IFAST Meeting / 2021 11 15

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WP13: Task 13.3 -New RF Amplifiers based on GaN Semiconductors

- The task 13.3 in IFAST project is supporting the R&D activity on GaN transistors at the FREIA laboratory. Our objective is to demonstrate the advantages and feasibility of this technology for high power and high efficiency amplifiers, as the next building blocks of larger amplifiers for particle accelerators.
- We have undertaken the development of a radio frequency amplifier at 750 MHz delivering around 1 kilowatt, with all specifications leading to an improvement of the state of the art.

It takes a handful of transistors (200) to replace one tetrode of 200 kW

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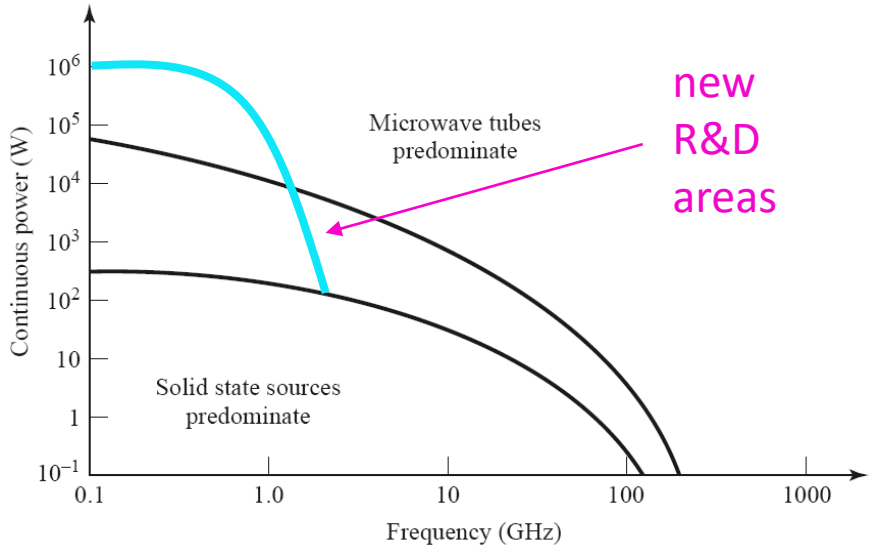
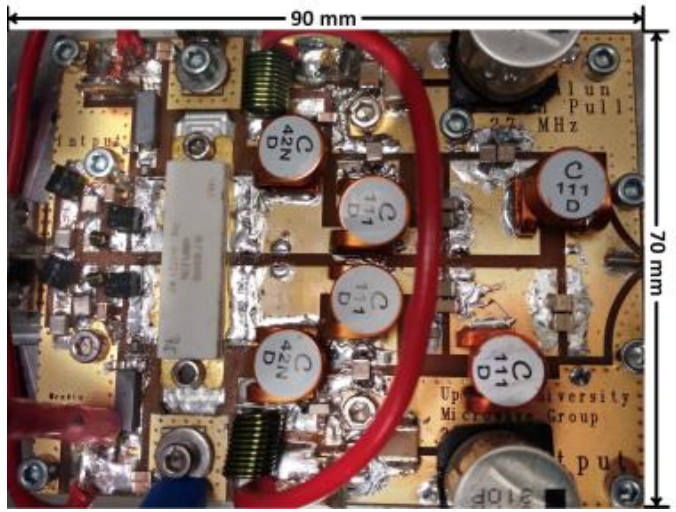


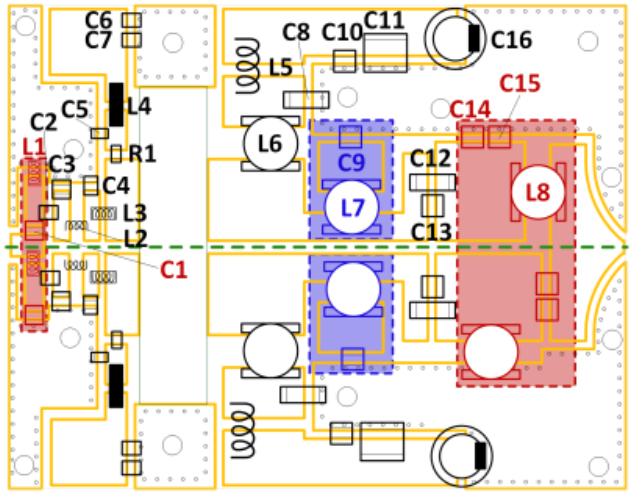
WP13: Task 13.3 -New RF Amplifiers based on GaN Semiconductors - Specifications

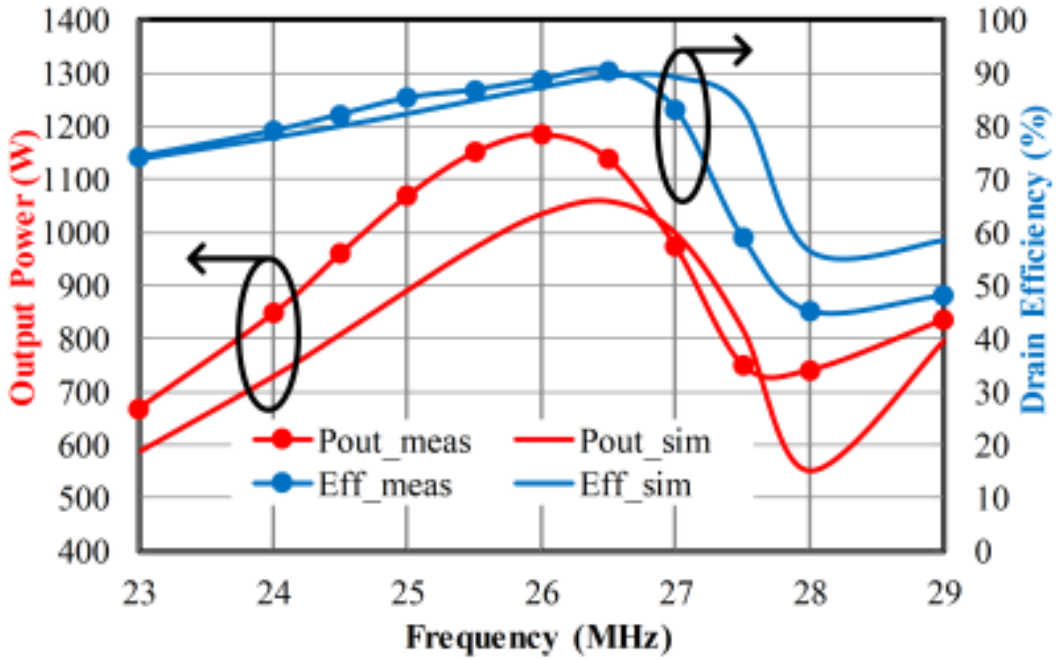
- Realisation and evaluation of a new RF amplifier based on GaN semiconductors at kilowatt level.
- Identification of the advantages of GaN semiconductor technology for accelerator RF amplifiers.
- Specifications
  - 1000 W combined output power
  - 750 MHz
  - High efficiency >70%
  - High breakdown voltage
  - GaN transistors from e.g. Ampleon, Qorvo, Cree - Wolfspeed, NXP Semiconductors, Infineon, etc.
- D13.3: GaN RF amplifier module at kW level.

Example of RF amplifiers developed at the FREIA laboratory Uppsala University, Technological Platform in AMICI.

SSPA at 27 MHz – 1kW efficiency of 90% (former results) (non linear class E – lumped push-pull)

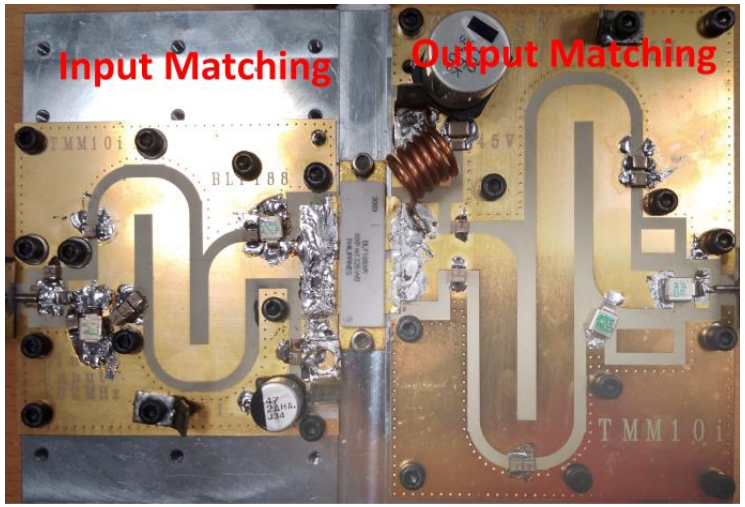


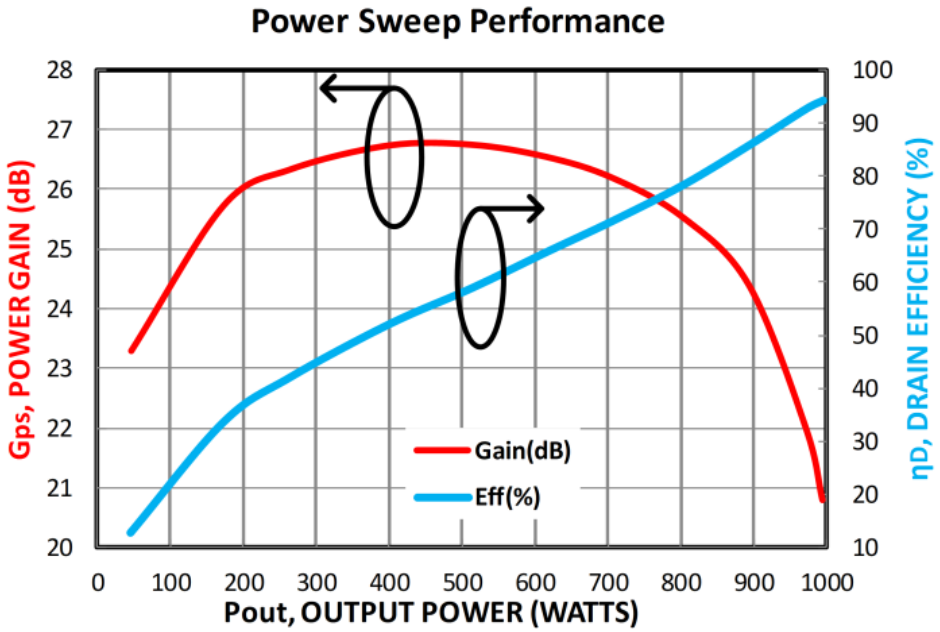


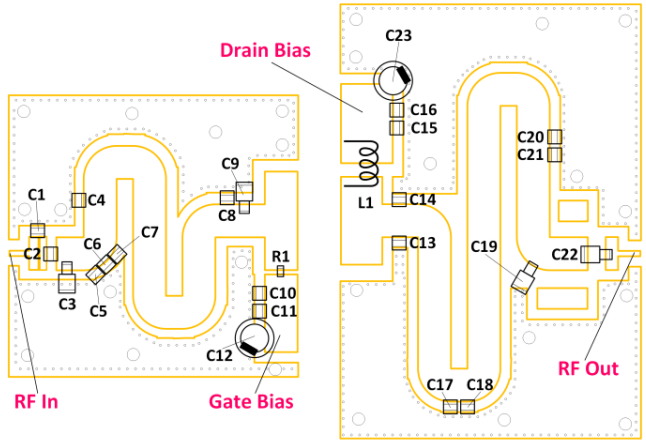


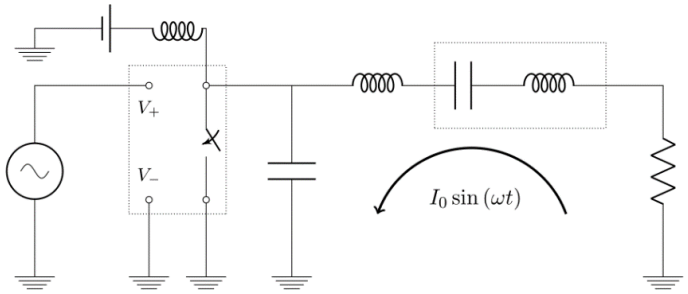
R. Tong and D. Dancila, “Compact and Highly Efficient Lumped Push-pull Power Amplifier at Kilowatt level with Quasi-static Drain Supply Modulation” in IEEE Transactions on Microwave Theory and Techniques, 2020.

SSPA class E at 100 MHz – 1kW efficiency of 93% (former results)



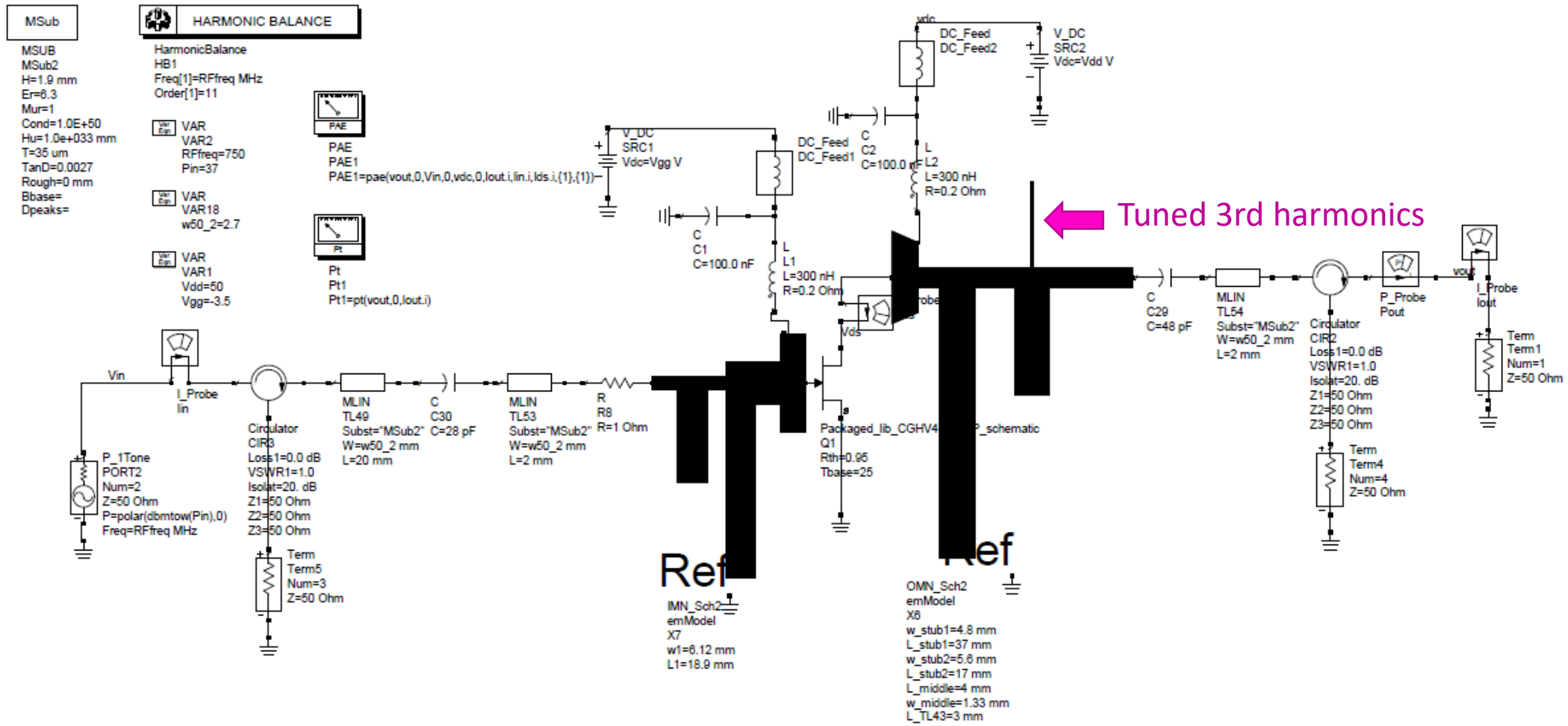






R. Tong, O. Bengtsson, A. Bäcklund and D. Dancila, "*Highly Efficient Kilowatt Power Amplifier Module as RF Source for Radioisotope Production Cyclotron System", IEEE Journal of Microwaves* 2020.

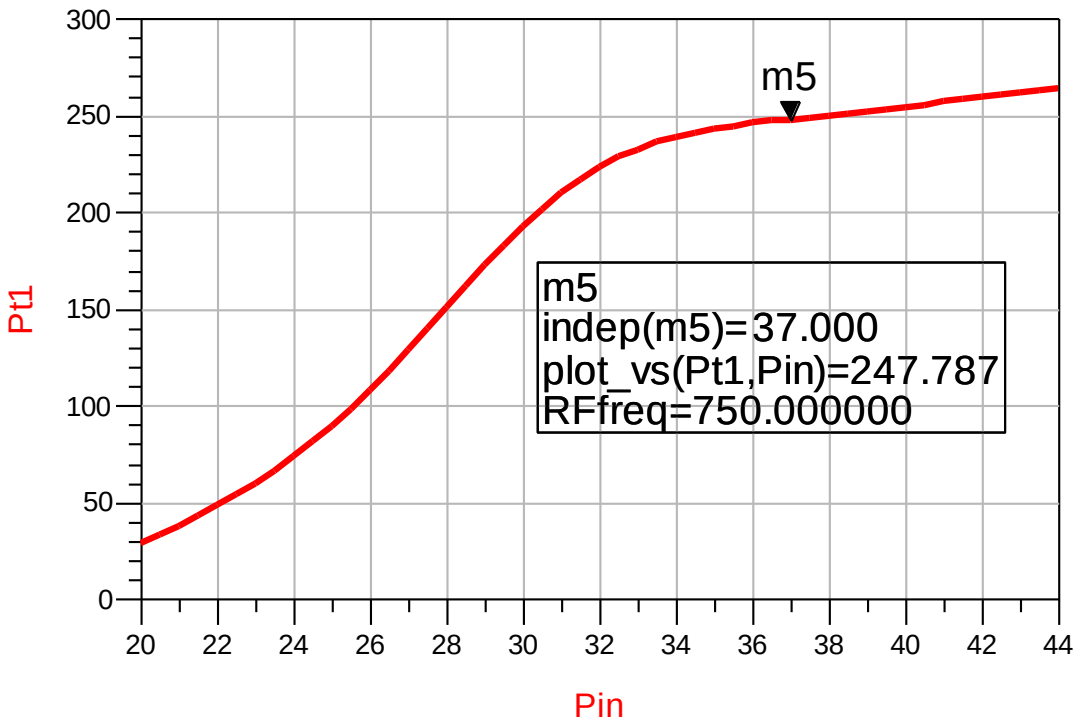
EM simulation-Optimized parameters - 750 MHz



The maximum efficiency and output power are easily shifted by varying stub length, and so the practical implementation of the PA will meet the targeted specifications.

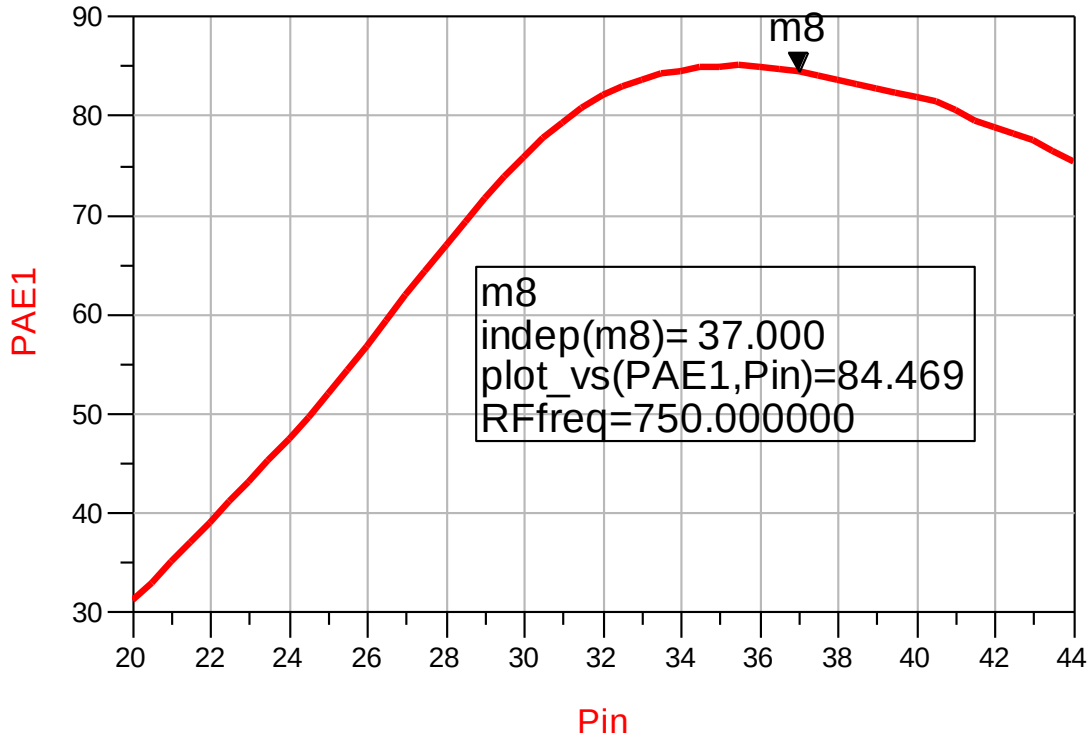
Simulation results of the GaN amplifier at 750 MHz

Output power versus input power



Pout=247 W (54 dBm) @ Pin=37 dBm

Power added Efficiency (PAE) versus input power



PAE = 84% @ Pin=37 dBm

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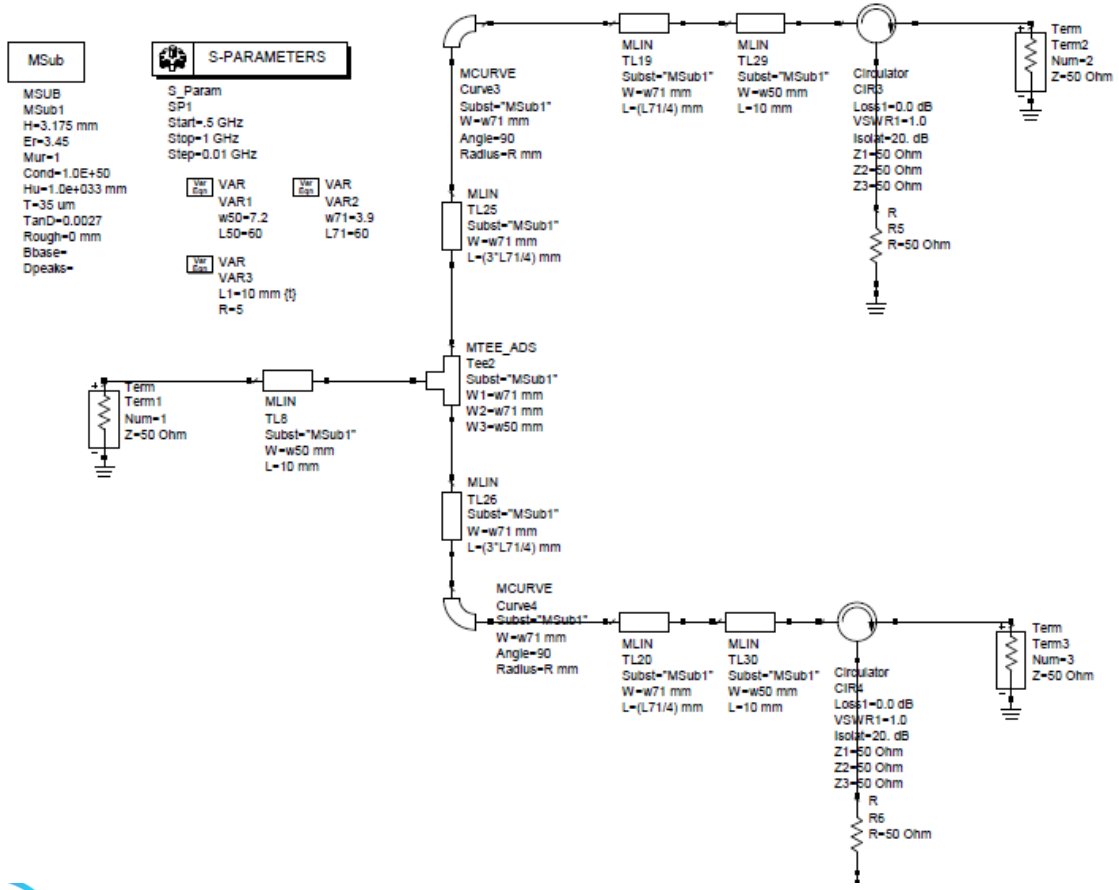
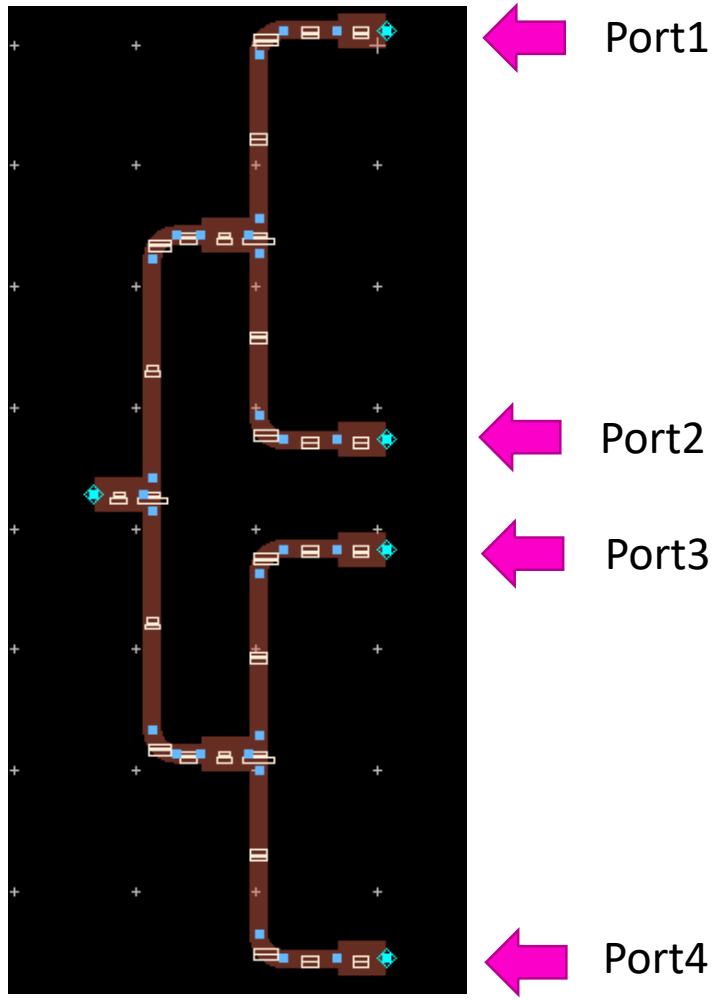
Planner Wilkinson power combiner 2:1 and 4:1





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IFAST is improving the State of the Art

No.	Operating class	F_{min} (MHz)	F_{max} (MHz)	Operation Voltage (V)	P_{out} (dBm)	Gain (dB)	PAE_{min} (%)	Chip	F_{max} of chip (MHz)	V_{DS} max	Technology	Package	Institution
2020[8]	Class E	400.8	-	145	63.6	22	70	-	-	500	GaN	Die	Integra Tech. - CA
2018[9]	Class E	680	750	28	47	-	80	CGH35030F	3900	120	GaN	packaged	U. of Cantabria
2018[10]	Class E	100	-	50	60.8	-	82	BLF188XR	600	135	LDMOS	packaged	FREIA – Uppsala U.
2017[11]	Harmonic tuned	420	450	75	60	40 (With Two stage)	75	-	-	-	GaN	Packaged	Integra Tech. – CA
2017[12]	Class E	670	900	28	44.7	-	70	CGH35030F	3900	120	GaN	packaged	U. of Cantabria
2016[13]	Class F	704	-	-	58	-	79	-	-	-	GaN	packaged	Green Mountain Radio Research
2016[14]	Class F	550	950	28	40	15	75	CGH40010F	4000	120	GaN	packaged	U. of Calgary
2011[15]	Class F	550	1100	28	40	10	74	CGH40010F	4000	120	GaN	packaged	Cardiff U.

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Pout = 54 dBm (60 dBm with combiner) / PAE = 84% @ 750 MHz

Overall contribution to task 13

- This Task 13.3 is an excellent opportunity to develop further our competence, at the FREIA Laboratory, as an AMICI associated facility. At FREIA, we are now producing a 352 MHz, 400 kW, 14 Hz pulsed SSPA station to be finished by end 2022. This could be an option for the ESS RF power sources.
- Furthermore, we have the ambitious goal to train the new generation of scientists and engineers, via the newly started Traineeship Programme. This would support the transfer of knowledge between laboratories and industry and enhance the collaboration possibilities with industrial partners and other technology stakeholders.
- On example reaching out, is the ongoing discussion on establishing a collaboration with the MINERVA/MYRRHA project from Belgium. In this project a similar amplifier module operating at 704 MHz would need to be developed. We plan also to develop further our testing facilities for modules and full stations, which is fully aligned with the needs for the MYRRHA project and FREIA's laboratory's development strategy.

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Thanks and questions

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