

CPRI RE Testing

Application Note

Products:

R&S®EX-IQ-BOX	R&S®SMBV100A
R&S®DigIConf	R&S®SMJ100A
R&S®SMW200A	R&S®AMU200A
R&S®SMU200A	R&S®WinIQSIM2

More and more mobile radio networks implement remote radio equipment (RE) that is connected to the base station main unit via a digital interface using standardized transmission protocols such as CPRI™.

For testing RE devices Rohde & Schwarz offers a complete test solution based on the R&S®EX-IQ-BOX [Model K04]. This key component is a configurable digital interface module that is used to connect Rohde & Schwarz test equipment to a RE under test using CPRI data transmission.

This application note explains in detail the instrument setup and configuration needed to successfully test your remote radio head.

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1 Note

Note that “CPRI” is a registered trademark of Nokia Siemens Networks.

Note that “CDMA2000” is a registered trademark of the Telecommunications Industry Association (TIA-USA).

Note that “WiMAX” is a registered trademark of the WiMAX Forum.

The following abbreviations are used in this application note for Rohde & Schwarz products:

- The R&S®EX-IQ-BOX [Model K04] digital interface module is referred to as EX-IQ-BOX.
- The R&S®DigIConf digital interface configurator software is referred to as DigIConf.
- The R&S®SMU200A vector signal generator is referred to as SMU.
- The R&S®FSQ spectrum analyzer is referred to as FSQ.
- The R&S®WinIQSIM2™ simulation software is referred to as WinIQSIM2.

2 Introduction

Previously, a base station was a rack of equipment inside a shelter, connected by RF cable to an antenna on a tower (Fig. 1). Nowadays, base stations more and more implement remote radio equipment. The RF module is placed into a weatherproof box mounted on the tower close to the antenna. The main unit that contains the control and baseband signal processing communicates with the remote RF module via a *digital* data connection. Such a digital interface offers several advantages over its analog counterpart:

- Significant loss of signal power due to long RF feeder cables does not occur. The digital connection is effectively lossless.
- Effects such as I/Q impairments (imbalance, offsets, ...) do not occur.
- Thus, the base station needs no longer to be placed relatively close to the antenna. It is possible to bridge bigger connection distances between the main unit and the antenna.
- The main unit can be placed at a conveniently accessible site where climate control, power supply and servicing is easier to manage and space is not restricted.
- The number of required interfaces can be reduced, since digital I/Q data can be combined with control data in just one interface.
- Also, one main unit can feed multiple RF modules, i.e. remote radio heads, which greatly reduces costs and facilitates network planning.

For these reasons, the distributed base stations concept becomes more and more popular taking advantage of digital interfaces (either optical or electrical).

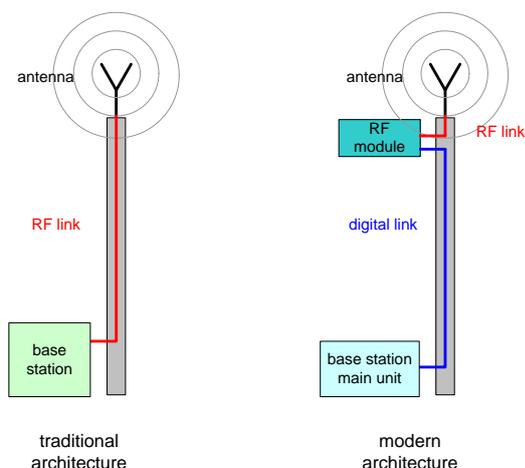


Figure 1: Comparison of traditional and modern base station architectures.

Network operators intend to combine main units (baseband) and RF modules manufactured by different vendors. Thus, these base station components are often developed and manufactured independently and also have to be tested independently by means of a digital interface. The industry has agreed upon defining common digital interface protocol standards, such as the common public radio interface (CPRI™). Test solutions thus need to provide a digital interface supporting the protocol standards.

Rohde & Schwarz offers a complete setup for base station component testing based on conventional signal generators and spectrum analyzers. The R&S® EX-IQ-BOX digital interface module [Model K04] provides the digital interface between the R&S test equipment and the base station component under test. Fig. 2 shows the principle. The testing is as usual, except that the digital I/Q link replaces the analog I/Q connection. By using the EX-IQ-BOX, conventional R&S test equipment can be also used for testing via the digital interface. This means, the R&S instruments can be used for testing in the RF as well as in the digital baseband domain: RF module (i.e. radio head) test as well as main unit (baseband unit) test is possible.

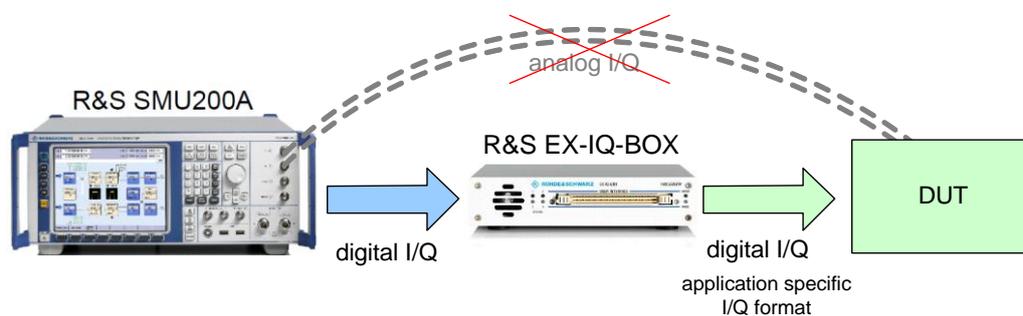


Figure 2 :Testing via the digital interface using the EX-IQ-BOX.

The EX-IQ-BOX digital interface module supports the **CPRI protocol (5.0) with line bit rates of up to 9830.4 Mbit/s (16x rate)** for standard-compliant communication with the device under test. Radio equipment (RE) test (i.e. RF module test) as well as radio equipment control (REC) test (i.e. baseband module test) is possible. Rohde & Schwarz offers thus a straightforward and elaborate solution for testing base station components over the digital CPRI interface. This application note presents the CPRI RE test solution.

The next section gives a brief overview of the CPRI interface. Section 4 shortly introduces the Ex-IQ-BOX and its role in the test setup. In section 5 the setup for testing RE devices in real-time is described in detail for downlink (5.1) and uplink (5.2). All necessary instrument settings are explained step-by-step. In addition, a troubleshooting procedure is provided to further facilitate commissioning of the setup. Section 5 also covers control and management data (5.5) as well as vendor specific data (5.6) transmission/reception. Section 6 describes the ARB-based setup for testing RE devices. This alternative setup is a simplified version of the real-time setup and is based on internal EX-IQ-BOX options that enable multi-signal generation and recording. Section 7 focuses on synchronization. A summary is given in section 8. Finally, section 9 shows some photographs of the EX-IQ-BOX and the CPRI breakout board.

3 CPRI Overview

The Common Public Radio Interface (CPRI™) is a standard developed by an industry cooperation that agreed upon defining a specification for the internal interface of base stations between the radio equipment control (REC) and the radio equipment (RE). The REC corresponds to the base station baseband unit that provides the access to the radio network, the control and management as well as the digital baseband processing. The RE corresponds to the base station RF unit, i.e. to a local or remote radio head, that serves as air interface to the user equipment. The RE provides the analogue and radio frequency functions such as filtering, modulation, frequency conversion and amplification. The REC and RE communicate over a generic interface based on digital I/Q data transfer. In addition to the user plane data (I/Q data), control and management as well as synchronization signals are exchanged between the REC and the RE. All information flows are multiplexed onto a digital serial communication line using appropriate layer 1 and layer 2 protocols [5]. The different information flows have access to the layer 2 via appropriate service access points (SAP).

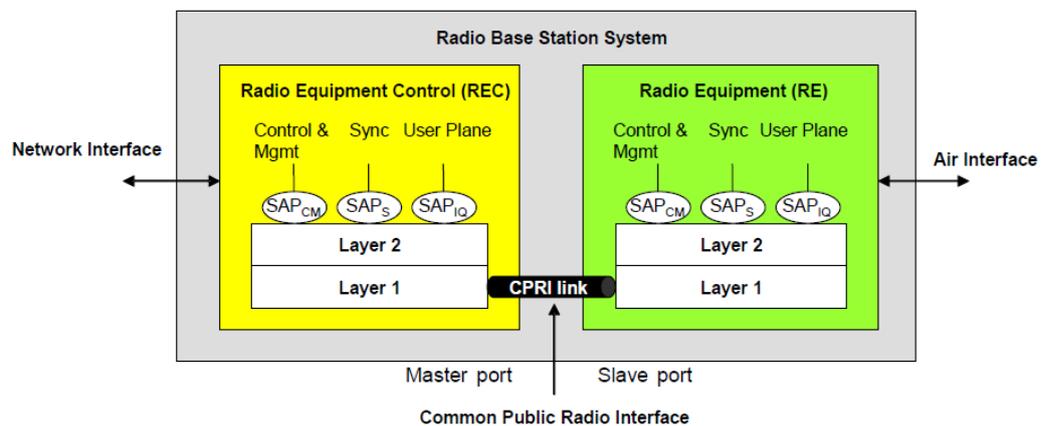


Figure 3: Basic system architecture and CPRI definition [5].

In detail, the following information flows are supported by CPRI [5]:

- I/Q data: The user plane information is sent in the form of I/Q data (digital baseband signals).
- Synchronization: Synchronization data used for frame and time alignment.
- L1 inband protocol: Signalling information that is related to the link and is directly transported by the physical layer.
- C&M data: Control and management information exchanged between the C&M entities within the REC and the RE. This information flow is given to the higher protocol layers. Two different layer 2 protocols for C&M data are supported: subset of High level Data Link Control (HDLC) and Ethernet.
- Vendor specific data: This information flow is reserved for the transfer of any type of vendor specific information.

The information flows are multiplexed by a time division multiplexing scheme onto an electrical or optical transmission line. Fig. 4 provides an overview on the basic protocol hierarchy.

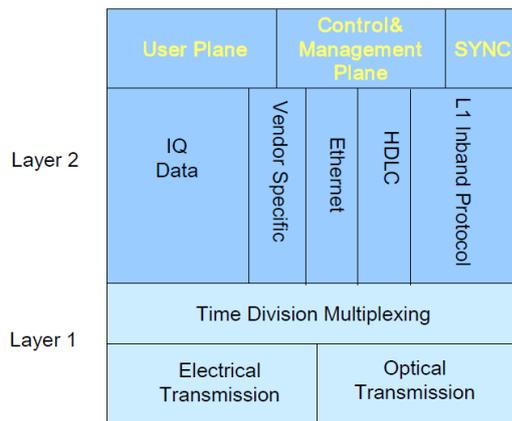


Figure 4: CPRI protocol overview [5].

The CPRI frame structure is illustrated in Fig. 5. A CPRI Node B frame is 10 ms long. This length is identical to the 3GPP radio frame length. A Node B frame consists of 150 hyperframes. Each hyperframe consists of 256 basic frames. The length of a basic frame is $1/3.84 \text{ MHz} = 260.4 \text{ ns}$. The structure of such a basic frame is also shown in Fig. 5. A basic frame consists of 16 words with index $w = 0 \dots 15$. The word with the index $w = 0$, is used as control word carrying control information. The remaining words ($w = 1 \dots 15$) are dedicated to the I/Q data transfer (I/Q data block). The control word ($w = 0$) of the basic frame is always transmitted first.

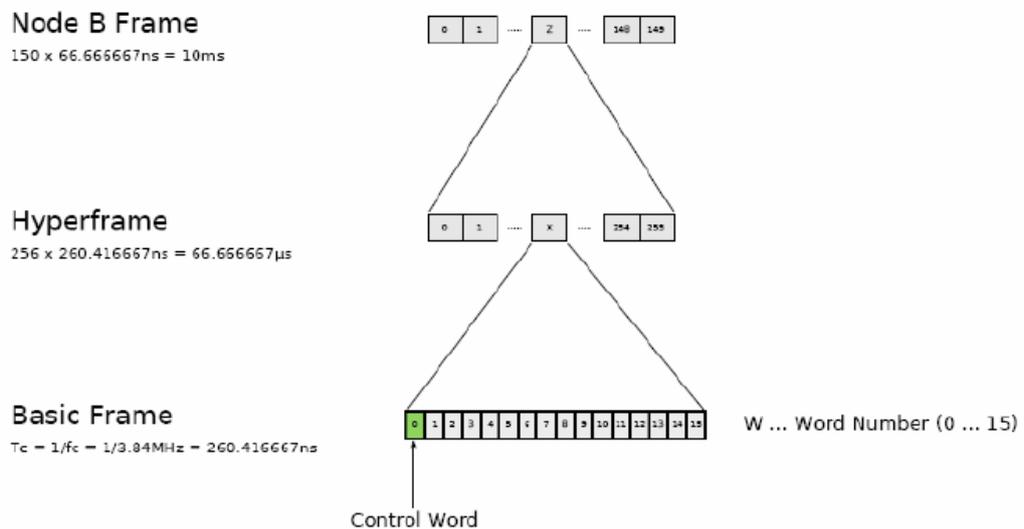


Figure 5: Illustration of the frame hierarchy.

4 EX-IQ-BOX & CPRI

Devices under test (DUT) utilize various different digital interfaces. They use either custom or standardized formats such as CPRI [4] for digital input/output. The EX-IQ-BOX can be used to convert between these customer-specific digital interfaces and the R&S digital I/Q interface used by R&S instruments such as spectrum analyzers, signal generators and wireless communication testers. (These R&S instruments offer digital inputs/outputs for receiving/providing digital I/Q data.)

The EX-IQ-BOX is a digital interface module that works with different digital I/Q formats, e.g. with the common public radio interface (CPRI™) protocol standard. CPRI is the internal base station interface between the radio equipment control (REC) and the radio equipment (RE). The REC corresponds to the base station baseband unit and the RE to the radio head. The EX-IQ-BOX can be used to simulate the REC which enables the user to test the RE independently from the REC in research and development, verification and production. The EX-IQ-BOX interfaces to the device under test (DUT) by means of a specific CPRI breakout board (option EXBOX-B85) and the CPRI RE Test software option (EXBOX-K10). The CPRI breakout board (variant .04) supports the **CPRI protocol (5.0) with line bit rates of up to 9830.4 Mbit/s (16x rate)**. The physical link between the CPRI breakout board and the DUT is an optical link with small form-factor pluggable (SFP) connectors at both ends. This optical interface is used for modern base stations with remote radio equipment. The test solution covers individual uplink or downlink operation as well as full duplex operation for a single point-to-point link. Downlink is the direction from the REC to the RE. Uplink is the direction from the RE to the REC.

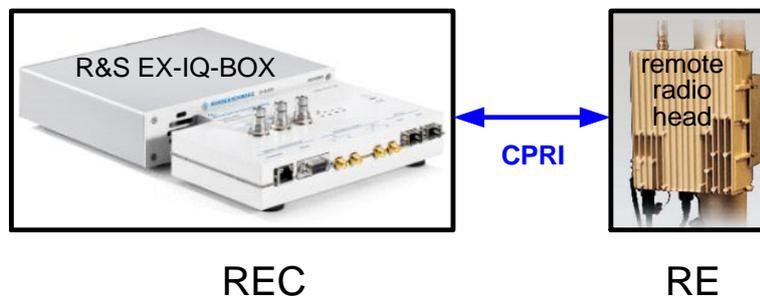


Figure 6: Single point-to-point CPRI link between the EX-IQ-BOX with CPRI breakout board (simulating the REC) and a RE under test.

Alternatively, the EX-IQ-BOX can also be used to simulate the RE for testing an REC by means of the CPRI REC Test software option (EXBOX-K11).

The EX-IQ-BOX [Model K04] is controlled and configured via the DigIConf digital interface configurator software running on an external PC. The DigIConf software is a common user interface for use of the EX-IQ-BOX with R&S signal generators (R&S®SMx), spectrum analyzers (R&S®FSx), and wireless communication testers (R&S®CMW). DigIConf can also be operated remotely via a local area network (LAN). For details about installation and remote control see references [1] and [2].

DiglConf allows for easy configuration of the CPRI link. All relevant standards such as 3GPP FDD (incl. HSDPA, HSUPA, HSPA+), LTE, WiMAX, CDMA2000 and GSM are supported as pre-defined interface settings. It is also possible to manually configure a custom CPRI link. Additionally, control and management (C&M) information can be inserted in realtime. Finally, also vendor specific information can be transferred over the CPRI link.

Fig. 7 gives an overview of the CPRI RE test solution presented in this application note. In combination with R&S signal generators and spectrum analyzers, the EX-IQ-BOX is able to utilize the enhanced functions of the signal generators (e.g. fading, AWGN, I/Q impairments) and the vast signal analysis features of the analyzers. The setup provides real-time signal generation and analysis and is described in detail in section 5. This setup offers maximum flexibility and is ideal for use during research and development.

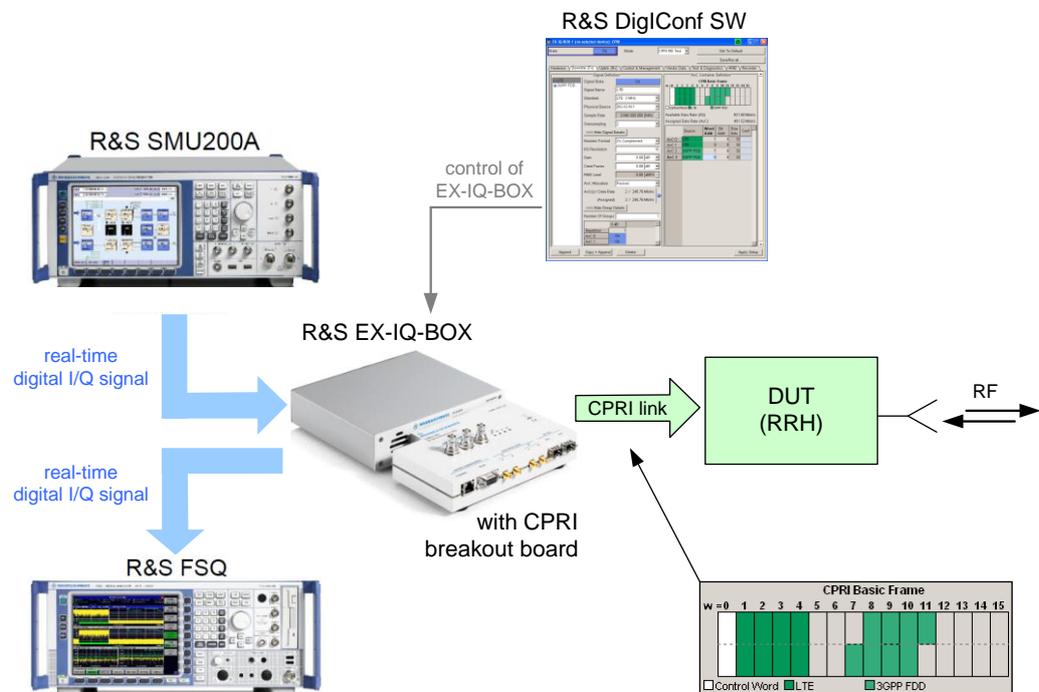
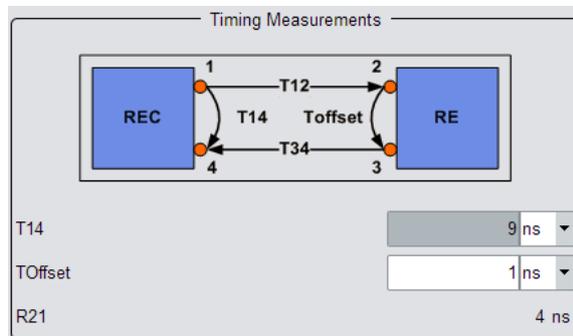


Figure 7: Overview of R&S CPRI RE test solution.

As a cost-efficient alternative to the comprehensive real-time setup, Rohde & Schwarz also offers an ARB-based setup. This setup is basically a simplified version of the real-time setup and is based on internal EX-IQ-BOX options. The EX-IQ-BOX can generate signals stand-alone when equipped with the internal waveform memory option (EXBOX-K90/-K91) which allows playback of pre-calculated waveforms, e.g. generated by WinIQSIM2 or Matlab™. With the option EXBOX-K91 up to four waveforms can be played back simultaneously. Thus, up to four different signals can be transmitted simultaneously over the same CPRI link, e.g. for multi-standard or MIMO applications. Furthermore, the EX-IQ-BOX can receive signals stand-alone when equipped with the internal recording memory option (EXBOX-K94) which allows recording of the digital signal. The recorded signal can then be analyzed by post-processing with third-party software or an R&S analyzer (I/Q file analysis). This cost-efficient solution is ideal for field use (minimal equipment) and for verification and production. The setup is described in detail in section 6.

Please note that the presented CPRI RE test solutions (real-time and ARB-based) are intended for testing the RF characteristics of a CPRI RE. We implement CPRI as essential part of the setup, but the test solution is not intended or usable for testing the CPRI protocol standard itself!

DigIConf supports the round trip cable delay measurement (R21 measurement) as specified in the CPRI standard (see reference [5] for details). The frame offset "TOffset" of the RE under test can be entered. This is a DUT-specific parameter. The EX-IQ-BOX measures the overall frame timing difference "T14" of the setup and calculates the cable delay "R21".



5 CPRI RE Testing

This section describes the typical setups for testing a CPRI Radio Equipment (RE), e.g. a remote radio head, in downlink and uplink direction. It is possible to test both directions individually as well as simultaneously, i.e. full duplex.

In the setups described below, the RE, i.e. the RF module, is the device under test (DUT). The EX-IQ-BOX emulates the CPRI interface of the Remote Equipment Control (REC) unit, i.e. the baseband module. The RE and the REC communicate using the standardized CPRI transmission protocol. In the downlink, the RE acts as RF transmitter. Section 5.1 describes a typical test setup for RE transmitter tests with RF analysis. In the uplink, the RE acts as RF receiver. Section 5.2 describes a typical test setup for RE receiver tests with baseband signal analysis.

Both, downlink and uplink test setups include a signal source. The R&S vector signal generators provide either digital baseband signals or RF signals compliant to all major mobile radio and wireless communications standards such as LTE, 3GPP FDD including HSPA(+), GSM/EDGE, CDMA2000®, WiMAX™ and WLANn. Enhanced functions such as fading, AWGN or I/Q impairments are also available.

5.1 Downlink

5.1.1 Overview

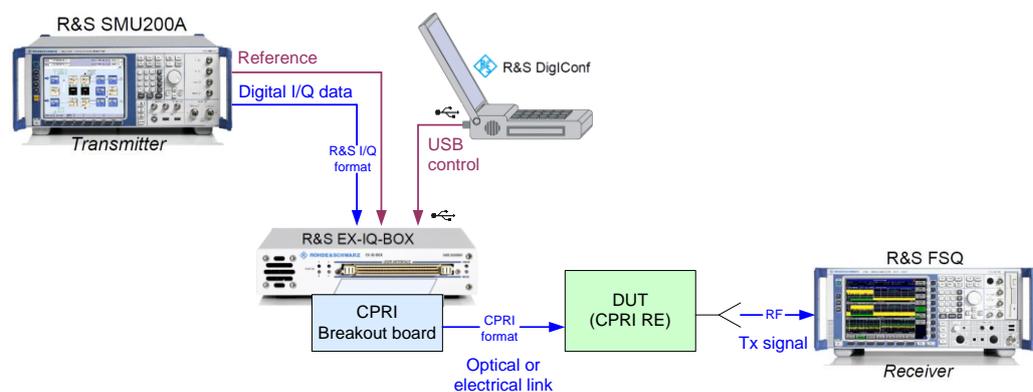


Figure 8: Test setup overview – Downlink direction.

Fig. 8 shows a typical setup for testing a CPRI RE in downlink direction. In this setup, the EX-IQ-BOX (in combination with the SMU) emulates the REC module. The EX-IQ-BOX is remote controlled via the DigiConf software running on a PC.

The signal flow is as follows:

The R&S signal generator supplies a baseband signal (e.g. an LTE downlink signal), which is fed digitally to the EX-IQ-BOX. The digital I/Q data is sent in a R&S specific I/Q format. The EX-IQ-BOX converts this R&S digital I/Q interface format into the CPRI transmission protocol by means of the CPRI breakout board. The I/Q data is then transmitted over an optical (or electrical) CPRI link to the DUT (CPRI RE). In addition to the I/Q data, control and management (C&M) information can also be sent over the CPRI link to the DUT. The CPRI RE extracts the I/Q signal from the received data stream and performs an I/Q modulation to a specific RF carrier frequency. The resulting RF signal is then sent to a spectrum analyzer to evaluate the signal, e.g. to perform adjacent channel power (ACP) or error vector magnitude (EVM) measurements.

The baseband signal is configured solely via the signal generator. The link between the signal generator and the EX-IQ-BOX uses a R&S specific protocol. This link does not need to be configured. In contrast, the link from the EX-IQ-BOX to the DUT, the CPRI link, needs to be configured by the user as it is DUT specific. This is done via the DigIConf software.

5.1.2 Equipment

For the downlink CPRI RE test shown in Fig. 8 the following equipment is needed:

Required Software	
R&S DigIConf SW (available at the Rohde & Schwarz website)	version 03.01.009.30 Build220 or higher

Required Devices	
R&S EX-IQ-BOX [Model K04] including external power supply and CPRI breakout board (option R&S EXBOX-B85)	with option R&S EXBOX-K10 for RE testing
SFP module for the SFP cage on the CPRI breakout board (third-party product, to be provided by the user)	compatible with SFP module of the DUT
R&S signal generator equipped with digital interface (option R&S SMU B18 digital baseband output) e.g. R&S SMU200A	optionally with options for digital standards
Spectrum analyzer capable of demodulating the wanted signals e.g. R&S FSQ optionally equipped with digital interface (option R&S FSU B17) for troubleshooting	optionally with options for digital standards
DUT with power supply, e.g. remote radio head	
PC running the DigIConf software	

Required Cables	
LVDS cable (comes with EX-IQ-BOX delivery)	
USB cable (comes with EX-IQ-BOX delivery)	
2 BNC cables	
RF cable	
Optical cable (duplex)*	compatible with SFP modules

* Establishing a CPRI link requires *bidirectional* communication between the EX-IQ-BOX and the DUT. For this reason, a duplex cable must be used. The term “downlink” basically refers to the unidirectional transmission of I/Q data.

5.1.3 Cabling

- Connect the EX-IQ-BOX to the external power supply.
 - Connect the EX-IQ-BOX to the PC using the USB cable.
- The “Power” LED must be green.



- Connect the EX-IQ-BOX to the signal generator using the LVDS cable. Use the DIG IQ IN/OUT 1 connector of the EX-IQ-BOX and the BASEBAND DIGITAL OUT connector of the signal generator.
- Connect the REF OUT connector of the analyzer to the REF IN connector of the signal generator.
- Connect the REF IN connector of the EX-IQ-BOX to the REF OUT connector of the signal generator.
- Connect the CPRI breakout board to the EX-IQ-BOX via the USER INTERFACE connector.
- Slide in an SFP module into the SFP cage on the CPRI breakout board.
- Connect the SFP connector of the CPRI breakout board to the DUT (RX/TX optical port) using an optical cable (duplex).
- Connect the RF output of the DUT with the RF input connector of the analyzer.



Make sure that you use adequate attenuation to avoid damaging the analyzer, as the DUT’s RF output power may exceed the maximum input power of the analyzer.

More details can be found in [1].

5.1.4 Configuration of the Signal Generator

- Preset the signal generator.
- Set the reference frequency to “external” (as the reference frequency is fed in from the analyzer via the BNC connector).

In this setup, the analyzer is the reference frequency source. However, it is also possible to use the signal generator or an external reference frequency (with high precision) as reference frequency source.

- Activate the wanted test signal, e.g. a 3GPP signal, in the baseband block.

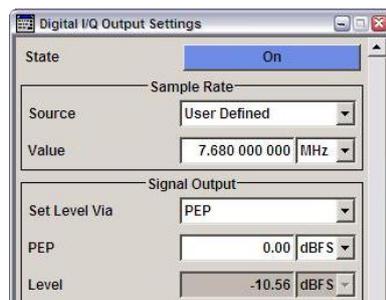


- Open the Digital I/Q Output Settings menu via the AWGN/IMP block and make the following settings:
- Set the sample rate to the data rate that shall be transmitted over the CPRI link (see following section). For example, set a sample rate of 7.68 MHz using the "User Defined" mode.



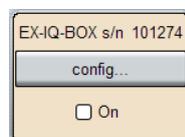
Note that the set sample rate must match the sample rate settings made in DigIConf as explained in detail in the following section.

- Set the "Set Level Via" parameter to "PEP".
 - Set the peak envelope power (PEP) value to 0 dBFS.
- The resulting average level will be displayed in units of dBFS.
- Enable the digital I/Q output by setting the "State" to "On".

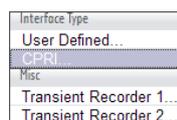


5.1.5 Configuration of the CPRI Link

- Start the DigIConf software on the PC.
- DigIConf recognizes the connected EX-IQ-BOX and indicates its serial number.

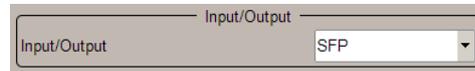


- Click on the "config..." button and select "CPRI" from the list to open the CPRI settings menu.



- Select the CPRI mode "CPRI RE Test".
- Click on the "Preset" button to start with a defined state.

- Select the “Hardware” tab and make the following settings:
- Set the CPRI line bit rate. Select the one which is supported by your SFP connection. Select the line bit rate according to the capabilities of the DUT.
- Select SFP as input/output port



- Switch to the “Downlink (Tx)” tab and make the following settings:
- Select “DIG IQ IN 1” as the physical source.
- Select the standard to be used. For example, select the 3GPP FDD standard.
→ The sample rate is automatically set according to the selected standard. For example, for the 3GPP FDD standard the sample rate is automatically set to 3.84 MHz. This sample rate constitutes a base sample rate which is not editable for a selected standard. Instead of selecting a digital standard you can also select “User defined”. With this setting the sample rate can be set to a custom value.



- Set the oversampling factor. For example set it to “2”.



The product of the base sample rate and the oversampling factor gives the actual sample rate which must match the sample rate set for the digital I/Q output of the signal generator:

$$\text{Sample_Rate}_{\text{EX-IQ-BOX}} \cdot \text{Oversampling}_{\text{EX-IQ-BOX}} = \text{Sample_Rate}_{\text{Dig. Out Generator}}$$

For example: 3.84 MHz · 2 = 7.68 MHz → The settings match.

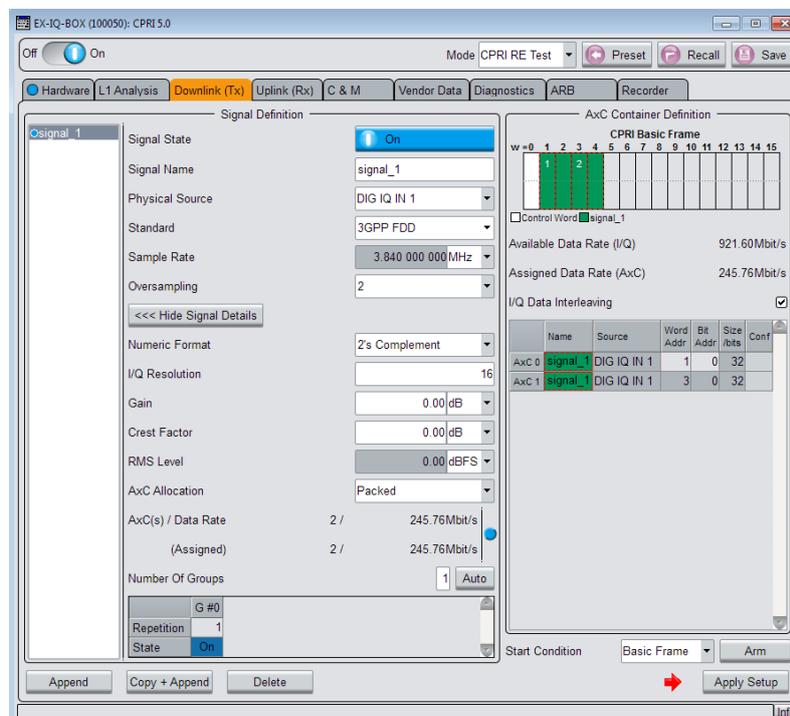


Figure 9: DigIConf user interface for CPRI – Downlink (Tx) tab.

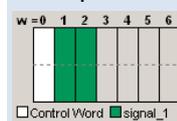
A detailed description of all the parameters in this menu can be found in [1].

At this point we want to describe in brief the right side of the “Downlink (Tx)” tab, i.e. the “AxC Container Definition” part of the menu.

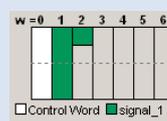
The graphic shows one CPRI basic frame (please see section 3 for a short introduction to the CPRI protocol frame structure). One basic frame consists of 16 words ($w = 0$ to 15). The first word in the basic frame ($w = 0$) is always the control word. The remaining 15 words can carry I/Q data.

The CPRI standard defines AxCs (antenna carriers) for transmission and reception of the digital I/Q data. An AxC is a container for *one* I/Q sample. The size in bits of such an AxC thus depends on the length of one IQ sample, e.g. 16 bits.

Examples:



one AxC of size 32 bits
I/Q resolution is 16 bit
(16 bits for I and 16 bits for Q)



one AxC of size 20 bits
I/Q resolution is 10 bit
(10 bits for I and 10 bits for Q)

The basic frames are transmitted over the CPRI link with a fixed clock rate of 3.84 MHz. This means, every $0.26 \mu\text{s}$ one basic frame is transmitted. Thus, the wanted data rate determines how many AxCs are needed per basic frame to carry the I/Q data. For example, for a 3GPP signal with a sample rate of 3.84 MHz only one AxC is needed per basic frame. Every $0.26 \mu\text{s}$ one basic frame is transmitted and with it one AxC, i.e. one I/Q sample. The resulting I/Q data rate over the CPRI link is thus 3.84 MHz. In contrast, for a signal with a wanted sample rate of 11.52 MHz three AxCs are needed per basic frame. Again, every $0.26 \mu\text{s}$ one basic frame is transmitted but this time with three AxCs, i.e. three I/Q samples. The resulting I/Q data rate over the CPRI link is thus $3.84 \text{ MHz} \cdot 3 = 11.52 \text{ MHz}$.

Examples:

	Source	Word Addr	Bit Addr	Size /bits
AxC 0	signal_1	1	0	32

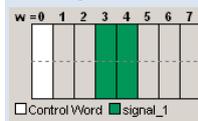
data sample rate is 3.84 MHz
one AxC of size 32 bits
I/Q resolution is 16 bit

	Source	Word Addr	Bit Addr	Size /bits
AxC 0	signal_1	1	0	32
AxC 1	signal_1	3	0	32
AxC 2	signal_1	5	0	32

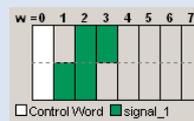
data sample rate is 11.52 MHz
three AxCs of size 32 bits
I/Q resolution is 16 bit

The position of an AxC inside the basic frame can be set via the word address and the bit address. For example, if the word address is 3, then the AxC starts with word 3.

Examples:



one AxC of size 32 bits
word address is 3
bit address is 0

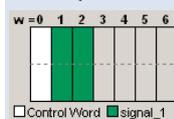


one AxC of size 32 bits
word address is 1
bit address is 8

The size in bits of a word depends on the set CPRI line bit rate (“Hardware” tab):

Line bit rate / Mbit/s	Word length / bits
1x (614.4)	8
2x (1228.8)	16
4x (2457.6)	32
5x (3072.0)	40
8x (4915.2)	64
10x (6144.0)	80
16x (9830.4)	128

Examples:



one AxC of size 32 bits
word length is 16

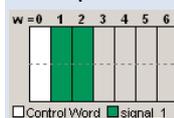


one AxC of size 32 bits
word length is 32

In the above example, a 32 bit AxC (i.e. one I/Q sample with 16 bit resolution) occupies two words if a line bit rate of 2x (1228.8 Mbit/s) is used but just one word if a line bit rate of 4x (2457.6 Mbit/s) is used.

The base sample rate and the oversampling determine the actual sample rate transmitted over the CPRI link. For example, if the base sample rate is 3.84 MHz, then the actual sample rate is 3.84 MHz in case there is no oversampling (i.e. oversampling is 1) and 7.68 MHz in case the oversampling is 2. In the first case, one AxC is needed for transmission, in the second case two AxCs are needed.

Examples:



oversampling is 1
one AxC of size 32 bits



oversampling is 2
two AxC of size 32 bits

- Click on the “Show Signal Details” button (on the left side of the “Downlink (Tx)” tab).
- Adjust the settings for the numeric format and the I/Q resolution depending on what the DUT supports.
- If necessary, set a gain value for the I/Q signal. You can reduce the digital level of the I/Q signal to not overdrive the input of your DUT. To apply a lower digital level enter for example -12 dB as gain value (corresponds to digital attenuation).

→ The LED must be blue.

AxC(s) / Data Rate	2 /	245.76Mbit/s	
(Assigned)	2 /	245.76Mbit/s	



A red LED indicates that there is a mismatch between the required and the assigned data rates. Note that the required data rate must match the assigned data rate.

The required data rate (in Mbit/s) can be calculated as follows:

$$\text{Data_Rate}_{\text{req}} = \text{Sample_Rate} \cdot \text{I/Q_Resolution} \cdot 2 \cdot \text{Oversampling}$$

The assigned data rate (in Mbit/s) can be calculated as follows:

$$\text{Data_Rate}_{\text{ass}} = 3.84 \text{ MHz} \cdot \text{I/Q_Resolution} \cdot 2 \cdot \#_AxCs$$

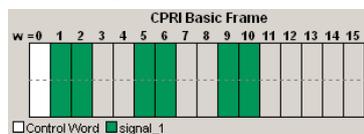
where #_AxCs is the number of allocated AxCs per basic frame

- If the LED is red, then click on the “Auto” button right below. The DigIConf software will then automatically adjust the group settings such that the assigned data rate matches the required data rate (see section 5.1.5.1 for details).

AxC(s) / Data Rate	2 /	184.32Mbit/s	
(Assigned)	2 /	245.76Mbit/s	
Number Of Groups	1	Auto	

- Set the “AxC Allocation” to “Flexible”.
- Adjust the position of the AxCs inside the CPRI basic frame by setting the word and bit address. The AxC allocation of the basic frame is DUT specific.

For example, an interleaved allocation can be set by adjusting the word addresses accordingly. (Word addresses are 1, 5, and 9 in this example, bit addresses are all 0).



- Check if there are any conflicts indicated in the “AxC Container Definition” list.

no conflict

	Source	Word Addr	Bit Addr	Size /bits	Conf
AxC 0	signal_1	1	0	32	
AxC 1	signal_1	3	0	32	

conflict

	Source	Word Addr	Bit Addr	Size /bits	Conf
AxC 0	signal_1	1	0	32	
AxC 1	signal_1	15	0	32	

→ There must not be any conflicts.



Conflicts can occur for example when the signal does not “fit” into the basic frame. Depending on the conflict cause, it can help to adjust the word and bit address of the AxCs, to use a higher CPRI line bit rate (if the DUT supports it) or to reduce the I/Q resolution or the sample rate.

- Set the “Signal State” to “On”
- Finally, turn on the CPRI RE test. 

→ The CPRI link is built up. I/Q data transmission starts as soon as the link is established.

Alternatively to this free running start, it is also possible to define a start condition, e.g. an external trigger for starting the I/Q data transmission (see section 7.2 for details).

If you change any settings in the “Downlink (Tx)” tab, the new settings must be applied to the CPRI link:

- Press the "Apply Setup" button.
- The CPRI link is shut down and updated. I/Q data transmission starts with new settings as soon as the link is re-established.



The new settings are not effective until you press the "Apply Setup" button. If you change any settings, a red arrow will appear next to this button indicating that the button needs to be pressed to actually apply the new settings.

5.1.5.1 CPRI Group Concept

Since the CPRI protocol is based on the 3GPP standards, the UTRA FDD chip period (1/3.84 MHz) is used as CPRI basic frame length. As a result, the possible data rates would be integer multiples of 3.84 MHz. In order to achieve different data rates, the CPRI standard has implemented a special method: the CPRI group concept. The following example will illustrate this concept.

Assuming we want to transmit the I/Q signal over the CPRI link with a sample rate of 5.76 MHz. The CPRI basic frames are transmitted over the CPRI link with a fixed clock rate of 3.84 MHz. This means, if we assign one AxC (i.e. one I/Q sample) per basic frame, we would have a sample rate of 3.84 MHz which is too low. If we assign two AxCs (i.e. two I/Q samples), we would have a sample rate of 7.68 MHz which is too high. To achieve the wanted sample rate of 5.76 MHz, we would need to assign 1.5 AxCs per basic frame which is not possible. We therefore need to assign two AxCs per basic frame. In addition, we can transmit empty basic frames. By transmitting three frames with two AxCs each followed by one empty frame we achieve the wanted sample rate of 5.76 MHz. This kind of transmission scheme needs two CPRI groups in this example.

- Click on the “Auto” button next to the entry field for “Number Of Groups”.

Number Of Groups

→ The DigiConf software automatically determines the required group settings. It sets the "Number of Groups" to “2”. The group table shows the two groups G #0 and G #1.

Number Of Groups

	G #0	G #1
Repetition	3	1
State	On	Off

Group G #0 corresponds to the basic frame with two AxCs. It is repeated three times. Group G #1 corresponds to a single empty frame (state is off, i.e. no I/Q data is transmitted). These group settings result in continuous transmission of three frames followed by one empty frame which yields an average sample rate of 5.76 MHz.

→ The LED changes its state from red to blue indicating that the wanted and the assigned data rates match.

AxC(s) / Data Rate	2 /	184.32Mbit/s	
(Assigned)	2 /	184.32Mbit/s	

When using the group concept you can achieve almost any average sample rate.



The automatically determined group settings yield the required average sample rate. However, the actually required group setting may be DUT-specific. It is therefore possible to edit the group settings manually.

5.1.6 Configuration of the DUT

The DUT, i.e. the remote radio head, is a user-specific device. Thus, the user must account for the correct configuration of the DUT.

Important DUT-specific properties such as supported CPRI line bit rates, bit resolution, CPRI basic frame allocation and group transmission pattern are specified in the data sheet of the device.

5.1.7 EX-IQ-BOX LED Indicators

The EX-IQ-BOX and the DiglConf software offer several LED indicators for signaling proper operation or malfunction. In particular, DiglConf offers LEDs that can be used to check if the CPRI link between the EX-IQ-BOX and the DUT works properly.

After the EX-IQ-BOX and the DUT have been connected and configured to establish a CPRI link, the state of the following LEDs should be checked:

- LEDs on the EX-IQ-BOX base unit
- LEDs on the EX-IQ-BOX CPRI breakout board
- LEDs in the CPRI “Hardware” tab of DiglConf
- LEDs in the CPRI “L1 Analysis” tab of DiglConf
- LEDs in the CPRI “Diagnostics” tab of DiglConf

The function and different states of these LEDs are described in detail in reference [1].

5.1.8 Configuration of the Analyzer

- Preset the signal analyzer.
- Set the reference frequency to “internal”.
- Set the center frequency according to the carrier frequency of the DUT
- Adjust the span and the reference level.
- Configure the analyzer for the desired measurement.
For example, select the respective personality (e.g. 3GPP BS) to demodulate the RF signal and measure the EVM.

More details can be found in [3].

5.1.9 Summary: Settings that must match

As mentioned already in the previous sections, there are some settings that need to match in order to establish a working CPRI connection.

- The reference frequency settings of the signal generator, the EX-IQ-BOX, and the analyzer must be coordinated. For example:

Reference frequency settings		
Signal generator	EX-IQ-BOX	Analyzer
External source	External source (REF IN)	Internal source

- The sample rate set for the digital I/Q output of the signal generator must match the base sample rate set for the EX-IQ-BOX times the oversampling factor.

Sample rate settings	
Signal generator	EX-IQ-BOX
Digital I/Q output sample rate	Base sample rate · Oversampling

- The assigned data rate must match the data rate of the CPRI link.
- The data rate of the CPRI link must match the data rate expected/required by the DUT.

Data rates		
EX-IQ-BOX	EX-IQ-BOX	DUT
Assigned data rate	Set data rate	Required data rate

- The allocation of the CPRI basic frame with AxCs set on the EX-IQ-BOX must match the basic frame allocation expected/required by the DUT.

CPRI basic frame allocation	
EX-IQ-BOX	DUT
Set basic frame allocation	Required basic frame allocation

5.1.10 Troubleshooting

The test setup consists of four interconnected components: signal generator, EX-IQ-BOX, DUT, and analyzer.

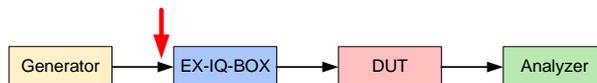


This section describes how to proceed when your setup does not work. In most cases only certain parts (or just one part) of the setup do not work properly resulting in a failure of the complete setup. The task is now to spot where in the setup the source of error hides. The source of error can be one of the four components (i.e. wrong configuration) or the transmission lines between two components.

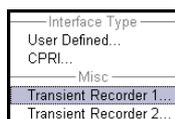
First, you can perform some fast checking by using the Transient Recorder of the EX-IQ-BOX as described below. Afterwards, you can proceed with testing the individual parts of the setup step by step to find the source of error. For these tests, you need a R&S analyzer which is capable of analyzing digital baseband signals. In the original setup, the function of the analyzer is to analyze an RF signal, but if the instrument is capable of analyzing digital baseband signals it can be disconnected and reused for debugging purposes as described below. For this, the instrument must be reconfigured accordingly.

5.1.10.1 Monitoring the input to the EX-IQ-BOX

The implemented Transient Recorder of the EX-IQ-BOX can be used for visual control of the digital input signal. The digital signal is displayed graphically. This provides a fast check of the characteristics of the input signal.



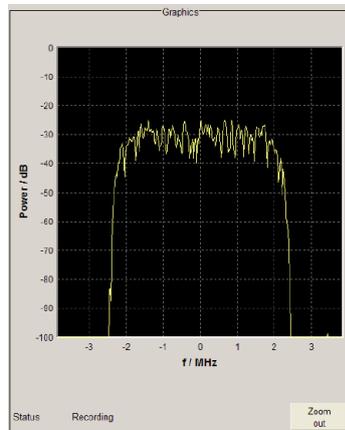
- Click on the "config..." button in the DiglConf block diagram and select "Transient Recorder 1" from the list.



(The EX-IQ-BOX has two transient recorders that can be used in parallel.)

- Select "DIG IQ IN 1" as the data source.
- Choose a display type:
 - Select "I/Q" to monitor the I and Q signals separately over time
 - Select "Vector" to view the vector diagram, i.e. the various states of modulation mapping.
 - Select "CCDF" to view the CCDF diagram, i.e. the probability of exceeding the average power.
 - Select "Power Spectrum" to view the power density plotted over frequency. The spectrum is calculated from the IQ data via a FFT.
- If desired, adjust the acquisition and trigger settings. Please see [1] for details.
- Set the "State" to "On".
- Evaluate visually if the signal characteristics look ok.

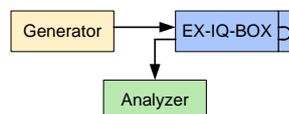
Example: The I/Q data of a digital 3GPP FDD signal is sampled and the corresponding power spectrum is displayed.



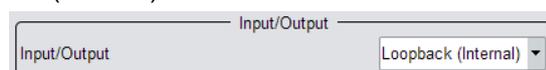
- If the input signal looks ok, then
 - check the settings of the EX-IQ-BOX.
 - it is recommended to proceed as described in section 5.1.10.2.
- If the input signal does not look ok, then
 - proceed as described in section 5.1.10.5.

5.1.10.2 Looping the signal at the EX-IQ-BOX

For testing and demonstration purposes the EX-IQ-BOX CPRI breakout board offers an internal loopback feature. With this feature enabled, the CPRI signal is internally routed back. Note that it is in fact the *CPRI signal* that is routed back. This means, the EX-IQ-BOX performs the conversion from the baseband signal to the CPRI signal and back again to a baseband signal which is output at the DIG IQ IN/OUT 2 connector of the EX-IQ-BOX. This output signal can be checked visually using the transient recorder of the EX-IQ-BOX (as described in section 5.2.10.1). Furthermore, the output signal can be analyzed using a spectrum analyzer that is capable of analyzing digital baseband signals as shown below. With these simple tests, the user can check if the EX-IQ-BOX works properly. However, the user should be aware that the analyzer can also be a “new” source of error (see last paragraph of this section).



- Enable the loopback mode by setting the “Input/Output” parameter to “Loopback (Internal)” in the “Hardware” tab.



- In the “Uplink (Rx)” tab, configure the identical signal as configured in the “Downlink (Tx)” tab.



The signal settings for downlink and uplink must be identical. The only difference between the settings is that in the “Uplink (Rx)” tab “DIG IQ OUT 2” is selected as the signal output.

- In the “Uplink (Rx)” tab, switch the signal state to “On”.
- Connect the analyzer to the DIG IQ IN/OUT 2 connector of the EX-IQ-BOX using a LVDS cable. (The DUT can be left connected.)
- Configure the analyzer for demodulating and analyzing the signal. Make sure that the analyzer settings are made correctly. Note that the analyzer must be configured to use the digital input as signal source.

For example:

- Select a digital standard personality (e.g. 3GPP BS) to demodulate the signal and show the EVM.
- Select “Baseband Digital” as signal source.
- Enter the sample rate as “Digital In Sample Rate” (e.g. 7.68 MHz). The entered sample rate must match the sample rate set for the digital I/Q output of the signal generator.



Make sure that you enter this value, otherwise the synchronization will fail and the analyzer will not demodulate. Forgetting to adjust the digital sample rate setting is one of the most common errors made!

→ If the signal is as expected, then

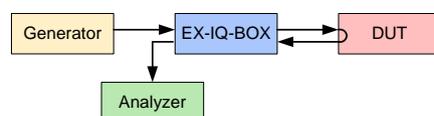
- proceed as described in section 5.1.10.3.

→ If there are problems with demodulation (e.g. synchronization failed) or if the signal is not like expected, then

- perform a fast visual check of the input and output signals to/from the EX-IQ-BOX using the transient recorders of the EX-IQ-BOX (as described in section 5.1.10.1). Since the EX-IQ-BOX has two implemented transient recorders, the input and the output signal (at connectors DIG IQ OUT 1 and 2, respectively) can be monitored in parallel.
- check the settings of the EX-IQ-BOX, in particular check the settings of the uplink signal.
- check the settings of the analyzer. In doubt, connect the signal generator directly to the analyzer via a LVDS cable (completely leaving out the EX-IQ-BOX) to verify the settings of the analyzer and the signal generator.
- check the settings of the generator, in particular check the baseband settings.

5.1.10.3 Looping the signal at the DUT

For testing purposes CPRI DUTs usually provide an internal loopback mode. In loopback mode the DUT receives the CPRI data at its optical input and directly routes this CPRI signal internally to its optical output (without any signal processing). This loopback mode is used to test the optical transmission lines.



- Set the “Input/Output” parameter to “SFP” in the “Hardware” tab.
- In the “Uplink (Rx)” tab, configure the identical signal as configured in the “Downlink (Tx)” tab and switch the signal state to “On”.



The signal settings for downlink and uplink must be identical. The only difference between the settings is that in the “Uplink (Rx)” tab “DIG IQ OUT 2” is selected as the signal output.

- Enable the loopback mode of the DUT.
- Check if there are any warnings or alarms in the “Diagnostics” tab and check the status of the three LEDs. All LEDs must be blue.

→ If the LED status is not ok, then the optical link does not work properly. A SFP module or the optical cable may be broken or not properly connected.

→ If the LED status is ok, then proceed as follows:

- Connect the analyzer to the DIG IQ IN/OUT 2 connector of the EX-IQ-BOX using a LVDS cable.
- Configure the analyzer for demodulating and analyzing the signal. Make sure that the analyzer settings are made correctly (see previous section).

→ If the signal is as expected, then the optical link works properly, i.e. the SFP modules on both ends and the optical cable are ok. The source of error might be, for example, that

- the DUT is not configured correctly. Check the settings of the DUT.
- the CPRI setting configured on the EX-IQ-BOX do not match the CPRI settings expected by the DUT. Check the needed CPRI settings.

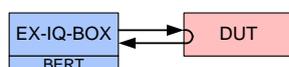
An alternative to the loopback test described in this section is the low-level BER test described in the following section. This BER test is also used to check the transmission line. The advantage is that no analyzer is required for this test.

5.1.10.4 Low-level BER test

The EX-IQ-BOX provides a low-level bit error rate (BER) test. This can also be used for checking the optical transmission line. For this test, the CPRI signal is looped back at the DUT (loopback mode without signal processing). When the BER test is running, the EX-IQ-BOX automatically generates a PRBS data sequence which is sent over the CPRI link. The data is routed back at the DUT. The EX-IQ-BOX automatically synchronizes to the incoming data stream and compares the received data to the (known) sent data. The BER is calculated by dividing the number of detected error bits by the total number of received bits. The resulting bit error rate is displayed in the “Uplink (Rx)” tab.

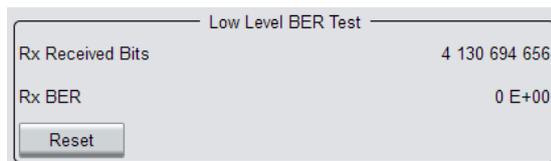


Note that this BER test must not be confused with a BER test of user data!



- Set the “Input/Output” parameter to “SFP” in the “Hardware” tab.
- In the “Downlink (Tx)” tab, select “PRBS” as the physical source and set the signal state to “On”.
- In the “Uplink (Rx)” tab, select “BER Test” as the signal output and set the signal state to “On”. The parameter “Pattern Length” must be identical for downlink and uplink.
- Enable the loopback mode of the DUT. (Note that the DUT itself is *not* tested now – only the optical transmission line is tested.)

The resulting bit error rate is displayed.



- If the “Rx Received Bits” are counting up and the “Rx BER” result is 0, then
 - the optical link works properly.
- If the “Rx Received Bits” are counting up and the “Rx BER” result is not 0, then
 - click on the “Reset” button.
 - check if the pattern length is identical for downlink and uplink.
- If the “Rx Received Bits” are counting up and the “Rx BER” result is still counting up, then
 - the optical link does not work properly. A SFP module or the optical cable may be broken or not properly connected.

5.1.10.5 Checking the generated baseband signal

The signal generator provides a graphics feature for visual control of the generated baseband signal. The signal is sampled with a transient recorder and the measured signal can be displayed graphically in different display modes (similar to the Transient Recorder of the EX-IQ-BOX) providing a fast check of the characteristics of the baseband signal.

- Click on the Graphics function block to open the Graphics settings menu.



- Select the display mode, i.e. “Constellation”.
- Set the “State” to “On”.
- Check if the baseband signal looks ok.

As an additional check, connect the signal generator directly to a spectrum analyzer for analyzing the digital baseband signal.

- Connect the BASEBAND DIGITAL OUT connector of the signal generator to the IQ DATA IN connector of the analyzer using a LVDS cable.
- Configure the analyzer for demodulating and analyzing the signal. Make sure that the analyzer settings are made correctly (see section 5.1.10.2).
- Check if the baseband signal is configured correctly.

5.1.11 Characterization of the DUT

After configuring the instruments and the DUT and establishing a working CPRI connection, the setup is now ready for performing measurements on the RE device. Some of these TX measurements are listed in the following overview:

- **Maximum output power**
The maximum output power is measured to verify the level specifications of the DUT across the frequency range.
- **Frequency error**
The frequency error is measured to verify the accuracy and stability of the transmit RF frequency.
- **Modulation accuracy (EVM)**
The error vector magnitude (EVM) measurement is performed to check the modulation accuracy of the transmitted RF signal. When the TX signal is demodulated and the received I/Q data is plotted as a constellation diagram, then the error vector is the vector between the ideal constellation point and the actual received point. Its length (or magnitude), defined as the Euclidean distance between the two points, is the EVM. The EVM evaluation is an important measurement that gives valuable information on the modulation accuracy and thus on the quality of the signal.

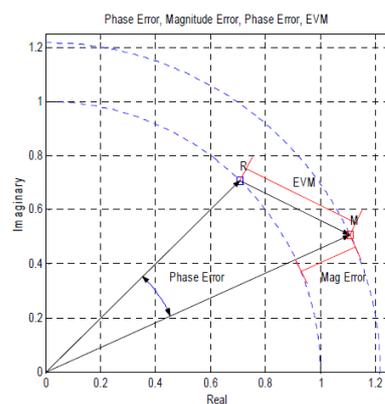


Figure 10: Graphical illustration of the error vector magnitude (EVM).

- **Occupied bandwidth**
The occupied bandwidth (OBW) is measured to verify that it is not exceeding the specification limits. The OBW is a measure of the frequency bandwidth containing 99% of the total integrated power of the transmitted spectrum.

- Out of band emission (ACLR, SEM)

The out of band emission is determined by an adjacent channel leakage ratio (ACLR) measurement or a spectrum emission mask (SEM) measurement. The ACLR is the ratio of the average power in the transmit channel to the average power in the adjacent channel. It is thus a measure of the out of band emission (e.g. spectral shoulders, sidebands) which must not exceed specified limits. Out of band emission limits can also be defined in terms of SEMs. Both measurements are intended to verify that the DUT will not interfere with adjacent channels utilized by other transmitters.

- Spurious emission

This measurement is performed to check whether the DUT emits spurious signals. Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emission, intermodulation products and frequency conversion products, but exclude out of band emissions (which are measured close to the carrier frequency).

- Transmit intermodulation

This measurement is performed to check whether the DUT generates intermodulation products in the presence of an interferer. An interfering signal reaching the DUT via the RX antenna could cause intermodulation distortion of the transmitted spectrum. Thus, the intermodulation products resulting from the wanted Tx signal and an applied interfering signal are analyzed by out of band and spurious emission measurements.

More information on how to perform the above measurements (e.g. instrument configuration) can be found for example in references [7] and [8].



Note that the presented test solution is intended for testing the RF characteristics of an RE device under test. We implement CPRI as essential part of the setup, but the test solution is not intended or usable for testing the CPRI protocol standard itself!

5.2 Uplink

5.2.1 Overview

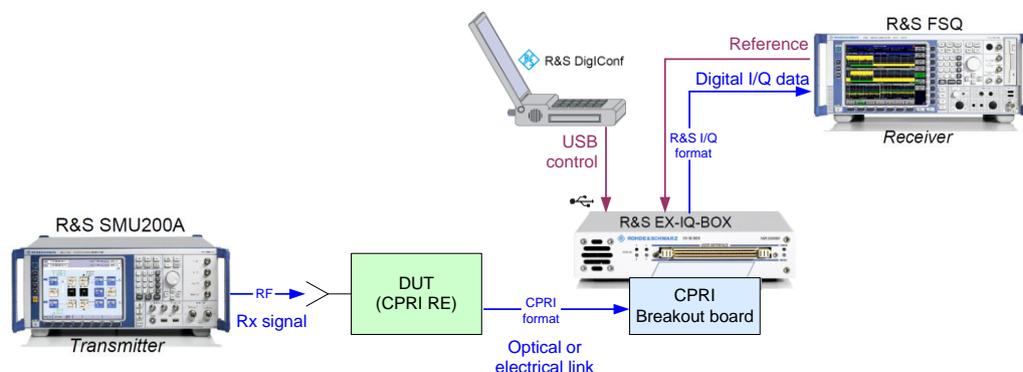


Figure 11: Test setup overview – Uplink direction.

Fig. 11 shows a typical setup for testing a CPRI RE in uplink direction. In this setup, the EX-IQ-BOX emulates the CPRI interface of the REC module. The EX-IQ-BOX is remote controlled via the DigiConf software running on a PC.

The signal flow is as follows:

The signal generator supplies an RF signal (e.g. an LTE uplink signal), which is fed to the DUT (CPRI RE). The DUT down-converts the signal from the RF to the baseband. The resulting baseband signal is then transmitted over an optical (or electrical) link to the EX-IQ-BOX using the CPRI transmission protocol. The EX-IQ-BOX extracts the I/Q data from the received data stream by means of the CPRI breakout board. In addition to the I/Q data, control and management (C&M) information can also be received over the CPRI link from the DUT. The digital I/Q data is then sent in the R&S specific I/Q format to the R&S signal analyzer. The analyzer demodulates the I/Q signal for evaluation. For example, an EVM measurement can be performed.

The RF signal is configured solely via the signal generator. The link between the DUT and the EX-IQ-BOX, the CPRI link, needs to be configured by the user. This is done via the DigiConf software. In contrast, the link from the EX-IQ-BOX to the analyzer uses a R&S specific protocol. This link does not need to be configured.

5.2.2 Equipment

For the uplink CPRI RE test shown in Fig. 11 the following equipment is needed:

Required Software	
R&S DigiConf SW (available at the Rohde & Schwarz website)	version 03.01.009.30 Build220 or higher

Required Devices	
R&S EX-IQ-BOX [Model K04] including external power supply and CPRI breakout board (option R&S EXBOX-B85)	with option R&S EXBOX-K10 for RE testing
SFP module for the SFP cage on the CPRI breakout board (third-party product, to be provided by the user)	compatible with SFP module of the DUT
Signal generator capable of generating the wanted RF signals e.g. R&S SMU200A or R&S SMBV100A optionally equipped with digital interface (option R&S SMU-B18) for troubleshooting	optionally with options for digital standards
R&S spectrum analyzer equipped with digital interface (option R&S FSQ-B17) e.g. R&S FSQ	optionally with options for digital standards
DUT with power supply, e.g. remote radio head	
PC running the DigIConf software	

Required Cables	
LVDS cable (comes with EX-IQ-BOX delivery)	
USB cable (comes with EX-IQ-BOX delivery)	
2 BNC cables	
RF cable	
Optical cable (duplex)*	compatible with SFP modules

* Establishing a CPRI link requires *bidirectional* communication between the EX-IQ-BOX and the DUT. For this reason, a duplex cable must be used. The term “uplink” basically refers to the unidirectional transmission of I/Q data.

5.2.3 Cabling

- Connect the EX-IQ-BOX to the external power supply.
 - Connect the EX-IQ-BOX to the PC using the USB cable.
- The “Power” LED must be green.



- Connect the EX-IQ-BOX to the spectrum analyzer using the LVDS cable. Use the DIG IQ IN/OUT 2 connector of the EX-IQ-BOX and the I/Q DATA IN connector of the analyzer.
- Connect the REF OUT connector of the analyzer to the REF IN connector of the signal generator.
- Connect the REF IN connector of the EX-IQ-BOX to the REF OUT connector of the signal generator.
- Connect the CPRI breakout board to the EX-IQ-BOX via the USER INTERFACE connector.
- Slide in an SFP module into the SFP cage on the CPRI breakout board.

- Connect the SFP connector of the CPRI breakout board to the DUT (RX/TX optical port) using an optical cable (duplex).
- Connect the RF output connector of the signal generator with the RF input of the DUT.

More details can be found in [1].

5.2.4 Configuration of the Signal Generator

- Preset the signal generator.
- Set the reference frequency to “external” (as the reference frequency is fed in from the analyzer via the BNC connector.)

In this setup, the analyzer is the reference frequency source. However, it is also possible to use the signal generator or an external reference frequency (with high precision) as reference frequency source.

- Set the RF frequency and the signal level as required by the DUT.
- Activate the desired test signal, e.g. a 3GPP uplink signal, in the baseband block.
- Activate the I/Q modulation block and the RF block, i.e. switch on the RF output.



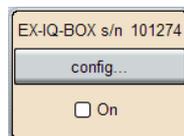
5.2.5 Configuration of the DUT

The DUT, i.e. the remote radio head, is a user-specific device. Thus, the user must account for the correct configuration of the DUT.

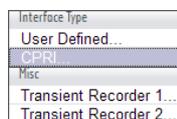
Important DUT-specific properties such as supported CPRI line bit rates, bit resolution, CPRI basic frame allocation and group transmission pattern are specified in the data sheet of the device.

5.2.6 Configuration of the CPRI Link

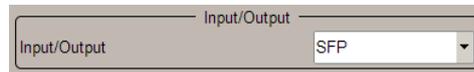
- Start the DiglConf software on the PC.
→ DiglConf recognizes the connected EX-IQ-BOX and indicates its serial number.



- Click on the "config..." button and select “CPRI” from the list to open the CPRI settings menu.



- Select the CPRI mode “CPRI RE Test”.
- Click on the "Preset" button to start with a defined state.
- Select the “Hardware” tab and make the following settings:
- Set the CPRI line bit rate. Select the one which is supported by your SFP connection. Select the line bit rate according to the capabilities of the DUT.
- Select SFP as input/output port



- Switch to the “Uplink (Rx)” tab and make the following settings:
 - Select “DIG IQ OUT 2” as the signal output.
 - Select the standard to be used. For example, select the 3GPP FDD standard.
- The sample rate is automatically set according to the selected standard. For example, for the 3GPP FDD standard the sample rate is automatically set to 3.84 MHz. This sample rate constitutes a base sample rate which is not editable for a selected standard. Instead of selecting a digital standard you can also select “User defined”. With this setting the sample rate can be set to a custom value.



- Set the oversampling factor. For example set it to “2”.



The product of the base sample rate and the oversampling factor gives the actual sample rate which must match the sample rate supplied by the DUT. Let us assume that the sample rate of the DUT is 7.68 MHz.

$$\text{Sample_Rate}_{\text{EX-IQ-BOX}} \cdot \text{Oversampling}_{\text{EX-IQ-BOX}} = \text{Sample_Rate}_{\text{DUT Output}}$$

For example: $3.84 \text{ MHz} \cdot 2 = 7.68 \text{ MHz}$ → The EX-IQ-BOX settings match the DUT sample rate.

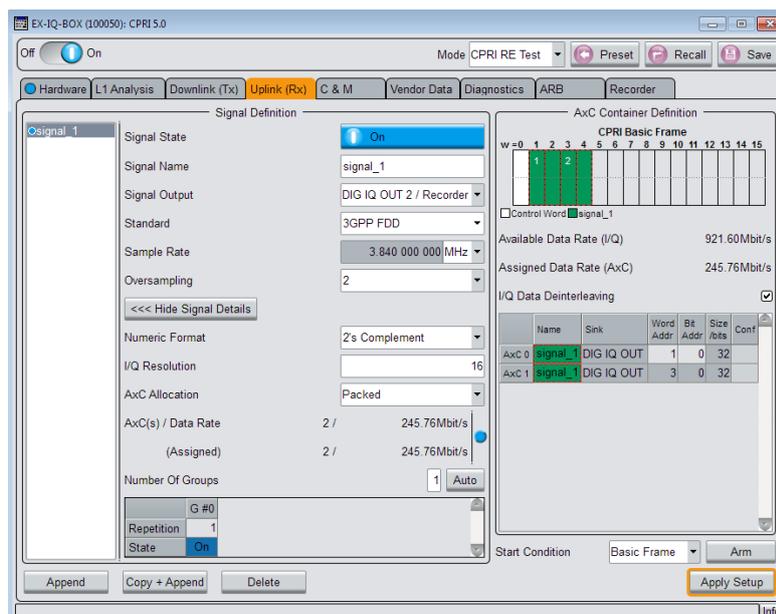


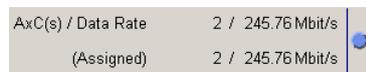
Figure 12: DigIConf user interface for CPRI – Uplink (Rx) tab.

A detailed description of all the parameters in this menu can be found in [1].

The right side of the “Uplink (Rx)” tab, i.e. the “AxC Container Definition” part of the menu is identical to the one of the “Downlink (Tx)” tab. Please refer to section 5.1.5 for a detailed description.

- Click on the “Show Signal Details” button (on the left side of the “Uplink (Rx)” tab).
- Adjust the settings for the numeric format and the I/Q resolution depending on what the DUT supports.

→ The LED must be blue.



A red LED indicates that there is a mismatch between the required and the assigned data rates. Note that the required data rate must match the assigned data rate.

The required data rate (in Mbit/s) can be calculated as follows:

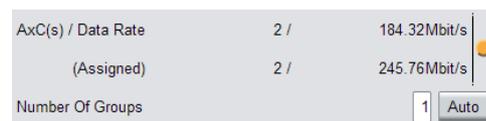
$$\text{Data_Rate}_{\text{req}} = \text{Sample_Rate} \cdot \text{I/Q_Resolution} \cdot 2 \cdot \text{Oversampling}$$

The assigned data rate (in Mbit/s) can be calculated as follows:

$$\text{Data_Rate}_{\text{ass}} = 3.84 \text{ MHz} \cdot \text{I/Q_Resolution} \cdot 2 \cdot \#_AxCs$$

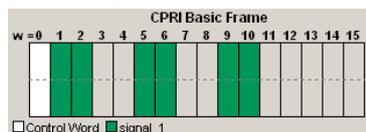
where #_AxCs is the number of allocated AxCs per basic frame

- If the LED is red, then click on the “Auto” button right below. The DigIConf software will then automatically adjust the group settings such that the assigned data rate matches the required data rate (see section 5.1.5.1 for details).



- Set the “AxC Allocation” to “Flexible”.
- Adjust the position of the AxCs inside the CPRI basic frame by setting the word and bit address. The AxC allocation of the basic frame is DUT specific.

For example, an interleaved allocation can be set by adjusting the word addresses accordingly. (Word addresses are 1, 5, and 9 in this example, bit addresses are all 0).



- Check if there are any conflicts indicated in the “AxC Container Definition” list.

no conflict

	Source	Word Addr	Bit Addr	Size /bits	Conf
AxC 0	signal_1	1	0	32	
AxC 1	signal_1	3	0	32	

conflict

	Source	Word Addr	Bit Addr	Size /bits	Conf
AxC 0	signal_1	1	0	32	
AxC 1	signal_1	15	0	32	

→ There must not be any conflicts.



Conflicts can occur for example when the signal does not “fit” into the basic frame. Depending on the conflict cause, it can help to adjust the word and bit address of the AxCs, to use a higher CPRI line bit rate (if the DUT supports it) or to reduce the I/Q resolution or the sample rate.

- Set the “Signal State” to “On”
- Finally, turn on the CPRI RE test. 

→ The CPRI link is built up. I/Q data reception starts as soon as the link is established. Alternatively to this free running start, it is also possible to define a start condition, e.g. an external trigger for starting the I/Q data reception (see section 7.2 for details).

If you change any settings in the “Uplink (Tx)” tab, the new settings must be applied to the CPRI link:

- Press the "Apply Setup" button.
- The CPRI link is shut down and updated. I/Q data reception starts with new settings as soon as the link is re-established.



The new settings are not effective until you press the "Apply Setup" button. If you change any settings, a red arrow will appear next to this button indicating that the button needs to be pressed to actually apply the new settings.

5.2.7 EX-IQ-BOX LED Indicators

The EX-IQ-BOX and the DigIConf software offer several LED indicators for signaling proper operation or malfunction. In particular, DigIConf offers LEDs that can be used to check if the CPRI link between the EX-IQ-BOX and the DUT works properly.

After the EX-IQ-BOX and the DUT have been connected and configured to establish a CPRI link, the state of the following LEDs should be checked:

- LEDs on the EX-IQ-BOX base unit
- LEDs on the EX-IQ-BOX CPRI breakout board
- LEDs in the CPRI “Hardware” tab of DigIConf
- LEDs in the CPRI “L1 Analysis” tab of DigIConf
- LEDs in the CPRI “Test & Diagnostics” tab of DigIConf

The function and different states of these LEDs are described in detail in reference [1].

5.2.8 Configuration of the Analyzer

- Preset the signal analyzer.
- Set the reference frequency to “internal”.
- Configure the analyzer for the desired measurement.
For example, select the respective personality (e.g. 3GPP BS) to demodulate the signal and show the EVM.
- Select the digital baseband input (“Baseband Digital”) as signal source.

- Enter the sample rate of the baseband signal (“Digital In Sample Rate”), e.g. enter 7.68 MHz.



The entered sample rate must match the actual sample rate supplied by the DUT. Make sure that you enter this value, otherwise the synchronization will fail and the analyzer will not demodulate. Forgetting to adjust the digital sample rate setting is one of the most common errors made!

- Adjust the reference level, e.g. by pushing the “Adjust Ref Level” button.

More details can be found in [3].

5.2.8.1 How to select the digital baseband input as signal source

R&S® FSQ:

3GPP FDD personality:

- Push the “SETUP” button.
- Push the “SIGNAL SOURCE” soft key.
- Push the “BASEBAND DIGITAL” soft key.
- Push the “DIGITAL IN SAMPLERATE” soft key and enter the sample rate value.

LTE and WiMAX personalities:

- Push the “SETTINGS GEN DEMOD” soft key.
- Switch to the “Advanced” tab.
- Configure the “Input Settings”: Select “Digital IQ” as “Source”.
- Configure the “Digital Baseband Settings”: Set the “Dig. Input Data Rate” to the correct value.

R&S® FSV:

3GPP FDD personality:

- Push the INPUT/OUTPUT button.
- Push the “Signal Source” soft key.
- Push the “Baseband Digital” soft key.
- Set the “Input Sample Rate” to the correct value.

LTE and WiMAX personalities:

Similar to the R&S® FSQ.

R&S® FSW:

3GPP FDD and LTE personalities:

- Push the INPUT/OUTPUT button.
- Push the “Input Source Config” soft key
- Select the “Digital IQ” tab
- Set the “Input Sample Rate” to the correct value.
- Push the “On” button.

5.2.9 Summary: Settings that must match

As mentioned already in the previous sections, there are some settings that need to match in order to establish a working CPRI connection.

- The reference frequency settings of the signal generator, the EX-IQ-BOX, and the analyzer must be coordinated. For example:

Reference frequency settings		
Signal generator	EX-IQ-BOX	Analyzer
External source	External source (REF IN)	Internal source

- The base sample rate set for the EX-IQ-BOX times the oversampling factor must match the sample rate of the DUT.
- The sample rate set on the analyzer must match the sample rate of the DUT.

Sample rate settings		
DUT	EX-IQ-BOX	Analyzer
Supplied sample rate	Base sample rate · Oversampling	Sample rate supplied by DUT

- The assigned data rate must match the data rate of the CPRI link.
- The data rate of the CPRI link must match the data rate supplied by the DUT.

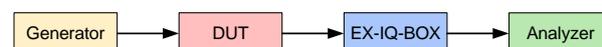
Data rates		
EX-IQ-BOX	EX-IQ-BOX	DUT
Assigned data rate	Set data rate	Supplied data rate

- The allocation of the CPRI basic frame with AxCs set on the EX-IQ-BOX must match the basic frame allocation expected/required by the DUT.

CPRI basic frame allocation	
EX-IQ-BOX	DUT
Set basic frame allocation	Required basic frame allocation

5.2.10 Troubleshooting

The test setup consists of four interconnected components: signal generator, DUT, EX-IQ-BOX, and analyzer.



This section describes how to proceed when your setup does not work.

First, you can perform some fast checking by using the Transient Recorders of the EX-IQ-BOX as described below. Afterwards, you can proceed with testing the individual parts of the setup step by step to find the source of error. For these tests, you need a signal generator which has a digital output. In the original setup, the function of the signal generator is to generate an RF signal, but if the instrument can output digital baseband signals it can be disconnected and reused for debugging purposes as described below. For this, the instrument's digital I/Q output settings must be configured accordingly.

5.2.10.1 Monitoring the output of the EX-IQ-BOX

The Transient Recorder of the EX-IQ-BOX can also be used for checking the characteristics of the digital output signal.



- Click on the "config..." button in the DigiConf block diagram and select "Transient Recorder 1" from the list.
- Select "DIG IQ OUT 2" as the data source.
- Choose a display type: "I/Q", "Vector", "CCDF", or "Power Spectrum".
- If desired, adjust the acquisition and trigger settings. Please see [1] for details.
- Set the "State" to "On".
- Evaluate visually if the signal characteristics look okay.

→ If the output signal looks ok, then

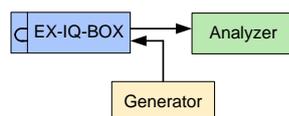
- check the analyzer settings. In doubt, connect the analyzer directly to the signal generator's digital I/Q output (if available) using a LVDS cable (completely leaving out the DUT and the EX-IQ-BOX) to verify the settings of the analyzer.

→ If the output signal does not look ok, then

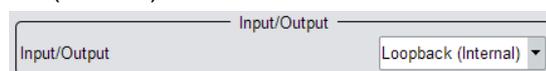
- proceed as described in section 5.2.10.2.

5.2.10.2 Looping the signal at the EX-IQ-BOX

The EX-IQ-BOX CPRI breakout board offers an internal loopback mode. With this mode enabled, the signal is internally routed back. With a simple test setup (shown below), the user can check if the EX-IQ-BOX works properly, i.e. if it is configured correctly. The needed digital baseband signal is supplied by a signal generator with digital output option. The user should be aware that the generator can also be a "new" source of error (see last paragraph of this section).



- Enable the loopback mode by setting the "Input/Output" parameter to "Loopback (Internal)" in the "Hardware" tab.



- In the “Downlink (Tx)” tab, configure the identical signal as configured in the “Uplink (Rx)” tab and switch the signal state to “On”.



The signal settings for downlink and uplink must be identical. The only difference between the settings is that in the “Downlink (Tx)” tab “DIG IQ IN 1” is selected as the physical source.

- Connect the signal generator to the DIG IQ IN/OUT 1 connector of the EX-IQ-BOX using a LVDS cable. (The DUT can be left connected.)
- On the signal generator, activate the desired test signal, e.g. a 3GPP uplink signal, in the baseband block.
- Configure and enable the digital I/Q output of the signal generator, i.e. set the sample rate (in “User Defined” mode) and set the PEP value (see section 5.1.4 for details).
- Analyze the signal.

→ If the signal is as expected, then

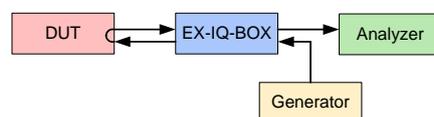
- proceed as described in section 5.2.10.3.

→ If there are problems with demodulation (e.g. synchronization failed) or if the signal is not like expected, then

- perform a fast visual check of the input and output signals to/from the EX-IQ-BOX using the transient recorders of the EX-IQ-BOX. Since the EX-IQ-BOX has two implemented Transient Recorders, the input and the output signal (at connectors DIG IQ OUT 1 and 2, respectively) can be monitored in parallel.
- check the settings of the signal generator and the analyzer. In doubt, connect the signal generator directly to the analyzer via a LVDS cable (completely leaving out the EX-IQ-BOX) to verify the settings of the analyzer and the signal generator.
- check the settings of the EX-IQ-BOX, in particular check the settings of the downlink signal.

5.2.10.3 Looping the signal at the DUT

For testing purposes CPRI DUTs usually provide an internal loopback mode. In loopback mode the DUT receives the CPRI signal and directly routes it back without any signal processing. This loopback mode is used to test the optical transmission line.



- Connect the signal generator to the DIG IQ IN/OUT 1 connector of the EX-IQ-BOX using a LVDS cable.
- Activate the desired test signal, e.g. a 3GPP uplink signal, in the baseband block of the signal generator.
- Configure and enable the digital I/Q output, i.e. set the sample rate (in “User Defined” mode) and set the PEP value (see section 5.1.4 for details).
- Set the “Input/Output” parameter to “SFP” in the “Hardware” tab.

- In the “Downlink (Tx)” tab, configure the identical signal as configured in the “Uplink (Rx)” tab and switch the signal state to “On”.



The signal settings for downlink and uplink must be identical. The only difference between the settings is that in the “Downlink (Tx)” tab “DIG IQ IN 1” is selected as the physical source.

- Enable the loopback mode of the DUT.
- Check if there are any warnings or alarms in the “Diagnostics” tab and check the status of the three LEDs. All LEDs must be blue.

→ If the LED status is not ok, then the optical link does not work properly. A SFP module or the optical cable may be broken or not properly connected.

→ If the LED status is ok, then

- measure the signal with the analyzer.

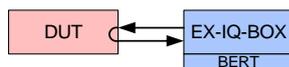
→ If the signal is as expected, then the optical link works properly, i.e. the SFP modules on both ends and the optical cable are ok. The source of error might be, for example, that

- the DUT is not configured correctly. Check the settings of the DUT.
- the CPRI setting configured on the EX-IQ-BOX do not match the CPRI settings expected by the DUT. Check the needed CPRI settings.

An alternative to the loopback test described in this section is the low-level BER test described in the following section. This BER test is also used to check the transmission line. The advantage is that no signal generator is required for this test.

5.2.10.4 Low-level BER test

Please refer to section 5.1.10.4.



5.2.10.5 Checking the generated signal

Baseband Signal

The signal generator provides a graphics feature (similar to the transient recorder of the EX-IQ-BOX) for visual control of the generated baseband signal.

- Click on the Graphics function block to open the Graphics settings menu.
- Select the display mode, i.e. “Constellation”.
- Set the “State” to “On”.
- Check if the baseband signal looks ok.

RF Signal

- Connect the RF output connector of the signal generator directly to the RF input connector of the analyzer.
- Configure the analyzer for demodulating and analyzing the RF signal. Make sure that the analyzer settings are made correctly (see section 5.1.8).
- Check if the RF signal is as expected.

5.2.11 Characterization of the DUT

After configuring the instruments and the DUT and establishing a working CPRI connection, the setup is now ready for performing measurements on the RE device. These measurements are aimed at characterizing the RF and demodulation properties of the DUT. For example:

- Noise figure

The noise figure is a measure of how much noise is added to the received signal by the DUT. A noise figure measurement gives a good indication of the receiver performance at low RF level input. The better the noise figure, the better the receive sensitivity of the DUT. Thus, the noise figure is measured to verify that the DUT meets a specified sensitivity level.

- Modulation accuracy (EVM)

The error vector magnitude (EVM, Fig. 10) measurement is performed to check the modulation accuracy of the demodulated RX signal. The EVM evaluation gives valuable information on the quality of the I/Q signal and thus this measurement is a good indicator for the quality of the RE.

EVM measurements can be performed under ideal reception conditions (i.e. reception of the wanted signal only) or under disturbed conditions such as additive white Gaussian noise (AWGN) or interfering signals in the reception frequency channel or interference from adjacent or other channels.



Note that the presented test solution is intended for testing the RF characteristics of an RE device under test. We implement CPRI as essential part of the setup, but the test solution is not intended or usable for testing the CPRI protocol standard itself!

5.3 Bidirectional Operation

The setups described independently for downlink and uplink can also be combined to a single setup, since it is possible to operate the EX-IQ-BOX in bidirectional mode. This means, the EX-IQ-BOX sends and receives data simultaneously over a duplex CPRI link. Fig. 13 shows the setup used for bidirectional operation.

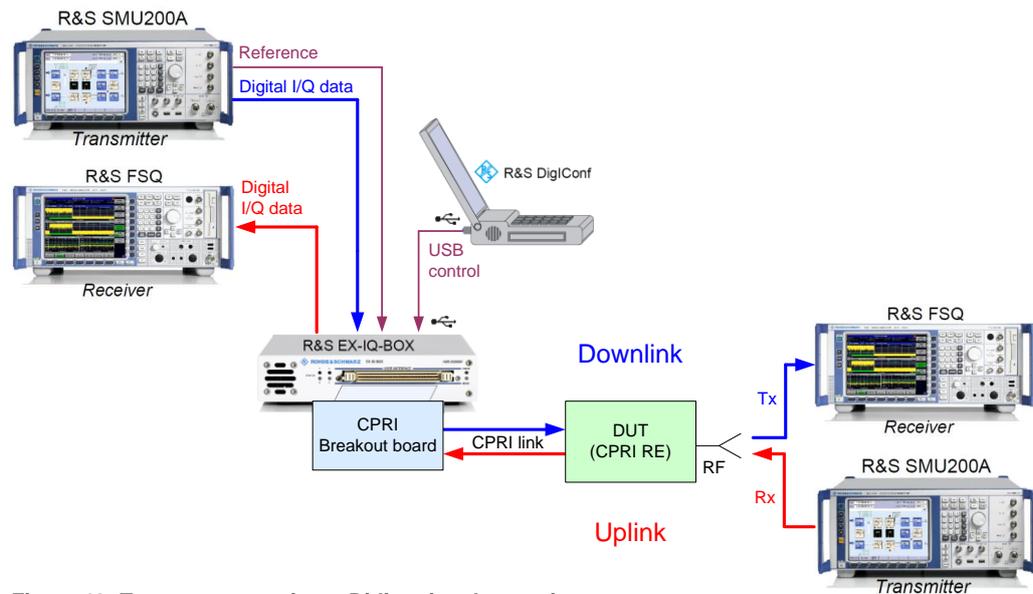


Figure 13: Test setup overview – Bidirectional operation.

If the DUT has only one common RF antenna port for RX and TX, then a circulator must be used in the above bidirectional setup in order to connect the analyzer and signal generator at the same time. The circulator separates the TX and RX transmission lines as shown in Fig. 14.

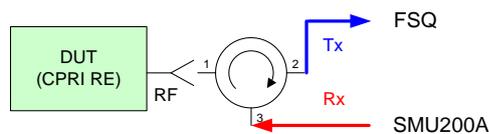


Figure 14: Bidirectional operation with circulator.

5.4 General Purpose Input/Output

The CPRI breakout board offers three BNC connectors for general purpose input/output (GPIO) to interface with the DUT or other test equipment. The GPIO connectors can be used as input to receive signals (e.g. trigger signals) or as output to supply control signals (e.g. marker and clock signals). The input and output voltage levels are LVTTTL. The three GPIO connectors can be configured independently for user-specific purposes in the “Hardware” tab (Fig. 15).

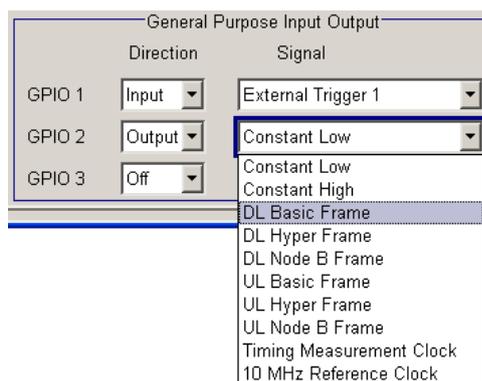


Figure 15: Overview of marker and clock signals provided via the GPIO connectors.

For example, the timing of the EX-IQ-BOX and the signal generator (downlink), i.e. the starting times of the digital I/Q data and the CPRI frames, can be aligned:

- Connect the GPIO 2 connector of the breakout board to the TRIGGER 1 connector of the signal generator using a BNC cable.
- Select “Output” as direction for GPIO 2.
- Select “DL Node B Frame” as signal for GPIO 2.
- Configure the trigger settings of the signal generator (baseband section):
 - Select trigger mode “Armed Auto”.
 - Select trigger source “External”.
 - Adjust the external trigger delay.

Please see also section 7 for more information on synchronization.

5.5 C&M

5.5.1 Background Information

In addition to I/Q data, control and management (C&M) information is also transmitted over the CPRI link, for example for adjusting the RF frequency and output level of the DUT. C&M information is conveyed in the control word of the CPRI basic frame. The control word is transmitted with each basic frame and it is always the first word in the basic frame ($w = 0$).

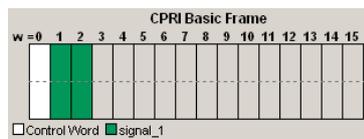


Figure 16: Position of the control word (white) within the CPRI basic frame.

256 CPRI basic frames form one CPRI hyper frame [5]. Thus, each hyper frame contains 256 control words. These 256 control words form one control block. The control block is arranged in 64 rows and 4 columns. Fig. 17 shows the organization of the control words within the control block. Besides the C&M information, the control words also convey other content such as synchronization information and vendor specific information. Please refer to reference [5] for detailed information.

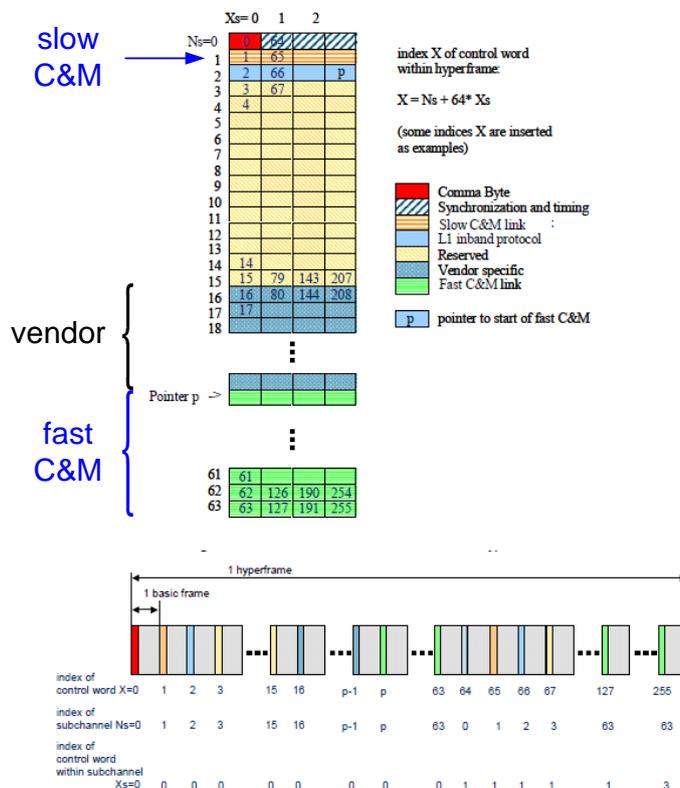


Figure 17: Illustration of control words within one hyper frame [5].

The CPRI standard supports two different types of C&M channels:

- Slow C&M channel based on HDLC.
- Fast C&M channel based on Ethernet.

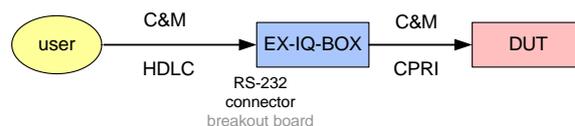
5.5.2 Slow C&M

The slow C&M channel is a low-rate channel based on the high-level data link control (HDLC) protocol standard. Four control words per control block are available for slow C&M data.

The EX-IQ-BOX provides two methods for transmitting and receiving slow C&M data:

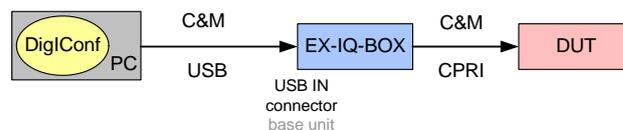
- Via RS-232 connector:

HDLC encoded C&M data can be fed into the EX-IQ-BOX via the RS-232 connector on the CPRI breakout board. The HDLC encoded C&M data must be provided by the user. The EX-IQ-BOX transmits the C&M data in real-time over the CPRI link to the DUT. The RS-232 connector can be used as input and output, i.e. C&M data can be sent and received.



- Via integrated terminal:

In the DiglConf software ("C & M" tab), C&M data can be entered as plain text commands. The EX-IQ-BOX encodes the plain text to the HDLC format and transmits the C&M data over the CPRI link to the DUT. The terminal can be used for sending C&M data as well as for displaying incoming C&M data. Received HDLC encoded C&M data is decoded by the EX-IQ-BOX and displayed as plain text.



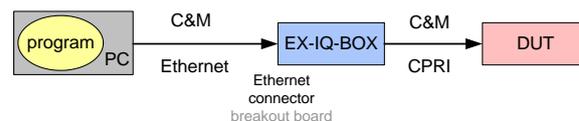
5.5.3 Fast C&M

The fast C&M channel is a high-rate channel based on the Ethernet protocol standard. The fast channel can be *flexibly* configured by an Ethernet pointer (see Fig. 17). This pointer represents the boundary between the vendor specific data and the fast C&M data in the control block. The pointer position can range from row 20 to 63 in the control block. Thus, up to 176 control words per control block are available for fast C&M data. The pointer determines the number of control words used for C&M data (the remaining control words are available for vendor specific data) and thus it determines the bit rate for C&M transmission.

The EX-IQ-BOX provides two methods for transmitting and receiving fast C&M data:

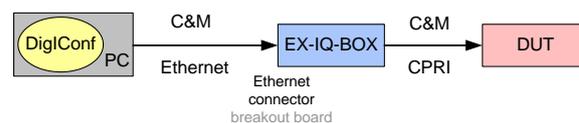
- Fast C&M via Ethernet connector.

This method can be used if the DUT has an Ethernet MAC (media access control) address. The EX-IQ-BOX acts as a transport medium for Ethernet MAC frames enabling an Ethernet connection between the control PC and the DUT. More precisely, the EX-IQ-BOX acts as a layer 2 Ethernet MAC bridge between the control PC and the DUT. The C&M data is sent from the control PC over Ethernet to the EX-IQ-BOX, which tunnels the Ethernet MAC frames over CPRI to the DUT. The Ethernet connector of the breakout board thus emulates the (often nonexistent) Ethernet connector of the DUT. The DUT can be accessed by its MAC address using third-party or user-written programs running on the control PC. The DUT may also support higher layer protocols such as layer 3 protocols (IP, ICMP, etc.), layer 4 protocols (TCP, UDP, etc.) and application layer protocols (Telnet, FTP, HTTP, etc.). If and which higher layers are supported depends on the DUT and is vendor-specific. For example, if the DUT supports the TCP/IP protocol stack, i.e. if the DUT has a MAC and an IP (internet protocol) address, it can be accessed by its IP address using a third-party terminal program running on a PC such as Tera Term, PuTTY or Microsoft's Telnet client. The role of the EX-IQ-BOX however remains the same: it forwards the Ethernet MAC frames (received at the Ethernet connector) to the MAC address of the DUT over the CPRI link.



- Fast C&M via integrated Telnet console.

This method can only be used if the DUT offers a Telnet server. The DUT is accessed by its IP address using a Telnet connection. The Telnet client (simple client) is integrated into DigIConf.



5.5.3.1 Ethernet

The raw C&M data need to be sent to the EX-IQ-BOX in form of Ethernet frames according to the standardized Ethernet protocol. If the DUT supports the TCP/IP protocol, you can use a third-party terminal program (application layer) such as Tera Term or PuTTY to generate the necessary Ethernet frames (layer 2). In the following, we assume the DUT has an IP address.

- Connect the control PC to the EX-IQ-BOX via the Ethernet connector on the CPRI breakout board.
 - Select the “C & M” tab.
 - Select the “Fast C&M (Ethernet)” tab and make the following settings:
 - Adjust the Ethernet pointer, e.g. enter 20 as preferred Ethernet pointer.
 - Set the “State” to “On”.
- The “Ethernet Active” LED must be blue.

→ After the handshake between the EX-IQ-BOX and the DUT the actually used Ethernet pointer is indicated. (It can be different to the entered preferred Ethernet pointer.)

→ The resulting bit rate for C&M transmission is indicated. It depends on the Ethernet pointer position and the CPRI line bit rate.

- Configure the terminal program for communication with the DUT. You will have to enter the IP address of the DUT (see example below).
- Send a control command or a series of control command using the terminal program (see example below).

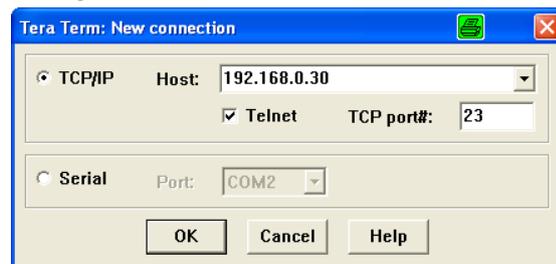
Normally, the C&M data can be entered as plain text commands.

The fast C&M data is transferred in real-time over the CPRI link. Since the Ethernet connector of the EX-IQ-BOX can be used as input and output, C&M data can be sent and received.

Example:

The third-party terminal program Tera Term running on the control PC is used to send several control commands to the DUT.

Configuration of Ethernet connection:



After login, three DUT-specific control commands (marked in red) are sent to the DUT. The response from the DUT is displayed.

```
Tera Term - 192.168.0.30 VT
File Edit Setup Control Window Help
Welcome to xXxXxXxX RRH Telnet Server

login: radiohead
password:

>> set rrrhmode txonly
RRH mode is txonly

>> set carrier 1 2600.00
Carrier configuration:
-----
State      : on
Frequency  : 2600.00 MHz

>> get ethptr
Ethernet pointer: 0x24

>> █
```

5.5.3.2 Telnet Console

- Connect the PC (DigIConf) to the EX-IQ-BOX via the Ethernet connector on the CPRI breakout board.
 - Select the “C & M” tab.
 - Select the “Fast C&M (Ethernet)” tab and make the following settings:
 - Adjust the Ethernet pointer, e.g. enter 20 as preferred Ethernet pointer.
 - Set the “State” to “On”.
- The “Ethernet Active” LED must be blue.
- The actually used Ethernet pointer is indicated.
- The resulting bit rate for C&M transmission is indicated.
- Configure the integrated Telnet client for communication with the Telnet server of the DUT as follows:
 - Enter the IP address of the DUT into the “Host” entry field.
 - Enter the TCP port address of the DUT into the “Port” entry field. The standard Telnet port is 23.
 - If a user name and password are required for access, enter the user name into the “Login” and the password into the “Password” entry field.
 - Click on the “Connect” button.
- The displayed connection status must be “connected”.
- Enter a control command (DUT-specific) into the command line.

Command	test cmd	Execute
---------	----------	---------

C&M information can be entered as plain text commands.

- Click on the “Execute” button.
- The C&M data is transferred over the CPRI link.
- The sent command is displayed in the console.

The console can be used for sending C&M data as well as for receiving and displaying incoming C&M data.

Example:

The DUT-specific control command “get cpristatus” is sent to the DUT. The response from the DUT is displayed.

Telnet Client			
Host	192.168.0.30	Port	23
Login	radiohead	Password	*****
			Connect

```

Welcome to XxXxXxXxX RRH Telnet Server

login: XZ #password:
Logged in
>>
get cpristatus
CPRI Status Information
-----
DL CPRI LOS: 0
DL CPRI LOF: 0
CPRI receive state: SYNC
Radio Frame Pulse (every 10 ms): 1
Line Code Violations: 0
BFM: 1009
>>

```

5.6 Vendor Data

Besides C&M or synchronization information, the control words also convey vendor-specific information, e.g. additional control data. Depending on how many control words are used for transmitting fast C&M data, up to 192 control words per control block are available for vendor specific data. A minimum of 16 control words per control block are always reserved for vendor data.

The EX-IQ-BOX can send and receive vendor-specific data over the CPRI link.

- Select the “Vendor Data” tab and make the following settings:
- Select the direction:
 - Downlink: vendor data is sent to the DUT.
 - Uplink: vendor data is received from the DUT and displayed.

For example, select “Downlink”.

- Adjust the Ethernet pointer in the “C & M” tab, e.g. enter 20 as preferred Ethernet pointer.

→ The used Ethernet pointer position is indicated in the “Vendor Data” tab.

→ The number of rows in the vendor data table are automatically adjusted depending on the Ethernet pointer position.

The vendor data table is a generic interface for transfer of vendor-specific data. It can be used to set vendor-specific data for transmission to the DUT (downlink) or to display the vendor data received from the DUT (uplink).

The first four columns of the table show the control words available for vendor data within the control block (Fig. 18). For example, if the Ethernet pointer position is 20 (minimum), 16 control words are available.

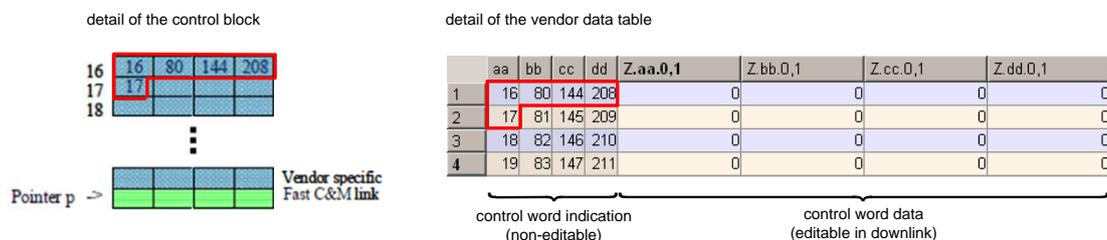


Figure 18: Description of the vendor data table.

These control words can be filled with vendor data using the adjacent four columns of the table. Per control word one user-specific data word can be entered (in hexadecimal format).

Downlink:

- Fill the table with your vendor-specific data.
For example, to use control word 81 for transmission, enter your user-specific data word into row 2 at column Z.bb.
- Set the “State” to “On”.

→ The vendor data is transmitted over the CPRI link to the DUT. The data specified in the table i.e. the default zeros or the user-specific data is transmitted in each hyperframe.

Uplink:

- Set the “State” to “On”.

→ The vendor data received over the CPRI link from the DUT are displayed. The data in the table is updated regularly but not every hyperframe, because the update rate of the graphical user interface of DigIConf is not as high as the hyperframe rate.

5.7 Settings Saving

After all settings in the DigIConf software have been configured, in particular the link settings for downlink and uplink, these user-specific CPRI settings should be saved in a file by clicking on the “Save” button.



The saved configuration may then be distributed e.g. among a company and reused. This way, manufacturer-specific CPRI settings can be prepared once and then recalled as a kind of user-preset configuration. To load a settings file click on the “Recall” button.

6 Alternative Setup for RE Testing

6.1 Compact Test Solution

6.1.1 Overview

Instead of using an SMU for generating the downlink signal, the internal EX-IQ-BOX option “Waveform Memory” (K90) can be used to play back pre-calculated waveforms. The EX-IQ-BOX itself thus acts as the I/Q data source by generating the downlink signal via its internal waveform memory (64 MSample, 256 MByte). The pre-calculated waveforms can be generated with WinIQSIM2 or third-party tools such as Matlab™. The playback of WinIQSIM2-generated standard-conform waveform files requires the respective digital standards option to be installed on the EX-IQ-BOX (see [1] for details).

Using the internal waveform memory of the EX-IQ-BOX it is possible to play back a single waveform or multiple waveforms at a time. Up to four waveforms can be played back simultaneously from the waveform memory. This multi-waveform playback mode requires the EX-IQ-BOX option K91. The EX-IQ-BOX is thus able to transmit multiple signals simultaneously over the *same* CPRI link. For example, the multi-waveform playback mode can be used for testing multi-antenna radio heads. These radio heads need to get the data for each transmit antenna separately from the REC. Thus, more than one antenna signal must be transmitted via the same CPRI link. By using the multi-waveform playback mode of the EX-IQ-BOX the complexity of the setup for testing MIMO capable REs is greatly reduced.

In the test setup shown in Fig. 13 the analyzer used for analysis of the uplink signal can be replaced by the internal EX-IQ-BOX option “Recording Memory” (K94). With its recording memory (512 MByte) the EX-IQ-BOX can receive and record the uplink signal. The recorded I/Q data is then available as a file for post-processing with external software (third-party tools) or an analyzer (I/Q file analysis). Both options, the waveform memory and the recording memory, reduce the number of instruments required in the test setup as shown in Fig. 19.

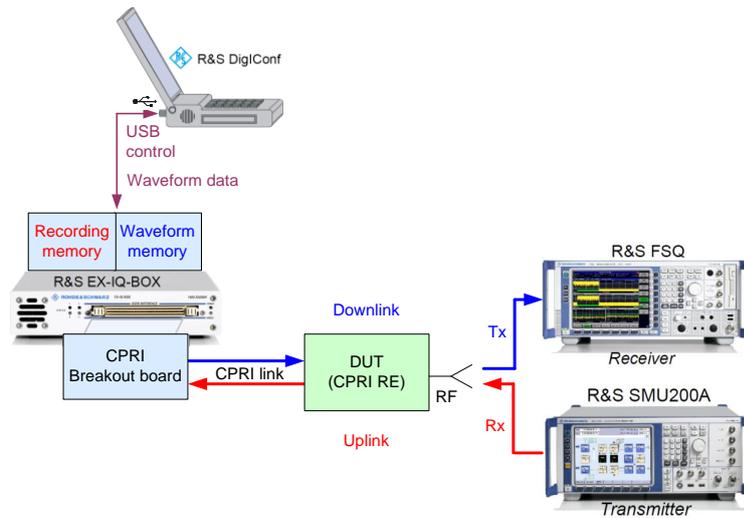


Figure 19: Test setup overview – Bidirectional operation with stand-alone EX-IQ-BOX.

The signal flow is as follows:

The EX-IQ-BOX generates a baseband signal (e.g. an LTE downlink signal) from its internal waveform memory. The I/Q data is then transmitted over an optical (or electrical) link to the DUT (RE) using the CPRI transmission protocol. The CPRI RE extracts the I/Q signal from the received data stream and performs an I/Q modulation to a certain RF carrier frequency. The resulting RF signal is then sent to a spectrum analyzer to evaluate the signal.

The signal generator supplies an RF signal (e.g. an LTE uplink signal), which is fed to the DUT (RE). The DUT down-converts the signal from the RF domain to the baseband. The resulting baseband signal is then transmitted over the CPRI link to the EX-IQ-BOX. The EX-IQ-BOX records the incoming I/Q signal with its internal recording memory and provides the recorded data as a file.

6.1.2 Equipment

For the CPRI RE test shown in Fig. 19 the following equipment is needed:

Required Software	
R&S DigIConf SW (available at the Rohde & Schwarz website)	version 03.01.009.30 Build220 or higher

Required Devices	
R&S EX-IQ-BOX [Model K04] including external power supply and CPRI breakout board (option R&S EXBOX-B85) with waveform memory (option R&S EXBOX-K90) and recording memory (option R&S EXBOX-K94)	with option R&S EXBOX-K10 for RE testing optionally with WinIQSIM2 options for digital standards
SFP module for the SFP cage on the CPRI breakout board (third-party product, to be provided by the user)	compatible with SFP module of the DUT
Spectrum analyzer capable of demodulating the wanted signals e.g. R&S FSQ	optionally with options for digital standards
Signal generator capable of generating the wanted RF signals e.g. R&S SMU200A or R&S SMBV100A	optionally with options for digital standards
DUT with power supply, e.g. remote radio head	
PC running the DigIConf software	
Circulator	if DUT has one common antenna port for TX and RX

Required Cables	
USB cable (comes with EX-IQ-BOX delivery)	
1 BNC cable	
2 RF cables	
Optical cable (duplex)	compatible with SFP module and DUT

6.1.3 Cabling

- Connect the EX-IQ-BOX to the external power supply.
 - Connect the EX-IQ-BOX to the PC using the USB cable.
 - Connect the CPRI breakout board to the EX-IQ-BOX via the USER INTERFACE connector.
 - Slide in an SFP module into the cage SFP on the CPRI breakout board.
 - Connect the SFP connector of the CPRI breakout board to the DUT (RX/TX optical port) using an optical cable (duplex).
 - Connect the REF IN connector of the EX-IQ-BOX to the REF OUT connector of the analyzer.
 - Connect the REF OUT connector of the analyzer to the REF IN connector of the signal generator.
 - Connect the RF input connector of the analyzer with the RF output of the DUT.*
-  Make sure that you use adequate attenuation to avoid damaging the analyzer, since the DUT's RF output power may exceed the maximum input power of the analyzer.
- Connect the RF output connector of the signal generator with the RF input of the DUT.*

* If the DUT has only one common RF antenna port for RX and TX, then a circulator must be used to separate the TX and RX transmission lines (see Fig. 14).

6.1.4 Configuration of the EX-IQ-BOX for Signal Generation

6.1.4.1 Single Waveform Playback

- Start the DiglConf software on the PC.
- DiglConf recognizes the connected EX-IQ-BOX and indicates its serial number.
- Click on the "config..." button and select "CPRI" from the list to open the CPRI settings menu.
- Select the CPRI mode "CPRI RE Test".
- Click on the "Preset" button to start with a defined state.
- Set the reference clock source to "REF IN" in the "Hardware" tab.
- Select the "ARB" tab and make the following settings:
- In the "ARB Sources" table click in the "File" column for ARB 1.

	File	Option(s)	Sample Rate /MHz	Samples	State	Option(s) Conflict
ARB 1	None	None	0.000	0	Off	

→ The ARB File 1 selection menu opens (explorer dialog).

- Select a waveform file.
- The file path and name as well as a possibly required EXBOX-K2xx option of the selected waveform file are displayed in the table. The sample rate and the number of samples are also shown.
- Set the State to "On" for ARB 1.

	File	Option(s)	Sample Rate /MHz	Samples	State	Option(s) Conflict
ARB 1	c:\3GPP.wv	EXBOX-K242	11.520	115 200	On	



Waveforms generated with WinIQSIM2 require the corresponding EXBOX-K2xx option for playback. If the selected waveform requires an EXBOX-K2xx option that is not installed, an option conflict will occur and the waveform will not be played back.

6.1.4.2 Multi Waveform Playback

To transmit multiple signals simultaneously over the CPRI link make the following settings in addition:

- In the "ARB Sources" table click in the "File" column for ARB 2.
- The ARB File 2 selection menu opens.
- Select a waveform file.
- Set the State to "On" for ARB 2.
- If desired, select a waveform file for ARB 3 and ARB 4 and
- Set the State to "On" for ARB 3 and ARB 4.

	File	Option(s)	Sample Rate /MHz	Samples	State	Option(s) Conflict
ARB 1	c:/3GPP.wv	EXBOX-K242	11.520	115 200	On	
ARB 2	c:/3GPP.wv	EXBOX-K242	11.520	115 200	On	
ARB 3	c:/3GPP.wv	EXBOX-K242	11.520	115 200	On	
ARB 4	c:/3GPP.wv	EXBOX-K242	11.520	115 200	On	

6.1.5 Configuration of the CPRI Link

6.1.5.1 Single Waveform Playback

- Select the “Hardware” tab and make the following settings:
- Set the CPRI line bit rate. Select the one which is supported by your SFP connection. Select the line bit rate according to the capabilities of the DUT.
- Set the input port to “SFP”.
- Select SFP as input/output port.
- In the “Downlink (Tx)” tab, select “ARB 1” as the physical source.

The name and the sample rate of the waveform file are displayed.

→ The LED must be blue.

Wave file	3GPP.wv
Sample Rate	11.520 000 000 MHz

The I/Q data of the downlink signal are transmitted over the CPRI link with the displayed sample rate, i.e. 11.52 MHz in this example. If another sample rate is desired, then the waveform file must be resampled. Waveform resampling can easily be performed using the R&S ARB Toolbox PLUS.

- In the “Uplink (Rx)” tab, select “Recorder” as the signal output.
- Make the following settings in the “Downlink (Tx)” and “Uplink (Rx)” tab:
- Select the standard to be used (only relevant for uplink signal).
- Set the oversampling factor (only selectable for uplink signal).
- Click on the “Show Signal Details” button.
- Adjust the settings for the numeric format and the I/Q resolution depending on what the DUT supports.

- Make sure that the required data rate matches the assigned data rate.

→ The LED must be blue. See section 5.1.5 for details.

If the LED is red, then click on the “Auto” button.

- Adjust the position of the AxCs inside the CPRI basic frame by setting the word and bit address. (The “AxC Allocation” must be set to “Flexible”.)
- Set the “Signal State” to “On”
- Finally, turn on the CPRI RE test.

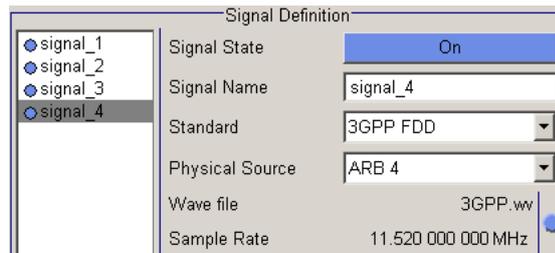
If you change any settings, the new settings must be applied to the CPRI link:

- Press the "Apply Setup" button.

6.1.5.2 Multi Waveform Playback

To transmit multiple signals simultaneously over the CPRI link you must define and configure multiple signals in the Downlink (Tx) tab as described in the following. Each signal corresponds to another waveform file.

- Make the following settings in the “Downlink (Tx)” tab.
- For the first signal select “ARB 1” as the physical source.
- Click on the “Append” or “Copy + Append” button to create a second signal.
- Configure the second signal and set the “Signal State” to “On”.
- For the second signal select “ARB 2” as the physical source.
- If desired, define a third and a fourth signal and set their “Signal State” to “On”.
- For the third signal select “ARB 3” as the physical source.
- For the fourth signal select “ARB 4” as the physical source.



→ All LEDs in the signal list (on the left side) must be blue.

On the right side of the “Downlink (Tx)” tab, the “AxC Container Definition” diagram shows the resulting CPRI basic frame.

- Adjust the position of the AxCs inside the CPRI basic frame by setting the word and bit address.



Make sure that no conflicts are indicated. Conflicts can occur for example when the signals do not “fit” into the basic frame or when they overlap.

If the signals do not fit into one basic frame, a solution would be to use a higher CPRI line bit rate (if the DUT supports it) or to reduce the I/Q resolution or the sample rate of the signals/ waveform files. If the signals overlap, then the word and bit address of the AxCs needs to be adjusted accordingly to resolve the overlap.

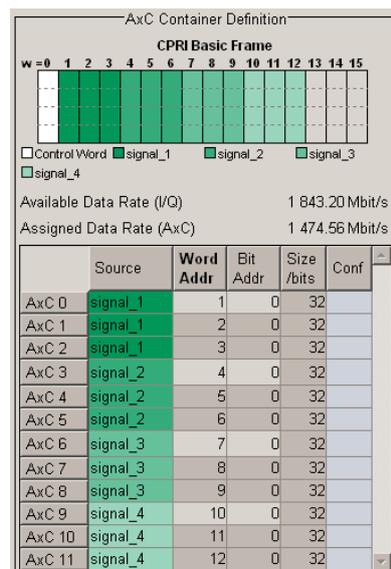
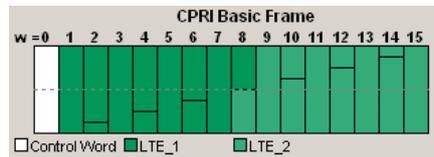


Figure 20: AxC Container Definition diagram (example) for multi waveform playback.

Example: Two 10 MHz LTE signals in one CPRI frame.

If we want to transmit two 10 MHz LTE signals with a CPRI line bit rate of 2x (1228.8 Mbit/s), we need to reduce the I/Q resolution from e.g. 16 to 15 bit in order to make the two signals fit into one basic frame. After adjusting the word and bit address of signal LTE_2 ("Word Addr" is 8, "Bit Addr" is 8) we get the following CPRI basic frame configuration. No conflicts occur.



6.1.6 Configuration of the DUT

The DUT, i.e. the remote radio head, is a user-specific device. Thus, the user must account for the correct configuration of the DUT.

Important DUT specific properties such as supported CPRI line bit rates, bit resolution, CPRI basic frame allocation and group transmission pattern are specified in the data sheet of the device.

6.1.7 Configuration of the Analyzer

The configuration of the analyzer is done as described in section 5.1.8.

6.1.8 Configuration of the Signal Generator

The configuration of the signal generator is done as described in section 5.2.4.

6.1.9 Configuration of the EX-IQ-BOX for Signal Recording

6.1.9.1 Uplink Signal Recording

The I/Q data embedded in the data stream coming from the DUT over the CPRI link can be recorded over a period of time and saved as a waveform file (.wv-format).

- Select the "Recorder" tab.
- Select the "Recorder 1" tab and make the following settings:
- Select the configured uplink signal as data source.



→ The LED must be blue.

→ The recording sample rate is indicated (read only). It results from the standard-specific base sample rate times the oversampling factor configured in the "Uplink (Rx)" tab.

- Set the recording length to the desired value.
- Select the trigger source, e.g. select “Software”.

If you select an external trigger, e.g. “External Trigger 1”, as trigger source, then one of the GPIO connectors must be configured as input and assigned to “External Trigger 1” in the “Hardware” tab (see section 5.4 for more details).

You can also select a frame trigger, e.g. “Rx Hyper Frame”, as trigger source. These trigger events are received over the CPRI link.

- If desired, modify the trigger position, i.e. change from conventional post-trigger recording (trigger position is 0) to pre-trigger recording (nonzero trigger position). To provide pre-trigger recording the signal is recorded continuously in a ring memory until a trigger event occurs. The trigger position determines how many samples before and after the trigger event are saved to the file – see [1] for more details.
- Click on the “File ...” button and enter or select a file name. Click on the “Save” button.
- Click on the “Record” button.

→ The recorder diagram displays the current recording status.

For example, “Wait for Trigger” status: The recorder is ready and waits for the trigger signal to start the recording.



When the recording is finished, the diagram displays “Record Done”.



- Click on the “Save” button to save the recorded signal. The signal is saved under the file path and name entered for “File ...”.

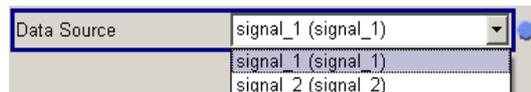
6.1.9.2 Multi Uplink Signal Recording

The EX-IQ-BOX offers two independent recorders for simultaneous recording of two uplink signals.



If you want to record two uplink signals that are sent by the DUT, two uplink signals must be configured accordingly in the “Uplink (Rx)” tab, e.g. signal_1 and signal_2.

- Select the “Recorder” tab.
- Select the “Recorder 1” tab.
- Select one of the configured uplink signals as data source, e.g. select signal_1.



→ The LED must be blue.

- Select the “Recorder 2” tab.
- Select the other configured uplink signal as data source, e.g. select signal_2.

→ The LED must be blue.

- Make the following settings in both “Recorder 1” and “Recorder 2” tab:
- Set the recording length to the desired value.
- Select the trigger source.

For simultaneous recording a common trigger for both recorders is recommended. Thus, the use of an external trigger or a frame trigger is recommended to start signal capturing at the same point in time.

- Specify a file name.
 - Click on the “Record” button.
- When the recording is finished, the recorder diagram displays “Record Done”.
- Click on the “Save” button to save the recorded signal.

7 Synchronization

This section describes how to synchronize

- the four internal ARBs (multi waveform playback)
- waveform playback and waveform recording
- I/Q data transmission/reception to the next hyperframe or Node B frame.
- the downlink/uplink scheduling in the EX-IQ-BOX and the RE when using custom sample rates, e.g. for GSM (“on/off-scheduling”)

7.1 Synchronizing the Internal ARBs

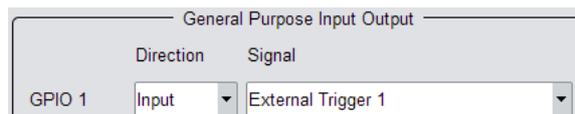
The four internal ARBs “ARB 1” to “ARB 4” are automatically synchronized. No user action is necessary to synchronize the signals from the different ARB sources.

For example, when testing multi-antenna REs, one waveform for each transmit antenna is used (see sections 6.1.4.2 and 6.1.5.2 for details). For these MIMO tests, it is automatically assured that all internal ARBs start synchronously.

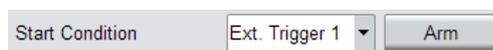
7.2 Synchronizing Waveform Playback and Recording

Synchronization of waveform playback and waveform recording can be achieved by using an external trigger signal.

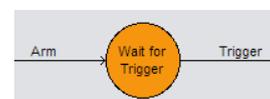
- Connect the external trigger signal to one of the GPIO connectors on the breakout board, e.g. to GPIO 1.
- In the “Hardware” tab, select “Input” as direction for GPIO 1. “External Trigger 1” appears automatically as signal for GPIO 1.



- Configure the ARB and the CPRI link as described in sections 6.1.4 and 6.1.5.
- In the “Downlink (Tx)” tab, set the start condition to “Ext. Trigger 1”.
→ The I/Q data transmission will start with the first trigger event. Before that first trigger event no I/Q data is sent over the CPRI link.



- Configure the recorder as described in section 6.1.9.
- In the “Recorder” tab, set the trigger source to “Ext. Trigger 1”.
→ The I/Q data recording will start with the first trigger event. Before that first trigger event the recorder waits for the trigger.



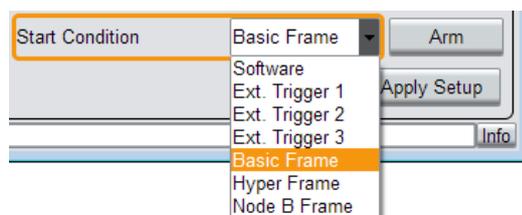
- Send an external trigger event.
→ This trigger event starts I/Q data transmission and recording simultaneously.

To stop I/Q data transmission click the “Arm” button in the “Downlink (Tx)” tab.
Transmission will restart with the next incoming external trigger event.

7.3 Synchronizing I/Q Data Transmission/Reception to CPRI Frames

In downlink direction, I/Q data transmission can be aligned to the next hyperframe or Node B frame. The same is possible in the uplink direction.

- Set the start condition to e.g. “Hyper Frame” in the “Downlink (Tx)” / “Uplink (Rx)” tab.
→ The I/Q data transmission/reception will start synchronous with the next hyperframe.



For example, if you provide test I/Q data (e.g. from the ARB) for exactly one Node B frame, this data can be put precisely into a single Node B frame:

- Set the start condition to “Node B Frame” in the “Downlink (Tx)” tab.
→ The I/Q data will be sent in the next Node B frame.

7.4 Synchronizing the Scheduling When Using Custom Sample Rates

When I/Q data shall be transmitted over the CPRI link using custom sample rates, then the group concept must be applied as described in section 5.1.5.1.

While some CPRI basic frames contain I/Q data, others do not (empty basic frames). Data transmission is either “on” or “off”. The “on/off-scheduling” of the EX-IQ-BOX must be synchronized to the “on/off-scheduling” of the RE. The following example is meant to explain why this is crucial.

Example: Assuming the on/off-scheduling in the EX-IQ-BOX is like this: One frame contains data, the following one is empty.

	G #0	G #1
Repetition	1	1
State	On	Off

The same scheduling is applied in the RE. The RE expects data in one frame and no data in the subsequent frame. However in worst case, the RE looks for the data in the empty frame and ignores the data in the full frame. To avoid this, the on/off-scheduling of the two devices must be synchronized such that the RE looks for the data in the full frame.

7.4.1 Alignment to Hyperframe

A hyperframe contains 256 basic frames. The on/off-scheduling can be aligned to a hyperframe in the following case: $256 / \Sigma$ repetition of all groups must be an integer number.

	G #0	G #1	G #2
Repetition	38	6	20
State	On	Off	On

For example, $256 / (38 + 6 + 20) = 4$. In this case:

- Set the start condition to “Hyper Frame” in the “Downlink (Tx)” / “Uplink (Rx)” tab.

Start Condition	Hyper Frame	Arm
-----------------	-------------	-----

7.4.2 Alignment to Node B Frame

A Node B frame contains 38400 basic frames. The on/off-scheduling can be aligned to a Node B in the following case: $38400 / \Sigma$ repetition of all groups must be an integer number.

	G #0	G #1
Repetition	209	175
State	On	Off

For example, $38400 / (209 + 175) = 100$. In this case:

- Set the start condition to “Node B Frame” in the “Downlink (Tx)” / “Uplink (Rx)” tab.

Start Condition	Node B Frame	Arm
-----------------	--------------	-----

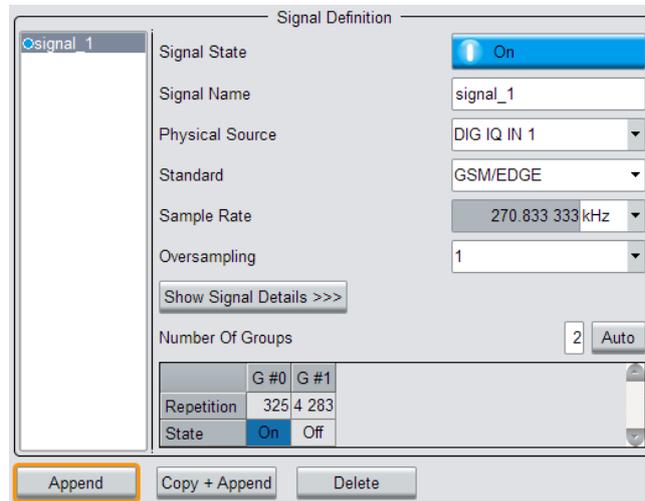
7.4.3 GSM/EDGE

In case of GSM/EDGE the sample rate is 270.833333 kHz and the on/off-scheduling is as follows:

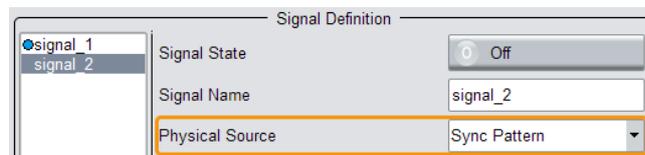
	G #0	G #1
Repetition	325	4 283
State	On	Off

$38400 / (325 + 4283) = 8.333333$. The result is not an integer. Neither the hyperframe, nor the Node B alignment can be applied. The synchronization between the EX-IQ-BOX and the RE must be achieved in a different way as explained in the following.

- Configure the GSM signal and click the “Append” button to add a second signal



- Select “Sync Pattern” as physical source.



- Adjust the length of the synchronization pattern.
- Set the number of groups to “2”.
- In the group table, set the repetition of G #0 to “1” and define the DUT-specific synchronization pattern, e.g. all ones.
- Set the repetition of G #1 to “4607” and set the pattern to all zeros.

The value 4607 results from the group settings of the GSM signal: $325 + 4283 = 4608$ repetitions in sum per cycle. Each cycle contains one basic frame with synchronization signal. Thus, there are 4607 frames without synchronization signal (pattern is all zeros).

- Position the AxC (containing the synchronization signal) inside the CPRI basic frame by adjusting the word and bit address. The required AxC position is DUT-specific.

	Name	Source	Word Addr	Bit Addr	Size /bits	Conf
AxC 0	signal_1	DIG IQ IN 1	1	0	32	
AxC 1	signal_2	Sync Pattern	5	0	16	

- Set the “Signal State” to “On”.

→ The RE can now synchronize to the defined pattern. The on/off-scheduling is thus synchronous in both devices and the RE looks for the data in the right basic frames.

A synchronization pattern can be defined in downlink and uplink direction.

8 Summary

This application note described the Rohde & Schwarz solution for testing a CPRI RE (e.g. a remote radio head). The EX-IQ-BOX emulates the CPRI interface of an REC and communicates with the RE under test over a digital link using the CPRI protocol standard. Both link directions, downlink and uplink, are supported – even bidirectional operation is possible.

In downlink direction, digital standard signals are provided by a signal generator or by the EX-IQ-BOX itself via internal ARB generator and are sent over the CPRI link to the RE under test. Up to four different signals can be sent simultaneously over the CPRI link using the internal ARB of the EX-IQ-BOX. In addition to the test signals, also slow and fast C&M as well as vendor specific data can be sent from the EX-IQ-BOX to the RE. The RE outputs a RF signal that is evaluated using a spectrum analyzer to characterize the performance of the radio head.

In uplink direction, RF test signals are provided by a signal generator and fed to the RE under test. The RE outputs a digital signal that is sent over the CPRI link to the EX-IQ-BOX. In addition to the test signals, also slow and fast C&M as well as vendor specific data can be received from the RE. The digital signals can be evaluated in real-time using a spectrum analyzer or the evaluation can be done later on by recoding the signal with the EX-IQ-BOX for post-processing. Up to two different signals can be recorded simultaneously using the internal recorder of the EX-IQ-BOX.

The EX-IQ-BOX offers several helpful features: Various marker signals can be output via BNC connectors such as Basic, Hyper and Node B frame markers that can be used for e.g. synchronization purposes. The operating status of the optical SFP module on the EX-IQ-BOX is constantly monitored and displayed. In addition, the L1 inband protocol as well as the link status and associated alarms are monitored and displayed. The generation of synchronization patterns and static frames as well as the built-in low level BER test function can be used for basic tests and debugging purposes. Furthermore, the user can perform the round trip cable delay measurement (R21 measurement) according to the CPRI standard.

All in all, the EX-IQ-BOX in combination with Rohde & Schwarz signal generators and analyzers form a complete and straightforward test solution for measurements on CPRI RE devices offering maximum flexibility and scalability.

EX-IQ-BOX Options for CPRI RE Testing at a Glance			
R&S® EXBOX-	Option	Benefit	Application
B85	CPRI Breakout Board	Conversion of the R&S-specific digital I/Q data format into the standardized CPRI protocol such that standard R&S T&M equipment can be used for testing via the CPRI interface.	Testing of a DUT via the CPRI interface.
K10	CPRI RE Test	Emulation of the CPRI interface of the baseband unit (REC) to test the RF unit (RE) independently from the REC.	CPRI radio equipment (RE) testing in uplink and downlink direction. E.g. remote radio head testing.
K90	Waveform Memory	The stand-alone ARB for digital signals minimizes the required T&M equipment and thus simplifies the test setup.	Playback of user-generated or WinIQSIM2 waveforms for ARB-based baseband signal generation (i.e. not real-time).
K91	Multi Waveform Playback	Simultaneous playback of up to 4 different waveforms from the internal ARB. Reduced complexity of the setup for testing MIMO capable devices.	Simultaneous transmission of multiple signals over the same CPRI link for MIMO testing of multi-antenna RRHs (one waveform for each transmit antenna).
K94	Recording Memory	The recorder for digital I/Q signals minimizes the required T&M equipment and thus simplifies the test setup.	Post-processing of the recorded I/Q data using custom software or post-analysis using R&S analyzers.
K2xx	WinIQSIM2	Easy and flexible waveform generation according to various digital standards using the WinIQSIM2 software.	Standard-conform signal generation via internal ARB for testing 3GPP FDD, CDMA 2000, LTE, WiMAX or multi-standard RRHs.

Overview of Signal Generators for Use in the Test Setups			
Signal Generator	Digital Baseband Output	RF Output	Test
R&S®SMU200A	✓ B18	✓	downlink, uplink
R&S®SMW200A	✓ K18	✓	downlink, uplink
R&S®AMU200A	✓ B18	✗	downlink
R&S®SMATE200A	✗	✓	uplink
R&S®SMJ100A	✓ B18	✓	downlink, uplink
R&S®SMBV100A	✓ K18	✓	downlink, uplink
R&S®AFQ100A	B18 not supported by the EX-IQ-BOX	✗	none

9 Pictures

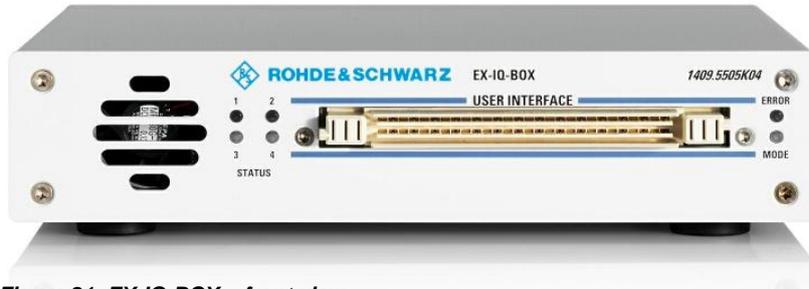


Figure 21: EX-IQ-BOX – front view.

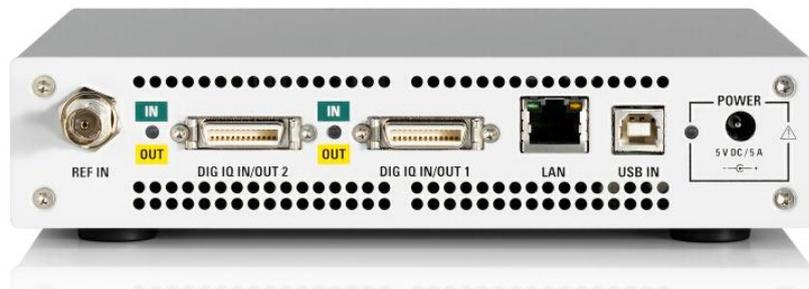


Figure 22: EX-IQ-BOX – rear view.



Figure 23: CPRI breakout board (variant .04) – top/front view.

10 Abbreviations

ARB	Arbitrary waveform generator
C&M	Control and Management
CPRI	Common Public Radio Interface
EVM	Error Vector Magnitude
DUT	Device Under Test
HDLC	High-Level Data Link Control
I/Q	In-phase and Quadrature
LVDS	Low Voltage Differential Signaling
PC	Personal Computer
RE	Radio Equipment
REC	Radio Equipment Control
RF	Radio Frequency
RRH	Remote Radio Head

11 References

- [1] Rohde & Schwarz, R&S EX-IQ-BOX Digital Interface Module & DigIConf Configuration Software Operating Manual
- [2] Application Note Rohde & Schwarz, "Successful Start with the R&S EX-IQ-BOX" (1MA168)
- [3] Rohde & Schwarz, R&S FSQ Operating Manual
- [4] Information on CPRI™ at www.cpri.info
- [5] Common Public Radio Interface (CPRI); Interface Specification V4.1
- [6] Application Note Rohde & Schwarz, "3GPP FDD Base Station Tests with Vector Signal Generator SMIQ" (1GP41)
- [7] Application Note Rohde & Schwarz, "Tests on 3GPP WCDMA FDD Node Bs in accordance with standard TS 25.141" (1MA67)
- [8] Application Note Rohde & Schwarz, "LTE Base Station Tests according to TS 36.141" (1MA154)

12 Ordering Information

Please visit the Rohde & Schwarz product websites at www.rohde-schwarz.com for comprehensive ordering information on the following Rohde & Schwarz instruments:

- R&S® EX-IQ-BOX digital signal interface module

Signal generators:

- R&S® SMW200A vector signal generator
- R&S® SMU200A vector signal generator
- R&S® SMBV100A vector signal generator
- R&S® SMJ100A vector signal generator
- R&S® AMU200A baseband signal generator and fading simulator

Signal analysis:

- R&S® FSW signal and spectrum analyzer
- R&S® FSQ signal analyzer
- R&S® FSV signal and spectrum analyzer
- R&S® FSVR signal and spectrum analyzer
- R&S® FSG signal analyzer
- R&S® FMU36 baseband signal analyzer

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