Bit Error Rate Analysis of Coded OFDM for Digital Audio Broadcasting System, Employing Parallel Concatenated Convolution Turbo Codes

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Abstract:

Bit Error Rate (BER), for Digital Audio Broadcasting (DAB) system, employing Coded OFDM with different channel coding schemes. Analysis is carried out for convolution coded and turbo coded data in an Additive White Gaussian Channel (AWGN) based on different constraint lengths and code generator polynomials used for coding. A comparative study on the computational complexity is also done by applying an audio signal and measuring the data processing time per frame, on computers with different processor speeds. It is shown that a coding gain of approximately 6 dB is achieved using turbo coding when compared to convolution coding, at a cost of higher computational complexity.

Keywords: DAB; OFDM; Convolution Codes; Turbo Codes.

1. INTRODUCTION:

The requirement of mobility while connected to network is fueling the growth of wireless communication. The conventional analog transmission techniques do not perform well in mobile environment, since suitable techniques to mitigate the effects of multipath propagation induced fading have not been developed for these systems. Orthogonal Frequency Division Multiplexing (OFDM) is one such technique to combat the effect of multipath fading, frequency selective fading and Inter symbol Interference (ISI). OFDM decreases the amount of hardware implementation since multiplexing and filtering operations can be performed by employing the Fast Fourier Transform (FFT). This eliminates the need to have multiple oscillators at the transmitter and synchronizing loops at the receiver. Due to the cyclic extension of signal period into a guard interval, OFDM system is suitable for Single Frequency Networks (SFN).

2. OBJECTIVE:

Digital Audio Broadcasting system using Coded OFDM is implemented and studied over an AWGN channel. Bit-Error-Rate (BER) is measured and compared by employing error correcting codes like, Convolution Code and Parallel Concatenated Convolution Turbo Code. A good BER for audio is considered to be 10-4. Using turbo coding, it is nearly achieved with an Eb/No of 3 dB. A coding gain of nearly 6 dB is achieved using turbo coding, when cThe channel selected only introduces

Gaussian noise. But problems faced by fading and multipath can be analyzed by choosing other channel models. Instead of QPSK modulation scheme, the same system can be analyzed using other modulation techniques like DQPSK and QAM. Instead of parallel concatenated convolution turbo codes, serial concatenated convolution turbo code also can be implemented and analyzed .ompared to convolution coding, at a cost of high computational complexity.
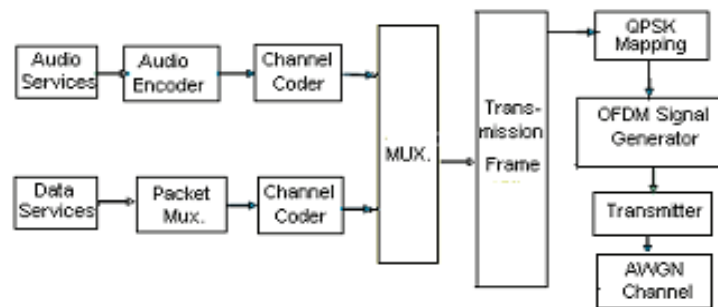
3. PROPOSED SCHEME:

Figure 1 . DAB transmitter – Block Diagram.

OFDM

Conceptually, OFDM is a specialized FDM, the additional constraint being: all the carrier signals are orthogonal to each other.

In OFDM, the sub-carrier frequencies are chosen so that the sub-carriers are orthogonal to each other, meaning that cross-talk between the sub-channels is eliminated and inter-carrier guard bands are not required. This greatly simplifies the design of both the transmitter and the receiver; unlike conventional FDM, a separate filter for each sub-channel is not required.

The orthogonality requires that the sub-carrier spacing is $\Delta f = \frac{k}{T_U}$ Hertz, where T_U seconds is the useful symbol duration (the receiver side window size), and k is a positive integer, typically equal to 1. Therefore, with N sub-carriers, the total passband bandwidth will be $B \approx N \cdot \Delta f$ (Hz).

The orthogonality also allows high spectral efficiency, with a total symbol rate near the Nyquist rate for the equivalent baseband signal (i.e. near half the Nyquist rate for the double-

side band physical passband signal). Almost the whole available frequency band can be utilized. OFDM generally has a nearly 'white' spectrum, giving it benign electromagnetic interference properties with respect to other co-channel users.

A simple example: A useful symbol duration T_U = 1 ms would require a sub-carrier spacing of $\Delta f = \frac{1}{1\,\text{ms}} = 1\,\text{kHz}$ (or an integer multiple of that) for orthogonality. N = 1,000 sub-carriers would result in a total passband bandwidth of $N\Delta f$ = 1 MHz. For this symbol time, the required bandwidth in theory according to Nyquist is $N/2T_U$ = 0.5 MHz (i.e., half of the achieved bandwidth required by our scheme). If a guard interval is applied (see below), Nyquist bandwidth requirement would be even lower. The FFT would result in N = 1,000 samples per symbol. If no guard interval was applied, this would result in a base band complex valued signal with a sample rate of 1 MHz, which would require a baseband bandwidth of 0.5 MHz according to Nyquist. However, the passband RF signal is produced by multiplying the baseband signal with a carrier waveform (i.e., double-sideband quadrature amplitude-modulation) resulting in a passband bandwidth of 1 MHz. A single-side band (SSB) or vestigial sideband (VSB) modulation scheme would achieve almost half that bandwidth for the same symbol rate (i.e., twice as high spectral efficiency for the same symbol alphabet length). It is however more sensitive to multipath interference.

OFDM requires very accurate frequency synchronization between the receiver and the transmitter; with frequency deviation the sub-carriers will no longer be orthogonal, causing *inter-carrier interference* (ICI) (i.e., cross-talk between the sub-carriers). Frequency offsets are typically caused by mismatched transmitter and receiver oscillators, or by Doppler shift due to movement. While Doppler shift alone may be compensated for by the receiver, the situation is worsened when combined with multipath, as reflections will appear at various frequency offsets, which is much harder to correct. This effect typically worsens as speed increases,[2] and is an important factor limiting the use of OFDM in high-speed vehicles. In order to mitigate ICI in such scenarios, one can shape each sub-carrier in order to minimize the interference resulting in a non-orthogonal subcarriers overlapping.[3] For example, a low-complexity scheme referred to as WCP-OFDM (*Weighted Cyclic Prefix Orthogonal Frequency-Division Multiplexing*) consists in using short filters at the transmitter output in order to perform a potentially non-rectangular pulse shaping and a near perfect reconstruction using a single-tap per subcarrier equalization.[4] Other ICI suppression techniques usually increase drastically the receiver complexity.[5]

OFDM extended with multiple access

OFDM in its primary form is considered as a digital modulation technique, and not a multi-

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user channel access method, since it is utilized for transferring one bit stream over one communication channel using one sequence of OFDM symbols. However, OFDM can be combined with multiple access using time, frequency or coding separation of the users.

In orthogonal frequency-division multiple access (OFDMA), frequency-division multiple access is achieved by assigning different OFDM sub-channels to different users. OFDMA supports differentiated quality of service by assigning different number of sub-carriers to different users in a similar fashion as in CDMA, and thus complex packet scheduling or Media Access Control schemes can be avoided. OFDMA is used in:

- the mobility mode of the IEEE 802.16 Wireless MAN standard, commonly referred to as WiMAX,
- the IEEE 802.20 mobile Wireless MAN standard, commonly referred to as MBWA,
- the3GPP Long Term Evolution (LTE) fourth generation mobile broadband standard downlink. The radio interface was formerly named High Speed OFDM Packet Access (HSOPA), now named Evolved UMTS Terrestrial Radio Access (E-UTRA).
- the now defunct Qualcomm/3GPP2Ultra Mobile Broadband (UMB) project,

intended as a successor of CDMA2000, but replaced by LTE.

OFDMA is also a candidate access method for the IEEE 802.22*Wireless Regional Area Networks* (WRAN). The project aims at designing the first cognitive radio based standard operating in the VHF-low UHF spectrum (TV spectrum).

In Multi-carrier code division multiple access (MC-CDMA), also known as OFDM-CDMA, OFDM is combined with CDMA spread spectrum communication for coding separation of the users. Co-channel interference can be mitigated, meaning that manual fixed channel allocation (FCA) frequency planning is simplified, or complex dynamic channel allocation (DCA) schemes are avoided.

Idealized system model

This section describes a simple idealized OFDM system model suitable for a time-invariant AWGN channel.

Transmitter
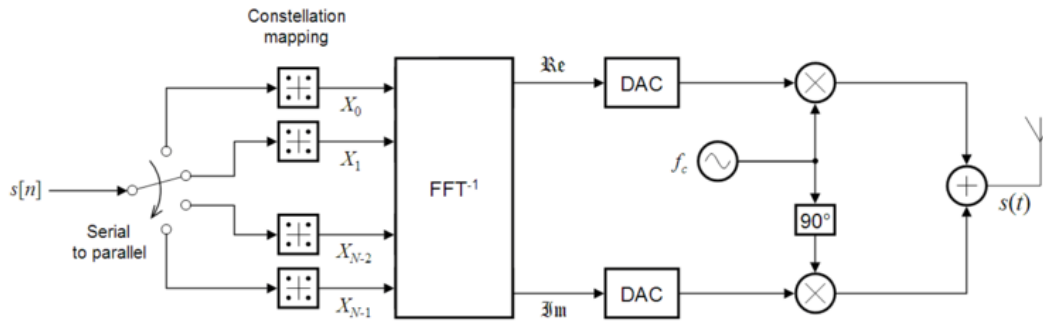
An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with baseband data on each sub-carrier being independently modulated commonly using some type of quadrature amplitude modulation (QAM) or phase-shift keying (PSK). This composite baseband signal is typically used to modulate a main RF carrier.

$s[n]$ is a serial stream of binary digits. By inverse multiplexing, these are first demultiplexed into N parallel streams, and each one mapped to a (possibly complex) symbol stream using some modulation constellation (QAM, PSK, etc.). Note that the constellations may be different, so some streams may carry a higher bit-rate than others.

An inverse FFT is computed on each set of symbols, giving a set of complex time-domain samples. These samples are then quadrature-mixed to passband in the standard way. The real and imaginary components are first converted to the analogue domain using digital-to-analogue converters (DACs); the analogue signals are then used to modulate cosine and sine waves at the carrier frequency, f_c, respectively. These signals are then summed to give the transmission signal, $s(t)$.

Receiver
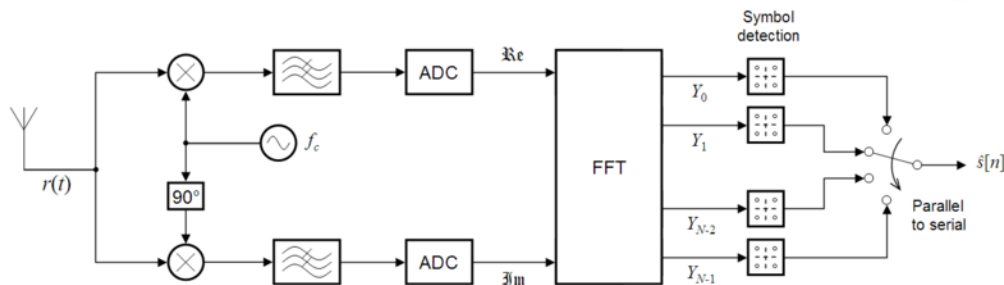
The receiver picks up the signal $r(t)$, which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency.

This also creates signals centered on $2f_c$, so low-pass filters are used to reject these. The baseband signals are then sampled and digitised

using analog-to-digital converters (ADCs), and a forward FFT is used to convert back to the frequency domain.

This returns N parallel streams, each of which is converted to a binary stream using an appropriate symbol detector. These streams are then re-combined into a serial stream, $\hat{s}[n]$, which is an estimate of the original binary stream at the transmitter.

Usage

OFDM is used in Digital Audio Broadcasting (DAB), Digital television DVB-T/T2 (terrestrial), DVB-H (handheld), DMB-T/H, DVB-C2 (cable), Wireless LAN IEEE 802.11a, ADSL (G.dmt/ITU G.992.1), Mobile phone 4G.

DOA

In signal processing literature, direction of arrival denotes the direction from which usually a propagating wave arrives at a point, where usually a set of sensors are located. These set of sensors forms what is called a sensor array. Often there is the associated technique of beamforming which is estimating the signal from a given direction. Various engineering problems addressed in the associated literature are:

- Find the direction relative to the array where the sound source is located.

- Direction of different sound sources around you are also located by you using a process similar to those used by the algorithms in the literature.

- Radio telescopes use these techniques to look at a certain location in the sky.

- Recently beamforming has also been used in RF applications such as wireless communication. Compared with the spatial diversity techniques, beamforming is preferred in terms of complexity. On the other hand beamforming in general has much lower data rates. In multiple access channels (CDMA, FDMA, TDMA), beamforming is necessary and sufficient.

- Various techniques for calculating the direction of arrival, such as Angle of Arrival (AoA), Time Difference of Arrival (TDOA), Frequency Difference of Arrival (FDOA), or other similar associated techniques.

Simulation and results

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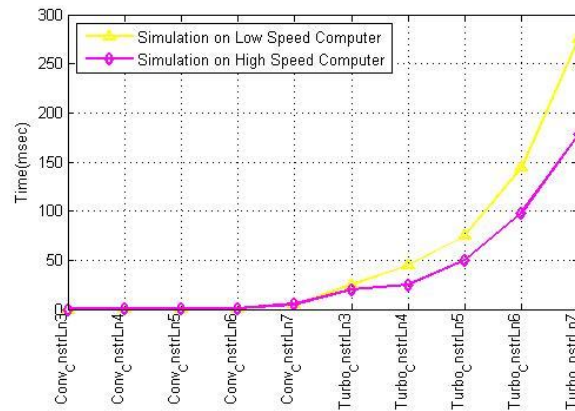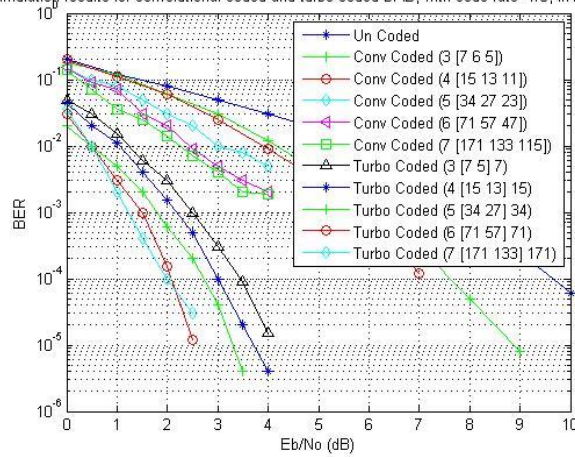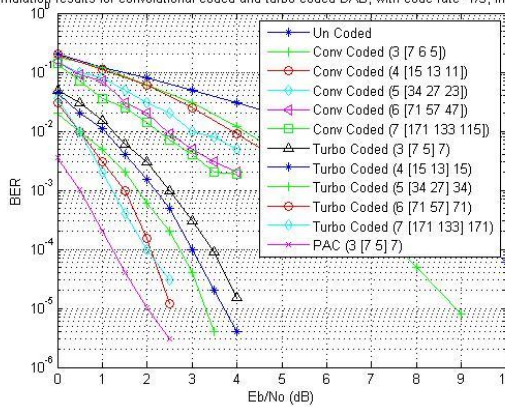
5. CONCLUSION:

The channel selected only introduces Gaussian noise. But problems faced by fading and multipath can be analyzed by choosing other channel models. Instead of QPSK modulation scheme, the same system can be analyzed using other modulation techniques like DQPSK and QAM. Instead of parallel concatenated convolution turbo codes, serial concatenated convolution turbo code also can be implemented and analyzed.

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