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DAB System Fine Time Synchronization for Rayleigh Channel

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Abstract
Synchronization is the key part of OFDM receivers. A method to estimate Fine Time Synchronization in DAB receiver in Rayleigh channel is based on analysis of phase reference symbol is given.

Keyword: Fine time synchronization: phase reference symbol; OFDM and DAB

Introduction
DAB System can be operated at any frequency from 30 MHz to 3GHz for mobile reception. It may be used on terrestrial, satellite, hybrid (terrestrial with satellite) and cable broadcast networks.

This System allows flexible, general purpose digital multiplex which can carry a number of services (Not just audio). This meets all the demanding requirements drawn up by the ITU (in ITU-R Recommendations 774 and 789). It is adopted by the European Telecommunications Standards Institute (ETSI) as an European Standard (ETS 300401, Mar 1997) [2].

The transmitted information is spread in both frequency and time so that the effects of channel distortions and fades are eliminated in the receiver, even under severe multipath propagation conditions.

Main System Feature
The DAB transmission signal carries a multiplex of several digital services (audio and data) simultaneously. Its overall bandwidth is 1.536 MHz, providing a useful bit-rate capacity of approximately 1.5 Mbit/s in a complete "ensemble". Each service is independently error protected with a coding overhead ranging from about 25% to 300% (25% to 200% for sound), the amount of which depends on the requirements of the broadcasters (transmitter coverage, reception quality). A specific part of the multiplex contains information on how the multiplex is actually configured, so that the receiver can decode the signal correctly. It may also carry information about the services themselves and the links between different services.

The working principle of the DAB system is illustrated in conceptual block diagram shown in Fig. 1. At the input of the system the analog signals such as audio and data services are MPEG layer-II encoded and then scrambled. In order to ensure proper energy dispersal in the transmitted signal, individual inputs of the energy dispersal scramblers is scrambled by modulo-2 addition with a pseudo-random binary sequence (PRBS), prior to convolutional coding [1]. The scrambled bit stream is then subjected to forward error correction (FEC) employing punctured convolutional codes with code rates in the range 0.25-0.88.

The coded bit-stream is then time interleaved and multiplexed with other programs to form Main Service Channel (MSC) in the main service multiplexer. The output of the multiplexer is then combined with service information in the Fast Information Channel (FIC) to form the DAB frame. Then after QPSK mapping with frequency interleaving of each subcarriers in the frame, $\pi/4$ shifted differential QPSK modulation is performed. Then the output of FIC and MSC symbol generator along with the Phase Reference Symbol (PRS) which is a dedicated pilot symbol generated by block named synchronization symbol generator is passed to OFDM signal generator. This block is the heart of the DAB system. Finally, the addition of Null symbol to the OFDM signal completes the final DAB Frame structure for transmission.

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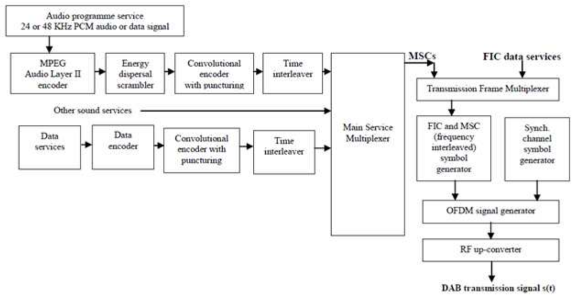

Figure 1. DAB transmission system

Simulation Model

Fig. 2 presents the complete block diagram of the DAB system which was modeled and simulated by us in MATLAB environment. The main objective of this simulation study is to explain the synchronization method based on phase reference symbol. The simulation parameters are obtained from Table I for transmission mode-II. A frame based processing is used in this simulation model. The system model was exposed to AWGN channel, Rayleigh fading channel and Rice channel to test the effectiveness of the synchronization block. The important blocks of the simulation model is discussed in detail in figure.

Phase Reference Symbol Generator

According to DAB standard the first OFDM symbol (without taking account Null symbol) in the transmission frame is the phase reference symbol which helps in receiver synchronization. Since it occurs once in a frame therefore the detection of this symbol can be used for frame synchronization.

It serves as reference for the differential modulation for the next OFDM symbols in the transmission frame. The phase reference symbol is defined [1] by the following expression:

$$z_{l,k} = \left\{ \begin{matrix} e^{j\Phi_k} \\ 0 \end{matrix} \right\} \quad \text{for k=0} \quad (1)$$

where

$$\Phi_k = \frac{\Pi}{2}(h_{l,k-k`} + n) \qquad (2)$$

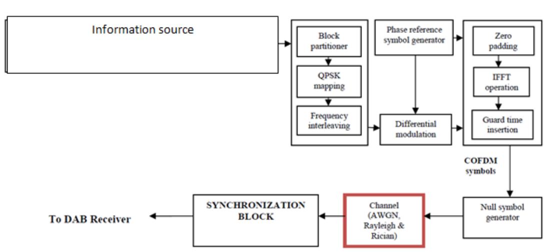

Figure 2. Simulated model for DAB system

The values of indices i, k' and the parameter n are given as functions of the carrier index k for all the DAB transmission modes. The values of the parameter hi,j is given as a function of its indices i and j [1].

Synchronization

Synchronization is a challenging but very important issue in a digital communication system. All digital communication systems require proper synchronization for decoding of the received signal in order to produce the original information transmitted.

The synchronization block is used to locate precisely each DAB frame, so that the demodulation can be performed frame by frame, symbol by symbol. DAB system explores the Null symbol and the phase reference symbol for synchronization purpose. Figure 2. illustrates the process of receiver synchronization.

The first is the synchronization channel which consists of two symbols. One is the Null symbol having duration TNULL. During null symbol period no information is transmitted. Null symbol gives coarse time synchronization. It gives the rough frame timing by envelope detection of the received signal i.e., detecting the null symbol by comparing average signal power during null symbol period TNULL with a set threshold. From the received signal, a data block of size 345 (equal to TNULL) samples is taken to measure the average signal power [4].

When this average signal power is less than half of the average transmitted signal power the null symbol has been detected, which indicates the start of the new frame [2]. This method of frame synchronization based on null symbol detection is not suited for low SNR conditions because high noise power will provide incorrect frame timing estimate. Therefore phase reference symbol detection is ideally well suited for correct symbol timing and frame timing. Fig. 4 illustrates the process of receiver synchronization.

Symbol Time Synchronization

Fine time synchronization or symbol timing synchronization [4] is performed by calculating the Channel Impulse Response (CIR) based on the actually received time frequency phase reference symbol (PRS) and the specified PRS stored in the receiver. To estimate the CIR, training Sequences (PRS in case of DAB system) are used. This means that a part (or the whole) of the transmitted signal is known from the receiver. As the receiver knows which signal is supposed to be observed, it can evaluate the distortion induced by the propagation channel and the modulation & demodulation stages.

Fine time synchronization is based on the phase reference symbol which is the dedicated pilot symbol in each DAB transmission frame [1]. Since the modulation each carrier is known [6][5],

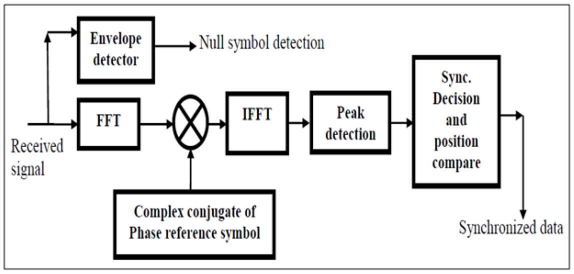

Figure 3 Process of Receiver Synchronization

multiplication of received PRS with complex conjugate of PRS at the receiver results in cancellation of the phase modulation of each carrier. The phase reference symbol can be converted to impulse signal or CIR can be obtained by an IFFT operation of the resultant product as illustrated in following formula:

CIR = IFFT{Received PRS• PRS*} (3)

Where PRS* is the complex conjugate of the phase reference symbol.

The peak of the impulse signal obtained from equation (3) will give position of the start of the PRS compared to a set threshold (T) providing symbol timing as well as frame timing. According to Figure 2. from the received signal a data sample block of FFT length is taken. Then FFT operation is performed on the block to convert the samples into frequency domain. Since FFT window length is 256 and size of PRS at the receiver is 192 (mode-III) therefore zero padding removal and data rearrangement has to be done [4]. The resulting sample block is of size 384 same as PRS. Now sample block is multiplied by the complex conjugate of the PRS known at the receiver which is then transformed into impulse signal in time by performing IFFT operation on the product .

The highest peak detection will indicate the start position of the PRS. To get a precise synchronization decision the peak obtained from every sample block taken from the received signal is compared to set threshold level (T). When the detected peak is less than the threshold level, then the peak found is not the desired peak and does not indicate the accurate start of the PRS. So the loop process has to be continued by taking the next sample block till the desired peak is obtained. The peak will be greater than the threshold only for the sample block which has phase reference symbol in it, since PRS have a high correlation with itself.

Results Analyses

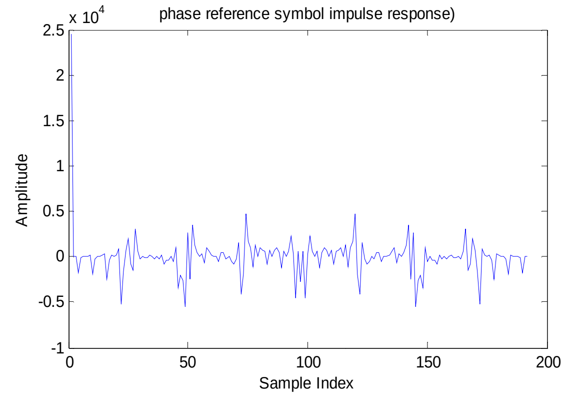

Figure 1 Phase reference impulse response

Figure 1 showing the peak when the Phase Reference Symbol is correlated by itself and then perform the IFFT operation.

Peak detection in noiseless channel environment.

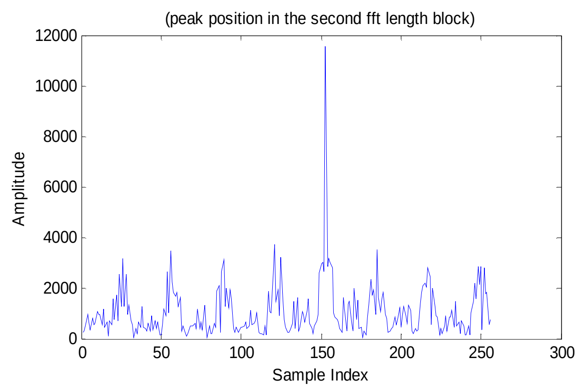

Figure 2. Desired peak detection in particular fft size block in noiseless channel .

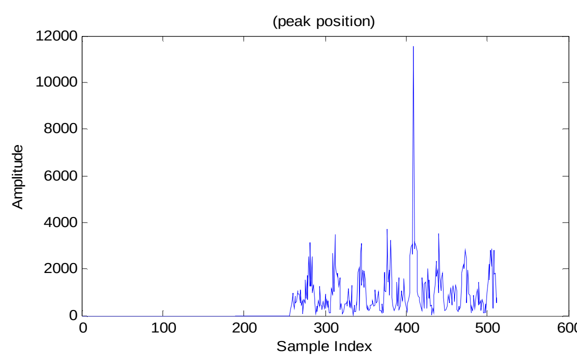

Figure 3. Desired peak detection in noiseless channel.

In Figure 2 and figure 3 the system symbol timing synchronization has been investigated in noiseless environment. From the figures the symbol timing synchronization peak is at sample index 409 of the received data array. The plot has only included the received data samples before synchronization peak detection and samples from where a peak has detected..

The transmission frame is the null symbol of sample length 345 and each OFDM symbol has the cyclic prefix sample of 63 (mode III) at the beginning of the sample. The useful symbol duration does not include the cyclic prefix. Adding null symbol samples and cyclic prefix samples we obtain 408, thus the synchronization peak is exactly at starting point of the effective symbol duration of the phase reference symbol as expected.

Peak Detection In Rayleigh Channel Under Better (20db) Snr Environment

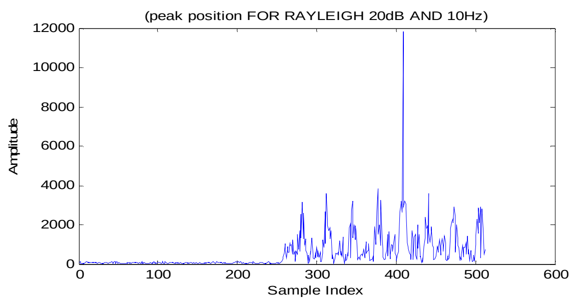

Figure 4. Desired peak detection in Rayleigh channel with 20 dB and 10Hz.

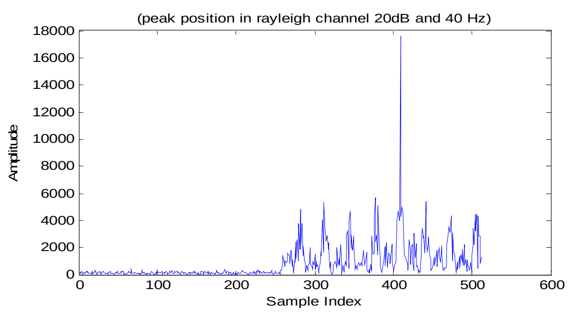

Figure 5. Desired peak detection in Rayleigh channel with 20 dB and 40Hz.

In Figure 4 and figure 5, the system symbol timing synchronization has been investigated in better signal to noise ratio (20dB) environment with Doppler shift 10Hz. From the figures the symbol timing synchronization peak is at sample index 409 of the received data array. The plot has included the received data samples before synchronization peak detection and samples from where a peak has detected

Peak Detection In Rayleigh Channel Under Worst (-8db) Snr Environment

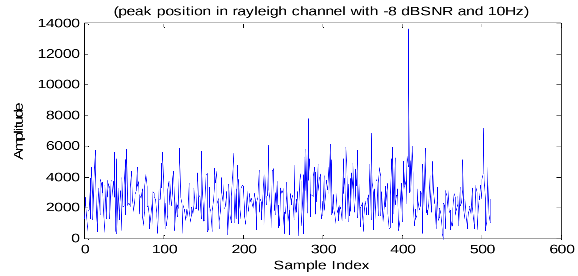

Figure 6. Desired peak detection in Rayleigh channel with -8 dB and 10Hz

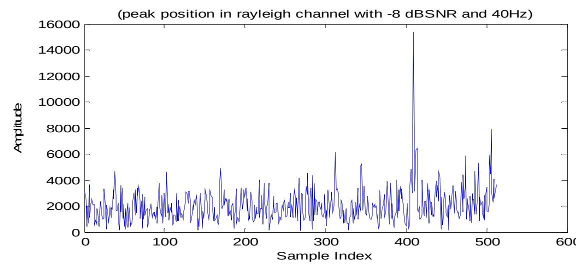

Figure 7. Desired peak detection in Rayleigh channel with -8 dB and 40Hz.

In Figure 6 and figure 7, the system symbol timing synchronization has been investigated in worst signal to noise ratio (-8dB) environment with Doppler shift 10Hz and 40 Hz. From the figures the symbol timing synchronization peak is at sample index 409 of the received data array. The plot has included the received data samples before synchronization peak detection and samples from where a peak has detected.

Conclusion

The proposed synchronization method of fine time synchronization using phase reference symbol provided correct frame synchronization even in the low SNR condition in all the three channels. It was observed that in all channel condition successful peak detection was obtained indicating exact position of PRS. From this position, the DAB frame and hence the ODFM symbols can be demodulated to extract the original information.

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