VIAVI Solutions

White Paper

NB-IoT: A Practical Guide for Field Testing

Cellular operators worldwide need to be ready for the coming massive IoT market demand. They require a technology that offers global compatibility as well as broad industry support. Narrowband Internet of Things (NB-IoT) is quickly becoming one of service providers' most popular choices.

NB-IoT was designed under 3GPP R13 (June 16) standards and aims to be easily adopted as a technology upgrade to new and existing cell sites (both macro base stations and small cells) that operate 4G today in the form of LTE standards. NB-IoT uses the same frequency bands for which wireless network operators have exclusive use rights, which makes it possible to secure the typical availability and QoS attributes that average customers enjoy today in cellular networks.

For those IoT applications with low to moderate throughput requirements, NB-IoT is thought to provide better coverage and spectral efficiency in challenging environments, particularly when compared to other Low Power Wide Area Network (LPWAN) solutions available in the market.

Notwithstanding those advantages, wireless operators need to ensure that LTE broadband networks and new NB-IoT services coexist in harmony, while maintaining the required quality of experience and service level agreements for each.

This application note discusses best practices for testing new NB-IoT networks in the field and identifying any potential issues associated with intra-network and external interference. It also includes several case studies that highlight familiar challenges when deploying NB-IoT in wireless networks, along with technical solutions and testing requirements that can help mobile operators make sure their networks are ready to deliver appropriate QoS.

These use cases specifically cover the NB-IoT in-band mode.

Overview of an NB-IoT In-Band Signal

NB-IoT signals may present different implementation modes; the most common at this early stage of the technology is the so-called in-band mode.

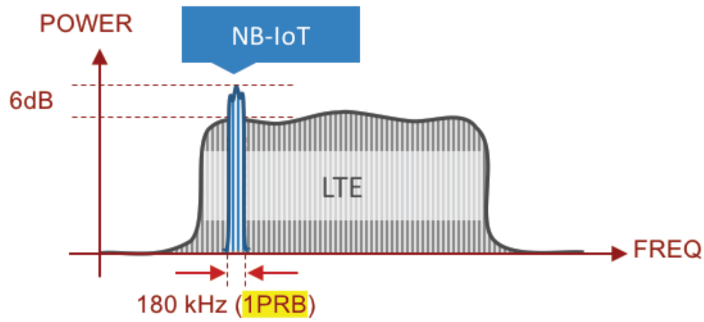


Fig.1 NB-IoT in-band operation

In in-band mode, the narrowband signal occupies 180kHz or basically one physical resource block (PRB) within the LTE broadband carrier spectrum as shown in Figure 1. This leverages the existing 4G radio-access infrastructure and allows mobile service operators to expedite the activation of new IoT services through simple e-Node B (eNB) software upgrades.

Because the NB-IoT carrier is a self-contained network signal that uses a single PRB, when there is no IoT traffic, the assigned PRB available for an NB-IoT carrier may be scheduled for other services as the infrastructure and spectrum usage of LTE and NB-IoT are fully integrated. The base station scheduler multiplexes NB-IoT and LTE traffic onto the same spectrum, which minimizes the total cost of operation for mobile operators, and also scales with the volume of traffic.

The LTE and NB-IoT signals may be seen as a single carrier occupying the given LTE channel bandwidth, where the output power over this carrier is shared between LTE and NB-IoT signals.

The following table shows the different frequency bands that are designated by the 3GPP standards to allocated NB-IoT services in combination with existing LTE spectrum:

NB-IOT Operating Band	Uplink (UL) operating band BS receive UE transmit F_{UL_low} – F_{UL_high}	Downlink (DL) operating band BS transmit UE receive F_{DL_low} – F_{DL_high}	Duplex Mode
1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	HD-FDD
3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	HD-FDD
5	824 MHz – 849 MHz	869 MHz – 894MHz	HD-FDD
8	880 MHz – 915 MHz	925 MHz – 960 MHz	HD-FDD
12	699 MHz – 716 MHz	729 MHz – 746 MHz	HD-FDD
13	777 MHz – 787 MHz	746 MHz – 756 MHz	HD-FDD
17	704 MHz – 716 MHz	734 MHz – 746 MHz	HD-FDD
19	830 MHz – 845 MHz	875 MHz – 890 MHz	HD-FDD
20	832 MHz – 862 MHz	791 MHz – 821 MHz	HD-FDD
26	814 MHz – 849 MHz	859 MHz – 894 MHz	HD-FDD
28	703 MHz – 748 MHz	758 MHz – 803 MHz	HD-FDD

Table1 (Source: 3GPP 36.802, 36.104, 36.211)

Also worth noting for the in-band operational mode is that the NB-IoT standard has allocated a limited list of certain physical resource blocks (PRB) allowed for NB-IoT transmission:

LTE System Bandwith	3MHz	5MHz	10 MHz	15 MHz	20 MHz
LTE PRB indices for NB-IoT synchronization	2, 12	2, 7, 17, 22	4, 9, 14, 19, 30, 35, 40, 45	2, 7, 12, 17, 22, 27, 32, 42, 47, 52, 57, 62, 67, 72	

The power boosting requirement for the NB-IoT signal is the ratio of its power, which again occupies only one PRB of the LTE carrier or 180kHz, compared with the average power over all the broadband carrier (both LTE and NB-IoT).

The minimum requirements for NB-IoT power boosting is +6dB and this should be one of the first measurements to validate in the field for new network implementations.

According to 3GPP Release 13, only one PRB can be boosted +6dB for in-band operation mode (also for guard-band mode and channel bandwidths of 10 MHz, 15 MHz or 20 MHz).

If you are interested in learning more details about 3GPP standard requirements for NB-IoT, the following link provides access to the 3GPP TR 36.802 V13.0.0 (2016-06) release specifications:

http://www.3gpp.org/ftp//Specs/archive/36_series/36.802/36802-d00.zip

Other NB-IoT signal configuration features of interest that are specified in the 3GPP standard are:

NB-IoT Signal Structure

- UL and DL bandwidth of 180KHz (equivalent to one Resource Block or PRB)
- Frequency error is specified to be ±0.1 PPM
- Modulation: BPSK or QPSK (highest)

Uplink Channels/Signals

- Narrowband Physical Uplink Shared Channel (NPUSCH)
- Narrowband Physical Random-Access Channel (NPRACH)

Downlink Channel/Signals

- Narrowband Physical Downlink Shared Channel (NPDSCH) → requires EVM ≤ 17.5%
- Narrowband Physical Broadcast Channel (NPBCH)
- Narrowband Physical Downlink Control Channel (NPDCCH)
- Narrowband Reference Signal (NRS) → subframes 0, 4, and 9
- Narrowband Primary/Secondary Synchronization Signal (NPSS and NSSS) → includes Cell ID

This document contains several references to the Error Vector Magnitude (EVM) metric. EVM is a measure of the modulation quality and error performance in the transmission or reception channels of complex wireless systems, including LTE and the new NB-IoT signals. EVM is essentially the difference between the ideal transmitted signal and the actual received (measured) one.

EVM is a very useful indicator of the signal quality (as a function of noise, interfering signals, distortion and even traffic load). Note EVM is typically expressed in dB and the 3GPP standards provide references for acceptable EVM values on a number of different transmission channels within an LTE frame period.

Later in this document we will review the specific measurements that we can apply to each of the above data, control and synchronization channels and how we can validate that they are compliant with the 3GPP requirements for Error Vector Magnitude (EVM) and other compliance metrics, to secure NB-IoT optimal performance.

A First Look at the Associated LTE Carrier

When analyzing an NB-IoT in-band signal, a best practice is to start the testing routine with an initial validation of its associated LTE broadband carrier: from the overall RF shape to a more detailed demodulation analysis, including allocation of resource blocks, etc. A successful validation of the overall LTE carrier performance will secure the best conditions to proceed next with a more detailed analysis of the new NB-IoT signal.

A major consideration when validating an NB-IoT signal in the field is to understand thoroughly the possible impact this new signal might inflict to the existing LTE carrier that has been normally broadcasting from the base station (eNodeB in LTE terminology) prior to the activation of the new IoT service. Whether the new NB-IoT signal is a potential aggressor (or the victim) to the LTE carrier, there are different scenarios to consider if we are operating in in-band, guard-band or standalone modes.

For NB-IoT in-band mode, the uplink path is the most sensitive in terms of co-located interference issues, and thereby is where network performance might be impacted the most.

Spectrum Analysis

Based on the simple characteristics of a narrowband signal as described in the previous section, one of the first steps to follow when testing a NB-IoT transmitter is to verify the signal behavior in the RF environment through a classic spectrum analysis view:

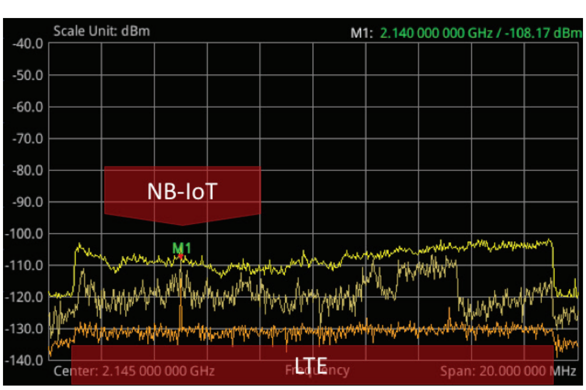


Figure 2 - LTE & NB-IoT Downlink Spectrum

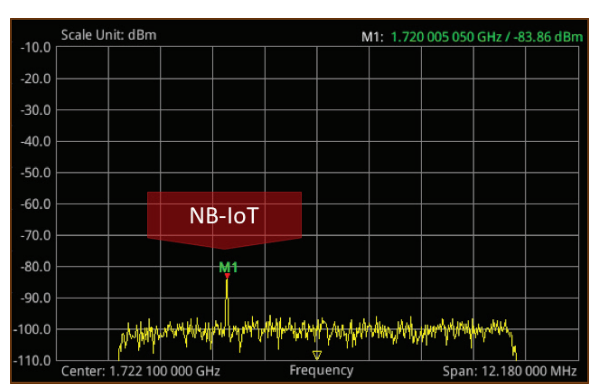


Figure 3 - LTE & NB-IoT Uplink Spectrum

Note the downlink capture above shows the LTE signal with both Max and Min Hold averages, a very convenient form of visualizing the maximum and minimum values of a real-life LTE signal through time.

This simple validation for the presence of the NB-IoT signal will allow us to verify the downlink RX power and SINR values, particularly in locations with coverage issues.

Note that for guard-band of standalone modes, it is important to distinguish between the NB-IoT signal and any other potential GSM carrier operating in that given location, given both type of RF signals have nearly identical bandwidth, though not the same shape.

Cell ID Analysis

Modern base station analyzers like the VIAVI CellAdvisor™ platform offer Cell ID scanning capabilities that can show the LTE reference signal signal-to-noise ratio (RS-SINR), which is a good indication of potential existing interference and other cell performance considerations. In real-life conditions with neighboring LTE cells sharing the same RF frequency but separated by the Cell ID code, a given UE (e.g. a smartphone) will receive signals from all the cell sites sharing the same RF frequency, which will pollute the LTE pilot channels and symbols. The RS-SINR value measures the amount of reference signal interference (pollution) received:

Figure 4 - Example channel analysis for Cell IDs #109 and #319

Ideally, we would like to measure RS-SINR values greater than +10 dB for the Cell ID of interest that has the NB-IoT service activated. For example, Cell ID #109 in Fig. 5 shows a value of 16.88 dB which indicates to the user that we have optimal test conditions to proceed with further analysis; whereas, for Cell ID #319 in the same example, the measured value is 7.46 dB, and would not provide favorable conditions to make further confident measurements, particularly for a more sensitive NB-IoT (in-band) signal. As a rule of thumb, RS-SINR values above 10 dB trigger a higher confidence for carrying out stable signal analysis measurements for LTE and for NB-IoT in-band mode in particular.

Datagram Analysis

Spectrogram views are another great resource to monitor the progression of RF signals over time, which is particularly useful for validating power levels of the narrowband signal in comparison with the broadband LTE carrier:

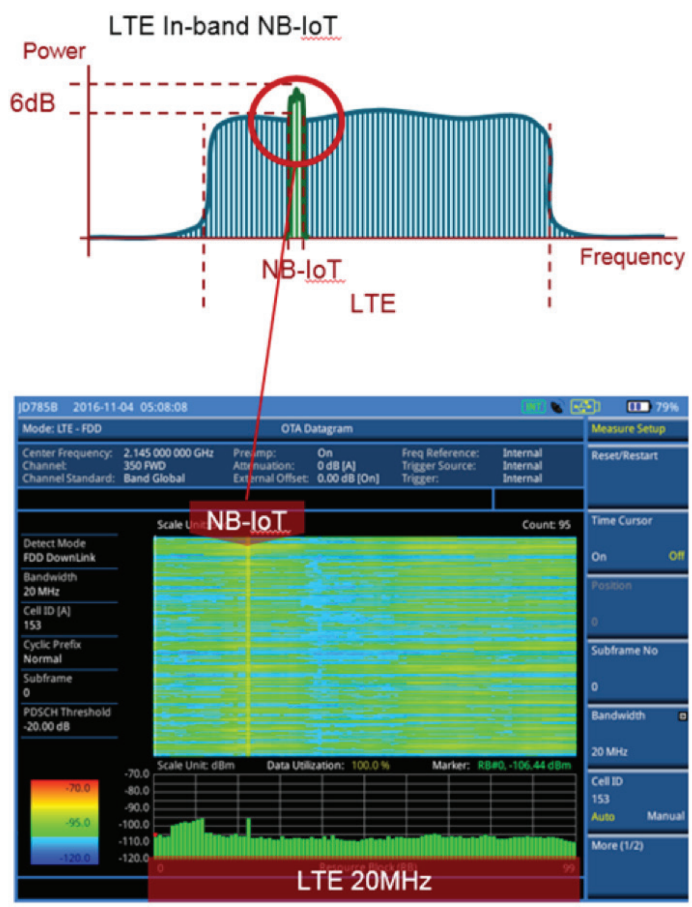


Figure 5 - Datagram view for LTE & NB-IoT (in-band) downlink PRBs

Note Fig. 5 above is showing a spectrogram view in LTE Datagram mode. This allows the user to quickly identify and monitor over time the given resource block (PRB) that the NB-IoT signal of interest is specifically using.

The NB-IoT PRB power dynamic range (also referred as NB-IoT power boosting) is the difference between the power of the NB-IoT carrier (which occupies one PRB of LTE carrier in-band or 180kHz in guard band) and the average power over all carriers (both LTE and NB-IoT).

As per 3GPP standard requirements, NB-IoT power dynamic range shall be larger than or equal to +6dB

As a matter of fact, that reference of +6 dB for power dynamic range is required for both in-band and guard-band operation modes.

LTE Data Allocation Map

Another useful alternative for identifying the specific PRB that is configured to provide NB-IoT in-band service, is to use a data allocation map feature available with the VIAVI CellAdvisor toolset.

A data allocation map quickly shows the actual utilization of LTE PRBs, including those allocated for the new NB-IoT service:

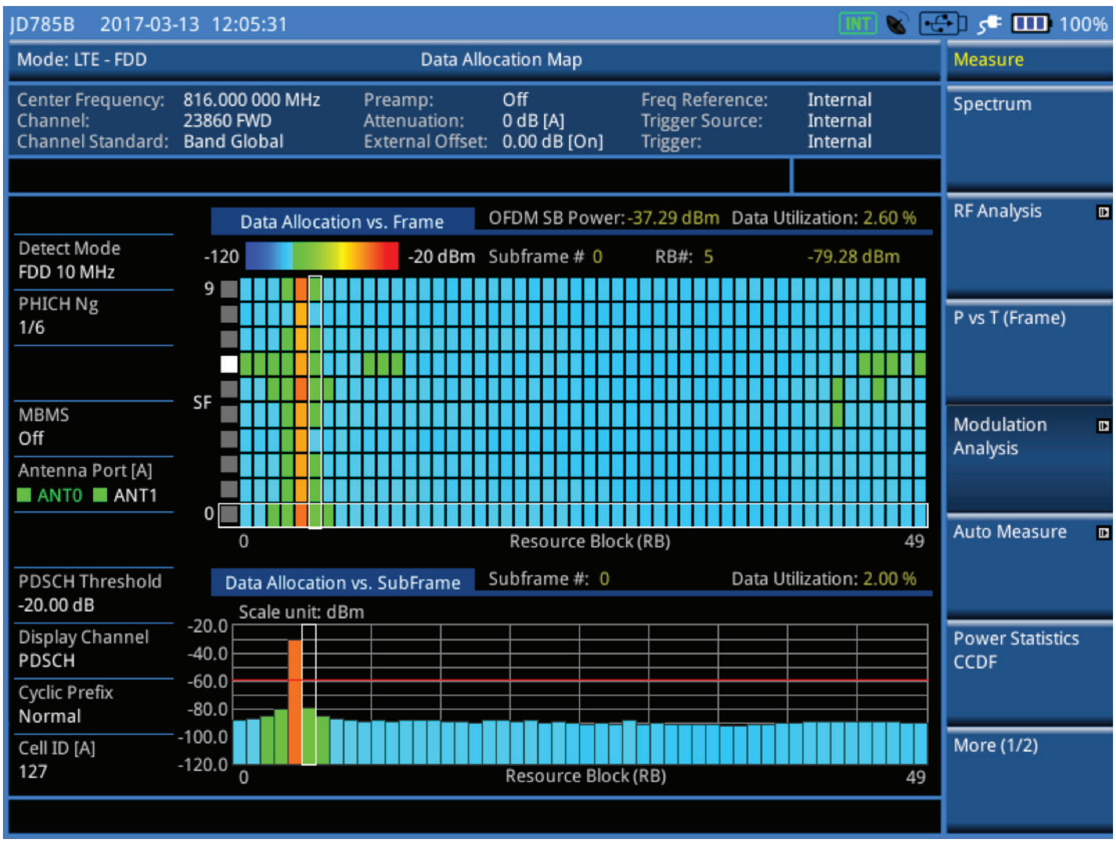


Figure 6 - Data Allocation Map

The Data Allocation Map in Fig. 6 shows the utilization status of each PRB in one full frame (10 milliseconds); the graphic presentation allows the technician to easily deduce which PRB is active. This is a very effective way to quickly validate the given active PRB that is assigned to the NB-IoT signal.

LTE Control and Synchronization Channels

One additional aspect to consider is the overall performance of the given LTE control channels. For example, in typical NB-IoT in-band configurations, the narrowband signal will share the same synchronization channels as the LTE carrier frame. While this may not always be the case, it has nevertheless been the most common scenario in early implementations of NB-IoT in-band technology so far.

VIAVI CellAdvisor provides signal analysis capabilities to demodulate the LTE carrier and perform a quick assessment for the performance of the control and data channels:

Channel	EVM (%)	Power (dBm)	Modulation Type
P-SS	1.11	-27.65	Z-Chu
S-SS	1.38	-27.66	BPSK
PBCH	1.08	-27.64	QPSK
PCFICH	1.12	-27.63	QPSK
PHICH	-0.00	-71.44	BPSK
PDCCH	----	----	QPSK
RS	1.08	-27.66	QPSK

Figure 7 - LTE Control Channels

Figure 8 - LTE Data Channels (PDSCH)

A Data Channel measurement can also show the power, modulation format, and EVM of each individual PRB to prove any potential interference to the other neighboring resource blocks.

This can be very useful because an NB-IoT signal really occupies only a single PRB, so this Data Channel analysis allows technicians to understand and identify any possible inter-PRB distortion problems.

By first validating that the LTE carrier presents optimal conditions for transmission power, resource block allocation, and control/data channel performance, we can proceed more confidently to the next stage and carry out a similar set of measurements over the given NB-IoT in-band signal associated with that LTE carrier.

Section Summary

Validation of the new physical channels and signals introduced in the downlink and uplink are necessary to ensure NB-IoT is not causing interference in the existing LTE network and vice versa.

The simple tests previously described allow technicians to validate the presence of the NB-IoT signal, and that both the broadband LTE and the narrowband NB-IoT carriers are being properly broadcasted in the RF environment, with correct power or noise levels, and within appropriate thresholds.

Particularly, by using the effective Datagram analysis with VIAVI CellAdvisor analyzer, the corresponding narrowband Resource Block can be identified, and a more advance demodulation analysis on the NB-IoT (in-band) signal of interest can be performed.

A Closer Look at NB-IoT (In-Band) Signal Quality

Network Performance Optimization

As previously mentioned, for NB-IoT service launch, inter-PRB interference is a key concern and one of the first verifications to carry out when validating the new narrowband service in the field.

Field technicians conducting commissioning and regular maintenance or troubleshooting need a test solution to verify potential inter-PRB interference.

As stated earlier, it is useful is to have a Data Allocation Map view that graphically shows the utilization status of each PRB in one full LTE frame to quickly identify which PRB is active at any time or even interfering with other adjacent PRBs.

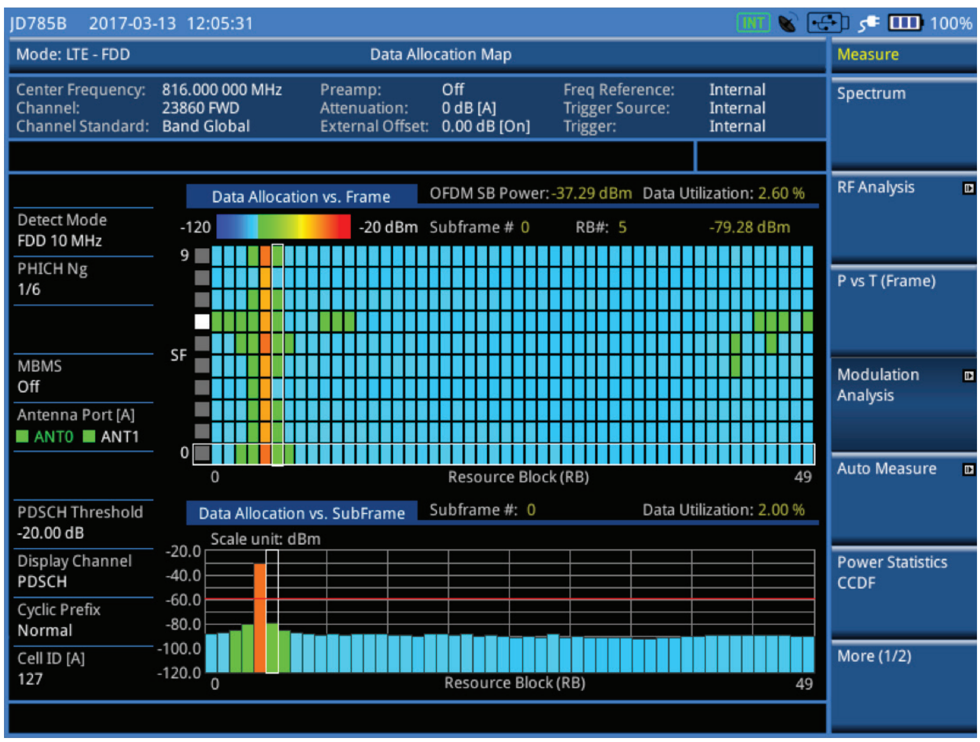


Figure 9

Figure 9 shows some spurious emission to the neighboring PRB. This interference impacts the signal quality of the neighboring channel (and vice versa, as multiple PRBs belonging to the LTE transmission can also impact the NB-IoT channel quality).

Reference Signal Analysis

One common procedure for measuring signal quality is analyzing some of the so-called Reference Signals of an LTE carrier. During normal network operation, both the eNodeB and the UE continuously measure signal quality using these Reference Signals. For example, the eNodeB calculates the UE-transmitted signal quality by measuring UE Reference Signals, and by requesting Channel Quality Indication (CQI) feedback from the UE and other performance indicators.

Narrowband Reference Signal (NRS)

One effective way to start assessing the NB-IoT signal of interest is by looking in more detail at the signal quality of the downlink Narrowband Reference Signal (also referred as NRS).

The Error Vector Magnitude (EVM) measurement as described in a previous section is a good starting point for verifying that the NB-IoT signal is being correctly transmitted from the eNodeB element (base station).

The 3GPP standards specify an NRS modulation requirement of EVM ≤ 17.5%, which can be easily validated with a dedicated analysis view like the one available with VIAVI CellAdvisor:

Figure 9 - NB-IoT (in-band) Signal Quality and Modulation Analysis

The above EVM test should be performed for each NB-IoT carrier over all allocated resource blocks and downlink subframes within 1 millisecond measurement periods (see Fig.10).

Keep in mind that the narrowband reference signals shall not be transmitted in sub-frames containing NPSS or NSSS sync channels.

NB-IoT In-Band Subframe Measurements

Although NB-IoT is integrated into the LTE standard, it can be considered a new air interface and thus not fully backward compatible with existing 3GPP devices.

A deep analysis of the NB-IoT frame structure is beyond the scope of this application note, yet it is always convenient to have a quick look at the signal frame and subframe configurations to understand the type of metrics and quality indicators that we can obtain by measuring a given subframe type:

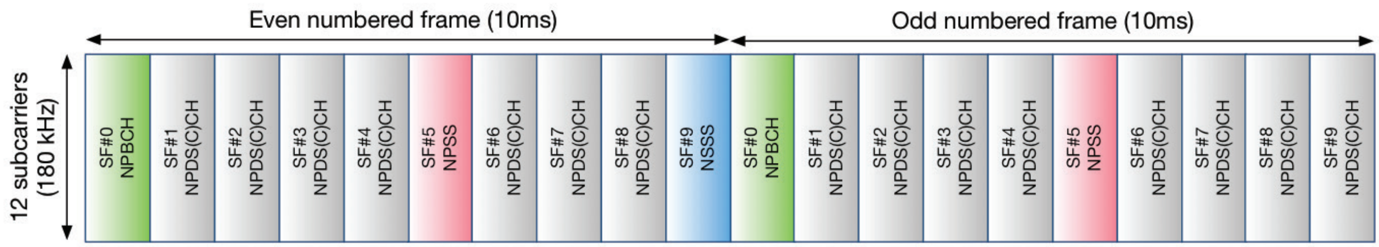


Figure 10 - NB-IoT Frame Structure. Note physical channels and signals are primarily multiplexed in time.

The NB-IoT subframe spans over one PRB (i.e., 12 subcarriers) in the frequency domain and 1ms in the time domain.

For example, when considering subframe #0, we will be able to perform an analysis of the NB-IoT NPBCH (Narrowband Physical Broadcast Channel) downlink control channel. A separate analysis on subframes #1 to #4 can provide a measure for quality of the NPDSC(S)CH (Narrowband Physical Downlink Control or Shared Channel), where the 3GPP standard has a specification for the EVM value to be ≤ 17.5%, which can be easily verified by configuring VIAVI CellAdvisor to look into each individual subframe number:

Figure 11 - Subframe #0 measuring NPBCH

Figure 12 - Subframe #1/2/3/4 measuring NPDSC(S)CH

VIAVI CellAdvisor can measure the EVM of an individual PRB carrying PDSCH so that a technician in the field can pinpoint the impacted PRBs and measure the signal quality degradation quantitatively.

Note how for the example above the NPDSC(S)CH channel in Subframe #3 presents a valid EVM value of 4.08% in compliance with the standard requirements. Also, be aware PDSCH may have higher gain than other PRBs during LTE data transmission periods.

In addition to the data and control channels included in the NB-IoT in-band signal frame, other possible subframes to validate are those related to synchronization like those within subframe #5 for NPSS and subframe #9 for NSSS (if applicable) for the primary and secondary narrowband synchronization signal:

Figure 13 - Subframe #5 measuring NPSS

Figure 14 - Subframe #9 measuring NSSS
(when available)

With VIAVI CellAdvisor, frame and subframe summary views are a useful way to complete conformance testing when it is required in a very short period of time:

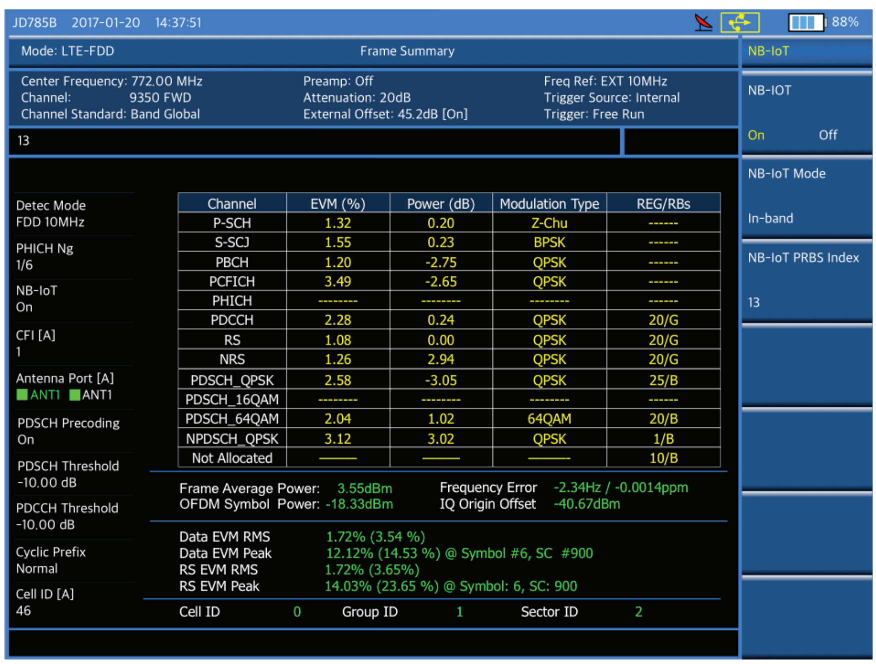


Figure 15 - Frame and subframe summary views
on VIAVI CellAdvisor

At this point, in addition to the individual subframes, it may also be convenient to check the status of the overall NB-IoT signal frame:

Figure 16

Why is important to check out the NB-IoT frame and sub-frame control and synch channels? Looking into the detail of these channels does require demodulating the signal for lower level analysis, which sometimes is perceived as a more specialized measurement that only needs to be conducted occasionally. However, it is important to understand the contribution these channels provide to the overall performance of the network and the reflection they have in the final quality of service delivered.

For example, the NPSS and NSSS channels are used by NB-IoT modems to perform cell site search, which includes time and frequency synchronization and cell identity detection. If your IoT devices placed in the field are struggling to attach properly to the network, looking into the quality of the transmission of the NPSS channel (also the NSSS if applicable), is a good place to start the troubleshooting.

Likewise, the NPBCH carries master information blocks (also referred as MIB messages), the NPDSCH carries paging and system information, and the NRS channels are used to provide phase reference for the demodulation of the downlink channels, a key element when MIMO is operating out of a cell site.

All these control and sync channels are in charge of different aspects of the NB-IoT network operation, and any issue during their transmission may have a direct impact in the overall service performance delivered to the IoT devices located in the field and being served by a new NB-IoT cell site.

Section Summary

In conjunction with VIAVI CellAdvisor's LTE signal analysis capability, the NB-IoT signal analyzer can also provide detailed information about NB-IoT channels per frame or per subframe. It allows an analytical approach to the root cause of any performance issues detected in the NB-IoT network.

The different tests described show how to effectively measure power and any potential presence of inter-PRB or other interference (using the EVM metric) for the new set of NB-IoT synchronization, control, and data channels.

It is important to carry out radio interference analysis when the network is under load (with actual data traffic) – both from the NB-IoT and LTE traffic perspectives, to verify the impact of NB-IoT on LTE (or other existing technologies) and vice versa, in order to detect any possible channel issues.

Testing Scenarios

Case Study A. Intra-PRB interference (same cell site)

When validating an LTE base station with a new NB-IoT service, one of the first items to check is any possible impact the active NB-IoT signal may have on adjacent PRBs that may be rendering Voice over LTE (VoLTE) or other traffic data to non-IoT devices like smartphones being served by that same cell site.

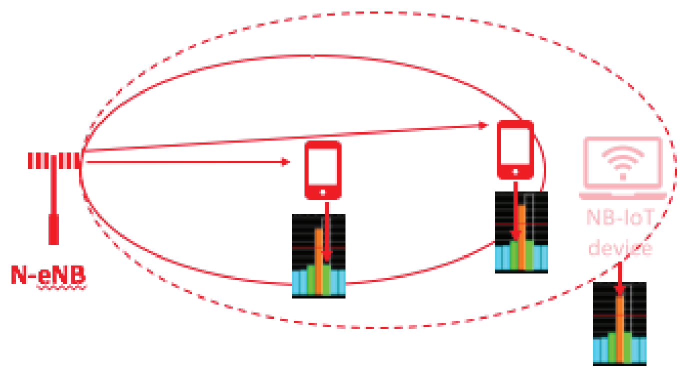


Figure 17 - Effect of NB-IoT power boosting on adjacent PRBs from the same cell site

In this scenario (as shown in Fig.17), it is important to ensure the NB-IoT PRB is not leaking any significant amount of power to adjacent PRBs allocated to other UE (User Equipment like smartphones, tablet devices with cellular service, etc.) being served by that same cell site.

Using the VIAVI CellAdvisor Data Allocation Map and measuring the power over-the-air (OTA) and EVM values for adjacent PRBs within the supported dynamic range is one of the most effective test procedures to detect intra-PRB interference in an LTE/NB-IoT combined cell site.

Case Study B. Two Co-Located Cells

In this case, the NB-IoT cell site produces a signal whose coverage overlaps adjacently with another base station that is broadcasting a standard LTE signal:

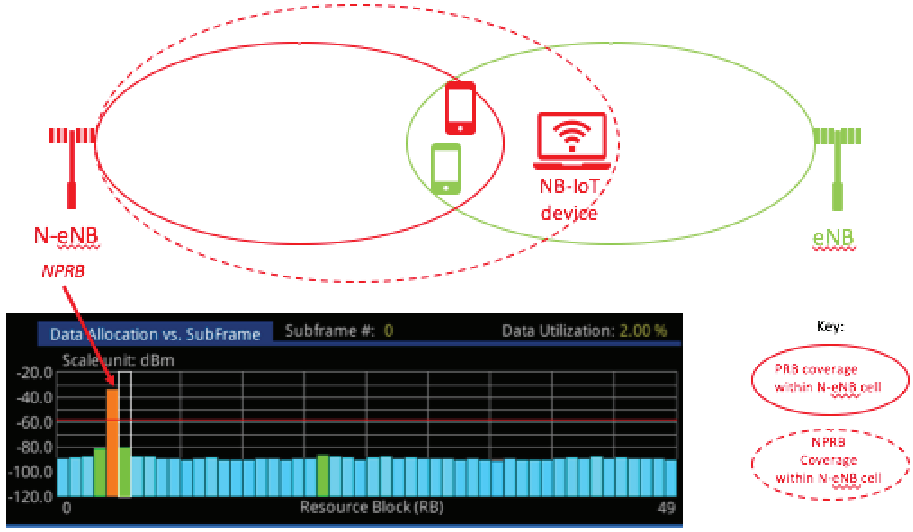


Figure 18

In this scenario, it may be of interest to analyze any potential changes for the actual coverage area of the LTE base station, when the NB-IoT signal service is activated from the adjacent base station and its associated PRB is actively transmitting.

Likewise, another validation worth performing in the field is the actual quality of service being delivered from the NB-IoT base station to the IoT device that may be placed in an overlapping area between the two base stations, to identify any potential interference issues from the LTE signal on the NB-IoT signal.

In this same co-located cell sites scenario, another downlink effect to monitor is possible excessive levels of NB-IoT PRB power boosting being transmitted (also referred as PSD boosting for power spectral density). This could produce a type of co-channel interference on neighboring UEs when they are using the same or even the adjacent PRBs originated from the other LTE base station:

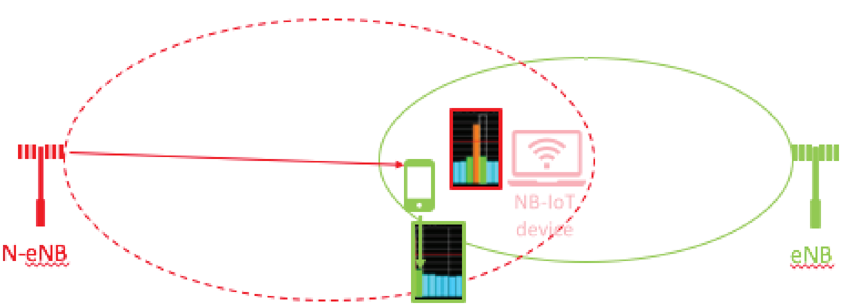


Figure 19

Fig. 19 Showing potential downlink impact from NB-IoT PRB into the same PRB of a co-located cell site serving a smartphone device.

An analogous situation of potential signal pollution could take place on the uplink path if the NB-IoT device originates an excessive level of PSD boosting or even an excess of signal repetition to ensure a better reach to the base station for data transmission. This could result in desensitizing the adjacent LTE base station and a significant decrease in the quality of service being delivered (similar to a near-far phenomenon).

Conclusion

Network operators need to manage complex and diverse types of connections while maintaining the required quality of experience for each, and minimizing the need to invest in new equipment.

VIAVI CellAdvisor is a cost-effective, handheld field solution that can support acceptance testing in compliance with 3GPP recommendations, focusing on the following compliance aspects:

- Max output power of PRB (Physical Resource Block) carrying NB-IoT signal and channels
- Total Power dynamic range of the NB-IoT active PRB, is it equal or greater than 6dB
- EVM measurement for NPDSCH and other control and synch channels
- (Downlink) NRS channel power and EVM measurements
- Frequency Error measurement

For new NB-IoT service activation, inter-PRB interference is a key concern. Verifying inter-PRB interference with the EVM measurement is the most accurate and cost-effective test procedure. Likewise, PRBs from the standard LTE transmission can also have an impact on NB-IoT channel quality.

In combination with traditional LTE signal analysis capabilities, VIAVI CellAdvisor can provide detailed information about NB-IoT channels per frame or per subframe, allowing an analytical approach to the root cause of potential issues.

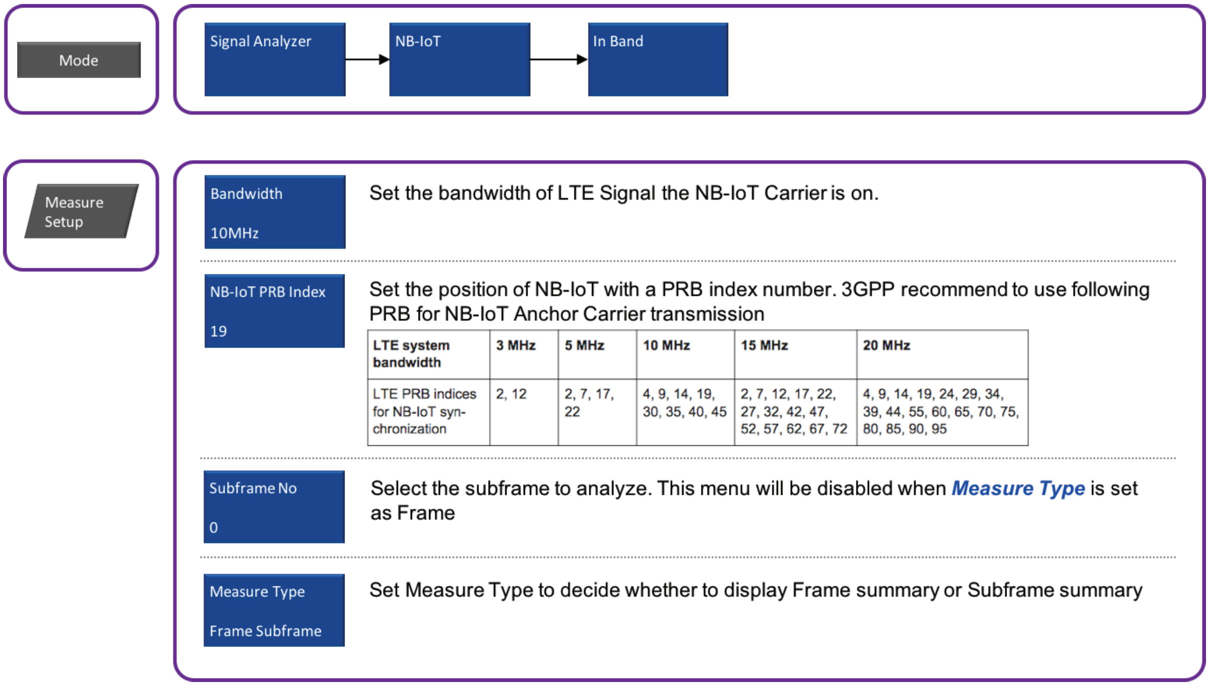
By reviewing and validating the above metrics during the commissioning stage of a new NB-IoT deployment, and also during regular maintenance checkups, mobile operators can guarantee optimal conditions for their new IoT service, and be assured that it will reach the required objectives in terms of coverage, capacity, and quality of service.

VIAVI Solutions has been at the forefront of new NB-IoT network implementations, already supporting renowned wireless operators and NEMs worldwide.

For more information about NB-IoT, visit viavisolutions.com/nbiot.

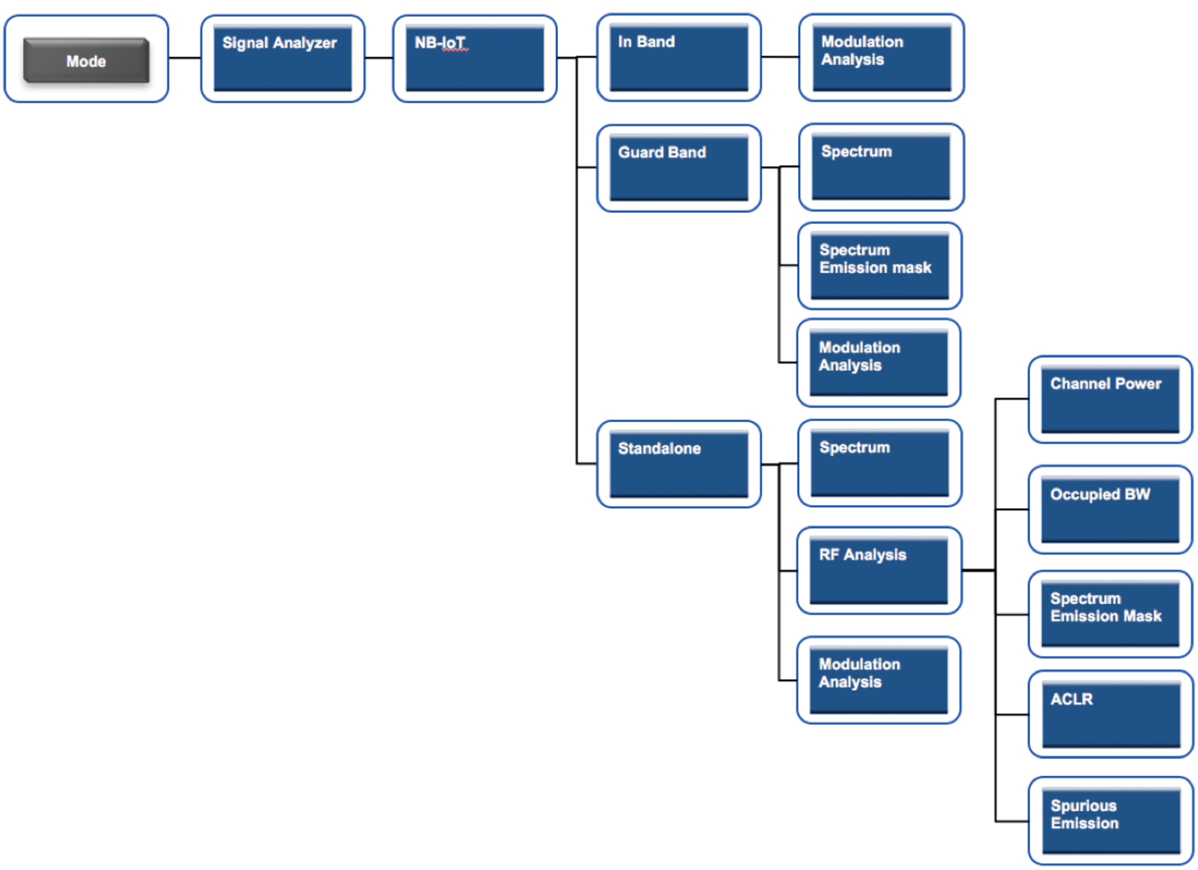
APPENDIX A. Measurement Flow with VIAVI CellAdvisor for NB-IoT Signal Analysis

- Reference Guide to configure a VIAVI CellAdvisor to measure a NB-IoT in-band signal:



LTE system bandwidth	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
LTE PRB indices for NB-IoT syn-chronization	2, 12	2, 7, 17, 22	4, 9, 14, 19, 30, 35, 40, 45	2, 7, 12, 17, 22, 27, 32, 42, 47, 52, 57, 62, 67, 72	4, 9, 14, 19, 24, 29, 34, 39, 44, 55, 60, 65, 70, 75, 80, 85, 90, 95

- Menu structure for NB-IoT measurements in all operational modes:



APPENDIX B. Glossary

3GPP	Third Generation Partnership Project
BPSK	Binary Phase-shift keying, a modulation technique
dB	Decibel measurement unit
dBm	Decibel measurement unit related to power in Watts (0dBm = 1mW)
DL	Downlink, radio path form base station to the UE/device in the field
EVM	Error Vector Magnitude, a measurement of signal quality
IoT	Internet of Things
inter-PRB	Inter-PRB interference or interference between two different PRB signals
KHz	Kilohertz, a frequency measurement unit
LTE	Long Term Evolution (a 3GPP 4G cellular technology)
LPWA	Low Power Wide Area
MHz	Megahertz, a frequency measurement unit
MNO	Mobile Network Operator
NB-IoT	Narrowband-Internet of Things, a 3GPP technology for the IoT market
NPSS	Narrowband Primary Synchronization Signal
NSSS	Narrowband Secondary Synchronization Signal
NPBCH	Narrowband Physical Broadcast Channel
NRS	Narrowband Reference Signal
NPDCCH	Narrowband Physical Downlink Control Channel
NPDSCH	Narrowband Physical Downlink Shared Channel
PRB	Physical Resource Block, also referred to as RB (Resource Block)
PSD	Power Spectral Density
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying, a modulation technique
RS-SINR	Reference Signal – Signal to Noise Ratio
UL	Uplink, radio path from the UE/device in the field to the base station

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