A Dual-Step-Mixing ILFD using a Direct Injection Technique for High-Order Division Ratios in 60GHz Applications

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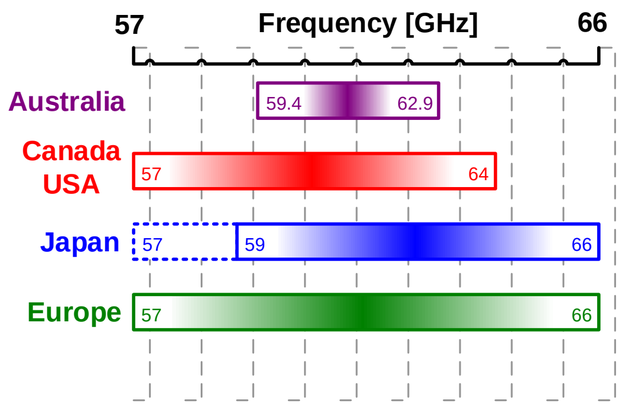
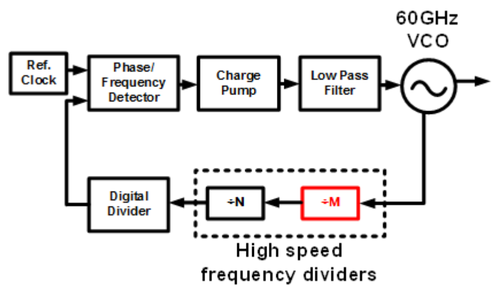
1. Motivation

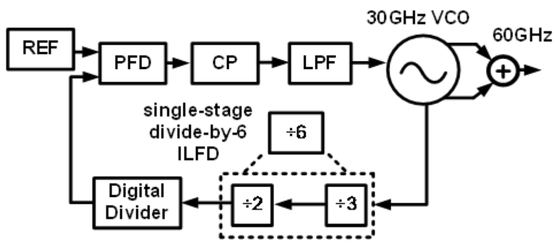
- 60 GHz Communications
  - 9 GHz unlicensed band
- Several Gbps wireless communications
  - 3.5 Gbps/ch (QPSK)
  - 7 Gbps/ch (16QAM)



1. 60GHz Frequency Synthesizers



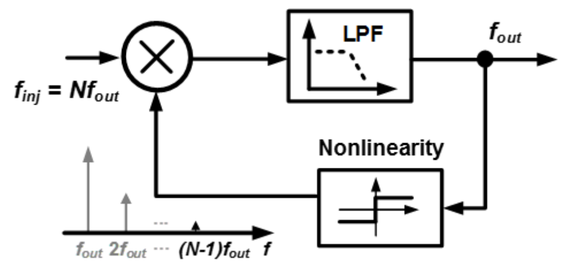
- Direct 60GHz VCO suffers from inferior phase noise
- Power-hungry frequency divider is required

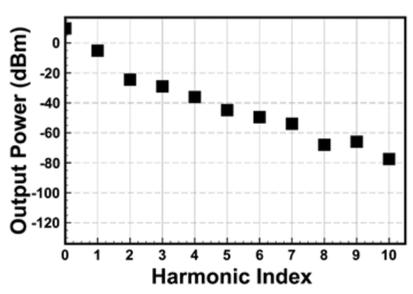


- Can alleviate oscillation speed of prescaler divider
- A technique to widen locking range of high-divide-ratio ILFD is required

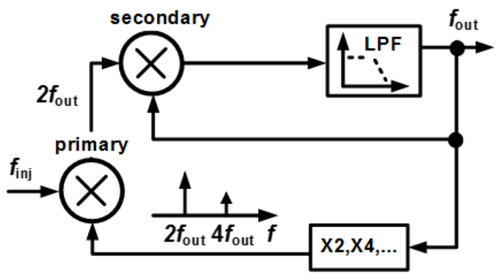
2. Principle of Operation

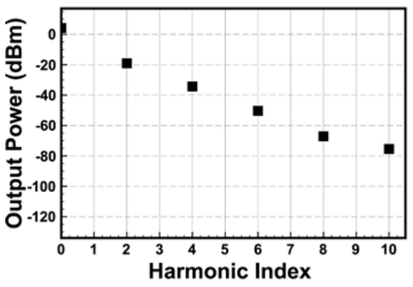
- Conventional Direct Mixing
  - Narrow locking range due to weak harmonic is utilized



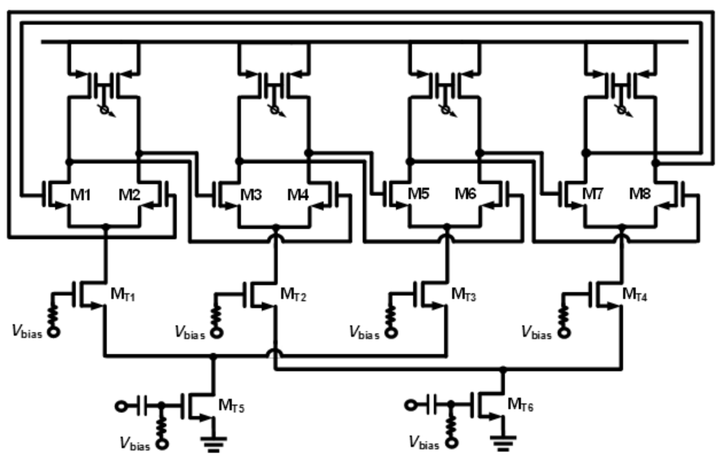


- Progressive Mixing
  - Stronger harmonic is utilized at the primary mixer





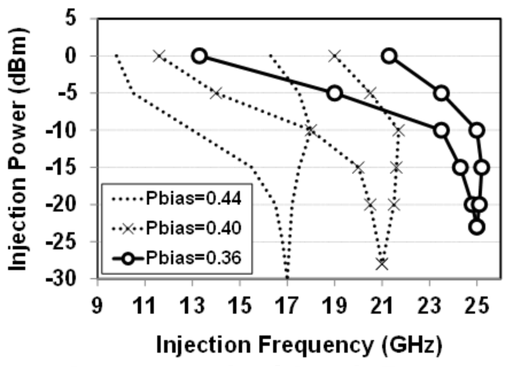
3. Conventional PMILFD



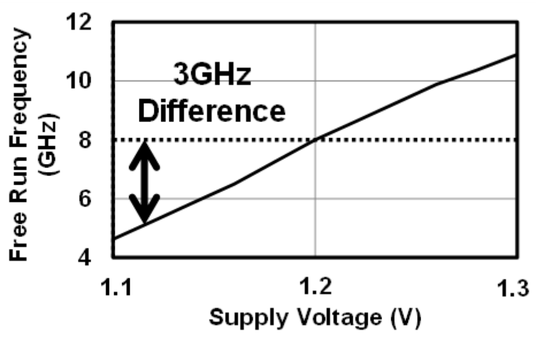
A. Musa., *et. al*, A-SSCC, 2011

Issues:

- Additional cascoded tail transistors increases headroom required
- Sensitive to supply pushing
- Sensitive to large injection amplitude



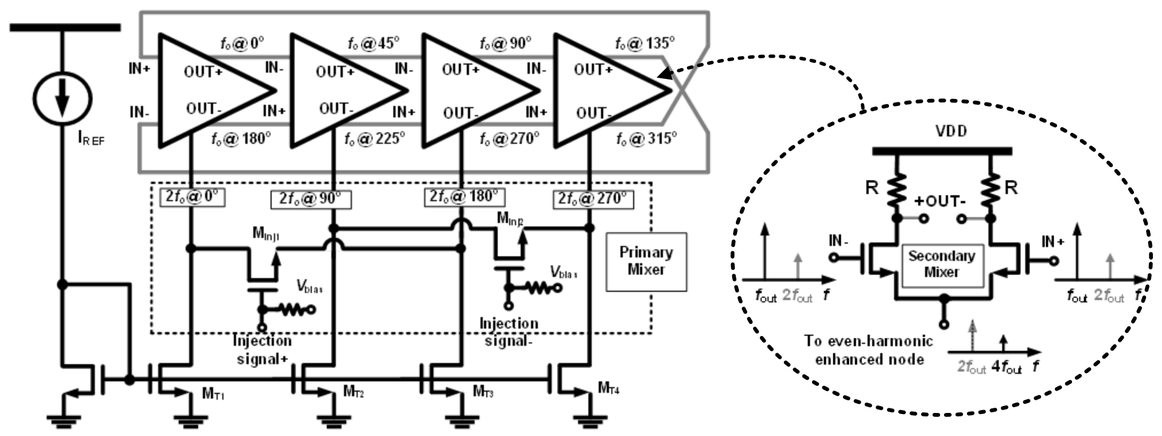
Asymmetrical Lock Range

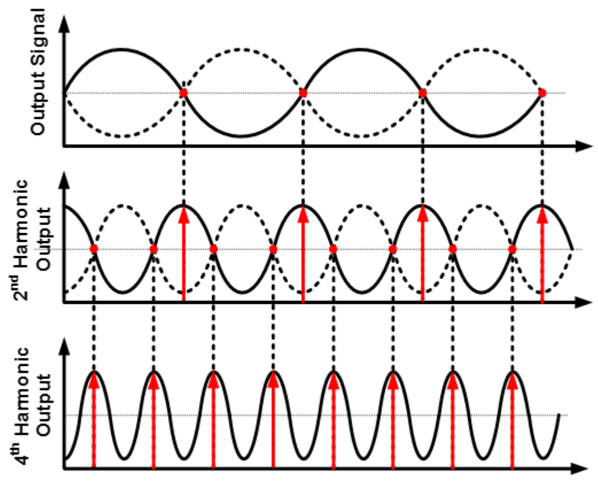


Sensitivity over Supply Pushing

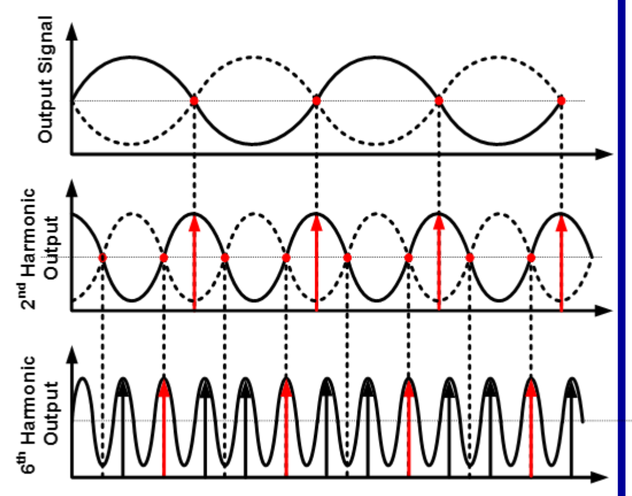
4. Proposed Dual-Step-Mixing ILFD

- Detailed Schematic



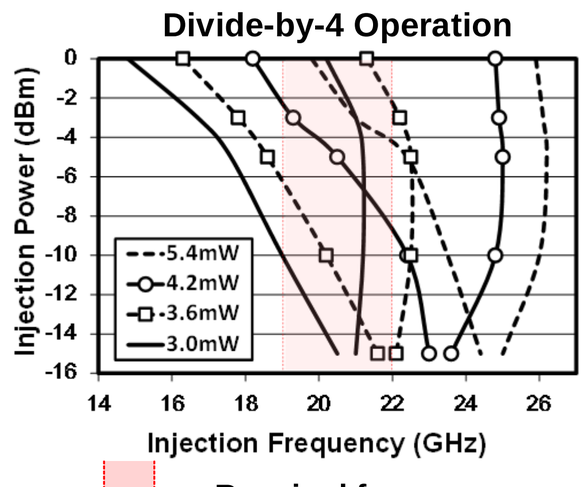


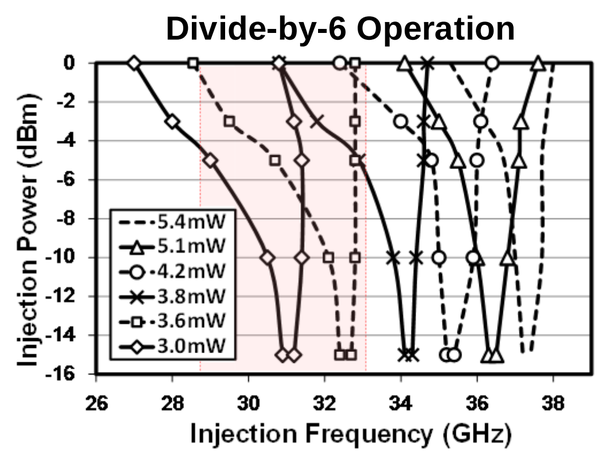
Locked state of divide-by-4 operation



Locked state of divide-by-6 operation

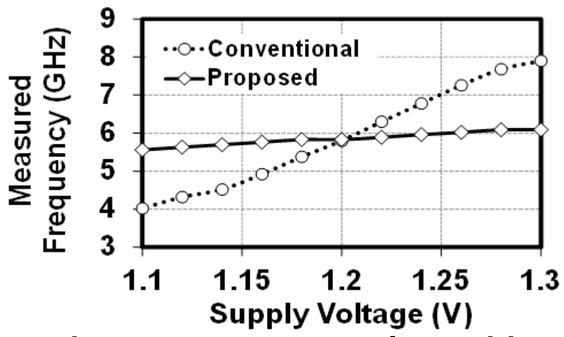
5. Measurement Results





Required frequency range for the 60GHz wireless standards

- 24% locking range for divide-by-4 operation
- 13% locking range for divide-by-6 operation
- Much more robust over supply pushing



Robustness over supply pushing

6. Conclusions

	Features	Div. Ratio	Locking Range* (GHz)	Locking Range* (%)	Power (mW)	FoM (%/mW)	Area (mm^2)
MTT'12	Direct mixing	3	21.7-24.9	13.7	8.3	1.7	0.140
ISSCC'09	Direct mixing	3	53.9-57.8	7.0	4.6	1.5	0.800
A-SSCC'11	Direct mixing	6	141.0-144.3	2.7	14.0	0.2	1.160
RFIC'04	Direct mixing	6	10.2-11.3	11.0	6.8	1.6	0.007
RFIC'05	Direct mixing	6	14.6-15.4	5.0	12.5	0.4	0.300
MTT'13	Current reused ILFD	6	121.0-124.8	3.5	4.5	0.8	0.140
This	Even-harmonic-enhanced	6	28.5-32.8	13.4	3.6	3.7	0.002

- The proposed ILFD achieves widest locking range reported for divide-by-6 operation
- It can support the required frequency range for 60GHz wireless standard in push-push or subharmonic injection architecture