

LCWS2024, July 9, 2024

The background of the slide is a photograph of a modern, multi-story office building with a grey facade and many windows. In the foreground, there are several trees with light pink blossoms, likely cherry blossoms. In the distance, the snow-capped peak of Mount Fuji is visible under a clear blue sky. The overall scene is bright and clear.

**Challenges and breakthroughs
in recent RF Solid State PA design
by Radial Combiner design with Initiatives for SDGs**

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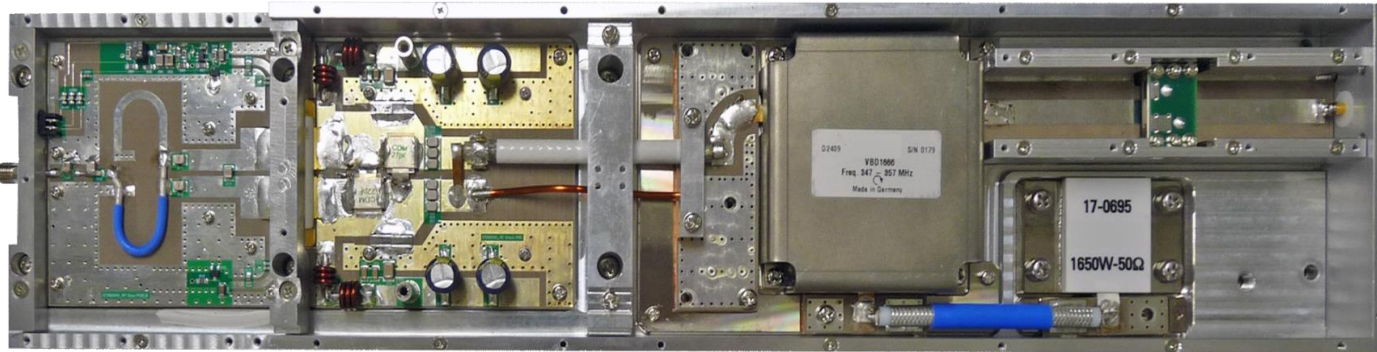
Abstract

R&K, an independent company, has achieved production of 2.3 million 1.9GHz microwave power amplifiers for mobile-comm's-base-stations and then also supplies wideband power amplifiers for automobile EMC testing for domestic automobile industries. Then 16 years ago, we started designing and producing some hundreds kW RF SSA for accelerator applications as alternatives to Klystron / tube.

The measure characteristics of SSA is a possibility to design a band in a very wide frequency range available from few MHz to 14 GHz, and its upgradability of max-power in few kW to few MW design even after system completed. Recently, SSA is being recognized the significant advantages over vacuum tubes in terms of size, low power consumption, higher efficiency, low cost, and adaptive power design. In addition to these, we have learnt that SSA has very low phase noise and low envelope noise that cannot be achieved with vacuum tubes.

All these advantages are transforming SSAs into the first-chosen RF power source even for particle accelerators. There is no doubt that all these improved performances of SSA will minimize overall resource utilization, and well match with sustainable industry and society.

352MHz > 1kW · CW · PA Module

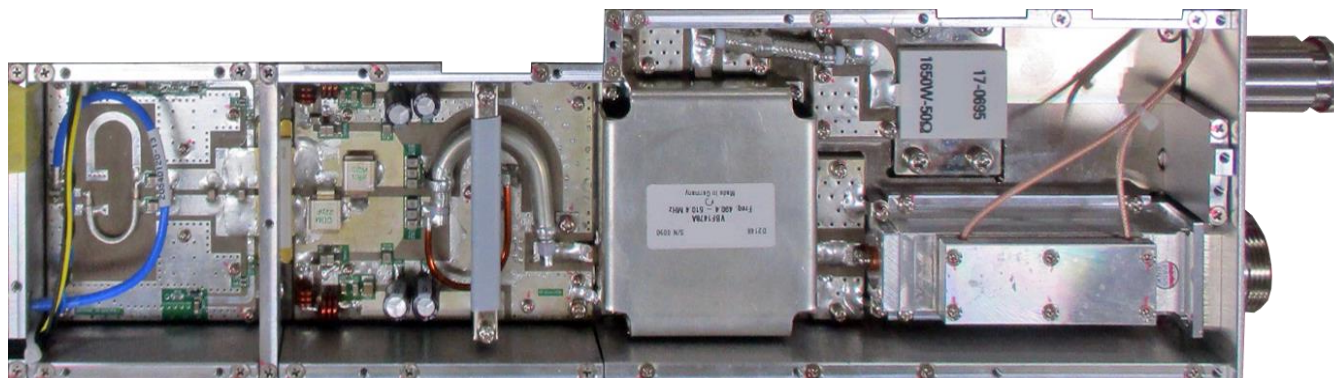


Final SSA Module “ SIZE-A”.

Typ. size for VHF SSA Module
400(L) x 92(W) x 30(H)mm,

G>+23dB, P-1dB>800W, and
P_{sat}>1.2kW at class AB biasing
Efficiency DC-RF >76% @+50V
with output Circulator protect.

500MHz > 1kW · CW · PA Module



Final SSA Module “ SIZE-B”.

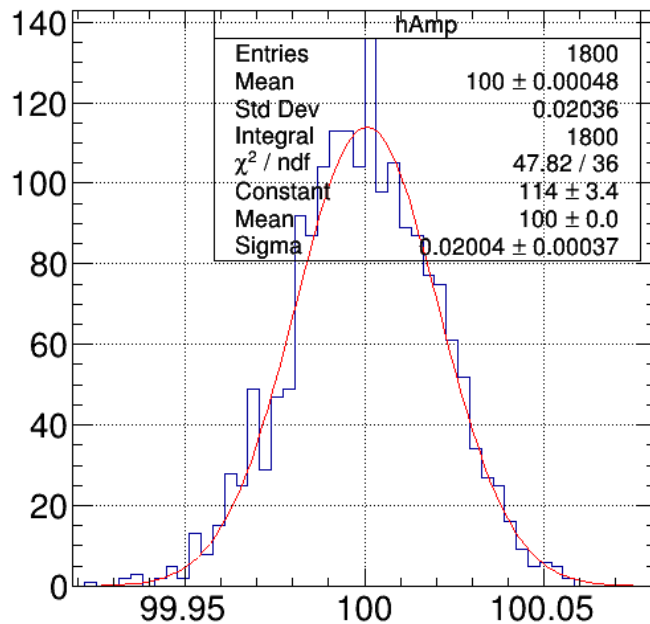
Typ. size for UHF SSA Module
350(L) x 88(W) x 33(H)mm,

G>+22dB, P-1dB>750W, and
P_{sat}>1kW at class AB biasing
Efficiency DC-RF >72% @+50V
with output Circulator protect.

Stability (short term)

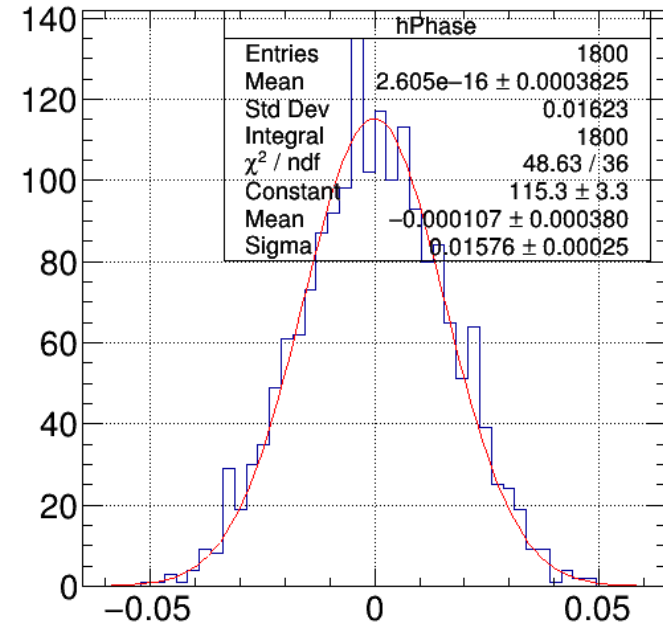
- ▶ RF-out @ 100kW @476MHz
0.020% , 0.016deg (sigma)

I would like to express my sincere gratitude to the RIKEN team for giving us the opportunity to collect "phase and level stability data under free-running conditions of RF over 100kW". For a long time, cost, reliability, and power efficiency came first, and it has been difficult for us to obtain such fulfilling stability data. Conventional vacuum tube amplifiers always have an electron transit time, and they are extremely sensitive to the thermal noise. They are noise source. However, as shown here, solid-state amplifier is now possible to achieve this level of stability even without locking the signal by LLRF.



Level vector stability σ A/A [%]

JASRI/RIKEN Eito Iwai, 2024, Private Communication



Phase vector stability σ phase [deg]

So far, we have covered the important aspects of the SDGs, such as SSA size, low power consumption, high efficiency, low cost, adaptive combiner design, very low phase noise and low envelope noise.

However, we will now move on to the most important topic of latest RF GaN products, where we will discuss the most important aspects of the SDGs, such as the outlook for GaN RF-Device power efficiency for the near future.

In the 1300 MHz band, the current LD-MOS efficiency is 58% for DC-RF, but R&K has already achieved a DC-RF efficiency of 70% with GaN device.

Also, in the 1500 MHz band, the current LD-MOS efficiency is 49% for DC-RF, but R&K has already achieved a DC-RF efficiency of 70% with GaN device.

Regretably, I am very sorry to say that as a result of discussions with the manufacturer, due to the NDA agreement, we are unable to disclose the detailed timeline of the semiconductor devices at this time. We are very sorry, but we will make an announcement at a later date, so I appreciate your understanding.

A large, stylized logo featuring the letters 'R', '&', and 'K' in a bold, blue, serif font. The letters are outlined in white and have a 3D effect with a drop shadow. The entire logo is enclosed in a thick blue rectangular border.

R&K Company Limited

RF/Microwave Power Amplifiers and Components

www.rk-microwave.com