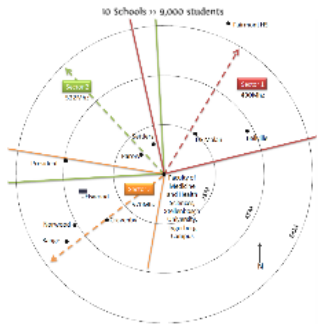
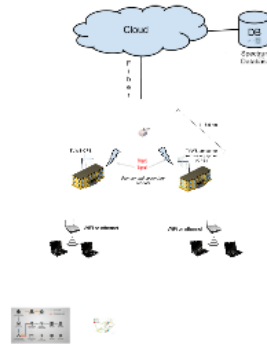




Cape Town TV White Spaces Trial

Arno Hart, TENET TVWS Trial Manager
arno@tenet.ac.za
@TVWhitespace
#TVWS
Reports: www.tenet.ac.za/tvws





Cape Town

T White Spaces Trial

Arno Hart, TENET TVWS Trial Manager
arno@tenet.ac.za
@TVWhitespace
#TVWS

Reports: www.tenet.ac.za/tvws



the doc

Department:
Communications
REPUBLIC OF SOUTH AFRICA



Joint Spectrum Advisory Group

Cape Town TVWS Trial Partners

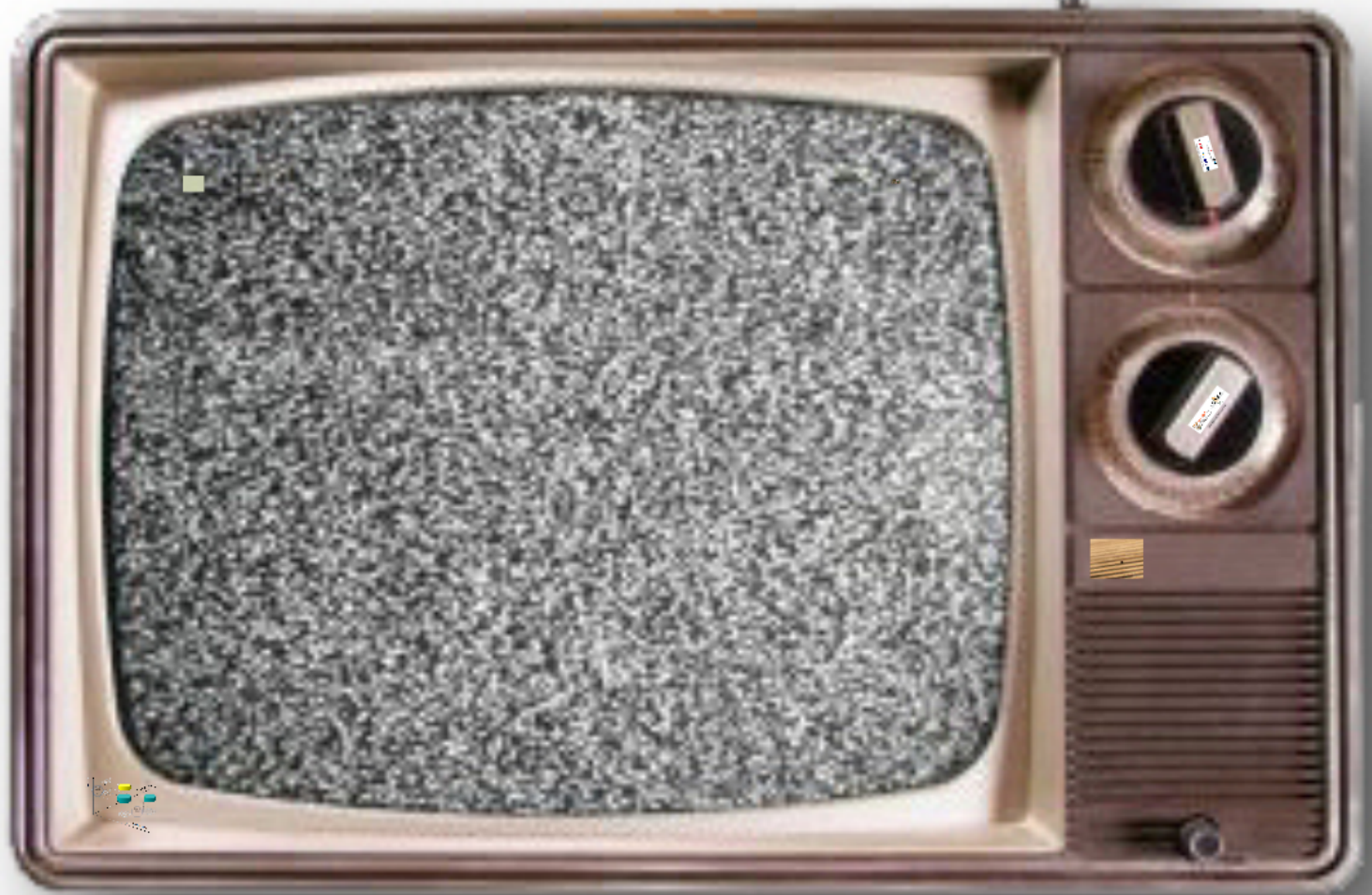


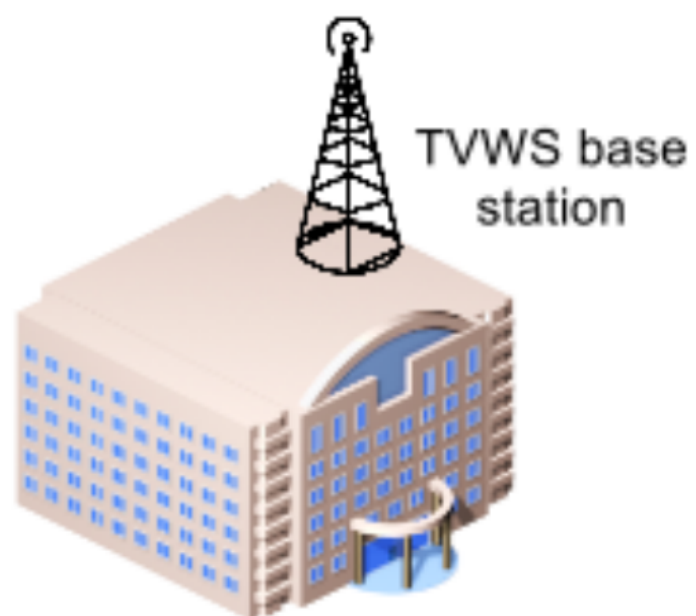
Cape Town TVWS Trial Vendors



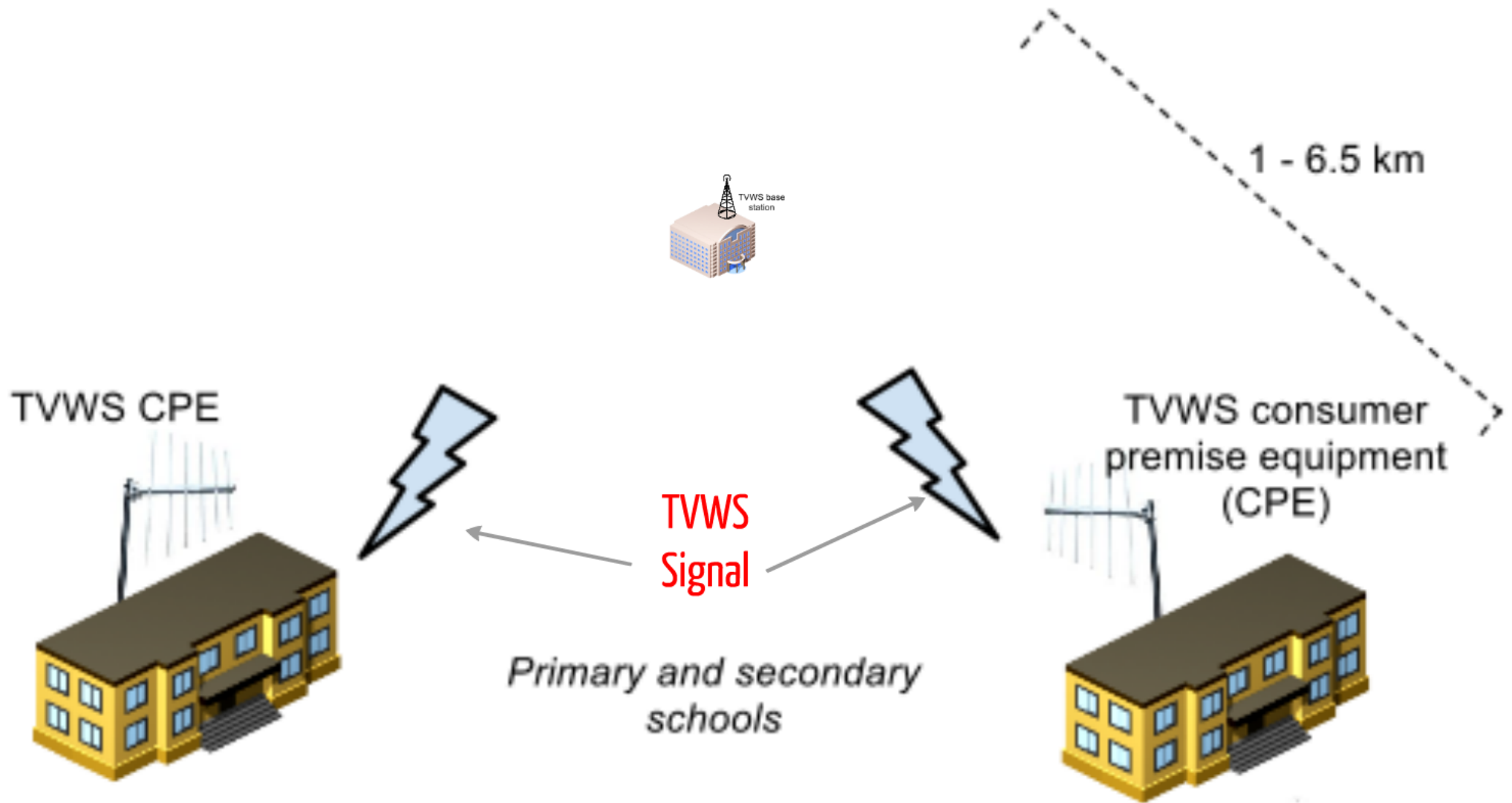
Four Best Practices for Operating a Zero-^{harmful}Interference TVWS Network

- 1 Spectrum Database
- 2 Network Design
- 3 TVWS Radio Design
- 4 Protocol/Rules





r |



1 - 6.5 km



TVWS CPE



TVWS
Signal

Primary and secondary
schools



TVWS consumer
premise equipment
(CPE)

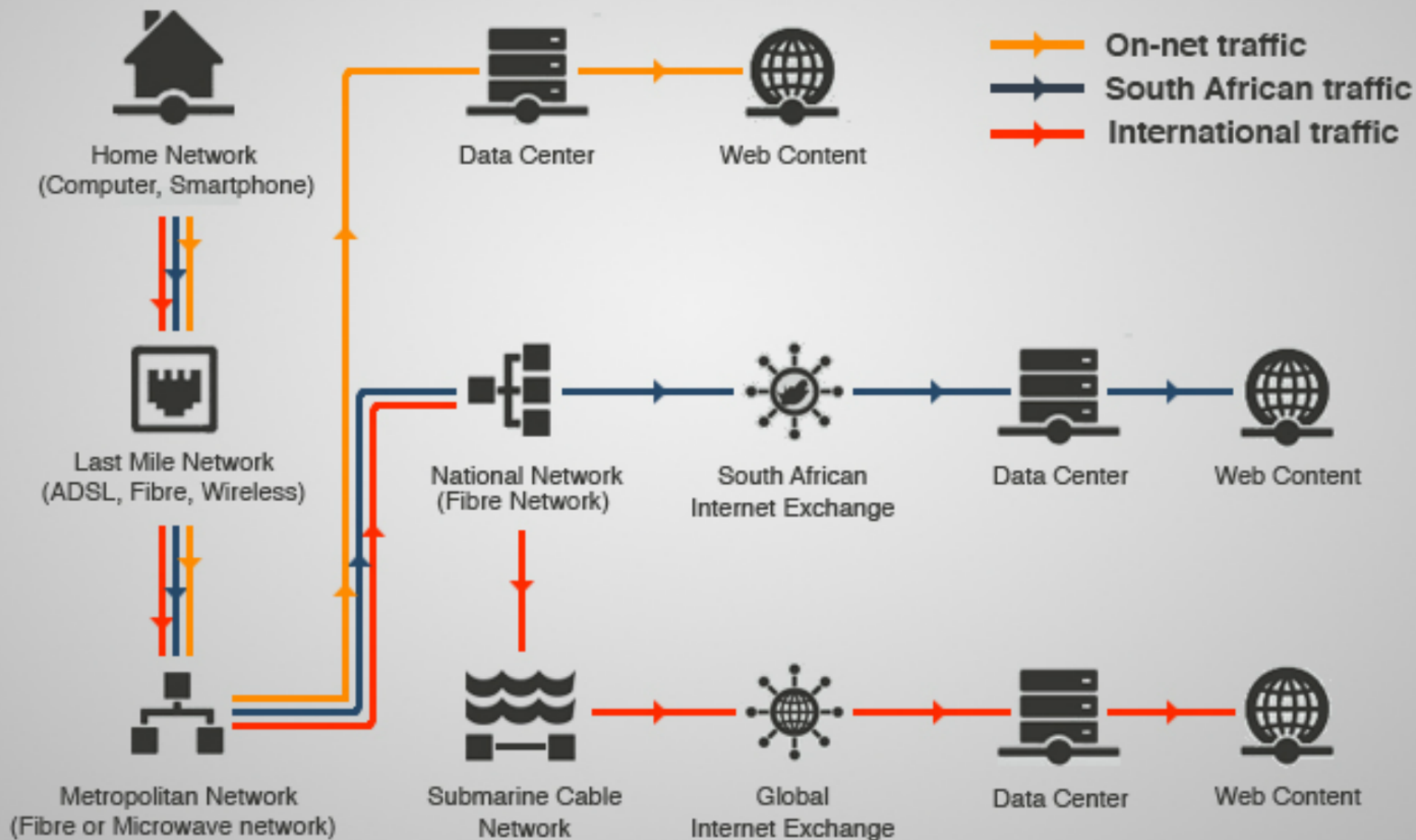


WiFi or ethernet



WiFi or ethernet





SANReN

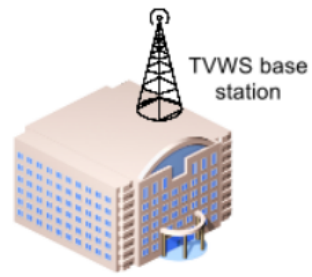
 Existing SANReN backbone

 Construction in progress

 Proposed extensions

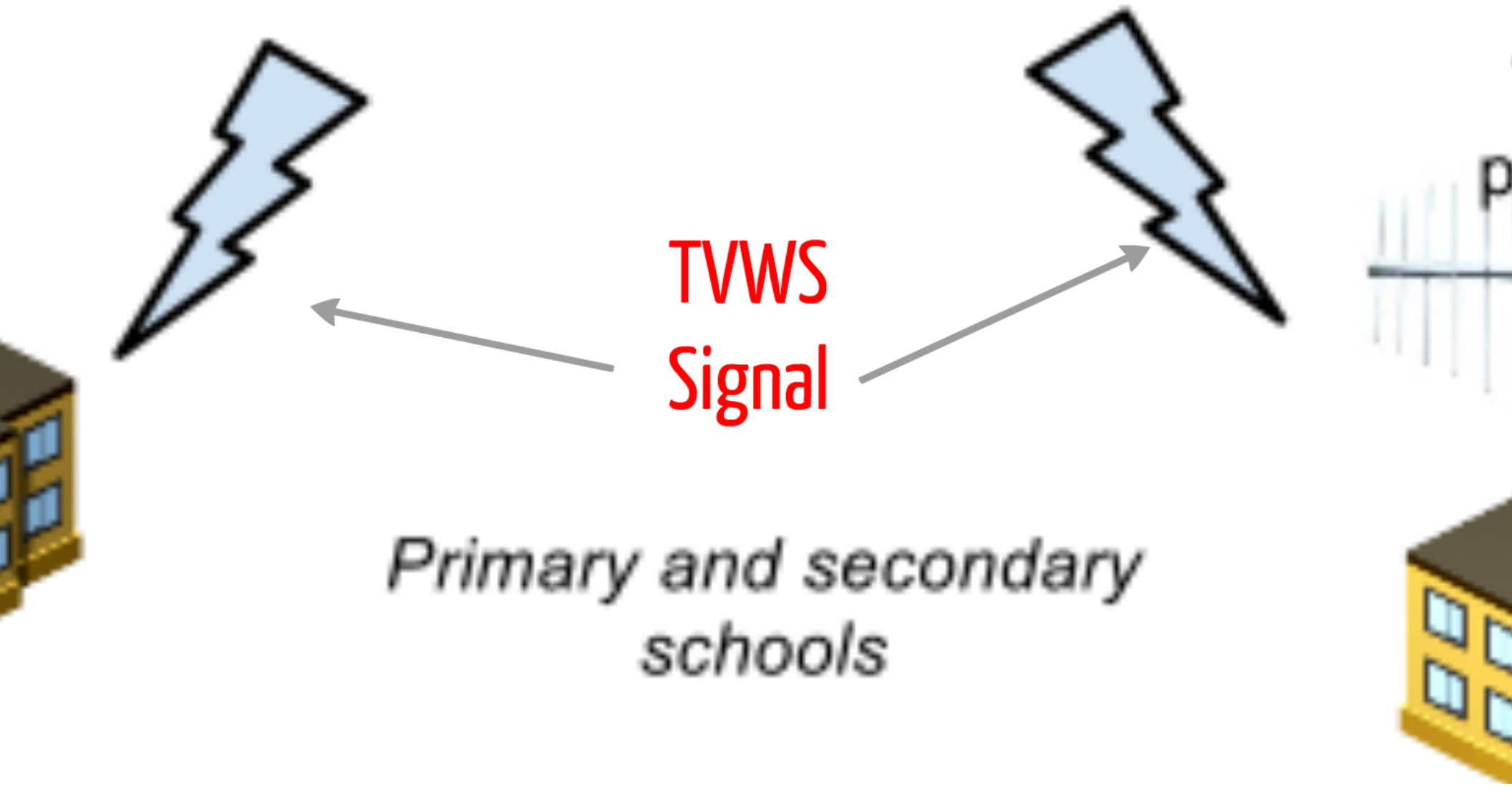
 TENET/SEACOM 10Gbps

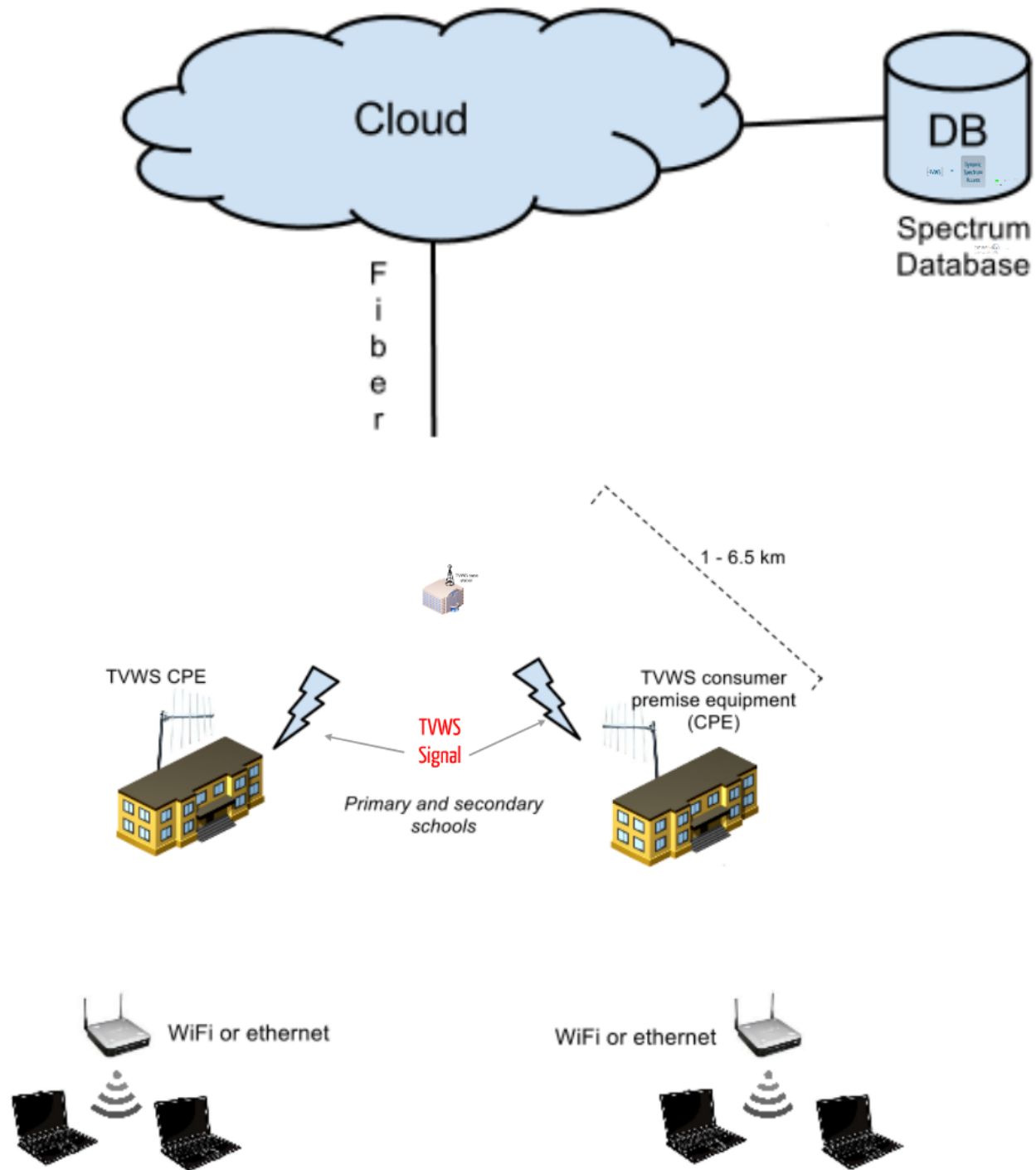




TVWS
Signal

*Primary and secondary
schools*





Frequency Range Specific
Dynamic Spectrum Access
[TVWS]

=

Dynamic
Spectrum
Access



Frequency Range Specific
Dynamic Spectrum Access

Two Evolving TVWS Industry Standards





SUPER

IEEE 802.11af

WiFi



Personal/other





LAST

IEEE 802.22

MILE



[2W output
(4W EIRP)]

Fixed/ rooftop



Evolving
S Industry
Standards



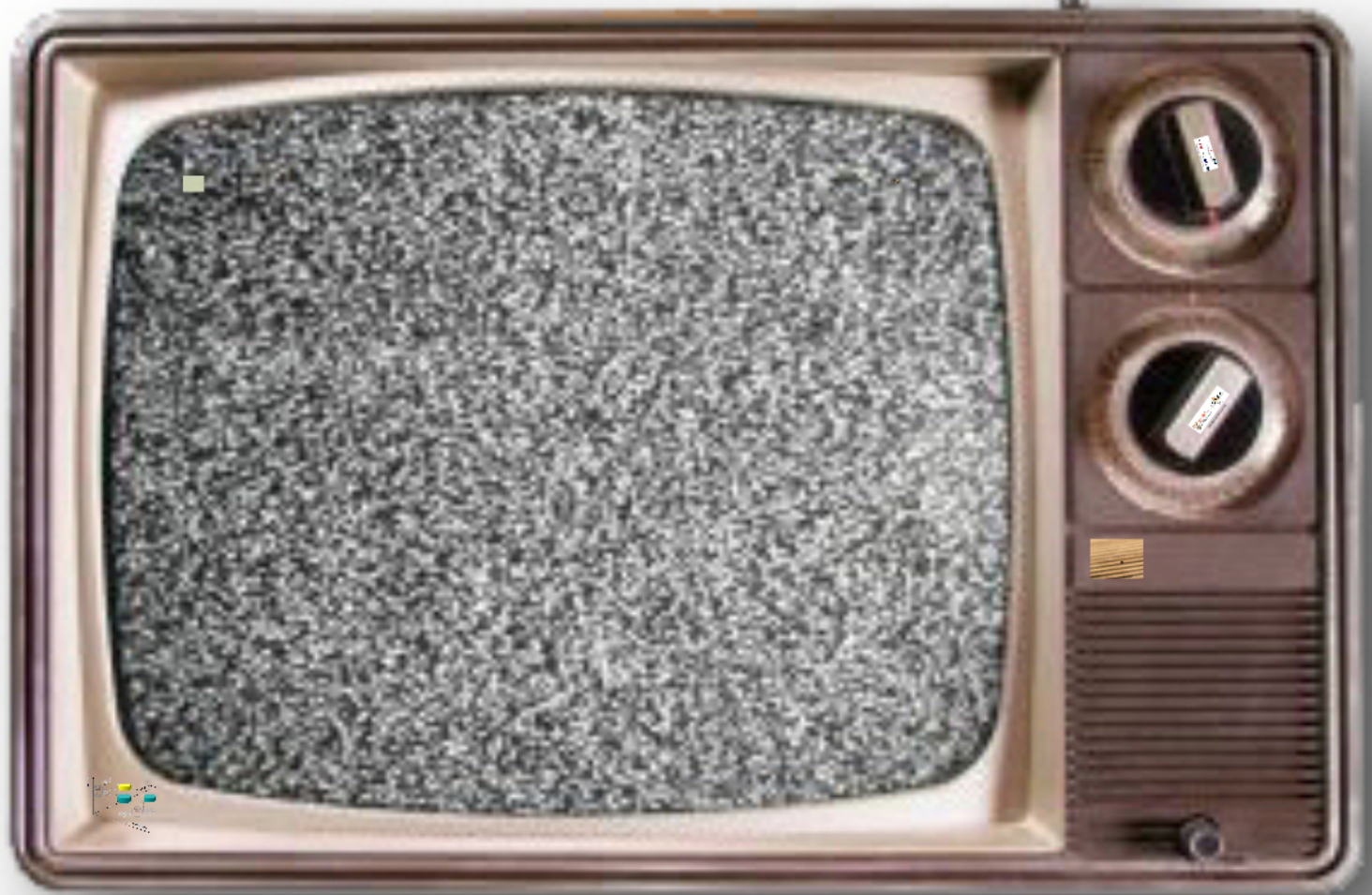


ADAPTRUM

redline[®]
communications

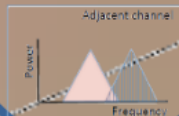
6Harmonics





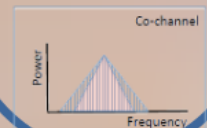
Frequency

Guard
bands



North distance

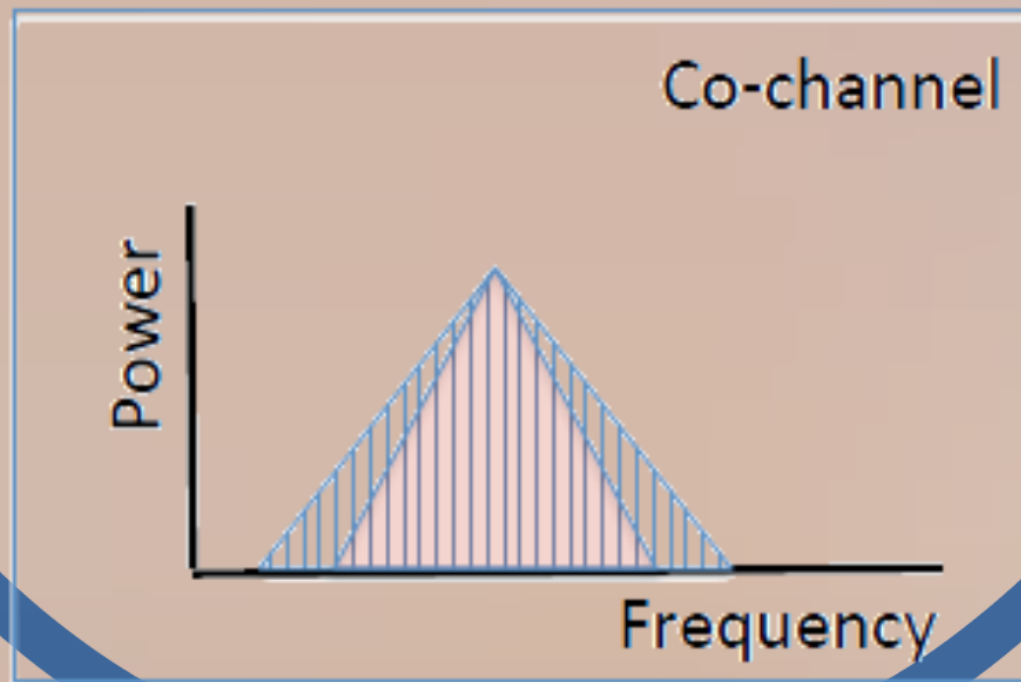
Distance
reuse



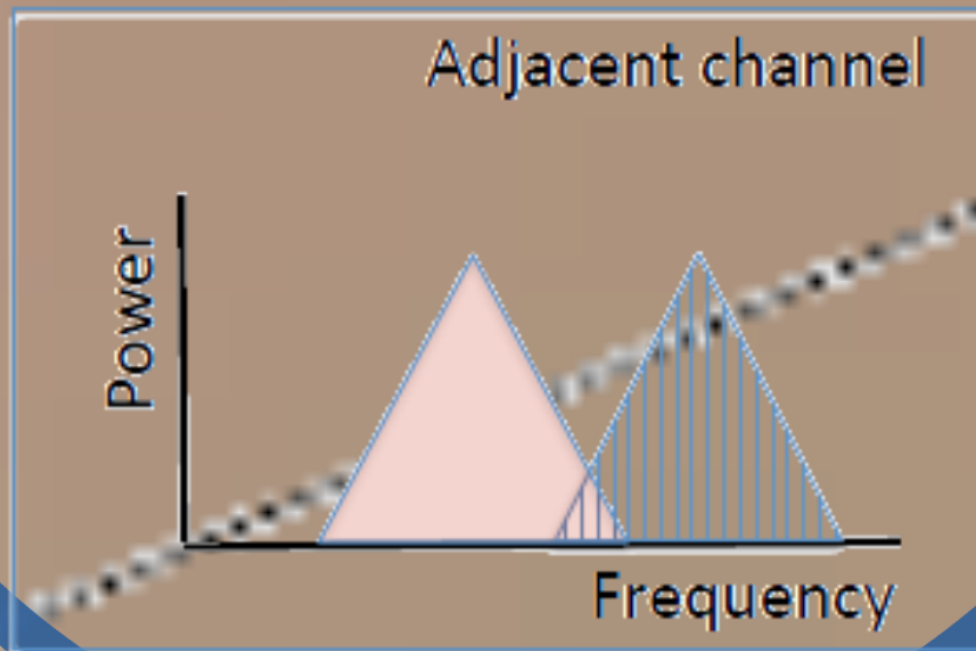
R Struzak

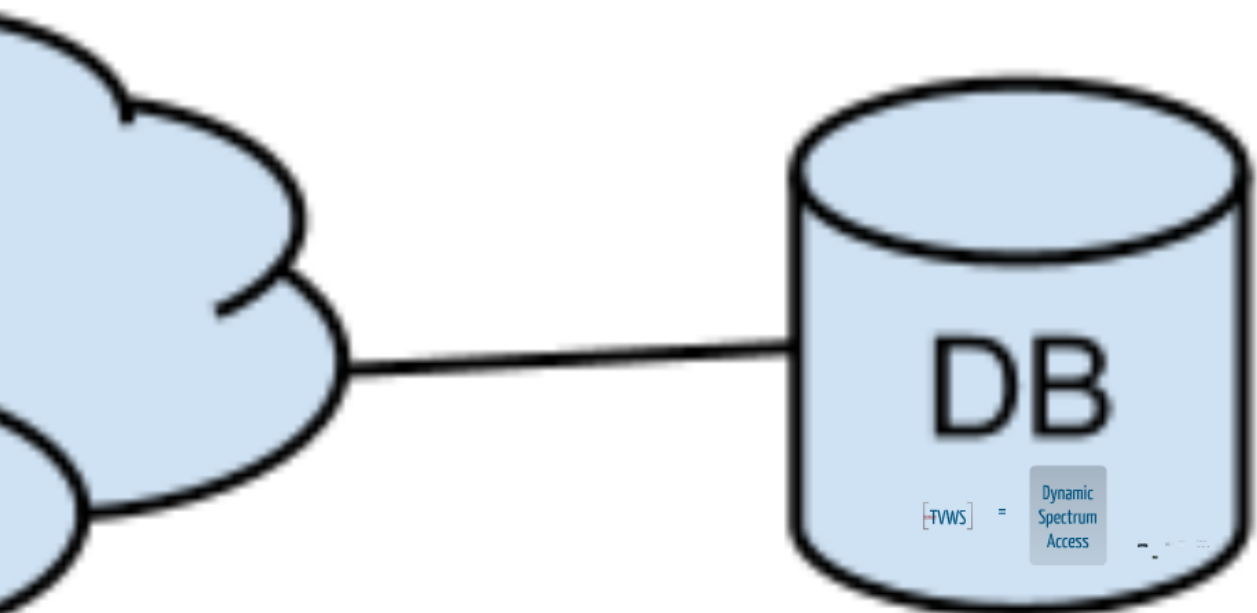
East distance

Distance reuse



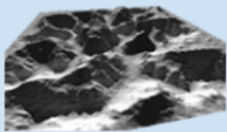
Guard bands



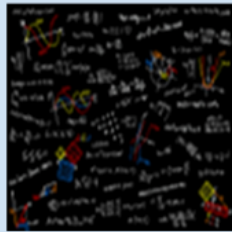


Spectrum
Database

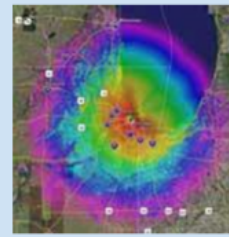
**Transmitter &
terrain data**



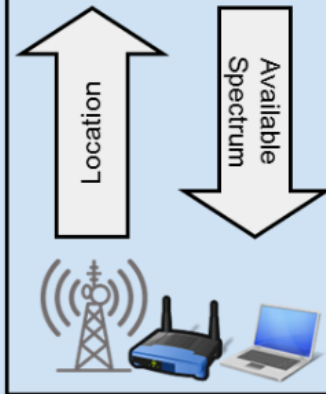
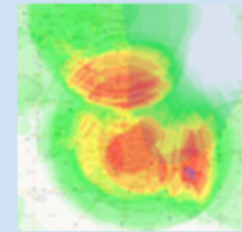
**Propagation
modeling**



**Calculate
spectrum**



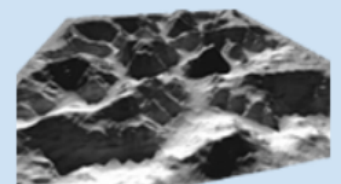
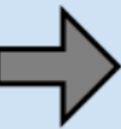
**Handle DB
queries**



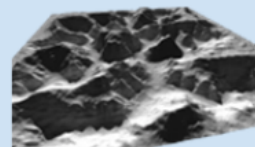
Transmitter & terrain data

A 3D-style icon of a spreadsheet document with a folded bottom-right corner.

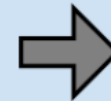
	A	B	C
1	~~~~~	~~~~~	~~~~~
2	~~~~~	~~~~~	~~~~~
3	~~~~~	~~~~~	~~~~~
4			
5			
6			



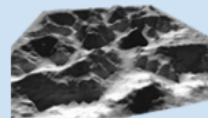
**Transmitter &
terrain data**



**Propagation
modeling**



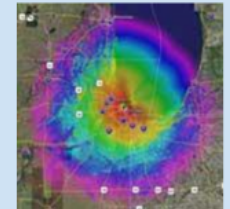
**Transmitter &
terrain data**



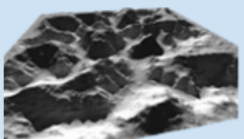
**Propagation
modeling**



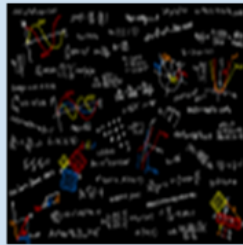
**Calculate
spectrum**



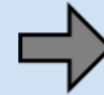
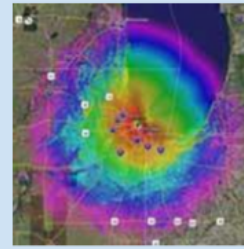
**Transmitter &
terrain data**



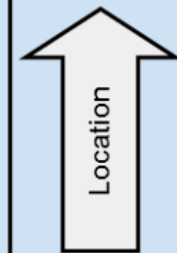
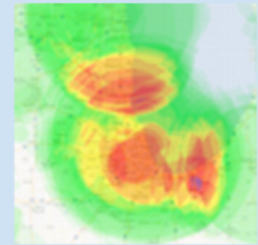
**Propagation
modeling**

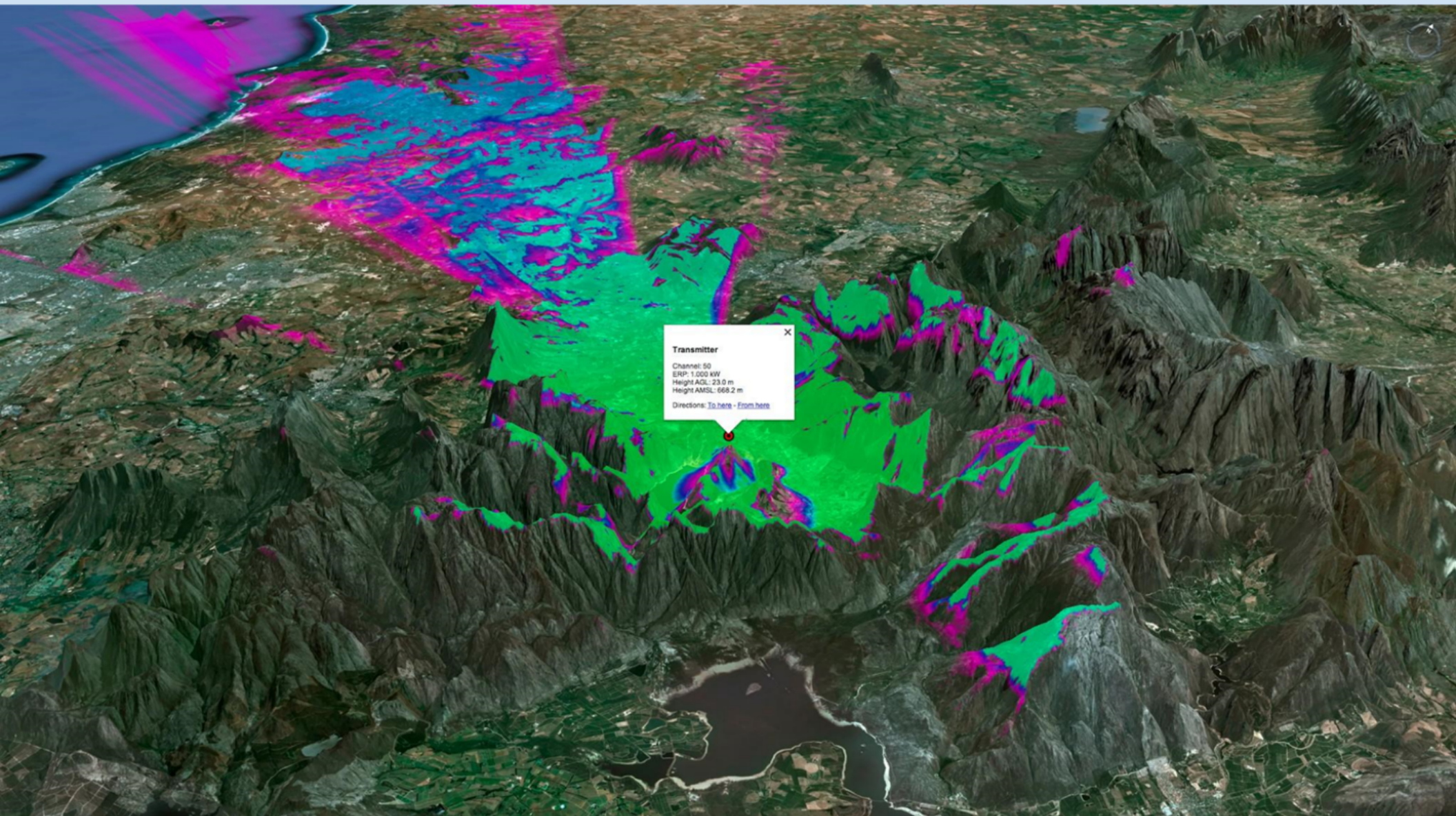


**Calculate
spectrum**



**Handle DB
queries**



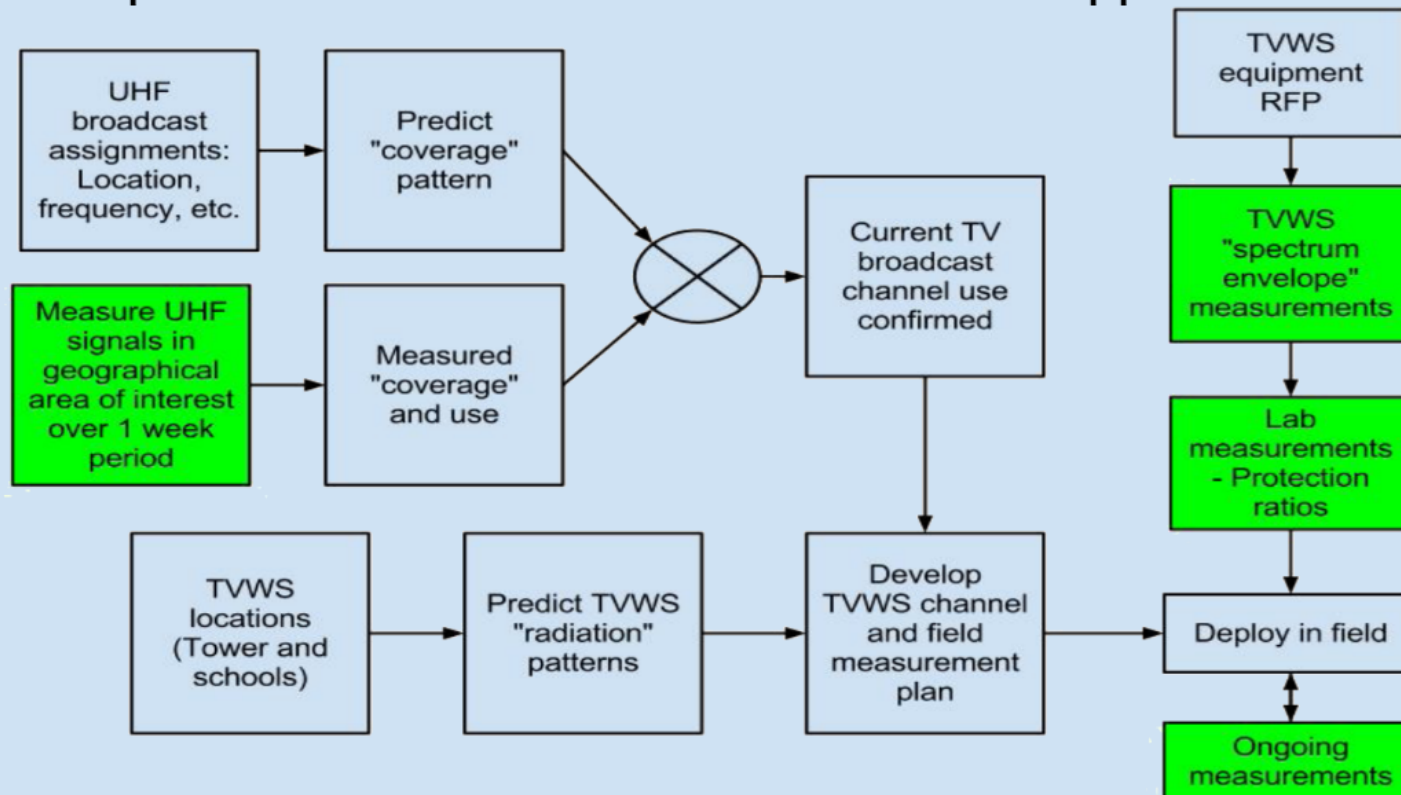


Transmitter

Channel: 50
ERP: 1,000 kW
Height AGL: 23.0 m
Height AMSL: 668.2 m

Directions: [To here](#) - [From here](#)

Spectrum Prediction and Measurement Approach

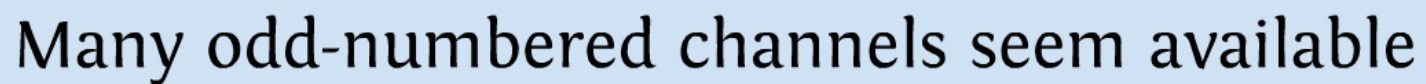




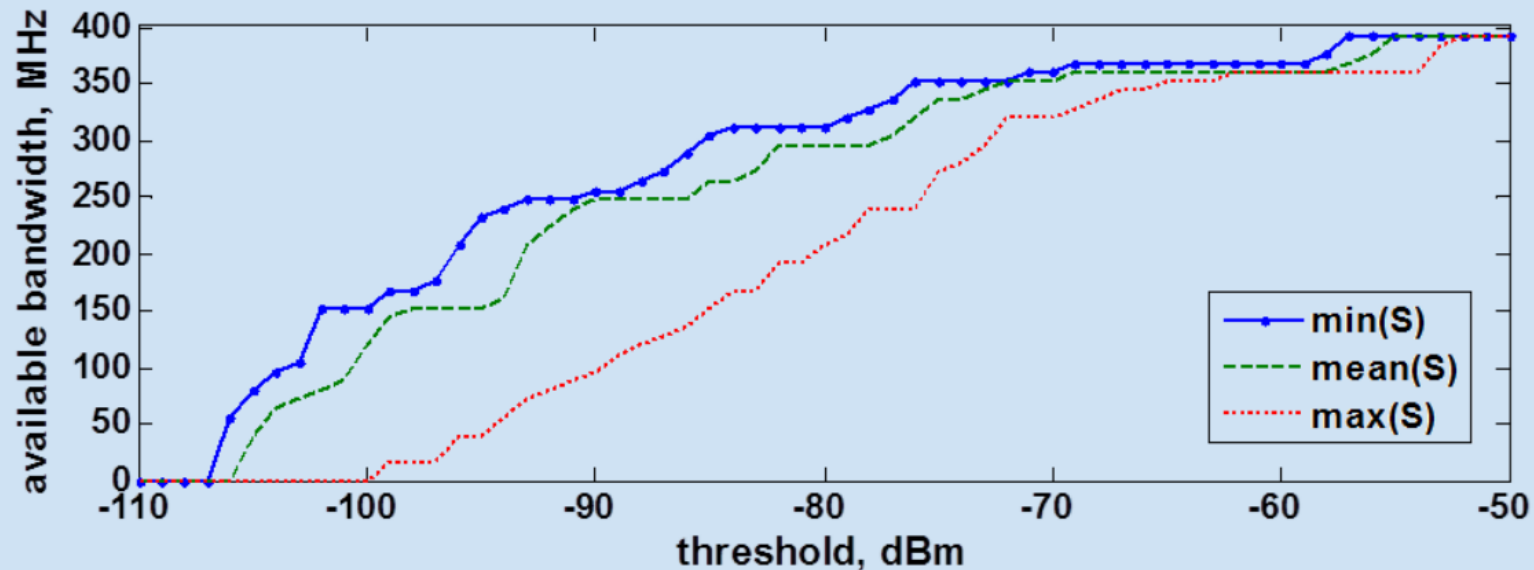




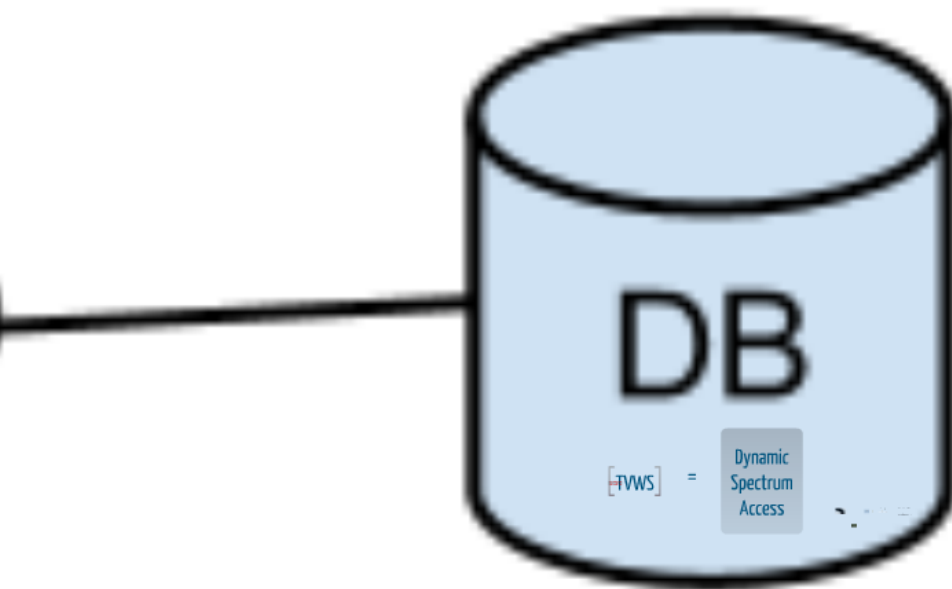




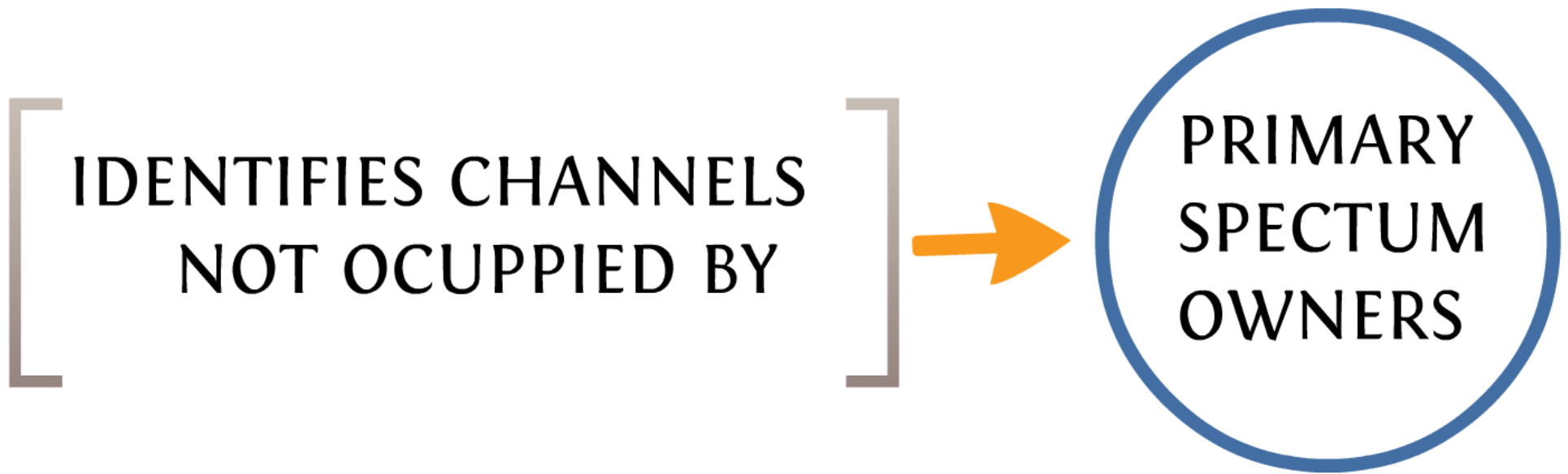
Is there white space in the area of the trial? YES



- Up to 200-300 MHz could be available for very low power devices
- Eight TV channels were found unused (locally; with high safety margin)
- Six channels selected as the most suitable, using several various criteria



Spectrum
Database

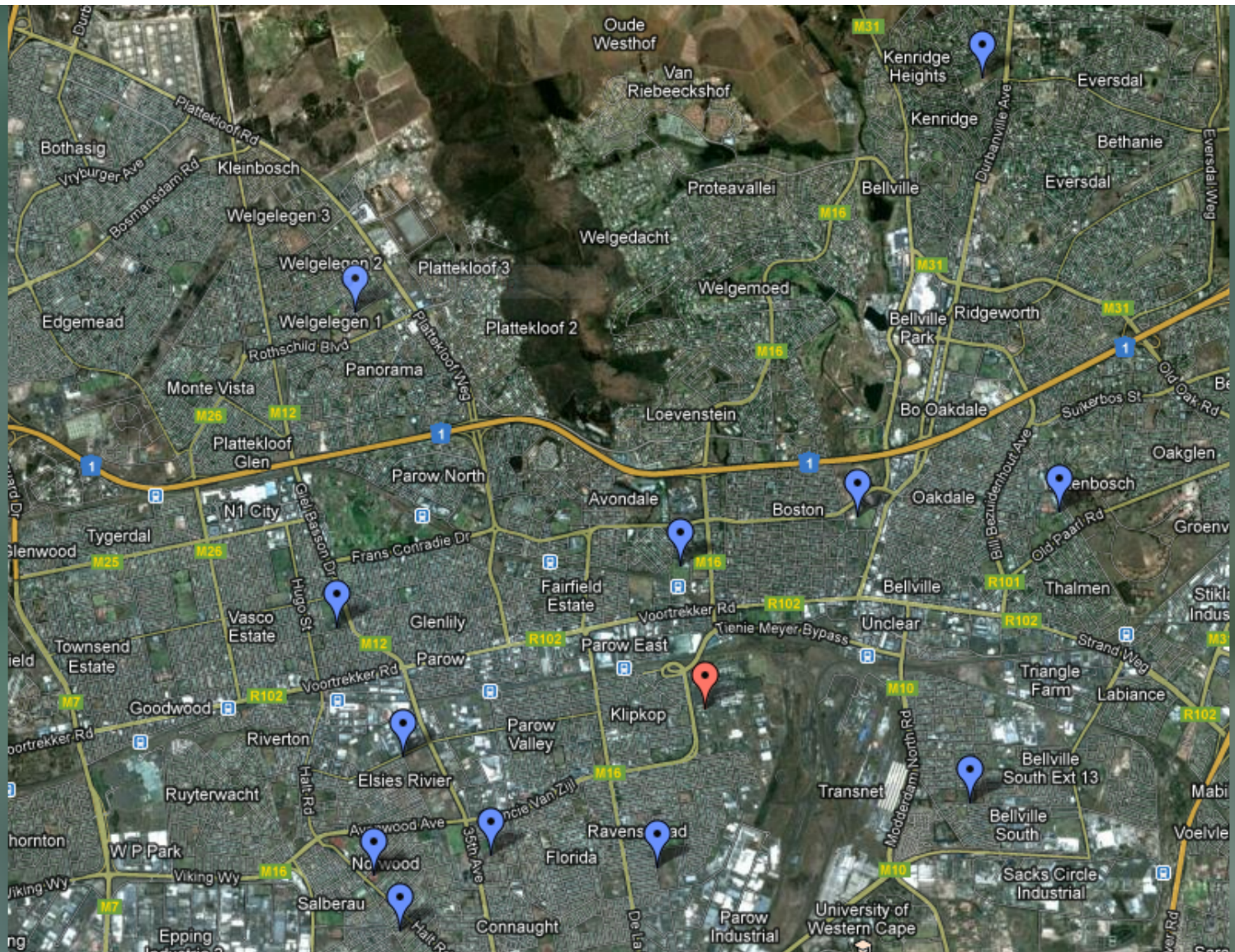


MANAGED CO-EXISTENCE WITH PRIMARY SPECTRUM OWNERS



Cape Town TV Transmitters





Faculty of Medicine and Health Sciences, Stellenbosch University, Tygerberg Campus

Access to Available Back Haul

Base Station
Tower

SANReN's
Bellville Grey
Ring



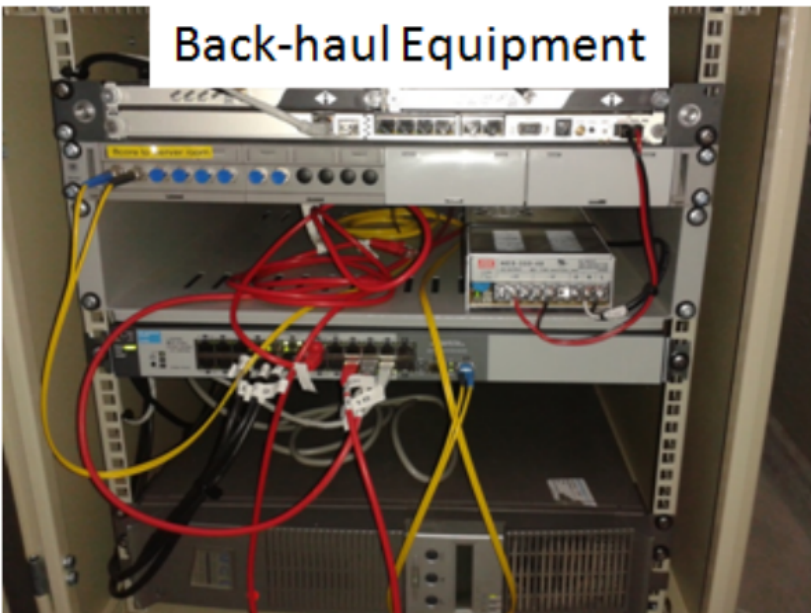
Base Station Equipment at the High Site

ENCLOSURE

3 Base Stations



Back-haul Equipment



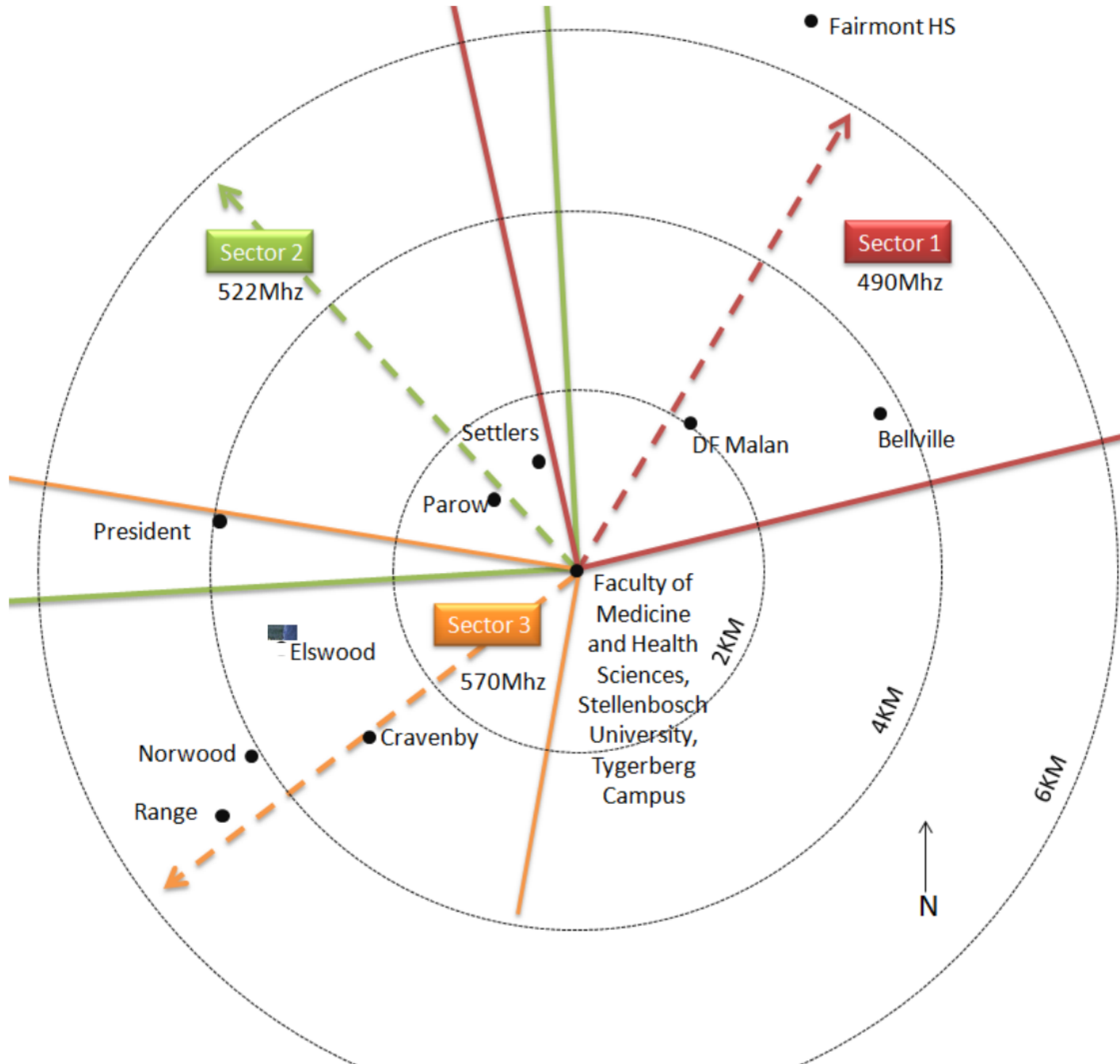
ANTENNA 1 & 3



ANTENNA 2



10 Schools >> 9,000 students





School LAN Equipment



School LAN Equipment

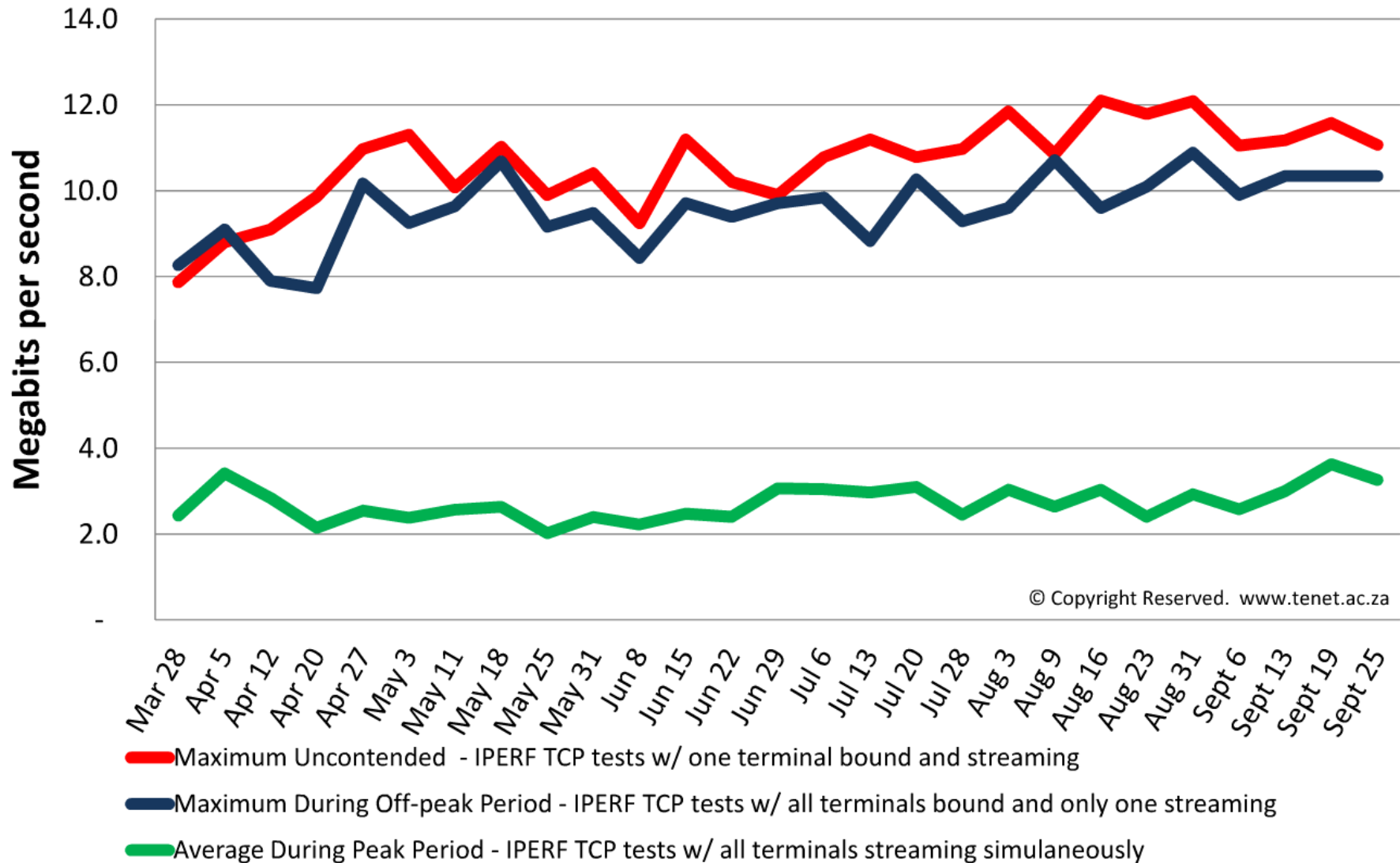


TVWS Radio
& Antenna

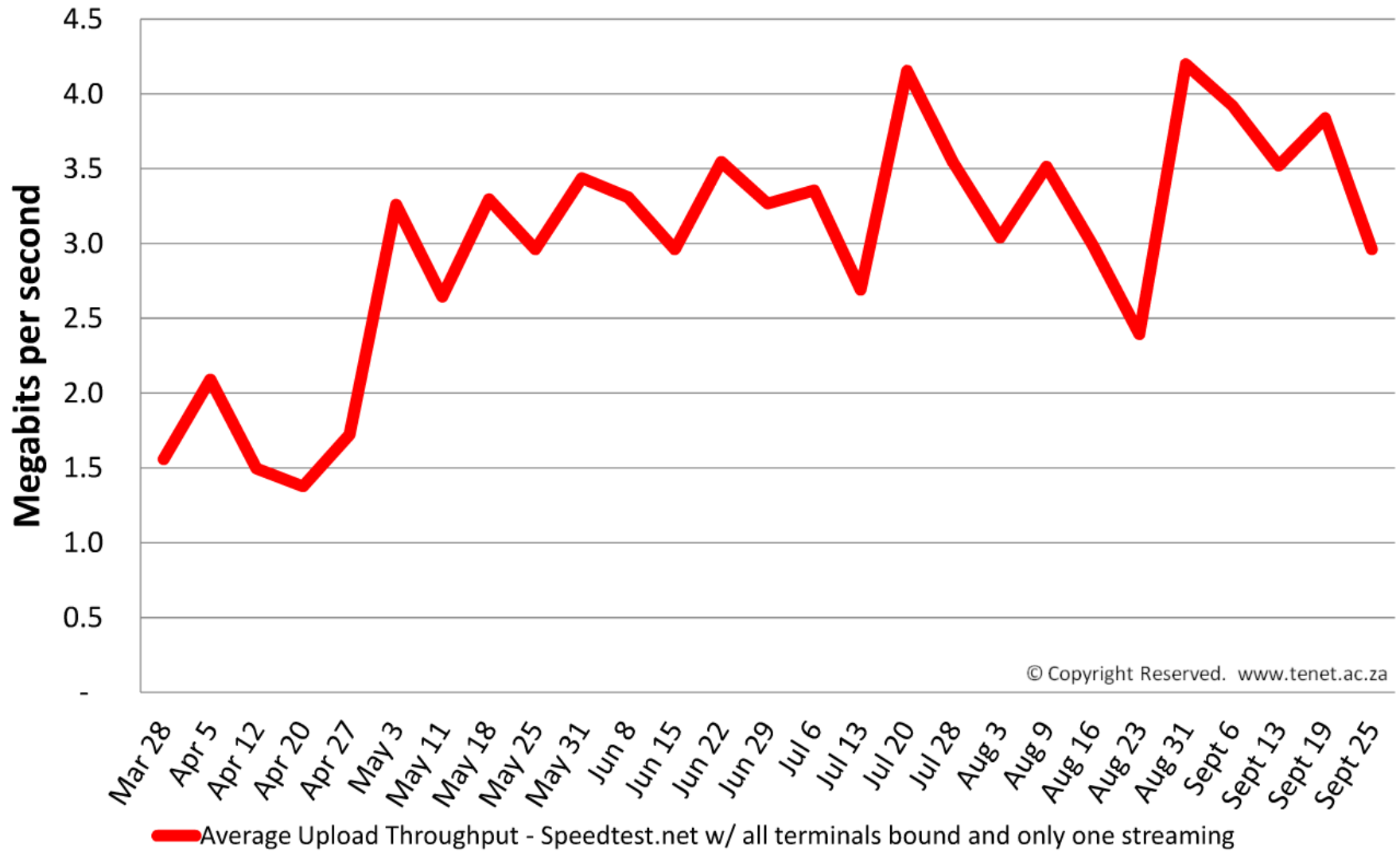


TVWS LAN
Equipment:
PEO Injector,
Router and
Server

CT TVWS Trial Download Throughput Tests - 2013



CT TVWS Trial Upload Throughput Tests - 2013



Cape Town



Arno Hart, TENET TVWS Trial Manager



LAST

IEEE 802.22

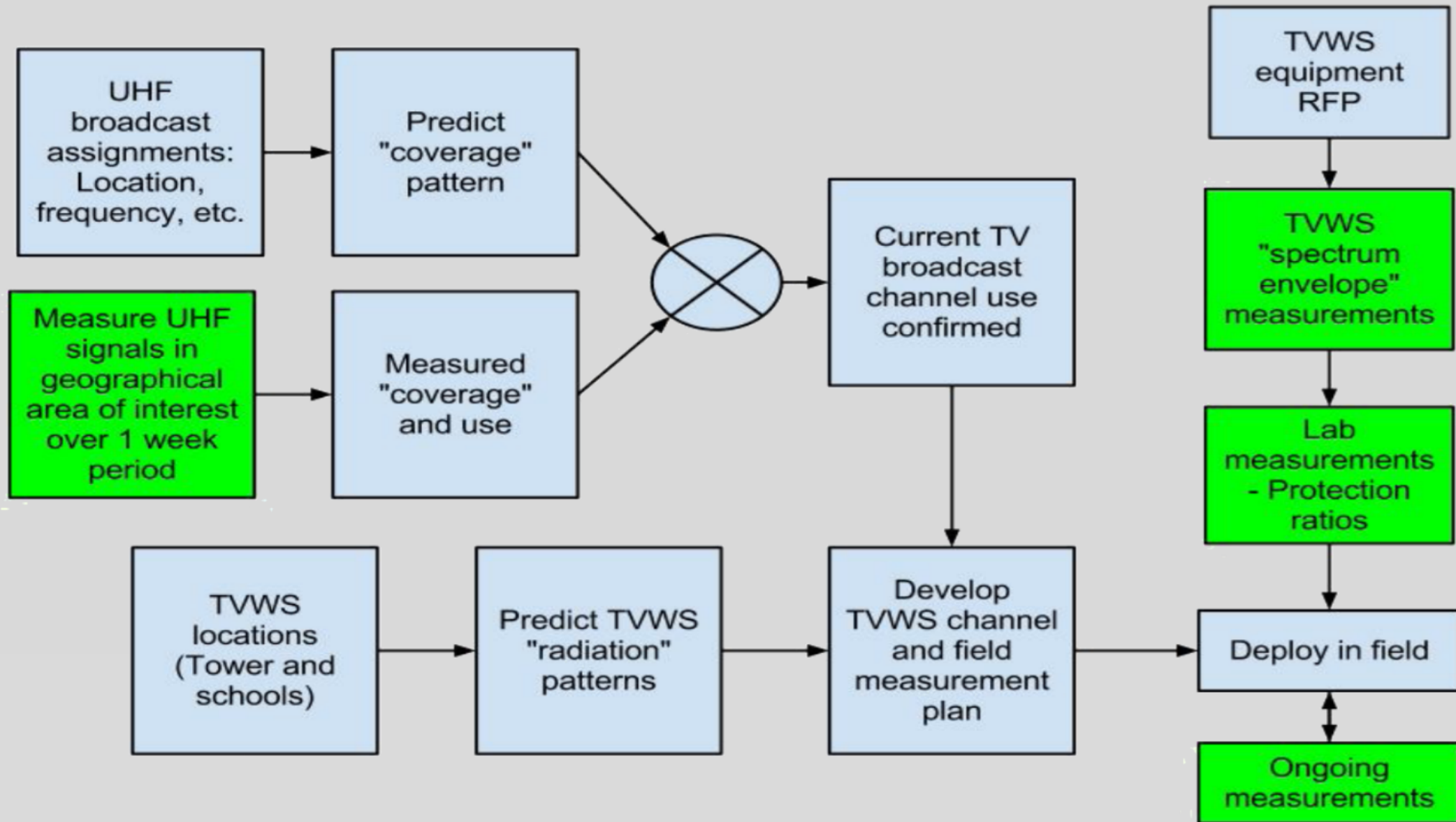
MILE

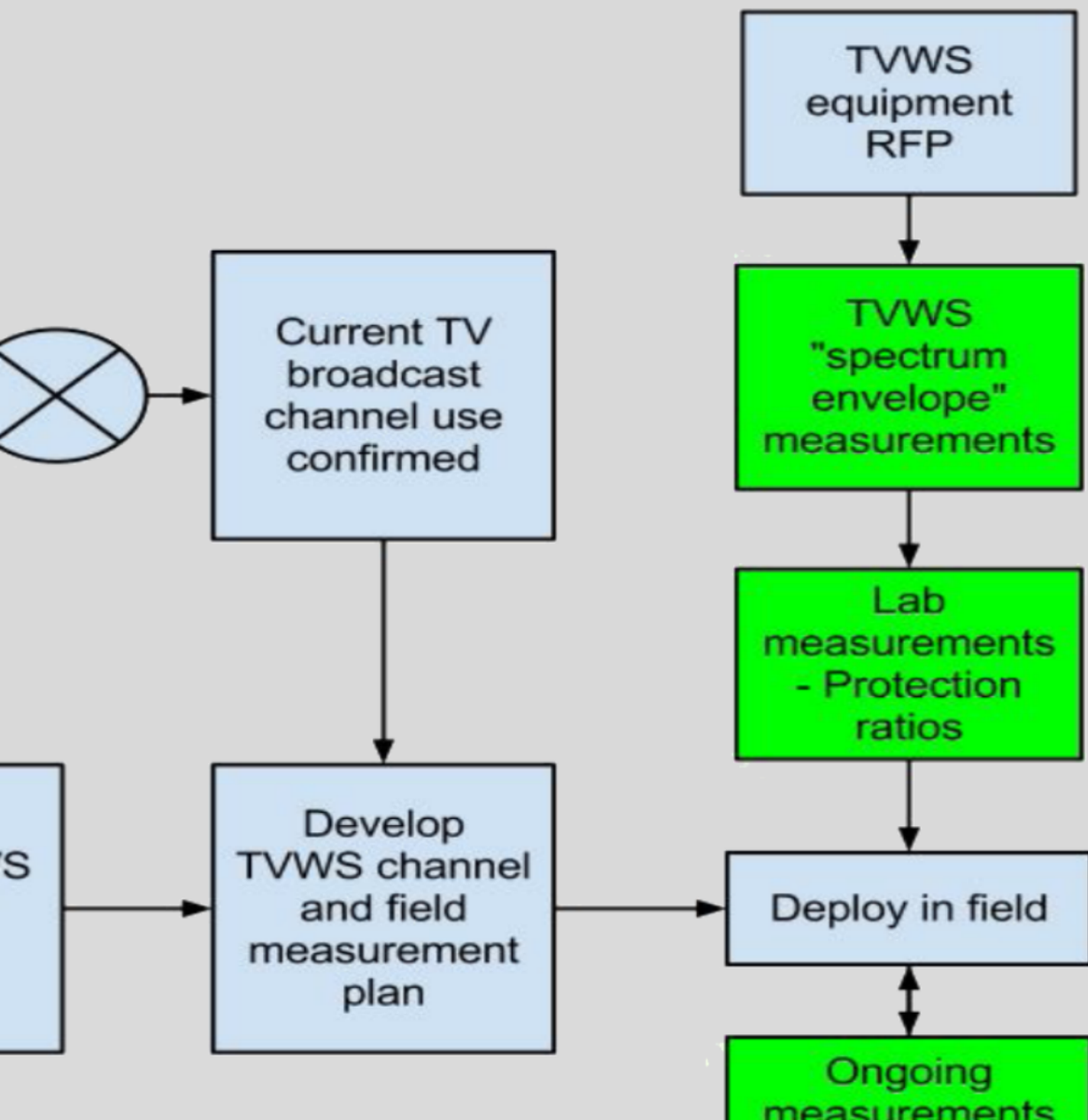


[2W output
(4W EIRP)]

2W output
(Total Potential Transmit Power)

(4W EIRP)
(27dBm Transmit -1dBm loss + 10dBi antenna)







Ref: -3.9 dBm

Att: 40 dB

RBW: 3 kHz

VBW: 30 kHz

SWT: 1.79 s

Trig: Free Run

Trace: Average

Detect: RMS

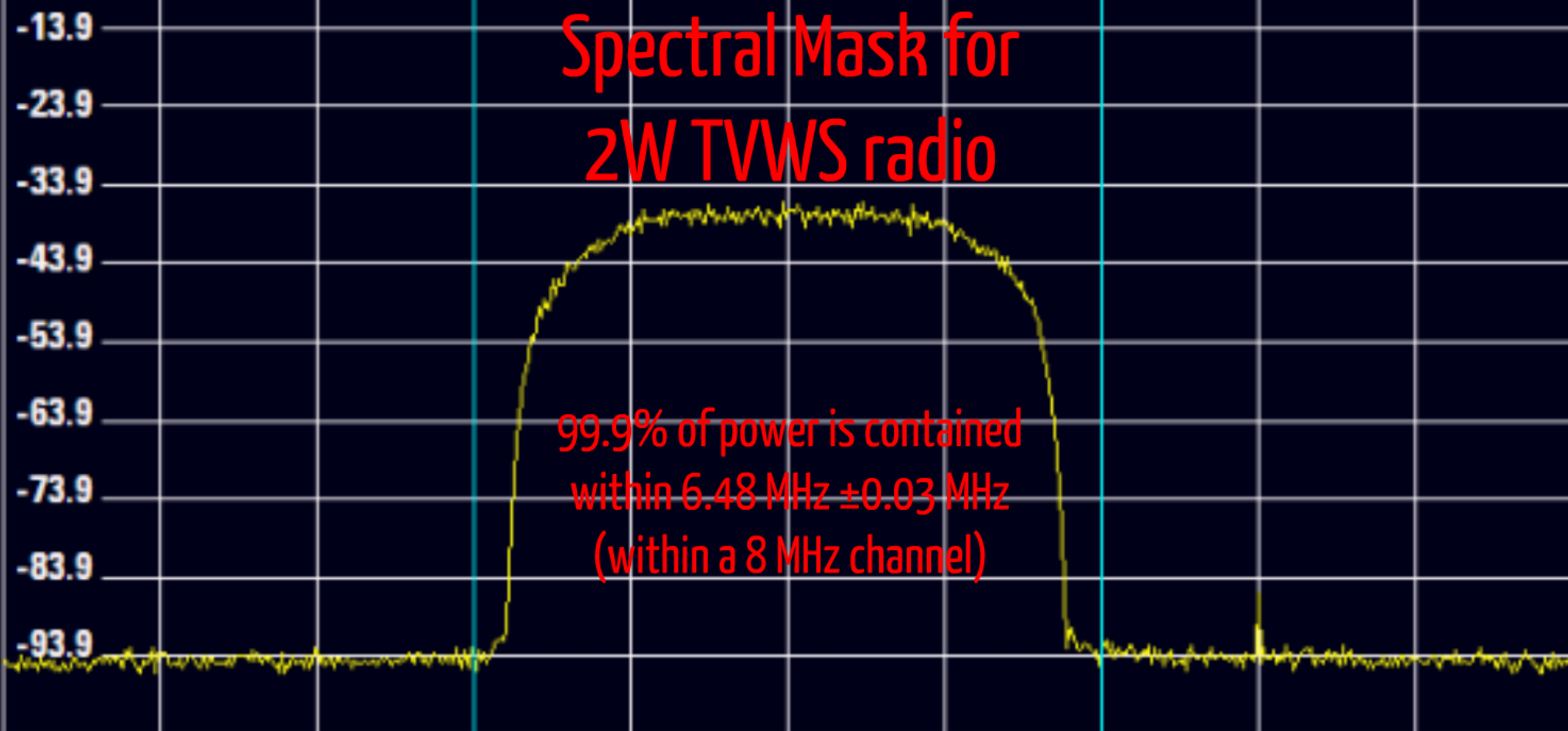
Power:

-6.0 dBm

Channel BW:

8.00 MHz

Sweep 10 of 10



Center:474 MHz

Span:20 MHz

Meas
Mode

Standard

Level
Adjust

Channel
BW

Power
Unit

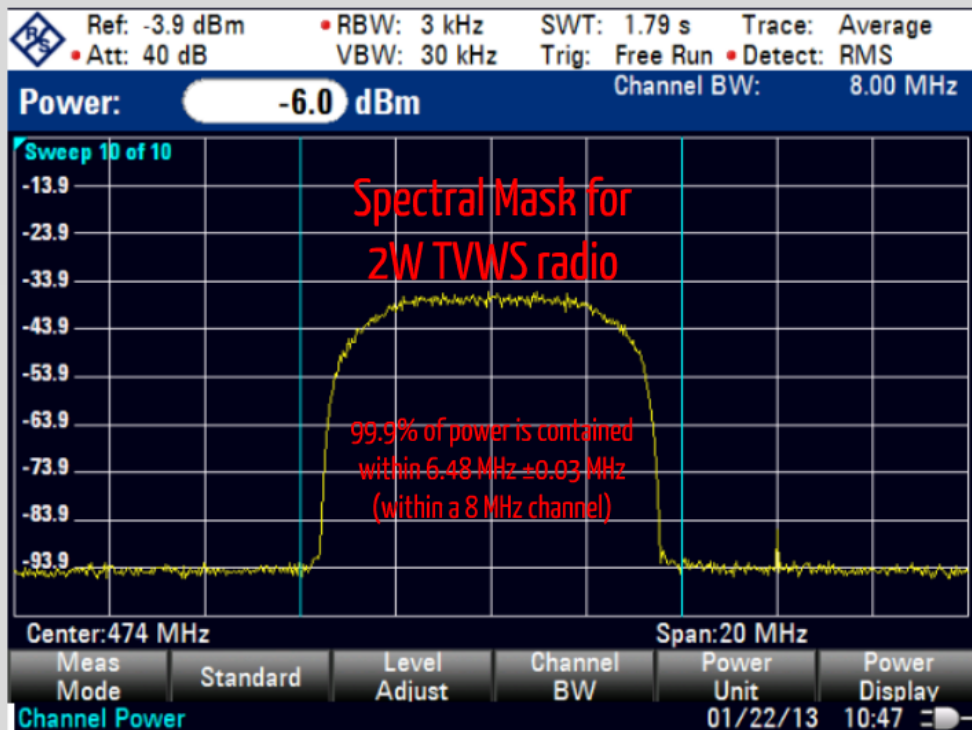
Power
Display

Channel Power

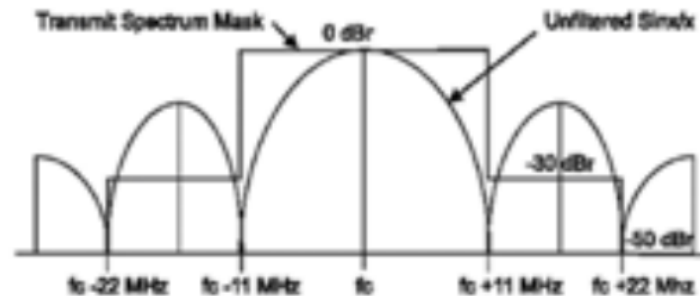
01/22/13

10:47

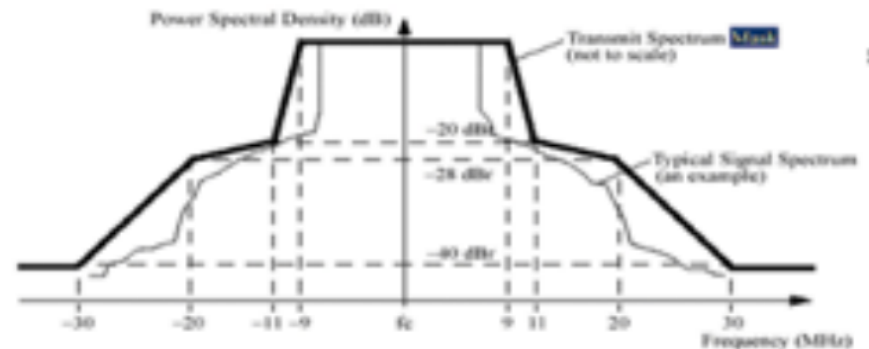




WiFi Spectral Mask (802.11)

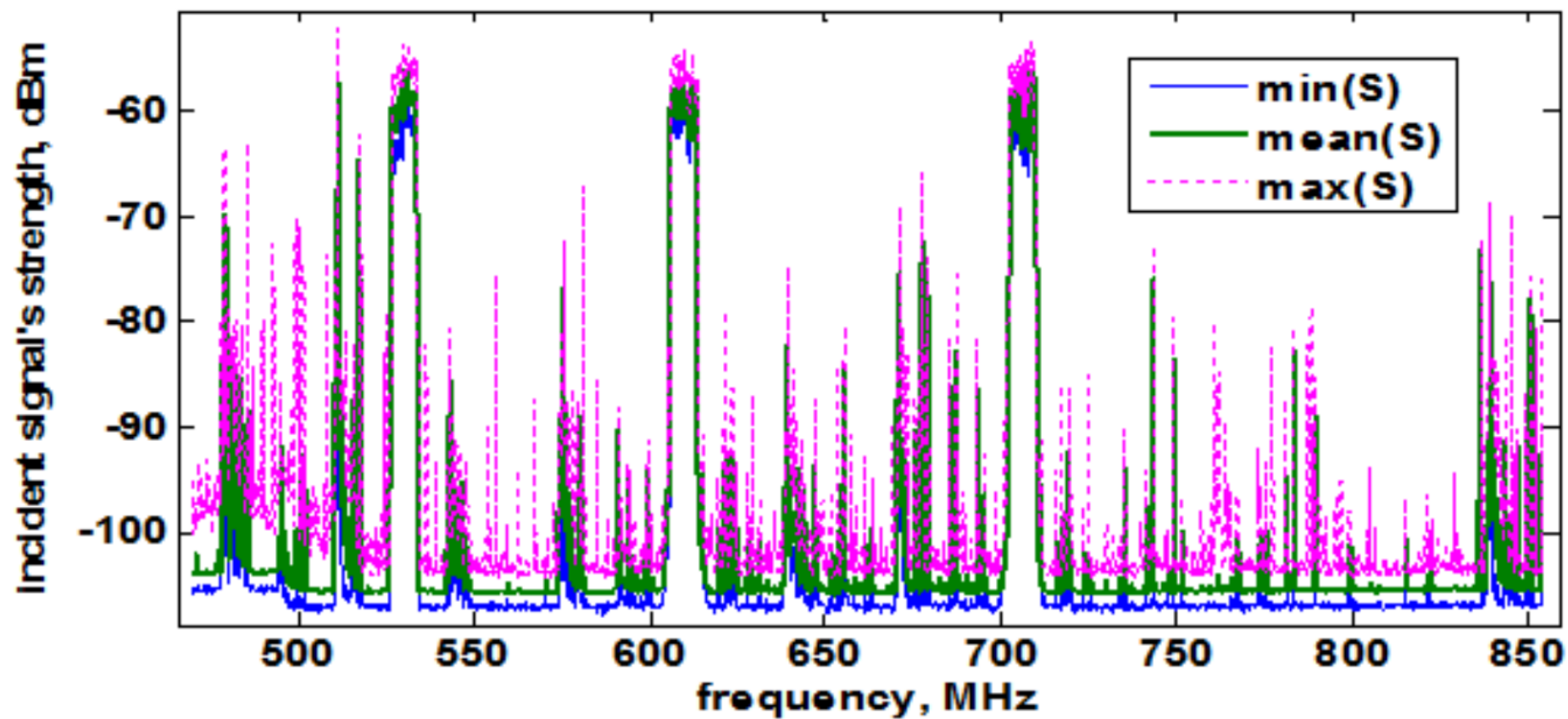


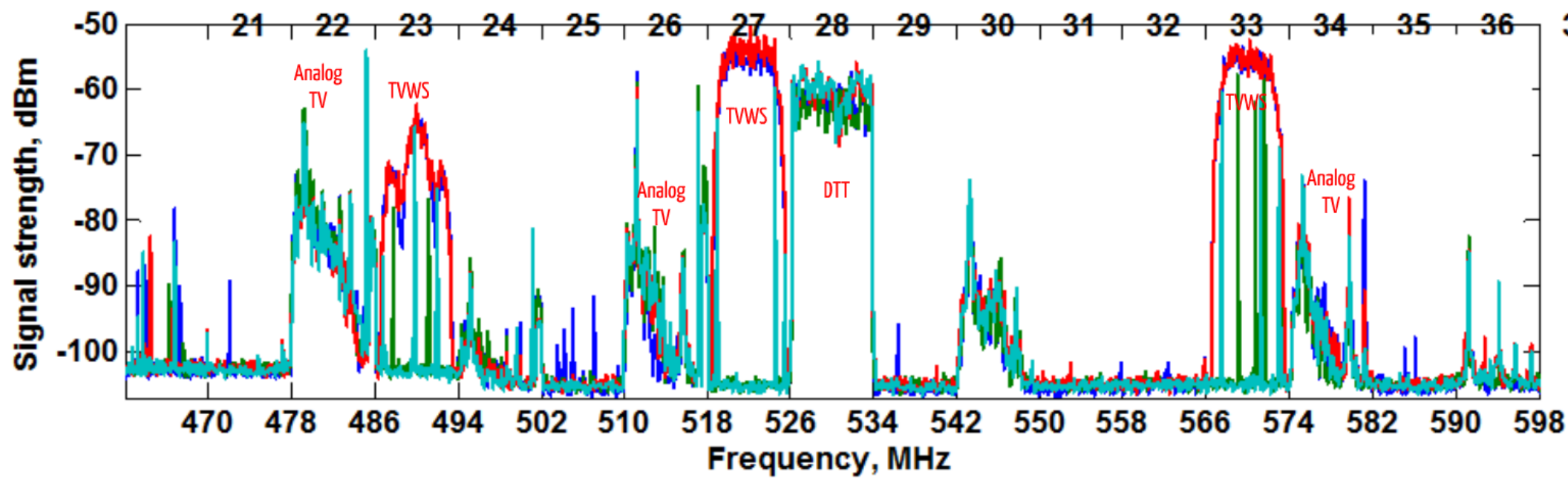
802.11b



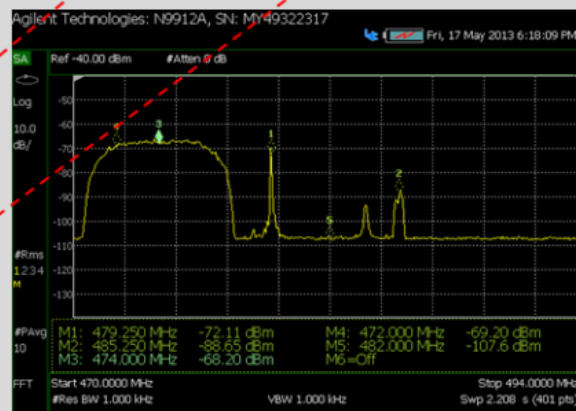
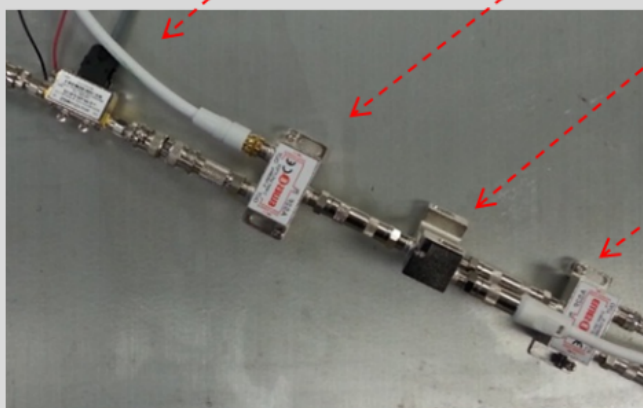
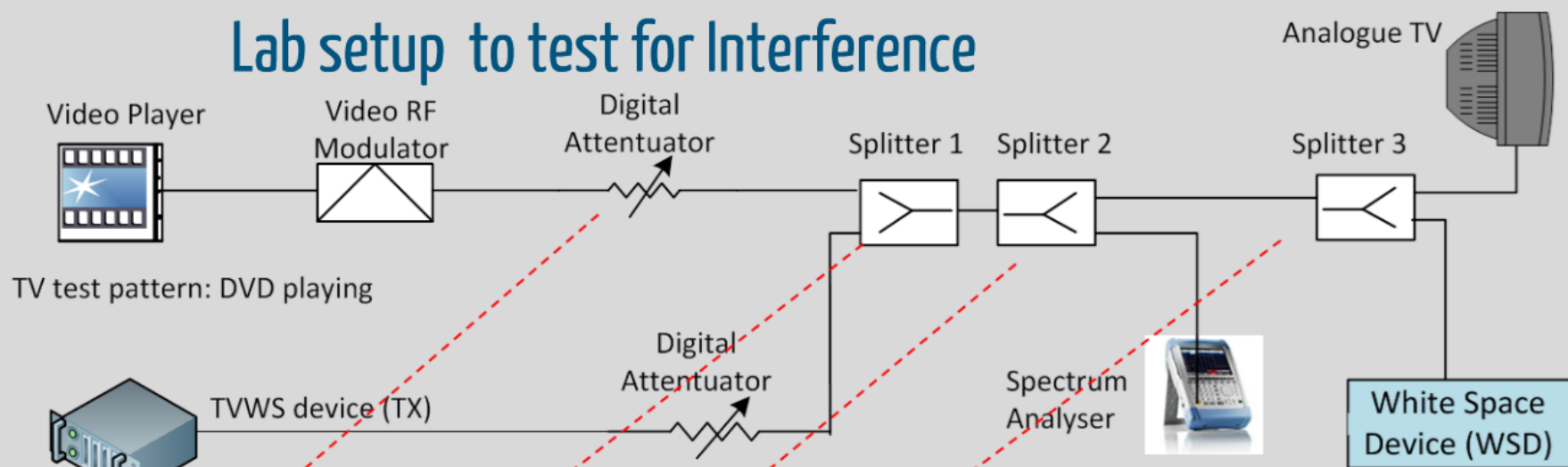
802.11a

measurements on the roof of the Tygerberg hospital

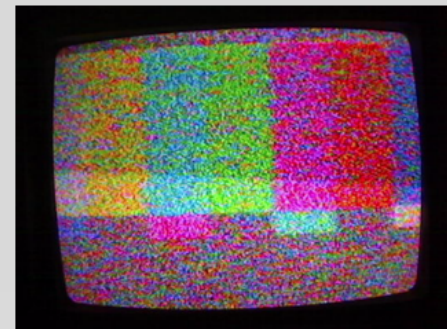
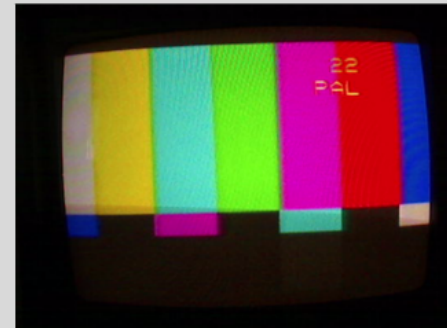
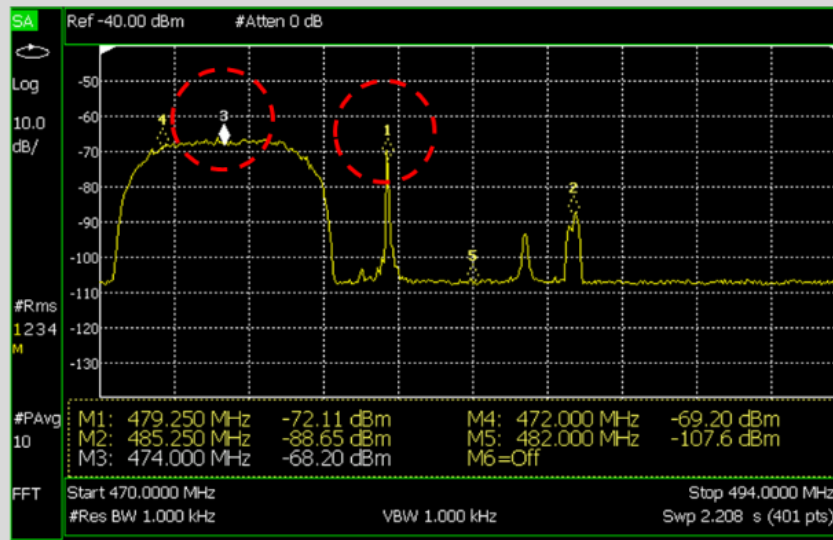




Lab setup to test for Interference



Perceptible levels of Interference



From a lower (N-1) channel interference from BS to TV

Imperceptible impairment (level 5)

Very annoying impairment (level 1)



Given these levels of perceived quality impairment

5 Imperceptible

4 Perceptible but not annoying

3 Slightly annoying

2 Annoying

1 Very annoying

and using this test Case:
Adjacent channel interference
by WSD to TV signal

The TV signal level was kept at around -51.3 dBm and WSD signal strength was varied using the digital attenuator 2, repeated several times.

we can conclude that maximum amplitude of the video carrier of the TV signal should exceed the max amplitude of WSD with digital modulation by at least

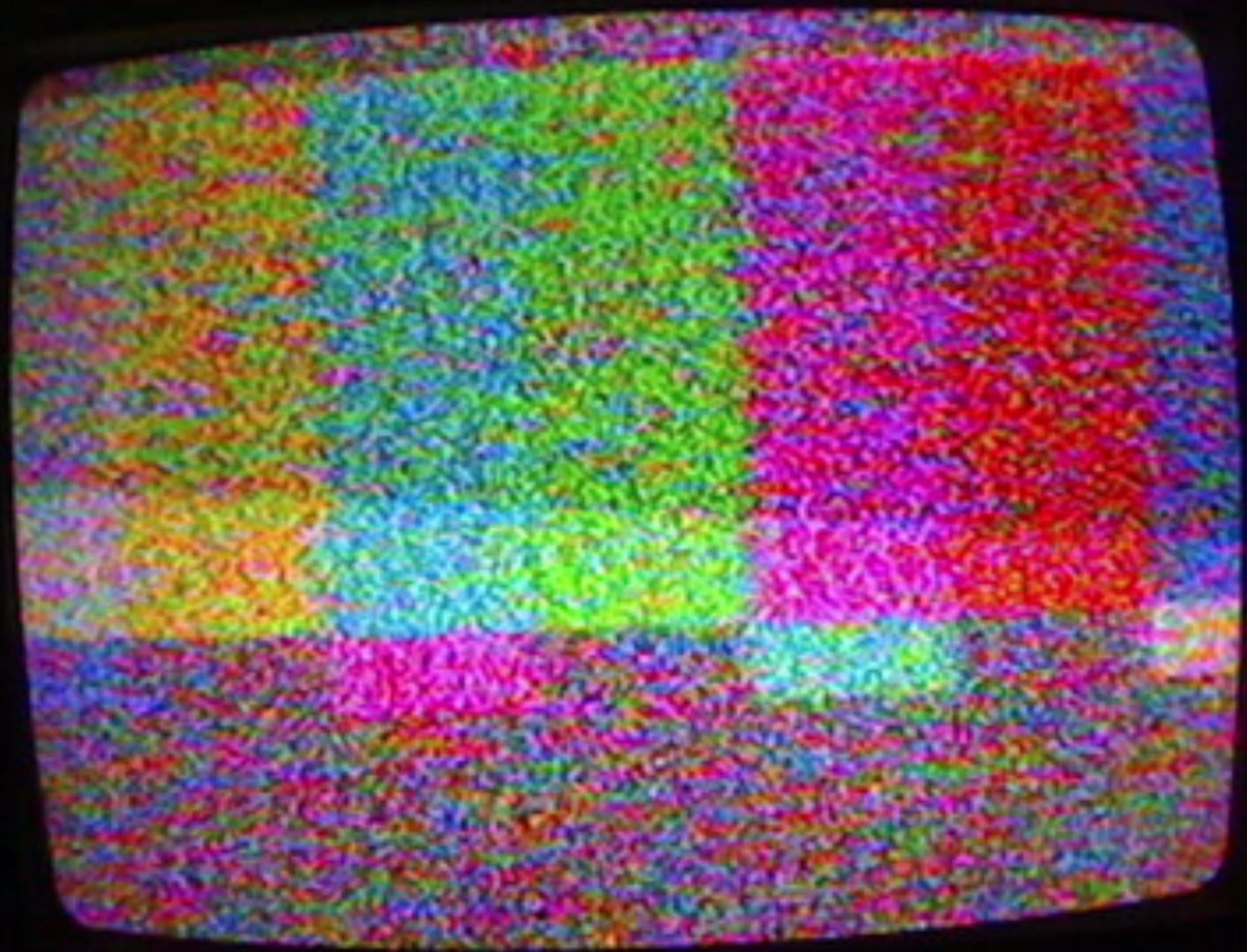
1 dB for level 4 quality
at N-1

-4.5 dB for level 4
quality at N+1

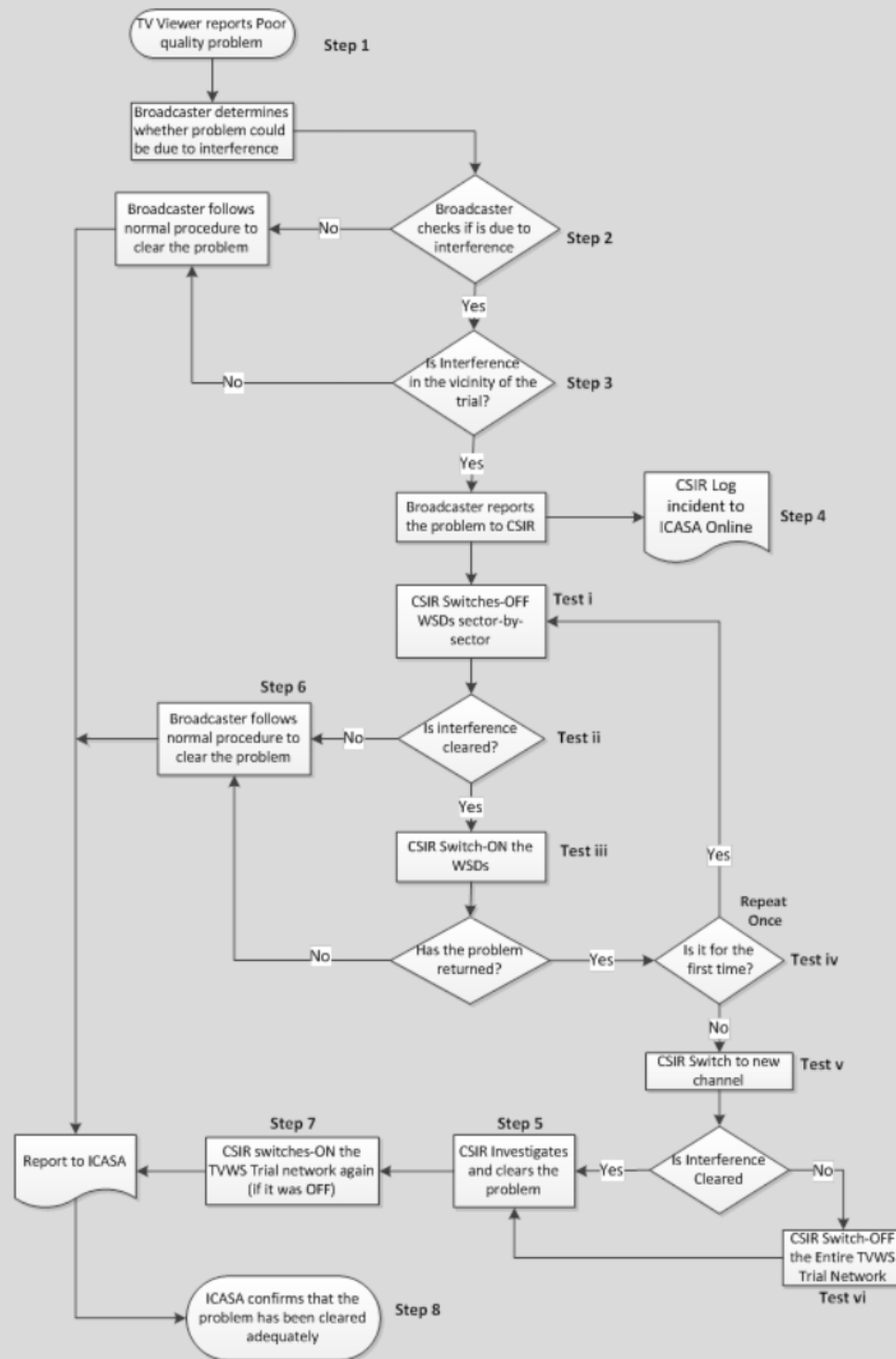
6 dB for level 5 quality
at N-1

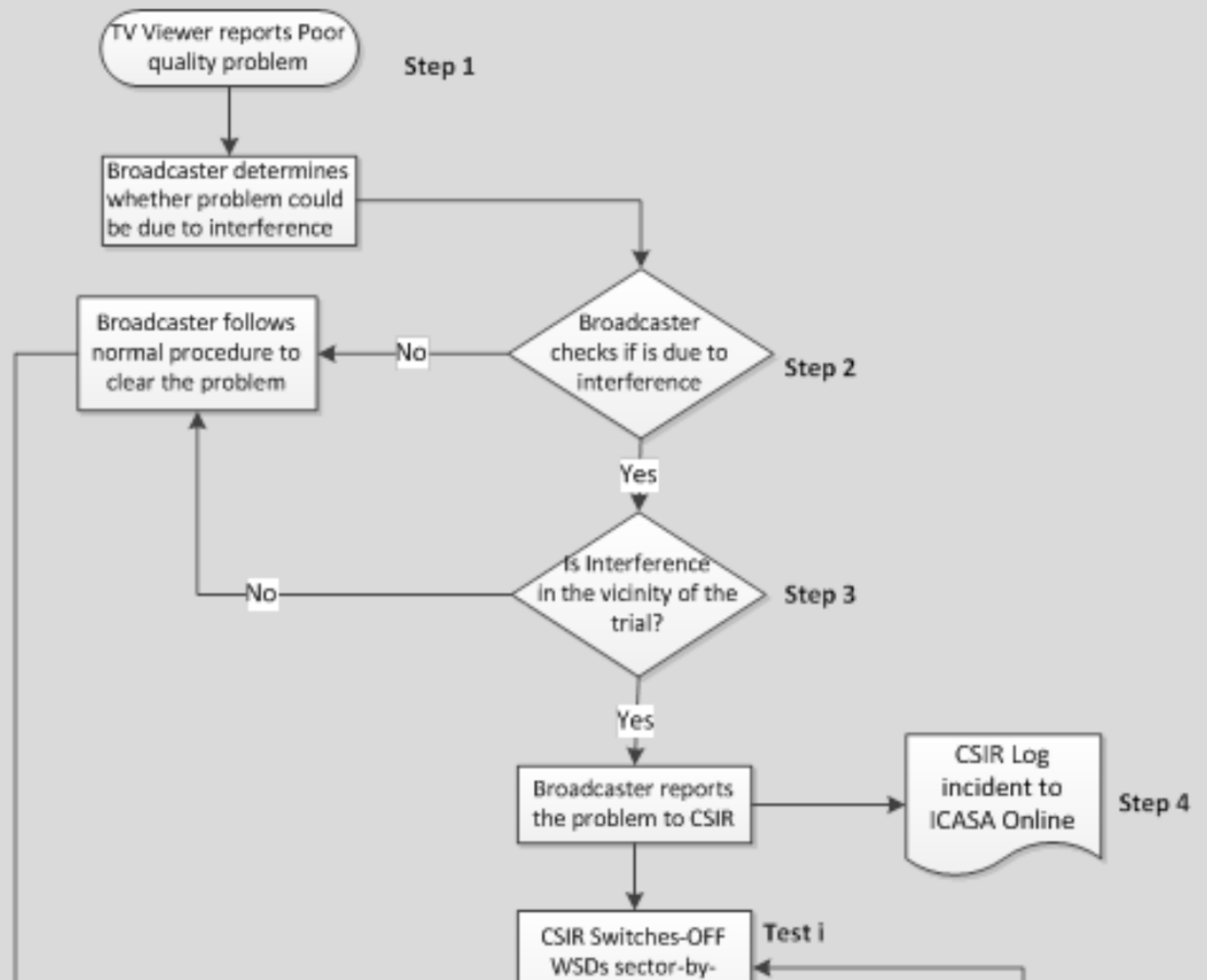
0 dB for level 5 quality
at N+1

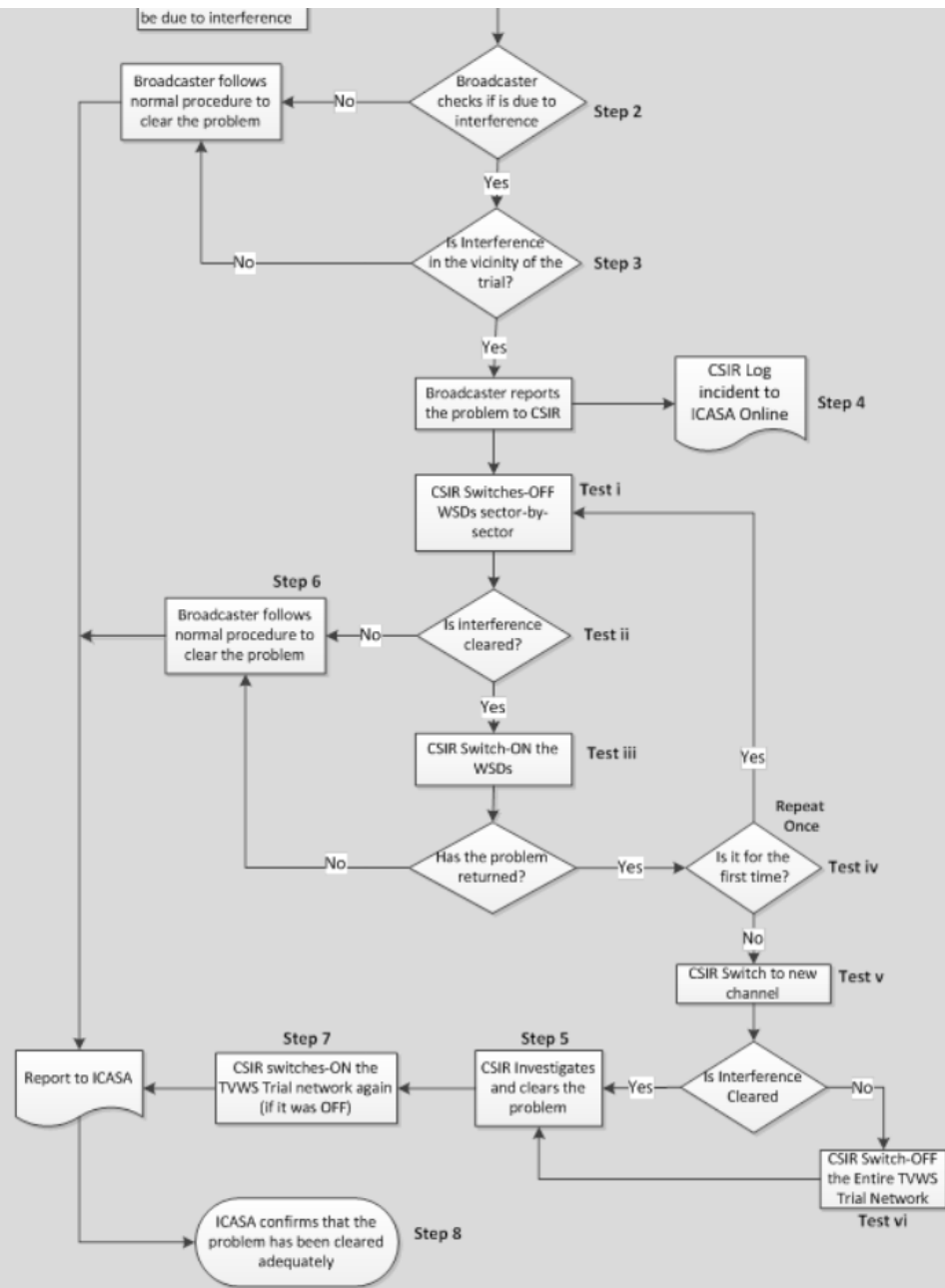
22
PAL



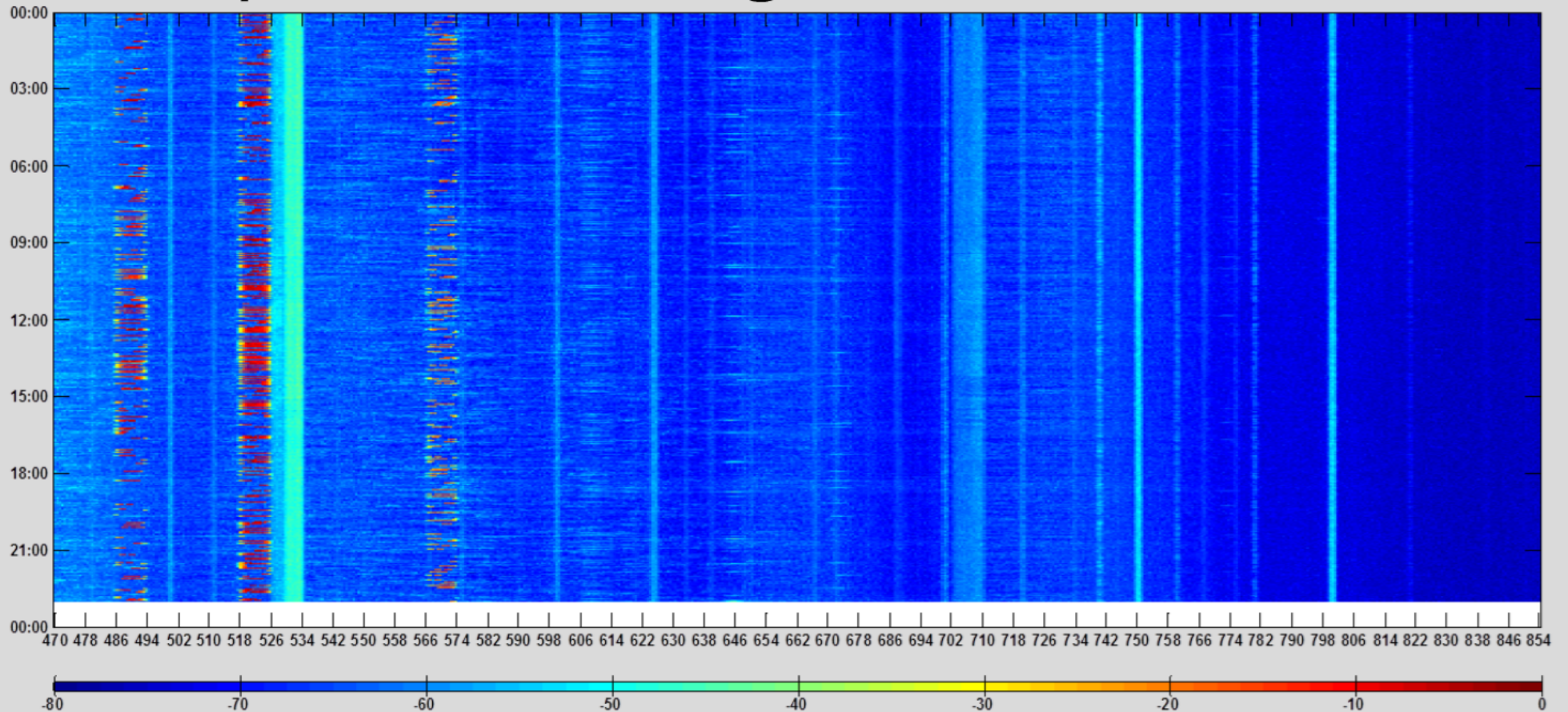
Interference Protocol







24/7 Monitoring at Base Station



Cape Town



Arno Hart, TENET TVWS Trial Manager









The Trial is over.
What's the
NEXT STEP?

Four Best Practices for Operating a Zero-^{harmful}Interference TVWS Network

- 1 Spectrum Database
- 2 Network Design
- 3 TVWS Radio Design
- 4 Protocol/Rules

4

Protocol/Rules

The logo for ICASA (Independent Communications Authority of South Africa) features the acronym 'ICASA' in a bold, black, serif font. It is centered within a blue circle. The background of the slide is white, with two large, red, curved shapes on the left and right sides, resembling stylized wings or abstract letterforms.

ICASA

The text 'Rule making process' is written in a black, serif font, centered within a large, light gray square bracket. The background of the slide is white, with two large, red, curved shapes on the left and right sides, resembling stylized wings or abstract letterforms.

Rule
making
process

#TVWS

Technical studies confirmed that the technology works

Study	Methodology	Observation
<i>Determine white space availability</i>	Predicted white space availability using Google's database and confirmed with spectral scans	8 available channels were selected for the trial
<i>Validate equipment for operation</i>	Measured out-of-band emissions in lab	Equipment operated as expected and has an appropriate spectrum mask (99.9% of power is contained within 6.48 MHz +/- 0.03 MHz)
<i>Estimate TV protection ratios</i>	Measured perceived interference on analogue TVs in lab	Protection ratios devised for for N+1 and N-1 channels
<i>Confirm that TV protection is consistent with the database</i>	Set up 24 hour monitoring spectrum analyzer at base station looking for changes in spectral emissions	Base station operation consistent with database
<i>Demonstrate non-interference to TV receivers</i>	<ul style="list-style-type: none">• Measured out-of-band emissions around schools and base station• Crowd-sourced interference reporting from radio groups and TV viewers	<ul style="list-style-type: none">• No interference measured/detected• Developed parameters for adjacent channel operation• No interference reported

Technical recommendations and propagation modeling

We have observed that for any analogue with sufficiently strong signal:

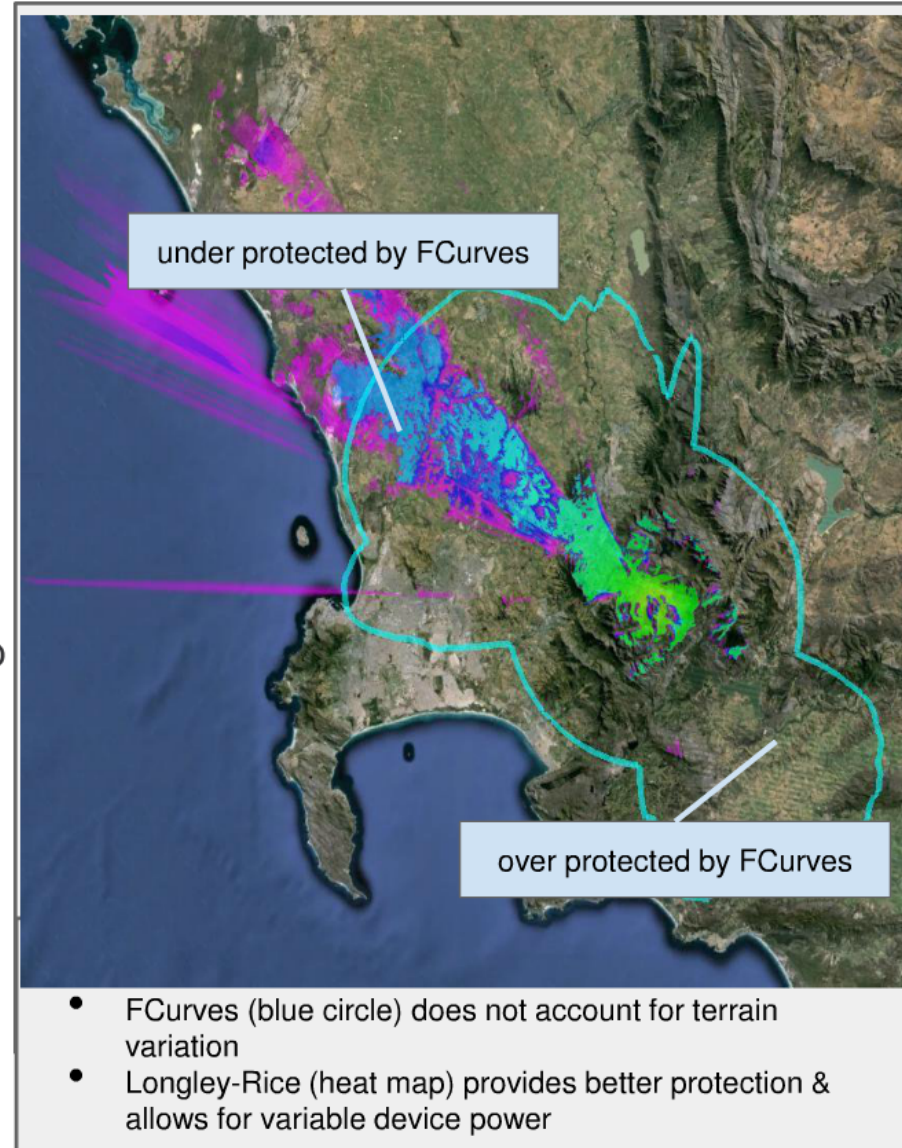
- WSD can be operated on the adjacent channel on its right-hand side without causing interference
- WSD may be operated on the adjacent channel on its left-hand side without causing interference, subject to the transmission power of the WSD being reduced

On the basis of the above observations, we recommend that a geo-location database be used for TVWS networks:

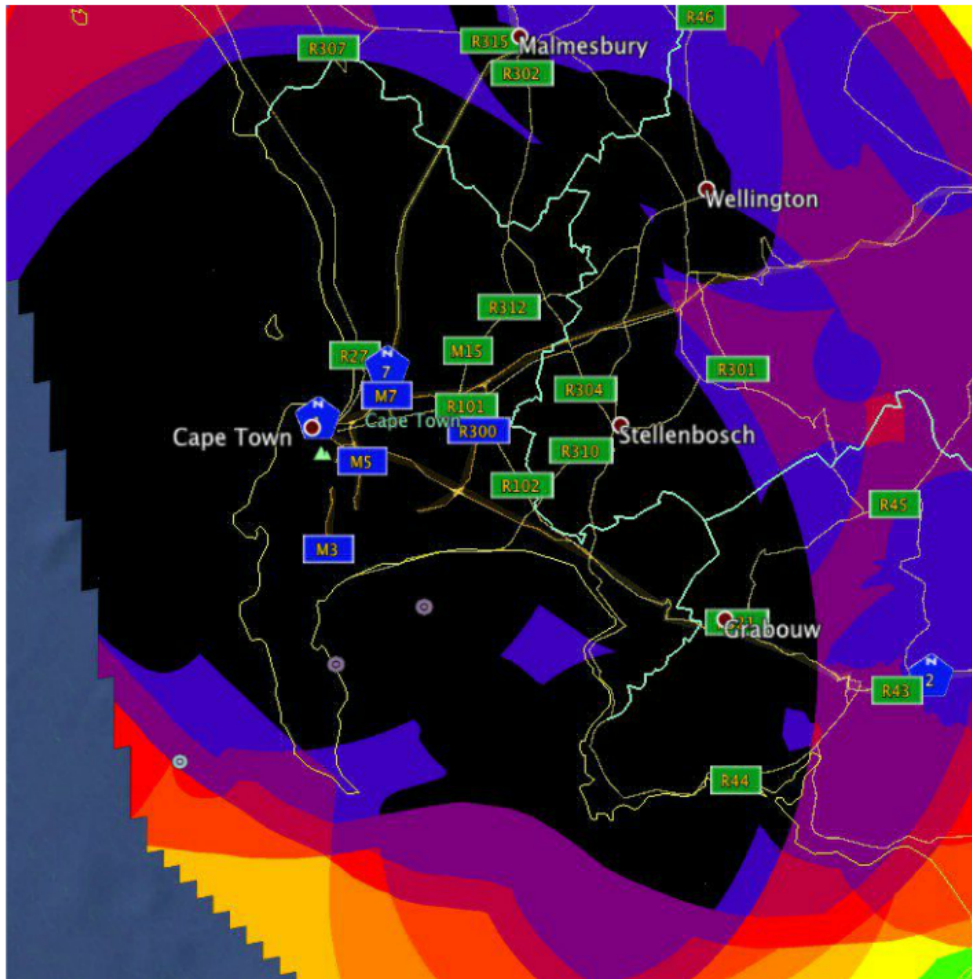
- Propagation modeled using Longley-Rice to protect TV transmitters
- The database must be able to estimate protection ratios for each of the adjacent channels
- Provide transmission power levels to the WSDs for each of the available channels

We further recommend that a study to determine protection ratios for digital TV channels be undertaken before the digital analogue dual illumination commences.

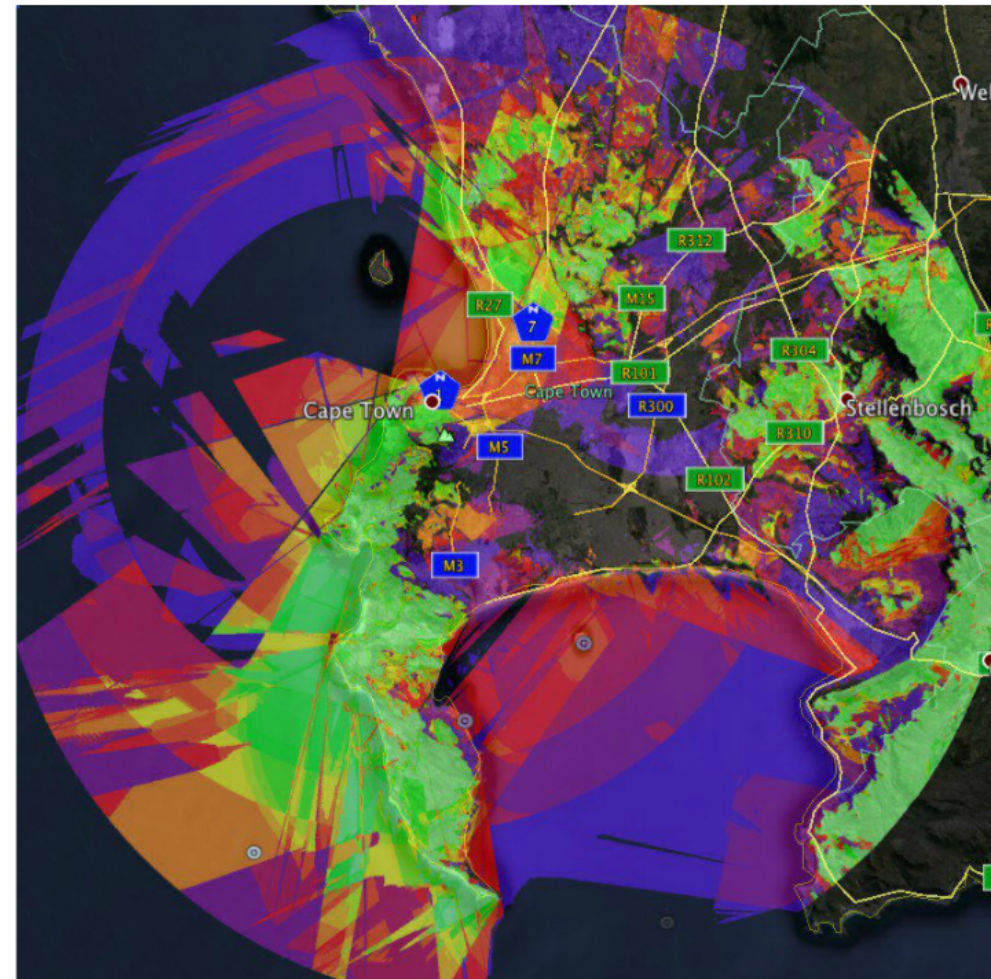
Conducting
further
studies



Impact of propagation models on channel availability



FCurves



Longley-Rice

Policy Recommendations

Policy Goal	Recommendations
<i>Improve Internet access</i>	<ul style="list-style-type: none">• Recognize that TVWS technology & database-enabled spectrum access can deliver wireless broadband to end users, especially in hard-to-serve areas, and address increasing demands on spectrum use
<i>Promote efficient use of spectrum</i>	<ul style="list-style-type: none">• Recognize that TVWS devices can co-exist with established services• Recognize the value of spectrum sharing and promote its use as part of a progressive approach to managing spectrum more efficiently• Determine protection requirements that are sufficient to avoid harmful interference while allowing maximum usage
<i>Support a competitive ecosystem to spur innovation</i>	<ul style="list-style-type: none">• Consider multiple TVWS device profiles for fixed and mobile devices for indoor and outdoor use• Recognize that TVWS spectrum access through a database can evolve to accommodate changes in technology, market requirements or regulatory mandates.• Encourage the development of multiple databases and promote competition to drive down costs and spur innovation
<i>Scale technology globally</i>	<ul style="list-style-type: none">• Promote an internationally harmonized approach to TVWS device characteristics and certification to take advantage of economies of scale• Consider a regional approach to license-exempt managed access spectrum & conformance regimes for the equipment• Promote the development of TVWS equipment standards

Outline for model rules documentation:

- Permissible Frequencies of Operation
- Protection of Licensed Incumbent Services
- Geolocation and Database Access
- Database Algorithm
- Database Administrator
- Spectrum Sensing in the Broadcast TV Frequency Bands
- Technical Requirements for WSDs Operating in the TV Broadcast Bands

<http://www.tenet.ac.za/tvws>



Tertiary Education and
Research Network of South Africa

HOME NEWS ABOUT CONTACT TVWS SERVICE SUPPORT

Search Site



THE CAPE TOWN TV WHITE SPACES TRIAL

TENET participates with a number of partners in the operation of the Cape Town TV White Spaces Trial Network.

LATEST - Trial Results, Reports and Recommendations

The Cape Town TV White Spaces (TVWS) trial concluded September 25, 2013. The following are draft technical reports, recommendations and other policy related resources from other trials. The Cape Town trial documents are preliminary, pending consultations and comments. Final reports to follow in the next few months.

Reports:

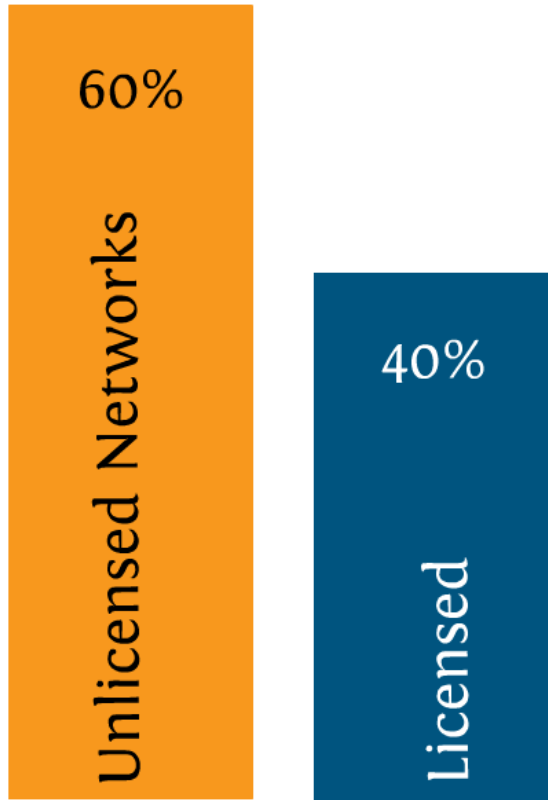
- Recommendations and Learnings from the Cape Town TV White Spaces Trial
- Suggested Technical Rules and Regulations for the use of TVWS and Managed Access Spectrum
- Cape Town TV White Spaces Trial Field Measurements Report
- FCC proposed rules (USA)
- Ofcom TV White Spaces - an approach to coexistence - Technical analysis (UK)

Presentations:

- Trial Network Overview and Accomplishments
- Trial Technical Monitoring and Evaluation Report
- Trial Learnings and Recommendations Report
- The User Experience
- Industry Support
- Remarks by Regulator ICASA

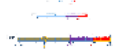
About the Trial

With the support of ICASA, the communications regulator of South Africa, a group of partners implemented a TVWS trial network covering ten



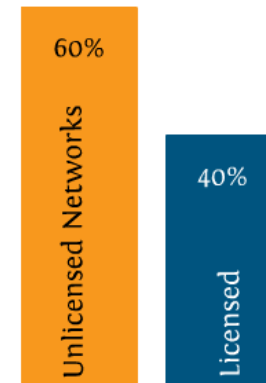
Share of Mobile Data 2017

Uniform
international
standards in the sub
1Gigahertz range.

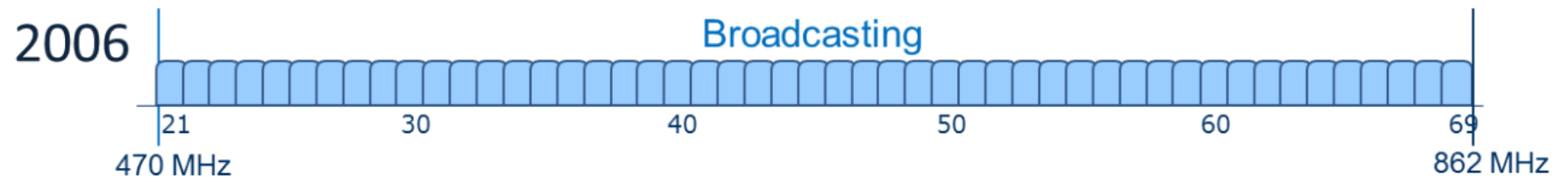


Regulatory Opportunity

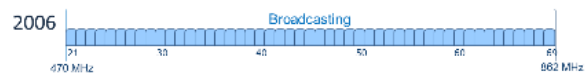
Unlicensed
Secondary
Access (TVWS)

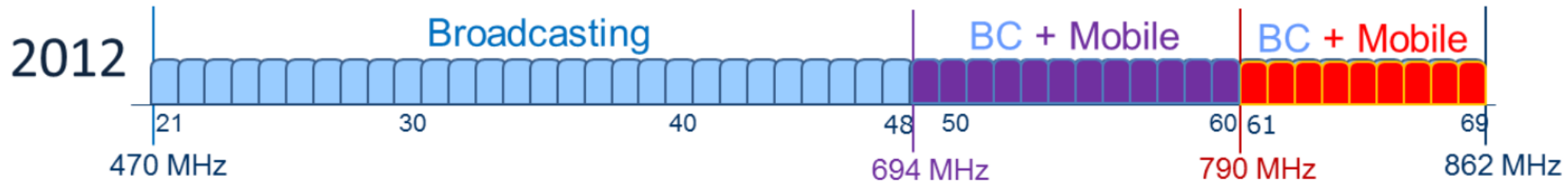
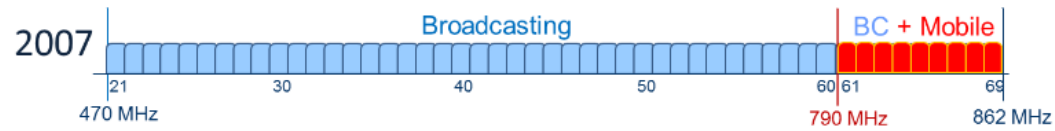


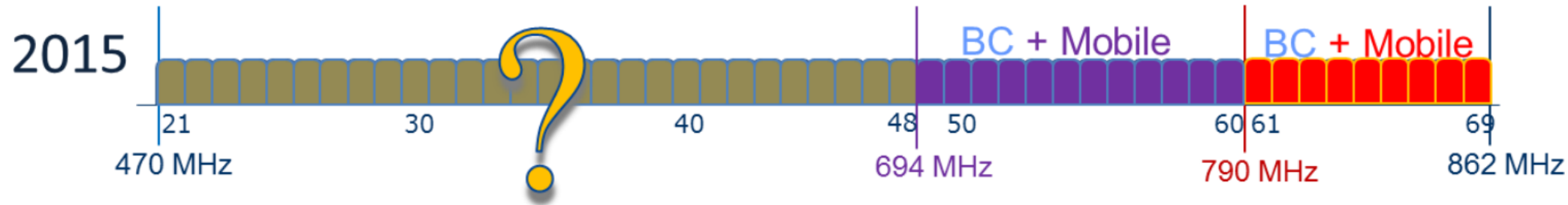
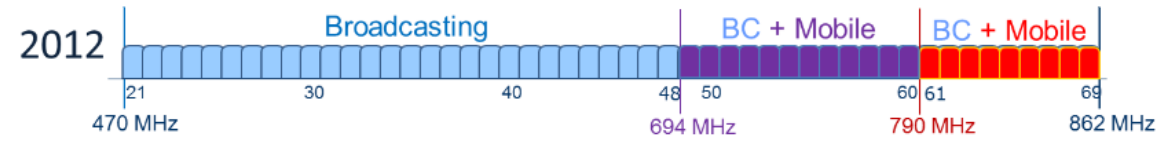
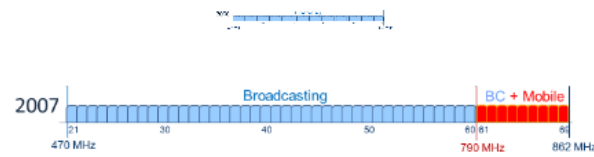
Share of
Mobile Data
2017



Broadcasting







Who will benefit?

- 1 Mobile carriers: data offload
- 2 Fixed-line providers: Extend services
- 3 WISPs: Underserved markets
- 4 Broadcasters: Video on demand
- 5 Small cell networks: Last-mile

Uniform
international
standards in the sub
1Gigahertz range.

Regulatory Opportunity

Unlicensed
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Access (TVWS)



Cape Town

T White Spaces Trial

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#TVWS

Reports: www.tenet.ac.za/tvws