ABSTRACT

The wireless systems demand increased performance and low power consumption. Many efforts are being carried out to increase the performance of wireless systems. This leads to research in implementation of RF circuits and new design techniques like beamforming in the physical layer of the wireless system. The transmitter and receiver in the wireless systems have the RF Circuits implemented in VLSI using CMOS technology. Beamforming techniques improve the coverage area of the wireless systems. The microstrip antennas are used for beamforming applications. Many wireless systems work in the 900MHz and 2.4GHz ISM band.

In this thesis, performance of RF circuits and active beamforming techniques in the front-end of wireless systems operating in the 900MHz and 2.4GHz band is studied. In 900MHz band, the transmitter operates with 25MHz bandwidth in 935-960MHz frequency range and receiver operates in 890-915MHz frequency range with 25MHz bandwidth. The transmitter and receiver operate with 20MHz bandwidth in the 2.4GHz band. The Intermediate frequency (IF) is 70MHz in the receiver and the IF is 45MHz in the transmitter of 900MHz systems. The IF is 45MHz in transmitter and receiver of 2.4GHz systems.

Class-E Power amplifiers for center frequency of 947.5MHz in 935-960MHz band and 2.4GHz in 2390-2410MHz band are proposed. The linearity of the power amplifiers are improved by analog predistortion method. Two analog predistortion methods, square law and cubic law methods are used. Using square law method the 2^{nd} order harmonic distortions

of the power amplifiers are reduced. 3rd order harmonic distortions of the power amplifiers are reduced using cubic law predistortion. Reduction in the harmonics leads to increased linearity and low power consumption of the power amplifiers. LNAs operating at the designed frequency for specified bandwidth with high gain and minimum noise figure are requirement in wireless systems. Three types of LNA namely; resistive termination, shunt-series feedback and inductive source degeneration are implemented. Based on various parameters, their performance is studied. The LNA with inductive source degeneration provides better results. The performance of LNA with inductive source degeneration is improved with MOSFET connected in cascode to the existing amplifier. Inductive source degeneration LNAs with bandwidth of 25MHz (890-915MHz) for center frequency of 902.5MHz is implemented with and without cascode transistor. Also inductive source degeneration LNAs for center frequency of 2.4GHz with bandwidth of 20MHz are implemented with and without cascode transistor and analyzed.

Mixer circuits are needed for up-conversion and down conversion of the signals in transmitters and receivers respectively. Mixer circuits with good conversion gain and better image rejection capability are preferred in wireless systems. Upconversion mixers for converting the IF signal from 45MHz to high frequency of 947.5MHz and 45MHz to 2.4GHz are implemented. Down conversion mixers for super heterodyne receivers to convert the RF signal from 902.5MHz to 70MHz and from 2.4GHz to 45MHz are implemented. Down conversion is performed in single stage and in two stages. Upconversion and down conversion mixers use the standard Gilbert cell multiplier as the basic element for conversion. The performances of both the upconversion mixers and down conversion mixers are studied in terms of conversion gain, dynamic range and noise figure. The conversion gain is better when signal is down converted in two stages. Performance of Image reject mixer for direct conversion receiver operating in the 900MHz band is studied. Image reject mixer is implemented using Sign Sign-Least Mean Square (SS-LMS) calibration. The image frequencies are rejected and the performance of the mixer is improved.

Band Pass Filters (BPFs) are used in the intermediate frequency range of wireless systems to reject the noise components from the signal source on the transmitter and to reject the noise in receivers before signal enters the baseband circuits. In this thesis, BPFs operating in the 45MHz and 70MHz IF ranges are implemented to provide a bandwidth of 3MHz. BPFs are implemented with Operational Transconductance Amplifiers (OTAs). Two different BPFs are implemented for both the IF ranges. BPFs are implemented with three different OTA structures namely Simple OTA, OTA with Wilson current mirror and OTA with Cascode current mirror and their performance is studied. Vector modulators are needed to change the phase of a signal in a particular direction in passive RF beamforming systems with control over the amplitude of the signal. In this research work, vector modulators are implemented for center frequencies of 902.5MHz, 947.5MHz and 2.4GHz. The control element in the vector modulator is a variable attenuator. Variable attenuators are designed with JFET and MOSFET. The vector modulators with JFET can be used for shifting phase of the signal in large steps and the vector modulators with MOSFET can be used for shifting phase of the signal in small steps.

Beamforming is the process of combining signals from different directions and steer the resultant signal into a particular direction. In beamforming, the interfering signals are directed towards the null of the antenna, reducing the effects of interfering signals. Beamforming is performed for wireless systems with active beamforming network and passive beamforming network. Phased Array Antenna (PAA) with 64 patch antenna elements as 8 x 8 Array is designed and implemented for both active and passive beamforming networks.

In active beamforming, beam steering is performed by applying necessary phase shifts along with excitation to the antenna elements. The excitation coefficients are calculated using non uniform amplitude distributions. Two non uniform amplitude distributions Taylor distribution and Dolph-Chebyshev distribution are used. RF beamformer is used to combine the signals from the 8 elements of each column of the PAA and to finally combine the output due to each row. RF beamformer consists of LNA, Variable attenuator and phase shifter.

In passive beamforming, RF switched beamforming system is proposed. The RF switched beamforming system is constructed with PAA, Butler matrices and Single Pole Eight Throw (SP8T) switches. The Butler matrix is constructed with 90° hybrids and cross couplers. The signal from each column of the PAA is passed through 8x8 Butler matrix and SP8T switch. The resultant signal from each row is passed again through the Butler matrix and SP8T switch and the signals are combined to form a single signal. The signals from different directions are combined to form unidirectional signal. The directivity and gain of the signal is improved after beamforming. RF circuits implemented and studied provide better results and improvement over the similar circuits available in the literature. Beamforming techniques proposed perform better by forming a unidirectional beam with high directivity and gain. Hence the circuits and beamforming techniques proposed and studied are found to be suitable for improving the performance of wireless systems.