A Proposal for a Final Review Session in Radiocommunications Laboratory Practice

L. Lubich[1]

Abstract – **The goal of the proposed final review session in radiocommunications laboratory practice is to illustrate and unify the topics presented in the lecture course. This session is designed for students, whose main field of studies is not radiocommunications. It is based on experimentation with a modern, real-life radiocommunication system - Digital Radio Mondiale (DRM). It allows the creation of an experimental setup using affordable and readily available components.**

Key words – **technical education, final review session, experimental setup, laboratory practice, demonstration, radiocommunications, Digital Radio Mondiale, DRM**

I. Introduction

The instructor in radiocommunications courses often has to teach students, whose main field of studies is not radiocommunications. The goal of these courses is the enhancement of the general technical knowledge, rather than dealing with specific technical issues. During the lectures, students learn the basics of the phenomena, concepts, and devices used in radiocommunications (radio waves radiation and propagation, antennas, radio channel specifics, modulations, coding, etc.). It would be valuable at the end of the course to illustrate this theoretical knowledge with a comprehensive practical example that would also unify the isolated topics. The best solution would be a complete radiocommunication system - from the source of information to its end user. Often the instructors use an artificial experimental setup that has been deliberately simplified, on one hand, to be more understandable for the students, and on the other, for financial reasons. This approach often decreases students' motivation. Many of them do not appreciate that although artificial and simplified, these experimental setups reflect concepts with widely used practical applications. Many students complain from the disconnect between what they are taught and real life. With this in mind, the options for the demonstration of a real-life modern radiocommunication system in the teaching laboratory were considered, and the selected option is presented in this paper.

II. Selection of a Radiocommunication System for the Demonstration

The following factors were considered for the selection of a specific radiocommunication system:

- Availability of most of the specific features of a typical modern radiocommunication system;
- Technical feasibility for its implementation in a teaching laboratory;
- The necessary hardware and software to be affordable for a university with a limited budget;
- The experimentation should not require specialized measuring equipment.

The system Digital Radio Mondiale (DRM) for digital audio broadcasting below 30MHz meets all these criteria.

III. DRM System Description

This system has been developed to replace the current analog audio broadcasting in short, middle and long waves. The main features of the system will be outlined here, while more details can be found in [1] and [2].

The synoptic diagram of the system is shown in Fig. 1 [1].

The source coding could be:

- AAC, a subset of MPEG-4 audio standard for audio coding;
- MPEG-4 CELP or HVXC (Harmonic Vector eXcitation Coding) for speech coding.

A high frequency reconstruction method - spectral band replication (SBR) can be used for improving the sound quality. Unequal error protection can be applied in case of error prone channels.

The system has 3 channels:

- Main service channel (MSC) that transmits the multiplex data stream containing audio and data services;
- Service description channel (SDC), containing the information needed for MSC decoding, as well as additional information;
- Fast access channel (FAC) that provides information on channel parameters, as well as service selection information to allow fast scanning.

The system uses OFDM to cope with the problems caused by multipath propagation. The subcarriers modulation is 4QAM, 16QAM и 64QAM, depending on the importance of the transmitted data and on the specifics of the radio channel used. Before the modulation, data is subjected to energy dispersal, coding and bit interleaving. For MSC only, cell interleaving is also applied.

Four robustness modes are available, depending on the specifics of the radio channel used. Different coding rates and constellations can be selected depending on the required error protection.

[1] L. Lubich is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria, E-mail: lvl@tu-sofia.bg.

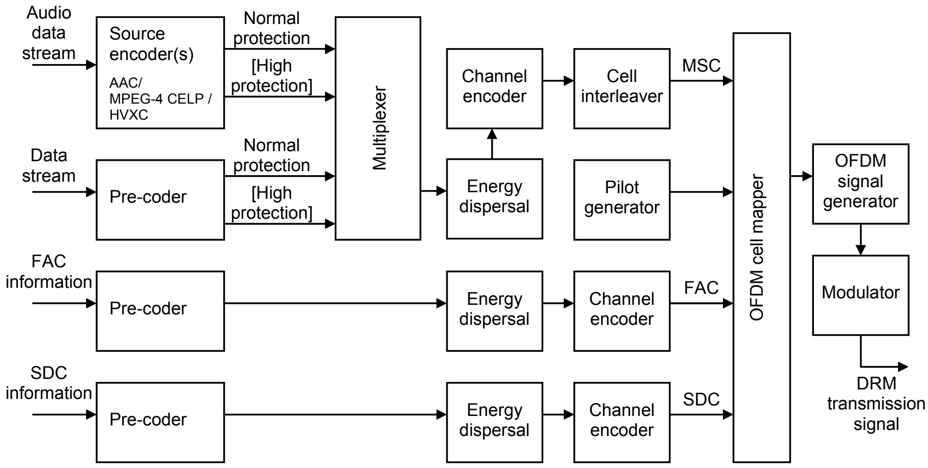


Fig. 1. Conceptual DRM transmission block diagram

During the development of DRM, the existing channel allocation with channel spacing of 9 or 10 kHz had been preserved. Therefore, the DRM radio signals are with a bandwidth of 9, 10, and sometimes 20 kHz (when a given operator can use two adjacent channels.)

IV. Experimental setup description

There were three possible options for the development of the setup:

- To rely on existing transmissions;
- To build a dedicated DRM transmitter;
- To use a radio channel emulator.

The first option was not appropriate since unfortunately the schedule of the DRM transmissions was not coordinated with the teaching schedule. The second option has a very important disadvantage - the transmitter and the receiver must be in the same building, if not in the same room. In such close proximity, it is not possible to demonstrate the specifics of the radio wave propagation over long distances (hundreds and thousands of kilometers).

Therefore, the only option left was to use a RF channel emulator.

The narrow bandwidth of the DRM signal allows the generation and decoding of these signals to be performed by software running on a standard PC without the need for additional data acquisition hardware. Almost any sound card can be used for the input and output of the DRM signals.

The Spark software [3] has been developed for the generation of DRM signals by the University of Applied Sciences Kaiserslautern (Germany). A free version is also available. This software can use the PC sound card as an output device for the generated signal. In order to transmit the DRM signal, it is necessary to build hardware that will move the spectrum of the PC-generated signal to the desired RF channel. A screenshot of the Spark software is shown in Fig.2.

There are several software products available for the reception of DRM signals. Dream, a GPL licensed open source software implementation of DRM software receiver, initially developed at the University Darmstadt (Germany) [4], was selected. An RF front end is necessary to receive DRM transmissions. It needs to move the spectrum of the DRM signal received through the antenna to a low intermediate frequency (approximately 10-12 kHz). The resulting signal is fed to the PC sound card. The Dream software performs the necessary signal processing and the sound can be heard from the PC speakers. The selected software has a valuable feature – the so called evaluation dialog. This is a dialog box that can be used to select different options and to view the following: input spectrum, estimated impulse response, estimated magnitude response of the channel, constellations of the FAC, SDC, MSC, etc. Screenshots are shown in Fig.3. In addition to the DRM signal reception mode, the Dream software features also a mode for reception of existing analog AM signals.

The experimental setup is shown in Fig.4.

Often, 10 or more students participate in the laboratory practice proposed here. Therefore, the monitor of the computer running the receiving software (the “receiving PC”) has been replaced with a video projector. It is recommended that the same projector is used to visualize the transmitting software window, which shows the selection of the parameters of the transmitted signal and its spectrum. The second computer, running the transmitting software (the “transmitting PC”) can be accessed from the receiving PC through a remote desktop connection.

A simplified radio channel emulator was designed and built for the experimental setup. It can emulate:

- Multipath propagation. The output signal is the sum of the original DRM signal and its delayed replica. The ratio of the levels of these two signals can be modified. The relative delay τ between the two receiving paths can be selected from 0.2 to 2 ms.
- Presence of additive white Gaussian noise (AWGN);
- Presence of narrowband interferer;
- Flat fading.

It would be valuable to demonstrate the difference in quality between the DRM reception and the traditional analog AM broadcasting system. A wav file containing a 12 kHz

Fig. 2. Screenshot of the Spark software.

amplitude-modulated carrier is loaded on the transmitting PC. The modulation is done with an audio signal, with bandwidth limited to 4.5 kHz. This file can be played and the signal can be transferred through the sound card and through the emulator to the receiving computer, where the Dream software is set in AM mode.

V. Topics to be Discussed Using the Experimental Setup

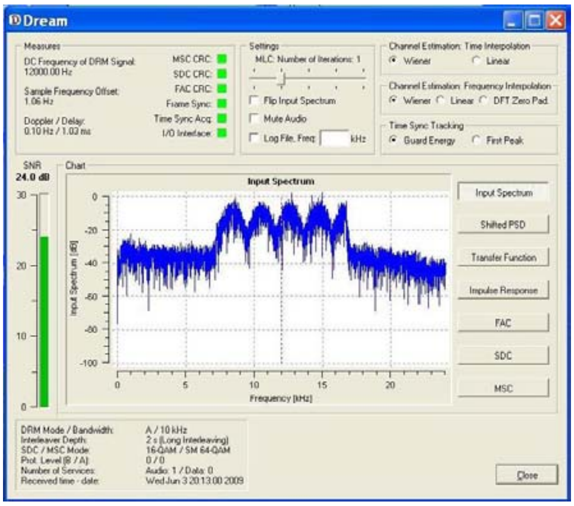
Since the precise details of each laboratory practice would depend on the level of the students' knowledge and the specifics of each course, a detailed plan for the practice would not be presented here. Instead, the topics that can be demonstrated and discussed with the students are outlined.

The following can be demonstrated during the practice:

- The difference in the behavior and quality of the information transfer between a digital radiocommunication system and its analog counterpart at different degrees of imperfection (e.g., interference and distortion) of the communication channel.
- The reception of the DRM signal in the presence of frequency selective fading[1] and flat fading, AWGN and narrowband interferer. In addition, this can demonstrate the changes in the spectrum of the received signal, in the magnitude and impulse response of the radio channel, and in the constellation of the used modulations.
- The possibility for selection of different transmission modes and transmission parameters according to the specifics of the radio channel used.

The following important issues can be discussed during the practice:

[1] Due to the narrow bandwidth of only 10 kHz, the initial reaction is to reject the possibility for the presence of frequency selective fading during the DRM reception. However, in reality its presence is very clear [5].



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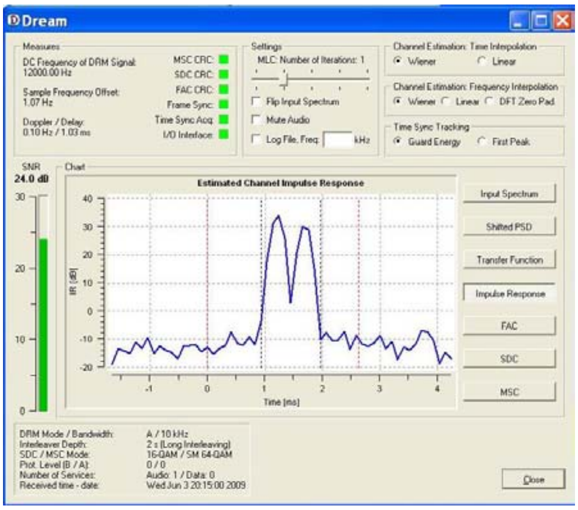

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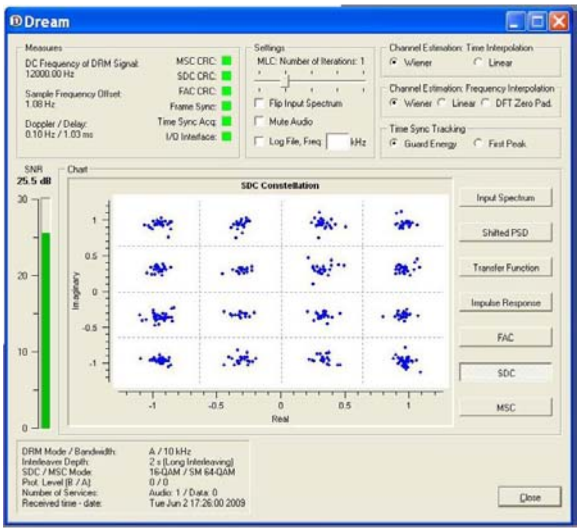

c

Fig. 3. Screenshots of the evaluation dialog of the Dream software, which is receiving DRM signal through the channel emulator used in the experimental setup.
a – input spectrum, $\tau \approx 0.5$ ms; *b* – estimated channel impulse response, $\tau \approx 0.5$ ms; *c* – SDC constellation diagram.

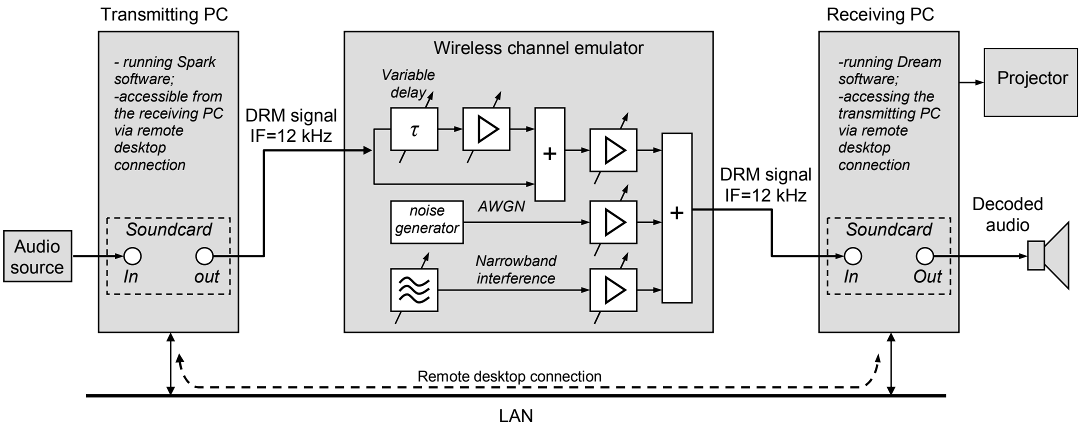

Fig. 4. The experimental setup.

- The "multipath propagation" issue, its adverse effects, and the corresponding approaches for dealing with them.
- OFDM as one of these approaches; the application of OFDM in other communication systems.
- The dependence between the impulse response and transfer function in a system (a radio channel in this case).
- The modulations used in modern radio-communication systems (in this case, QAM):
  - The representation of the modulations using constellations.
  - The practical application of constellations in the evaluation of the radio channel distortions.
  - The dependence of the noise immunity of the signals on the modulation order. It can be demonstrated how with the noise level increase, the reception of the main service channel (that uses QAM with the highest order) fails first, then fails the reception of the service description channel that uses QAM with a lower order. The reception of the fast access channel that uses 4QAM fails last. It is appropriate in this context to discuss the tradeoffs between noise immunity, bit rate and channel bandwidth.
- The formation of multiplex
- The need for source coding and the different types of source coding.
- Channel coding, hierarchical modulation, multilevel coding, equal and unequal error protection, energy dispersal, interleaving.
- The need for channel estimation and the methods for performing it.
- The issues with the synchronization in a radiocommunication system (in this case, frequency synchronization and time synchronization), the use of pilot symbols;
- The possibility to select different parameters of the transmission in a modern radiocommunication system according to the channel specifics, the available bandwidth and the specific goals of the broadcaster.
- The "software radio" concept.

VI. Conclusions

It was demonstrated that using affordable and easily available components, it was possible to create a comprehensive and content-rich experimental setup that could be used in the final review session of the laboratory practice. In this session, the basic phenomena, problems and concepts in radiocommunications can be demonstrated and summarized based on a real-life modern radiocommunication system. In addition, other topics for further study can be suggested.

Further improvements of the setup include: increasing the number of delayed paths in the channel emulator to 2-3, and raising the maximal relative delay between the two receiving paths to at least (1.5...2)t_G, where t_G is the duration of the OFDM guard interval. The latter allows another useful experiment, leading to a better understanding of the problems that led to the creation of OFDM and the solution offered by OFDM. Results from a similar experiment have been shown in [6]. This experiment demonstrated the dramatic worsening of the reception when the relative delay exceeds the guard interval..

References

[1] European Standard 201 980: Digital Radio Mondiale (DRM); System Specification, V2.3.1 (2008-02)

[2] www.drm.org

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[6] Rimac-Drlje, S.; Matic, T.; Zagar, D., Digital radio mondiale (DRM) system performances in multipath fading environment, ELMAR, 2005. 47th International Symposium, Volume , Issue , 8-10 June 2005 pp 299 – 302