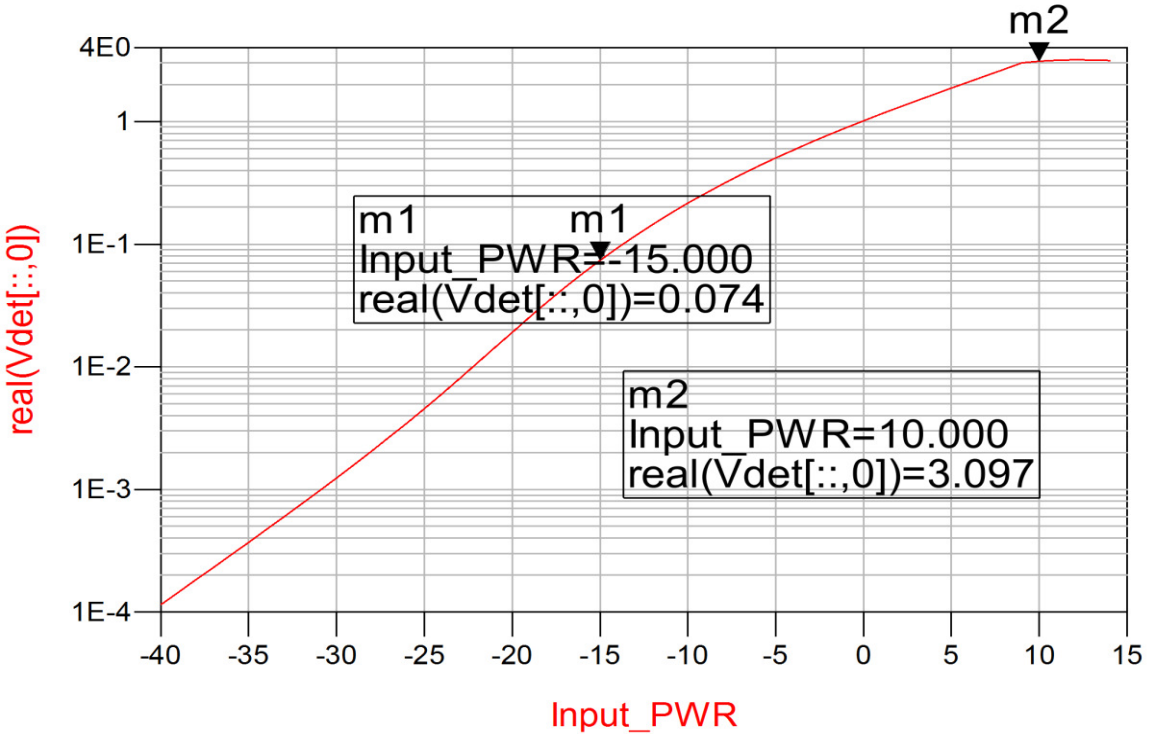
HarmonicBalance
HB1
Freq[1]=2.4 GHz
Order[1]=3
SweepVar=
SweepPlan=
Start=-25
Stop=15
Step=1

VAR
VAR1
Input_PWR=1.0

PARAMETER SWEEP

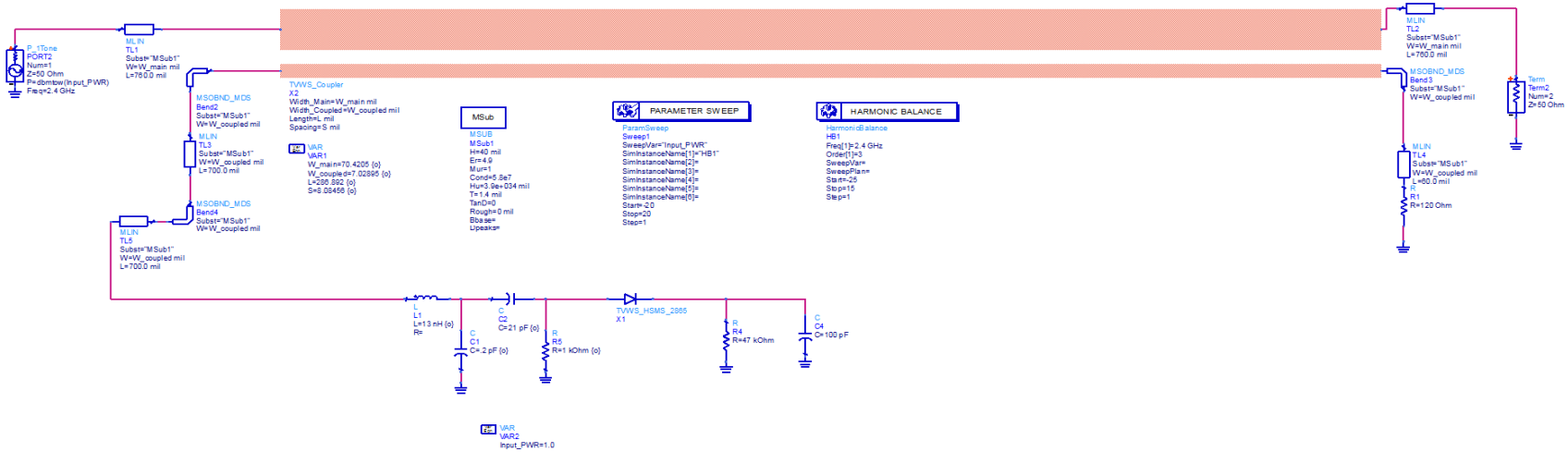
ParamSweep
Sweep1
SweepVar="Input_PWR"
SimInstanceName[1]="HB1"
SimInstanceName[2]=
SimInstanceName[3]=
SimInstanceName[4]=
SimInstanceName[5]=
SimInstanceName[6]=
Start=-40
Stop=14
Step=1

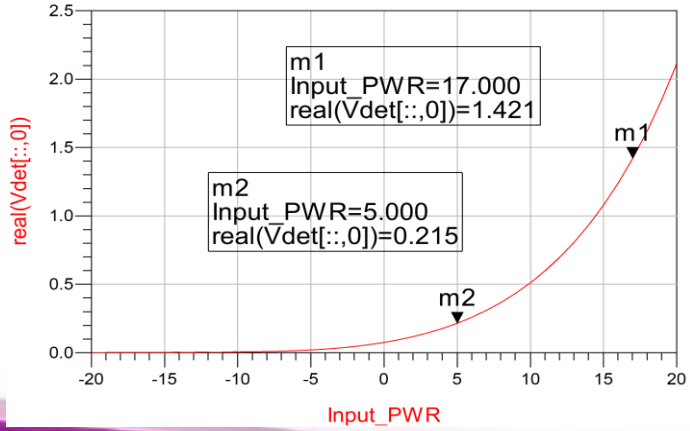
Peak Detector Simulation result



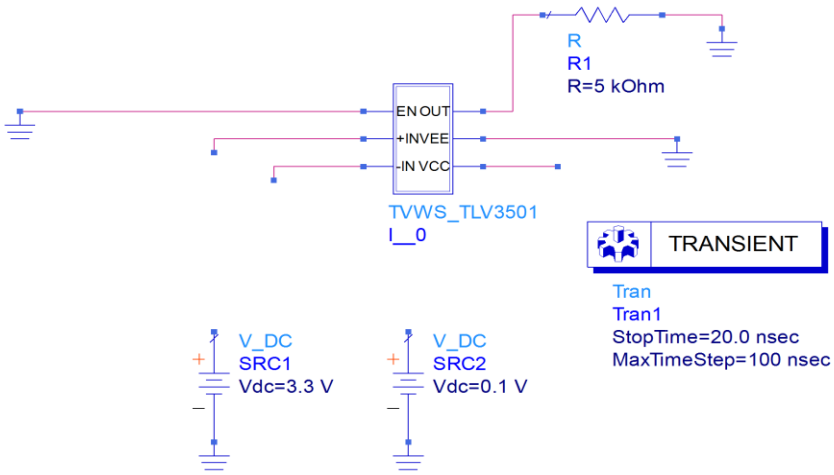
Close enough to specification in the datasheet for HSMS-2865. We can get this closer if the Schottky is biased as prescribed.

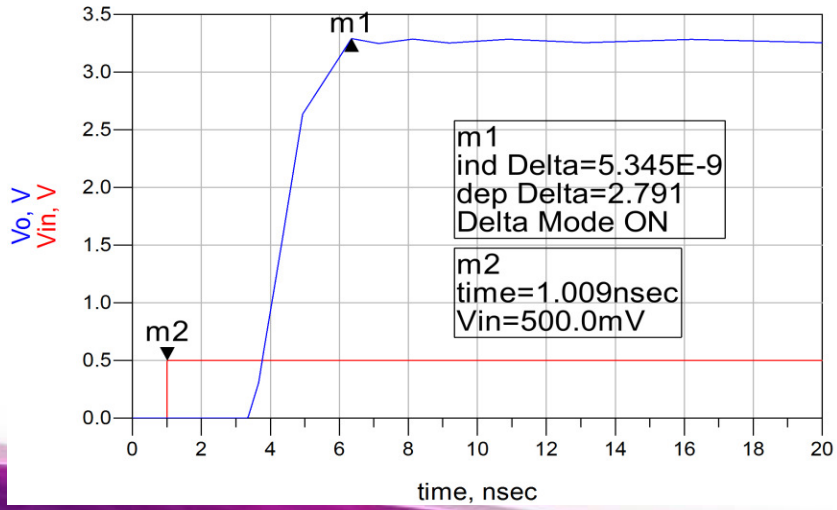
Pin versus Vdetected – Power detector and Coupler circuit





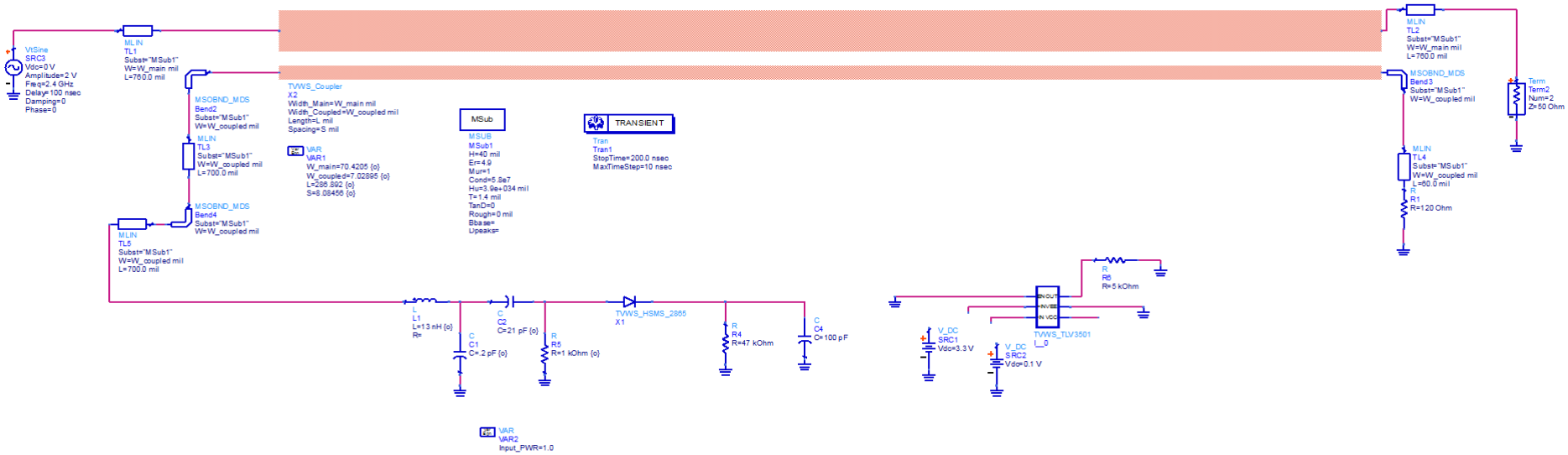
Comparator Circuit Delay Simulation





About 5 nS delay in response = 0 to 100%

All system Simulation

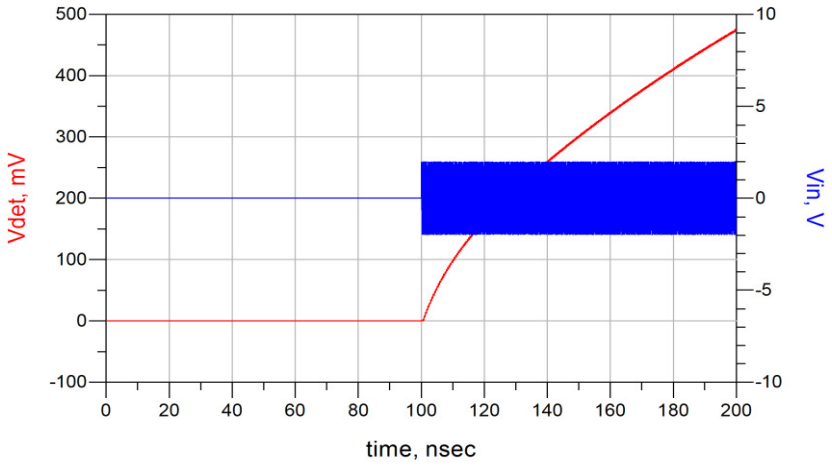


PD – Schottky – Agilent :- HSMS-2865

Comparator – Texas Instrument TLV3501

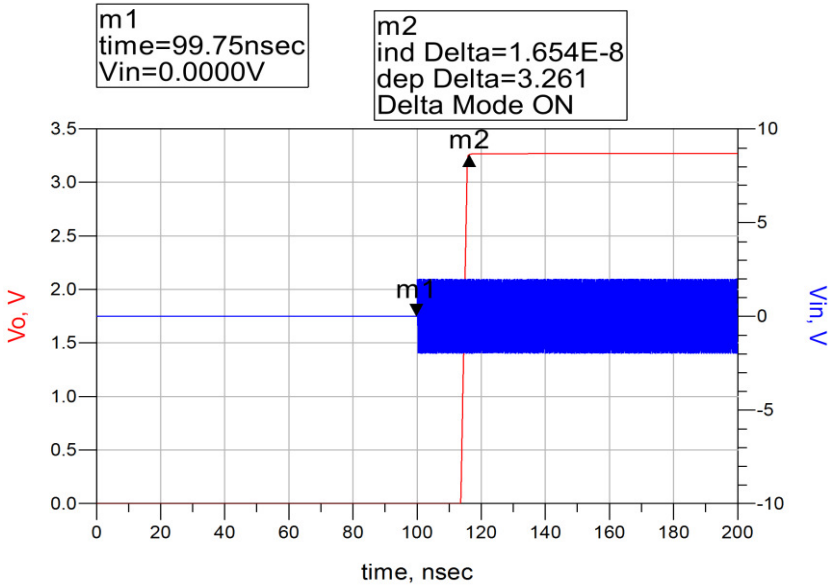
Coupler – In house built

Result – Overall Simulation



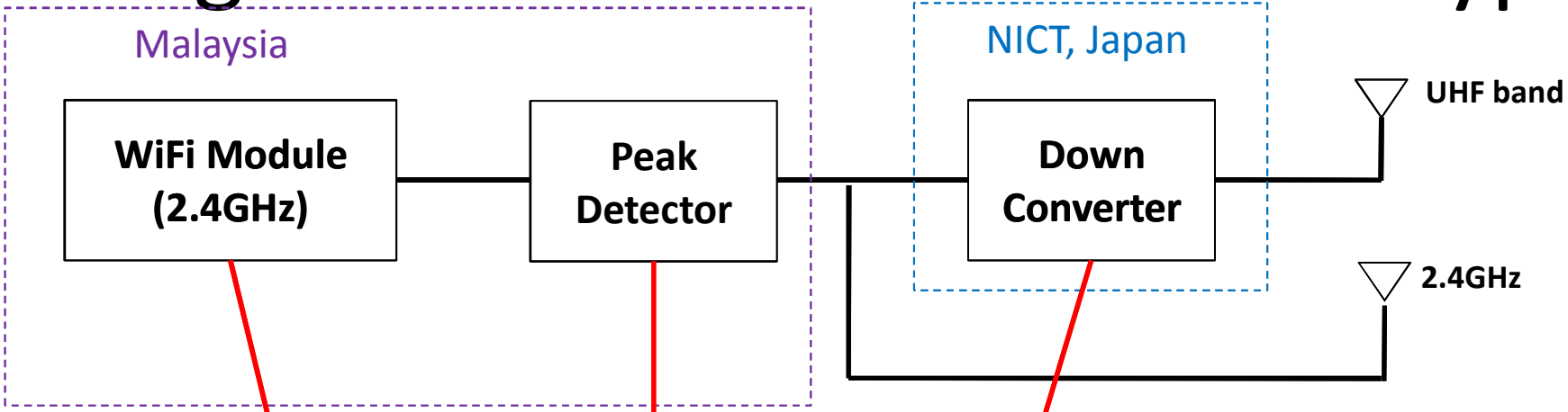
Delay resulted from Schottky – 10 nS

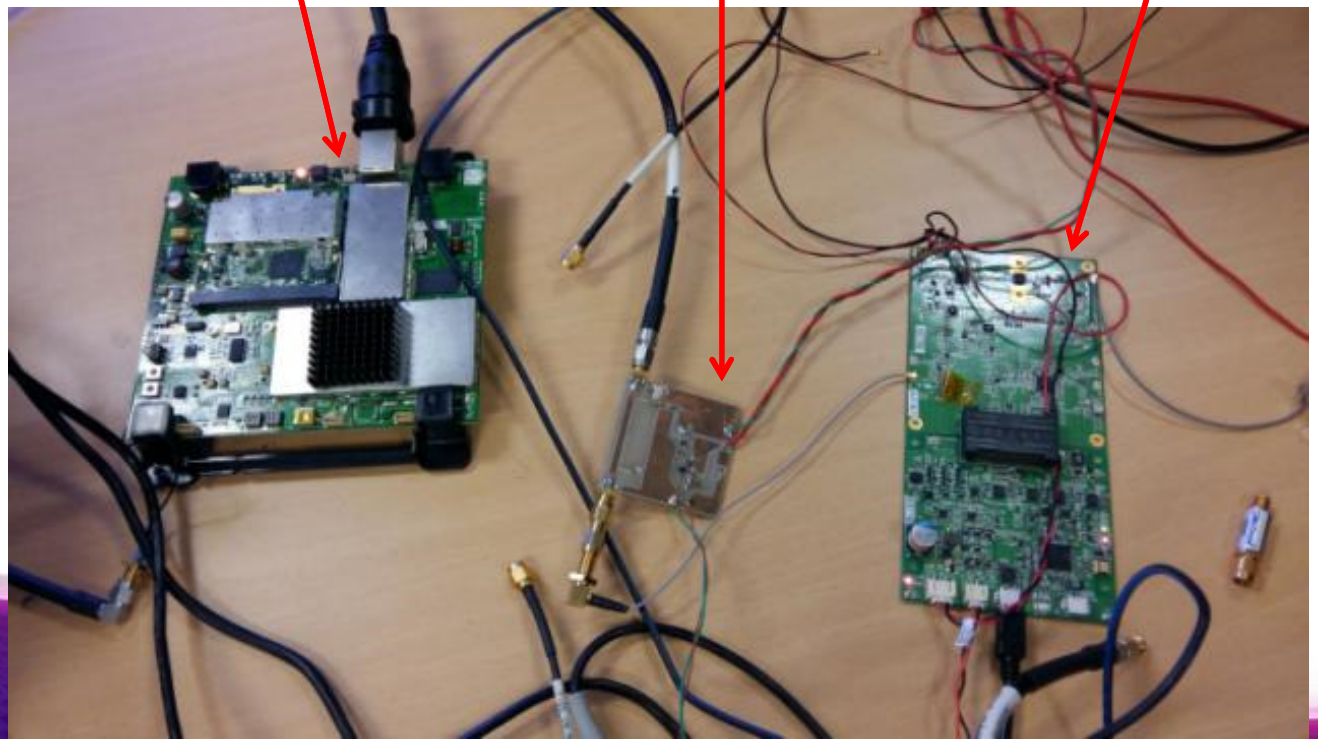
Note: measured from 0 mv to 0.1 V – Because the comparator is set at 100 mV



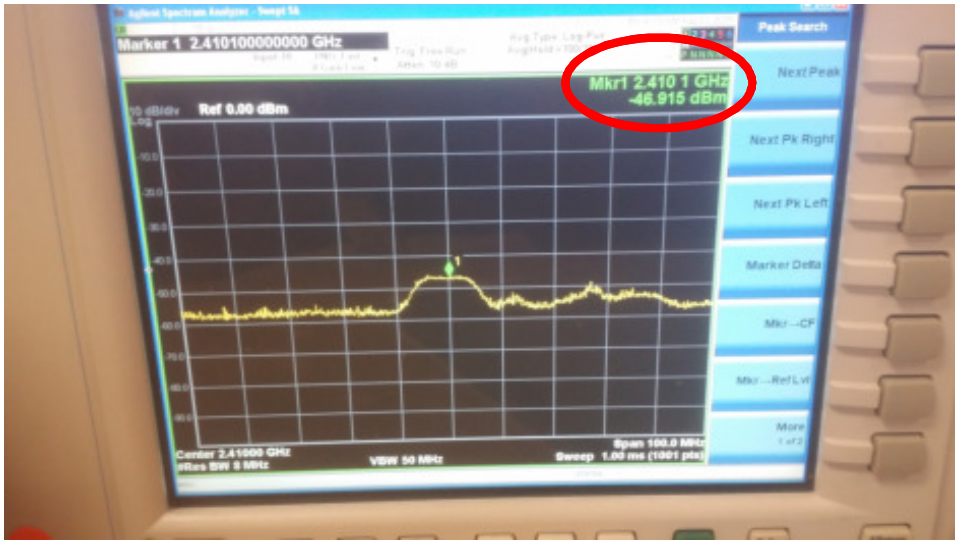
Delay – Overall ~16 nS

Integration Work & TVWS Prototype





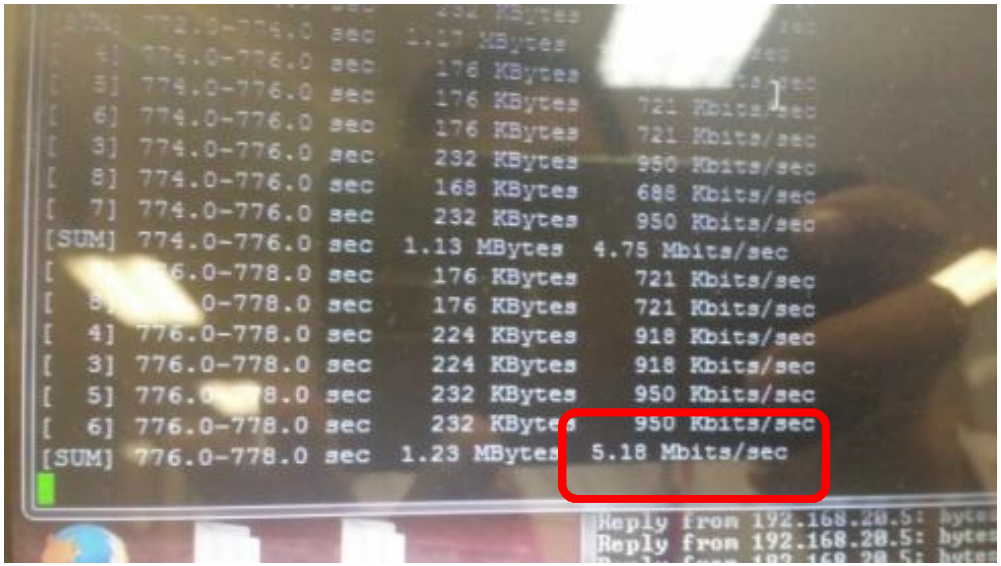
TVWS Prototype Results *(Spectrum Analyzer)*

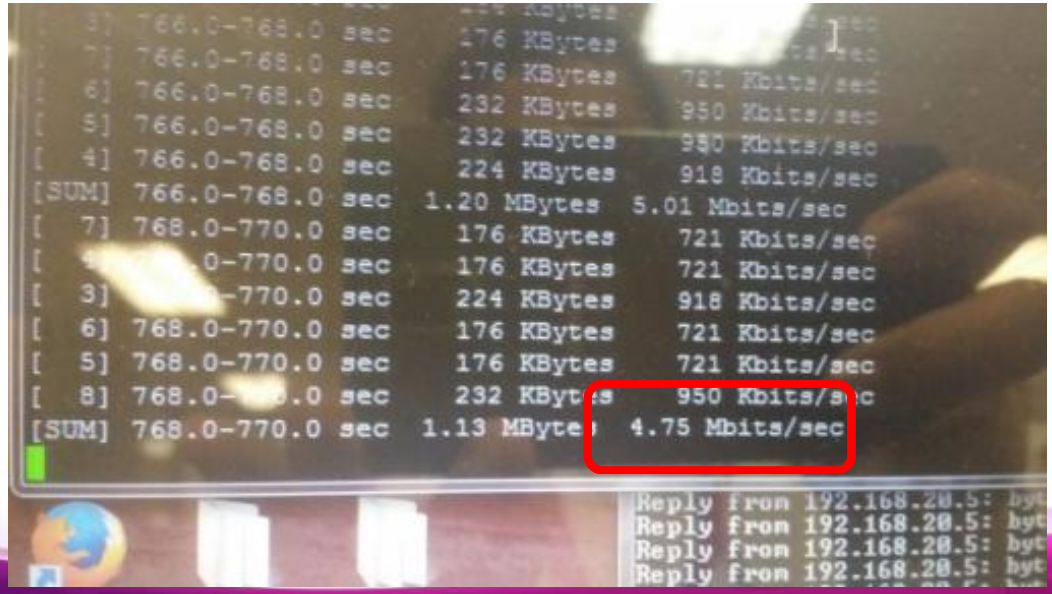


- Transmitter: WiFi at 2.41GHz

- Receiver: TVWS at 456.8MHz (UHF band)

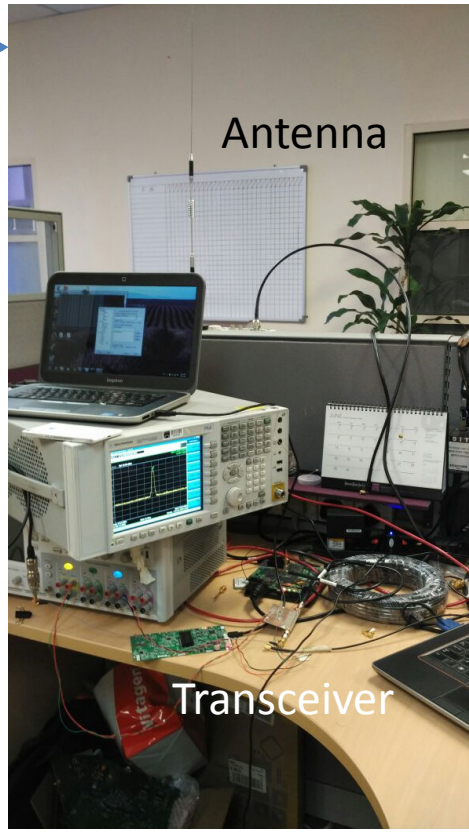
TVWS Prototype Results
(Throughput Test)





Lab experimental

30 meters



Outline

- Introduction
  - TV White Space
- Spectrum Measurement
  - VHF and UHF Band Utilization
- Downconverter Implementation
- Integration Work and TVWS Prototype
  - Power Detector
  - Lab Experimental and Results
- **Moving Forward**
- Conclusion

Moving Forward

- Field experiment of TVWS transmission for the rural communications / disaster management
- Objectives
  - To improve the performance of TVWS transceiver (continuation)
  - To clarify regulations for TVWS system in Malaysia
  - To formulate requirement for database setup in Malaysia

Outline

- Introduction
  - TV White Space
- Spectrum Measurement
  - VHF and UHF Band Utilization
- Downconverter Implementation
- Integration Work and TVWS Prototype
  - Power Detector
  - Lab Experimental and Results
- **Moving Forward**
- **Conclusion**

Conclusion

- The availability of TVWS has been investigated by analyzing spectrum utilization in Malaysia to gain insight into current TV band spectrum usage.
- TVWS transceiver has been developed and tested. Power Detector was proposed to determine the transmission timing of radio.
- Future TVWS field experimental is planned for rural communications and disaster management purposes.

Thank You!