15 dB Conversion Gain, 20 MHz Carrier Frequency AM Receiver in Flexible a-IGZO TFT Technology with Textile Antennas

K. Ishida[1], R. Shabanpour[1], T. Meister[1], B. K. Boroujeni[1], C. Carta[1], L. Petti[2],
N. Münzenrieder[2], G. A. Salvatore[2], G. Tröster[2], and F. Ellinger[1]
[1]Technische Universität Dresden, Dresden, Germany, [2]Swiss Federal Institute of Technology Zurich, Zurich, Switzerland

Abstract

This paper presents an AM receiver implemented in a flexible a-IGZO TFT technology. The circuit consists of a four-stage cascode amplifier at the RF input, a detector based on a source follower, and a common source circuit for the baseband amplification. The measured conversion gain is very flat and exceeds 15 dB from 2 to 20 MHz carrier frequency range, which covers a relevant portion of the shortwave radio band. The 3 dB-bandwidth of the audio signal is 400 Hz to 10 kHz, which is comparable to the so-called voice band, and it is also suitable to low-rate data communication. In addition, an integrated demonstration of the AM receiver and textile antennas is carried out. The flexible a-IGZO receiver successfully detected the baseband signal through the textile antennas, demonstrating for the first time wireless transmission for this class of technologies.

Introduction

With the increase of the operation speed of flexible devices, wireless communication is becoming one of the promising applications and is being widely studied [1-6]. However, most of the previous works are proximity links such as RFIDs [3-6]. Although an RFID with an active envelope detector was reported [4], AM receivers with flexible devices have not been presented so far.

We aim at realizing multifunctional, ultra-lightweight, ultrathin, bendable organic and large-area electronics within the frame of the EU project FLEXIBILITY [7]. The target applications include an audio bag and receiver label, which require an AM receiver. In this context, we present the first AM receiver in a flexible a-IGZO TFT technology and its demonstration with textile antennas.

Circuit Design

Fig. 1 shows the schematic of the flexible AM receiver. The circuit consists of a four-stage cascode amplifier at the RF input, a detector based on a source follower and a common source circuit for the baseband amplification. Although the topology itself is simple, it is quite difficult to implement high-impedance elements, which are required in bias circuits, with meander lines in our a-IGZO TFT technology. In particular, a 1 MΩ meander resistor consumes a 3.74×8 mm^2 rectangular area, which is almost equal to the area of the overall AM receiver in this work. To solve this, we use oppositely stacked MOS diodes (OSMD) as shown in Fig. 2. To make the resistance at the biasing point symmetry, two nMOS diodes are stacked in opposite polarity. Fig. 3 shows the simulated I_R-V_R curves and equivalent resistances of OSMDs (W=40 µm, L=5 µm/25 µm). The characteristics are symmetry at the biasing point (=0V). Each OSMD consumes only 0.4×0.5 mm^2. The overall circuit is carefully designed through the simulations by Agilent ADS. Fig. 4 shows the simulated waveforms of the overall AM receiver circuit with a 1 MHz carrier and a 5 kHz audio signal. The simulation results shows a conversion gain of 15.3 times (=23.7dB). These simulations are carried out by using our TFT models based on the RPI-aTFT (Rensselaer Polytechnic Institute- amorphous TFT) model [8].

Experimental Results

The circuit is fabricated on a flexible polyimide film using the a-IGZO TFT process in [9]. The TFT device and the interconnections consisting of three metal layers are fabricated on a 50 µm-thick polyimide substrate as shown in Fig. 5. The mobility of the a-IGZO TFT formed at room temperature still exceeds 10 cm^2/Vs, which enables high-speed application. Fig. 6 shows a photograph of the fabricated AM receiver on a polyimide substrate. The area of the actual implemented circuit is 3.0×8.95 mm^2.

Fig. 7 shows the measurement configuration of the stand-alone operation of the AM receiver. An AM signal source is directly connected to RFIN of the receiver operating at 5 V V_{DD}. The measurement is carried out with 1 MΩ resistance and 15 pF capacitive load, which comes from the passive probe of the oscilloscope. Fig. 8 shows the measured waveform of the AM receiver. The carrier frequency (f_C) and audio frequency (f_A) are 2 MHz and 2 kHz, respectively. The AM receiver well rectified the input AM signal, and the measured conversion gain is 15.27dB.

Fig. 9 shows the measured frequency response of the conversion gain vs. carrier frequency. The conversion gain is very flat and exceeds 15 dB from 2 to 20 MHz carrier frequency range, which covers a relevant portion of the shortwave radio band. Fig. 10 shows the measured frequency response of the conversion gain vs. audio signal. The 3 dB-bandwidth of the audio signal is 400 Hz to 10 kHz, which is comparable to the so-called "voice band", and it is also suitable to handle low-rate data communication. Figs. 11 and 12 show the measured conversion gain vs. modulation depth and the input voltage of the carrier, respectively. Both measurements are carried out with f_C=2 MHz and f_A=1 kHz and show consistent data. The total supply current is 7.2 mA.

An integrated operation, which demonstrates the wireless communication with the flexible AM receiver and textile antennas, is also carried out. Fig. 13 shows a picture of the textile antennas fabricated for both Tx and Rx circuits. Each spiral antenna is formed on a 30×40 cm^2 textile. The measurement setup of the integrated operation is shown in Fig. 14. The AM receiver operating at 5 V V_{DD} is directly connected to the Rx textile antenna and a tuning capacitor of 300 pF. The Tx antenna is driven by an AM signal source with a tuning capacitor of 30 pF. The carrier and audio frequencies are 1 MHz and 2 kHz, respectively. Fig. 15 shows the measured waveforms of the integrated operation. The AM receiver successfully detected the baseband signal through the textile antennas. The FFT spectrum of the detected baseband signal verifying the good linearity of the AM receiver is also shown in Fig. 15.

Acknowledgment

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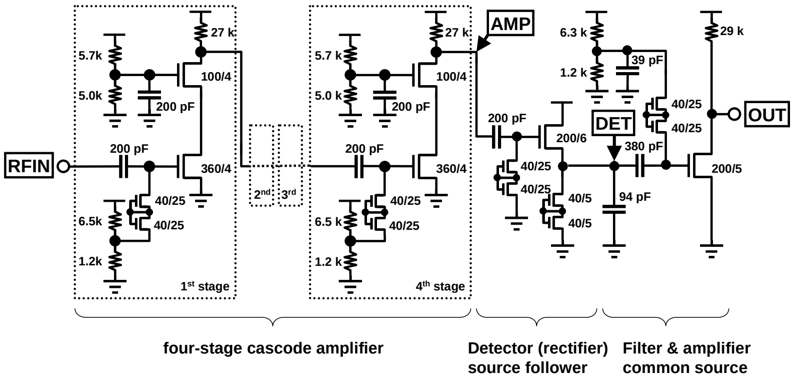

Fig. 1. Schematic of the flexible AM receiver. The circuit consists of a four-stage cascode amplifier at the RF input, a detector based on a source follower, and a common source circuit for the baseband amplification.

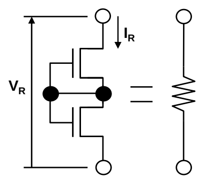

Fig. 2. Oppositely stacked MOS diodes (OSMD) as a high-impedance element.

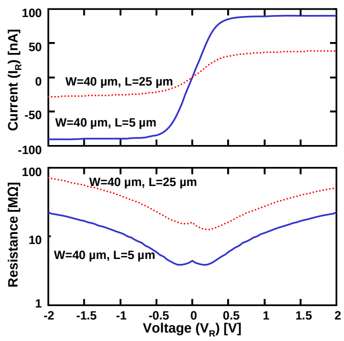

Fig. 3. Simulated I_R-V_R curves and equivalent resistances of OSMDs (L=5 µm, 25 µm).

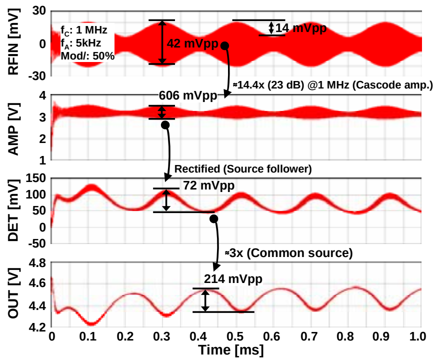

Fig. 4. Simulated waveforms of the AM receiver with a 1 MHz carrier and a 5 kHz audio signal. The simulation result shows a conversion gain of 23.7 dB.

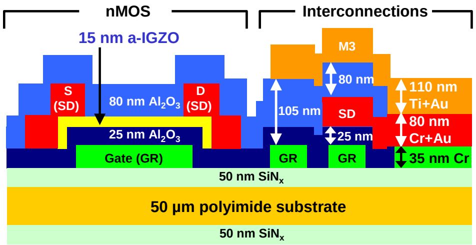

Fig. 5. Device structure of flexible a-IGZO TFT. The devices and interconnection with three metal layers are formed on a 50 µm-thick polyimide substrate.

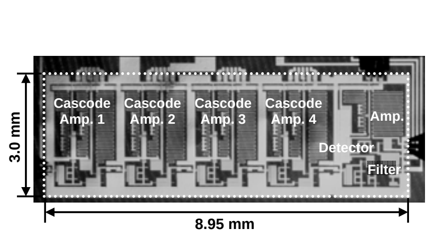

Fig. 6. Photograph of the fabricated AM receiver on a flexible polyimide substrate. The area of the implemented circuit is 3.0 x 8.95 mm².

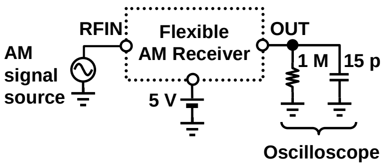

Fig. 7. Measurement configuration of the stand alone operation of the flexible AM receiver.

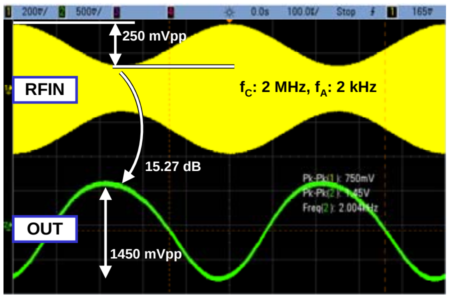

Fig. 8. Measured waveform of the AM receiver with f_C=2 MHz and f_A=2 kHz. Conversion gain is 15.27 dB.

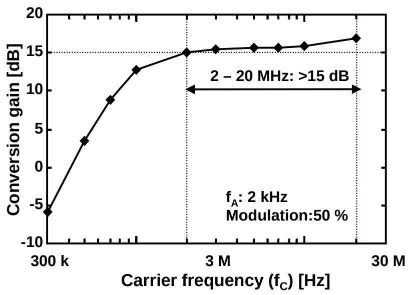

Fig. 9. Measured frequency response of the conversion gain vs. carrier frequency. The gain exceeds 15 dB with 2-20 MHz carriers.

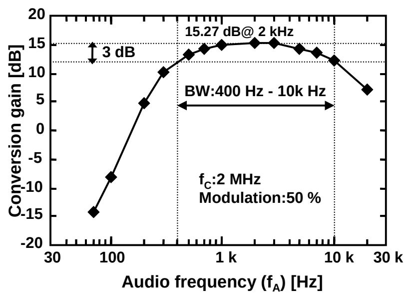

Fig. 10. Measured frequency response of the conversion gain vs. audio signal. The measured 3 dB-bandwidth is 400 Hz to 10 kHz.

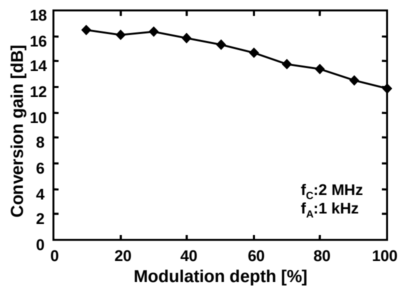

Fig. 11. Measured conversion gain vs. modulation depth (f_c=2 MHz, f_A=1 kHz).

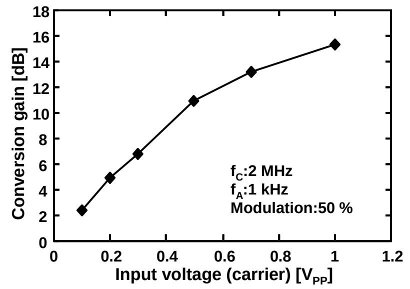

Fig. 12. Measured conversion gain vs. input voltage (amplitude of the carrier).

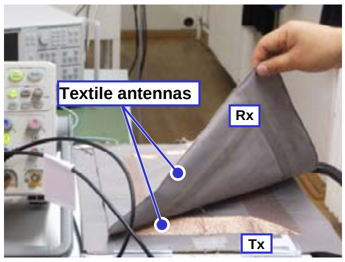

Fig. 13. Picture of the textile antennas for both Tx and Rx. Each spiral antenna is formed on a 30x40 cm² textile.

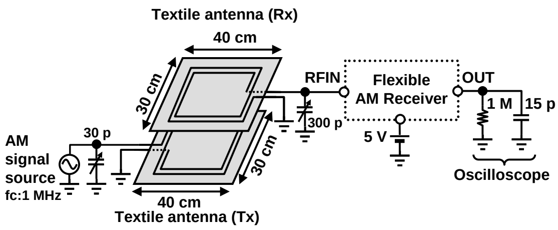

Fig. 14. Measurement setup of an integrated operation of the flexible AM receiver and textile antennas for the wireless communication.

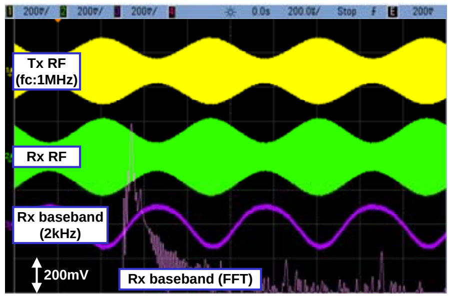

Fig. 15. Measured waveforms of the integrated operation that demonstrates wireless communication with the flexible AM receiver and textile antennas.