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IPAC13

Dual chip in single module solid-state power amplifier design for compact transmitter architecture

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Outline

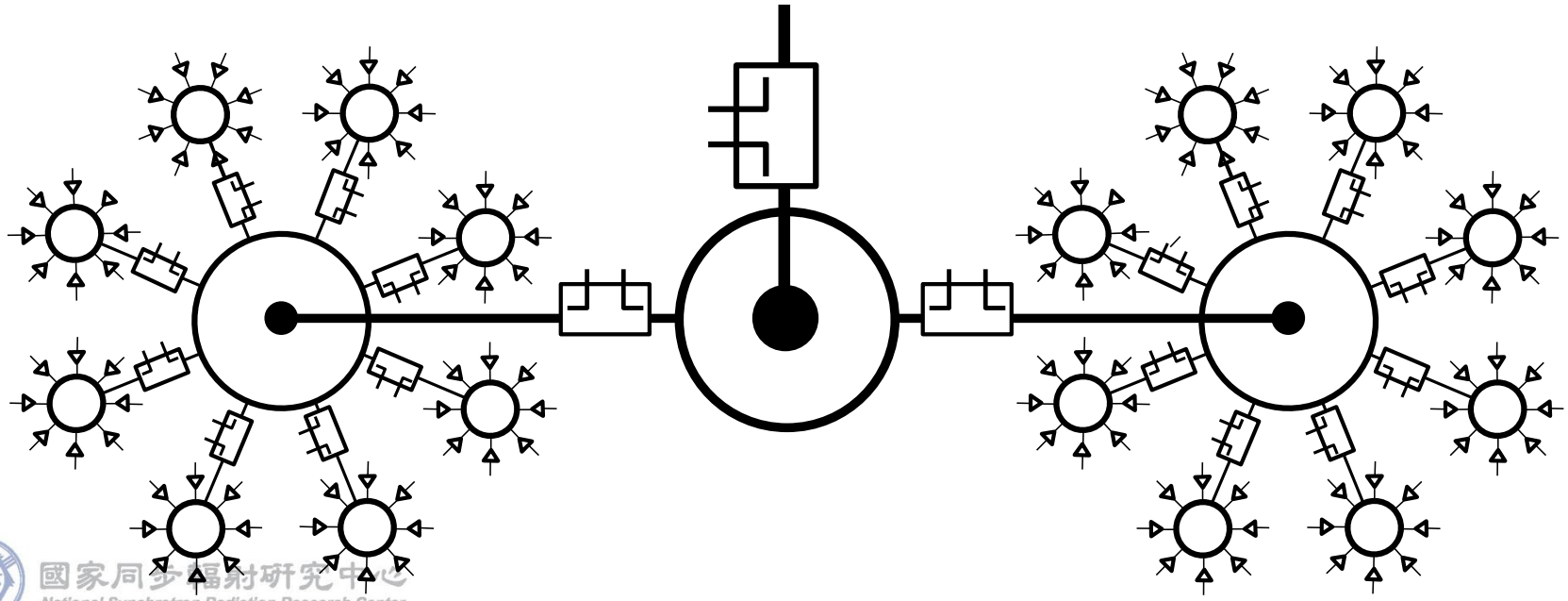
- Introduction
- SSPA transmitter module number reduction
  - 1kW SSPA module for 100kW
  - 2kW SSPA module for 100kW
- Low profile planar balun
- 500MHz, 1kW SSPA using old version planar balun : the drawback
  - Iteration design of the planar baluns
  - SSPA design and results using latest planar balun
- Dual chip combination concept: small SSPA and planar combiners
- Planar power splitting/combining methods
  - Y-junction two-way power divider/combiner
  - Wilkinson two-way power divider/combiner
  - Gysel two-way divider/combiner
  - Planar balun two-way power divider/combiner
- Power combining efficiency
- The dual chip in single module concept realization – in progress
- Conclusion

Introduction

- 3GeV/3.3GeV Taiwan Photon Source, in NSRRC is under construction and planned to be commissioned in 2014
- At present, two 300kW klystron transmitters are available for initial TPS operation.
- With more insertion devices or higher beam current, more RF power will be required
- Solid-state power amplifier (SSPA) transmitter is the next candidate for economic RF power upgrade.
- The experience of SSPA circuits development will be presented here.

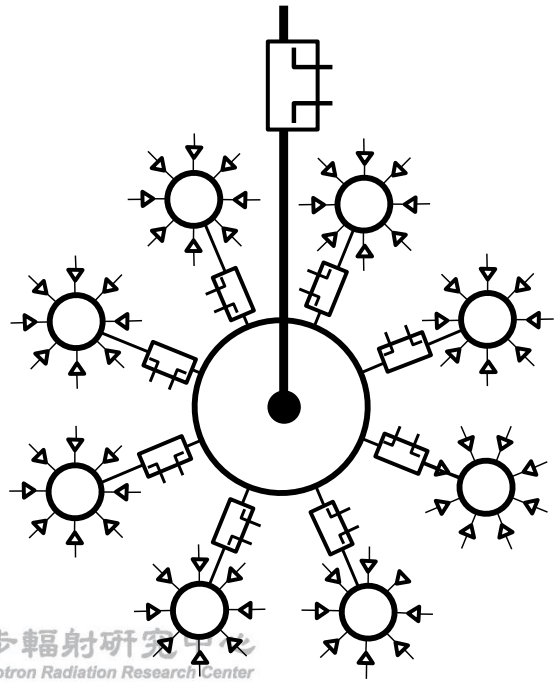
1kW PA modules: 100kW solid-state transmitter needs 128 modules

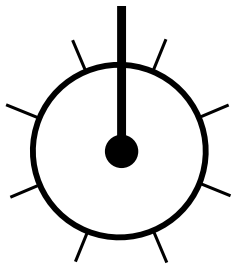
- This topology needs quite large number of modules
- Eight 1kW-SSPA modules as a basic group for 8kW
- 16 8kW-groups for 100kW transmitter
- Each SSPA module will operate at 850W nominally



2kW PA modules: 100kW solid-state transmitter needs only 64 modules

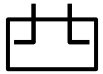
- With 2kW SSPA modules, total number of modules can be reduced in half for the same output power
- Space, control and maintenance requirement can greatly be released.





16kW in 128kW out
8way power combiner

2kW in 16kW out
8way power combiner



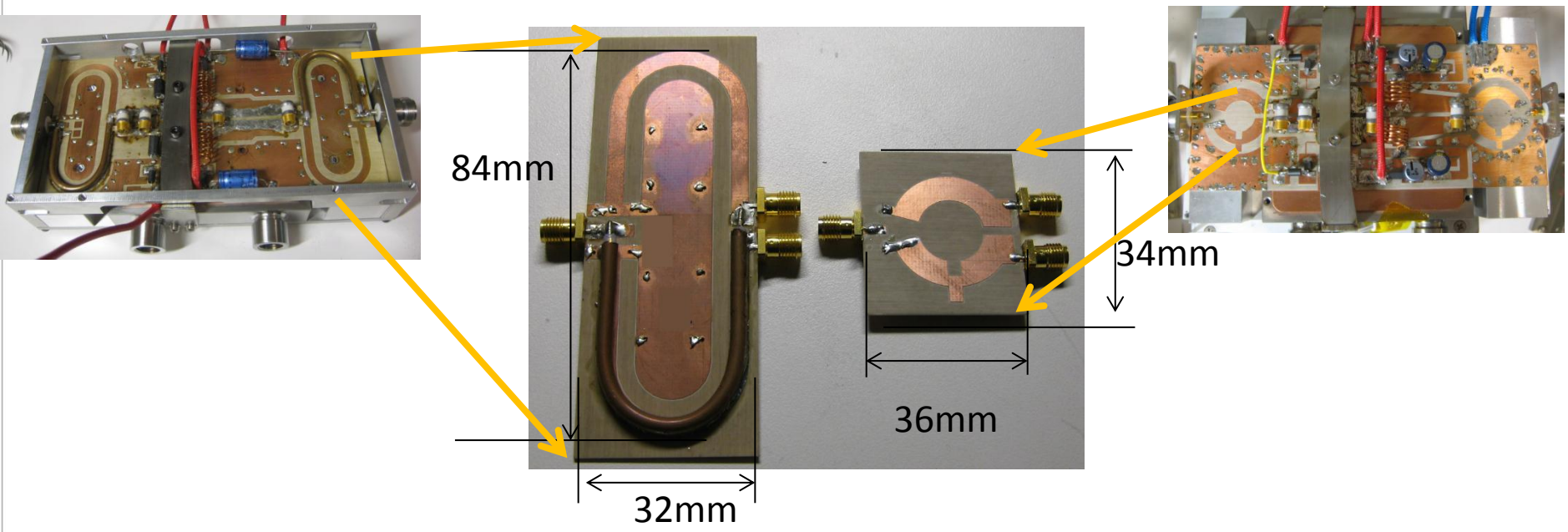
128kW directional coupler

16kW directional coupler

2kW PA module

Low profile planar balun

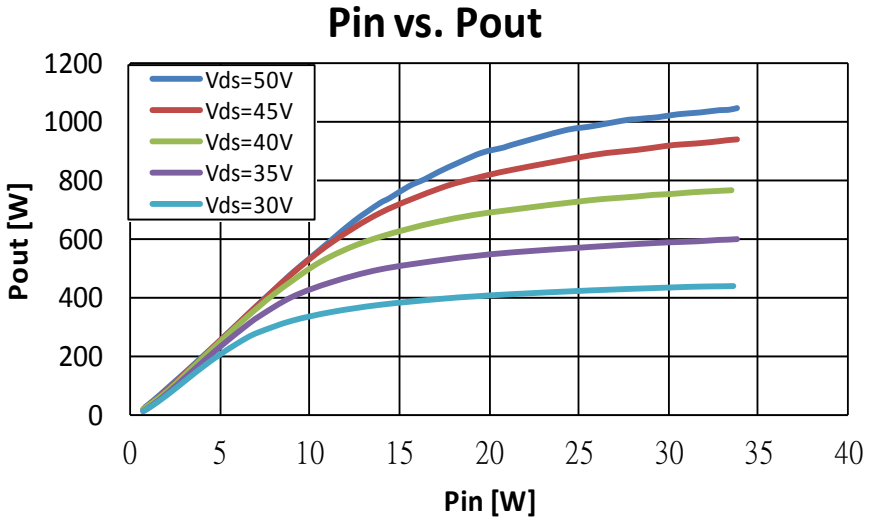
- With the proposed compact planar balun for 500MHz solid-state power amplifier[1], dual-chip combination within in single module becomes attractive.

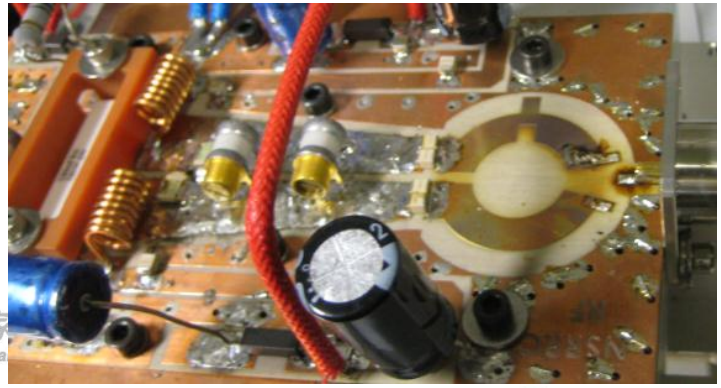


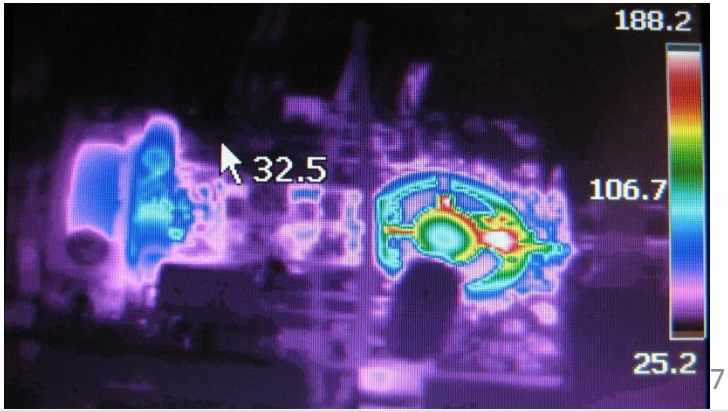
[1]T.C. Yu, Ch. Wang, L.H. Chang etc. ,"A novel planar balun structure for continuous wave 1kW, 500MHz solid-state amplifier design

500MHz, 1kW SSPA using old version planar balun : the drawback

- The 1kW SSPA reported in IPAC 2012
- Reach 1kW per module
- Heat generated at output balun (>188degC@1kW)

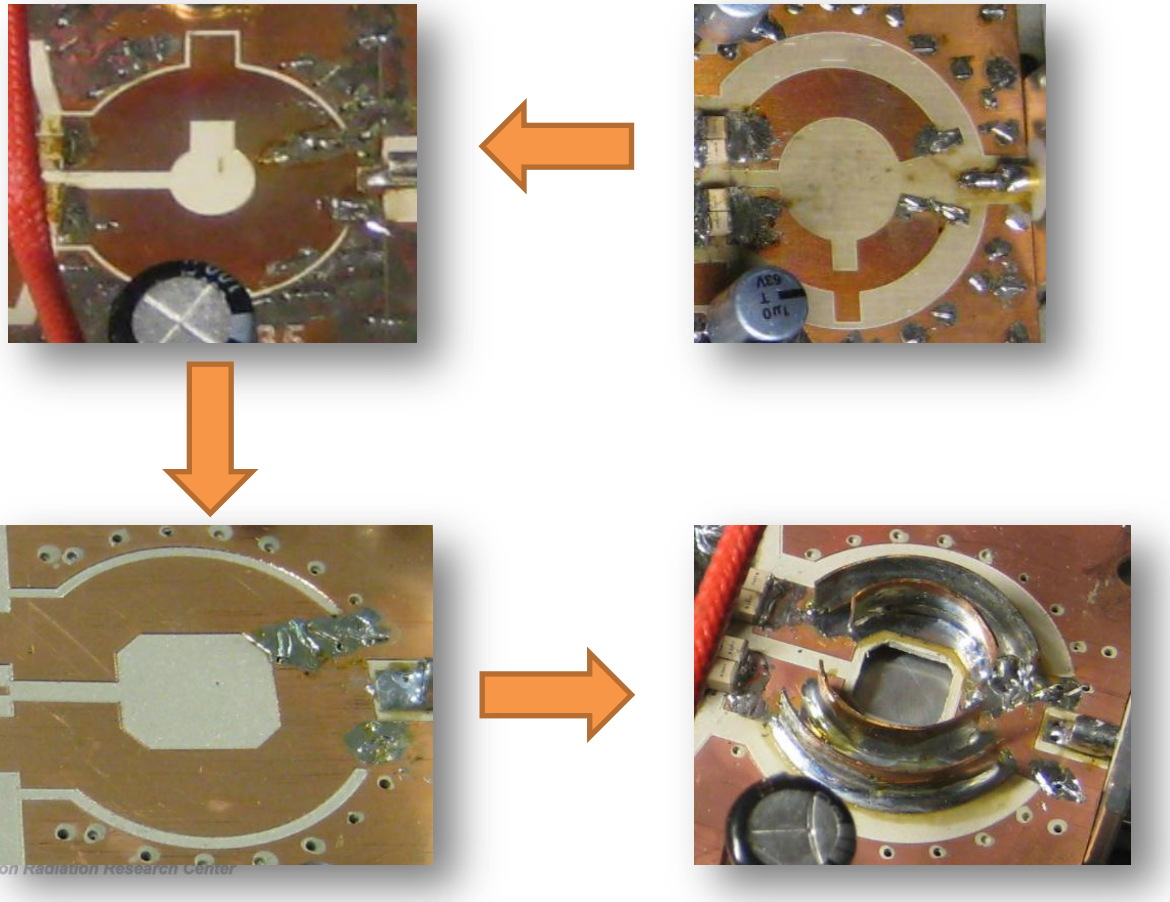






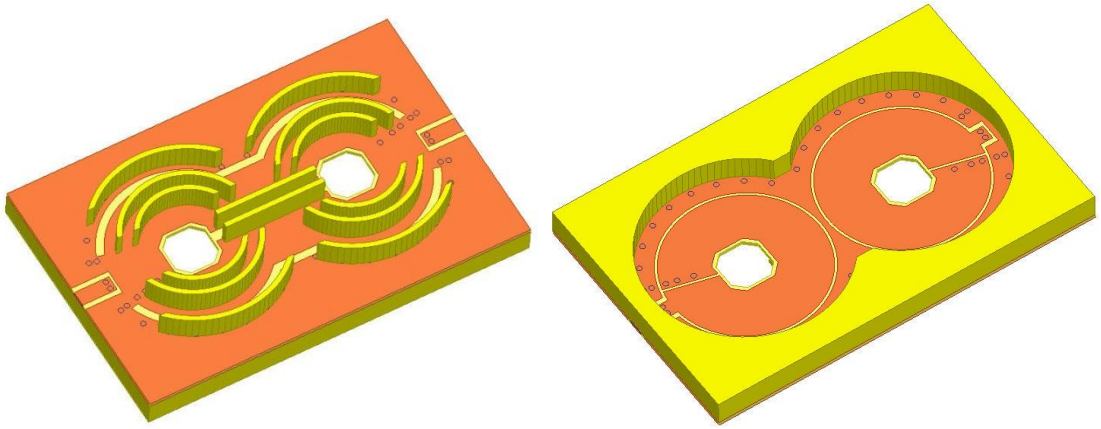
Iteration design of the planar baluns

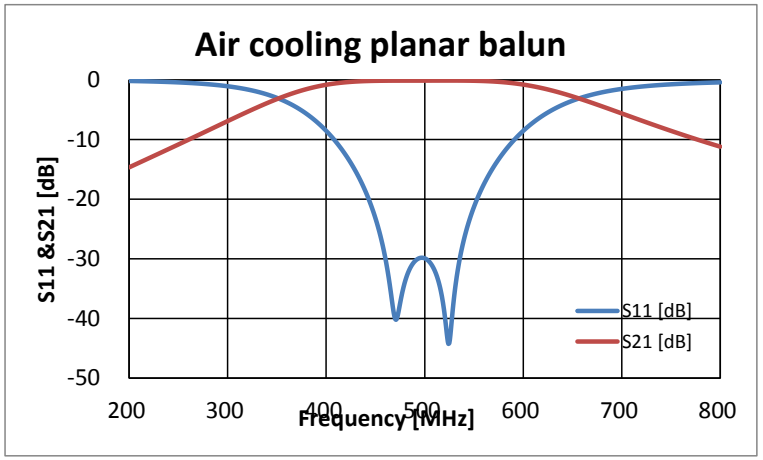
- The temperature decreases one by one



The latest planar balun for 1kW power

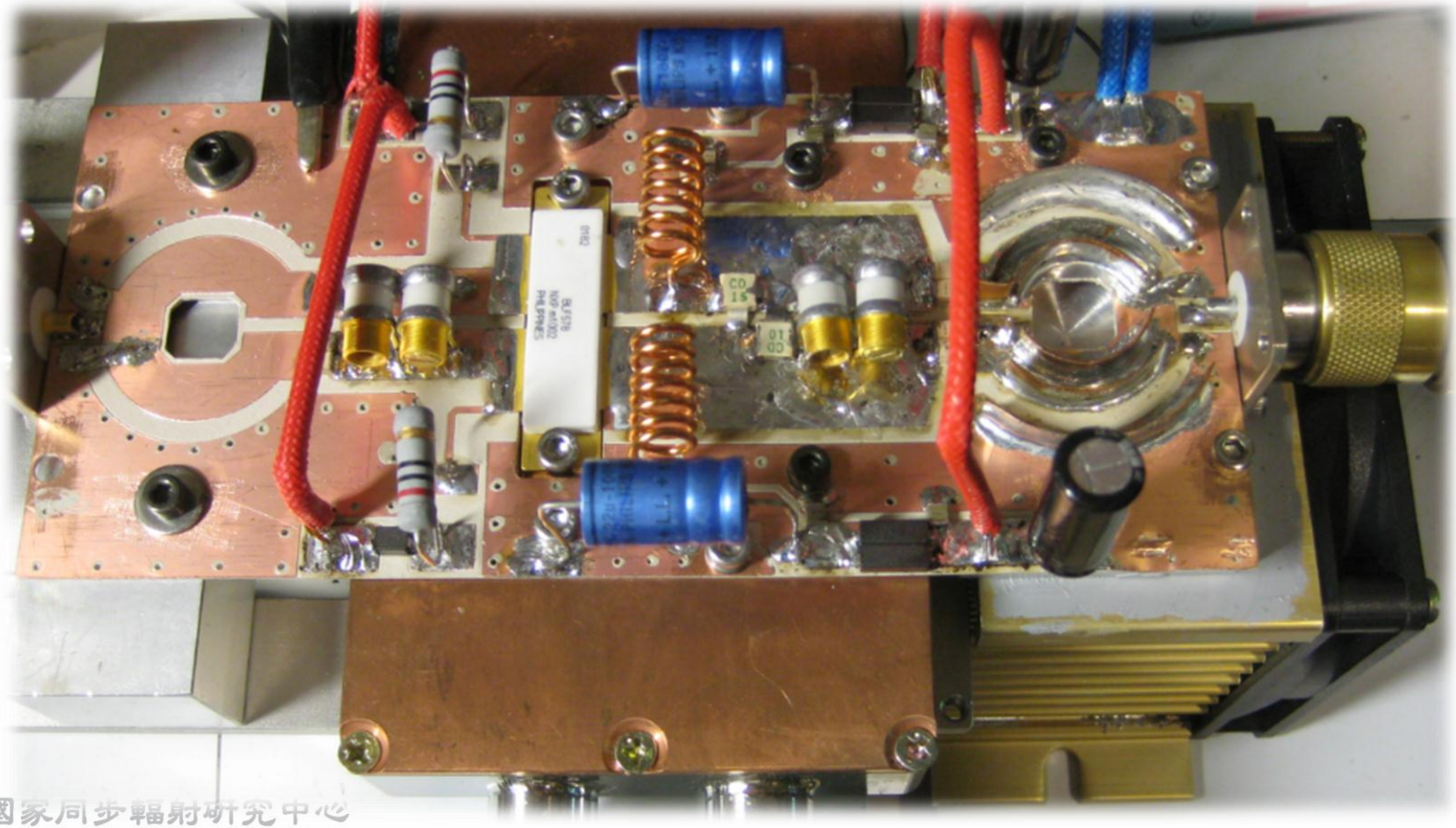
- Features:
  - Add air cooling fin on the top
  - Heat sink surround the balun at bottom
  - The cooling structure has no effects on RF performance
  - Low insertion loss: 0.1dB loss back-to-back (0.05dB/1.15% loss for one)





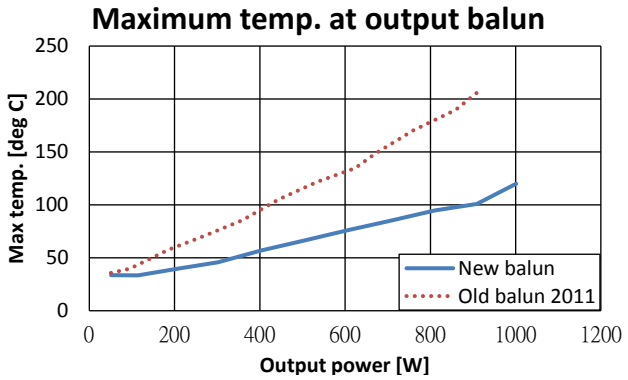
1kW SSPA with latest balun design

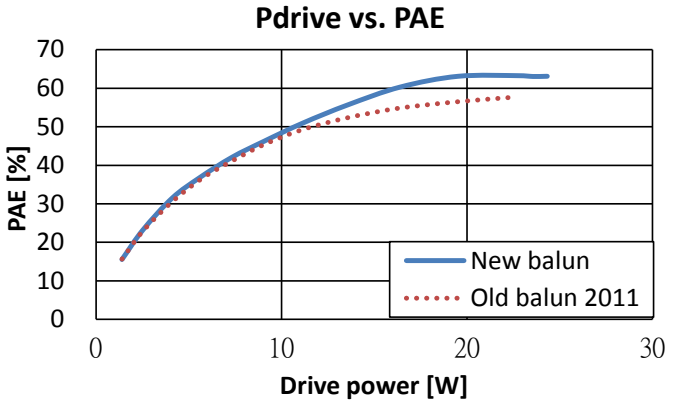
- Operation with fan cooling

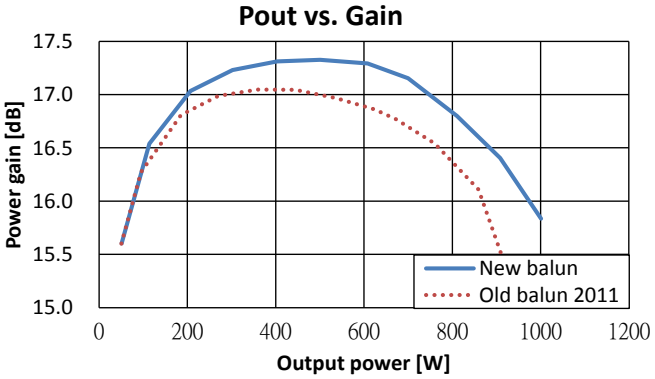


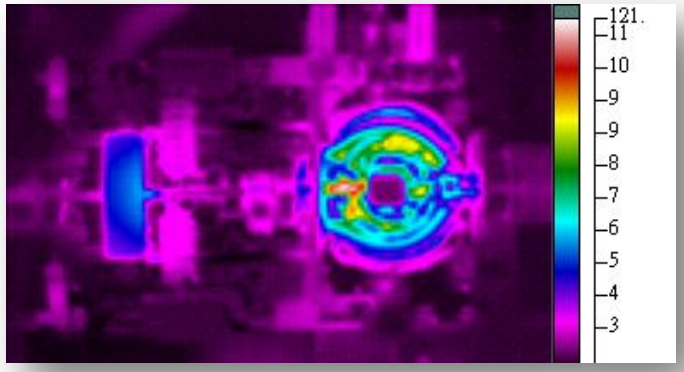
Test results

- Compare with the prior version SSPA
  - Temperature decreased by about 85 degC
  - ~4% efficiency enhancement
  - ~0.5-1dB power gain improvement



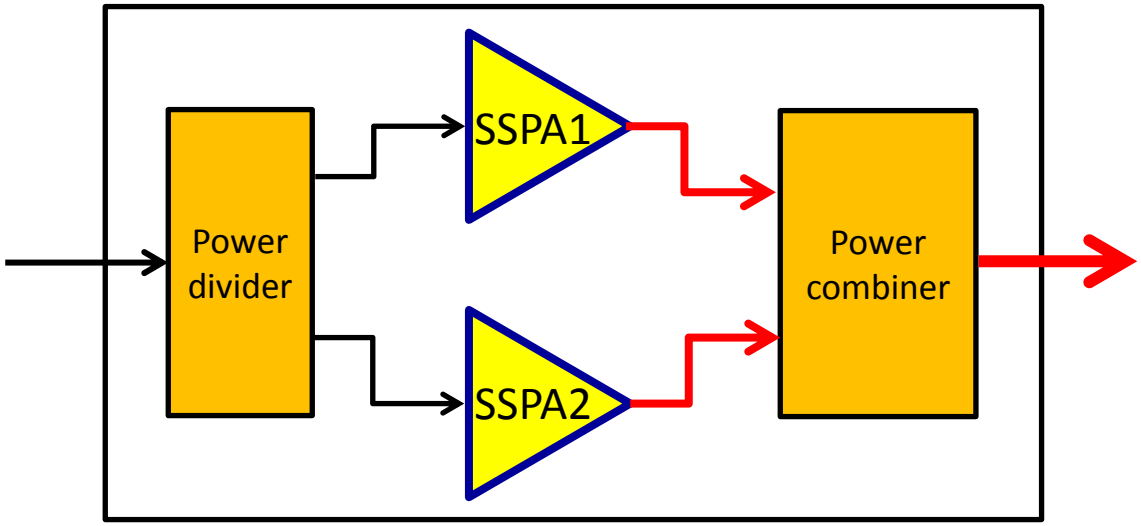






Dual-chip combination within single module

- Two identical SSPAs with planar two-way power divider/combiner

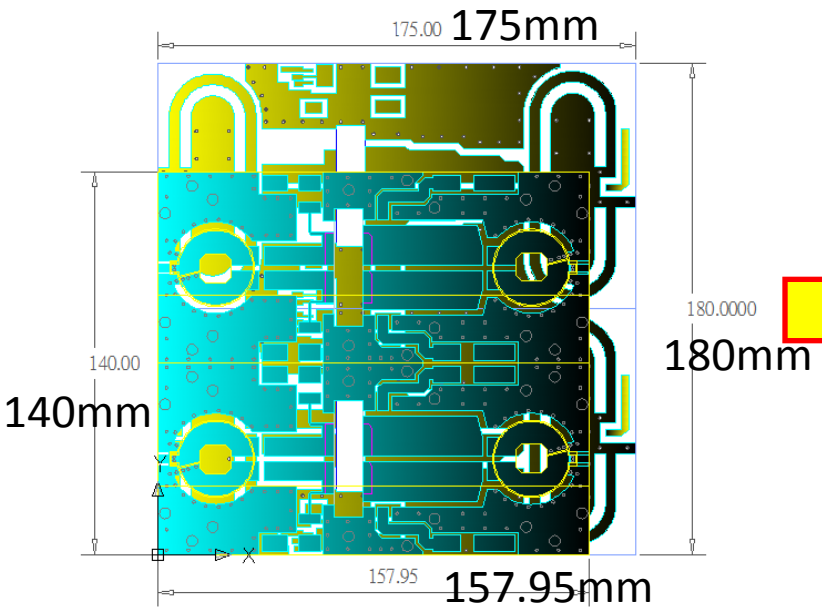


Two amplifiers in single module

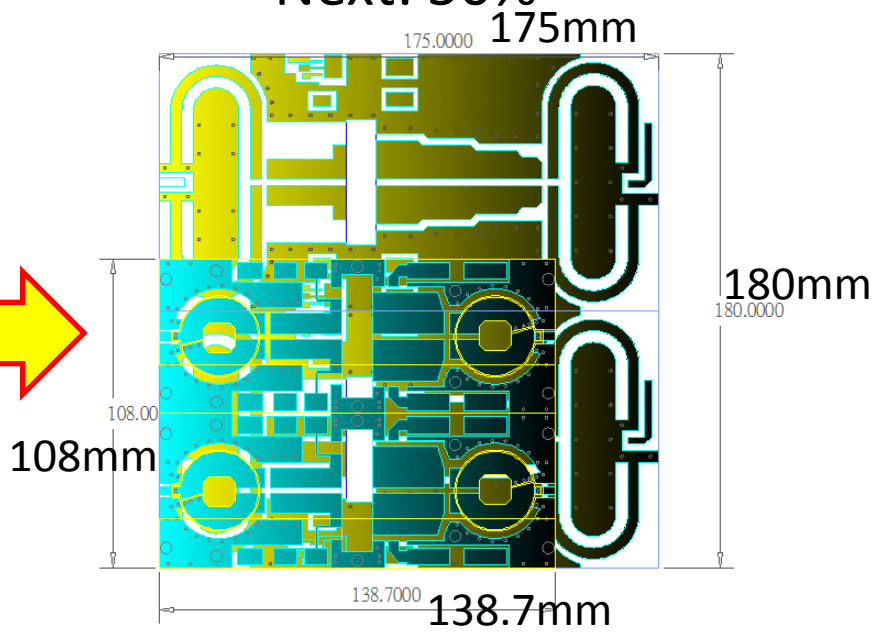
Compact dual chip SSPA module using planar balun

- SSPA size reduction by the compact planar balun
- 50% area saving is applicable

Present: 30%

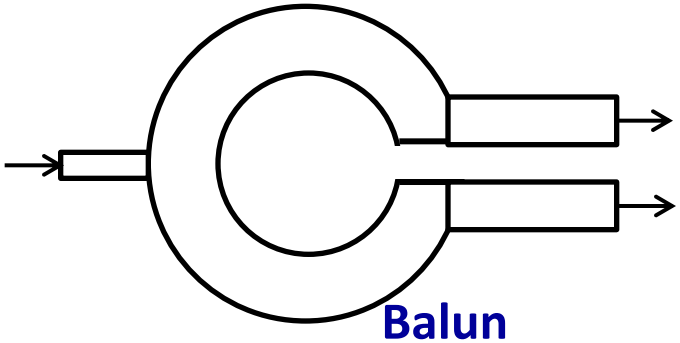


Next: 50%

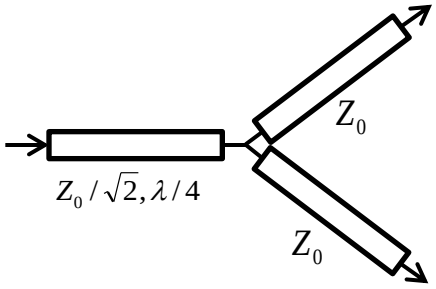


Planar power splitting/combining methods

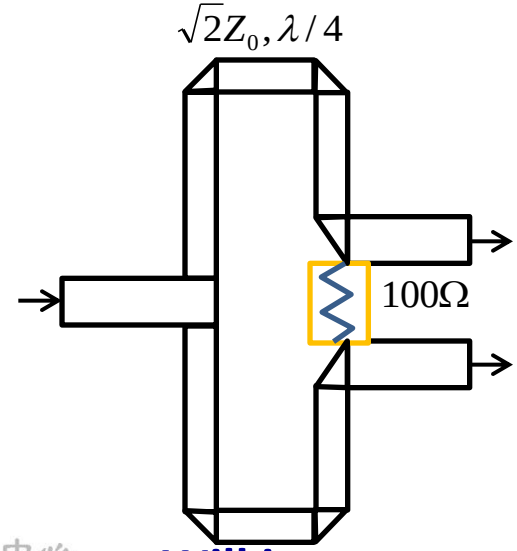
- Four methods are chosen:
  - Y-junction power divider/combiner
  - Wilkinson power divider/combiner
  - Gysel power divider/combiner
  - Balun power divider/combiner



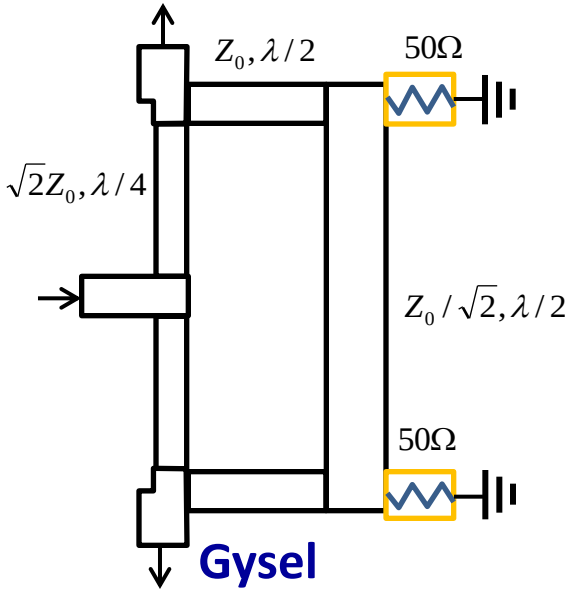
Balun



Y-junction



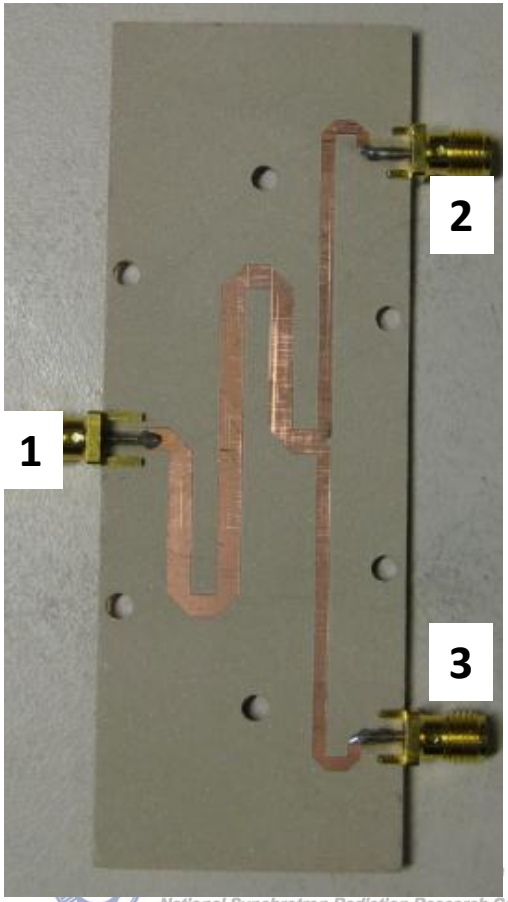
Wilkinson

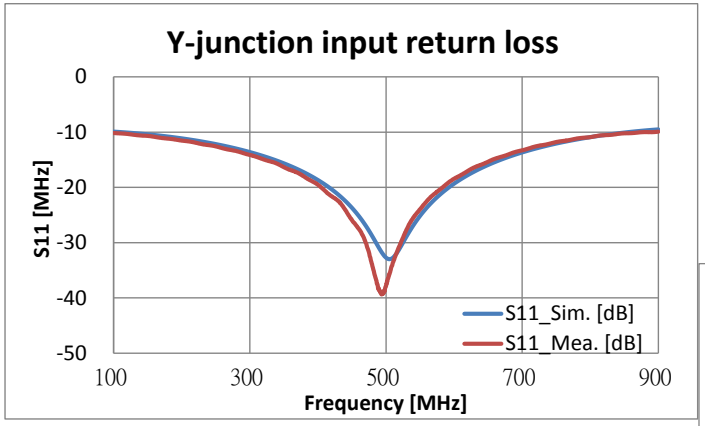


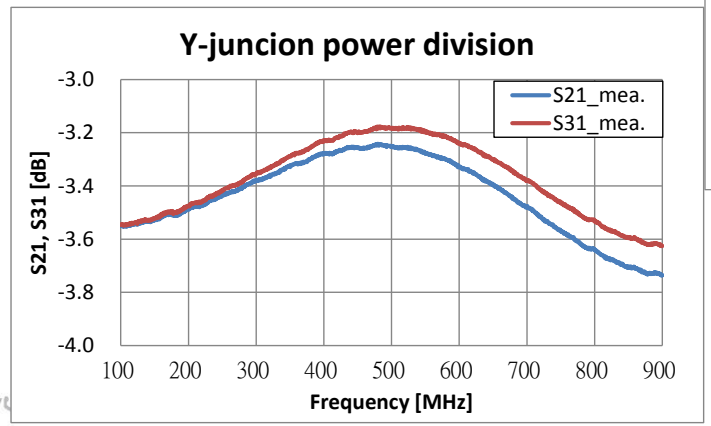
Gysel

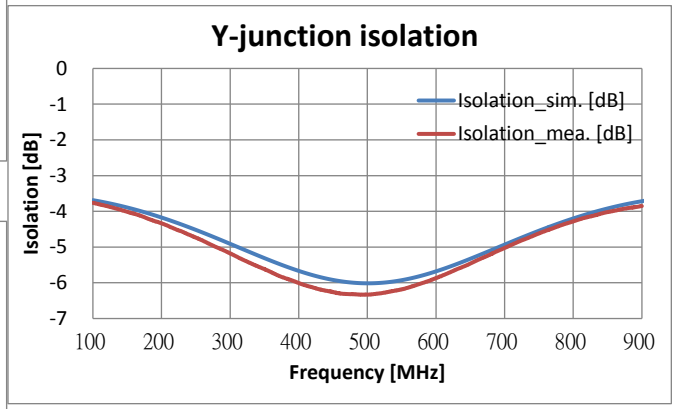
Planar combiners (1)

- Y-junction two-way power divider/combiner



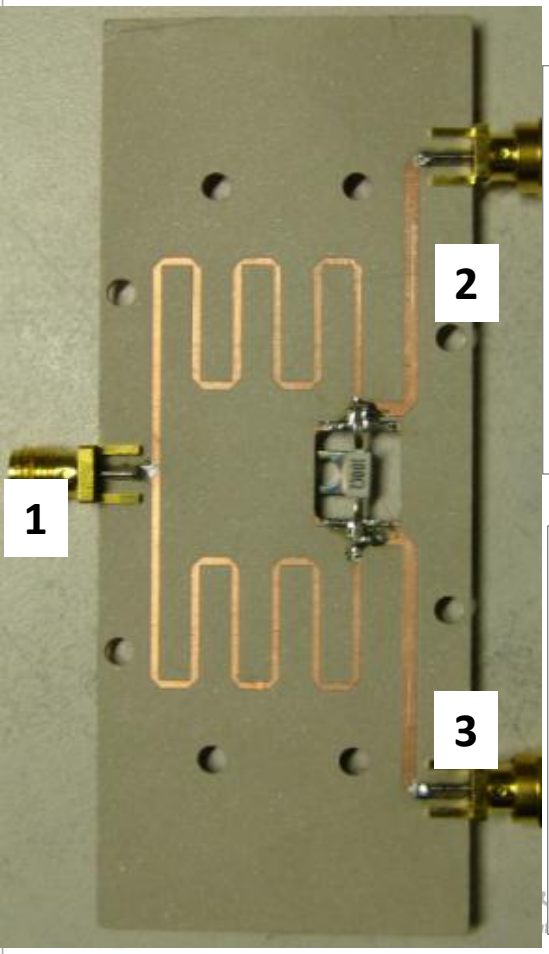


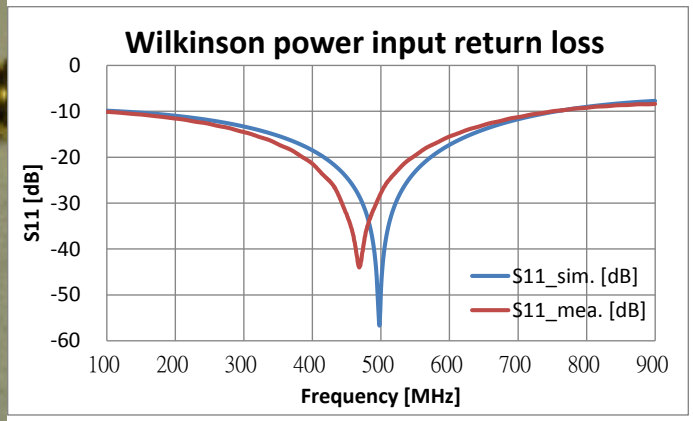


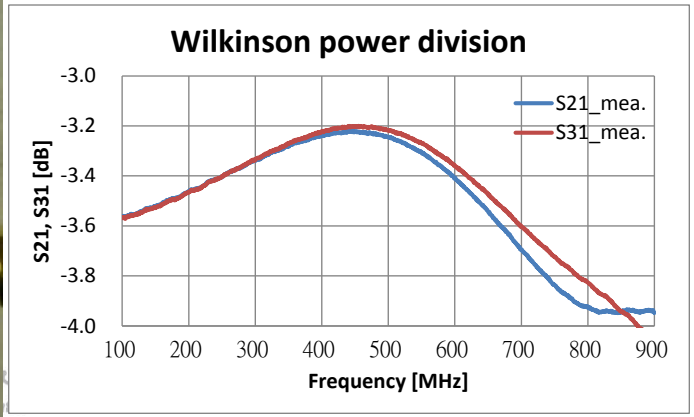


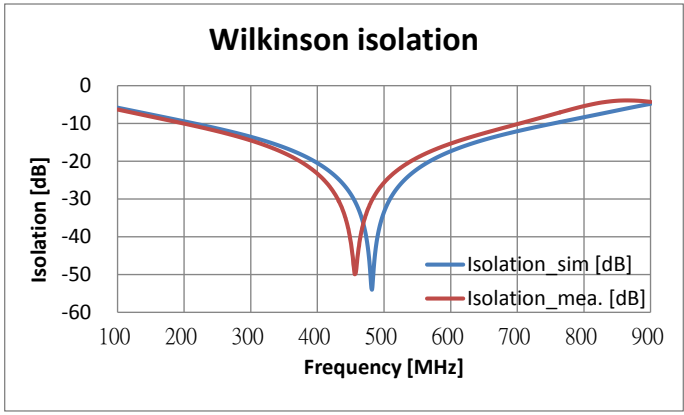
Planar combiners (2)

- Wilkinson two-way power divider/combiner



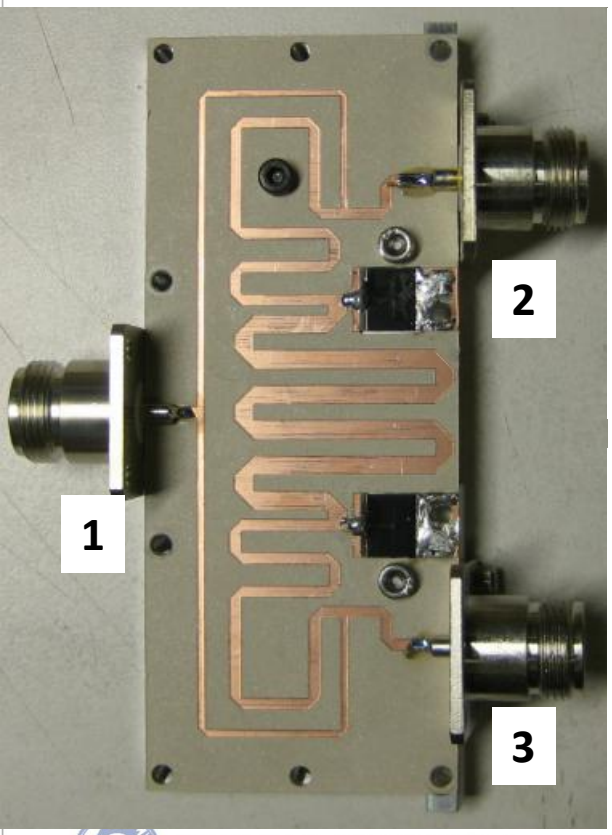


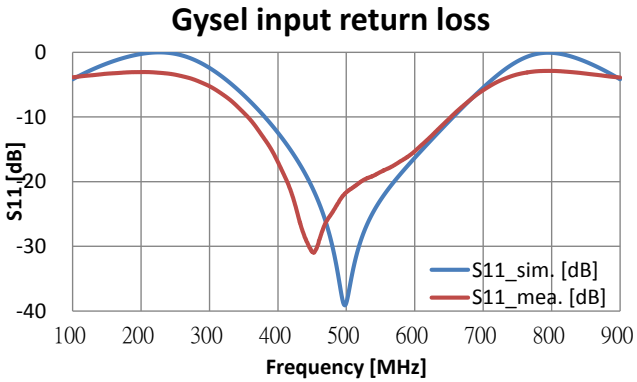


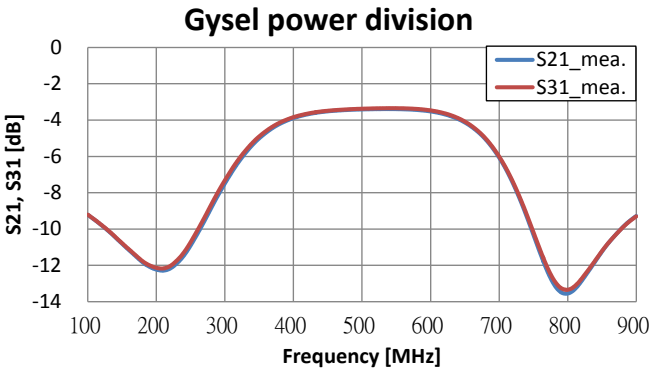


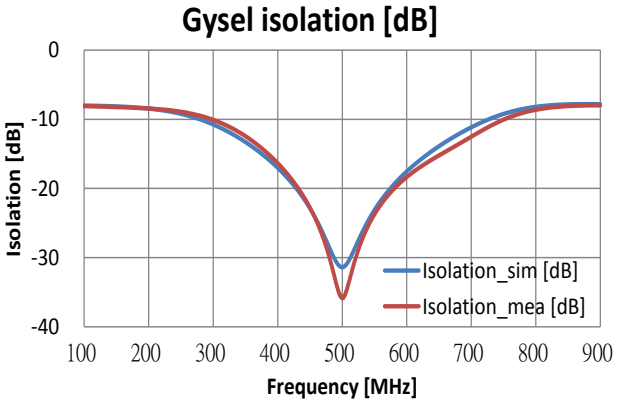
Planar combiners (3)

- Gysel power two-way divider/combiner



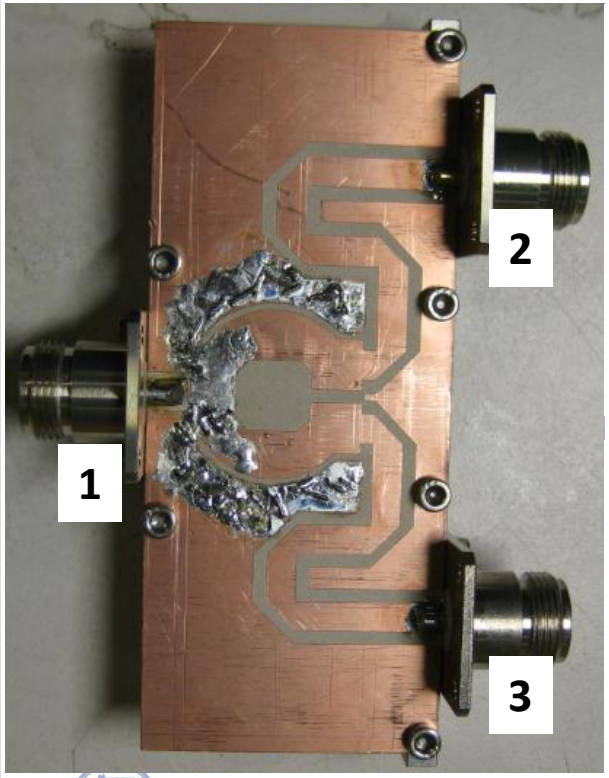


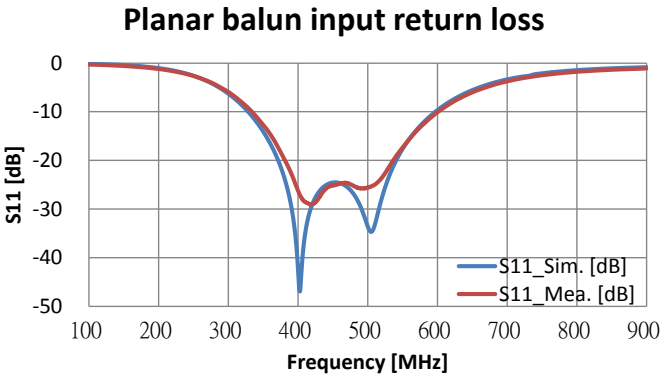


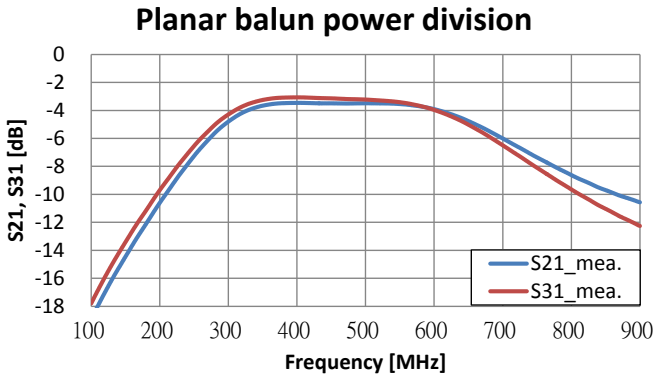


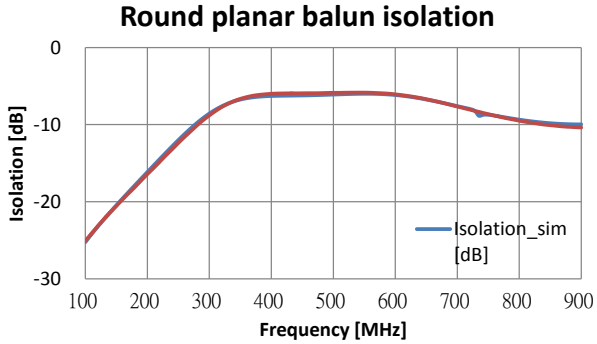
Planar combiners (4)

- Planar balun two-way power divider/combiner





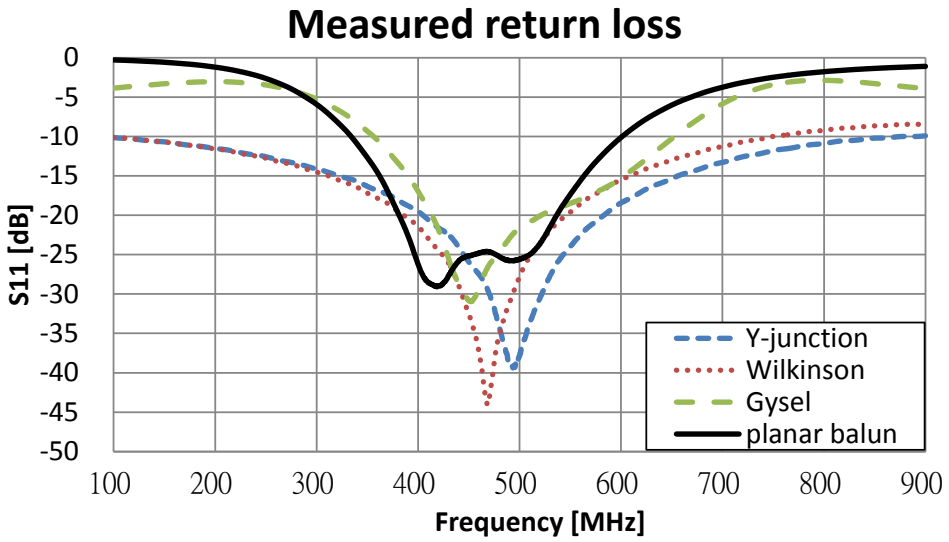


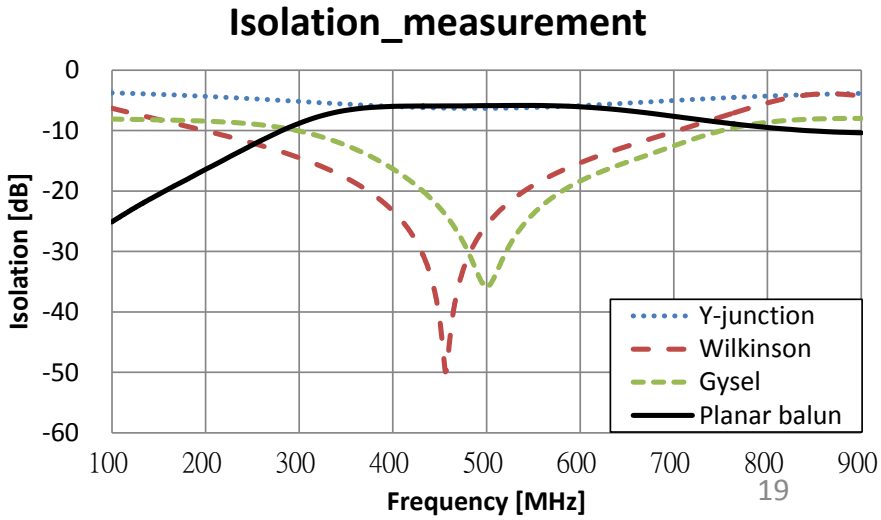


Summary of above planar splitters/combiners

- Bandwidth of S11 and isolation

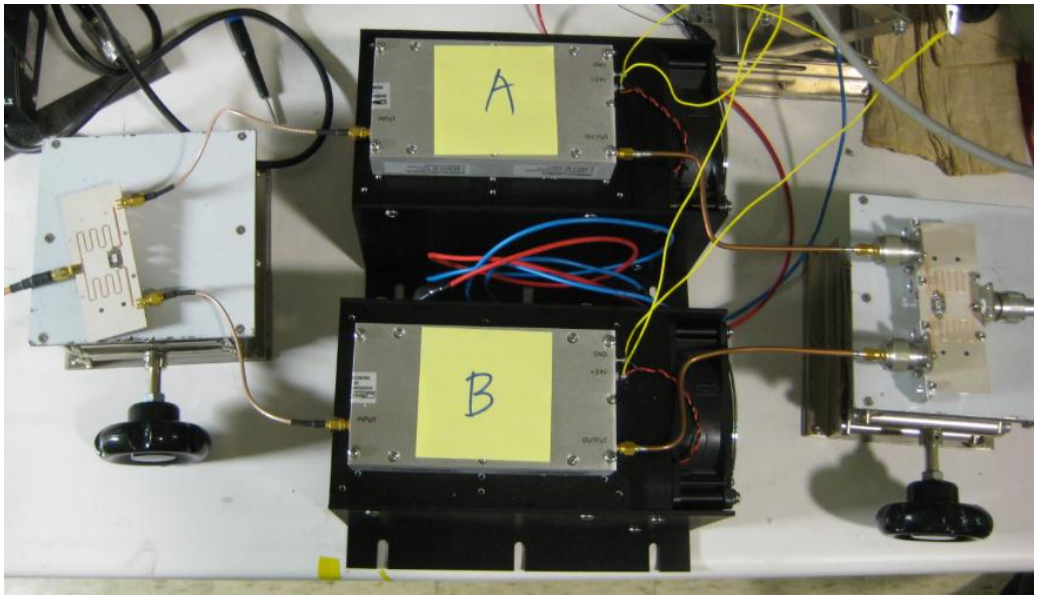
Type	Y-junction	Wilkinson	Gysel	Planar balun
S11 bandwidth [MHz]	178	160	107	155
Isolation@500MHz[dB]	6.33	25.68	35.84	5.87

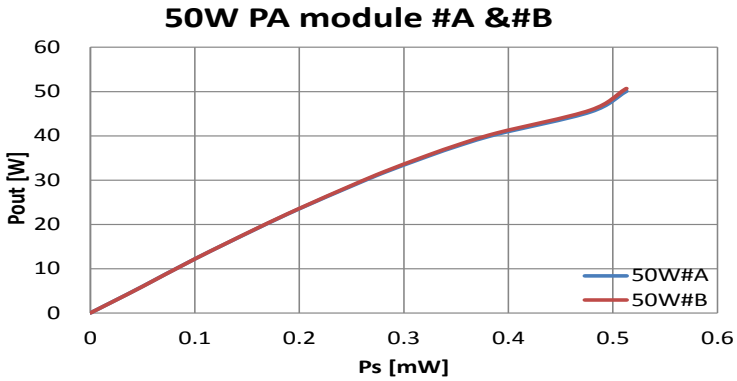


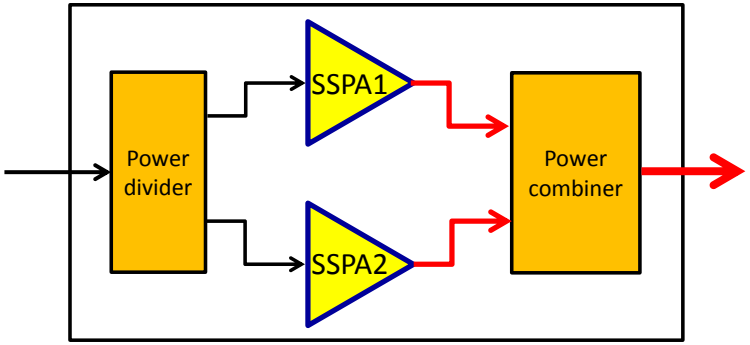


Combining efficiency investigation (1)

- Adopting two identical 50W PA for power combination
- The setup is as below:



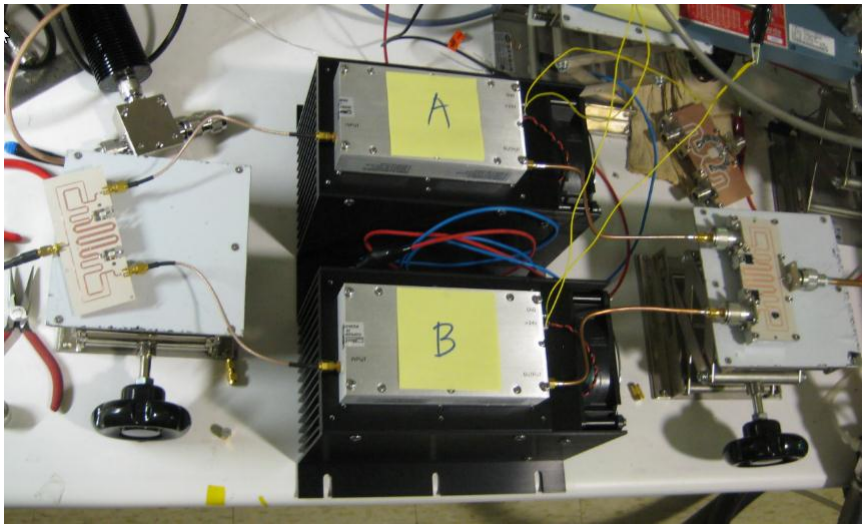




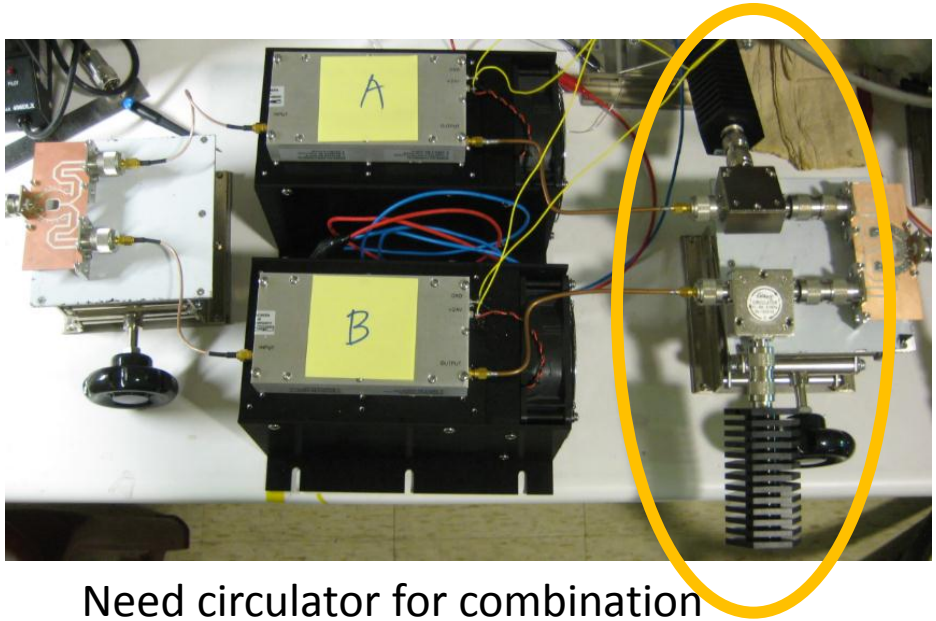
- Combination efficiency can be found by driving power and output power

Combining efficiency investigation (2)

- Y-junction and balance combiner need isolators
- Wilkinson and Gysel do not
- Isolators will bring additional insertion loss



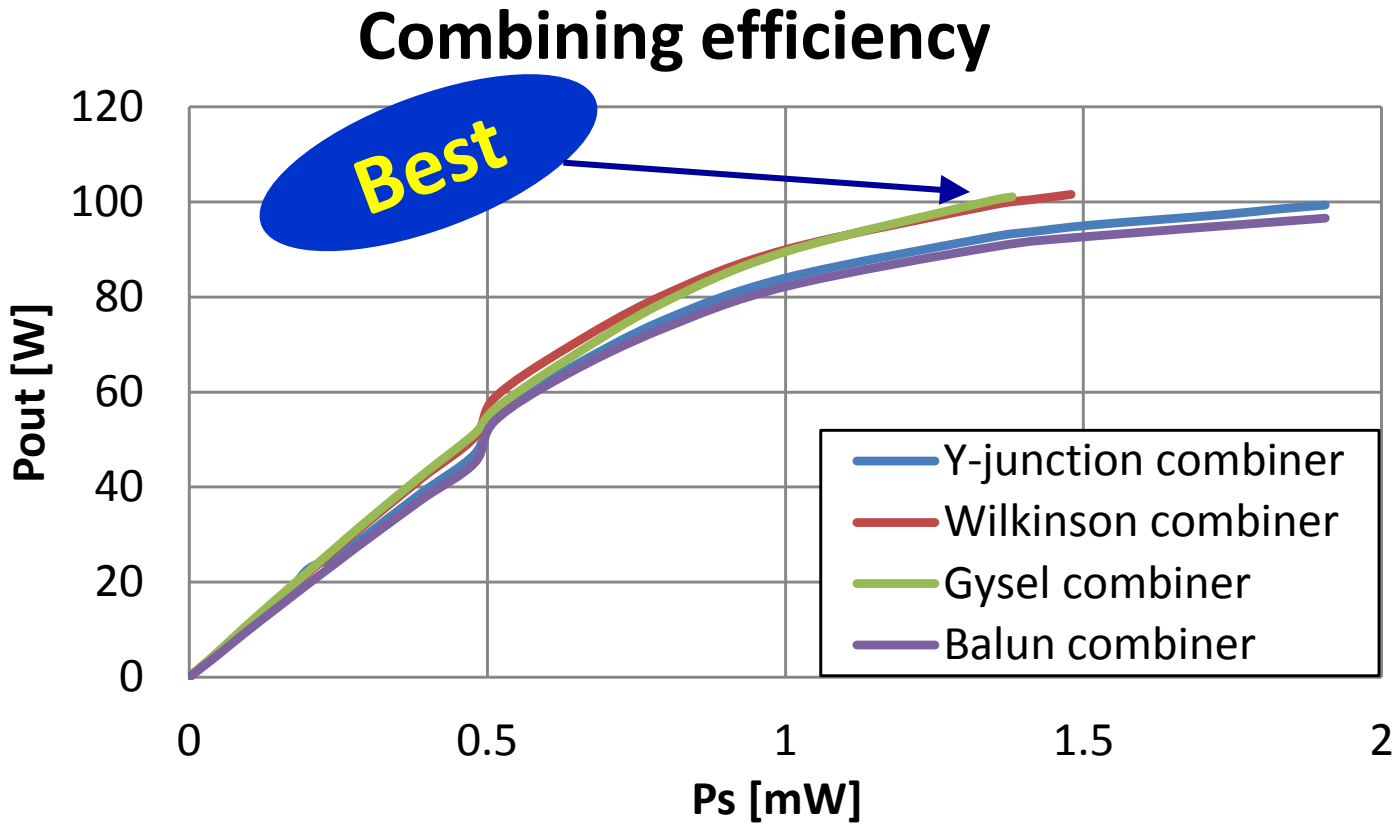
No circulator for combination



Need circulator for combination

Combining efficiency investigation (3)

- Combining efficiency: P_{in}=? for the same P_{out}
- Gysel combiner reach 100W with minimum input power



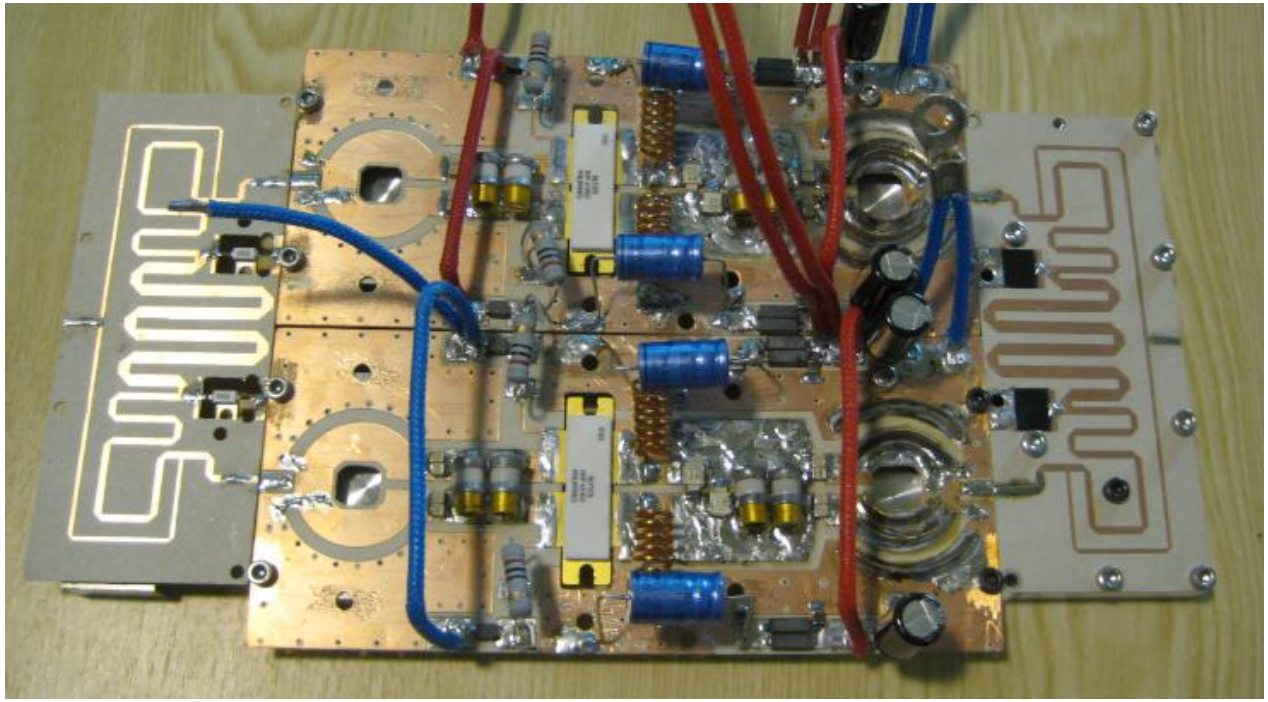
Performance comparison of the planar dividers/combiners

Although the bandwidth of Gysel combiner is narrow, it brings the best efficiency for power combination

Planar power two way divider/combiner type	Bandwidth [MHz]	Additional component	Special cooling	Efficiency in actual combination
Y-junction	178	Two circulators	Bottom cooling	3rd
Wilkinson	160	One 100Ohm resistor	Bottom cooling	2nd
Gysel	107	Two 50Ohm resistor	Bottom cooling	Best
Planar balun	155	Two circulators	Air cooling and bottom cooling	4th

Dual chip combination concept

- The cooling structure for high power test is under construction



Conclusion

- New planar balun design with better cooling
- Compact SSPA and dual chip in single module: planar balun and combiner
- Gysel power divider/splitter has best combining efficiency without circulators

Thank you for your attention