

SaskTel 5G Innovation Lab

User Guide

SaskTel 

| *Business Solutions* |

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Radio Access Network (RAN) System Description

System Architecture

ENDC refers to E-UTRAN-NR Dual Connectivity. This is a technology that enables mobile devices to simultaneously connect to both LTE (4G) and NR (5G) networks.

Here's a breakdown of what ENDC involves:

E-UTRAN (Evolved Universal Terrestrial Radio Access): This is the technical name for LTE, the fourth generation (4G) wireless communication standard. LTE provides high-speed data transmission for mobile devices.

NR (New Radio): This is the technical name for 5G, the fifth-generation wireless communication standard. 5G networks promise even higher data speeds, lower latency, increased capacity, and more efficient use of spectrum compared to LTE.

Dual Connectivity: This term signifies the ability of a mobile device to maintain connections with multiple networks simultaneously. In the context of ENDC, it means that the device can be connected to both LTE and 5G networks at the same time.

By utilizing ENDC, mobile operators can leverage both LTE and 5G networks to provide better coverage, higher data rates, and improved overall performance for their subscribers. This technology is particularly useful during the transition period from LTE to 5G, as it allows for seamless integration of the two technologies and ensures a smoother migration process for users and operators alike.

A detailed description of the ENDC architecture can be found here: [4G-5G Interworking - White Paper](#).

Frequency Channels

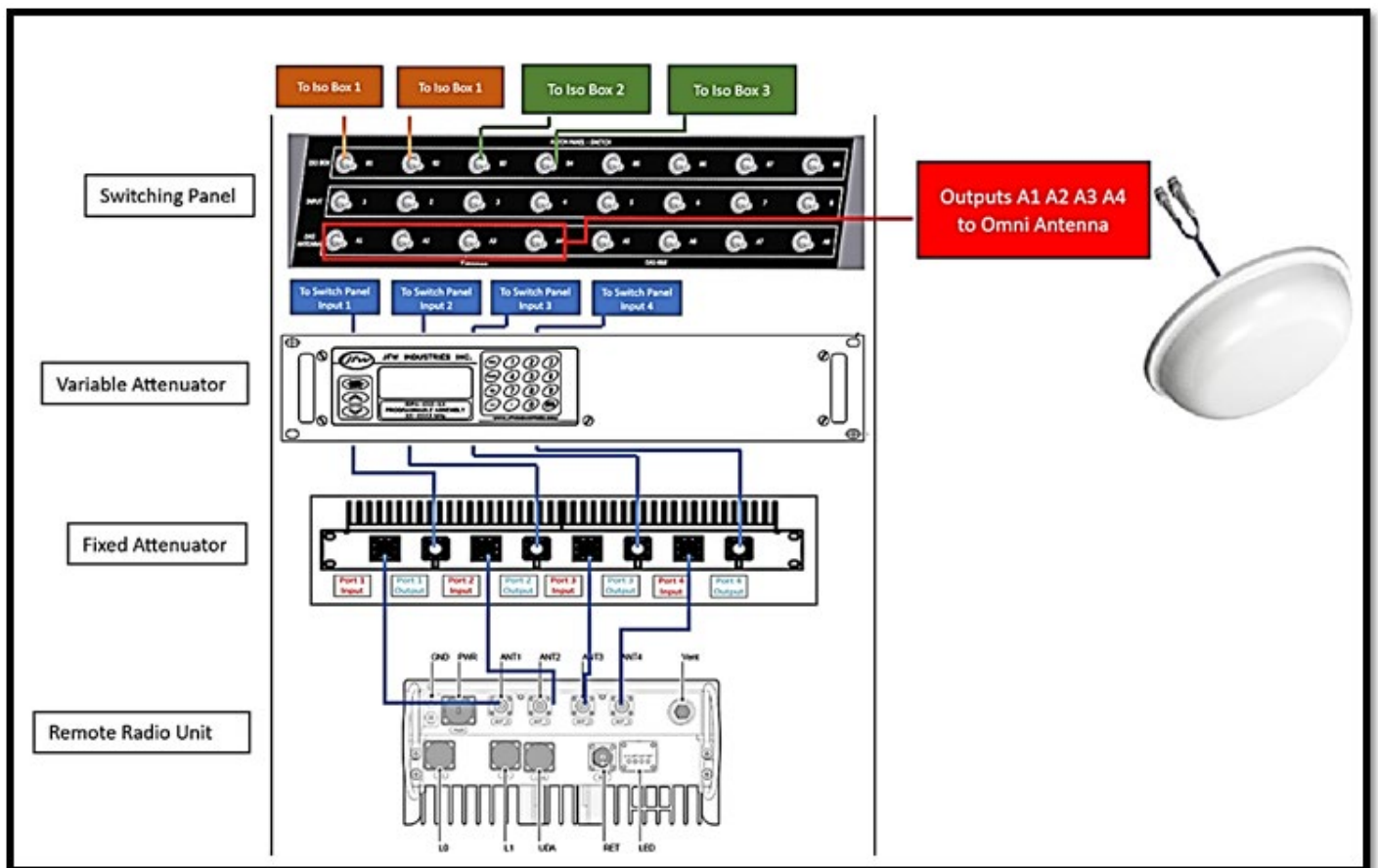
Four frequency channels are being broadcast in the lab: three LTE channels and one 5G channel. The tables below show the frequency band, channel numbers, center frequencies (downlink - DL & uplink - UL) and bandwidth of each channel. The top table applies to the lab in Regina, the bottom table applies to the lab in Saskatoon.

| | | Band | Name | DL Ch Number | DL (MHz) | UL (MHz) | UL Ch Number | BW (MHz) |
|-----|------|------|----------|--------------|----------|----------|--------------|----------|
| LTE | 1900 | 2 | 1900 PCS | 1125 | 1982.5 | 1902.5 | 19150 | 15 |
| | 2100 | 66 | AWS-1 | 66636 | 2130 | 1730 | 20150 | 20 |
| | | 66 | AWS-1 | 66811 | 2147.5 | 1747.5 | 20325 | 15 |
| NR | 2100 | 66 | IMT-2000 | 432530 | 2162.5 | 1762.5 | 352530 | 15 |

| | | Band | Name | DL Ch Number | DL (MHz) | UL (MHz) | UL Ch Number | BW (MHz) |
|-----|------|------|----------|--------------|----------|----------|--------------|----------|
| LTE | 1900 | 2 | 1900 PCS | 1125 | 1982.5 | 1902.5 | 19150 | 15 |
| | 2100 | 66 | AWS-1 | 66686 | 2135 | 1735 | 20200 | 20 |
| | | 66 | AWS-1 | 66511 | 2117.5 | 1717.5 | 20025 | 15 |
| NR | 2100 | 66 | IMT-2000 | 432530 | 2162.5 | 1762.5 | 352530 | 15 |

Hardware

Rack Layout/Wiring Diagram.



Cabinet Digital Unit (CDU)



Source: Samsung

The CDU is the “brain” of the cell site or base station. Think of it like the control center that manages communication between your mobile phone and the network.

Functions of the CDU:

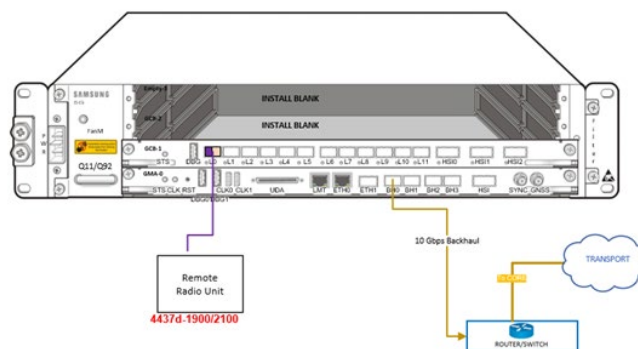
Signal Processing: The CDU handles the original signals (before they get converted to radio waves). It converts these signals from analog to digital and vice versa.

Traffic control: Imagine a busy intersection with traffic lights. The CDU controls the flow of data traffic between hundreds of phones and the network.

Making Sense of Data: When you send a message or browse the internet, the CDU helps make sure your data gets to the right place without getting lost.

For ENDC systems, the CDU integrates the function of both technologies: the eNB for LTE and the DU for 5G NR.

The figure below shows a diagram of the CDU in this lab. The diagram shows the fibre link to the remote radio unit and the backhaul link that connects the CDU to the Core network.

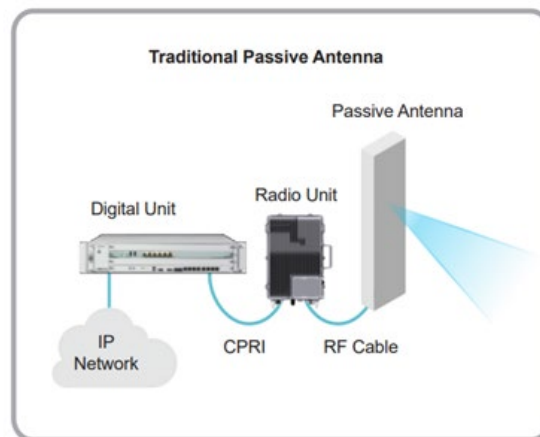


Samsung CDU Wiring Diagram

Remote Radio Unit (RRU)

The RRU is the “radio heart” of a cell site. The RRU is a critical component in cellular networks, especially in distributed base station (cell sites) architectures. Its primary role is to handle the radio frequency (RF) signals that travel between the base station and mobile devices. These RF signals carry voice, data, and other communication traffic.

A fibre link connects the RRU to the CDU, the RF signal out of the radio is transmitted to an antenna through a coaxial cable (RF cable) as shown below:



Source: Samsung

Functions of the RRU:

- **Frequency Conversion:** It converts baseband signals (digital data) from the CDU into RF signals suitable for wireless transmission.
- **Amplification:** The RRU amplifies the weak RF signals received from mobile devices before converting them to digital signals and sending them to the CDU.
- **Noise Filtering:** The RRU filters out unwanted noise and interference to ensure clean and reliable signals.
- **Power Control:** It adjusts the transmission power based on network conditions and user demand.
- **Adaptive Modulation:** The RRU adapts the modulation scheme (like QPSK, 16-QAM, etc.) to optimize data rates and coverage.

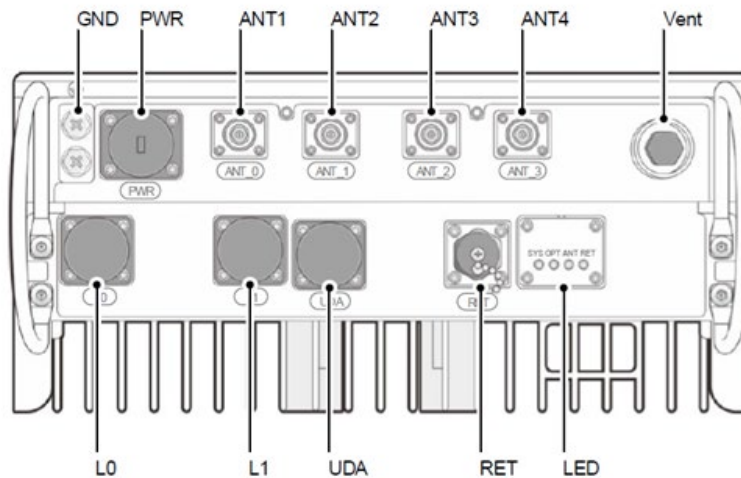
Scalability and Flexibility in 5G:

- In 5G networks, the RRU architecture has evolved. The functional split between the Central Unit (CU) and Distributed Unit (DU) allows for more flexibility. Some RRU's can now handle specific frequency bands or serve specific areas, optimizing network resources.

The lab is equipped with a micro radio unit (mRU). This is a dual-band/dual-technology radio capable of broadcasting and receiving LTE/NR signals in frequency bands B2 and B66/N66. Below is a table with a summary of the specifications.

| | |
|-------------------------------|--|
| Air Technology | LTE, NR |
| Band / Duplex | B2, B66 (B4), n66 (n4) / FDD |
| Frequency range | DL: B2: 1930 - 1995 MHz / B66(B4): 2110 - 2200 MHz |
| | UL: B2: 1850 - 1915 MHz / B66(B4): 1710 - 1780 MHz |
| TRX path configuration | 4T4R |
| Conductive power | 40W (10 W × 4 ports) |
| Input Voltage | 110 V AC (100 to 240 V AC) |

The image below shows a diagram of the different input/output ports available on the mRU.



| Port | Description |
|----------------|---|
| ANT 1 to ANT 4 | RF input/output ports. Signal from each port is a MIMO stream |
| L0/L1 | CPRI port (fibre link to the CDU) |
| GND | Ground |
| PWR | Input Power |
| RET | Remote Electrical Tilt (to control tilt on external antennas) |
| UDA | To monitor environmental alarms (open/close door alarms) |

Passive Components

Variable/Fixed Attenuation

An RF attenuator is a passive device capable of reducing the power of amplitude on an RF signal while keeping its waveform and frequency content intact. Like the way we adjust the volume of a song on the FM/AM radio, the RF attenuator does the same for RF signals. The value of the attenuation is measured in decibals (dB).

In this lab you will find two types of attenuators: fixed and variable. The RF ports of the mRU are connected to the fixed attenuator first. These attenuators are a safeguard, their role is to prevent high power signals from reaching sensitive components (like the isolation boxes).

The fixed attenuator is used in RF systems to reduce the power level of an input signal while maintaining impedance matching and signal integrity.



Example of a Fixed Attenuation Tray (4 Inputs/4 Outputs)

The variable attenuators work just like the volume knob on an FM/AM radio. By adjusting the value of the attenuation, we can control the power of the RF signal that is fed to the omnidirectional antenna or to the isolation boxes. The higher the value of the attenuation, the weaker the RF signal.



Programmable attenuator: each RF path from the radio can be attenuated independently via the front panel or remotely from the Windows PC. RF ports at the back of the unit.

Adjusting the Signal Power Remotely

The programmable attenuator can be controlled remotely via a graphical user interface (GUI). The system is connected to the Windows PC via Ethernet cable.

After opening the GUI (found on the Desktop folder under Variable Attenuator Documents -> 50PA - XXX.exe), the main screen will look like the image below. To establish a connection to the attenuator system, click on "Connect Ethernet" button (top left button), there is no need to change the IP address/port number, this has been pre-configured.

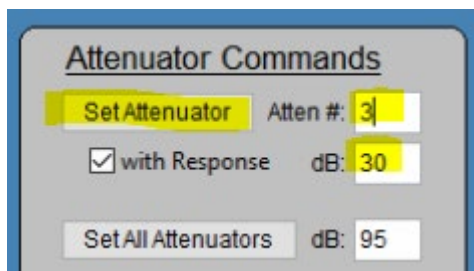


Programmable attenuator GUI

Changing attenuation values

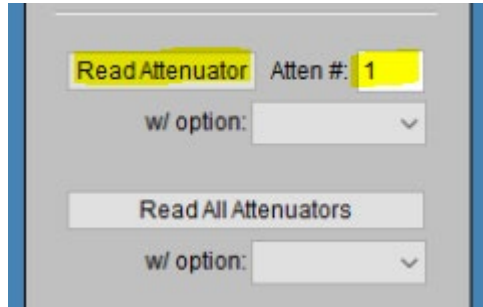
The attenuation tray supports up to 8 RF ports, this means the attenuation value can be modified for 8 different attenuators. At this moment, only the first four ports are being utilized (attenuator #1 to attenuator #4). Note that the RF switching paths must be properly set up to determine which RF port to attenuate (see the Switching Panel section).

To change the value for a given attenuator, the "Attenuator Commands" section of the GUI can be used (gray section of the main screen). Enter the attenuator number and the corresponding value of the attenuation in dB, then click "Set Attenuator". For example, the image below shows the attenuator #3 being set to 30dB.



Example: Setting attenuator #3 to 30dB

If desired, all attenuators can be set to the same value at once, using the "Set All Attenuators" button. To read the current value of any attenuator, enter the number of the attenuator or click on the "Read Attenuator" button as shown below. The value of the selected attenuator will be shown in the "Data Received" section on the main screen. If desired, all attenuators can be read at once, using the "Read All Attenuators" button.

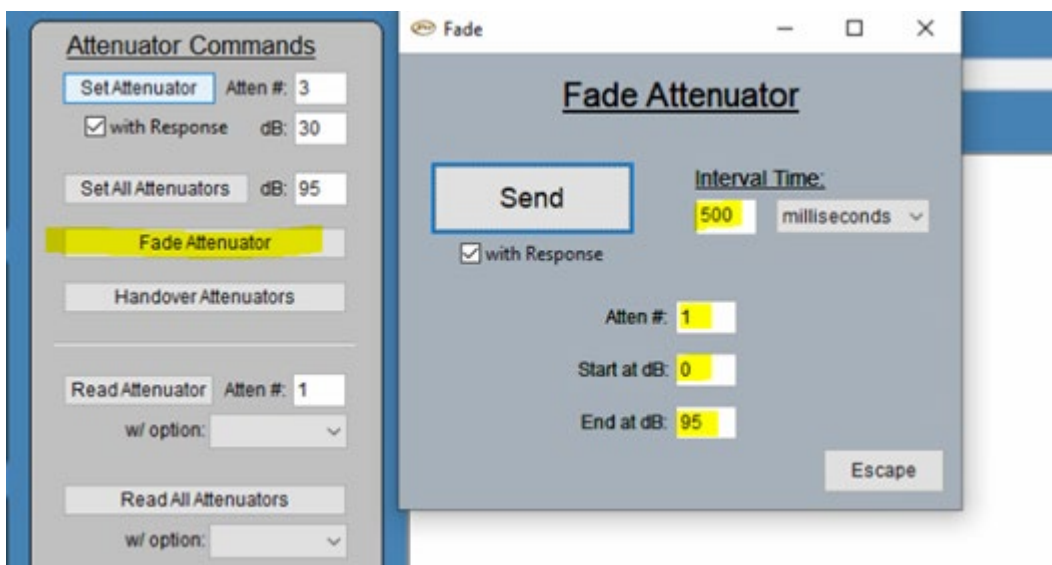


Example: Reading the value of attenuator #1

Simulating Fading

Fading refers to the progressive attenuation (weakening) of a radio signal. For example, in the real world this happens as a receiver moves further away from the transmitter or if an obstacle blocks the direct line of sight between the receiver and the transmitter. Click on the "Fade Attenuator" button found in the "Attenuator Commands" section to open a new window where fading parameters can be set.

To simulate fading of the signal on a given port, simply set the attenuator number, the start value of the attenuation (for example 0dB means no attenuation), the max value of the attenuation (maximum supported value is 95 dB) and set the interval time to determine how fast or slow the fading will occur. After clicking "Send", the attenuation will be changed in 1dB steps from the start to the end value.



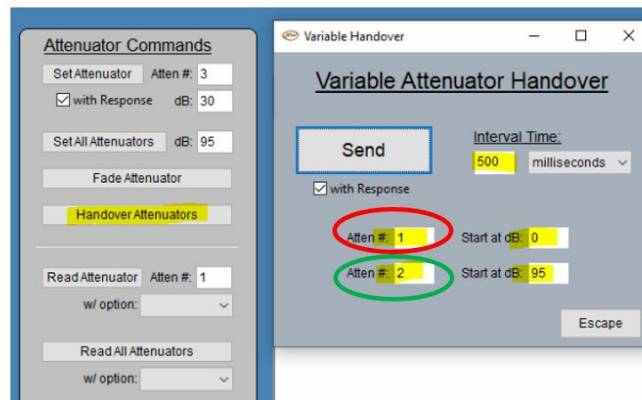
Example: Simulating fading on attenuator #1, starting from 0dB and ending at 95dB in 1dB steps (each step occurs every 500 milliseconds)

Simulating Handovers

A handover is the process of seamlessly transitioning the phone's connection from one cellsite to another. Usually, handovers happen as the mobiles are moving away from the coverage of a cellsite (signal gets weaker) and entering the coverage area of another cellsite (signal from the new cellsite gets stronger). Therefore, to simulate handovers, the values of at least two attenuators must be modified, one attenuator will start from a low value and end at a large value to simulate fading of that RF signal. The other attenuator will be changed in the opposite fashion, starting at a large value and ending at a low value to simulate the signal from the new cellsite getting stronger (the new cellsite is the handover target).

If only two RF ports are involved, then a handover can be accomplished with "Handover Attenuator" window. Clicking on the "Handover Attenuator" button will open the window where two attenuators can be changed progressively (see image below).

To simulate the handover, select the attenuator number of the RF port to fade (circled in red in the image below), then enter the attenuator number of the RF port whose signal will get stronger (circled in green), this is the handover target signal. Then define the start value for each attenuator and the interval to determine how fast or slow the handover will occur.



Example: Simulating a handover. Signal on attenuator #1 will fade with attenuation changing from 0 to 95dB (signal will get weaker). Signal on attenuator #2 will get stronger, its attenuation will change from 95 to 0dB (handover target signal).

Advanced Options

The variable attenuator supports other advanced options, for example the attenuation values can be scripted, and handovers could be executed indefinitely adjusting more than two attenuators at the same time. For more information about these advanced options and script samples, visit: <http://www.jfwindustries.com/pdf/50PA-Description.pdf>.

Switching Panel

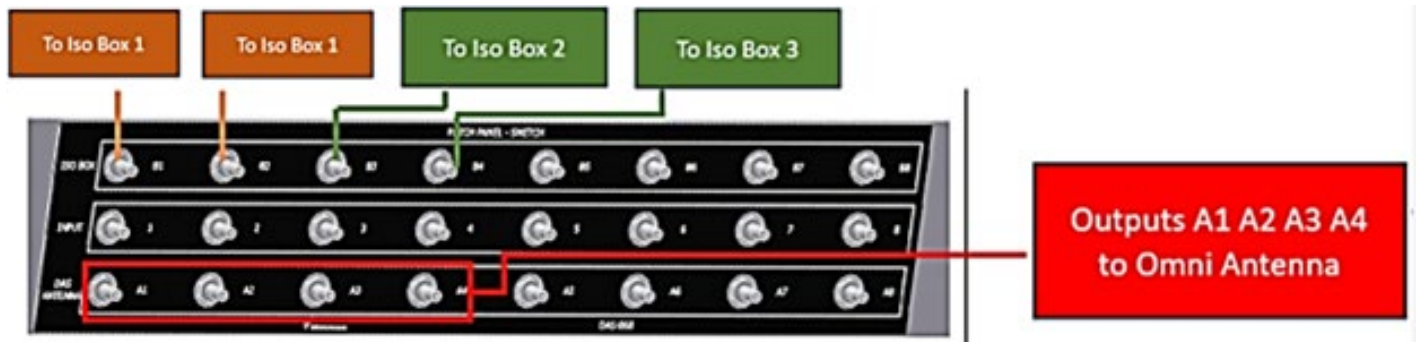
The switching panel is used to manage the flow of multiple RF signals, also known as switching matrix. Imagine an RF switching panel as a traffic controller for radio waves, it works like a smart junction that routes RF signals between inputs and outputs.

The image below shows how the front of the switching panel looks like. The ports are organized in three rows. The top and bottom rows are the outputs, while the input signal is available in the middle row.



RF Switching Panel

The RF signal coming from the mRU is present in the ports in the middle row. With RF cables, we can then connect each input port to one of the output ports depending on where we want the signal to be sent to, the top row sends the signal to the isolation boxes, the bottom row sends the signal to the omnidirectional antenna. See diagram below for details.



RF Switching Panel Layout

Isolation Box

An RF Isolation box, also known as an RF shielded box or RF test enclosure, is a specialized enclosure used in the electronics industry for testing and evaluating RF (radio frequency) devices and components. It provides a controlled environment where RF interference from external sources is minimized, allowing accurate testing and measurements of RF devices without external influences.

These boxes are essential tools in RF testing laboratories, production facilities, and research institutions involved in the development and manufacturing of wireless communication systems and electronic devices.

STE4430

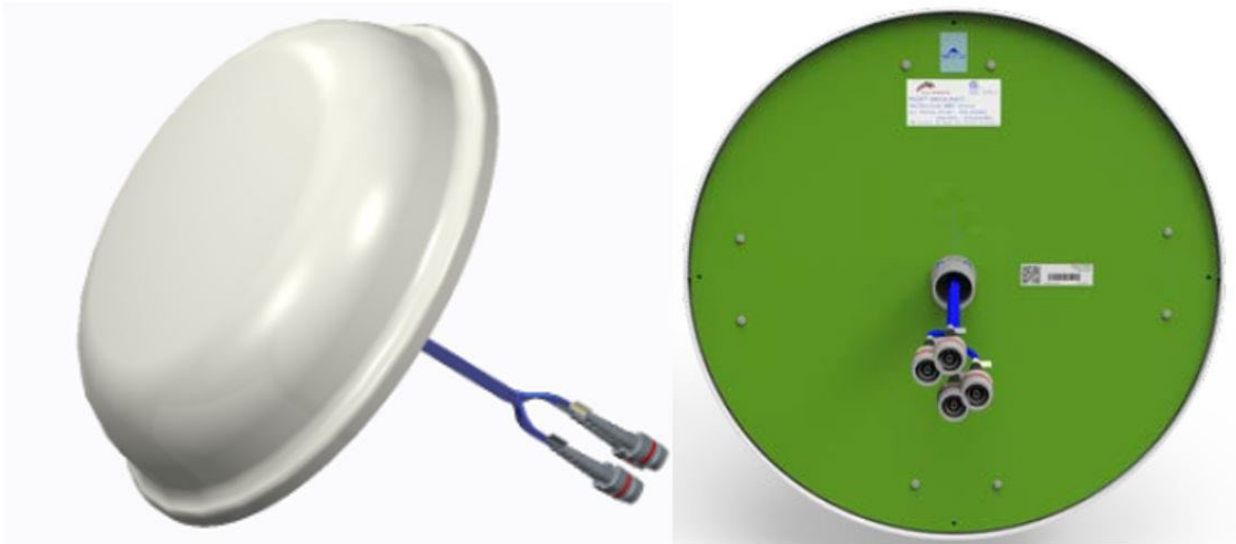


STE4430 - 19" RACK MOUNTABLE RF SHIELDED TEST ENCLOSURE

Omnidirectional Antenna

An omni antenna, short for omnidirectional antenna, is a type of antenna used in wireless communication systems to transmit or receive radio signals in all directions equally. It radiates or captures electromagnetic waves uniformly in all directions around its axis, providing 360-degree coverage horizontally.

PEAR™ GI1604-06837 Omni-Directional Antenna



| Electrical Specifications | | | | | | | | | | | |
|---------------------------|-------------------------------------|-----------|---------|-----------------|-----------|-----------|-----------|-----------|-----------|-----------------|--|
| Frequency Band [MHz] | 617-698 | 698-806 | 806-960 | 1695-1850 | 1850-1990 | 1990-2200 | 2200-2400 | 2405-2700 | 3300-4200 | 5000-6000 | |
| Input Connector Type | 4x 4.3-10(F) Pigtail (17", 43.2 cm) | | | | | | | | | | |
| VSWR (max.) /RL (min.) | 1.8:1 / 11.0 dB | | | 1.7:1 / 12.0 dB | | | | | | | |
| Impedance | 50 Ω | | | | | | | | | | |
| Polarization | Linear | | | | | | | | | | |
| Horizontal Beamwidth | Omni (360°) | | | | | | | | | | |
| Isolation (min.) | 10 dB | 12 dB | | 17 dB | | | | 20 dB | | | |
| Gain (max.) | 5.8 dBi | 6.1 dBi | 5.7 dBi | 5.7 dBi | 5.8 dBi | 7.9 dBi | 7.9 dBi | 7.4 dBi | 8.1 dBi | 9.7 dBi | |
| Gain (avg.) | 4.8 dBi | 4.9 dBi | 5.1 dBi | 5.1 dBi | 5.3 dBi | 6.4 dBi | 6.3 dBi | 6.7 dBi | 6.5 dBi | 8.0 dBi | |
| Max Power / Port | 50 W @77°F (25°C) | | | | | | | | | 1W @77°F (25°C) | |
| PIM @ 2x43 dBm | N/A | <-153 dBc | | | | | | | N/A | N/A | |

RF Cabling Safety Considerations

When disconnecting RF (Radio Frequency) jumpers, it is essential to follow safety regulations to prevent injury to personnel and damage to equipment. Here are some general safety regulations to consider:

- **Power Down Equipment:** Before disconnecting RF jumpers, ensure that all associated equipment, such as transmitters, amplifiers, or radios, are powered down and safely deactivated. This prevents accidental exposure to high-power RF signals during the disconnection process.
- **Wear Personal Protective Equipment (PPE):** It is advisable to wear appropriate PPE, including safety goggles and insulated gloves, especially when working with high-power RF systems. This protects against potential electrical hazards and prevents injuries from accidental contact with live components.
- **Identify RF Hazards:** Before disconnecting RF jumpers, identify any potential RF hazards in the vicinity, such as high-power antennas or transmitters. Maintain a safe distance from active RF sources to minimize exposure to electromagnetic fields (EMF) and radiation.
- **Use Proper Tools:** Use insulated or non-conductive tools when handling RF jumpers to minimize the risk of electrical shock or short circuits. Avoid using metallic tools that may inadvertently come into contact with live RF components.
- **Inspect Jumpers and Connectors:** Before disconnecting, visually inspect RF jumpers and connectors for any signs of damage, wear, or corrosion. Damaged or degraded jumpers should be replaced to maintain signal integrity and prevent potential safety hazards.
- **Proper Disconnection Technique:** When disconnecting RF jumpers, avoid excessive force or twisting, which can damage connectors or components. Use gentle, steady pressure to release connectors, and ensure that the disconnection is performed smoothly to avoid abrupt movements.
- **Secure Disconnected Jumpers:** After disconnecting RF jumpers, securely stow or label them to prevent tripping hazards and ensure easy identification during reconnection.

By following these safety regulations and best practices, personnel can safely disconnect RF jumpers while minimizing the risk of injury and equipment damage in RF-intensive environments

Software Tools

Nemo Outdoor

Nemo Outdoor is a comprehensive drive test tool used in the telecommunications industry to measure and analyze the performance of wireless networks, including LTE (Long-Term Evolution), 5G, and other technologies. It is designed to be used in field testing scenarios, typically involving driving or walking around an area while collecting data on network performance.

Here are some key features and functionalities of Nemo Outdoor software:

- **Data Collection:** Nemo Outdoor allows users to collect various types of data related to network performance, including signal strength, throughput, latency, and coverage. This data is collected using specialized measurement equipment such as smartphones, tablets, or dedicated test devices equipped with GPS receivers and RF measurement capabilities.
- **Drive Testing:** The software supports drive testing, where testers drive predefined routes or areas to collect data on network performance. During the drive, the software continuously collects data from multiple measurement points, providing insights into network performance across different locations.
- **Data Visualization:** Nemo Outdoor provides visualization tools to display collected data in a user-friendly format. This includes maps showing coverage areas, signal strength heatmaps, throughput graphs, and other visual representations of network performance metrics.
- **Analysis and Reporting:** Users can analyze the collected data using various built-in analysis tools. This includes identifying areas with poor coverage or high interference, analyzing handover performance between different cells or technologies, and evaluating the quality of service (QoS) experienced by users. The software also supports customizable reporting, allowing users to generate detailed reports summarizing the test results.
- **Multi-Technology Support:** Nemo Outdoor is capable of testing and analyzing various wireless technologies, including LTE, 5G, 3G, and Wi-Fi. This makes it suitable for network testing in multi-technology environments or during technology transitions.
- **Integration:** The software can integrate with other tools and platforms used in network planning, optimization, and troubleshooting. This includes integration with network planning tools, GIS (Geographic Information System) software, and network management systems.

Overall, Nemo Outdoor is a powerful tool used by SaskTel to evaluate the performance of our wireless network in real-world conditions, identify potential issues, and optimize network parameters to ensure optimal performance and quality of service for users.

*Please see the *"NEMO Innovation Lab User Guide"* for step-by-step instructions.