Multimedia Broadcasting to mobile, portable and fixed Receivers using the Eureka 147 Digital Audio Broadcasting System

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Abstract: The Digital Audio Broadcasting (DAB) system developed within the Eureka 147 project is well adapted to the requirements of broadcasting audio, programme associated data and general data including e.g. video, still images and coded traffic messages. The configuration of the DAB multiplex (i.e data rates and error protection of the different applications) is flexibly adjustable.

Having evaluated the performance of DAB data channels in typical mobile reception situations, we conclude that the system will allow multimedia services to be reliably broadcast to mobile, portable and fixed receivers. To demonstrate this capability of DAB, we set up and operated experimental low bitrate video and still image transmissions associated to audio programmes.

I. INTRODUCTION

The Eureka 147 Digital Audio Broadcasting (DAB) system [1], [2] has been designed for broadcasting to mobiles with audio quality comparable to CD without any impairment even in severe multipath reception situations. This has been achieved by applying a wide band (1.5 MHz) transmission scheme known as Orthogonal Frequency Division Multiplexing (OFDM) [3] in conjunction with Rate Compatible Punctured Convolutional Codes (RCPC) [4] to allow for an efficient forward error correction mechanism adapted to the characteristics of the sources. To maintain high spectrum efficiency, audio sources are encoded according to the ISO 11172-3 (MPEG audio) Layer 2 standard [5]. For other than audio components, a number of transmission mechanisms including a packet mode are provided.

The maximum net data rate of the DAB system is 1.728 Mbit/s providing capacity for a multiplex of services containing e.g. several audio components, data components (e.g. coded traffic messages, text channels etc.) and even still or moving picture channels. This makes DAB highly appropriate to multimedia broadcasting in a sense that audio, video, text and other data all related to one programme can be delivered to the listener in parallel.

After a brief description of the DAB multiplex structure, this paper focuses on two issues: Firstly, measurements of the performance of the DAB audio and data channels using prototype equipment will be reported. The results show that components carried by the different DAB transport mechanisms can all be reliably received at a signal-to-noise-ratio of about 10..12 dB. Secondly, we describe multimedia broadcasting experiments which we performed to demonstrate the capability of the system to transmit still images associated to an audio programme and moving pictures in a separate data channel.

II. DAB MULTIPLEX AND SERVICE STRUCTURE

The data of audio components and other applications in a DAB multiplex are carried in what is called the Main Service Channel (MSC), which is devided into subchannels. Data carried in a subchannel are commonly convolutionally encoded and time interleaved. Fig. 1 shows the conceptual multiplexing scheme of the DAB system. The data rates available for individual subchannels are given by integer multiples of 8 kbit/s. There are two transport mechanisms: stream mode and packet mode.

Stream mode subchannels may contain audio encoded according to ISO 11172-3 Layer 2. Within each DAB

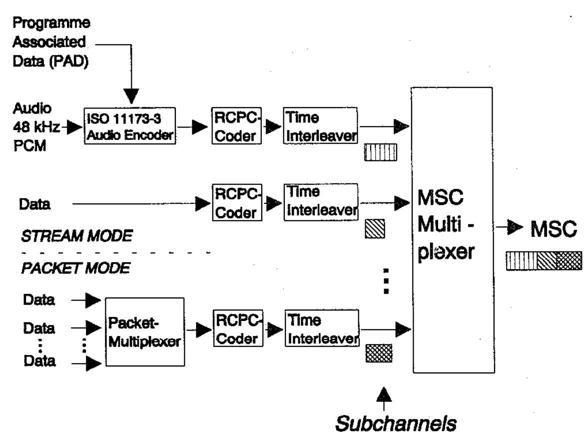

Fig. 1: Conceptual multiplex of the DAB Main Service Channel.

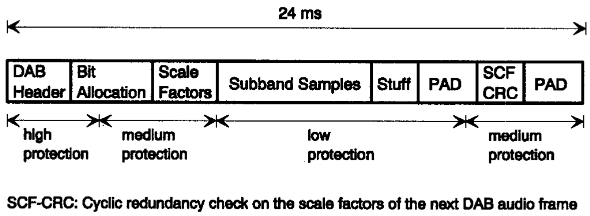

Fig. 2: Provisions for Programme Associated Data (PAD) in the DAB Audio frame and unequal error protection levels.

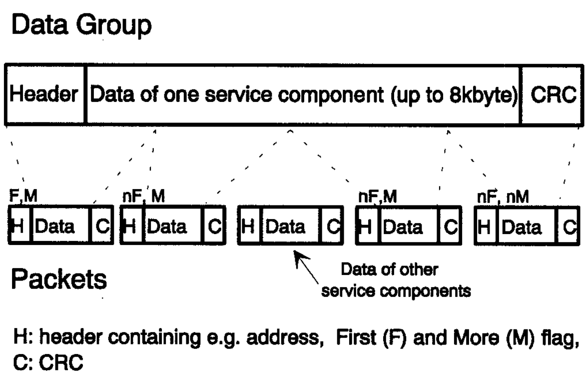

Fig. 3: DAB Packet Mode

audio frame corresponding to a 24ms time interval, a data field is available for Programme Associated Data (PAD, Fig. 2). The PAD channel is intended to carry data which is intimately related to the audio programme and has a strong real time aspect. A number of applications may be carried in parallel in PAD. General data may also be carried in a stream mode subchannel.

The most general DAB transport mechanism is the packet mode subchannel structure. Up to 1023 applications may be multiplexed in a packet mode subchannel. Data is organised in data groups (length up to 65536 bit) which are transmitted in a number of packets with the same address (Fig. 3). Packets have lengths from 24 to 96 bytes. In each packet, a cyclic redundancy check (CRC) is included for the detection of transmission errors. The completeness of received data groups can also be checked by a CRC.

The subchannel structure of DAB is flexible [6]. Therefore, the "Multiplex Configuration Information", i.e. how the MSC is devided into subchannels and which code rates are used, has to be broadcast to receivers. A dedicated part of the multiplex, the Fast Information Channel (FIC), is used for this purpose.

III. EVALUATION OF THE PERFORMANCE OF DAB DATA CHANNELS

Radio reception is quite different in different reception environments. Portable and mobile reception often suffer from multipath propagation, low field strength and man made noise, whereas fixed reception using an outdoor antenna or cable distribution enjoys high field strength and good signal quality. For a multimedia service, consisting for example of a stereophonic audio programme, a still picture channel carried in a different subchannel and some other components, it is desirable that the coverage areas of the different components can be tailored to the user groups addressed (e.g. listeners in mobiles, at home etc.). To achieve this, a wide range of code rates is available for the MSC subchannels. For audio, unequal error protection (UEP) profiles have been defined taking into account the different sensitivity to bit errors of the different parts of the audio frame [7], see Fig. 2. This results in a subjectively more acceptable degradation of the system when leaving the coverage area. For each audio data rate, five UEP profiles with different average code rates (0.34, 0.43, 0.5, 0.6, 0.72) are defined. For general data, four code rates (0.25, 0.38, 0.5, 0.75) are available (equal error protection, EEP). In the measurements described below, we investigated the performance of an EEP subchannel in different fading channels to test whether the coverage expected for data transmission is comparable to that achieved for audio including PAD.

a) DAB experimental equipment and measurement set-up

For field trials and demonstrations of DAB, test equipment has been developed and produced within the Eureka 147 consortium. The multiplex used by this equipment is composed of six audio subchannels with various bit rates and UEP coding profiles and two data subchannels with EEP and data rates of 64 and 24 kbit/s. Data interfaces are available to feed the coders and to transfer data from receivers to external decoders or to a PC for on- or off-line evaluation of the data. For the field trials in Germany, a central DAB transmitter is operated jointly by German Telecom and Institut für Rundfunktechnik in Munich. The signal is frequency modulated and distributed to the terrestrial DAB transmitters via a 30/20 GHz transponder of DFS Kopernikus.

The bit error measurements and multimedia transmission experiments described below made use of feeding data into this transmission chain and receiving the signal at our laboratory via the satellite link. The experimental set-up is shown in Fig. 4. After FM demodulation, the DAB signal was mixed to 225.5 MHz. A fading channel simulator was used to provide typical mobile reception situations. The channel parameters used

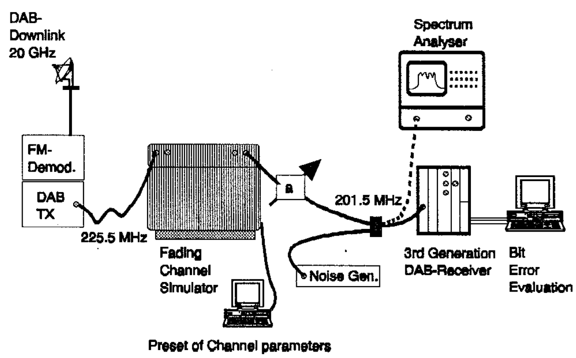

Fig. 4: Experimental set-up for bit error rate and error gap distribution measurements.

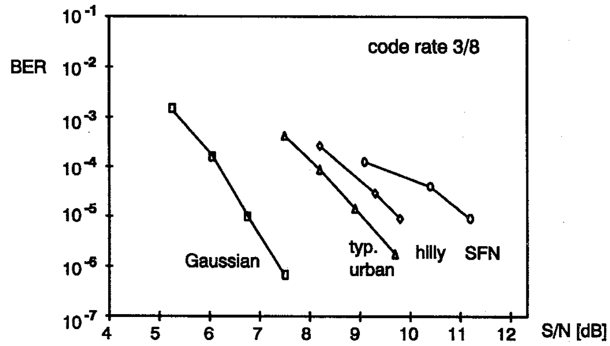

Fig. 5: Bit error rate (BER) versus signal-to-noise-ratio (S/N) measured in the Gaussian channel and in three different fading channels.

for setting up the channel simulator were some of the ones defined for GSM[8] and a specific DAB one (single frequency network, SFN). To adjust the signal-to-noise-ratio (S/N), a variable attenuator was inserted in the DAB signal path and noise was added. The S/N was measured with a spectrum analyser, the result being improved by averaging 256 traces of the DAB signal in fading channels. For the measurements, the signal was fed to a DAB receiver. After channel decoding, the bit stream was transferred to a PC where it was compared with the transmitted bit stream to detect bit errors. Due to Viterbi decoding, the errors were expected to occur in bursts. Therefore, the "error gap distribution"[9] was calculated. An error gap is defined as the string of consecutive correctly received bits between two bit errors. Its length is the number of the correctly received bits plus one. The error gap distribution EGD(j) is the probability that the gap length is greater or equal than j, j being an integer. All measurements were performed in the EEP subchannel with a data rate of 24 kbit/s and a code rate of 0.38.

b) Results and discussion

The results on the bit error rates versus S/N (Fig. 5) indicate that the error probability increases with the delay spread of the channel and decreases with S/N. The plots of the error gap distributions (Fig. 6a-d) show that the errors indeed occur in bursts, even in the Gaussian channel. The gap lengths inside an error burst usually are shorter than 15 bit due to the properties of Viterbi decoding. The probability of an error gap shorter than about 15 bit to occur is higher than 80%, so we can assume that error bursts will typically contain a number of errors separated by short gaps. Long error gaps (> $10^5 \cdots 10^6$ bit) are observed between these error bursts.

During the long error gaps, a large number of packets (several thousands) can be successfully transmitted. Consequently, a single or two consecutive packets out of several thousand packets are expected to be rejected by the CRC due to an error burst. The length of data groups is limited to 65536 bits in the DAB system. This figure is considerably smaller than the length of the long error gaps measured at S/N $\geq \approx 10$ dB. Therefore, even complete data groups can successfully be transmitted during an error gap. These results clearly show that a packet mode transmission using the code rate we investigated is feasible at S/N$\approx$10 dB even under severe multipath conditions.

During audio reception using the same set-up, a subjective impairment of the sound due to transmission errors in the samples of the audio frame at average code rates of 0.5 was observed at S/N values of about 8 and 10...12 dB in the Gaussian and the fading channels, respectively. Therefore, it is expected that audio, PAD (which in its majority enjoys the same protection as the audio samples) and general data carried in a packet mode subchannel with suitable code rate all begin to fail below about the same value of S/N. Nearly identical coverage areas can hence be expected for all the components of a multimedia broadcasting service on DAB.

IV. EXAMPLES OF MULTIMEDIA BROADCASTING USING THE DAB SYSTEM

To demonstrate the potential of the DAB system for multimedia broadcasting, experiments have been performed focusing on the transmission of images associated to the audio. For still picture transmission, JPEG coding was used. A low bitrate videophone codec was used for moving picture transmission.

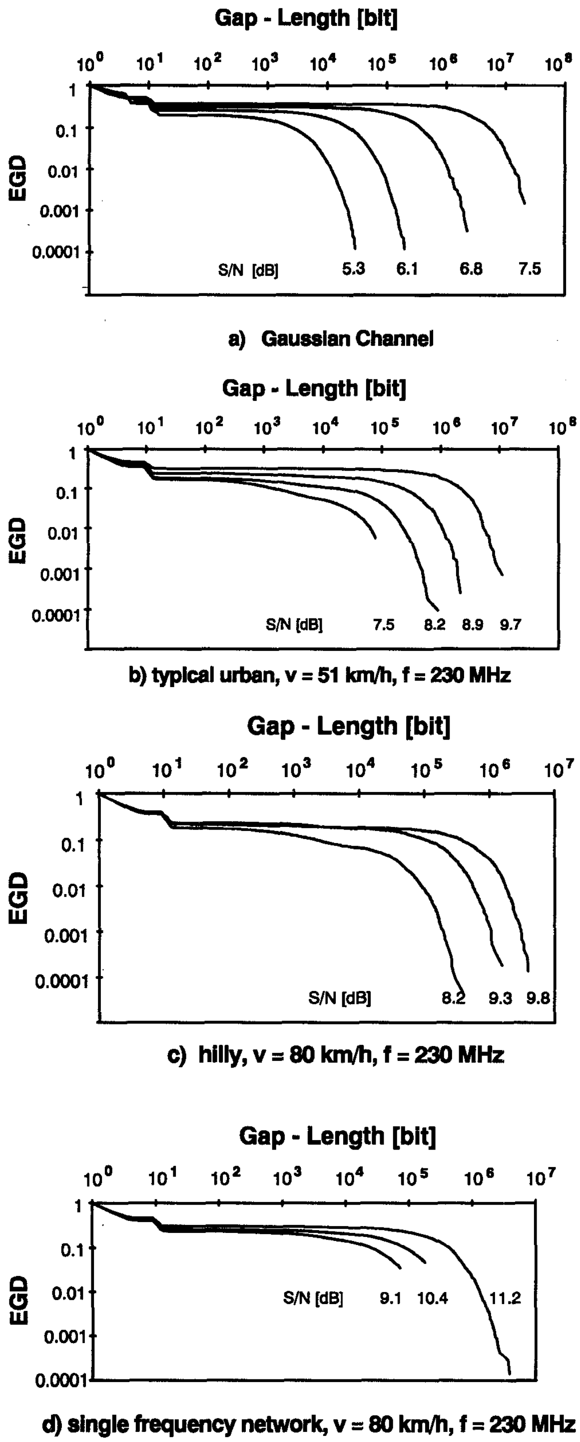

Fig 6 a-d: Error gap distribution versus gap-length measured in different channels

a) Still picture transmission in the PAD channel

During the CeBIT fair in Hannover in March '94, a slide show broadcast using a DAB audio subchannel (192 kbit/s, average code rate 0.5) was demonstrated. To achieve synchronisation of the still pictures with the audio, photographs and computer graphics coded according to the JPEG [10] format were transported in the PAD part of the audio subchannel. The PAD data rate available in the existing DAB equipment is 16 kbit/s. The JPEG compression factor was chosen such that a picture could be transmitted within a few tens of seconds while maintaining a high picture quality. A command byte was inserted in each DAB audio frame to indicate the start, continuation or end of a JPEG file and providing a "show next image" command to achieve synchronisation with the audio. A PC based JPEG hardware was used for decoding and display: the JPEG data read from the PAD interface of the DAB receiver were written to files. As soon as the "show picture" command was received, the next image file was sent to the JPEG decoder and displayed on the monitor. An example of a multimedia programme was produced explaining some technical background of DAB and presenting examples of a news message, a weather forecast, traffic messages and musical entertainment, all illustrated by suitable pictures, e.g. a weather satellite photo, a map with traffic jams indicated and the cover photo of the CD a track of which was played. Due to the high quality stereo sound, the high resolution of JPEG encoded photographs and the easy synchronisation of both, this arrangement certainly is a promising one for a later multimedia service on DAB.

b) Low Bitrate (24 kbit/s) Moving Picture Transmission in an MSC data Channel

In another experiment, a low bitrate moving picture transmission in a data subchannel of the MSC was tested and demonstrated. A video codec developed for videophone systems in our laboratory [11] was used at a data rate of 24 kbit/s. A six minute sequence of different still and moving pictures had been compiled showing a newscaster, several maps with traffic related information, some logos, and fish in an aquarium. Although only the equal error protection of DAB was applied (code rate 0.38) and although the very low bit rate video coding is extremely sensitive to bit errors due to interframe coding and the high compression ratio, the system worked in multipath channels without any perceptual transmission errors at S/N values only 3 to 5 dB higher than that required for reception of an audio signal without impairment of the sound (UEP, average code rate 0.5). Due to the limited resolution of the low bitrate video codec (176x144 pixels) it turned out that the symbols and texts on the maps were not very well legible. The slowly changing moving pictures showing the newscaster and the fish, however, gave a very good impression of what was going on.

V. CONCLUSIONS

There clearly is an excellent potential for broadcasting multimedia services using the Eureka 147 Digital Audio Broadcasting system. It provides a number of transport mechanisms suiting a wide range of needs regarding data rates, forward error correction and synchronisation with other components of the same service. The multiplex structure being highly flexible, DAB offers the possibility to adapt the capacity assigned to the individual components to their specific requirements. In this paper, we focused on the performance of transport mechanisms provided to broadcast other applications than audio. The experimental results of bit error measurements and examples of video transmissions in DAB showed that a sufficient performance of still and moving picture transmission systems can be achieved near the minimum signal levels required for reception of audio without impairment of the sound without the need for a further source adapted outer code. The progress already made in a JESSI project (AE14) towards developing Integrated Circuits [12] for mass production of low cost consumer receivers will result in a fast penetration of the market with DAB. This will make multimedia broadcasting services on DAB available for many listeners at home and in mobiles in the near future.

VI. ACKNOWLEDGMENTS

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VII. REFERENCES

[1] European Telecommunications Standards Institute (ETSI), Draft pr ETS 300401: *Radio broadcast systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers.* Sophia Antipolis, 1994

[2] Paul Ratliff, *Eureka 147 Digital Audio Broadcasting - The System for Mobile, Portable and Fixed Receivers.* Proc. 2nd International Symposium on DAB, Toronto 1994, Vol. I, p. 294

[3] B. Le Floch, *Channel coding and modulation for DAB.* Proc. 1st International Symposium on DAB, Montreux 1992, p. 99

[4] J. Hagenauer, *Rate compatible convolutional codes (RCPC-codes) and their applications.* IEEE Transactions on Communications, Vol. COM-36, p. 389 (1988)

[5] G. Stoll, *Source Coding for DAB and the Evaluation of its Performance: A major Application of the new ISO Audio Coding Standard.* Proc. 1st International Symposium on DAB, Montreux 1992, p. 83

[6] A. Müller, *Dynamic multiplexing for integrated services digital broadcasting to mobile receivers.* Proc. 2nd International Symposium on DAB, Toronto 1994, Vol. I, p. 392

[7] Ch. Weck, *Optimierung der Empfangsqualität durch angepaßten Fehlerschutz bei DAB.* ITG Fachbericht 118 Hörrundfunk, vde-verlag, Berlin und Offenbach 1992, p. 109

[8] COST 207 WG 1, *Proposal on channel transfer functions to be used in GSM tests late 1986.* COST 207 TD (86) 51 Rev. 3, 1986

[9] L.N. Kanal, A.R.K. Sastry, *Models for Channels with memory and their applications to error control.* Proc. IEEE, Vol. 66, p. 724, 1978

[10] W.B. Pennebaker, J.L. Mitchell, *JPEG Still Image Data Compression Standard.* Van Nostrand Reinhold, New York 1993

[11] R. Mann Pelz, D. Biere, *Bild- und Sprachübertragung in Mobilfunkkanälen.* Nachrichtentechnik, Elektronik Vol. 42, p. 7, 1992

[12] J. Hallier, L.v.d. Kerkhof, H. Kling, J.L. Sicre, *Preparing Low-cost ICs for DAB: The Jessi-DAB Programme.* Proc. 2nd International Symposium on DAB, Toronto 1994, Vol. II, p. 154