Dual Band VCO with Transformer Coupled Resonator and Automatic Amplitude Control

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About this project

- Analysis of Transformer Coupled Resonator
- Optimization techniques for Superior and Inferior mode resonances
- Q-Enhancement techniques for Transformer Coupled Resonator Design
- Accurate modeling of transformer
- Dual Band VCO design using both Superior and Inferior mode
- Automatic Amplitude Control (AAC) and adaptive power consumption for the VCO.

Analysis of Transformer Coupled Resonator

- There are two resonances: Superior mode and Inferior mode Resonances

Oscillation Frequencies:

**Superior**

\[
\omega_1^2 = \frac{2}{L_2C_2 + L_1C_1 + \sqrt{(L_2C_2 - L_1C_1)^2 + 4k^2L_1C_1L_2C_2}}
\]

**Inferior**

\[
\omega_2^2 = \frac{2}{L_2C_2 + L_1C_1 - \sqrt{(L_2C_2 - L_1C_1)^2 + 4k^2L_1C_1L_2C_2}}
\]

Dependency of resonant frequencies in effect of \( L_1C_1: L_2C_2 \)

Superior resonant frequency depends more on \( \text{Max}\{ L_1C_1, L_2C_2 \} \)

Inferior resonant frequency depends more on \( \text{Min}\{ L_1C_1, L_2C_2 \} \)

Optimization for quality factor and Q-Enhancement

- Superior mode: \( C_2 \) dominates the secondary branch. In order to minimize the degradation due to \( L_2-M \Rightarrow \text{Make: } L_2:L_1 = k^2 \) so that \( L_2-M=0 \). (Inferior mode will be suppressed). With this technique the quality factor of Superior mode can be enhanced \( 1+k \) times.

- Inferior mode: \( L_2-M \) dominate \( \Rightarrow \text{make } L_2>>L_1 \) or \( L_2:L_1 = k^2/4 \) (most negative inductance of \( L_2-M \) will be resulted)
**Dual Band VCO with Automatic Amplitude Control**

**Block Diagram**

- **Switched Capacitor Array**
- **Transformer Coupled resonator**
- **Vtune**
- **Mode Switching**
- **R\textsubscript{tank1} @ superior**
- **R\textsubscript{tank2} @ inferior**
- **Out+**
- **Out-**
- **-Gm cell**
- **Biasing Circuitry**
- **LPF**
- **Amp_Det**
- **Vref**

**Tuning Range**

- Tuning Range of Superior mode is 2.6GHz to 7.2 GHz
- Inferior mode is 6.8GHz to 10.6GHz

**Adaptive Power Consumption**

- The power consumption is adaptively controlled by the AAC with constant oscillation amplitude. For 0.8Vpp amplitude, power consumption is from 776uW to 5.89mW.

**Phase Noise**

- Phase noise can be enhanced by increasing the oscillation amplitude.
- -148.8dBc@ 10MHz offset can be achieved
Measurement Results

On-Wafer Measurement photo

- Large variation of oscillation amplitude due to variation of $R_{Tank}$
- Constant power consumption

Output power Without AAC

Output power with AAC

Power consumption adaptively controlled by AAC

- Adaptive Power Consumption