

# A Wideband CMOS LC-VCO Using Variable Inductor

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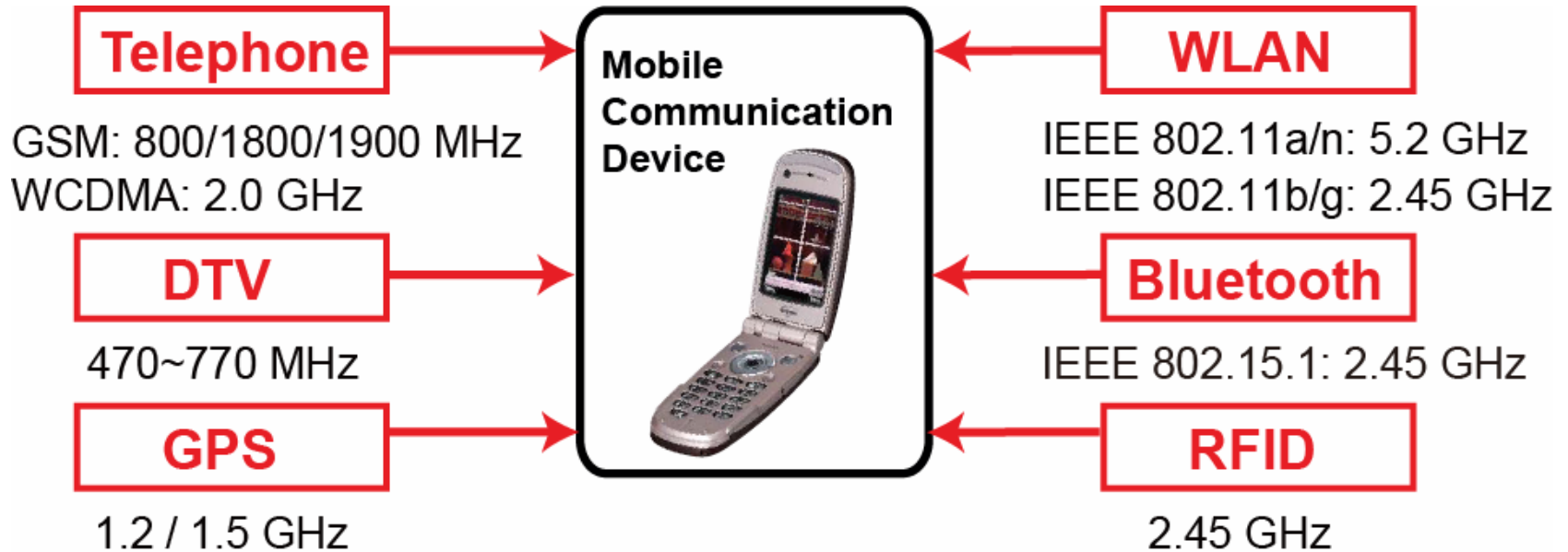
# 1. Background

## Mobile Communication Device

- ⇒ More multi-band/mode function
- ⇒ Smaller size
- ⇒ Lower power operation

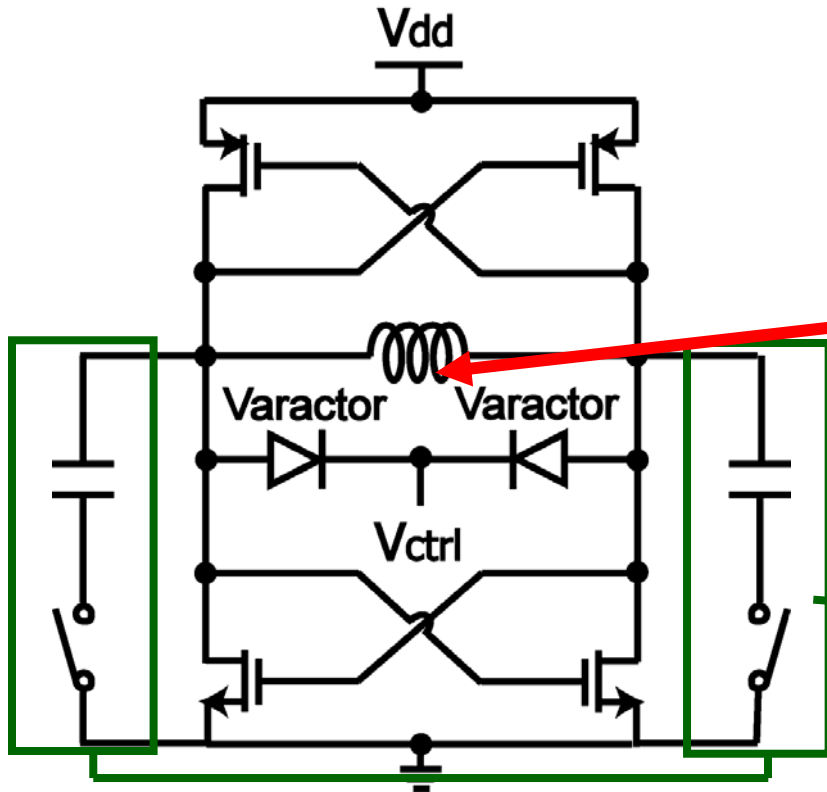
## More Multi-band/mode function

Multi-band RF front-end is required.



# 2. Proposed wideband LC-VCO

## Wide Tunable CMOS LC-VCO



## Oscillation Frequency

$$f_{osc} = \frac{1}{2\pi \sqrt{L_{tank} C_{tank}}}$$

Conventional **Varactor only**

~~Variable Inductor~~

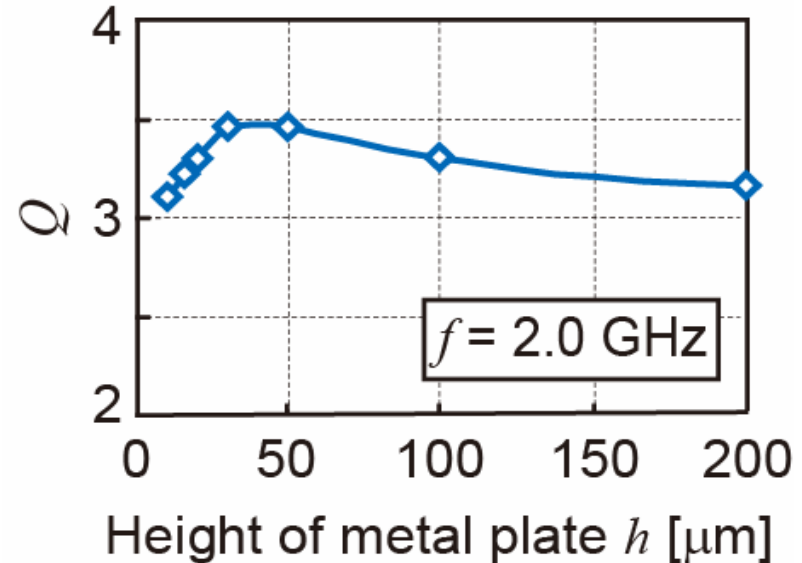
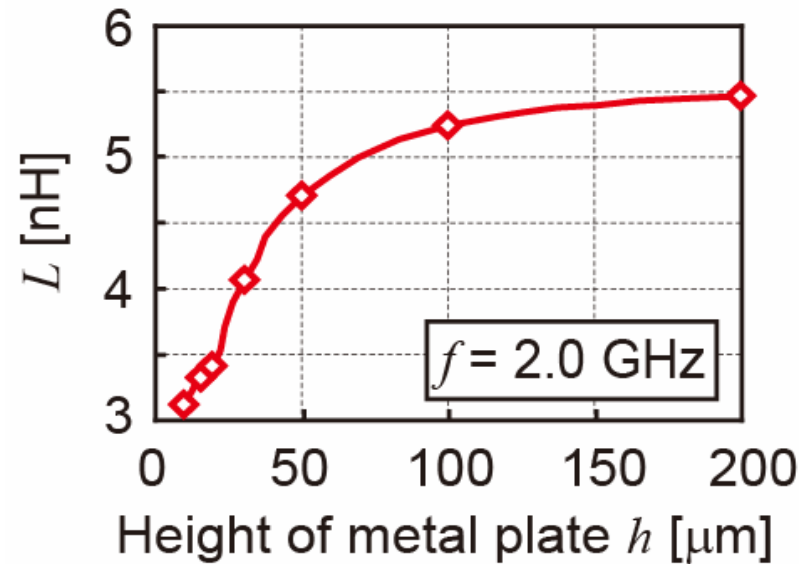
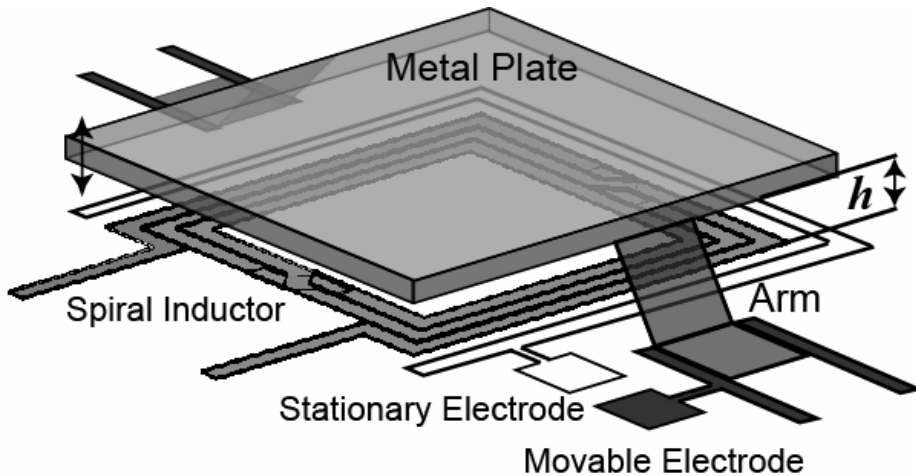
$\Rightarrow L_{tank}$  is varied

**Switched Capacitor**

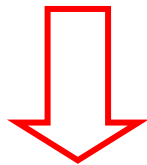
$\Rightarrow C_{tank}$  is varied

- Oscillation frequency can be tuned by variable inductor, switched capacitor and varactor.
- CMOS LC-VCO can achieve wider tuning range.

# 3. Variable inductor

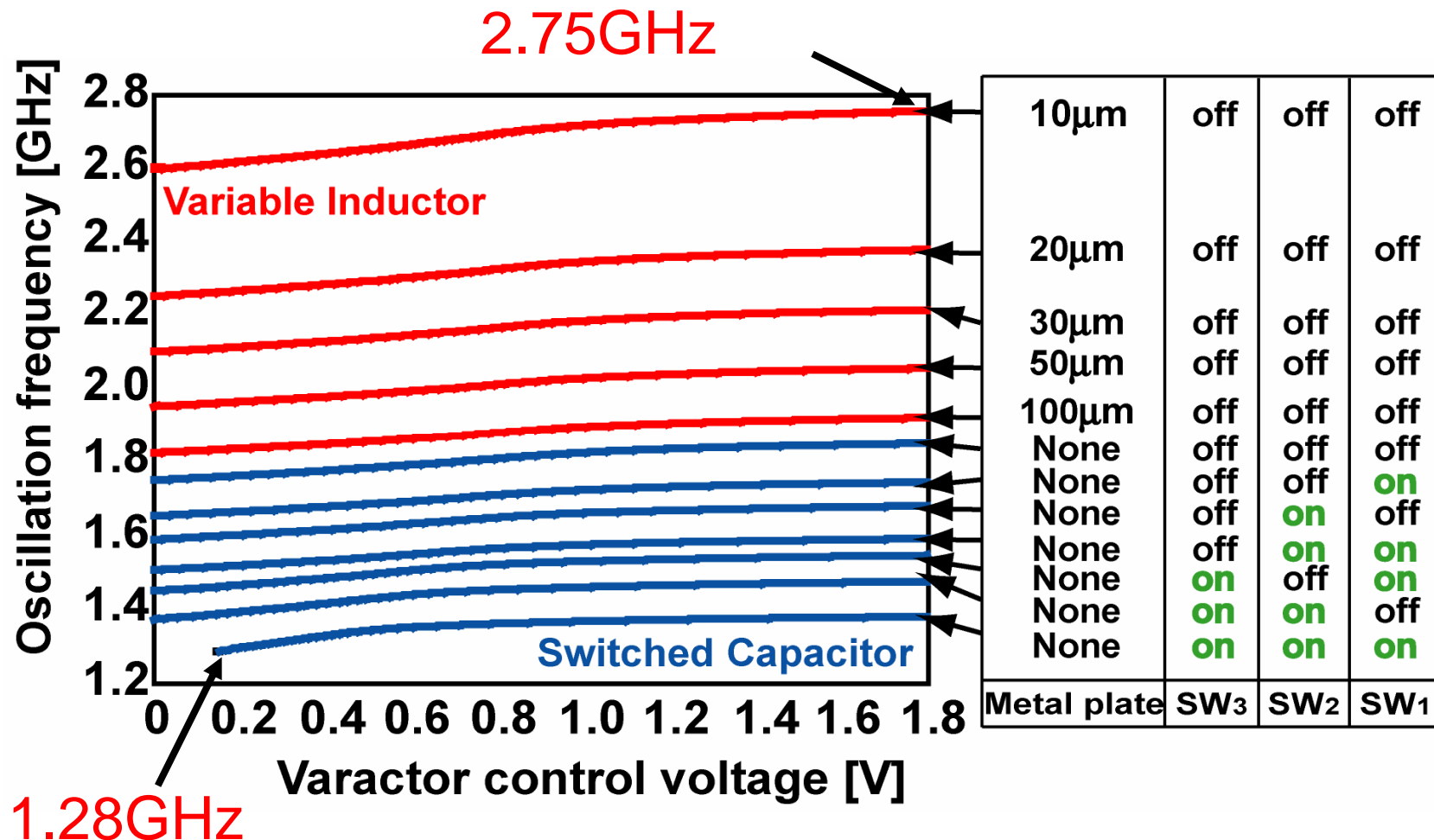


- Inductance : 3.1nH ~ 5.5nH
- Variable Ratio ( $L_{max}/L_{min}$ ) : 1.8
- Little degradation of Q



**Advantageous to LC-VCO**

# 4. Measurement result



**Center frequency**  
2.02GHz

**Tuning range : 72%**  
(1.28 ~ 2.75GHz)

# 5. Evaluation of VCO characteristics

## FOM<sub>T</sub> [1]

⇒ Normalizing VCO phase noise ( $L\{f_{\text{offset}}\}$ ) by oscillation frequency ( $f_o$ ), power consumption ( $P_{\text{dc}}$ ) and **tuning range (FTR)**.

$$FOM_T [\text{dBc/Hz}] = L\{f_{\text{offset}}\} - 20 \log \left( \frac{f_o}{f_{\text{offset}}} \cdot \frac{FTR}{10} \right) + 10 \log \left( \frac{P_{DC}}{1\text{mW}} \right) = FOM - 20 \log \left( \frac{FTR}{10} \right)$$

Ref.	Tech.	Center Freq. (GHz)	Core Power (mW)	FTR	Phase Noise 1MHz offset (dBc/Hz)	FOM (dBc/Hz)	FOM <sub>T</sub> (dBc/Hz)
[2]	0.18μm CMOS	1.80	4.8	73%	-127	-184.8	-202.1
[3]	0.18μm CMOS	5.88	7.65	13%	-124	-190.7	-193.0
This Work	0.18μm CMOS	2.02	18.2	72%	-135	-188.7	<b>-205.9</b>

[1] J. Kim, et al., IEEE International Solid-State Circuits Conf., Feb. 2005, pp. 416-417.

[2] A. D. Berny, et al., IEEE Journal of Solid-State Circuits, vol. 40, no. 4, Apr. 2005, pp. 909-917.

[3] T. Song, et al., IEEE Radio Frequency Integrated Circuits Symposium, June. 2004, pp. 127-130.

# 6. Conclusion

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- The proposed LC-VCO can achieve wide tuning range using variable inductor and switched capacitor.

**FTR=72% FOMt=-205dBc/Hz**

- Wide tuning range can be achieved by the variable inductor without phase noise degradation.

The wide-band tunable LC-VCO using variable inductor and switched capacitor is useful for multi-band RF front-end with reconfigurable RF circuit.