# High-Linearity High-Power GaN Active Circulators

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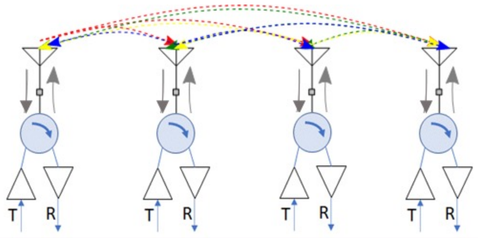
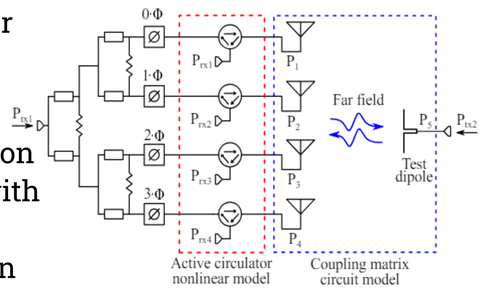
## BACKGROUND

- Off-the-shelf circulators use ferrites / external magnets → Bulky, cannot be integrated with other components
- Active MMIC circulator allow for smaller footprint, gain and integration with the front-end
- GaN technologies have higher power handling, and better linearity

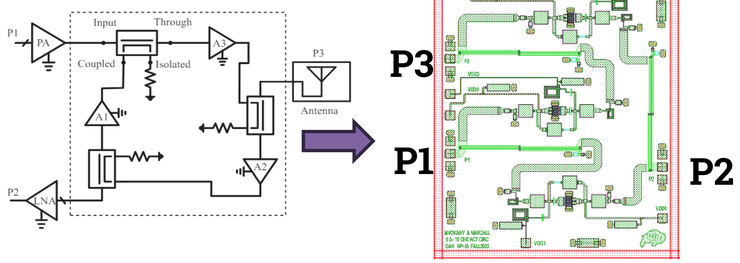



## RESEARCH QUESTIONS

- Using GaN technologies, is it possible to improve power handling and linearity of MMIC active circulator?
- Can we eliminate distortion in the rx path observed with GaAs circulator, without compromising isolation in GaN ?




## METHODS AND MATERIALS




- Use of the non-reciprocity of GaN transistors to design a high-linearity high power active circulator
- 3 resistive-feedback, gain-matched amplifiers and 3 asymmetric Lange couplers are connected in a ring topology to achieve circulation

## RESULTS

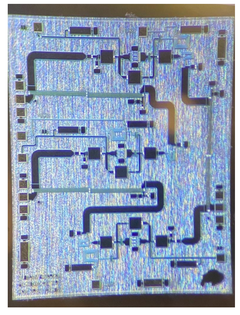
**Accomplished:**

- MMIC Circulators designed in both GaAs and GaN WIN semiconductors processes
- NP15 150 nm RF GaN-on-SiC technology through 40 GHz
- 6x75 um devices for both MMIC
- Comparison paper in progress

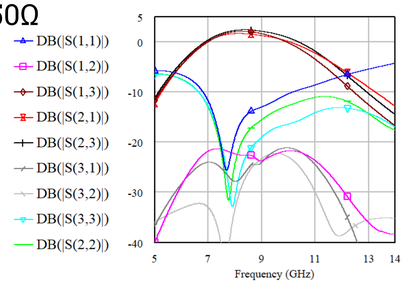
**Simulated performance:**

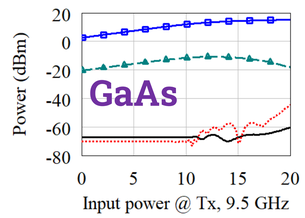
- EM simulated in 2.5D simulator AXIEM in Cadence Microwave Office
- Performance includes off-chip capacitors, bond wires and 50Ω loaded ports
- BW: 7 to 10 GHz
- Small signal IL 2.4 dB @ 8.5 GHz
- More than 20 dB of isolation across X-band

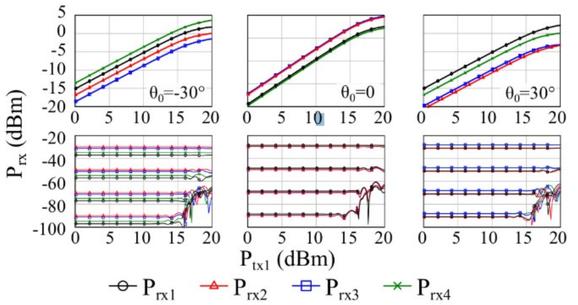
**Picture of MMIC die in GaN NP15 WIN process**

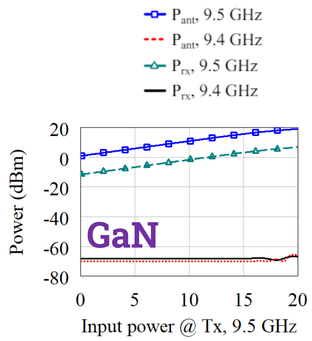


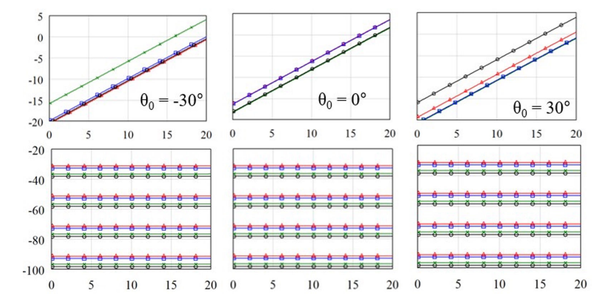
**Simulated S-parameters of GaN MMIC circulator**




## CONCLUSION AND DISCUSSION

**Conclusion and Discussion**

- A comparison between GaAs and GaN circulators in large signal shows higher linearity and higher power handling in GaN MMIC circulators
- In phased array environment, distortion in isolation observed starting at 15dBm in GaAs is remedied due to higher compression point in the GaN device

**Future work:**

- Investigate the effects of mismatched ports on isolation levels in GaN circulator
- Integration of tunable loads on packaged circulator.
- Compare GaAs and GaN latest designed MMIC circulators under large signal measurements

## ACKNOWLEDGEMENTS

This work has been supported in part through SpectrumX, the National Science Foundation (NSF). We thank WIN Semiconductors for providing the MMIC runs that enabled this work.

win SEMICONDUCTORS

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