Simulation and Implementation of SNR Measurement processor for Adaptive Communication Systems

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Abstract: -

The measurement of SNR is the backbone of the adaptive modulation (AM) system to select the type of modulation techniques according to the data rate required. In this paper simulation, implementation and evaluation of SNR for selectable adaptive modulation are given. BPSK, QPSK and QAM modulation techniques are used in this work. The main units of this system are BPSK modem, QPSK modem, 8QAM modem, inserting pilot channel and SNR measurement channel. Separation of the noise from received signal is required to find SNR. Experimental results show difference between the set value and measured value of SNR in the presence of AWGN for BPSK modem and QPSK modem. Losses by using pilot symbol assisted modulation (PSAM) (±0.85) dB in the presence of AWGN for QPSK and MQAM. Experimental result proved also the pilot technique is better than data and using the pilot technique is independent on the type of modulation and the results show that there is coincidence between transmitted and received data with a delay of (0.3-0.4μs). However, the combination of MATLAB (Simulink and M-file) and Simulink HDL Coder provides flexible capabilities for analysis, design, simulation, implementation and verification.

Keywords
BPSK, modulation, pilot, FPGA, simulation, SNR.

محاكاة وتنفيذ نسبة الأشارة الى الضوضاء لأنظمة الاتصالات التكيفية

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المستخلص:

يعتبر قياس نسبة الإشارة الى الضوضاء (SNR)العامود الفقري لنظام التكيفي (AM) من خلال اختيار نوع التضمين تبعا الى معدل البيانات. في هذا البحث تم تصميم وتنفيذ وقياس SNR لانواع مختلفة من التضمين (BPSK, QPSK, QAM). الوحدات لهذا النظام هي مودم(BPSK, QPSK, QAM) , ادخال قناة تجريبية (pilot) وقياس SNR. لايجاد SNR يتطلب فصل الضوضاء عند الاستلام وتظهر النتائج التجريبية الفرق بين القيم المحددة والقيم المقاسة لل SNR في وجود AWGN لمودم (BPSK, QPSK)
الخسائر بوجود AWGN لمودم (BPSK, QPSK) باستخدام (PSAM) هي (±0.85) والنتائج بينت ان استخدام (pilot+data) افضل من ارسال المعلومات فقط ولكن هناك فرق بين البيانات المرسلة والمستقبلة بتأخير(μs 0.3-0.4) . طريقة دمج الماتلاب مع HDL يوفر مرونة للتصميم والتنفيذ والمحاكاة والتنفيذ.

1. Introduction

Adaptive modulation is a shows potential technique to raise the data rate that can be consistently transmitted over fading channels. For this cause, some form of adaptive modulation is projected. The adaptive modulation system is based on the variation in the transmitted power or symbol rate transmission or BER or coding rate/schemes, or any amalgamation of these parameters [1]. The disadvantages of the adaptive modulation need an exact channel estimate at the transmission, added hardware complexity to execute adaptive transmission, and buffering/delay of the input data because the transmission rate vary with channel conditions [2,3].

There are many algorithms or technique which can be used to implement SDR in FPGA. The first technique writes direct VHDL. The second technique includes compiling the VHDL code by using Quartus II. However, in 2006, Math Works introduce Simulink HDL Coder, which automatically generates synthesizable Hardware Description Languish HDL Coder [4].

Modulation Scheme (Coherent)	BER< 1×10^{-4}		BER< 1×10^{-5}	
	Required SNR (dB)	Spectral Efficiency	Required SNR (dB)	Spectral Efficiency
BPSK	6<SNR<8	2	7<SNR<9	2
QPSK	8≤SNR<12	2.2	9≤SNR<13	2.3
8QAM	12≤SNR<14	2.5	13≤SNR<15	3.1
16QAM	14≤SNR<16	3.2	15≤SNR<17	3.4
32QAM	16≤SNR<19	4	17≤SNR<20	4.5

Tab. 1 Required SNR for different modulation and BER value.

Simulink HDL Coder with MATLAB facility can be considered as a compact package which includes the analysis, design, accomplishment and certification of hardware, thus providing a path directly from system models to programming FPGA [4].

Figure (1) shows the main units of (AM) system. The AM is based on SNR measurement and depending on the value of SNR selected the type of modulation. Figure (2) shows the BPSK required the minimum SNR but the BER is higher. Table (1) shows the SNR required for different modulation and different BER [5]. Channel is estimated to suitably choice the system parameters chosen in employment for the next transmission, a reliable estimate of the channel state information (CSI) through the next active transmission time slot are essentially. Pilot symbol assisted modulation (PSAM) former projected as an attractive technique to sense the CSI by measurement of the SNR [6].

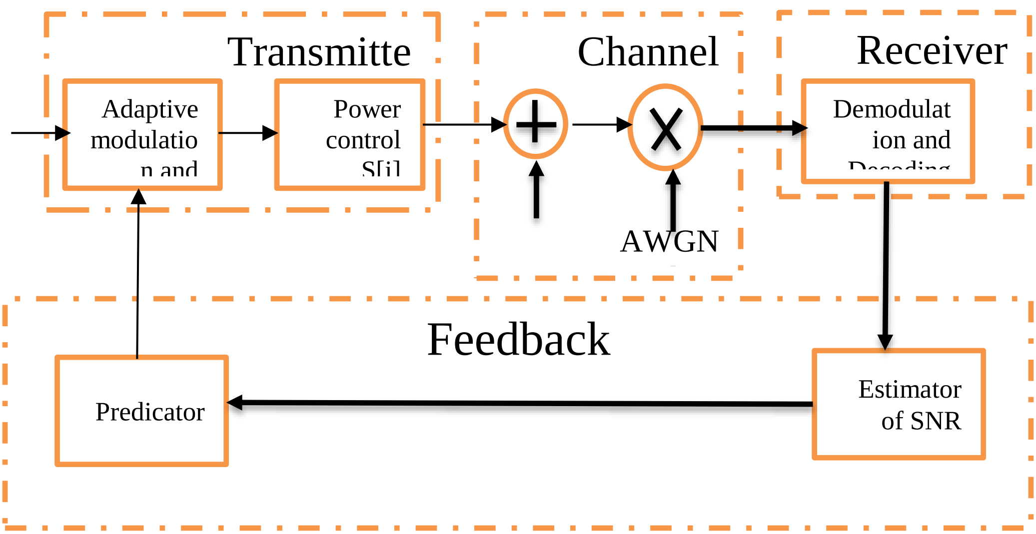


Fig.1. Typical adaptive modulation system

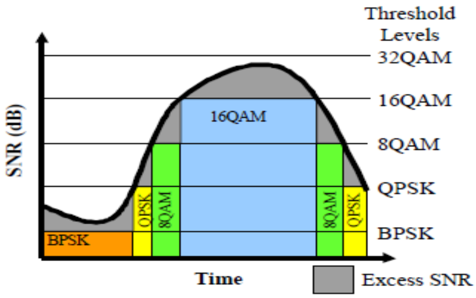


Fig. 2. Adaptive Modulation, the modulation schemes are set based on the (SNR) of the channel.

2. Signal to Noise Ratio (SNR) Measurement Techniques.

The signal-to-noise ratio of a received signal gives a measurement of the quality of that signal. The adaptive modulation scheme needs the measurement of the SNR by measure the quantity of noise with the receiving signal. Figure (3), shows a diagram of the measured signal to noise and the estimated SNR if noise power less than signal power by ten times [5, 7].

There are two manners for measuring the quantity of noise amongst the received signals that passed during the channel. They can be summarized as shown in Figure (3). The pilot symbols with known transmission vector are used in the first manner. This manner is more stable and speedier, but more complication. However, the second manner, demodulated of known transmitted data is used in order to define approximately the reference noise. [5].

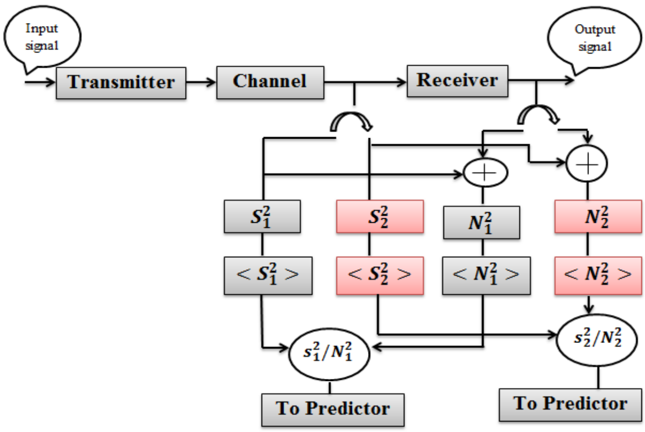


Fig. 3 Block diagram to measure and estimate the SNR [5].

Pilot symbols are inserted into the generated data symbols sequence as shown in Fig (4) [8, 9, and 10].

No information transmitted by pilot symbols, as well as the transmission time of pilot is ignored for transmitting information [11, 12]. Pilot symbols are used to estimation, predication and adaption processes

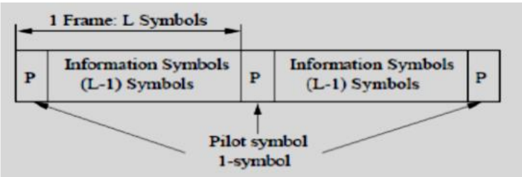


Fig.4. Transmitted frame structure.

Pilot symbol are carries no information on the data, the time tired on sending pilot symbols are time ignored for transmitting information. The power allocated too pilots is power in use from data [10, 11, 12]. The noise can be reduced by allocating extra energy to the pilot tones/symbols, which can be realized by raising the relative power of the pilot tones/symbols, or by averaging many pilot symbols [9, 13]. The extra frequency pilot symbols are transmitted at the well again the estimation and tracking, and the more robust the receiver [13]. Pilot symbols are used to achieve channel estimation. This pilot symbols are subject matter to channel noise and as a result in imperfect channel estimations and a raise in the BER [10, 12].

3. Software-Defined Ratio

The majority radios are hardware defined with small or no software controls; they are permanent in function for nearly all consumers item for broadcast reception. They have a short life and rate designed to be discarded and replaced. Software defined radio (SDR) uses programmable digital device to achieve the signals processing necessary to transmit and receive baseband information at radio frequency [14, 15]. A significant confront for software defined radios is equal to the effectiveness of the pure hardware solution while given that the flexibility and intelligences that software can put forward. The rate per information bit can measure the efficiencies; the power consumed per information bit, and the physical volumes consumed per information bit [14].

The SDR hardware platforms may consist of one or more of the following: -

a) Application Specific Integrated Circuit (ASIC).

b) General Purpose Processor (GPP).

c) Digital Signals Processors (DSP).

d) Field Programmables Gate Arrays (FPGA).

SDR is used to implement the proposed system due to the following reasons [7, 10, and 16]:

a) SDR can be modified quickly to support multiple standards.

b) With SDR, the same hardware will be configured to achieve different functions.

c) SDR enhances the interoperability of different systems in many applications.

d) SDR can support a variety of air interface standards, modulation schemes and protocols, at the same time.

4. Downloading Bit Streams File to FPGA on Altera DE2 Board

The synthesis method would also produce a bits stream file so as to can be downloaded into the FPGA board. The bits stream file of the SDR has been successfully downloaded too Altera-Cyclone II FPGA family-DE2 board. The test operation of the physical functionality of the SDR has been made by interfacing a function generator to apply input data and oscilloscope to monitor the recovered data.

5. Simulation Results Based on SDR using MATLAB

The simulation based on MATLAB is used as the first step in the design and evaluation of the proposed system based on SDR. To evaluate the SNR subsystem for an adaptive system, different signal modulation techniques such as BPSK, QPSK and MQAM, must be generated. Figure (7) shows the 8QAM transmitted signal and pilot transmitted signal. Figure (8) shows the received signal in the presence of AWGN. The selection of their signals (or modulation technique) is based on the value of SNR. In this work, only the MQAM signal will investigated.

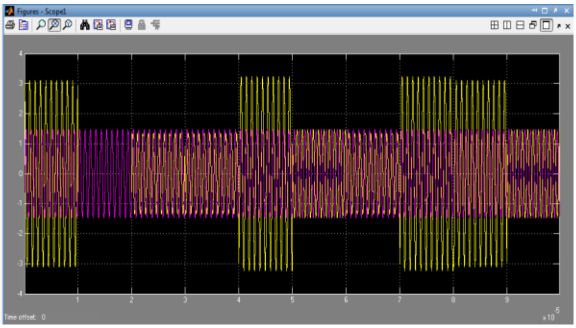


Fig.7. 8QAM transmitted signal and pilot transmitted signal.

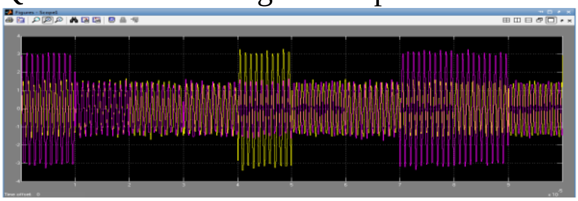


Fig. 8. Received 8QAM modem in the presence of AWGN

5.1Evaluation of SNR channel

To evaluate SNR in the presence of AWGN channel the following procedure is used.

1. Using Matlab Simulink and set SNR of AWGN for different values (10, 15, 20, and 25).
2. Measure SNR by a magnitude squaring device, with an integrator to control the observation time.
3. Compare the value of measure SNR by designing SNR channel in the proposed system with the preset value of SNR.

6. Evaluation of SNR channel of BPSK

Figure (9) confirms the received signal (BSK) with SNR=10dB. Figure (10) confirms the received signal (QPSK) with SNR=10dB. Figure (11) shows the received signal (8QAM) with SNR=10dB.

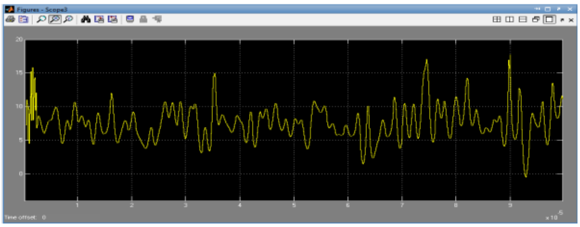
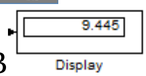


Fig.9. Received signal with SNR (BPSK) =10dB 

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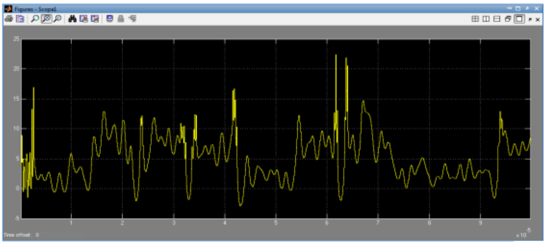


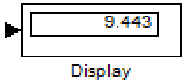
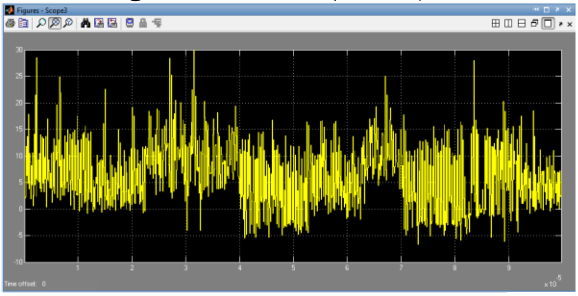


Fig.10. Received signal with SNR (QPSK) =10dB .



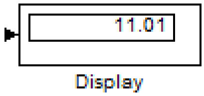


Fig.11. Received signal with SNR (8QAM) =10dB .

7. Simulation Results Based on ModelSim

The simulation results obtained by using ModelSim-Altera 6.4a (Quartus II 9.0) represent the second step in the simulation process. Figure (12) shows the details of the bandpass8QAM signal.

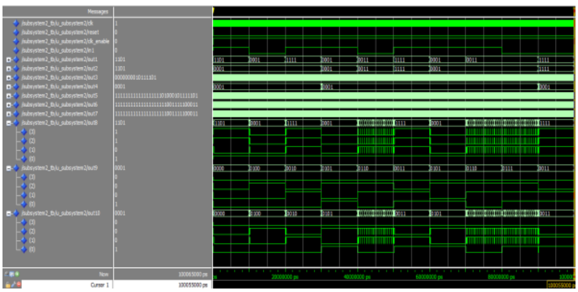


Fig.12. The details of 8QAM band pass modulated signal.

8. Experimental Results

The VHDL is compiled code using Quartus II and downloading the bits stream successfully to Cyclone II FPGA family, Altera (DE2) kit. Figure (13) shows the input data and output data of the BPSK modem.

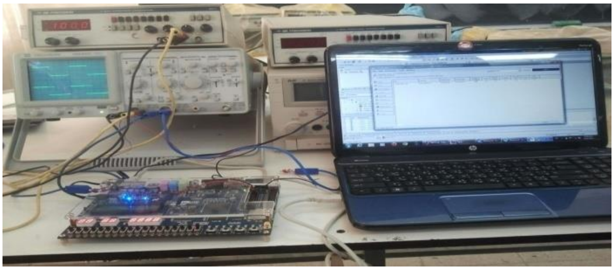


Fig.13 BPSK modems.

9. Conclusion

FPGAs provide an ideal platform for implementing adaptive communications system because FPGA is capable of accommodating multiple communications protocols and upgrading without the need for new hardware. The simulation and experimental results show the capability, efficiency and flexibility of HDL Simulink technique implements the sophistication communication system (modulation, insert pilot, demodulation, filter and measure SNR) and provides the compacted system stander for analysis, design, implementation and verification. However, these techniques require the simplification of the system units before the implementation.

Table 2. Comparison between the set value of SNR and the measured of SNR.

Set value of SNR	SNR measured for implemented BPSK modem		SNR measured for implemented QPSK modem		SNR measured for implemented 8QAM	
dB	Data	Pilot	Data	Pilot	Data	Pilot
5	4.441	4.32	6.172	6.76	7.652	6.768
10	9.445	9.33	9.443	11.79	11.01	11.79
15	14.45	14.33	14.45	16.79	13.91	16.79
20	19.45	19.34	19.45	21.79	16.57	21.79
25	24.46	24.34	24.45	26.77	19.09	26.77

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