Digital aspects of ra

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The Digital Audio Broadcasting (DAB) system has been developed by the European research program EUREKA 147 in the early nineties of the last century. Nowadays, it is also called ‘digital radio’. DAB provides excellent mobile reception and the possibility of single frequency transmission. The first version of the current European standard [1] was completed in 1995. DAB is primarily an audio broadcasting system offering excellent sound of near CD-quality. But due to digitalization, DAB can send along many other data services. In contrast to analogue technology (FM) where audio signals are directly converted to analogue radio frequency variations, DAB encoding uses the binary symbols ‘0’ and ‘1’. So a binary data stream is created that may contain different information, e.g. sound, text, images or random data and software. The term ‘audio broadcasting’ can thus comprise multimedia radio, if corresponding services are transmitted.

radio
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1. Introduction and technical basics

DAB uses a standardized method for data reduction to ensure transmission of large data volumes generated during audio signal digitalization. This method is based on psychoacoustic properties of human hearing. The human ear e.g. does not perceive sound below a certain minimum loudness, the so-called auditory threshold in quiet. The sound can be filtered accordingly omitting these components. Another psychoacoustic property of human hearing is the overlaying of weaker with louder components of an audio signal, so they are below masking threshold. These components then can be eliminated as well. Both effects result in a considerable reduction of the data stream to be transmitted without leading to an audible difference in sound. This process is called MUSICAM (Masking Pattern Universal Sub-Band Integrated Coding and Multiplexing). It is part of the MPEG (Motion Pictures Expert Group) Audio Layer II audio encoding used by DAB. This audio encoding applies sample rates of 24 to 48 kHz and produces a compressed audio data stream with data rates of 8 to 384 kBit/s.

When preparing transmission of such compressed binary data, **error protection** is applied. Error protection enables the receiver to restruct transmitted information, even if errors occurred during transmission. DAB folding can be adjusted to different codes by puncturing. A special characteristic of DAB error protection is the so-called “unequal error protection”,

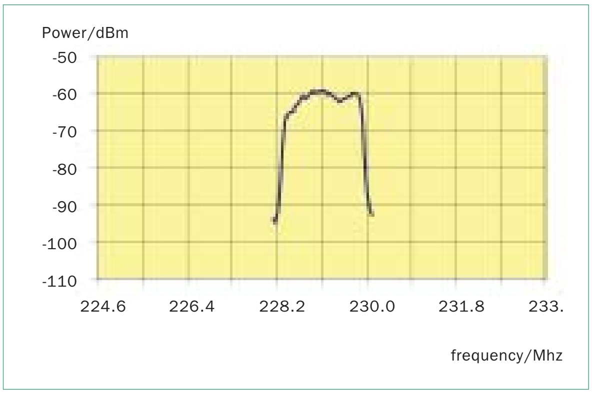

Fig. 1: Measured DAB frequency spectrum

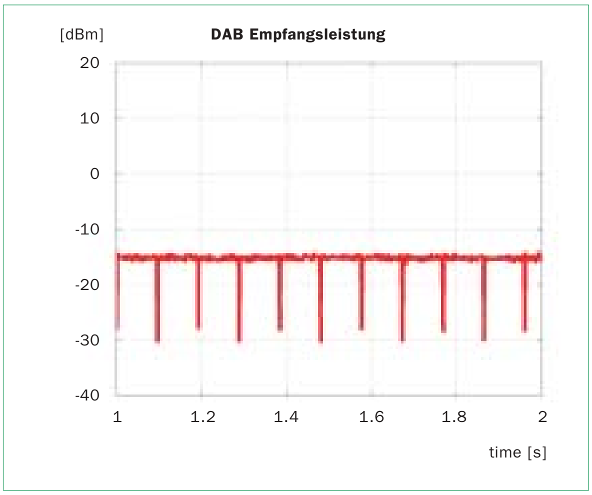

Fig. 2: DAB signal reception power

ie the most important information gets a higher level of error protection, less sensitive information a lower level. For current mobile applications, a medium code rate of approx. 0.5 is applied, allowing a DAB channel rate of approx. 1.2 Mbit/s. Another characteristic of DAB is the so-called **time interleaving** where information is transmitted by interlocking and original information is reconstructed at the receiver. This increases integrated error protection capacity to suppress short-term interferences and provides an error-free reception.

The compressed, interlocked and error protected data then are distributed among the up to 1536 frequency carriers of an OFDM (Orthogonal Frequency Division Multiplexing) modulator. A measured frequency spectrum with a total bandwidth of 1.5 MHz is depicted in fig. 1. The distribution over a wide frequency spectrum lessens data sensitivity to narrowband interferences, so that, in general, only a part of information is lost. The original signal can be restored via error protection.

A special characteristic of OFDM technique is that it allows for a long symbol period T, due to its frequency structure where no individual modulated frequencies are not changed. An artificial lengthening of symbol period by the so-called protection interval makes DAB robust against multi-path interferences and allows single frequency transmission characterized by an improved spectrum efficiency.

The reflections from houses and mountains interfering with FM signals thus lead to an improved reception in DAB. With a channel grid of approx. 1.75 MHz, DAB operates using different frequency ranges in the VHF spectrum (174 to 230 MHz) and the L-band (1452 to 1492 MHz). Different modes with different numbers of frequency carriers are defined in order to guarantee very good mobile reception across all frequency ranges [1]. Since OFDM transmission technique can be used efficiently only when error protection is integrated, it is often also called coded OFDM (COFDM). For synchronization, DAB sends a so-called zero symbol after every 96 symbols, that is, every 0.1 seconds;

Fig. 3: Sites of WDR 2 FM transmitters (WDR 2 = public radio station)

Fig. 4: Sites of the WDR 2 program DAB transmitters in Northrhine-Westphalia (WDR 2 = public radio station)

the power level is lowered then, as internal system information is sent. The time course of reception output can be seen in fig. 2. Thus, DAB is a system with constant average power. If pulsation – often seen as a potential health risk by mobile radio critics – is understood as the spectral component of a signal between 1 Hz and 1 kHz, related to the effective value of the signal [4], it is rather low in the DAB signal.

DAB combines several programs to form so-called ensembles. An ensemble, also called multiplex, comprises 5 to 9 radio programs and additional data services. The total capacity of an ensemble is defined, and the available data rate is flexibly distributed over various different programs and services. Thus, all programs and services within an ensemble have the same propagation area, which, in a random transmission network, is also called coverage. Coverage can comprise a city, a county or even the whole country. Each ensemble is transmitted via a single frequency channel; so several ensembles can be transmitted at different frequencies in the same area.

2. DAB radiation emission

In the following, digital terrestrial (DAB) radiation emission and radiation emission of analogue terrestrial coverage (FM) are compared in order to evaluate DAB radiation emission. We will use Northrhine-Westphalia as an example to examine the coverage area of the radio program WDR 2 that currently is transmitted both digitally and analoguely. To ensure full analogue coverage, 26 transmitters with a total of approx. 400 kW transmission power, are needed. The sites of FM transmitters broadcasting the program WDR 2 are depicted in fig. 3. At present, 88% of the area and 90% of the population of Northrhine Westphalia are supplied by DAB (source: www.digitalradiowest.de). 33 operating transmitters with a total power of approx. 23 kW are required for this. The sites of the DAB transmitters are shown in fig. 4. They carry an ensemble of 9 programs and services, respectively, with different data rates. The proportionate power of the DAB broadcasting segment for WDR 2 is only 2.5 kW. This example shows that digi-

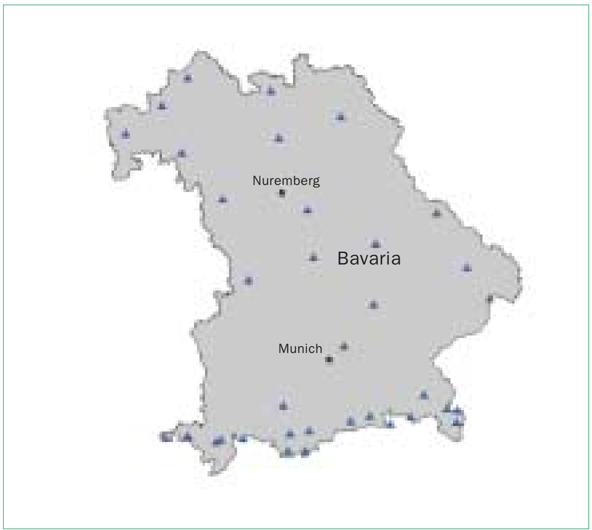

Fig. 5: Sites of the Bayern 3 FM transmitters (Bayern 3 = public radio station)

Fig. 6: Sites of Bayern Mobil DAB transmitters in Bavaria (Bayern mobil = DAB traffic news program)

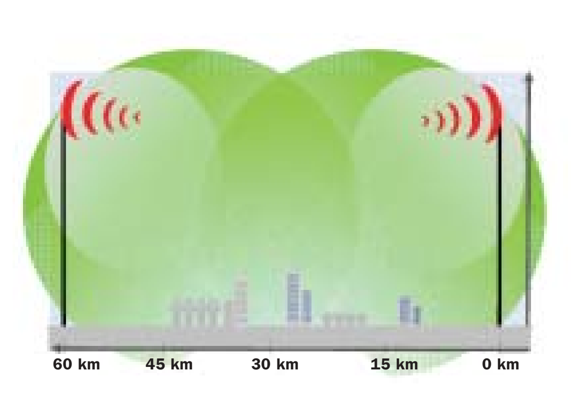

Fig. 7: Network structure with few high power transmitters (macrocell structure)

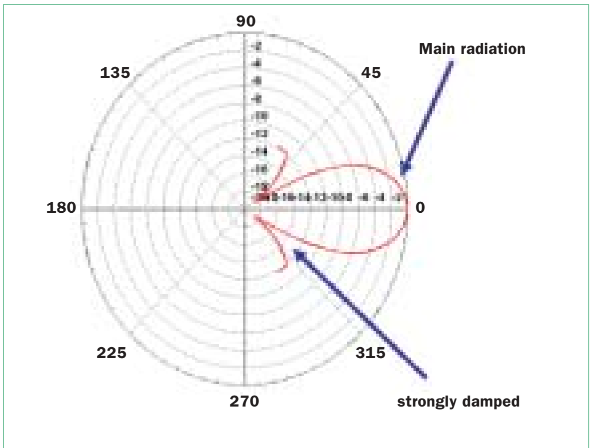

Fig. 8: Typical vertical antenna diagram of a radio broadcasting antenna

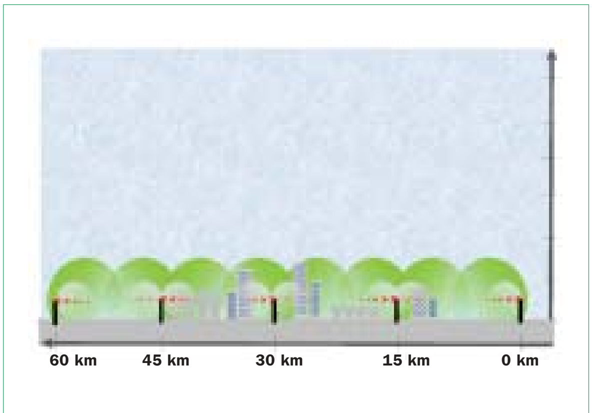

Fig. 9: Network structure with many low-power transmitters (microcell structure)

tal radio broadcasting technology based on the efficient COFDM technique allows a distinct reduction of radiation emission – in this case by a factor 160 -, at the same time improving mobile reception quality.

A comparison between analogue and digital radiation emissions in Bavaria leads to similar results. In the following, the required transmission power for the analogue program Bayern 3 will be compared to the DAB traffic news program Bayern Mobil. The sites of all transmitters are depicted in figs. 5 and 6. In the case of analogue technology, 36 FM transmitters with a power of approx. 790 kW are required. When comparing the depictions, one can see that, especially in the subalpine area, considerably more FM than DAB transmitters are required. This shows the advantages DAB has over analogue technology, particularly in topographically difficult terrain. According to www.bayerndigitalradio.de, more than 92 % of the Bavarian State area is aready supplied via DAB. At present, 37 DAB transmitters with a total transmission power of less than approx. 30 kW are in operation. Since 9 programs and services with different data rates make up a DAB ensemble in Bavaria, a power of 4 kW is sufficient for the transmission of Bayern Mobil. Thus it is possible to distinctly reduce radiation emission, simultaneously improving mobile reception quality, namely in this case, compared to FM transmission, by the factor 190.

3.Comparison of transmission network structures of broadcast and mobile radio

The structure of radio broadcasting networks is characterized by the low number of transmitters with relatively large power ensuring full coverage (fig. 7). Since these are large-range transmitters, the term **macrocell structure** is used in this context. To keep radiation exposure of the general population to a minimum, antennas for vertical transmission are applied and set up at considerable altitudes (e.g. 300 m). A typical diagram is shown in fig. 8. It depicts the elevation angle (vertical angle) dependent damping. Fig. 8 demonstrates that the antenna are strongly damped in the direction of the ground, thus distinctly reducing exposure in the area of the transmitter site. Aside from the few powerful large transmitters, so-called gap filling transmitters operating at smaller power levels are used for the supply of area segments which, e.g. due to topography, cannot be supplied by the large transmitters. Since the information has to be fed into each transmitter individually, a network structure with few transmitters implies simpler and thus more cost effective feeding.

In contrast to radio broadcasting, mobile radio uses many transmitters (base stations) operating at small power levels. Since these transmitters have a considerably smaller range, this is called microcell structure (fig. 9). Mobile radio systems allow bidirectional communication, meaning information is sent not only by base stations but also by mobile stations. As mobile stations are battery-operated, it is important to keep the distance between mobile and base stations as small as possible, so that mobile stations with small power levels can work and have long battery life. This also helps to maintain lower exposure levels of users from the mobile station. Further, the information transmitted to individual users varies. Therefore network capacity grows with the number of base stations, since more users can simultaneously send and/or receive different information. Mobile radio therefore needs a microcell structure, due to the required small distance between mobile and base stations and the required capacity.

In contrast, a broadcasting system is based on one-directional communication, ie information is sent by the transmitters and simultaneously received by all users via their end devices. Moreover, all users within a transmission area shall be able to receive the same program. Due to this, broadcasting networks employ a macrocell structure. However, theoretically, they could also employ a microcell structure. There would have to be many more transmitters in this case for full coverage, with a more sophisticated input feed. This is why there is a lack of adequate sites for transmitters at high altitudes. Instead, sites near or in residential areas must be found – and this is getting increasingly difficult nowadays. Also, the radiation from transmitter sites at lower altitudes may point in the direction of buildings. As a result, exposure in a microcell network concerns a larger part of the population than in a macrocell network. Thus, the disadvantages of microcell structures for radio applications prevail; macrocell structure is preferable here.

4.Implementation of DAB – present situation

There has been made great progress in the implementation of DAB transmission networks in Germany. Technological infrastructure is already available for 80% of the population. Information on current distribution and broadcast programs is found on the homepage www.digitalradio.de. A worldwide overview is given at www.worldDAB.org. However, to date few receivers (approx. 80,000; source: www.lvn.parlanet.de) have been sold in Germany. This is partially due to high prices of end devices, but also to the lack of knowledge of consumers about the excellent quality of mobile reception. In addition, DAB radios are not part of in-car equipment yet. The German Electrotechnics and Electronics Industries Association (Zentralverband der Elektrotechnik- und Elektronikindustrie – ZVEI) estimates a number of 10,000 cars being equipped with a DAB end device at present. There are some manufacturers, however, who recently began to offer DAB radio as an option. At www.reinhoeren.de, you will find all there is to know about digital radio DAB, either newly offered programs or new end devices.

The development in Great Britain could be a new impetus for the introduction of DAB in Germany. More than 400,000 end devices have been sold there; this number is expected to increase to one million by the end of 2004. Attractive programs only attainable with DAB have succeeded in arousing the interest of radio users, going hand in hand with cheaper end devices. There is a variety of DAB devices available, the cheapest ones for less than 150 euros.

5. Conclusion

DAB is an efficient digital radio broadcasting system allowing excellent mobile reception even in hilly areas. Due to its use of single frequency transmission, DAB moreover provides good spectrum efficiency. This is achieved by using a fraction of usual transmission power levels, ie radiation emission is reduced by a factor 160 to 190 compared to FM radio in the demonstrated examples. Therefore, DAB could be more than a mere substitute for traditional FM radio broadcasting.

6.References

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