5.7 GHZ ON-CHIP ANTENNA/RF CMOS TRANSCEIVER FOR WIRELESS SENSOR NETWORKS

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Abstract: This paper describes a chip-size antenna for operation at 5.7 GHz, assembled with a low-power, low-voltage RF CMOS transceiver, fabricated in UMC RF CMOS 0.18 μm process. Measurements shown a patch antenna with the central frequency of 5.705 GHz, a bandwidth of 90 MHz at –10 dB of return loss, a directive gain of 0.3 dB, with an efficiency of 18%, and a transceiver with a measured total power consumption of 23 mW.
Keywords: Wireless sensor networks, On-chip antenna, RF transceiver.

INTRODUCTION

Wireless communication microsystems with high density of nodes and simple protocol are emerging for low-data-rate distributed sensor network applications such as those in home automation and industrial control [1]. This type of wireless microsystem with sensors and electronics are of interest for electronic textiles as the application presented in this paper. Moreover, in order to implement an efficient power-consumption wireless sensor network in clothes (e.g. a electronic shirt), it is necessary to develop a low-power low-voltage RF transceiver, mounted with a patch antenna.

ANTENNA DESIGN

Different solutions have been suggested to achieve antenna integration within a single chip. Since high losses of standard-resistivity silicon are prohibitive for antenna integration, most of the proposed solutions rely on high-resistivity silicon (HRS) or micromachined substrates. The HRS solution uses a bulk substrate having the same electrical permittivity but lower losses. In micromachined substrates, the losses are reduced by selective substrate removal underneath the metal patch. The drawback is an increase of antenna size due to the effective electrical permittivity reduction resulting from the partial replacement of silicon by air. It was used for the substrate, high-resistivity silicon (HRS) together with insulations layers to keep the losses at low as possible. The HRS substrate has a dielectric permittivity of 11.7, conductivity in the range 0.02-0.05 S/m, and the wafer thickness of 525 μm ± 25 μm. The use of HRS is enough to provide considerable loss reduction. Nevertheless, the losses can be reduced even further with the use of a dioxide layer between the silicon wafer and the metal patch. This layer has a permittivity of 3.9 and is an insulator. The ground and metal patches were made of aluminum, with a thickness of 2 μm. Fig. 2 illustrates the materials and configuration used in the fabrication. Antenna feeding was carefully designed, in order to provide a correct input impedance (50 Ω) to do the measurements. A photo of the fabricated patch antenna prototype, with 7.7×7.6 mm^2 area dimensions is illustrated in Fig. 3.

TRANSCEIVER DESIGN

It was fabricated a RF CMOS transceiver operating at 5.7 GHz ISM band, with ASK modulation [Fig. 4]. The UMC RF 0.18 μm CMOS process allows to trade the high-frequency capability of minimum-length transistors with lower current consumption by biasing the devices at lower current densities, even for devices working at RF. This process provides a poly and six metal layers, the use of integrated spiral inductors (with a quality factor of 10), high-resistor values (a special layer is available) and a low-power supply of 1.8 V. The transceiver has a low-noise amplifier that provides a 50 Ω input impedance, the amplified RF signal is directly converted to the baseband with a single balanced active MOS mixer. The Internal oscillator is a phase-locked loop working at 5.7 GHz.

APPLICATIONS

As the operating frequencies are increasing (IEEE802.11a), on-chip antenna integration with RF CMOS transceivers with reasonable efficiency becomes feasible. Moreover, due to the frequency increase, the provided bandwidth becomes also acceptable both for data communications and sensor applications. A good example for application of this RF microsystem is in electronic textiles where garments have not only wearable capabilities, but also have local monitoring and computational, as well as wireless communications facilities. Fig. 5 shows the implementation of a wireless sensor network in a wireless electronic shirt for monitoring the cardio-respiratory function. A single channel ECG measures heart rate, a network of accelerometers records patient posture and activity level and inductive sensors are used for monitoring the respiratory function.

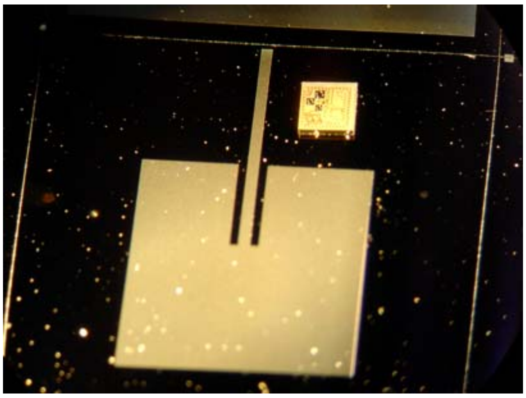

Fig. 1. Chip-size antenna for operation at 5.7 GHz assembled with a RF CMOS transceiver.

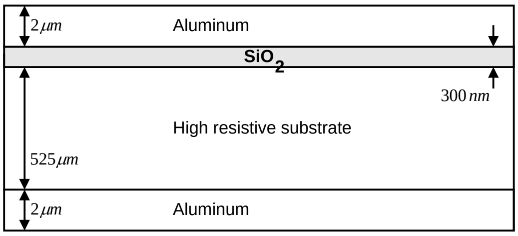

Fig. 2. Cross-section of the patch antenna design in HRS wafer.

Fig. 3. A photo of the patch antenna fabricated on a HRS wafer, already mounted for measurements.

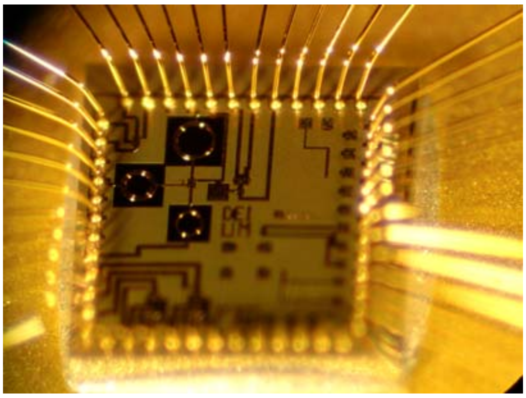

Fig. 4. A photo of the transceiver used for the transmission at 5.7 GHz.

Fig. 5. A photo of the patient wearing a electronic shirt ready to plug the RF microsystem (antenna + transceiver). We can see the three connections for heart-rate with a single electrode, respiratory function and posture

REFERENCES

1. P. Choi, H. Park, S. Kim, S. Park, I. Nam, T. W. Kim, S. Park, S. Shin, M. S. Kim, K. Kang, Y. Ku, H. Choi, S. M. Park, K. Lee, *An experimental coin-sized radio for extremely low-power WPAN (IEEE 802.15.4) application at 2.4 GHz*, IEEE Journal of Solid State Circuits, Vol. 38, No. 12, pp. 2258-2268, December 2003.
2. S. Cho, A. P. Chadrakasan, *A 6.5-GHz energy-efficient BFSK modulator for wireless sensor applications*, IEEE Journal of Solid State Circuits, Vol. 39, No. 5, pp. 731-738, May 2004.