ISBN: 978-3-95450-199-1 doi:10.18429/JACoW-SAP2017-MOPH25

DEVEOPMENT OF LLRF SYSTEM FOR TSINGHUA X-BAND HIGH POWER TEST FACILITY

M. Peng†, J. Shi*, P. Wang, Department of Engineering Physics, Tsinghua University, Beijing, China
also at Key Laboratory of Particle & Radiation Imaging, Tsinghua University, Ministry of Education, Beijing, China
Z. Sun, D. Zhang, HZCY Technologies Co., Ltd., Beijing, China

Abstract

Tsinghua X-band high power test stand is under construction. A new LLRF system based on the original S-band LLRF system has been designed and tested. A 1 U chasses called X-Adapter was constructed, which has the ability of up-converting and down-converting the signals between 2.856 GHz and 11.424 GHz. The goal of the LLRF system development is to modulate and measure the phase and amplitude of the RF signals. The test results are presented and analysed.

INTRODUCTION

Tsinghua has been preparing for a high power test stand based on the 50 MW klystron. The 50 MW CPI klystron and ScandiNova modulator will be installed in this September, and then are the waveguides, cooling system, and RF load. Some tests of RF components and high power experiments are under planning. To do these experiments, one or more amplitude and phase tunable RF signals are required.

There are basically two ways to approach this goal. One is to quadruple the frequency of the 2856 MHz signal directly to 11.424 GHz. The other one is to triple the 2856 MHz signal and then multiply it with the original one. The first method has been tested on CERN's Xbox 2 [1]. Since the limited input power range of quadrupler, the output power of 11.424 GHz can only vary in a very small range, which is not suitable for some RF tests. So we chose the second way.

All the components used in the X-Adapter are small in size. So this adapter can be packaged in an individual 1 U chassis or assembled with the S-band LLRF chasses by adding 1 U in height. For preliminary research on the feasibility of the X-Adapter, we packaged the RF circuits on a plate. The test results show that the X-Adapter can generate RF signal with modulated phase or amplitude, which is enough for the experiments of the high power test stand in the early stage. More functions of the X-Adapter will be added in the future.

SCHEMATIC DESIGN

The signal flow of the X-Adapter is shown in Fig. 1. The whole adapter has at most seven connectors, three S-band input signals for three phase and amplitude modulated X-band outputs, one X-band input signal for S-band output to be measured in S-band LLRF.

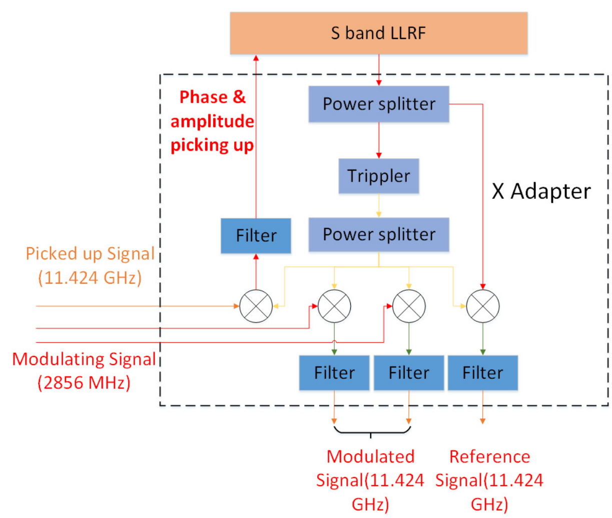

Figure 1: Schematic diagram of the X-Adapter.

Generation of RF Signal

The generation of X-band signal is achieved by the up conversion of S-band RF signal. A prerequisite signal $\cos(\omega_0 t + \varphi_0)$ from S-band LLRF, named input reference signal, first split into two same one by the power splitter. One of them then becomes $\cos(3\omega_0 t + 3\varphi_0)$ after the Tripler, as the LO of the four frequency mixers, the other one becomes the IF of one frequency mixer. It is obvious that the RF of this frequency mixer is $\cos(\omega_0 t + \varphi_0) \times \cos(3\omega_0 t + 3\varphi_0) = \frac{1}{2}[\cos 4(\omega_0 t + \varphi_0) + \cos 2(\omega_0 t + \varphi_0)]$. At the output of the filter, we have the reference X-band RF signal $\cos 4(\omega_0 t + \varphi_0)$, named output reference signal. The phase and amplitude of the reference signal is only depending on the input reference signal of S-band LLRF.

Two alternative modulated X-band signals are provided by inputting modulating S-band signals. For modulating signal $A\cos(\omega_0 t + \varphi_1)$, the modulated X-band signal is $\frac{1}{2}A\cos(4\omega_0 t + \varphi_0 + \varphi_1)$ after frequency the mixer and filter. The input S band signals and output X band signals are called modulating signal and modulated signal. The relative phase and amplitude of the modulated signals are alterable by changing A and φ_0.

† pmm15@mails.tsinghua.edu.cn
*shij@tsinghua.edu.cn

ISBN: 978-3-95450-199-1 doi:10.18429/JACoW-SAP2017-MOPH25

Phase and Amplitude Picking Up

As the LO has provided when generating 11.424 GHz signal, the input signal for phase and amplitude picking up can be easily down converted to 2856 MHz. We suppose the input signal is $\cos(4\omega_0 t + \varphi_2)$, and the output to S-band LLRF is $\cos(\omega_0 t + \varphi_2 - 3\varphi_0)$. We should notice that the phase of S band LLRF get is not φ_0 but $\varphi_2 - 3\varphi_0$.

EXPERIMENTS

The photograph of the X-Adapter is shown in Fig. 2. For the convenience to test, all the components are fixed on a slab by tape. Only phase and amplitude modulating are tested up to now, the RF picking is still untested. For there are only two outputs of the original S-band LLRF chasses, we tested one reference signal and one modulated signal.

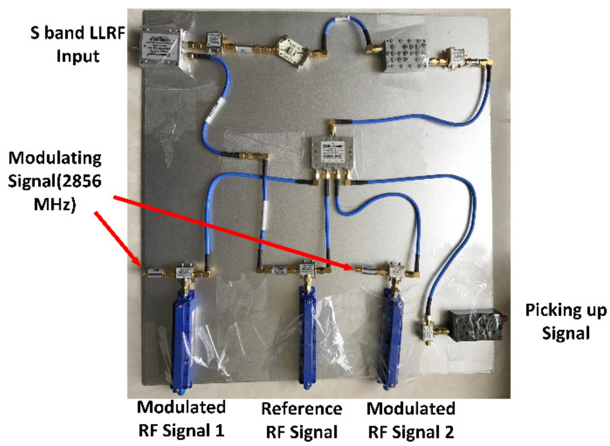

Figure 2: The X-Adapter.

The 11.424 GHz reference and modulated signal were measured by a Lecroy oscilloscope in Fig. 3, which has sampling rate of 80GHz and passband of 25GHz. Then we get the phase and amplitude by I/Q demodulating the data saved in the oscilloscope. The output signal's power was measured by a ROHDE&SCHWARZ power meter in Fig.4. The GUI of the power meter gives the profile of the pulse, and peak value and period. A wide band frequency from 50MHz to 18 GHz with power from -60 dBm to +20dBm can be measured safely.

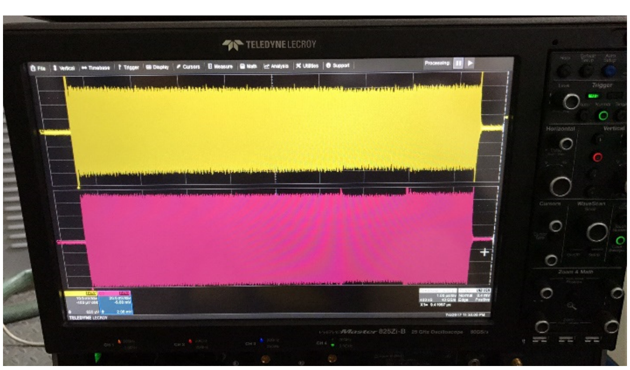

Figure 3: The reference and modulated signal measured by Lecroy oscilloscope.

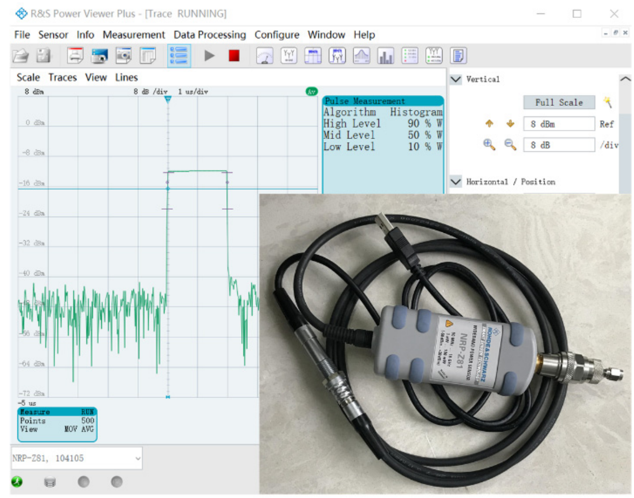

Figure 4: ROHDE&SCHWARZ power meter and its GUI on computer.

Amplitude Modulating

We modulated the amplitude of the RF signal and the results are shown in the Fig. 5. With the reference input signal fixed, the amplitude at last 1.5μs of input S-band modulating signal becomes half of the front. The amplitude of output X band RF changes from 80 mV to 40 mV. This result indicates that the LLRF system can generate RF signal with different amplitude. Moreover, we can modulate the amplitude the amplitude of the RF signal in the RF pulse.

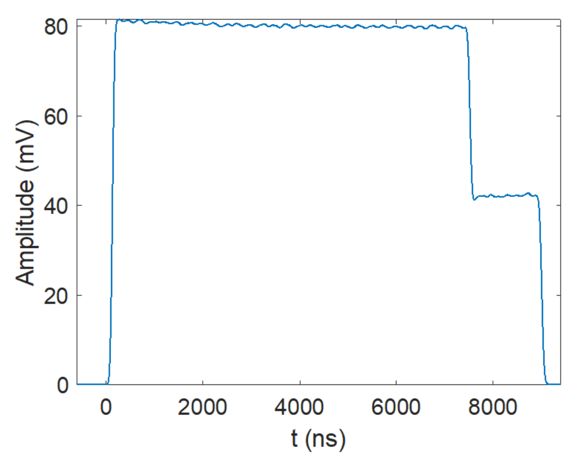

Figure 5: Amplitude modulating of the modulated signal.

Phase Modulating

Keeping the input reference signal and the amplitude of modulating signal constant, we reverse the phase of modulating signal at 6μs and reverse it back at 7.5μs. In Fig. 6, Fig. 7, Fig. 8, Fig. 9 are the amplitude and phase of output reference and modulated signals.

In Fig. 4, the amplitude of output reference signal keeps 52.5 mV and low noise from time 0 to 9μs, which means no interference from the modulated signal. At beginning and end of Fig. 7, there are some phase oscillations, but it doesn't matter because of the zero amplitude.

ISBN: 978-3-95450-199-1 doi:10.18429/JACoW-SAP2017-MOPH25

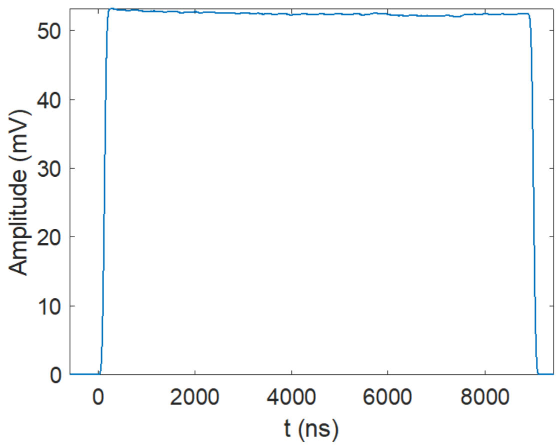

Figure 6: Amplitude of the output reference signal.

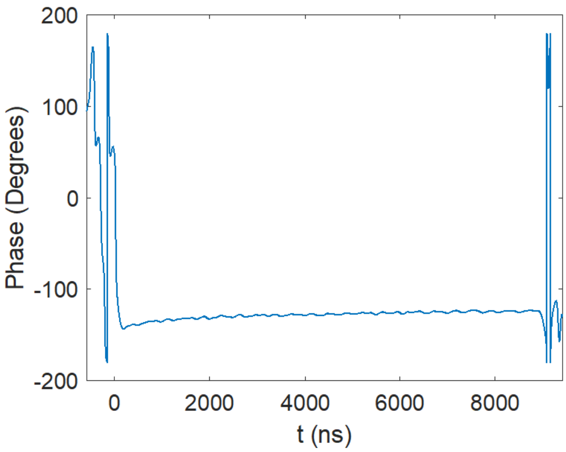

Figure 7: Phase of the output reference signal.

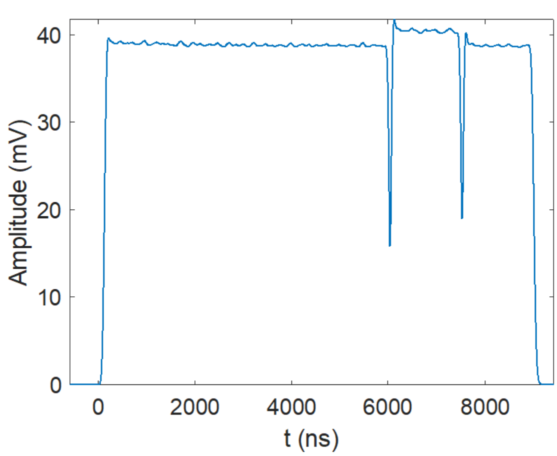

Figure 8: Amplitude of the modulated signal.

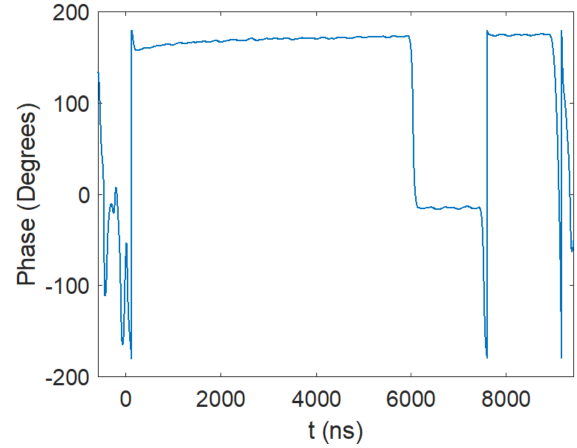

Figure 9: Phase of the modulated signal.

The modulated signals are shown in Fig. 8 and Fig. 9. The amplitude changes about 2.5% when its phase reversed and then coming back. This result is caused by the reflection of the wires and other components. The phase of modulating signal in S-band LLRF is changed by increasing or decreasing its frequency [2]. For a signal $\cos(\omega_0 t + \varphi_0)$, to advance its phase, we first add a frequency Δω and becomes $\cos((\omega_0 + \Delta\omega)t + \varphi_0)$. At $\mathrm{t} = \mathrm{t} + \Delta\mathrm{t}$, the signal turns into $\cos(\omega_0 t + \varphi_0 + \Delta t \cdot \Delta\omega)$. As 11.424 GHz output is on the edge of passband of the filter, there is a downward peak when the phase is changing. In Fig. 9, the phase reversed from 180° to 0° as expected. However, the rising time of reversing phase is 100 ns, which is beyond the acceptance of pulse compressor tests. Replace the output filter should help.

CONCLUSION

The X-Adapter provides a highly flexible and low cost solution for X-band high power RF test stand and make full use of the S-band LLRF system. Further experiments needed to be conducted after adding external isolator and replacing the filter with one have a suitable passband.

REFERENCES

[1] Woolley B, Dexter A, Syratchev I *et al.*, High power X-band RF test stand development and high power testing of the CLIC crab cavity[D]. Lancaster University, 2015: 44-48.
[2] Jin, Yang, Research on Synchronization System based on Tsinghua Thomson scattering X-ray source [D].Beijing: Tsinghua University, 2016: 51-83.