

EXPERIENCE WITH A 5 kW, 1.3 GHz SOLID STATE AMPLIFIER

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Abstract

This study describes the experience with and performance of a commercially available 1.3 GHz 5kW Solid State Amplifier in various experiments at Cornell University. High power amplifiers are usually built with multiple RF power modules and the individual output signals are then combined in a power combiner. Therefore, the phases of the individual RF output power signals have to be adjusted within tight tolerances. The relative phases can be affected by different lengths cables and also affect the overall gain performance of the amplifier. This paper focuses on several key factors in testing the performance of the amplifier. Among those are phase and amplitude stability, gain linearity, and operational experience.

INTRODUCTION

Cornell has recently purchased a 5kW, Solid State Amplifier [1] for use in different experiments, such as the Horizontal Test Cryostat (HTC) [2], testing of the input coupler [3] for use in the HTC, etc. The amplifier was built to our specification to suit our needs in different experiments. The amplifier was purchased from Bruker and was built with high power and efficiency FET transistors within the power modules. The specification of the amplifier is listed in Table 1. Since the amplifier is the first of its kind, intensive testing in different scenarios was done to see the actual performance of the amplifier.

Table 1: Specification of the Amplifier

Operation Frequency	1300MHz +/- 5MHz
Gain	67 dB
Power RF Efficiency	40% at 5kW Output

This paper describes the experiences while testing the 5kW, Solid State Amplifier at Cornell University. The performance of the amplifier with the resolved issues is also presented.

EXPERIENCE WITH AMPLIFIER

High power amplifiers are usually built with multiple power modules for easier power upgrade to meet the needs for different experiment's specifications. At our facility, the solid state amplifier contains 3 power modules, as shown in Fig. 1. Each module outputs approximately 1.67kW. A waveguide power combiner is connected with the power modules via 1-5/8" flex foam cables.

Initial Performance

During initial testing of the amplifier, we encountered two issues. During medium power of operation around 2kW with reflected power less than 5W, one of the connectors on a 1-5/8" cable failed as shown in Fig. 2. It was found that the cables' connector was loosely connected at the waveguide combiner end and as a result, it was burnt due to high power transmitted through the cable.



Figure 1: The 1.3GHz, 5kW, Solid State Amplifier. The three power modules are installed on the left side, the right side contains the power transformer and the status screen is located on the top right panel.



Figure 2: The Damaged Cable Connector.

This event caused one of the power modules to fail due to the reflected power resulting in a transistor catastrophic failure. Figure 3 shows an example screen of the power module after the transistor failure. Due to this event, the Solid State Amplifier's performance has degraded as

shown in Fig. 4.

From the gain plot shown in Fig. 4, it can be seen that the amplifier maximum output power has degraded by 1.2kW, down to 3.8kW when input is at 1mW. To address these initial problems, both the burnt cable and one of the power modules were replaced.

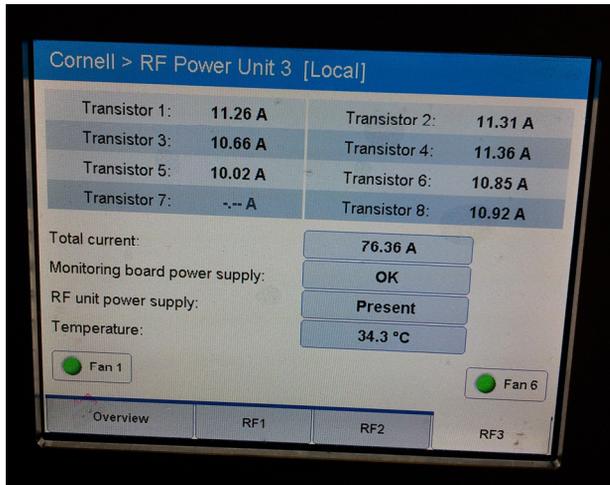


Figure 3: Transistors' Status Screen of the Amplifier. It is observed from the screen that Transistor #7 of the power module failed to respond after the event occurred.

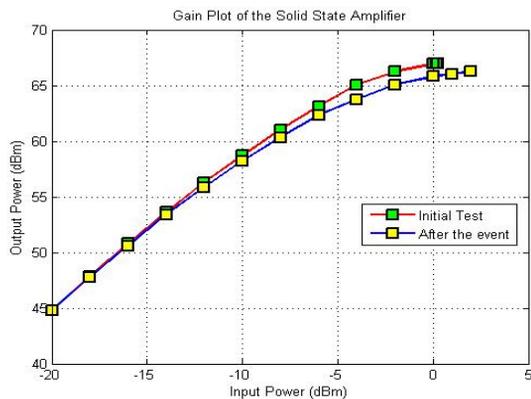


Figure 4: Gain Plot of the Amplifier.

With the new set of cables and the replaced power module, we have tested the relative output phases off the 3 power modules with the setup shown in Fig. 5. It is suggested by the manufacturer to check the relative phase of each individual module with the other modules terminated with a 50Ω load at very low input power. Figure 6 shows an example of the oscilloscope output. It is observed from the results that the relative phase of each individual module is within +/- 5 deg.

The new setup was tested again and its performance compare with the initial gain of the amplifier. As shown in Fig. 7, the results are within 3-5% difference as compare to the conditions when the amplifier first arrived at Cornell.

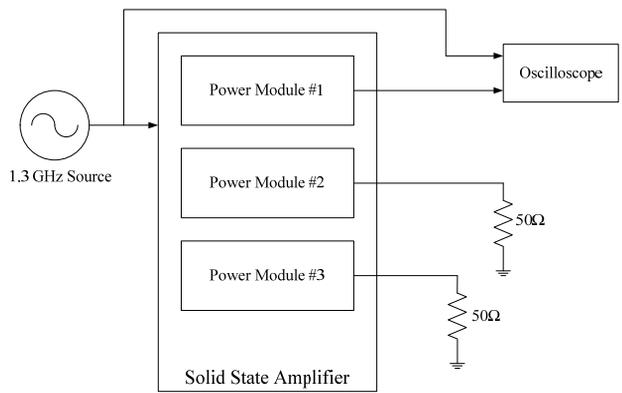


Figure 5: Test Setup to Check Phase Stability.

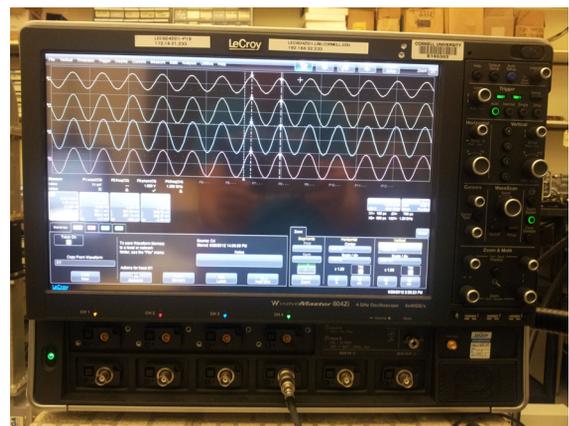


Figure 6: Phase Measurement of the new cables. The top trace represent the input signal. Trace 2 to 4 represent the signal output at the end of cable from each power modules. The relative phase measured to be less than +/- 5 deg, which met the criteria from the manufacturer.

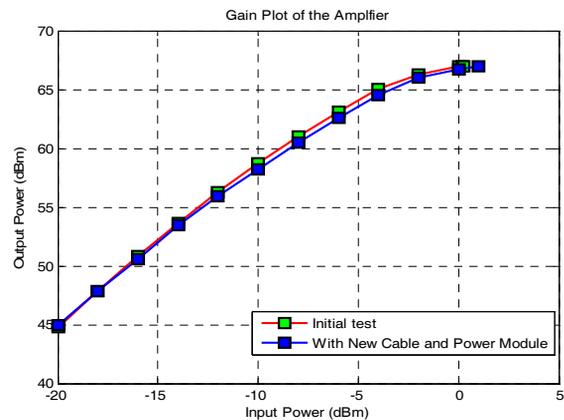


Figure 7: Gain Plot Comparison with Initial Test.

Current Performance

After the improvement we implemented, the amplifier was used for testing SRF cavities in a prototype cryomodule at Cornell.

During these tests, we have encountered additional problems with the amplifier again. We observed a few trips on the amplifier due to fast increase in the input power. The power levels that we have reached during our tests were less than 2kW. After a few trips, it was found that two of the power modules, some of the transistors were degraded in performance to half of their optimal values. Due to the lack of performance of the transistors, the amplifier's maximum output power had degraded to less than 3kW. It was found that the transistor failure was caused by insufficient cooling capacity of the system.

To improve cooling, all three power modules were sent back to the manufacturer for an upgrade. After installing the new modules at Cornell, the amplifier performs well and no further transistor failure has occurred. However, one problem that still remains occasionally trip due to fast increase of input power.

SUMMARY

We gained experience in using the commercially available 1.3 GHz, 5 kW Solid State Amplifier. We have encountered some problems, however, most of them were resolved and the amplifier is now operating at its specification.

REFERENCES

- [1] Bruker, *BLA5000CW 1300MHz Amplifier Manual*, 2012.
- [2] N. A. Valles et al., "Testing of the Main-Linac Prototype Cavity in a Horizontal Test Cryomodule For Cornell ERL," IPAC 2012, LA, USA.
- [3] V. Veshcherevich and S. Belomestnykh. "Input Coupler for Main Linac of Cornell ERL," SRF 2009, Berlin, Germany