A 20GHz Push-Push Voltage-Controlled Oscillator for a MM-wave Frequency Synthesizer

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Outline

- Background
- State-of-the-art 60GHz Local Oscillators
- Comparison of 20GHz vs 10GHz
- Proposed Schematic
- Measurement Results
- Performance comparison
Background

- 9-GHz unlicensed bandwidth at 60 GHz
- Several Gbps wireless communication

60GHz LO Architectures

60GHz QPLL

- 9GHz tuning range
- Low quality factor for capacitors

Poor Phase Noise

[1] IMEC, ISSCC 2009

30GHz PLL + Polyphase Filter

- 2nd harmonic utilized
- Polyphase filter for quadrature generation

High power consumption I/Q mismatch


20GHz PLL + Injection Locked Osc.

best phase noise reported

Comparison of 10GHz and 20GHz

At 10GHz, quality factor of resonator is relatively higher

\[ L(f_{offset}) = 10 \log \left( \frac{2kT}{P_{sig}} \left( \frac{f_o}{2Q_{tank} f_{offset}} \right)^2 \right) \]

Quality factor of resonator:

\[ Q_{tank} = \frac{Q_L \cdot Q_C}{Q_L + Q_C} \]


At 10GHz, quality factor of resonator is relatively higher
Proposed VCO in 60GHz LO

- Higher Quality Factor of tank
- Less concern for parasitics
- High frequency prescaler can be eliminated
- Low output power
- Large Area

$$ PN_{ILO} = PN_{input} + 20 \log n $$

$$ PN_{ILO} = PN_{10GHzPLL} + 15.5dB $$

<table>
<thead>
<tr>
<th>PN requirement (16QAM)</th>
<th>10GHz</th>
<th>60GHz</th>
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</thead>
<tbody>
<tr>
<td>-105.5 dBc/Hz</td>
<td></td>
<td>-90 dBc/Hz</td>
</tr>
</tbody>
</table>

| Tuning range           | 9.5-11 GHz | 57-66 GHz |

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Proposed Schematic

10GHz QVCO
+ 3-bit capacitor bank

20GHz resonator
+ 2-bit capacitor bank

Cross Coupling

20GHz + output

10GHz QVCO

20GHz - output
20GHz Resonator

- Impedance of resonator can be tuned by 2-bit capacitor

Improves

1) phase noise (as tail filtering)*
2) Improve output power

Tail Modulation

This mechanism acts as tail feedback modulation [3]

Measurement Result

Die Photo

Phase noise at 19.1GHz
-105dBc/Hz @ 1MHz offset
## PLL Performance Comparison

<table>
<thead>
<tr>
<th>Features</th>
<th>CMOS Tech.</th>
<th>Frequency [GHz]</th>
<th>Phase Noise [dBc/Hz]</th>
<th>Power [mW]</th>
<th>Output type</th>
</tr>
</thead>
<tbody>
<tr>
<td>QVCO@60GHz+ Foreground Calibration</td>
<td>45nm</td>
<td>57 - 66</td>
<td>-75@1MHz</td>
<td>78</td>
<td>Quad.</td>
</tr>
<tr>
<td>Push-push VCO@30GHz+ Hybrid Coupler</td>
<td>65nm</td>
<td>59.6 - 64</td>
<td>-73@1MHz</td>
<td>76</td>
<td>Quad.</td>
</tr>
<tr>
<td>VCO@20GHz</td>
<td>65nm</td>
<td>17.9-21.2</td>
<td>-105@1MHz</td>
<td>19.2</td>
<td>Diff.</td>
</tr>
<tr>
<td>Sub-harmonic Injection</td>
<td>65nm</td>
<td>58 – 65.4</td>
<td>-96@1MHz</td>
<td>80</td>
<td>Quad.</td>
</tr>
<tr>
<td>Push-push VCO@10GHz</td>
<td>65nm</td>
<td>16.3-19.3</td>
<td>-105@1MHz</td>
<td>7.5</td>
<td>Diff.</td>
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<tr>
<td>This</td>
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<tr>
<td>Push-push VCO@10GHz + 60GHz ILO [3] (based on calculation)</td>
<td>65nm</td>
<td>-</td>
<td>-96@1MHz</td>
<td>-</td>
<td>Quad.</td>
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Conclusion

• A 10GHz QVCO for 20GHz push-push operation is implemented in 65nm CMOS process.

• It shows capability of maintaining low phase noise while consuming 14% less power consumption than previously-implemented 20GHz VCO for 60GHz sub-harmonic injection LO.
Thank you for your attention