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A 26GHz Transceiver Chipset for Short Range Radar using Post-Passivation Interconnection

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1. Introduction

Millimeter-wave Si-IC for radar applications has recently emerged as a choice for its low cost implementation together with enhanced functionalities by Si-based digital circuits. In particular, short range radar at 26GHz is promising for object detection as well as imaging in various security applications. Spread-spectrum (SS) radar architecture enables high sensitivity with high resolution keeping relatively small transmitting output and thus suitable at such frequencies so-called ultra-wide-band (UWB) [1-3], in which the maximum power is limited under the regulation set by Federal Communications Commission (FCC) [4]. In this paper, we present a 26GHz spread-spectrum transceiver chipset for the UWB short range radar using SiGe BiCMOS technology. Integrated frequency triplers lower the local oscillation frequency down to 8.8GHz, which effectively suppress the carrier leakage in the transmitting SS signal keeping high output just below the regulation. An on-chip balun placed in a BPSK (Binary Phase Shift Keying) modulator of the Rx IC increases the dynamic range of the receiving signal. Key device technologies for the chip are the low-loss transmission lines formed on thick low-k dielectrics with fine pitch interconnects on the SiGe IC, which is applied to the balun. The above features enable high sensitivity and high resolution of the short range radar so that detection of objects located 7m away from the system is experimentally confirmed.

2. Architecture of SS Radar system

Fig. 1 shows a schematic diagram of the short range SS radar system in which the presented transceiver chipset is shown. The delay of the PN (pseudo noise) signal is varied so as to appear a peak in the receiving spectrum, which corresponds to the range between the object and the system.

The most notable feature in this architecture is lowering the local oscillation (LO) frequency down to 8.8GHz by the integrated frequency triplers. The low LO frequency effectively suppresses carrier leak in the transmitting signal by the elimination of the interferences so that a high sensitivity is achieved by the increased output. Fig. 2 shows the obtained spectra of the transmitting SS signal by a 2047bit M-series PN code with the bit rate of 2.5Gbps. The signal intensity is maintained certainly below the FCC regulation without any peak which would be caused by the carrier leak.

3. On-chip balun fabricated using Post-Passivation Interconnection

A BPSK modulator with an on-chip balun is integrated to de-spread the receiving signal, of which the detailed circuit diagram is shown in Fig. 3. The modulator consists of a double-balanced mixer with differential inputs which can suppress the common-mode noise. The balun is placed to convert the single-end receiving signal to the differential inputs as well as it can reduce the number of the transistors in the double-balanced mixer. The elimination of the pre-amplifier in the mixer by the balun greatly helps to increase the conversion gain at higher input power as shown in Fig. 4. It effectively increases the dynamic range of the Rx IC which enables more accurate detection of objects.

Since the balun needs to be as compact as possible to reduce the loss, fine-pitch transmission lines are formed for it on thick low-k dielectric above the SiGe IC by so-called post-passivation interconnection process. The scanning electron microscopy (SEM) image of the transmission lines is shown in Fig. 5. 15μm-thick low-k benzo-cyclo-butene (BCB) is formed on the ground plane over the SiGe IC. The BCB is chosen since it serves very low dielectric loss among the possible thick dielectric. The transmission lines are formed by 4μm/4μm line and space at finest. Fig. 6 shows the frequency dispersion of the insertion loss S_{21} of the fabricated 50Ω microstrip line on the BCB and that formed within the SiGe IC. The loss is effectively reduced by forming it on the low-k dielectric, enabling a compact balun with reduced loss. The fabricated on-chip balun occupies the area as small as 870μm x 150μm. in the TX/RX chip.

4. Performance of fabricated TX/RX chipset

The transceiver chipset is fabricated by using 0.18μm SiGe BiCMOS technology. The fabricated chipset is for a radar system characterized by connecting the TX and RX through an attenuator. The attenuation can simulate a human body target. Fig. 7 shows the resulted base-band output of the RX IC, where the single peak implies the successful detection of the object within a short-range. Note that the condition corresponds to detecting a human-model target located at 7m away from the radar system. This demonstrates the fabricated chipset can be used for a short range radar for human detection.

5. Conclusions

We demonstrate a 26GHz SiGe TX/RX chipset for short range SS radar system. Integrated triplers eliminate the carrier leak in the output signal which enables high sensitivity. The on-chip balun successfully increases the dynamic range in the RX modulator. Low-loss transmission lines are fabricated by post-passivation interconnection process using low-k and thick BCB.

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References

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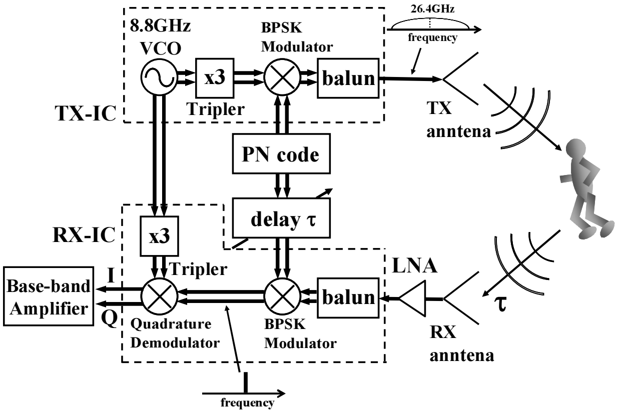

Fig. 1 Block diagram of short range spread-spectrum radar with integrated triplers

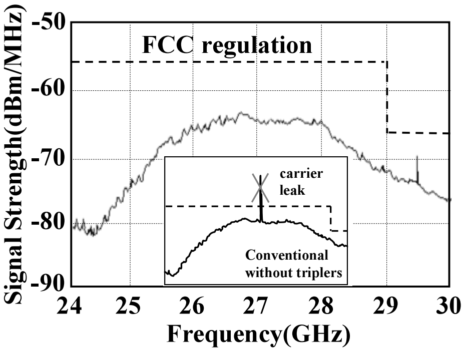

Fig. 2 Transmitting spread-spectrum signal from TX chip using integrated triplers. The insert shows conventional one without triplers

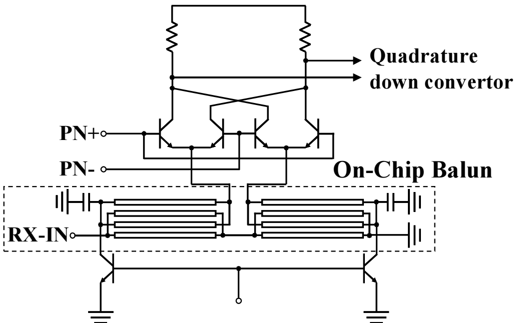

Fig. 3 Circuit diagram of BPSK modulator in RX-IC with on-chip balun

[4] "Second Report and Order and Second Memorandum Opinion and Order," FCC 04-285, 2004

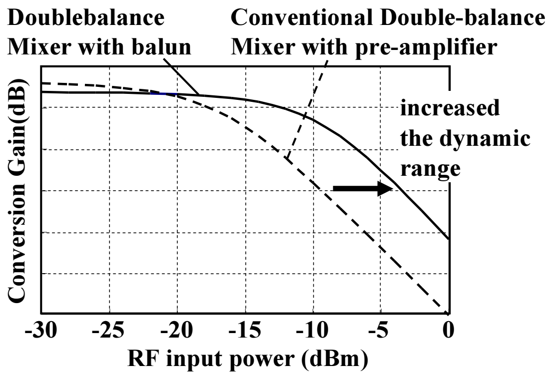

Fig. 4 Conversion gain of double-balanced mixer with on-chip balun, as compared with that of conventional one with pre-amplifiers

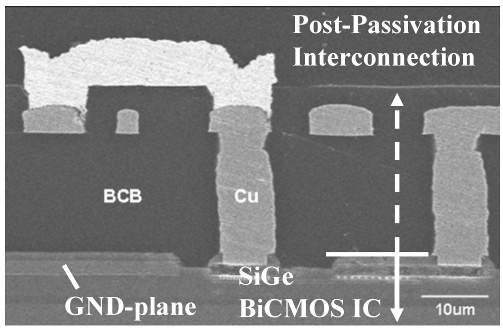

Fig. 5 Cross Sectional SEM image of the post-passivatin interconnection formed over SiGe IC

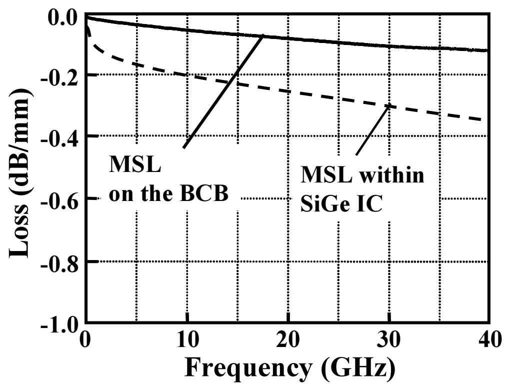

Fig. 6 Transmission loss of Microstrip line on thick low-k dielectric for various frequencies

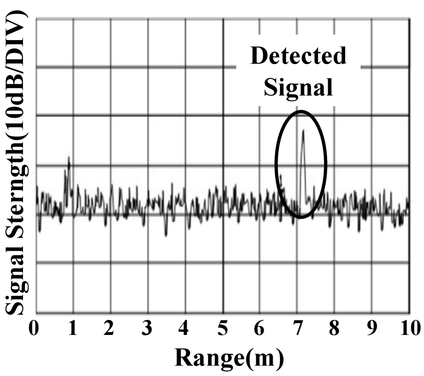

Fig. 7 Operation of 2.5Gbps SS Radar detecting the human model located 7m away from the system