RTM RF Backplane for MicroTCA.4 Crates
Krzysztof Czuba, Member, IEEE, Tomasz Jezynski, Tomasz Leśniak, Frank Ludwig, Uros Mavric and Holger Schlarb

Abstract—We developed a new Rear Transition Module (RTM) Backplane for MicroTCA.4 crates that is compliant with the PICMG standard and is an optional crate extension. The RTM Backplane provides multiple links for high-precision clock and RF signals to analog µRTM cards. Usage of an RTM Backplane allows to significantly simplify the cable management, and therefore to increase the reliability of electronic controls when multiple analog RF front-ends are required.

In addition, the RTM backplane allows to add so called extended RTM (eRTM) and RTM Power Modules (RTM-PM) to a 12-slot MicroTCA crate. Up to four 6 HP wide eRTMs and two RTM-PMs can be installed behind the front PM and MCH modules. An eRTM attached to the MCH via Zone 3 connector is used for analog signal management on the RTM backplane. This eRTM allows also installing a powerful CPU to extend the processing capacity of the MTCA.4 crate. Remaining three eRTMs provide additional space for analog and digital electronics that may not fit on the standard RTM cards.

The RTM-PMs deliver managed low-noise (separated from front crate PMs) analog bipolar power (+VV, -VV) for the µRTMs and an unipolar power for the eRTMs. This extends functionality of the MicroTCA.4 crate and offers unique performance improvement for analog front-end electronics. This paper covers a new concept of the RTM Backplane, a new implementation for the real-time LLRF control system and performance evaluation of designed prototype.

Index terms – MicroTCA.4, Accelerator control systems, Accelerator instrumentation, Free electron laser, Front-end electronics

I. INTRODUCTION

The modern superconducting linear accelerator based on coherent light sources, such as FLASH [1], [2] and the European-XFEL (E-XFEL) [3], use precisely controlled RF field for electron beam acceleration. Real-time field stabilization is performed by a Low Level Radio Frequency (LLRF) control system [4], [5], [6], designed to assure up to $10^5$ of amplitude and $0.01^\circ$ of phase regulation accuracy. The control system must also fulfill stringent reliability and maintainability requirements while processing almost 100 RF signals in each of 25 RF stations. Simplified scheme of the LLRF control system with marked count of signals in one station is shown in Fig. 1. Basing on requirements mentioned above, the LLRF system designers selected the MTCA.4 hardware platform to build a modular system capable to integrate powerful digital processing units together with high-precision RF and analog circuits within one crate. Special units were developed for this system such as: the RTM Vector Modulator card DRTM-VM2LF [7], the AMC Controller card DAMC-TCK7 [8], and 10-channel downconverter module DWC-DWC10 [9].

Besides cavity signals provided to the DRTM-DWC10 card inputs, in each RF station there are up to 18 LO and RF Reference signals (1.354 GHz and 1.3 GHz respectively) and up to eighteen high performance clock signals that must be delivered to the rear panels of the LLRF MTCA.4 crate. Such a large number of RF cables on a relatively small area of µRTM front panels significantly complicates system installation and affects maintainability and reliability of the hardware. To improve this issue, the idea of an RTM Backplane, called also µRTM RF Backplane (µRFB), was developed [10] for distribution of RF signals inside of the MTCA.4 crate. The µRFB eliminates cable interconnections between the LO, CLK and RF Reference signal source and all µRTM boards. The feasibility and performance of the RF Backplane were proven with a prototype card in 2012 [11]. Further development was done to finalize the concept and make use of RF Backplane features to extend MTCA.4 capabilities. This paper covers new concept of the µRFB and modules supported by this backplane.

II. RTM RF BACKPLANE CONCEPT

The RTM Backplane is located behind the standard AMC backplane in the MTCA.4 crate, as shown in Fig. 2. Up to twelve modified µRTM cards can be interfaced with the RF Backplane with multicoax RF connectors of Zone 1 and ADF connectors of Zone 2 as shown in Fig. 3. The multicoax RF connectors are used for RF signal distribution. ADF connectors deliver clock, additional power supply and management signals to µRTM cards.
The µRFB allows also to use empty space available behind the front Power Modules (PM) and Module Carrier Hubs (MCH) shown in Fig. 2.

![Fig. 2. Slot arrangement of MTCA.4 crate with the RTM Backplane.](image)

The space behind right-side MCH and PM was used for extended RTMs (eRTMs). There can be up to three double-width, full-size (6HP) eRTMs installed in the crate. Those eRTMs increase significantly space available for electronics and are ideally suited for installing RF front-end circuits with relatively large components like filters.

The space behind left-side PMs was used for installation of RTM Power Modules (RTM-PM). Those are non standard PMs that can deliver +12 V payload power to eRTMs and bipolar (+/- VV) voltage to µRTM cards. This power supply system is foreseen to be separated from noisy front power supply, used for high-speed digital system.

The last of introduced modules is the RTM Backplane Management (MCH-RTM-BM) [12] card used to manage the RTM Backplane system. The MCH-RTM-BM is connected via the MicroTCA Zone 3 connector to the front MCH. The benefit of this is that the rear side can take advantage of the already existing management functions of the front MCH. The MCH-RTM-BM can support up to 12 µRTMs, 3eRTMs and 2 redundant RTM-PMs.

- fun-out of 18 CLK signals (81 MHz differential AC-coupled LVPECL)

Furthermore there were implemented also DC power distribution network for each µRTM (+VV, -VV) and eRTM (PP) together with management signals and LVDS communication links needed to support up to 12 µRTMs, 4 eRTMs and 2 redundant RTM-PMs.

Simplified block diagram the new RF Backplane prototype is shown in Fig. 4.

![Fig. 4. Simplified connectivity diagram of the RTM Backplane](image)

Assembled prototype of RF Backplane is shown in Fig. 5. In order to deliver enough space for routing of all interconnections a 14-layer PCB was built. Since phase drifts limit the long-term phase stability of RF systems, high performance material from Rogers (R4350B) was chosen as a substrate for laying out RF single-ended and differential lines. Selected PCB substrate and connector types extends board operation to frequency band from DC to 6 GHz. Therefore the RF Backplane can be used for many applications different from the XFEL LLRF System.

![Fig. 5. RF Backplane prototype (version 3.1)](image)

Appropriate grounding techniques were applied to maintain a low impedance and to shorten the return loops for DC, to achieve a good signal integrity and to isolate low-noise RF signals from high-speed digital subsystems surrounding the RF Backplane. Additional isolation was achieved by introducing of an RF Backplane shield board between the µRFB and the AMC backplane.

Power distribution network was optimized to withstand high total currents supplied by the RTM Power Modules.

### III. RF Backplane Prototype and Preliminary Tests

The prototype of the RF Backplane for E-XFEL LLRF system was designed to fulfill the following requirements imposed by LLRF system architecture:

- slot #15 is dedicated for RF and CLK signals transmitter for the entire RF Backplane. An example of such device was developed and evaluated [14].
- distribution of 27 RF signals (18 x 1300 MHz and 9 x 1354 MHz).

### IV. Performance Tests

Since the RF Backplane serves for transmission of precise RF signals (REF, LO an CAL signals: reference, heterodyne and calibration signal, respectively), channel-to-channel
crosstalk can be a problem, that limits the dynamic range and measurement resolution of RF devices plugged into the RF Backplane. It was identified, that acceptable crosstalk levels between any two of RF lines should be lower than 80 dB at 1300 MHz and between any of CLK and any of RF signals crosstalk should not exceed 100 dB at 81 MHz. Crosstalk values have been measured for all possible combinations of signals. Due to huge matrix of results obtained with these measurement, only the worst case levels are shown in the Table I. It can be concluded, that no crosstalk between RF channels lower than -87 dB was observed and the RF Backplane provides a sufficient suppression of CLK signals leakage (of at least -106 dB) to RF channels. Thereby, transmission of CLK signals has no detectable impact on the spectrum and jitter of high-precision RF signals.

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V. SUMMARY AND PLANS

The newly introduced RTM RF Backplane offers significant extension of MTCA.4 crate capabilities and can significantly improve the cable and hardware management in complex real-time data processing and control systems.

The near future RF Backplane evaluation plans include accurate high-frequency characterization of RF signal distribution network in frequency range DC to 6 GHz, measurements of RF signal phase drifts in the system and detailed tests of newly developed RTM-PMs and MCH-RTM-BM cards.

REFERENCES