2 mm x 2 mm HoP (Helix on Pad) - type Power Amplifier for W-CDMA Handset Applications

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Outline

- Motivation
- Module Size Evolution
- Idea Suggestion

  ➔ *HoP (Helix on Pad) and iPD (integrated Passive Device) for Matching Network*
- Low-band 2 x 2 mm^2 PA (Band5 application)
- High-band 2 x 2 mm^2 PAs (Band1 and 2 applications)
- Further Work
- Conclusion

Motivation

❑ Primary PA requirements

- gain, ACLR, efficiency, ruggedness, reliability, stability, etc.

❑ Size and Cost

- Mobile phone is getting smaller and lighter toward a low cost unit (LCU)
- PA module (PAM) size is especially important issue for LCU
- To the best of my knowledge, the smallest size of PAM is 3 x 3 mm^2 so far

❑ Motivation

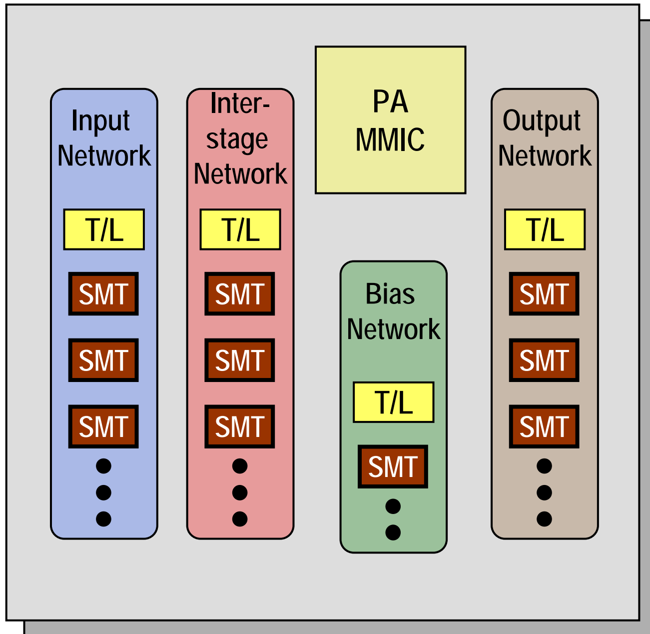
- Let's check if "EXTRA REDUCTION" on module size is possible !

: What is limitation on development of the size reduced module ??

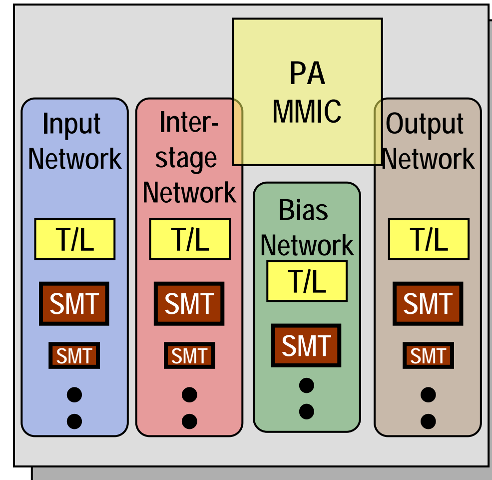
: What is idea to overcome this limitation ??

Module Size Evolution

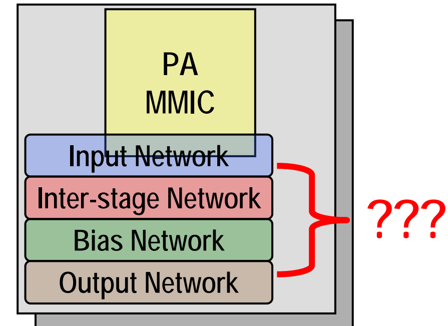
4x4 Module



3x3 Module



2x2 Module



- Input / Inter-stage / Bias / Output matching networks, and PA MMIC are needed for PA module
- Additional logic IC can be complemented, if necessary

- Aggressive integration or consolidation of matching components into an MMIC must be needed for size reduction
- Smaller size SMTs can be required, if necessary

- Probably, *IMPOSSIBLE*
  ➔ Need new idea for it

Idea Suggestion

❑ Output Matching Network (MN)

- Conventional output MN occupies the largest area in total module
- Also, it should be carefully designed for required power delivery, high efficiency, and good linearity
- Idea for smaller size (maintaining good RF characteristics)

  : Transmission line (T/L) on substrate → *"Helix on Pad (HoP)"*

  : SMTs → *"integrated Passive Device (iPD)"*

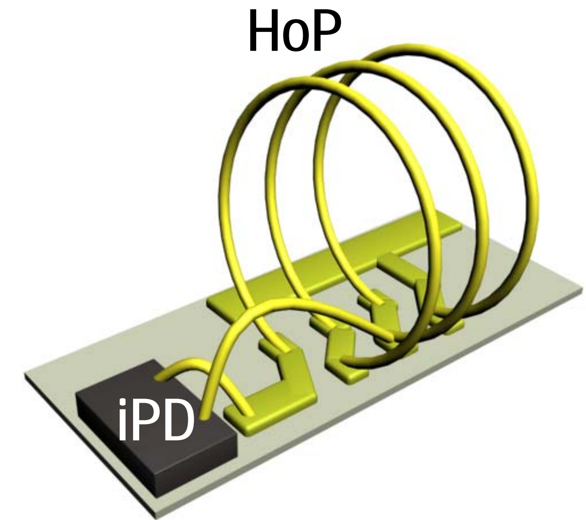
❑ Other Sections

- Input / inter-stage MNs → fully integrated in an MMIC except just two SMTs.
- Bias-line → implemented on backside of substrate.
- Use of 0402 size SMTs

HoP-iPD Matching Network (MN)

❑ Helix on Pad (HoP) Implementation

- Using wire-bonding in the manner of enhancing magnetic flux ➔ Very small area on substrate is occupied !!
- Multiple bonding wires (effective wire diameter ~ 1.7 mil) ➔ free from path loss



❑ integrated Passive Device (iPD) Implementation

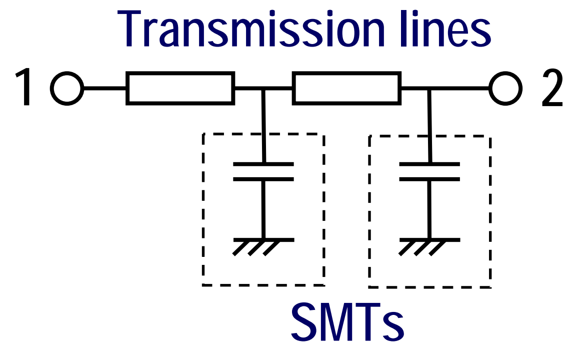
- Composed of high-Q Capacitors for output matching components
- High cap-ratio: 900 pF/mm^2 by stacked MIM structure

Low Band (B5) Application

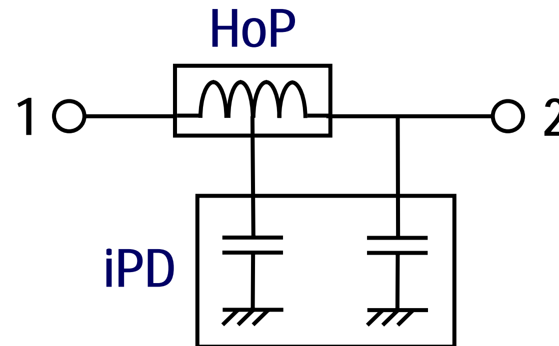
❑ Application

- UMTS uplink Band5 (824-849 MHz)
- Target Pout = 28 dBm

Load MN of conventional PA



Load MN of the proposed PA



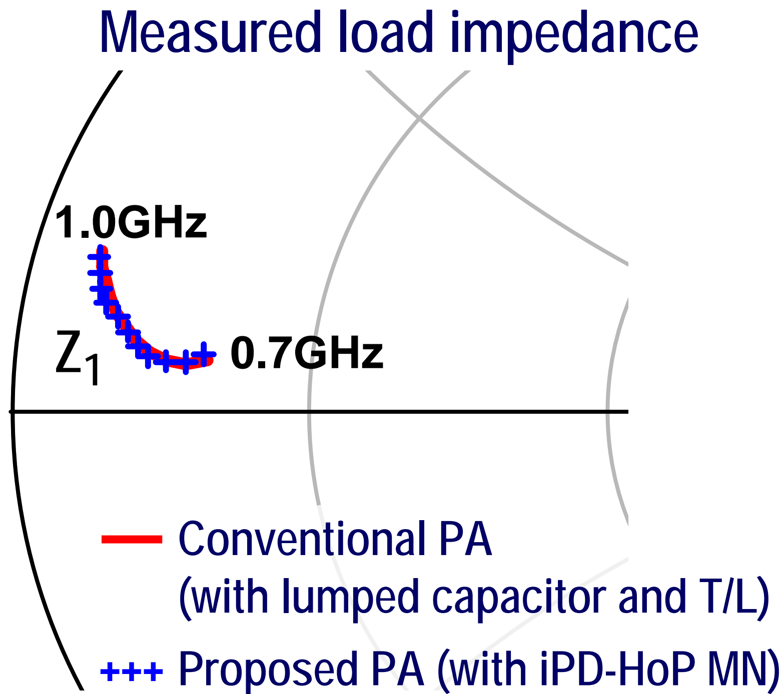
❑ Performance comparison b/w conventional MN and HoP-iPD MN

- Load impedance: Z_1
- Power loss: $P_{21} = P_1 - P_2$

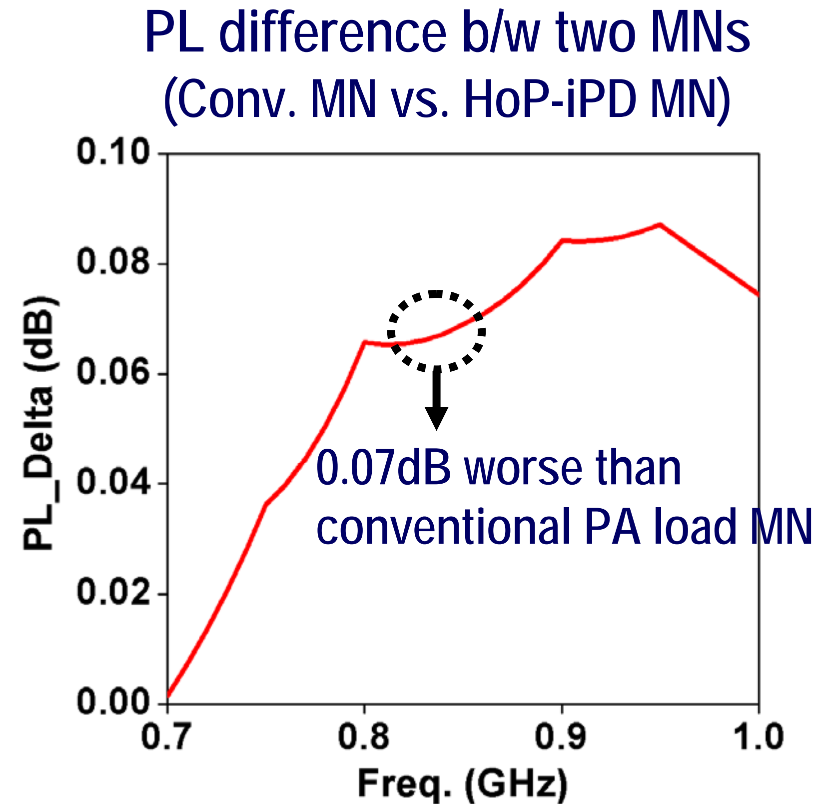
HoP-iPD Verification

- Load impedance: Z_1
- Power loss (PL): $P_{21} = P_1 - P_2$

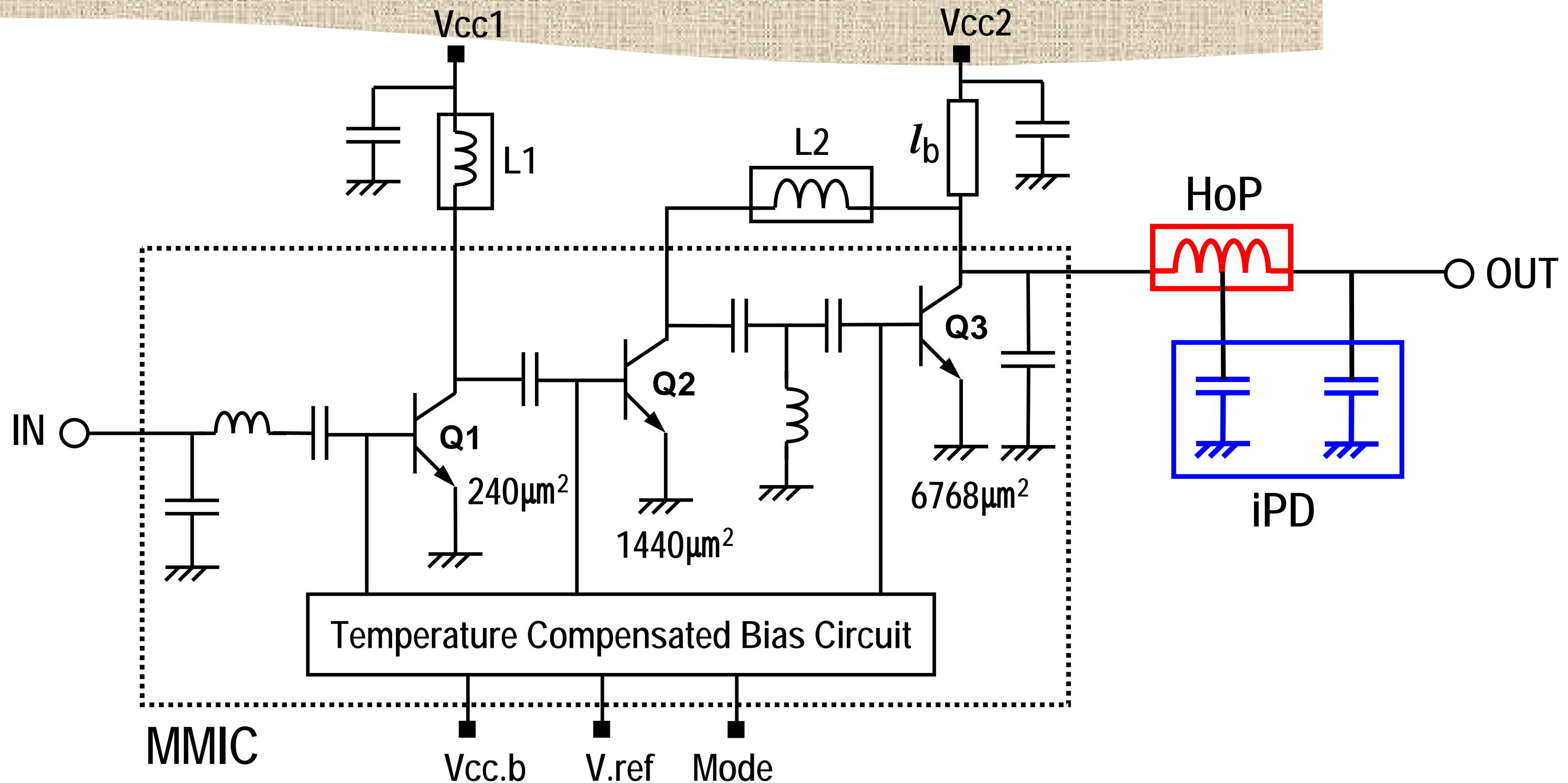
Measured load impedance



PL difference b/w two MNs
(Conv. MN vs. HoP-iPD MN)

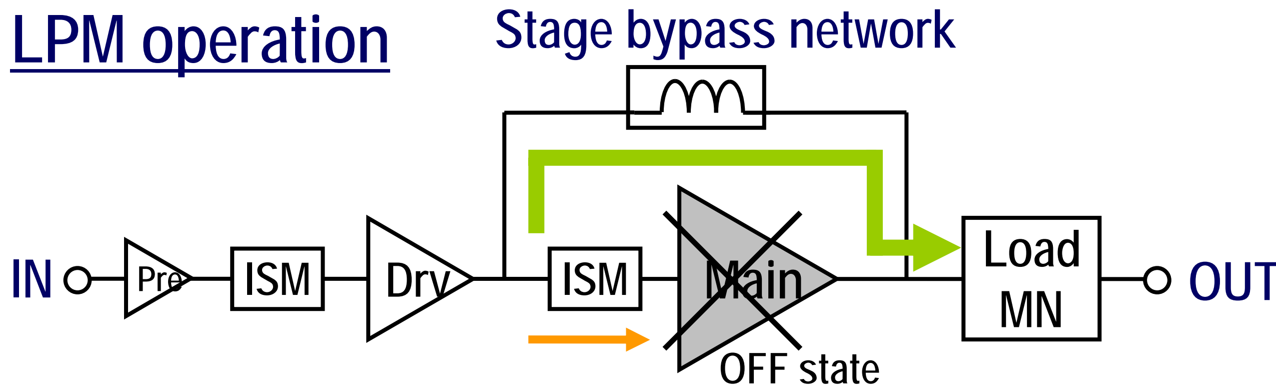


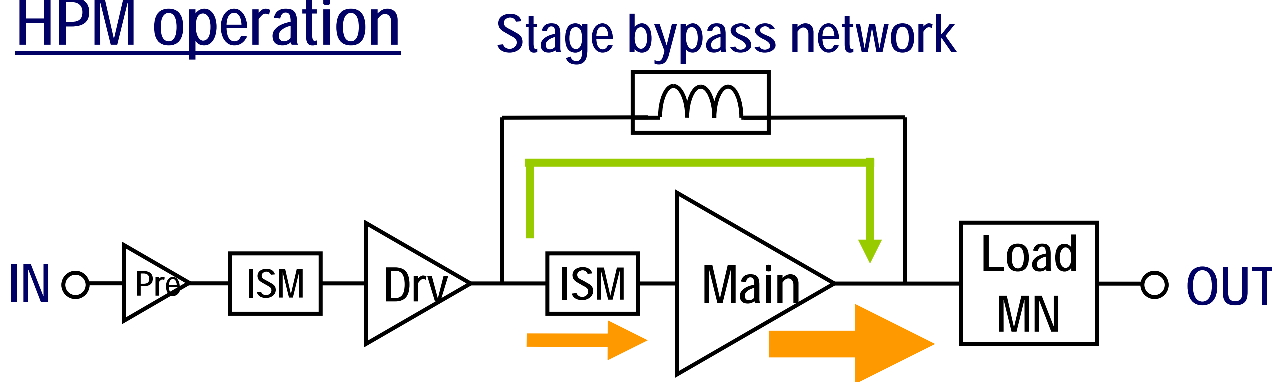
Design Schematic



- MMIC (GaAs HBT), HoP-iPD MN, bias-line, two SMTs
- Stage-bypass technique (CoolPAM™): high PAE at low output power region

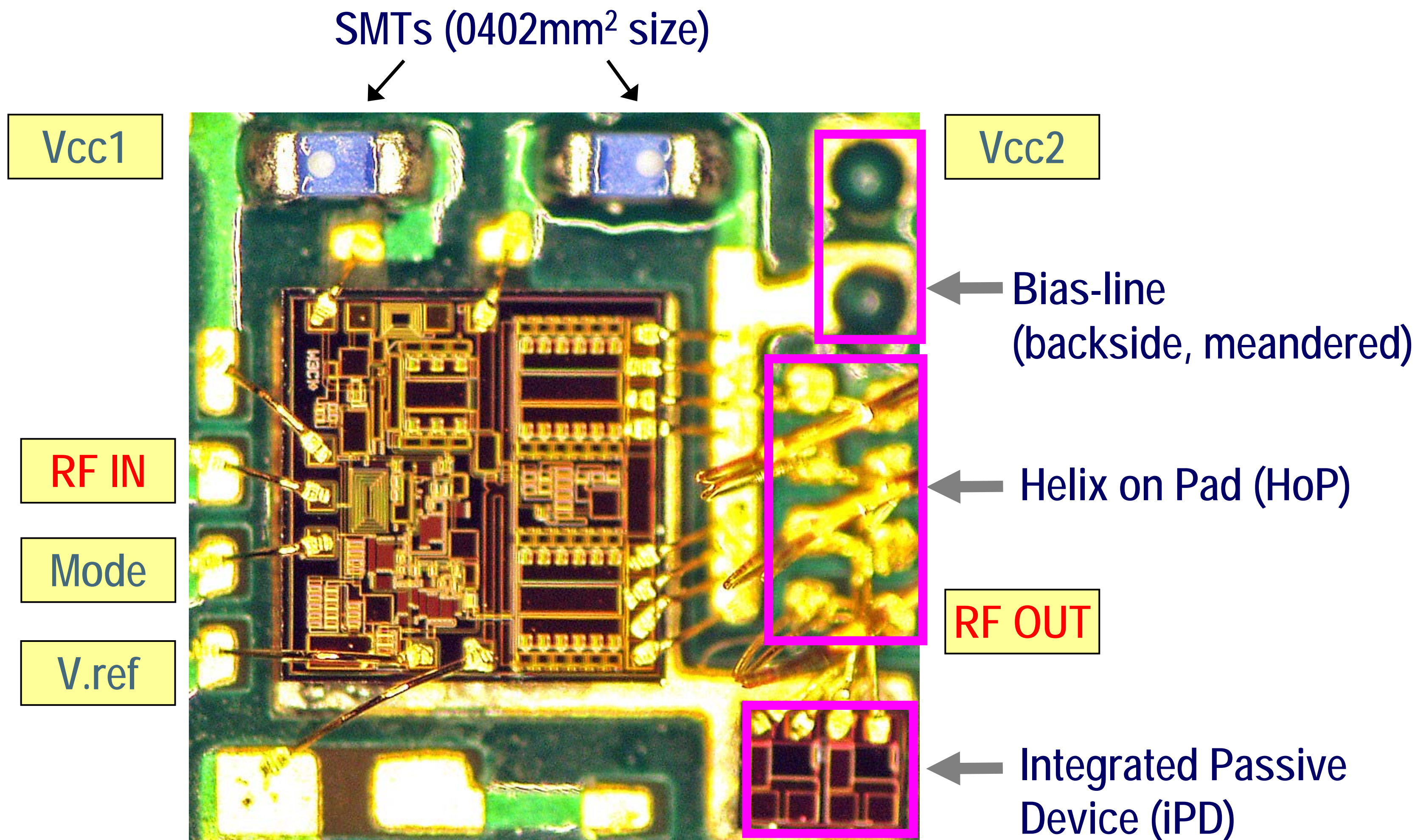
Stage Bypass PA (CoolPAM^{TM})





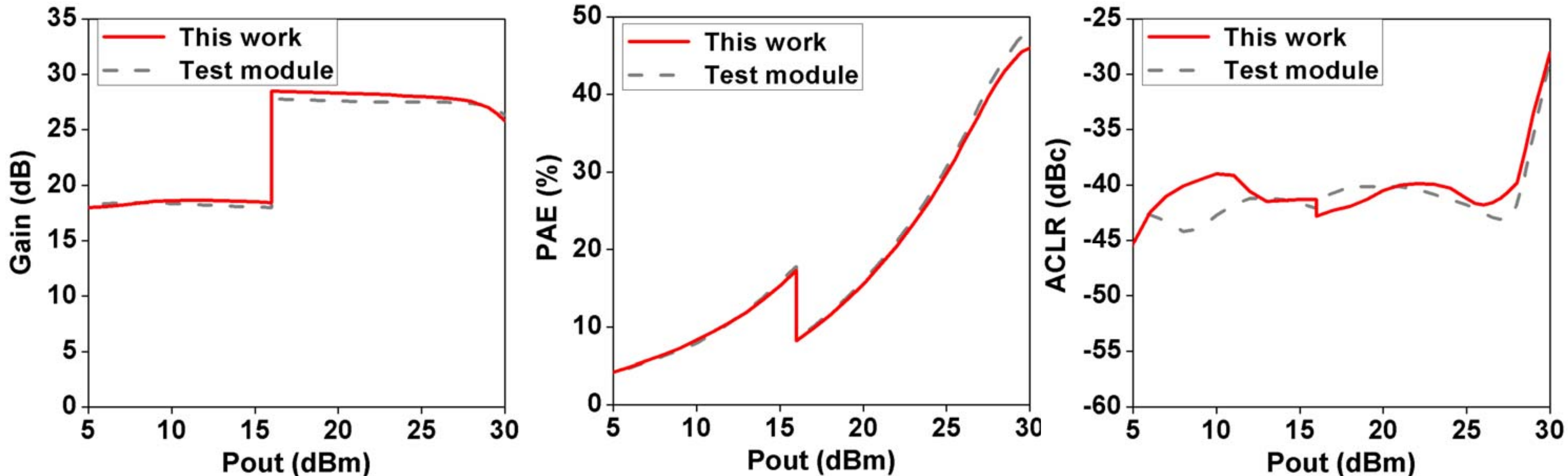
Switching point:
Pout = 16 dBm

Integrated PA Module (UMTS B5 Target)



Measurement Results

Target: Band5 (836.5 MHz), Iq = 13 mA



- High efficiency, good ACLR
- Gain curve is in agreement with that of the conventional test module
- PAE: slightly lower than test module

Note that the proposed PA maintained its RF characteristics close to the conventional test PA

2 x 2 mm^2 HoP-type PA:

High-Band (HB) Implementation

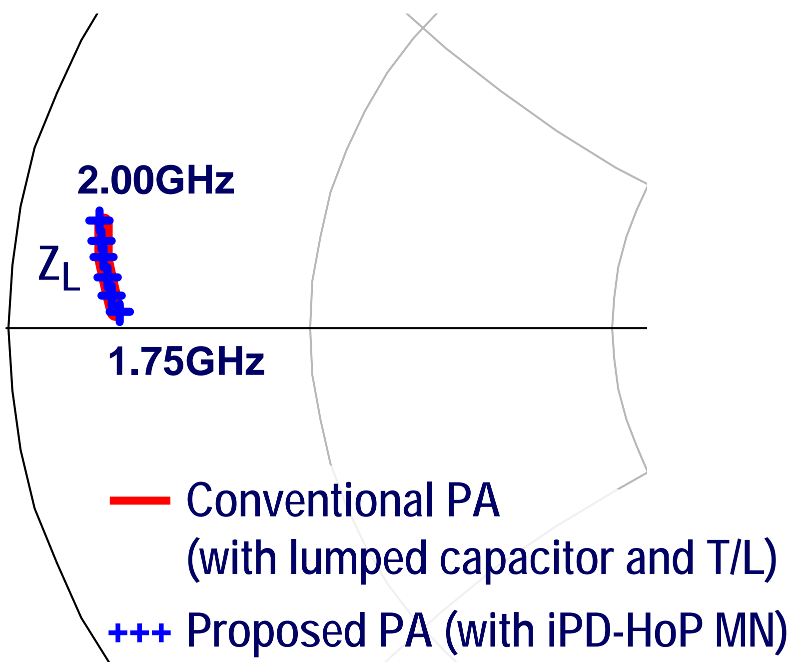
1. Band1 applications: 1920-1980 MHz, Pout = 28.0 dBm
2. Band2 applications: 1850-1910 MHz, Pout = 28.5 dBm

HoP-iPD Verification on Band2 PA

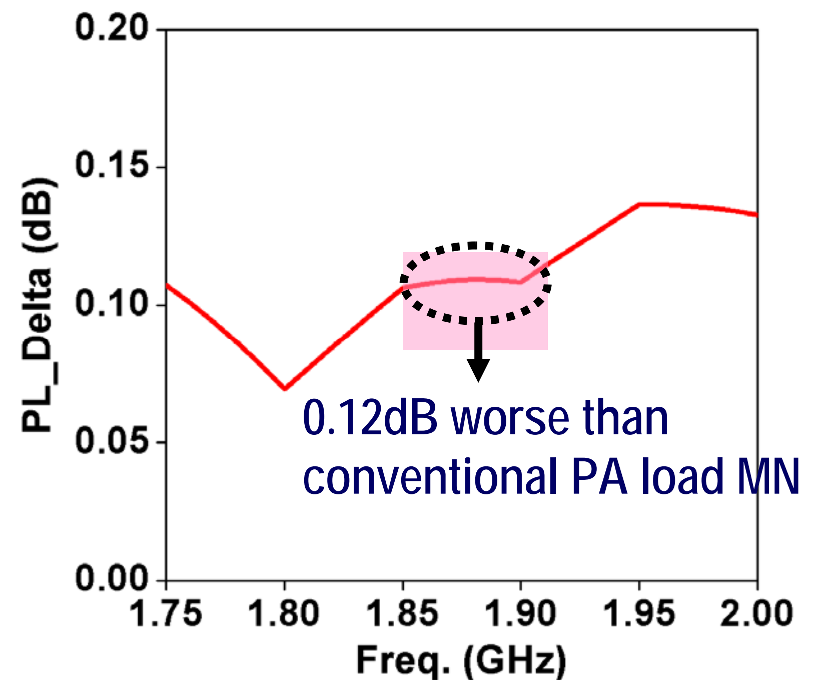
❑ Performance comparison b/w conventional MN and HoP-iPD MN

- Load impedance
- Power loss

Measured load impedance

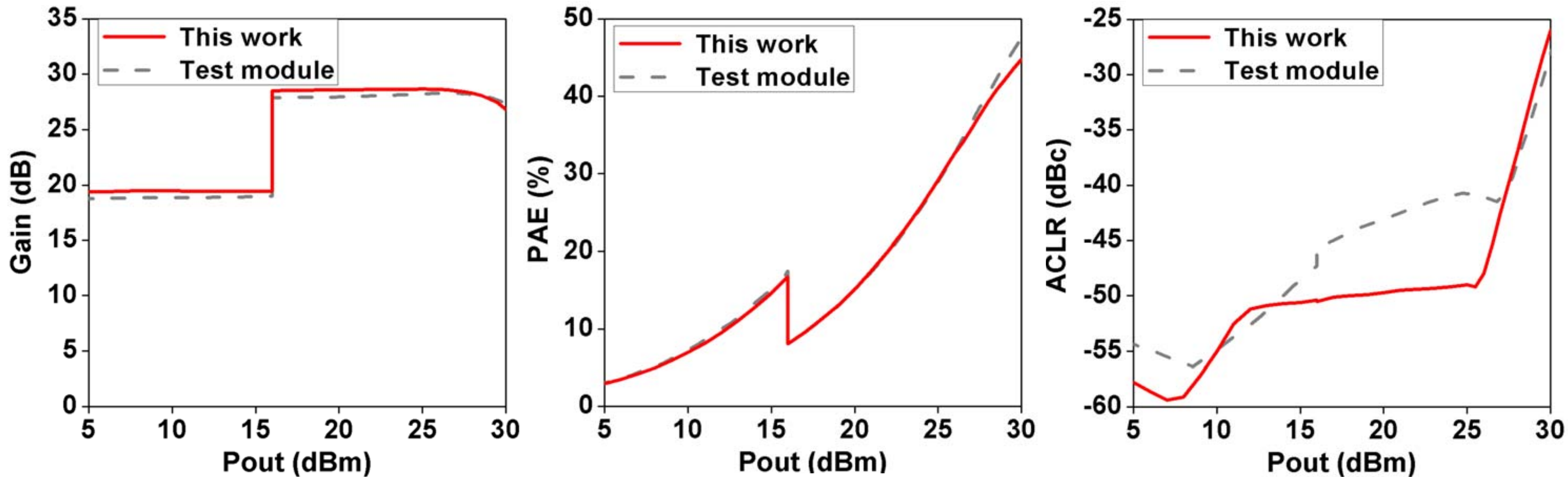


PL difference b/w two MNs
(Conv. MN vs. HoP-iPD MN)



High-band PA: Measurement (1)

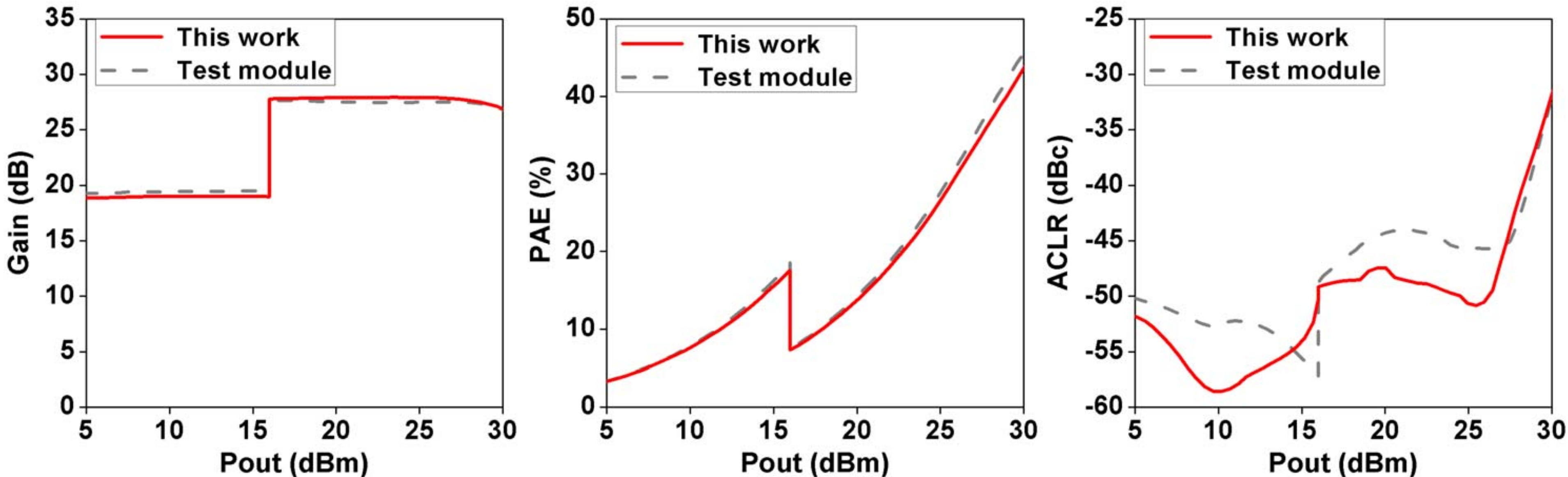
Target: optimized at Band1 (1950 MHz), Iq = 20 mA



- High efficiency, good ACLR
- Gain curve is in agreement with that of the conventional test module
- PAE: slightly lower than test module

High-band PA: Measurement (2)

Target: optimized at Band2 (1880 MHz), Iq = 20 mA



- ❑ This band also shows good RF characteristics

HoP-iPD MN is proven to be suitable for both LB & HB application
w/o any excessive performance degradation

Challenges & Further Work

❑ Challenges for practical use

① No bottom pin pads for practical use

② Dual-band & single-module requirement

③ Logic IC requirement for enabling PA and power mode selection (low/high mode)

④ HoP height: total module height MUST be < 1.0 mm

❑ Further Work

①, ② → Dual-band PA module with 3 x 3 mm^2 footprint (in progress)

③, ④ → Further work

Further Work: Dual-Band PA Implementation

- Minimum size of single-band PA for practical use

  Considering minimum required bottom pad area, spacing, and functions → 2 x 2.2 mm^2

- Lets try to 3 x 3mm^2 dual-band PA

Conclusions

- ❑ **Mobile phone is getting smaller and lighter for a low cost unit (LCU)**
  - Handset PA module has been reduced up to 3 x 3 mm^2 so far.
- ❑ **2 x 2 mm^2 PAs were implemented using HoP-iPD MN**
  - HoP was implemented as solenoid type bonding-wires to enhance mutual inductance.
  - iPD, which was fabricated using GaAs HBT process in this work, was used for smaller die-size.
  - Stage-bypass PA was designed to improve PAE at low power mode.
  - To verify the idea, we applied HoP-iPD MNs to the PAs for UMTS B1, B2, and B5 applications.
  - As expected measured 2 x 2 mm^2 PAs showed good linearity and PAE characteristics
- ❑ **Dual-band PA with 3 x 3 mm^2 footprint has been fabricated.**
  - The PA, targeted at UMTS B2 & B5, has been evaluated and measured (The result will be announced soon - through presentation or article)