

Capturing IQ data with NRA and IDA

A brief theoretical outline with practical examples



With the Scope/IQ option, the NRA and IDA instruments allow you to generate IQ data from the received data and display, demodulate, and store them, and transmit them block by block or as a continuous stream via a remote interface. What, though, is the significance of this I/Q data? What are they used for? And, how are they obtained using NRA and IDA?

Communications systems

To transmit data wirelessly it must be modulated onto a suitable, usually high frequency, carrier signal. This gives a basic setup as shown in figure 1. The demodulator must perform exactly the opposite function to the modulator. The receiver must also be able to cope with the impairments to the modulated signal that are added as it passes through the communications channel.

The type of modulation has to be suitable for the signal content and the communications channel. Various techniques are used to transmit different signals together through the same medium and then separate them again, e.g.:

- Frequency multiplex,
- Time multiplex and / or
- Code multiplex

The following types of modulation are commonly used for sinusoidal carriers:

- AM, FM, PM, (angle modulation) for analog signals
- ASK, FSK, PSK, APSK, QAM for digital signals

If a prominent but unknown signal in the spectrum is to be classified or even its message content reconstructed, various parameters such as

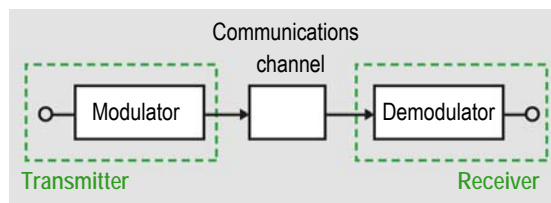


Figure 1: Basic setup for a communications system

See last page for abbreviations

the type of modulation need to be determined before a matching receiver can be produced for the unknown transmitter. This is not possible “on the fly”, so the NRA and IDA provide facilities for recording the unknown signal in the form of IQ data so that it can subsequently be subjected to a more precise investigation.

IQ data

Generally speaking, the IQ data consists of pairs of data describing an instantaneous time signal in the complex plane, as shown in figure 2. “I” stands for the in phase component, which has a phase angle of 0° relative to the converted carrier, and which therefore forms the real component in the complex plane. In contrast, “Q” is the quadrature component, which is phase shifted by 90° relative to the carrier, thus forming the imaginary component.

The values for an IQ data pair describe the instantaneous amplitude M and the phase angle ϕ of a signal. Changes in the time signal are reflected as a shift in the IQ data point in the complex plane.

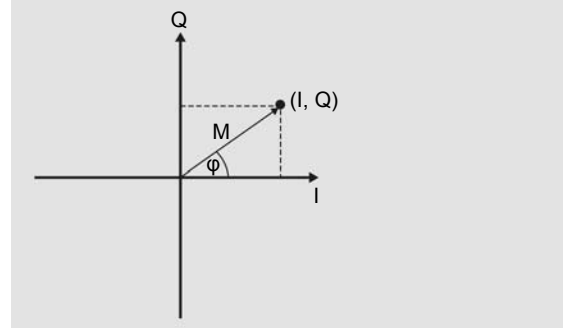
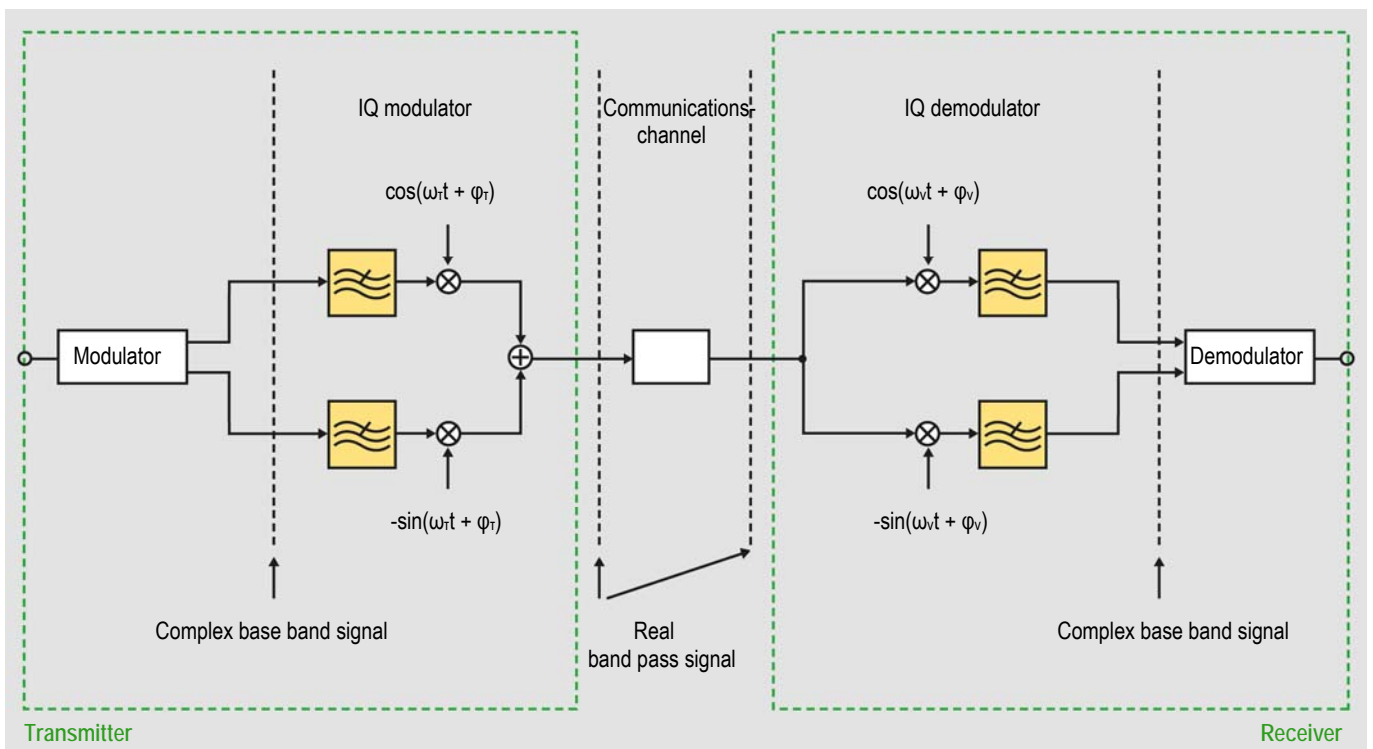


Figure 2: Representation of an IQ data pair in the complex plane

Figure 3: Basic representation of an IQ based communications installation



The IQ data find application in the transmitters and receivers in communications installations. They are also suitable for recording signals from the communications channel itself.

From the point of view of a basic communications installation – as depicted in figure 3 – the IQ data appear before conversion from the base band into the actual transmission band in the transmitter and after conversion from the transmission band to the base band in the receiver.

The payload signal or data stream is fed to the IQ modulator in the transmitter in the form of IQ data. The IQ modulator limits the bandwidth of the signal and converts it into the transmission frequency band. After addition of the I and Q components, the real, band-limited signal can be transmitted in a radio channel.

The received signal together with any captured interference is converted back to the base band again and band limited by the IQ demodulator in the receiver, so that the original payload signal or data stream together with the interference is available at the output of the IQ demodulator as IQ data.

The signal can be captured by the NRA and IDA during transmission over the radio channel. In this case, the instrument takes over the role of a receiver that can store IQ data. The IQ data represent a specific section of the spectrum in the time domain shifted into the base band, as depicted clearly in figure 4.

Signals that have known modulation, such as AM or FM, can often be directly demodulated by the IDA and output to a loudspeaker or headphones. Experts can discern other types of modulation by the sound after AM or FM demodulation.

The IDA can also demodulate a UMTS or LTE signal and determine certain parameters of the transmitted signal.

Things are more difficult if the modulation of the signal is unknown. The modulation type needs to be identified, and the characteristic of the matching receive filter, the exact carrier frequency, the phase, and the line digit rate all need to be determined. NRA and IDA can save the corresponding section from the spectrum in the form of IQ data for this purpose for subsequent processing or export to another device over an interface.

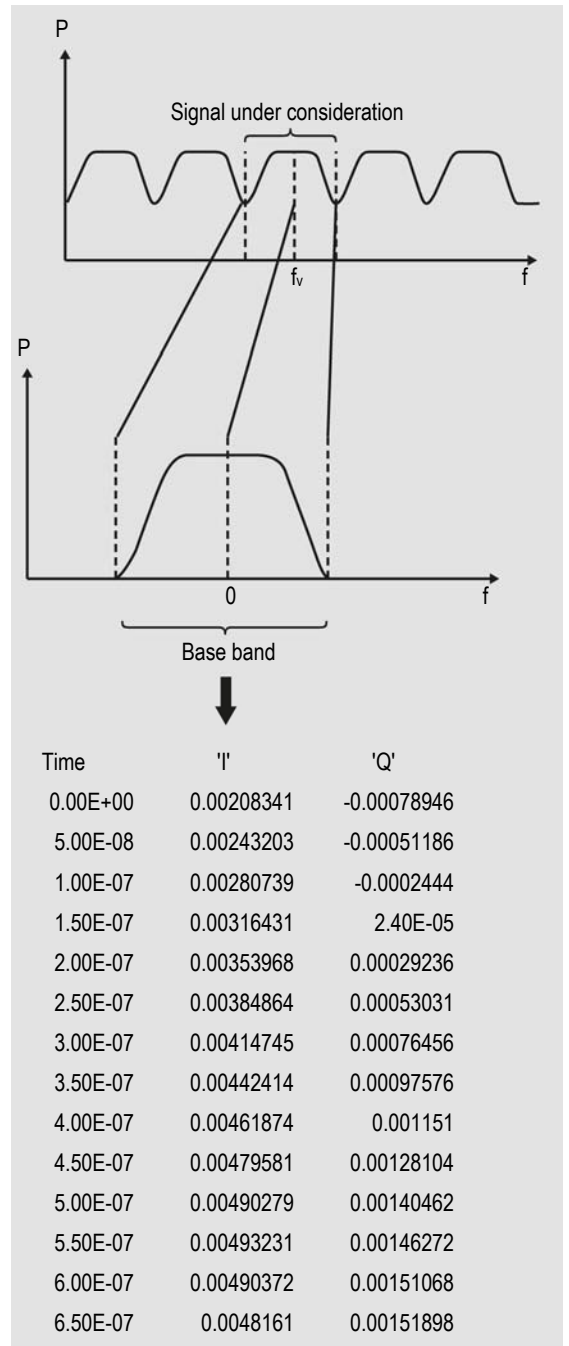


Figure 4: Spectrum and IQ data.
– Top: The entire spectrum,
– Center: Spectrum of signal converted to the base band,
– Bottom: A time section of the signal converted to the base band expressed as IQ data.

Recovering the IQ data: How it is done in NRA and IDA

NRA and IDA combine analog and digital techniques for signal analysis: a classic heterodyne receiver for pre-selection is followed by a digital analyzer for fine selection and further processing. To help you understand IQ data recovery, the block diagram can be simplified as follows:

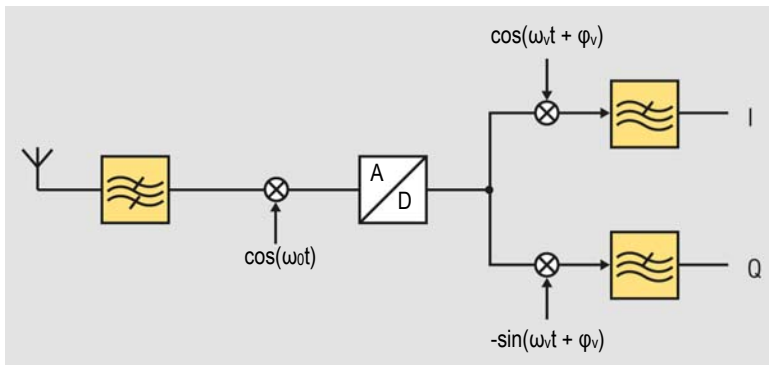


Figure 5: Simplified block diagram of NRA and IDA for recovering the IQ data. From the A/D converter onwards, it corresponds to the receiver structure shown in figure 3

Following pre-selection, frequency conversion, and A/D conversion, the received signal is mixed down to a base band and split into its in phase and quadrature components in the process. The subsequent filters limit the bandwidth. It should be noted here that the frequency of the IQ demodulator can only be roughly selected because the exact signal frequency is unknown; the phase is initially arbitrary. Generally, too, the selection filter does not correspond to that used in the correct receiver, as the filter parameters are also not known at this point in time. The parameter settings merely serve to allow the part of the spectrum of interest to be saved as IQ data.

There are basically two modes for storing the IQ data: block mode and streaming mode.

A maximum 250,000 points per block are available in **block mode**. The maximum bandwidth here is 32 MHz. NRA and IDA capture the data block by block, i.e. take sections from the time signal. Time gaps in the recording thus occur between the blocks. The advantage of block mode is the high bandwidth.

In **streaming mode**, the NRA captures the data continuously and outputs them without interruption via one of the interfaces. The maximum bandwidth is 400 kHz. The advantage of streaming mode is that the data are without time interruptions. The limitation of the bandwidth to 400 kHz is a disadvantage.

	Display	Demodulate	Store internally / SD card	Block mode	Streaming mode
IDA	•	•	• ¹⁾	•	–
NRA	²⁾	–	–	•	•

¹⁾ Export using IDA-Tools or on SD card
²⁾ With NRA demo program

Table 1: IQ data handling facilities of NRA and IDA

Example 1: IQ data captured with IDA

In this example, the signal is a 16QAM signal; this is in fact not known at the start of the measurement.

The signal can be seen in Spectrum mode (figure 6). The center frequency and bandwidth must be entered to tune the IDA to the signal. The center frequency, which is used to mix the signal down to the base band, does not necessarily correspond exactly to the carrier frequency, as this is not directly discernible from the signal itself. This has to be corrected later by calculation.

AM or FM demodulation can be tried in order to find out more about the signal type. If this does not give a clear indication, switch from Spectrum to Scope mode using Extras > Go to. The IDA uses the same settings made in Spectrum mode for this.

The Time Span and Channel Bandwidth (CBW) settings need to be made, depending on whether you want to view or store the signal. The CBW has to be set such that the Nyquist-Shannon sampling theorem is at least fulfilled if the signal is to be displayed and further processed. This means that the CBW must be at least twice the signal bandwidth. Since the selection filter of the IDA limits the signal bandwidth, it is a good idea to select a more generous CBW than this, otherwise the edges of the selection filter in the IDA (used to capture the data) and those of the actual receive filter (in the emulated receiver) will overlap in the subsequent emulation of the actual receiver.

The IDA can display the IQ data directly as a graph versus time (figure 7). They can be transferred to an SD card, read out using the IDA-Tools software and exported, or accessed directly via one of the available remote interfaces for further processing using a PC.

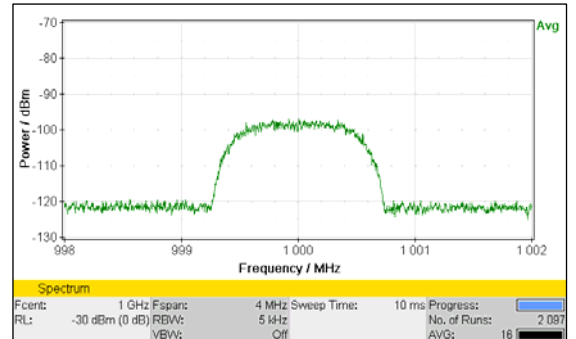


Figure 6: The signal spectrum (zoom display)

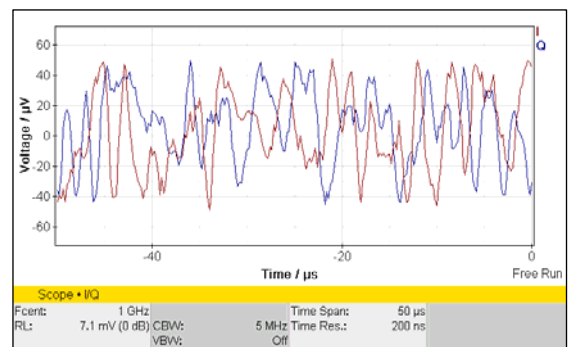


Figure 7: The IQ data of the signal shown graphically versus time

Example 2: IQ data captured with NRA

A 16QAM signal is also used here as an example of how the IQ data are captured using the NRA.

Transfer of the data to a PC can be done in **block mode** using the “Scope-Demo” demo program or by direct access through a remote interface. The NRA sends the data over the remote interface following a request.

To get started quickly, it is a good idea to use the demo programs. You can set up the NRA directly from the “Scope-Demo” program and export the IQ data blocks as .csv or .wav files. To help you get started with programming, as well as referring to the [Command Reference Guide](#), you can activate the Communication Log, which records all the commands sent from the demo program to the NRA. Once you have set the parameters and recalled the data with the demo, you can read out the commands needed for this from the log file. Communication can then take place using these commands with a terminal program. You can then integrate the entire communication and evaluation into your own application. You can see from figure 8 that each IQ block must be requested individually by the PC in block mode.

In **streaming mode**, the NRA communicates with the PC via a remote link and sends the IQ data as a stream over a stream link. Both links are via a single physical interface. Once started, the NRA transmits IQ data continuously over the stream link. Figure 8 shows that the PC sends commands to the NRA over the remote link and the NRA also uses this link to send responses to these commands to the PC. The NRA starts to stream the IQ data over the stream link following the Start command and continues until it receives the Stop command from the PC.

Communication and evaluation of the data typically takes place directly from a client specific application.

Regardless of whether block or streaming mode is used, mainstream software such as RadiInspector or the Satellite Link Planner from Inradios can be used to transfer the IQ data to the PC and evaluate them from within the software.

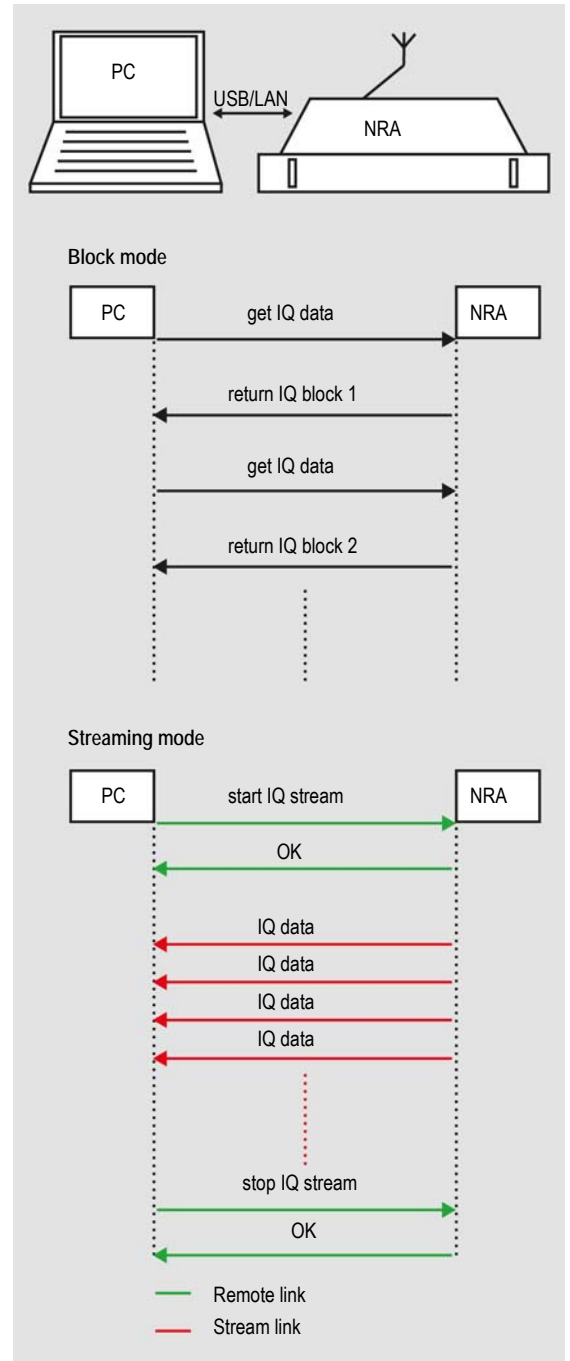


Figure 8: IQ data, transmitted as a block or as a stream

Example 3: Evaluation by constellation diagram

The data captured from example 1 or 2 can now be analyzed on the PC, for example by generating a constellation diagram.

The sample points are shown as a vector diagram in figure 9. The values are scaled by level; the carrier frequency and phase are already recovered, which can be seen from the square appearance of the vector diagram (correct carrier frequency) which is aligned parallel to the axes (correct phase). A receive filter matching the transmit filter has been used.

Despite the oversampling, which is not synchronized with the line digit rate, the aggregation at 16 points expected from a 16QAM signal can already be seen.

Figure 10 shows only those values that correspond to the line digit rate and which form the constellation diagram. It should be noted that you cannot discern which of the four states (0° , 90° , 180° or 270°) corresponds to the actual phase. This information can be obtained, for example, by synchronization to IQ sequences known to the receiver that are intended for this purpose. If this information is also known, the states of the transmitted symbols can be reconstructed from the chronological sequence.

Summary

This Technical Note gives a brief overview of what IQ data are, where they find application, and how the NRA and IDA instruments can record these data. It also gives an example of how a constellation diagram can be generated from the recorded IQ data.

NRA and IDA provide the functions needed for receiving and capturing IQ data.

The real challenge in practical application is usually determining the type of an unknown signal source. The recorded IQ data allow comprehensive analysis and further processing of the information at any future time.

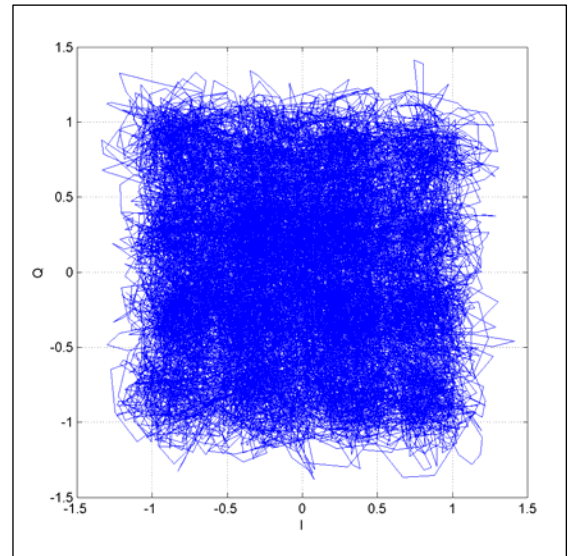


Figure 9: Vector diagram after clock recovery and phase correction

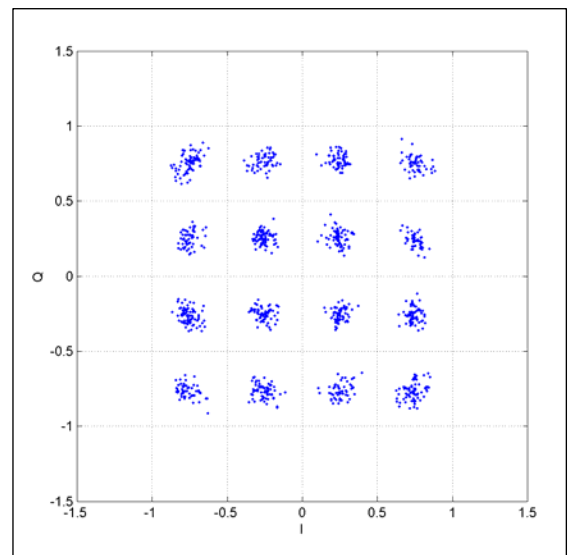


Figure 10: 16QAM constellation diagram

Abbreviations

AM	Amplitude modulation
FM	Frequency modulation
PM	Phase modulation (Frequency and phase modulation are forms of angle modulation)
ASK	Amplitude shift keying
FSK	Frequency shift keying
PSK	Phase shift keying
APSK	Asymmetric phase shift keying
QAM	Quadrature amplitude modulation
NRA	Narda Remote Spectrum Analyzer
IDA	Interference and Direction Analyzer

Links

[NRA data sheet](#)
[NRA operating manual](#)
[NRA Command Reference Guide \(extract\)](#)

[IDA data sheet](#)
[IDA operating manual](#)

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