High Speed Modem

The new "Highspeed Multimedia Modem" for the QO-100 NB transponder

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QO-100 is soon two years in very successful operation. It covers almost half of the earth's surface and thanks to its very stable propagation conditions it offers excellent radio communication and this 24h a day and 7 days a week. So far it has been used mainly in CW/SSB and DATV. To stimulate the use of other digital modes, DJØABR as a member of AMSAT-DL has developed the “Highspeed Multimedia Modem” software.

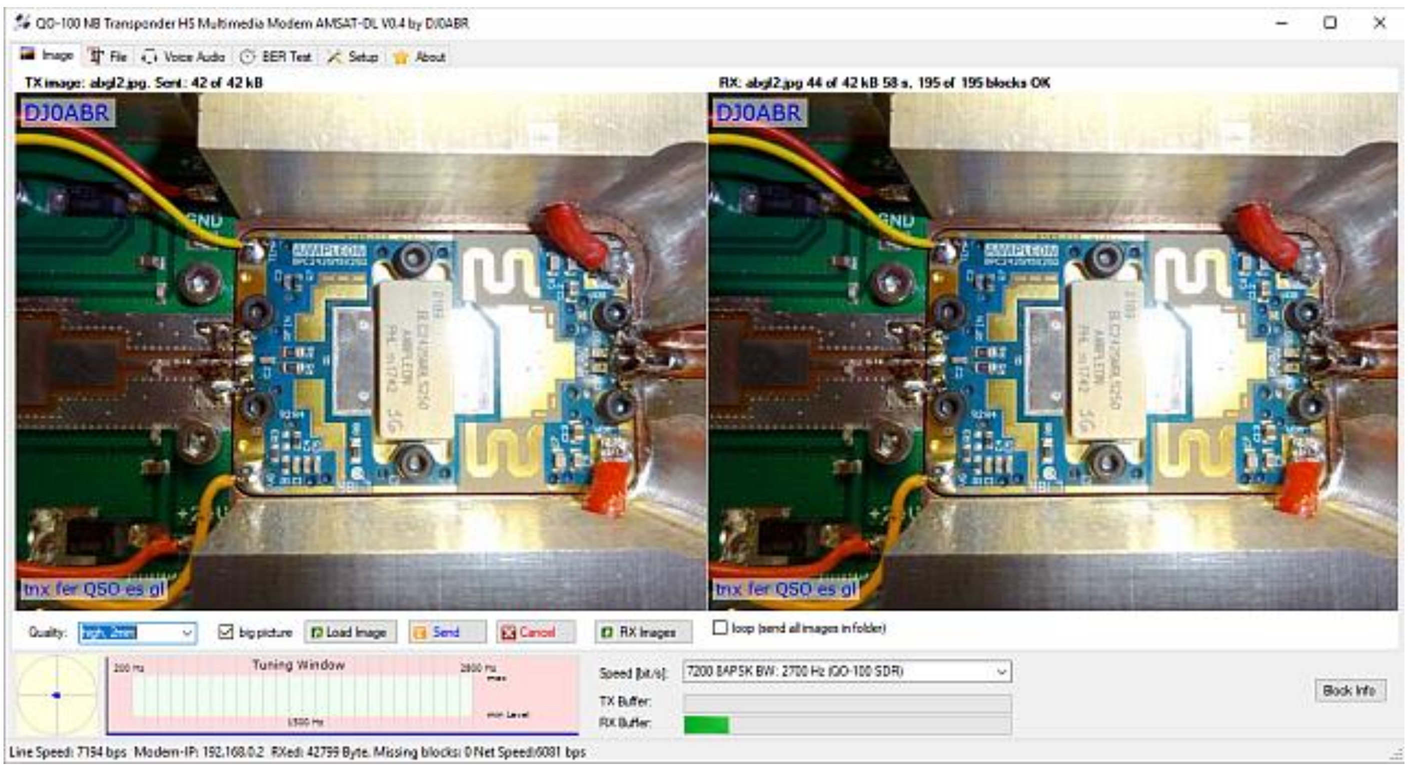

Figure 1: Transmission of a high-resolution image via QO-100

Motivation

Less than a year ago, in late summer 2019, a demonstration of satellite operation via QO-100 was held in District U, hosted by DH5RAE. Many visitors from other clubs and unlicensed private individuals were present, including a surprisingly large number of young technology enthusiasts.
The visitors were very surprised by the excellent, interference-free transmission quality. SSB sounds almost as good as FM via QO-100. The highlight was a QSO between Iceland, Brazil and DL, a combination that is practically impossible on shortwave.
Then some Digimodes were demonstrated, first RTTY, followed by analogue SSTV and finally KGSTV for digital image transmission. At this point, the interest of the younger OMs in particular was noticeably waning. In the later discussion round it was critically noted that we have an ultra-modern satellite, but use digital modes on it, which 30 years ago already belonged to the oldtimers and only allow slow text transmission or pictures in stamp size.
This was a clear thought-provoking impulse and finally the motivation to use the state of the art to enable modern, fast transmission.

Technical specifications and theoretical limits

There are two limit values to be observed, which are prescribed for operation above QO-100: the maximum bandwidth is 2.7kHz and the maximum signal must not exceed the beacon level. These two values result in a window for the maximum achievable transmission speed of digital data.
According to Shannon-Hartley's law, the bandwidth determines the maximum number of symbols per unit of time. Shannon does not initially define how many bits are packed into a symbol.
Since the symbol rate has this physical limit, in order to increase the transmission speed, we have to increase the number of bits/symbol. There are many ways to do this. Using phase modulation, for example, you can change the phase more or less. Each phase position then corresponds to one bit. At this point the second QO-100 rule "no signal stronger than the beacon" kicks in. This rule specifies basically a maximum signal to noise ratio. Noise leads to the points in the constellation diagram being blown up into "clouds".
If too many phase states are used, it will eventually become impossible for the receiver to reliably distinguish individual symbols as noise increases (Fig. 2a-2c).
Since practically no interference, but only Additive White Gaussian Noise (AWGN) influences the signal when transmitting via QO-100, the following formula applies to the maximum bit rate:

$$\text{max. bit rate [bps]} = B * \log(1+S/N) / \log(2),$$

with B=bandwidth and S/N=signal to noise ratio.
We use a maximum permissible bandwidth of 2700 Hz and an S/N of 10, which corresponds to a signal which is +10 dB above noise. This results in a theoretically maximum achievable Bit rate of 9340 bps (bits per second). Of course, one could also expect a higher SNR, but in satellite operation we want to work with low power and stations with small parabolic dishes.
A detailed explanation of these relationships can be found in [1].

Current transmission methods

In order to set the goals for the new modem, we first look at the common modulation types that are regularly seen in the digital band segment of QO-100:

RTTY:

RTTY is one of the oldest and best-known transmission methods for text. Instead of the usual ASCII code, a 5-bit Baudot code is transmitted by frequency shift keying. A logical "0" corresponds to the frequency 2125 Hz and a "1" to a frequency of 2295 Hz. At the usual bit rate of 45.45 bps, one bit takes 22 ms. During this time, almost 50 oscillations of the signal are transmitted, so the symbol rate is approx. 0.02 S/s.
RTTY is extremely inefficient by today's standards, but easy to decode by the simplest means. PSK31 offers a significant improvement, but this shortwave mode is practically never heard on QO-100.

SSTV:

Classic SSTV is used for analogue image transmission. Brightness and colour values are assigned to different AF frequencies and transmitted together with a synchronisation signal. This method originally dates from the 1950s and is a real old-timer, but is still widely used on QO-100 and even the ISS. There are a number of similar coding schemes, on QO-100 you can usually hear "Scottie" or "Martin". The image resolution varies, on average it is about 350 × 240 pixels. Depending on the method, the transmission time is e.g. 110 seconds.
Analogue transmission is difficult to convert into digital speeds. An estimation with "Martin-1" would result in a corresponding bit rate of approx. 6800 bps. Unfortunately, analogue SSTV is very error-prone, since every slightest fluctuation in the received signal has an immediate effect on the picture content.

KGSTV:

This program, developed by JJØOBZ, is used for digital image transmission and is frequently found on QO-100. Pictures with a resolution of 320 x 240 pixels are transferred in blocks of 16 ×16 pixels. There are two methods to choose from: MSK at 1200 bps and 4FSK at 2400 bps.
If the receiver was unable to decode individual blocks, it requests these again by transmitting an error list until the picture is complete. Due to the low level of interference on QO-100, however, the pictures are often complete on the first pass.

FreeDV:

The motivation for developing this mode of operation for digital voice transmission was that the digital voice systems (like D-Star and DMR) uses a proprietary codec (AMBE). This CODEC has to be bought as hardware as the software version is practically unaffordable for radio amateurs.
Therefore, the free and open source Codec-2 was developed, on which FreeDV is based.
On QO-100, work is mostly done in FreeDV-2020. This system was revised for QO-100. It uses an OFDM system with a bit rate of max. 2400 bps (2400A mode) if all OFDM carriers can be used for transmission. Of course, the good signal-to-noise ratio of QO-100 must be exploited to keep the error rate low.

All these systems were primarily developed for communication on short wave, only FreeDV got some adaptations to QO-100. Accordingly, they are of course designed for the high noise level on short wave and a significant part of the valuable bandwidth has to be used for error correction.

The target of the new high-speed modem is to supplement those currently common operating modes.

Technical data of the new high-speed modem "HS Multimedia Modem

The theoretical limit of 9340 bps at a given bandwidth and S/N may have to be corrected to take into account the limited capabilities of the hardware used, especially the transceiver. For example, ICOM transceivers in DATA mode have a fixed Tx bandwidth of 2400 Hz. This results in a maximum bit rate of 8300 bps for an S/N = 10dB.
Older transceivers have different bandwidths. Especially near the filter edges the linearity and phase response start to drop off, which is why an additional reserve distance is necessary (excess bandwidth). Further adjustments to the filter curve are made with a digital equalizer.
An attempt was made to determine the achievable limits for QPSK and 8APSK modulation by measurements with several different transceivers.

This project is still very young and is currently available in version 0.42. Especially the modulation procedures will surely be followed by some more steps. For a stable starting point, two modulation types were initially implemented:

- QPSK with a bit rate from 3000 bps to 4800 bps (nominal 4410 bps)
- 8APSK with a bit rate from 5500 bps to 7200 bps (nominally 6000 bps when using an ICOM IC-9700 or 7200 bps when using an SDR such as Pluto or LimeSDR)
- Error correction: Reed Solomon Code [3]
- Full duplex (reception of own transmission possible, important on QO-100)
- Full duplex QSOs in split operation
- Transmission of any data such as images, text, HTML pages, entire web presences, binary data
- Transmission of file names and file size as well as CRC secured transfer of files via QO-100
- Automatic scaling of images according to the desired transmission time
- Automatic ZIP compression
- Digital voice transmission using CODEC-2 or OPUS

Initial tests have been conducted by DJØABR, DH5RAE, DL1EV and DL3MX. Alfred, DL3MX, had set up a very small system with a 40 cm parabolic dish on a tripod. The following results were achieved:

Operating mode	0-error SNR	0-error power	Minimum SNR	Minimum performance
QPSK-4410	+13dB	500mW	+11dB	300mW
8PSK-6000	+19dB	1,25W	+17dB	800mW

The performance data refer to a transmitter which reaches beacon levels at 5 W in SSB mode. In these measurements, the average BPSK-400 beacon was received with an SNR of approx. +25 dB (fluctuating between +24 to +28 dB). Since an error rate of (almost) 0 is already achieved with very small dishes, procedures involving the request of new data blocks are deemed to not be necessary. In case of an error, images are simply sent again, which is no problem with short transmission times of 10 to 30 seconds.
In further work to improve data rate and SNR, attention must always be paid to the widest possible range of use with a large number of radios.

Transceiver requirements

In order to be able to transmit high bit rates, good linearity and a perfect phase response are required. Devices with integrated sound cards, which have been available from all well-known manufacturers for years, work optimally. A connection via the normal microphone socket of older transceivers will only work at the lower transmission rates because of the internal speech filters. SDR transceivers like ADALM Pluto or LimeSDR work very well.
Filters, speech processors, noise blankers (NB) or noise reduction functions (NR) must
must always be switched off.
The constellation diagram can be used to assess the reception quality. A too weak, noisy signal can be recognized by diffusely distributed pixels. However, if it stretches the pixels, the phase information is disturbed, e.g. by phase jitter in the received signal. On QO-100 this can be caused by the use of an impure GPS reference in the transmitter or receiver. This is also the reason why an OCXO is recommended instead of GPS for DVB-S2 operation (which is also QPSK modulated). The effects mentioned are shown in the following constellation diagrams using the example of a QPSK-4410 signal (Fig. 2a-c).

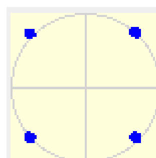

Figure 2a: Optimum constellation diagram for SNR >40 dB

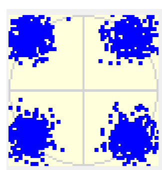

Figure 2b: Constellation diagram via QO-100 at SNR 15 dB

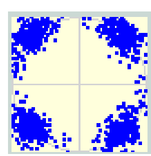

Figure 2c: Constellation diagram with jitter of the LNB reference frequency

Examples of transmission times (8APSK-6000)

- Image with 320 × 240 pixels (as usually used for SSTV or KGSTV): approx. 8 seconds
- Image with 640 × 480 pixels (low quality, see explanation later): approx. 33 seconds
- Image with 640 × 480 pixels (medium quality, see explanation later): approx. 55 seconds
- HTML web page with 14 kB: approx. 7 seconds

Especially with texts or HTML pages, net speeds of more than 16 kbps can be achieved through automatic compression. A pure text station presentation can thus be sent in just 2 to 3 seconds, a detailed presentation with an image of the QSL card in about 30 to 40 seconds. Due to these short transmission times, block repetitions are unnecessary in case of errors. If necessary, simply send the file again. For very large files (the maximum is fixed at 200 kB) HS Multimedia Modem can make additions on the basis of the block number and thus produce an error-free file from two faulty transmissions, unless the same block was faulty by chance.

Structure of the Highspeed Multimedia Modem

Modulator and demodulator were developed in GNU-Radio and then, because of better portability, implemented with Liquid-SDR. Together with the radio equipment they form the (faulty) physical transmission medium.

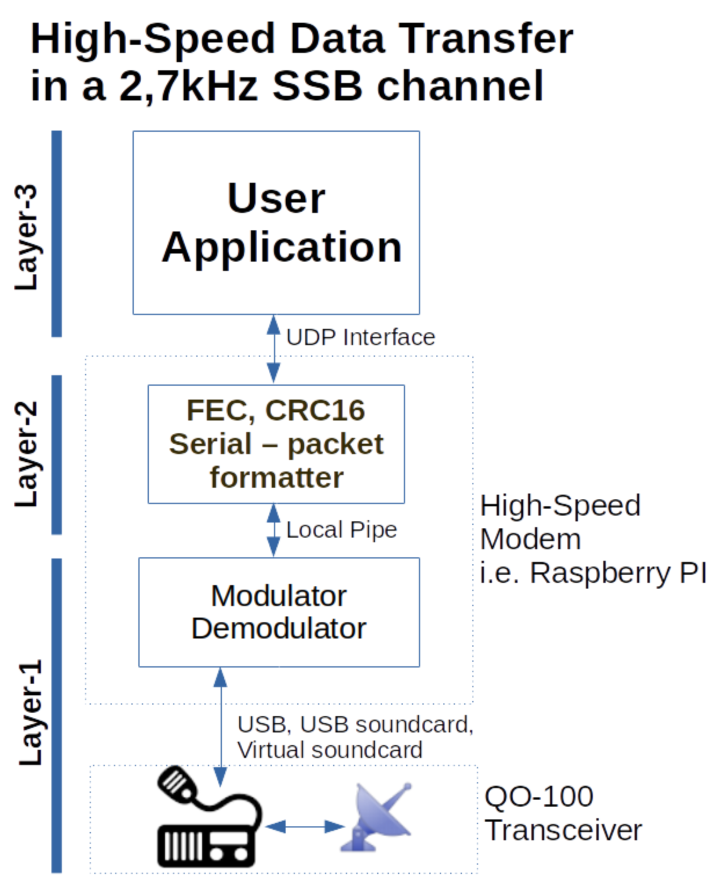

Figure 3: Layer structure of the highspeed multimedia modem

UDP ports are used as interfaces to the user program. This makes it easier for other developers to use the modem, offers independence from devices and operating systems and provides network capability (Fig. 3).

The Highspeed Multimedia Modem in practice

The Highspeed Multimedia Modem is a system for fast transmission of data in a normal 2.7 kHz voice channel via QO-100. Compared to conventional systems, the transmission speed is increased by a factor of 5 to 10.
This modem is suitable for the transmission of images, any files, texts, HTML web files and program files up to complete web presences as well as for digitized speech.
For a station presentation, for example, you can send the image of your QSL card together with cleanly formatted text and the receiver will automatically open the web browser to display the received presentation.
The high-speed modem works full duplex, i.e. transmission and reception run simultaneously. This allows you to check your own transmission, as requested by the satellite operator. A full duplex QSO is possible in split mode (TX and RX frequency offset by e.g. 5 kHz). This allows true intercom in digital speech.
By the way, if you only want to receive a transmission, you only need to set the reception frequency and the transmission rate announced by synthesised speech. After that you can simply let the receiver run along. The reception software automatically recognises the data type (e.g. images, ASCII files, binary files, etc.) and carries out the appropriate actions.
The error-free blocks of faulty files are stored internally. If a file is received a second time, the software automatically corrects erroneous blocks with previously correctly received data and can thus generate an error-free file from two incorrect transmissions.
Here is an example of the transmission results for a cleanly configured system: 50 images with approx. 20kByte/image were sent several times in succession, each making a total of 1Mbyte.
The signal was received simultaneously in full duplex mode. Of every 50 images, on average one image was faulty (one block of 258 bytes). So usually 49 pictures arrived immediately correct, only one picture had to wait for the repetition.

Required equipment

- QO-100 radio system
- PC with Windows (Version 10, probably executable from V7, but not tested) or
- PC with Linux (all distributions) or
- Single-board computer, currently supports Raspberry Pi 4 and Odroid N2, N2+, C2 and C4 (Raspberry Pi 3B+ only with remote network operation)
- Optional for remote network operation: any PC (Windows, Linux, Mac) for the user interface.

Installation

Windows Desktop PC:

Download the installation file from [5]. By executing the file hsmodem_setup.exe [5], the complete program (modem and user interface) is installed automatically. After the first start Windows 10 shows two dialogues to get the permission for network access, both have to be confirmed. If a message about missing DLLs appears when starting the program, the Microsoft package vc_redist.x86.exe must be installed. Please use only the Microsoft original, which can be found here [6].
Attention: Always select the x86 version (vc_redist.x86.exe) even if you have a 64-bit PC!

Linux Desktop PC:

Load the project from [2] and start the script hsmodem.sh in a console, the program will be installed.

Single board computer Raspberry PI or Odroid:

1. Download the corresponding preconfigured image from [4],
2. unzip the image,
3. flash the image to an SD card (32 GB micro SD card recommended),
4. insert the card into the single-board computer (monitor/keyboard is not required, but of course possible)
5. connect the single-board computer to the home network using an Ethernet cable.

Transceiver:

The modem transmits and receives in the LF range (maximum from 150 Hz to 2.85 kHz) via a sound card connected to a suitable transceiver. Many modern transceivers already have a built-in sound card and a USB port, e.g. most ICOM transceivers. In this case you simply connect the modem and transceiver with a USB cable. In figure 4 the modem runs on an Odroid SBC. But it can also run on the PC itself.

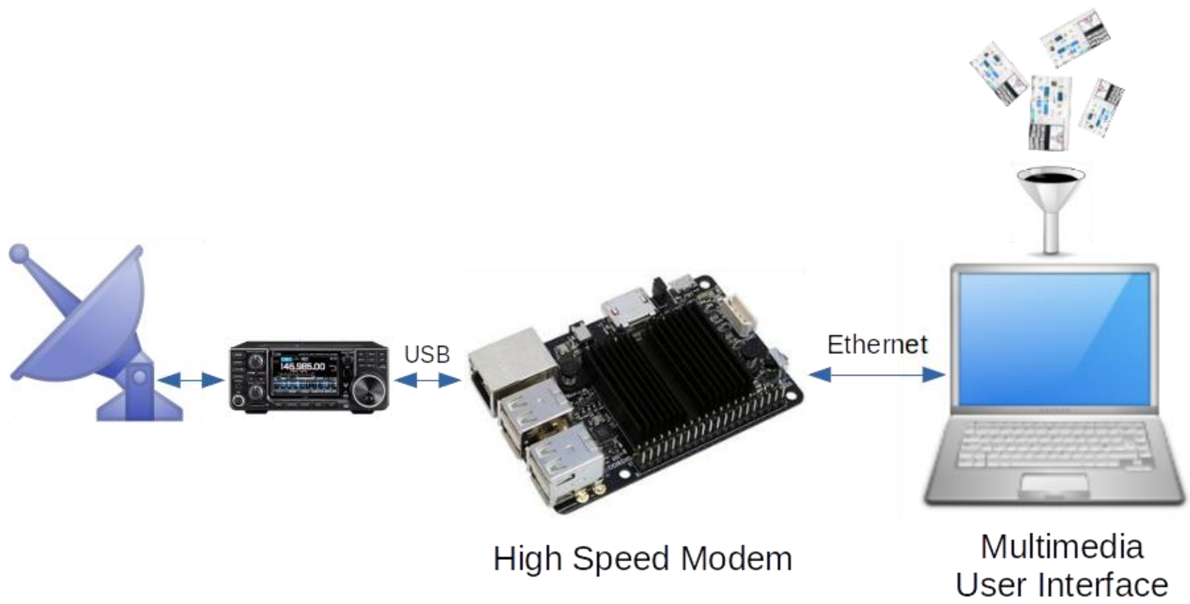

Figure 4: Connecting modern transceivers to the Highspeed Multimedia Modem on a single-board computer

If the transceiver has no built-in USB card, you can use a USB sound stick or other sound card (Fig. 5). USB sound cards with line-in input are ideal. USB sticks that only have a microphone input are less ideal and need a careful setting because they are very sensitive.

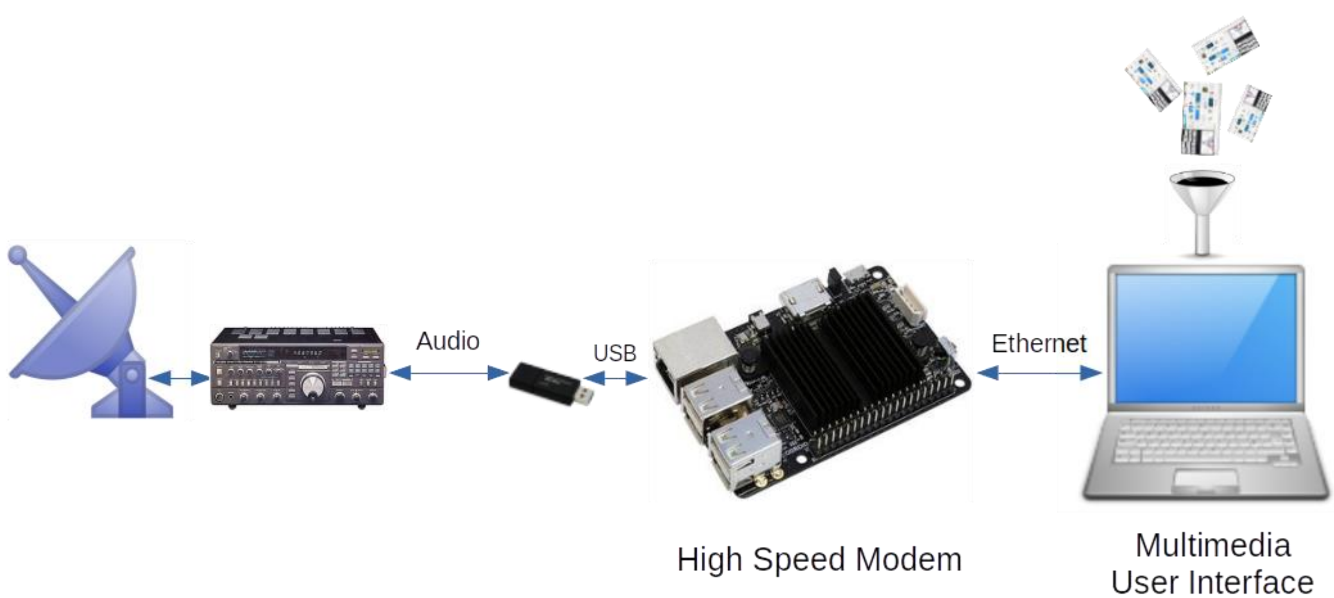

Figure 5: Connection via sound card to the Highspeed Multimedia Modem on a single-board computer

Important: for optimal performance of the Highspeed Multimedia Modem the signal must be transmitted with good linearity and clean phase response. Using the normal microphone and loudspeaker connection you will only be able to work with a significantly reduced data rate. Well suited are transceivers with integrated sound card and SDR transmitter/receiver.

SDR transceiver and connection via virtual sound card:

The use of an SDR transceiver is particularly elegant (Picture 6). This receives the IF signal from the LNB and transmits directly on the uplink frequency. It is usually connected to the PC by means of a USB cable. In the case of the ADALM Pluto, this can alternatively be done via an Ethernet connection. On the PC you now need a suitable software, very widespread is the freeware "SDR-Console" by Simon Brown.
The Highspeed Modem can be connected to the used SDR software like any other digital mode of operation (fldigi, freeDV etc.) by means of a virtual sound card (virtual audio cable VAC).
Since this topic depends strongly on the operating system and the software used, it is planned to write a separate documentation for this.

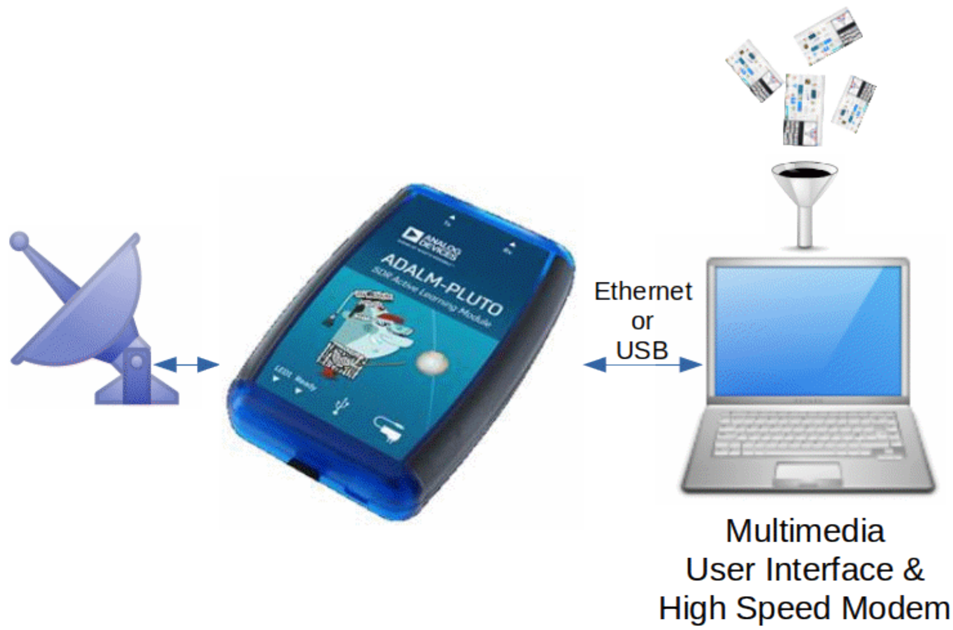

Figure 6: Using an SDR-TRX with the Highspeed Multimedia Modem including the GUI on a Windows PC

Single board computer:

If the modem is running on a Raspberry Pi or Odroid, you will usually run the user interface on another PC in your home network. Only a C4 or N2 Odroid has enough computing power to run the modem and user interface simultaneously. You connect the single-board computer to the home network with an Ethernet cable. The IP address is assigned automatically (DHCP). The recognition of the modem in the home network is also automatic. The user does not need to worry about the network. Once everything is connected, the single-board computer is switched on. A sufficiently strong power supply and good cables should be used. Since one often loses several 100 mV of the supply voltage when using cheap USB cables, one should not save money here.

User interface / operation

The user interface will run on any computer (Windows PC, Linux PC, single-board computer, probably also Mac-OS, which has not been tested yet). After starting the program, the modem is automatically found in the home network, no matter whether it is running on the same or another computer. The program is called "oscardata.exe" and is located on the SD card in the directory: /home/odroid/modem or /home/pi/modem or as a download on this page [5].

Windows: the program is installed as described and started from the menu as usual.

Linux: the file runs under the Linux package: mono-complete from version 6.12.0. In the preconfigured images this is already installed.
To start the program, you open a console and go to /home/odroid/modem or /home/pi/modem and start there: "mono oscardata.exe".

After starting oscardata.exe you will see the user interface (Fig. 7), for the time being still without content.

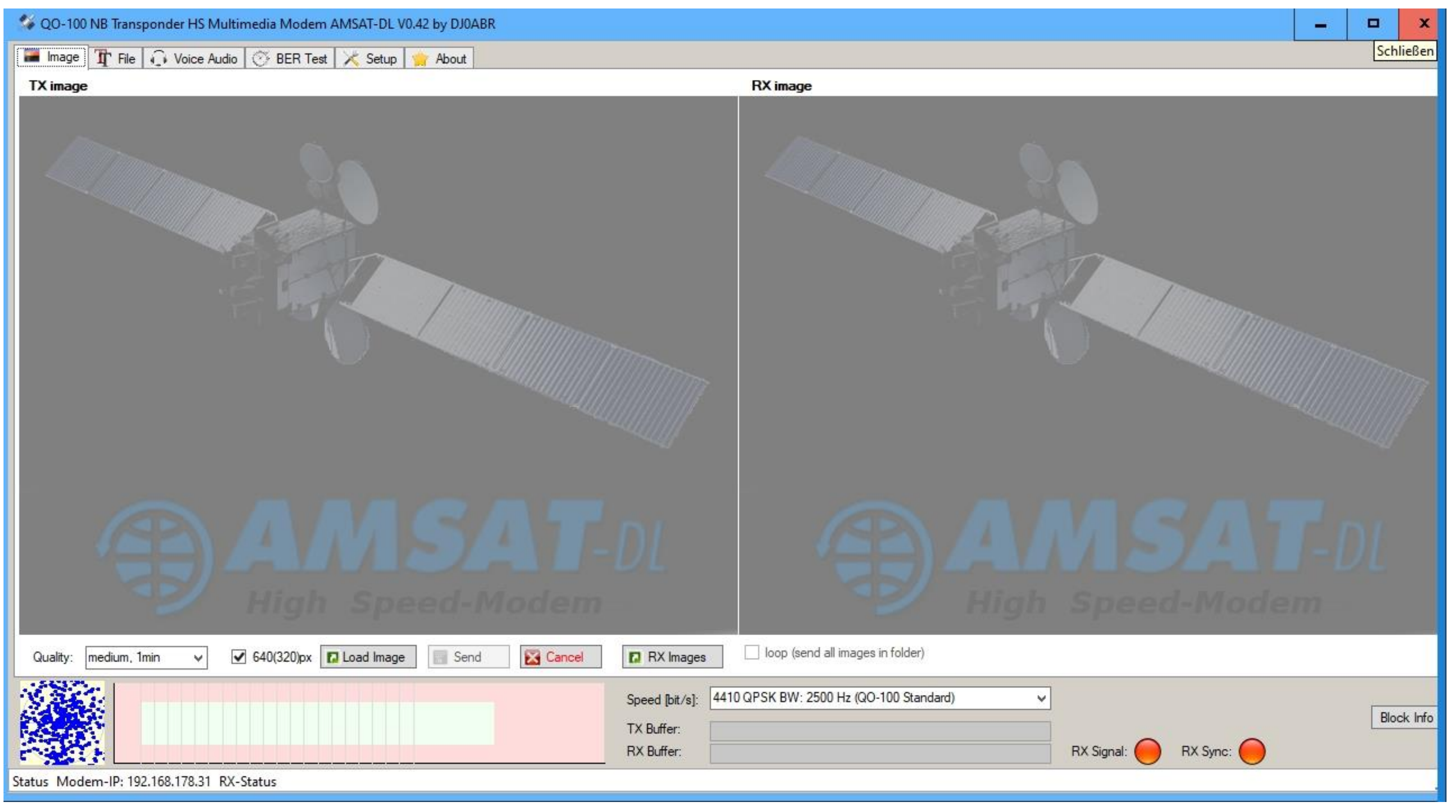

Figure 7: User interface

The IP address of the modem appears in the status line. If not, there is no network connection yet. As soon as the transceiver is switched on you can see noise in the constellation diagram on the lower left.

Setup:

In the menu item "Setup" the necessary basic settings are defined (Fig. 8).

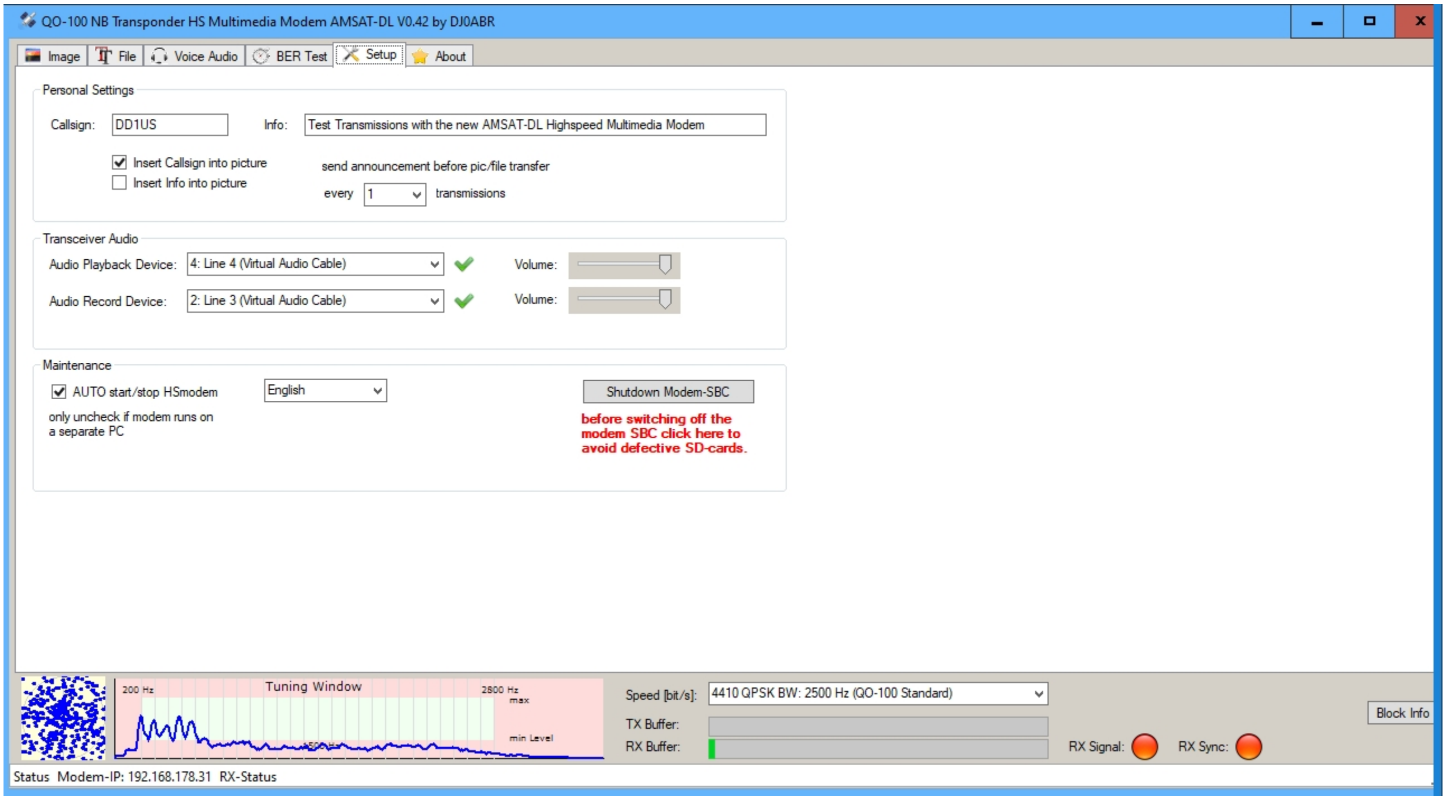

Figure 8: Basic settings in the menu item Setup

- Personal Settings:
  First you enter your own callsign, the info text is optional. This text and the callsign can be inserted into a transmitted picture. Whether the type of modulation and data rate used is transmitted before each transmission by means of an artificial voice or, as in the example (Fig. 8), before every fourth transmission can be freely defined.
- Transceiver Audio:
  Here you define the audio sources for the transmitter (Audio Playback Device) or the audio sink for the receiver (Audio Record Device). These can be the microphone and the loudspeaker of the PC. In the example two "virtual audio cables" are used to connect the Highspeed Modem with the SDR-Console. The volume settings can be optimized later.
- Maintenance:
  If the modem is running on the same PC as the user interface, a tick must be placed at "AUTO start/stop HSmodem". If a Raspberry Pi or Odroid computer is used for the modem and another computer is used for the user interface, you should uncheck this option.
  In the menu right of that button you can select the language of the user interface. Presently the languages German/Deutsch and English are supported.
  The button "Shutdown Modem-SBC" shall be used before shutting off a single-board computer to avoid damaging the SD-card in the SBC.

Send and receive test data simultaneously:

In the "BER Test" window, test data can be sent and received in order to use a bit-error-test to verify the correct functioning of your own system (Fig. 9).

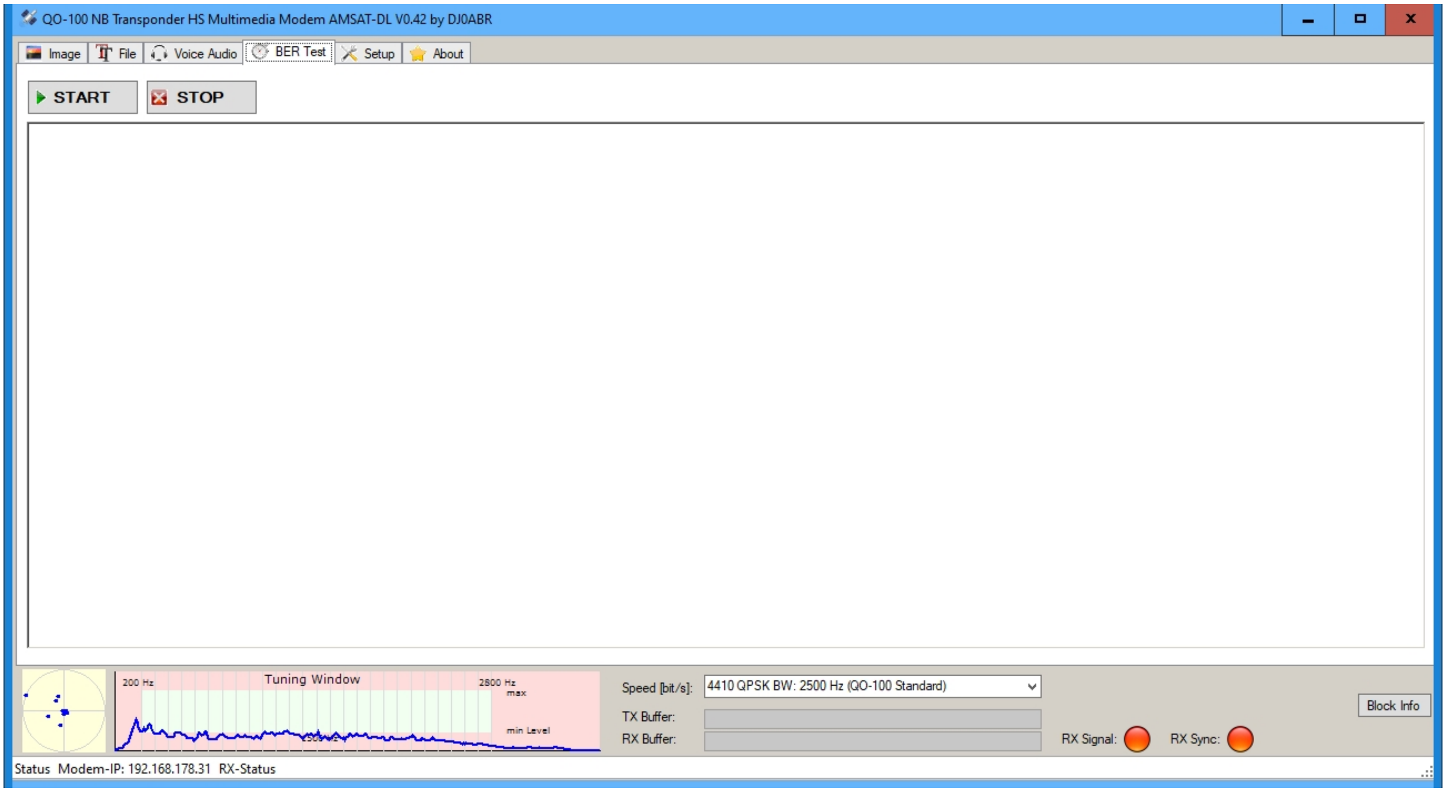

Figure 9: BER Test

Different bandwidths and speeds are available (Fig. 10). For operation on QO-100, 4410 bps QPSK and 6000 bps 8APSK modes are recommended. For the first tests, 3000 QPSK should be selected, since this is where the requirements on the radio system are lowest.

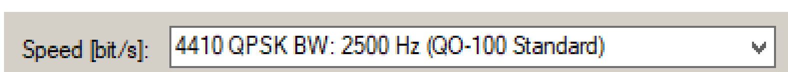

Figure 10: Speed selection

Now click the "START" button and the modem will send test data. Switch the transceiver manually to transmit (there is no automatic PTT yet) and check the output power. Your received own signal must always be below beacon level. When using an SDR-TRX and the SDR-Console you can use their VOX function. There are two possibilities to adjust the transmitter:
1. the level of the sound card and
2. the setting of the transmission power.

Details of how to set this on the IC-9700 are given in a later chapter. For reception, it is important that the input level of the sound card is set so that the spectrum display is in the green range (Fig. 11a).

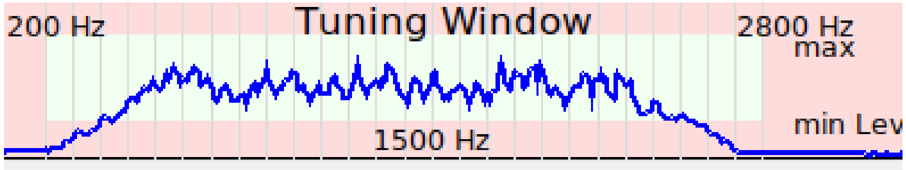

Fig. 11a: Level and frequency adjustment

There can sometimes be a small offset between the transmit and receive frequencies. Even with GPS stabilised systems there can be a deviation of up to ±50 Hz depending on the system.
The RIT function of the transceiver corrects any deviations to place the spectrum in the middle of the green area (as shown in Fig. 11a). Figure 11b shows a wrong setting, the frequency is set too low here.

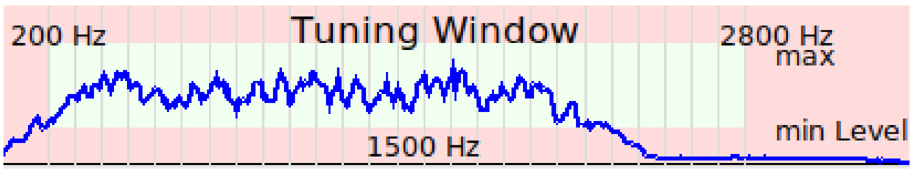

Fig. 11b: Incorrect frequency setting

The modem has a capture range of approx. ±200 Hz, but the transceiver's receive filters are usually not as wide and would weaken the signal at the edges if they were set incorrectly. An exact setting is also possible with the constellation diagram.

The points should be as sharp as possible. Here are two examples with 6000 bps 8APSK:

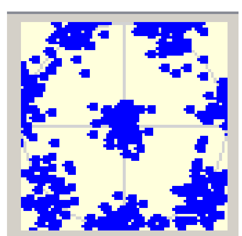

Fig. 12a: Wrong setting, the signal is very noisy, the error rate is high

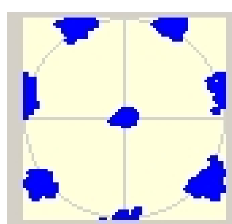

Figure 12b: Correct setting with low error rate

As soon as the level and frequency are set correctly, the test data runs through the window (Fig. 13).

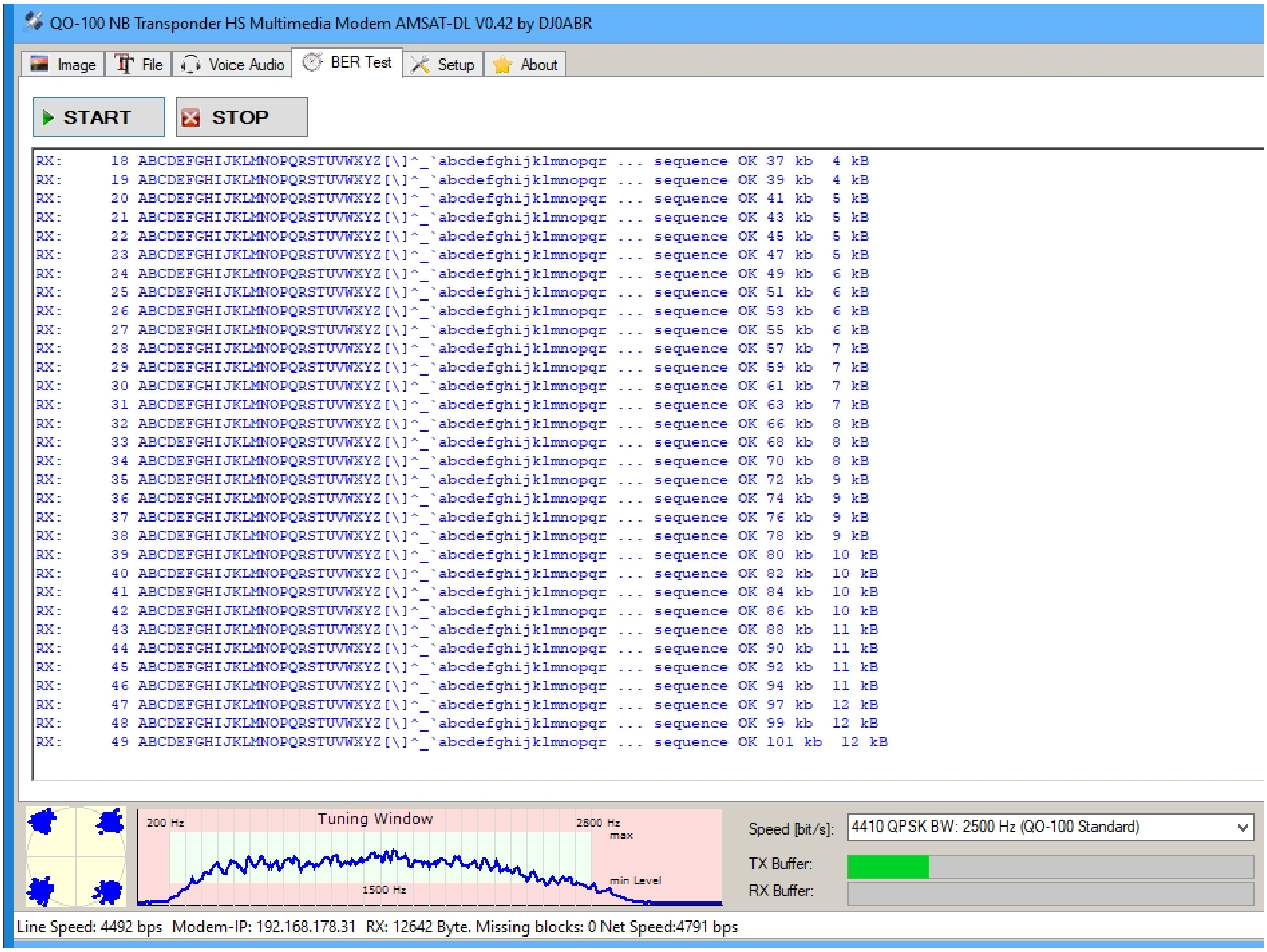

Figure 13: Bit Error Rate test

If all adjustments are properly done, "sequence OK" is always displayed. Error messages (frame lost) should occur very rarely. Of course, you can receive test data from other stations as well.

Send and receive images:

If the test data has been received correctly as explained in the previous chapter, you can now switch to the menu item "Image" (Fig. 14) and try to receive and transmit images (Fig. 15).

Figure 14: Image window selection

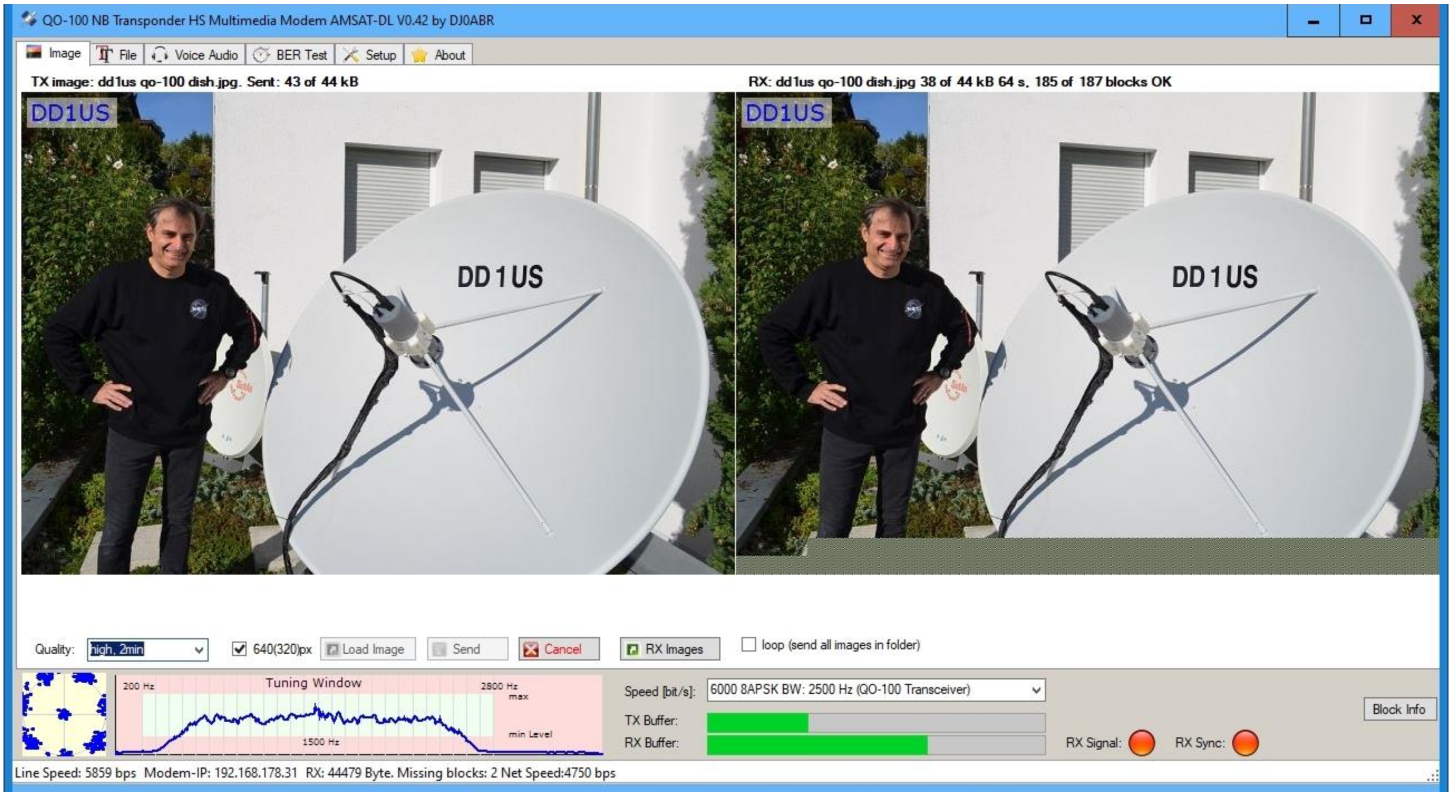

Figure 15: An image is transmitted via QO-100

- Quality:
  Four resolutions (detail, sharpness) can be selected. This setting determines the transmission time, which is given as a rough estimate. With the setting "medium, 1min", very sharp pictures can already be sent. Higher „Quality“ settings are only required for extreme requirements.
- 640(320)px:
  The images are automatically scaled regardless of the image format. Almost any picture type and resolution can be sent. The scaling depends on the setting “640(320)px”: not activated: 320 × 240 pixels, activated: 640 × 480 pixels.
- Load Image:
  Click on "Load Image" to select an image to be sent. The storage location for images to be sent can be selected via the embedded file browser.
- Send:
  Click "Send" to send the selected image.
- Cancel:
  If you want to terminate a running transmission of a picture you can simply click on this button.

- Rx Images:
  The storage location for received images can be accessed by clicking on "RX Images".
- Loop (send all images in folder):
  When this is enabled, all images in the same folder are sent in an endless loop.

Left part in Fig. 15: the original image, already scaled automatically.

Right part in Fig. 15: image received via QO-100. The transmission is almost complete. Above the received image, the file name, received bytes, file size, transmission time, number of correctly received blocks and total number of received blocks are displayed. If reception is correct, it is a 100% copy of the left image.

Send and receive files:

The menu item "File" permits the transmission of ASCII, HTML and binary files (Fig. 16).

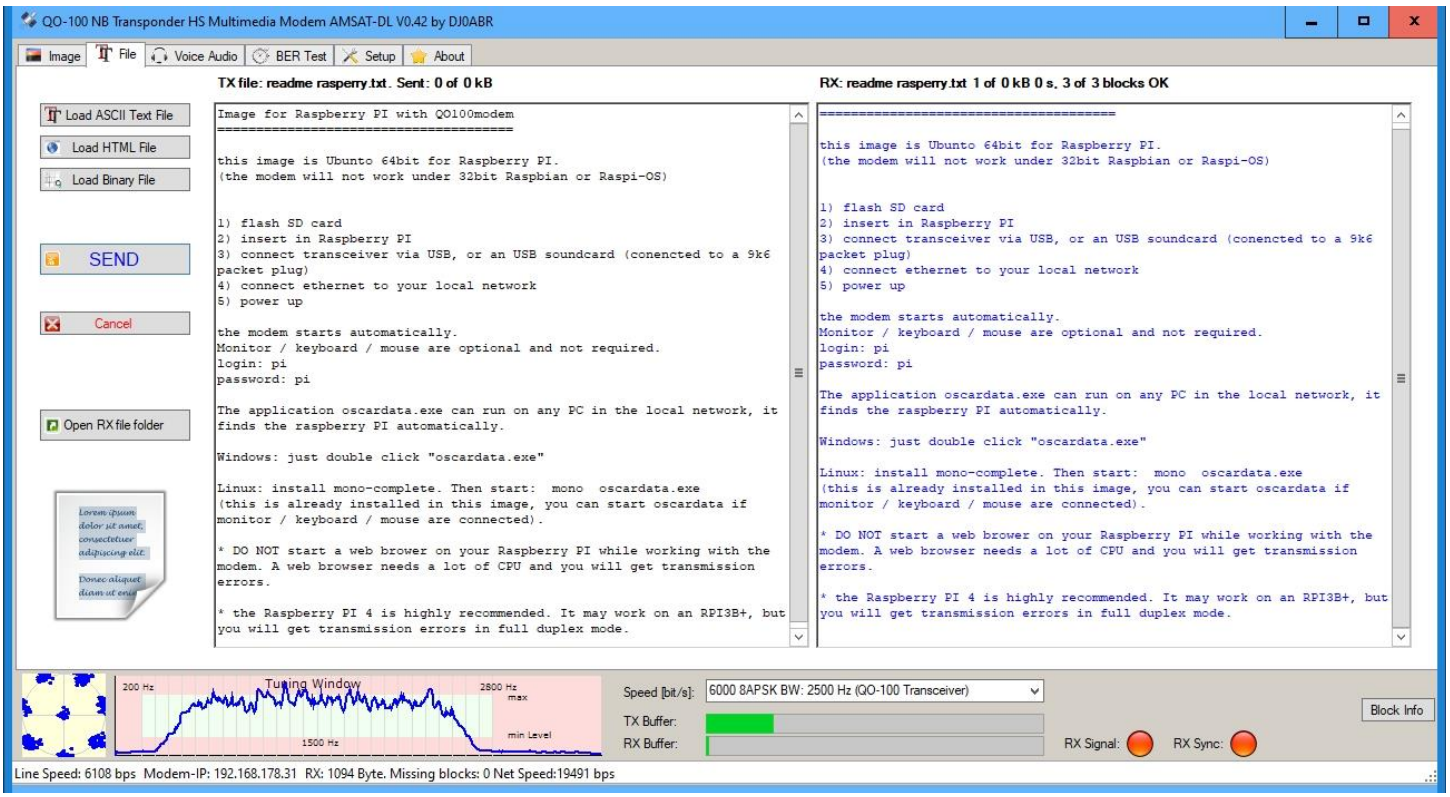

Figure 16: A text file was transferred via QO-100

- Load ASCII Text File:
  In this menu item you select a pure text file for transmission. It is shown in the left window.
- SEND:
  Sends the file. If you receive yourself, the received text file is displayed on the right.

In the example (Fig. 16), a text file describing the installation of the Highspeed Multimedia Modem on a Raspberry Pi was transmitted at an effective transmission speed of 8761 bps. Since text files can be compressed well, this high speed was achieved. Compression is automatically applied to all files except image files.

- Load HTML File:
  In this menu item you select an HTML file to be sent. HTML (web) files are transmitted in the same way as text files, except that a web browser opens automatically when received and displays the HTML page.
- Load Binary File:
  Analogous to the previous points, a binary file is selected here.

Of course, binary files are not displayed after reception. Instead, the right-hand window shows transmission statistics (Fig. 17).

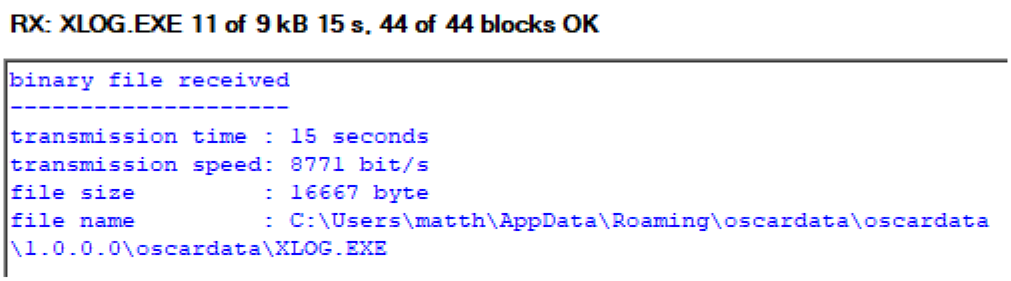

Figure 17: A binary file was transferred via QO-100

- Cancel:
  If you want to terminate a running transmission of a file you can simply click on this button.
- Open RX file folder:
  All received files can be accessed.

Digital voice transmission:

The high-speed multimedia modem would not deserve the name if it could not also transmit digital speech. Therefore, this possibility was also implemented in the menu item "Voice Audio" (Fig. 18).

Figure 18: Both, CODEC-2 and OPUS are supported

- Loudspeaker / Microphone / Headset:
  Here the inputs and outputs of the sound card or, as in the example (Fig. 18), virtual audio cables (Virtual Audio Cable VAC) are selected.
- Voice Audio Operating Mode:
  Only one of the five operating modes can be selected at a time
  - Digital Monitor: the reception signal is looped through directly to the loudspeaker. This mode is used to observe the frequency or to evaluate the received signal.
  - Internal Loop: the microphone is connected directly to the loudspeaker. This allows the function of the sound card and the volume settings to be checked.
  - Codec Loop: in this test mode the selected codec is additionally looped in. This allows you to check the actual quality of the audio transmission at the different bit rates without going on air.
  - Digital Voice RX: in this mode you can listen to a running Highspeed Modem QSO
  - Digital Voice RX+TX: this is the actual QSO mode
    If you offset Tx and Rx frequency by at least 5 kHz, true intercom (full duplex) is possible.
- Codec Selection:
  Here you can choose between two voice codecs. CODEC-2 works with a fixed audio rate of 3200 bps and is particularly suitable for low data rates. OPUS scales the audio rate in a ratio of 84 % to the data rate and offers a more natural speech quality at higher data rates (8APSK modes).

Transmit and receive level adjustment using the example of ICOM transceivers:

Tested: IC-9700, IC-7100 and (Rx only) IC-7300 and IC-7610. The settings shown below refer to these four transceivers. IC-910 and IC-9100 also work, only the names of the menu items are slightly different on these units. The IC-705 has not been tested, but it can be assumed that Highspeed Multimedia Modem works with it as well.

Preparation of the transceiver:

- USB-D:
  USB is usually set for analogue voice operation. For data operation, you must switch to USB-D. To do so, press [USB], and then enable DATA. This must be performed for both the transmitting and the receiving side. Then, you can view your own images which you are transmitting for checking purposes.

Figure 19: Setting the data mode

If you want to use analogue voice operation again, you have to switch back to normal USB.

- Filter:
  The reception filter is set to FIL1. Then check the bandwidth: press FIL1 for 2 s until the filter menu is displayed. The filter curve is set to SHARP. Then tap on BW and set to 3.6 k with the big knob.

Fig. 20: Setting the reception filter

- Frequency:
  The satellite band plan reserves the frequency range 10489.580 to 10489.650 MHz for "digital operation with a bandwidth of up to 2.7 kHz". Alternatively, the "Mixed/Special" range above 10489.850 MHz can be used.

Transmission level, output power:

The output power is influenced by both the sound card output level and the transceiver power setting. It is important that the sound card is not overdriven, as any overdriving will severely disturb the QPSK/8APSK signal.

Below please find the setting using the example of ICOM transceivers:

MENU button - SET - CONNECTORS - MOD INPUT:

- Set everything to 50%
- DATA OFF MOD: MIC/ACC
- DATA MOD: USB

With the setting "USB MOD LEVEL" you can adjust the level of the transmitted signal, about 40-50 % should be optimal.

Reception level:

The reception level must be set so that when a signal is received, the spectrum is within the green range.

MENU button - SET - CONNECTORS - USB AF/IF OUTPUT:

- OUTPUT SELECT: AF
- AF OUTPUT LEVEL: approx. 50%, depending on spectrum display (Fig. 11a)

References:

You can download the project data via the AMSAT-DL or DJØABR Github Repository. It is under steady development. We always try to provide updated executable versions. Currently there are updates almost weekly, which improve the function of the modem and the compatibility with new devices. In a planned second article the internal processes of modulation and demodulation of QPSK and 8APSK signals will be described.

Links:

[1] Calculation of the maximum bit rates: *https://de.wikipedia.org/wiki/Shannon-Hartley-Gesetz*
[2] Software sources in AMSAT-DL Github repository: *https://github.com/amsat-dl/QO-100-modem*
[3] Error correction procedures: *https://www.schifra.com/fqa.html*
[4] Images Highspeed Multimedia Modem for Raspberry PI and Odroid: *https://t1p.de/a4am*
[5] Program with the user interface for Windows: *https://t1p.de/a4am*
[6] DLL package from Microsoft: *https://t1p.de/b68y*