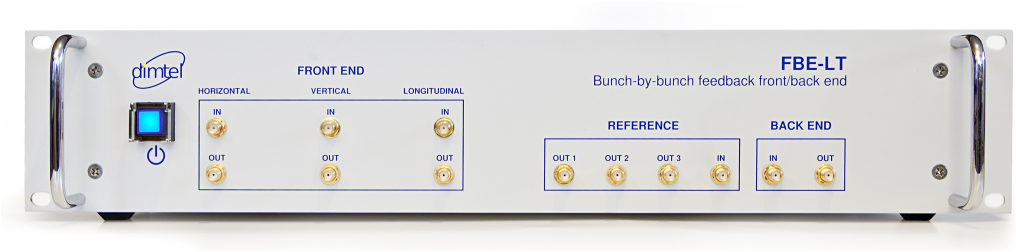

FBE-500LT Bunch-by-bunch Feedback Front/Back-End

Technical User Manual

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1 Regulatory Compliance Information

This equipment requires a ground connection provided by the power source. The exposed metal parts of the unit are connected to the power ground to protect against electrical shock. Always use an outlet with properly connected protective ground.

FBE-500LT was designed and tested to operate safely under the following environmental conditions:

- indoor use;
- altitude to 2000 meters;
- temperatures from 5 to 40 °C;
- maximum relative humidity 80% for temperature 31 °C, decreasing linearly to 50% @ 40 °C;
- pollution category II;
- overvoltage category II;
- mains supply variations of ±10% of nominal.

FBE-500LT contains no user serviceable parts inside. Do not operate with the cover removed. Refer to qualified personnel for service.

NOTE: *This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.*

NOTE: *This Class A digital apparatus complies with Canadian ICES-003. Cet appareil numérique de la classe A est conforme à la norme NMB-003 du Canada.*

2 Introduction

2.1 Delivery Checklist

1. FBE-500LT chassis;
2. AC power cord;
3. GPIO 68-pin male to 68-pin male cable;
4. User manual.

2.2 System Overview

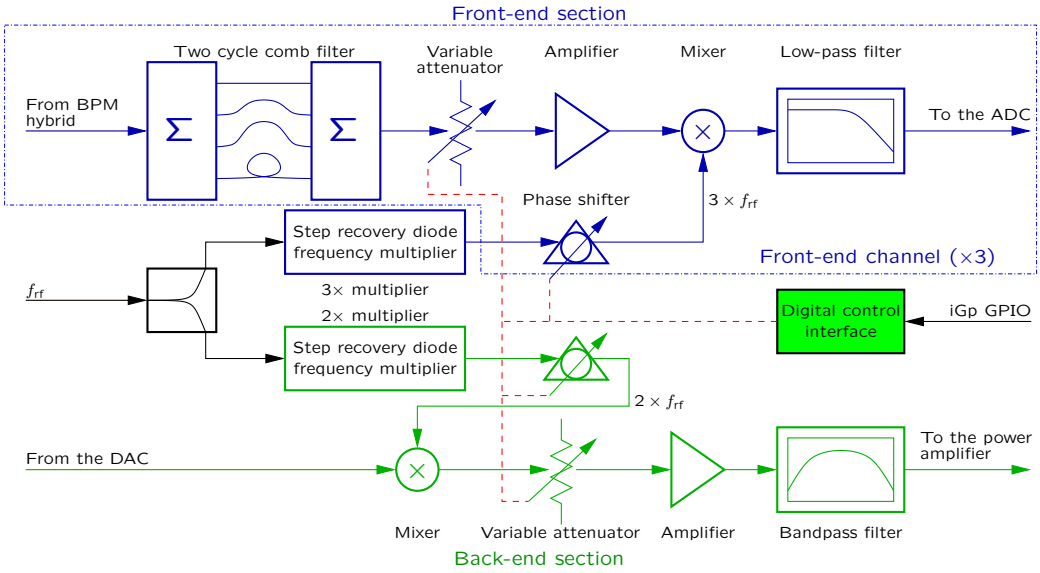

Figure 1: Bunch-by-bunch feedback front/back-end block diagram

The FBE-500LT RF signal processor incorporates front-end and back-end electronics for a complete bunch-by-bunch feedback system in a storage ring. The unit is equipped with three identical front-end channels — for processing horizontal, vertical, and longitudinal signals. Front-end channels are designed for converting the beam position monitor (BPM) output to the baseband signal which can be directly digitized by the iGp/iGp12. Each channel operates at 1500 MHz and uses a 2-cycle comb filter to produce a

detected pulse of 1.3 ns. The back-end channel upconverts the baseband kick signal to 1000 MHz carrier for driving the power amplifier and the kicker. The FBE-500LT interfaces to the iGp/iGp12 digital general-purpose input/output (GPIO) port for control and monitoring. Control channels include front- and back-end attenuators and phase shifters and fan speed. Through the GPIO port, iGp/iGp12 is also able to read out the unique FBE-500LT serial number and to monitor the internal temperature.

2.3 Front Panel Features

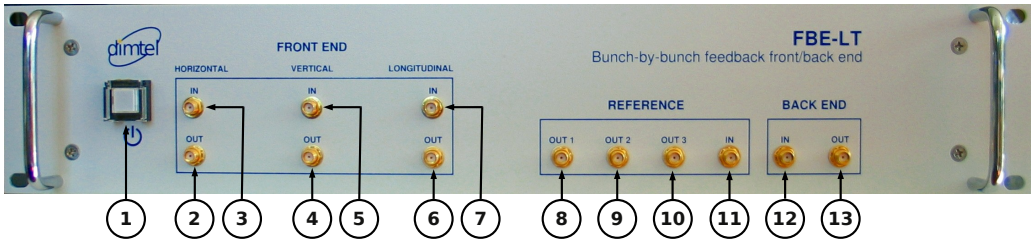

Figure 2: Front panel features

1) Power switch
This on-off lighted switch turns FBE-500LT on and off.

2) Horizontal front-end output
Baseband output to iGp/iGp12.

3) Horizontal front-end input
This input receives the beam signal from the BPM difference hybrid network. Maximum continuous wave (CW) level is 33 dBm. For typical beam signal this limitation can be expressed as maximum swing of 14 V.

4) Vertical front-end output
Baseband output to iGp/iGp12.

5) Vertical front-end input
This input receives the beam signal from the BPM difference hybrid network. Maximum CW level is 33 dBm. For typical beam signal this limitation can be expressed as maximum swing of 14 V.

6) Longitudinal front-end output
Baseband output to iGp/iGp12.

7) Longitudinal front-end input
This input receives the beam signal from the BPM combiner network. Maximum CW level is 33 dBm. For typical beam signal this limitation can be expressed as maximum swing of 14 V.

8–10) Reference outputs
Master oscillator outputs to baseband processors (iGp/iGp12). These outputs are 7 dB below the reference input level, nominally at −4 dBm.

11) Reference input

Master oscillator reference. This reference drives front and back-end local oscillators, as well as the outputs to iGp/iGp12. Nominal input level is 3 dBm.

12) Back-end input

This input should be driven by one of iGp/iGp12 high-speed digital-to-analog converter (DAC) outputs. Nominal swing expected at this input is ±250 mV. For iGp12 use a 4 dB attenuator.

7) Back-end output

Output to the power amplifier. At 0 dB back-end attenuation and full 250 mV baseband drive the output level is 4 dBm.

2.4 Rear Panel Features

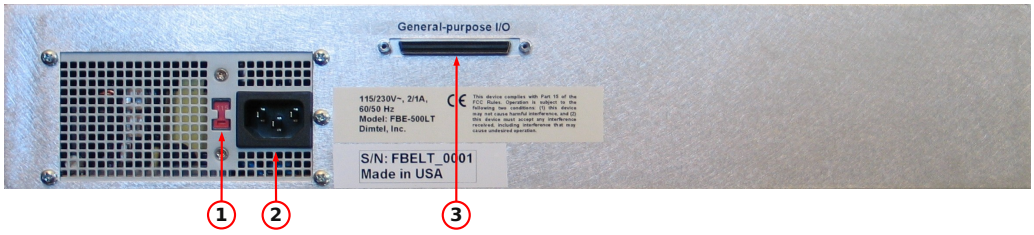

Figure 3: Rear panel features

1) Voltage selection switch Slide switch for selecting appropriate mains voltage: 115 or 230 V.

2) Power entry socket IEC-320 power input socket. Always use an outlet with properly connected protective ground.

3) iGp/iGp12 interface This 68-pin connector must be attached to the iGp/iGp12 for proper operation of the control elements within FBE-500LT.

2.5 Cooling Fan Filter Maintenance

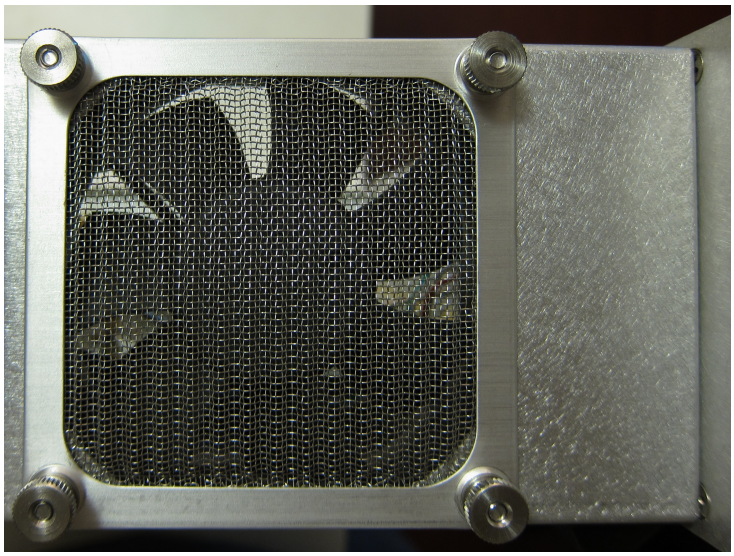

Figure 4: Fan filter mounted using four thumb nuts

Cooling fan is located on the left side of the FBE-500LT. An stainless-steel mesh filter is mounted externally with four thumb nuts.

WARNING: Fan filter protects the system from contamination. Operating the unit without the filter can lead to overheating as well as to premature failure of the cooling fans.

WARNING: Before performing any work on the fan filter, power down the system and unplug the AC power cord. Fan blades are exposed when the filter is removed.

The filter should be periodically serviced to maintain adequate air flow. Vacuuming, washing or replacement are the acceptable maintenance options. Replacement filter is manufactured by Qualtek Electronics Corporation, part number 06325-M.

In order to remove the filter, undo the four thumb nuts. If filter servicing involves washing, make sure the filter is completely dry before reinstallation. To reinstall, orient the filter so that the mesh corrugations are vertical and slide it onto the mounting studs. Reinstall and hand tighten the thumb screws.

2.6 Getting Started

In this section we will present a quick step-by-step guide to get your new RF front/back-end processor running in a minimal (single-channel) configuration.

WARNING: Before connecting power to the unit make sure the voltage selection switch (Fig. 3, item 1) is in the correct position (115 or 230 V).

WARNING: Signals beyond +33 dBm CW or 14 V peak can permanently damage the front-end input circuitry! Before connecting to FBE-500LT, measure BPM signals using a high-speed oscilloscope at maximum bunch currents to determine the necessary input attenuation level.

1. Configure voltage selection switch (Fig. 3, item 1). Mains supply requirements for the FBE-500LT are listed in Table 4;
2. Connect radio frequency (RF) clock at 3 dBm nominal level (Fig. 2, item 5);
3. Connect the reference output (Fig. 2, item 8) to the CLK input of the iGp/iGp12;
4. Terminate unused reference outputs with wideband 50 Ω SMA terminators;
5. Connect the front-end input (Fig. 2, item 3, 5, or 7) to the beam signal at the appropriate level;
6. Connect the front-end output (Fig. 2, item 2, 4, or 6) to the IN+ or IN- of the iGp/iGp12. Terminate the unused iGp/iGp12 input with a wideband 50 Ω SMA terminator;
7. Connect the back-end input (Fig. 2, item 6) to the OUT+ or OUT- of the iGp/iGp12. Terminate the unused iGp/iGp12 output with a wideband 50 Ω SMA terminator. When using iGp12, place a 4 dB attenuator between the DAC output and the back-end input;
8. Connect the back-end output (Fig. 2, item 7) to the power amplifier input;
9. Using the supplied 68-pin GPIO cable connect the iGp/iGp12 interface (Fig. 3, item 3) to the GPIO connector on the iGp/iGp12;

10. Push the power button (Fig 2, item 1) to turn on the system;

At this point your system is ready for use in beam diagnostics and feedback. The system must be appropriately phased and timed to the beam. This ensures proper phase detection in the front-end and correct sampling of the detected signal as well as the correct phase of the kick signal and its timing relative to the bunch arrival in the kicker.

3 Setup

As mentioned in Subsection 2.6, the FBE-500LT must be properly phased and timed to the beam. In this section several possible methods for achieving proper timing and phasing will be described. Let us start with the front-end setup.

WARNING: The FBE-500LT must be operated for at least two hours in the installation environment to achieve thermal equilibrium. Do not perform phase-sensitive front- and back-end adjustments before the equilibrium has been achieved.

3.1 Front-end

WARNING: Front-end circuitry is sensitive to peak and average signal levels. Absolute maximum input level is +33 dBm CW or 14 V peak. However within these ranges internal amplifier damage is possible if the front-end attenuator is set too low for the input signal level! Before changing per bunch currents set the front-end attenuator to nominal attenuation at that bunch current.

In order to time the front-end to the beam, a single-bunch filling pattern should be used. With a single bunch filled, connect the front-end output to a scope and adjust front-end phase for amplitude detection, producing a large pulse in the baseband signal. Next, connect the signal to the iGp/iGp12 input and adjust the timing in 100 ps steps (10 units of 10 ps delay line) to produce maximum displacement in the mean offset of one bunch. This operation results in somewhat coarse front-end timing. For more precise adjustment one can use `sweep.sh` script supplied with iGp/iGp12.

Once the front-end is timed, adjust the front-end phase for amplitude detection in the horizontal and vertical channels and for phase detection in the longitudinal channel.

3.2 Back-end

Back-end timing consists of two parts: phasing the back-end local oscillator to produce maximum kick, and adjusting kick envelope timing to line up the single-bunch kick with the beam.

In the first step, configure the iGp/iGp12 to generate sinewave drive at the synchrotron frequency using the turn-by-turn option of the drive generator. At this point all bunches should be driven. Next, adjust back-end phase to produce maximum longitudinal excitation, as measured by the iGp/iGp12 or by an external instrument. Drive amplitude might need to be reduced to precisely find the optimal phase.

At this point we need to determine which bunch in the iGp/iGp12 processing is lined up with the beam. To do so, bisection is typically used. Initially our bunch drive pattern might look like `1:64`. Select the first half of the ring using `1:32`. If the beam is still excited one of the first 32 bunches in iGp/iGp12 processing coincides with the beam in the kicker. Continue the bisection until one bunch is identified. At this point one can adjust the output (one-turn) delay so that the excited bunch number agrees with the bunch number seen in the front-end. Once such agreement is reached the back-end can be considered coarsely timed. For finer timing the iGp/iGp12 output timing must be adjusted in sub-RF-period steps to maximize the beam response.

4 Specifications

Table 1: General specifications

Parameter	Definition
Operating frequency	500 MHz
RF input level	3 ± 1 dBm
Reference output level	-7 dB relative to the input
Temperature sensing resolution	0.0625 °C
Fan speed control range	1600–4100 RPM
Unique ID	Provided by Maxim DS1822 device

Table 2: Front-end specifications

Parameter	Definition
Detection frequency	1500 MHz
Maximum operating input level	9.3 V peak
Absolute maximum input level	14 V peak
Attenuation range	0–31.5 dB
Output level at 1 dB compression	+5 dBm
3 dB bandwidth	600MHz
Baseband pulse width	1.5 ns
Phase shifter range	> 360 degrees
Phase shifter resolution	< 0.2 degrees/step

Table 3: Back-end specifications

Parameter	Definition
Modulation frequency	1000 MHz
Input level	±250 mV
Attenuation range	0–31.5 dB
Maximum output level (DC input of 250 mV, 3 dBm reference)	4 dBm
Output filter	5^{th} order Bessel band-pass
Output bandwidth	550 MHz
Phase shifter range	$>$ 360 degrees
Phase shifter resolution	$<$ 0.2 degrees/step

Table 4: Input Power Requirements

Parameter	Definition
Input voltage	115/230 VAC
Input current	2/1 A
Frequency	60/50 Hz
Voltage selection	Switch
Low voltage range	104–126 V
High voltage range	207–253 V

5 Warranty and Support

5.1 Warranty

Dimtel Inc. warranties this product for a period of one year from the date of shipment against defective workmanship or materials. This warranty excludes any defects, failures or damage caused by improper use or inadequate maintenance, installation or repair performed by Customer or a third party not authorized by Dimtel, Inc. Warrantied goods will be either repaired or replaced at the discretion of Dimtel, Inc. The above warranties are exclusive and no other warranty, whether written or oral, is expressed or implied.

5.2 Support

Dimtel Inc. will provide technical support for the product free of charge for a period of one year from the date of shipment. Such support is defined to include:

- Gain partitioning;
- System interconnection issues;
- iGp/iGp12 interface support.

Free of charge technical support specifically excludes:

- Commissioning with beam;
- Feedback algorithm development and testing;
- Beam dynamics characterization;
- Operational support related to dynamic system operation.

6 Glossary

Glossary

beam position monitor (BPM)

An RF structure that couples to the beam in the accelerator. The output signal of such a structure allows measurement of the transverse or the longitudinal beam position. 3, 5, 9

continuous wave (CW)

A signal of constant amplitude and frequency. 5, 9, 10

digital-to-analog converter (DAC)

A hardware device to convert a sequence of digital codes to corresponding analog voltages or currents. 6

general-purpose input/output (GPIO)

A 32-bit wide digital input/output port of the iGp/iGp12. 3, 9

radio frequency (RF)

In the accelerator context, a constant frequency constant amplitude signal derived from or phase locked to the storage ring master oscillator. 9, 12