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Performance Affected by Guard Period with Cyclic Prefix Introducing in OFDM Technology in DAB System

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Abstract: OFDM is a special form of multicarrier modulation (MCM), where a single data stream is transmitted over a number of lower rate subcarriers. OFDM is a combination of modulation and multiplexing. Multiplexing generally refers to independent signals, those produced by different sources. So it is a question of how to share the spectrum with these users. In OFDM the question of multiplexing is applied to independent signals but these independent signals are a sub-set of the one main signal. In OFDM the signal itself is first split into independent channels, modulated by data and then re-multiplexed to create the OFDM carrier. One of the main reasons to use OFDM is to increase the robustness against frequency selective fading and narrowband interference. In a single carrier system, a single fade or interferer can cause the entire link to fail, but in a multicarrier system, only a small percentage of subcarriers will be affected. Error correction coding can then be used to correct the few erroneous sub carriers. This paper presents the use of guard period with cyclic prefix in OFDM's current form and its impact.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), BER, ISI, PAPR, DAB.

Introduction

In order to overcome the problem of multipath fading environment and bandwidth efficiency OFDM technology was proposed for implementing DAB technology. OFDM is a combination of modulation and multiplexing. OFDM is based on a parallel data transmission scheme that reduces the effect of multipath fading and makes the use of complex equalizers unnecessary. OFDM is derived from the fact that the high bit stream data is transmitted over large number sub-carriers (obtained by dividing the available bandwidth), each of a different frequency and these carriers are orthogonal to each other

1.1 Introduction of Guard band with Cyclic Prefix in OFDM Signal

Consider a distortion that a frequency selective fading channel gives to an OFDM signal. Frequency selective fading channel can be characterized by an impulse response with delay spread in the time domain, which is not negligibly small as compared with one symbol period. Figure 1 shows an instantaneous impulse response of a frequency selective fading channel, where we can see two paths and τmax denotes the time delay between the first and second paths.

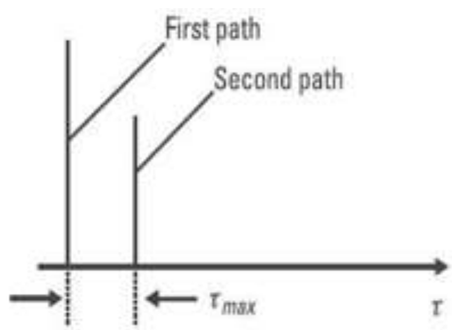

Figure 1: Instantaneous impulse response of a frequency selective fading channel

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Through the channel, the first path generates the desired signal and the second path the delayed signal at the receiver. Figure 2(a–c) shows three transmitted signals and Figure 3 (a–c) shows the corresponding three received signals. Here, we pay attention only to waveforms at a certain sub-carrier (k = 2).

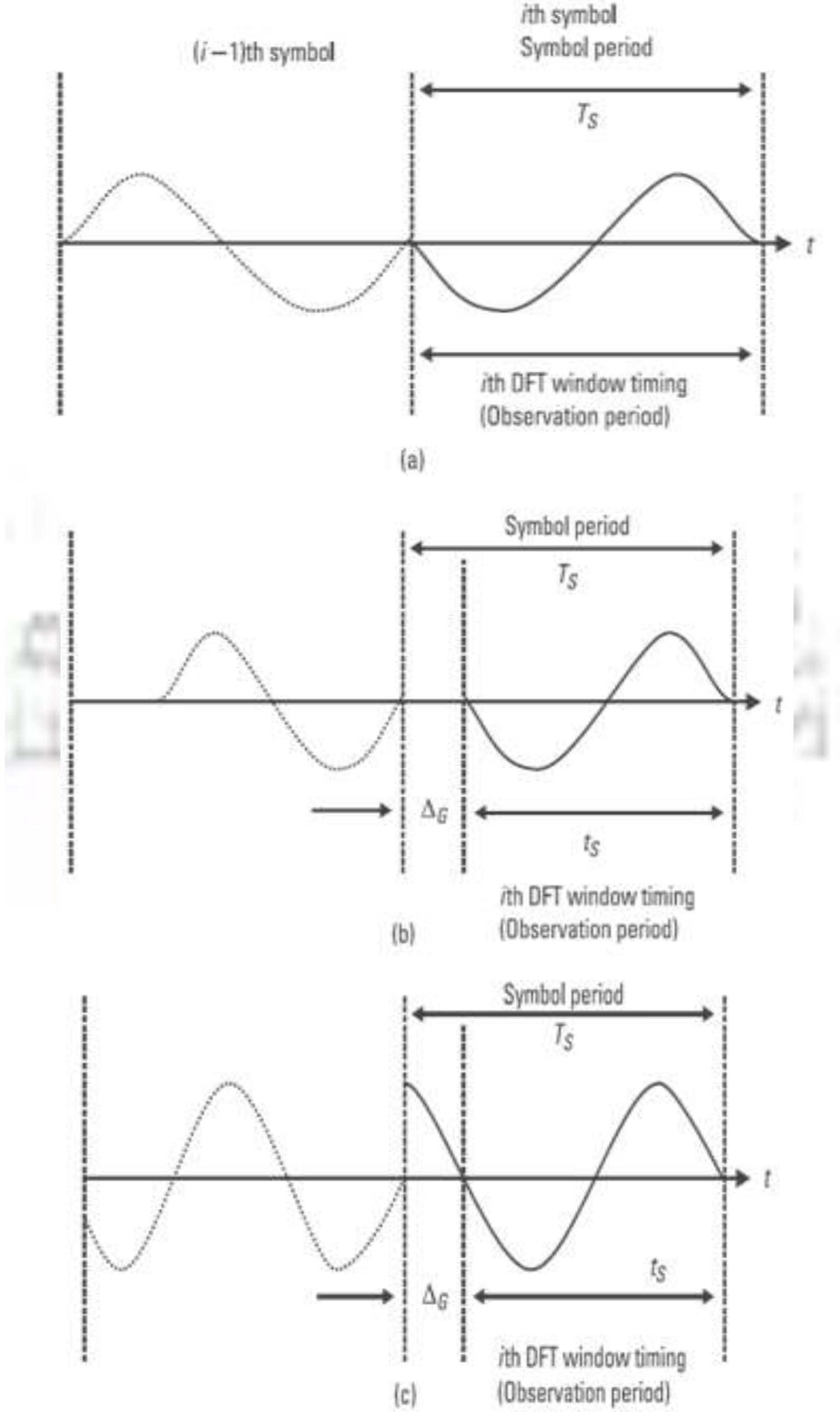

Figure 2: Transmitted signals: (a) no guard interval insertion; (b) guard interval insertion; and (c) guard interval insertion with cyclic prefix.

Without a guard interval between successive OFDM symbols, inter-symbol interference (ISI) from the (i - 1)th symbol gives a distortion to the i th symbol [compare Figure 2(a) with Figure 3(a) and see the thick line in Figure 3(a)]. If we employ a guard interval (no signal transmission) with length of ΔG > t max , we can perfectly eliminate ISI, but a sudden change of waveform contains higher spectral components, so they result in inter-subcarrier interference.

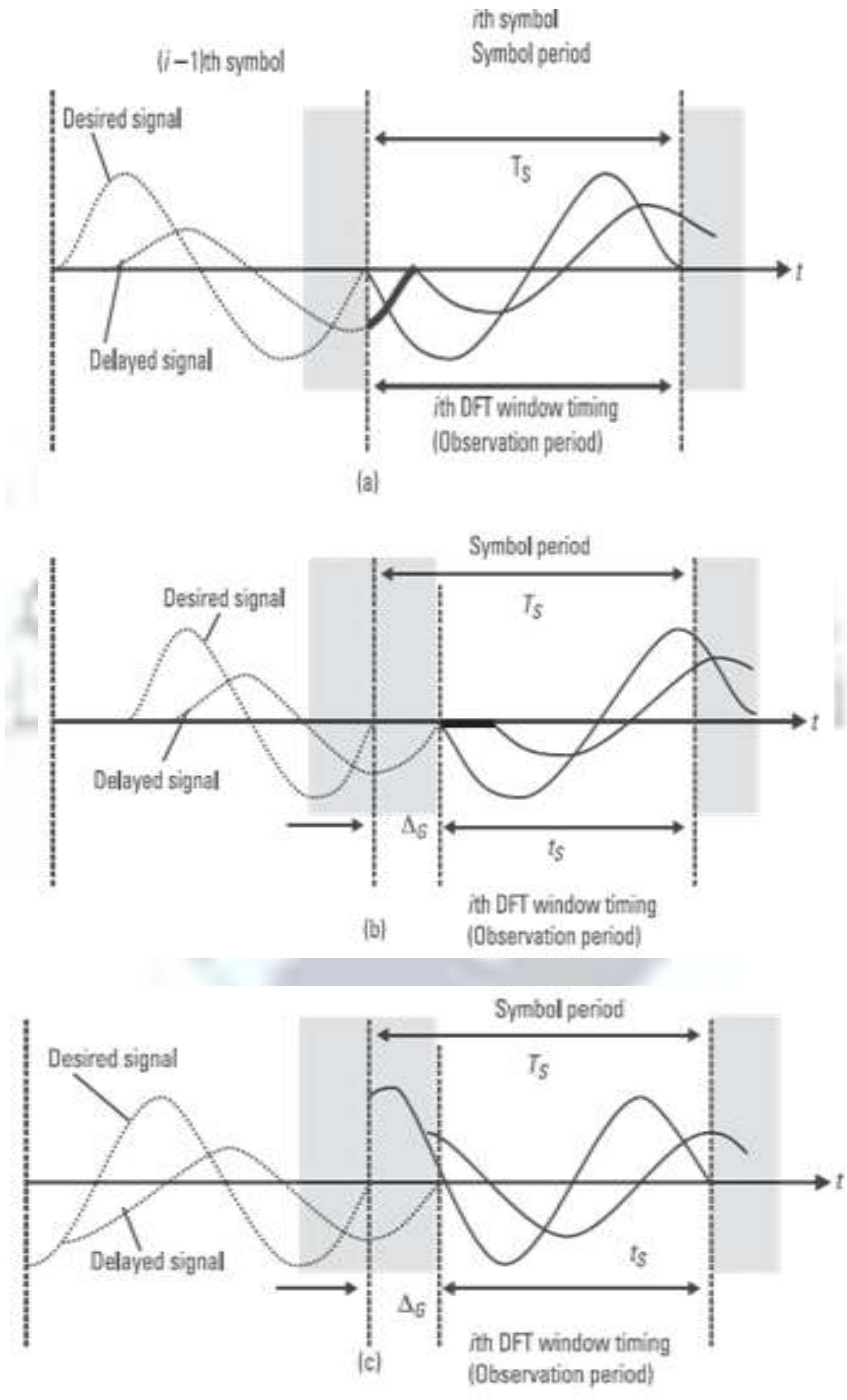

Figure 3: Received signals: (a) no guard interval insertion; (b) guard interval insertion; and (c) guard interval insertion with cyclic prefix.

Figure 2(c) shows the guard interval insertion technique with cyclic prefix to perfectly eliminate intersubcarrier interference, where the OFDM symbol is cyclically extended in the guard time. Note that the OFDM symbol is T_s long but the subcarrier frequency is an integer multiple of $1/t_s$. This implies that the subcarrier separation now becomes a bit larger, namely, $1/t_s$.

The transmitted signal with the cyclic extension is finally written as:

$$s(t) = \sum_{i=-\infty} \sum_{k=1} c_{ki}\, e^{j2p\, fk\,(t - iTs)}\, f(t - iTs)$$

$$f(t) = \begin{cases} 1, & -\Delta_G < t < t_s \\ 0, & \text{Elsewhere} \end{cases} \qquad (2)$$

$$f(k) = (k-1)/\, t_s\,,\ \Delta f = 1/\, t_s. \qquad (3)$$

where c_{ki} is the i th information symbol at the kth subcarrier, and $f(t)$ is the pulse waveform of the symbol. Ts, Δ_G and t_s are the OFDM symbol period, guard interval length, and observation period (often called ‘‘useful symbol length’’), respectively, and they satisfy the following equation:

$$Ts = \Delta_G + t_s \qquad (4)$$

The OFDM waveform of all the systems is mathematically expressed by (1) to (4) in the sense that it is transmitted and received with the IDFT and DFT and that it has a guard interval. Now, it can be called ‘‘the current form of OFDM.’’
For the OFDM signal, the total symbol transmission rate is given by

$$R = 1/T = N_{SC}/\, T_S \qquad (5)$$

and the bandwidth in terms of main lobe is written as

$$B_{OFDM} = 2/T_S + (N_{SC}-1)/(1-\alpha_G)T_S \qquad (6)$$

Where α_G is guard interval factor, which is defined as

$$\alpha_G = \Delta_G/T_S \qquad (7)$$

When the number of subcarriers is large, the bandwidth of the OFDM signal normalized by R is written as

$$B_{OFDM}/R = 1/(1-\alpha_G) \qquad (8)$$

Figure 4 shows the cyclic extension technique, frequency spectrum of pulse waveform, and frequency spectrum of transmitted signal in the current form of OFDM.

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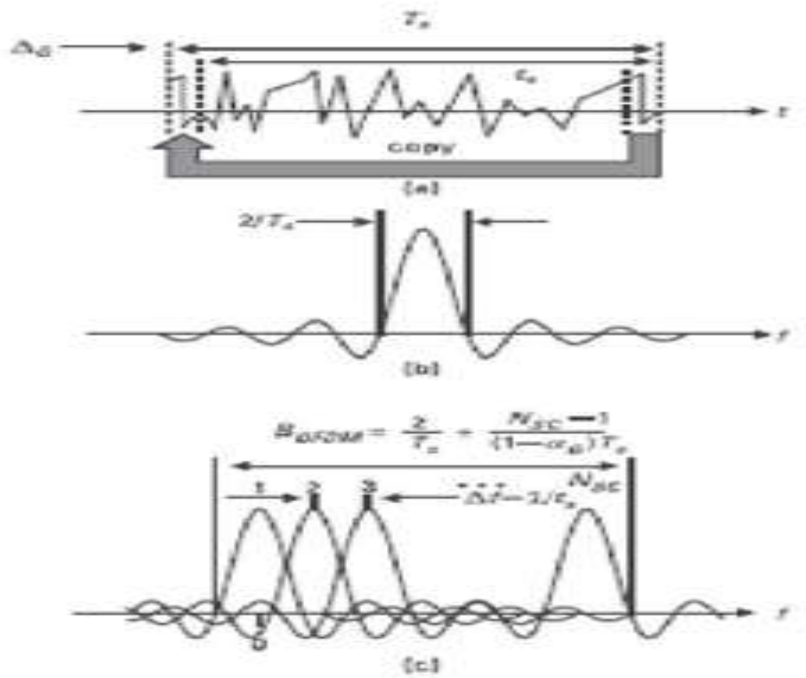

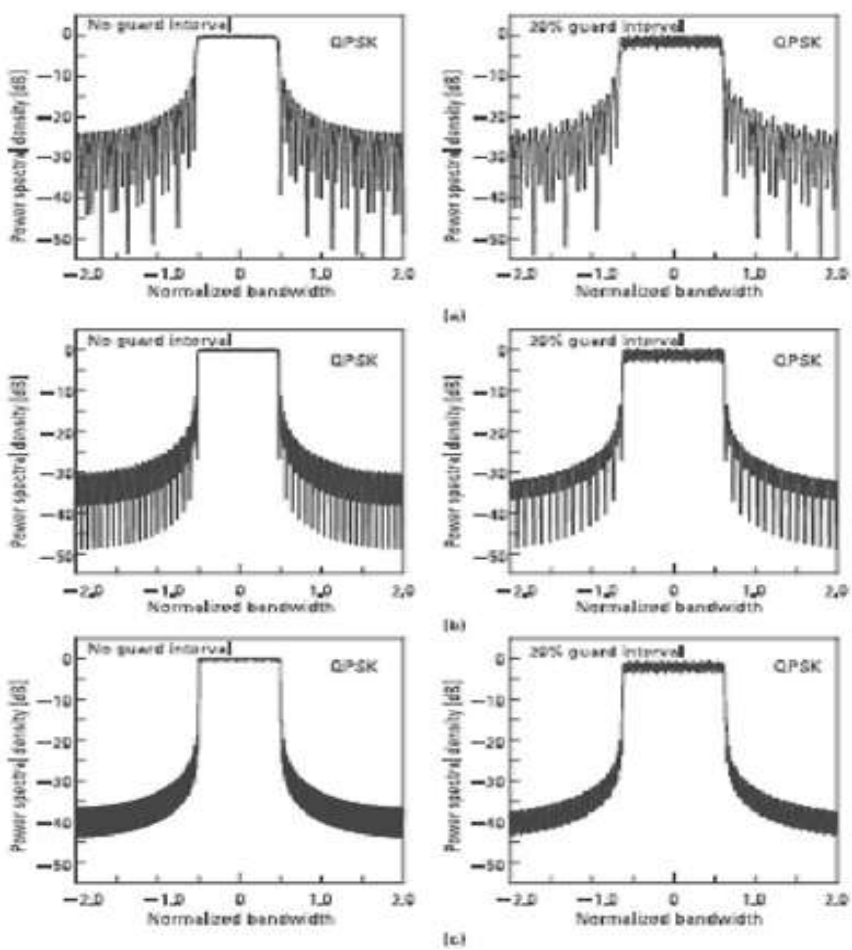

Fig 5: Transmitted power spectra of OFDM signals: (a) 16 subcarriers; (b) 64 subcarriers; and (c) 256 subcarriers.

Conclusions

OFDM system has its own advantages & disadvantages like High Inter-channel/ Symbol interference (ISI/ICI), Sensitiveness to frequency synchronization (PAPR) peak to average power ratio, Sensitive to Doppler Shift & problem.. This gave rise to find the solution for overcoming or reducing to the extent The time till the multi path propagation delays do not exceed the duration of the interval, zero inter symbol interference occurs and no channel equalization is required. The OFDM is implemented to combat transmission channel impairments. Its applications have been extended from high frequency (HF) radio communication to telephone networks, digital audio broadcasting, and digital television terrestrial broadcasting. The advantage of OFDM, especially in the multipath propagation, interference, and fading environment, makes the technology a promising alternative in digital broadcasting and communications.

These systems suffer from two major impairments namely Inter Symbol Interference and Inter Subcarrier Interference. While insertion of guard band eliminates the former, a cyclic prefix in the guard band eliminates the later.

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