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Large Signal Equivalent Circuit Modeling of AlGaN/GaN HEMTs

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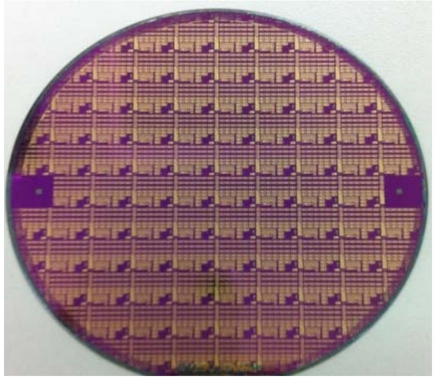
Advantages of AlGaN/GaN HEMTs

- High 2DEG
- High saturation drift velocity
- High breakdown voltage



power amplifier

important

large signal equivalent circuit model

Design and fabrication

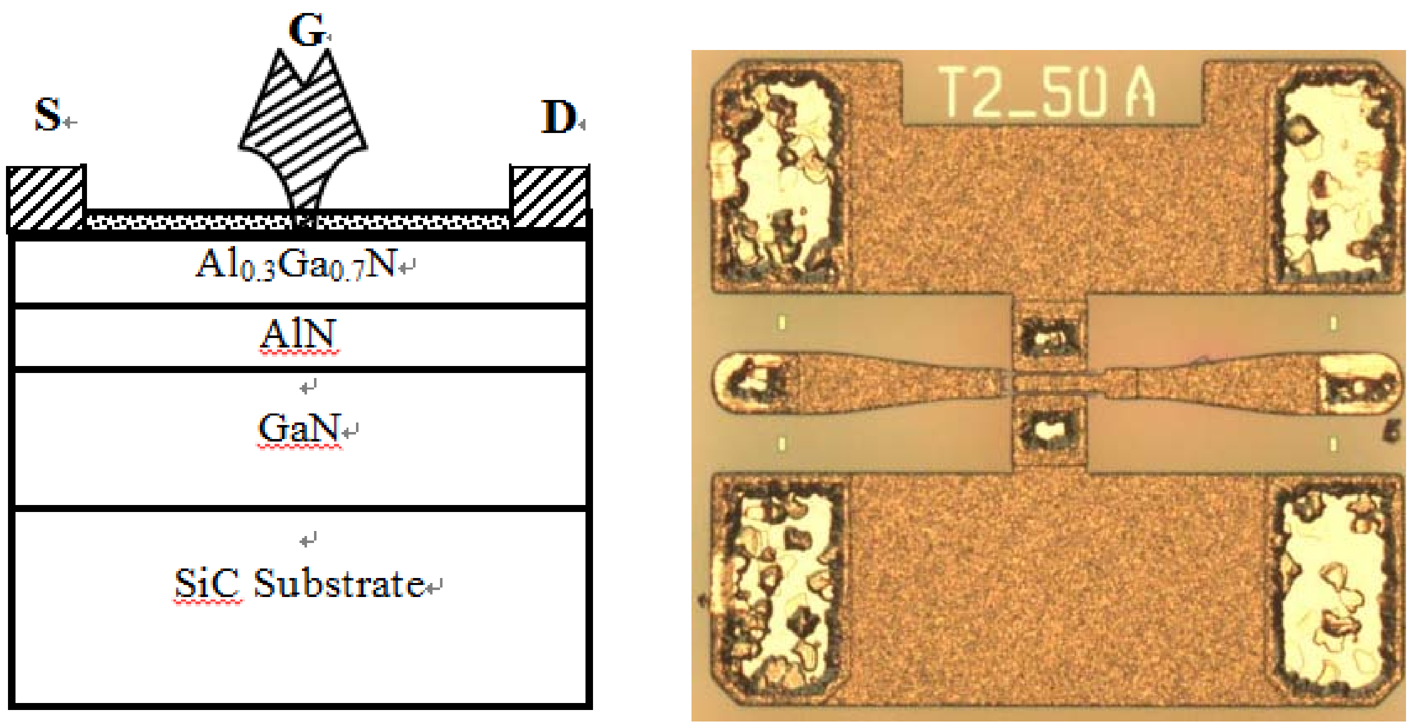


Fig.1. Cross section (left) and micrograph (right) of GaN HEMTs

We have completed fabrication of a 2*50um AlGaN/GaN HEMT with 0.1um gate-length and 2um source-drain distance in the paper.

Measurement system

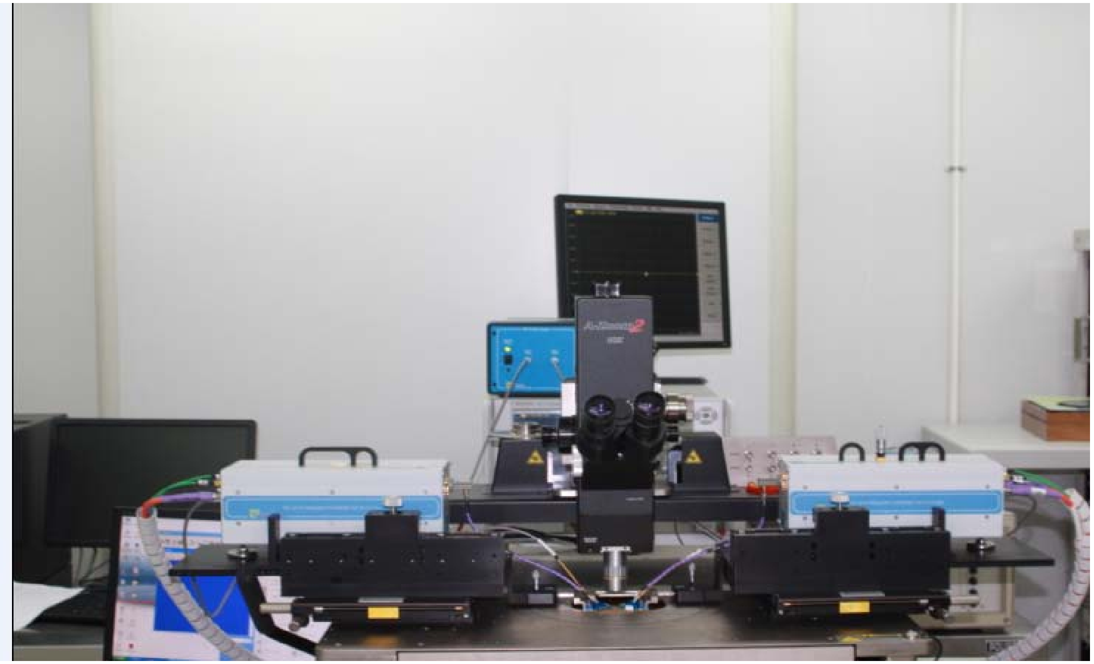
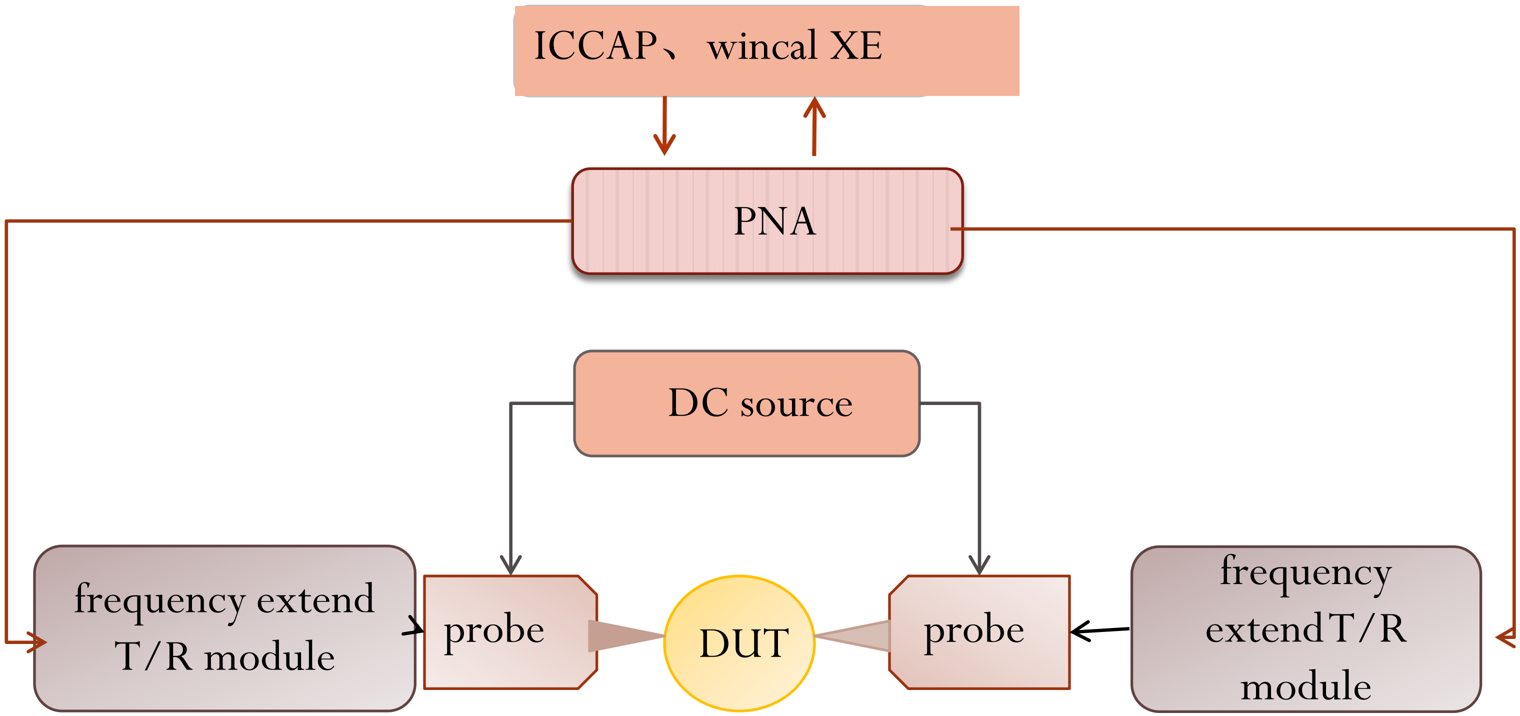


Fig.2.on-wafer measurement system

Measurement setup



wafer-probe station	Cascade	Summit 12000M
DC source	HP	4142B
PNA	Agilent	PNA-X N5247A
frequency extend T/R module	Farren	Fev-10-TR

Small signal model

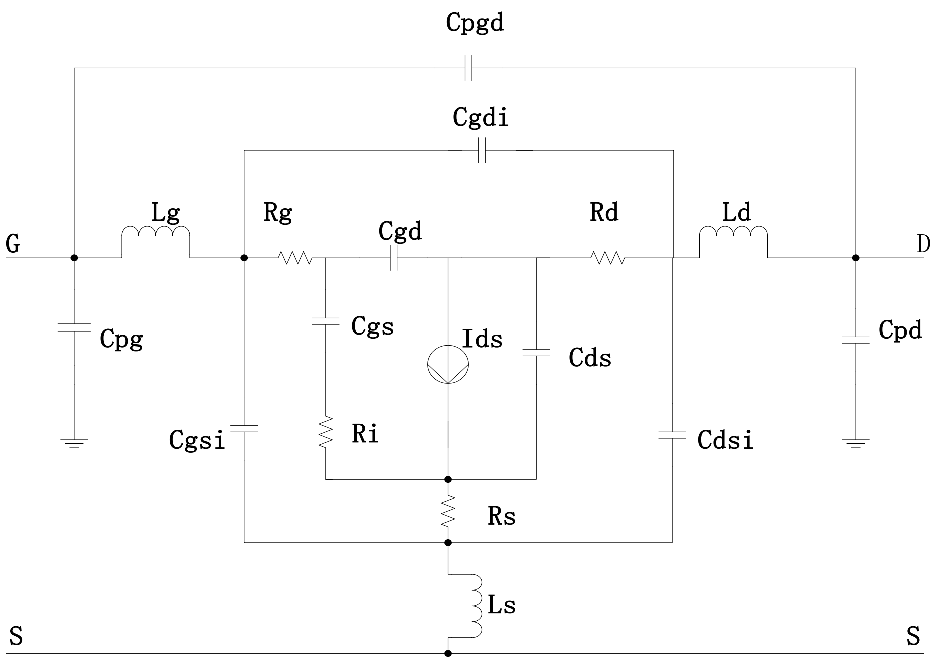


Fig.3. Small signal equivalent circuit model

Cpg,Cpd,Cpgd parasitic capacitances of PADs

open

Lg,Ld,Ls parasitic lead inductances

short

Rg,Rd,Rs parasitic resistances of HEMTs

reverse cuto
method

Cgsi,Cgdi and Cdsi are coupling capacitances between electrodes

Intrinsic parameters Cgs,Cgd,Cds,Ri,Gm and tau can be determined according to the Y-parameters.

Large signal model

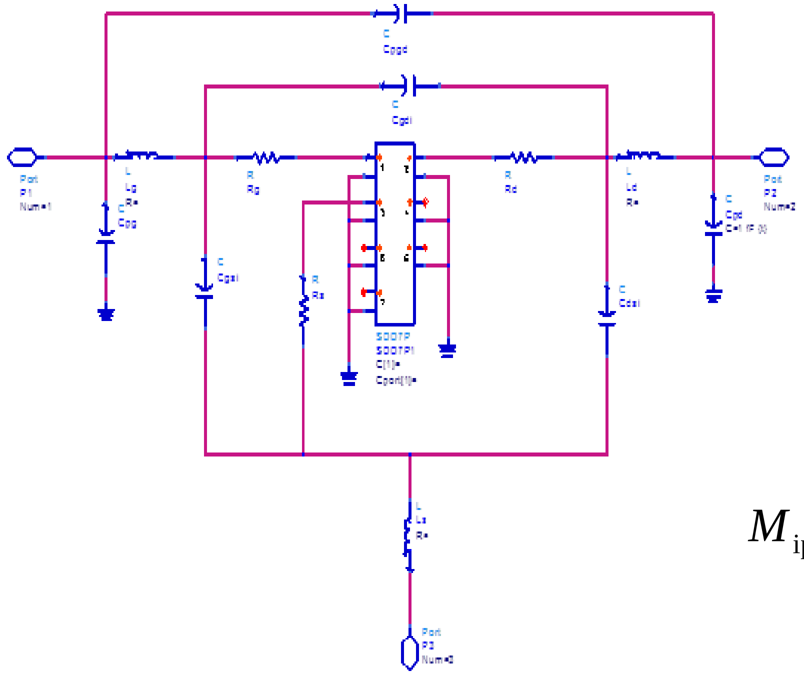


Fig.4. SDD large signal equivalent circuit model

$$I_{ds} = I_{pk} \times (1 + M_{ipk} \times \tanh(\psi)) \times \tanh(\alpha V_{ds})$$

$$\psi = P_{k1} \times (V_{gs} - V_{pk1}) + P_{k2} \times (V_{gs} - V_{pk2})^2 + P_{k3} \times (V_{gs} - V_{pk3})^3$$

$$P_{\mathrm{kn}} = K_{n0} + (K_{n0} + K_{n1} \times V_{ds}) \times \tanh(\alpha_n \times V_{ds})$$

n=1,2,3

$$M_{\mathrm{ipk}} = 1 + 0.5 \times (M_{\mathrm{ipk1}} - 1) \times (1 + \tanh(qm \times (V_{gs} - V_{gsm})))$$

The equivalent circuit model can be implemented nonlinear characteristics by using the 7 port SDD form

I. Angelov, K. Anderson, D. M. M.-P. Schreurs, D. P. Xiao, N. Rorsman, V. Desmaris, M. Sudow, and H. Zirath, "Large-signal modelling and comparison of AlGaN/GaN hemts and SiCMESFETs," inProc.Asia-PacificMicrow.Conf.,Dec.2006,pp.279–282.

IV Verification

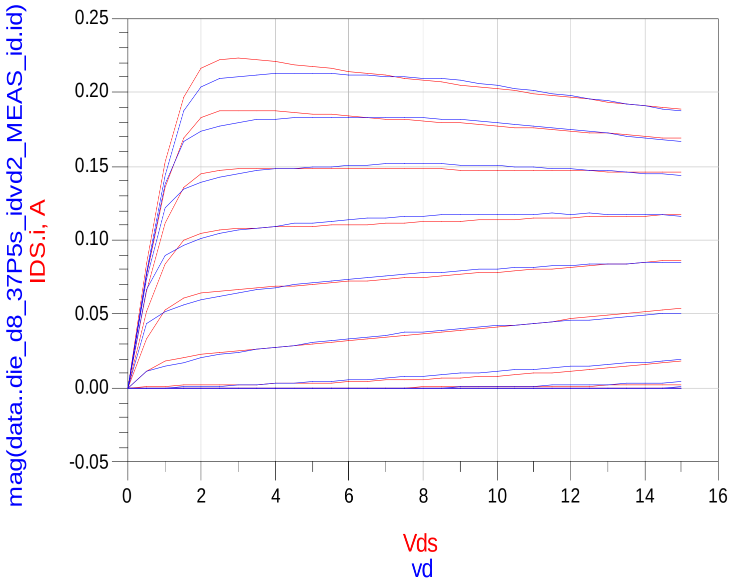


Fig.5. DC I-V characteristics

Comparision of IV measurements and simulation are shown in Fig.5.

Verification Tests with S-Parameters

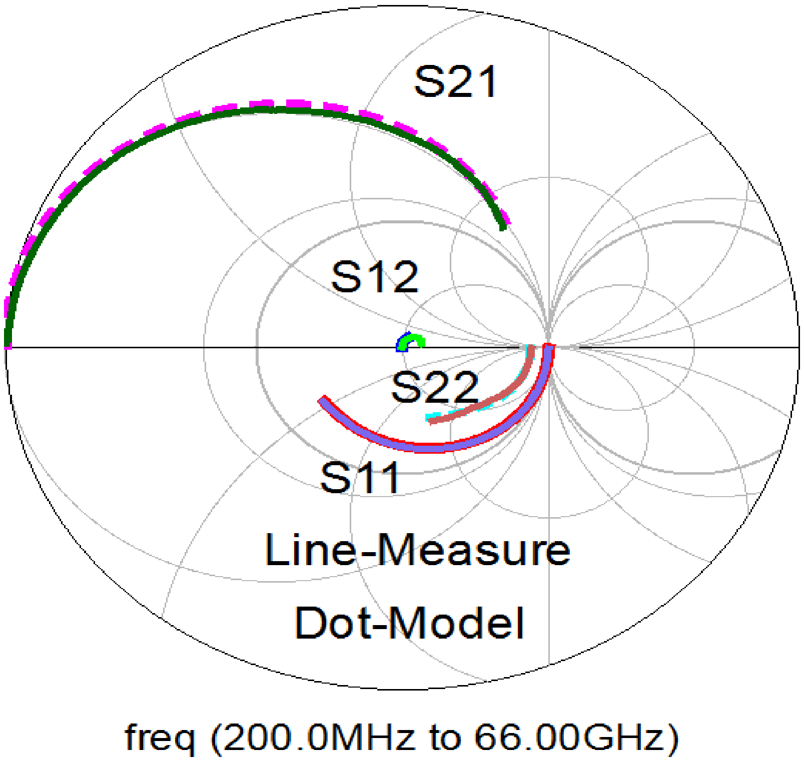


Fig.6. S-parameter fitting to 66GHz
(Vgs=-1V and Vds=20V)

The developed large-signal models were implemented in ADS and the S-parameters were simulated, then the received simulations were compared with measured S-parameters. The results of such comparison are shown in Fig.6.

Verfication test with Single-tone Stimuli

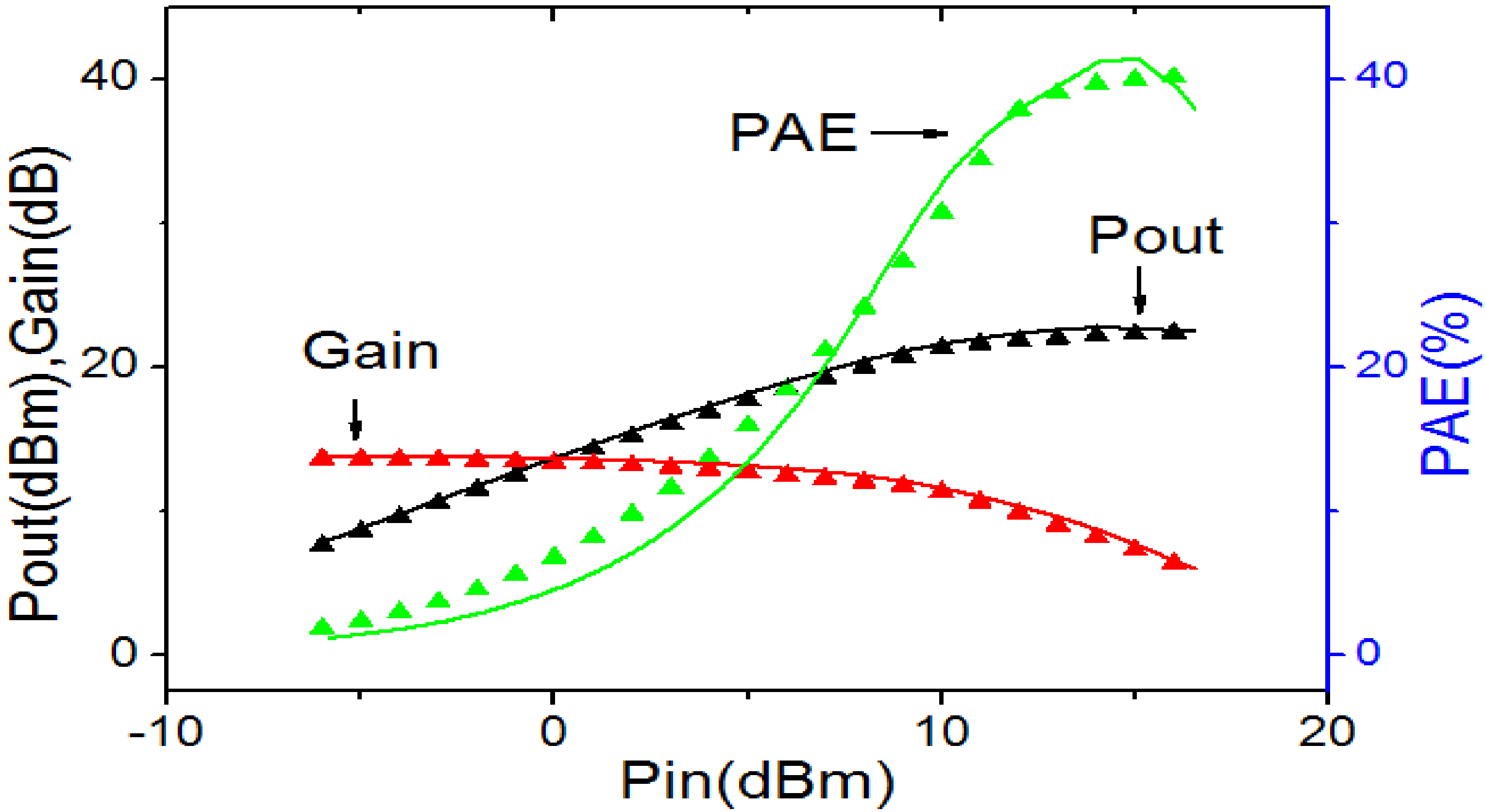


Fig.7. Large signal characteristics fitting at 18GHz
(Vgs=-1.4V and Vds=10V)

Single tone on wafer load-pull measurements at 18GHz is carried out for verification purposes.

CONCLUSION

- *A large signal equivalent circuit modeling of AlGaN/GaN HEMTs is presented in this paper.*
- *The IV characteristics and* S-parameter from 0.2 to 66GHz *are verified*.
- Single tone on wafer load-pull measurements at 18GHz is also carried out for verification purposes.

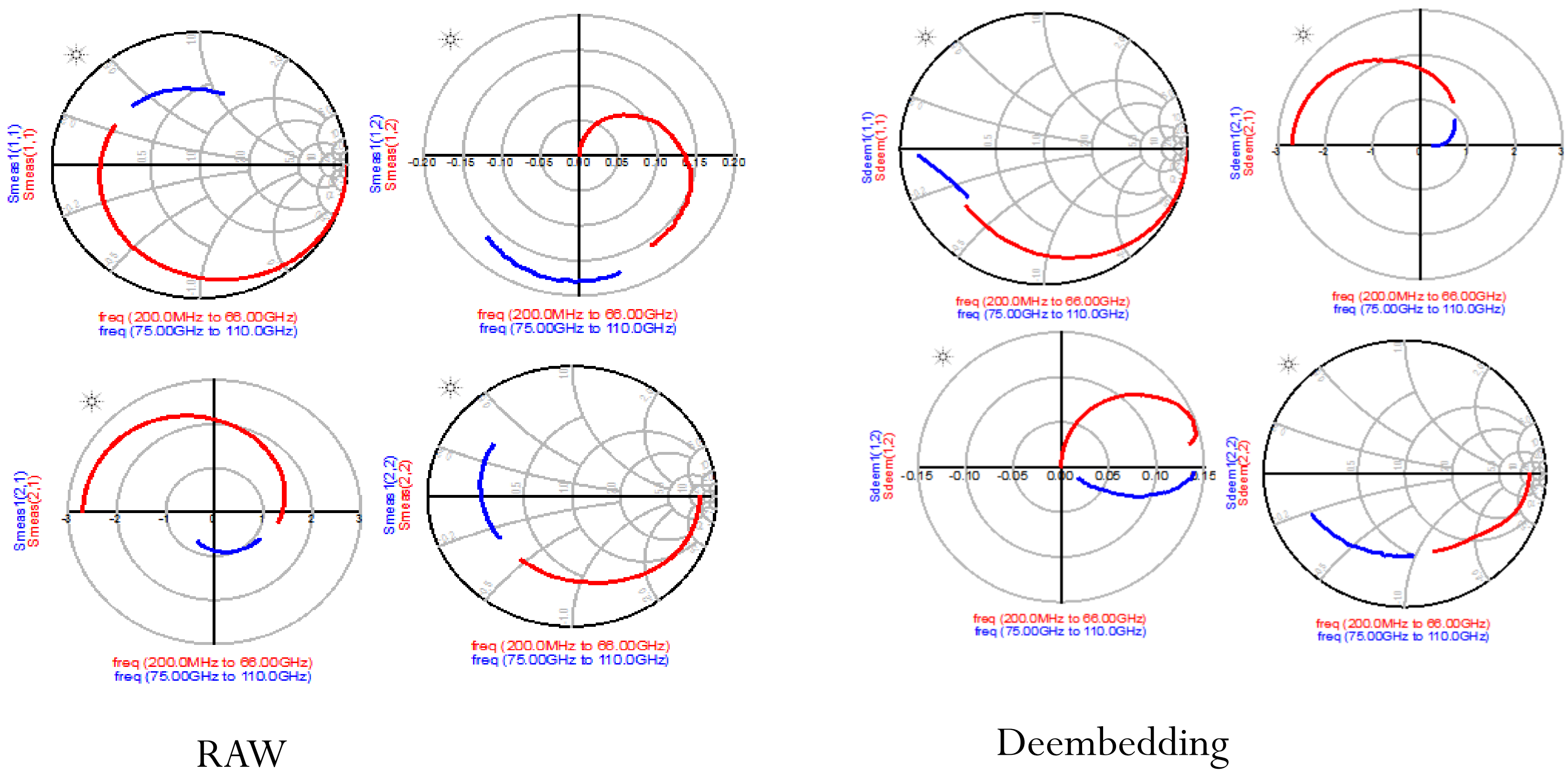


Fig.8. Measurement result to 110GHz

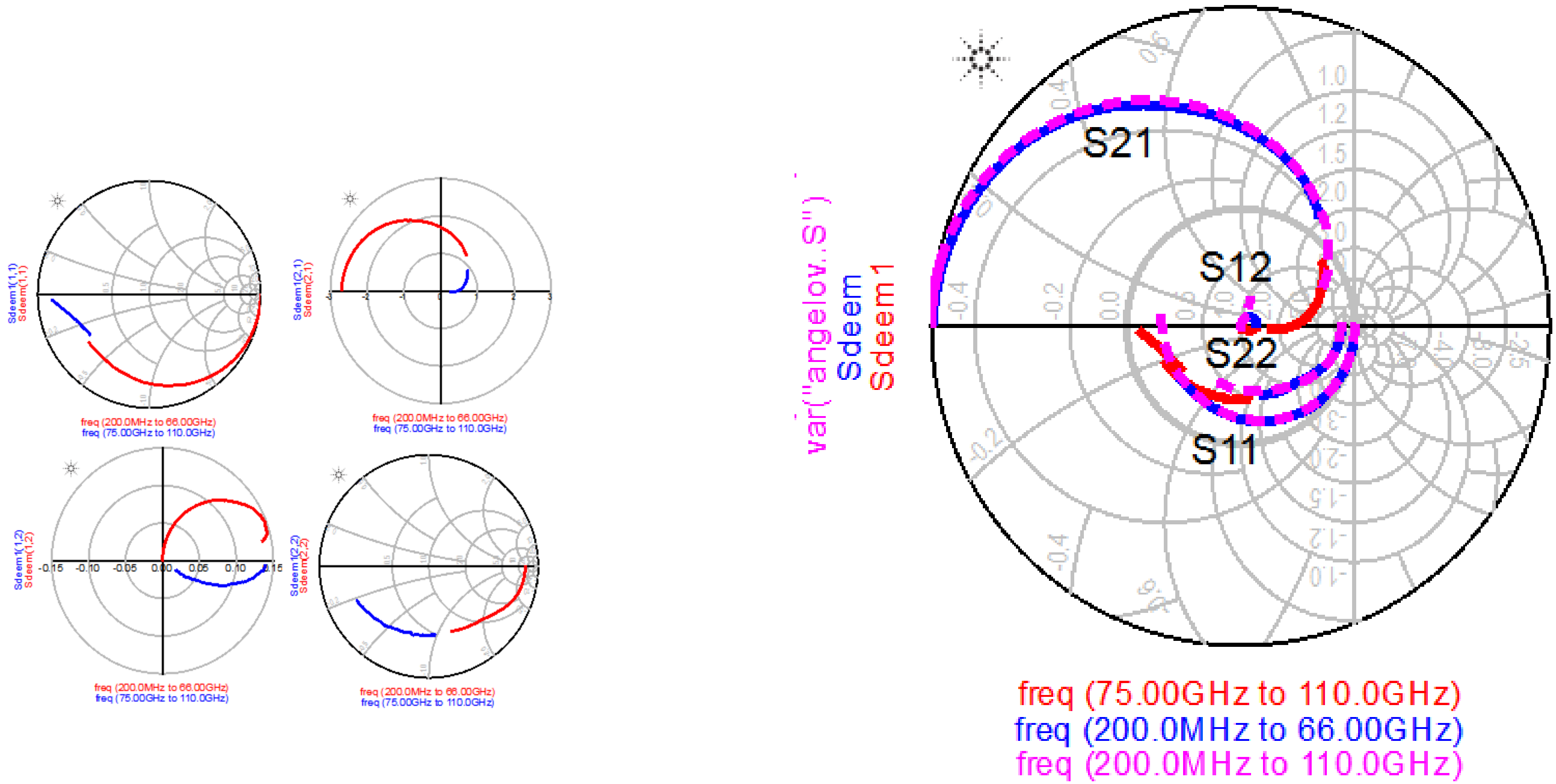
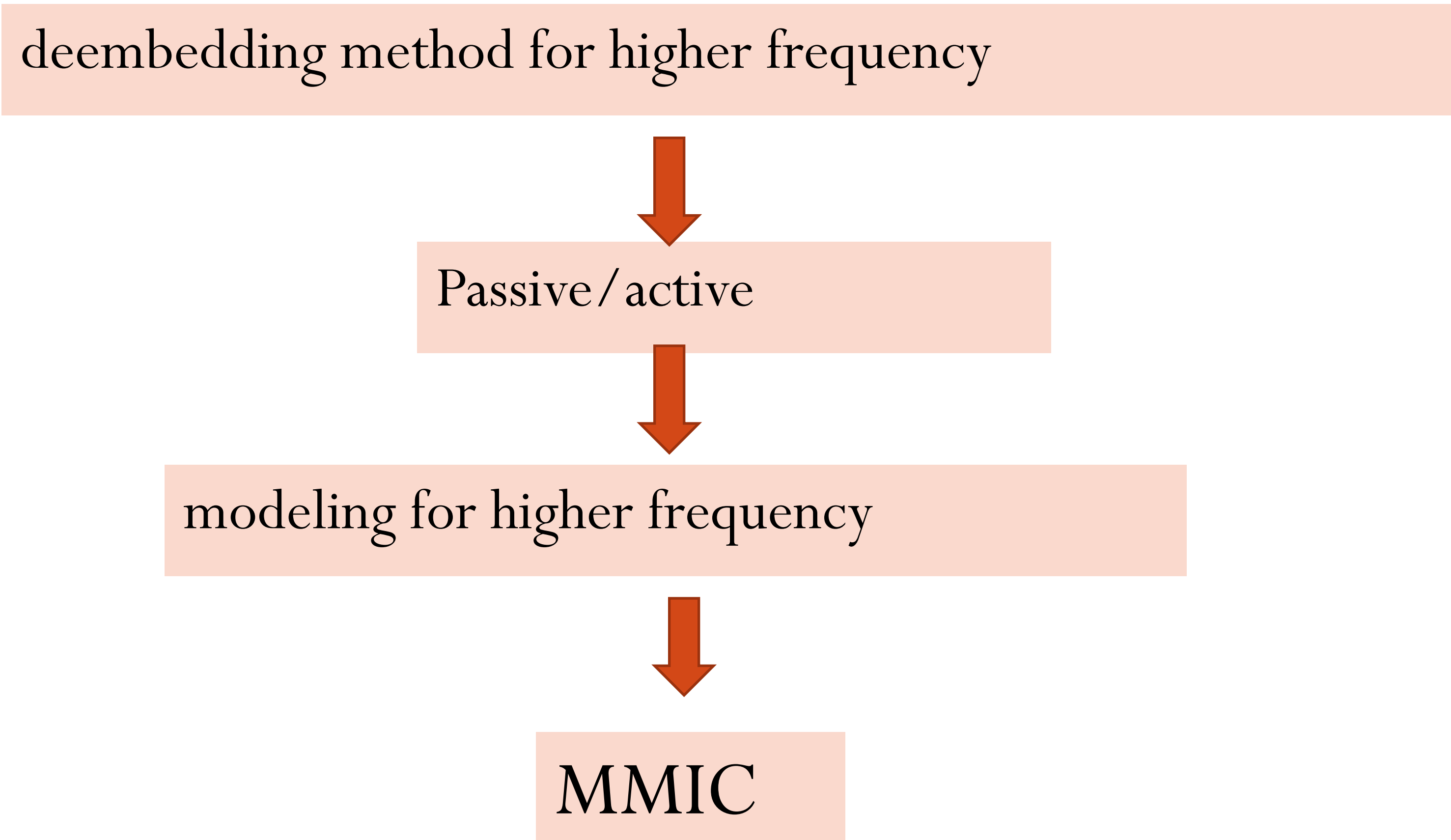


Figure 9. S-parameter to 110GHz
(Vgs=-1V and Vds=20V)

Future Work

New deembedding method will be used in GaN HEMT measurement for higher frequency. Modeling and power amplifer will be made from the result.



Thank you for your attention!