Active RF Phase Shifter
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Introduction
The 5G wireless system data rates are multifold higher than 4G wireless communication systems. To handle these higher data rates, wideband phase shifter becomes an important element of 5G equipment. The phase shifters shift the phase of the radiated and receiving signals.

This “Active RF Phase shifter” implementation uses Vector Modulator/Vector summer (IQVM) architecture to achieve 360 Degree phase shift in 22.5 degree steps for signal frequency from 6GHz-24GHz. This architecture has the following major blocks:
- Signal source, IQ signal generation circuit (Polyphase filter), Vector Modulator, and variable gain amplifier (VGA).

In this architecture, input signal passes through Polyphase filter and produces the I/Q signals. These signals fed into a vector-summing core and this converts the IQ signals to 4 phase output currents “0 Degree (i+), 90 Degree (i–), 180 Degree (i^)+ and 270 Degree (i^)”. Adding two of these currents generates the required phase shift over 360 Degree. The amplitude control of the combined signal generates the continuous phase output. Current mode VGAs at the output of vector sum select polarities and adjust the magnitude of the quadrature currents.

LC Polyphase filter
There are many ways the low pass and high pass filters can be constructed and one of them is LC Polyphase filter. As we know that Inductor and Capacitors are a very good phase differing element compared to resistors and capacitors. At the resonant frequency (f0), the output changes to 90 Degree perfectly, if the input is a differential signal with a perfect 180 Degree.

IQVM – Gilbert Multiplier
The Double balanced Gilbert cell has two pairs of MOSFETs connected in symmetrical manner. This symmetrical structure attenuates the unwanted signals at the output. One of the usages of the Gilbert mixer is a frequency multiplier, which multiplies the signals.

There are two pairs of symmetrical MOSFET transistors are used for I and Q differential signals, which will feed into top transistors referenced, M2, M3, M5 & M6, respectively. The respective I & Q control voltage feed happens to VRF^+ & VRF^- Normally, this is generated with the help from Digital to Analog Converter (DAC).

Variable Gain Control
As the name suggests Variable Gain Amplifier (VGA) amplifies the input signal based on the control voltage applied to the circuit to produce the variable gain. Variable Gain Amplifiers are also known as "Signal-conditioning amplifiers." The Variable Gain Amplifiers support to compensate for the variable losses occurred at Gilbert cell.

Methodology

Analysis and Results
The simulation for 6GHz-24GHz was performed using Cadence Virtuoso tool.

Following Figure shows the 24GHz phase variation with various I & Q control using Double balanced Gilbert Multiplier with tail current source.

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Summary/Conclusions
The Active RF phase shifter has been designed using 45 nm CMOS Technology. This phase shifter is designed with the help of Polyphase filter, Gilbert Multiplier based Vector Modulator and Variable Gain Amplifier. This RF phase shifter is controlled using 4 bits for phase and 2 bits for gain control to achieve the complete 360° phase rotation in 22.5° phase shift steps by using the IQVM with Double balanced Gilbert cell multiplier with tail current source. The total power consumption is less than 50 mW at 24 GHz. This phase shifter supports wide frequency range from 6GHz to 24GHz. The phase shifter could support beyond 24 GHz as well, but the output swing is limited by the stacking transistors of Gilbert Multiplier.

Key References
4. B. Pham, “A 13GHz Gilbert Mixer in 0.18nm CMOS For a Cable Tuner,” Bachelor Thesis, Carleton University.

Acknowledgements
I would like to take this opportunity to thank Prof. Dr. Sotoudeh Hamed-Hagh for giving me the guidance and support to work on this project at San Jose State University.