論文内容の要旨

論文題目
Low-Power CMOS Circuits for Millimeter-wave Impulse Radio
（ミリ波インパルス無線通信用低消費電力 CMOS 回路の研究）

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The history millimeter-wave began in late 1890s by the time of Heinrich Hertz's invention of spark-gap transmitter and detector. History of silicon circuits began in 1960s. These two fields developed separately until the operating frequency of the silicon circuits reached to millimeter-wave frequencies. The operation frequency of silicon circuits reach to millimeter-wave frequencies in 1990s, since then the silicon circuits have been developing for the millimeter-wave applications in the direction of the conventional radio circuits used in microwave band which results in high power consumption. In this research, low-power CMOS circuits have been studied for millimeter-wave wireless communication.

Scaling in CMOS technology has led to the realization of new electronic appliances with a processing power of over 1Gbps and a memory of tens of gigabits. Demand for low-power over-gigabit-per-second (over-Gbps) wireless multimedia communication is increasing. Until now there was no any technology which will provide low-power over-Gbps wireless communication. With license-free bandwidths of 9GHz in

Europe and 7GHz in Japan, USA, Canada and Korea, the 60GHz millimeter-wave band is promising for realizing short-range over-Gbps wireless communication applications worldwide where low-cost and low-power wireless multimedia communication is required. Recently, conventional millimeter-wave transceiver building blocks in CMOS have been reported. The conventional high-speed wireless transmitter modulates the carrier signal by using complex modulation schemes and multiplexing methods such as orthogonal frequency division multiplexing (OFDM). The conventional receiver downconverts the received signal by a synchronized local oscillator and then coverts to digital signal using a high-speed analog-to-digital converter (ADC) and high-speed demodulator. When the frequency reaches to millimeter-wave range and the data rate exceeds 1Gbps, the conventional receiver requires large power due to LO synchronization and high-speed modulator, demodulator and ADC circuitries. To overcome high-power consumption, we proposed a millimeter-wave impulse radio.

At First, pulse generator circuits are studied which will be used in the pulse transmitter. The pseudo-millimeter-wave band, which stays in the lower edge of the millimeter-wave band, is attractive for applications in short-range automotive radar systems using 22 to 29 GHz in order to realize road safety and intelligent transportation. Although the CMOS is suitable for shortrange radar since processing units can be implemented in the same chip as the UWB front-end building block, it is difficult to operate CMOS pulse generators at such a high frequency. To realize the pseudo-millimeter-wave band using CMOS, we have proposed a new pulse generator consisting of a series of delay cells and edge combiners with waveform shaping for short-range radar. As a result of measurement using 90-nm CMOS technology, 1 Gb/s/bit pulses with 71 mV peak-to-peak, 39.2 ps monopulse width and 552 ps envelope width are successfully generated with a power consumption of 1.4 mW at a supply voltage of 0.91 V. This result will be the key technology for a one-chip short-range radar system.

This pulse generator's operating speed determined by the internal speed of the transistors. If the operating frequency is increased from pseudo-millimeter-wave to 60GHz millimeter-wave band, the 90nm CMOS technology does not provide sufficient millimeter-wave pulse power. Therefore, we studied a millimeter-wave CMOS amplitude-shift-keying (ASK) modulator for 60GHz wireless communication at greater than 1Gbps. It is designed using shunt NMOSFET switches between the signal and the ground line of a transmission line. A reduced-switch architecture is used to achieve high speed. The transmission line length between switches is adjusted to achieve high isolation with a reduced number of switches. A 60GHz millimeter-wave ASK modulator is successfully realized by using a 6-metal 1-poly 90nm CMOS process. The size of the chip is 0.8mm × 0.48mm including the pads. The core size is 0.61mm × 0.3mm. The isolation and maximum data rate of the modulator at 60GHz are measured to be 26.6dB and 8Gbps, respectively. The product of the maximum data rate and the isolation of this modulator is 170GHz, which is the highest value among over-Gbps ASK modulators. The data rate of this modulator is the fastest among the reported 60GHz modulators.

To detect 60GHz pulses in a receiver, a single-ended MESFET detector or a diode was conventionally used. However, the MESFET detector cannot be integrated on the silicon substrate with the CMOS building blocks of the receiver and a diode is unavailable in general design rules. To overcome this issue, a common-source amplifier, utilizing a square-law relationship between the drain current I_d and the gate voltage V_g of an NMOSFET, is proposed as a detector. A nonlinear amplifier (NLA) using a standard 90nm CMOS process is designed and fabricated. It has a voltage responsivity of 1110 mV/mW and power dissipation of 840μW. The results show that, using the proposed NLA, it is possible to design low-cost, over-Gbps, low-power fully CMOS-compatible and compact 60GHz receiver systems.

A low-power 60GHz pulse receiver has been fabricated for over-Gbps wireless communication by a standard 90nm CMOS process. The receiver consists of a nonlinear detecting amplifier, a limiting amplifier, an offset canceller and a buffer. The measured sensitivity is the average power of -20dBm for millimeter-wave pulses of 60GHz. The power dissipation and maximum data rate of the receiver are 19.2mW and 2Gbps, respectively. These results indicate the possibility of new low-power and ultrahigh-speed wireless communication using millimeter-wave impulse radio pulses with CMOS implementation.