RTM RF Backplane Extensions for MicroTCA.4 Crates – Concept and Performance Measurements

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***Abstract*–The idea of the Rear Transition Module (RTM) Backplane was originally created to simplify cable management of an MicroTCA.4 based LLRF control system for the European XFEL project. The first RTM backplane (called an RF Backplane) was designed to distribute about dozen of precise RF and clock signals to uRTM cards. It was quickly found out, that this backplane offers very powerful extension possibilities for the MTCA.4 standard and can be used also more widely than for the RF applications only. Nowadays, the RTM Backplane is compliant with the PICMG standard and an optional crate extensions. The RTM Backplane provides multiple links for high-precision clock and RF signals (DC to 6GHz) to analog µRTM cards it) together with distribution of a low noise managed power supply and data transmission to RTM cards.**

In addition, the RTM backplane offers a possibility to add so called extended RTMs (eRTM) and RTM Power Modules (RTM-PM) to a 12 slot MicroTCA crate. Up to three 6 HE 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. Three additional eRTMs provide significant space extensions of the MTCA.4 crate that can be used e.g. for analog electronics designed to supply RF signals to the uRTMs.

The RTM-PMs deliver a managed low-noise (separated from front crate PMs) analog bipolar power supply (+VV, -VV) for the µRTMs and an unipolar power supply 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, including precise measurements of RF loss, impedance matching and crosstalk.

I. Introduction

THE modern superconducting linear accelerator based 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° 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 DRTM-DWC-10 [9].

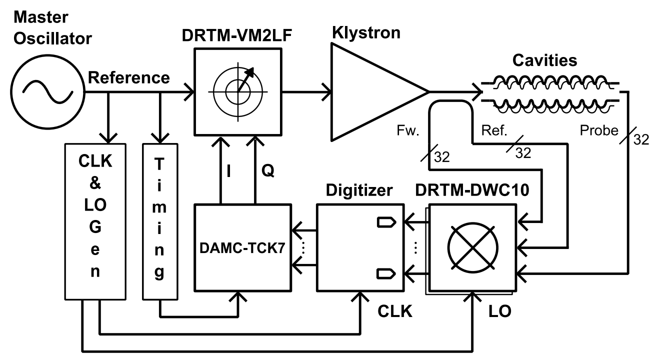

Fig. 1. LLRF system architecture and signal flow.

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.

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II. RTM RF Backplane Concept Development

RTM RF Backplane was originally designed to distribute RF (1300 MHz), LO (1354 MHz) and clock signals (50 – 100 MHz) together with analog power supply to analog RTM cards in the MTCA.4 crate based LLRF control system of the European-XFEL accelerator. It was quickly found out, that this backplane offers very powerful extension possibilities for the MTCA.4 standard and can be used also more widely than for the RF applications only. Therefore design was extended by adding so called eRTMs and Rear Power Modules and allowing the RTM Backplane to distribute signals in the range between DC and 6 GHz. Rear slot coverage by the one of RTM Backplane realizations is shown in Fig. 1.

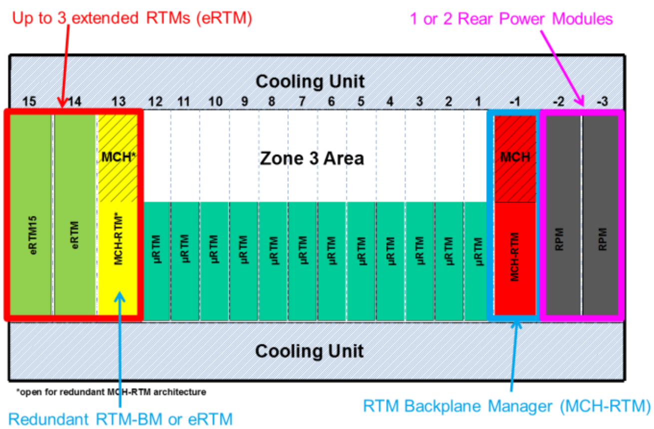

Figure 1. RTM Slots coverage by the RF Backplane (crate rear view)

The RTM Backplane idea found significant interest in the MTCA.4 community. Therefore it was introduced to the PICMG committee for standardization and will appear as an official extension to the hardware standard.

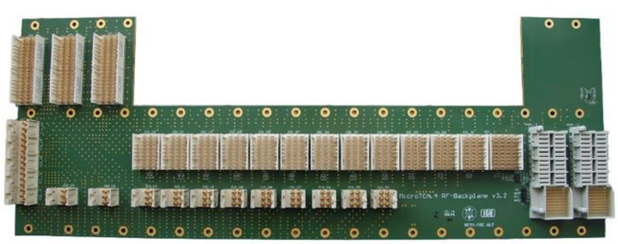

Figure 2. RTM Backplane prototype.

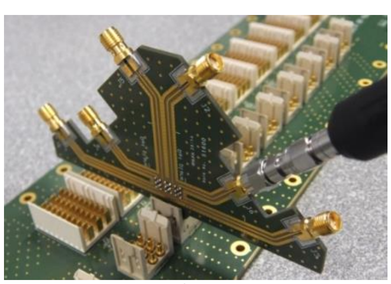

Figure 3.Test board for the RTM Backplane.

This contribution describes the concept of the RTM Backplane extensions, new capabilities of the MTCA.4 crates with the RTM backplane and the joint effort put in working out the entire RTM Backplane extension: starting from the design of high-performance PCB (Fig. 2) able to distribute tens of clock and RF signals (DC to 6 GHz) together with low noise power supply and data transmission. Special attention was put to techniques used to characterize the system performance with description of measurement tools (Fig. 3 and 4), characterization methods and test results. Exemplary test results measured at frequency of 1.3 GHz. are collected in Table I. Signal was sent from slot #15 to slots #12 to #4, while the most distant, and therefore most difficult to maintain high RF performance was slot #4. Achieved insertion loss of maximum 2.4 dB is a very good result for this kind of board. Matching vary between moderate (-16.2 dB) to excellent (-30 dB) for multilayer PCB with small multi-coax interfaces.

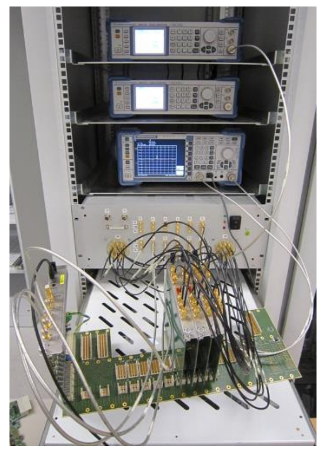

Figure 4. Automated test stand for RTM Backplane RF performance tests.

Table I. Selected results of RF loss and reflection measurements @ 1.3 GHz

Slot	A_{REF} [dB]	$\|\Gamma_{REF}\|$ [dB]	A_{LO} [dB]	$\|\Gamma_{LO}\|$ [dB]	A_{CAL} [dB]	$\|\Gamma_{CAL}\|$ [dB]
4	2.4	-24.3	2.9	-40.0	2.5	-26.1
5	2.1	-23.4	2.7	-20.5	2.4	-17.9
6	2	-20.4	2.3	-25.7	2.3	-22.4
7	2	-15.9	2.2	-18.7	2.1	-22.3
8	1.6	-22.5	2.2	-21.0	2.0	-19.0
9	1.6	-24.5	2.0	-23.0	1.7	-26.8
10	1.5	-16.0	1.9	-18.6	1.6	-18.8
11	1.4	-19.4	1.5	-22.4	1.5	-19.6
12	1.1	-16.2	1.4	-19.1	1.4	-30.0

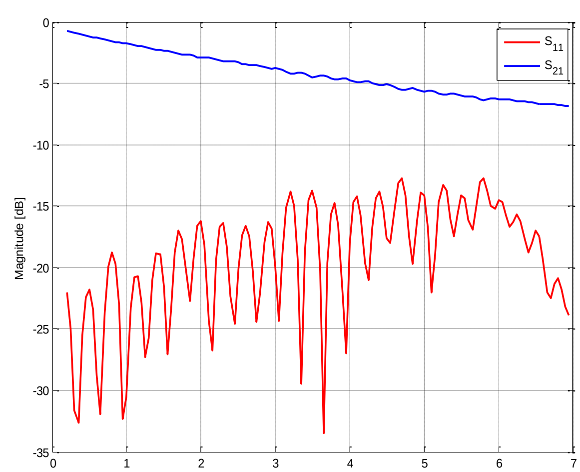

Figure 5. Reflections (red) and RF loss (blue) for the most distant slot from the signal input measured in full frequency range.

Reflection and RF loss measured from DC to 6 GHz (7GHz equipment range) shown in Fig. 5. Fulfill requirements for the RF RTM Backplane and guarantee effective RF signal distribution in the MTCA.4 crate.

III. Summary

The concept and capabilities of a new RTM Backplane extension for the MTCA.4 crates was presented. It gives powerful options for the crate such as additional modules (eRTMs), additional payload power allowing for removing computing power limitations of the MTCA.4 standard, low noise bipolar power supply for sensitive analog applications, possibility of internal distribution of multiple, high-performance RF and clock signals. Design of RTM RF Backplane prototype was presented together with measurement setup description and very god test results. Important outcome of presented work is that it was accepted by the PICMG committee, it was significantly extended by the working group (not a topic of this paper) and it will became an official standard extension.

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