Design of Software Defined AM radio receiver

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Abstract: This paper present design of Software Defined radio AM Receiver using Spartan 3E FPGA Board. This system is designed to demodulate AM signal by software and not by traditional hardware. VHDL is used to demodulate AM signal in FPGA Board. This SDR Am receiver is also simulated in Matlab using Simulink. For AM signal generation we have used Analog IC AD633 which is an analog multiplier IC. Input signal is give from Function Generator to IC AD633 and it generates an AM signal. This AM signal is then give to FPGA where demodulation of AM takes place.

Keywords: SDR, Matlab, FPGA, VHDL, AM, demodulation, ASICs, GPP, Simulink

1. Introduction

Conventional radios have fixed hardware and fixed working. It cannot be modified or changed its functionality but in Software Defined radio we have advantage of modifying Radio according to our needs. SDR is very flexible compared to normal radio. Software Defined Radio (SDR) is a new digital technology all physical layers are implemented by signal processing software running on generic hardware platforms like FPGA or DSP or GPP. Today all systems are replaced by digital system, since they are less prone to noise and are more reliable. We have used Xilinx Spartan 3E FPGA board instead of DSP, as FPGA are far more advanced and capable of signal processing [5].

In this project first Matlab Simulink model of AM modulation and demodulation has been simulated. Matlab R2015a model is used for creating Simulink model. After successfully simulation VHDL code is generated by using VHDL Toolbox. VHDL coder for Matlab is very handy to use but need modification as FPGA is a different type device. All fixed point input and output has to be converted into floating point. For modification and pin assignment Xilinx ISE 14.7 is used. Xilinx ISE is and IDE in which we can program any FPGA or draw any Schematics. For generation of AM signal, analog IC AD633 is used to create AM signal instead of RF Front end. Message signal and Carrier signal is given from Function Generator to IC and at the output we get AM signal. Then AM signal is fed to FPGA for demodulation via ADC 8080 and via DAC TLC7528 we get the received message signal. Output signal is fed to Oscilloscope where we can see both input AM signal and Sinusoidal message signal.

2. System Design

Whole project is divided into two part, one on Software i.e. Matlab/Simulink and other on hardware part i.e. FPGA board. In both we have successfully demodulated AM signal and obtained message signal. AM i.e. Amplitude Modulation is type of modulation scheme in which amplitude is varied at regular interval and frequency is being kept constant [1].

Am generation Principle:

\[ y(t) = [1 + m(t)] \cos(2\pi fct) \]

Where

- \( \cos(2\pi fct) \) - Carrier signal
- \( m(t) \) - Message signal

\[ m(t) \rightarrow [1 + m(t)] \rightarrow \cos(2\pi fct) \rightarrow s(t) \]

**Figure 1 AM Modulation Principle**

When message signal is multiplied by carrier signal, we get AM signal. Here \( S(t) \) is AM signal.
Am Receiver (Square Root Demodulator) Principle: For AM receiver Square law detector (SQRT) is used both on Matlab and in FPGA. In this demodulation, output voltage is proportional to the square of the amplitude-modulated input voltage. Also known as square-law demodulator. [1]

\[
y(t) = s(t)^2
\]

**Fig 2. Square Law Demodulation Principle**

Square law detector is used in both Matlab and FPGA to detect and demodulate AM signal.

### 2.1 Matlab/Simulink Design

Matlab Simulink model is to verify initial design and to convert into VHDL code by VHDL coder [6, 4].

**Figure 3. Matlab/Simulink Model**

At output of Scope we get two waveforms one of AM signal and another of demodulated messages signal.

**Figure 4. Simulink output**

Here AM signal is detected by Square law demodulation. Upper signal is AM signal and below is Message signal. After simulation Simulink model is converted into VHDL Code by using VHDL Coder.

### 2.2 IC AD633 design

The AD633 is a functionally complete, four-quadrant, analog multiplier. It includes high impedance, differential X and Y inputs, and a high impedance summing input (Z). The AD633 can be used as a linear amplitude modulator with no external components. The carrier and message signal to the AD633 are multiplied to produce AM signal. The input range of operating voltages for this IC is from +15 V to -15 V.

**Figure 5. AM generation**

### 3. Implementation of AM Receiver on FPGA

FPGA is a programmable logic device in which we can build any logic and execute them. FPGA is very advanced hardware with high speed signal processing capabilities [2, 3].

**Figure 6. Spartan 3E FPGA Board**

The key features of the VLSI Spartan 3 E Development board are [7]:
- Spartan-3E XC3S250E FPGA
- Up to 172 user-I/O pins
- 208-pin FBGA package
- Over 5,000 logic cells
Xilinx 2 Mbit Platform Flash configuration PROM

Am signal which is generated by IC AD633 is given to ADC 0808 as FPGA only works in digital Domain and AM signal is analog in nature. Hence it is necessary to convert analog signal into digital signal. FPGA the process i.e. demodulate AM signal by SQRT demodulator. All filters and detectors are in software form i.e. VHDL language.

VHDL code is checked and executed by Xilinx ISE. Synthesize, floor plan and Bit file generation all done ISE 14.7. Result of FPGA is given to DAC as we have to again convert digital signal to analog. DAC TLC7528 is used to convert digital signal to analog signal. Output of DAC is given to Oscilloscope and hence successfully demodulated AM signal.

4. Conclusion

In this project we successfully designed Software Defined AM Radio receivers in Matlab/Simulink and in FPGA also. A software AM radio receiver was implemented using Matlab Simulink. Using Simulink, AM audio signals were successfully demodulated. The block level design was verified by simulations in Simulink and Matlab. VHDL code is Modified and executed in Xilinx ISE.

5. Future Scope

In future we can also integrate transmitter with receiver so that software defined Radio Transceiver can be built. In addition to AM modulation scheme we can add different modulation schemes such as FM, QPSK, and FSK etc.

Commercial Software defined radio can built and sold for general public. There are many more future scope of SDR.

6. References

[1] OpenStax “From MATLAB and Simulink to Real-Time with TI DSP’s” http://cnx.org/contents/UAIFGC3y@1.2:b8NLhy8i@2/Amplitude-Modulation


