



TVWS Devices User Manual and Installation Guide

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Contents

1) FCC Regulatory Information.....	3
2) Abbreviations	6
3) Glossary.....	6
4) TVWS Meghdoot (Base Station) and Dhaval (Customer Premise Equipment) radio.....	6
5) TVWS Debug Application	8
6) BS Installation	10
7) BS Configuration	11
7.1 Configure a WSDB provider	11
7.2 Provision the BS and CPE devices	13
7.3 Discover BS devices.....	14
7.4 Configure the BS device	15
7.5 Monitoring the operation of BS device.....	20
8) CPE Installation	21
9) CPE Configuration	22
9.1 Discover CPE devices.....	22
9.2 Configure CPE device	23
9.3 Scan for Available Networks	24
9.4 Register with selected Network.....	25
9) White Space Database Usage	25
10) FCC Test Mode	26
11.1 FCC test for Base Station.....	26
11.2 FCC test for CPE.....	27
11.3 Switch from FCC mode to Normal mode	29
11) Upgrading Firmware	30
12) Troubleshooting and Maintenance.....	31
12.1 Decoding the LED status	31
12.2 BER (Bit Error Rate) measurement	32
12.3 SDRAM Data Capture	33
12.4 TVWS Base Station & CPE GUI Uninstallation.....	34

1) FCC Regulatory Information

This device complies with Part 15 of FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment

Part §15.706 TV Band Device Notice

This equipment has been tested and found to comply with the rules for white space devices, pursuant to part 15 of the FCC rules. These rules are designed to provide reasonable protection against harmful interference. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- (1) Reorient or relocate the receiving antenna.
- (2) Increase the separation between the equipment and receiver.
- (3) Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- (4) Consult the manufacturer, dealer or an experienced radio/TV technician for help.

Caution: Exposure to Radio Frequency Radiation

To comply with FCC RF exposure compliance requirements, for fixed configurations, a separation distance of at least 40cm must be maintained between the antenna of this device and all persons.

This device must not be co-located or operating in conjunction with any other antenna or transmitter.

Part §15.105 Information to the user

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.

SL-TVWS-1001-User Manual and Installation Guide

- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Supplier's Declaration of Conformity

47 CFR § 2.1077 Compliance Information

Unique Identifier: Meghdoot Base station (FCC ID – 2AUUC-MEGHDOOT) and Dhaval CPE (FCC ID – 2AUUC-DHAVAL)

Responsible Party – U.S. Contact Information

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FCC Compliance Statement

This device complies with Part 15 of FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

2) Abbreviations

Acronym	Expansion
ACLR	Adjacent channel leakage ratio
BS	Base station
BER	Bit Error Rate
CPE	Customer Premise Equipment
EIRP	Effective Isotropic Radio Power
GI	Guard Interval
GPS	Global Positioning System
PoP	Point of presence
TVWS	TV white space
WRAN	Wireless Regional Area Network
WSD	White Space Device
WSDB	White Space Database Provider
PAWS	Protocol to Access White-Space Database
PoE	Power over Ethernet

3) Glossary

Base Station or Base Unit is the WSD which is configured to bridge the packet flow to a router or point of presence (PoP). Several CPEs or Client Units connect to the Base Unit

Bit Error Rate is the %age of bits which are in error on the radio link. The target BER can be configured based on the current deployment conditions

Customer Premise Equipment or Client Unit is the WSD at the user end and registers with the Base Unit.

Effective isotropic radiated power is the radio power in dBm measured at the output of antenna. It is equal to the total conducted power + the antenna gains in dBi

TV White spaces are the unoccupied bands between TV channels which are used for broadband service

Wireless Regional Area Network is a wireless broadband specification defined by IEEE802.11a specifications

White Space Device is a wireless communication device that works in TVWS

White Space Database is the database of usage of TVWS in a given region

4) TVWS Meghdoot (Base Station) and Dhaval (Customer Premise Equipment) radio

Saankhya TVWS devices are fixed cognitive radio devices operating in TVWS bands ranging from 470-608 MHz. The devices can be configured as either Base radio or Client radio and are compliant with rules specified in CFR 47 Part 15 subpart H of FCC regulations. When acting as a Base radio, device acts as a master and Client radios act as slave. All the communication with external network (including with WSDB) is handled through the Base radio

Performance				
Maximum data rate	26Mbps/8MHz, 16Mbps/6MHz		Air interface data rates, can be multiples of these with channel bonding	
User throughput	25Mbps/8MHz, 14Mbps/6MHz		UDP, measured with iperf3, can be multiples of these with channel bonding	
Spectral efficiency	3.4b/s/Hz			
Link Latency	35ms typical			
Radio Characteristics				
Operating Frequencies	470 to 608 MHz		Center frequencies aligned as per TV bands	
Channel Bandwidths	6, 7, 8MHz			
Modulations supported	QPSK, QAM16, QAM64 with code rates up to 5/6			
Maximum EIRP	Meghdoot: 31.5 dBm Dhaval: 34.5 dBm		With 6dBi antenna gain With 9dBi antenna gain	
Maximum conducted power	25.5 dBm		Including all tolerances	
ACLR (adjacent channel leakage ratio)	-55 dB			
Duplexing	TDD		Allows configurable UL-DL split	
Receiver Sensitivity	Modulation	SNR (dB)	Sensitivity	Data rate
	QPSK 1/2	4	-94.0 dBm	5 Mbps
	QPSK 3/4	9.8	-90.2 dBm	8 Mbps
	QAM 16 3/4	14.6	-84.4 dBm	16 Mbps
	QAM 64 3/4	21	-78.8 dBm	24 Mbps
	QAM 64 5/6	21.7	-76.8 dBm	28 Mbps
Power				
Power supply	48V DC, 110V-230V A/C		DC Using PoE injector and adaptor Solar power option available	
Power Consumption	25W typical		With 60:40 TDD split	
External Interfaces				
Antenna interface	N-type (male)		Impedance 50ohm	

GPS Antenna	N-type (male)	
Data	10/100Mbps Ethernet (RJ45)	
Recommended Antenna		
BS Antenna	Omni antenna with 6dBi gain with vertical polarization	Antenna mounted with clamps provided with package
CPE Antenna	Yagi Antenna with 9dBi gain with vertical polarization	
GPS Antenna	Right hand circular polarized with 50-ohm impedance	
Mechanical specifications		
Dimensions (LxBxW)	481mm x 127.5mm x 111.5mm	
Weight	2.5 kg	
Water resistance	IP65 compliant	
Operating temperatures	-10° to 50° Celsius	
Regulatory Approvals		
FCC		Meets FCC specifications for RF mask as per FCC part 15 sub-part H

5) TVWS Debug Application

Saankhya™ TVWS Application is used to configure and monitor the TVWS devices. The tools are provided both for 64-bit Windows 10 and Ubuntu Linux platforms. Follow the steps indicated in Figure 1 to install the TVWS Application.

SL-TVWS-1001-User Manual and Installation Guide

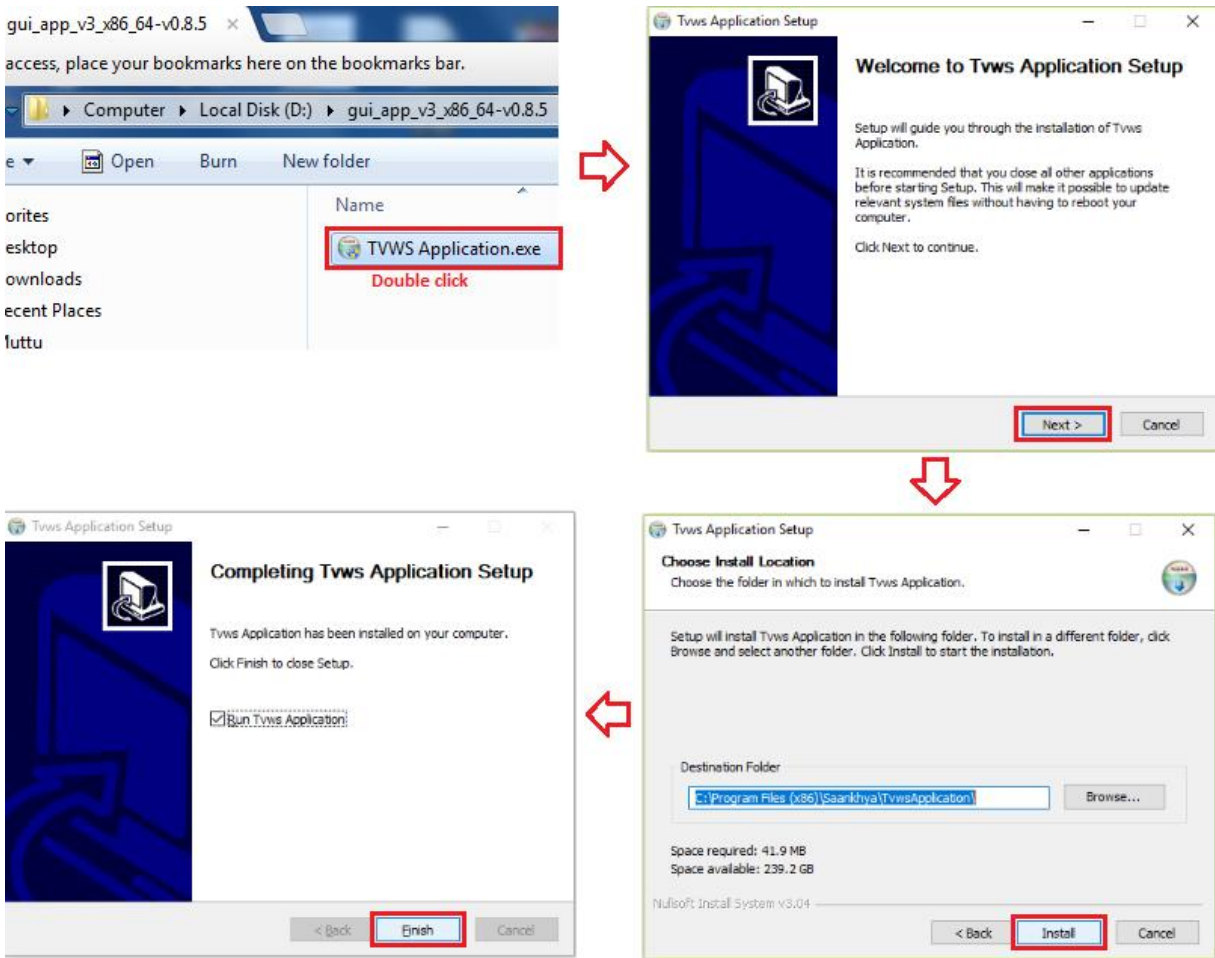


Figure 1 TVWS GUI Application Installation

On Successful installation a shortcut icon will be created on Desktop and configuration files will be copied under c:\Users\<profile name>\.saankhya\.atconfig. Follow the steps indicated in Figure 2 to start the TVWS GUI Application.

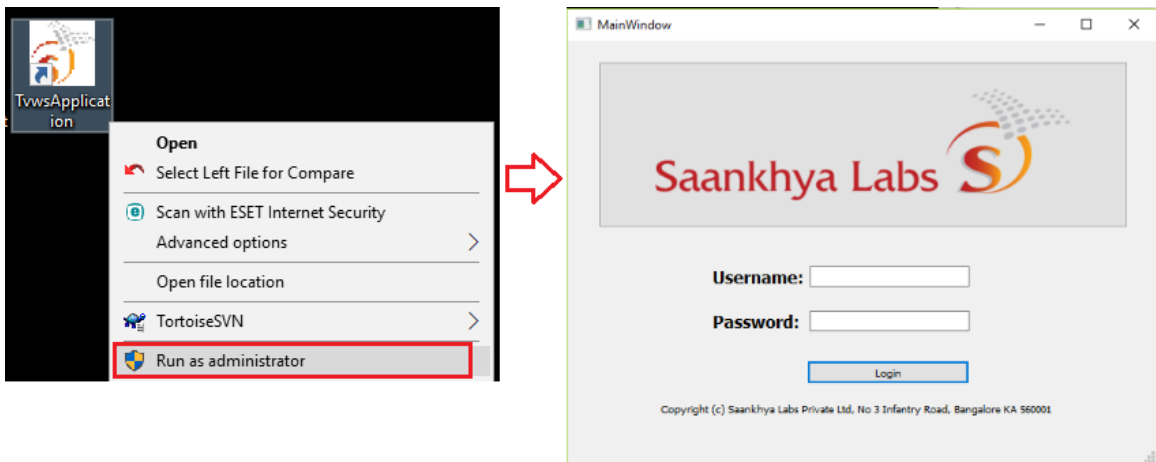


Figure 2 Start TVWS GUI Application

6) BS Installation

Meghdoot BS should be installed by an authorized professional only. Installation and operation of the devices by persons other than the professional installers might cause permanent damage to the device and malfunction.

Saankhya TVWS devices have 3 ports – 2 for antenna and 1 for PoE as shown in Figure 4. These devices are mounted on a pole with the help of clamps and screws provided with standard shipment. The antenna are connected to the N-type connectors for the purpose on the top section of the devices. The RJ45 PoE port on the device is connected to PoE injector (Figure 3) using Ethernet cable.



Figure 3 PoE Injector and connections

The Ethernet cable on the PoE injector which forks from the power connector should be connected to backhaul – either a switch or a router depending on the operator topology.

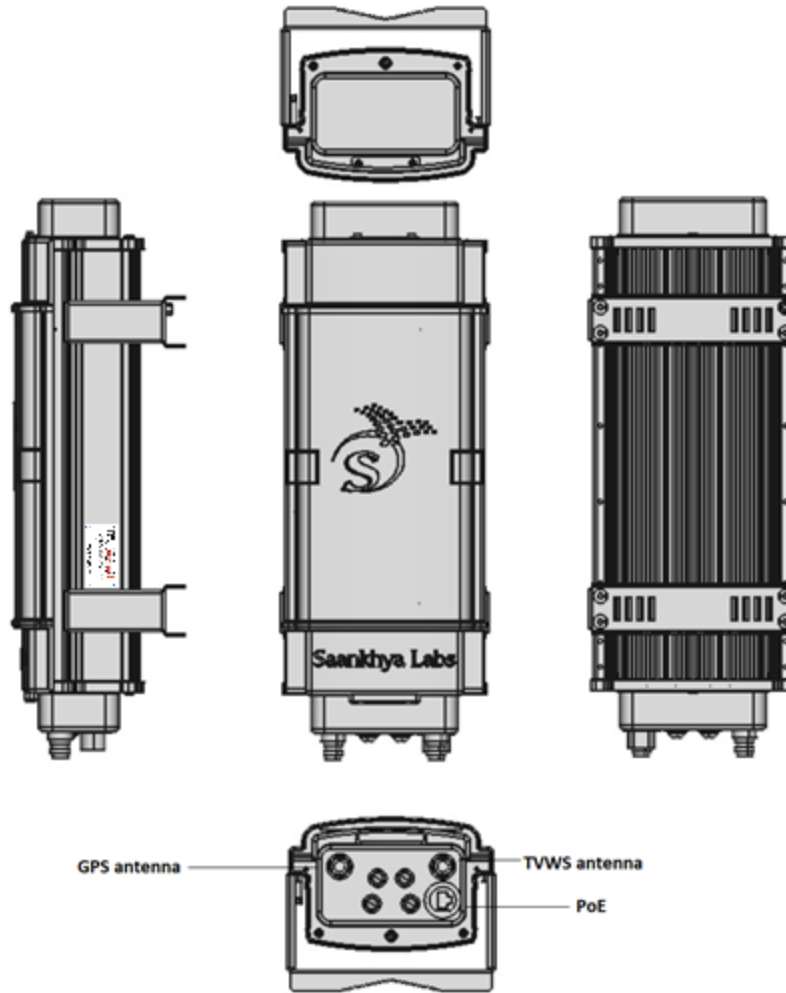


Figure 4 Saankhya TVWS Device

Notes:

- 1) The devices should be mounted vertically with the PoE port facing earth in order to reduce wind resistance
- 2) Clamps should be secured firmly in order to avoid any injury or damage resulting from the box slipping down the pole

7) BS Configuration

Make sure that all the connections are done as described in Section 6) Launch the TVWS GUI Application by double clicking on the application icon. Follow the steps as described below to configure the base station

7.1 Configure a WSDB provider

Note:

- 3) This step is optional and required only if TVWS databases need to be accessed. Otherwise go directly to Section 7.3 (at locations where WSDB services are not mandated by law)

Database services might be required as per the regulations of the country where TVWS device is being operated. One needs to configure the URL and the API-key provided by the service provider before accessing the database

If you operate in a region where database services are not mandatory, this step can be skipped. Please ensure that in such a case DB query option is disabled on TVWS. On launching the gui_app_v3.exe application for the first time, the user should go through steps shown in Figure 5 to logon to the application with both user name and password as *admin*¹

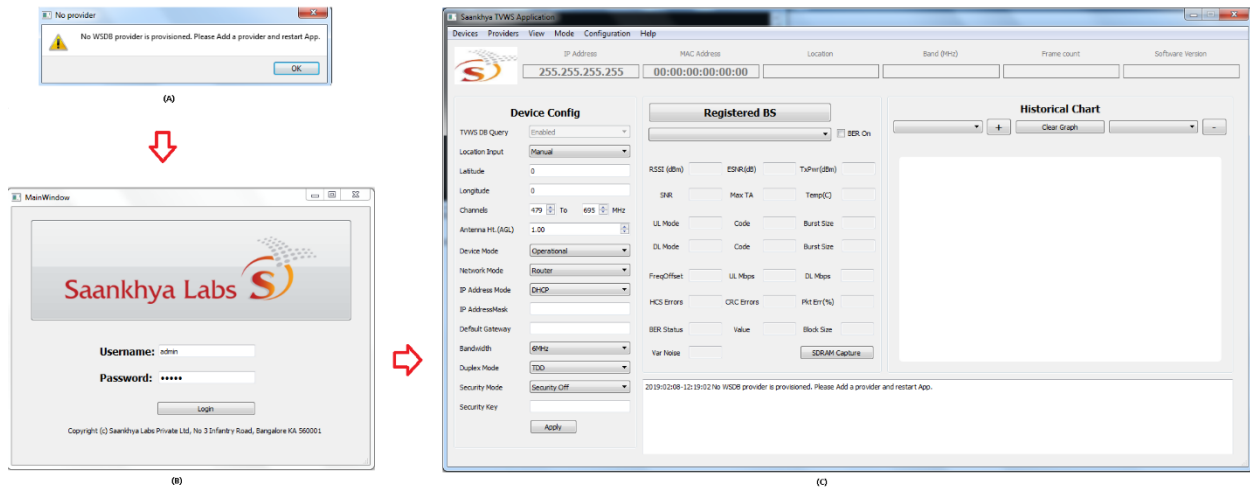


Figure 5 TVWS GUI Log on and Opening Screen

From here, add the service provider details (URL and the API-key) as shown in Figure 6 and restart the application as requested below. These parameters are used to make HTTPS/POST requests to the service provider. The security of the connection to the PAWS server is guaranteed by use of HTTPS

¹ The username and password cannot be changed in this version (v1.0.10-fcc) of application

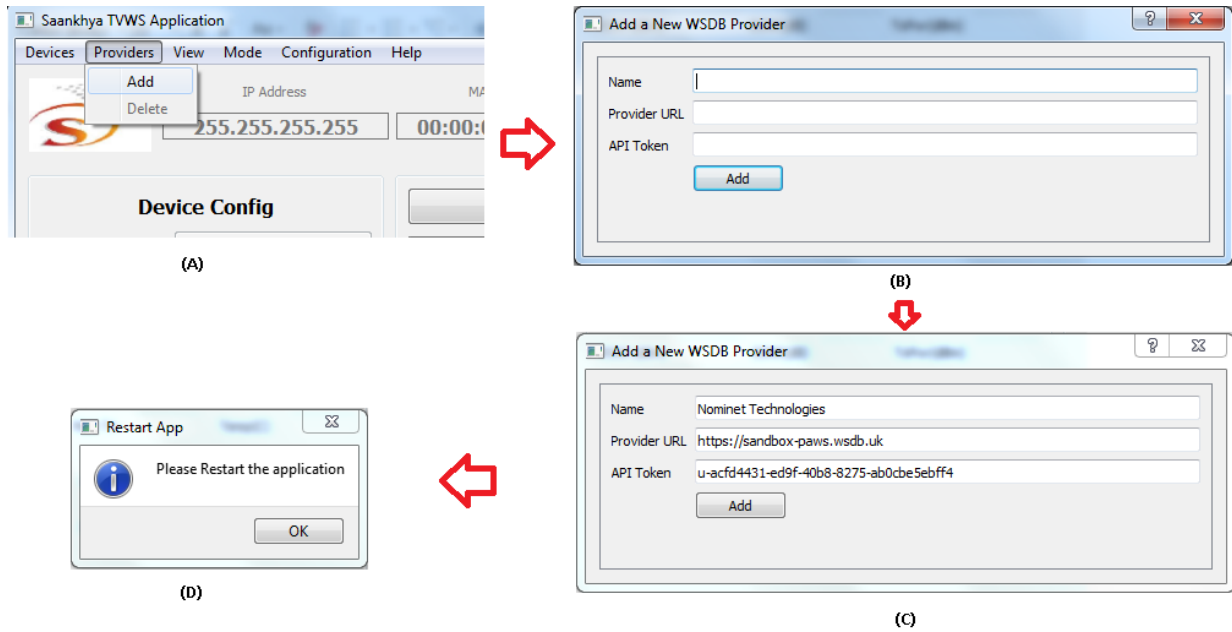


Figure 6 Adding WSDB provider

7.2 Provision the BS and CPE devices

To use any device (BS or CPE) it should first be provisioned into the system. There are several parameters which need to be specified. Incorrect provisioning will result in the WSDB rejecting the requests and failure to operate the device. Please consult your data base provider for the details required and their respective ranges²

Illustrative values for Nominet WSDB services provider are shown in Figure 7

² Master MAC-ID is not required while provisioning the base station

SL-TVWS-1001-User Manual and Installation Guide

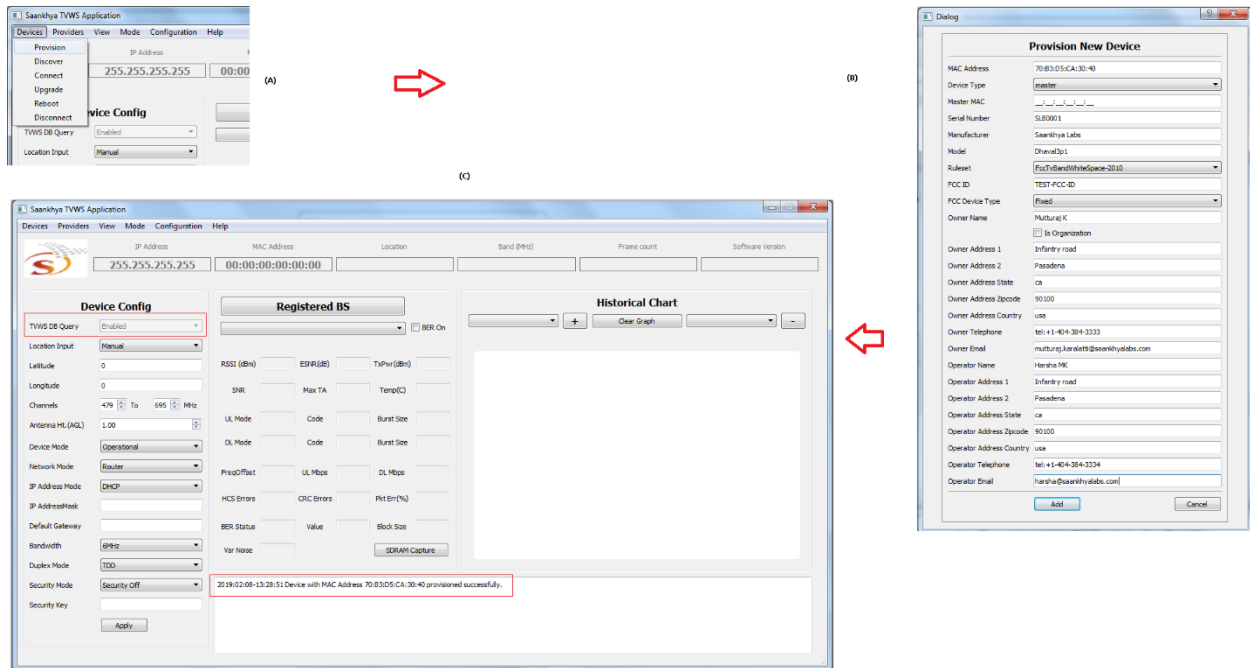


Figure 7 Provisioning Base station with TVWS GUI

On successful provisioning, a message is displayed in the log window at the bottom. Also ensure that the DB query parameter as shown in above figure is set to enabled.

7.3 Discover BS devices

After provisioning, we need to connect to the device and apply configuration and start the radios. The devices can be discovered if they are on the same IPv4 subnet as that of the PC running the TVWS Application. Follow the steps in Figure 8 to discover the devices. Once discovered, select the device based on the MAC address

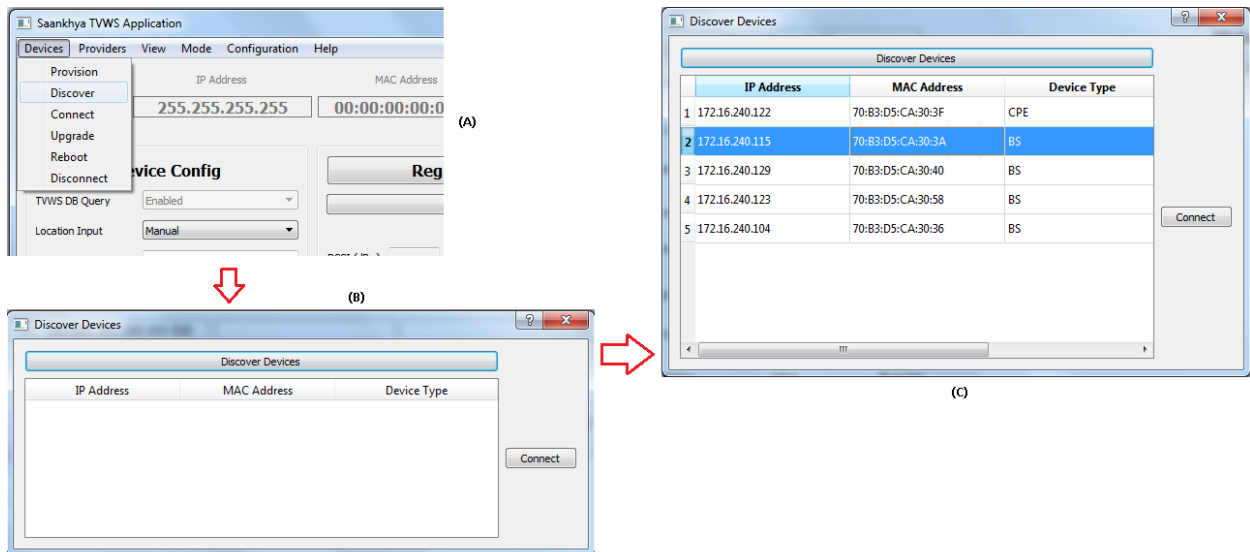


Figure 8 Discovering TVWS devices

On successful connection to the device, the following screen appears please note the 3 important points marked on the screenshot

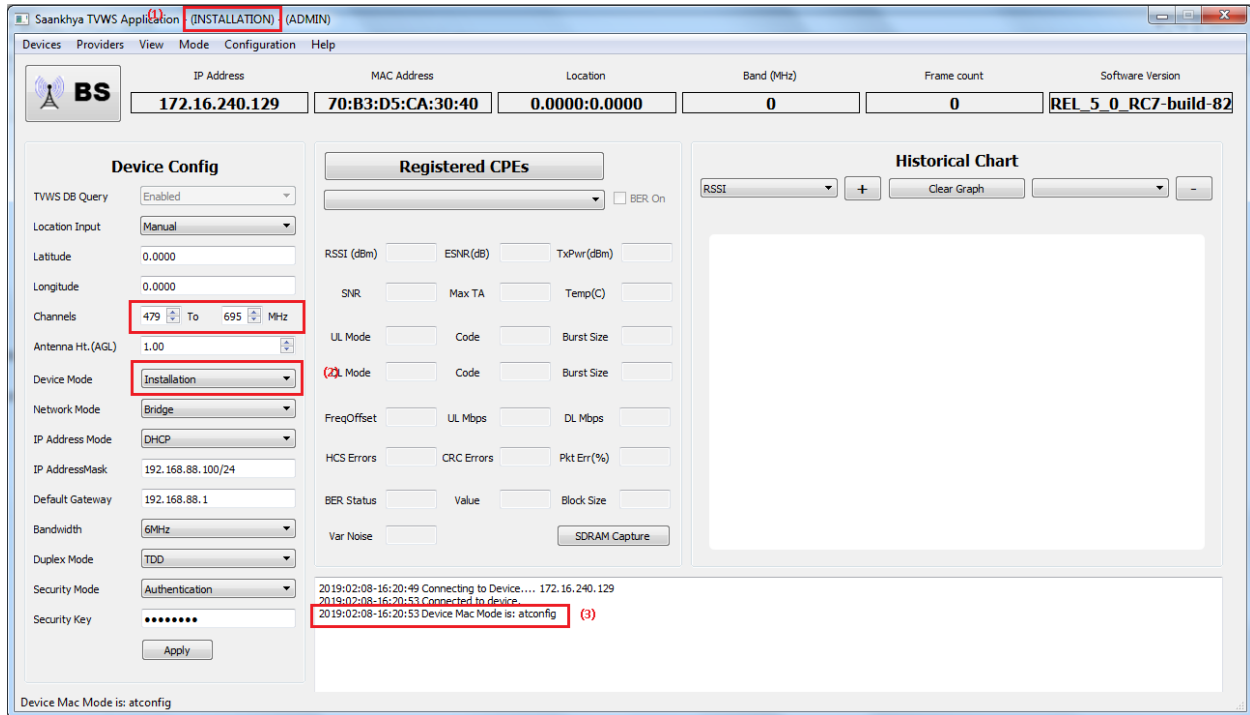


Figure 9 TVWS BS Opening Screen

Notes:

- 8) All devices are shipped in 'Installation' mode. In this mode, the device radios are not turned on unless user applies a valid configuration
- 9) On successful application of configuration, device moves to 'Operational' mode. No parameter change is allowed in this state

7.4 Configure the BS device

Before we load the configuration files, please check that the selected source of location information shows GPS on the GUI. Please ensure that the GPS is latched on by checking the appropriate LED at the bottom of device. Use of GPS for geolocation is mandatory on devices certified under FCC.

The above steps are to be performed by a professional installer conversant with the operations of the device.

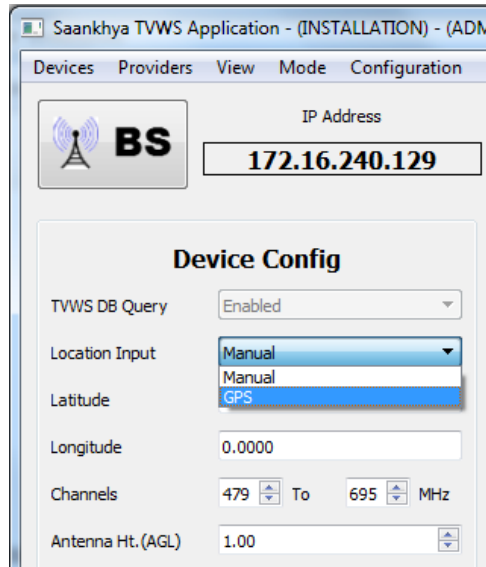


Figure 10 Location Data source selection

Configuration files are provided for devices with following naming convention:

<Duplex Mode>_<Device Type>_<Description>_<GI length>_<Bandwidth>_<Device Model>_<Antenna Gain>.ini where

Duplex Mode: TDD or FDD

Device Type: BS or CPE

GI length is the length of cyclic prefix in terms of symbol size (1by32, 1by16, 1by8, 1by4)

Bandwidth: 6MHz or 8MHz

Device Model: Dhaval2p1 or Dhaval3p1

Antenna Gain: (0 dBi, 6 dBi, 9 dBi)

For use with 6MHz channel, the suggested profile is TDD_BS_TPC-DSM-SCU_1by4_6MHz.ini whereas for 8MHz channel it is TDD_BS_TPC-DSM-SCU_1by16_8MHz.ini. These files are available in "C:\Users\<profile>\.saankhya\.atconfig". Refer to Figure 11 for list of configuration files. At this stage the configuration is loaded into the TVWS internal database but not applied to the device. Follow the steps indicated in Figure 12.

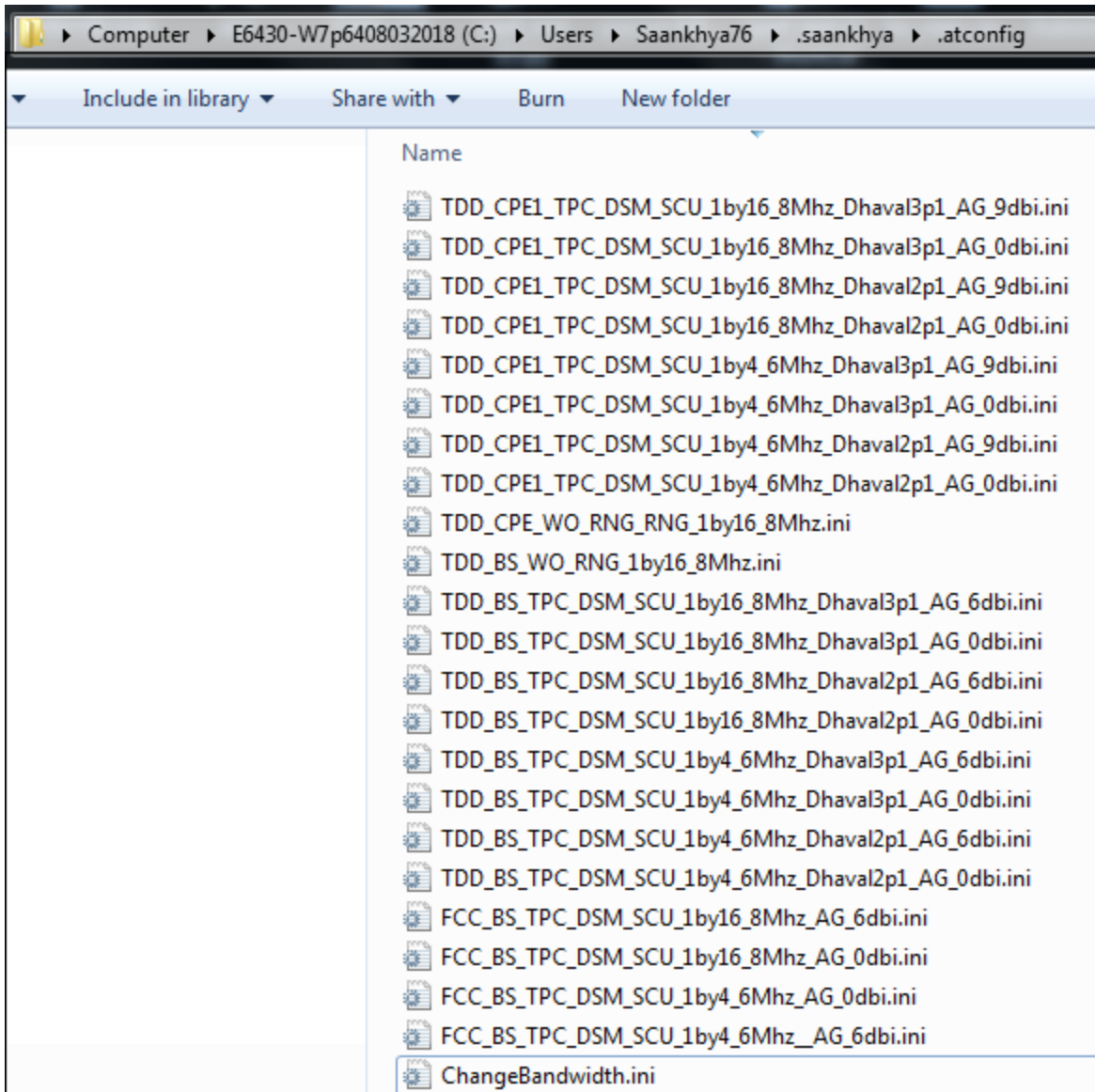


Figure 11: List of available configuration files

Before applying the configuration to the device (using the 'Apply' button as shown in Figure 9) please double check the following:

- TVWSDB Query is set to Enabled
- The location co-ordinates are correct or if using GPS, it is in locked state (using the LED status)
- The Antenna Height above ground level (AGL)
- The range of channels is set appropriately. The start and the stop bands increment in multiples of the selected bandwidth
- The bandwidth is selected correctly

It takes a while (about 60 seconds) for the configuration to be applied and a message is displayed at the bottom of the TVWS GUI application.

SL-TVWS-1001-User Manual and Installation Guide

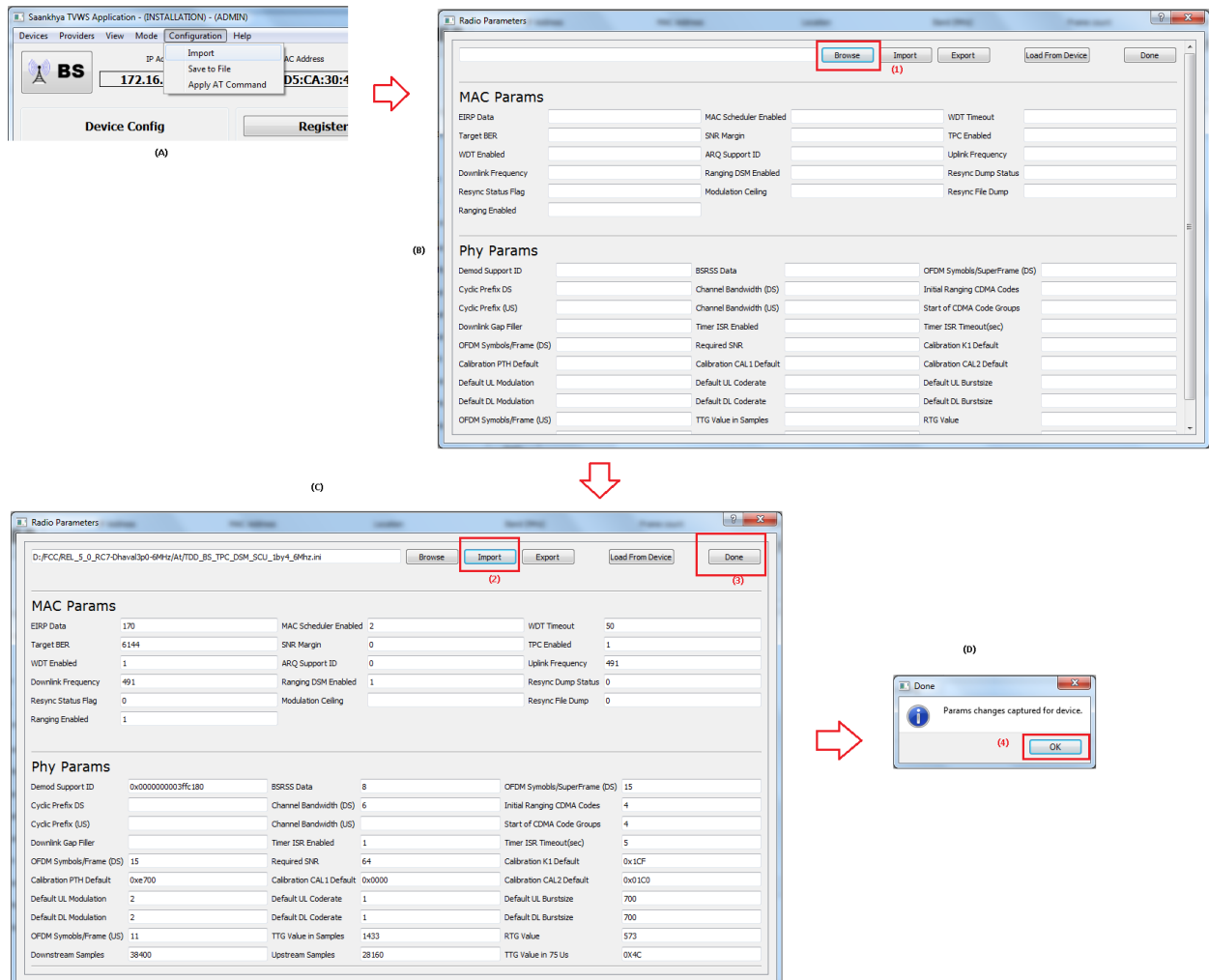


Figure 12 Loading Configuration from INI files

Once the configuration is applied, the TVWS Application queries the WSDb for available spectrum and the same is presented to user for selection as shown in Figure 13.

SL-TVWS-1001-User Manual and Installation Guide

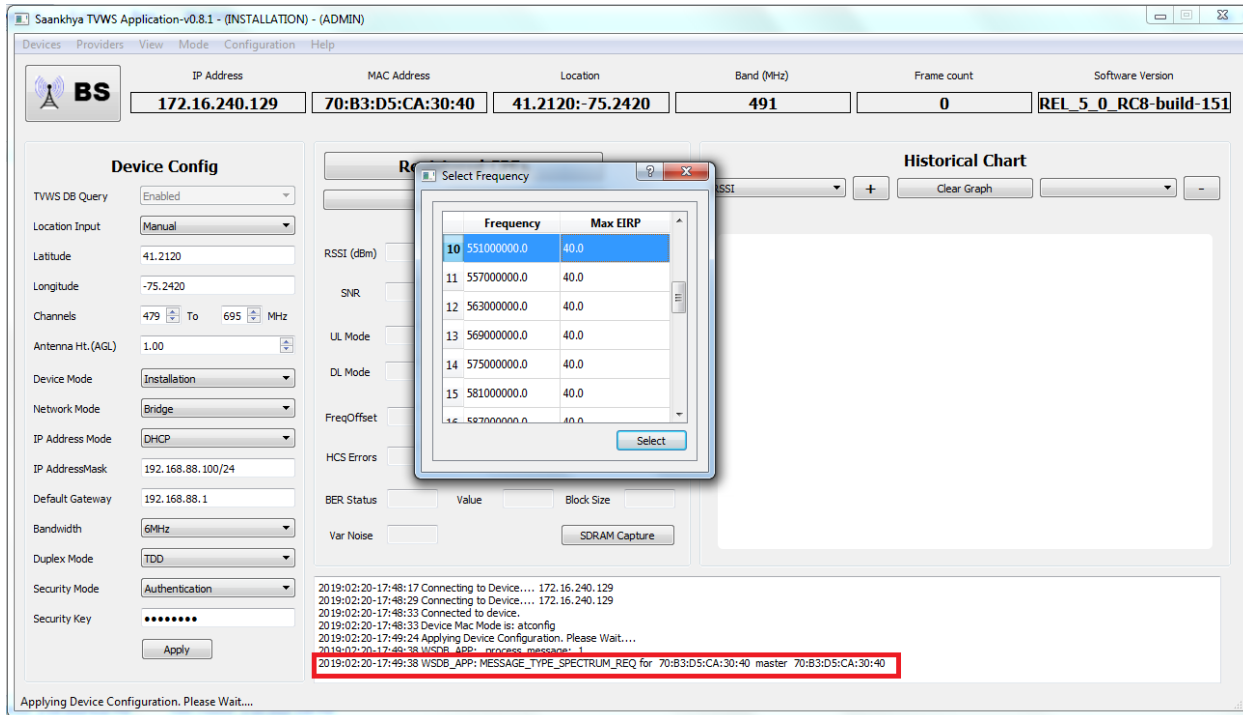


Figure 13 Frequency Selection for Base Station

After selection of suitable frequency, the radios are turned on which can be seen from the items marked in figure below

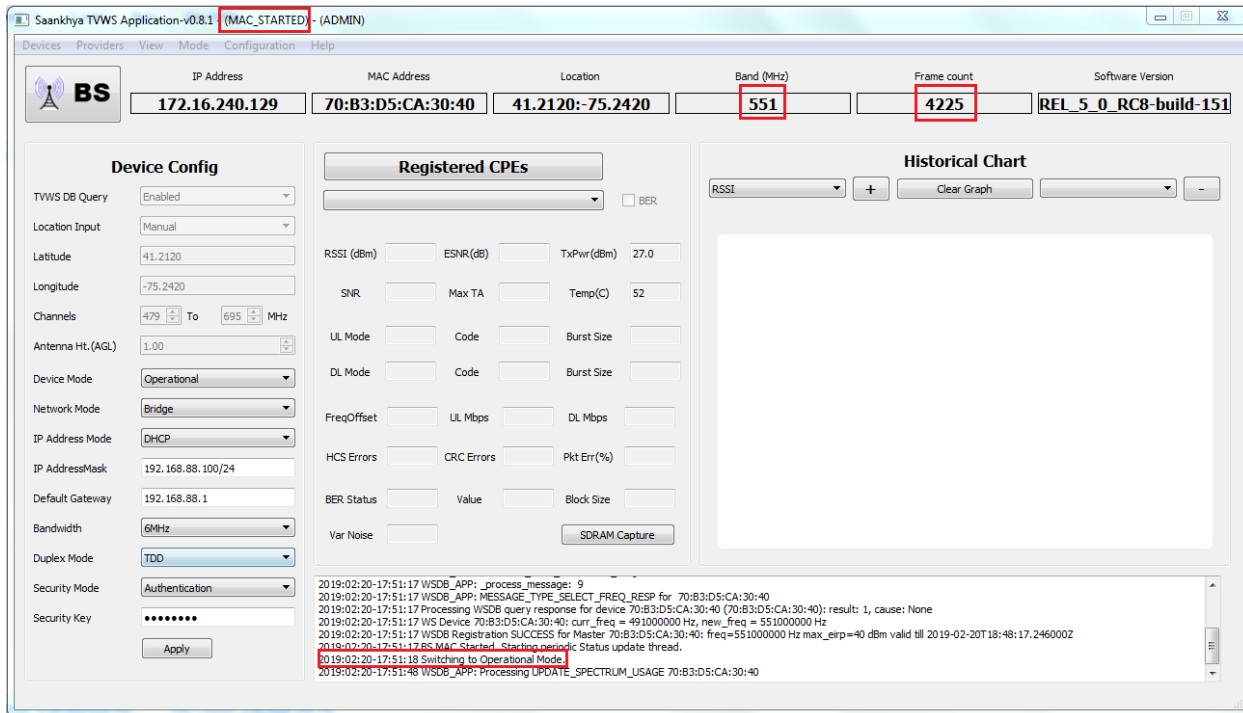


Figure 14 Successful Triggering of Base Station into Operational Mode

Notes:

- 1) TVWS Base Station GUI application acts as proxy for all the devices connected to it. It must be kept running all the time
- 2) TVWS Base Station GUI application will prompt user for frequency selection only in Installation Mode. In Operational mode it selects the last selected frequency on subsequent interactions with the WSD. If this frequency is not available, it selects the first frequency available in the range of operation.

7.5 Monitoring the operation of BS device

Once the BS is in operational state, user can monitor the uplink state of the registered CPEs on the dashboard. These parameters can be plotted in the 'Historical Chart' shown alongside.

7.5.1 Selecting the CPE to monitor UL parameters

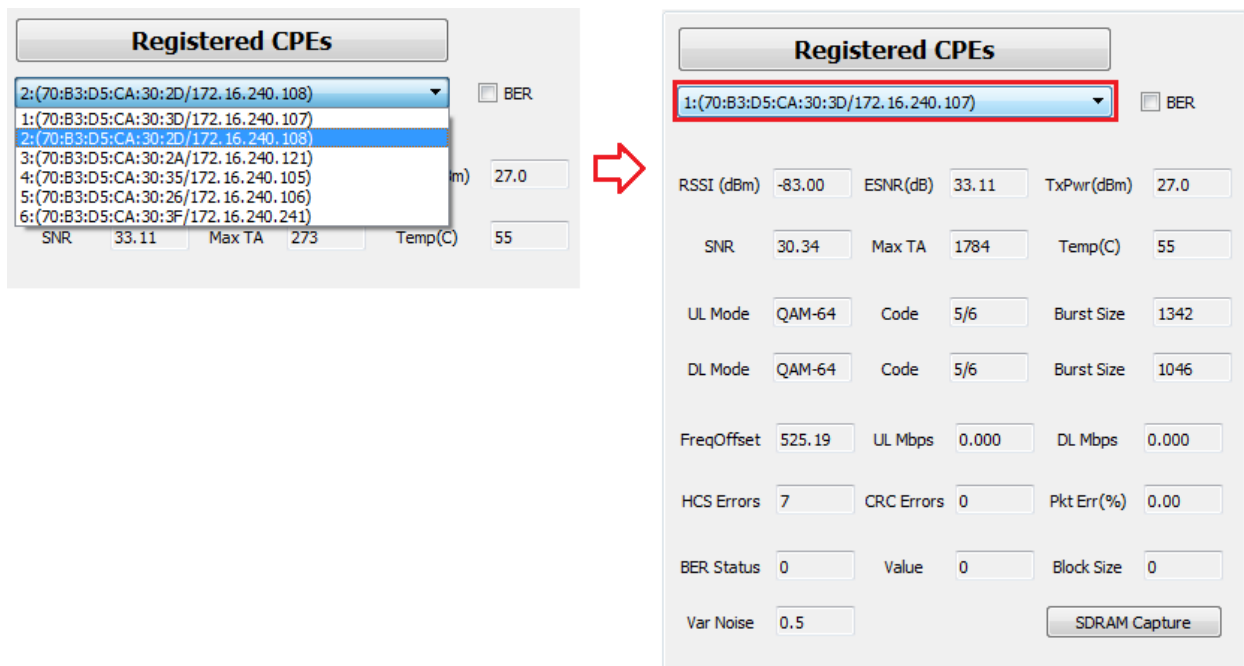


Figure 15 Selecting CPE for UL parameter monitoring

7.5.2 Plotting charts for selected CPE

Follow the steps indicated in Figure 16. One or more parameters can be viewed at the same time as shown in Figure 16. Scale is displayed for selected parameter from added group.

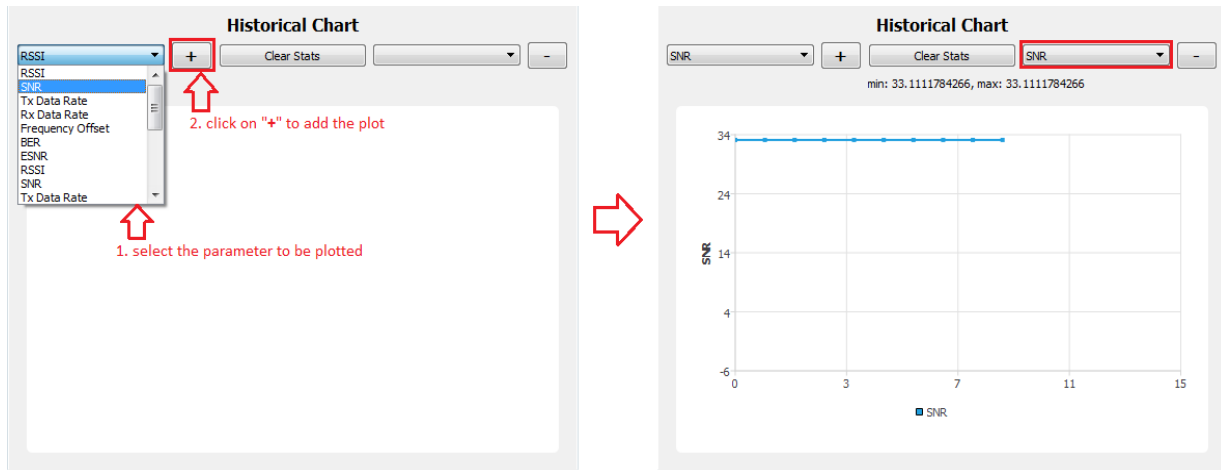


Figure 16 Selecting UL Parameters for selected CPE



Figure 17 Plotting Multiple Parameters

7.5.3 Changing BS parameters in Operational Mode

To make any change in parameter, user needs to move to 'Installation' mode from the Mode-> Installation menu option.

Notes:

- 1) Switching to installation mode will cause the BS to reboot

8) CPE Installation

Dhaval CPEs should be installed by an authorized professional only. Installation and operation of the devices by persons other than the professional installers might cause permanent damage to the device and malfunction.

Installation of the CPE devices is identical to that of the Base station devices except for connecting the laptop directly to the Ethernet cable. In case a WiFi router is to be used, the Ethernet cable from CPE should be connected to the WAN port of WiFi router.

The CPE is configured to act as a router and assign IP addresses to the devices connected to it. The IP addresses assigned by the CPE are in subnet 192.168.88.0/24. This can be changed once the CPE is discovered through the GUI.

9) CPE Configuration

On CPE devices, it is not mandatory to program the WSDb service provider and any other device details. User can directly proceed to connect to CPE devices

9.1 Discover CPE devices

The discovery mechanism is identical to that of the Base station. Few points to note in the process:

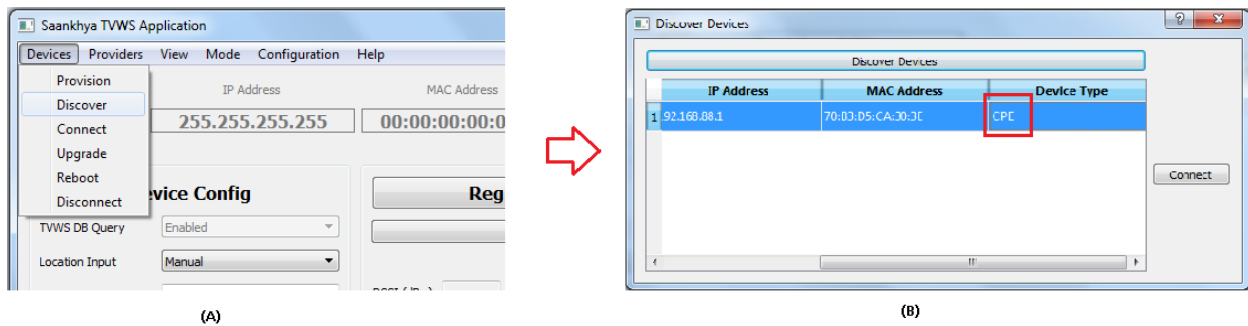


Figure 18 Discovering CPE devices

Notes:

- 1) CPE devices by default come with DHCP option enabled, hence any laptop or device connected to CPE should be configured to work with DHCP. CPE always allocates IP address in range 192.168.88.0/24 unless it is changed by the user. This allows CPE to be connected at a well-known address
- 2) A CPE is also discoverable from the Base station once it is attached to the BS

On logging into CPE device, the screen should show as in Figure 19. The devices are always shipped in installation mode, so the title bar should show that device is in installation mode

SL-TVWS-1001-User Manual and Installation Guide

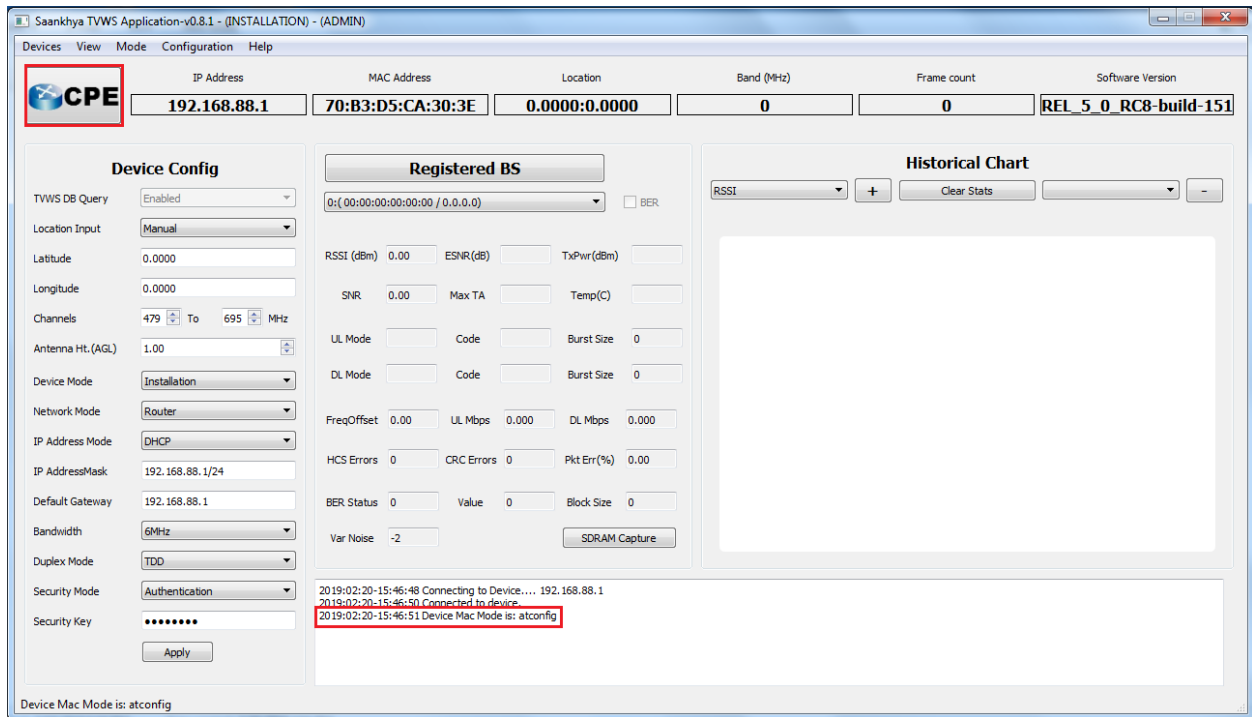


Figure 19 CPE Login Screen

9.2 Configure CPE device

CPE configuration files naming convention is similar to BS configuration files. Refer Section 7.4 for the naming convention and select appropriate file as indicated in Figure 20.

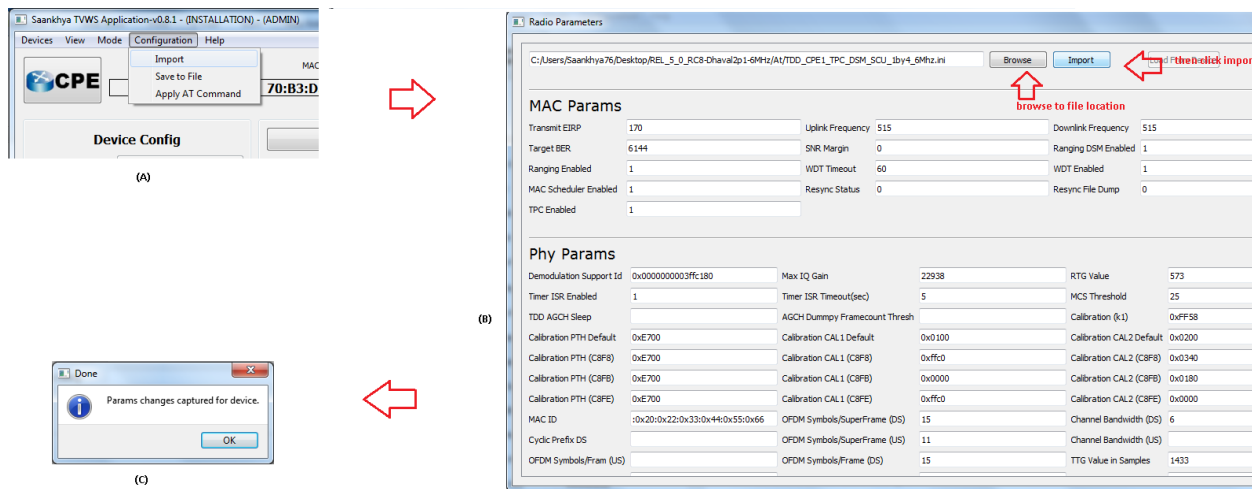


Figure 20 Selecting CPE configuration

On coming back to main screen, enter the location information manually or select GPS as source. Also enter the antenna height above ground level (AGL) and frequency bands to scan.

Note:

- Depending on the Bandwidth selected, the frequency bands will increment by multiples of the bandwidth

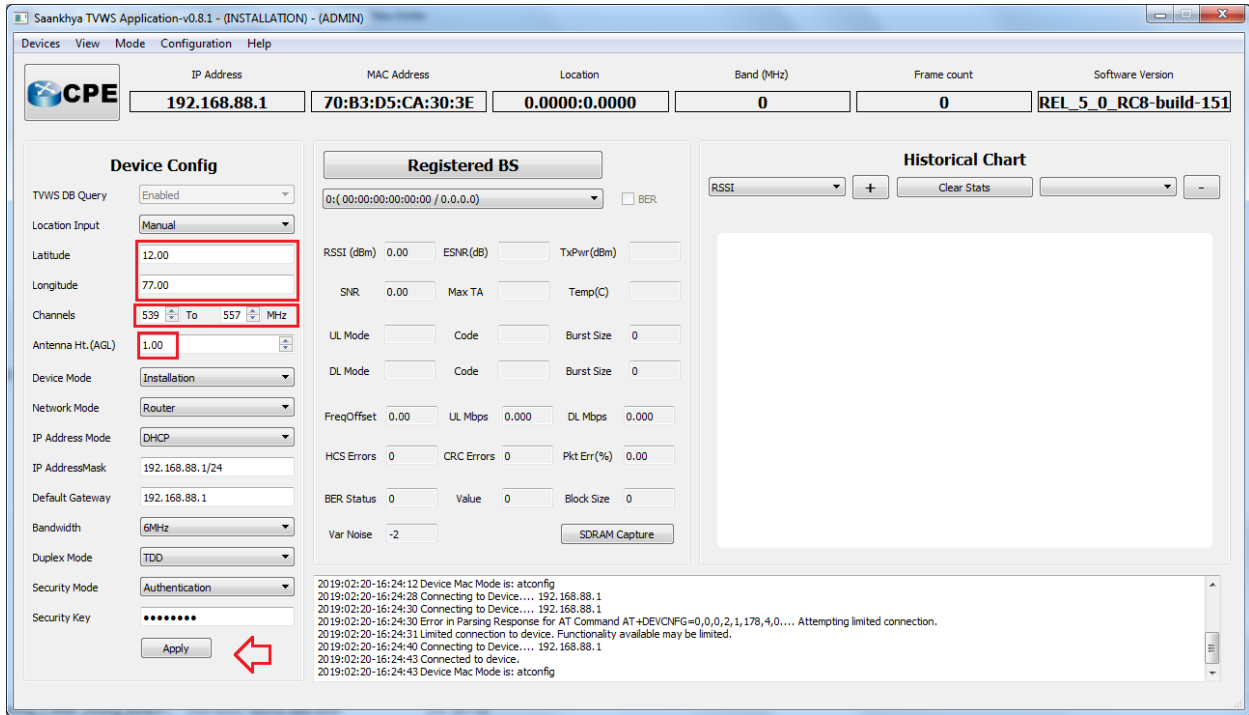


Figure 21 Additional CPE configurations

9.3 Scan for Available Networks

On applying the configurations above, CPE starts scanning for available networks. It might take a while depending on the range of scan. For entire TV band it might take as long as 15-20 minutes. Once the scan is complete, the following pop-up shows up:

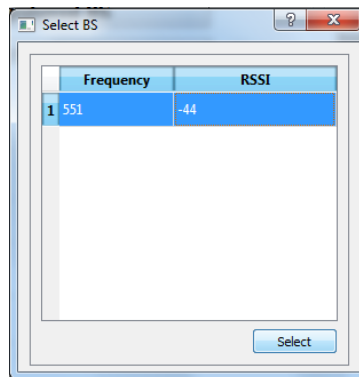


Figure 22 Frequency selection at CPE

In case there are multiple networks shown, select the desired frequency to register with the network. It takes a while (about 5minutes) to complete the registration and on successful registration, CPE moves to operational mode

Notes:

- 4) If there are no networks found the CPE will reboot on its own
- 5) After moving to operational mode if CPE loses the network it will perform scan for the last registered band and then full range of frequencies automatically.

9.4 Register with selected Network

On successful registration, the CPE screen should display the following information as indicated in Figure 23

- The frequency at which CPE is registered
- Incrementing values of frame count
- Base station MAC address and IP address (IP address always shown as 0.0.0.0 in current release)

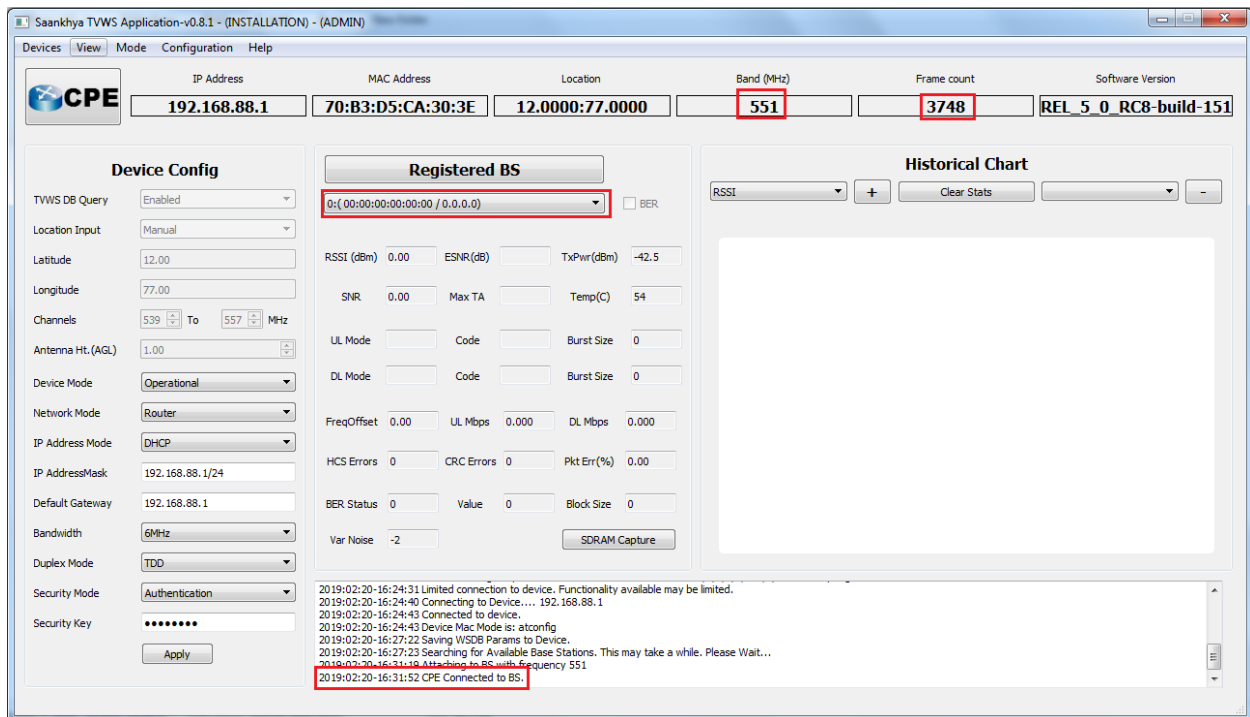


Figure 23 CPE successful registration at CPE GUI

Similarly, on the Base station side, you would see logs corresponding to CPE registration as indicated in Figure 23.

9) White Space Database Usage

In geographies which have regulations on usage of TV white space frequencies, the sharing of the spectrum is controlled by White Space Data Base (WSDB). Saankhya Labs sells devices with the WSDB feature enabled in these geographies and the configuration of the service providers described in Section 7) and 9)

It is advised that the source of location information be set to GPS as against manual while using this feature, although it is not mandatory. The GPS device used provides 95% location accuracy when latched.

10) FCC Test Mode

In this mode device continuously transmits without any quite period. It is supported as per the FCC test requirements. In this mode ACLR and transmit power can be measured more accurately.

11.1 FCC test for Base Station

11.1.1 Switch to FCC mode

Connect TVWS GUI Application to Base Station and follow the steps indicated in Figure 24 to configure the device to FCC test Mode. Please make sure TVWS DB Query is disabled for FCC testing.

Use the TVWS DB Query dropdown in Device-Config section to disable the TVWS DB Query.

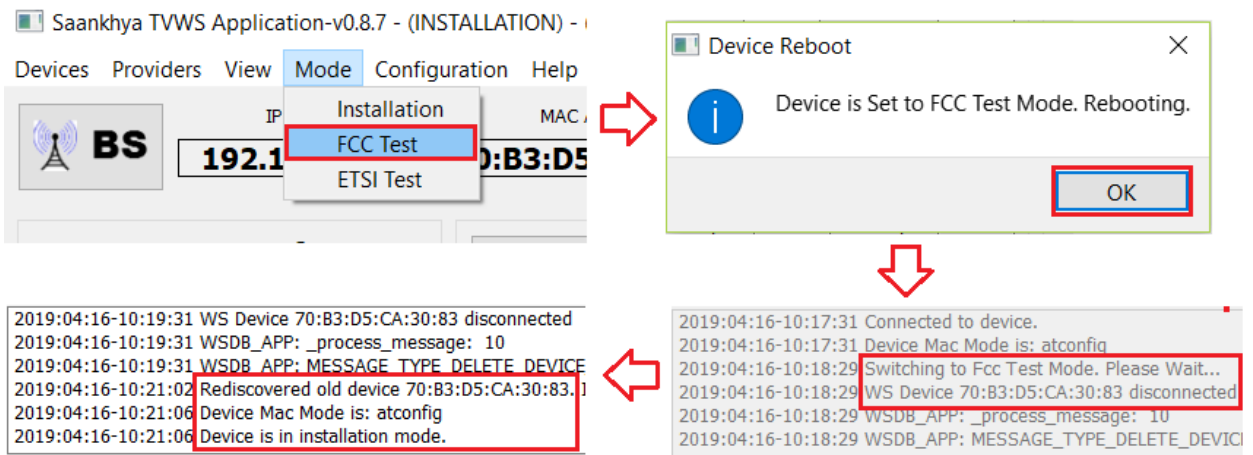


Figure 24 Switch BS to FCC test mode

11.1.2 Trigger Device in FCC mode

Follow the steps indicated in Figure 25 to trigger the device in FCC mode.

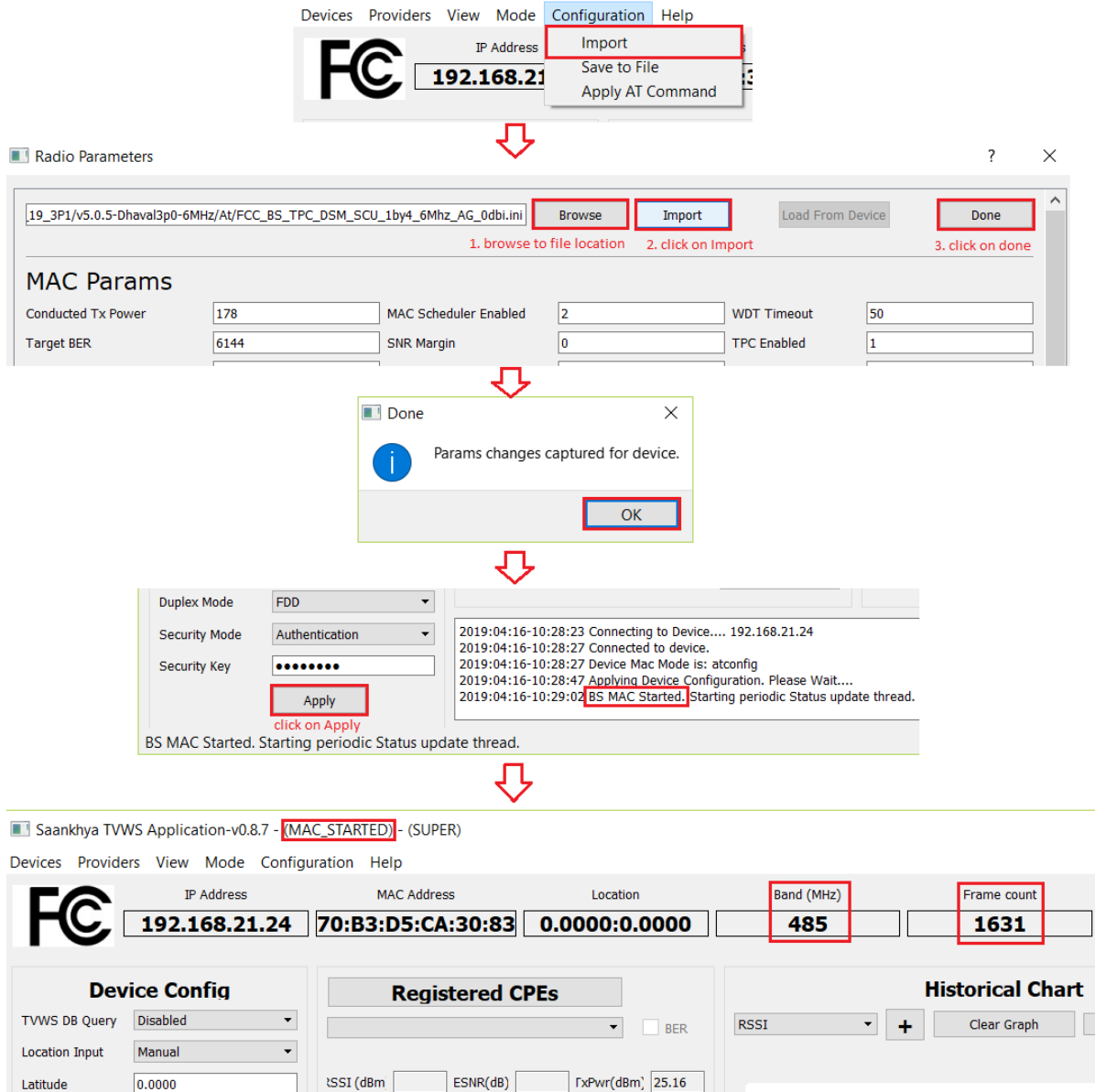


Figure 25 Trigger Base Station in FCC test mode

11.2 FCC test for CPE

11.2.1 Switch to FCC mode

Connect TVWS GUI Application to CPE and Follow the steps indicated in Figure 26 to configure the device to FCC test Mode. Please make sure TVWS DB Query is disabled for FCC testing. Use the TVWS DB Query dropdown in Device-Config section to disable the TVWS DB Query.

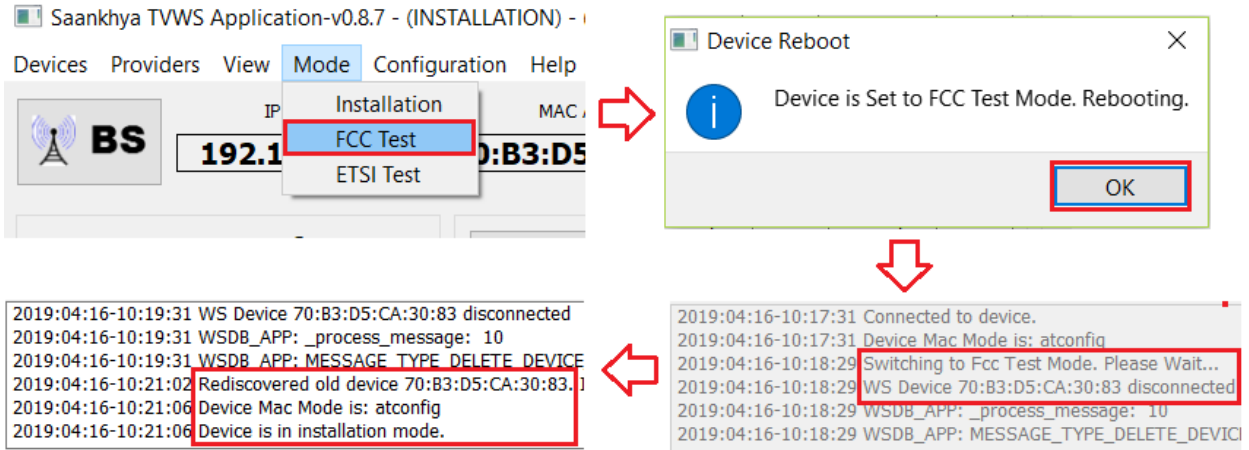


Figure 26 Switch CPE to FCC test mode

11.2.2 Restart the TVWS GUI Application

Close and open the TVWS GUI Application and connect back to CPE.

11.2.3 Trigger Device in FCC mode

Follow the steps indicated in Figure 27 to trigger the device in FCC mode.

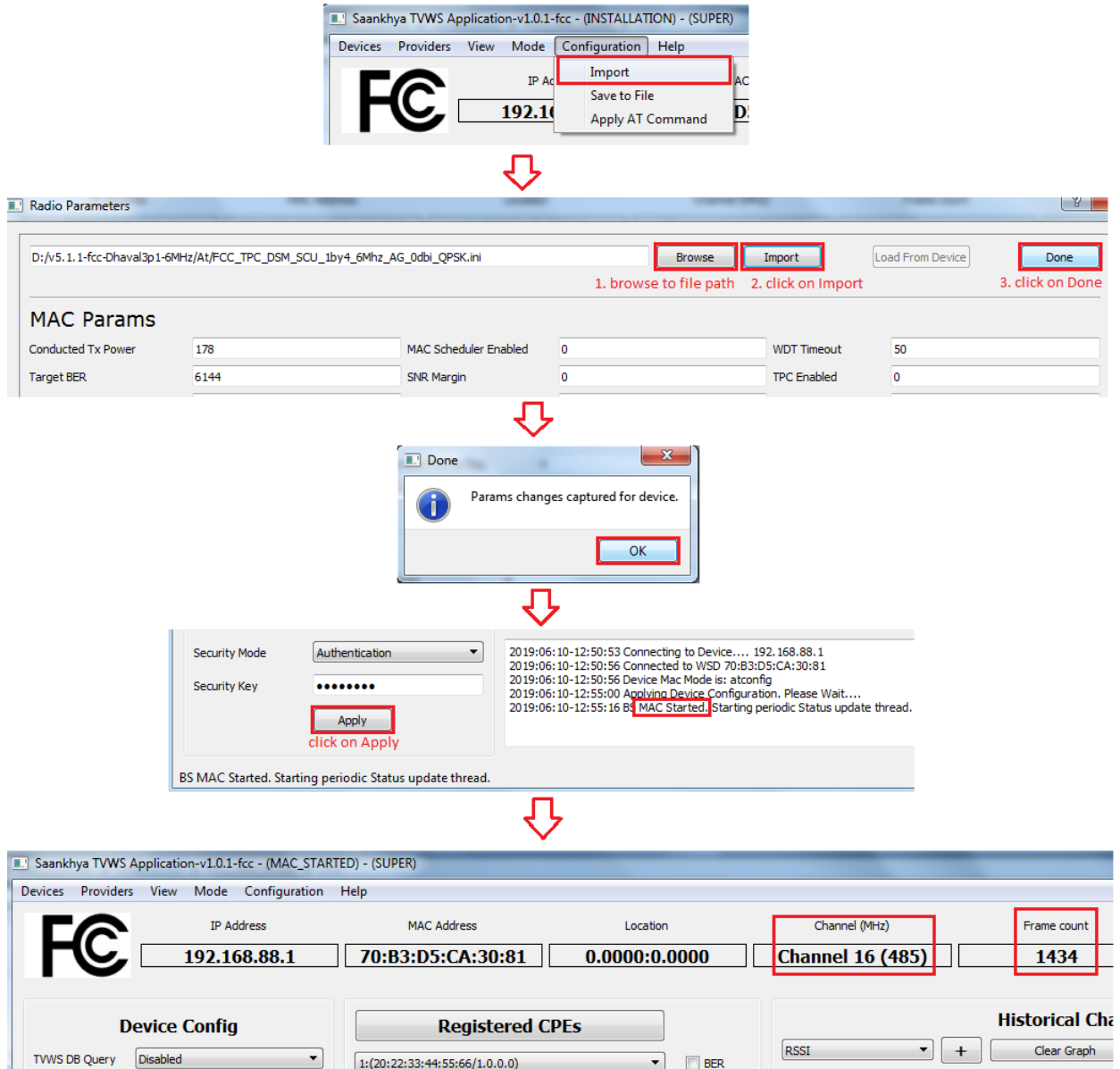


Figure 27 Trigger CPE in FCC mode

11.3 Switch from FCC mode to Normal mode

Follow the steps indicated in Figure 28 to configure the device to Normal mode.

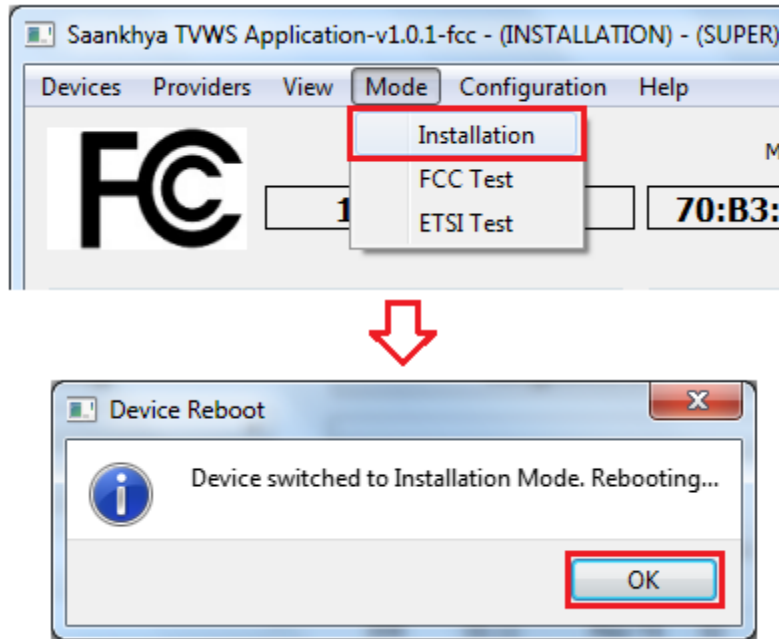


Figure 28 Switch form FCC mode to Normal mode

11) Upgrading Firmware

Firmware upgrade procedure is identical for both BS and CPE. The new firmware is updated on the device via FTP server hosting the release package. The FTP server needs to point to the release package as shown in Figure 29. Follow the steps indicated in Figure 30 to upgrade the firmware.

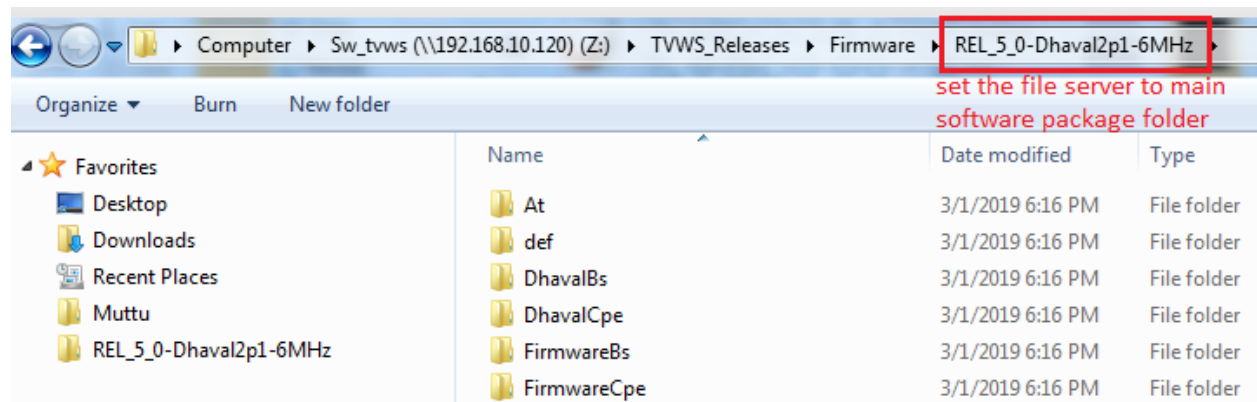


Figure 29 Release package contents and base of FTP server

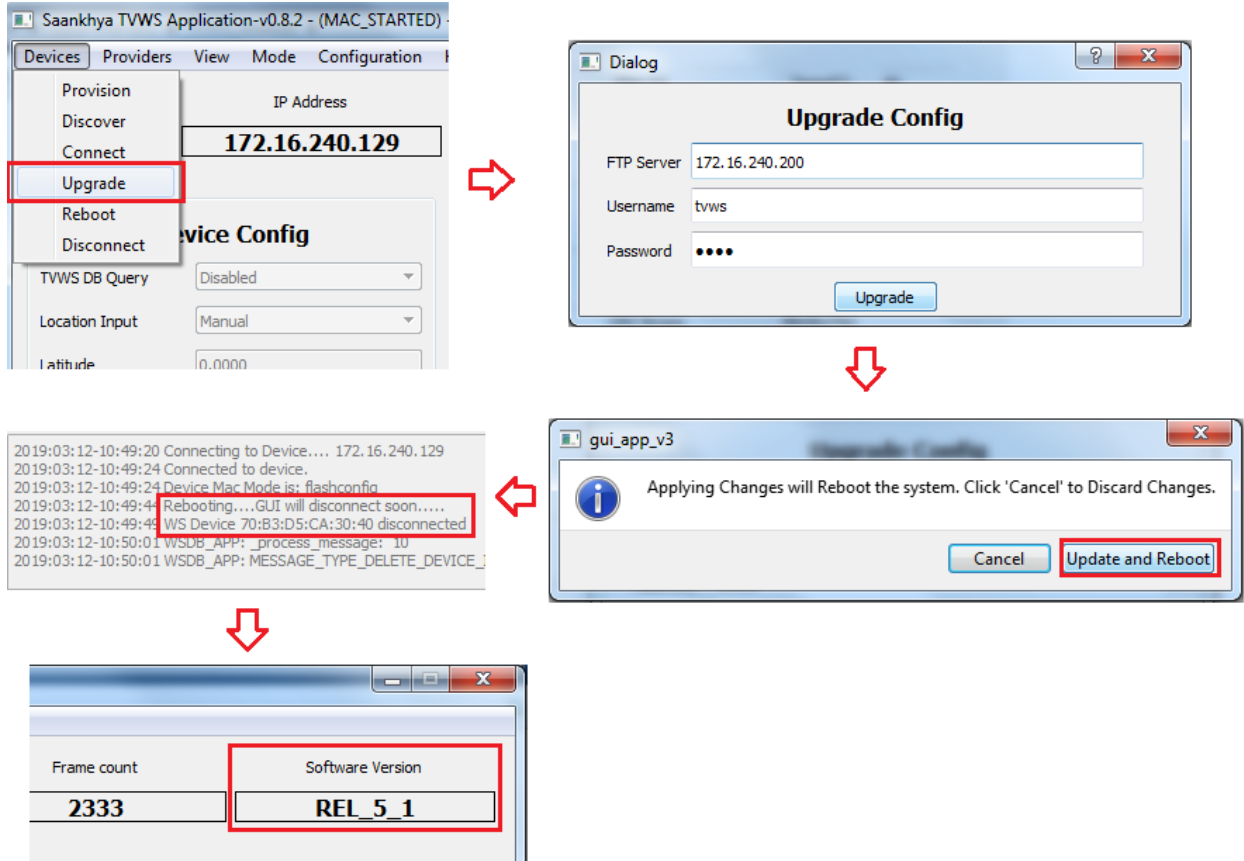


Figure 30 Firmware Upgrade Procedure

On successful upgrade of the firmware, the device comes up with the new version as indicated in the Software version field of the GUI.

Notes:

- 1) The file server should be running on the same IPv4 subnet as that of the PC running the TVWS Application
- 2) Do not try to upgrade CPE package on BS device or vice versa. Doing so might render the device unusable
- 3) Do not try to upgrade an 8MHz package on 6MHz or 7MHz device or vice versa. Doing so might render the device unusable

12) Troubleshooting and Maintenance

12.1 Decoding the LED status

TVWS devices are fitted with 4 LED at the bottom of the panel as shown in Figure 31. Combination of these LED states indicate various states of the system as indicated in Table 1

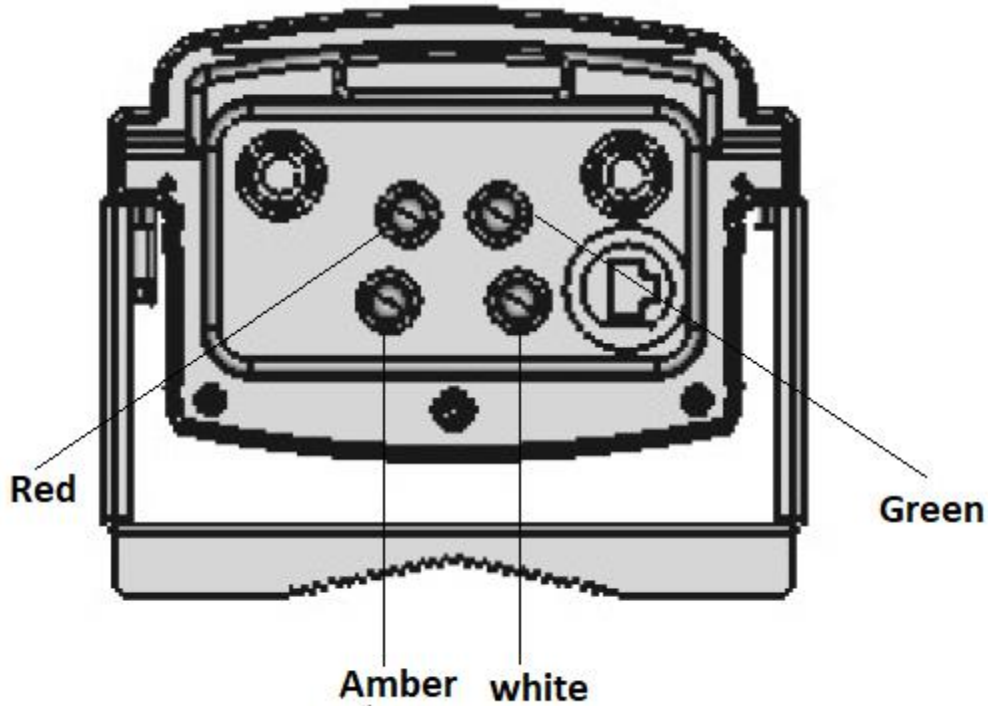


Figure 31 Status LED position and numbering

LED state combination ³				Interpretation
White	Amber	Green	Red	
G	X	X	X	Power ON – indicates if system is powered up
G	B	X	X	GPS signal acquiring
G	G	X	X	GPS signal latched
G	B	X	X	GPS signal acquiring
G	X	OFF	X	NO network connection
G	X	B	X	Network connection acquiring
G	X	G	X	Connected to Backhaul
G	X	X	OFF	System booting up
G	X	X	B	DSP code download in progress or resync occurred
G	X	X	G	Device operational
G	B	B	B	Malfunction... device needs reboot

Table 1LED states

12.2 BER (Bit Error Rate) measurement

This feature allows to measure the BER which helps observe the performance w.r.t channel quality index.

12.2.1 Enable BER

³ G: glow (constant ON), B: Blink, X: Don't care

Follow steps indicated in Figure 32 to start BER measurement.

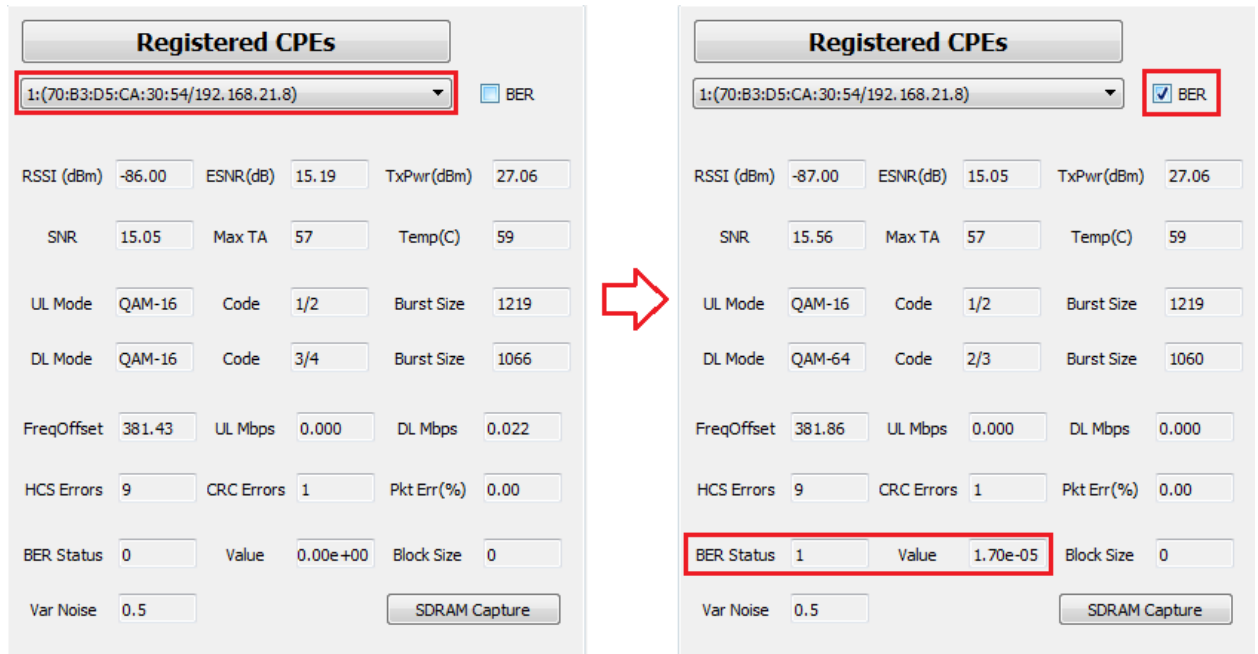


Figure 32 Start BER measurement

12.2.2 Plot BER Historical chart

Refer Section 3.5.2 to start BER plot.

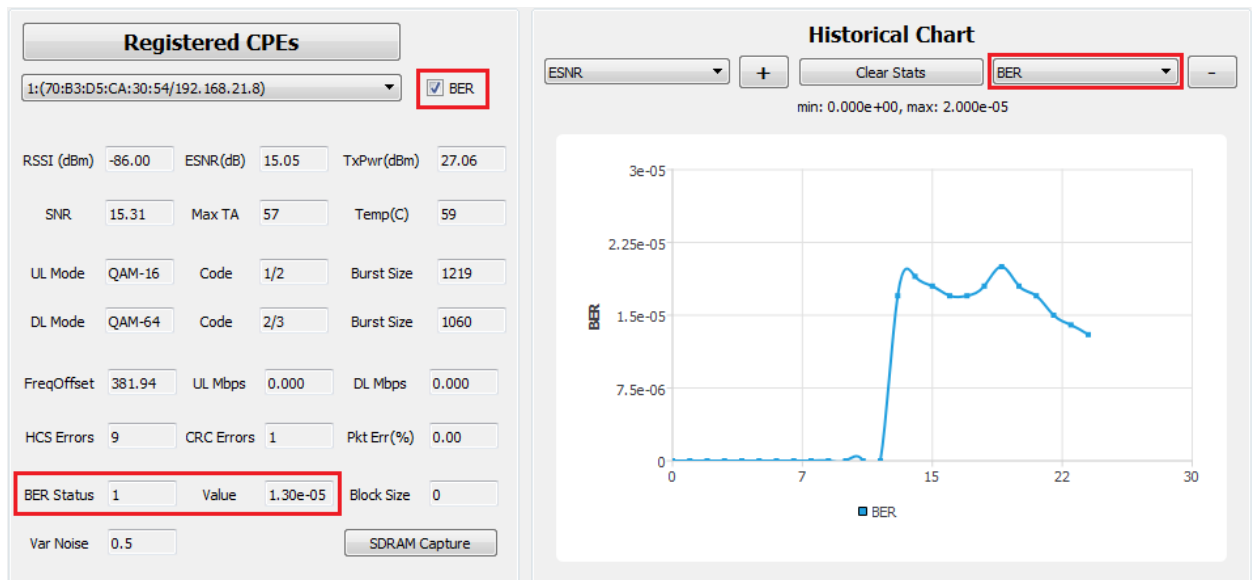


Figure 33 BER Plot

12.3 SDRAM Data Capture

SL SDR chipsets allow capture of the baseband samples to analyze the signal for debugging unexpected scenario and to store them in internal SDRAM. TVWS GUI application provides way of pulling out these samples for further analysis. The procedure for capturing this debug data is shown in Figure 34.

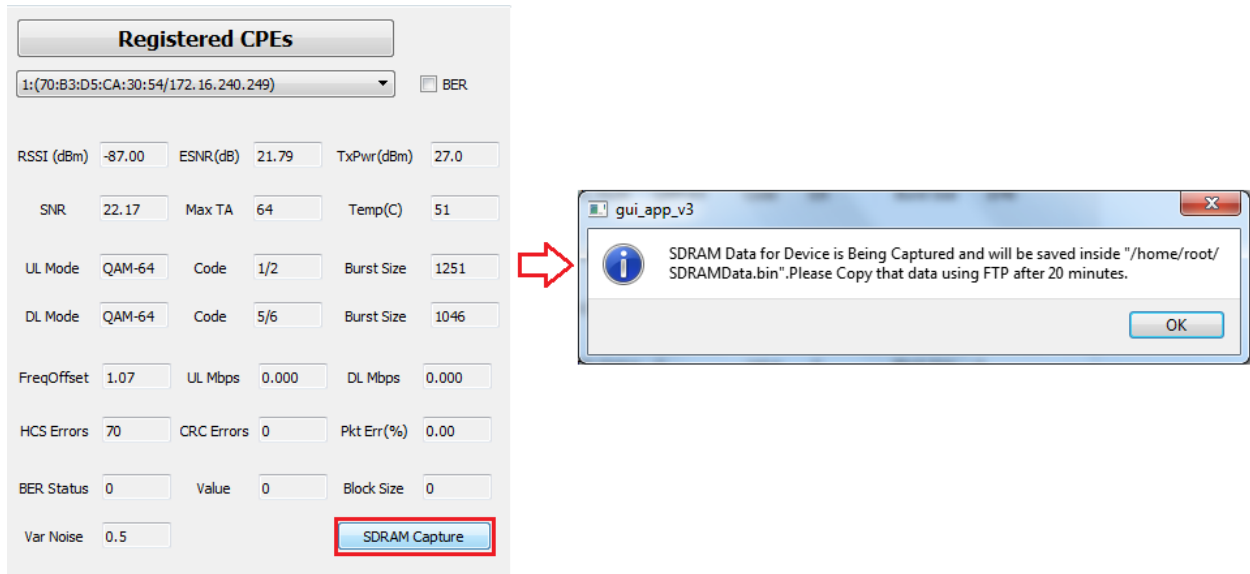


Figure 34 SDRAM Capture Procedure

12.4 TVWS Base Station & CPE GUI Uninstallation

Follow the steps indicated in Figure 35 to uninstall the TVWS GUI Application

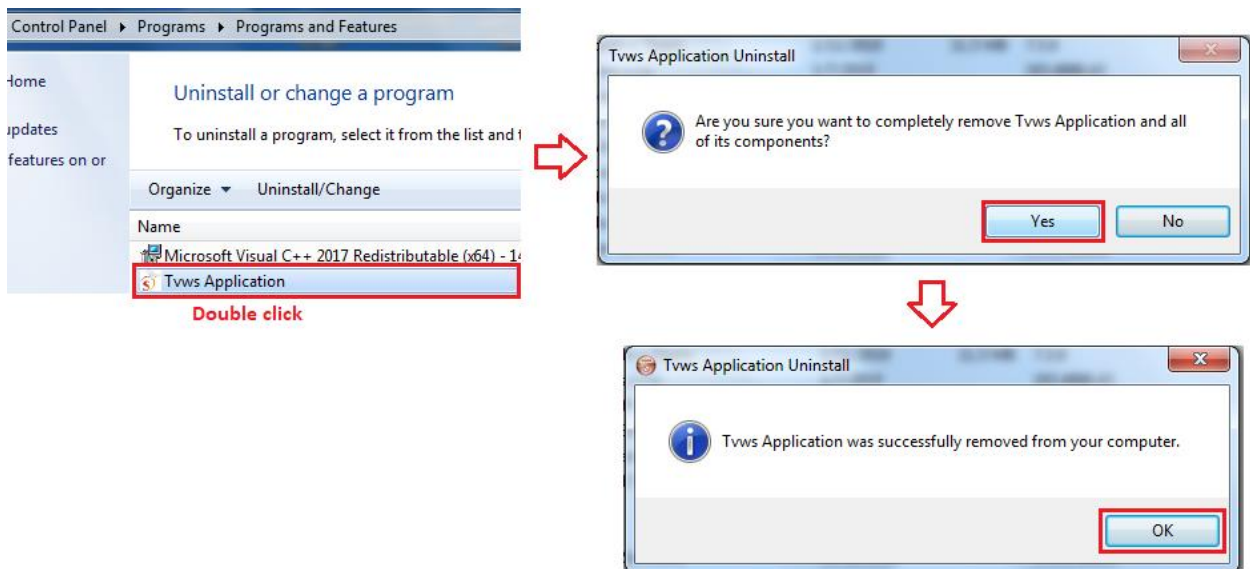


Figure 35: TVWS Base Station and CPE GUI Uninstallation