Products: AMIQ / WinIQSIM, SMIQ, FSE

Bit Error Rate Measurements with **AMIQ** and **WinIQSIM**

Application Note

This application note describes the principle of the bit error rate test with AMIQ / WinIQSIM and provides two example setups demonstrating the capabilities of the AMIQ-B1 option. One demo setup is for stand-alone demonstration and requires only WinIQSIM and AMIQ, the second uses an FSE spectrum analyzer as the device under test, and can easily be adapted to real test environments.

ROHDE&SCHWARZ

Subject to change – Dr. René Desquiotz 12.98 - Application Note 1GP36_0E

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1 Introduction

The I/Q modulation generator AMIQ with option AMIQ-B1 can measure bit error rates (BER) for user data consisting of a PRBS sequence. The data is decoded by the device under test (DUT) and forwarded to the AMIQ BER tester, which synchronizes to the known PRBS sequence and counts the bit errors. For generating and checking the PRBS a feedback shift register is used.

This method has two major advantages. First, the bit error detector only requires the calculation algorithm, not the total sequence. Second, the analysis can be started anywhere in the bit stream, as the shift register synchronizes itself to the sequence at the beginning of the measurement.

This application note describes the principle of the bit error rate test with AMIQ / WinIQSIM and provides two example setups demonstrating the capabilities of the AMIQ-B1. One demo setup is for stand-alone demonstration and uses only WinIQSIM and AMIQ, the second uses an FSE spectrum analyzer as the device under test, and can easily be adapted to real test environments.

The archive contains the WinIQSIM settings used in the examples, see sections 4 and 5.

2 BER measurement setups

Two setups are possible: the clock signal for the system (and possibly trigger signals) can be provided either by the DUT itself, or by AMIQ. In the first case the BER test is performed independently of the signalling part and the setup is quite simple.

Clock provided by DUT

The BER test is performed independently of the signalling part. The desired waveform can be calculated with WinIQSIM and loaded into AMIQ[1]. The D/A converted signal is then applied to the SMIQ I/Q modulator, the RF signal is forwarded to the DUT, which demodulates the received source bits and returns them to AMIQ's BER tester input together with a transfer clock. In the AMIQ BER tester, the data bits are checked for errors. The total of the transmitted bits and the faulty bits are counted. The quotient of error bits / total bits is the bit error rate. If the data stream also contains parts not to be counted (such as headers or guard bits) the AMIQ BER tester may also be controlled via its mask input by sending a data enable trigger signal from the DUT (see fig. 1).

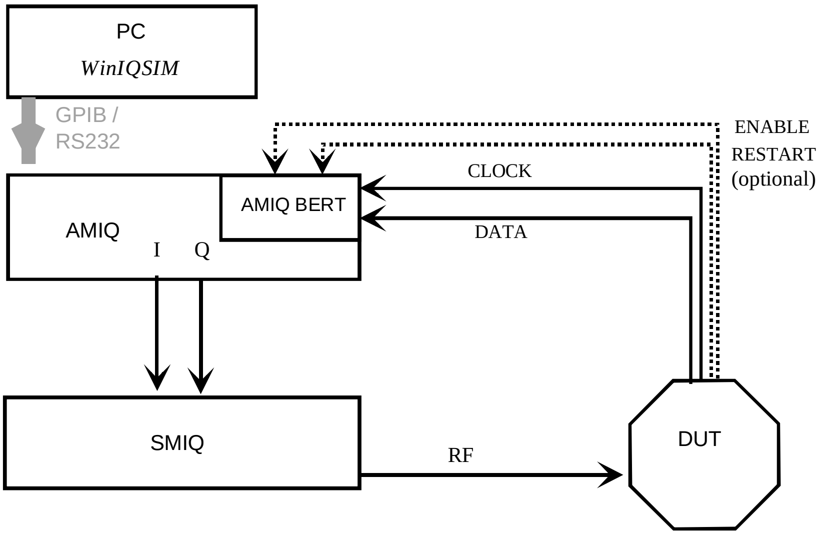

Fig. 1: BER test setup: clock provided by DUT

Clock provided by AMIQ

The signal has to be calculated with WinIQSIM. In addition to the data, WinIQSIM is able to generate appropriate trigger signals for clock, data enable and restart. The trigger signals are sent via the AMIQ marker outputs (see fig. 2). To compensate for the delay in the signal path, the markers can be shifted with reference to the I/Q output signal. A coupling of the clock reference between AMIQ and SMIQ may be necessary to keep data signal and control signal paths synchronized.

[1] As the transmitter part of the setup and the BER tester are independent of each other, one could also use the SMIQ internal coder (-B10+-B11 options) as the data source in this case.

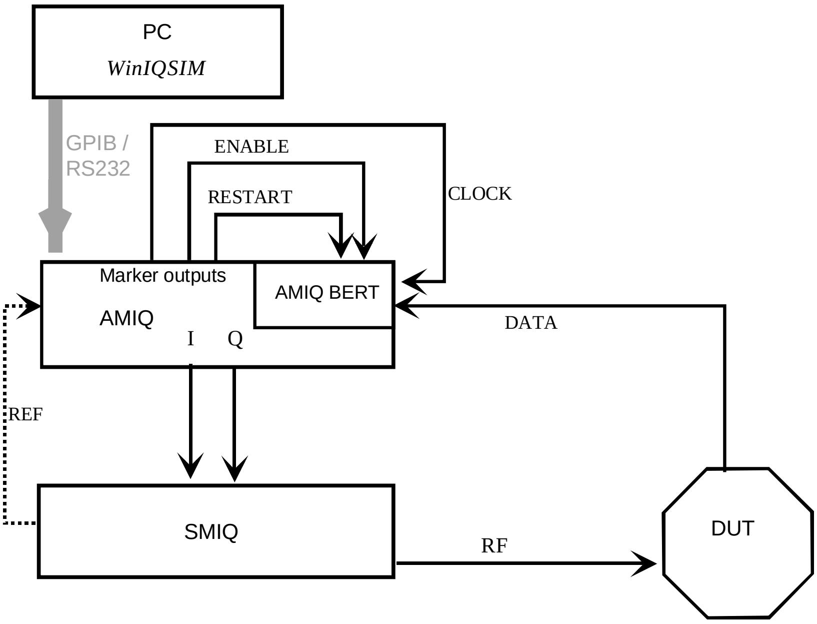

Fig. 2: BER test setup: clock, data enable and restart provided by AMIQ

3 A typical application: BER measurements with new TDMA standards

With WinIQSIM installed on a PC used in conjunction with AMIQ-B1, full control of BER measurement is provided by the PC, including setting up specialized BER tests. This is especially useful for TDMA systems still under development. WinIQSIM can create the appropriate TDMA signal structure and, in addition, program all the necessary control signals to perform a BER measurement with the signal. This section describes the principles, two examples follow in the sections 4 and 5.

First the appropriate signal has to be calculated with WinIQSIM. A typical TDMA timeslot structure in a data stream is shown in fig. 3. The timeslot consists of a header, an access pattern, a user data part and some guard bits. The bit error rate need only be measured for the user data, the other parts of the timeslot do not have to be counted.

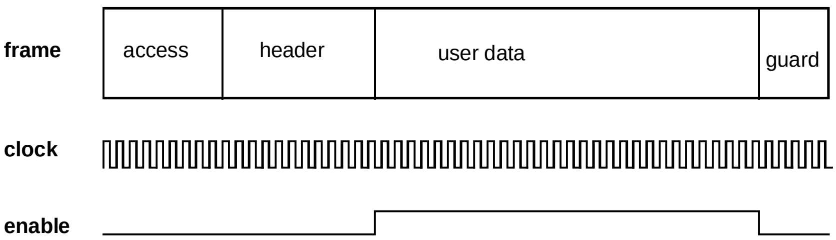

Fig. 3: Typical timeslot structure of a TDMA system and appropriate clock and data enable signals.

Such a timeslot structure can be created with the WinIQSIM data editor. (Fig. 4 shows a timeslot with the four data fields access, header, user data and guard.) Access, header and guard consist of bit patterns specified for the TDMA system. The user data field is filled with BERT-PRBS data, a

PRBS-like data sequence to be counted by the BER tester. Three of the four marker outputs can be programmed automatically with appropriate bit clock, data enable and restart signals:

- The bit clock is set according to the modulation rate of the system.
- The data enable signal has high level whenever data is of type BERT-PRBS and low level otherwise. The signal is fed into the data enable input of the BER tester.
- In the enable mode, the BER tester counts whenever enable input is at high level.

The modulation parameters, such as modulation rate and baseband filtering, can be programmed by WinIQSIM.

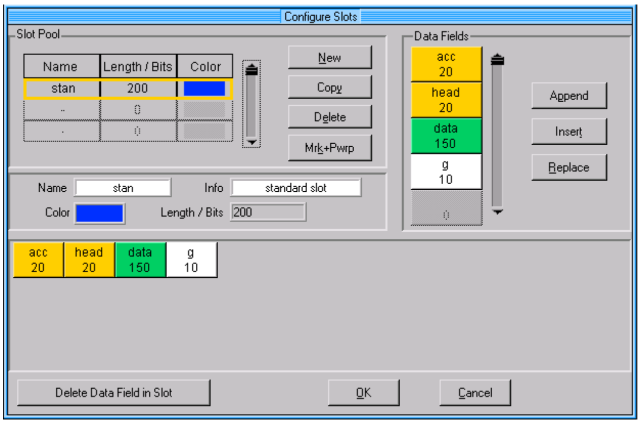

Fig. 4: Realization of the timeslot in fig. 3 in WinIQSIM

Two additional issues have to be taken into account. Generally a user data field is not long enough to store a complete PRBS sequence. If, for example, the data field contains 150 bits, more than 3 timeslots are required to accomodate a complete PRBS9 sequence (511 bits). Furthermore the timeslot structure and the PRBS length do not match. Then a continuous PRBS must be generated and correctly distributed to the timeslots (see fig. 5). WinIQSIM provides continuous PRBS mode automatically with the BER test feature.

As the AMIQ is an arbitrary waveform generator, it continuously repeats a sequence of finite length. This length is limited by the memory of the AMIQ (4 MSamples). With a typical oversampling factor of 8 the maximum number of symbols would be 500,000. In most cases the PRBS sequence will not fit in the overall sequence length, and this causes a break in the PRBS pattern. Repeating the same data sequence requires restarting the PRBS „generation" and informing the BER tester with a restart signal.

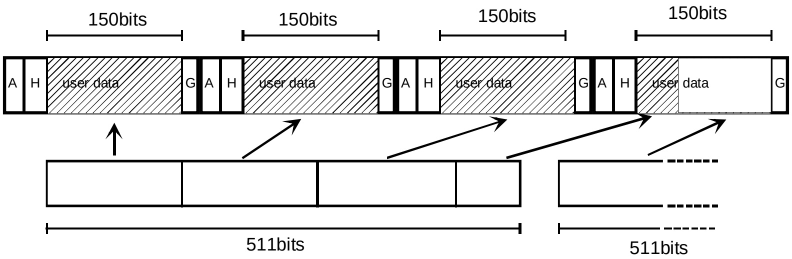

Fig. 5: Distributing a PRBS 9 sequence to the user data fields of sucessive timeslots

In this setup the data signal is coupled to the clock and trigger signals. As the DUT always causes a time delay, the marker channels have to be shifted with respect to the I/Q signal. The actual delay is set by controlling AMIQ hardware, either from WinIQSIM or from SMIQ. The delay can easily be checked with an oscilloscope.

4 Example : BER test stand-alone demonstration setup

Real BER measurements are performed with the device under test receiving the modulated RF signal and giving back the demodulated digital data. For demonstrating the BER test capabilities of AMIQ / WinIQSIM, however, there is no need for a DUT. (This is a benefit in that a DUT may not be available.) The BER test functions can be demonstrated using just WinIQSIM and AMIQ.

To prepare the demonstration we will first build an example TDMA structure with the data editor.

TDMA data structure for BER measurement

Suppose that the TDMA signal to be used has the following simple structure: a 20-bit header, a 150-bit user data field and a 10-bit guard closing the timeslot.

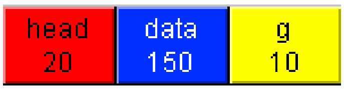

Fig. 6: Structure of the TDMA signal used for the BER demonstration

From the **data editor** open the data field panel. Create the three data fields. Use **all zero** as data for the header and the guard bits. For the user data choose data type **BERT-PRBS**.

We create three additional data fields which we need later for calibrating a BER test setup with a „real“ DUT. Build a data field (called „**del**“ or similar) containing a single **one** and another one with 149 **zeroes**. We also need a dummy field with 180 **zeroes**. The data field pool should look like this:

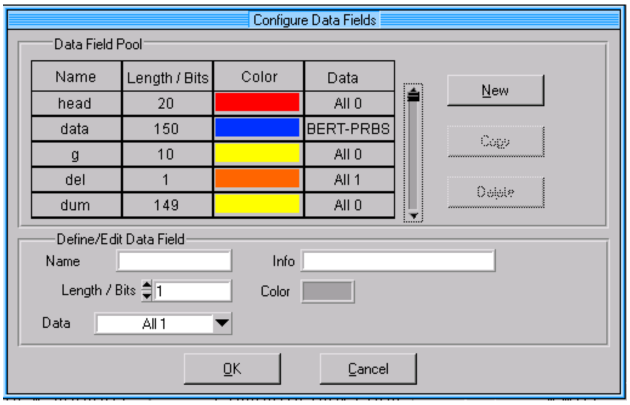

Fig. 7: Data fields used for the BERT demonstration. An additional dummy data field with 180 **zero** bits is not shown in the figure.

Now open the slot panel and build three different slots, all 180 bits long.

- First, the „normal slot“ **norm** of our TDMA system containing header, user data and guard.
- The second slot - called **dly** - is build from header, **del** field, the 149 **zeroes** field and again the guard. This slot contains overall **zeroes** except for a single **one** at the 21st bit. Open the marker settings panel for this slot and set a **ramp up down** signal for marker 4. Ramp up should be at position 20 (this is the 21st bit as position counter starts at 0), ramp down at position 21. Then marker 4 is at high level exactly where the data bit **one** occurs.
- The third slot consists of the **dummy** field and has only **zeroes**.

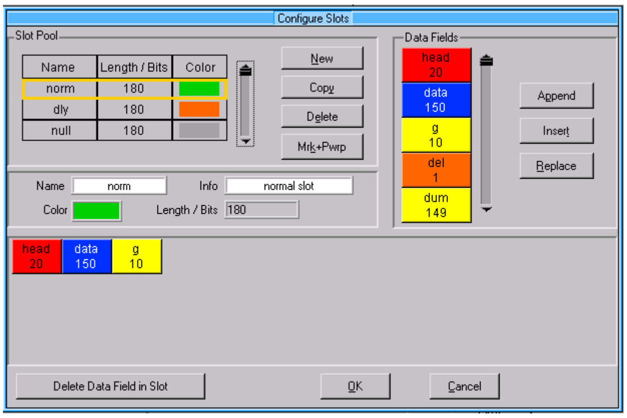

Fig. 8: Slots used for the BERT demonstration. The structure of the normal slot is indicated in the lower part of the panel.

This is the pool of data fields and slots we will use for the rest of this chapter. To keep it, save the data editor settings as BER_TEST.DED.

Before calculating the whole data sequence and adjusting the BER test settings we have to set the modulation parameters, as these affect the marker settings used for BER measurement.

Settings for stand-alone demonstration

For this simple demo setup we will use the AMIQ **I** output as data source for the BER test. Then we need a signal at the **I** output resembling a digital data stream of ones and zeroes. This can be realized using a **BPSK** modulation with filter type **rect**. The **data polarity** of the BER tester has then to be set to **inverted** to identify **one** with high level and **zero** with low level.

The modulation symbol rate must match the hardware limitations (maximum clock rate of the BER tester is 20 MHz). We set the symbol rate to 1 MHz and the oversampling to 16. The entire parameter values of the **`modulation settings`** panel are shown in fig. 8.

Back in the **`data editor`** complete the data and BER test settings. Open the **`BERT settings`** panel in the data editor and activate all control signals:

- **data enable** on marker 1
- **clock** on marker 2
- **restart** on marker 3.

Set **BERT PRBS** type to **PRBS 9** and switch on the **BERT mode**.

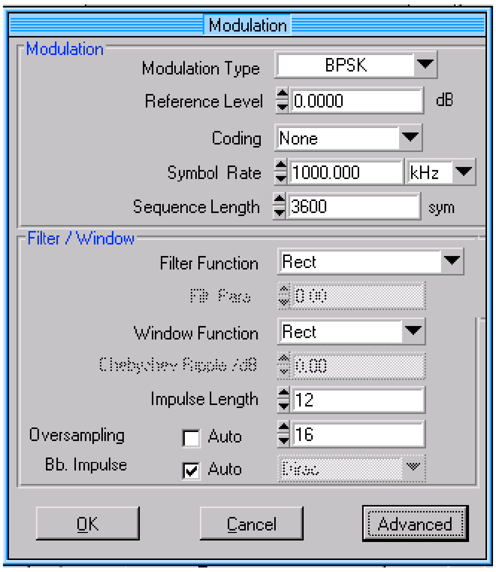

Fig. 9: Modulation parameters for stand-alone demonstration

Now build a frame containing 20 of the **norm** slots. This sequence is 3600 bits long, 3000 of them are user data bits to be counted. Calculate and save the sequence as BER_SELF_TEST.DBI. The data sequence is then stored into this file and the marker channels are programmed with the control signals **enable**, **clock** and **restart** for the BER measurement. At this point it is a good idea to save the WinIQSIM settings (including the current marker parameters) as BER_SELF_TEST.IQS.

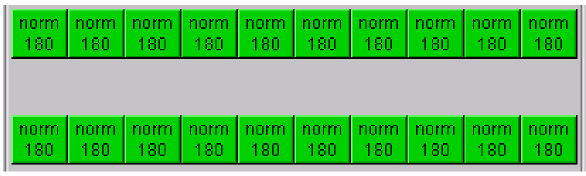

Fig. 10: A frame containing 20 normal slots gives the data sequence BER_SELF_TEST.DBI for the BERT stand-alone demo.

Calculate the signal and transmit it to AMIQ. Check the marker settings in the menu **`AMIQ --> marker settings...`** At the top of the panel the messages „**defined by data editor**" and „**BERT mode**" should appear.

To connect the AMIQ BER tester you need the appropriate adaptor cable. Connect **data** to the **I** output of the AMIQ and **mask** (=**enable**) / **clock** / **restart** to the marker outputs 1 / 2 / 3.

Open the **`AMIQ --> remote control and BERT...`** menu. Choose **`hardware settings`** and set the **I** output to **VAR mode** and maximum level (1 V). Close the **`hardware settings`** panel, now you are back in **`remote control and BERT`**. Open the **`BERT`** panel and set the parameters as shown in fig. 10.

The number of enabled data bits is shown in the file info box on the bottom of the panel (here: 3000). The total number of bits to be counted is set to a slightly smaller value here to avoid restarting before a single measurement is finished. To obtain good statistics in one single measurement, make the waveform sequence as long as possible. The data polarity has to be set to **inverted**.

Now start the BER test in **single** mode and check the bit error rate. As we have pure PRBS as enabled data, the bit errors should count zero. If some errors are detected there may be a small delay on the signal path with respect to the markers. Try shifting the markers by 16 samples (= 1 symbol). If the bit error rate increases, shift in the other direction. Set the marker shift values so that the bit error rate is zero.

If AMIQ cannot synchronize or the error reads about 50 %, the data signal might be received at the same time as the edge of the clock signal (means, data and clock are shifted half a symbol with respect to each other). Then shift the clock signal (marker 2) by a few samples.

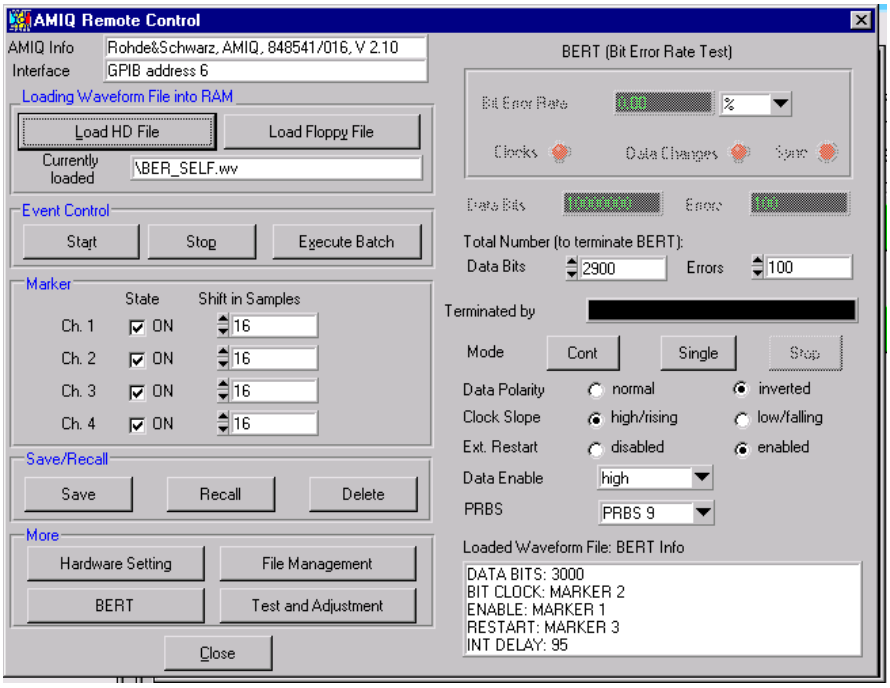

Fig. 11: AMIQ BER test settings for the stand-alone demonstration.

Creating a data source with bit errors

So far, the data source does not contain any errors. This might be not the best way to show the capabilities of a bit error rate tester. So we continue with creating a data source containing errors.

Close the AMIQ control panel(s), but leave the hardware settings unchanged. Open the data editor (BER_SELF_TEST.DED) and calculate the same sequence again, but save it as a different file (BER_ERROR.DBI). Load this data sequence file into an ASCII text editor and change the bits #299 and #300 (from one to zero or vice versa). These are two user data bits from the second timeslot in the sequence. Do not close WinIQSIM in between, so as not to lose the marker settings and the data source file path. At least save the WinIQSIM settings.

Save the modified file, exit the ASCII editor and return to WinIQSIM. Calculate the waveform with the modified sequence as data source and transmit it to the AMIQ. A BER measurement should deliver 2 errors now instead of 0.

5 Example: BER test demo setup with FSE as device under test

Test setup

It is also possible to show the BER test features of AMIQ / WinIQSIM in a „real“ test setup by using an FSE spectrum analyzer as demodulating unit. This application is described in a Rohde & Schwarz application note (1MA16_0E) written by Roland Minihold. The test setup used is shown in fig. 12.

The FSE (with option FSE-B7) is used as online FSK demodulator (setting: analog demodulation, FM signal, DC coupling, real time on). The AF output signal of the FSE available on the front panel is connected by means of a jack plug (stereo 3.5 mm)[2] to the data input of the AMIQ. The other connections (clock, enable, restart) are as in the stand-alone demo setup.

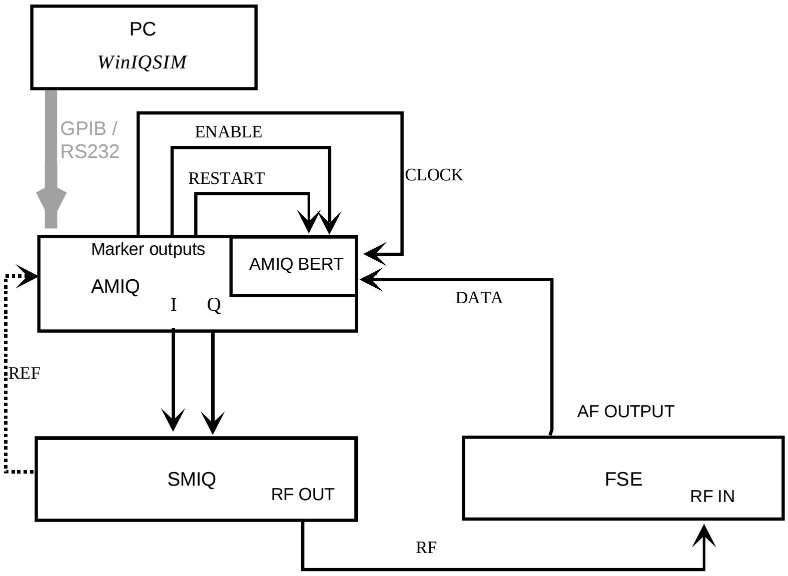

Fig. 12: Test setup for BER measurement demonstration using FSE spectrum analyzer as device under test.

Creating the data sources

We can reuse the data sources from the stand-alone demo setup, adapting the modulation settings to the new scenario and reprogramming the markers.

Open the settings file BER_SELF_TEST.IQS and save it as BER_TEST.IQS. (This is to keep the stand-alone demo settings for later use.) Change the modulation settings in BER_TEST.IQS as shown in Fig. 13. As the control signals clock, enable and restart depend on the modulation used, we have to program the markers again. Load the data editor settings file BER_SELF_TEST.DED and save it as BER_TEST.DED. Change the name of the sequence to be calculated to BER_TEST.DBI, then activate „calculate and save sequence“. Save the data editor settings (BER_TEST.DED) again.

[2] For this you need again the appropriate AMIQ-B1 cable and an adaptor with the jack plug (stereo 3.5 mm, both center connectors tied together) on one side and a BNC connector on the other.

To keep these settings, save BER_TEST.IQS again, then calculate the waveform and transmit it to the AMIQ harddisk as file BER_TEST.

Now we produce a second waveform containing some errors. With the settings BER_TEST.IQS, open the **`data source`** panel and change the data source **file** from BER_TEST.DBI to BER_ERR.DBI. *Don't change anything else* and calculate the waveform. As we designed all data sequences with the same structure and length, the marker settings need not be changed. Save the waveform on AMIQ harddisk as BER_ERR.

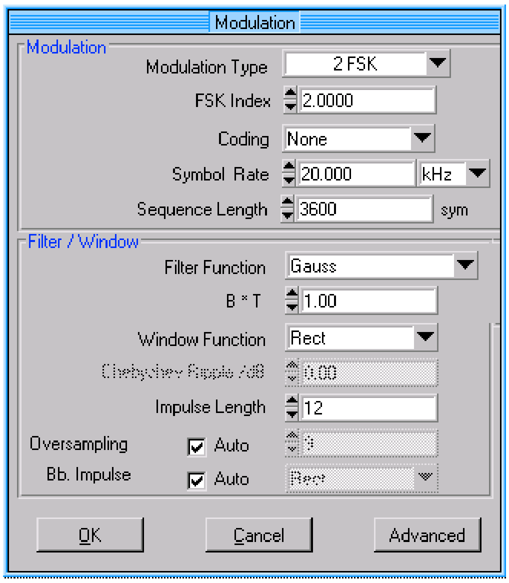

Fig. 13: Modulation settings for the BER test demo with FSE

Measuring the delay in the signal path

In this setup there is a significant delay in the RF signal path with respect to the control signals. For correct BER tester performance this delay has to be measured using the MARK slot created above. Open the data editor again (BER_TEST.DED) and create a frame with one MARK slot and 19 dummy slots. Save this sequence as BER_DELAY.DBI, the data editor settings as BER_DELAY.DED and the WinIQSIM settings as BER_DELAY.IQS. Calculate the waveform and transmit it ito the AMIQ RAM and harddisk. This is a signal containing overall **zeroes**, except for a single **one**. At the position of this **one**, there is a trigger signal with length one symbol on marker 4. Connect the signal from FSE AF output and the AMIQ marker 4 output to a 2-channel oscilloscope.

Open the **`AMIQ --> remote control and BERT...`** panel and shift marker 4 with respect to the signal output so that the data bit **one** and the marker 4 signal appear at the oscilloscope at the same time.

The value of the marker shift depends on the units in the signal path and the cable lengths. For this setup it will probably be in the range of 450 samples (about 2.5 ms). Set all marker shifts to the measured value.

Measuring the bit error rate

Now connect the FSE AF output to the AMIQ BER tester data input again and set SMIQ and FSE as shown in the table below.

SMIQ:

PRESET

FREQ 1 GHz

LEVEL 0.0 dBm

VECTOR MOD: STATE ON

FSE:

PRESET

CENTER 1GHz

LEVEL REF 0 dBm

MODE: VECTOR ANALYZER: ANALOG DEMOD

MEAS RESULT: FM SIGNAL: REAL TIME ON

VOLUME: 80%

MODULATION PARAMETER: AF COUPL'G DC

RANGE: Y PER DIV: 10 kHz

SWEEP: SWEEP TIME 1 ms

Load the waveform BER_TEST into AMIQ RAM and open the **BERT** panel (menu **`AMIQ --> remote control and BERT --> BERT`**). Set the BERT parameters as shown below, with the marker shift value you measured. **Data polarity** must be **inverted**.

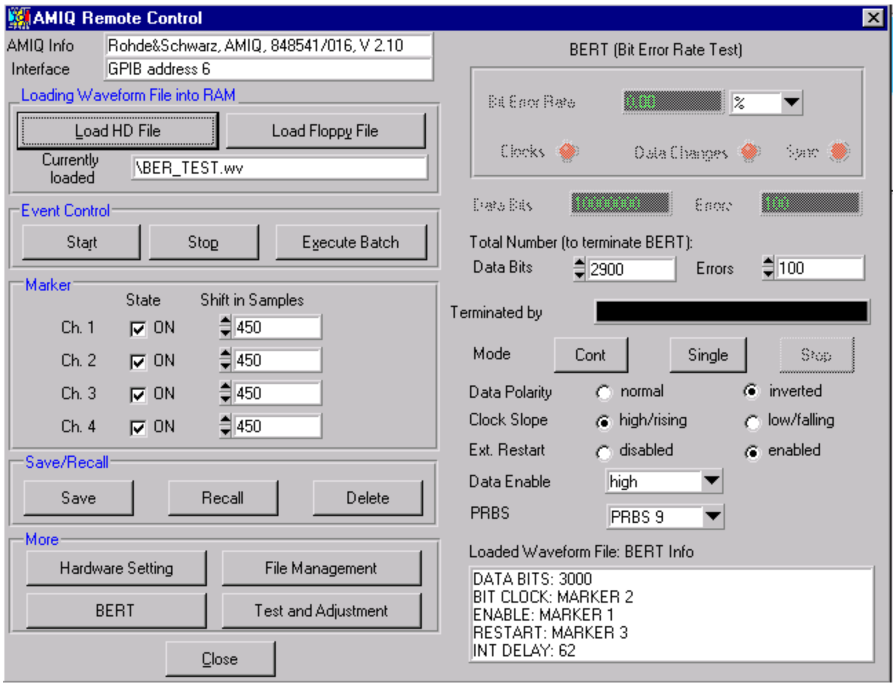

Fig. 14: AMIQ BER test parameters for the test setup with FSE

Start the BER measurement with **single**. If everything was set correctly the BER tester should work, indicated by the green lights at the top of the panel, and show an error rate of zero .

If the BER tester does not count, check the cabling and the marker outputs (maybe they are switched off).

If an error of about 50% occurs, check the data polarity, the PRBS type (PRBS 9) and the marker delay. Sometimes the clock signal is just shifted half a symbol with respect to the data signal, which may cause faulty triggering. Try shifting the clock by one or two samples.

If the error indicator reads a small but nonzero error, the markers are positioned not exactly and the BER tester counts one bit of the header or guard of the sequence. Shift the enable and restart markers in multiples of 9 samples (= 1 symbol) forward or backward until BER reads zero error.

Bit errors can be introduced by decreasing the SMIQ output level significantly. You can also try the same test with the waveform BER_ERR. This should result in 2 errors per single measurement (at 0.0 dBm SMIQ level).

6 References

R. Minihold: *Demonstration of BER Test with AMIQ controlled by WinIQSIM*, Application Note 1MA16_0E, Rohde & Schwarz, 1998

I/Q Modulation Generator AMIQ, Operating Manual, Rohde & Schwarz, 1998

Software WinIQSIM for Calculating I/Q Signals for I/Q Modulation Generator AMIQ, Software Manual, Rohde & Schwarz, 1998

7 Contents of file archive

The archive AMIQBERT.EXE (self-extractable WinZip archive) contains the following files. Extract the archive into your WinIQSIM\EXAMPLES folder to get the correct file paths.

BER_SELF_TEST.IQS	WinIQSIM settings for the stand-alone demo described in section 4.
BER_SELF_TEST.DED	WinIQSIM data editor settings for the stand-alone demo described in section 4.
BER_SELF_TEST.DBI	WinIQSIM data file with error-free user data for the stand-alone demo described in section 4.
BER_SELF.WV	Waveform file ready for transmission to AMIQ for the stand-alone demo described in section 4 (User data error-free).
BER_SELF_ERR.IQS	WinIQSIM settings for the stand-alone demo described in section 4, data source is BER_SELF_ERR.DBI here.
BER_SELF_ERR.DBI	WinIQSIM data file for the stand-alone demo described in section 4, user data contain 2 errors.
BER_SERR.WV	Waveform file ready for transmission to AMIQ for the stand-alone demo described in section 4 (User data contains 2 errors).
BER_TEST.IQS	WinIQSIM settings for the demo with FSE described in section 5.
BER_TEST.DED	WinIQSIM data editor settings for the demo with FSE described in section 5.
BER_TEST.DBI	WinIQSIM data file with error-free user data for the demo with FSE described in section 5.
BER_TEST.WV	Waveform file ready for transmission to AMIQ for the demo with FSE described in section 5 (User data error-free).
BER_ERR.IQS	WinIQSIM settings for the demo with FSE described in section 5, data source is BER_ERR here
BER_ERR.DBI	WinIQSIM data file for the demo with FSE described in section 5, user data contain 2 errors.
BER_ERR.WV	Waveform file ready for transmission to AMIQ for the demo with FSE described in section 5 (User data contains 2 errors).
BER_DELAY.IQS	WinIQSIM settings for the demo with FSE described in section 5, to measure the delay between signal path and control path.
BER_DELAY.DED	WinIQSIM data editor settings for the demo with FSE described in section 5, to create data file for measuring the between signal path and control path
BER_DELAY.DBI	WinIQSIM data file for the demo with FSE described in section 5, to measure the delay between signal path and control path.
BER_DEL.WV	Waveform file ready for transmission to AMIQ for the demo with FSE described in section 5 (to measure the delay between signal path and control path)

8 Ordering information

I/Q Modulation Generator		
AMIQ / WinIQSIM		1110.2003.02
Option required for AMIQ		
AMIQ-B1	BER Measurement	1110.3500.02
Vector Signal Generator:		
SMIQ02	300 kHz to 2.2 GHz	1084.8004.02
SMIQ03	300 kHz to 3.3 GHz	1084.8004.03
SMIQ02E	300 kHz to 2.2 GHz	1106.1506.02
SMIQ03E	300 kHz to 3.3 GHz	1106.1506.03
Spectrum Analyzer		
FSEA20	9 kHz to 3.5 GHz	1065.6000.20
FSEA30	20 Hz to 3.5 GHz	1065.6000.30
FSEB20	9 kHz to 7.0 GHz	1066.3010.20
FSEB30	20 Hz to 7.0 GHz	1066.3010.30
FSEM20	9 kHz to 26.5 GHz	1080.1505.20
FSEM30	20 Hz to 26.5 GHz	1079.8500.30
FSEK20	9 kHz to 40 GHz	1088.1491.20
FSEK30	20 Hz to 40 GHz	1088.3494.30
Option required for FSE		
FSE-B7	Vector Signal Analyzer	1066.4317.02

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