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TRANSMISSION QUALITY MEASUREMENTS IN DAB+ BROADCAST SYSTEM

Przemysław Gilski, Jacek Stefański

Gdańsk University of Technology, Faculty of Electronics, Telecommunications and Informatics, G. Narutowicza 11/12, 80-233 Gdańsk, Poland (✉ pgilski@eti.pg.edu.pl, +48 58 347 6335, jstef@eti.pg.edu.pl)

Abstract

In the age of digital media, delivering broadcast content to customers at an acceptable level of quality is one of the most challenging tasks. The most important factor is the efficient use of available resources, including bandwidth. An appropriate way of managing the digital multiplex is essential for both the economic and technical issues. In this paper we describe transmission quality measurements in the DAB+ broadcast system. We provide a methodology for analysing parameters and factors related with the efficiency and reliability of a digital radio link. We describe a laboratory stand that can be used for transmission quality assessment on a regional and national level.

Keywords: broadcast technology, Digital Audio Broadcasting, Quality of Service, transmission quality, radio communication.

1. Introduction

Digital broadcasting systems, whether talking about DAB/DAB+ (*Digital Audio Broadcasting plus*) [1, 2] or other popular systems such as DMB (*Digital Multimedia Broadcasting*) [3] and DRM/DRM+ (*Digital Radio Mondiale*) [4], enable to transmit high quality speech and music signals compared with analogue AM (*Analog Modulation*) or FM (*Frequency Modulation*) radio. Aside from digital terrestrial services, there are also many satellite broadcasting systems operating worldwide [5, 6]. Furthermore, digital standards require less bandwidth per radio station, *i.e.* a single FM radio station requires a channel of 250 kHz, whereas about 12−15 radio programs in DAB+ require a channel of 1.5 MHz. This clearly shows that DAB+ is at least 2 times more bandwidth-efficient than FM.

The DAB+ standard is an evolution of the DAB standard, with a different source codec used for processing audio content. DAB+ uses an MPEG-4 (*Moving Picture Experts Group*) codec, compared with MPEG-2 used in DAB, which is more efficient and delivers higher quality at lower bitrates [7]. Additionally, all digital broadcasting standards enable to transmit additional information, including images and other interactive elements, *e.g.* EPG (*Electronic Program Guide*), well known from digital TV, programmable recording, *etc.* [8]. The digital standard has broad capabilities of regionalization, *i.e.* one nationwide service could be sacrificed in favor of a number of regional services.

Terrestrial broadcasting is the only free-to-air and cost-effective method for a truly mobile reception. However, broadcasters are not the same. They consist of public and private service broadcasters with a variety of national and regional stations. According to the EBU (*European Broadcast Union*), radio is: of vital cultural importance through Europe, consumed by a vast majority of Europeans every week, consumed at home, at work and on the move.

Conventional terrestrial radio transmission is faced with an increasingly strong competition from numerous streaming platforms and non-broadcast media, which use digital multimedia

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techniques to produce the optimum performance. Therefore, there is a growing demand for efficient ways of delivering high quality audio material at low bitrates, especially under bandwidth restrictions. This implies a necessity to monitor the transmission quality of offered services. Because the signal is affected by numerous factors in the propagation channel, it is necessary to control the quality of the broadcasted signal [9−11]. A case study concerning user expectations related with DAB+ can be found in [12].

2. DAB+ signal transmission

The DAB+ broadcasting system, based on OFDM (*Orthogonal Frequency-Division Multiplexing*) [13], can operate in a number of transmission modes, which define the number of parameters related to *e.g.* frame structure, subunits' quantity and length. The choice of a mode depends on system requirements and a type of transmission, *i.e.* terrestrial, satellite or hybrid, and carrier frequency. The DAB+ system can operate in 4 transmission modes:

1) Mode I – designed for terrestrial transmission in Band I (47–88 MHz), Band II (87.5–108 MHz) and Band III (174–240 MHz).
2) Mode II – used in terrestrial, satellite and hybrid transmission in L-Band (1452–1492 MHz).
3) Mode III – intended for terrestrial, satellite and hybrid transmission below 3 GHz.
4) Mode IV – applied similarly as Mode II.
5) The structure of a DAB+ frame consists of 3 elements, as shown in Fig. 1.

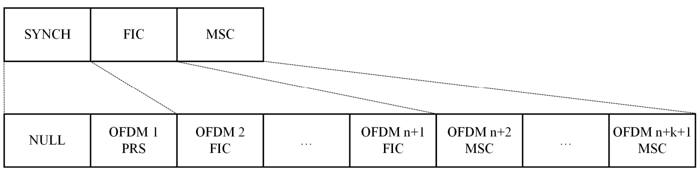

Fig. 1. A DAB+ frame structure.

The DAB+ frame comprises the following parts:

1) SYNCH (*Synchronization*) – responsible for synchronizing the transmitter and receiver, as well as frequency and gain adjustments.
2) FIC (*Fast Information Channel*) – transmits information about the configuration of the multiplex, including the number of services and assigned bitrate.
3) MSC (*Main Service Channel*) – contains the actual audio data.

The NULL symbol is used to determine the beginning of the DAB+ frame. If two successive symbols are known, the transmission mode can be easily determined on the receiver side. The PRS (*Phase Reference Symbol*) is the second OFDM symbol in the synchronization part. The receiver can also employ the PRS for more precise frame synchronization and frequency offset correction, which is accomplished by cross-correlation in time between the received and theoretical PRS.

The FIC contains information on how the multiplex is organized. Every receiver must process this data in order to present a list of available DAB+ services. The FIC consists of multiple FIBs (*Fast Information Blocks*), where each FIB contains 30 bytes of data and 16 bits of CRC (*Cyclic Redundancy Code*). Additional information concerning CRC algorithms can be found in [14]. Each FIB consists of multiple FIGs (*Fast Information Group*), which contain information about available services, their names and configuration.

The MSC is a time-interleaved data channel divided into a number of sub-channels, individually convolutionally coded, with EEP (*Equal Error Protection*) or UEP (*Unequal Error Protection*) error protection. Each sub-channel may carry one or more service components, *i.e.*

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audio or data, referred to as PAD (*Program Associated Data*). The information about sub-channel parameters is transmitted within CIFs (*Common Interleaved Frame*), as shown in Fig. 2.

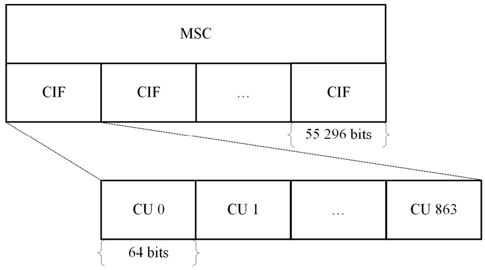

Fig. 2. An inner structure of MSC.

Each CIF comprises 55 296 bits, the smallest addressable unit is a CU (*Capacity Unit*), containing 64 bits. Therefore, a single CIF contains 864 CUs, addressed 0 to 863. Each CU may only be used for one sub-channel. After inserting additional correction mechanisms, an effective bitrate of the DAB+ stream is equal to 1152 kbps. Of course, a bitrate assigned to a particular service has a significant impact on quality perceived by the end user. Additional information may be found in [15].

3. Transmission quality measurements

Nowadays, mobile broadband networks carry multiple services that share radio access and core network resources. In addition, wireless networks must support delay-sensitive real-time services. Each service has different QoS (*Quality of Service*) requirements in terms of *e.g.* packet delay tolerance, acceptable packet loss rates and required minimum bit rates.

3.1. Quality of Service

The QoS parameter can be defined as a set of predefined technical specifications necessary to achieve the required service functionality. This can be an important factor when comparing services offered by different vendors or providers. When both price and feature are similar, quality becomes the key differentiator. Depending on the service being used, users have varying expectations concerning quality of performance and usability. Operators know, the better the experience, the longer and more frequently subscribers will consume content.

Quality plays a major role in wireless networks. Traffic management and optimization technologies enable network operators, as well as service providers and vendors, to improve subscriber QoS. As a result, it can help to attract new customers and raise their satisfaction. Additional information on quality measurements may be found in [16, 17].

3.2. Measurement stand

Broadcasting systems are capable of providing reliable digital services in real time to all users located in a predefined covered zone. One of the main factors is clearly the cost of an infrastructure and transmission power required to cover a given area. Another crucial aspect is the efficient way of monitoring transmission quality of offered services.

The measurement stand consists of a programmable receiver based on a DAB+ FM Digital Radio Development Board Pro platform for developing and evaluating DAB/DAB+, SLideShow and FM with RDS (*Radio Data System*) services. It supports decoding multiple audio services, including DAB/DAB+ Band III and L-Band. The board contains a Keystone T2_L4A_8650C DAB/FM module and a Microchip PIC18F14K50 microcontroller. The device is powered by a USB Mini B connection, which is also used for communicating with the host computer. It has a 3.5 mm Stereo Jack connector for listening and a SMA (*SubMiniature version A*) connector for an external antenna [18]. A photo of the operating programmable receiver is shown in Fig. 3. Additional information on the design of a DAB/DAB+ receiver can be found in [19–21].

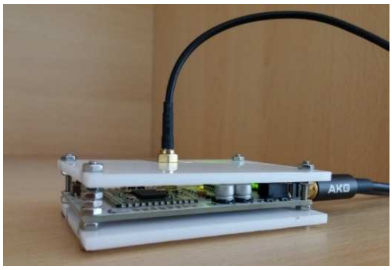

Fig. 3. Operating programmable DAB+ receiver.

The programmable receiver's GUI (*Graphical User Interface*) interface, written in C/C++, responsible for handling the device, is shown in Fig. 4.

Fig. 4. DAB+ receiver user interface.

The user interaction with the GUI is accomplished using a computer mouse and keyboard. The software has been designed to operate on any PC (*Personal Computer*) running Windows XP or higher.

3.3. Multiplex configuration

Today, one of the main objectives of national broadcasters and content providers is to design and implement viable services, which are based on new universal digital delivery systems. In Oct. 2016, the DAB+ multiplex in Gdańsk operated on channel 10D (215.072 MHz), transmission mode I. The configuration of the ensemble is described in Table 1. Each service had an EEP 3-A error correction and a coding efficiency of ½.

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Table 1. DAB+ ensemble configuration in Gdańsk (Oct. 2016).

No.	Service	Bitrate [kbps]	No. of CU	Sub-channel	Start CU	Stop CU
1	PR Jedynka	112	84	1	0	83
2	PR Dwójka	128	96	2	84	179
3	PR Trójka	112	84	3	180	263
4	PR Czwórka	112	84	4	284	347
5	Radio Poland	64	48	5	348	395
6	Polskie Radio 24	64	48	6	396	443
7	Radio Rytm	96	72	7	444	515
8	Radio Gdańsk	104	79	8	516	593
9	Radio Dzieciom	72	54	9	594	647
10	Data	16	12	10	648	659
11	Journaline	16	12	11	660	671

According to the analysis, 672 CUs were allocated, whereas 192 CU remained free. All 11 services available in the ensemble occupied a total of 896 kbps, whereas 256 kbps remained unoccupied. The bandwidth occupancy of Band III (174–240 MHz) is shown in Fig. 5. This analysis was performed using an Anritsu Spectrum Master MS2724B [22].

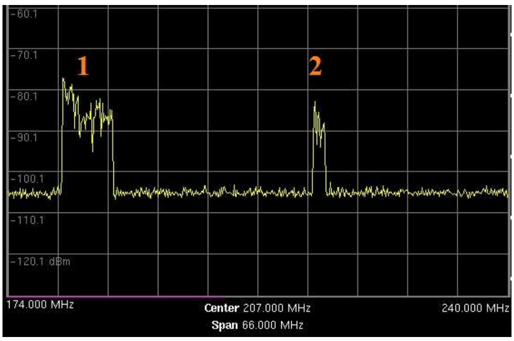

Fig. 5. Band III bandwidth occupancy.

As observed in Fig. 5, the signal at a centre frequency 184.5 MHz and a channel width 7 MHz (1) represents one of the DVB-T (*Digital Video Broadcasting – Terrestrial*) digital terrestrial television multiplex *MUX-8*, whereas the one at a centre frequency 215.072 MHz and a channel width 1.536 MHz (2) represents the DAB+ multiplex *DAB-GDA* [23].

3.4. Quality evaluation

In order to keep track whether the contracted QoS is being met, the parameters must be monitored and resources should be reallocated in response to system anomalies. If a change of state happens and the resource management cannot make resource adjustments to compensate it, the application can either adapt to the new level of QoS or to degrade to a reduced service level. The measurement of QoS is based on parameters including: delay, jitter, packet loss, throughput, SNR (*Signal-to-Noise Ratio*) and many other, depending on the application and management scheme. To ensure the transmission quality criterion, the DAB+ radio link was monitored over a period of 60 minutes during primetime, that is between 9 am and 10 am. The laboratory stand was set indoors. The structure of the DAB+ frame, as well as other parameters related with the standard, enable to monitor QoS in a number of ways. The operating parameters of the commercially available multiplex, concerning FIB Count, FIB CRC Errors, FIB Error Rate and SNR, are shown in Figs. 6–9.

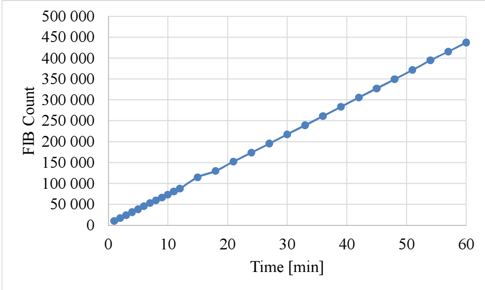

Fig. 6. Multiplex FIB Count.

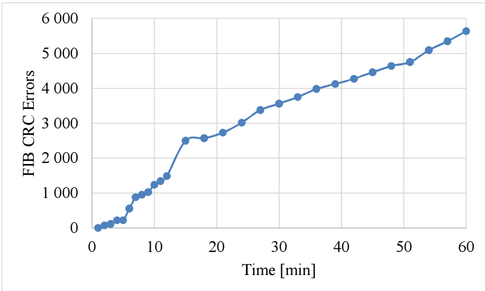

Fig. 7. Multiplex FIB CRC Errors.

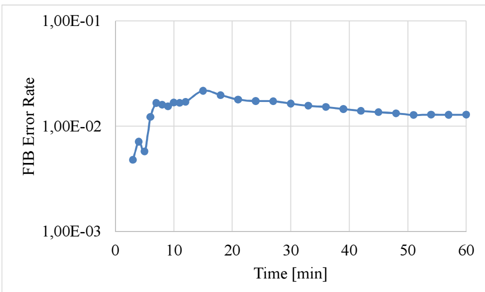

Fig. 8. Multiplex FIB Error Rate.

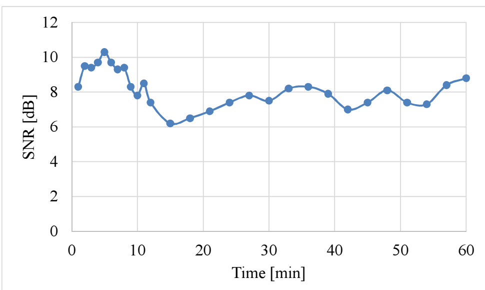

Fig. 9. Multiplex SNR.

As shown in Figs. 6–7, the commercial multiplex operates in an appropriate way. The character of both FIB Count, representing the total number of received FIB frames, defined as:

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$$FIB\_Count = \sum_{i=1}^{N} FIB_i \,, \tag{1}$$

and FIB CRC Errors, representing the total number of CRC errors, defined as:

$$FIB\_CRC\_Errors = \sum_{i=1}^{N} CRC\_Error_i \,, \tag{2}$$

is nearly linear. Otherwise, it would mean that a malfunction had appeared on the transmitter side. An FIB Error Rate – representing the relation between received erroneous and total FIB frames, defined as:

$$FIB\_Error\_Rate = \frac{N_E}{N_T} \,, \tag{3}$$

where N_E is the number of received erroneous FIB frames and N_T is the total number of received FIB frames – of $1.36 \cdot 10^{-2}$ was achieved by the multiplex. The average SNR oscillated around 8 dB.

Any malfunction on the transmitting side would lead to changes in the character of the FIG graphs, which are currently nearly linear. Additionally, any signal loss or occurring errors would lead to a decrease in SNR. When transferring these QoS parameters into QoE (*Quality of Experience*), of course this would be indicated by the user side, *i.e.* some services would be simply unavailable in particular conditions or time periods. Eventually, this would be clearly visible in lower values during assessment of the user quality. Currently, any interruption in offered services is viewed by the user as unacceptable.

If data continue to grow, broadcasters will be forced to manage quality in a more efficient way. The economic reality and physical limitations of available spectrum of resources prevent operators from simply adding more and more services. Broadcasters must plan today for future evolution of the network, which means working with parties that have a solid roadmap for QoS and transmission quality control mechanisms.

Additional to the transmission quality criterion, whenever planning a general or SFN (*Single Frequency Network*) DAB+ network, further studies on the electromagnetic compatibility, as well as compatibility with existing broadcasting services and networks should be carried out [24–27].

4. Conclusions

According to the report [28], as well as the European Radio Forum held in Kraków on Oct. 6th 2016 [29], a full introduction of DAB+ should be performed in cooperation with both the public and private broadcasters. Furthermore, as pointed out by the representatives of governments and the business sector, it should be preceded by further studies and research.

Moreover, national broadcasters of the Visegrad Group are planning to team up and introduce a new radio program, Radio V4. This program will be broadcasted in national languages of each country of the V4. It will include news and current affairs, as well as cultural, social and political topics [30]. This indicates that further work is required in order to provide reliable services at an acceptable level of quality. Additionally, transmission quality of offered services will have to be measured on regional, national and international levels.

As observed, the digital radio market continues to grow, and so does the demand for new efficient and reliable services. The proposed approach for monitoring transmission quality in the DAB+ broadcast system could be employed during the design and planning phases of a particular ensemble for both public and private broadcasters. Thanks to its portability and compatibility with Windows, it could be also used for evaluation and maintenance purposes on regional and nationwide levels.

Broadcasters, telecoms and content providers see the opportunity to offer more services, manufacturers look forward to selling larger quantities of devices and associated equipment. Network operators are keen on building new infrastructure. It is important to understand the pros and cons of different technologies and their commercial, economical and operational implications. Broadcasters will always aim to use the best possible means to reach the user. Users will welcome every new technology that offers more features and high quality content. When it comes to broadcasting, listeners are only interested in the quality, reliability and cost of a particular service.

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