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Adaptive Modulator Design (S/W) for SDR

KEYWORDS: Cognitive radio, SDR ,Matlab, M-file, Total Harmonic Distortion ,Cognitive radio network.

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ABSTRACT *With the exponential growth in the ways and means by which people need to communicate – data, voice, video, broadcast message, command and control communications etc. modifying radio devices easily and cost-effectively has become critical. The future information age is equipped with rich and affordable telecommunication services. So in future people will need flexibility while using the wireless equipments. Consider a radio which autonomously detects and exploits empty spectrum to increase your file transfer rate. What if this same radio could remember the locations where your calls tend to drop and arrange for your call to be serviced by a different carrier for those locations. These are some of the ideas motivating the development of cognitive radio (CR). In effect, a cognitive radio is a software radio whose control processes leverage situational knowledge and intelligent processing to work towards achieving some goal related to the needs of the user, application, and/or network.*

Wireless communications systems and standards have been developed around the world without any global plan. Recently hardware technology evolved significantly. Some of the key milestones in this progress are transition from analog hardware to digital hardware and then introduction of sophisticated processors. This is followed by the development of Software Defined Radio (SDR) structures and virtual hardware that are still in development process currently. Software Defined Radio (SDR) system is a useful and adaptable future-proof solution to cover both existing and emerging standards, it provides elements with re-configurability, intelligence and software programmable hardware. Moreover, it has capability of providing global seamless connectivity and solves the interoperability issue. The operating carrier frequency range for various modulation scheme is depicted in the paper. The effects of carrier noise on the modulated signal is also depicted.

1. INTRODUCTION

Wireless communication devices are composed of three main entities; signalling, physical hardware, and its functionalities. These three main streams, which complement each other, have evolved since the invention of the radio transmission by Guglielmo Marconi. The primitive communication devices had very simple signaling, analog hardware and limited functionality. In time, each of these entities evolved significantly. Different signalling methods have been invented and used around the world. Furthermore, numerous different . SDR is envisioned initially to be a promising solution for interoperability, global seamless connectivity, multi-standard, and multi-mode issues.

Software defined radio (SDR) technology brings the flexibility, cost efficiency and power to drive communications forward, with wide-reaching benefits realized by service providers and product developers through to end users.

Also in parallel, the functionality of wireless devices is increased by SDR and they become more and more sophisticated. For instance, the cellular technology was developed to provide voice communications for mobile users initially. However, current cellular phones have multi-functionalities such as internet access, digital camera, Global Positioning Systems (GPS), games, personal assistance, and music player. Ever increasing demands from the users and service providers result in continuously increasing Quality of Service (QoS) requirements. This trend requires adding intelligent functionalities to the wireless devices, which introduced cognitive radio technology. Nowadays, these three streams start to merge under the umbrella of cognitive radio technology. It is an emerging technology to realize wireless devices with cognition capabilities such as learning, sensing, awareness, and reasoning. Moreover, it has capability of providing global seamless connectivity and solves the interoperability issue. SDR is a key enabling technology to realize cognitive radios.

2. Sofware Defined Radio

Software Defined Radio is defined as "Radio in which some or the entire physical layer functions are software defined"[9].

A software Defined Radio system, or SDR, is a radio communication system where components that have been typically implemented in hardware (e.g mixers, filters ,amplifiers, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a personal computer or embedded system.

Software-defined radio will make it possible to use the electromagnetic spectrum in fundamentally new ways. Most radio standards today are designed to use a fixed, narrow frequency band. In contrast, software-defined radio devices can tune into many different frequencies simultaneously, making possible communications schemes that wouldn't be feasible with conventional radio gear.

A software-defined radio can be flexible enough to avoid the "limited spectrum" assumptions of designers of previous kinds of radios, in one or more ways including:

spread spectrum and ultrawideband techniques to allow several transmitters to transmit in the same place on the same frequency with very little interference, typically combined with one or more error detection and correction techniques to fix all the errors caused by that interference.

3. Cognitive Radio

A cognitive radio is a transceiver which automatically detects available channels in wireless spectrum and accordingly changes its transmission or reception parameters so that more wireless communications may run concurrently in a given spectrum band at a place. This process is also known as dynamic spectrum management. There are likely to be a variety of different views of exactly what a cognitive radio

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may be. Accordingly a definition of a cognitive radio may be of use in a number of instances. In general the cognitive radio may be expected to look at parameters such as channel occupancy, free channels, the type of data to be transmitted and the modulation types that may be used. It must also look at the regulatory requirements. In response to the operator's commands, the cognitive engine is capable of configuring radio-system parameters. These parameters include "waveform, protocol, operating frequency, and networking". It functions as an autonomous unit in the communications environment, exchanging information about the environment with the networks it accesses and other cognitive radios (CRs). A CR "monitors its own performance continuously", in addition to "reading the radio's outputs"; it then uses this information to "determine the RF environment, channel conditions, link performance, etc.", and adjusts the "radio's settings to deliver the required quality of service subject to an appropriate combination of user requirements, operational limitations, and regulatory constraints". These processes have been described as "reading the radio's meters and turning the radio's knobs"[8]. They envision an 802.11 like access-point based scenario for the cognitive radio system consisting of a cognitive radio base-station and cognitive radio mobile users and do not assume any changes to licensed user systems.

4. Cognitive Radio Network

Thomas *et al.* (Thomas 2005) defines the CN as a network with a cognitive process that can perceive current network conditions, plan, decide, act on those conditions, learn from the consequences of its actions, all while following end-to-end goals. This loop, the cognition loop, senses the environment, plans actions according to input from sensors and network policies, decides which scenario fits best its end-to-end purpose using a reasoning engine, and finally acts on the chosen scenario as discussed in the previous section. The system learns from the past (situations, plans, decisions, actions) and uses this knowledge to improve the decisions in the future.

This definition of CN does not explicitly mention the knowledge of the network; it only describes the cognitive loop and adds end-to-end goals that would distinguish it from CR or so called cognitive layers. This definition of CN seems to be incomplete since it lacks knowledge which is an important component of a cognitive system as discussed in,[1][2][3][4] and.[5]

Balamuralidhar and Prasad [4] gives an interesting view of the role of ontological knowledge representation: "The persistent nature of this ontology enables proactiveness and robustness to 'ignorable events' while the unitary nature enables end-to-end adaptations."

In,[1] CN is seen as a communication network augmented by a knowledge plane that can span vertically over layers (making use of cross-layer design) and/or horizontally across technologies and nodes (covering a heterogeneous environment). The knowledge plane needs at least two elements: 1) a representation of relevant knowledge about the scope (device, homogeneous network, heterogeneous network, etc.); 2) a cognition loop which uses artificial intelligence techniques inside its states (learning techniques, decision making techniques, etc.).

Furthermore, in[3] and,[5] a detailed cross-layer network architecture was proposed for CNs, where CN is interpreted as a network that can utilize both radio spectrum and wireless station resources opportunistically, based upon the knowledge of such resource availability. Since CR has been developed as a radio transceiver that can utilize spectrum channels opportunistically (dynamic spectrum access), the CN is therefore a network that can opportunistically organize CRs.

5. Modulator Design using Matlab

Matlab is an interactive system for doing numerical Computations. A numerical analyst called Cleve Moler wrote. The First version of Matlab in the 1970s. It has since evolved into a successful commercial software package. Matlab makes use of highly respected algorithms and hence you can be condensing about your results. Powerful operations can be performed using just one or two commands. You can build up your own set of functions for a particular application. The MATLAB high-performance language for technical computing integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. [7,8]

Typical uses include

- Math and computation
- Algorithm development
- Data acquisition
- Modelling,simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building.

Modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal which typically contains information to be transmitted.Thus, the various parameters can affect the performance of the modulator.

Some of them are listed below.

- Carrier frequency
- Modulating frequency
- Modulation index
- Signal-to-noise ratio
- Channel bandwidth

A. Carrier Frequency

The available spectrum band is limited, thus restricting the number of user. If the available carrier frequency is used by a secondary user when it is not used by its primary user then the total number of user can be increased. These is the fundamental idea behind the design of the adaptive modulator.

While designing the above modulator, we have considered only the carrier frequency as the affecting parameter by keeping the other parameters as constant and analysed the performance on the same. For the performance evaluation, we have used the MATLAB simulink software. The programs for each modulation techniques were written separately using standard MATLAB functions. The basic logic used to develop the programs was to realize the mathematical equations of respective modulation into MATLAB instruction and to plot the corresponding output plots. These output plots were used to decide the suitable operating band of respective modulation technique. The carrier frequency range for different modulation schemes is depicted in Tab.1. The output plot of the modulated signal remains undistorted when working under the indicated frequency ranges. When a message signal destined to be modulated under a specific modulation technique (AM) as indicated by Tab.1 is modulated by any other technique (FM), the output plot of the modulated signal starts to distort. The increase in the amount of distortion beyond the indicated frequency range is projected in Tab.2 . We are assuming that the sensing of the available spectrum is done at beforehand, Once the carrier signal is detected the adaptive modulator [DSP Processor Or FPGA] selects the corresponding modulation schemes & modulates the message signal.

Sr No	Modulation technique	Carrier Frequency Range(MHz)
1	AM	0.585-1.065
2	FM	88.5-108
3	ASK	2350-2400
4	FSK	2400-2425

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5	BPSK	2425-2450
6	QPSK	2450-2475

Tab 1.Carrier Frequency Ranges For Different Modulation schemes.

B. Signal to Noise ratio

The other factor affecting the quality of the signal is the carrier noise content. In this part we used the M-file for 64 QAM & Inserted noise signal of 14 & 40 dB respectively. The output plots for the same is depicted in fig.1 below.

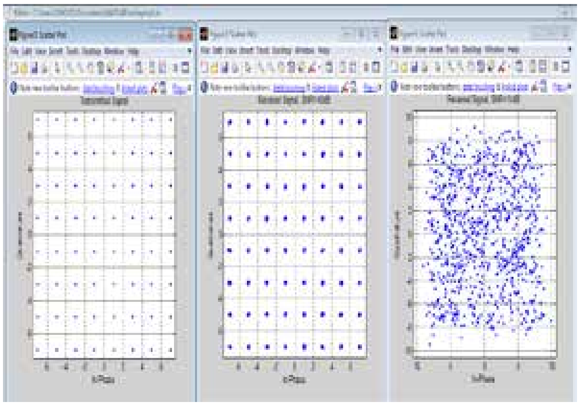

FIG 1. Signal to Noise ratio of 64-QAM

1. The first part indicates the original transmitted signal with signal to noise ratio of 25dB which is recovered faithfully.
2. In first part of the received signal indicates the distortion[s/n=40dB] with respect to transmitted signal.
3. In second part of the received signal indicates the distortion[s/n=40dB] with respect to transmitted signal.

5. RESULTS

1. Every modulation scheme has a particular frequency range as depicted in the Tab.1
2. The modulated signal has a constant minimum distortion when the particular modulation scheme is used in its prescribed frequency range.
3. If a carrier signal lying in the range of a particular modulation schemes is modulated using another modulation technique the total harmonic distortion (THD) increase as depicted in Tab.2
4. As the noise content on the transmission channel increases the signal to noise ratio reduces & themodulated signal is increasingly distorted. The 64 quadrature amplitude modulation (QAM) received signal with noise content of 40dB & 60dB is shown in fig.1.

AM

5. Each transmitted signal should have noise content in the range of 14dB to 40 dB beyond which signal starts to deteriorate.

fc (Khz)	590	900	1200	500
THD1 (message signal)	0.5976	0.5976	0.5976	0.5976
THD2 (demodulated signal)	1.5144	1.5144	1.5146	1.5143
THD2-THD1	0.9168	0.9168	0.9169	0.9167
10LOG10(THD2-THD1)	-0.3773	-0.3773	-0.3767	-0.3777

FM

fc (Khz)	90	100	120	80
THD1 (message signal)	0.2721	0.2721	0.2721	0.2721
THD2 (demodulated signal)	1.4223	1.4235	1.4651	1.4646
THD2-THD1	1.1502	1.1514	1.193	1.1925
10LOG10(THD2-THD1)	0.6077	0.6123	0.7664	0.7646

Tab 2.THD for various carrier frequency

6. CONCLUSION

Adaptive modulator is an intelligent technique which can be used to increase the available spectrum by using dynamic allocation of unused spectrum in a changing environment. We have proposed the favourable carrier frequency ranges for every particular modulation scheme, to have minimum distortion. The carrier noise content is also a concern of adaptive modulator to reproduce the undistorted message signal.

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