A Wideband Receiver Front-End Employing Feedback Input Matching and Feed-Forward Blocker Cancelling

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***Abstract*— In this paper, we propose a wideband receiver that can achieve wideband input matching characteristic and remove out-of-band blocker signals. A wideband input matching is achieved by adding a feedback path to a basic wideband receiver structure consisting of low-noise transconductance amplifier (LNTA), passive mixer, and baseband transimpedance amplifier (TIA). We also proposed a method of cancelling the blocker signal by adding an auxiliary downconversion path. This method can minimize the additional circuit by using the transparent characteristics of the passive mixer and can eliminate the blocker signal without causing the performance degradation of the receiver to be large. A wideband receiver circuit designed with 65nm process was simulated. The receiver can cover the frequency range from 50 MHz to 1.95 GHz and has 47.9 dB gain and 4.1 dB noise figure performance. It also achieves an additional 9.8 dB of blocker signal cancellation over the basic wideband receiver.**

Keywords—wideband receiver; passive mixer; blocker; blocker cancelling

I. Introduction

In recent years, attempts have been made to replace multiple narrowband receivers with a single wideband receiver. The biggest problem with wideband receivers is the inability to use filters in the RF band. Large interference signals that cannot be removed in the RF band can distort the signal of the desired band and may saturate the receiver itself. Therefore, various studies have been made on a receiver having a structure capable of removing an interference or blocker signal without using an RF bandpass filter [1]-[2]. In these papers, the voltage gain in the RF band is excluded as much as possible to prevent saturation of the receiver due to the out-of-band large blocker signal. However, most of these receiver structures rely on the frequency response characteristics of the baseband circuit to remove the blocker signal.

In this paper, we propose a receiver architecture that can achieve input matching over a wide bandwidth and effectively remove blocker signals. The proposed receiver achieves wideband input matching by adding a feedback structure to a conventional receiver using LNTA, and eliminates the blocker signal while minimizing the attenuation of the desired band signal using the feed-forward blocker signal cancelling method through the auxiliary path. The proposed structure has the advantage that the feedback and feed-forward paths can be processed by one mixer using the characteristics of the passive mixer. The design procedure of the proposed receiver is described in section II. Section III shows the simulation results of the designed receiver and concludes in section IV.

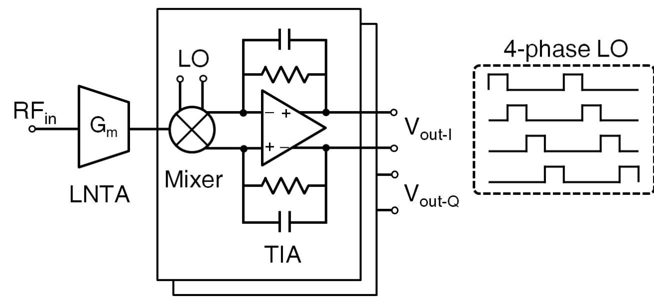

Fig. 1. Block diagram of the basic wideband receiver.

II. Circuit Design

A. Basic Wideband Receiver Architecture

Fig. 1 shows the structure of a basic wideband receiver. This structure consists of an LNTA, a passive mixer, and a baseband TIA. The LNTA converts the input RF voltage signal into a current, and since the output of the LNTA is a current other than a voltage, it does not saturate the receiver even when there is a large blocker signal at out-of-band. The output current of the LNTA is downconverted to baseband through a passive mixer. The baseband current signal is converted back into a voltage signal by the TIA. This TIA circuit also shows the frequency response of the low pass filter by the feedback resistor R_{TIA} and the capacitor C_{TIA}, which can attenuate the out-of-band blocker signal.

In this structure, the LNTA is generally based on the inverter circuit, and since the inverter circuit has only the input and output nodes, it has the advantage that the degradation due to the parasitic at the high frequency can be minimized. Although it is suitable for constructing the RF portion of a wideband receiver front-end, however, it also has a disadvantage that 50 Ω input matching is difficult to achieve on its own because the input impedance is very large.

B. Input Matching with Feedback

There are many ways to achieve good input matching, but the feedback method is widely used because it can create the

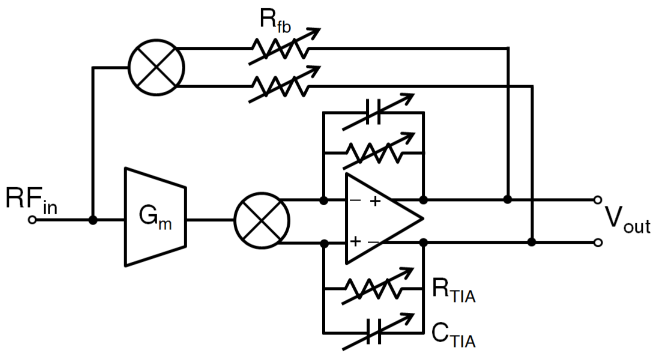

Fig. 2. Receiver block diagram with feedback topology for input matching.

desired input impedance across the wideband [3]-[4]. Fig. 2 shows a wideband receiver structure that meets input matching using feedback. It detects the voltage at baseband TIA output, converts it to current through feedback resistor R_{fb}, upconverts it to RF band with another passive mixer, and feeds back to input of LNTA. The input impedance Z_{in} of the receiver with feedback topology becomes

$$Z_{in}\left(\omega_{LO}+\Delta\omega\right)\approx\frac{\pi}{2\sqrt{2}}\frac{R_{fb}}{1+G_m\dfrac{\sqrt{2}}{\pi}Z_{BB}\left(\Delta\omega\right)}, \tag{1}$$

where G_m is the transconductance of the LNTA and Z_{BB} is the transimpedance of the baseband TIA. The voltage sensing port for feedback is defined as the baseband output of the receiver, since the output node of the LNTA must maintain a very low impedance value. This can achieve input matching of 50 Ω across a wideband.

C. Blocker Rejection Using Feed-forward Cancelling

Another drawback of conventional wideband receivers is that the attenuation of the out-of-band blocker signal is dependent on the frequency response of the baseband TIA. In the receiver circuit of Fig. 1, the frequency response of the baseband TIA has the shape of a first-order low-pass filter, requiring a large C_{TIA} value for greater blocker attenuation. This can increase the burden of the baseband circuit in the presence of a large blocker signal, and may reduce the linearity of the entire receiver. Therefore, in this paper, we propose a feed-forward blocker signal cancellation scheme using an auxiliary downconversion path.

Fig. 3 shows a wideband receiver using the proposed feed-forward blocker cancellation technique. A capacitor and a baseband LNTA circuit were added in the receiver circuit of Fig. 2. Here, the capacitors serve as high-pass filter that prevents the in-band signal, which is downconverted through the mixer in the RF band, from entering the auxiliary LNTA. By using the transparent nature of the passive mixer [5], the in-band signal of the baseband TIA output is upconverted by the mixer, while the RF blocker signals are downconverted into the auxiliary path. The baseband LNTA has the same structure as the RF LNTA and is designed based on the inverter circuit.

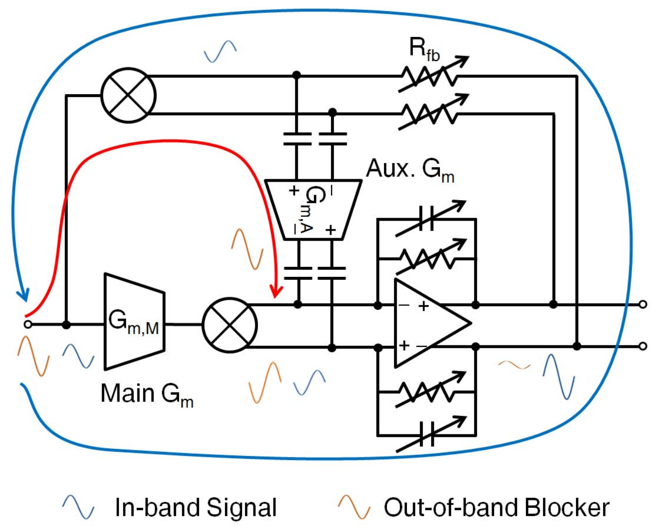

Fig. 3. Block diagram of the proposed receiver circuit.

The added circuits can further attenuate the blocker signal while minimizing the attenuation of the in-band signal.

To maximize the amount of attenuation of the blocker signal, the frequency corresponding to the blocker signal at the TIA input node must be the same in magnitude in the main path and the auxiliary path, and the phase difference should be 180 degrees. The signal magnitude can be adjusted by adjusting the capacitor value and the G_m value of the baseband LNTA, and a phase difference of 180 degrees can be achieved by cross-coupling the I signal and the Q signal.

D. Generation of Non-overlapping 25% Duty-cycle Local Oscillator (LO) Signal

The clock generator is designed to generate the LO signal. This receiver requires a non-overlapping LO signal with 25% duty-cycle to make the I and Q signals. The circuit that generates the LO signal employing the frequency divider and the logic gate is integrated with the receiver.

III. Simulation Results

The wideband receiver circuit was designed using a 65nm CMOS process. The entire system uses a supply voltage of 1.2 V and consumes 18.92 mA of current. Fig. 4 shows the simulation results for the frequency response characteristics. The operating range of the designed receiver is from 50 MHz to 1.95 GHz and the maximum gain is 51.21 dB. S_{11} simulation results show that the input matching is satisfied over the wideband by using the feedback method. The lowest noise figure value of the receiver was confirmed to be 4.10 dB. The reason for limiting the operating frequency range of the receiver is the LO signal generator. Because the reference clock is required to be 4 times faster for 25% duty-cycle clock generation, operation of the mixer is restricted at very high frequencies.

Fig. 5 shows the result of simulating the baseband output while moving the RF input frequency offset when operating at

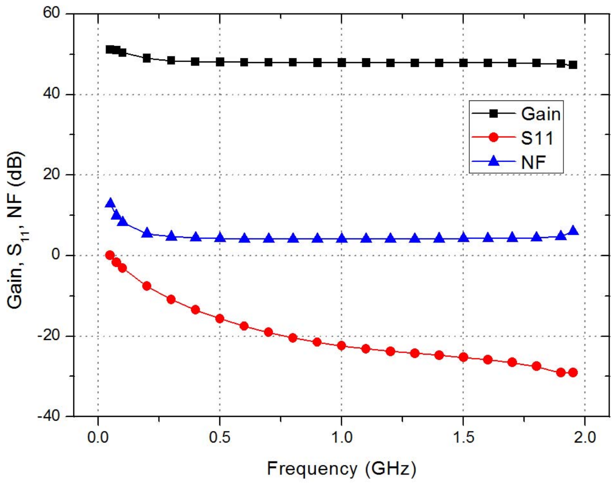

Fig. 4. Gain, S_{11} and noise figure simulation results.

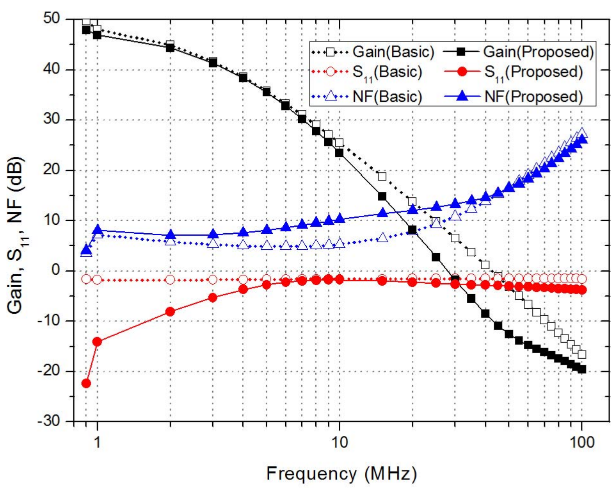

Fig. 5. Gain, S11 and noise figure simulation results of the basic wideband receiver and proposed receiver.

the LO frequency of 1 GHz. In order to compare the effects of input matching and blocker cancellation, the basic wideband receiver structure of Fig. 1 and the proposed structure are shown at the same time. Since the feedback structure is used, it can be seen that the proposed receiver circuit shows good input matching in the S_{11} simulation results. Also, when the gain graph is compared, it can be seen that the gain in the out-of-band where the blocker may exist is reduced by 9.8 dB at the maximum. Of course, because the high-pass filter used in the auxiliary path consists only of a capacitor, there is an in-band signal attenuation of about 1 dB. The noise figure increased by 0.54 dB due to the increase in noise due to additional circuitry.

TABLE I. PERFORMANCE SUMMARY AND COMPARISON

	Basic wideband receiver architecture	***This work***
Frequency (GHz)	0.05 - 1.95	
Gain (dB)	49.64[a]	47.90[a]
NF(dB)	3.57[a]	4.10[a]
Supply Voltage (V)	1.2	
Current (mA)	16.02	18.92
Attenuation of blocker at 50 MHz offset (dB)	-3.12[a]	-12.57[a]
Process (nm)	65	

[a] Result at the center frequency of 1 GHz.

The simulation results of the basic receiver structure of Fig. 1 and the simulation results of the proposed receiver structure of Fig. 3 are compared in Table 1. It is shown that the added circuit increases the current consumption, the in-band gain and the noise figure performance are lowered, but the S_{11} result is greatly improved and the elimination effect of the out-of-band blocker signal is increased.

IV. CONCLUSION

A wideband receiver structure has been proposed to effectively remove blocker signals. Input matching is achieved by adding a feedback path to the basic receiver structure, and a feed-forward structure is added to implement a circuit that further attenuates out-of-band blocker signals. Using the transparent nature of the passive mixer, the additional circuit was composed of a mixer, a baseband LNTA, and capacitors. The designed receiver shows 9.8 dB improved blocker rejection than the basic receiver structure.

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