



Whitepaper

Licensed Narrowband Radio Performance Testing



Introduction

The latest technology of narrowband radios introduces new modulation schemes such as Quadrature Amplitude Modulation (QAM) and advanced Forward Error Correction (FEC) that provide significant radio performance increases over traditional narrowband FSK radios. The purpose of this document is to provide test methods to measure the performance of MDS Orbit licensed narrowband radios (Orbit LN) in laboratory environments. This document can also serve as a guide on, how to perform comparative testing between vendor radios.

Background

When measuring radio performance there's several performance indicators to consider.

Sensitivity – The radio's ability to correctly receive at weaker signal levels. Lower is better. With FEC enabled the radio can reach unprecedented sensitivity performance. Better sensitivity increases the useable range of each supported modulation (4 QAM, 16 QAM, 32 QAM, 64 QAM etc.) and overall network coverage.

Latency – The time it takes to send traffic through the wireless network. Lower latency is better as this allows more traffic to be sent more often.

Point to Point Maximum Throughput – An indication of how well the radio transports application data in the simplest point-to-point configuration. Higher is generally better, but not in all cases. For example, a radio may have excellent point to point throughput at the expense of poor point to multi-point performance as the radios may not participate fairly for channel access.

Point to Multi-Point Performance – The majority of narrowband networks contain numerous remotes connected to a single Access Point (AP), and each remote will have different signal conditions. For example, there may be remotes with very strong signals, and remotes with very weak signals. This test measures how well the radio shares the narrowband channel between strong and weak remotes. This is an excellent indicator of overall radio network performance.

Orbit LN supports several operating radio modes (Standard, Store and Forward, Legacy Packet with MAC, Advanced and Advanced-Polling). The following test methods can be used in any radio mode, however if you are unsure, we recommended using the latest development in Orbit LN radio modes and use Advanced or Advanced-Polling. Advanced Mode is fine tuned for peak data performance whereas Advanced-Polling is tailor-made for maximum density (or large) networks.

What You Will Need

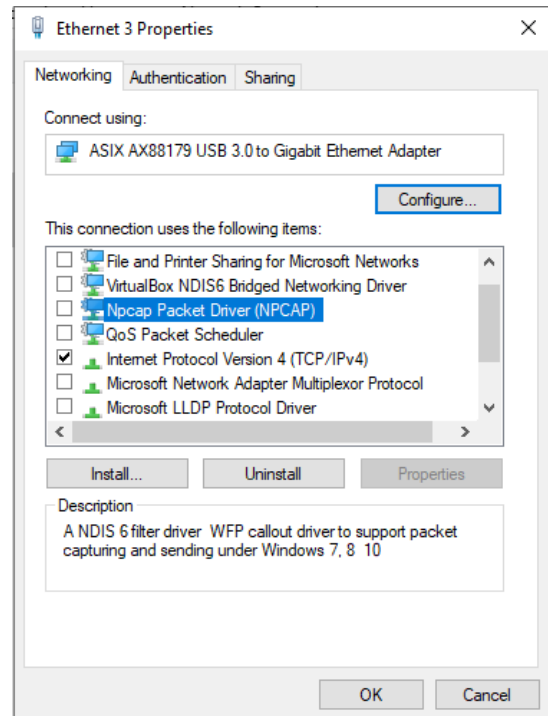
The following equipment will be needed to perform the tests:

- RF Cables
- Fixed (10W rated) and Variable Attenuators
- RF Power Divider supporting unit under test (UUT) frequency (100, 200, 400, 700, 800, 900 MHz)
- PCs or Laptops
- Optional shielded RF test enclosure
- Iperf a network traffic tool for measuring TCP performance.
(<https://sourceforge.net/projects/iperf2/>)
- An ICMP Ping utility. Standard Windows ping.exe works perfect or FPING is a good alternative with more options. (<https://github.com/dexit/fping-windows>)

Test Preparation

The tests require using a PC connected to the radio. If using a Windows PC, it is recommended to disable all properties except Internet Protocol Version 4 (TCP/IPv4), otherwise there will be copious PC generated traffic that will make predicable test results difficult.

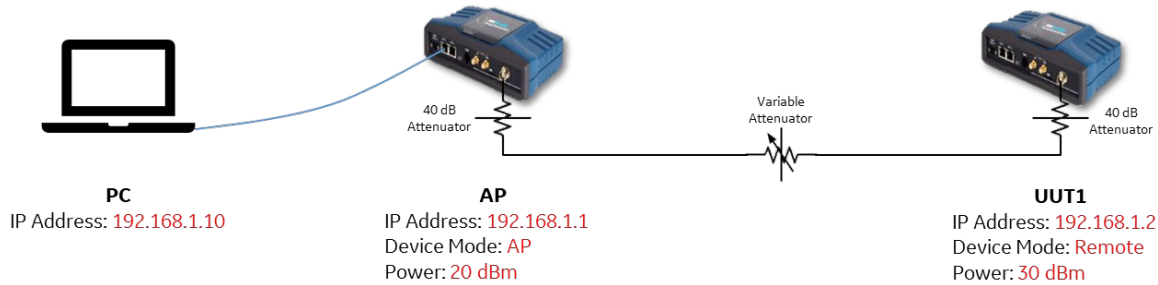
All tests can be performed using any Orbit LN licensed narrowband variant, this includes MPRL fully redundant master station installed with Orbit licensed narrowband modules, or Orbit MCR and ECR radio terminals.



NOTE: Orbit LN is a 10W peak power radio. It is recommended in all testing to protect your equipment, attach a fixed 20-40 dB attenuator on the TNC RF connector of each radio to reduce the output power before connecting to other equipment.

Sensitivity Testing

Sensitivity is a measure of the absolute minimum signal that can be correctly demodulated (decoded) by the radio's receiver and is a key specification used to establish the range and reliability of an RF communication system. Of equal importance to the specifications itself when comparing various radio solutions is the consistency of the methods, criteria, and metrics used for measurement. This is because there are no published standards on how sensitivity is reported which in turn makes referencing datasheets alone a challenge. The following exercise will guide you through an unbiased evaluation of radio receiver sensitivity.



1. Configure each radio and the PC with a unique IP address.
2. Set the Power of the Access Point (AP) to minimum 20 dBm.
3. Set the Power of the Remote to 30 dBm. The remote is the UUT and will be receiving the weaker signal.
4. Set Radio Mode, channel size, and FEC setting as desired on both radios.
5. From the PC open a command prompt and use the PING command to continuously ping the remote radio (-t option).
6. Adjust the variable attenuator, adding more attenuation until you start taking consistent timeouts.
NOTE: Each time you adjust the attenuator this can create an RF "pop" and can potentially cause a timeout, ignore this type of timeout during testing.
7. Record the RSSI (Receive Signal Strength Indicator) of the remote unit, this will be considered our sensitivity metric.

```
C:\>ping 192.168.1.2 -t
Pinging 192.168.1.2 with 32 bytes of data:
Reply from 192.168.1.2: bytes=32 time=55ms TTL=128
Reply from 192.168.1.2: bytes=32 time=49ms TTL=128
Reply from 192.168.1.2: bytes=32 time=61ms TTL=128
Reply from 192.168.1.2: bytes=32 time=63ms TTL=128
.
. (Increase Attenuation)
.
Reply from 192.168.1.2: bytes=32 time=83ms TTL=128
Timeout
Timeout
Timeout
```

```
>show interfaces-state interface LnRadio In-
status last-rx-packet
In-status last-rx-packet last-rssi -85
In-status last-rx-packet last-evm 0
In-status last-rx-packet last-modulation qam64
In-status last-rx-packet rate 120
```

Last Rx Packet

Last RSSI

-85 dBm

Address	IP Address	Time to Live	Link Status	RSSI	Evm	Rx Modulation
00:06:3d:09:b9:db	192.168.1.21	899	associated	-85	0	qam64

Showing 1 to 1 of 1

With regards to sensitivity, Orbit's *Advanced mode* is tuned for high speed performance and does not use as much FEC to reduce overhead incurred. If you want to test maximum sensitivity it is recommended to test *Advanced-Polling* FEC Level 3, or Standard mode with FEC low or auto.

In general, using FEC will increase sensitivity by 3-6 dB depending on the modulation, and will also increase packet sizes by roughly 25% as most FEC rates are close to 0.75 rate block codes.

All modulations can be tested without FEC in a lab environment. However, when deploying live on-air networks FEC is recommended for higher order modulations (16, 32, 64 QAM) to maximize robustness. Otherwise occasional errors will occur over the channel and force the radio to retry, reducing system capacity.

NOTE: Proper isolation is required to achieve sensitivity testing. Ideally an RF Enclosure is used to completely filter any radiated RF power between the units. If this is not available, however, try to maximize the distance between the radios and/or place an attenuating object between the radios such as a large or dense object.

NOTE: If you wish to test the sensitivity of each modulation (4 QAM, 16 QAM, 64 QAM etc.) it is recommended to use radio mode Standard and fix the modulation and FEC (low, auto, none) as needed on both units. (32 QAM is only available in Advanced & Advanced-Polling, see Advanced Config->Modulation Mask for details.)

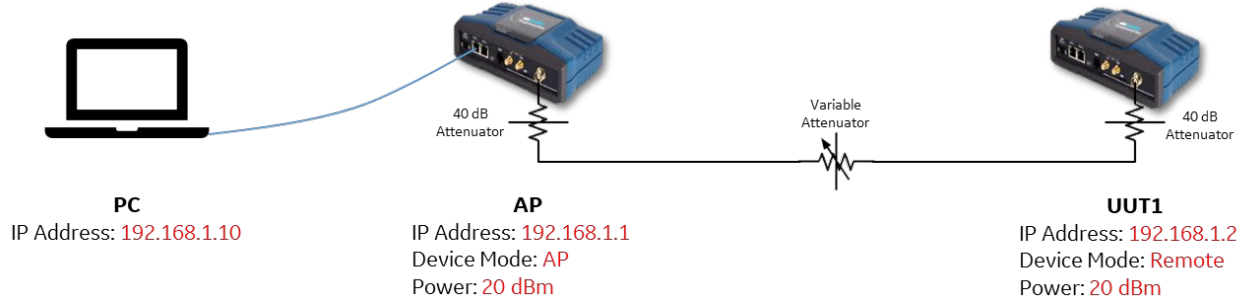
(Advanced and Advanced-Polling can also be tested this way, but these radio modes always have Adaptive Coded Modulation (ACM) enabled and will adjust the modulation automatically as the signal changes. Instead of using timeouts to determine sensitivity you may monitor the average ping latency and record when it increases for 10 or more ping replies, indicating the modulation has changed. This method requires the link to be void of any other IP/Ethernet traffic that could affect ping times. Use NETDUMP feature to verify a quiet link.)

Modulation	Sensitivity (dBm)	FEC
4 QAM		ON/OFF
16 QAM		
32 QAM		
64 QAM		

Template for recording test results

Latency Testing

Latency is a good measure of how quickly the radio can transport application data. Lower latency implies overall higher packet per second (PPS) delivery of the radio, allowing for more traffic to flow through the network at any given time. Keep in mind latency is affected by both radio mode, active modulation, and FEC.



1. Configure each radio and the PC with a unique IP address.
2. Set the Power of the Access Point (AP) to 20 dBm.
3. Set the Power of the Remote to 20 dBm.
4. Set the Radio Mode, channel size, and FEC setting as desired on both radios.
5. From the PC open a command prompt and use the PING command to continuously ping the remote radio (ping [remote-radio-IP-address] -t) .
6. Adjust the variable attenuator until the radio reported Rx Modulation reports the modulation you expect (4, 16, 32, 64 QAM).
7. Wait for the ping time to settle, they should be within +/- 10ms of each successive ping. If you see a sudden increase in ping time(s) this could be indicative of other IP traffic in the network. You may want to filter that traffic in the firewall, or only consider the minimum recorded latency.
8. Record the ping time for this modulation. Keep in mind this is a total Round Trip Time (RTT) from the PC to the AP out to the remote and back.

```

Reply from 192.168.1.21: bytes=32 time=47ms TTL=64
Reply from 192.168.1.21: bytes=32 time=52ms TTL=64
Reply from 192.168.1.21: bytes=32 time=63ms TTL=64
Reply from 192.168.1.21: bytes=32 time=58ms TTL=64
Reply from 192.168.1.21: bytes=32 time=52ms TTL=64
Reply from 192.168.1.21: bytes=32 time=54ms TTL=64
Reply from 192.168.1.21: bytes=32 time=65ms TTL=64
Reply from 192.168.1.21: bytes=32 time=58ms TTL=64
Reply from 192.168.1.21: bytes=32 time=51ms TTL=64
Reply from 192.168.1.21: bytes=32 time=61ms TTL=64
Reply from 192.168.1.21: bytes=32 time=65ms TTL=64
Reply from 192.168.1.21: bytes=32 time=58ms TTL=64
  
```

```

>show interfaces-state interface LnRadio In-
status last-rx-packet
In-status last-rx-packet last-rssi -85
In-status last-rx-packet last-evm 0
In-status last-rx-packet last-modulation qam64
In-status last-rx-packet rate 120
  
```

Address	IP Address	Time to Live	Link Status	RSSI	Evm	Rx Modulation
00:06:3d:09:b9:db	192.168.1.21	899	associated	-85	0	qam64

Showing 1 to 1 of 1

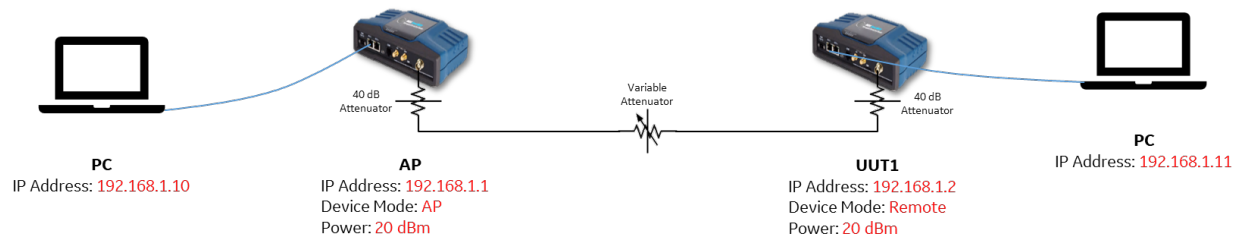
Modulation	PING Latency (ms)	FEC
4 QAM		ON/OFF
16 QAM		
32 QAM		
64 QAM		

Template for recording test results

Point to Point Maximum Throughput Testing

Point to point throughput performance is sometimes a misleading metric. It does provide the maximum expected throughput that the radio will be able to produce. However, it doesn't provide insight on the overall network throughput when multiple traffic flows exist on the network from multiple radios. It is a good metric to keep in mind, but it is not recommended to use this as a primary metric in determining radio performance. Often point to multipoint performance is a better indicator of overall radio capability.

Configured Radio Mode, active modulation and FEC will affect maximum throughput.



To measure throughput, we will be using the tool Iperf. Iperf is a command line tool that measures throughput between a client and server. Depending on who is the client and who is the server you can adjust testing upstream or downstream throughput. If the server is off of (connect to) the remote radio, then you are testing downstream throughput. If the server is off of the access point (AP) you will be testing upstream throughput. We recommend using iperf2 as it is more stable than iperf3 at the time of this publication.

Iperf is a free and robust tool to use for throughput testing but it can provide inconsistent results unless properly configured. By default, Iperf will use the largest TCP window size available as it is expecting a high-speed link. If you use that window size Iperf will send too many TCP packets before the TCP cumulative ACK, and TCP will then back off causing a throughput sawtooth, resulting in throughput thrashing and your results will be very inconsistent. It is recommended to adjust the TCP window size smaller (16Kbyte) which will yield higher and more consistent throughput results, as it avoids the thrashing condition.

We will test with two types of data sets. The first set is Iperf's default data, which is highly compressible. This will show absolute maximum throughput performance with compressible data. The second set is with uncompressible data, such as a data that is already compressed like a .zip or .jpg file. This will provide the maximum uncompressible throughput.

NOTE: *It is recommended to always use Iperf server results versus client results which the latter are calculated before the full Iperf session and tend to be very inconsistent and inaccurate.*

1. Configure each radio and the PC with a unique IP address.
2. Set the Power of the Access Point (AP) to 20 dBm.
3. Set the Power of the Remote to 20 dBm.
4. Set the Radio Mode, channel size, and FEC setting as desired on both radios.
5. Adjust the variable attenuator and ping the remote radio until the radio reported Rx Modulation reports the modulation you expect (4, 16, 32, 64 QAM).
6. On the Server PC start the Iperf server with a 16Kbyte window size
 - a. "iperf.exe -s -w 16k"
7. On the Client PC start the Iperf client with a 16Kbyte window size
 - a. "iperf.exe -c <IP Addr> -w 16k" for the compressible test

- b. "iperf.exe -c <IP Addr> -w 16k -F picture.jpg" for the uncompressible test
8. Wait for the server results to display and record the results.
Ignore the clients results as they are calculated before the entire test is complete and are often inaccurate. The server results are the most accurate and consistent result.
9. It is recommended to run the test several times and record the maximum result.

NOTE: Do not start another Iperf test until the server displays the result. Otherwise you may have two tests running simultaneously and the results will be inaccurate.

PC1> iperf -s -w 16k

 Server listening on TCP port 5001
 TCP window size: 16 KByte

[4] local <IP Addr node2 > port 5001 connected with <IP Addr node1> port 6902
 [ID] Interval Transfer Bandwidth
 [4] 0.0-10.2 sec 640 kBytes **475 Kbits/sec**

PC2> iperf -c 192.168.1.11 -w 16k

 Client connecting to node2, TCP port 5001
 TCP window size: 16 KByte

Modulation	Compressible Maximum (kbit/s)	Uncompressible Maximum (kbit/s)	FEC	Direction
4 QAM			ON/OFF	UP/DOWN
16 QAM				
32 QAM				
64 QAM				

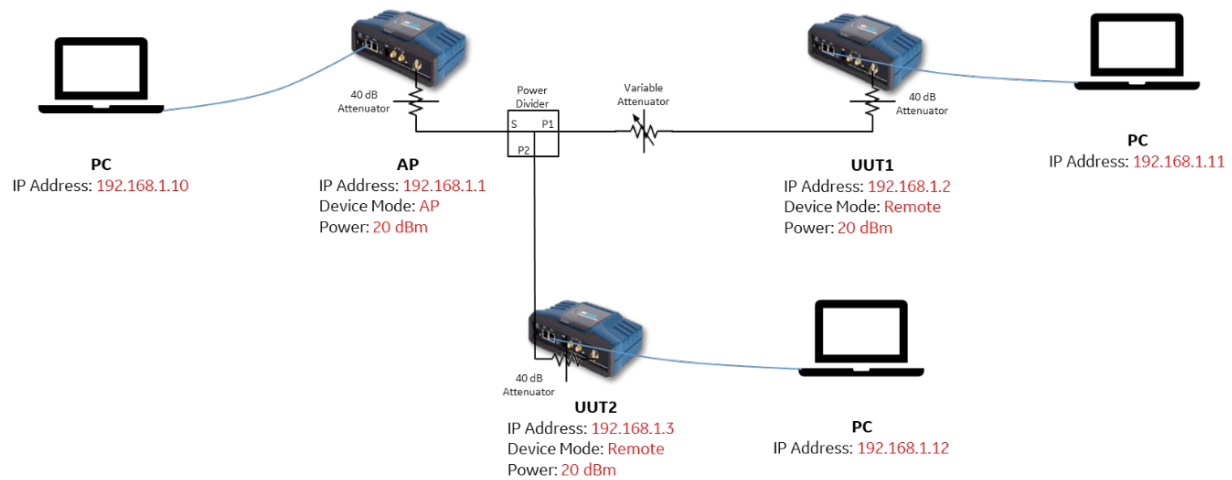
Template for recording test results

Point to Multi-Point Testing

The vast majority of licensed narrowband networks are point to multi-point with many remotes connected to a single AP all sharing channel access between them. Each remote will have it's own unique channel conditions based on its own scatter, distance, antenna height etc. In point to multi-point networks stronger remotes can overpower the signal of weaker remotes, effectively starving them out of channel access. This is especially important in IP networks because there is a high propensity of simultaneous traffic in IP networks, and point to multi-point radio performance is critical. In this test we will highlight the radio's ability to share the channel effectively between a strong and weak signal remote.

We will test upstream transfers with Iperf, so that the remotes are constantly requesting access at the same time. The goal of this test isn't so much the total overall throughput, but how quickly does the radio finish both transfers. This is a good worst-case test scenario with 100% congestion between the two simultaneous file transfers. The stronger signal radio will generally finish first, but the overall time to finish both transfers is the metric of importance. The faster both transfers finish the better point to multipoint performance and overall network performance the radio network will provide.

Configured Radio Mode, active modulation and FEC will affect overall transfer time.



1. Configure each radio and the PC with a unique IP address.
2. Set the Power of the Access Point (AP) to 20 dBm.
3. Set the Power of the Remotes to 20 dBm.
4. Set the Radio Mode, channel size, and FEC setting as desired on both radios.
5. Adjust the attenuation of UUT2 (Unit under test) and ping the remote until the Rx Modulation reports 64 QAM
6. Adjust the variable attenuator of UUT1 and ping the remote radio until the radio reported Rx Modulation reports QPSK (4 QAM).

Address	IP Address	Time to Live	Link Status	RSSI	Evm	Rx Modulation
00:06:3d:09:b9:1b	192.168.1.22	891	associated	-112	0	qpsk
00:06:3d:09:b9:db	192.168.1.21	868	associated	-75	0	qam64

7. On the PC connected to the AP start 2 lperf servers with unique ports and a 16Kbyte window size
 - a. "iperf.exe -s -w 16k -p 5001"
 - b. "iperf.exe -s -w 16k -p 5002"
8. On each remote radio PC start the lperf client with a 16Kbyte window size and send 128Kbytes. Use a file that is indicative of the type of traffic you might expect to see
 - a. "iperf.exe -c <IP Addr> -w 16k -n 128k -F file.log -p 5001"
 - b. "iperf.exe -c <IP Addr> -w 16k -n 128k -F file.log -p 5002"
9. Record the total transfer time reported by the lperf server

 Server listening on TCP port 5001
 TCP window size: 16.0 KByte

[4] local 192.168.1.199 port 5001 connected with 192.168.1.200 port 52184
 [4] local 192.168.1.199 port 5001 connected with 192.168.1.200 port 52408
 [4] 0.0 - **2.7 sec** 128 KBytes 389 Kbits/sec

RX Modulation	Transfer Time (s)	FEC
64 QAM		ON/OFF
4 QAM		

Template for recording test results

Closing Thoughts

When performing comparative testing on licensed narrowband radio systems it is important to do an apples-to-apples comparison by ensuring the systems are configured consistently as explained in this paper. Some vendors ship equipment with defaults ideal only for lab based experimental testing. For example, to maximize ping results in a simple point to point setup. These same radios may perform poorly with these factory default configurations when deployed in-field into a more realistic point to multipoint network. Some vendors, including GE MDS, ship units configured with defaults that are more consistent with in-field environments. Regardless of the vendor, it's advisable to understand equipment factory defaults so that equipment can be properly configured to optimize network performance prior to deployment.

For more information on the MDS Orbit platform, visit:

<http://www.gegridsolutions.com/Communications/catalog/MDSOrbit.htm>

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