A CMMB Mobile TV Tuner Frontend with Integrated RSSI for Dual-band Applications

Hua Xu, Yin Shi, Member, IEEE, Fa Foster Dai*, Fellow, IEEE,

Abstract — This paper presents a dual band CMMB mobile TV tunner frontend RFIC with integrated Received Signal Strength Indicator (RSSI). The tuner RFIC includes two sets of receiver front-ends for terrestrial and satellite applications. The front-ends further include LNAs with dual gain adjusting, variable gain amplifiers (VGAs), and a mixer with two gm cells plus a common LO switch cell. The built-in Automatic Gain Control (AGC) loop meets wide dynamic range requirement of the mobile TV tuner. The tuner is integrated in a 0.5um SiGe BiCMOS technology and consumes 16mA current from 2.8V supply. The RSSI is fully integrated with only two off-chip capacitors for low pass filtering. The tuner frontend RFIC achieves 45dB of maximum gain, 70dB gain control range, and an IIP3 higher than 18 dBm in minimum gain mode.

Index Terms — Automatic Gain Control, CMMB, direct conversion, LNA, mixer, VGA, RSSI.

I. INTRODUCTION

The Chinese Mobile Multimedia Broadcasting (CMMB) is the emerging mobile TV standard based on a mixed satellite and terrestrial wireless broadcasting system designed to provide audio, video and data services for handheld receivers. CMMB utilizes two S-band satellites to cover the digital video broadcasting (DVB) over the wide area. In the populated metropolitan areas, CMMB utilizes the cellular base stations to enhance the digital video transmission in order to allow DVB reception with low-cost terminals. The service operates in both S-band (2635~2660MHz) and U-band (470~860MHz).

An important specification for mobile reception is the system sensitivity. The noise figure (NF) of the receiver directly affects the signal demodulation with a given bit-error rate (BER). On the other hand, adjacent channels could be broadcast at significantly higher power. Therefore, linearity performance (IIP3) needs to support the desired channel reception while dealing with interferers at adjacent channels up to 50dB higher.

Additionally, low-cost and low power consumption is critical for mobile applications [1]-[3]. With these requirements, Zero-IF or Low-IF is more suitable for tuners for handheld devices. This work reports the design and implementation of a dual-band direct-conversion Zero-IF BiCMOS SiGe mobile tuner front-end RFIC. RF-VGAs with large dynamic range are included to achieve high IIP3 performance. A simplified block diagram of the proposed CMMB tuner receiver is shown in Fig. 1. Next, we will present the circuit design and implementation of the CMMB tuner frontend RFIC in details. The experimental results and conclusion are given in Section III and Section IV respectively.

II. CIRCUITS IMENPLETATION

As illustrated in Fig.1, the tuner receiver front-end includes two single-ended low-noise amplifiers (LNAs) with two gain modes (high gain/low gain, HG/LG). The LNA for the S-band reception uses on-chip inductor degeneration and LC tank load for realizing narrow-band match and low NF. Another LNA for the U-band reception employs a resistor-capacitor shunt feedback and resistive load for realizing wide-band match and transfer function. Both of the LNAs attain NF lower than 2dB in high gain mode and IIP3 of more than 20dBm in low gain mode. Following the LNAs, continuously tuned RF-VGAs with 50dB gain control range for both bands are implemented to meet the high linearity requirement. A resistive degenerated double-balanced Gilbert cell mixer for down conversion with different input Gm cells to amplify the signals...
from different RF-VGAs. A received signal strength indicator (RSSI) circuit with only 1.8mA current consumption detects the signal power from the output of the down-conversion mixer and generates the DC control signal to tune the gain of the RFVGAs. With the RSSI loop, the dynamic range of the front-end is greatly improved without the need of the feedback from baseband.

A. Low-Noise Amplifier

![Fig. 2 U-band LNA architecture](image)

The LNAs for both bands provide two gain modes, 20dB for high gain mode and -5dB for low gain mode. In the high gain mode, NF is optimized to be within 2dB and in the low gain mode, IIP3 is greatly improved to be larger than 20dBm due to the direct couple of signal from input to output through a high-linearity MOS switch and some passive linear components. Poly resistor and MIM capacitor is used in this design. Resistor is used for attenuation of large signal and capacitor for ac coupling of RF signal from input to output. Both LNAs consume no more than 4mA current from a 2.8V power supply. Fig. 2 shows the architecture of the U-band LNA, which uses shunt feedback for wide band impedance matching.

B. RF Variable Gain Amplifier

![Fig. 3 RFVGA schematic diagram.](image)

The RF variable gain amplifier (RF-VGA) following the LNA, is used to attain power gain and achieve wide tunable gain range for the front-end. Since the CMMB receiver must be able to handle signals with a wide input dynamic range from -100dBm to 0dBm, wide gain tuning at the front-end is thus necessary to meet the noise and linearity requirements over the entire input range. As shown in Fig. 3, the core of the RF-VGA circuit consists of a three-stage capacitive attenuator with 14dB per stage attenuation and four amplifiers which smoothly switch outputs from the ladder attenuator. The VGA architecture has its origin in the VGA using resistive attenuator proposed by [4]. The modification with capacitive attenuator is reported in [5]-[7]. By distributing a fixed amount of current to the input transistor collector with an appropriate ratio corresponding to the control voltage, the gain of the VGA can be tuned continuously.

C. Received Signal Strength Indicator (RSSI)

![Fig. 4 Proposed RSSI architecture.](image)

A received signal strength indicator (RSSI) is employed to sense the received signal strength. In this design, it is used to adjust the gains of the RF front-end. The RSSI is generally realized in logarithmic format because the wide dynamic variation of the received signal can be represented within a limited indication range. Successive-detection architecture is adopted for realizing the logarithmic amplifier. It is essentially composed of several full-wave rectifiers and a low-pass filter, which are in combination with the existing limiting amplifier circuits. Thus successive-detection is power efficient [8]-[11].

In Fig. 4, the topology of the adopted RSSI is provided. It detects the output signal amplitude of the down-conversion mixer and produces a detected DC level to control the gain of both RF-VGAs. As shown in Fig. 4, each power detector detects the signal from the output of each limiting amplifier and generates a dc current after filtering. All of the currents are added at one port of the load resistor and capacitor. Another port of the load resistor and capacitor is connected to ground.

On the other hand, due to the large gain of the chain of limiting amplifiers, a dc-offset cancellation circuit is essential since any offset caused by device mismatch may degrade small input signal. The input offset voltage of this negative feedback cancellation, as shown
in Fig. 4, is reduced by a factor of the cascaded voltage gain of the forward path [5]. An n-well resistor and off-chip capacitor filter the high-speed data waveform of the limiting amplifier output, and extract the dc offset voltage. An offset subtractor then subtracts the feedback dc offset information from the input signal. The subtracting operation is accomplished by the cross-connected circuit topology. The voltage gain of the voltage subtractor is 0dB.

A quadrature mixer shown in Fig. 7 has been developed to provide improved image rejection ratio (IRR) and reduced phase error [12]-[13]. It is basically a combination of two Gilbert mixers with shared transconductance stages. The local signals turn on in the order: LOQp, LOIp, LOQn, LOIn. For example, when the RF signal on transistor Q1 is high and the LOQp signal on Q7 is high, the voltage of the collector terminal of Q1 is pulled high and the transistors Q3, Q4, and Q8 are shut off. In this way, the total available current (Ic1+Ic2) must flow through only a selected transistor according to the local signal sequence. In Fig. 7, the capacitors C1 to C4 are used to filter out the RF and LO frequency and their harmonics. In this design, for receiving signals from RF-VGAs of different bands, double Gm cell is employed. When one band is started, the corresponding Gm is then activated while the other Gm cell is powered down. The additional parasitical capacitors brought by the powered down one will not deteriorate the performance of the down conversion. This greatly saved the chip area for using only one set of LO switches and decoupling capacitors.

### III. Experimental Results

The die photo of the CMMB tuner front-end implemented in a 0.35um SiGe BiCMOS technology is shown in Fig. 10. The presented tuner RFIC has been tested and the front-end performs meet the CMMB system requirements. The measured performance of the front-end is summarized in TABLE I. The measured overall tuner NF is 2.2dB in maximum gain, and its IIP3 is 18dBm in minimum gain.

![Fig. 5 Simplified schematic of RSSI input buffer.](image)

![Fig. 6 Simulated output of the RSSI vs input voltage.](image)

In this design, an input buffer is used to combine I/Q output signals of the down-conversion mixer for balance, as shown in Fig. 5. It contributes 0dB gain in the chain of the limiting amplifiers. Fig. 6 gives the simulated transfer curve of the RSSI. It can be seen the RSSI can detect signal as low as 1mV, which meets the need of gain control for wide input dynamic range.

#### D. I/Q Down-Conversion Mixer

![Fig. 7 Double-Gm quadrature down-conversion mixer.](image)

Fig. 8 shows the performance of the S-band LNA. It can be seen that the S11 is lower than -15dB, the S22 is within -9dB, and the S21 is peaked at 2.68GHz. Fig. 8 also gives the measured noise performance of the LNA with NF of 2.077dB at 2.68GHz. Fig. 9 shows the measured AGC characteristic of the closed loop, (a) for U-band and (b) for S-band respectively. It gives the
A CMMB mobile TV tuner frontend with integrated RSSI for dual-band applications has been implemented in a 0.35um BiCMOS SiGe technology. The measurement results show that the front-end tuner RFIC is compliant with the newly released Chinese CMMB mobile TV requirements with a state of the art gain control range of 65dB and overall NF of 2.2dB. Low power consumption of 48mW is achieved, which is suitable for the CMMB receiver integrated in a mobile environment.

**REFERENCES**


