High-Sensitivity and High-Mobility Compact DVB-T Receiver for In-Car Entertainment

Chua-Chin Wang[1,2], *Senior Member,* IEEE, Tzung-Je Lee[1], Hoi Kam Lo[2], Shih-Ping Lin[2], and Ron Hu[2]

Abstract—*A compact DVB-T receiver with better than -94 dBm sensitivity for in-car usage is presented in this work. Dual tuners are included in the receiver to reduce multi-path effects as well as realize the diversity technique. A robust audio/video interface (AVIO) is defined to accommodate different kinds of in-car displays with a variety of A/V specs. In addition, a protection circuit is proposed to provide the convenience that either active antennas or passive antennas can be plugged in the same antenna sockets. Field trials proved that the receiver works perfectly when the car is running over 180 Km/hr.*

Index Terms — DVB-T receiver, sensitivity, multi-path effects, interface.

I. INTRODUCTION

A mobile DVB-T digital TV receiver [1], or a portable indoor digital TV unit, typically receives many multi-path signals. Additionally, the movement of the TV receiver causes so-called Doppler effects, distorting the DVB-T channel information owing to the speed of the mobile receiver and the DVB-T transmission frequency and the direction of the incoming echo. Each multi-path signal received by the receiver will be influenced by the Doppler effects, resulting in a complex, time-varying channel shape, [2], [3], [4]. When receiving DVB-T TV programs in a moving car, the receiver must be able to handle fast channel variations and deep fading effects. Diversity techniques significantly improve reception performance by using two antenna/demodulator combinations. A diversity system uses the information of each demodulator and obtains the best possible quality for each data-carrier of the COFDM (coded orthogonal frequency division multiplexing) signal. In case one antenna is experiencing poor reception conditions, for example deep or flat fading, the other antenna will probably receive a better signal. By continuously combining the antenna information at the correct moment with correct weighting, a diversity receiver will deliver an optimal output signal to ensure the A/V quality.

Meanwhile, the active antenna needs the control signals and the power supply from the controller. Therefore, a protection circuit is required to avoid the possible power surge. However, the load of the protection circuits is reduced if a cheaper passive antenna is used. It might increase the power dissipation or cause the unwanted oscillation in the protection circuit and even the device breakdown. Several previous works were focused on the generation of the supply voltage for the active antenna, which did not care about the situation when a passive antenna is employed [8], [9] accidentally. Thus, a protection circuit is proposed in this work to provide the dual usage for the passive or active antenna.

Additionally, in order to supply the connection for the traditional analog TV signals, e.g., YCbCr, S-Video, YPbPr or CVBS, …,etc. It requires an interface to couple with the receiver. The considerations of such an interface include reducing the usage complexity and device area. However, several works have been done to identify the interface adapter [5] or introduce the system structure for signal transformation [6], [7]. They neglected the area and complexity cost of the interface. Thus, this work proposes an interface which can support various formats of TV signals with the advantages of area saving and easy expansion.

The proposed car-use DVB-T receiver has been proved to possess -94 dBm sensitivity and produce perfect A/V signals even when the care is racing over 180 km/hr.

II. CAR-USE DVB-T RECEIVER DESIGN

An overview of the proposed high-sensitivity and high-mobility compact DVB-T receiver is shown in Fig. 1.

A. *Anti-Doppler 2-NIM Demod Front End*

Dual antennas as well as dual NIMs (network interface modules) are employed to resolve the multi-path and Doppler effects. Each NIM coupled with a respective antenna contains an RF tuner and a COFDM demodulator to convert the received signal into MPEG2 transport stream (TS).

The received signal in the antenna is down-converted by RF and IF circuits which contains dual AGCs. The dual AGCs are controlled by a PWM (pulse width modulation) digital control signal to compensate the signal amplitude to maintain the input of the following 10-bit ADC. The output of the ADC is further converted to a baseband signal. The baseband signal needs to be interpolated to construct a re-sampling frequency of 18.28 MHz for the DVB-T channel. The interpolated signal requires to be filtered for rejecting the power from the adjacent channels. The filtered signal is then sent to a guard interval removal circuit to estimate the ISI (inter-symbol interference). Afterward, the FFT circuit is followed to perform the inverse FDM (frequency division multiplexing) procedure. The channel estimation and correction are now computed based on the pilots in the COFDM symbol such that the later inner

[1] Dr. Wang is a professor of Dept. of Electrical Engineering, National Sun Yat-Sen University, Kaohsiung, Taiwan. T.-J. Lee is also with Dept. of Electrical Engineering, National Sun Yat-Sen University, Kaohsiung, Taiwan.

[2] The authors are with Asuka Semiconductor Inc., Hsinchu, Taiwan.

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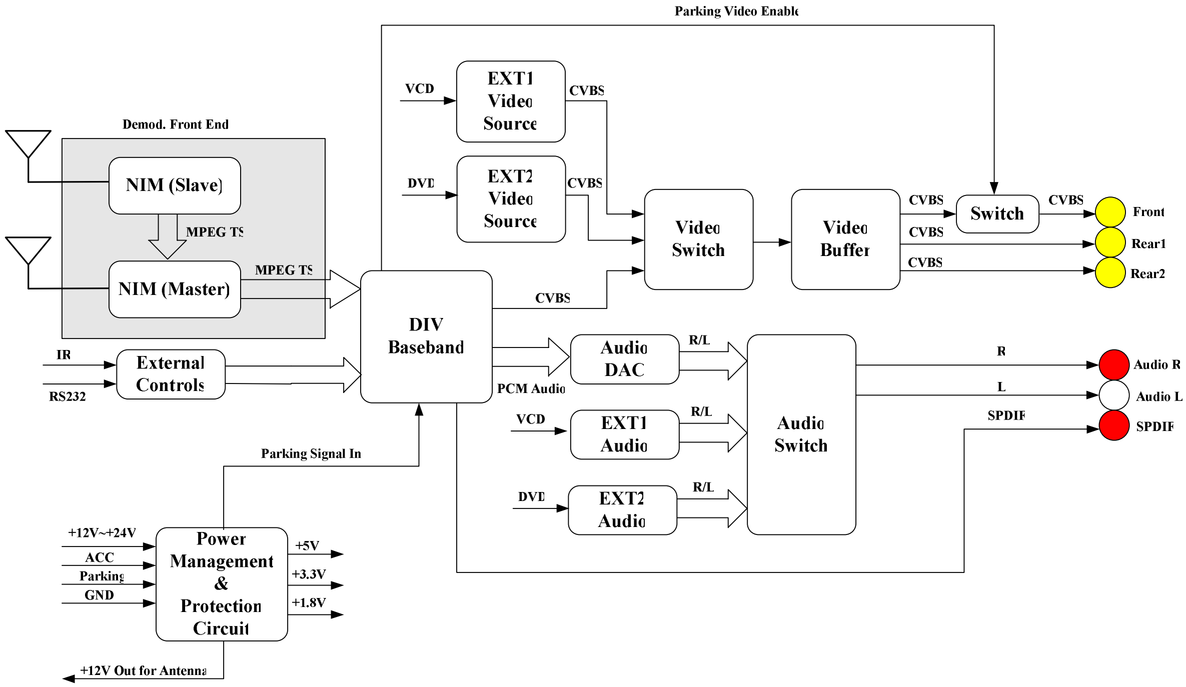

Fig. 1 Overview of the proposed car-usr DVB-T receiver.

decoder can work correctly. Then, the inner de-interleaving and the Viterbi decoding are done to reverse the process performed at the transmitter. The output of the Viterbi decoder is outer de-interleaved, Reed Solomon decoded, and then de-scrambled. The de-scrambled signal is sent to a FIFO to produce an adequate data rate. Now, the output of the FIFO can be converted into the MPEG2 TS for further processing. The TPS (transmission parameter signaling) which contains the system information is extracted during the demodulation process. The extracted information is helpful for adjusting the performance of the system.

The slave NIM generates its own TS to the master NIM which will decide either one of the two TS's, the TS of the slave NIM or that of the master NIM, is going to the baseband module, DIV, depending on the BER and the signal strength of the two TS's.

B. Diversified Baseband and Peripherals

The baseband IC, DIV, is the core of the entire receiver. It accepts external control commands to carry the following major functions,

- decode the selected TS by an embedded MPEG2 decoder
- convert the selected programs into a CVBS signal by an embedded video encoder
- control all of the peripherals, including, Video Buffer, A/V Switches, etc., by an embedded 8-bit micro-controller
- monitor the power supply variations and the position of the stick shift such that the driver can only enjoy the TV programs on the front in-dash display panel when the car stick shift is placed in the "P" gear.

Notably, two extra external A/V sources are included to accommodate popular VCD and DVD players such that entertainment function in a vehicle can be integrated in a single and compact module.

C. Power Management & Protection

Fig. 3 shows a typical power protection circuit for the active antenna. There is a possibility that active antennas, which contain a booster to compensate the gain loss resulted from long wires, will be utilized with car-use DTV receivers. However, if a passive antenna which is either accidentally or deliberately hooked up with a power supply and protection circuit for active antennas will cause oscillations, since the small input impedance of the passive antenna will almost short-circuit the output to the ground. As the equivalent

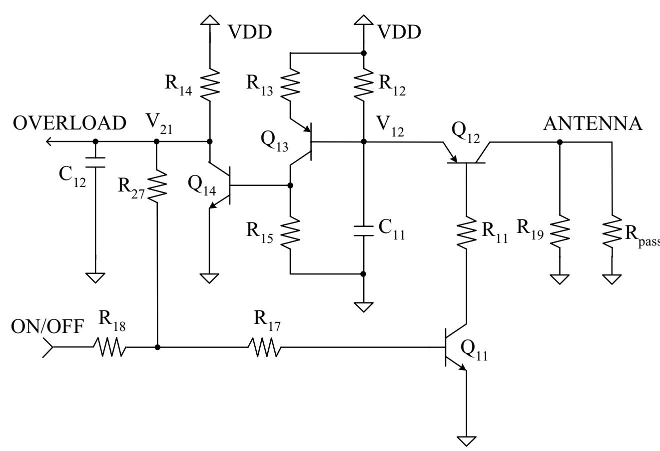

Fig. 2. A typical antenna protection circuit.

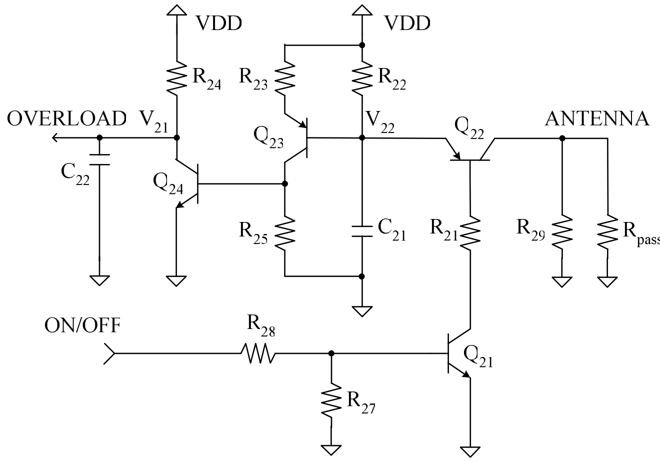

Fig. 3. Proposed antenna protection circuit.

resistor of the passive antenna, Rpass in Fig. 2, is connected at the output of the typical power protection circuit. When the circuit works, transistor Q12 is turned on such that voltage V12 is pulled low. Q13 is then switched on and voltage, V13, is high enough to turn Q14 on in case of an adequate resistor R15 existed. The V11 which is pulled low would cause Q11 and Q12 to be turned off. Thus, V12 is high enough to turn Q13 off. It follows that Q14 is off as well. V11 is high now and Q11 is turned on. This process repeats again and again, resulting in an oscillation in the loop.

Therefore, we propose an open-loop power protection circuit as shown in Fig. 3. Without any feedback loop, the proposed protection circuit won't introduce any oscillation or short circuit. Besides, a voltage divider generating a stable voltage to the base drive of Q21 ensures the functionality of supplying power to the load. Therefore, either active antenna or passive antenna can be hooked up with the car-use DVB-T receiver without any trouble.

Low drop-out circuitry is required for the power management of the entire system, since most of the power supply of automotives is either 12 V or 24 V. By contrast, different supply voltages are needed on the PCB, because there are a variety of chips thereon. For example, 5 V, 3.3 V and 1.8 V are basic voltages required. Last but not least, many countries don't allow drivers to enjoy any visual entertainment when they are driving vehicles. Hence, the car-use DVB-T receiver provides an option, "Parking Video Enable", which will turn off the front display if the vehicles are not in a "parking" situation. Drivers can only watch programs when the vehicles are parked.

D. *AVIO interface*

Owing to the fact that there are lots of add-on audio (e.g., AM/FM, stereo) and video (DVD, VCD) devices, an interface on the PCB is needed to achieve purposes of easy installation and expansion. We define an AVIO (audio/video I/O) interface thereon to support many A/V signals compliant with a plurality of different specifications by pin sharing and grouping. Referring to Fig. 5, an interface that includes 20 pins and their groups is shown. There are five pins, PIN03, PIN12, PIN14, PIN16, and PIN18 are shared by more than two sets of different signals. Thus, the number of the required pins is reduced. The functions and interfaces that can be supported by the groups of the proposed AVIO interface are revealed in Table I. When a display, a traditional mobile TV set, or a traditional bearable analog TV set which possess a CVBS connection need to be connected, the pins in Group 3 can be used. The connection with I^2C is achieved by using the pins in Group 8 such that the expansion with other circuits, e.g., a master-slave structure, can be constructed. Therefore, the proposed interface can be applied for various usages. In short, a total of 20 pins in such an interface can support VGA, YCbCr, S-Video, YPbPr, CVBS, audio L/R, GPIO (general-purposed I/O), I^2C, or grounding signals. By contrast, if without pin sharing and grouping, it needs 32 pins to cover the mentioned various signals.

III. Implementation And Field Trial

The proposed car-use DVB-T reciever has been field trialed in Hannover, Germany during CeBIT 2005 (March 10-16, 2005). Fig. 5 shows the photo that the car-use DVB-T receiver was tested in a renatl taxi running with 180 Km/hr in a freeway close to Hannover. The picture of the car-use DVB-T receiver is shown in Fig. 6. The overall characteristics of the proposed car-use DVB-T receiver are summarized in Table II.

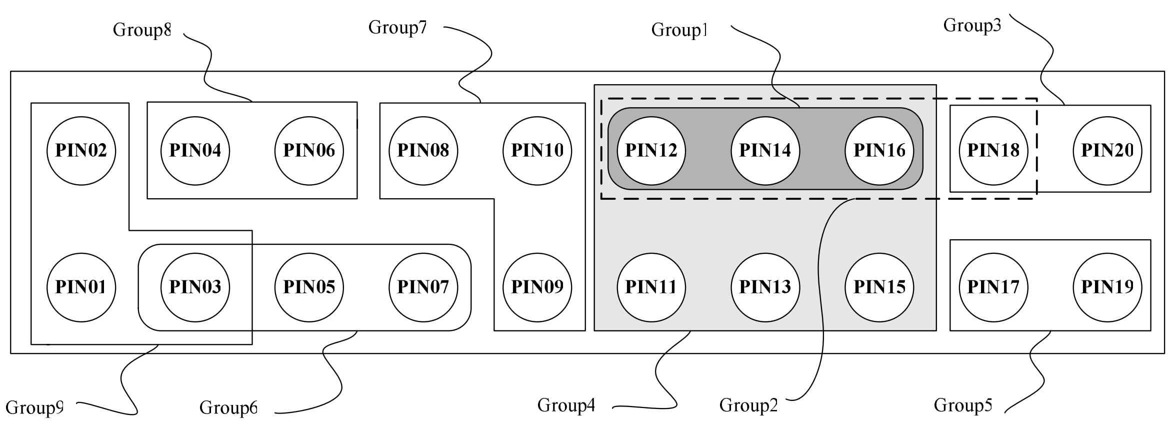

Fig. 4. The AVIO interface.

TABLE I
GROUP DESCRIPTIONS OF THE PROPOSED AVIO INTERFACE

Group #	The interface or functions to be supported
Group 1	GRB of YCbCr, S-Video (Y and C), YPbPr, or VGA
Group 2	YCbCr, S-Video (Y and C), YPbPr, or VGA
Group 3	CVBS
Group 4	VGA (PIN11-Hsync, PIN13-Vsync, PIN15-ground, PIN12-B, PIN14-G, PIN16-R)
Group 5	Signals of a remote controller (PIN17-ground, PIN19-signal)
Group 6	Left and right sound channel (PIN03-ground)
Group 7	GPIO (general-purposed I/O for digital control or data transmission)
Group 8	I^2C
Group 9	Power supply (PIN01-VDD, PIN02-VDD, PIN03-ground)

IV. CONCLUSIONS

A high-sensitivity and high-mobility DVB-T receiver is proposed for in-car entertainment in this work. Dual tuners are employed to reduce the multi-path effects. There are diversified functions performed by the baseband circuits to apply for lots of in-car displays with various A/V specs through a defined AVIO interface. Moreover, a protection circuit is introduced to support the active or passive antenna to be connected in the same socket conveniently. The results of the field experiments show that the receiver works correctly even if the car is running over 180 Km/hr.

Fig. 5. Field test of the proposed car-use DVB-T receiver.

Fig. 6. Outlines of the proposed car-use DVB-T receiver.

TABLE II
PERFORMANCE OF THE PROPOSED CAR-USE DVB-T RECEIVER

Outlines	12.9cm x 17.9 cm x 3cm
Frequency range	145.1MHz ~ 862 MHz
RF input impedance	75 Ohm
Channel bandwidth	6/7/8 MHz
Input signal range	-20dBm ~ -80dBm
Demodulation	QPSK, 16-QAM, and 64QAM
Input voltage	9V ~ 25V DC
Sensitivity	-94 dBm
Highest car speed	180 Km/hr

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Chua-Chin Wang (M'90-SM'05) was born in Taiwan in 1962. He received the B.S. degree in Electrical Engineering from National Taiwan University in 1984, and the M.S. and Ph.D. degree in Electrical Engineering from State University of New York in Stony Brook in 1988 and 1992, respectively. He is currently a Professor in Department of Electrical Engineering, National Sun Yat-Sen University, Kaohsiung, Taiwan. His recent research interests include low power and high speed logic circuit design, VLSI design, neural networks, and interfacing I/O circuits.

Tzung-Je Lee was born in Taiwan in 1979. He received the B.S. and M.S. degrees in electrical engineering from National Sun Yat-Sen University, Taiwan, in 2002 and 2004, respectively, and is currently working toward the Ph.D. degree in electrical engineering at the National Sun Yat-Sen University.

His current research interests are VLSI design, mixed-signal circuit design, and implantable bio-chips.

Hoi Kam Lo has been serving as a senior product engineer in Asuka Semiconductor, Inc., since 2001. His expertise includes PCB design, and TV product design.

Shih-Ping Lin has been serving as a product manager in Asuka Semiconductor, Inc., since 2002. His expertise includes ASIC design, and TV product design.

Ron Hu was born in Tainan, Taiwan, in 1962. He received the B.S. degree from National Taiwan Institute of Technologies, Taipei, Taiwan, in 1987, the M.S. degree from Utah State University, Logan, in 1990, and the Ph.D. degree from the State University of New York, Stone Brook, 1994, all in electrical engineering.

He jointed Holtek Semiconductor Inc., Taiwan, in 1994. He became General Manager of Asuka Semiconductor, Inc., Hsin-Chu, Taiwan, in 2001. His research interests include consumer product circuit design and wireless communication.