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Overview of the Key Advantages of OFDM System and its Effects of Drawbacks

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Abstract: ***Due to increasing data traffic worldwide, the demands on optical communication systems in terms of bit rate, spectral efficiency and bandwidth flexibility will increase in the coming years. To cope with this, among other things, the multi-carrier orthogonal frequency division multiplexing (OFDM) in combination with coherent reception is under discussion for future systems. However, as OFDMS systems are sensitive to nonlinear perturbations, this work presents Procedures that reduce such influences. Thus, impairments of the channel estimation are examined by transmitter-side quantization errors and possibilities are shown of reducing them or even eliminating them altogether. In addition, the influence of the non-linear characteristic of the electro-optical modulator is studied and demonstrated that nonlinear distortions can be significantly reduced by digital preprocessing of the transmission signal. On the receiver side, this work deals with synchronization procedures for frame detection and estimation of the frequency deviation between carrier and local oscillator. For this purpose, digital methods are developed which provide a sufficiently accurate estimate for modulation formats with high spectral efficiency under the influence of chromatic dispersion and amplifier and phase noise.***

Keywords: Overview, advantages, OFDM, drawbacks, disadvantages

1. Introduction

The aim of this paper is to provide some theoretical background on the OFDMtransmission technique, which is the general topic of the rest of this paper. We review the block diagram of a “classic” OFDM system, which employs a guard interval to mitigate the impairments of the multipath radio channel.

Modulation techniques for wireless communication systems can be divided into two basic approaches. On the one hand, there is intruder modulation, where data is modulated and transmitted to a single carrier frequency. Entry procedures are used, for example, in second and third generation mobile communication systems (GSM, UMTS).On the other hand, there is the concept of multi-carrier modulation. In this case, the data is transmitted in parallel over several sub-carriers. Orthogonal Frequency Division Multiplexing (OFDM) is one of these multi-carrier modulation techniques.Due to the particularly efficient use of bandwidth, OFDM is of interest as a modulation method for high-speed as example fortrain communication systems. Since OFDM is used as a basic system in this work, it will be explained below.Figure.1 shows the block diagram of a simplex transmission system using OFDM and forward error correction coding. The three main principles incorporated are: [1,2]

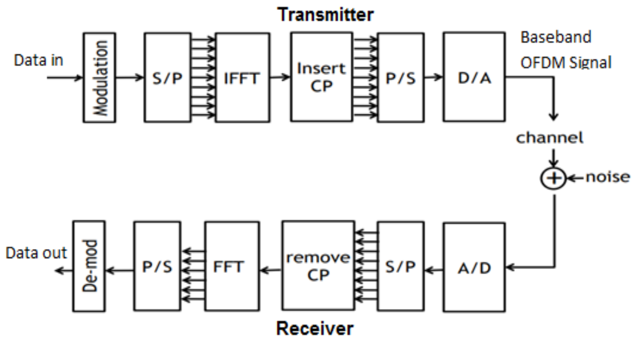

Figure 1: A block diagram representation of a baseband OFDM transmission system

2. Modulation Method

Each carrier is first modulated separately. Depending on which of the three free parameters frequency, amplitude and phase are used for it, it carries per bit of information one or more bits. The signal curve of a symbol is composed of the sum of all modulated carriers in OFDM. Thus, in OFDM, a very large number of bits are transmitted in parallel. If, for example, as in practical applications, approximately 7,000 carriers are used and four bits are transmitted per carrier, a symbol has an information content of a maximum of 28,000 bits, which are transmitted in parallel in one symbol step. In practice, the number of bits is slightly lower, as some carrier frequencies are used for synchronization, as a pilot tone, and for operation. The channel coding for forward error correction also reduces the useful data quantity.According to the low spectral distance of the carrier frequencies with each other is modulated with only a small bandwidth. Therefore, the symbol duration in OFDM is much longer compared to single-carrier methods. Thus, with a total bandwidth of 8 MHz and 7000 carrier frequencies, the rough guideline value is a symbol duration of 875 µs. The achievable maximum bit rate is around 32 Mbps. For accurate interpretation, several other parameters such as the maximum delay spread for multipath must be considered.[3]

2.1 OFDM-Modulator

OFDM signals are generated with the complex calculating inverse discrete Fourier transforms (IDFT). The IDFT assumes that all subcarrier frequencies are orthogonal to each other. The block length of the IDFT corresponds to the number of subcarriers. IDFT can be completely realized in digital technology with digital signal processors, so that the high-frequency part of the circuit remains relatively simple. Orthogonality exists if and only if: [3,4]

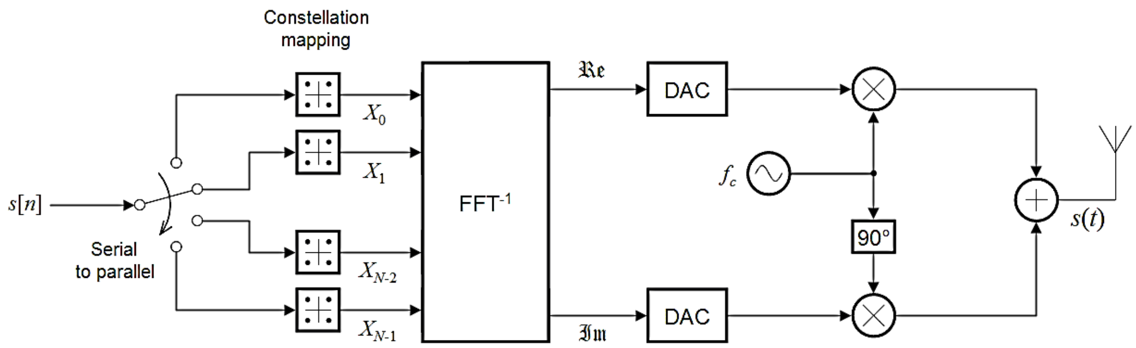

Figure 1.1: Transmitter

2.2 OFDM-Demodulator

On the receiver side, the individual carriers must be separated from the signal mixture. This could be done with individual filters, which, however, is too costly for more than a handful of frequencies. Therefore, all OFDM decoders today use a Fast Fourier Transform (FFT) which undoes the IFFT at the transmitter. The input data of the FFT are the digitized values of the signal from an analog-to-digital converter (ADC).

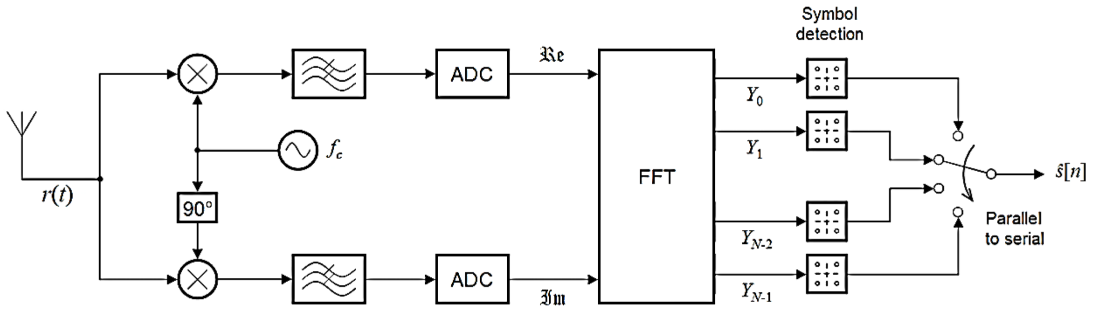

Figure1.2: Receiver

3. Development of OFDM

The OFDM technique has been known since the late 1960s. The patent [Cha70] by R.W. Chang contains the basic idea of the procedure. S. B. Weinstein and P.M. Ebert [1971] provide in the first description of the OFDM method as used today. However, the method was not used for a long time because the computing power required in the sender and receiver was not available or was too time-consuming. Before OFDM eventually became part of wireless communication systems (1994 US patent [FZ94]), it has found application in wired systems such as Digital Subscriber Line (DSL).Today, OFDM is already used in several broadcasting systems: Digital Audio Broadcast (DAB), Digital Video Broadcast Terrestrial (DVB-T), Digital Video Broadcast Handheld (DVB-H). In addition, it is the basis of various standards of the Institute of Electrical and Electronics Engineers (IEEE) for wireless communication.An overview of some of these standards is shown in Table1. From the table goesThe faster a participant moves, the harder it is to get a high data rate. The most well-known application of OFDM is the communication within wireless local area networks (WLAN, also known as Wireless Fidelity, Wi-Fi), which is now integrated in almost every laptop.

OFDM is considered the most promising candidate for future fourth-generation mobile communications systems [Cor06, Gol05, RA + 02, Lu03]. This is mainly thanks to OFDM's flexibility and advances in processor technology.

3.1. OFDM transmission

OFDM is a multi-carrier method in which the information symbols on many Carriers are transmitted in parallel. In contrast to conventional frequency division multiplex systems, the individual carriers overlap in OFDM.

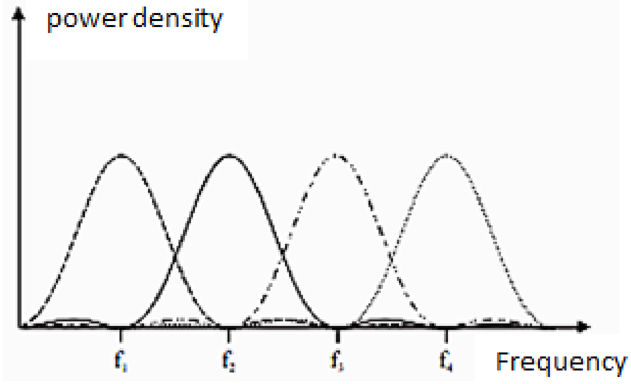

Figure 2: OFDM carrier with overlapping spectra

However, they remain at a suitable choice of the subcarrier spacing $\Delta f = | fn - fn-1 |$ orthogonal, allowing interference-free transmission with high spectral efficiency. Figure 2.2 illustrates the power density spectrum of an OFDM system with four carriers.

If at the center frequency of a carrier fn all other carriers have a zero crossing, the system remains interference free.

In general, all carrier pairs fm and fn with a real-valued pulse shaping g (t) are orthogonal, if applicable

$$g2e{-j}^{2\pi fmt}\cdot e\int_{-\infty}^{\infty} j^{2\pi fnt}\,dt = C\cdot\delta(m-n)\ \forall\ 0\leq m,n\leq K-1,\quad (1)$$

where K represents the number of carriers in the OFDM system.

A particularly simple way of constructing a system which satisfies the condition (1) is to select all carriers in the baseband as an integer multiple of a fundamental frequency Δf, so that

$$fk = k\cdot\Delta f\ with 0\leq k\leq K-1 \qquad (2)$$

applies. If one now chooses a rectangle of length T S as a pulse shape, then Condition (2.1) satisfies, if the window length and thus the symbol duration T S assumes the reciprocal value of the carrier distance, i.e.

$$TS = 1 / \Delta f. \qquad (3)$$

Then applies

$$e^{-j2\pi fmt}.\int_{0}^{T_S} e^{j2\pi fnt}dt = 0\ \forall\ m\neq n. \qquad (4)$$

The subcarriers of an OFDM system can be represented as a Dirac comb in the frequency domain. The windowing in the time domain corresponds in the frequency domain to a convolution of this Dirac comb with a sin(x)/x function.[5]

4. System Description

Unlike admission procedures, OFDM allocates a data stream to different sub-carriers within the available bandwidth. The resulting sub-data streams are processed by means of inverse discrete Fourier transformation in the transmitter and discrete Fourier transformation in the receiver. Figure 3 schematically illustrates an OFDM system from transmitter to receiver. Such a system offers advantages in the case of a frequency-selective radio channel, as the bandwidth of each subcarrier is much smaller than the overall bandwidth of the single carrier system. The bandwidth of the subtractions is chosen so that it is not frequency selective, i.e. less than the outer bandwidth. Due to the simultaneous transmission of several bits on the subcarriers, the symbol duration of a single bit compared to the original data stream increases by the number of subcarriers. If the radio channel has too long after-effects (time dispersion due to multipath propagation), previous symbols may disturb the current symbol.

The heart of an OFDM system is the inverse discrete Fourier transformation in the transmitter or the discrete Fourier transformation in the receiver, which is formally described in accordance with Figure3.An input signal Xn (k) consists of a sequence of already modulated code bits. A series-to-parallel converter divides the sequence into n blocks of length N, where N equals the subcarrier number. A block (e.g., from X1 (1) to X1 (N)) corresponds to the amount of data contained in an OFDM payload symbol. The blocks are then transformed by means of inverse discrete Fourier transformation (IDFT). The transformation results in the discrete transmission signal in the time domain Xn (t), where the index denotes the nth time slot. Formally, Xn (t) can be described by equation (5).

$$I(t)^n = 1/\sqrt{T}\sum_{k=1}^{n} X(k)e^{j2\pi fkt} \qquad \text{with } 0\leq t\leq Ts \quad (5)$$

k stands for the subcarrier index, which takes integer values between 1 and N. N represents the total number of bits in an OFDM symbol, or the number of subcarriers. Ts denotes the symbol duration.[6,7]

Table 1: Some IEEE standards for wireless communication based on OFDM

Name	Norm	frequency band	purpose
Wireless Local Area Network (WLAN), Wireless Fidelity (Wi-Fi)	IEEE 802.11 IEEE 802.11a/h IEEE 802.11b/g IEEE 802.11n	2,4GHz 5GHz 2,4GHz 2,4GHz / 5 GHz	Data transmission up to 2 Mbps up to 11 Mbps / 54 Mbps up to 11Mbps / 54Mbps MIMO extension up to 600 Mbps (draft)
Wireless Metropolitan Area Network (WMAN), WorldwideInteroperabilityfor Microwave Access (WiMAX)	IEEE 802.16	2-66 GHz	up to 1GBit / s for stationary participants(Broadband Fixed Wireless Access),up to 100MBit/s for mobile applications low speed
Mobile Broadband WirelessAccess (MBWA)	IEEE 802.20	< 3,5GHz	Mobility extension to IEEE 802.16, up to 1 Mbps at <250 km / h

For the subcarrier frequency fk in the baseband, the following applies: $f_k = k\cdot\Delta f$
Δf indicates the sub-carrier distance at a channel bandwidthof the total system of BW = N · Δf.

In addition, a cyclic prefix is added to the signal, it goes through a parallel-to-serial converter and is converted from a digital to an analog signal (D/A). Finally, it is mixed up in the frequency range of the transmission f_0 and transmitted via the radio channel. On the receiving side, the signal is mixed down and converted from an analog to a digital signal (A/D).

This is followed by a series-parallel conversion and the cyclic prefix is removed again. The remaining signal is transformed back by means of a discrete Fourier transform (DFT) and then runs through a parallel-to-serial converter. In reality, the radio channel and the analog hardware alters the transmit signal Xn (t), which can be described by a convolution with the time-variant channel impulse response and additive noise. By means of channel estimation the original bit sequence is restored in the receiver.[4,9]

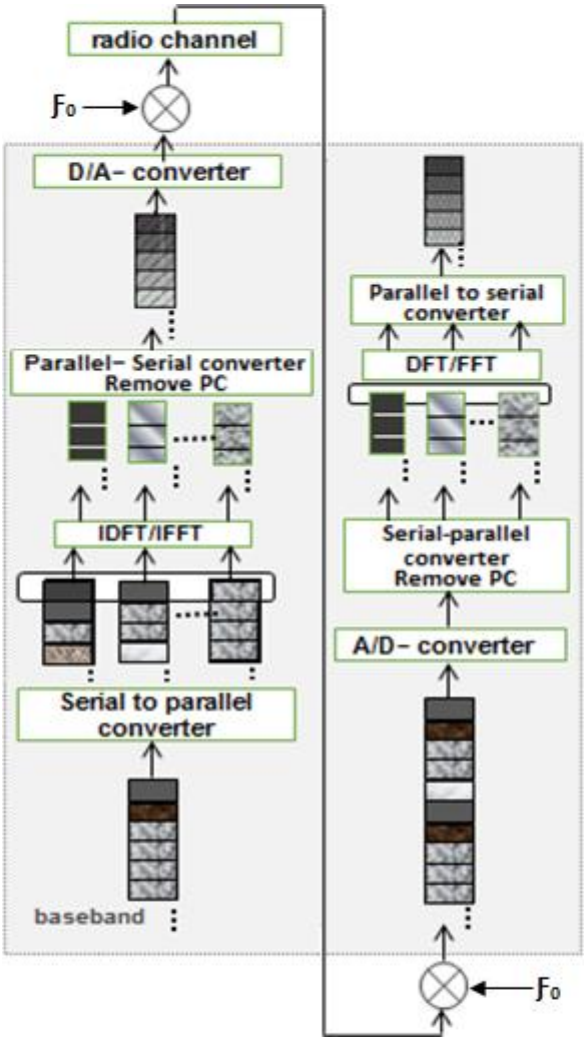

Figure 3: Schematic representation of an OFDM system from the transmitter to the Receiver

For reasons of clarity, the equations for the ideal case of the return transformation in the receiver are given here. In the ideal case, the original signal xn (t) is available for the DFT. If the symbol duration of the orthogonal condition

$$Ts = 1/\Delta f \tag{6}$$

if sufficient, the OFDM signal in the receiver can be correctly recovered by means of a DFT:

$$X_n(k) = \frac{1}{\sqrt{T_s}} \sum_{t=0}^{T_s} x_n(t)\, e^{-j2\pi f_k t} \tag{7}$$

After inserting equation (7) and resolutions, the input signal divided into n OFDM symbols results:

$$\begin{aligned} X_n(k) &= \frac{1}{\sqrt{T_s}} \sum_{t=0}^{T_s} \frac{1}{\sqrt{T_s}} \sum_{k=1}^{N} X_n(k)\, e^{j2\pi f_k t}\, e^{-j2\pi f_k t} \\ &= X_n(k) \end{aligned} \tag{8}$$

The original input signal Xn (k) is restored after the parallel-to-serial conversion. In the case of a modification of the transmitted signal by the radio channel and noise, not the original sequence is recovered, but a changed sequence Xn (k).

In order to reduce the complexity of the transmitter and the receiver, the IDFT is realized by an inverse fast Fourier transform (IFFT) and the DFT by a fast Fourier transform (FFT). In the OFDM transmitter, the cyclic prefix is preceded by the useful signal during parallel-to-serial conversion. In the receiver, it is removed during serial-parallel conversion. The following two subchapters first describe the OFDM signal in the time domain, then in the frequency domain. The cyclic prefix is explained in the context of the time domain.

4.1 OFDM in the time domain

Figure 4. shows how to generate an OFDM symbol in the transmitter. The generated signal can be illustrated in the time domain according to Figure 5. The total signal consists of the OFDM payload of duration Ts, preceded by a cyclic prefix of length T_{CP}. In the literature, the term guard interval (GI) is often used instead of the cyclic prefix. The cyclic prefix copies a portion of the generated OFDM symbol and is present either before, after, or before and after the payload. In the further description it is assumed that the cyclic prefix is prefixed to the OFDM symbol. The repetition of the last part of the OFDMS symbol gives the total symbol the periodicity which is required for a transformation with the efficiently implementable IFFT or FFT. In a real radio channel with multipath propagation, the transmitted symbols arrive at the receiver via different propagation paths of different lengths. This leads to a temporal widening of the symbols, the pulse broadening. Multipath paths that arrive at the receiver with a time delay are completely reset due to the CP's periodicity and contribute constructively to the signal. [10]

$$T_{total} = TCP + Ts \tag{9}$$

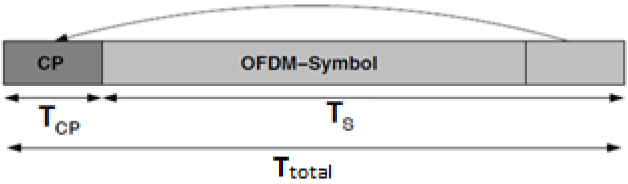

Figure 4: OFDM symbol in the time domain

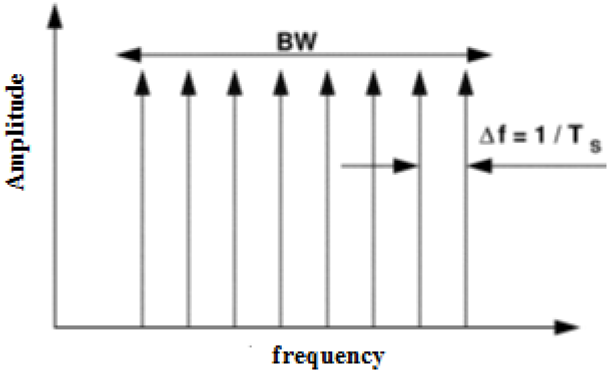

Figure 5: Spectrum of an OFDM signal in the frequency domain, for illustrative purposes, the sub-carriers are represented as delta pulses.

Therefore, in an OFDM system, the cyclic prefix is not just the temporal oneSeparation of the symbols, but also the complete re-transformation of the time-delayed paths.

4.2 OFDM in the frequency domain

An OFDM symbol generated in the transmitter according to Figure 3. results in a baseband signal.For wireless transmission, the baseband signal is mixed with a carrier frequency and thereby converted into a suitable frequency band. On the receiver side, before the demodulation of the OFDM symbol, conversion to baseband is done by down mixing. The spectrum of an OFDM system in the frequency domain and its parameters are shown schematically in Figure 6. Over the total bandwidth BW of the system, subcarriers are arranged at a distance Δf. For the sake of clarity, in this figure the sub-carriers are simplified by delta pulses. In real systems, the sub-carriers have a certain bandwidth.Therefore, the total bandwidth is equal to the subcarrier number multiplied by the subcarrier distance or subcarriers bandwidth. The number N of sub transfers is given by the total bandwidth and the subcarrier distance to:

$$N = BW / \Delta f \qquad (10)$$

Due to the orthogonality of the subcarriers, several parallel data streams can be transmitted without interference in a comparatively small frequency bandwidth.[6,10]

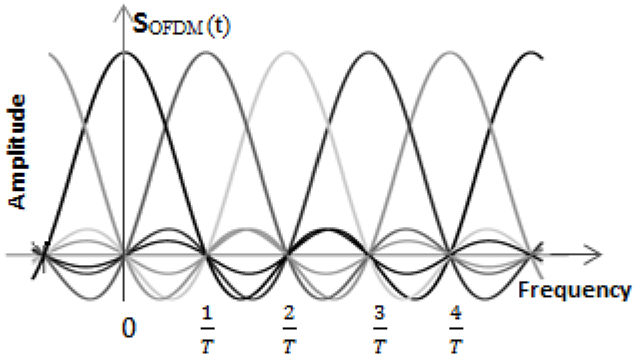

Figure 6: Orthogonal sub-carrier spectra of an OFDM signal in the frequency domain

Figure 6. shows the superimposition of the orthogonal sub-carriers in the spectral range. Each individual subcarriers has the shape of a sin curve **(**SINf /f) and overlaps the other subcarriers. The maximum of one sub-carrier is exactly above the zeros of all remaining sub-carriers, which causes no interference between the carriers. This is valid only as long as the orthogonality condition (Figure5) is satisfied.

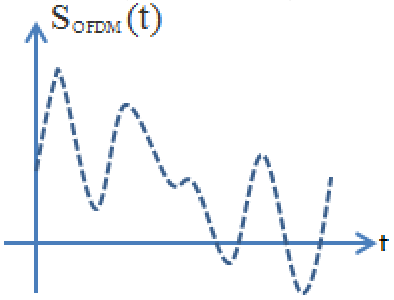

Figure 7: A symbol in OFDM with four carrier frequencies in the time domain

5. Design of the System Parameters

When planning a wireless communication system, there is usually little scope for the design of the system sizes. The frequency range, the maximum bandwidth

In any case, under all the constraints, it is necessary to use the available bandwidth as efficiently as possible. For wireless communication systems, this means achieving the highest possible data rate for a given transmission quality. The transmission quality is determined by the bit error rate.

The parameters of an OFDM system are described in the sections above. At this point, the influence of the parameters on the data rate or on the bandwidth efficiency is to be explained. The data rate in an OFDM system can be increased by:

- The total bandwidth BW is increased,
- The distance of the sub-carriers Δf is reduced or
- The length of the cyclic prefix T_{CP} is shortened.

Increasing the data rate by choosing a higher-valued modulation would be another option. However, this is not discussed, since the OFDM System per se and not the coding should be described. With otherwise identical parameters, the increase in the total bandwidth BW leads to an increase in the number of subcarriers or the data streams transmitted in parallel.

A predetermined minimum bit error rate with the same radio channel therefore defines the limit of the minimum subcarrier distance. [4,9]

6. Reducing nonlinear effects in OFDM systems

The principle of OFDM is the division of the transmission bandwidth into many (typically several hundred) narrowband carriers that are modulated individually and at a comparatively low rate. Although the subcarrier spectra overlap, as shown in Figure.7a, they can still be separated at the receiver due to their mutual orthogonality OFDM was already used in wired and wireless communication systems in the mid-1990s. In addition to the spectral efficiency, the fundamental unlimited tolerance of OFDM. This aspect is becoming increasingly important in modern optical networks, since the recently used optically transparent switching does not allow a rigid dispersion management with dispersion-compensating fibers. Rather, it requires a flexible and dynamic adaptation of the transmission system to the available connection quality and bandwidth. This requirement is inherently met by optical OFDM systems, because in its conventional form, the modulation scheme is based on both digital sender and receiver digital signal generation and processing. OFDM systems thus have the prerequisite for a software-side adaptation of the modulation level to the desired range and available connection quality. In this case, not only sub channels as in Figure7c, but also so-called super channels are needed, which combine several 50 GHz channels to those with 100 GHz to several hundred gigahertz bandwidth (Figure7d) and transport high bit rates.

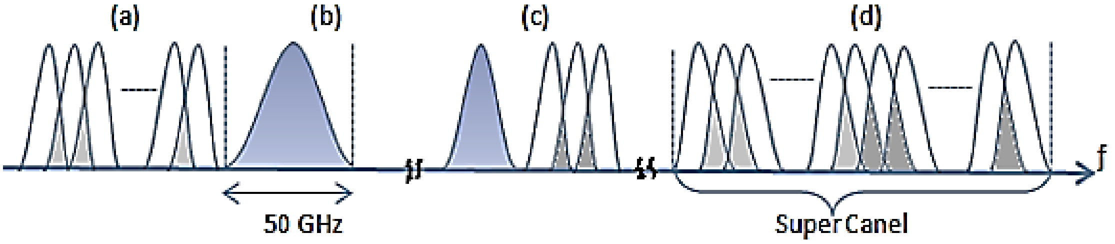

Figure 1.2: OFDM in the context of bandwidth-flexible Wavelength Division Multiplexing(WDM) systems

The fact that OFDM has not been considered for optical transmission systems until recently, despite the advantages mentioned above, is not least due to the development of digital circuit technology. Because the desired bit rates of 100 Gbit In addition, digital-to-analog converters (DAC) and analog-to-digital converters (ADC) with speeds of over 30 GHz and corresponding Bandwidths of over 15 GHz needed. In the absence of such components.

Therefore, the first experimental implementations of optical OFDM systems were based on playing recalculated signals with programmable signal generators and recording the received signal with digital storage oscilloscopes and then computer evaluation. Further research activities focus on application-specific integrated circuits with the aim of further increasing the bit rates of optical OFDM real-time systems [4,10].

7. OFDM system parameters

In DRM, different values of the signal bandwidth and the other OFDM parameters, the QAM modulation of the multiplex baseband, the error protection classes and the time interleaving can be set. These multiple values are subdivided into four OFDM modes A to D, with modes A-D defined for transmission up to 30 MHz (DRM30). Within the OFDM modes, there are several error protection classes that compensate for the typical propagation effects such as fading, selective fading, atmospheric noise, and adjacent transmitter interference. Due to the limited data rate, in case of critical propagation conditions and other compromises between a higher error protection for a good reception security and the concomitant lower net bit rate for the audio and data services transmission can be found..[10,12]

Table 1: Modulation and error protection

OFDM-Mode		MSC-QAM	error protection	Protection Level	Interleave	bandwidth (kHz)
A	DRM30	64-QAM	R=0,5 / 0,6 / 0,71 / 0,78	PL = 0 / 1 / 2 / 3	0,4 s / 2 s	4,5 / 5 / 9 / 10/18/2020
B						
C		16-QAM	R=0,5 / 0,62	PL= 0 / 1		
D						

Table 2: OFDM carrier and bandwidth

OFDM-Mode	Subcarrier spacing [Hz]	Number of subcarriers at bandwidth				
		9 kHz	10 kHz	18 kHz	20 kHz	100 kHz
A	41 2/3	204	228	412	460	---
B	46 7/8	182	206	366	410	---
C	68 2/11	---	138	---	280	---
D	107 1/7	---	88	---	178	---

Table 3: OFDM-symbol duration

OFDM-Mode	Symbol duration Tu [ms]	Guard interval Tg [ms]	Entire symbol duration Ts [ms]
A	24,00	2,66	26,66
B	21,33	5,33	26,66
C	14,66	5,33	20,00
D	9,33	7,33	16,66

- Mode A is mainly intended for local broad and medium wave broadcasts, where the transmission through the bump predominates and there is therefore little fading. Under certain conditions, Mode A (using 16-QAM) is also used for shortwave transmissions to improve data rate and thus sound quality.
- Mode B is mainly used for short wave transmissions with only one reflection at the ionosphere (so-called "single hop"). The mode B is also used at night in the long and medium wave range, since then in these bands the space wave is involved in the wave propagation.
- Mode C can be used for shortwave transmissions over long distances. Since at these distances the waves are repeatedly reflected back and forth between the ionosphere and the earth (so-called "multi-hop"), the superposition of waves with different transit times and thus signal amplifications and signal extinctions occurs here.
- Mode D is the most interference-resistant transmission mode and is mainly used for NVIS (Near Vertical Incidence Sky wave) transmissions. This type of transmission can be used in tropical regions.
- The following table shows the typical net bit rates in the respective OFDM modes and protection classes when using EEP (equal error protection) for tenders.

Table 4: Transmission rates in the respective OFDM modestransmission rates

OFDM-Mode	MSC-Modulation (nQAM)	error protection	Signal bandwidth						
			4,5 kHz	5 kHz	9 kHz	10 kHz	18 kHz	20 kHz	100 kHz
			Net data rate in Kbit / s usable for offers (equal error protection)						
A	64	max.	14,7	16,7	30,9	34,8	64,3	72,0	
		min.	9,7	10,6	19,7	22,1	40,9	45,8	
	16	max.	7,8	8,8	16,4	18,4	34,1	38,2	
		min.	6,3	7,1	13,1	14,8	27,3	30,5	
B	64	max.	11,3	13,0	24,1	27,4	49,9	56,1	
		min.	7,2	8,3	15,3	17,5	31,8	35,8	
	16	max.	6,0	6,9	12,8	14,6	26,5	29,8	
		min.	4,8	5,5	10,2	11,6	21,2	23,8	
C	64	max.				21,6		45,5	
		min.				13,8		28,9	
	16	max.				11,5		24,1	
		min.				9,2		19,3	
D	64	max				14,4		30,6	
		min.				9,1		19,5	
	16	max				7,6		16,2	
		min.				6,1		13,0	

8. Advantages and Disadvantages of OFDM-System

This section summarizes the advantages and disadvantages of OFDM technology:[1,11]

Advantages:
As advantages are the following System Description to name the aspects:

- High spectral efficiency through nearly constant spectral power densityand steeply sloping flanks for a large number of subcarriersK.
- By dividing the channel into narrowband flat fading sub channels, OFDM is more resistant to frequency selective fading than single carrier systems are.
- With a suitable design, OFDM can be very robustOwn Doppler shifts.
- Channel equalization becomes simpler than by using adaptive equalization techniques with single carrier systems.
- It is possible to use maximum likelihood decoding with reasonable complexity.
- Sufficient sizing occurs by the introduction of a guard interval no ISI on, allowing for simple channel equalizers.
- OFDM is computationally efficient by using FFT techniques to implement the modulation and demodulation functions.
- Provides good protection against co-channel interference and impulsive parasitic noise.

Disadvantages
However, OFDM also has some disadvantages that should be mentioned here.

- Accurate frequency and time synchronization are for reliable operationessential.
- Due to the superposition of many parallel carriers has the OFDM signala high ratio of peak power to average power (English: Peak to average power ratio (PAPR)), which above all high demands on thePower amplifier provides.
- The OFDM signal has a noise like amplitude with a very large dynamic range, therefore it requires RF power amplifiers with a high peak to average power ratio.
- It is more sensitive to carrier frequency offset and drift than single carrier systems are due
- to leakage of the DFT.

9. Conclusions and Recommendations

The derivation of the OFDM system model has confirmed that data symbols can be transmitted independently over multipath fading radio channels. It has to be assumed, however, that the channel's maximum excess delay is shorter than the guard interval, and that the system has been synchronized sufficiently. Small synchronization errors lead to systematic phase rotations of the data constellation points – a property which can be exploited for estimating synchronization offsets. If the timing- or frequency synchronization error becomes too large, the orthogonality of the sub-carriers is partly lost and the signal-to-noise ratio of the system is degraded.

This paper discusses the basic idea of the system of OFDM, the most emerging technologies at the time of the ban. Here we take a look at its concept, its characteristics in terms of its advantages and disadvantages, its limits and therefore its applications in different fields. This paper explored the role of OFDM in wireless communications and its advantages over single carrier transmission. Multicarrier systems are proving better in transmission than single carrier systems. OFDM is a digital multi-carrier modulation method where a large number of closely spaced orthogonal subcarriers are used to carry data. One of the serious drawbacks of in OFDM systems is that the composite transmit signal can exhibit a very high peak-to-average power ratio (PAPR) when the input sequences are highly correlated. However, the advantages outweigh the versatility of the OFDM technique in wireless and wired systems mentioned.[1,7,12]

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