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Adaptive Front-end blocks for Digital Receivers

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Abstract

The Front-end RF blocks play an important role in High Definition receivers like Televisions, Set Top Boxes (STBs) to receive, demodulate and decode the RF signal. Concept of Adaptive front-end blocks will enable to receive and process multiple types of signals. Programmable demodulator which works on Software Defined Radio Technology (SDR) is used in the architecture of proposed design. The concept is to receive and demodulate multiple types of signals, without changing the hardware. Hence the proposed front-end blocks bring flexibility in design, manufacturing, procurement and other operational issues related to the Receivers design and manufacturing process. This technical paper also discuss about adding Trans- modulation capabilities at front-end blocks to design smart receivers. Trans-modulation capability will enable to change signal formats according to the requirements of device under use, which will help to implement smart receivers for smart homes.

Keywords: *RF; HD; SDR*

INTRODUCTION

High Definition receivers like HD TVs or STBs are very frequently used in homes. The concept of designing adaptive front-end block for the receivers is discussed in this technical paper. Adaptive front–end block with multifunctional capabilities play a major role to enhance the features of the digital receiver.

In the present scenario, a receiver is designed to perform specific function and cannot demodulate different types of signal. For example, a receiver designed to receive Satellite signal cannot receive and process digital cable signal. Hence to receive different types of signals, different receivers are to be used. It is practically impossible to have multiple receivers to handle different types of signals as and when required. Different signal modulations are used at different parts of world, which demands use of different receiver designs to meet the requirements. For example, a receiver which is designed to work on ATSC signal cannot work on PAL or QPSK modulations. This will force to introduce different types of receivers, even though control system, power supply module, display module are common in receiver architecture.

Non-flexible font-end block is the main cause which forces to have different types of receivers for different types of signal reception or the modulation methods. The proposed method brings out an approach to have a programmable and adaptive front–end block.

As the post demodulation process like video & audio decoding are common for different types of signals, it will be good to have a single receiver designed with adaptive multifunctional front-end module. This will reduce e-waste and helps to implement efficient and smart receiver. Programmable demodulators will bring flexibility to change the functionality of the receivers, without changing the hardware. For example, by using programmable demodulators, receiver can receive DVBT/C/S signal, just by changing the software.

Signal re-generation feature is required in smart homes, as there is need to communicate with different devices, which are compatible to work with different types of modulated signal. Hence there is need to transform one type of signal in to another type, which is called as Signal regeneration or Signal Trans-modulation. The designed front-end is capable to perform Trans- modulation of signal also, which will be discussed in this paper. Software Defined Radio (SDR) technology based Modulators and Demodulators are used in designing these front-end blocks, which brings adaptive and multifunctional features to the receivers.

DESIGN CONCEPT

The architecture of presently available HD receiver is shown in Figure 1, which consists of Tuner, Demodulator, Decoder and Control unit. Tuner and demodulator could be in a single chip in some designs or both could be in a single SOC. [1]

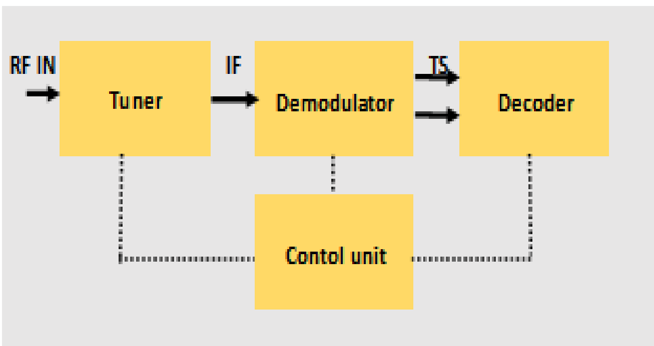

Figure 1. Block diagram of conventional digital HD receiver

Tuner will convert RF in to Intermediate Frequency (IF). Demodulator will give out Digital Transport stream (TS), which will be processed at decoder. [2].Normally conventional receiver will perform a specific task. Digital Video Broadcast Cable receiver (DVBC) use QAM demodulator where as Digital Video Broadcast Satellite signal receivers (DVBS) designed with QPSK demodulator. Hence they are application specific. Integrated SOC or multiple modules are used in present architecture. However, in all these designs specific function is targeted and receiver cannot work for different types of signals. [3]. No scope for design up gradation or design change with integrated front-end block designs.

Proposed adaptive front-end block design consists of Tuner and programmable demodulator, which brings flexibility to change the demodulation requirement, just by changing the program, which works on Software Defined Radio (SDR) based technology. [4].

The proposed design will be able to perform multiple tasks like capable to receive & demodulate different types of signals and also can modulate signal. This feature is as Signal regeneration. In a modem smart home concept, it is required to have different types of signals to communicate with different types of devices. The signal regeneration feature will help to convert one form of signal into another, so that it can be processed at different devices in a home. Top level block diagram of the proposed receiver architecture is shown in Figure 2, wherein Receiver block, Trans- modulator block, Decoder and Control unit are shown.

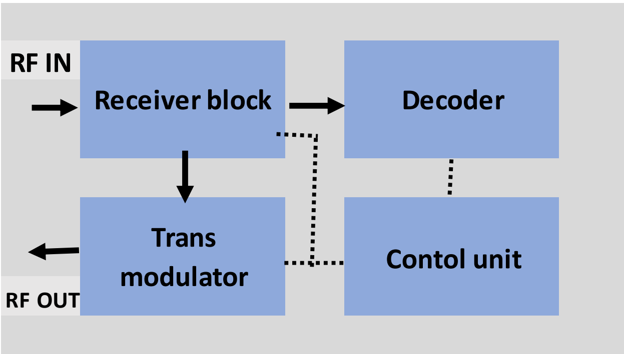

Figure 2. Block diagram of Receiver with adaptive front-end block

Functions targeted at adaptive front-end block are:

- Capability to receive & demodulate multiple types of signal
- Capability to trans- modulate the signal

DESIGN IMPLEMENTATION

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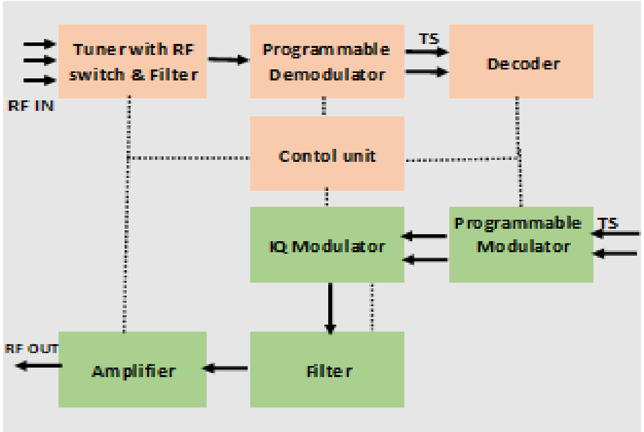

Figure 3. Adaptive Front-end block architecture

A. Receiver block

This consists of Tuner, Programmable Demodulator and Decoder. RF switch enables to select different types of input signal. Module with IF & Wi-Fi Filters and High voltage protection circuit is connected at front-end of the Tuner. Tuner will convert RF in to Intermediate frequency or IF. [5,6]. IF will be processed further at SDR based demodulator. The required program will be selected at demodulator to demodulate the signal.

An architecture of SDR based demodulator consist of Analog to Digital Converters (ADC), Digital Signal Processor for Sampling, Demodulator, Forward Error correction block (FEC) and Digital to Analog Converter (DAC), along with SDRAM, Controller and Memory. [7]. Viterbi algorithm is used for signal sampling and demodulation is done by Turbo decoder to decode the bit stream. Reed-Solomon algorithms and Low-Density Parity-Check codes (LDPC) are used for Forward Error Correction (FEC). Reed-Solomon is a BCH error correction algorithm and LDPC is a linear error correction code algorithm. [8]. Output from the SDR is a Transport Stream (TS), which is processed at Decoder to get Video and Audio. Tuner, programmable demodulator and the decoder operations are controlled through IIC. [9,10].

B. Trans-modulator block

Trans-modulators will convert the signal formats. One of the main requirements of smart homes is to have a capability to regenerate signal of known format which can be used by another device. For example, DVBC signal can be converted in to DVBT and transmit over air and then receive back at another device. If a device 1 can operate with DVBT signal and device 2 needs NTSC, then the receiver can regenerate the required signal and other devices can work using these signals. Figure 3 shows the main parts of Trans-modulator block.

Digital Programmable Modulator will take Transport stream as input. The output from the programmable modulator is I & Q signal, which will be processed by I,Q Modulator and RF Up converter. RF MD device RF 2080 is used in this design to perform this function. [11] The RF output is in the range of 50 to 1000 MHz, which will be amplified to Transmit in the form of DVBT or DVBC. The regenerated signal can be made to receive only by a specific device, by controlling the modulation and demodulation process. This will help to achieve secured communication between the devices, which can be extended to other applications such as military applications, where secured communication is essential between Transmitter and Receiver.

SDR based Modulator consists of DSP based Channel encoder, Modulator and signal conditioners, which gives out I Q signal. RF up converter will up convert the I Q signal in to RF frequency range from 50 to 2.5 GHz. An amplifier is used at the output stage, which is connected to a small antenna to transmit the signal locally through DVBT.

Modulator used is programmable. Required program is down loaded in to the modulator to perform signal modulation. For example, parameters required to modulate the signal need to be set as per the requirement (Ex: DVBC, 256 QAM, symbol rate 6875K sps,) It is possible to modulate different types of signal like DVBC, DVBT, DVBS, ATSC etc, by downloading the different programs from the controller. Third harmonics at the RF up converter output are suppressed by introducing a filter bank, which operates from 40 to 1000MHz. [13, 14].Variable gain amplifier is used to amplify signal by 5 dB

C. Challenges in handling signals at IQ modulators

Problems of 3rd harmonics after the IQ modulation need to be addressed. The effect of 3rd harmonics cannot be ignored as it will adversely affect the quality of the signal. This is achieved by introducing a filter block after IQ Modulator and just before the signal amplification. Different filter blocks are made to operate for a specific range to avoid the third harmonics in that range. [12]. Filter block connected with RF switch is shown in Figure 4.

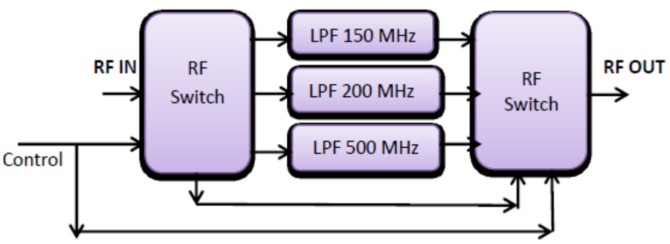

Figure 4. Harmonics suppression filter

Suppose if the desired range of RF up converter is 50 to 900 MHz, then it is required to suppress the 3rd harmonics in this entire range. For example, input frequency of 300 MHz will create 3rd harmonics at 900 MHz. Hence the filter bank has to suppress harmonics for the input frequency up to 300 MHz. [13]

Theoretically, the odd harmonics generated during the mixing process will have higher amplitude and these signals are the major concerns to affect the quality of the signal. For example, if the desired channel is tuned to 50 MHz, then the 3rd harmonics will appear at 150 MHz, which will distort the desired signal. It is not practically feasible to use one filter to suppress harmonics for the entire rage. Hence the system is designed with filter banks & RF switch as shown in Figure 4.

Filter 1 has pass band of 0 to 150 MHz, which will work for the frequency 50 to 100 MHz. At this frequency range, the maximum third harmonic frequency fall at 300 MHz for input frequency of 100 MHz.

Filter 2 has pass band of 0 to 200 MHz, which work for the frequency range from 91 to 190 MHz. When the input is 190 MHz, the third harmonic will be at 570 MHz. This filter will suppress the harmonics for the input frequency up to 190 MHz.

Filter 3 has pass band of 0 to 500 MHz, and work for the frequency range from 191 to 390 MHz. When the input is 390 MHz, the third harmonic will be at 1170 MHz.

Above 390 MHz, the third harmonics frequency is greater than 1100 MHz, which is not in operating range of Cable or Terrestrial TV channel band. Hence no need to use filter to suppress the harmonics for the input frequency above 390 to 900 MHz, if the desired maximum frequency of operation is 1000 MHz. All filters are designed to suppress harmonics by about 35 to 40 dB [14]

PERFORMANCE EVALUATION

Performance of the adaptive front-end block is tested with various input signals. Its demodulation and Trans- modulation capability are checked integrating the system with decoder.

Target Specifications:

SNR	: Better than 30 dB
Power gain	: Better than 80 dB
Image rejection	: Minimum 60 dB
IF rejection	: Minimum 60 dB
Noise Figure	: Max. 8
MER	: Better than 30 dB
BER	: Less than .10.0 E-06

Receiver section:

Different signal frequencies are tuned and demodulator output is checked with different types of demodulation like QAM, QPSK, ATSC. Etc. Signal to noise ratio (SNR) is measured for different frequencies and Tuner parameters like Power Gain, Image rejection, IF rejections and Noise Figure are checked and found to be OK as indicated in Table 1. Some of the measured parameters are as shown below:

DVBT:

At RF -50MHz: SNR	: 33.1 dB
350 MHz: SNR	: 35.8 dB
850MHz: SNR	: 34.4 Db

DVBC, 256 QAM, Symbol rate 6.952 Msps:

At RF -50MHz: SNR	: 33.3 dB
350 MHz: SNR	: 34.8 dB
850MHz: SNR	: 34.4 Db

Table 1: Front-end Tuner parameter measurement

Frequency	PG (dB)	Image Rej. (dB)	IF Rej (dB)	NF (dB)
50 MHz	90	64	66	5.0
150 MHz	90	72	>70	5.0
700 MHz	92	62	>70	5.5

Transmitter section:

Performance of Trans-modulator module is tested by observing parameters like output level, Bit error Ratio (BER) & Modulation Error Ratio (MER) of modulated output signal.

Output level from the Trans modulator amplifier:

At 50MHz / DVBT : - 10.8 dbm
At 350MHz / DVBT : - 12.6 dbm
At 50MHz / DVBC : - 13.8 dbm
At 350MHz / DVBC : - 13.2 dbm

Programmable modulator output is a low IF as shown in Figure 5

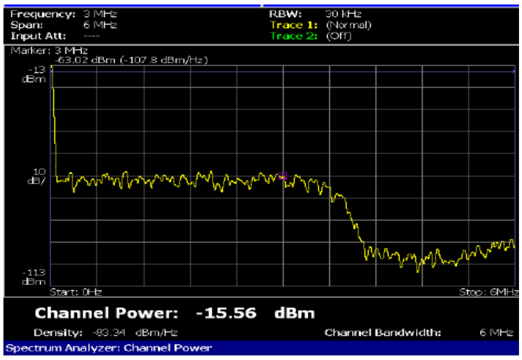

Figure 5. Modulator output (Low IF)

Measured BER and MER are indicated in Table 2, which meet the target specification.

Table 2. Measurement of BER & MER

Signal type, DVBC	MER (dB)	BER
64 QAM, 100 MHz	39.	2 .0 E- 06
,256 QAM, 250 MHz	38.4	2 0 E -06
256 QAM, 850 MHs	38.4	3 .0 E- 06

CONCLUSION

Adaptive front-end modules are useful to implement flexible receiver designs. It can receive and demodulate different types of modulated signals. The programmable SDR based Modulator has capability to Trans- modulate the signal. This is one of the very useful requirements to implement interactive smart receivers wherein different signal formats can be regenerated to communicate with different devices. Adaptive front-end blocks will also help to upgrade the features of Digital receivers. The implemented front-end design can be used to design any commercial digital receiver. It reduces receiver design cycle time and simplifies manufacturing process, as a single receiver architecture can be made to work for different communication protocol of different parts of the world because of the programmable demodulator and modulator used in the architecture. It is also possible to design Transmitter and receivers with SDR devices to have secured communications.

REFERENCES

[1] H. Seung Jun Lee "A precisely gain controlled RF front end for T-DMB Tuner ICs" IEICE 2012 , Vol 9, No. 1, pp 23 - 29, Jan 10, 2012

[2] V. Vresh babu "Design of RF Tuner for Cable Modem Applications" Proceedings of the 17th International Conference on VLSI Design (VLSID'04) 1063-9667/04 $ 20.00 © 2004 IEEE

[3] Rabindra K. Mishra "Architecture and system design aspect of RF Front – end blocks for an advanced CATV STB Converter" International Journal of Information Technology and knowledge Management, July –Dec 2012, Vol 5, No. 2, PP409 – 412

[4] Oveek Chatterjee,Dr.(Mrs) R. D. Raut, "SDR Based Modulator Design and Implementation Using GNU Radio" International Conference on Recent Trends in Engineering and Science (ICRTES 2017), ISSN (Online) : 2319 – 8753, Volume 6, Special Issue 1, January 2017

[5] Nerey H. Mvungi "Set-Top-Box for Terrestrial Digital Broadcasting: Compatibility Issues" International Conference on Computer Science and Information Technology (ICCSIT'2011) Pattaya Dec. 2011

[6] Jianhong Xiao, "Low power fully integrated CMOS DTV Tuner front-end for Terrestrial broadcasting", research article, VLSI design, Vol. 2007, Article Id 71974,doi.10.1155/2007/71974, pp 1-13.

[7] D. C. Tucker and G. A. Tagliarini, "Prototyping with GNU Radio and the USRP - where to begin", Proc. IEEE Southeastcon, Atlanta, GA, pp.50-54, Mar. 2009

[8] Rajesh Bhambare, Rajeshree Raut, A Survey on Digital Modulation Techniques for Software Defined Radio Applications, International Journal of Computer Networks and Wireless Communications (IJCNWC), ISSN: 2250-3501 Vol.3, No3, June 2013

[9] Data book, Silicon labs ,"RF front end solutions", www.silabs.com, Jan 2016

[10] Document, NXP, "RF design solutions" NXP,www.nxp.com & www.nxp.com/pip/TDA18274HN, 2013

[11] Data book, RFMD, "Applications notes",www.rfmd.com, Jan 2014

[12] Zubi HM, Dunn RW, Robinson FVP, "Comparison of different common passive filter topologies for harmonic mitigation", UPEC 2010 Aug 31–Sep 3; 2010.

[13] J.-H. Park, S. Lee, and Y. Lee, "Extremely miniaturized band pass filters based on asymmetric coupled lines with equal reactance," IEEE Transactions on Microwave Theory and Techniques, vol. 60, no. 2, pp. 261–269, 2012

[14] Document, Coil craft , "Document Low pass LC filter modules", www.coilcraft.com, 118-2,24/01/2012,