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Ultra-Broadband GaAs HIFET MMIC PA

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Outline

- Introduction
- Brief description of HIFET configuration
- HIFET design considerations
- MMIC design & process
- RF data results
- Conclusion

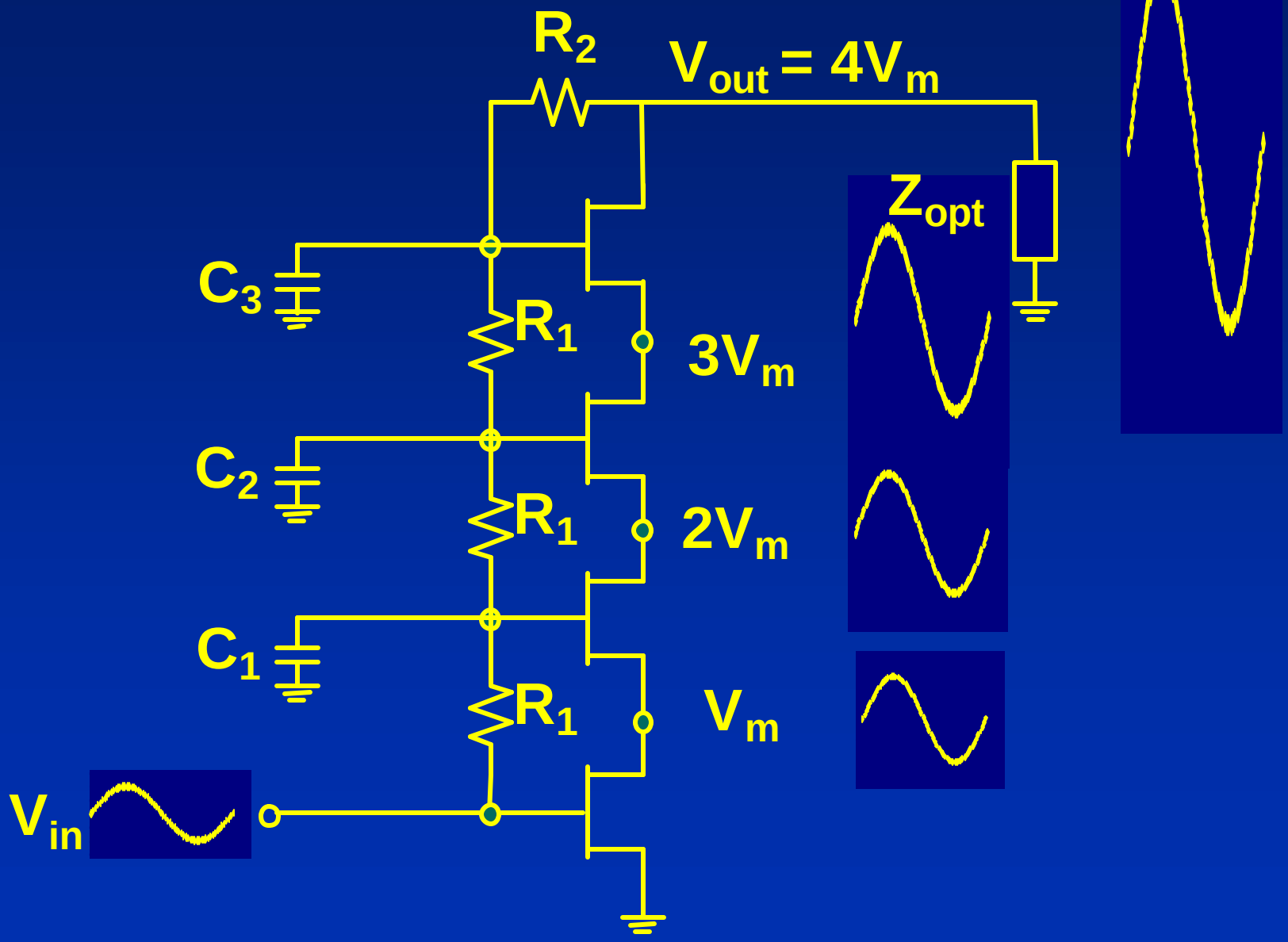
Introduction

- Broadband PA design is a major challenge
- This paper presents a unique design technique for Ultra-Broadband MMIC PA
- Feasibility of the HIFET configuration demonstrated in this paper
- This MMIC has several potential applications for broadband communications: Software radio, Broadband jammer, Instrumentations …etc

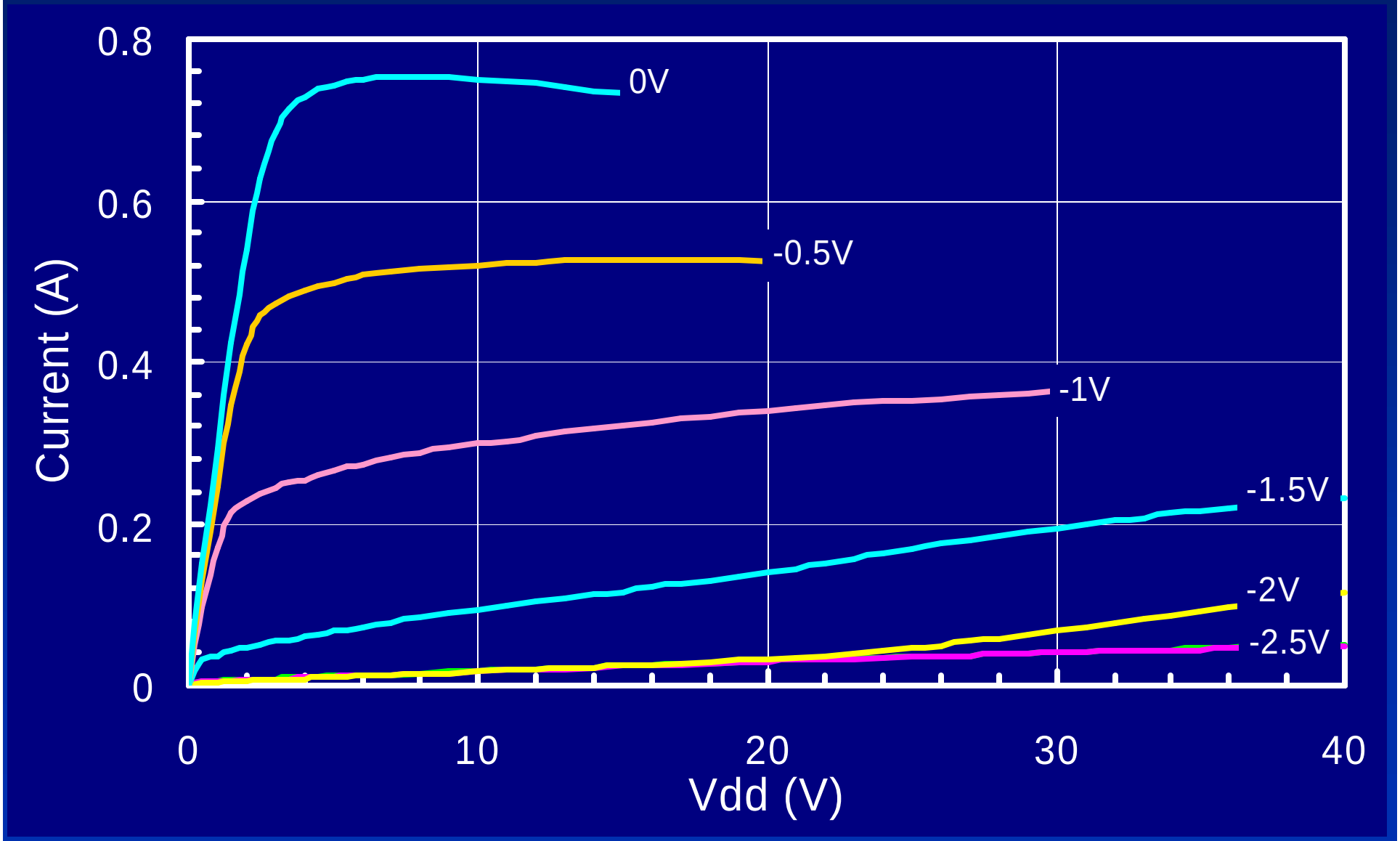
What is HIFET?

- HIFET is an innovative power combining technique connecting identical FETs RF & DC in series.
- HIFET has high voltage and high impedance.
- Output impedance could be tailored to be 50Ω.
- HIFET enjoys a bonus gain of 10 Log N dB.
- HIFET is broad bandwidth (Leading to constant phase and amplitude in-band, making it easy for linearization).
- HIFET concept applies to all devices such as MESFET, CMOS, LDMOS, GaN, SiC etc.

HIFET Voltage Waveforms



I-V of a 3mm x 4 MESFET HIFET



HIFET MMIC Design

- 1st stage: 4 x 2mm; 2nd stage: 2 x (4 x 1.8mm)
- Feedback resistors for gain flatness, good input & output VSWR and stability
- Input series and inter-stage series resistors for good gain flatness and stability
- Bias provided thru external chokes
- Large blocking capacitors for maximum bandwidth
- Air voltage breakdown design rule (~ 0.8 to 3V/μm)
- Pout = $(N \cdot V_{ds})^2 / 2 / Z_{out}$
- Stability & device thermal considerations

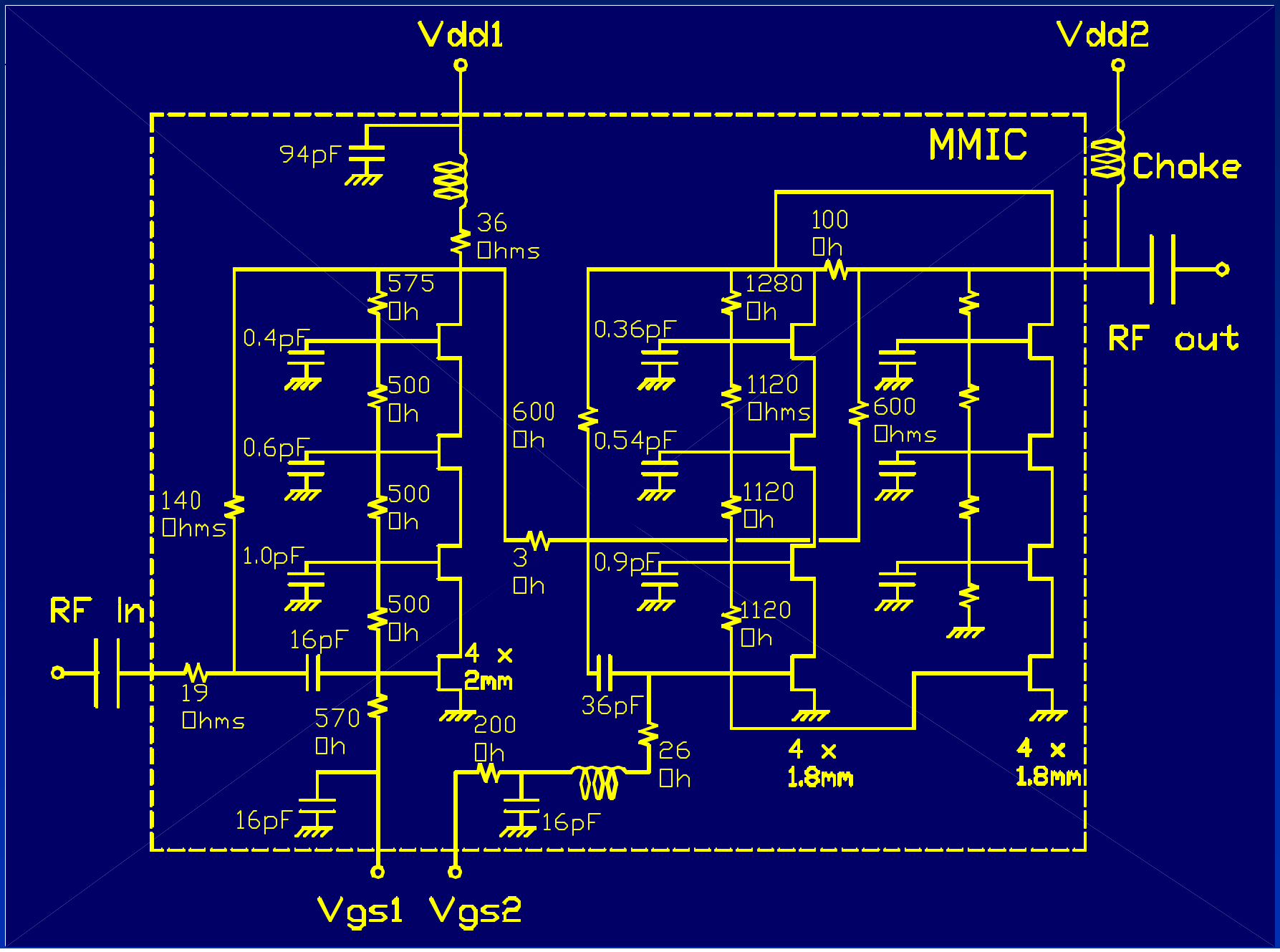
Output Matching Circuit

- $Z_{opt} = N (V_{ds}-V_{knee}) / I_{ds}$.
- We have 2 degrees of freedom: N & I_{ds} (Device size)
- In this 2-stage MMIC PA: Output stage is 2 x (4 x 1.8mm). Hence V_{ds} = 5V, I_{ds} = 0.36A
- Z_{opt} = 4 (5 - 0.5) / 0.36 = 50-ohm
- No output matching is needed because the device output impedance is designed to be 50Ω

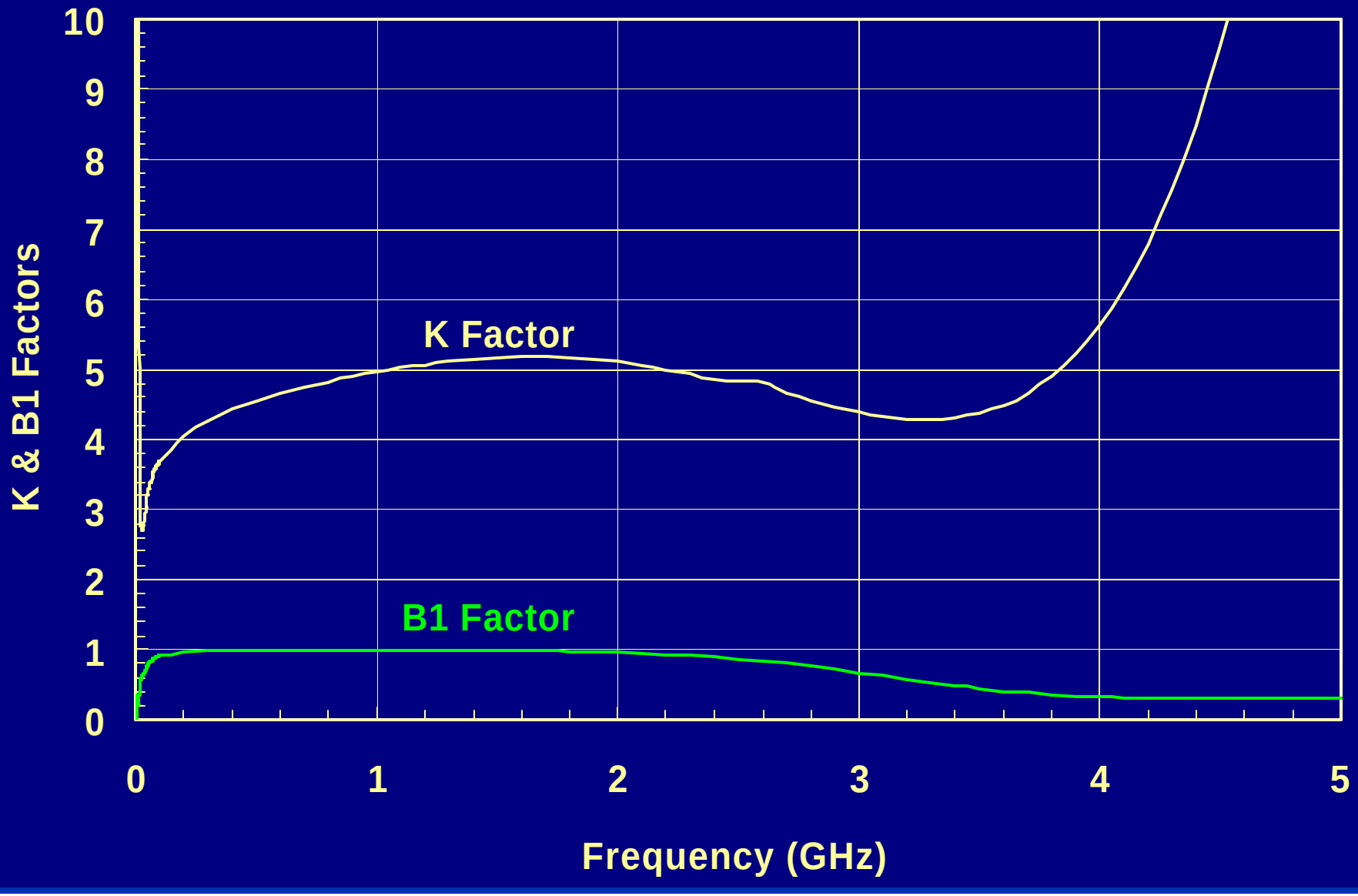
MMIC Process (MA/COM Lowell, MA)

- 0.5μm gate length, single-recess
- Epitaxial and thin film Nichrome resistors
- Silicon Nitride capacitor and passivation
- BCB layer for surface protection
- I_{dss} ~ 190 – 220mA/mm
- 4 mils substrate

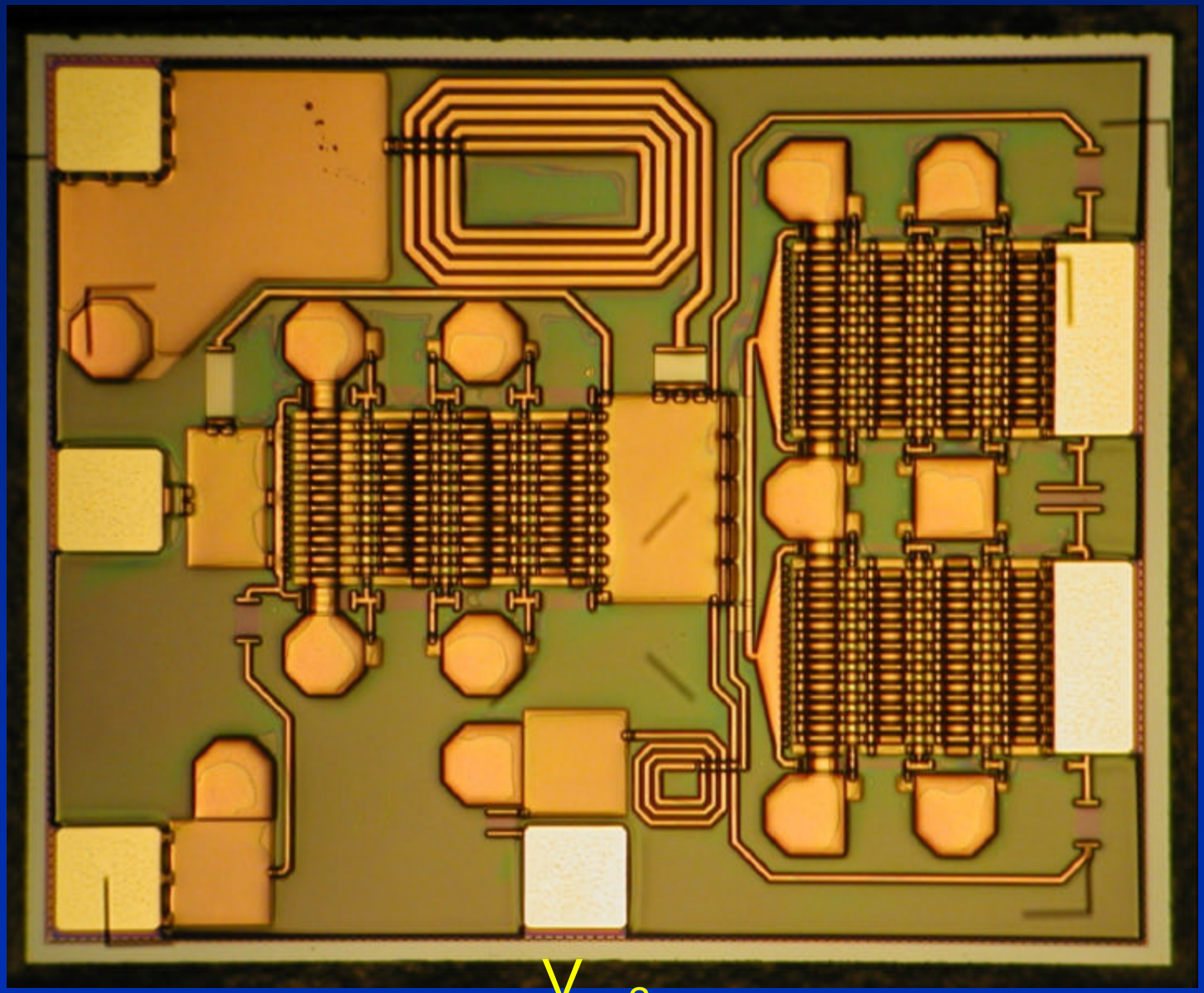
MMIC Schematic



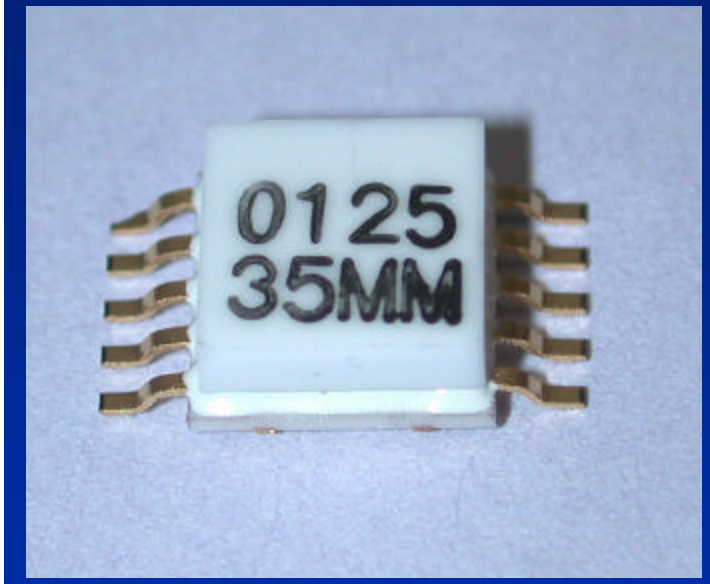
MMIC Stability



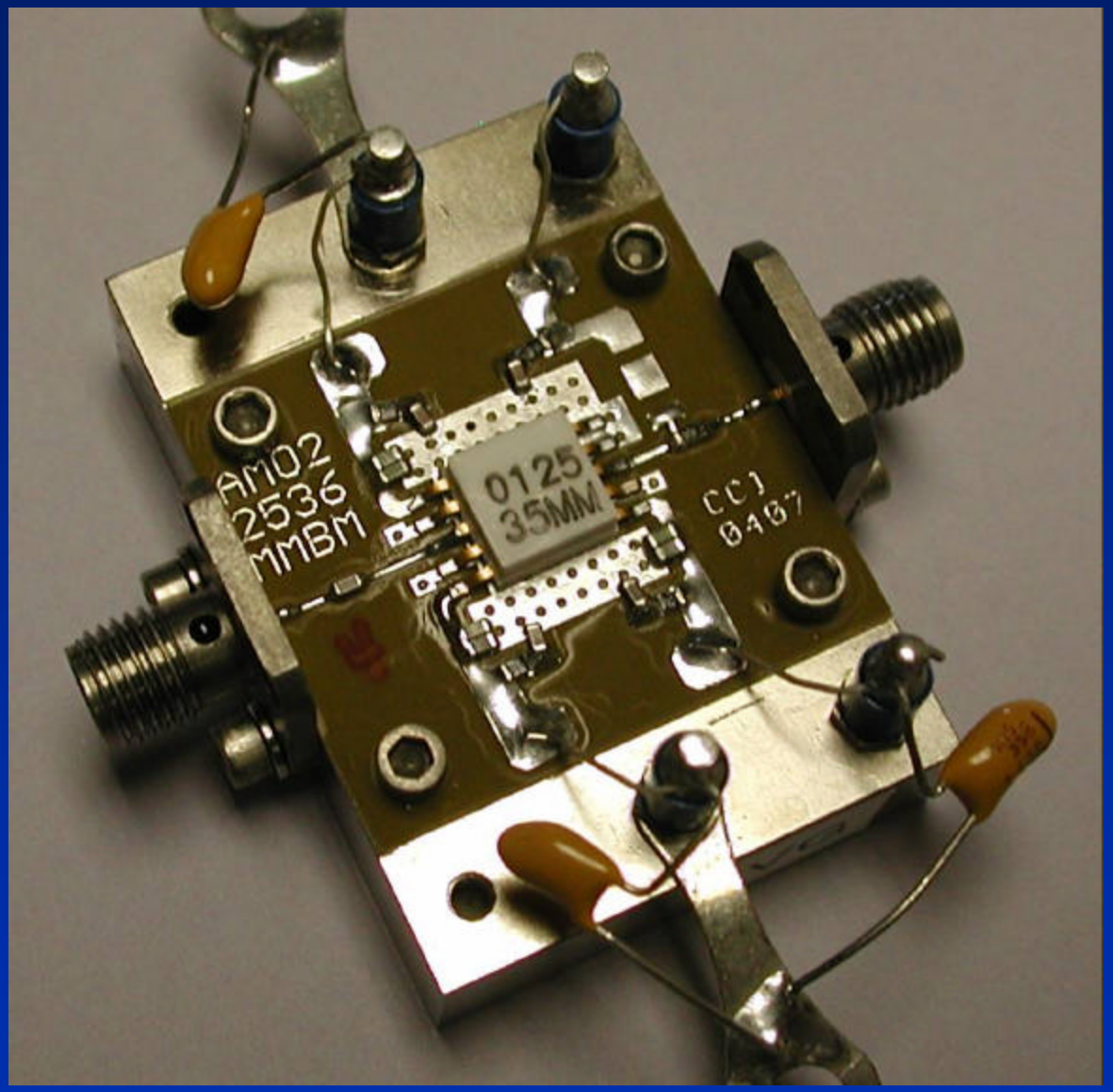
MMIC Photo – Die Size 2.2x1.8mm



Packaged MMIC & Test Fixture

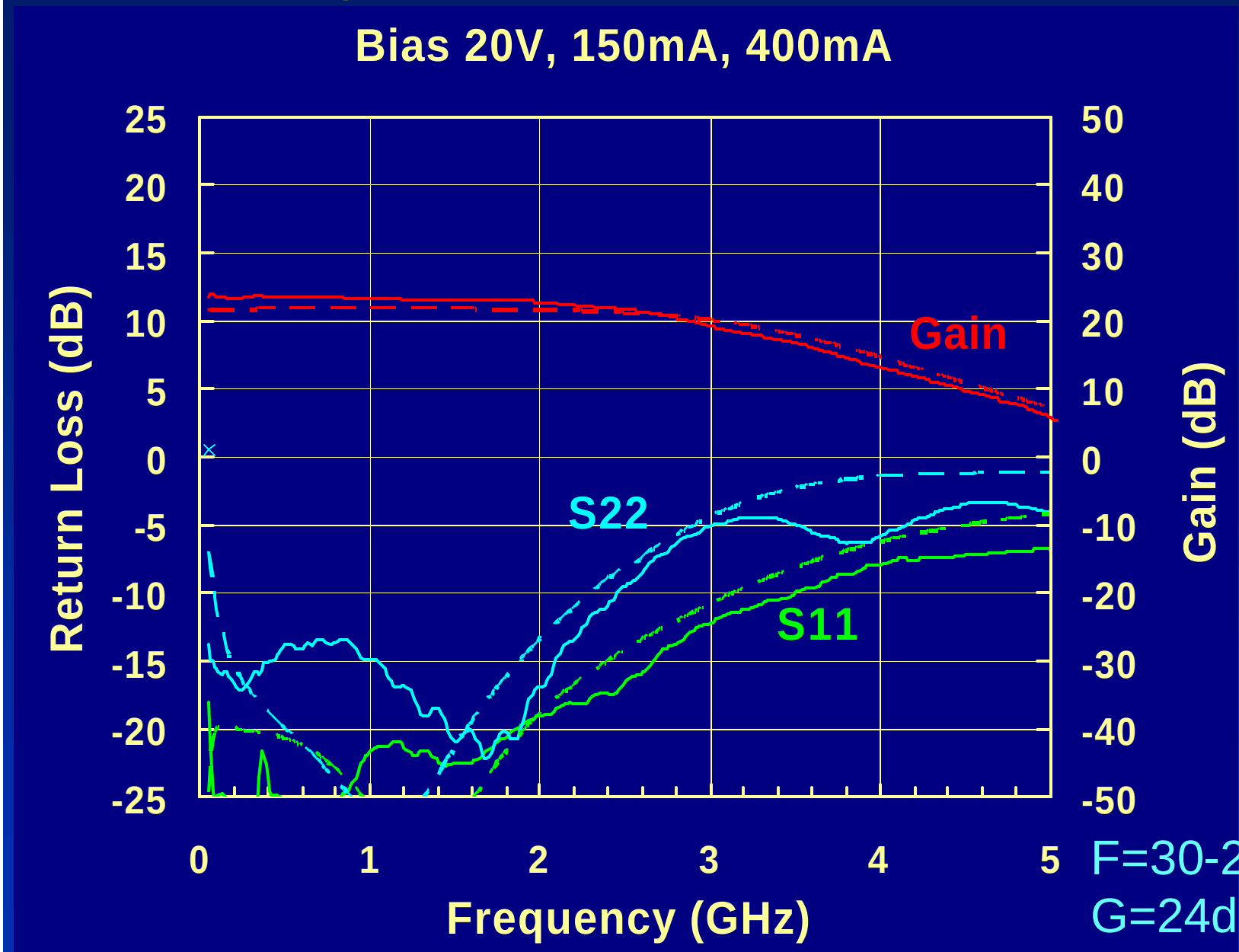


Package size
7 x 7 mm



10mils FR4 substrate

Packaged MMIC Gain & Return Losses



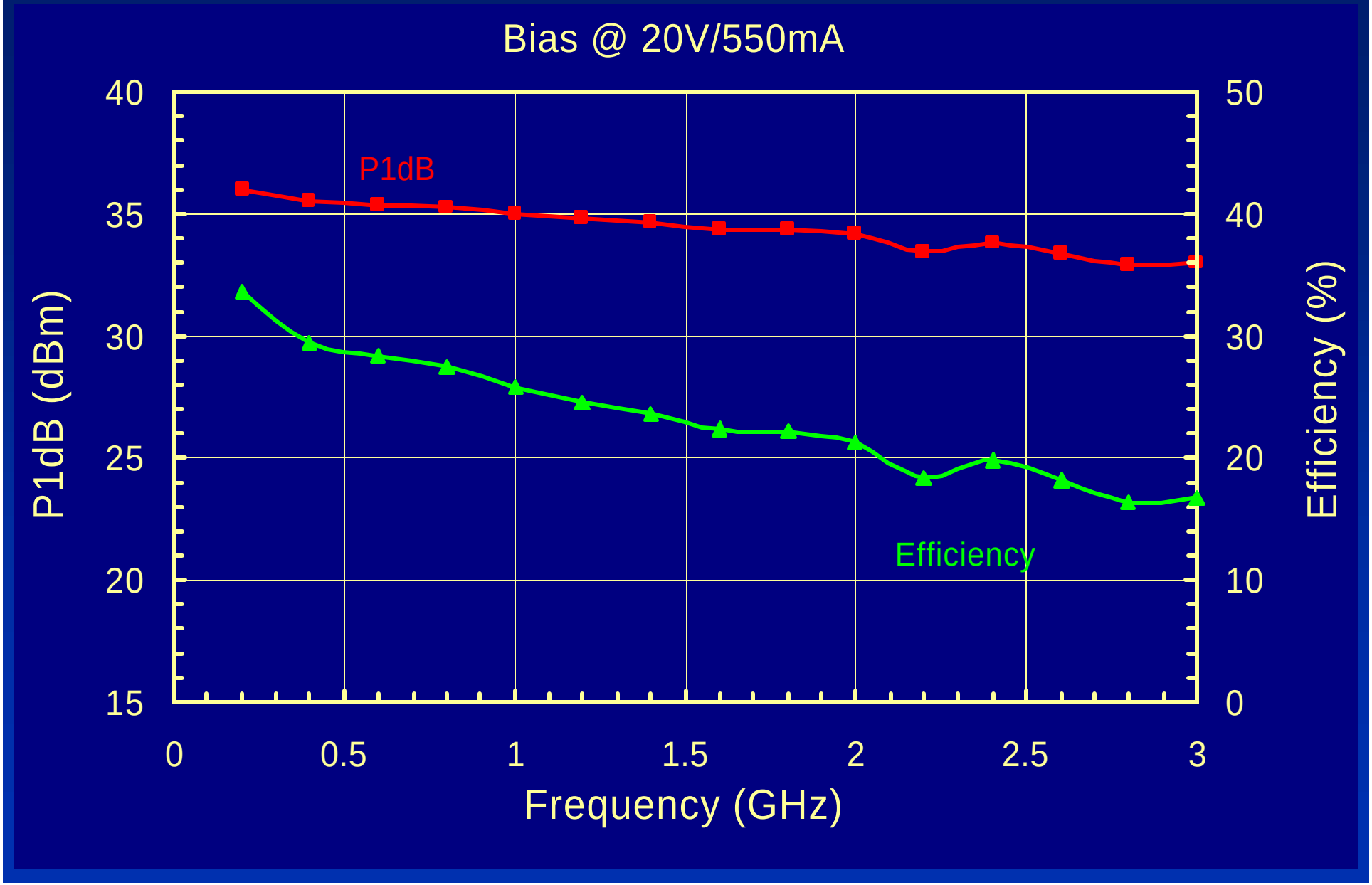
F=30-2500MHz

G=24dB

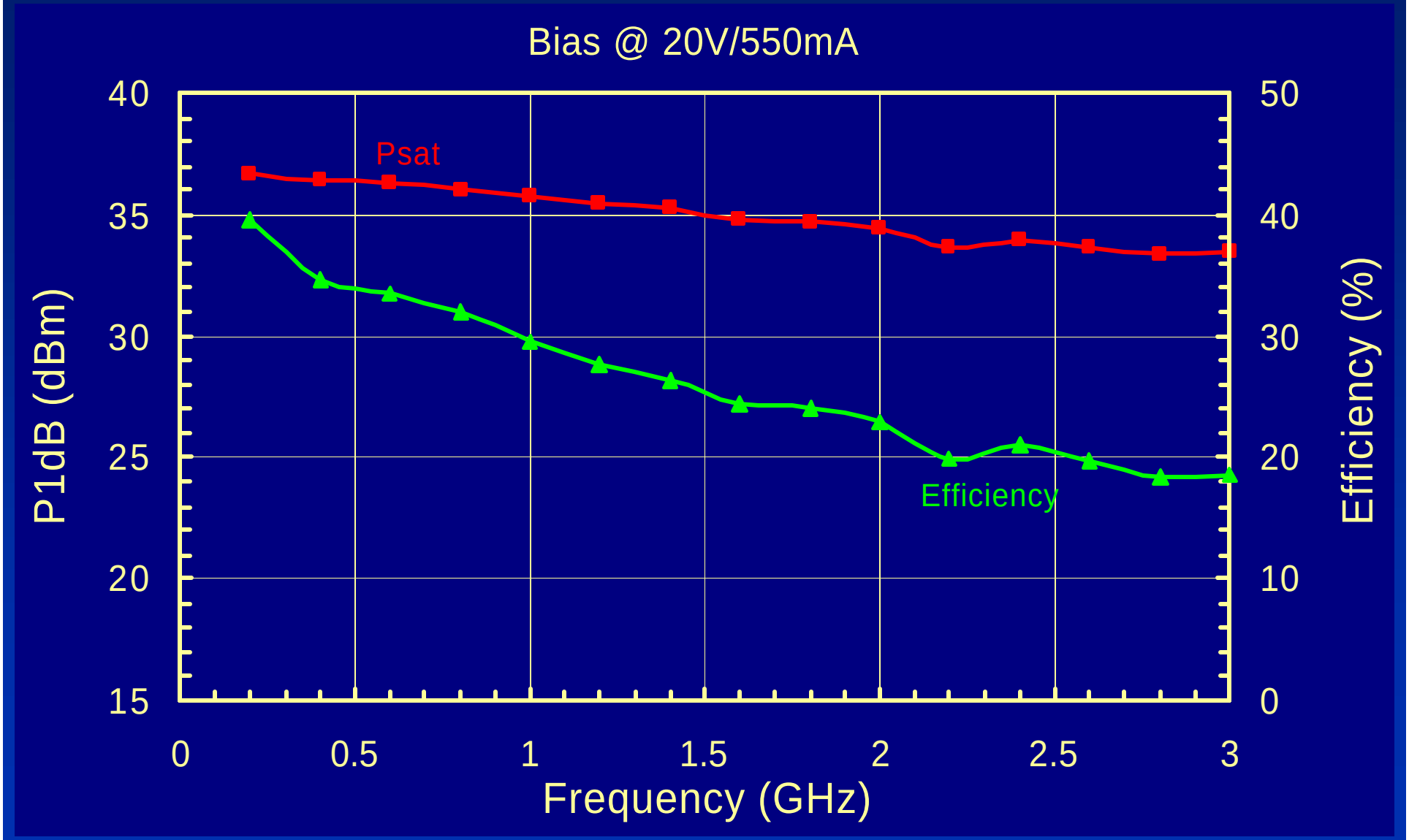
VSWR 2:1

Note: Dotted line for simulation

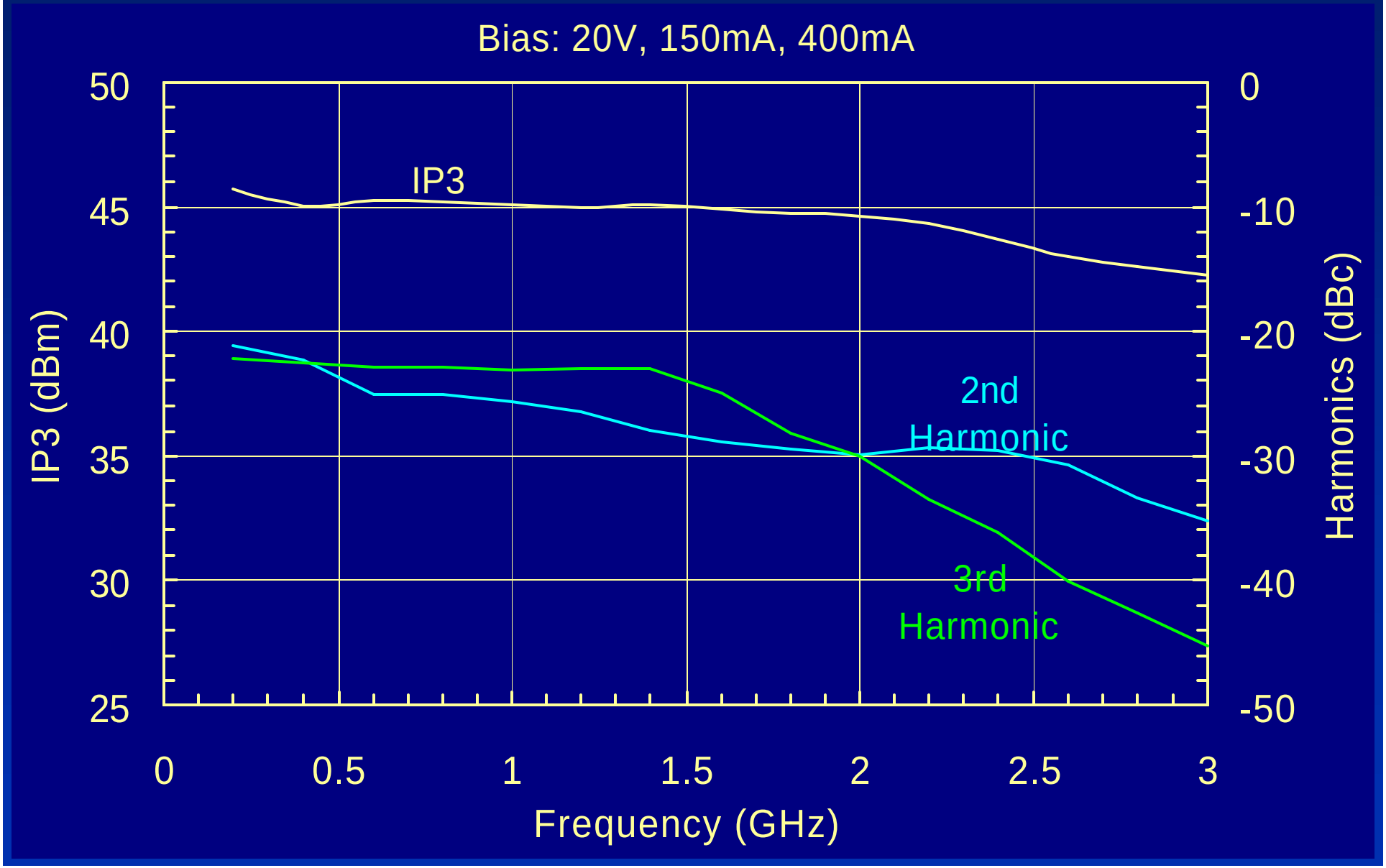
P1dB & Efficiency vs Frequency



Psat & Efficiency vs Frequency



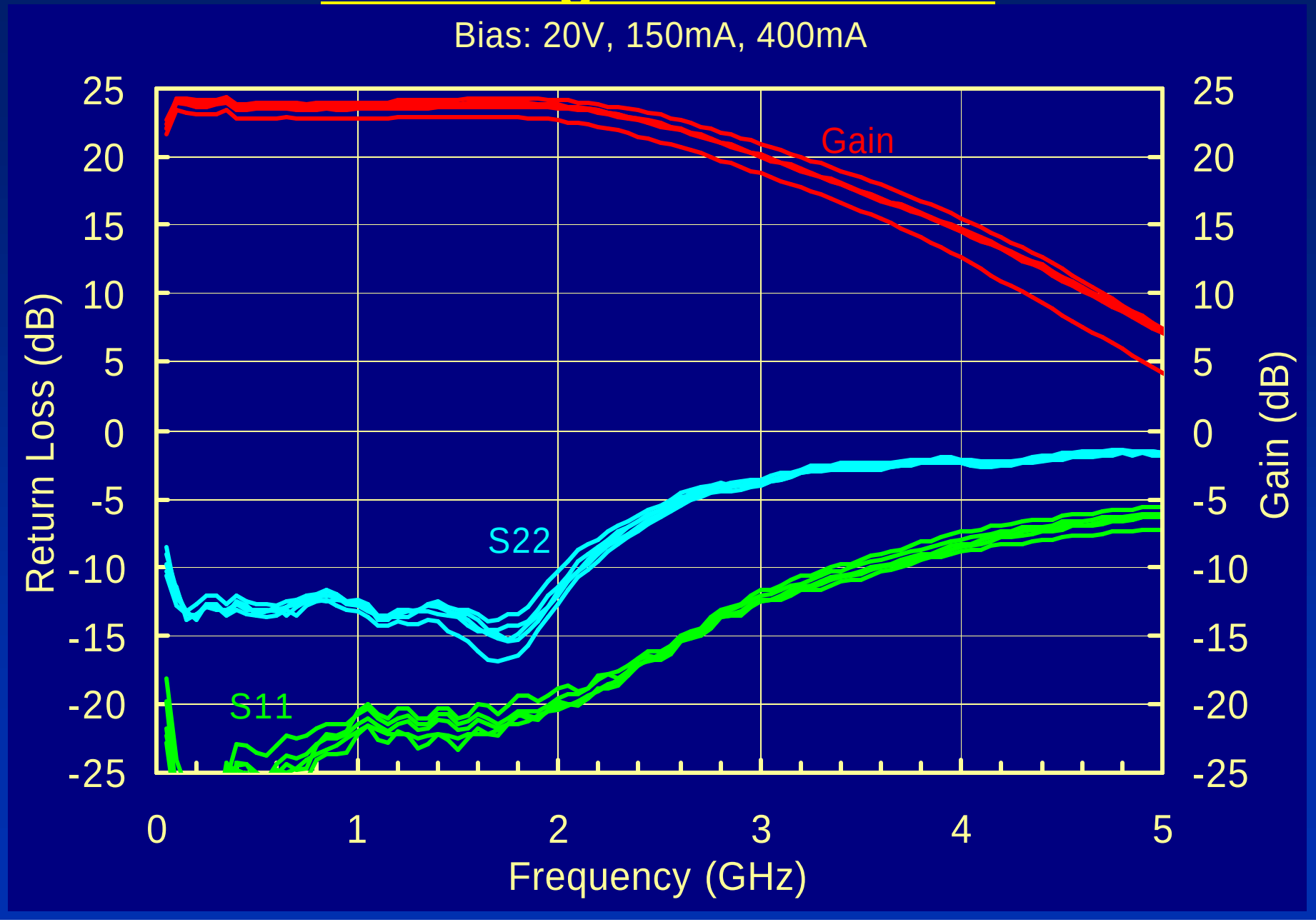
IP3 & Harmonics versus Frequency



Conclusion

- This HIFET MMIC demonstrates simultaneous broadband, high-power, high-voltage and high-efficiency performance
- First MMIC with 2W from 30 to 2500MHz with 24dB gain and good linearity
- HIFET could be applied to other technologies such as GaN and Silicon to deliver high power levels
- HIFET could be applied to CMOS to overcome low-voltage operation

Small Signal Variations



Psat & Efficiency at Low Frequency