Exhibit C-10

Invalidity of U.S. Patent No. 10,389,568 in View of Motorola StarTAC 7868 ("StarTAC")

The asserted claims of U.S. Patent No. 10,389,568 ("the '568 patent") obvious over Motorola StarTAC 7868 (including StarTAC 7868w) ("StarTAC") in view of the knowledge of the person of ordinary skill in the art and one or more of the following references: "A Low Complexity Transmitter Structure for OFDM-FDMA Uplink Systems" ("Galda-2002"), "A Spread-Spectrum Multi-Carrier Multiple-Access System for Mobile Communications," to Kaiser et al. ("Kaiser-1997"), "Multi-Carrier CDMA Mobile Radio Systems - Analysis and Optimization of Detection, Decoding, and Channel Estimation" ("Kaiser-1998"), "IEEE Std 802.11a-1999" ("IEEE"), U.S. Patent No. 6,188,717 to Kaiser et al. ("Kaiser-717"), "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Physical layer - General description (Release 4)" ("3GPP-25.201"), and "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Spreading and modulation (FDD) (Release 4)" ("3GPP-25.213").

Motorola StarTAC 7868 was released in or before 2000 and thus qualifies as prior art under pre-AIA § 102(b) or post-AIA § 102(a)(1).

Galda-2002 was published on May 06, 2002. Therefore, Galda-2002 qualifies as prior art under pre-AIA 35 U.S.C. § 102(a) or post-AIA § 102(a)(1).

Kaiser-1997 issued/published on Aug. 31, 1997. Therefore, Kaiser-1997 qualifies as prior art under pre-AIA 35 U.S.C. § 102(b) or post-AIA § 102(a)(1).

Kaiser-1998 published in Jan. 1998. Therefore, Kaiser-1998 qualifies as prior art under pre-AIA 35 U.S.C. § 102(b) or post-AIA § 102(a)(1).

IEEE published on Dec. 30, 1999. Therefore, IEEE qualifies as prior art under pre-AIA 35 U.S.C. § 102(b) or post-AIA § 102(a)(1).

Kaiser-717 issued/published on Feb. 13, 2001. Therefore, Kaiser-717 qualifies as prior art under pre-AIA 35 U.S.C. § 102(b) or post-AIA § 102(a)(1).

3GPP-25.201 published on Apr. 04, 2001. Therefore, 3GPP-25.201 qualifies as prior art under pre-AIA 35 U.S.C. § 102(b) or post-AIA § 102(a)(1).

3GPP-25.213 published on Apr. 04, 2001. Therefore, 3GPP-25.213 qualifies as prior art under pre-AIA 35 U.S.C. § 102(b) or post-AIA § 102(a)(1).

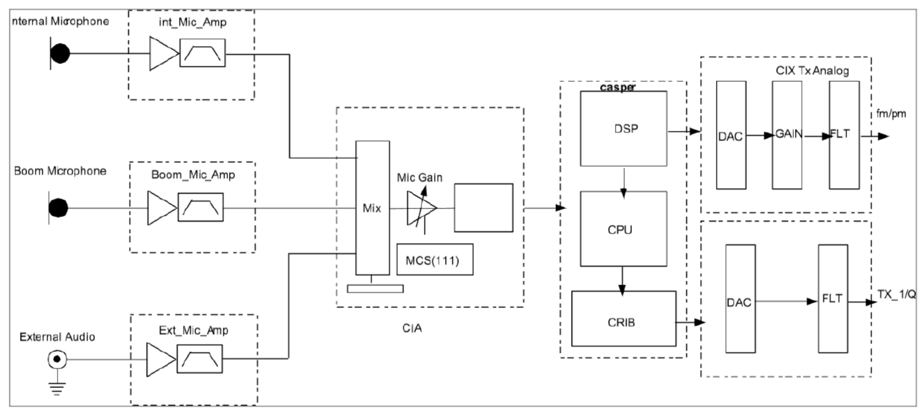
The asserted claims and the alleged priority date of the '568 patent are identified below:

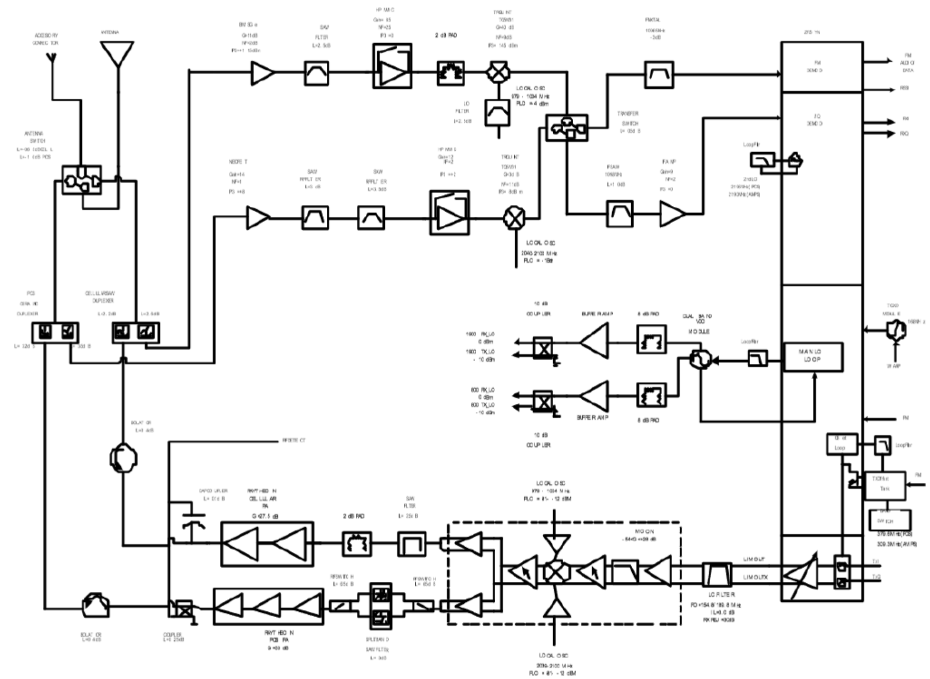
'568 Patent Asserted Claims	Alleged Priority Date
24, 25, 26, 29, 32, 33, 34, 44	"May 14, 2002" (ACICS at 8)

The Court has not yet construed the claims and therefore the meaning of the terms in the claims has yet to be resolved by the Court. The support identified herein may be responsive at least in part to Plaintiff's infringement contentions, with which Defendant does not necessarily agree. As such, nothing in Defendant’s claim charts should be construed as an admission regarding infringement, or as an admission regarding Defendant’s understanding of the proper scope of the asserted claims. Defendant reserves the right to rely on additional citations or sources of evidence that also may be applicable, or that may become applicable in light of claim construction, changes in Plaintiff’s infringement contentions, and/or information obtained during discovery.

Where Defendant cites a particular figure, such citation should be understood to encompass the caption and description of the figure, in addition to the figure itself. Conversely, where a cited portion of text refers to a figure, the citation should be understood to include the figure as well.

Defendant reserves the right to amend or supplement this claim chart at a later date as more fully set forth in the Cover Pleading based on, for example and without limitation, any amendments to the pleadings, or applicable rulings from the Court.

Claim Language	StarTAC and Other References
[24PRE] An apparatus, comprising:	To the extent the preamble of claim 24 is found to be limiting, StarTAC had a DS-CDMA transmitter, which is an apparatus. *See, e.g.*, Motorola CDMA ST7868W Dual Band/Tri Mode, Service Manual Level III, pp. 15-17 (describing the “Transmitter Circuitry” used in the StarTAC).  *Id.*, p.19.



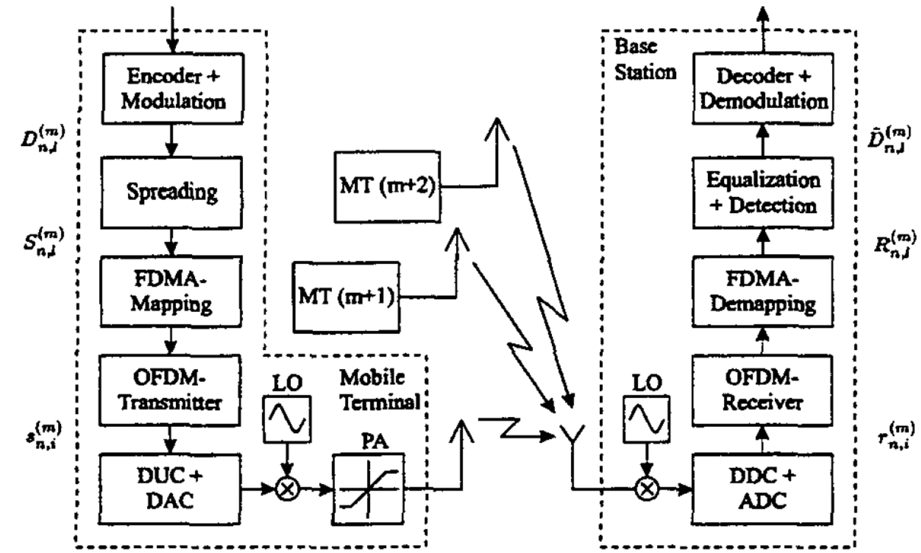
Id., p.21; *see also id.*, pp.80-84 (schematics showing processor, transmitter, and other RF communications components for CDMA communications).

But, StarTAC is not an OFDM product, and thus does not have an OFDM transmitter. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter:

For example, Galda-2002 discloses:

> Abstract- The orthogonal frequency division multiplex (OFDM) transmission technique can efficiently deal with the effects of multi-path

	propagation in the broadband radio channel. It also has a high system inherent flexibility for designing a multiple access scheme by combining the conventional TDMA, FDMA and CDMA approaches with the OFDM modulation scheme. The FDMA multiple access scheme is especially interesting for an uplink of a communication system since it can completely avoid any multiple access interferences (MAI). Moreover, the peak-to-average ratio (PAR) of the uplink OFDM transmit signal can be greatly reduced if this OFDM-FDMA multiple access scheme is additionally combined with a data spreading technique based on a Discrete Fourier Transform (DFT) spreading matrix using only the user specific subcarriers. Since the DFT spreading operation and the IDFT operation used as a part of the OFDM modulation scheme cancel out each other the complexity of the transmitter structure for an OFDM-FDMA uplink can be greatly reduced. Galda-2002 at 1737.

	 Fig. 1. Baseband system model for the OFDM-FDMA uplink with individual spreading of user data Galda-2002 at Fig. 1.

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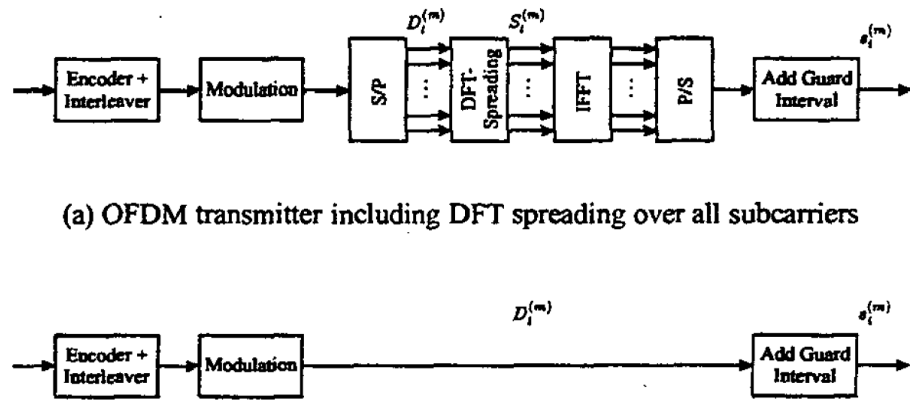

(a) OFDM transmitter including DFT spreading over all subcarriers

(b) Realistic but simplified OFDM transmitter structure

Fig. 4. In an OFDM system including a DFT spreading matrix and an IFFT for the OFDM modulation process both matrices cancel out each other.

Galda-2002 at Fig. 4.
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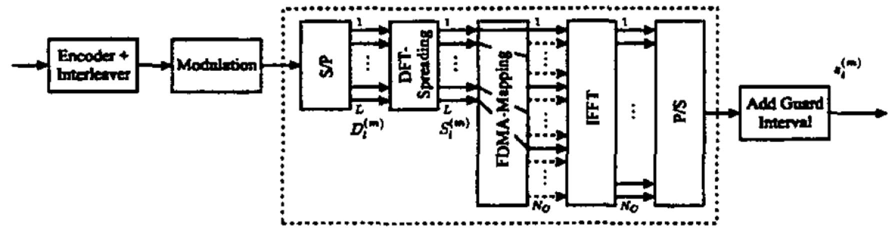
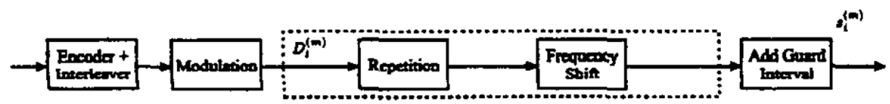


(a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers



(b) Realistic but simplified OFDM transmitter structure

Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other.

Galda-2002 at Fig. 6.
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<td>**[24A]** a processor; and</td>
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StarTAC included a processor. *See, e.g.*, Motorola CDMA ST7868W Dual Band/Tri Mode, Service Manual Level III, pp. 16-17 (describing a "microprocessor U1100" used in the StarTAC).

StarTAC's processor used CDMA, an earlier generation of wireless communication technology. As such it did not include a processor that used OFDM wireless communication technology.

A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the processor used in, for example, StarTAC. A POSA thus
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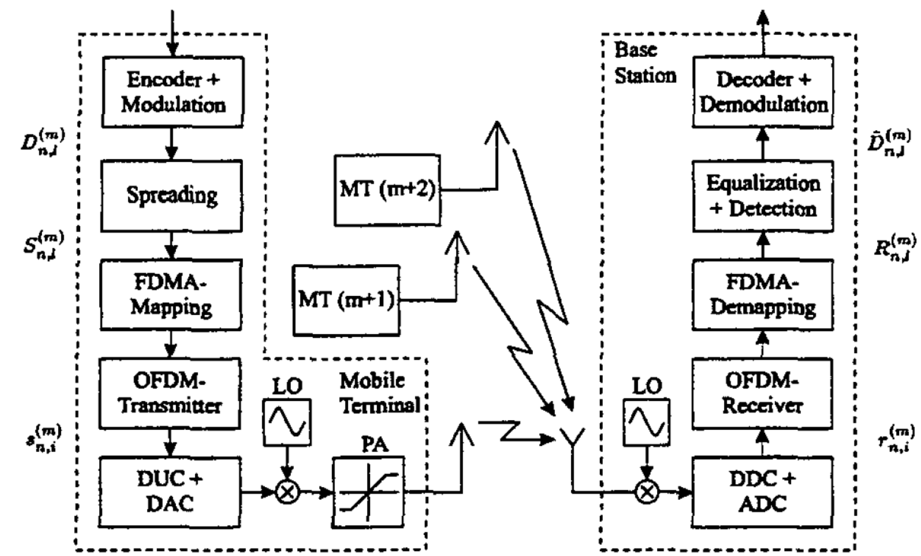
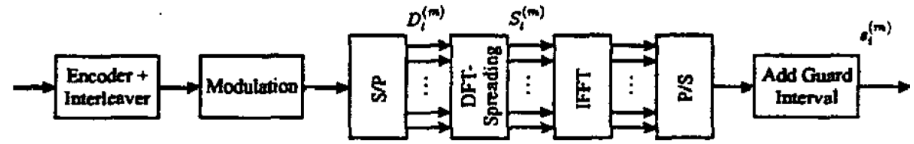
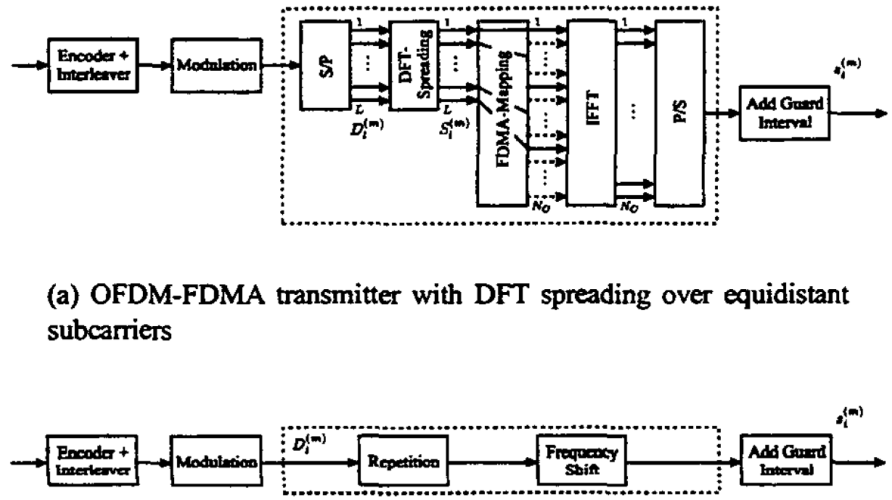
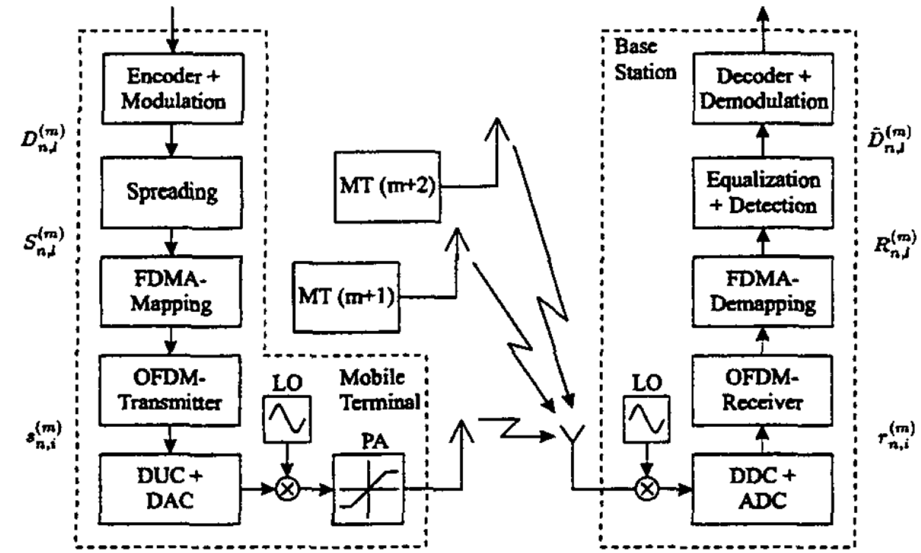


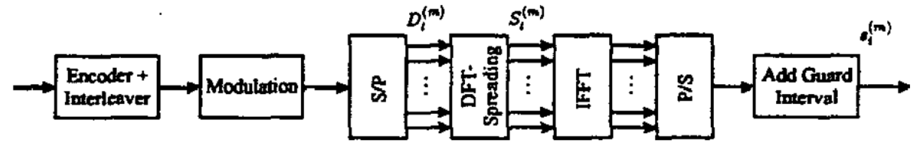
Fig. 1. Baseband system model for the OFDM-FDMA uplink with individual spreading of user data

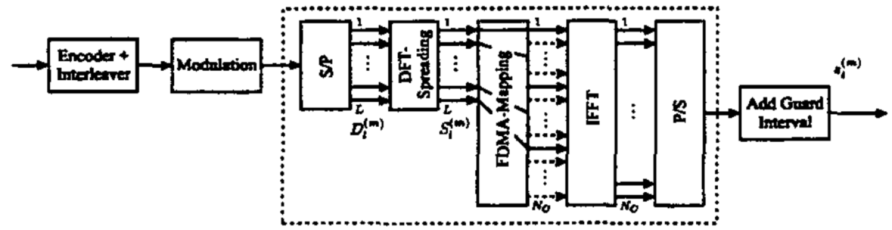
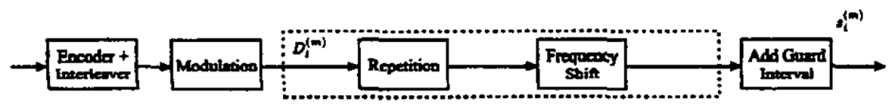
Galda-2002 at Fig. 1.

	 (a) OFDM transmitter including DFT spreading over all subcarriers  (b) Realistic but simplified OFDM transmitter structure Fig. 4. In an OFDM system including a DFT spreading matrix and an IFFT for the OFDM modulation process both matrices cancel out each other. Galda-2002 at Fig. 4.

	 (a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers (b) Realistic but simplified OFDM transmitter structure Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other. Galda-2002 at Fig. 6.
[24B] a non-transitory computer-readable memory communicatively coupled to the processor, the memory including a set of instructions stored thereon and executable by the processor for:	StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. *See, e.g.*, Motorola CDMA ST7868W Dual Band/Tri Mode, Service Manual Level III, pp.5, 23, 37, 43 (describing memory used in the StarTAC). Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus

	would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and implement them in instructions stored on a medium/in memory such that when they were executed by a processor, they executed the claimed functionality: For example, Galda-2002 discloses:  Fig. 1. Baseband system model for the OFDM-FDMA uplink with individual spreading of user data Galda-2002 at Fig. 1.

	 (a) OFDM transmitter including DFT spreading over all subcarriers  (b) Realistic but simplified OFDM transmitter structure Fig. 4. In an OFDM system including a DFT spreading matrix and an IFFT for the OFDM modulation process both matrices cancel out each other. Galda-2002 at Fig. 4.

	 (a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers  (b) Realistic but simplified OFDM transmitter structure Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other. Galda-2002 at Fig. 6.
[24C] dividing a block of complex-valued symbols into a plurality of sets of complex-valued symbols;	StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and

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For example, Galda-2002 discloses:

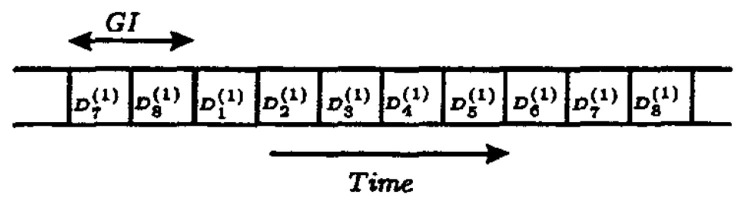
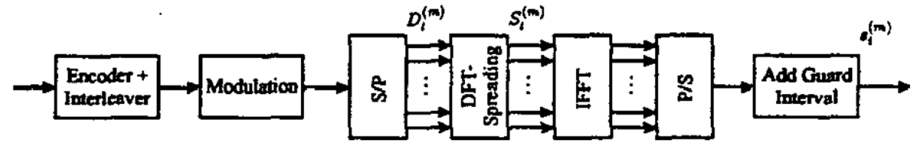
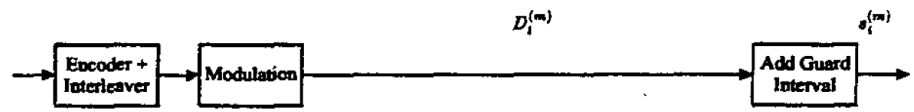


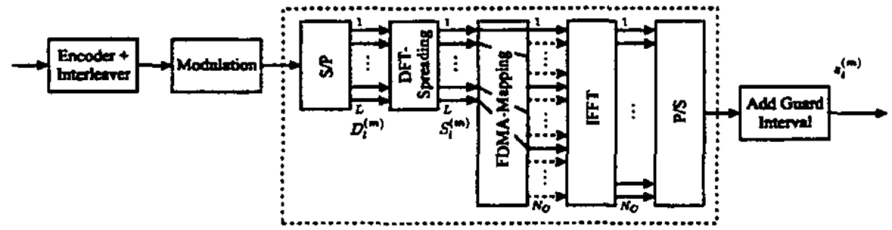
Fig. 3. Time signal of an OFDM-TDMA system with DFT spreading

Galda-2002 at Fig. 3.

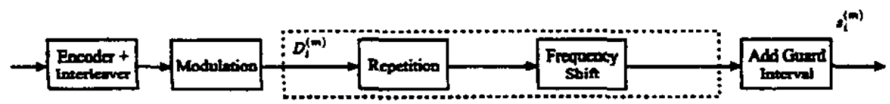
> A. OFDM-TDMA with DFT Spreading
>
> In [3] the Discrete Fourier Transformation (DFT) matrix has been used for spreading the vector $\vec{D}$ of length $L = N_C$ over all subcarriers of an OFDM system. If a single user is assumed in this OFDM system the spreading operation includes all subcarrier within the entire bandwidth. In this case the DFT spreading matrix and the IDFT operation in the OFDM modulation process cancel out each other. The OFDM transmitter structure with DFT spreading matrix is therefore technically reduced to the serial sequence of complex transmit data symbols D_i to which a guard interval is added in the time domain as a cyclic prefix
>
> $$s_i^{(1)} = D_{i\ mod\ N_C} \quad \text{for} \quad i = -N_G, \dots, 0, \dots, N_C \qquad (5)$$
>
> where mod denotes the modulo operation, as shown in Fig. 3.

Galda-2002 at 1739.

	 (a) OFDM transmitter including DFT spreading over all subcarriers  (b) Realistic but simplified OFDM transmitter structure **Fig. 4. In an OFDM system including a DFT spreading matrix and an IFFT for the OFDM modulation process both matrices cancel out each other.** Galda-2002 at Fig. 4. After calculating the FFT in the receiver which splits the received time signal into the orthogonal sub-channel the same single- or multi-code detection techniques can be applied which are well known from OFDM-CDMA receiver structures. The same bit error rate (BER) performance compared to a system using a Walsh-Hadamard spreading matrix can therefore be achieved if a DFT spreading matrix is considered instead. But in case of a DFT spreading matrix the resulting PAR is significantly reduced. The general structure of an OFDM transmitter including DFT spreading is shown in Fig. 4. Galda-2002 at 1739.



(a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers



(b) Realistic but simplified OFDM transmitter structure

Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other.

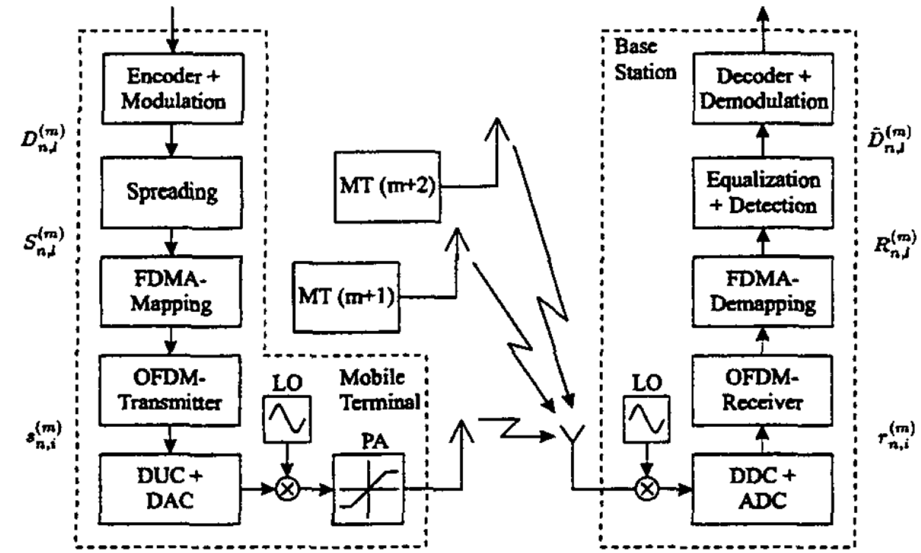
Galda-2002 at Fig. 6.

> The structure of the OFDM transmitter can be simplified by this approach since both the DFT spreading operation and the IFFT calculation of the conventional OFDM transmitter cancel out and can be removed in the technical realization completely and will be replaced by a simple repetition process of the considered user data $D_l^{(m)}$. The simplified transmitter structure is depicted in Fig. 6. Any equidistant subcarrier allocation can be used with the proposed FDMA scheme since it only influences the number of periods of the transmit signal. Therefore the user data rate can be flexibly adjusted by assigning the required number of subcarriers to each user.

	Galda-2002 at 1740.
[24D] transform precoding each of the plurality of sets of complex-valued symbols into a block of transform precoded complex-valued symbols; and	StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and implement them in instructions stored on a medium/in memory such that when they were executed by a processor, they executed the claimed functionality: For example, Galda-2002 discloses: Abstract- The orthogonal frequency division multiplex (OFDM) transmission technique can efficiently deal with the effects of multi-path propagation in the broadband radio channel. It also has a high system inherent flexibility for designing a multiple access scheme by combining the conventional TDMA, FDMA and CDMA approaches with the OFDM modulation scheme. The FDMA multiple access scheme is especially interesting for an uplink of a communication system since it can completely avoid any multiple access interferences (MAI). Moreover, the peak-to-average ratio (PAR) of the uplink OFDM transmit signal can be greatly reduced if this OFDM-FDMA multiple access scheme is additionally combined with a data spreading technique based on a Discrete Fourier Transform (DFT) spreading matrix using only the user specific subcarriers. Since the DFT spreading operation and the IDFT operation used as a part of the OFDM modulation scheme cancel out each other the complexity of

	> the transmitter structure for an OFDM-FDMA uplink can be greatly reduced. Galda-2002 at 1737. > The subdivision of the transmission bandwidth into a set of orthogonal subcarriers can additionally be exploited by an OFDM-FDMA multiple access scheme. By allocating distinct sets of subcarriers to different users the available bandwidth can be flexibly shared between different mobile terminals while avoiding any multiple access interferences (MAI) between different users. The FDMA multiple access scheme offers not only a high flexibility for the radio resource management (RRM) but can also increase the bandwidth efficiency of the complete system by avoiding the use of highly attenuated subcarriers for specific users based on the knowledge of the channel transfer function [2]. Moreover, the OFDM-FDMA multiple access scheme can be adapted to the measured radio channel knowledge at the transmitter site using bit-loading techniques. If channel state information is not available the performance can be increased using an additional spreading over the subcarriers assigned to one user. The resulting computation complexity of the total system can by this means be adopted to the given system requirements which is especially of importance for the mobile terminal and in the uplink case. The alternative OFDM-FDMA multiple access scheme is therefore of importance for the uplink case and can be advantageous over OFDM-CDMA schemes because of its ability to avoid MAI if ideal carrier synchronization is assumed for all mobile terminals and the base station. Galda-2002 at 1737. > Since the OFDM transmit signal results from the superposition of a large number of independent data symbols the envelope of the complex baseband time signal has in general a large peak-to-average ratio (PAR). The largest output power value of the amplifier will limit the maximum amplitude of the signal in the transmitter. Therefore, non-linear distortions due to

	clipping and amplification effects in the transmit signal will lead to both in-band and out-of-band emissions. In the past different techniques for reducing the PAR by changing the transmit signal independently from knowledge of other parts of the OFDM transmitter have been developed. But the PAR of the transmit signal envelope which employs an OFDM-FDMA multiple access scheme can significantly be reduced if additional spreading techniques are applied which spread the user data over the allocated subcarrier only. In this case an appropriate spreading technique must be designed reducing the PAR to a minimum value. It will be shown in this paper that using the Discrete Fourier Transform (DFT) matrix as an orthogonal spreading technique will reduce the PAR significantely [3]. Furthermore, the DFT based spreading operation and the IDFT based OFDM modulation technique cancel out each other which means that the transmitter structure can be simplified to a single carrier transmitter with an additional guard interval in this specific case which helps to reduce the computational complexity of the transmitter of the mobile terminal. Galda-2002 at 1737-38. This paper shows how an OFDM-FDMA uplink system can be combined with a user data spreading technique based on the DFT spreading matrix to reduce the PAR of the uplink signal without increasing the computational complexity of the transmitter. In Section II the structure of the analyzed OFDM-FDMA system combined with a DFT spreading matrix is described for the uplink application. In Section III the influence of a DFT matrix applied for data spreading is analyzed for an OFDM-TDMA multiple access scheme and is extended to an OFDM-FDMA system in a separate subsection. The general topic of non-linearities in an OFDM system is reviewed in Section IV. Quantitative results are given in Section V and Section VI summarizes the papers content. Galda-2002 at 1738.

	 **Fig. 1. Baseband system model for the OFDM-FDMA uplink with individual spreading of user data** Galda-2002 at Fig. 1. The baseband system model of an OFDM-FDMA uplink with individual spreading of user data is shown in Fig. 1. In this case M different users are considered and each user allocates L different subcarrier exclusively. The total number of subcarrier in the considered transmission system is $N_C = L \cdot M$. The input data stream for each mobile user $m, m = 0, \ldots, M - 1$, is convolutionally encoded in a first step. The bit sequence is then mapped onto L complex modulation symbols $D_l^{(m)}, l = 0, \ldots, L - 1$, of a coherent, higher-level modulation scheme. The L modulation symbols are spread over the L user specifically allocated subcarrier with an unitary spreading matrix $[C]$ resulting in L complex transmit symbols $S_l^{(m)}$. The spreading

	operation can be denoted mathematically by the following simple matrix multiplication $$\vec{S}^{(m)} = [C]\vec{D}^{(m)} \quad (1)$$ where each complex transmit symbol $S_l^{(m)}$ is calculated by the sum of L user modulation symbols $D_l^{(m)}$ weighted by L orthogonal code vectors $\widetilde{C_l} = (C_{l,0}, C_{l,1}, \ldots, C_{l,l})$ with $l = 0, \ldots, L-1$ $$S_l^{(m)} = \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} \quad \text{for} \quad l = 0, \ldots, L-1 \quad (2)$$ The transmit symbols $S_l(m)$ are then mapped onto L of the available N_C subcarrier which are exclusively allocated to user m. In principle, the set of subcarrier assigned to each user can be composed of any L out of N_C subcarrier that have not been assigned to another user. Galda-2002 at 1738. Independent of the considered spreading matrix C but assuming the equidistant allocation of subcarrier over the entire bandwidth the resulting OFDM time signal of user m can analytically be described as $$s_i^{(m)} = e^{j2\pi im/N_C} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} S_l^{(m)} e^{-j2\pi il/L} \quad \text{for} \quad i = -N_G, \ldots, 0, \ldots, N_C \quad (3)$$ where N_G denotes the length of the guard interval which is inserted into the transmit time signal. Galda-2002 at 1738. III. DFT SPREADING The spreading matrix $[C]$ of an OFDM-FDMA system is often only characterized by its frequency diversity properties. It therefore is chosen to

> be unitary in order to make the detection process easier, to distribute the signal energy of the superimposed code symbols uniformly over all subcarrier and not to change the distance of the code vectors. Thus, in many OFDM systems with additional spreading the Walsh-Hadamard (WH) matrix is employed since it has the additional advantage that it only consists of only "+1" and "-1" elements which can reduce the computational complexity. The discrete Fourier matrix is also unitary but additionally has an influence on the PAR of an OFDM transmit signal. In this Section the influence of such an Fourier sp[r]eading matrix on the resulting PAR will be discussed.

Galda-2002 at 1739.

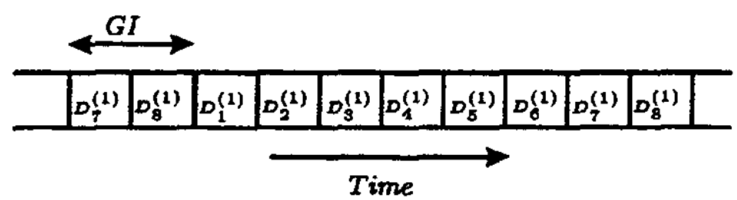


Fig. 3. Time signal of an OFDM-TDMA system with DFT spreading

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> A. OFDM-TDMA with DFT Spreading
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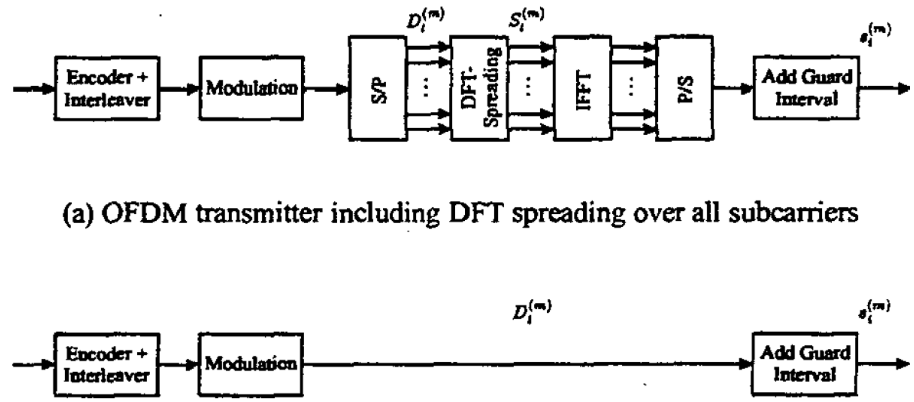
	sequence of complex transmit data symbols D_i to which a guard interval is added in the time domain as a cyclic prefix $$s_i^{(1)} = D_{i\ mod\ N_C} \quad \text{for} \quad i = -N_G, \ldots, 0, \ldots, N_C \qquad (5)$$ where mod denotes the modulo operation, as shown in Fig. 3. Galda-2002 at 1739.  (a) OFDM transmitter including DFT spreading over all subcarriers (b) Realistic but simplified OFDM transmitter structure **Fig. 4. In an OFDM system including a DFT spreading matrix and an IFFT for the OFDM modulation process both matrices cancel out each other.** Galda-2002 at Fig. 4. After calculating the FFT in the receiver which splits the received time signal into the orthogonal sub-channel the same single- or multi-code detection techniques can be applied which are well known from OFDM-CDMA receiver structures. The same bit error rate (BER) performance compared to a system using a Walsh-Hadamard spreading matrix can

> therefore be achieved if a DFT spreading matrix is considered instead. But in case of a DFT spreading matrix the resulting PAR is significantly reduced. The general structure of an OFDM transmitter including DFT spreading is shown in Fig. 4.

Galda-2002 at 1739.

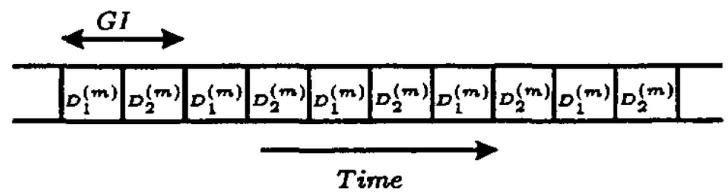
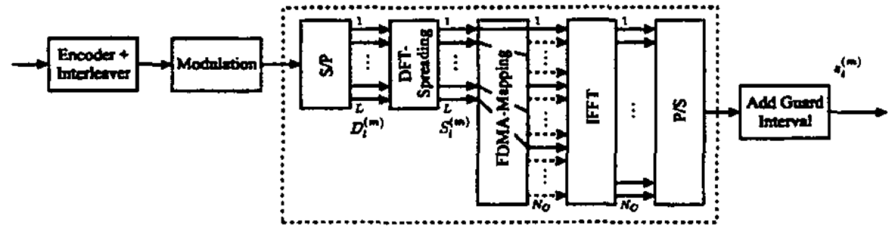
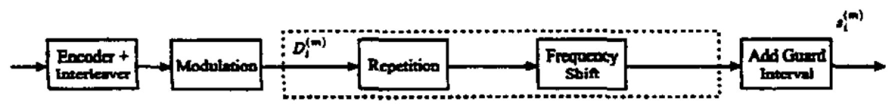


Fig. 5. Time signal of an OFDM-FDMA uplink system with DFT spreading is characterized by a periodic repetition ($N_C = 8, M = 4$)

Galda-2002 at Fig. 5.

> B. OFDM-FDMA with DFT Spreading
>
> The advantage of a DFT spreading matrix can also be exploited in the uplink of an OFDM-FDMA system. If the user data is spread only over $L < N_C$ subcarriers then the DFT of length L used for spreading does not directly cancel out with the length N_C IDFT of the OFDM modulator in general. Only when the spreaded symbols $S_l^{(m)}$ are mapped onto equidistant located subcarriers with a spacing of $N_C/L = M$ the DFT spreading and the OFDM modulation can be removed in the transmitter structure. This can be seen by inserting Equation (2) into Equation (3) using the elements of the discrete Fourier matrix
>
> $$C_{i,j} = \frac{1}{\sqrt{L}} \cdot e^{j2\pi ij/L} \qquad (6)$$
>
> the transmit signal of user m can be written as

	$$\begin{aligned} s_i^{(m)} &= e^{j2\pi im/N_C} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} e^{-j2\pi il/L} \\ &= e^{j2\pi im/N_C} \frac{1}{L} \sum_{\nu=0}^{L-1} D_\nu^{(m)} \underbrace{\sum_{l=0}^{L-1} e^{j2\pi(\nu-i)l/L}}_{=L\delta_L(\nu-i)} \\ &= e^{j2\pi im/N_C} \sum_{\nu=0}^{L-1} D_\nu^{(m)} \delta_L(\nu-i) \\ s_i^{(m)} &= e^{j2\pi im/N_C} D_{i\,mod\,L}^{(m)} \qquad (7) \end{aligned}$$ for $i = -N_G, \ldots, 0, \ldots, N_C$ and the periodic dirac pulse sequence $\delta_L(\ \ )$. The transmit time signal $s_i^{(m)}$ of user m in an OFDM-FDMA uplink using DFT spreading matrix and an equidistant subcarrier allocation results therefore in a periodic repetition of the complex user data symbol $D_l^{(m)}$ sequence including an added guard interval as cyclic prefix, shown in Fig. 5. This periodic data sequence is multiplied by a user specific complex signal $e^{j2\pi im/N_C}$ due to the user individual frequency shift by m subcarriers of the complete allocated subcarrier set. The number of periods inside a single OFDM symbol is equal to the spacing M of the subcarriers allocated to user m. Galda-2002 at 1739-40.

	 (a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers  (b) Realistic but simplified OFDM transmitter structure Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other. Galda-2002 at Fig. 6. The structure of the OFDM transmitter can be simplified by this approach since both the DFT spreading operation and the IFFT calculation of the conventional OFDM transmitter cancel out and can be removed in the technical realization completely and will be replaced by a simple repetition process of the considered user data $D_l^{(m)}$. The simplified transmitter structure is depicted in Fig. 6. Any equidistant subcarrier allocation can be used with the proposed FDMA scheme since it only influences the number of periods of the transmit signal. Therefore the user data rate can be flexibly adjusted by assigning the required number of subcarriers to each user.

	Galda-2002 at 1740. > In order to avoid non-linear distortions even in the case of a highly linear power amplifier a sufficient input-backoff (IBO) of the transmit signal to the amplifier has to be used. Even though the clipping probability of the OFDM signal can be reduced or even be avoided for an IBO larger than the PAR a system with large energy efficiency loss results. Alternatively, the effects which a non-linear device can have on the transmit power spectrum can be influenced by a reduction of the OFDM transmit signal PAR Different techniques have been developed which reduce the PAR of the OFDM signal by the means of a modified channel coding [5], an additive [6] or multiplicative [7] correction function or a selective mapping of modulation symbols to subcarriers [8]. A majority of these techniques has a high computational complexity due to the fact that they analyze the generated transmit signal and modify it either in the frequency or time domain to reduce its peak amplitudes. For a system employing coherent subcarrier modulation the PAR can also be reduced if the data symbols are spread by a Fourier matrix in frequency direction [3]. Galda-2002 at 1740. > In this paper an OFDM-FDMA system concept for the uplink of a multi user communication system has been studied. It had be shown that if an OFDM-FDMA system with equidistant subcarrier allocation is combined with a user specific spreading using an discrete Fourier transform as a spreading matrix the transmitter structure can be greatly simplified without any performance degradation. Moreover, the peak-to-average ratio of the transmit signal is reduced to the PAR of the subcarrier modulation scheme which can limit the out-of-band and in-band emissions when the transmit signal is passed through a non-linear device. With the opportunity to independently adjust the user data rates the proposed technique offers an interesting alternative for reducing the complexity of the mobile terminal in the broadband radio uplink.

	Galda-2002 at 1741.
[24E] generating an Orthogonal Frequency Division Multiplex (OFDM) signal comprising a plurality of OFDM subcarriers modulated with the transform-precoded complex-valued symbols,	StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and implement them in instructions stored on a medium/in memory such that when they were executed by a processor, they executed the claimed functionality: For example, Galda-2002 discloses: Abstract- The orthogonal frequency division multiplex (OFDM) transmission technique can efficiently deal with the effects of multi-path propagation in the broadband radio channel. It also has a high system inherent flexibility for designing a multiple access scheme by combining the conventional TDMA, FDMA and CDMA approaches with the OFDM modulation scheme. The FDMA multiple access scheme is especially interesting for an uplink of a communication system since it can completely avoid any multiple access interferences (MAI). Moreover, the peak-to-average ratio (PAR) of the uplink OFDM transmit signal can be greatly reduced if this OFDM-FDMA multiple access scheme is additionally combined with a data spreading technique based on a Discrete Fourier Transform (DFT) spreading matrix using only the user specific subcarriers. Since the DFT spreading operation and the IDFT operation used as a part of the OFDM modulation scheme cancel out each other the complexity of the transmitter structure for an OFDM-FDMA uplink can be greatly reduced.

	Galda-2002 at 1737. The broadband radio channel is characterized by its frequency selective fading due to multi-path propagation. In mobile communications applications the radio channel is additionally time-variant due to the movement of the mobile terminal. The orthogonal frequency division multiplexing (OFDM) transmission technique can cope with the effects of frequency selectivity and time variance with a low implementation and computation complexity. Inter symbol interferences (ISI) as well as inter carrier interferences (ICI) can be completely avoided by dividing the total system bandwidth into a large number of spectrally overlapping but mutually orthogonal non-frequency selective narrow-band subchannels and by introducing an additional guard interval into the OFDM symbol. Even at the output of a frequency-selective channel this orthogonality of the subcarriers can be maintained. The equalization of each subchannel is then reduced to a single complex multiplication per subchannel [l]. Galda-2002 at 1737. Since the OFDM transmit signal results from the superposition of a large number of independent data symbols the envelope of the complex baseband time signal has in general a large peak-to-average ratio (PAR). The largest output power value of the amplifier will limit the maximum amplitude of the signal in the transmitter. Therefore, non-linear distortions due to clipping and amplification effects in the transmit signal will lead to both in-band and out-of-band emissions. In the past different techniques for reducing the PAR by changing the transmit signal independently from knowledge of other parts of the OFDM transmitter have been developed. But the PAR of the transmit signal envelope which employs an OFDM-FDMA multiple access scheme can significantly be reduced if additional spreading techniques are applied which spread the user data over the allocated subcarrier only. In this case an appropriate spreading technique must be designed reducing the PAR to a minimum value. It will be shown

	in this paper that using the Discrete Fourier Transform (DFT) matrix as an orthogonal spreading technique will reduce the PAR significantely [3]. Furthermore, the DFT based spreading operation and the IDFT based OFDM modulation technique cancel out each other which means that the transmitter structure can be simplified to a single carrier transmitter with an additional guard interval in this specific case which helps to reduce the computational complexity of the transmitter of the mobile terminal. Galda-2002 at 1737-38. This paper shows how an OFDM-FDMA uplink system can be combined with a user data spreading technique based on the DFT spreading matrix to reduce the PAR of the uplink signal without increasing the computational complexity of the transmitter. In Section II the structure of the analyzed OFDM-FDMA system combined with a DFT spreading matrix is described for the uplink application. In Section III the influence of a DFT matrix applied for data spreading is analyzed for an OFDM-TDMA multiple access scheme and is extended to an OFDM-FDMA system in a separate subsection. The general topic of non-linearities in an OFDM system is reviewed in Section IV. Quantitative results are given in Section V and Section VI summarizes the papers content. Galda-2002 at 1738.

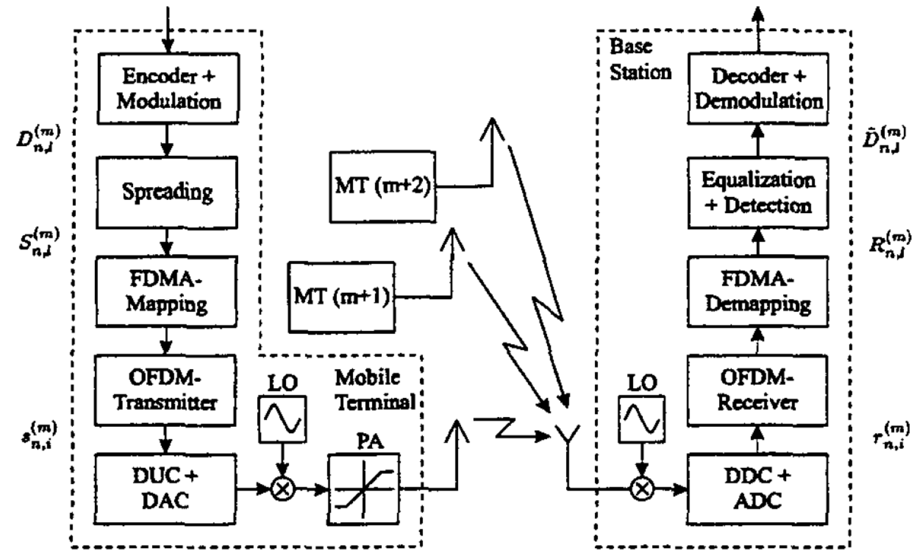
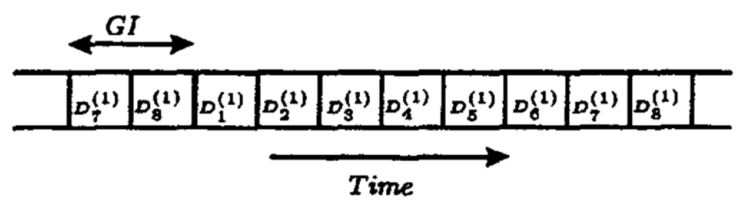


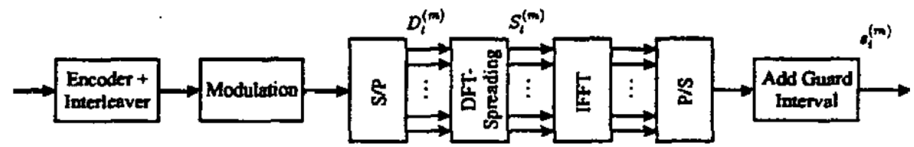
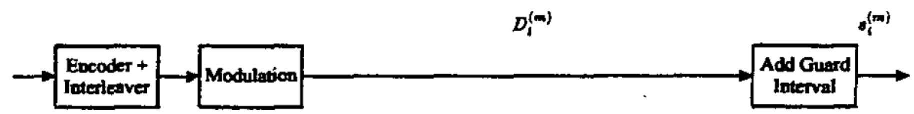
Fig. 1. Baseband system model for the OFDM-FDMA uplink with individual spreading of user data

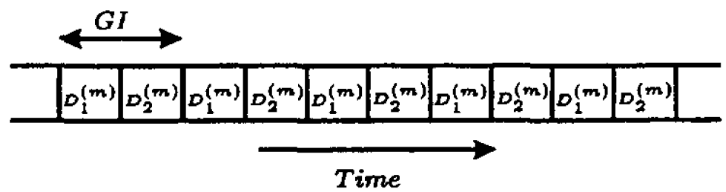
Galda-2002 at Fig. 1.

> The baseband system model of an OFDM-FDMA uplink with individual spreading of user data is shown in Fig. 1. In this case M different users are considered and each user allocates L different subcarrier exclusively. The total number of subcarrier in the considered transmission system is $N_C = L \cdot M$. The input data stream for each mobile user $m, m = 0, \dots, M - 1$, is convolutionally encoded in a first step. The bit sequence is then mapped onto L complex modulation symbols $D_l^{(m)}, l = 0, \dots, L - 1$, of a coherent, higher-level modulation scheme. The L modulation symbols are spread over the L user specifically allocated subcarrier with an unitary spreading matrix $[C]$ resulting in L complex transmit symbols $S_l^{(m)}$. The spreading

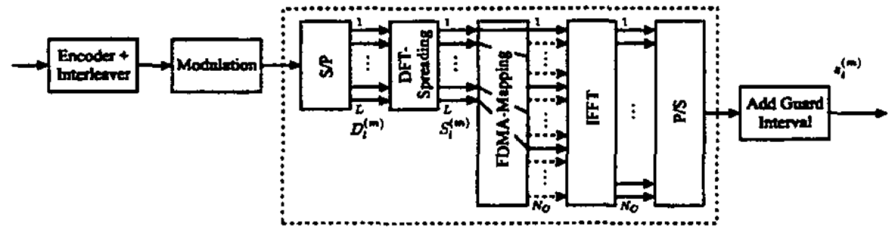
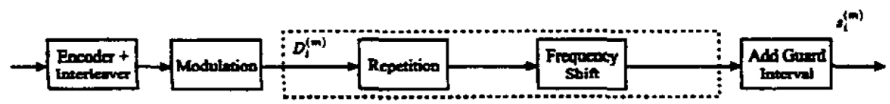
	operation can be denoted mathematically by the following simple matrix multiplication $$\vec{S}^{(m)} = [C]\vec{D}^{(m)} \quad (1)$$ where each complex transmit symbol $S_l^{(m)}$ is calculated by the sum of L user modulation symbols $D_l^{(m)}$ weighted by L orthogonal code vectors $\widetilde{C_l} = (C_{l,0}, C_{l,1}, \dots, C_{l,l})$ with $l = 0, \dots, L-1$ $$S_l^{(m)} = \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} \quad \text{for} \quad l = 0, \dots, L-1 \quad (2)$$ The transmit symbols $S_l(m)$ are then mapped onto L of the available N_C subcarrier which are exclusively allocated to user m. In principle, the set of subcarrier assigned to each user can be composed of any L out of N_C subcarrier that have not been assigned to another user. Galda-2002 at 1738. Independent of the considered spreading matrix C but assuming the equidistant allocation of subcarrier over the entire bandwidth the resulting OFDM time signal of user m can analytically be described as $$s_i^{(m)} = e^{j2\pi im/N_C} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} S_l^{(m)} e^{-j2\pi il/L} \quad \text{for} \quad i = -N_G, \dots, 0, \dots, N_C \quad (3)$$ where N_G denotes the length of the guard interval which is inserted into the transmit time signal. Galda-2002 at 1738. III. DFT SPREADING The spreading matrix $[C]$ of an OFDM-FDMA system is often only characterized by its frequency diversity properties. It therefore is chosen to

	be unitary in order to make the detection process easier, to distribute the signal energy of the superimposed code symbols uniformly over all subcarrier and not to change the distance of the code vectors. Thus, in many OFDM systems with additional spreading the Walsh-Hadamard (WH) matrix is employed since it has the additional advantage that it only consists of only "+1" and "-1" elements which can reduce the computational complexity. The discrete Fourier matrix is also unitary but additionally has an influence on the PAR of an OFDM transmit signal. In this Section the influence of such an Fourier sp[r]eading matrix on the resulting PAR will be discussed. Galda-2002 at 1739.  **Fig. 3. Time signal of an OFDM-TDMA system with DFT spreading** Galda-2002 at Fig. 3. A. OFDM-TDMA with DFT Spreading In [3] the Discrete Fourier Transformation (DFT) matrix has been used for spreading the vector $\vec{D}$ of length $L = N_C$ over all subcarriers of an OFDM system. If a single user is assumed in this OFDM system the spreading operation includes all subcarrier within the entire bandwidth. In this case the DFT spreading matrix and the IDFT operation in the OFDM modulation process cancel out each other. The OFDM transmitter structure with DFT spreading matrix is therefore technically reduced to the serial

	sequence of complex transmit data symbols D_i to which a guard interval is added in the time domain as a cyclic prefix $$s_i^{(1)} = D_{i\ mod\ N_C} \quad \text{for} \quad i = -N_G, \ldots, 0, \ldots, N_C \qquad (5)$$ where mod denotes the modulo operation, as shown in Fig. 3. Galda-2002 at 1739.  (a) OFDM transmitter including DFT spreading over all subcarriers  (b) Realistic but simplified OFDM transmitter structure Fig. 4. In an OFDM system including a DFT spreading matrix and an IFFT for the OFDM modulation process both matrices cancel out each other. Galda-2002 at Fig. 4. After calculating the FFT in the receiver which splits the received time signal into the orthogonal sub-channel the same single- or multi-code detection techniques can be applied which are well known from OFDM-CDMA receiver structures. The same bit error rate (BER) performance compared to a system using a Walsh-Hadamard spreading matrix can

	therefore be achieved if a DFT spreading matrix is considered instead. But in case of a DFT spreading matrix the resulting PAR is significantly reduced. The general structure of an OFDM transmitter including DFT spreading is shown in Fig. 4. Galda-2002 at 1739.  **Fig. 5. Time signal of an OFDM-FDMA uplink system with DFT spreading is characterized by a periodic repetition ($N_C = 8, M = 4$)** Galda-2002 at Fig. 5. B. OFDM-FDMA with DFT Spreading The advantage of a DFT spreading matrix can also be exploited in the uplink of an OFDM-FDMA system. If the user data is spread only over $L < N_C$ subcarriers then the DFT of length L used for spreading does not directly cancel out with the length N_C IDFT of the OFDM modulator in general. Only when the spreaded symbols $S_l^{(m)}$ are mapped onto equidistant located subcarriers with a spacing of $N_C/L = M$ the DFT spreading and the OFDM modulation can be removed in the transmitter structure. This can be seen by inserting Equation (2) into Equation (3) using the elements of the discrete Fourier matrix $$C_{i,j} = \frac{1}{\sqrt{L}} \cdot e^{j2\pi ij/L} \quad (6)$$ the transmit signal of user m can be written as

	$$s_i^{(m)} = e^{j2\pi im/N_C} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} e^{-j2\pi il/L}$$ $$= e^{j2\pi im/N_C} \frac{1}{L} \sum_{\nu=0}^{L-1} D_\nu^{(m)} \underbrace{\sum_{l=0}^{L-1} e^{j2\pi(\nu-i)l/L}}_{=L\delta_L(\nu-i)}$$ $$= e^{j2\pi im/N_C} \sum_{\nu=0}^{L-1} D_\nu^{(m)} \delta_L(\nu - i)$$ $$s_i^{(m)} = e^{j2\pi im/N_C} D_{i\,mod\,L}^{(m)} \quad (7)$$ for $i = -N_G, \ldots, 0, \ldots, N_C$ and the periodic dirac pulse sequence $\delta_L(\quad)$. The transmit time signal $s_i^{(m)}$ of user m in an OFDM-FDMA uplink using DFT spreading matrix and an equidistant subcarrier allocation results therefore in a periodic repetition of the complex user data symbol $D_l^{(m)}$ sequence including an added guard interval as cyclic prefix, shown in Fig. 5. This periodic data sequence is multiplied by a user specific complex signal $e^{j2\pi im/N_C}$ due to the user individual frequency shift by m subcarriers of the complete allocated subcarrier set. The number of periods inside a single OFDM symbol is equal to the spacing M of the subcarriers allocated to user m. Galda-2002 at 1739-40.

	 (a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers  (b) Realistic but simplified OFDM transmitter structure Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other. Galda-2002 at Fig. 6. The structure of the OFDM transmitter can be simplified by this approach since both the DFT spreading operation and the IFFT calculation of the conventional OFDM transmitter cancel out and can be removed in the technical realization completely and will be replaced by a simple repetition process of the considered user data $D_l^{(m)}$. The simplified transmitter structure is depicted in Fig. 6. Any equidistant subcarrier allocation can be used with the proposed FDMA scheme since it only influences the number of periods of the transmit signal. Therefore the user data rate can be flexibly adjusted by assigning the required number of subcarriers to each user.

	Galda-2002 at 1740. We consider an OFDM-FDMA system with N_C = 512 subcarriers and a guard interval of N_G = 64 shared between M = 16 users. The continuous-time transmit signal $s(t)$ is simulated by a discrete-time signal oversampled by a factor of K = 8 and bandlimited by a root-raised cosine Nyquist filter. The oversampled and filtered signal is then passed through a non-linear device modelled by a soft-limiter as it has been described in Section IV. The distorted signal $\tilde{s}(t)^{(m)}$ is then analyzed by measuring its power spectral density (PSD) and its clipping probability. Since only the transmit signal is analyzed in this paper no assumption about the channel have to be made. Galda-2002 at 1741. In this paper an OFDM-FDMA system concept for the uplink of a multi user communication system has been studied. It had be shown that if an OFDM-FDMA system with equidistant subcarrier allocation is combined with a user specific spreading using an discrete Fourier transform as a spreading matrix the transmitter structure can be greatly simplified without any performance degradation. Moreover, the peak-to-average ratio of the transmit signal is reduced to the PAR of the subcarrier modulation scheme which can limit the out-of-band and in-band emissions when the transmit signal is passed through a non-linear device. With the opportunity to independently adjust the user data rates the proposed technique offers an interesting alternative for reducing the complexity of the mobile terminal in the broadband radio uplink. Galda-2002 at 1741.
[24F] wherein the transform precoding generates a plurality of orthogonal spreading codes to provide a superposition of the	StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation

plurality of OFDM subcarriers with a reduced peak-to-average-power ratio.	of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and implement them in instructions stored on a medium/in memory such that when they were executed by a processor, they executed the claimed functionality: For example, Galda-2002 discloses: Abstract- The orthogonal frequency division multiplex (OFDM) transmission technique can efficiently deal with the effects of multi-path propagation in the broadband radio channel. It also has a high system inherent flexibility for designing a multiple access scheme by combining the conventional TDMA, FDMA and CDMA approaches with the OFDM modulation scheme. The FDMA multiple access scheme is especially interesting for an uplink of a communication system since it can completely avoid any multiple access interferences (MAI). Moreover, the peak-to-average ratio (PAR) of the uplink OFDM transmit signal can be greatly reduced if this OFDM-FDMA multiple access scheme is additionally combined with a data spreading technique based on a Discrete Fourier Transform (DFT) spreading matrix using only the user specific subcarriers. Since the DFT spreading operation and the IDFT operation used as a part of the OFDM modulation scheme cancel out each other the complexity of the transmitter structure for an OFDM-FDMA uplink can be greatly reduced. Galda-2002 at 1737. Since the OFDM transmit signal results from the superposition of a large number of independent data symbols the envelope of the complex baseband

	time signal has in general a large peak-to-average ratio (PAR). The largest output power value of the amplifier will limit the maximum amplitude of the signal in the transmitter. Therefore, non-linear distortions due to clipping and amplification effects in the transmit signal will lead to both in-band and out-of-band emissions. In the past different techniques for reducing the PAR by changing the transmit signal independently from knowledge of other parts of the OFDM transmitter have been developed. But the PAR of the transmit signal envelope which employs an OFDM-FDMA multiple access scheme can significantly be reduced if additional spreading techniques are applied which spread the user data over the allocated subcarrier only. In this case an appropriate spreading technique must be designed reducing the PAR to a minimum value. It will be shown in this paper that using the Discrete Fourier Transform (DFT) matrix as an orthogonal spreading technique will reduce the PAR significantely [3]. Furthermore, the DFT based spreading operation and the IDFT based OFDM modulation technique cancel out each other which means that the transmitter structure can be simplified to a single carrier transmitter with an additional guard interval in this specific case which helps to reduce the computational complexity of the transmitter of the mobile terminal. Galda-2002 at 1737-38. This paper shows how an OFDM-FDMA uplink system can be combined with a user data spreading technique based on the DFT spreading matrix to reduce the PAR of the uplink signal without increasing the computational complexity of the transmitter. In Section II the structure of the analyzed OFDM-FDMA system combined with a DFT spreading matrix is described for the uplink application. In Section III the influence of a DFT matrix applied for data spreading is analyzed for an OFDM-TDMA multiple access scheme and is extended to an OFDM-FDMA system in a separate subsection. The general topic of non-linearities in an OFDM system is reviewed in Section IV. Quantitative results are given in Section V and Section VI summarizes the papers content.

	Galda-2002 at 1738. III. DFT SPREADING The spreading matrix $[C]$ of an OFDM-FDMA system is often only characterized by its frequency diversity properties. It therefore is chosen to be unitary in order to make the detection process easier, to distribute the signal energy of the superimposed code symbols uniformly over all subcarrier and not to change the distance of the code vectors. Thus, in many OFDM systems with additional spreading the Walsh-Hadamard (WH) matrix is employed since it has the additional advantage that it only consists of only "+1" and "-1" elements which can reduce the computational complexity. The discrete Fourier matrix is also unitary but additionally has an influence on the PAR of an OFDM transmit signal. In this Section the influence of such an Fourier sp[r]eading matrix on the resulting PAR will be discussed. Galda-2002 at 1739. Since the transmit signal of this OFDM system consist of a sequence of complex modulation symbols D_i, it has the same PAR as the modulation scheme employed for single carrier transmission techniques. Galda-2002 at 1739. After calculating the FFT in the receiver which splits the received time signal into the orthogonal sub-channel the same single- or multi-code detection techniques can be applied which are well known from OFDM-CDMA receiver structures. The same bit error rate (BER) performance compared to a system using a Walsh-Hadamard spreading matrix can therefore be achieved if a DFT spreading matrix is considered instead. But in case of a DFT spreading matrix the resulting PAR is significantly

	reduced. The general structure of an OFDM transmitter including DFT spreading is shown in Fig. 4. Galda-2002 at 1739. With the same argumentation the PAR can also be reduced for the OFDM-FDMA downlink even though not the same simple transmitter structure can be used. The PAR of the time signal is in this case determined by the number of users $M = N_C/L$ instead of the number of used subcarrier and will therefore in most cases be lower than for a conventional OFDM-FDMA system without additional spreading. Galda-2002 at 1740. Since the time signal of the OFDM-FDMA uplink with DFT spreading is identical to a single carrier transmission additional techniques to reduce the PAR originally developed for single carrier systems like the π/4-QPSK can be employed. Galda-2002 at 1740. For a sufficiently large number L of used subcarrier per user the time discrete OFDM signal $s_i^{(m)}$ of user m given in Equation (3) has an approximately Gaussian amplitude distribution due to the superposition of statistically independent modulation symbols $S_l^{(m)}$ on all used subcarriers. The maximum peak-to-average ratio (PAR), defined by $$PAR = 10\log_{10}\left(\frac{\max(\|s(t)\|^2)}{\sigma_s^2}\right)[dB] \quad (8)$$ where σ_s^2 denotes the average transmit power, occurs only if the identical modulation symbol S_l is transmitted on all used subcarriers. In this case the PAR is determined by the number of used subcarriers L.

	Galda-2002 at 1740. > A non-linear device is often modelled by a soft-limiter described by its non-linear amplitude modulation and phase modulation characteristic as > $$g(a) = \begin{cases} a & \lvert a \rvert \le A_0 \\ A_0 & \text{else} \end{cases} \quad (9)$$ > where a is the magnitude of the time signal and A_0 defines the maximum output amplitude of the device. Galda-2002 at 1740. > In order to avoid non-linear distortions even in the case of a highly linear power amplifier a sufficient input-backoff (IBO) of the transmit signal to the amplifier has to be used. Even though the clipping probability of the OFDM signal can be reduced or even be avoided for an IBO larger than the PAR a system with large energy efficiency loss results. Alternatively, the effects which a non-linear device can have on the transmit power spectrum can be influenced by a reduction of the OFDM transmit signal PAR Different techniques have been developed which reduce the PAR of the OFDM signal by the means of a modified channel coding [5], an additive [6] or multiplicative [7] correction function or a selective mapping of modulation symbols to subcarriers [8]. A majority of these techniques has a high computational complexity due to the fact that they analyze the generated transmit signal and modify it either in the frequency or time domain to reduce its peak amplitudes. For a system employing coherent subcarrier modulation the PAR can also be reduced if the data symbols are spread by a Fourier matrix in frequency direction [3]. Galda-2002 at 1740.

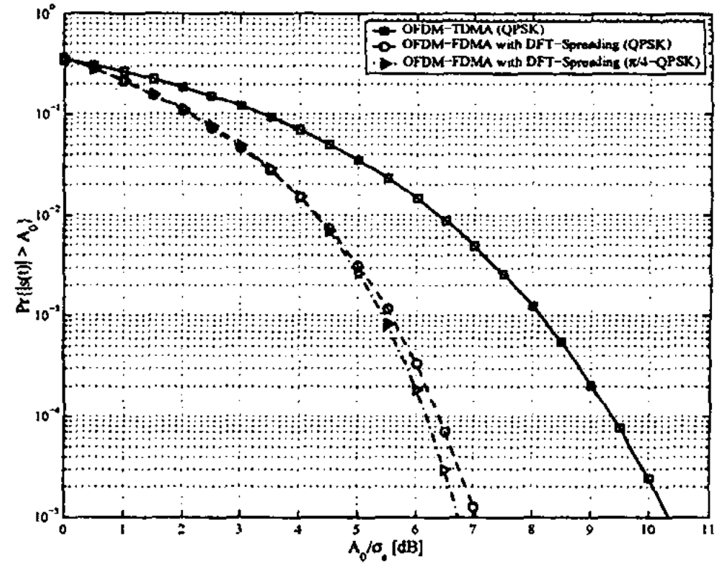


Fig. 8. Clipping probability of a conventional OFDM system and an OFDM-FDMA system for the uplink versus the signal input backoff to a soft limiter

Galda-2002 at Fig. 8

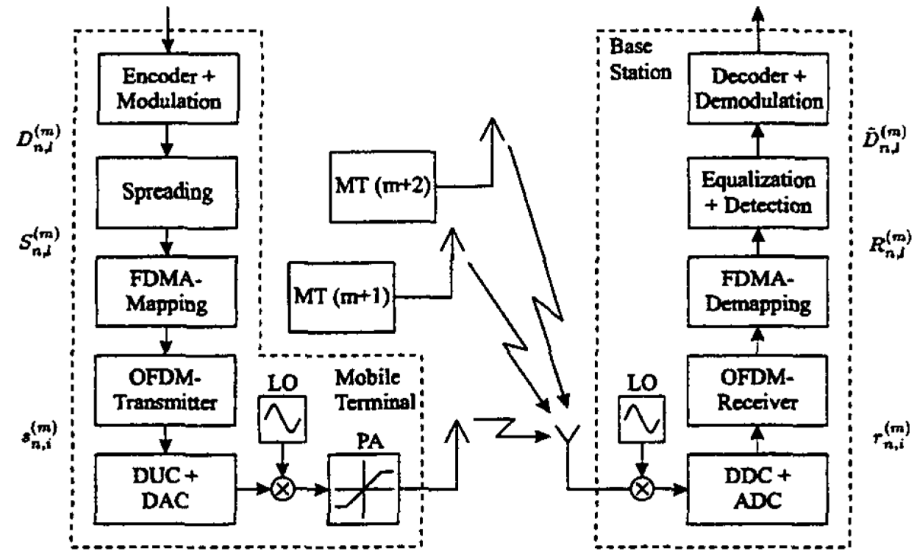
> B. Amplitude Distribution
>
> The probability that the instantaneous power $|s(t)|^2$ exceeds the threshold A_0^2 is depicted in Fig. 8 versus the normalized threshold. As can be seen from this Figure the power efficiency can be increased by 3.6 dB for the OFDM-FDMA uplink with DFT spreading and a QPSK modulation and by an additional 0.3 dB for a π/4-QPSK for a probabilistic PAR of 10^{-5}.

Galda-2002 at 1741.

	In this paper an OFDM-FDMA system concept for the uplink of a multi user communication system has been studied. It had be shown that if an OFDM-FDMA system with equidistant subcarrier allocation is combined with a user specific spreading using an discrete Fourier transform as a spreading matrix the transmitter structure can be greatly simplified without any performance degradation. Moreover, the peak-to-average ratio of the transmit signal is reduced to the PAR of the subcarrier modulation scheme which can limit the out-of-band and in-band emissions when the transmit signal is passed through a non-linear device. With the opportunity to independently adjust the user data rates the proposed technique offers an interesting alternative for reducing the complexity of the mobile terminal in the broadband radio uplink. Galda-2002 at 1741.
[Claim 25] The apparatus of claim 24, wherein the transform precoding spreads the block of complex-valued symbols with a plurality of orthogonal spreading codes comprising complex-valued coefficients of a discrete Fourier transform (DFT) to produce the block of transform-precoded complex-valued symbols.	StarTAC, alone or in combination with one or more other prior art references, renders obvious the apparatus of claim 24, as set forth above with respect to claim 24. *See, e.g.*, claim elements 24PRE, 24A, 24B, 24C, 24D, 24E, 24F. StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and implement them in instructions stored on a medium/in memory such that when they were executed by a processor, they executed the claimed functionality:

	For example, Galda-2002 discloses: Abstract- The orthogonal frequency division multiplex (OFDM) transmission technique can efficiently deal with the effects of multi-path propagation in the broadband radio channel. It also has a high system inherent flexibility for designing a multiple access scheme by combining the conventional TDMA, FDMA and CDMA approaches with the OFDM modulation scheme. The FDMA multiple access scheme is especially interesting for an uplink of a communication system since it can completely avoid any multiple access interferences (MAI). Moreover, the peak-to-average ratio (PAR) of the uplink OFDM transmit signal can be greatly reduced if this OFDM-FDMA multiple access scheme is additionally combined with a data spreading technique based on a Discrete Fourier Transform (DFT) spreading matrix using only the user specific subcarriers. Since the DFT spreading operation and the IDFT operation used as a part of the OFDM modulation scheme cancel out each other the complexity of the transmitter structure for an OFDM-FDMA uplink can be greatly reduced. Galda-2002 at 1737. Since the OFDM transmit signal results from the superposition of a large number of independent data symbols the envelope of the complex baseband time signal has in general a large peak-to-average ratio (PAR). The largest output power value of the amplifier will limit the maximum amplitude of the signal in the transmitter. Therefore, non-linear distortions due to clipping and amplification effects in the transmit signal will lead to both in-band and out-of-band emissions. In the past different techniques for reducing the PAR by changing the transmit signal independently from knowledge of other parts of the OFDM transmitter have been developed. But the PAR of the transmit signal envelope which employs an OFDM-FDMA multiple access scheme can significantly be reduced if additional spreading techniques are applied which spread the user data over the allocated subcarrier only. In this case an appropriate spreading technique

	must be designed reducing the PAR to a minimum value. It will be shown in this paper that using the Discrete Fourier Transform (DFT) matrix as an orthogonal spreading technique will reduce the PAR significantely [3]. Furthermore, the DFT based spreading operation and the IDFT based OFDM modulation technique cancel out each other which means that the transmitter structure can be simplified to a single carrier transmitter with an additional guard interval in this specific case which helps to reduce the computational complexity of the transmitter of the mobile terminal. Galda-2002 at 1737-38. This paper shows how an OFDM-FDMA uplink system can be combined with a user data spreading technique based on the DFT spreading matrix to reduce the PAR of the uplink signal without increasing the computational complexity of the transmitter. In Section II the structure of the analyzed OFDM-FDMA system combined with a DFT spreading matrix is described for the uplink application. In Section III the influence of a DFT matrix applied for data spreading is analyzed for an OFDM-TDMA multiple access scheme and is extended to an OFDM-FDMA system in a separate subsection. The general topic of non-linearities in an OFDM system is reviewed in Section IV. Quantitative results are given in Section V and Section VI summarizes the papers content. Galda-2002 at 1738.

	 Fig. 1. Baseband system model for the OFDM-FDMA uplink with individual spreading of user data Galda-2002 at Fig. 1. The baseband system model of an OFDM-FDMA uplink with individual spreading of user data is shown in Fig. 1. In this case M different users are considered and each user allocates L different subcarrier exclusively. The total number of subcarrier in the considered transmission system is $N_C = L \cdot M$. The input data stream for each mobile user $m, m = 0, \ldots, M-1$, is convolutionally encoded in a first step. The bit sequence is then mapped onto L complex modulation symbols $D_l^{(m)}, l = 0, \ldots, L-1$, of a coherent, higher-level modulation scheme. The L modulation symbols are spread over the L user specifically allocated subcarrier with an unitary spreading matrix $[C]$ resulting in L complex transmit symbols $S_l^{(m)}$. The spreading

	operation can be denoted mathematically by the following simple matrix multiplication $$\vec{S}^{(m)} = [C]\vec{D}^{(m)} \quad (1)$$ where each complex transmit symbol $S_l^{(m)}$ is calculated by the sum of L user modulation symbols $D_l^{(m)}$ weighted by L orthogonal code vectors $\widetilde{C}_l = (C_{l,0}, C_{l,1}, \dots, C_{l,l})$ with $l = 0, \dots, L-1$ $$S_l^{(m)} = \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} \quad \text{for} \quad l = 0, \dots, L-1 \quad (2)$$ The transmit symbols $S_l(m)$ are then mapped onto L of the available N_C subcarrier which are exclusively allocated to user m. In principle, the set of subcarrier assigned to each user can be composed of any L out of N_C subcarrier that have not been assigned to another user. Galda-2002 at 1738. Independent of the considered spreading matrix C but assuming the equidistant allocation of subcarrier over the entire bandwidth the resulting OFDM time signal of user m can analytically be described as $$s_i^{(m)} = e^{j2\pi im/N_C} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} S_l^{(m)} e^{-j2\pi il/L} \quad \text{for} \quad i = -N_G, \dots, 0, \dots, N_C \quad (3)$$ where N_G denotes the length of the guard interval which is inserted into the transmit time signal. Galda-2002 at 1738. III. DFT SPREADING The spreading matrix $[C]$ of an OFDM-FDMA system is often only characterized by its frequency diversity properties. It therefore is chosen to

> be unitary in order to make the detection process easier, to distribute the signal energy of the superimposed code symbols uniformly over all subcarrier and not to change the distance of the code vectors. Thus, in many OFDM systems with additional spreading the Walsh-Hadamard (WH) matrix is employed since it has the additional advantage that it only consists of only "+1" and "-1" elements which can reduce the computational complexity. The discrete Fourier matrix is also unitary but additionally has an influence on the PAR of an OFDM transmit signal. In this Section the influence of such an Fourier sp[r]eading matrix on the resulting PAR will be discussed.

Galda-2002 at 1739.

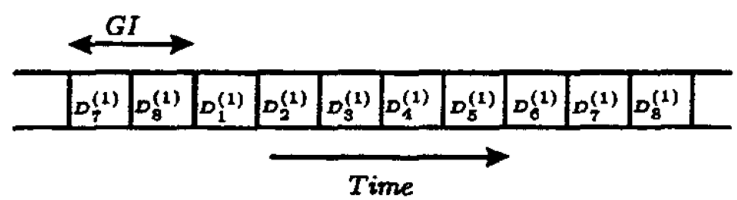


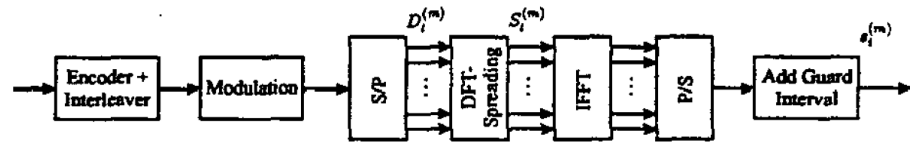
Fig. 3. Time signal of an OFDM-TDMA system with DFT spreading

Galda-2002 at Fig. 3.

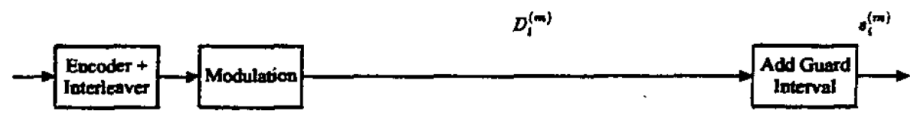
> A. OFDM-TDMA with DFT Spreading
>
> In [3] the Discrete Fourier Transformation (DFT) matrix has been used for spreading the vector $\vec{D}$ of length $L = N_C$ over all subcarriers of an OFDM system. If a single user is assumed in this OFDM system the spreading operation includes all subcarrier within the entire bandwidth. In this case the DFT spreading matrix and the IDFT operation in the OFDM modulation process cancel out each other. The OFDM transmitter structure with DFT spreading matrix is therefore technically reduced to the serial

> sequence of complex transmit data symbols D_i to which a guard interval is added in the time domain as a cyclic prefix
>
> $$s_i^{(1)} = D_{i \, mod \, N_C} \quad \text{for} \quad i = -N_G, \ldots, 0, \ldots, N_C \qquad (5)$$
>
> where mod denotes the modulo operation, as shown in Fig. 3.

Galda-2002 at 1739.



(a) OFDM transmitter including DFT spreading over all subcarriers

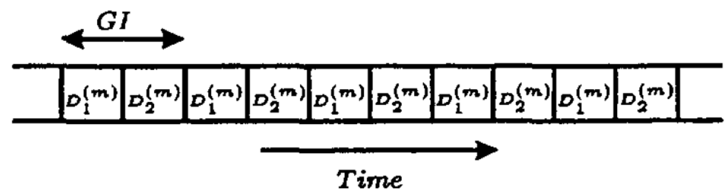


(b) Realistic but simplified OFDM transmitter structure

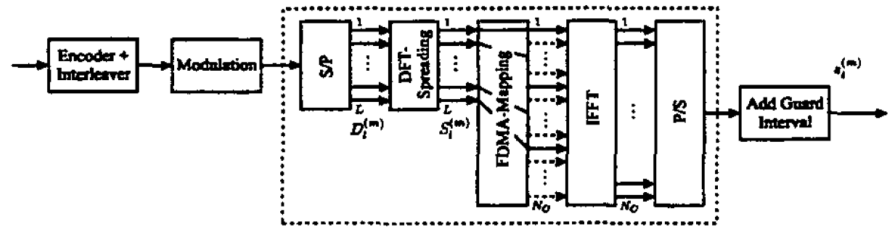
Fig. 4. In an OFDM system including a DFT spreading matrix and an IFFT for the OFDM modulation process both matrices cancel out each other.

Galda-2002 at Fig. 4.

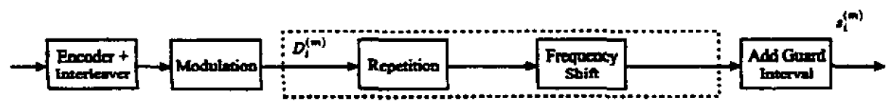
> After calculating the FFT in the receiver which splits the received time signal into the orthogonal sub-channel the same single- or multi-code detection techniques can be applied which are well known from OFDM-CDMA receiver structures. The same bit error rate (BER) performance compared to a system using a Walsh-Hadamard spreading matrix can

	therefore be achieved if a DFT spreading matrix is considered instead. But in case of a DFT spreading matrix the resulting PAR is significantly reduced. The general structure of an OFDM transmitter including DFT spreading is shown in Fig. 4. Galda-2002 at 1739.  **Fig. 5. Time signal of an OFDM-FDMA uplink system with DFT spreading is characterized by a periodic repetition ($N_C = 8, M = 4$)** Galda-2002 at Fig. 5. B. OFDM-FDMA with DFT Spreading The advantage of a DFT spreading matrix can also be exploited in the uplink of an OFDM-FDMA system. If the user data is spread only over $L < N_C$ subcarriers then the DFT of length L used for spreading does not directly cancel out with the length N_C IDFT of the OFDM modulator in general. Only when the spreaded symbols $S_l^{(m)}$ are mapped onto equidistant located subcarriers with a spacing of $N_C/L = M$ the DFT spreading and the OFDM modulation can be removed in the transmitter structure. This can be seen by inserting Equation (2) into Equation (3) using the elements of the discrete Fourier matrix $$C_{i,j} = \frac{1}{\sqrt{L}} \cdot e^{j2\pi ij/L} \qquad (6)$$ the transmit signal of user m can be written as

	$$\begin{aligned} s_i^{(m)} &= e^{j2\pi im/N_C} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} e^{-j2\pi il/L} \\ &= e^{j2\pi im/N_C} \frac{1}{L} \sum_{\nu=0}^{L-1} D_\nu^{(m)} \underbrace{\sum_{l=0}^{L-1} e^{j2\pi(\nu-i)l/L}}_{=L\delta_L(\nu-i)} \\ &= e^{j2\pi im/N_C} \sum_{\nu=0}^{L-1} D_\nu^{(m)} \delta_L(\nu-i) \\ s_i^{(m)} &= e^{j2\pi im/N_C} D_{i\,mod\,L}^{(m)} \qquad (7) \end{aligned}$$ for $i = -N_G, \ldots, 0, \ldots, N_C$ and the periodic dirac pulse sequence $\delta_L(\ )$. The transmit time signal $s_i^{(m)}$ of user m in an OFDM-FDMA uplink using DFT spreading matrix and an equidistant subcarrier allocation results therefore in a periodic repetition of the complex user data symbol $D_l^{(m)}$ sequence including an added guard interval as cyclic prefix, shown in Fig. 5. This periodic data sequence is multiplied by a user specific complex signal $e^{j2\pi im/N_C}$ due to the user individual frequency shift by m subcarriers of the complete allocated subcarrier set. The number of periods inside a single OFDM symbol is equal to the spacing M of the subcarriers allocated to user m. Galda-2002 at 1739-40.



(a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers



(b) Realistic but simplified OFDM transmitter structure

Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other.

Galda-2002 at Fig. 6.

> The structure of the OFDM transmitter can be simplified by this approach since both the DFT spreading operation and the IFFT calculation of the conventional OFDM transmitter cancel out and can be removed in the technical realization completely and will be replaced by a simple repetition process of the considered user data $D_l^{(m)}$. The simplified transmitter structure is depicted in Fig. 6. Any equidistant subcarrier allocation can be used with the proposed FDMA scheme since it only influences the number of periods of the transmit signal. Therefore the user data rate can be flexibly adjusted by assigning the required number of subcarriers to each user.

	Galda-2002 at 1740. > In this paper an OFDM-FDMA system concept for the uplink of a multi user communication system has been studied. It had be shown that if an OFDM-FDMA system with equidistant subcarrier allocation is combined with a user specific spreading using an discrete Fourier transform as a spreading matrix the transmitter structure can be greatly simplified without any performance degradation. Moreover, the peak-to-average ratio of the transmit signal is reduced to the PAR of the subcarrier modulation scheme which can limit the out-of-band and in-band emissions when the transmit signal is passed through a non-linear device. With the opportunity to independently adjust the user data rates the proposed technique offers an interesting alternative for reducing the complexity of the mobile terminal in the broadband radio uplink. Galda-2002 at 1741.
[Claim 26] The apparatus of claim 25, wherein the DFT is a fast Fourier transform (FFT).	StarTAC, alone or in combination with one or more other prior art references, renders obvious the apparatus of claim 25, as set forth above with respect to claim 25. *See, e.g.*, claim 25. StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and

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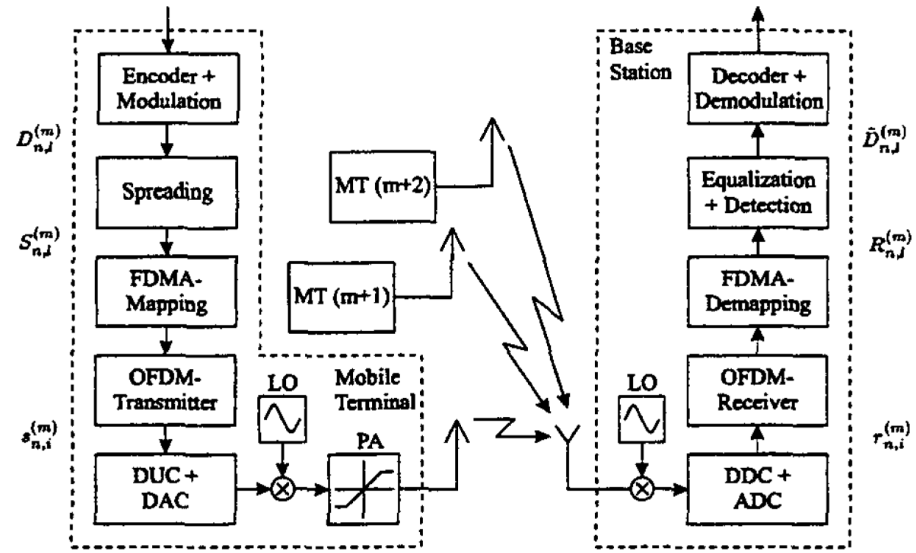
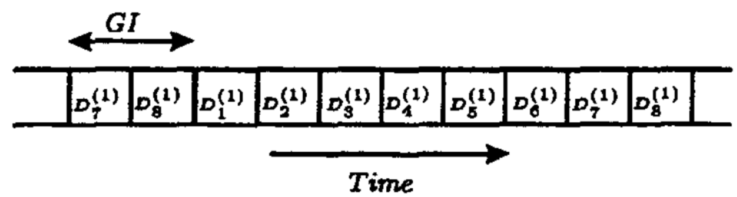


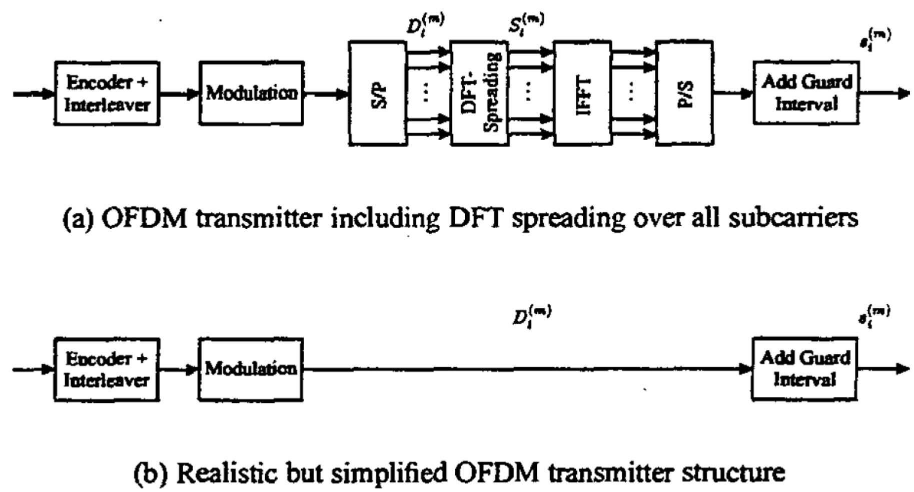
Fig. 1. Baseband system model for the OFDM-FDMA uplink with individual spreading of user data

Galda-2002 at Fig. 1.

> The baseband system model of an OFDM-FDMA uplink with individual spreading of user data is shown in Fig. 1. In this case M different users are considered and each user allocates L different subcarrier exclusively. The total number of subcarrier in the considered transmission system is $N_C = L \cdot M$. The input data stream for each mobile user $m, m = 0, \ldots, M-1$, is convolutionally encoded in a first step. The bit sequence is then mapped onto L complex modulation symbols $D_l^{(m)}, l = 0, \ldots, L-1$, of a coherent, higher-level modulation scheme. The L modulation symbols are spread over the L user specifically allocated subcarrier with an unitary spreading matrix $[C]$ resulting in L complex transmit symbols $S_l^{(m)}$. The spreading

	operation can be denoted mathematically by the following simple matrix multiplication $$\vec{S}^{(m)} = [C]\vec{D}^{(m)} \quad (1)$$ where each complex transmit symbol $S_l^{(m)}$ is calculated by the sum of L user modulation symbols $D_l^{(m)}$ weighted by L orthogonal code vectors $\widetilde{C_l} = (C_{l,0}, C_{l,1}, \dots, C_{l,l})$ with $l = 0, \dots, L-1$ $$S_l^{(m)} = \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} \quad \text{for} \quad l = 0, \dots, L-1 \quad (2)$$ The transmit symbols $S_l(m)$ are then mapped onto L of the available N_C subcarrier which are exclusively allocated to user m. In principle, the set of subcarrier assigned to each user can be composed of any L out of N_C subcarrier that have not been assigned to another user. Galda-2002 at 1738. Independent of the considered spreading matrix C but assuming the equidistant allocation of subcarrier over the entire bandwidth the resulting OFDM time signal of user m can analytically be described as $$s_i^{(m)} = e^{j2\pi i m/N_C} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} S_l^{(m)} e^{-j2\pi i l/L} \quad \text{for} \quad i = -N_G, \dots, 0, \dots, N_C \quad (3)$$ where N_G denotes the length of the guard interval which is inserted into the transmit time signal. Galda-2002 at 1738. III. DFT SPREADING The spreading matrix $[C]$ of an OFDM-FDMA system is often only characterized by its frequency diversity properties. It therefore is chosen to

	be unitary in order to make the detection process easier, to distribute the signal energy of the superimposed code symbols uniformly over all subcarrier and not to change the distance of the code vectors. Thus, in many OFDM systems with additional spreading the Walsh-Hadamard (WH) matrix is employed since it has the additional advantage that it only consists of only "+1" and "-1" elements which can reduce the computational complexity. The discrete Fourier matrix is also unitary but additionally has an influence on the PAR of an OFDM transmit signal. In this Section the influence of such an Fourier sp[r]eading matrix on the resulting PAR will be discussed. Galda-2002 at 1739.  **Fig. 3. Time signal of an OFDM-TDMA system with DFT spreading** Galda-2002 at Fig. 3. A. OFDM-TDMA with DFT Spreading In [3] the Discrete Fourier Transformation (DFT) matrix has been used for spreading the vector $\vec{D}$ of length $L = N_C$ over all subcarriers of an OFDM system. If a single user is assumed in this OFDM system the spreading operation includes all subcarrier within the entire bandwidth. In this case the DFT spreading matrix and the IDFT operation in the OFDM modulation process cancel out each other. The OFDM transmitter structure with DFT spreading matrix is therefore technically reduced to the serial

	sequence of complex transmit data symbols D_i to which a guard interval is added in the time domain as a cyclic prefix $$s_i^{(1)} = D_{i\,mod\,N_C} \quad \text{for} \quad i = -N_G, \ldots, 0, \ldots, N_C \qquad (5)$$ where mod denotes the modulo operation, as shown in Fig. 3. Galda-2002 at 1739.  Fig. 4. In an OFDM system including a DFT spreading matrix and an IFFT for the OFDM modulation process both matrices cancel out each other. Galda-2002 at Fig. 4. After calculating the FFT in the receiver which splits the received time signal into the orthogonal sub-channel the same single- or multi-code detection techniques can be applied which are well known from OFDM-CDMA receiver structures. The same bit error rate (BER) performance compared to a system using a Walsh-Hadamard spreading matrix can

therefore be achieved if a DFT spreading matrix is considered instead. But in case of a DFT spreading matrix the resulting PAR is significantly reduced. The general structure of an OFDM transmitter including DFT spreading is shown in Fig. 4.

Galda-2002 at 1739.

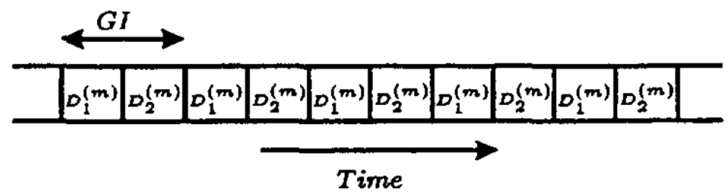


Fig. 5. Time signal of an OFDM-FDMA uplink system with DFT spreading is characterized by a periodic repetition ($N_C = 8, M = 4$)

Galda-2002 at Fig. 5.

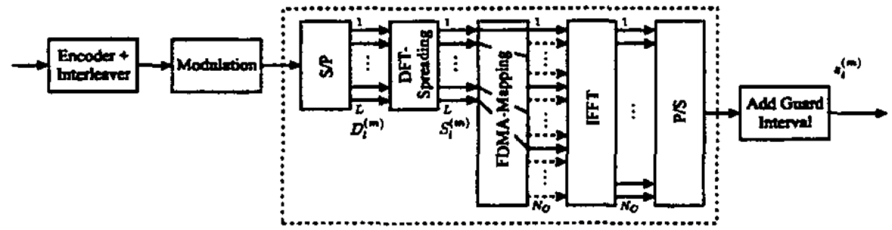
B. OFDM-FDMA with DFT Spreading

The advantage of a DFT spreading matrix can also be exploited in the uplink of an OFDM-FDMA system. If the user data is spread only over $L < N_C$ subcarriers then the DFT of length L used for spreading does not directly cancel out with the length N_C IDFT of the OFDM modulator in general. Only when the spreaded symbols $S_l^{(m)}$ are mapped onto equidistant located subcarriers with a spacing of $N_C/L = M$ the DFT spreading and the OFDM modulation can be removed in the transmitter structure. This can be seen by inserting Equation (2) into Equation (3) using the elements of the discrete Fourier matrix

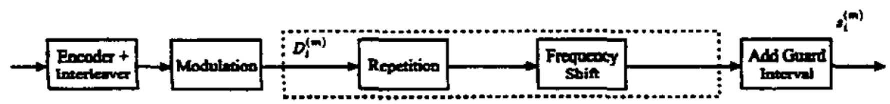
$$C_{i,j} = \frac{1}{\sqrt{L}} \cdot e^{j2\pi ij/L} \qquad (6)$$

the transmit signal of user m can be written as

	$$\begin{aligned} s_i^{(m)} &= e^{j2\pi im/N_C} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} e^{-j2\pi il/L} \\ &= e^{j2\pi im/N_C} \frac{1}{L} \sum_{\nu=0}^{L-1} D_\nu^{(m)} \underbrace{\sum_{l=0}^{L-1} e^{j2\pi(\nu-i)l/L}}_{=L\delta_L(\nu-i)} \\ &= e^{j2\pi im/N_C} \sum_{\nu=0}^{L-1} D_\nu^{(m)} \delta_L(\nu-i) \\ s_i^{(m)} &= e^{j2\pi im/N_C} D_{i\,mod\,L}^{(m)} \qquad (7) \end{aligned}$$ for $i = -N_G, \dots, 0, \dots, N_C$ and the periodic dirac pulse sequence $\delta_L(\quad)$. The transmit time signal $s_i^{(m)}$ of user m in an OFDM-FDMA uplink using DFT spreading matrix and an equidistant subcarrier allocation results therefore in a periodic repetition of the complex user data symbol $D_l^{(m)}$ sequence including an added guard interval as cyclic prefix, shown in Fig. 5. This periodic data sequence is multiplied by a user specific complex signal $e^{j2\pi im/N_C}$ due to the user individual frequency shift by m subcarriers of the complete allocated subcarrier set. The number of periods inside a single OFDM symbol is equal to the spacing M of the subcarriers allocated to user m. Galda-2002 at 1739-40.



(a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers



(b) Realistic but simplified OFDM transmitter structure

Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other.

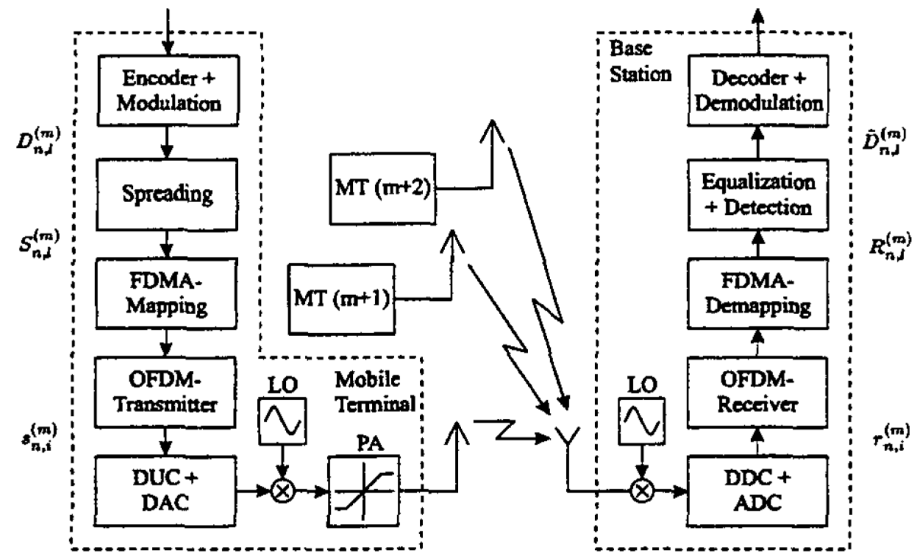
Galda-2002 at Fig. 6.

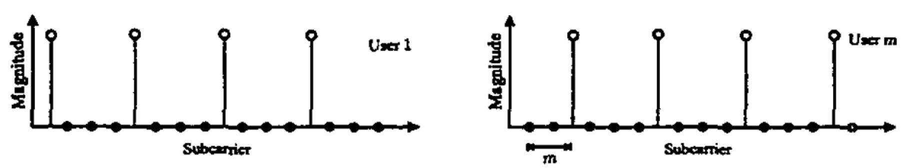
> The structure of the OFDM transmitter can be simplified by this approach since both the DFT spreading operation and the IFFT calculation of the conventional OFDM transmitter cancel out and can be removed in the technical realization completely and will be replaced by a simple repetition process of the considered user data $D_l^{(m)}$. The simplified transmitter structure is depicted in Fig. 6. Any equidistant subcarrier allocation can be used with the proposed FDMA scheme since it only influences the number of periods of the transmit signal. Therefore the user data rate can be flexibly adjusted by assigning the required number of subcarriers to each user.

	Galda-2002 at 1740. In this paper an OFDM-FDMA system concept for the uplink of a multi user communication system has been studied. It had be shown that if an OFDM-FDMA system with equidistant subcarrier allocation is combined with a user specific spreading using an discrete Fourier transform as a spreading matrix the transmitter structure can be greatly simplified without any performance degradation. Moreover, the peak-to-average ratio of the transmit signal is reduced to the PAR of the subcarrier modulation scheme which can limit the out-of-band and in-band emissions when the transmit signal is passed through a non-linear device. With the opportunity to independently adjust the user data rates the proposed technique offers an interesting alternative for reducing the complexity of the mobile terminal in the broadband radio uplink. Galda-2002 at 1741.
[Claim 29] The apparatus of claim 24, comprising instructions for: mapping the block of transform-precoded complex-valued symbols to physical resource blocks assigned for transmission of a physical uplink shared channel.	StarTAC, alone or in combination with one or more other prior art references, renders obvious the apparatus of claim 24, as set forth above with respect to claim 24. *See, e.g.*, claim elements 24PRE, 24A, 24B, 24C, 24D, 24E, 24F. StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and

	implement them in instructions stored on a medium/in memory such that when they were executed by a processor, they executed the claimed functionality: For example, Galda-2002 discloses: > Abstract- The orthogonal frequency division multiplex (OFDM) transmission technique can efficiently deal with the effects of multi-path propagation in the broadband radio channel. It also has a high system inherent flexibility for designing a multiple access scheme by combining the conventional TDMA, FDMA and CDMA approaches with the OFDM modulation scheme. The FDMA multiple access scheme is especially interesting for an uplink of a communication system since it can completely avoid any multiple access interferences (MAI). Moreover, the peak-to-average ratio (PAR) of the uplink OFDM transmit signal can be greatly reduced if this OFDM-FDMA multiple access scheme is additionally combined with a data spreading technique based on a Discrete Fourier Transform (DFT) spreading matrix using only the user specific subcarriers. Since the DFT spreading operation and the IDFT operation used as a part of the OFDM modulation scheme cancel out each other the complexity of the transmitter structure for an OFDM-FDMA uplink can be greatly reduced. Galda-2002 at 1737. > The subdivision of the transmission bandwidth into a set of orthogonal subcarriers can additionally be exploited by an OFDM-FDMA multiple access scheme. By allocating distinct sets of subcarriers to different users the available bandwidth can be flexibly shared between different mobile terminals while avoiding any multiple access interferences (MAI) between different users. The FDMA multiple access scheme offers not only a high flexibility for the radio resource management (RRM) but can also increase the bandwidth efficiency of the complete system by avoiding the use of highly attenuated subcarriers for specific users based on the knowledge of the channel transfer function [2]. Moreover, the OFDM-FDMA multiple

	access scheme can be adapted to the measured radio channel knowledge at the transmitter site using bit-loading techniques. If channel state information is not available the performance can be increased using an additional spreading over the subcarriers assigned to one user. The resulting computation complexity of the total system can by this means be adopted to the given system requirements which is especially of importance for the mobile terminal and in the uplink case. The alternative OFDM-FDMA multiple access scheme is therefore of importance for the uplink case and can be advantageous over OFDM-CDMA schemes because of its ability to avoid MAI if ideal carrier synchronization is assumed for all mobile terminals and the base station. Galda-2002 at 1737. Since the OFDM transmit signal results from the superposition of a large number of independent data symbols the envelope of the complex baseband time signal has in general a large peak-to-average ratio (PAR). The largest output power value of the amplifier will limit the maximum amplitude of the signal in the transmitter. Therefore, non-linear distortions due to clipping and amplification effects in the transmit signal will lead to both in-band and out-of-band emissions. In the past different techniques for reducing the PAR by changing the transmit signal independently from knowledge of other parts of the OFDM transmitter have been developed. But the PAR of the transmit signal envelope which employs an OFDM-FDMA multiple access scheme can significantly be reduced if additional spreading techniques are applied which spread the user data over the allocated subcarrier only. In this case an appropriate spreading technique must be designed reducing the PAR to a minimum value. It will be shown in this paper that using the Discrete Fourier Transform (DFT) matrix as an orthogonal spreading technique will reduce the PAR significantely [3]. Furthermore, the DFT based spreading operation and the IDFT based OFDM modulation technique cancel out each other which means that the transmitter structure can be simplified to a single carrier transmitter with

	an additional guard interval in this specific case which helps to reduce the computational complexity of the transmitter of the mobile terminal. Galda-2002 at 1737-38.  **Fig. 1. Baseband system model for the OFDM-FDMA uplink with individual spreading of user data** Galda-2002 at Fig. 1. The baseband system model of an OFDM-FDMA uplink with individual spreading of user data is shown in Fig. 1. In this case M different users are considered and each user allocates L different subcarrier exclusively. The total number of subcarrier in the considered transmission system is $N_C = L \cdot M$. The input data stream for each mobile user $m, m = 0, \ldots, M-1$, is convolutionally encoded in a first step. The bit sequence is then mapped

	onto L complex modulation symbols $D_l^{(m)}, l = 0, \ldots, L-1$, of a coherent, higher-level modulation scheme. The L modulation symbols are spread over the L user specifically allocated subcarrier with an unitary spreading matrix $[C]$ resulting in L complex transmit symbols $S_l^{(m)}$. The spreading operation can be denoted mathematically by the following simple matrix multiplication $$\vec{S}^{(m)} = [C]\vec{D}^{(m)} \quad (1)$$ where each complex transmit symbol $S_l^{(m)}$ is calculated by the sum of L user modulation symbols $D_l^{(m)}$ weighted by L orthogonal code vectors $\widetilde{C_l} = (C_{l,0}, C_{l,1}, \ldots, C_{l,l})$ with $l = 0, \ldots, L-1$ $$S_l^{(m)} = \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} \quad \text{for} \quad l = 0, \ldots, L-1 \quad (2)$$ The transmit symbols $S_l(m)$ are then mapped onto L of the available N_C subcarrier which are exclusively allocated to user m. In principle, the set of subcarrier assigned to each user can be composed of any L out of N_C subcarrier that have not been assigned to another user. Galda-2002 at 1738.  **Fig. 2. User m allocates the equidistant subset of subcarriers shift by m subcarriers in the frequency domain** Galda-2002 at Fig. 2.

> If a spreading technique is employed including the user specific subcarriers and the spreading gain should be maximized then the selected subcarrier set should be more or less uncorrelated [4]. Therefore in this paper a subset is considered where the selected subcarrier are placed on equidistant subcarriers over the entire bandwidth, see Fig. 2. In this case the selected subcarrier set can be assumed to be mutually independent which leads to a maximum spreading gain, the subcarrier selection is exclusive for each user, which avoids any MAI, and the signalling overhead is minimized. Furthermore, it is assumed in the sequel that the set of equidistant subcarrier are shifted by m subcarrier in the frequency domain if the subset is assigned to user m. The proposed subcarrier selection and modulation process does not need any radio channel state information in this case.

Galda-2002 at 1738.

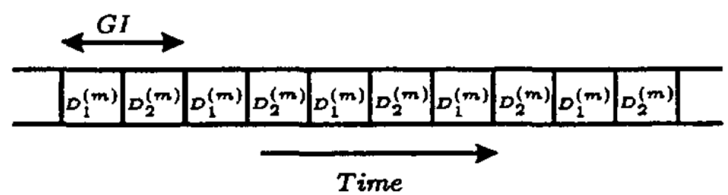


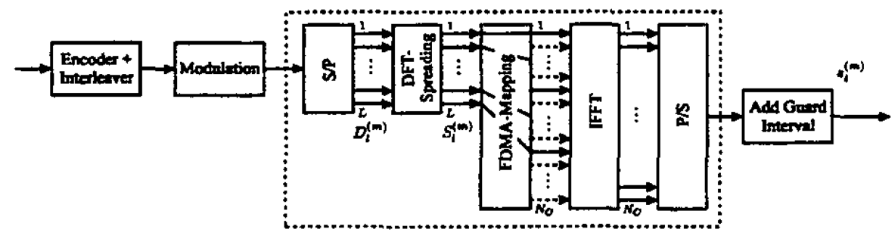
Fig. 5. Time signal of an OFDM-FDMA uplink system with DFT spreading is characterized by a periodic repetition ($N_C = 8, M = 4$)

Galda-2002 at Fig. 5.

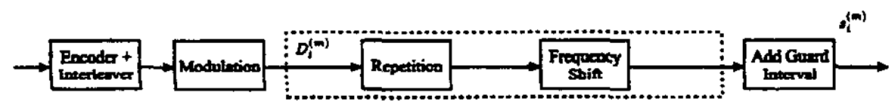
> B. OFDM-FDMA with DFT Spreading
>
> The advantage of a DFT spreading matrix can also be exploited in the uplink of an OFDM-FDMA system. If the user data is spread only over $L < N_C$ subcarriers then the DFT of length L used for spreading does not directly cancel out with the length N_C IDFT of the OFDM modulator in general. Only when the spreaded symbols $S_l^{(m)}$ are mapped onto equidistant located subcarriers with a spacing of $N_C/L = M$ the DFT

	spreading and the OFDM modulation can be removed in the transmitter structure. This can be seen by inserting Equation (2) into Equation (3) using the elements of the discrete Fourier matrix $$C_{i,j} = \frac{1}{\sqrt{L}} \cdot e^{j2\pi ij/L} \quad (6)$$ the transmit signal of user m can be written as $$\begin{aligned} s_i^{(m)} &= e^{j2\pi im/N_C} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} e^{-j2\pi il/L} \\ &= e^{j2\pi im/N_C} \frac{1}{L} \sum_{\nu=0}^{L-1} D_\nu^{(m)} \underbrace{\sum_{l=0}^{L-1} e^{j2\pi(\nu-i)l/L}}_{=L\delta_L(\nu-i)} \\ &= e^{j2\pi im/N_C} \sum_{\nu=0}^{L-1} D_\nu^{(m)} \delta_L(\nu - i) \\ s_i^{(m)} &= e^{j2\pi im/N_C} D_{i \bmod L}^{(m)} \quad (7) \end{aligned}$$ for $i = -N_G, \ldots, 0, \ldots, N_C$ and the periodic dirac pulse sequence $\delta_L(\quad)$. The transmit time signal $s_i^{(m)}$ of user m in an OFDM-FDMA uplink using DFT spreading matrix and an equidistant subcarrier allocation results therefore in a periodic repetition of the complex user data symbol $D_l^{(m)}$ sequence including an added guard interval as cyclic prefix, shown in Fig. 5. This periodic data sequence is multiplied by a user specific complex signal $e^{j2\pi im/N_C}$ due to the user individual frequency shift by m subcarriers of the complete allocated subcarrier set. The number of periods inside a single OFDM symbol is equal to the spacing M of the subcarriers allocated to user m.

Galda-2002 at 1739-40.



(a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers



(b) Realistic but simplified OFDM transmitter structure

Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other.

Galda-2002 at Fig. 6.

> The structure of the OFDM transmitter can be simplified by this approach since both the DFT spreading operation and the IFFT calculation of the conventional OFDM transmitter cancel out and can be removed in the technical realization completely and will be replaced by a simple repetition process of the considered user data $D_l^{(m)}$. The simplified transmitter structure is depicted in Fig. 6. Any equidistant subcarrier allocation can be used with the proposed FDMA scheme since it only influences the number

	of periods of the transmit signal. Therefore the user data rate can be flexibly adjusted by assigning the required number of subcarriers to each user. Galda-2002 at 1740. In this paper an OFDM-FDMA system concept for the uplink of a multi user communication system has been studied. It had be shown that if an OFDM-FDMA system with equidistant subcarrier allocation is combined with a user specific spreading using an discrete Fourier transform as a spreading matrix the transmitter structure can be greatly simplified without any performance degradation. Moreover, the peak-to-average ratio of the transmit signal is reduced to the PAR of the subcarrier modulation scheme which can limit the out-of-band and in-band emissions when the transmit signal is passed through a non-linear device. With the opportunity to independently adjust the user data rates the proposed technique offers an interesting alternative for reducing the complexity of the mobile terminal in the broadband radio uplink. Galda-2002 at 1741. In this paper an OFDM-FDMA system concept for the uplink of a multi user communication system has been studied. It had be shown that if an OFDM-FDMA system with equidistant subcarrier allocation is combined with a user specific spreading using an discrete Fourier transform as a spreading matrix the transmitter structure can be greatly simplified without any performance degradation. Moreover, the peak-to-average ratio of the transmit signal is reduced to the PAR of the subcarrier modulation scheme which can limit the out-of-band and in-band emissions when the transmit signal is passed through a non-linear device. With the opportunity to independently adjust the user data rates the proposed technique offers an interesting alternative for reducing the complexity of the mobile terminal in the broadband radio uplink. Galda-2002 at 1741.

[Claim 32] The apparatus of claim 29, wherein the mapping is configured to select the plurality of OFDM subcarriers according to at least one of a frequency division multiple access scheme, a time division multiple access scheme, a space division multiple access scheme, a code division multiple access scheme, and a frequency-hoping scheme.	StarTAC, alone or in combination with one or more other prior art references, renders obvious the apparatus of claim 29, as set forth above with respect to claim 29. *See, e.g.*, claim 29. StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and implement them in instructions stored on a medium/in memory such that when they were executed by a processor, they executed the claimed functionality: For example, Galda-2002 discloses: > Abstract- The orthogonal frequency division multiplex (OFDM) transmission technique can efficiently deal with the effects of multi-path propagation in the broadband radio channel. It also has a high system inherent flexibility for designing a multiple access scheme by combining the conventional TDMA, FDMA and CDMA approaches with the OFDM modulation scheme. The FDMA multiple access scheme is especially interesting for an uplink of a communication system since it can completely avoid any multiple access interferences (MAI). Moreover, the peak-to-average ratio (PAR) of the uplink OFDM transmit signal can be greatly reduced if this OFDM-FDMA multiple access scheme is additionally combined with a data spreading technique based on a Discrete Fourier Transform (DFT) spreading matrix using only the user specific subcarriers. Since the DFT spreading operation and the IDFT operation used as a part

	of the OFDM modulation scheme cancel out each other the complexity of the transmitter structure for an OFDM-FDMA uplink can be greatly reduced. Galda-2002 at 1737. Recently, the combination between the classical multiple access schemes "TDMA", "FDMA" and "CDMA" and the OFDM transmission technique have been intensively discussed [2]. For the synchronous downlink MC-CDMA or OFDM-CDMA can offer a good performance but due to the loss of orthogonality of the used codes in a frequency selective radio channel the receiver of a mobile terminal has to cope with MAI by single or multi user detection (SUD, MUD) scheme. The effect of MAI is even increased if OFDM-CDMA is used in the uplink due to the independent channels which affect the transmission of different mobile terminals. Galda-2002 at 1737. The subdivision of the transmission bandwidth into a set of orthogonal subcarriers can additionally be exploited by an OFDM-FDMA multiple access scheme. By allocating distinct sets of subcarriers to different users the available bandwidth can be flexibly shared between different mobile terminals while avoiding any multiple access interferences (MAI) between different users. The FDMA multiple access scheme offers not only a high flexibility for the radio resource management (RRM) but can also increase the bandwidth efficiency of the complete system by avoiding the use of highly attenuated subcarriers for specific users based on the knowledge of the channel transfer function [2]. Moreover, the OFDM-FDMA multiple access scheme can be adapted to the measured radio channel knowledge at the transmitter site using bit-loading techniques. If channel state information is not available the performance can be increased using an additional spreading over the subcarriers assigned to one user. The resulting computation complexity of the total system can by this means be adopted to the given system requirements which is especially of importance

> for the mobile terminal and in the uplink case. The alternative OFDM-FDMA multiple access scheme is therefore of importance for the uplink case and can be advantageous over OFDM-CDMA schemes because of its ability to avoid MAI if ideal carrier synchronization is assumed for all mobile terminals and the base station.

Galda-2002 at 1737.

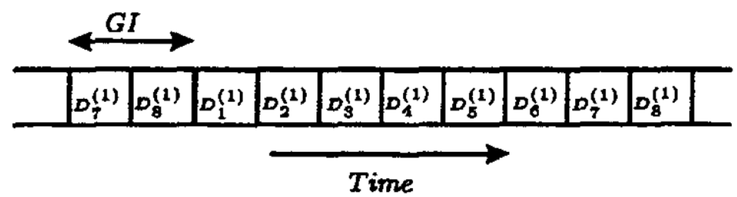
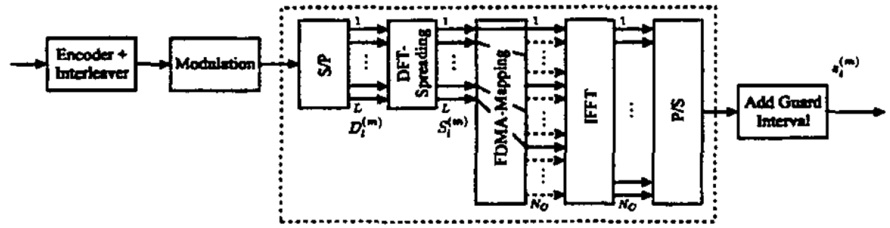


Fig. 3. Time signal of an OFDM-TDMA system with DFT spreading

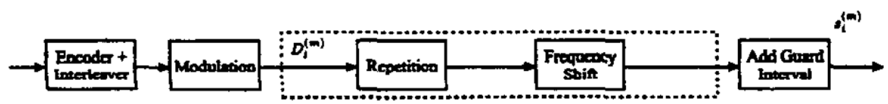
Galda-2002 at Fig. 3.

> A. OFDM-TDMA with DFT Spreading
>
> In [3] the Discrete Fourier Transformation (DFT) matrix has been used for spreading the vector $\vec{D}$ of length $L = N_C$ over all subcarriers of an OFDM system. If a single user is assumed in this OFDM system the spreading operation includes all subcarrier within the entire bandwidth. In this case the DFT spreading matrix and the IDFT operation in the OFDM modulation process cancel out each other. The OFDM transmitter structure with DFT spreading matrix is therefore technically reduced to the serial sequence of complex transmit data symbols D_i to which a guard interval is added in the time domain as a cyclic prefix
>
> $$s_i^{(1)} = D_{i \, mod \, N_C} \quad \text{for} \quad i = -N_G, \dots, 0, \dots, N_C \qquad (5)$$
>
> where mod denotes the modulo operation, as shown in Fig. 3.

	Galda-2002 at 1739.



(a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers



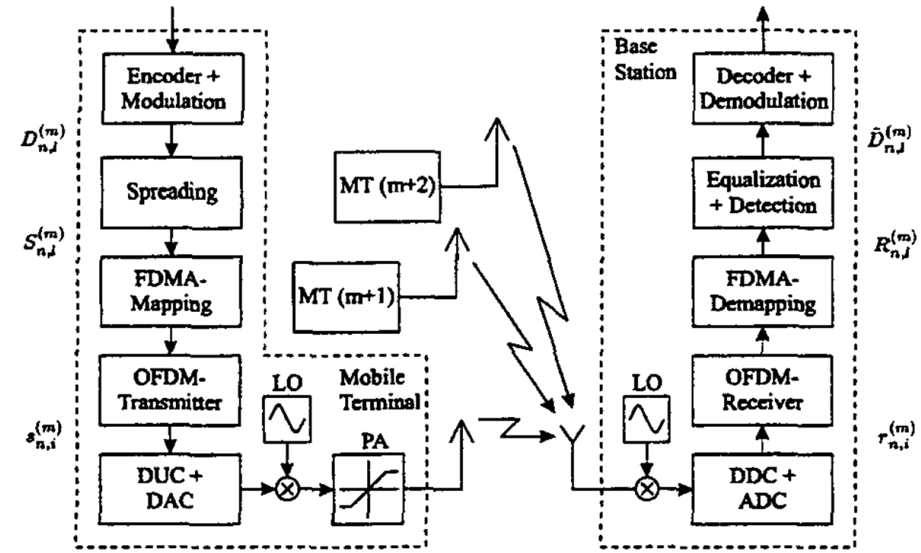
(b) Realistic but simplified OFDM transmitter structure

Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other.

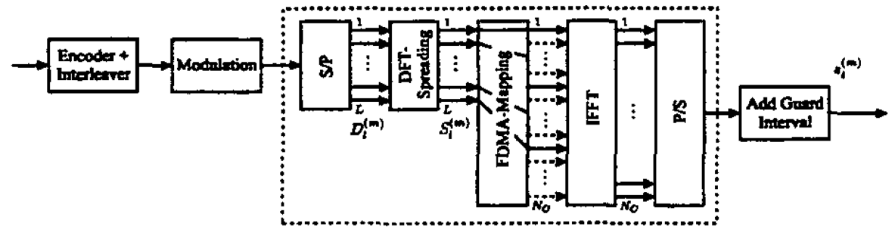
Galda-2002 at Fig. 6.

> The structure of the OFDM transmitter can be simplified by this approach since both the DFT spreading operation and the IFFT calculation of the conventional OFDM transmitter cancel out and can be removed in the technical realization completely and will be replaced by a simple repetition process of the considered user data $D_l^{(m)}$. The simplified transmitter structure is depicted in Fig. 6. Any equidistant subcarrier allocation can be used with the proposed FDMA scheme since it only influences the number

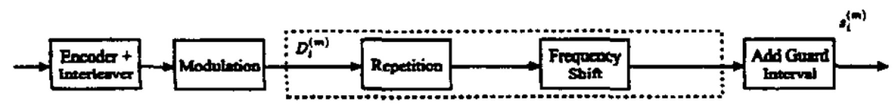
	of periods of the transmit signal. Therefore the user data rate can be flexibly adjusted by assigning the required number of subcarriers to each user. Galda-2002 at 1740.
[Claim 33] The apparatus of claim 24, comprising instructions for: scrambling a block of bits of one subframe of a physical uplink shared channel resulting in a block of scrambled bits; and modulating the block of scrambled bits resulting in the block of complex-valued symbols.	StarTAC, alone or in combination with one or more other prior art references, renders obvious the apparatus of claim 24, as set forth above with respect to claim 24. *See, e.g.*, claim elements 24PRE, 24A, 24B, 24C, 24D, 24E, 24F. StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and implement them in instructions stored on a medium/in memory such that when they were executed by a processor, they executed the claimed functionality: For example, Galda-2002 discloses:

	 Fig. 1. Baseband system model for the OFDM-FDMA uplink with individual spreading of user data Galda-2002 at Fig. 1. The baseband system model of an OFDM-FDMA uplink with individual spreading of user data is shown in Fig. 1. In this case M different users are considered and each user allocates L different subcarrier exclusively. The total number of subcarrier in the considered transmission system is $N_C = L \cdot M$. The input data stream for each mobile user $m, m = 0, \ldots, M - 1$, is convolutionally encoded in a first step. The bit sequence is then mapped onto L complex modulation symbols $D_l^{(m)}, l = 0, \ldots, L - 1$, of a coherent, higher-level modulation scheme. The L modulation symbols are spread over the L user specifically allocated subcarrier with an unitary spreading matrix $[C]$ resulting in L complex transmit symbols $S_l^{(m)}$. The spreading

	operation can be denoted mathematically by the following simple matrix multiplication $$\vec{S}^{(m)} = [C]\vec{D}^{(m)} \quad (1)$$ where each complex transmit symbol $S_l^{(m)}$ is calculated by the sum of L user modulation symbols $D_l^{(m)}$ weighted by L orthogonal code vectors $\widetilde{C_l} = (C_{l,0}, C_{l,1}, \ldots, C_{l,l})$ with $l = 0, \ldots, L-1$ $$S_l^{(m)} = \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} \quad \text{for} \quad l = 0, \ldots, L-1 \quad (2)$$ The transmit symbols $S_l(m)$ are then mapped onto L of the available N_C subcarrier which are exclusively allocated to user m. In principle, the set of subcarrier assigned to each user can be composed of any L out of N_C subcarrier that have not been assigned to another user. Galda-2002 at 1738.



(a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers



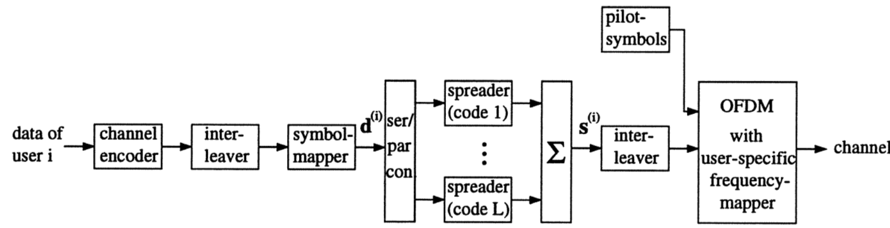
(b) Realistic but simplified OFDM transmitter structure

Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other.

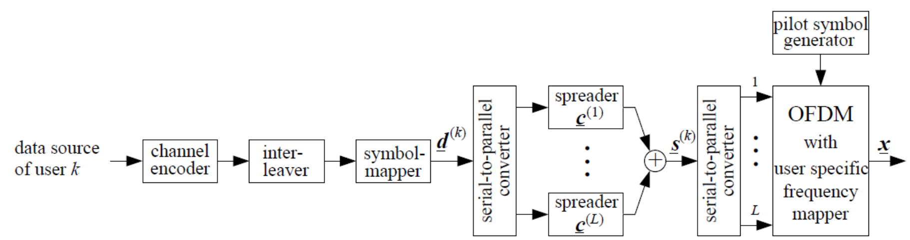
Galda-2002 at Fig. 6.

Kaiser-1997, which discloses:

> ABSTRACT. A flexible multiple access scheme based on a novel combination of the spread-spectrum technique and orthogonal multi-carrier modulation is presented in this paper. The scheme is called spread-spectrum multi-carrier multiple access (SS-MC-MA). Its concept is similar to the concept of multi-carrier (MC)-CDMA. However, its basic difference is, that with SS-MC-MA the code division is used for simultaneous transmission of the data of a single user on the same sub-carriers, where with MC-CDMA, it is used for the simultaneous transmission of the data of different users on the same sub-carriers. The proposed scheme is

	investigated with channel coding and real channel estimation. SS-MC-MA achieves a high bandwidth efficiency for the up-link and for the down-link. Kaiser-1997 at abstract.  Figure 1: SS-MC-MA transmitter for the data of user i. Kaiser-1997 at Fig. 1. The block diagram of the SS-MC-MA transmitter (same for up- and down-link) for the data of user i, $i = 1 \ldots N_u$, is shown in Fig. 1. N_u is the number of active users within a cell. After channel encoding, interleaving, and symbol mapping, L subsequent complex data-symbols $d_l^{(i)}, l = 1 \ldots L$, of user i are serial to parallel converted. The vector $d^{(i)}$ represents one block of L complex data-symbols of user i, $d^{(i)} = \left(d_1^{(i)}, d_2^{(i)}, \ldots d_L^{(i)}\right)^T$, where $(.)^T$ denotes the transposition. Each of the L data-symbols is multiplied with another orthogonal spreading code (e.g. Walsh-Hadamard code) of length L. The $L\ x\ L$ matrix C represents the L orthogonal spreading codes. The modulated spreading codes are added symbol- and with that chip-synchronously, resulting in the transmission vector $$s^{(i)} = C \cdot d^{(i)} = \left(S_1^{(i)}, S_2^{(i)}, \ldots S_L^{(i)}\right)^T, \quad (1)$$ consisting of L chips. To increase the robustness of the SS-MC-MA scheme e.g. against inter cell interference, less than L modulated spreading codes of length L can be added to one transmission vector $s^{(i)}$. The chips of M

	subsequent vectors $s^{(i)}$ are frequency- and time-interleaved and fed to the OFDM unit, which also performs a user-specific frequency mapping. Kaiser-1997 at §2.1. The speech encoder of the mobile station delivers a data rate of 10.46 kbit/s to the channel encoder. The binary data are convolutionally encoded with rate 1/2 and memory 6. A block of 348 code bits is randomly interleaved and QPSK-mapped into 192 data-symbols. A block of 8 serial data-symbols is parallel converted and spread with orthogonal Walsh-Hadamard codes of length L = 8, where each of the 8 data-symbols is multiplied with another spreading code. The 8 data modulated spreading codes are added symbol-, and with that, chip-synchronously, resulting in a transmission sequence of 8 complex chips. A block of 192 chips of M = 24 subsequent transmission sequences are randomly frequency- and time-interleaved. In the OFDM unit 8 chips are modulated on 8 sub-carriers of an OFDM-symbol, where the user-specific sub-carriers are located in distances of 250 kHz, distributed over the whole bandwidth. On each of the 8 sub-carriers in a distance of 5 symbols a pilot-symbol is transmitted, which is known in the receiver (see Fig. 3). Kaiser-1997 at §4. Kaiser-1998, which discloses: This section presents a novel multiple access scheme which is referred to as spread spectrum multi-carrier multiple access (SS-MC-MA). Similar to MC-CDMA, SS-MC-MA exploits the advantages given by the combination of the spread spectrum technique with MC modulation [KaF96, KaF97a]. An SS-MC-MA system is superior compared to an MC-CDMA system in the uplink of a mobile radio system due to a simple channel estimation and a low-complex data detection. Whereas, an MC-CDMA system outperforms an SS-MC-MA system in the downlink, as it will be shown at the end of this section. Before presenting the SS-MC-MA signal structure and its uplink performance, the basic similarities and

	differences between SS-MC-MA and MC-CDMA systems are pointed out. This can preferably be done by comparing the SS-MC-MA and the MC-CDMA transmitter for the downlink. Fig. B.1 shows the SS-MC-MA transmitter for the downlink. The counterpart is the MC-CDMA transmitter with M-Modification shown in Fig. 3.8. For convenience, the case with M equal to L and K_{max} equal to L is considered in this comparison. It can be observed that both transmitters are identical except for the mapping of the user data to the subsystems. In SS-MC-MA systems, one user maps L data symbols to one subsystem which this user exclusively uses for transmission. Consequently, different users use different subsystems in SS-MC-MA systems. In MC-CDMA systems, M data symbols per user are mapped to M different subsystems where each subsystem is shared by different users. Kaiser-1998 at 130-131.  Figure B.2: SS-MC-MA transmitter of the kth user for the uplink Kaiser-1998 at Fig. B.2. SS-MC-MA Transmitter: Fig. B.2 shows an SS-MC-MA transmitter with channel coding for the data of the kth user, $k = 1 \ldots K$, for the uplink. The components channel encoding, interleaving, and symbol mapping are identical to those described in Chapter 4 for MC-CDMA systems. In SS-MC-MA systems, L subsequent complex-valued data symbols $\underline{d}_l^{(k)}, l = 1 \ldots L$, of user k are serial-to-parallel converted. The vector

	$$\underline{d}^{(k)} = \left(\underline{d}_1^{(k)}, \underline{d}_2^{(k)}, \ldots, \underline{d}_L^{(k)}\right)^T \quad (B.1)$$ represents one block of L parallel converted data symbols of the kth user. Each of the L data symbols is multiplied with another orthogonal spreading code of length L. The $L \times L$ matrix $$\underline{C} = \left(\underline{c}_1\ \underline{c}_2\ \ldots\ \underline{c}_L\right) = \begin{pmatrix} \underline{C}_{1,1} & \underline{C}_{2,1} & \cdots & \underline{C}_{L,1} \\ \underline{C}_{1,2} & \underline{C}_{2,2} & \cdots & \underline{C}_{L,2} \\ \vdots & \ddots & \cdots & \vdots \\ \underline{C}_{1,L} & \underline{C}_{2,L} & \cdots & \underline{C}_{L,L} \end{pmatrix} \quad (B.2)$$ represents the L different spreading codes $\underline{c}_l, l = 1, \ldots, L$, used by user k. The matrix $\underline{C}$ is the same for all users. The modulated spreading codes are data symbol and, thus, chip synchronously added, resulting in the transmission vector $$\underline{s}^{(k)} = \underline{C}\ \underline{d}^{(k)} = \left(\underline{S}_1^{(k)}, \underline{S}_2^{(k)}, \ldots, \underline{S}_L^{(k)}\right)^T \quad (B.3)$$ consisting of L components. To increase the robustness of SS-MC-MA systems e.g. against inter cell interference, less than L data modulated spreading codes can be added to one transmission vector $\underline{s}^{(k)}$. Kaiser-1998 at 131-132.

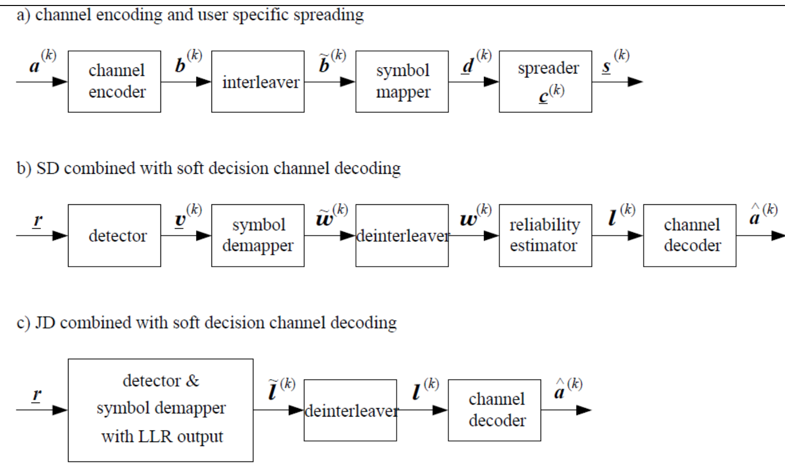
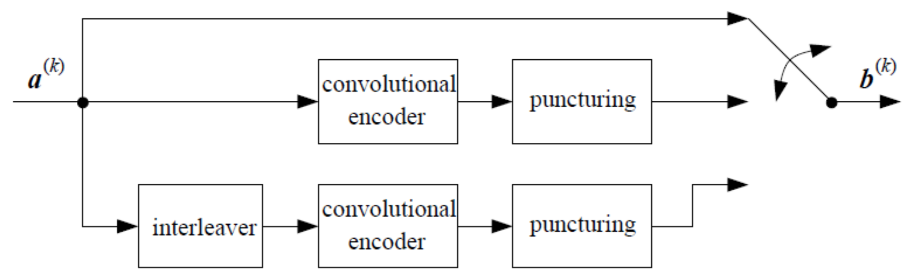


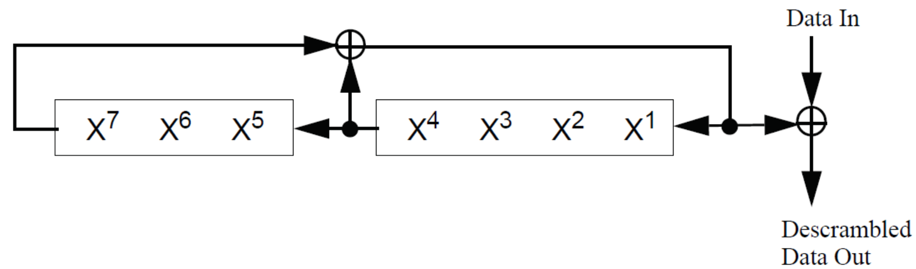
Figure 4.1: Concatenation of the spread spectrum technique with channel coding; a) channel encoding with subsequent data symbol spreading; b) SD and c) JD with optimum soft decision decoding

Kaiser-1998 at 65.

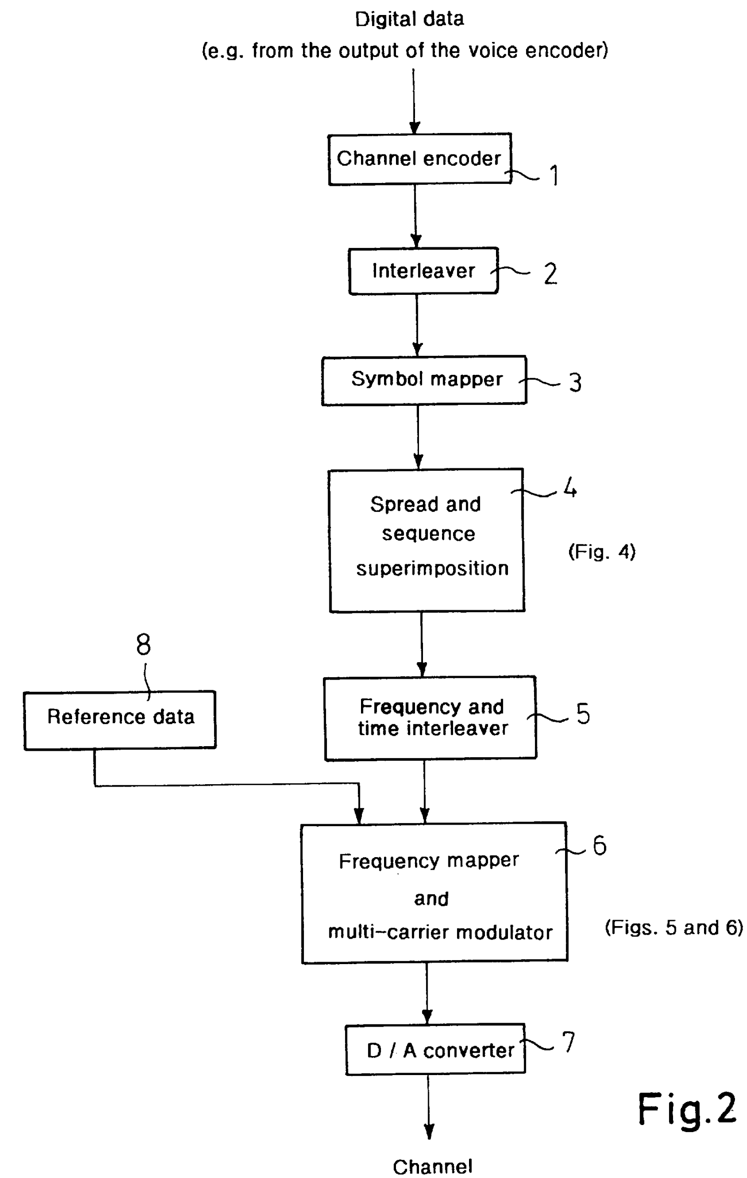
> Channel coding with code bit interleaving is an efficient technique to combat the degradations due to fading, noise, interference, and other channel impairments. The basic idea of channel coding is to introduce controlled redundancy into the transmitted data that is exploited at the receiver to correct channel induced errors by means of forward error correction. There are many different types of error correcting codes. Historically, they have been classified into block codes and convolutional codes [LiC83]. Binary convolutional codes are chosen as channel codes in most second generation mobile radio systems and also for the MC-CDMA mobile radio system presented in this thesis, since there exist very simple decoding algorithms that can achieve a soft decision decoding gain. The channel decoding strategies used in the investigated MC-CDMA receiver are based on the Viterbi algorithm which can exploit soft decided values in an optimum manner [For73].

	Many of the codes that have been developed for increasing the reliability in the transmission of information are effective when the errors caused by the channel are statistically independent. Signal fading due to time-variant multipath propagation often causes the signal to fall below the noise level, thus, resulting in a large number of errors, called burst errors. An efficient method for dealing with burst error channels is to interleave the code bits in such a way that the bursty channel is transformed into a channel having independent errors. Thus, a code designed for independent errors or short bursts can be used. Code bit interleaving has become an extremely useful technique in all second generation digital cellular systems, and can for example be realized as block, diagonal, or random interleaver [Ste94]. Kaiser-1998 at 64.  Figure 4.3: Turbo encoder Kaiser-1998 at Fig. 4.3. IEEE, which discloses: 17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details described in these subclauses:

	. . . e) Initiate the scrambler with a pseudorandom non-zero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled "zero" bits following the "data" with six nonscrambled "zero" bits. (Those bits return the convolutional encoder to the "zero state" and are denoted as "tail bits.") Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of N_{CBPS} bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of N_{CBPS} bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. IEEE at 7-8. 17.3.5.4 PLCP DATA scrambler and descrambler The DATA field, composed of SERVICE, PSDU, tail, and pad parts, shall be scrambled with a length-127 frame-synchronous scrambler. The octets of the PSDU are placed in the transmit serial bit stream, bit 0 first and bit 7 last. The frame synchronous scrambler uses the generator polynomial $S(x)$ as follows, and is illustrated in Figure 113: $$S(x) = x^7 + x^4 + 1 \quad (14)$$ The 127-bit sequence generated repeatedly by the scrambler shall be (leftmost used first), 00001110 11110010 11001001 00000010 00100110

	00101110 10110110 00001100 11010100 11100111 10110100 00101010 11111010 01010001 10111000 1111111, when the "all ones" initial state is used. The same scrambler is used to scramble transmit data and to descramble receive data. When transmitting, the initial state of the scrambler will be set to a pseudo random non-zero state. The seven LSBs of the SERVICE field will be set to all zeros prior to scrambling to enable estimation of the initial state of the scrambler in the receiver.  **Figure 113—Data scrambler** IEEE at 16. 17.3.5.7 Subcarrier modulation mapping The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM modulation, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of NBPSC (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 116, with the input bit, b0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (20). $d = (I + jQ) \times K_{\mathrm{MOD}}$ (20) The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 81. Note that the modulation type can be different from

	> the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 107. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6. IEEE at 19. Kaiser-717, which discloses:

Digital data
(e.g. from the output of the voice encoder)
Channel encoder
1
Interleaver
2
Symbol mapper
3
Spread and sequence superimposition
4
(Fig. 4)
8
Reference data
Frequency and time interleaver
5
Frequency mapper and multi-carrier modulator
6
(Figs. 5 and 6)
D / A converter
7
Channel

Fig.2

	Kaiser-717 at Fig. 2. As shown in FIG. 2, on the transmission side, a channel encoder 1 provides the digital data coming from, for example, the output of a voice encoder with error protection against channel disturbances. Convolution codes, turbo codes or block codes, for example, can be used as channel codes. The code bits are scrambled in blocks or pseudo-randomly, for example, with an interleaver 2 to avoid long error bursts at the input of the channel decoder in the receiver, which will be described later. The scrambled code bits are mapped into complex data symbols in a data-symbol mapper 3, for example with a BPSK (Binary Phase Shift Keying) or a QPSK (Quadrature Phase Shift Keying). Kaiser-717 at 5:22-33. At a rate of ½, the channel encoder 34 encodes the binary data coming from the voice encoder of a subscriber station at a data rate of 10.46 kbit/s. The channel encoder is a convolutional encoder having a memory length of 6. A pseudo-random interleaver 35 scrambles 348 consecutive code bits, which are QPSK-modulated afterward in a symbol mapper 36. The employed multi-carrier modulation technique OFDM uses 256 sub-carriers with a carrier spacing of 7.81 kHz, and is realised in a 256 point Inverse Fast Fourier Transformation IFFT. The result is an OFDM symbol duration of Ts=128 μs, which is lengthened by a guard interval having the duration Δ=20 μs. Kaiser-717 at 8:5-16. 3. The method according to claim 1, wherein on the transmission side, a channel encoder first provides the digital data with an error-protection channel code against channel disturbances. Kaiser-717, claim 3.

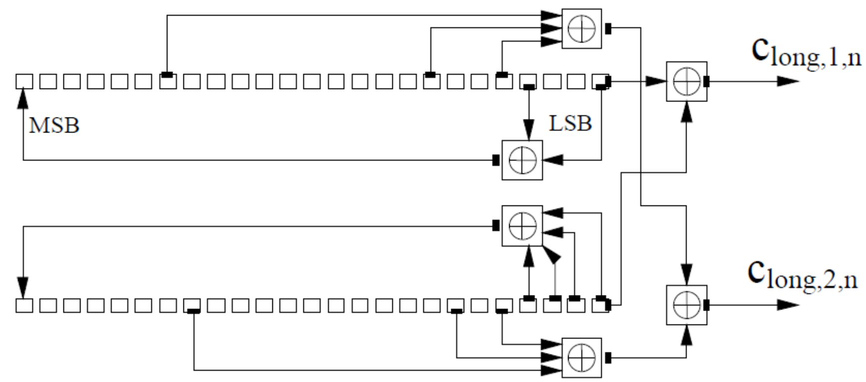
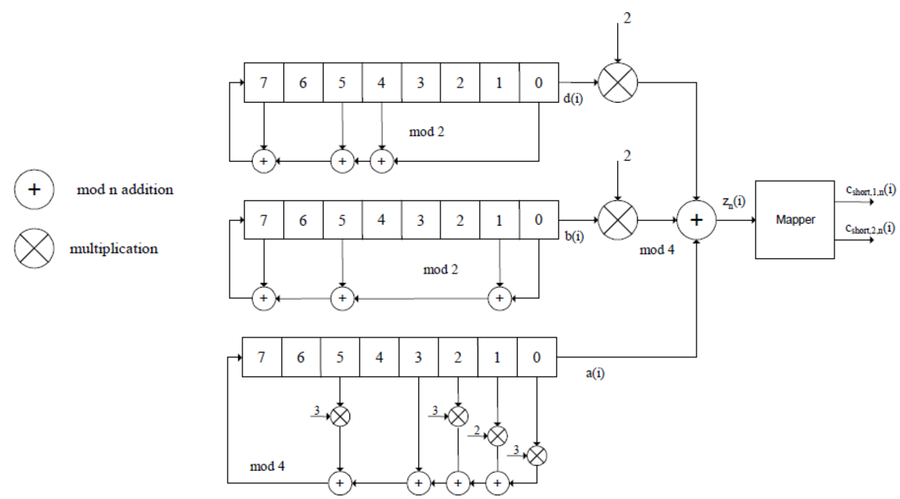
	4. The method according to claim 3, wherein the channel code includes at least one of convolution codes, turbo codes or block codes. Kaiser-717, claim 4. 5. The method according to claim 3, including scrambling of code bits obtained from the channel encoder with an interleaver. Kaiser-717, claim 5. 6. The method according to claim 5, wherein the scrambling is carried out in blocks. Kaiser-717, claim 6. 7. The method according to claim 5, including mapping and digitally modulating the scrambled code bits into complex data symbols in a symbol mapper. Kaiser-717, claim 7. 8. The method according to claim 7, including performing a digital modulation in the symbol mapper by phase shift keying including at least one of Binary Phase Shift Keying (BPSK) modulation or a Quadrature Phase Shift Keying (QPSK) modulation, wherein the complex data symbols are present in a respective modulated form at an output of the symbol mapper. Kaiser-717, claim 8. 3GPP-25.201, which discloses: 4.2.3 Modulation and spreading

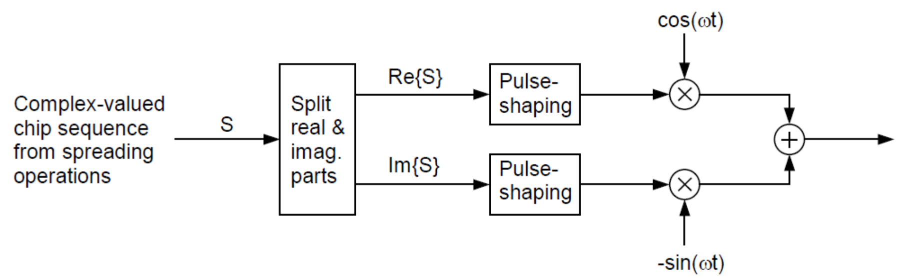
	The UTRA modulation scheme is QPSK (8PSK is also used for 1.28Mcps TDD option). Pulse shaping is specified in the TS 25.100 series. With CDMA nature the spreading (& scrambling) process is closely associated with modulation. In UTRA different families of spreading codes are used to spread the signal: - For separating channels from same source, channelisation codes derived with the code tree structure as given in TS 25.213 and 25.223 are used. - For separating different cells the following solutions are supported. - FDD mode: Gold codes with 10 ms period (38400 chips at 3.84 Mcps) used, with the actual code itself length 218-1 chips, as defined in TS 25.213. - TDD mode: Scrambling codes with the length 16 used as defined in TS 25.223. - For separating different UEs the following code families are defined. - FDD mode: Gold codes with 10 ms period, or alternatively S(2) codes 256 chip period. - TDD mode: codes with period of 16 chips and midamble sequences of different length depending on the environment. 3GPP-25.201 at 8-9. 5.5 TS 25.213: Spreading and modulation (FDD) The scope is to establish the characteristics of the spreading and modulation in the FDD mode, and to specify: - the spreading (channelisation plus scrambling); - generation of channelisation and scrambling codes; - generation of RACH and CPCH preamble codes;

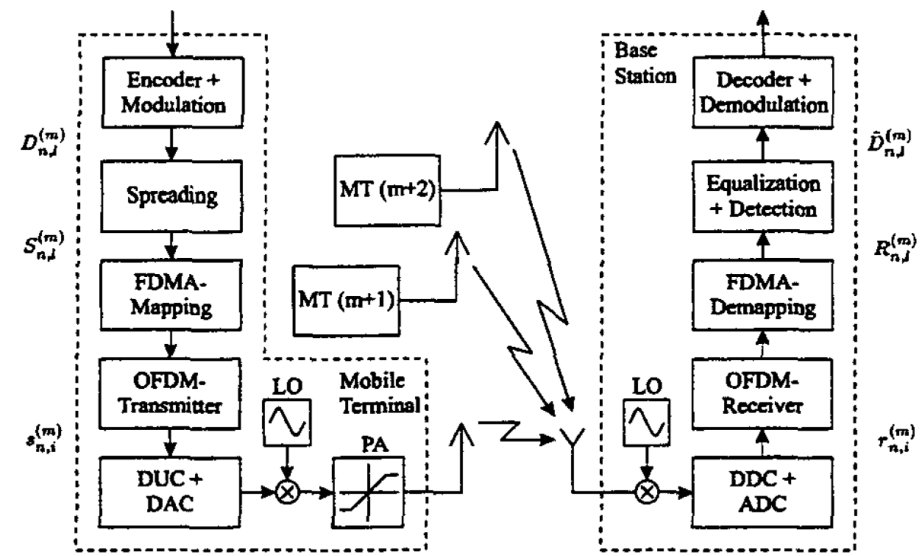
	- generation of SCH synchronisation codes; - modulation. RF channel arrangements and Pulse shaping are specified in TS 25.101 for UE and in TS 25.104 for Node-B. 3GPP-25.201 at 11. 3GPP-25.213, which discloses: 4 Uplink spreading and modulation 4.1 Overview Spreading is applied to the physical channels. It consists of two operations. The first is the channelization operation, which transforms every data symbol into a number of chips, thus increasing the bandwidth of the signal. The number of chips per data symbol is called the Spreading Factor (SF). The second operation is the scrambling operation, where a scrambling code is applied to the spread signal. With the channelization, data symbols on so-called I- and Q-branches are independently multiplied with an OVSF code. With the scrambling operation, the resultant signals on the I- and Q-branches are further multiplied by complex-valued scrambling code, where I and Q denote real and imaginary parts, respectively. 3GPP-25.213 at 7. 4.3.2 Scrambling codes 4.3.2.1 General All uplink physical channels are subjected to scrambling with a complex-valued scrambling code. The DPCCH/DPDCH may be scrambled by either long or short scrambling codes, defined in section 4.3.2.4. The PRACH message part is scrambled with a long scrambling code, defined in section

	4.3.2.5. Also the PCPCH message part is scrambled with a long scrambling code, defined in section 4.3.2.6. There are 224 long and 224 short uplink scrambling codes. Uplink scrambling codes are assigned by higher layers. The long scrambling code is built from constituent long sequences defined in section 4.3.2.2, while the constituent short sequences used to build the short scrambling code are defined in section 4.3.2.3. 4.3.2.2 Long scrambling sequence The long scrambling sequences $c_{long,1,n}$ and $c_{long,2,n}$ are constructed from position wise modulo 2 sum of 38400 chip segments of two binary m-sequences generated by means of two generator polynomials of degree 25. Let x, and y be the two m-sequences respectively. The x sequence is constructed using the primitive (over GF(2)) polynomial $X^{25} + X^3 + 1$. The y sequence is constructed using the polynomial $X^{25} + X^3 + X^2 + X + 1$. The resulting sequences thus constitute segments of a set of Gold sequences. The sequence $c_{\text{long},2,n}$ is a 16777232 chip shifted version of the sequence $c_{\text{long},1,n}$. Let $n_{23}, \ldots, n_0$ be the 24-bit binary representation of the scrambling sequence number n with n_0 being the least significant bit. The x sequence depends on the chosen scrambling sequence number n and is denoted x_n in the sequel. Furthermore, let $x_n(i)$ and $y(i)$ denote the i-th symbol of the sequence x_n and y, respectively. The m-sequences x_n and y are constructed as: Initial conditions: - $x_n(0) = n_0, x_n(1) = n_1, \ldots, x_n(22) = n_{22}, x_n(23) = n_{23}, x_n(24) = 1$. - $y(0) = y(1) = \cdots = y(23) = y(24) = 1$.

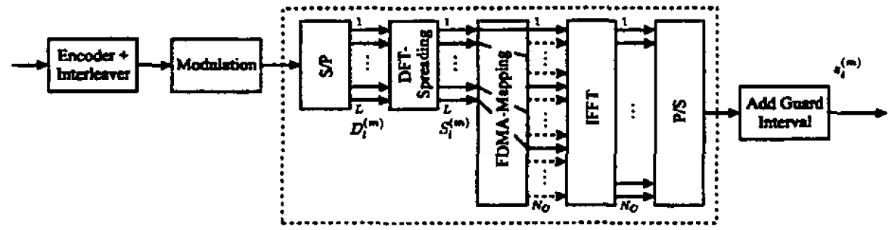
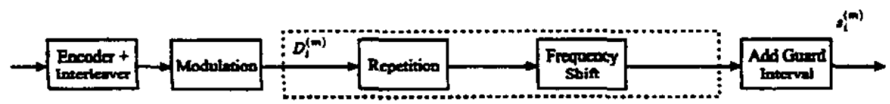
	Recursive definition of subsequent symbols: - $x_n(i+25) = x_n(i+3) + x_n(i)\ modulo\ 2, \quad i = 0, \dots, 2^{25}-27.$ - $y(i+25) = y(i+3) + y(i+2) + y(i+1) + y(i)\ modulo\ 2, \quad i = 0, \dots, 2^{25}-27.$ Define the binary Gold sequence z_n by: - $z_n(i) = x_n(i) + y(i)\ modulo\ 2, \quad i = 0,1,2, \dots, 2^{25}-2.$ The real-valued Gold sequence Z_n is defined by: $$Z_n(i) = \begin{cases} +1 \text{ if } z_n(i) = 0 \\ -1 \text{ if } z_n(i) = 1 \end{cases} \quad \text{for } i = 0,1, \dots, 2^{25}-2.$$ Now, the real-valued long scrambling sequences $c_{\text{long},1,n}$ and $c_{\text{long},2,n}$ are defined as follows: - $c_{\text{long},1,n}(i) = Z_n(i), \quad i = 0,1,2, \dots, 2^{25}-2$ - $c_{\text{long},2,n}(i) = Z_n\big((i + 16777232)\ modulo\ (2^{25}-1)\big), \quad i = 0,1,2, \dots, 2^{25}-2.$ Finally, the complex-valued long scrambling sequence $C_{\text{long},n}$ is defined as: $$C_{\text{long},n}(i) = c_{\text{long},1,n}(i)\left(1 + j(-1)^i c_{\text{long},2,n}\left(2\left\lfloor \frac{i}{2} \right\rfloor\right)\right)$$ where $i = 0,1, \dots, 2^{25}-2$ and $\lfloor \cdot \rfloor$ denotes rounding to the nearest lower integer.

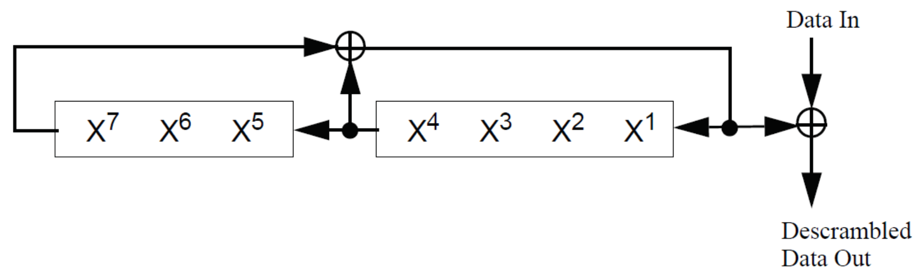
	 **Figure 5: Configuration of uplink scrambling sequence generator** 3GPP-25.213 at 12-13.  **Figure 6: Uplink short scrambling sequence generator for 255 chip sequence** 3GPP-25.213 at 14.

	4.4 Modulation 4.4.1 Modulating chip rate The modulating chip rate is 3.84 Mcps. 4.4.2 Modulation In the uplink, the complex-valued chip sequence generated by the spreading process is QPSK modulated as shown in Figure 7 below:  **Figure 7: Uplink modulation** The pulse-shaping characteristics are described in [3]. 3GPP-25.213 at 18.
[Claim 34] The apparatus of claim 33, wherein the scrambling is configured to scramble the block of bits into a block of scrambled bits with at least one pseudo-noise code.	StarTAC, alone or in combination with one or more other prior art references, renders obvious the apparatus of claim 33, as set forth above with respect to claim 33. *See, e.g.*, claim 33. StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality.

	A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and implement them in instructions stored on a medium/in memory such that when they were executed by a processor, they executed the claimed functionality: For example, Galda-2002 discloses:  Fig. 1. Baseband system model for the OFDM-FDMA uplink with individual spreading of user data Galda-2002 at Fig. 1.

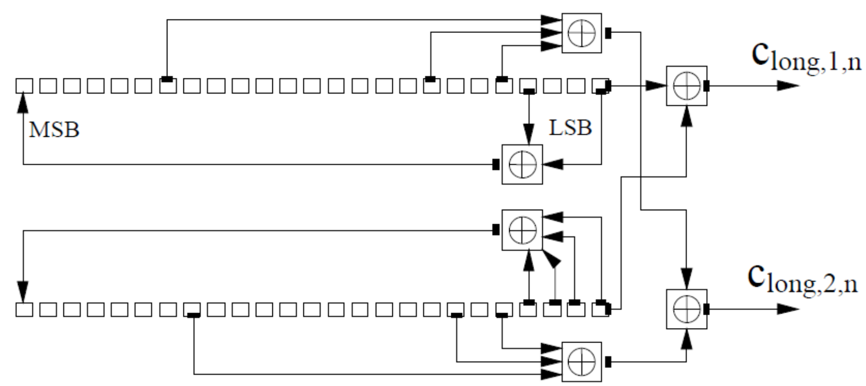
	The baseband system model of an OFDM-FDMA uplink with individual spreading of user data is shown in Fig. 1. In this case M different users are considered and each user allocates L different subcarrier exclusively. The total number of subcarrier in the considered transmission system is $N_C = L \cdot M$. The input data stream for each mobile user $m, m = 0, \ldots, M - 1$, is convolutionally encoded in a first step. The bit sequence is then mapped onto L complex modulation symbols $D_l^{(m)}, l = 0, \ldots, L-1$, of a coherent, higher-level modulation scheme. The L modulation symbols are spread over the L user specifically allocated subcarrier with an unitary spreading matrix $[C]$ resulting in L complex transmit symbols $S_l^{(m)}$. The spreading operation can be denoted mathematically by the following simple matrix multiplication $$\vec{S}^{(m)} = [C]\vec{D}^{(m)} \quad (1)$$ where each complex transmit symbol $S_l^{(m)}$ is calculated by the sum of L user modulation symbols $D_l^{(m)}$ weighted by L orthogonal code vectors $\widetilde{C_l} = (C_{l,0}, C_{l,1}, \ldots, C_{l,l})$ with $l = 0, \ldots, L-1$ $$S_l^{(m)} = \sum_{\nu=0}^{L-1} C_{l,\nu} D_\nu^{(m)} \quad \text{for} \quad l = 0, \ldots, L-1 \quad (2)$$ The transmit symbols $S_l(m)$ are then mapped onto L of the available N_C subcarrier which are exclusively allocated to user m. In principle, the set of subcarrier assigned to each user can be composed of any L out of N_C subcarrier that have not been assigned to another user. Galda-2002 at 1738.

	 (a) OFDM-FDMA transmitter with DFT spreading over equidistant subcarriers  (b) Realistic but simplified OFDM transmitter structure **Fig. 6. In an OFDM-FDMA uplink system including DFT spreading matrix applied to a set of equidistant subcarriers the DFT spreading matrix and the OFDM IFFT transformation cancel out each other.** Galda-2002 at Fig. 6. IEEE, which discloses: 17.3.5.4 PLCP DATA scrambler and descrambler The DATA field, composed of SERVICE, PSDU, tail, and pad parts, shall be scrambled with a length-127 frame-synchronous scrambler. The octets of the PSDU are placed in the transmit serial bit stream, bit 0 first and bit 7 last. The frame synchronous scrambler uses the generator polynomial $S(x)$ as follows, and is illustrated in Figure 113: $$S(x) = x^7 + x^4 + 1 \quad (14)$$

	The 127-bit sequence generated repeatedly by the scrambler shall be (leftmost used first), 00001110 11110010 11001001 00000010 00100110 00101110 10110110 00001100 11010100 11100111 10110100 00101010 11111010 01010001 10111000 1111111, when the "all ones" initial state is used. The same scrambler is used to scramble transmit data and to descramble receive data. When transmitting, the initial state of the scrambler will be set to a pseudo random non-zero state. The seven LSBs of the SERVICE field will be set to all zeros prior to scrambling to enable estimation of the initial state of the scrambler in the receiver.  **Figure 113—Data scrambler** IEEE at 16. Kaiser-717, which discloses: As shown in FIG. 2, on the transmission side, a channel encoder 1 provides the digital data coming from, for example, the output of a voice encoder with error protection against channel disturbances. Convolution codes, turbo codes or block codes, for example, can be used as channel codes. The code bits are scrambled in blocks or pseudo-randomly, for example, with an interleaver 2 to avoid long error bursts at the input of the channel decoder in the receiver, which will be described later. The scrambled code bits are mapped into complex data symbols in a data-symbol mapper 3, for example with a BPSK (Binary Phase Shift Keying) or a QPSK (Quadrature Phase Shift Keying).

	Kaiser-717 at 5:22-33. > At a rate of ½, the channel encoder 34 encodes the binary data coming from the voice encoder of a subscriber station at a data rate of 10.46 kbit/s. The channel encoder is a convolutional encoder having a memory length of 6. A pseudo-random interleaver 35 scrambles 348 consecutive code bits, which are QPSK-modulated afterward in a symbol mapper 36. The employed multi-carrier modulation technique OFDM uses 256 sub-carriers with a carrier spacing of 7.81 kHz, and is realised in a 256 point Inverse Fast Fourier Transformation IFFT. The result is an OFDM symbol duration of Ts=128 μs, which is lengthened by a guard interval having the duration Δ=20 μs. Kaiser-717 at 8:5-16. 36. The method according to claim 5, wherein the scrambling is carried out pseudo-randomly. Kaiser-717, claim 1. 3GPP-25.213, which discloses: 4.3.2 Scrambling codes 4.3.2.1 General All uplink physical channels are subjected to scrambling with a complex-valued scrambling code. The DPCCH/DPDCH may be scrambled by either long or short scrambling codes, defined in section 4.3.2.4. The PRACH message part is scrambled with a long scrambling code, defined in section 4.3.2.5. Also the PCPCH message part is scrambled with a long scrambling code, defined in section 4.3.2.6. There are 224 long and 224 short uplink scrambling codes. Uplink scrambling codes are assigned by higher layers.

	The long scrambling code is built from constituent long sequences defined in section 4.3.2.2, while the constituent short sequences used to build the short scrambling code are defined in section 4.3.2.3. 4.3.2.2 Long scrambling sequence The long scrambling sequences $c_{long,1,n}$ and $c_{long,2,n}$ are constructed from position wise modulo 2 sum of 38400 chip segments of two binary m-sequences generated by means of two generator polynomials of degree 25. Let x, and y be the two m-sequences respectively. The x sequence is constructed using the primitive (over GF(2)) polynomial $X^{25} + X^3 + 1$. The y sequence is constructed using the polynomial $X^{25} + X^3 + X^2 + X + 1$. The resulting sequences thus constitute segments of a set of Gold sequences. The sequence $c_{\text{long},2,n}$ is a 16777232 chip shifted version of the sequence $c_{\text{long},1,n}$. Let $n_{23}, \ldots, n_0$ be the 24-bit binary representation of the scrambling sequence number n with n_0 being the least significant bit. The x sequence depends on the chosen scrambling sequence number n and is denoted x_n in the sequel. Furthermore, let $x_n(i)$ and $y(i)$ denote the i-th symbol of the sequence x_n and y, respectively. The m-sequences x_n and y are constructed as: Initial conditions: - $x_n(0) = n_0, x_n(1) = n_1, \ldots, x_n(22) = n_{22}, x_n(23) = n_{23}, x_n(24) = 1$. - $y(0) = y(1) = \cdots = y(23) = y(24) = 1$. Recursive definition of subsequent symbols: - $x_n(i + 25) = x_n(i + 3) + x_n(i)\ modulo\ 2, \quad i = 0, \ldots, 2^{25} - 27$. - $y(i + 25) = y(i + 3) + y(i + 2) + y(i + 1) + y(i)\ modulo\ 2, \quad i = 0, \ldots, 2^{25} - 27$.

	Define the binary Gold sequence z_n by: - $z_n(i) = x_n(i) + y(i)\ modulo\ 2, \quad i = 0,1,2,\dots,2^{25}-2.$ The real-valued Gold sequence Z_n is defined by: $Z_n(i) = \begin{cases} +1 \text{ if } z_n(i) = 0 \\ -1 \text{ if } z_n(i) = 1 \end{cases} \quad \text{for } i = 0,1,\dots,2^{25}-2.$ Now, the real-valued long scrambling sequences $c_{\text{long},1,n}$ and $c_{\text{long},2,n}$ are defined as follows: - $c_{\text{long},1,n}(i) = Z_n(i), \quad i = 0,1,2,\dots,2^{25}-2$ - $c_{\text{long},2,n}(i) = Z_n\big((i + 16777232)\ modulo\ (2^{25}-1)\big), \quad i = 0,1,2,\dots,2^{25}-2.$ Finally, the complex-valued long scrambling sequence $C_{\text{long},n}$ is defined as: $C_{\text{long},n}(i) = c_{\text{long},1,n}(i)\left(1 + j(-1)^i c_{\text{long},2,n}\left(2\left\lfloor\frac{i}{2}\right\rfloor\right)\right)$ where $i = 0,1,\dots,2^{25}-2$ and $\lfloor\cdot\rfloor$ denotes rounding to the nearest lower integer.  **Figure 5: Configuration of uplink scrambling sequence generator**

	3GPP-25.213 at 12-13.
[Claim 44] The method of claim 24, wherein each of the plurality of sets of complex-valued symbols is a single carrier frequency division multiple access (SC-FDMA) symbol.	StarTAC, alone or in combination with one or more other prior art references, renders obvious the apparatus of claim 24, as set forth above with respect to claim 24. *See, e.g.*, claim elements 24PRE, 24A, 24B, 24C, 24D, 24E, 24F. StarTAC had a non-transitory memory coupled to the processor, the non-transitory memory including a set of instructions stored therein and executable by the processor. Nevertheless, StarTAC included a CDMA transmitter that used an earlier generation of wireless communication technology. As such it did not include memory that included instructions to perform the claimed functionality. A POSA would have been aware of developments seeking to add data and higher transmission rates and overall network throughput in cellular and other wireless communications technologies. Such technologies were designed to improve on the technology underlying the transmitter used in, for example, StarTAC. A POSA thus would have found it obvious to modify StarTAC using the technologies described in one or more of the following references and arrive at the claimed subject matter and implement them in instructions stored on a medium/in memory such that when they were executed by a processor, they executed the claimed functionality: For example, Galda-2002 discloses: > Since the OFDM transmit signal results from the superposition of a large number of independent data symbols the envelope of the complex baseband time signal has in general a large peak-to-average ratio (PAR). The largest output power value of the amplifier will limit the maximum amplitude of the signal in the transmitter. Therefore, non-linear distortions due to clipping and amplification effects in the transmit signal will lead to both in-band and out-of-band emissions. In the past different techniques for reducing the PAR by changing the transmit signal independently from knowledge of other parts of the OFDM transmitter have been developed. But the PAR of the transmit signal envelope which employs an OFDM-FDMA multiple access scheme can significantly be reduced if additional

> spreading techniques are applied which spread the user data over the allocated subcarrier only. In this case an appropriate spreading technique must be designed reducing the PAR to a minimum value. It will be shown in this paper that using the Discrete Fourier Transform (DFT) matrix as an orthogonal spreading technique will reduce the PAR significantely [3]. Furthermore, the DFT based spreading operation and the IDFT based OFDM modulation technique cancel out each other which means that the transmitter structure can be simplified to a single carrier transmitter with an additional guard interval in this specific case which helps to reduce the computational complexity of the transmitter of the mobile terminal.

Galda-2002 at 1737-38.

> Independent of the considered spreading matrix C but assuming the equidistant allocation of subcarrier over the entire bandwidth the resulting OFDM time signal of user m can analytically be described as

$$s_i^{(m)} = e^{j2\pi im/N_C} \frac{1}{\sqrt{L}} \sum_{l=0}^{L-1} S_l^{(m)} e^{-j2\pi il/L} \quad \text{for} \quad i = -N_G, \dots, 0, \dots, N_C \qquad (3)$$

> where N_G denotes the length of the guard interval which is inserted into the transmit time signal.

Galda-2002 at 1738.

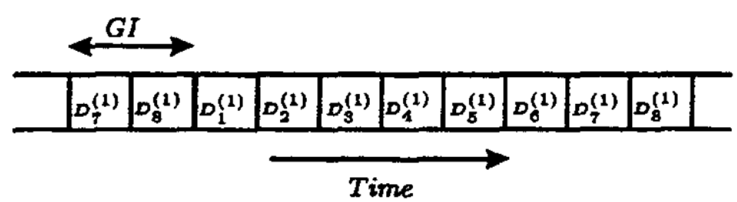


Fig. 3. Time signal of an OFDM-TDMA system with DFT spreading

	Galda-2002 at Fig. 3. > A. OFDM-TDMA with DFT Spreading > In [3] the Discrete Fourier Transformation (DFT) matrix has been used for spreading the vector $\vec{D}$ of length $L = N_C$ over all subcarriers of an OFDM system. If a single user is assumed in this OFDM system the spreading operation includes all subcarrier within the entire bandwidth. In this case the DFT spreading matrix and the IDFT operation in the OFDM modulation process cancel out each other. The OFDM transmitter structure with DFT spreading matrix is therefore technically reduced to the serial sequence of complex transmit data symbols D_i to which a guard interval is added in the time domain as a cyclic prefix > $s_i^{(1)} = D_{i\ mod\ N_C} \quad \text{for} \quad i = -N_G, \ldots, 0, \ldots, N_C \quad (5)$ > where mod denotes the modulo operation, as shown in Fig. 3. Galda-2002 at 1739. > Since the transmit signal of this OFDM system consist of a sequence of complex modulation symbols D_i, it has the same PAR as the modulation scheme employed for single carrier transmission techniques. Galda-2002 at 1739. > Since the time signal of the OFDM-FDMA uplink with DFT spreading is identical to a single carrier transmission additional techniques to reduce the PAR originally developed for single carrier systems like the π/4-QPSK can be employed. Galda-2002 at 1740.