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Digital Audio Broadcasting Simulation: A Microwave Communications' Exercise at the Technological Educational Institute of Crete

I.O. VARDIAMBASIS, G. LIODAKIS, E. ZAOUTIS, J.P. MAKRIS, I. KALIAKATSOS,
G. GLENTIS, and V. ZACHAROPOULOS

Microwave Communications & Electromagnetic Applications Laboratory,
Department of Electronic Engineering TE,
Technological Educational Institute (T.E.I.) of Crete - Chania Branch,
Romanou 3, Chalepa, 73133 Chania, Crete,
GREECE
ivardia@chania.teicrete.gr

Abstract: - Digital audio broadcasting (DAB) is a medium designed especially for the needs of the multimedia age, which provides distortion-free reception and transmission of high-quality sound, along with text, pictures, additional data and even videos. DAB to mobile and fixed users exploits the latest advances in compression, coding, and transmission techniques representing an appealing application for communication systems analysis. This work's objective is to present an exercise suitable for an advanced course on microwave communications, which outlines the basic concept and performance analysis of a terrestrial DAB system.

Keywords: - Digital audio broadcasting, DAB, microwave communications, communication engineering.

1 Introduction

1.1 Microwave communications education

The end of the cold war era, the globalisation of industry, and the rapid emergence of wireless communications in all aspects of today's society have provided a renewed prominent role to microwave and RF sciences and technologies [1]. Microwaves and RF are no longer crucial primarily for military systems, but are also playing a very significant role in the current climax of wireless communication systems. So today, electromagnetics education is facing new challenges and is ready for a major shift, because of the rapid technological changes unleashed by the evolution in wireless communications and internet technology.

The Technological Educational Institute of Crete Greece (TEI-C), as any other university, is considered to have three major objectives, i.e., the education of students, the generation and assignment of competent young engineers to industries, and the evolvement of basic and applied research. Combining these roles, our Microwave Communications & Electromagnetic Applications (MCEMA) Laboratory has comprehensive modern facilities for teaching and research activities in theoretical and computational electromagnetics, antenna analysis and design, microwave theory and applications, advanced communication and radar systems, and electromagnetic compatibility issues. This work's focus is on microwave communications

engineering education at TEI-C's Electronic Engineering Dept., whose undergraduate curriculum includes an advanced course in communication systems engineering, called: *Analysis, Simulation & Design of Communication Systems*. This course is fully supported by the MCEMA Lab, with many exercises and computer simulations, like the DAB system simulation presented herein.

1.2 Digital audio broadcasting

AM and FM radio stations are capable of providing acceptable services to properly installed receivers, but they are not capable of delivering compact disk quality sound especially to vehicular receivers. In addition, multipath propagation in built up areas causes severe distortion to the radio signal, resulting in very poor reception at many locations. Besides, AM and FM have not the data capacity to satisfy the running demand for various services, i.e. weather, paging, navigation. Moreover, FM broadcasters face rapidly growing spectrum congestion that increases the interference at a receiver.

The Eureka DAB system [2]-[3] is designed to provide reliable, multi-service, digital sound broadcasting for reception by mobile, portable and fixed receivers, using a simple, non-directional antenna. It can be operated at any frequency up to 3 GHz for mobile reception (and even higher for fixed reception) and may be used on terrestrial, satellite, hybrid, and cable broadcast networks. In addition to

supporting a wide range of sound coding rates and qualities, DAB also has a flexible, general-purpose digital multiplexer, which can support a wide range of source and channel coding options, including sound-program associated data and independent data services.

The feasibility of novel applications like DAB, greatly depends on the use of data compression techniques, which reduce data transmission rate and memory storage requirements. Thus terrestrial/satellite transmission channels can be employed for economic single- or multi-channel audio data transmission, and also data storage media can be utilized for efficient storing of lengthy acoustic signals. The storage and transmission of such high-quality audio data (with the 44.1 kHz sampling rate and the 16 bit resolution of the compact disc format) results in the relatively high bit-rate of 706 kb/s per data channel. This data rate can be technically or economically prohibited for many applications, necessitating the introduction of data compression, preferably by using low-complexity methods and without insertion of perceptually detectable distortions. DAB uses the MPEG Audio Layer II system to achieve a compression ratio of 7:1 without perceptible loss of quality. This system is modelled on the human ear characteristics, and retains only the audible components of the sound. The signal is then encoded at a bit rate of 8-384 kb/sec, depending on the desired sound quality and the available bandwidth. Program Associated Data (PAD) is incorporated and the signal is individually error protected and labelled prior to multiplexing. Independent data services are similarly encoded.

Multiplexing fits the labeled packages from each signal into a standard 'outer container' to ensure efficient use of the radio spectrum. Broadcasters can dynamically adjust the composition of the multiplexed signal to provide any desired combination of services, from 6 high-quality stereo programs to as many as 20 mono programs. Information about the current configuration of the multiplexed signal together with additional error protection data is also included. By employing Coded Orthogonal Frequency Division Multiplexing (COFDM), the 2.3 million bits of the multiplexed signal are spread out in time and across 1,536 distinct frequencies within the 1.5 MHz band, so that even if some frequencies are affected by interference, the receiver will still be able to recover the original signal. In this way, the transmitted information is spread in both the frequency and time domains so that the deflections of channel distortions

and fades may be eliminated from the recovered signal in the receiver, even when working in conditions of severe multi-path propagation, whether stationary or mobile.

2 DAB simulation

This DAB simulation aims to give TEI-C's students some of the most important aspects of a DAB transmission system, using friendly interface and detailed documentation, and asking the students to evaluate the results and conduct a report.

Mathworks' Simulink software is used to implement the various blocks of the DAB system, along with the blocks used to collect data during the simulation, i.e. the error rate calculation block, the spectrum scope block, the discrete-time scatter plot scope block, the discrete-time signal trajectory scope block and others.

In order to simulate efficiently the conceptual DAB emission block diagram of [2; p.23], the T-DAB system is resolved into three basic subsystems (shown in Fig. 1): the ensemble multiplexer, the COFDM unit (consisted of encoder, transmitter, tuner and decoder) and the ensemble demultiplexer. Thus, the students conceive the use of the various units and the effect of changing a single group of variables in specific simulation characteristics. Various inputs can either be standard random generators or external sources, except from the fast information block assembler which depends on the various system parameters. Each subsystem is masked and internal variables are either automatically changed or altered by the student. The contribution of each of the simulated blocks is analytically explained in the following paragraphs.

The first simulated block (needed in subsystems of Figs. 2 and 3) is the energy dispersal scrambler, which prevents transmission of signal patterns with unwanted regularity, because the DAB system works better with random bit sequences rather than long strings of 1 or 0 (and since long strings of 1 or 0 may appear in the output of any information source, they need to be coded for transmission). In this case, the general scrambler block found in the sequence operations of the communications blockset of Simulink is used and programmed as described in [2; pp.152-153].

The second simulated block (in subsystems of Figs. 2 and 3) is the convolutional encoder. Channel encoding is based on punctured convolutional coding, which allows both equal and unequal error protection matched to bit error sensitivity

characteristics. In this case, several Simulink blocks from the communications and the signal processing blocksets were used, i.e. the convolutional encoder (found in the communications blockset under error detection and correction) and the puncture block (also found in the communications blockset under

sequence operations). Each block's variables are defined in accordance to [2; pp.153-160]. Various bit rates and types of transmitted data have several coding parameters, as expected.

Digital Audio Broadcasting - Terrestrial

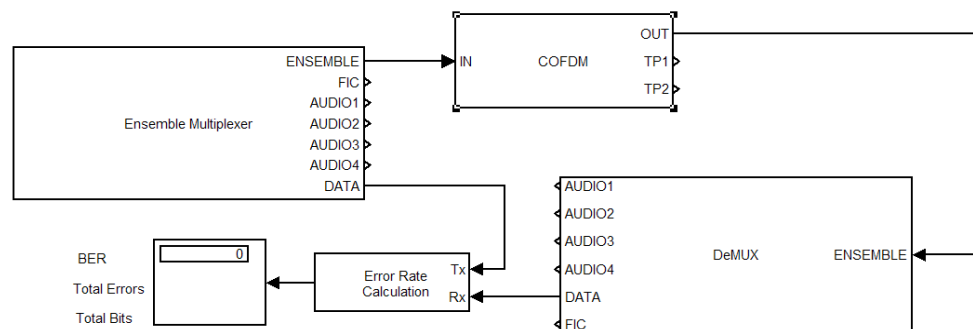


Figure 1. Simulation of the Terrestrial Digital Audio Broadcasting (T-DAB) system.

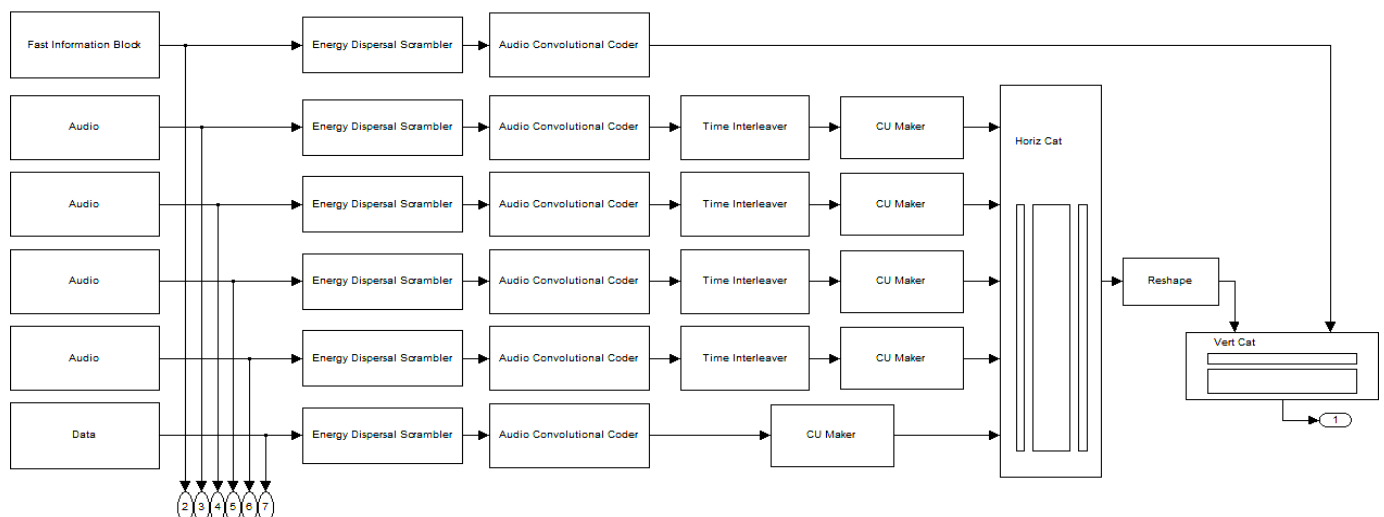


Figure 2. Ensemble multiplexer subsystem of the simulated T-DAB.

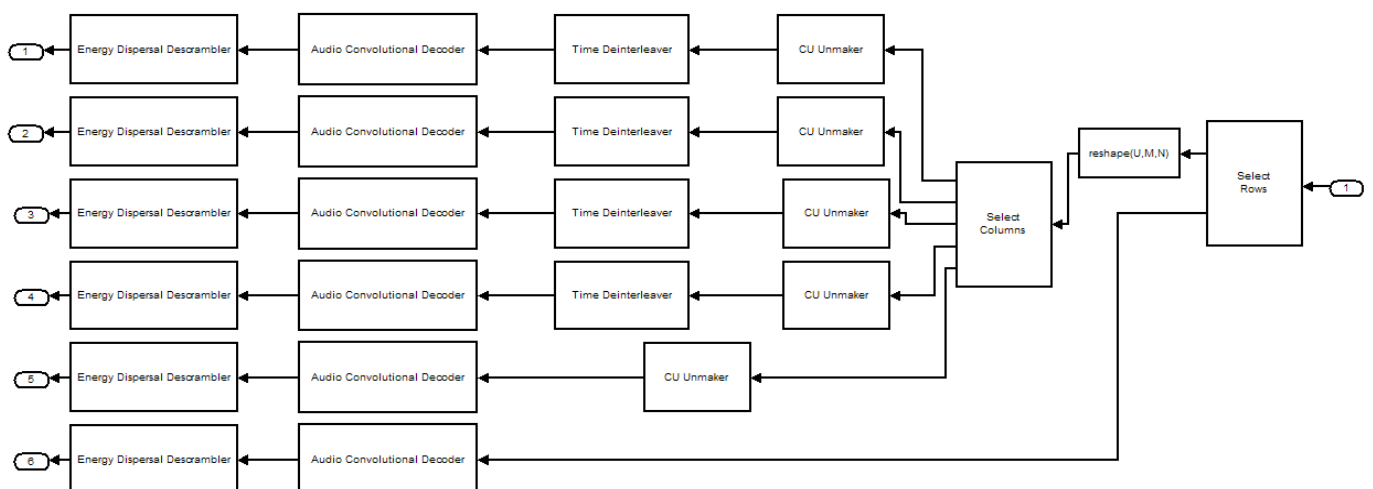


Figure 3. Demultiplexer subsystem of the simulated T-DAB.

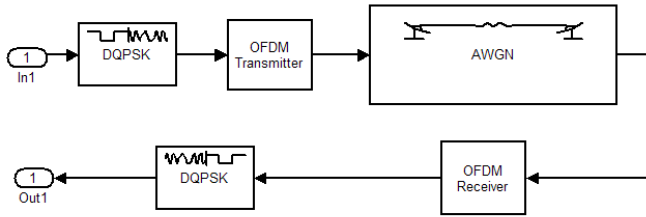


Figure 4. COFDM subsystem of the simulated T-DAB.

The time interleaving block (Fig. 2) is built upon a matrix interleaver [2; pp.161-166], which consists of a number of lines and columns mainly depending on the used transmission mode. Time interleaving is applied to the output of each convolutional encoder for all sub-channels of the Main Service Channel and not to the Fast Information Channel (in order to re-distribute contiguous bursts of coded data and spread them over time distant OFDM symbols). Time interleaving compensates the effect of long duration frequency fading over several COFDM symbols, where the receivers interpret the Doppler frequency shift as noise on sub-channels.

The CU maker block (Fig. 2) separates the data stream into capacity units with varying size depending on the transmission mode used. This way the output of the ensemble multiplexer is controllable and easily comprehensible by students.

The ensemble multiplexer subsystem of Fig. 2 has (except from the main output) six additional outputs used as test points to extract bit error ratio information between bits inserted in the multiplexer and bits received at the demultiplexer's outputs.

The demultiplexer subsystem of Fig. 3 consists of four basic blocks: the viterby decoder, the insert zero, the descrambler and the matrix deinterleaver. These blocks, in conjunction with blocks inserted to shape the signals when needed, are responsible for restoring the data streams in their original form. Note that the tuner block is not included in the demultiplexer but in the COFDM subsystem, along with the transmitter block, as depicted in Fig. 4.

The COFDM subsystem of Fig. 4 accumulates all the blocks needed for simulation of the DAB signal transfer mechanism, along with various types of channels used to simulate losses during the signal transfer. It simulates additive white noise and/or multipath propagation phenomena. DQPSK and OFDM blocks are used in accordance with [2], while channel synchronization is not currently implemented.

When the simulation is done, students have to compare the simulated data with experimental data

acquired by the use of MCEMA Lab's DAB exciter and experimental receiver (interconnected through a PC with properly developed software).

3 Conclusion

In this work it was presented an exercise on DAB system simulation, designed and developed at the MCEMA Lab of TEI-C, aiming to introduce the students to the design of advanced communication systems. Furthermore, the students have the opportunity to acquire experience on high level programming.

The presented exercise demands the activation, participation, concentration and alertness of every student, cultivating the collaboration skills and fundamental qualifications of the future engineers. Moreover, although the exercise does not take a lot of laboratory time to complete, a good preparation is need for a successful execution. Finally, there are a lot of ideas to enrich the exercise. As indicative examples we just mention here: the conditional access scrambler block, the service information assembler block and the multiplex controller block, aspects that already we are working on.

Acknowledgment

This work was supported by the Greek Ministry of National Education and Religious Affairs and the European Union under the EΠΕΑΕΚ II projects: "Archimedes – Support of Research Groups in TEI of Crete – Smart antenna study & design using techniques of computational electromagnetics and pilot development & operation of a digital audio broadcasting station at Chania (SMART-DAB)" and "Reformation of the Electronics Dept's syllabus".

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