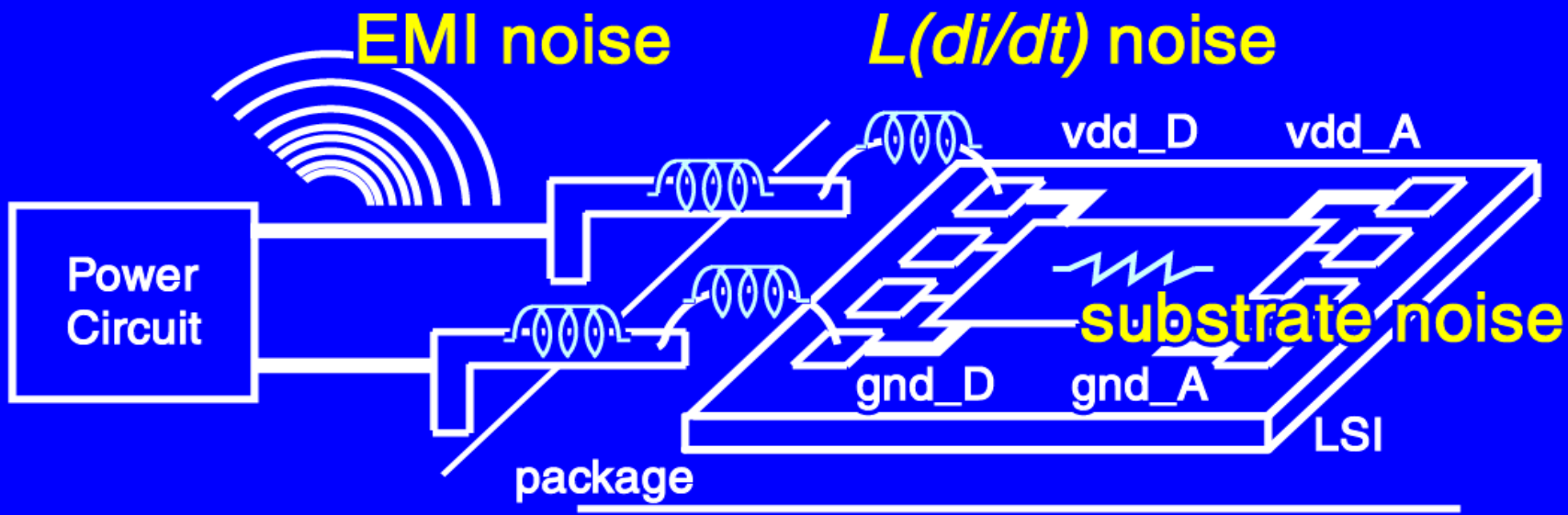
Preliminary Experiments for Power Supply Noise Reduction using Stubs

Toru Nakura[#], Makoto Ikeda*, Kunihiro Asada*

[#]Dept. of Electronic Engineering,
**VLSI Design and Education Center,*
University of Tokyo, Tokyo, Japan

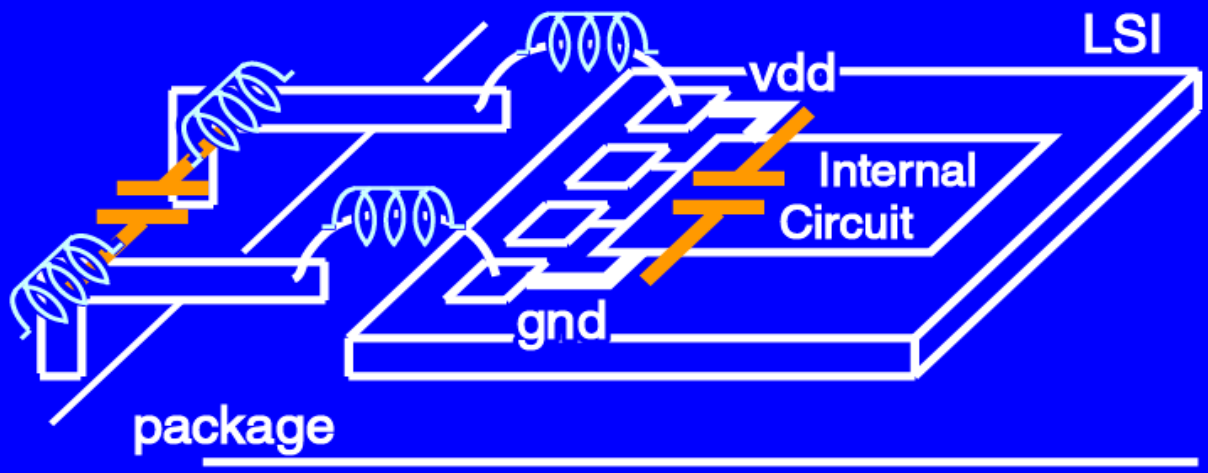
Background – di/dt and SI

- Power supply noise : L(di/dt)
- EMI noise : caused by di/dt
- Substrate noise : related to power noise



Background – Decoupling Cap.

- Decoupling capacitors
  - On-chip capacitor: area penalty
  - Off-chip capacitor: parasitic inductance

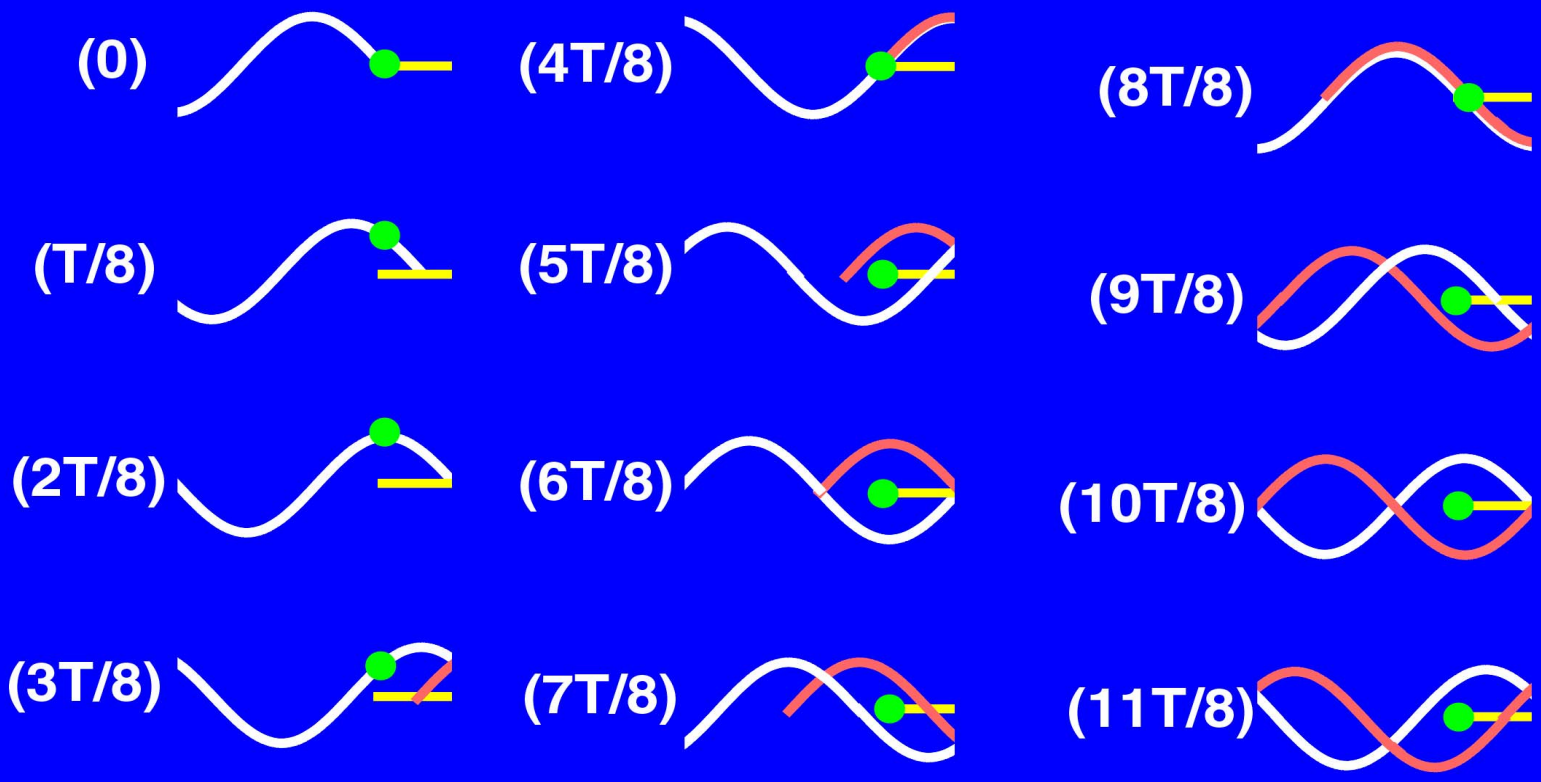


Contents

- Stub theorem
- Measurement Setups
- Measurement Results
  - Power supply noise reduction
  - Frequency dependence
- Summary

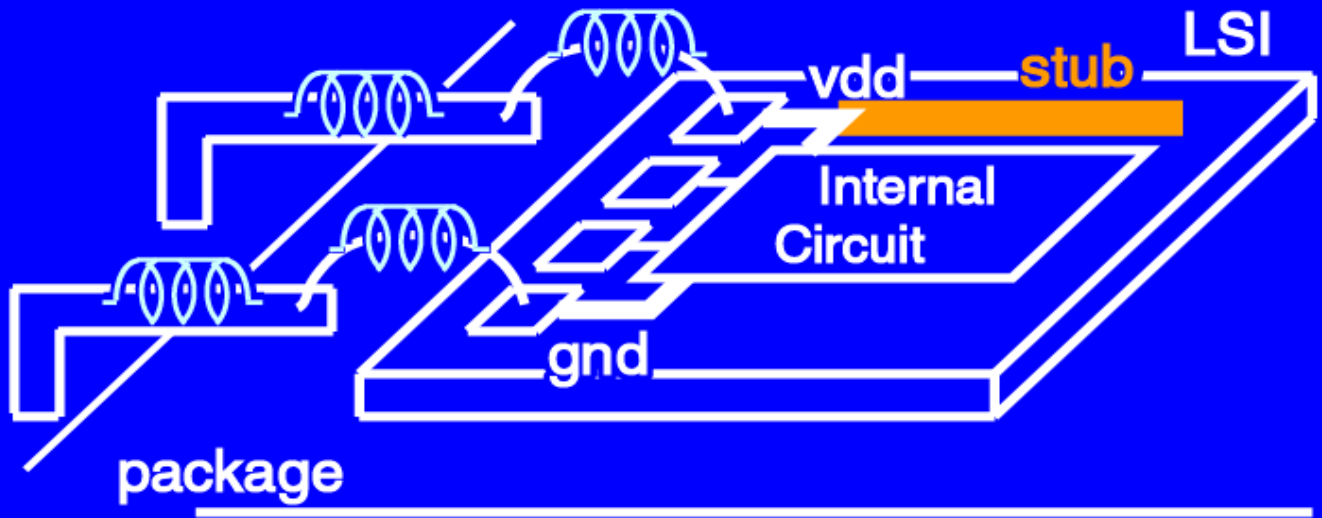
Waveform in Ideal λ/4 Stub

- **The forward- and backward-going waves are cancelled on λ/4 stub**

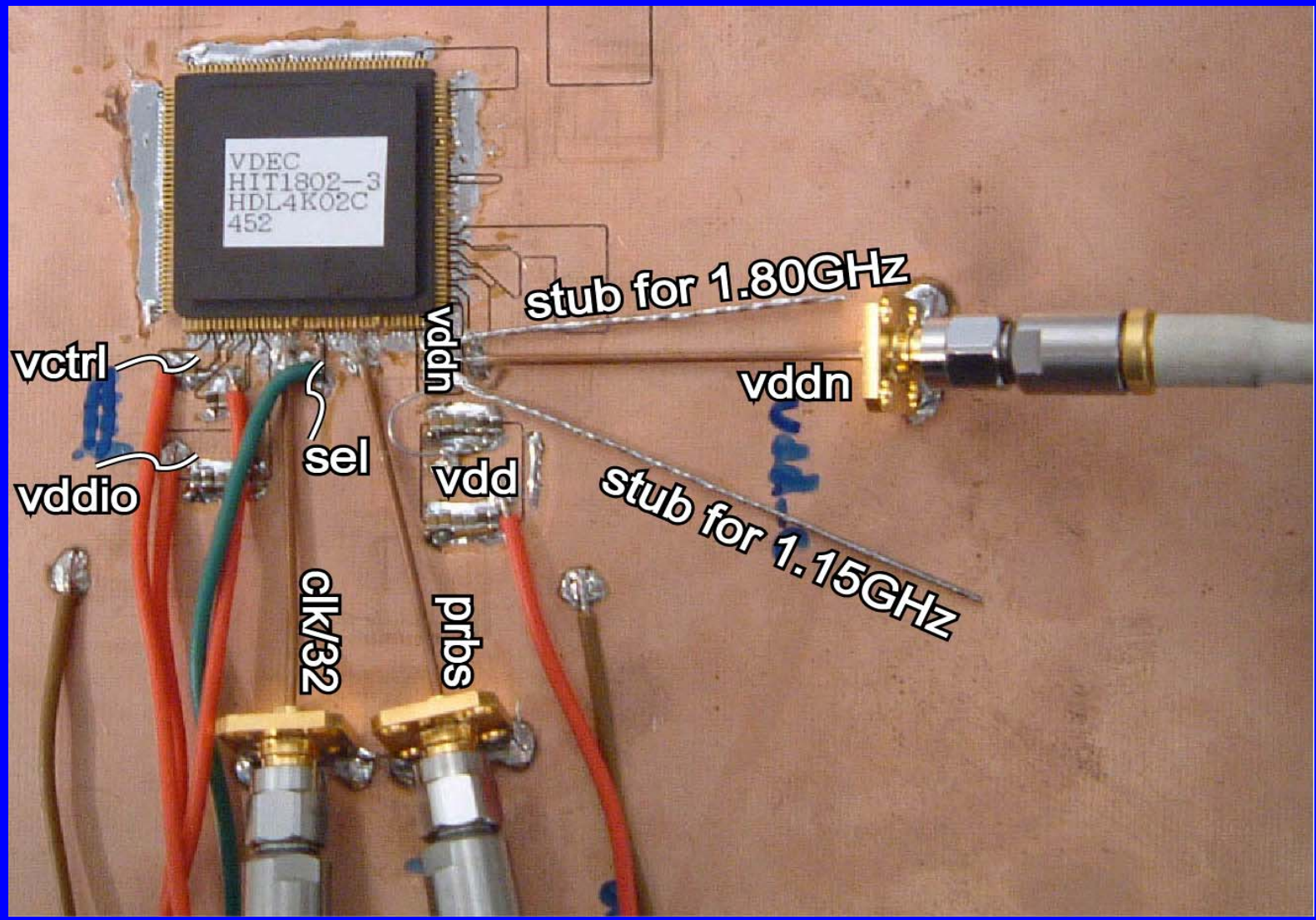


Power Supply Noise Reduction

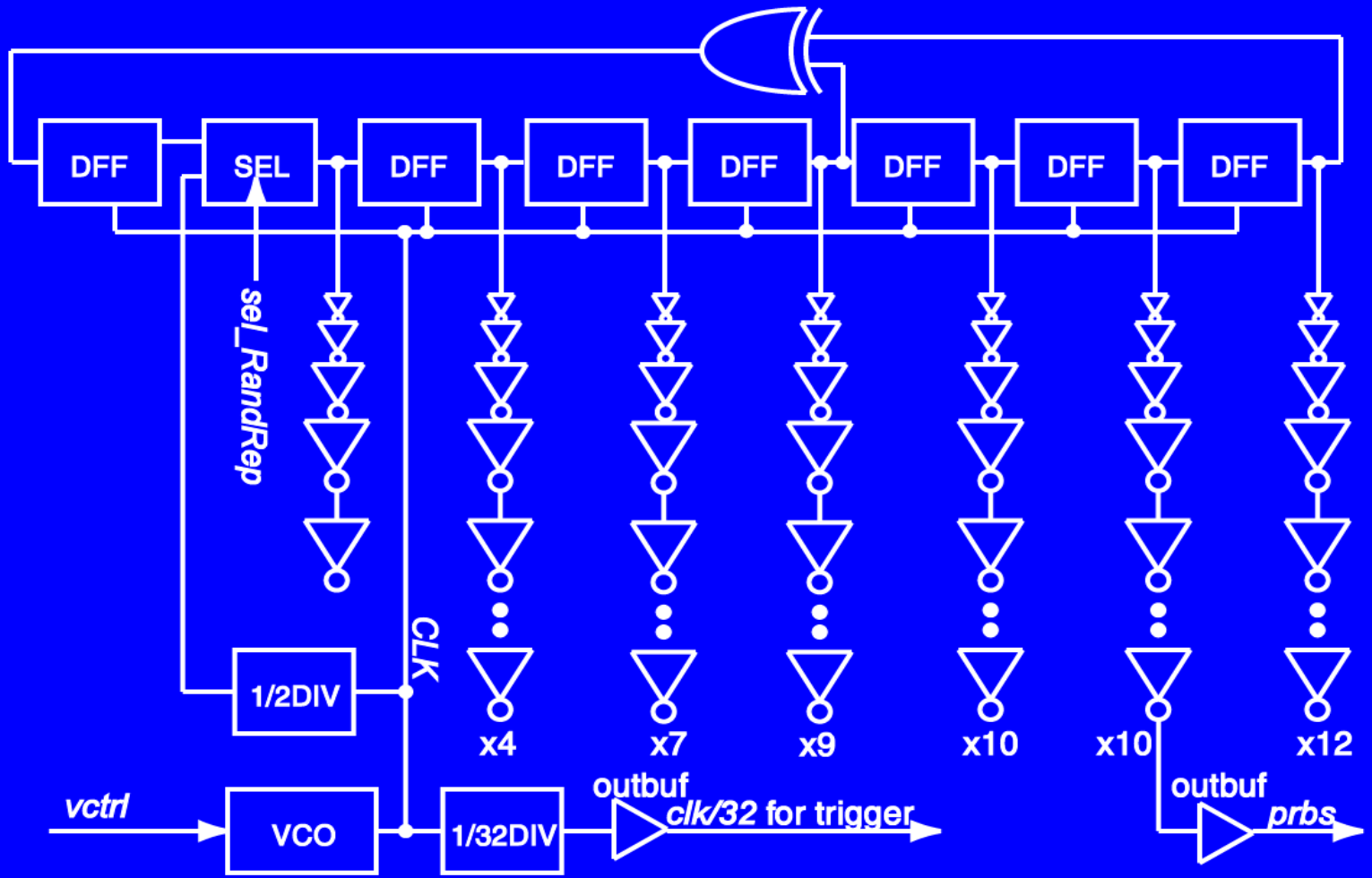
- Attach the stub to the power line will reduce the power supply noise
- $\lambda/4 < 1.5$cm at 2.5GHz, use off-chip stub



Off-chip Stubs

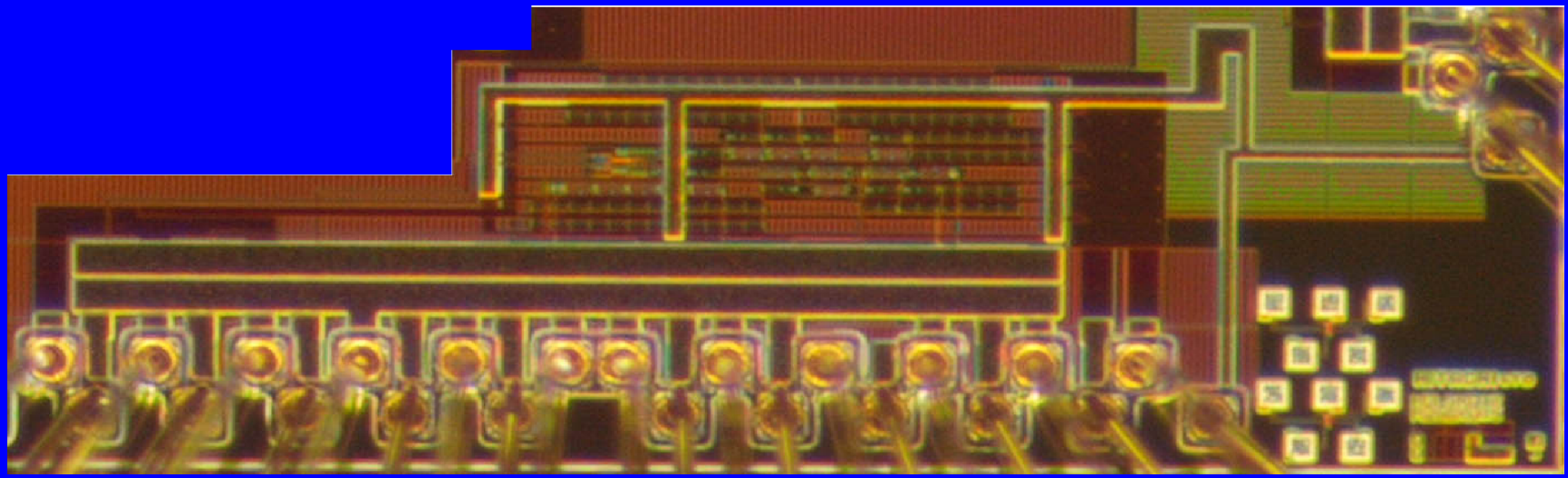


Internal Circuit as Noise Source

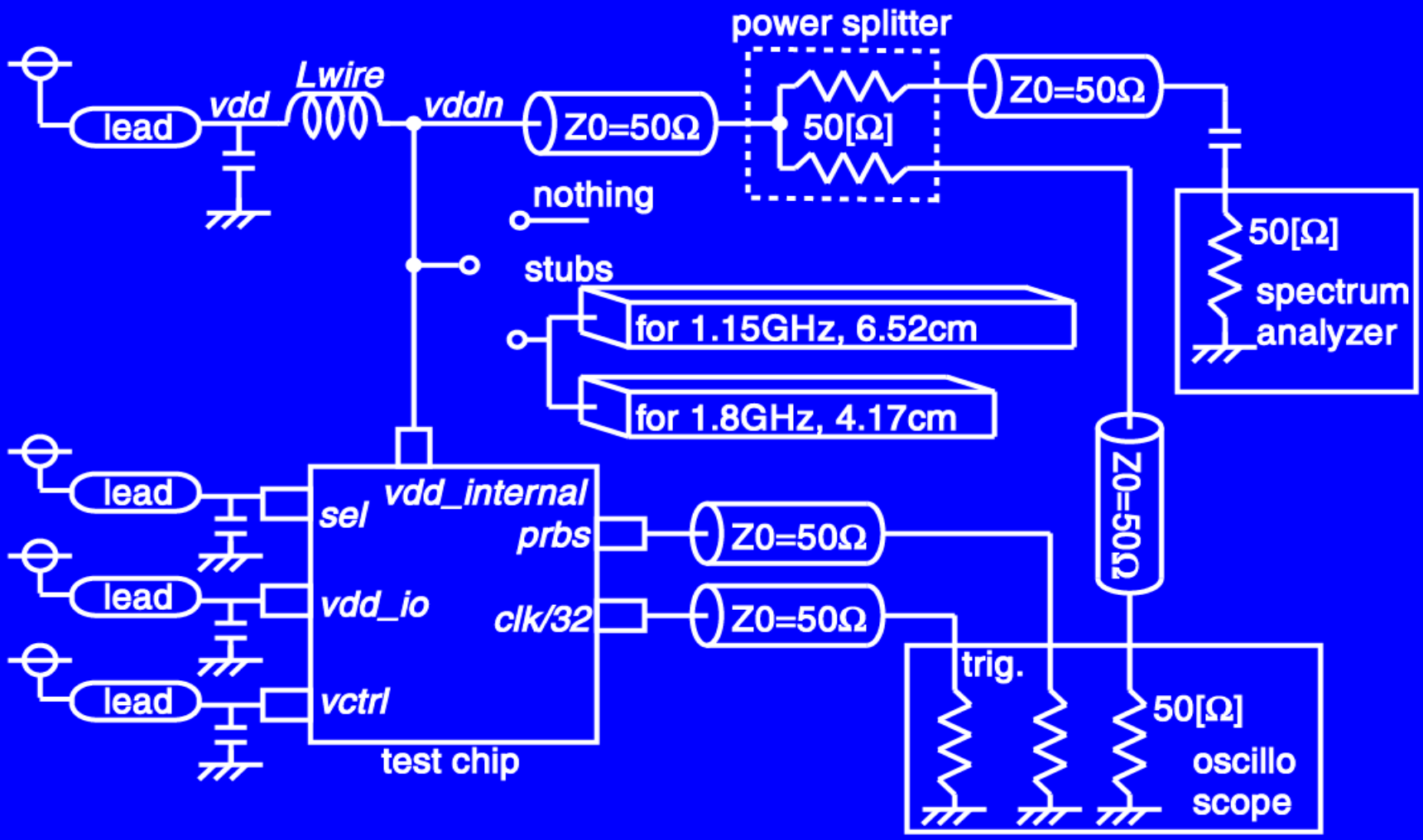


Chip Photograph

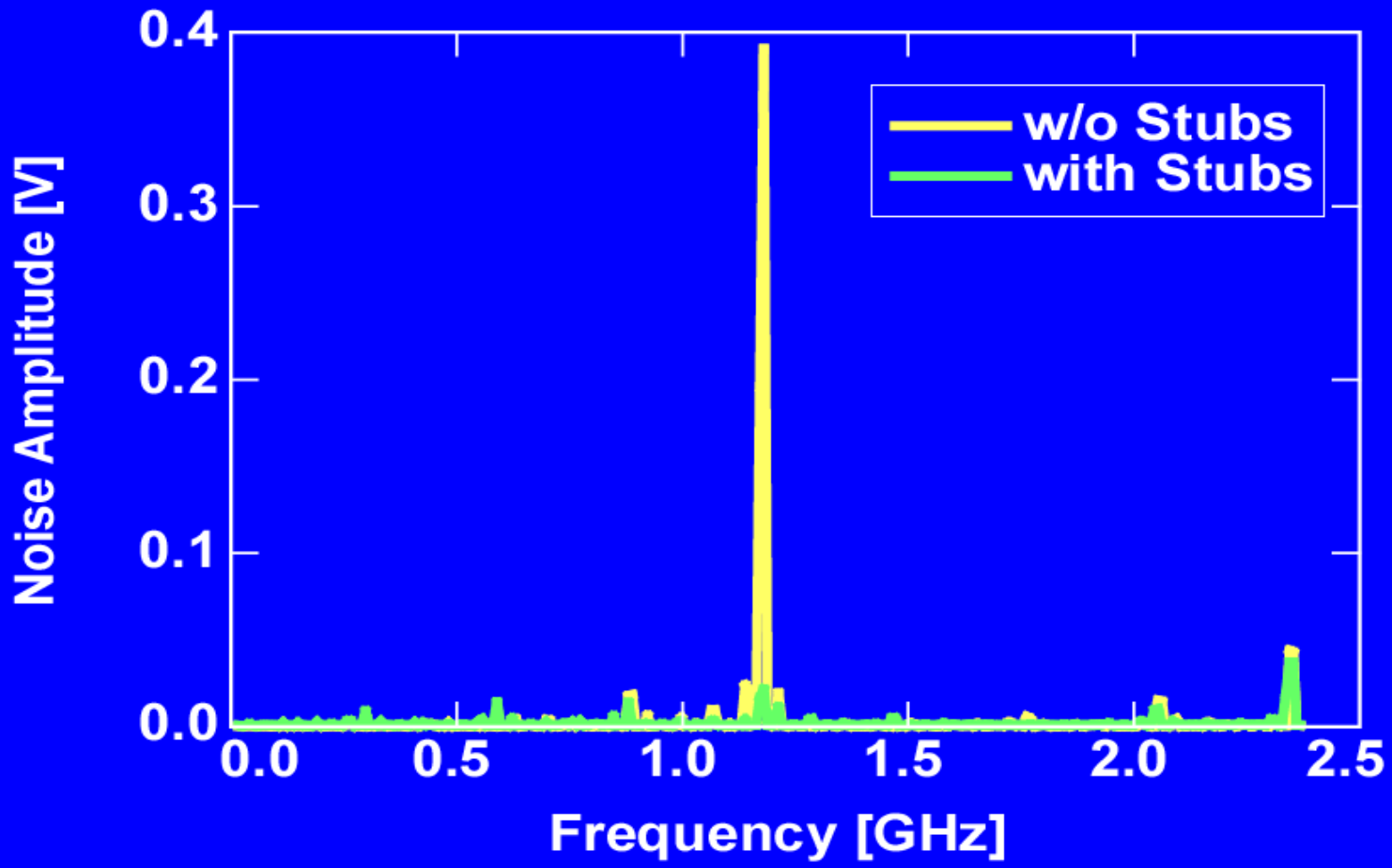
- 0.18um 5ML standard CMOS
- 2mm x 0.5mm



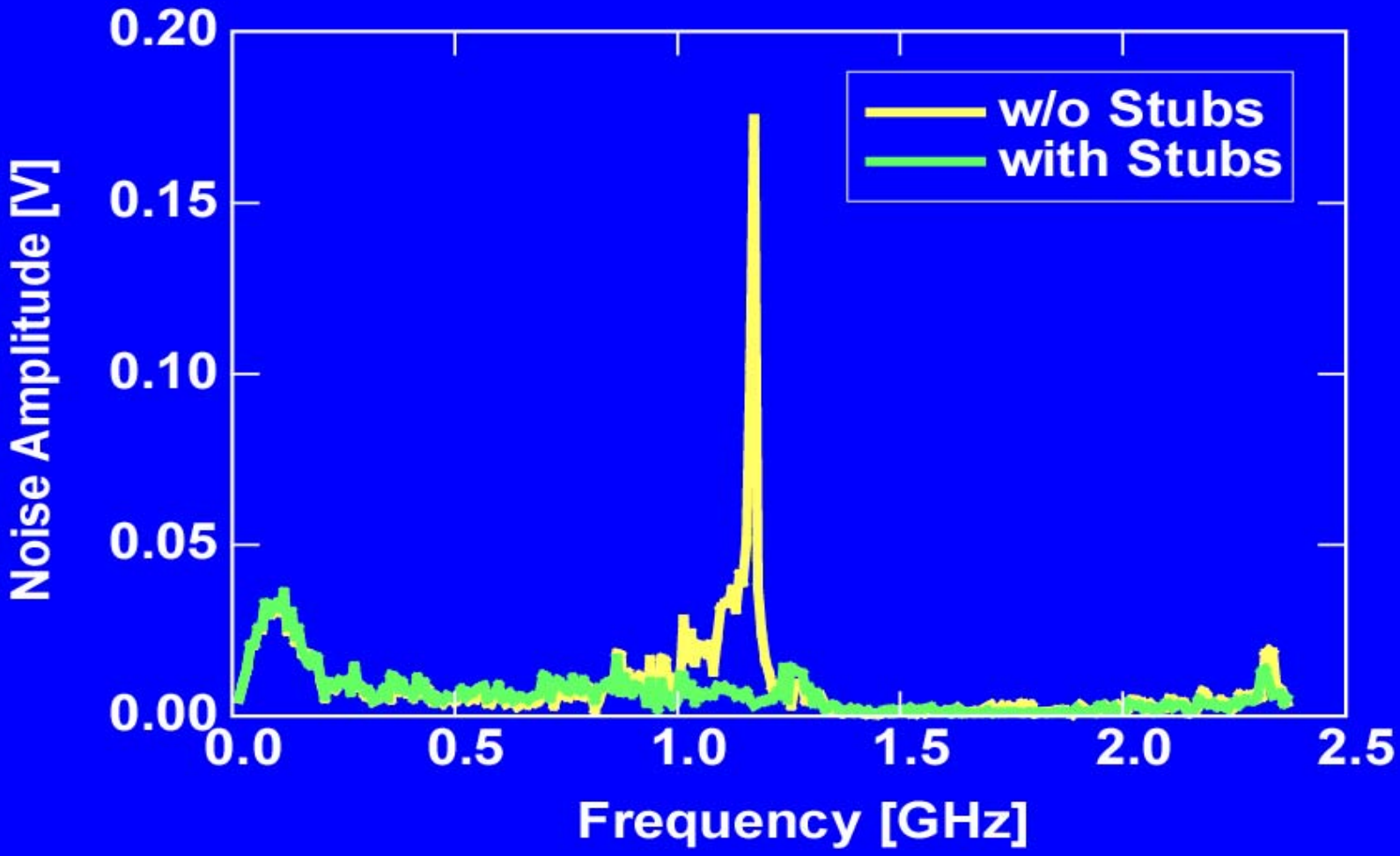
Schematic


power splitter
lead
vdd
Lwire
vddn
Z0=50Ω
50[Ω]
Z0=50Ω
nothing
stubs
for 1.15GHz, 6.52cm
for 1.8GHz, 4.17cm
50[Ω]
spectrum
analyzer
lead
lead
lead
sel
vdd_internal
prbs
vdd_io
clk/32
vctrl
test chip
Z0=50Ω
Z0=50Ω
Z0=50Ω
trig.
50[Ω]
oscillo
scope

Spectrum @1.15GHz Repeat

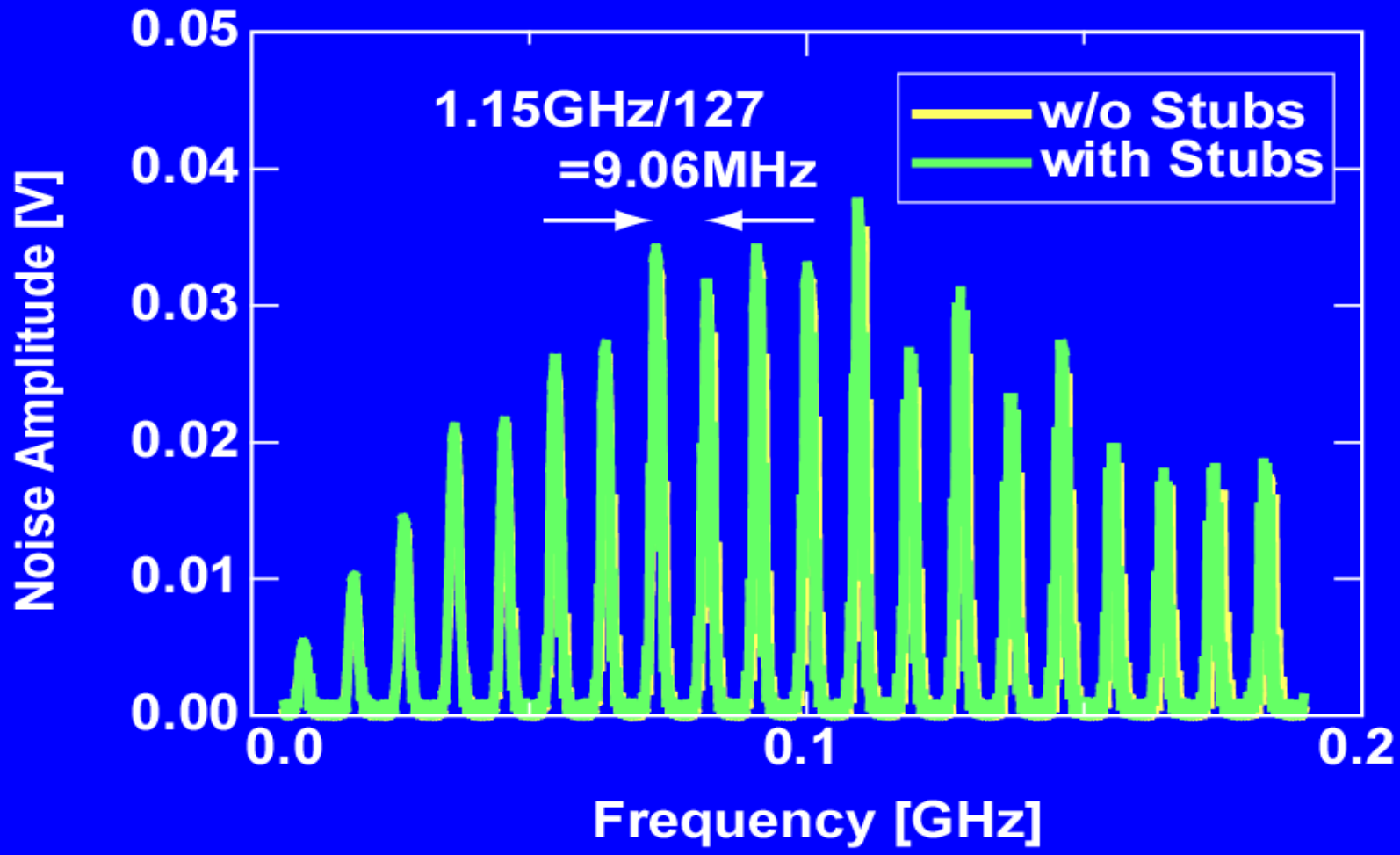


Spectrum @1.15GHz Random



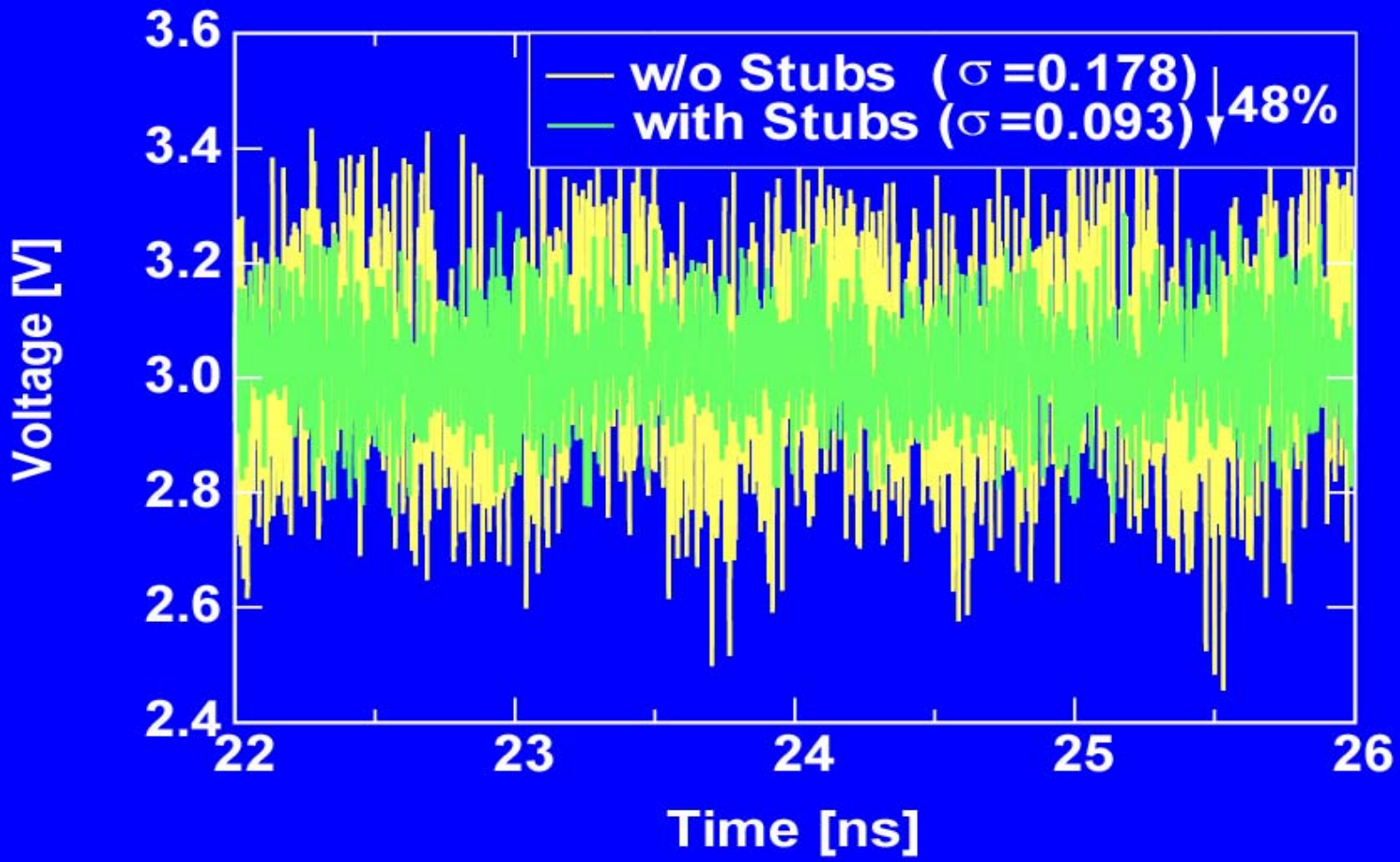
Spectrum of Lower Frequency

- PRBS 2^7-1 characteristics

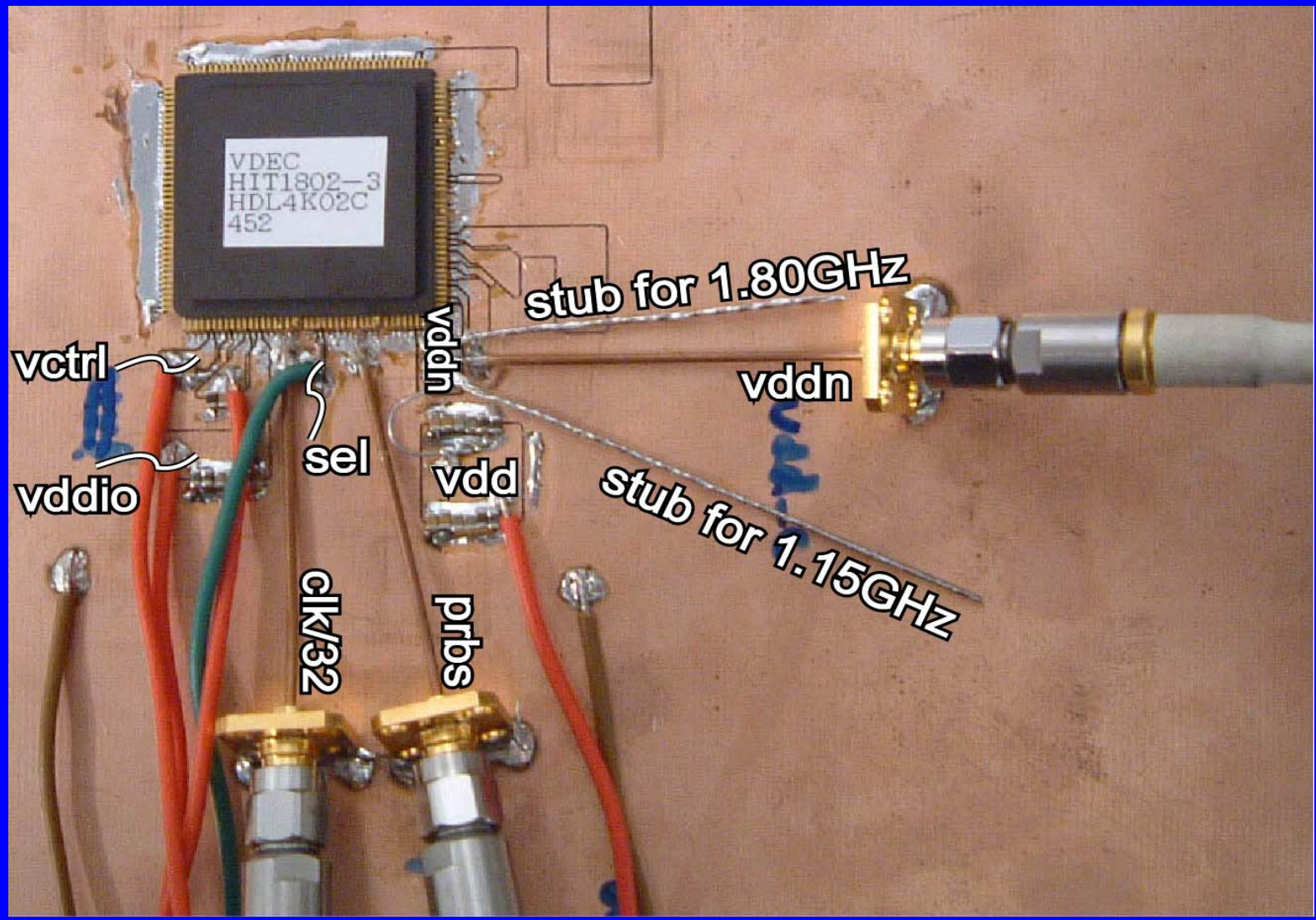


Waveforms @1.15GHz Random

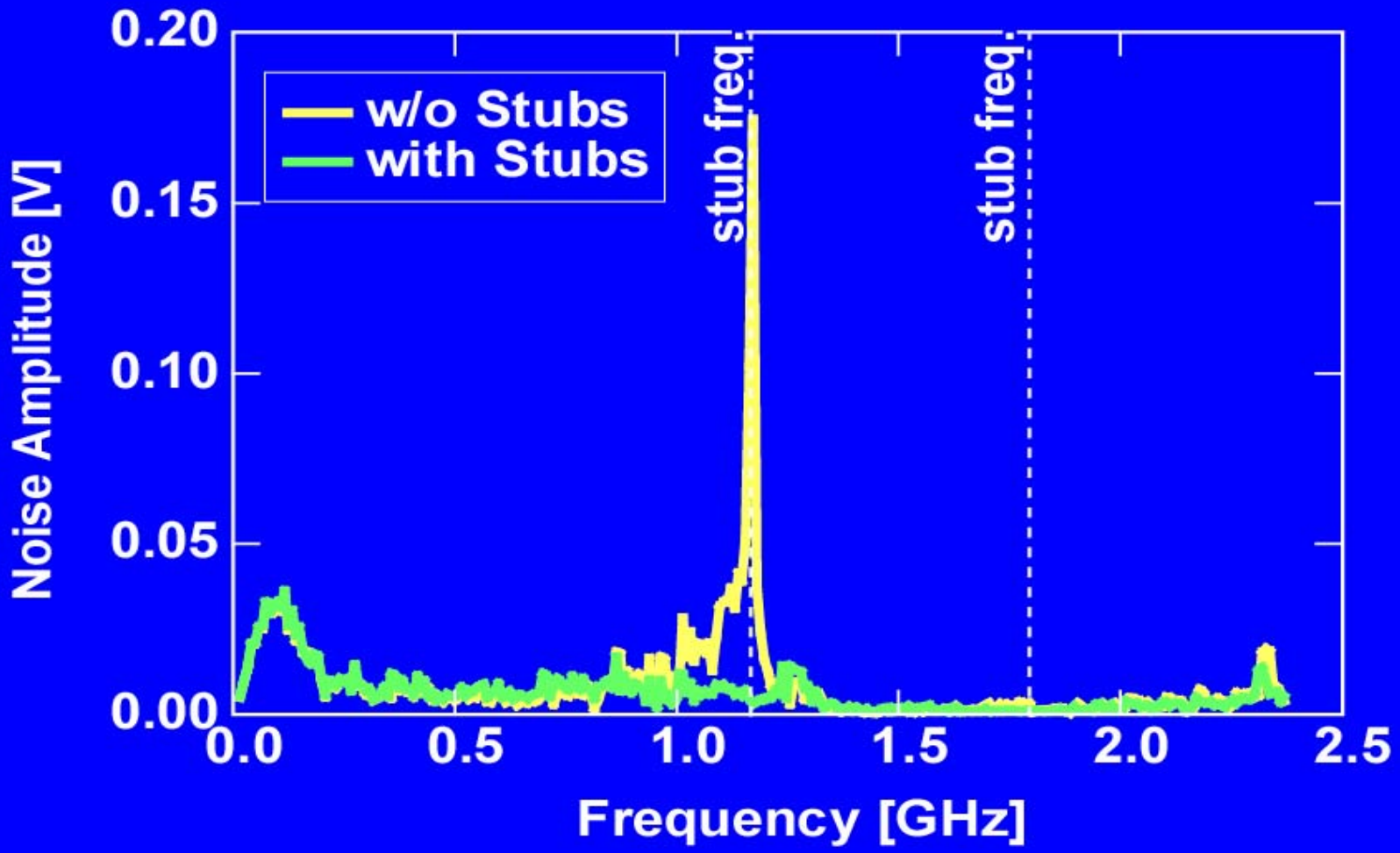
- **Noise amplitude is evaluated by σ**



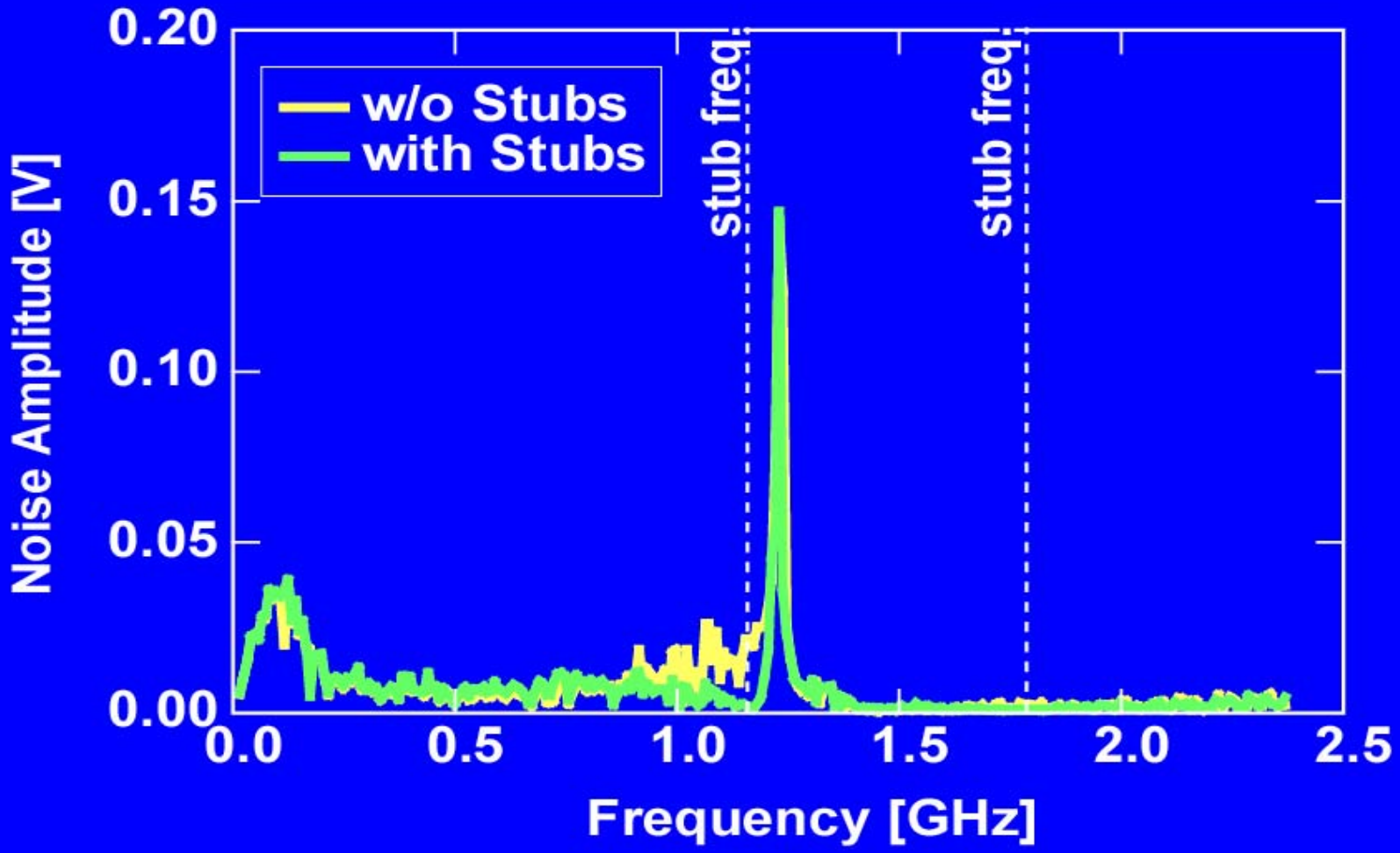
Off-chip Stubs



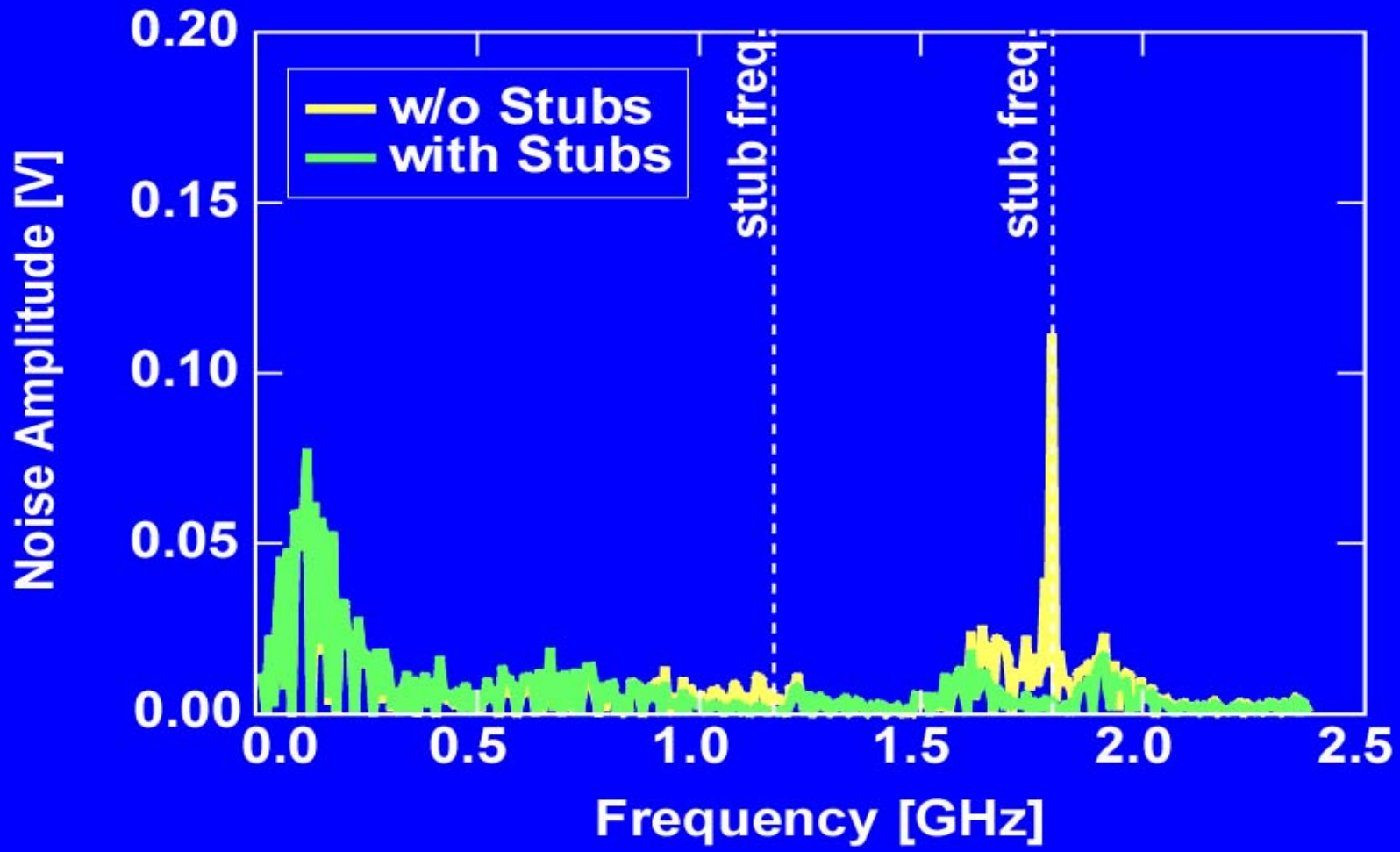
Freq. Dependence @1.15GHz



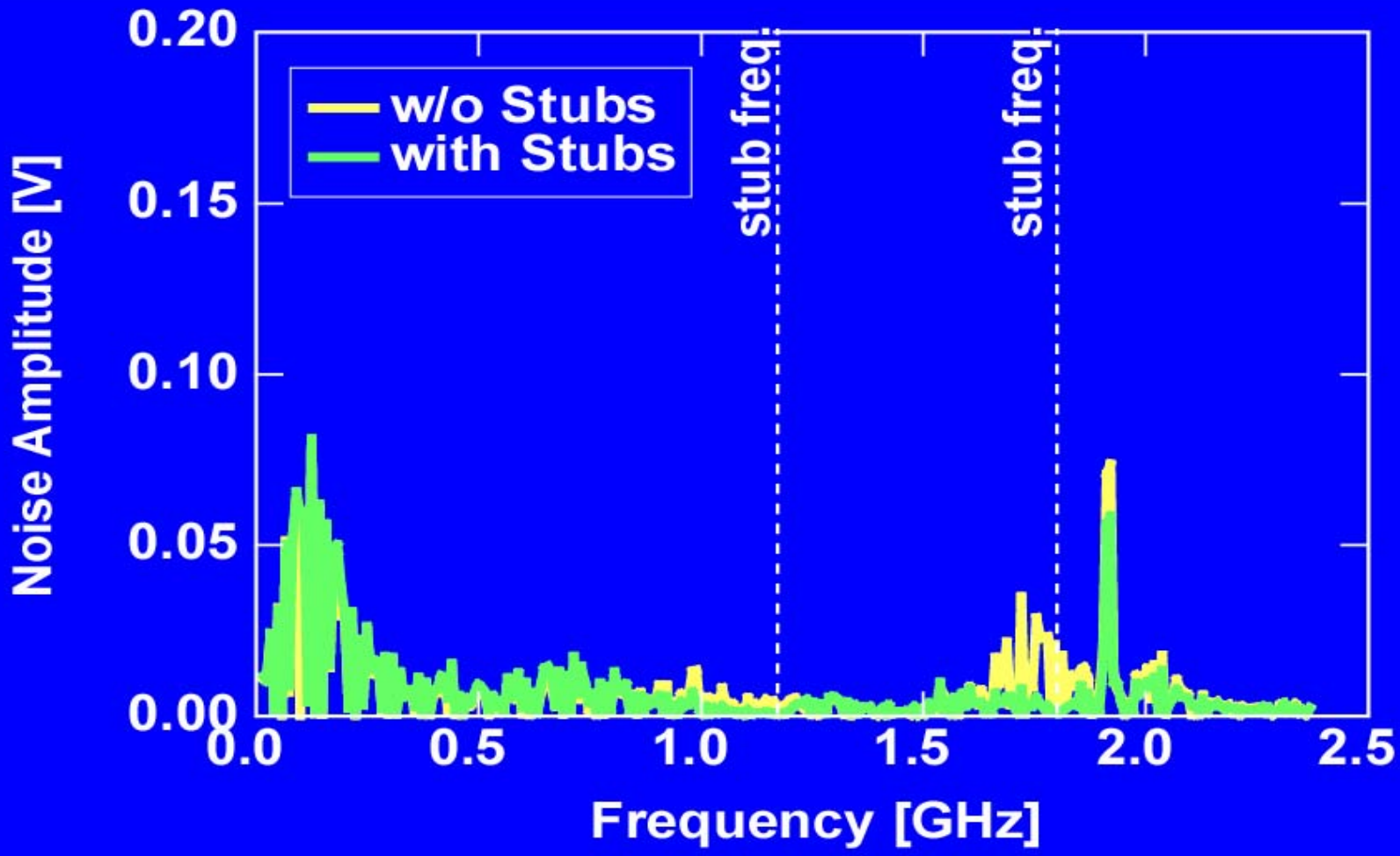
Freq. Dependence @1.25GHz



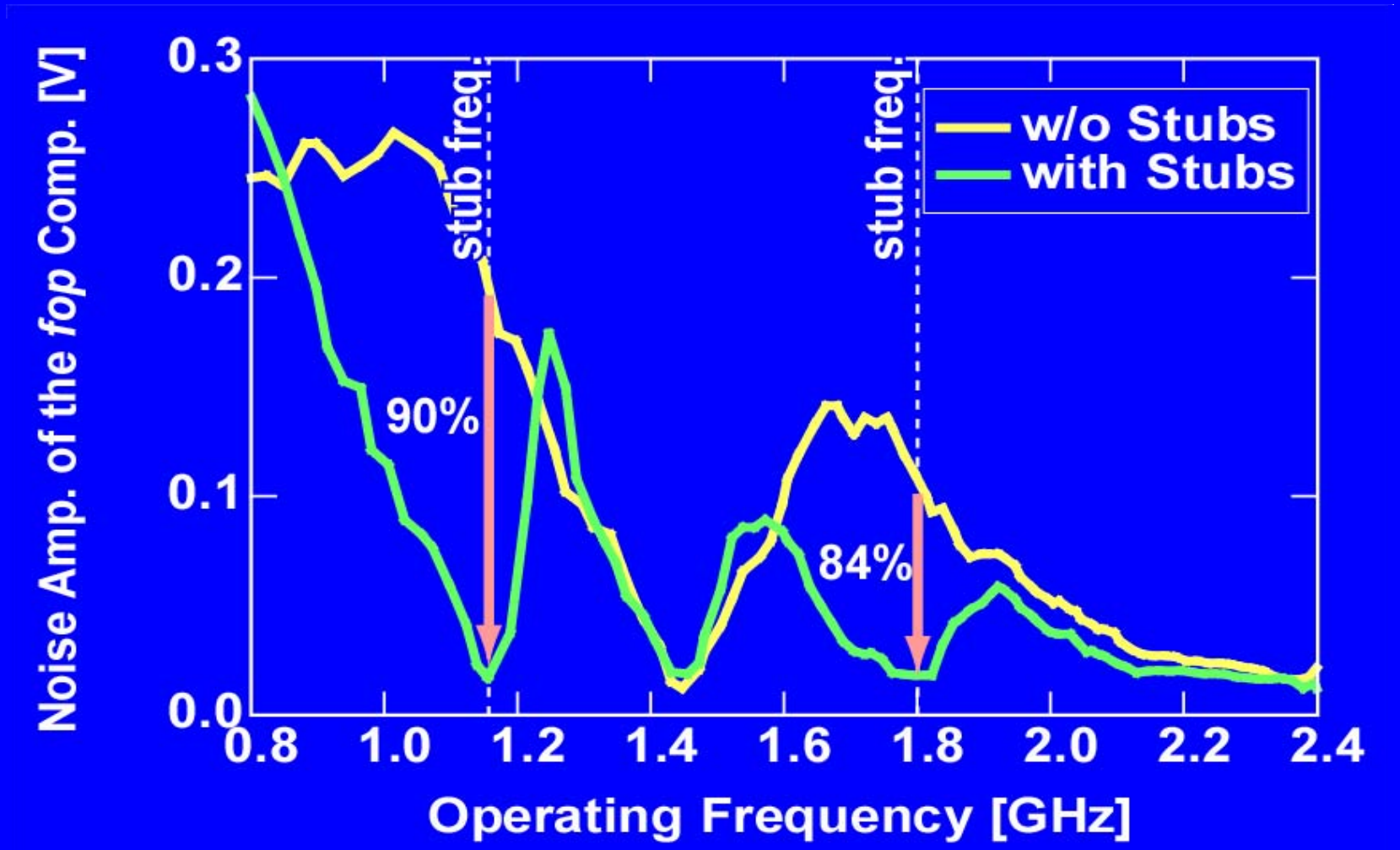
Freq. Dependence @1.80GHz



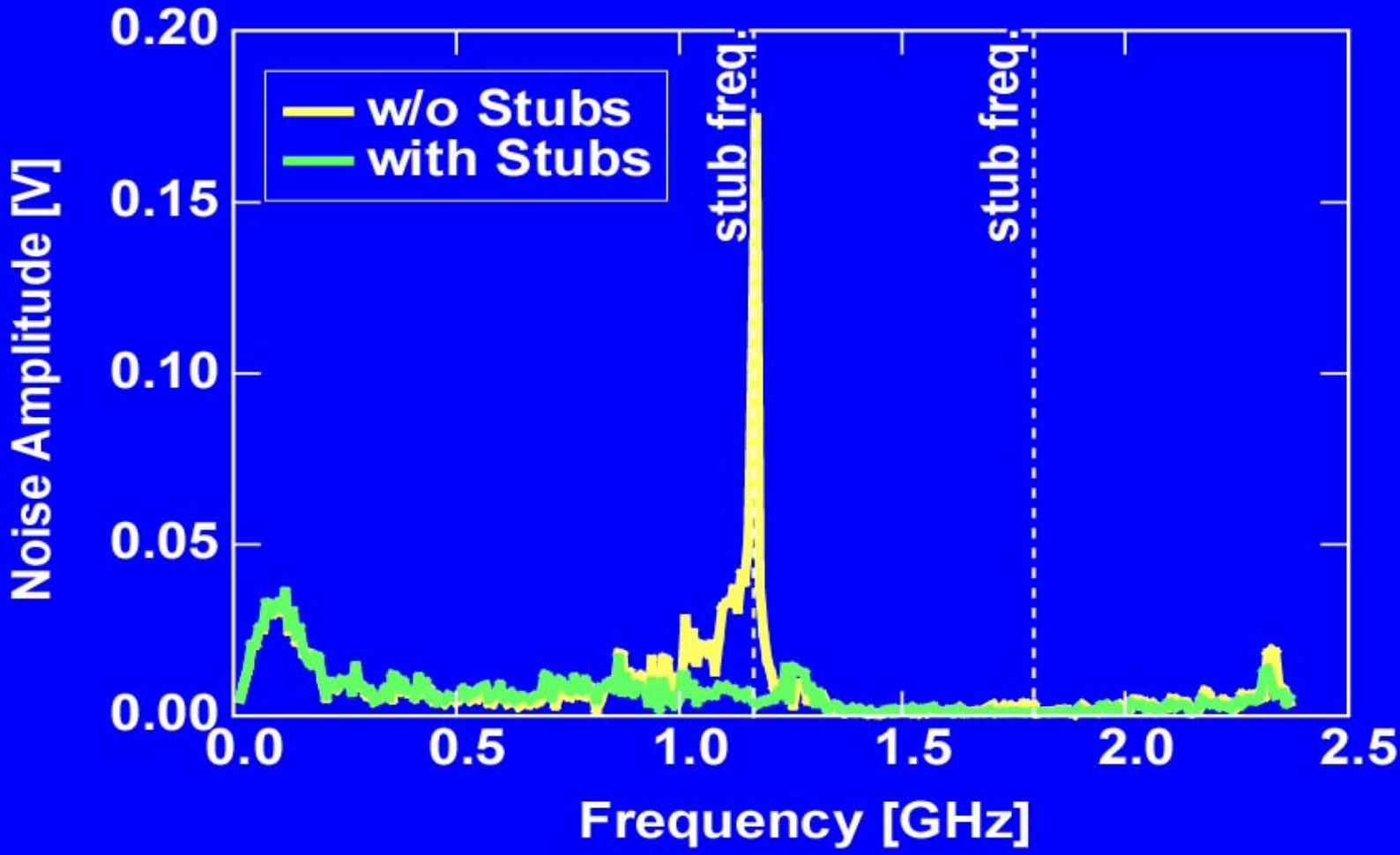
Freq. Dependence @1.85GHz



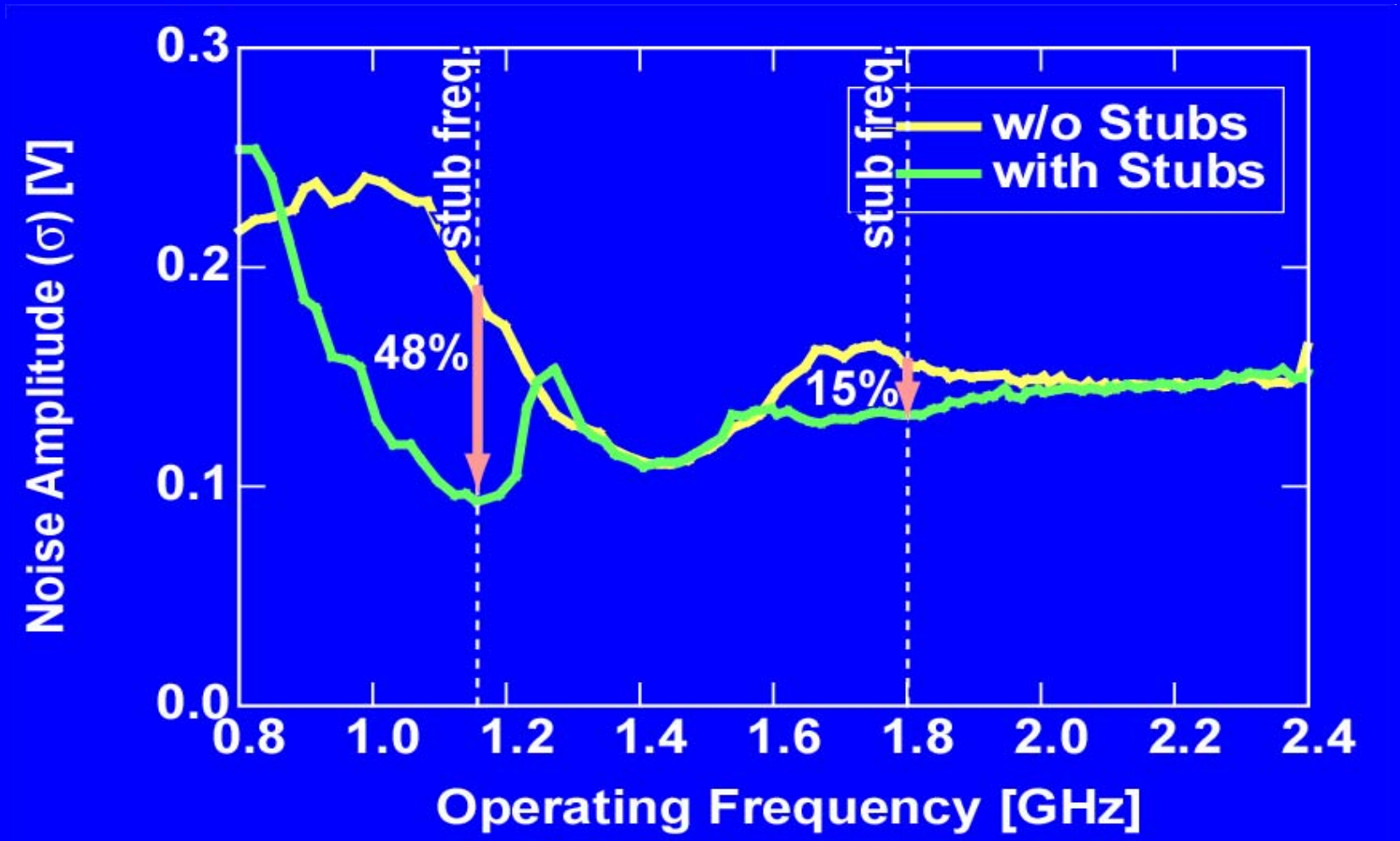
Noise of the *fop* Component



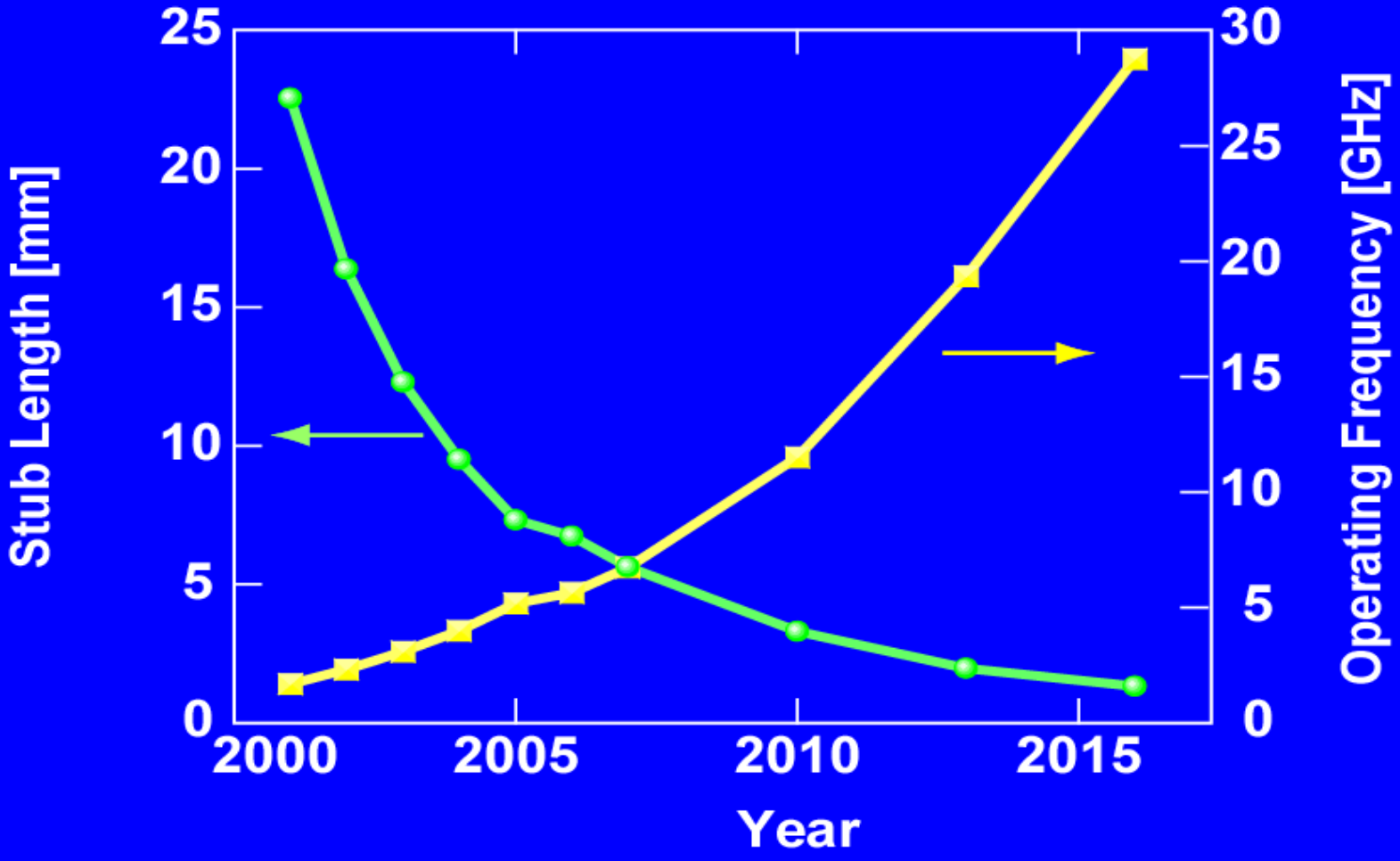
Freq. Dependence @1.15GHz



Total Noise Amplitude (σ)



Possibility of On-chip Stub



ITRS 2002 Roadmap

Summary

- Power supply noise reduction using off-chip stubs are demonstrated.
- Noise reduction is clearly observed.
  - 90% and 84% of the operating frequency component, 48% and 15% of total noise is suppressed by 1.15GHz and 1.8GHz stubs
  - Stub frequency dependence is observed
- On-chip stub integration will be possible in the near future

Q&A

Stub Theorem

- Input impedance of the transmission line of Z0, β, l, and ZL termination :

$$Z_{stub} = Z_0 \frac{Z_L \cos\beta l + Z_0 \sin\beta l}{Z_0 \cos\beta l + Z_L \sin\beta l}$$

- When open termination (ZL=infty)

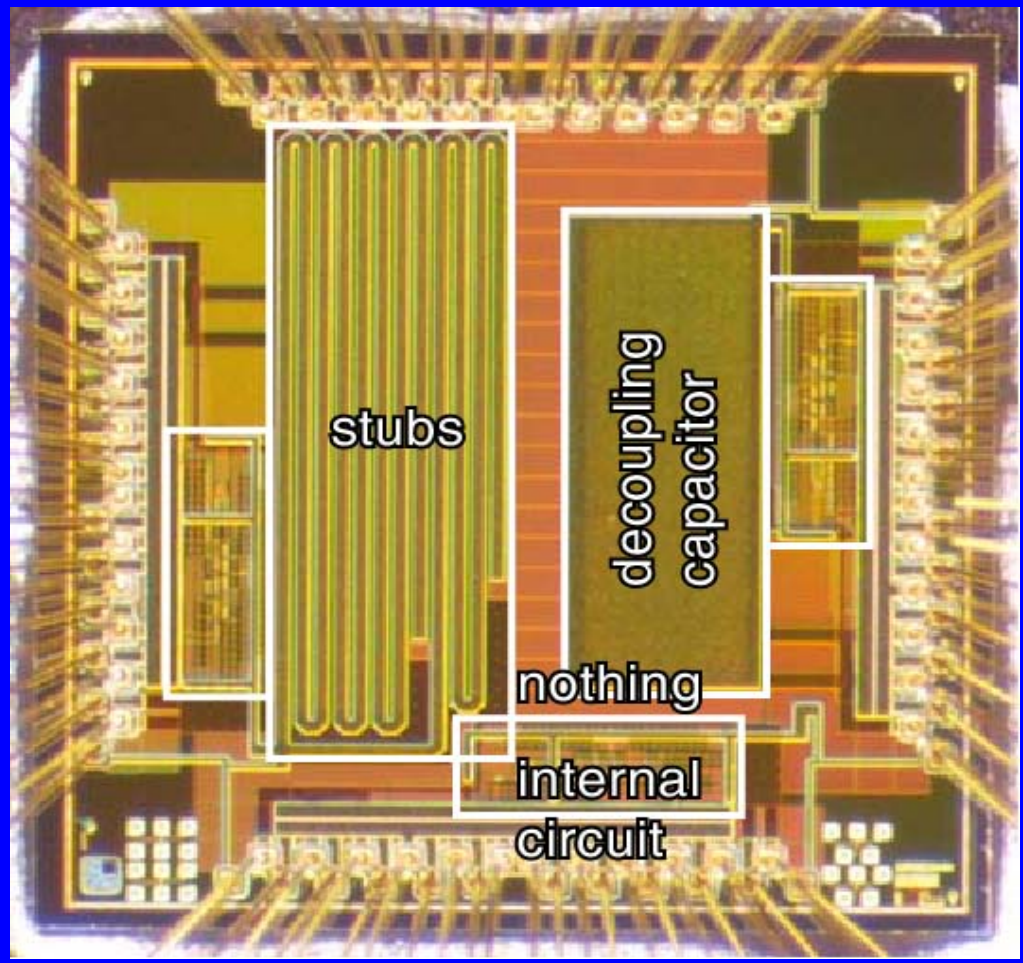
$$Z_{stub} = Z_0 \frac{\cos\beta l}{j \sin\beta l}$$

- When the line length is quarter of the wavelength ($\beta l = \pi/2$), no loss (R=G=0)

$$Z_{stub} = 0$$

Chip Photograph

- 0.18um 5ML standard CMOS



Freq. Dependence @1.45GHz