The progress of 300kW home-made fully solid-state transmitter for TPS

TUPAB -- TUESDAY POSTER SESSION, 05/25/2021 0800 – 1000

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IPAC2021

Outline

Introduction

500 MHz 300 kW SSPA System

Single 80 kW SSPA Tower

Performance of Each RF Tower

Power Combination of 2 Towers

Long-term Reliability Test

Future Work

Introduction

The demand of 3rd RF plant for Taiwan Photon Source (TPS) storage ring (SR)

- For high beam current (500 mA)
- More Insertion Devices (IDs) in the coming future

A new 300kW RF system is planned to be installed in area SRF #4 of TPS

- 500MHz KEKB superconducting RF cavity module
- 500MHz 300kW transmitter
- RF feed lines
- LLRF

Fully solid-state power amplifier (SSPA) is chosen for 300 kW RF transmitter

- With the success of 80kW home-made Solid-state Power Amplifier (SSPA) prototype in 2019

Elements of 300kW fully solid-state transmitter

- Four 80 kW SSPA towers
- 3 WR1800 3dB hybrid couplers
- 3 80 kW water loads
- WR1800 waveguides piping

Construction schedule for 3rd RF system

- Complete the 300kW SSPA system within 2 year (2020-2021) and
- Integration with LLRF and SRF cavity module in 2022

500MHz 300 kW SSPA System Design

Frequency: 499.65 MHz

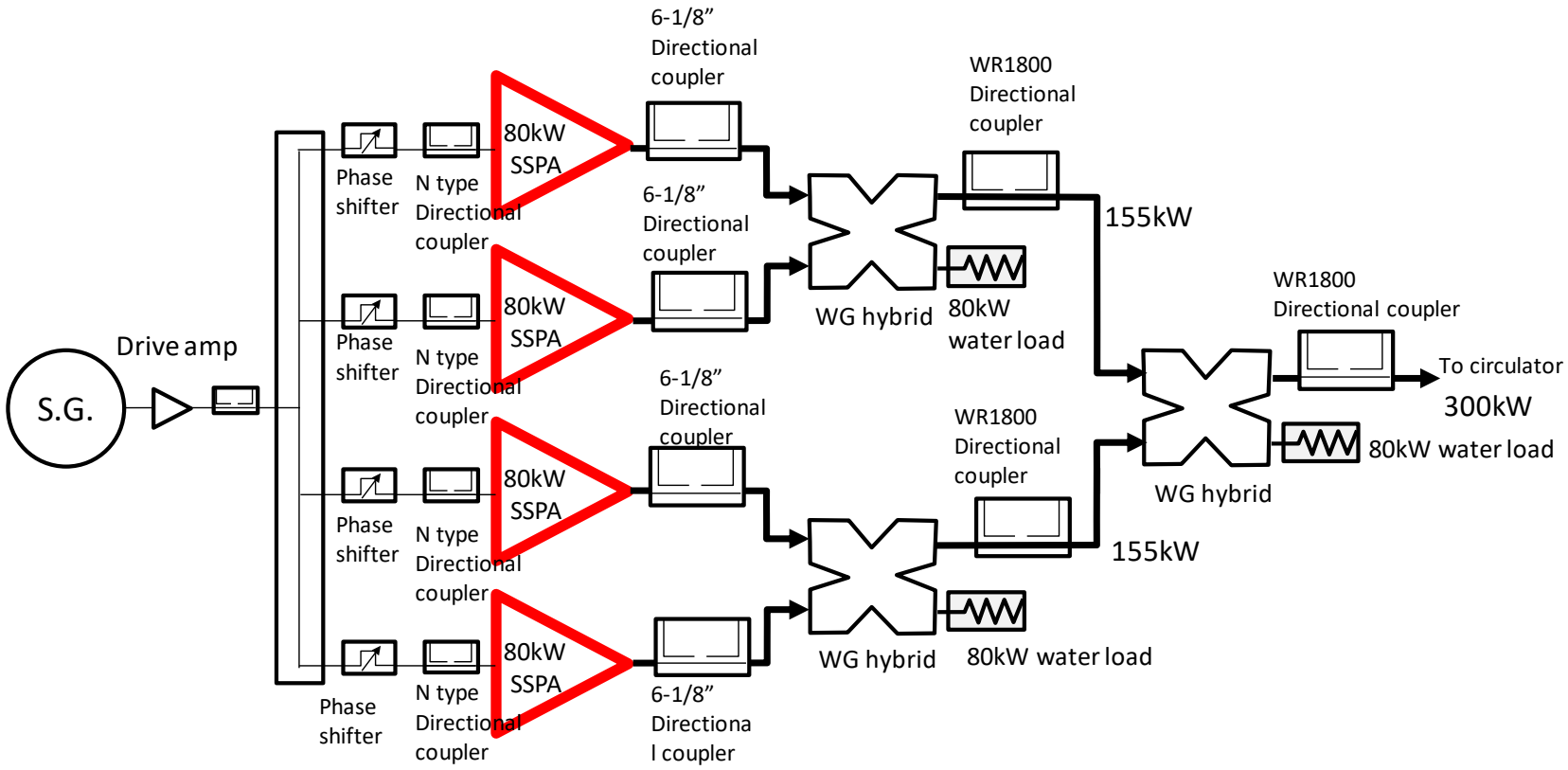
Power rating: ≥ 300 kW

Bandwidth: ≥ +/-1 MHz

Power gain: ≥ 75 dB

Side band noise: ≤ 65 dBc

Harmonic: ≤ 40dBc



Single 80kW SSPA Tower design

Frequency: 499.65 MHz

Power rating: ≥ 80 kW

Bandwidth: ≥ +/-1 MHz

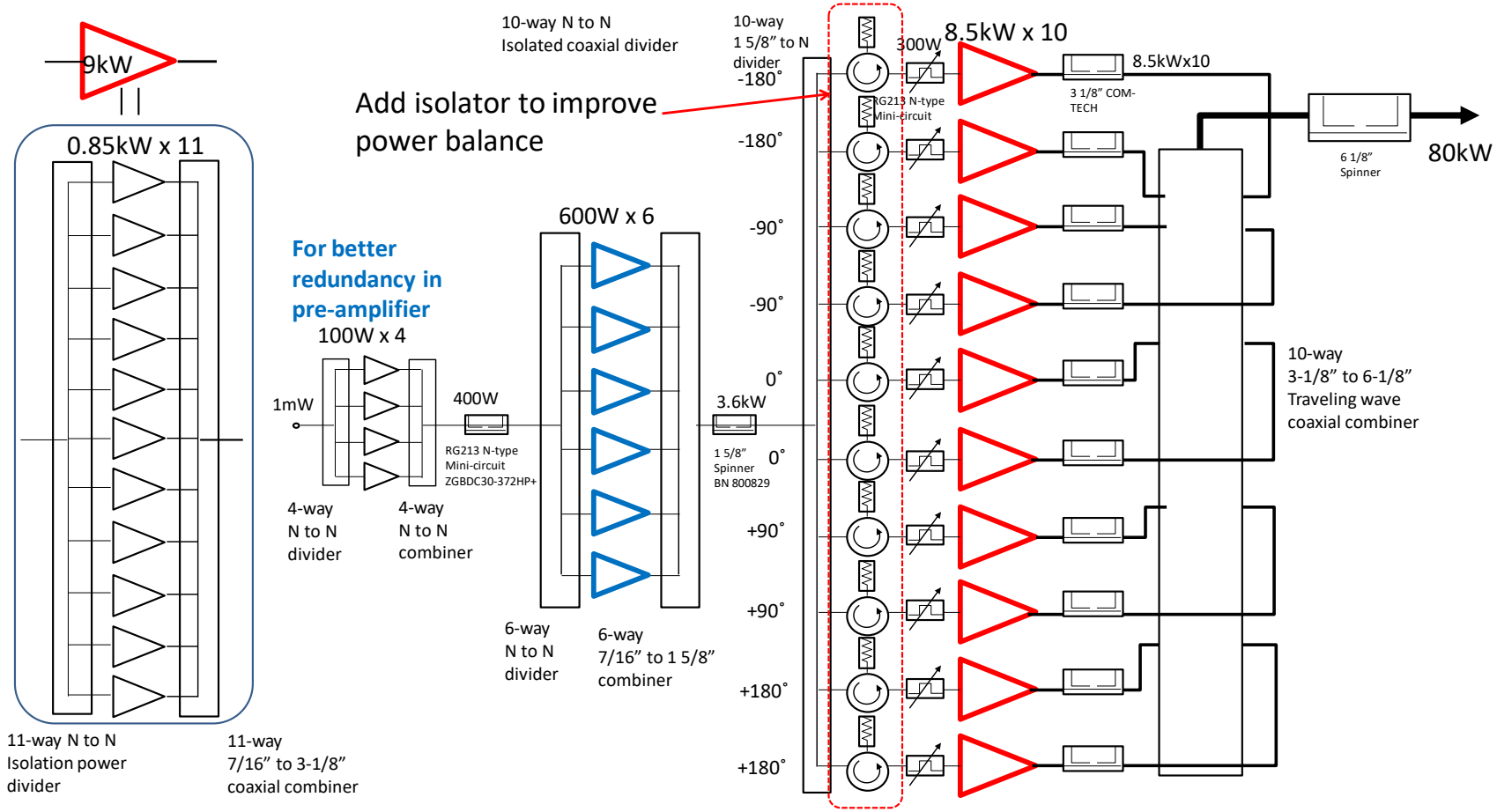
Power gain: ≥ 80 dB

Side band noise: ≤ 65 dBc

Harmonic: ≤ 40 dBc

Elements:

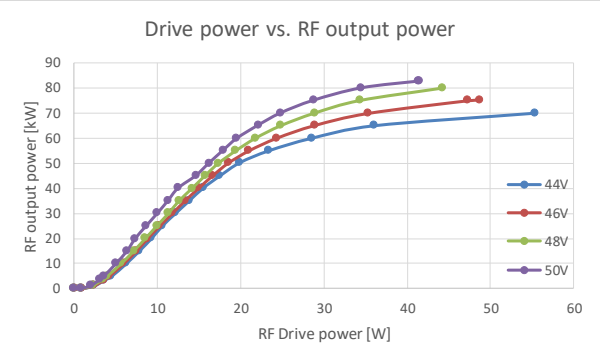
- 100 W pre-amplifier x4
- 600 W drive amplifiers x6
- 880 W amplifiers x110
- 4-way divider/combiner (400 W) x2
- 6-way combiner (3.6 kW) x1
- 10-way divider (3.6 kW) x1
- 11-way divider (300 W) x10
- 11-way combiner (8.5 kW) x10
- 10-way combiner (80 kW) x1

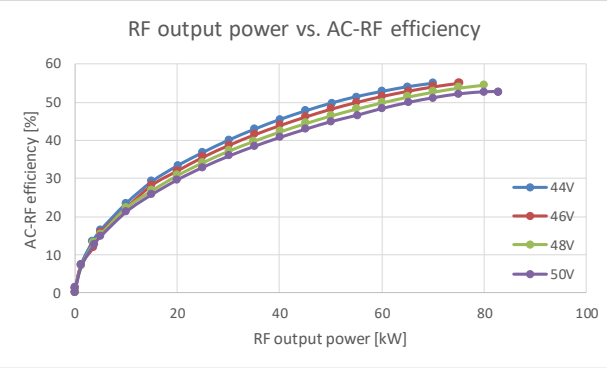


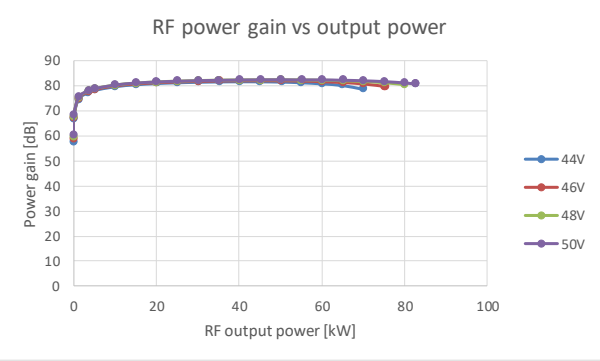
Power performance of one 80kW SSPA tower

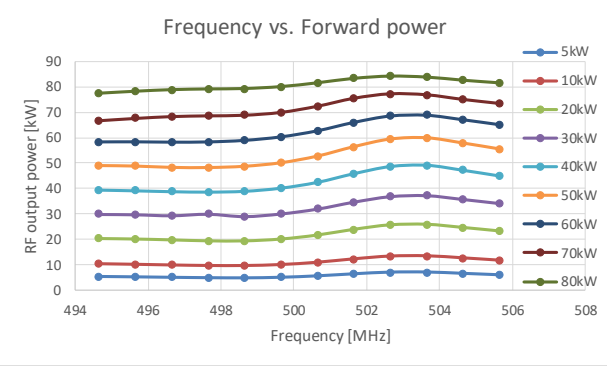
Tower #1 and #2 are accomplished in 2020

- AC-RF efficiency: 54%@80kW&48V





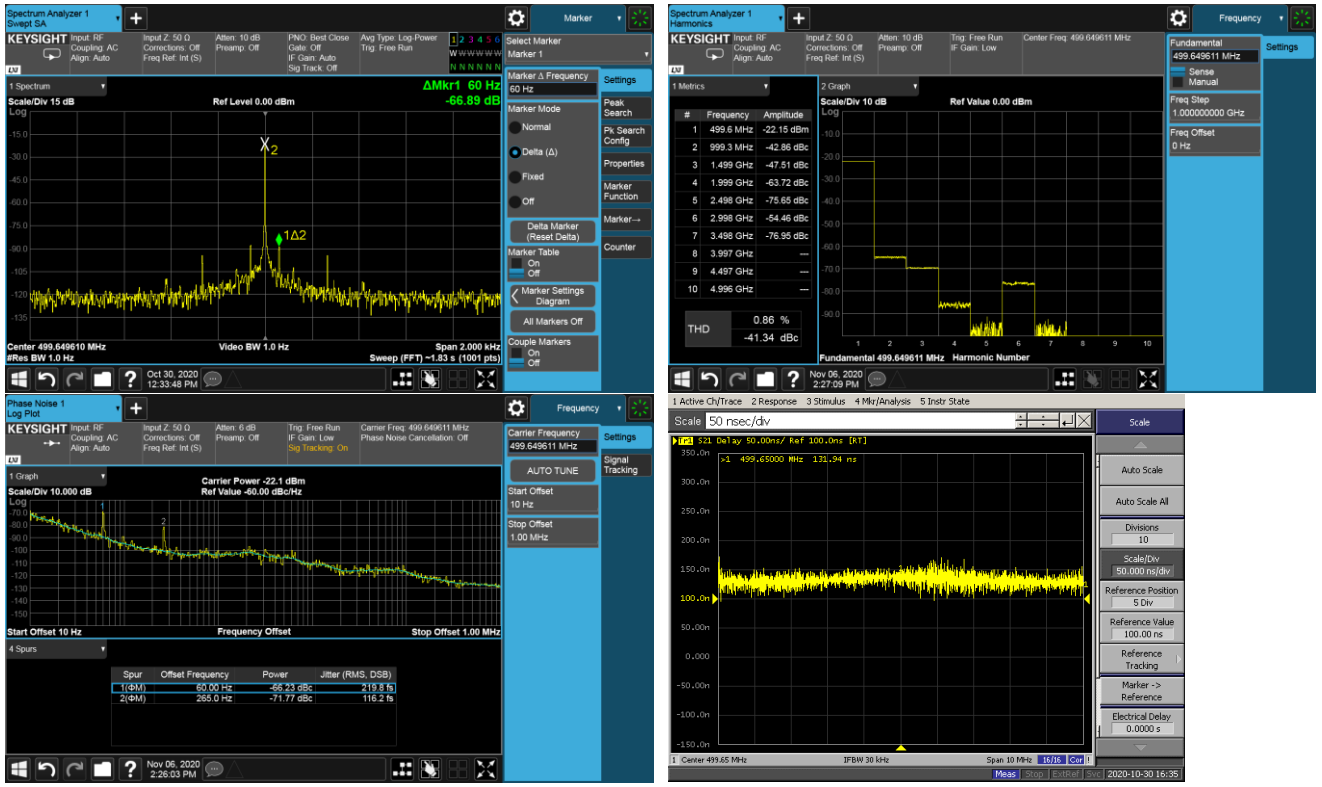




Quality Performance of one 80kW SSPA tower

Tower #1 and #2 are accomplished in 2020

- Side band noise = -66.7dBc @ 60Hz
- 2nd Harmonic = - 42.86 dBc
- 3rd Harmonic = -47.51 dBc
- Phase noise = -66.23dBc @ 60Hz
  -71.77dBc @ 265Hz
- Group delay = 131 ns



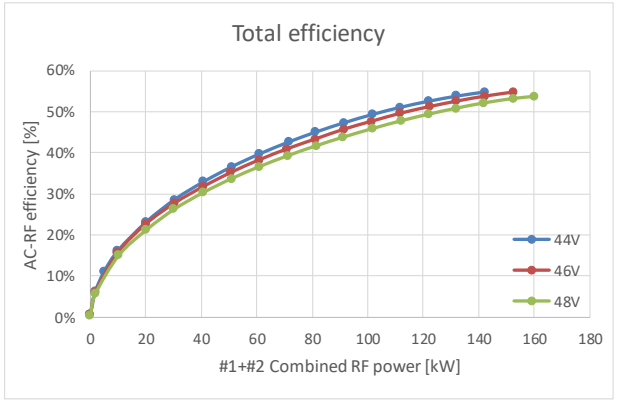
Power combination of 2 SSPA towers

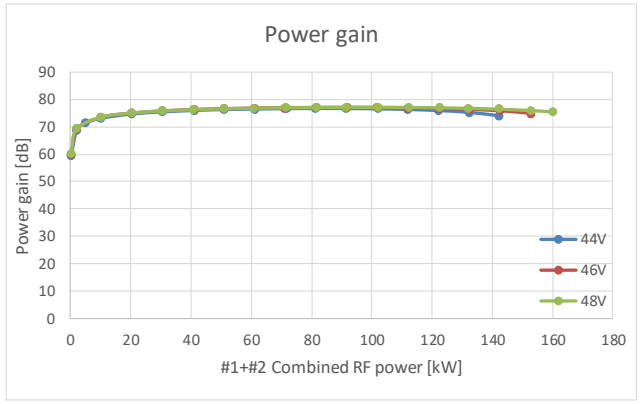
DC voltage range: 44, 46 and 48V

Opt. Eff. @ 44V=54.87%@142kW

Opt. Eff. @ 46V=54.76%@152kW

Opt. Eff. @ 48V=53.67%@160kW



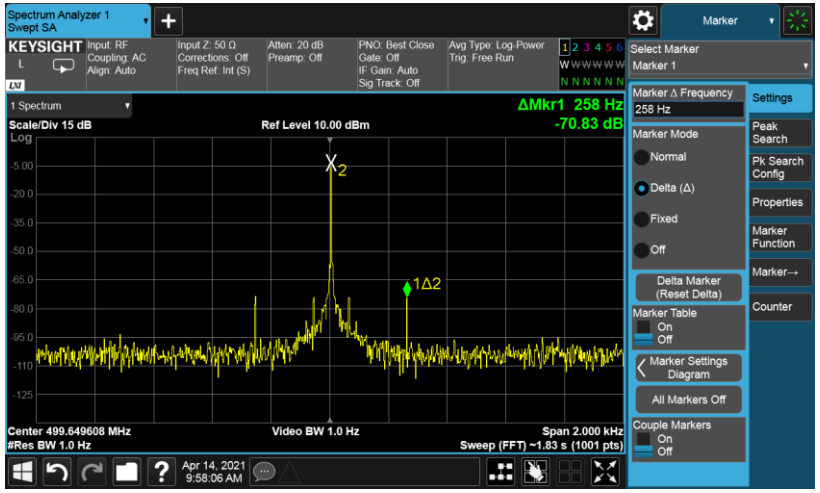


Quality performance of 2 SSPA towers combine

Meet the specification

Sideband noise

-70.83dB @ 258Hz



Phase noise

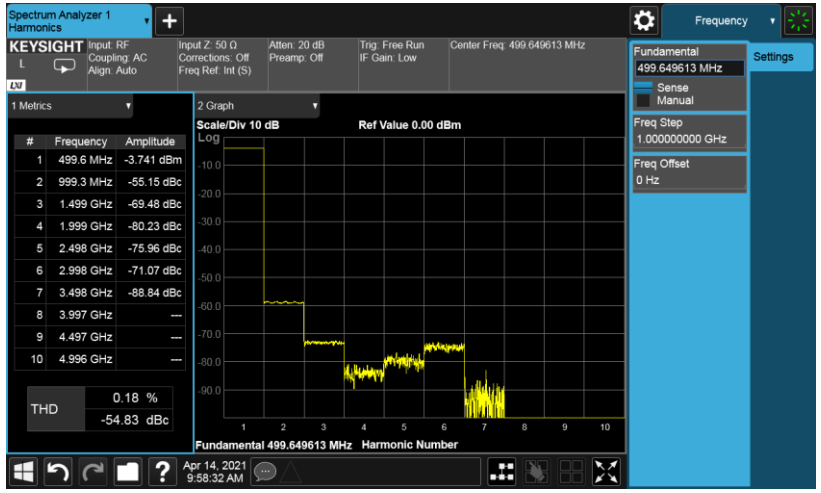
-70.92Bc@60Hz

-70.58dBc@258Hz

Harmonics

-55.15dBc @ 2nd harmonic

-69.48dBc @ 3rd harmonic



Long-term reliability of 2 tower combine

Start from 2021/4/13: interrupted by interlock and repeat test twice (1st is AC copper wire burn, 2nd is water flow sensor wrong action)

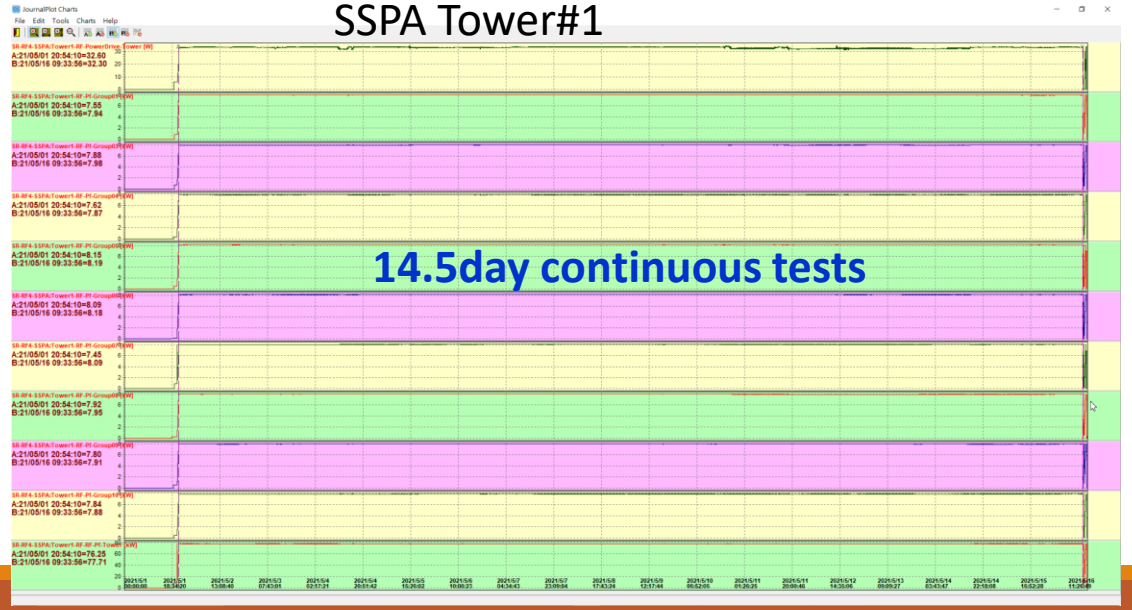
3rd Start at 2021/05/01: 2021/05/01 21:00 ~05/16 9:00 **14day+12hr** 150kW CW test OK

Total combined test period: **11days18hr**+**2days18.5hr**+**14days12hr** = **29days0.5hr**

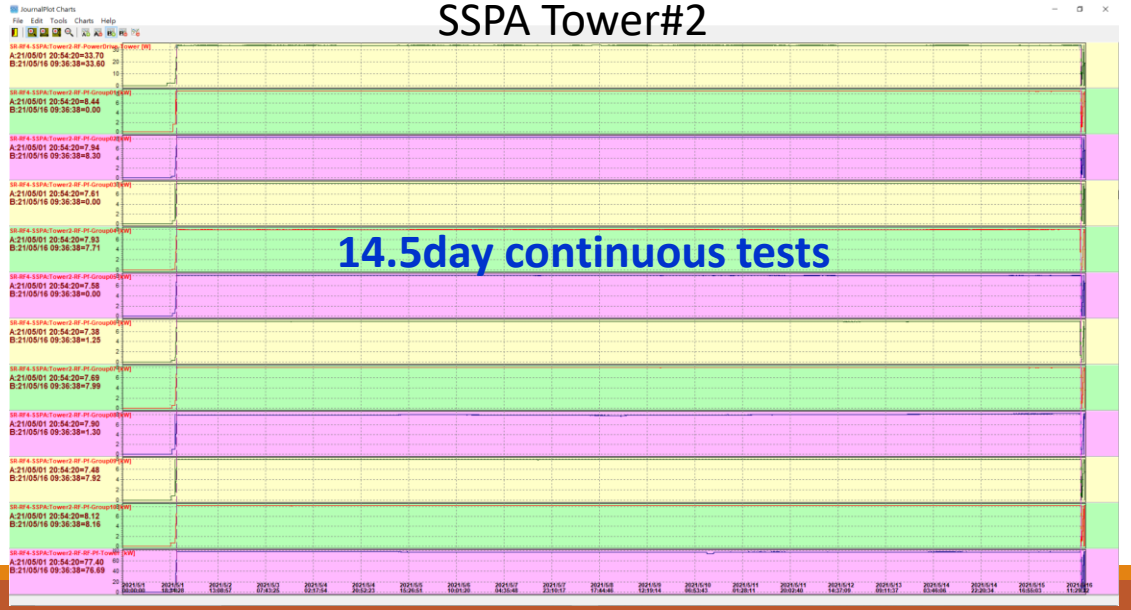
Test condition: to RF load no reflection,

Results: No SSPA module fault or power degradation

SSPA Tower#1



SSPA Tower#2



Future work

Finish the other 2 SSPA towers in 2021

Apply RF power test for last 2 SSPA towers separately

Accomplish 4 SSPA towers power combination for 300 kW