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# GBTx Communication Document

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## 1 Hardware setup

### 1.1 Overview

Our current setup consists of one master and one slave GBTx board. The master is connected to the MiniDAQ GBTx channel 3 (fiber 8), and the slave can be connected to either GBT channel 0 (fiber 6) or channel 6 (fiber 11). The master synchronizes its on-board clock to the signal from the MiniDAQ, and propagates its clock signal to the slave. The slave does not have an on-board clock, and is configured to obtain clock signal externally.

The master I<sup>2</sup>C port is connected to an external USB device. The slave I<sup>2</sup>C port is connected to the master. Both are set to be programmed by the I<sup>2</sup>C channel, rather than GBT-IC channel.

The current setup is capable of:

1. Program the slave GBTx board with MiniDAQ directly.
2. Read/Write the register value of the master GBTx board with GBT-IC specification on the MiniDAQ.
3. Do PRBS tests from MiniDAQ to the slave, then back to the MiniDAQ. The master is also required<sup>1</sup> as the slave can only obtain its reference clock from the master.

### 1.2 Configure GBTx to use external I<sup>2</sup>C adapter

This setup is required to program a GBTx board using an external I<sup>2</sup>C adapter. Follow Figure 1 to connect an external I<sup>2</sup>C adapter.

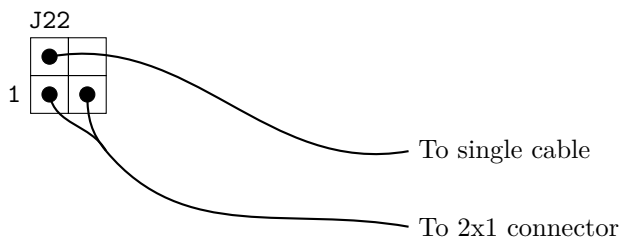


Figure 1: Schematic for external I<sup>2</sup>C adapter setup.

The I<sup>2</sup>C adapter used in our lab is made in-house. For the 2x1 connector, make sure the side that has *no* metal contact is facing up.

### 1.3 Configure slave GBTx to use master SCA channel

This setup is required to program a slave via a master SCA channel. In a typical scenario, the master is connected to a MiniDAQ so that programming the slave using the MiniDAQ directly<sup>2</sup> is possible. Follow Figure 2 to connect a slave GBTx to the SCA channel of a master GBTx board.

<sup>1</sup> The master GBTx is also connected to the MiniDAQ with a different channel, to provide reference clock to the slave.

<sup>2</sup> MiniDAQ → master GBTx → slave GBTx.



Figure 2: Schematic for slave to master SCA setup.

The black ground cable can be connected to any of the ground pin on the master GBTx.

There is a 2x1 to 2x1 cross-type cable made in-house to replace the red-blue cables. To use that cable, make sure the two 2x1 connectors have the same orientation (e.g. the sides *without* metal contact are both facing up).

#### 1.4 Configure GBTx to use GBT-IC channel

It might be useful to read/write individual registers from/to a GBTx board. In this case, follow the Figure 3 to flip the `configSelect` switch.

Flip the `configSelect` switch will render the external I<sup>2</sup>C adapter ineffective. None of the GBTx register value is fused onto the board, so a GBTx board in our lab must always be programmed externally via I<sup>2</sup>C before flipping the switch.

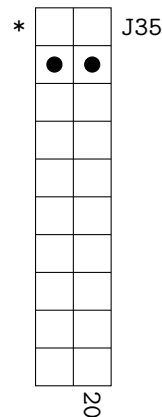


Figure 3: Schematic for flipping the `configSelect` switch. A jumper should be used to connect the two pins marked above.

## 1.5 Configure GBTx in transmitter/transceiver and widebus/FEC mode

GBTx boards can be configured to operate as a transmitter or a transceiver, with a communication protocol of widebus or FEC, by hardware pins. There are a total of 4 pins; these related pins are shown in Figure 4.

GBTx operations mode is completely determined by these 4 pins (corresponding to 4 bits). The 4-bit operation modes are listed in GBTx operation modes.

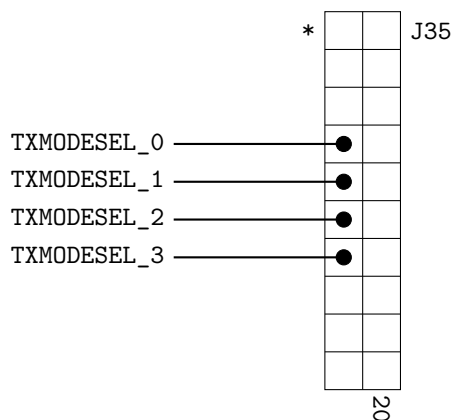


Figure 4: Schematic showing all 4 related configuration pins. Note that the right column is a common ground. To switch a pin *off*, connect it to a common ground pin.

## 1.6 Reset GBTx

Sometimes GBTx boards will not be properly reset by reprogramming. In such case, a hard reset is needed. Follow the Figure 5 to reset GBTx boards.

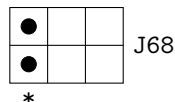


Figure 5: Schematic for resetting GBTx boards. A jumper should be used to connect the two pins marked above.

## 2 Software setup

### 2.1 Program master GBTx with external I<sup>2</sup>C adapter

Before proceed, follow the instruction on subsection 1.2 to configure the hardware first. As said in the previous section, the master GBTx board must be programmed via an external I<sup>2</sup>C adapter first. A Windows 7 computer on the rack is used. The **GBTX programmer** is located at:

```
DT_Rack\GBTx_programmer\GBTxProgrammer.jar
```

Launch the programmer, a typical UI is shown in Figure 6, Click **Load GBTX configuration** and load a configuration file, which is located at:

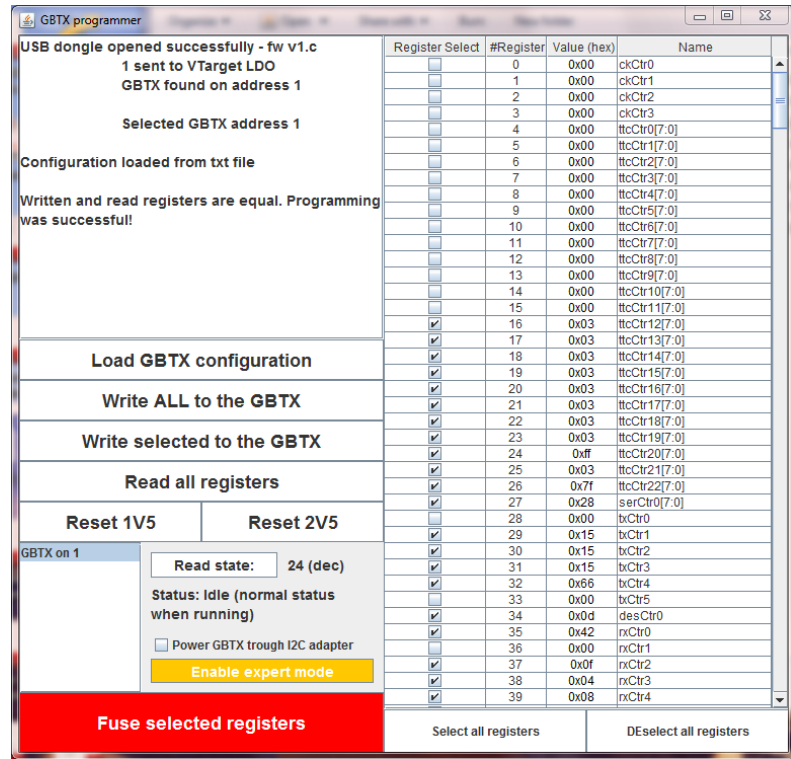


Figure 6: A typical UI for GBTX programmer.

```
DT_Rack\GBTx_programmer\GBTx_TRx_v12_test_withWatchDog.
↪ txt
```

Then click **Write ALL to the GBTX**. Check the returned message to make sure everything works (supposedly). Now click **Read state**. If the master GBTx is configured correctly and is connected to a working MiniDAQ, the return value should be:

```
24 (dec): Idle (normal status when running)
```

## 2.2 Check communication between master GBTx and MiniDAQ

After program the master GBTx board and verify the return value, we can check the communication between the GBTx and the MiniDAQ with **GBT Client**.

Here we need to use the Linux server on the rack. To launch that program, locate the **gedi** panel. Under **JCOP framework**, click the **GBT Client**. Choose **GBT** option under the **Communication** tab. Navigate to **SCA** tab.

To check whether the link between GBTx and MiniDAQ is successfully established, configure the parameters *exactly* as shown in Figure 7. Now click

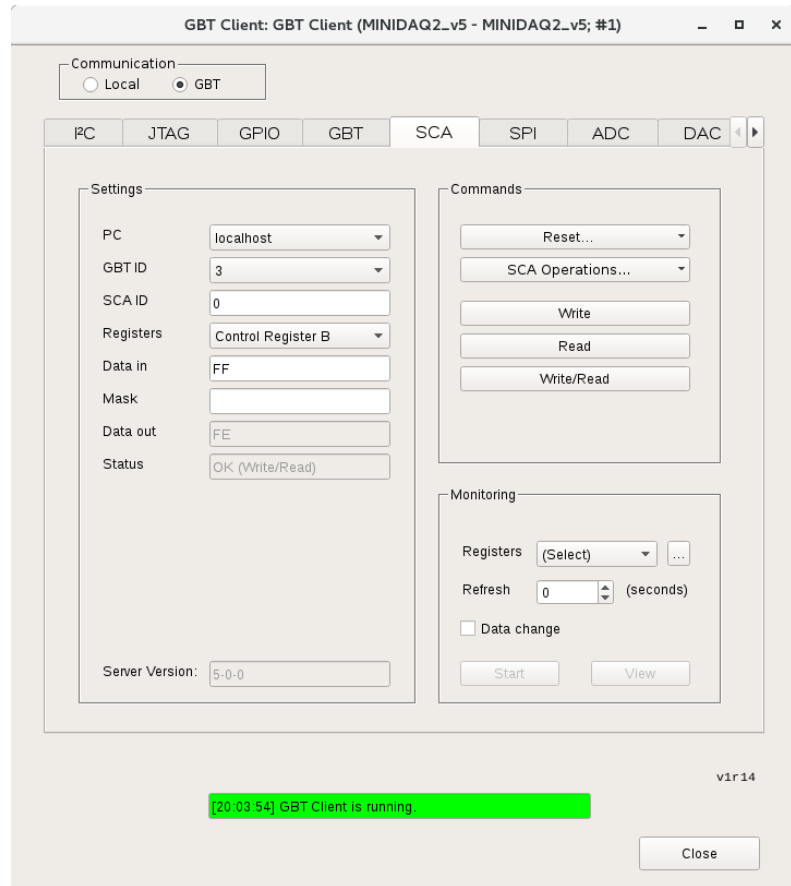


Figure 7: A typical UI for GBT Client, SCA tab.

**Write/Read.** The **Data out** field should have a value of “FE”, and the **Status** should be “OK (Write/Read)”.

**GBT ID** corresponds to the physical optical link that is connected to the master GBTx board. Recall that in our setup, the master is connected to optical fiber 8, which is mapped to GBT channel 3.

There are only 4 **Registers**. All 4 registers work, the “Control Register B” is chosen for no apparent reason. What matters is the return value should be consistent with our expectation.

### 2.3 Program individual registers of slave GBTx

Before proceed, follow subsection 1.3 to set up hardware. Again we use **GBT Client** to program individual registers of the slave GBTx. Configure the parameter *exactly* as shown in Figure 8.

If the **Write** command failed, try **Activate Channel** first.

**Address** corresponds to GBTx index, which is configured via an onboard DIP switch. Default to 1.

Recall that 1 *Byte* is 8 *bits*, and 1 Byte corresponds to a 2-digit hex number.

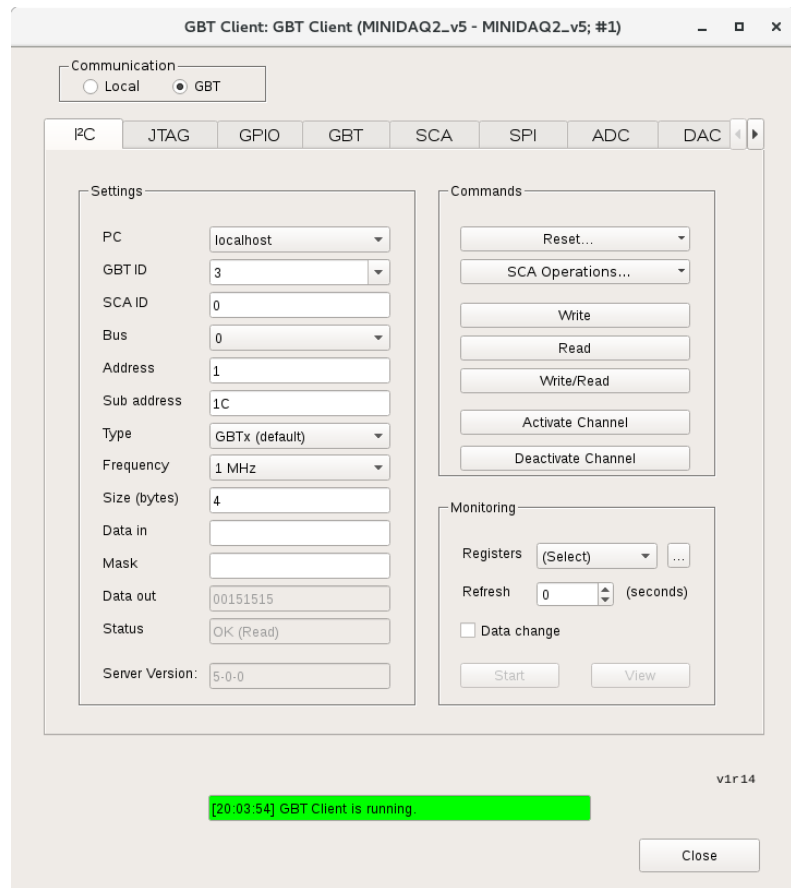


Figure 8: Correct parameters to configure GBT I<sup>2</sup>C tab.

Notice in the **Data out** field, the last 3 numbers are the same. This is a requirement in the GBT specification that the configuration registers must be triplicated to minimize error.

## 2.4 Program slave GBTx with configuration files

Configure the parameter as shown in Figure 9.

The configuration file should be supplied to the **Data in** field with the following syntax:

```
file:<path_to_configuration_file>
```

The actual configuration file, depends on whether the slave is configured in transmitter or transceiver mode, is located at:

```
/home/admin/Public/slave-{Tx,TRx}.txt
```

This is equivalent to program the slave with an external I<sup>2</sup>C adapter. The advantage of doing this way is we don't need to remove the I<sup>2</sup>C adapter from the master. In other words, once the hardware setup is done, we

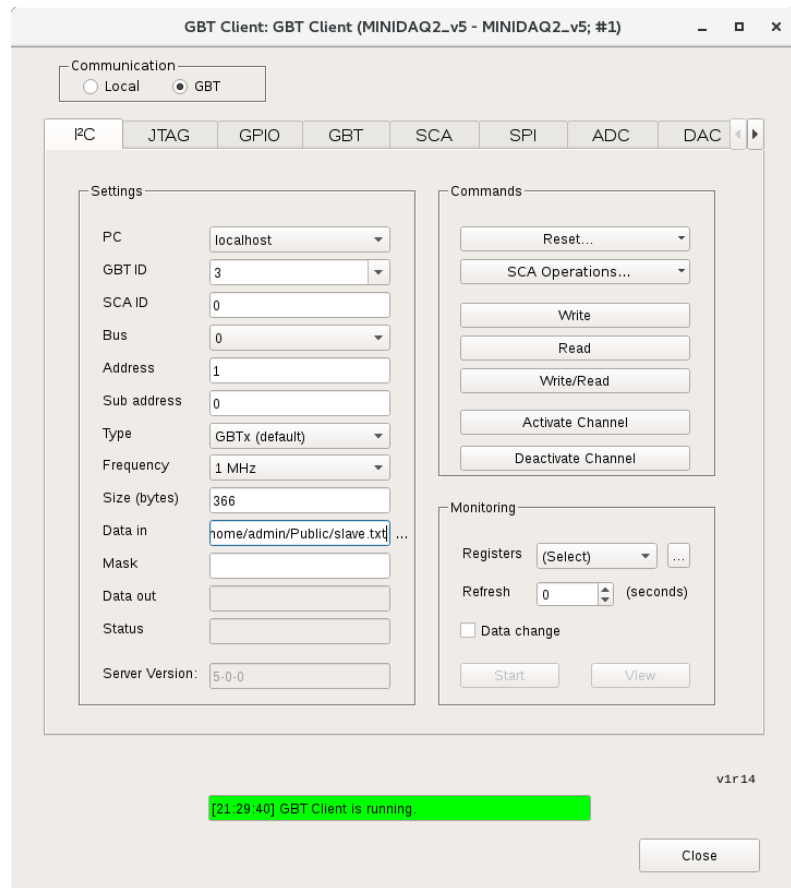


Figure 9: Parameters to program slave GBTx with a configuration file.

don't have to touch them anymore; whereas if we program both master and slave with an I<sup>2</sup>C adapter, it must be moved around between the master and the slave.



## Appendices

### A Fix “Waiting for a GBT server to run”

Sometimes when we launch the **GBT Client**, it would claim that it is “Waiting for a GBT server to run”. Take this warning literally: It means that currently there is no GBT server that is alive. The fix is easy: fire up a terminal, and type in “GbtServ”.

### B Bypass components in GBT data path

As shown in Figure 10, we can bypass components in GBT input/output path.

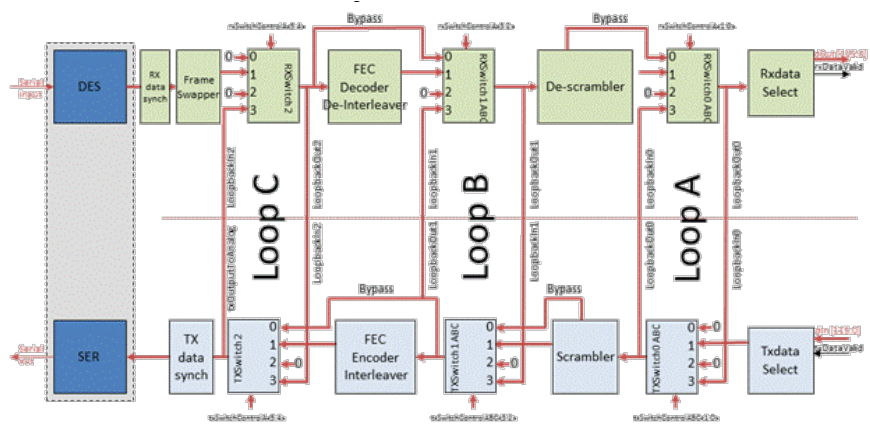


Figure 10: GBT data path. Stolen from LHCb *GBTX manual*.

The register `0x1c` and 3 subsequent registers control the output path; `0x2d` controls the input path. Each of the paths have 3 configurable selectors, each has 4 operations modes ( $0_{10} - 3_{10}^3$ , which translate to  $0_2 - 11_2$ ). According to Figure 10, the control sequence should be given in:

TXSwitch2 -> TXSwitch1 -> TXSwitch0

Here is an example. Let us consider the Tx normal operating case (i.e. all 3 switches are configured to 1). We have:

$$\begin{array}{ccc}
 \underbrace{1}_{10} & \underbrace{1}_{10} & \underbrace{1}_{10} \\
 \text{TXSwitch2} & \text{TXSwitch1} & \text{TXSwitch0} \\
 \Downarrow & & \\
 \underbrace{01}_{2} & \underbrace{01}_{2} & \underbrace{01}_{2} \\
 \text{TXSwitch2} & \text{TXSwitch1} & \text{TXSwitch0}
 \end{array}$$

To convert binary  $010101_2$  to hexadecimal, we left pad the result with 2 additional 0's:  $0001,0101_2$ . The end result is  $15_{16}$ .

<sup>3</sup> The subscript indicates the base.

15<sub>16</sub> is exactly the last 3 bytes in **Data out** field in Figure 8. This is not a coincidence.

Recall that each 4 digits in binary exactly correspond to 1 digit in hexadecimal.

## C PRBS tests

**Test 1.** Follow the following steps:

1. Configure the GBTx slave to send PRBS data. Write “03151515” to slave register 0x1c, setting size to 4.
2. Go to the top MiniDAQ hardware panel, click on **PRBS**.
3. In the **PRBS** panel, click in sequence: **Stop All Generators** → **Reset All Counters** → **Start All Generators** → **Start All Checkers** → **Start All Counters**.

The result should be the same as shown in Figure 11.

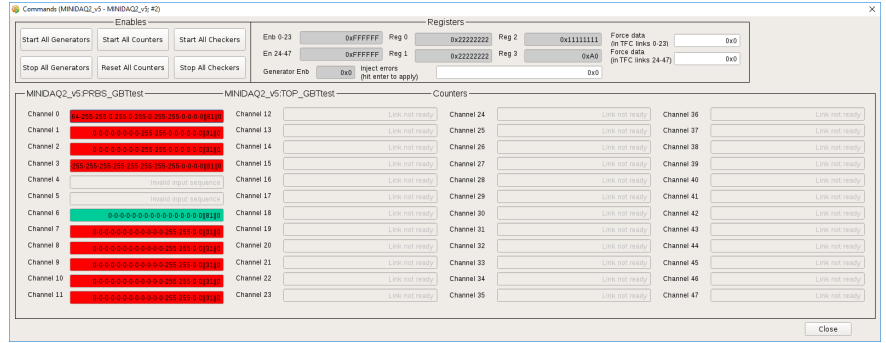


Figure 11: Expected result for PRBS test 1.

Channel 6 (optical fiber 11, which is connected to slave GBTx) should go green and show a bunch of 0s. These 0s are the PRBS nibbles (7 bits) each from the GBT.

Channel 7 or any other channels should go red and show a lot of errors, because these are receiving the FE data in loopback and not the “correct” random data that the checkers are expecting.

After replacing the loaned MiniDAQ board with our original board, we no longer can reproduce the exact behavior: All loopback channels go green, instead of error out. We deem it acceptable, at least for the time being.

**Test 2.** Follow the following steps:

1. Configure the GBTx slave to send PRBS data. Write “00171717” to slave register 0x1c, setting size to 4.
2. Go to the top MiniDAQ hardware panel, click on **PRBS**.
3. In the **PRBS** panel, click in sequence: **Stop All Generators** → **Reset All Counters** → **Start All Generators** → **Start All Checkers** → **Start All Counters**. (same as in test 1).

The result should be the same as shown in Figure 12.

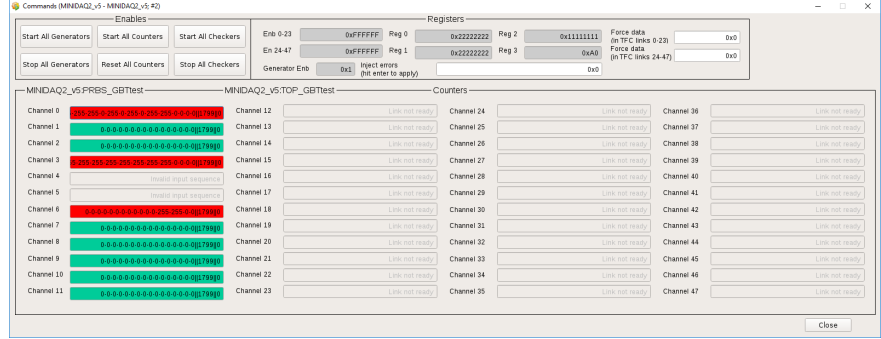


Figure 12: Expected result for PRBS test 2.

All channels that are in loopback should go green: Now the PRBS data is generated inside FPGA, it overwrites the FE data and goes back in loopback to the checkers.

Channel 6 shows counting errors on two nibbles. The reason, according to expert Federico Alessio, is the clock-crossing domain inside the GBTx chip that generates errors in the loopback path, which is a feature of the GBT.

The increasing counter to the right of each line in the PRBS block is the number of seconds since we started the counters.

To have again FE data we need to disable the generators: **Stop All Generators** in the **PRBS** panel.

When the PRBS panel shows “Input data not valid”, it means that the system is generating all 0s.

## D GBTx operation modes

Enconding/Bus mode	Transceiver mode	MODE [3:0]
FEC	Simplex TX	0000
FEC	Simplex RX	0001
FEC	Transceiver	0010
FEC	Test	0100
WideBus	Simplex TX	0100
WideBus	Simplex RX	0101
WideBus	Transceiver	0110
WideBus	Test	0111

Figure 13: GBTx operation modes (dubbed as “Transceiver modes”). Stolen from LHCb *GBTX manual*.