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16306693.9 15 December 2016 (15.12.2016) EP(71) Applicant: **ALCATEL LUCENT** [FR/FR]; 148/152
Route de la Reine, 92100 Boulogne-Billancourt (FR).(72) Inventors: **RHEINSCHMITT, Rupert**; Nokia Solutions
and Networks GmbH & Co. KG, Lorenzstrasse 10, 70435
Stuttgart (DE). **FUCHS, Rolf**; Nokia Solutions and Net-
works GmbH & Co. KG, Lorenzstrasse 10, 70435 Stuttgart
(DE).(74) Agent: **WETZEL, Emmanuelle**; Nokia Solutions and Net-
works GmbH & Co. KG, Lorenzstrasse 10, 70435 Stuttgart
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(54) Title: COMBINING SMALLER FFTS TO RECEIVE SIGNAL MODULATED BY LARGER IFFT

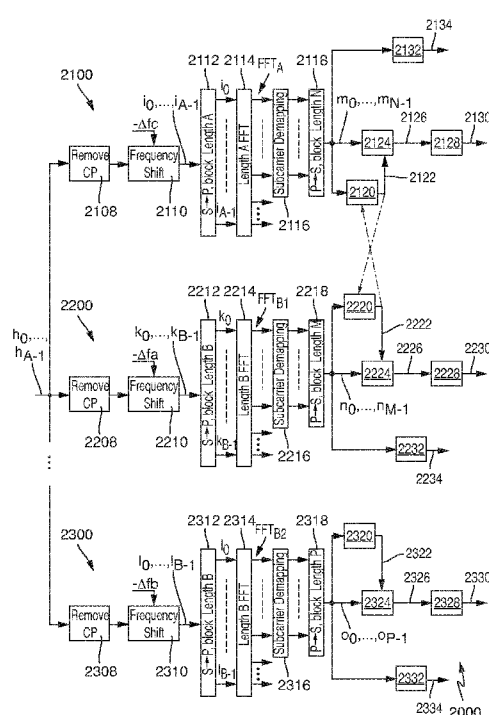


Fig. 3

(57) Abstract: It is proposed an OFDM-demodulator (2000) for operating in a device (BS; UE) of a radio communications network (RCN). A first and second egress sample stream ($n_0, \dots, n_{M-1}$, $O_0, \dots, O_{P-1}$) is determined in dependence on a first and second forward Fast Fourier Transform (FFT_{B1} , FFT_{B2}), respectively. It is determined a synchronization sequence (SS) in dependence on the first and second egress sample stream ($n_0, \dots, n_{M-1}$, $O_0, \dots, O_{P-1}$).

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25 **Title: COMBINING SMALLER FFTS TO RECEIVE SIGNAL MODULATED BY LARGER IFFT**

Specification

30 **Field of the invention**

The present disclosure is directed to an OFDM-demodulator,
and a method to operate an OFDM-demodulator.

35 **Background**

Evolving radio communications standards like 5G permit an
efficient multi-cell / multi-TP (transmission point)
support of mixed numerologies, namely mixed carrier
40 configurations. 5G in general and specifically 3GPP New
Radio targets multi-service support within one carrier. As

5 the different service use cases are very different from each other, they motivate different multi-carrier waveform parameters each.

10 **Summary**

An object of the disclosure is to propose an OFDM-demodulator for operating in a device of a radio communications network, wherein the OFDM-demodulator
15 comprises a processor and a memory being configured to: receive a down-converted sample stream; determine at least a first and second ingress sample stream of the down-converted sample stream of same block length and of different frequency offsets, respectively; determine a
20 first and second forward Fast Fourier Transform of the same block length in dependence on the first and second ingress sample stream, respectively; determine a first and second egress sample stream in dependence on the first and second forward Fast Fourier Transform, respectively; and determine
25 a synchronization sequence in dependence on the first and second egress sample stream.

This allows synchronizing the OFDM-demodulator and the corresponding radio device to a synchronization signal of a
30 radio cell, wherein the synchronization signal has been modulated with a larger inverse FFT block length as the block length of the forward FFT which is used to determine the synchronization sequence at the side of the OFDM-demodulator. Therefore, a reduced set of FFTs in the sense

5 of providing only small FFT block lengths is provided in the proposed OFDM-demodulator. The energy consumption and complexity of the OFDM-demodulator can be drastically reduced and at the same time latency induced by modulation/demodulation benefits by a reduced FFT block
10 length. Therefore, cheap and energy-saving machine-type radio devices and intelligent sensor radio devices are able access a cellular radio communications network.

According to an advantageous embodiment the determination
15 of the synchronization sequence comprises: determining a component of the synchronization sequence from a fixed position in the egress sample stream, respectively; and determining the synchronization sequence by concatenating the components of the synchronization sequence. A simple
20 determination is therefore provided.

According to an advantageous embodiment the received down-converted ingress symbol stream comprises a synchronization signal which has been modulated with a main block length,
25 wherein the same block length of the first and second forward Fast Fourier Transforms multiplied with an integer factor equals the main block length. Consequently, radio devices comprising a reduced set of forward FFTs in the sense of a reduced block length can be operated in a cell
30 providing the synchronisation signal modulated with the main block length.

According to an advantageous embodiment the main block length equals 2048. This and an dangerous embodiment allows

5 to operate the OFDM-demodulator and the corresponding device in an LTE/4G radio communications network.

According to an advantageous embodiment the same block length equals 128, wherein the synchronization sequence
10 comprises 62 synchronization symbols. Advantageously, a synchronisation sequence according to 3GPP 36.211 section 6.11 can be reconstructed and used for synchronisation.

According to an advantageous embodiment the processor and
15 the memory are further configured to: determine a successful detection of the synchronization sequence; receive the down-converted sample stream comprising first and second control or payload data; determine at least a third and fourth ingress sample stream of the down-
20 converted sample stream of same block length and of different further frequency offsets, respectively; determine a third and fourth forward Fast Fourier Transform of the same block length in dependence on the third and fourth ingress sample stream, respectively; determine a
25 third and fourth egress sample stream in dependence on the third and fourth forward Fast Fourier Transform, respectively; and determine first and second control or payload data in dependence on the third and fourth egress sample stream, respectively. This advantageously allows the
30 reuse of the respective FFT blocks after a synchronized state has been reached. Hardware complexity and resulting costs are reduced.

Another aspect of the present disclosure relates to a
35 method to operate an OFDM-demodulator.

5

Brief description of the figures

Figure 1a, 3, 4 and 5 show a schematic block diagram of an OFDM-demodulator, respectively;

10 Figures 1b shows a schematic sequence diagram, respectively; and

Figure 2 shows a schematic cellular radio communications network.

15 Description of the embodiments

Figure 1a shows a schematic block diagram of an OFDM-demodulator 2000. A down-converted sample stream $h_0, \dots, h_{B-1}, \dots$ is received from an A/D-converter of the respective radio module R2. A block 2202 of a first processing chain 2200
20 determines a first ingress sample stream $k_0, \dots, k_{B-1}$ of the first block length B in dependence on the down-converted sample stream $h_0, \dots, h_{B-1}, \dots$ and in dependence on a first synchronization frequency offset Δf_{s1} to a subcarrier
25 frequency, wherein the first ingress sample stream $k_0, \dots, k_{B-1}$ is shifted in frequency by the synchronization frequency offset Δf_{s1} . A block 2204 determines a first forward Fast Fourier Transform FFT_{B1} of the first block length B in dependence on the first ingress sample stream $k_0, \dots, k_{B-1}$. A
30 block 2206 determines a first egress sample stream $n_0, \dots, n_{M-1}$ in dependence on the first forward Fast Fourier Transform FFT_{B1} .

The wording ingress and egress have the following meaning:

35 The ingress symbol stream, for example the ingress

5 modulation-symbol stream, is located toward an input side of the respective processing entity, for example a processing chain. The egress symbol stream is located toward an output side of the processing entity, for example a processing chain. Therefore, the ingress symbol stream
10 may differ from an actual input symbol stream at the beginning of the processing chain. The same applies to the egress symbol stream.

Moreover the wording block length of a Fourier Transform
15 can be used interchangeably with the wording length of a Fourier Transform or FFT length or IFFT length.

A block 2302 of a second processing chain 2300 determines a second ingress sample stream $l_0, \dots, l_{B-1}$ in dependence on the
20 down-converted sample stream $h_0, \dots, h_{B-1}, \dots$ of the first block length B and in dependence on a second synchronization frequency offset Δf_{s2} to the subcarrier frequency, wherein the second ingress sample stream $l_0, \dots, l_{B-1}$ is shifted in frequency by the second synchronization frequency offset
25 Δf_{s2} . A block 2304 determines a second forward Fast Fourier Transform FFT_{B2} of the first block length B in dependence on the second ingress sample stream $l_0, \dots, l_{B-1}$. A block 2306 determines a second egress sample stream $o_0, \dots, o_{P-1}$ in dependence on the second forward Fast Fourier Transform
30 FFT_{B2} .

A block 2400 determines a synchronization sequence SS or at least a part thereof in dependence on the first egress sample stream $n_0, \dots, n_{M-1}$ and the second egress sample stream
35 $o_0, \dots, o_{P-1}$.

5

Figure 1b shows a schematic sequence diagram 2800 to operate an OFDM-demodulator 2000 comprising steps 2802, 2804, 2806, 2808 and 2010.

10 Figure 2 shows a schematic cellular radio communications network RCN. The cellular radio communications network RCN is a cellular network, wherein the first radio device BS establishes a radio cell C. The first radio device BS is a base station, a LTE eNodeB, a 5G transmission point, a WiFi
15 access point, a remote radio head, RRH, or else. The first radio device BS is in particular suitable to serve the radio cell C and to connect user equipment in the sense of radio devices UE, UE_leg inside the radio cell C to the cellular radio communications network RCN. The first radio
20 device BS is e.g. implemented as a stand-alone equipment. The second and third radio devices UE, UE_leg reside in the radio cell C and may be referred to as user equipment or machine equipment.

25 The third radio device UE_leg is a LTE legacy device and fulfils 3GPP TS36.211 V14.00 Sep.2016, which is incorporated herein by reference. The first and second radio devices BS and UE comprise an OFDM-modulator 1000 and/or an OFDM-demodulator 2000, respectively. Many of the
30 embodiments of this description allow operating the third radio device UE_leg in the cell C together with the first and second radio devices BS and UE.

The first radio device BS comprises a memory M1, a
35 processor P1, a radio module R1, and an antenna A1. The

5 second radio device UE comprises a memory M2, the processor P2, a radio module R2, and an antenna A2. The third radio device UE_{leg} comprises a memory and 3, processor P3, a radio module are 3 and an antenna A1. The processors P1, P2, P3 are implemented using e.g. a DSP, FPGA, or the like
10 or a combination thereof. The memory M1, M2, M3 is implemented using e.g. a RAM, ROM, DDR, Flash memory, or the like, or a combination thereof. The memory M1, M2, M3 stores e.g. computer readable instructions, thus instructions executable by the processor P1, P2, P3. The
15 processor P1 processes data to be transmitted to the first and second radio device UE, UE_{leg}. The processing includes the steps necessary to fulfil the requirements set by the radio communications network RCN.

20 At least parts of the above described cellular radio communications network RCN including sender and/or receiver of the first radio device BS could be implemented using network functions virtualization (NFV). NFV is a network architecture that makes use of technologies of computer
25 virtualization. Entire network equipment like sender or receiver or parts thereof or part of their functions can be virtualized using software building blocks that may connect, or interact, to create communication services. A virtualized network function of e.g. a sender or receiver
30 may include at least one virtual machine running different software and processes, on top of standard high-volume servers, switches and storage, or a cloud computing infrastructure, instead of having customized hardware appliances for each network function. As such a sender or

5 receiver function may be implemented in a computer program using a computer program product embodied on a non-transitory computer readable medium for performing operations, wherein the computer program product comprises instructions, that when executed by a processor, perform
10 the operations of the specific base station, eNodeB, network node, MME (Mobility Management Entity) and/or UE function.

The methods described herein relate to digital signal
15 processing and could thus be implemented using a processor like a digital signal processor, or the like. At least some of the functions relate to baseband processing and could thus be implemented using a transceiver, e.g. a baseband transceiver. The radio module is e.g. a radio module, or a
20 remotely located so called RRH (Remote Radio Head). The constellation with a RRH is often used in connection with a so called NFV (Network Functions Virtualization) implementation, where a substantial part of processing is centralized in a server farm with a plurality of processors
25 and a plurality of memory, and the radio specific up-conversion, the antenna and the digital-to-analog converter for data transmission in downlink to the user equipment and the analog-to-digital converter for receiving data from the user equipment in uplink is remotely located. The radio
30 module is also called radio frontend and includes e.g. a digital-to-analog converter, a low-pass filter, a mixer, a local oscillator, a power amplifier and an antenna. The local oscillator generates the radio frequency which is mixed on the processed data. The aforementioned
35 modules/functions could be placed in serial order. Some

5 modules might be not be used or replaced by others
dependent on the technology used. For MIMO or massive MIMO
some modules need to be duplicated, e.g. a plurality of
antennas is used instead of one and corresponding
amplifiers, etc. Additional modules might be added for
10 performing und/or supporting specific functions as e.g.
beamforming, CoMP (coordinated multipoint), eICIC (enhanced
inter-cell interference control), or the like. User
equipment (UE) could be implemented as a device with a
radio module, e.g. smartphone, tablet, smartwatch, sensor,
15 actuator, equipment inside a vehicle, machine-to-machine
equipment, or else. The radio communications network RCN is
an OFDM (Orthogonal Frequency Division Multiplex) type
network, e.g. UF-OFDM, F-OFDM, ZT-s-OFDM, P-OFDM, FC-OFDM,
or another multi-carrier network, e.g. FS-FBMC, QAM-FBMC,
20 etc. E.g. QAM - Quadrature Amplitude Modulation and/or QPSK
- Quadrature Phase Shift Keying are used as modulation
technique. The radio network RCN allocates resources using
a scheduler and a time-frequency-resource grid, a t-f-
resource. The t-f-resource includes time slots and
25 associated subcarriers. The subcarriers are e.g. grouped in
frequency subbands. A subband is assigned at least one
subband parameter. A subband parameter is e.g. subcarrier
spacing, other parameters are e.g. symbol duration, time
overhead, time overhead type like zero postfix or cyclic
30 prefix, windowing or filtering parameters. Dependent on the
assigned or selected parameters the subband is
characterized for a specific transmission type and is in
particular suitable for the transmission of specific
services. A service is e.g. eMBB (enhanced mobile
35 broadband), mMTC (massive machine-type-communication),

5 URLLC (ultra reliable low latency communication), vehicle-to-vehicle communication, voice, video, etc. An allocated physical resource block thus assigns a dedicated time slot associated with one or more subcarriers or a subband to a data packet. A physical resource block assigns one time
10 slot to a subcarrier. A time slot is e.g. called a TTI (transmission time interval). The period of time could e.g. be one or more time slots. Data and control signals are transmitted using physical channels, e.g. physical downlink shared channel, physical downlink control channel, common
15 control physical channel. Further data and control signals could be transmitted using broadcast channel, paging channel, multicast channel.

Figure 3 shows a schematic block diagram of an OFDM-
20 demodulator 2000 with a plurality of processing chains 2100, 2200, 2300. Of course, further processing chains are possible. The processing chain 2100 is described in detail in the following, wherein the further processing chains are similar to the processing chain 2100. A cyclic prefix
25 remover 2108 removes a cyclic prefix CP. The cyclic prefix remover 2108 can also be omitted. The frequency shifter 2110 back-shifts the down-converted sample stream $h_0, \dots, h_{A-1}, \dots$ not comprising the cyclic prefix in dependence on the supplied third frequency offset Δf_c . The frequency shifter
30 2110 determines the third ingress sample stream $i_0, \dots, i_{A-1}$, which is parallelised by a serial-to-parallel converter 2112. A forward Fast Fourier Transform block 2114 determines the third forward Fast Fourier Transform FFT_A of the further block size A in dependence on the parallelised

5 ingress sample stream $i_0, \dots, i_{A-1}$. A demapper 2116 demaps the subcarriers. A parallel-to-serial converter 2118 of block length N determines the third egress sample stream $m_0, \dots, m_{N-1}$ in dependence on the third forward Fast Fourier Transform FFT_A . A channel estimator 2120 determines a channel
10 estimate 2122 in dependence on reference symbols contained in the third egress sample stream $m_0, \dots, m_{N-1}$. An equalizer 2124 determines an equalized egress modulation-symbol stream 2126 in dependence on the third egress sample stream $m_0, \dots, m_{N-1}$ and in dependence on the channel estimate 2122. As
15 indicated with arrows the channel estimates 2122 and 2222 can be exchanged, wherein for example the estimator 2120 receives the channel estimate 2222. A block 2128 determines an egress data stream 2130 in dependence on the equalized egress sample stream 2126. The channel estimator 2120 and
20 the equalizer 2124 are only exemplary and may comprise other taps regarding the respective input and output symbol streams. The block 2128 comprises a QAM-demodulator (Quadrature Amplitude Modulation) and/or a QPSK-demodulator (Quadrature Phase Shift Keying), a channel de-coder, and/or
25 further processing entities. The egress data stream 2130 equals an ingress data stream at the side of the transmitter. A correlator 2132 detects a synchronization symbol in the third egress sample stream $m_0, \dots, m_{N-1}$ and determines a synchronization state 2134. The
30 synchronization symbol comprises a CAZAC symbol. Therefore, the output of the OFDM-demodulator comprises modulation symbols and CAZAC symbols.

The processing chains 2200, 2300 differ from the processing
35 chain 2100 as described above in the following: The egress

5 data streams 2130 and 2230 and 2330 are mutually different with respect to their contents. The block length B of the first and second forward Fast Fourier Transform FFT_{B1} , FFT_{B2} multiplied with the K-factor equal a main block length A. According to an embodiment the OFDM-demodulator 2000
10 comprises only processing chains operating with a block length smaller than the main block length A, therefore not comprising a processing chain operating with the main block length A.

15 Given the largest block length of the fourier transform in the sense of the main block length A, each processing chain has to fulfil the following equation (1) with a block length bl and the corresponding K-factor K.

20
$$bl * K = A \quad (1)$$

For cellular radio communications network RCN with the main block length A of 2048 also legacy LTE devices can be attended. In this case the subcarrier spacing f0 providing
25 a fixed subcarrier spacing grid for all of the other processing chains is 15 kHz. Of course, the main block length A can be chosen differently, however loosing compatibility with legacy LTE devices. The sample time Ts for each K-Factor system can be determined according to
30 equation (2).

$$Ts(K) = 1 / (bl(K) * f0) \quad (2)$$

For applications with a demand for low energy consumption
35 and short symbol rates, the second radio device UE may only

5 comprise processing chains with a high K-Factor,
particularly a K-factor K greater than 1.

The following equations (3) to (6) show that the modulation
and demodulation scheme proposed in this description still
10 provides that the subcarriers are orthogonal. Equation (3)
provides the forward Fast Fourier Transform FFT_R of block
length R with the parameter k. In equation (4) the right
hand term is separated into two components X_I and X_{II}
each representing Fast Fourier Transforms. Equation (5)
15 comprises a parameter transform from parameter k of
equation (4) to the parameter $2*u$. Equation (6) represents
equation (5) in a rewritten form. Equations (5) and (6)
provide two Fourier transforms $X_I(u)$ and $X_{II}(u)$ with a
block length of R/2 in comparison with the Fast Fourier
20 Transform of block length R in equations (3) and (4).
Consequently, subcarrier orthogonality is maintained while
FFT block lengths are used that comply with the K-factor
scheme described in equation (1).

25

$$FFT_R(k) = \sum_{n=0}^{R-1} x(n) * e^{-j\frac{2\pi}{R}kn}$$

(3)

$$FFT_R(k) = \underbrace{\sum_{r=0}^{\frac{R}{2}-1} x(r) * e^{-j\frac{2\pi}{R}kr}}_{X_I(k)} + \underbrace{\sum_{r=\frac{R}{2}}^{R-1} x(r) * e^{-j\frac{2\pi}{R}kr}}_{X_{II}(k)}$$

(4)

30

15

5

$$FFT_R(2u) = \underbrace{\sum_{r=0}^{\frac{R}{2}-1} x(r) * e^{-j\frac{2\pi}{R}2ur}}_{X_I(u)} + \underbrace{\sum_{r=\frac{R}{2}}^{R-1} x(r) * e^{-j\frac{2\pi}{R}2ur}}_{X_{II}(u)}$$

(5)

$$FFT_R(2u) = \underbrace{\sum_{r=0}^{\frac{R}{2}-1} x(r) * e^{-j\frac{2\pi}{R}ur}}_{X_I(u)} + \underbrace{\sum_{r=\frac{R}{2}}^{R-1} x(r) * e^{-j\frac{2\pi}{R}ur}}_{X_{II}(u)}$$

(6)

10

The following table 1 shows possible configurations for processing chains of the OFDM-modulator 1000 and the OFDM-demodulator 2000.

15

FFT Length	Num N of PRBs	K-Factor	N * K	Symbol Length in μ s	Bandwidth	Integration in LTE 20MHz
16	1	128	128	0,5	23,04MHz	No
32	1	64	64	1,0	11,52MHz	Yes
64	1	32	32	2,1	5,76MHz	Yes
	2		64		11,52MHz	
	3		96		17,28MHz	
128	1	16	16	4,2	2,88MHz	Yes
	2		32		5,76MHz	
	3		48		8,64MHz	

	4		64		11,52MHz	
	5		80		14,40MHz	
	6		96		17,28MHz	
256	1	8	8	8,33	1,44MHz	Yes
	2		16		2,88MHz	
	3		24		4,32MHz	
	4		32		5,76MHz	
	5		40		7,20MHz	
	6		48		8,64MHz	
	7		56		10,08MHz	
	8		64		11,52MHz	
	9		72		12,96MHz	
	10		80		14,40MHz	
	11		88		15,84MHz	
	12		96		17,28MHz	
512	1	4	4	16,65	0,72MHz	Yes
	2		8		1,44MHz	
	3		12		2,16MHz	
	4		16		2,88MHz	
	5		20		3,60MHz	
	6		24		4,32MHz	
	7		28		5,04MHz	
	8		32		5,76MHz	
	9		36		6,48MHz	
	10		40		7,20MHz	
	11		44		7,92MHz	
	12		48		8,64MHz	

	13		52		9,36MHz	
	14		56		10,08MHz	
	15		60		10,80MHz	
	16		64		11,52MHz	
	17		68		12,24MHz	
	18		72		12,96MHz	
	19		76		13,68MHz	
	20		80		14,40MHz	
	21		84		15,12MHz	
	22		88		15,84MHz	
	23		92		16,56MHz	
	24		96		17,28MHz	
	25		100		18,00MHz	
1024	1	2	2	33,3	0,36MHz	Yes
	2		4		0,72MHz	
	3		6		1,08MHz	
	4		8		1,44MHz	
	5		10		1,80MHz	
	6		12		2,16MHz	
	7		14		2,52MHz	
	8		16		2,88MHz	
	9		18		3,24MHz	
	10		20		3,60MHz	
	11		22		3,96MHz	
	12		24		4,32MHz	
	13		26		4,68MHz	
	14		28		5,04MHz	

	15		30		5,40MHz	
	16		32		5,76MHz	
	17		34		6,12MHz	
	18		36		6,48MHz	
	19		38		6,84MHz	
	20		40		7,20MHz	
	21		42		7,56MHz	
	22		44		7,92MHz	
	23		46		8,28MHz	
	24		48		8,64MHz	
	25		50		9,00MHz	
LTE: 2048	1 ... 100	1	1 ... 100	66,6	0,18...18MHz	Yes

Table 1

The wording ingress and egress has the meaning that the respective ingress symbol stream is located toward an input side of the processing chain and that the egress symbol stream is located toward an output side of the processing chain. Therefore, the ingress symbol stream may differ from an actual input symbol stream at the beginning of the processing chain. The same applies to the egress symbol stream.

The serial-to parallel-converters and the parallel-to-serial converters in figure 3 and 4 are arranged at an exemplary position. Of course these converters can be

5 arranged at other positions to optimize the respective processing chain.

Figure 4 shows a schematic block diagram of the OFDM-demodulator 2000. The first processing chain 2200 is
10 described in detail. After removing the cyclic prefix CP the down-converted sample stream $h_0, \dots, h_{B-1}, \dots$ is applied to a switch 2240. According to the shown state of the switch 2240 a frequency shifter 2242 determines a frequency shifted instance of the down-converted sample stream
15 $h_0, \dots, h_{B-1}, \dots$ in the sense of the first ingress sample stream $k_0, \dots, k_{B-1}$ in dependence on the first synchronization frequency offset Δf_{s1} . The first egress sample stream $n_0, \dots, n_{M-1}$ is applied to a switch 2244. According to the shown state of the switch 2244 an extractor 2246 extracts a
20 synchronization symbol SS_2 at a fixed position and of fixed size in the first egress sample stream $n_0, \dots, n_{M-1}$.

The second processing chain 2300 is configured to operate with a second synchronization frequency offset Δf_{s2} to
25 extract a synchronization symbol SS_3 by means of the extractor 2346. Of course, further processing chains operating with a different synchronization frequency offset provide further synchronization symbols to concatenate the synchronization symbols SS_2 to SS_3 resulting in the
30 synchronization sequence SS. The synchronization sequence SS is supplied to the correlator 2402 which compares the determined synchronization sequence SS with a a-priori known synchronization sequence. If the determined synchronization sequence SS highly correlates to the a-
35 priori known synchronization sequence, the correlator 2402

5 generates a signal 2404 for signalling that the radio device UE acquired synchronization to the cell C within the network RCN.

The position of the switches 2240, 2340, 2244 and 2344 shown in figure 4 is shown in a non-synchronized state of the OFDM-demodulator 2000. The switches 2240, 2340, 2244 and 2344 receive the signal 2404 and are operated to switch to a synchronized switch position. In this synchronized switch position / in the synchronized state the respective processing chains a) apply a different frequency offsets - Δf_a , $-\Delta f_b$ to the down-converted sample stream $h_0, \dots, h_{B-1}, \dots$; and b) determine egress data streams 2230, 2330 comprising first and second control or payload data in dependence on a third and fourth egress sample stream $n_0, \dots, n_{M-1}$, $o_0, \dots, o_{P-1}$, respectively.

Figure 5 shows a schematic block diagram of the OFDM-demodulator 2000 in a non-synchronized state. The processing chains 2200 to 2300 are operated to extract a number of 62 synchronization symbols SS_2 to SS_3 and concatenate the plurality of 62 synchronization symbols to the synchronization sequence SS. The synchronization sequence SS is applied to the correlator 2402 to determine the signal 2404. If no synchronization sequence is detected the OFDM-demodulator 2000 remains in its unsynchronized state.

The synchronization sequence SS and the corresponding synchronization signal is determined on transmitter side according to 3GPP 36.211 section 6.11, which is

5 incorporated by reference, and is mapped to 62 subcarriers
around the DC carrier to the third and seventh of the
(largest) OFDM-symbol of an OFDM-frame. Of course, other
forms of synchronization sequences can be detected with the
methods proposed in this description. In particular
10 synchronization sequences modulated with an IFFT block
length greater than the FFT block length of the OFDM-
demodulator 2000 can be reconstructed.

5 The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

The functions of the various elements shown in the FIGs., including any functional blocks labelled as "processors", may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate

5 array (FPGA), read only memory (ROM) for storing software,
random access memory (RAM), and non volatile storage. Other
hardware, conventional and/or custom, may also be included.
Similarly, any switches shown in the FIGS. are conceptual
only. Their function may be carried out through the
10 operation of program logic, through dedicated logic,
through the interaction of program control and dedicated
logic, or even manually, the particular technique being
selectable by the implementer as more specifically
understood from the context.

15 It should be appreciated by those skilled in the art that
any block diagrams herein represent conceptual views of
illustrative circuitry embodying the principles of the
invention. Similarly, it will be appreciated that any flow
charts, flow diagrams, state transition diagrams, pseudo
20 code, and the like represent various processes which may be
substantially represented in computer readable medium and
so executed by a computer or processor, whether or not such
computer or processor is explicitly shown.

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Claims

1. An OFDM-demodulator (2000) for operating in a device (BS; UE) of a radio communications network (RCN), wherein the OFDM-demodulator (2000) comprises a processor (P1; P2) and a memory (M1; M2) being configured to:
 - receive a down-converted sample stream ($h_0, \dots, h_{B-1}, \dots$);
 - determine at least a first and second ingress sample stream ($k_0, \dots, k_{B-1}, l_0, \dots, l_{B-1}$) of the down-converted sample stream ($h_0, \dots, h_{B-1}, \dots$) of same block length (B) and of different frequency offsets ($\Delta f_{s1}, \Delta f_{s2}$), respectively;
 - determine a first and second forward Fast Fourier Transform (FFT_{B1}, FFT_{B2}) of the same block length (B) in dependence on the first and second ingress sample stream ($k_0, \dots, k_{B-1}, l_0, \dots, l_{B-1}$), respectively;
 - determine a first and second egress sample stream ($n_0, \dots, n_{M-1}, o_0, \dots, o_{P-1}$) in dependence on the first and second forward Fast Fourier Transform (FFT_{B1}, FFT_{B2}), respectively; and
 - determine a synchronization sequence (SS) in dependence on the first and second egress sample stream ($n_0, \dots, n_{M-1}, o_0, \dots, o_{P-1}$).
2. The OFDM-demodulator (2000) according to claim 1, wherein the determination of the synchronization sequence (SS) comprises:
 - determining a component of the synchronization sequence (SS) from a fixed position in the egress sample stream, respectively; and

- 5 - determining the synchronization sequence (SS) by concatenating the components of the synchronization sequence (SS).
3. The OFDM-demodulator (2000) according to claim 1 or 2,
- wherein the received down-converted ingress sample
10 stream $(h_0, \dots, h_{B-1}, \dots)$ comprises a synchronization signal (PSS; SSS) which has been modulated with a main block length (A); and
- wherein the same block length (B) of the first and second forward Fast Fourier Transforms (FFT_{B1} , FFT_{B2})
15 multiplied with an integer factor (K) equals the main block length (A).
4. The OFDM-demodulator (2000) according to claim 3,
- wherein the main block length (A) equals 2048.
5. The OFDM-demodulator (2000) according to claim 3 or 4,
20 - wherein the same block length equals 128, and
- wherein the synchronization sequence (SS) comprises 62 synchronization symbols.
6. The OFDM-demodulator (2000) according to one of the preceding claims, wherein the processor (P2) and the
25 memory (M2) are further configured to:
- determine a successful detection of the synchronization sequence (SS);
- receive the down-converted sample stream $(h_0, \dots, h_{B-1}, \dots)$ comprising first and second control or payload
30 data;
- determine at least a third and fourth ingress sample stream $(k_0, \dots, k_{B-1}, l_0, \dots, l_{B-1})$ of the down-converted

- 5 sample stream $(h_0, \dots, h_{B-1}, \dots)$ of same block length (B) and of different further frequency offsets $(\Delta f_a, \Delta f_b)$, respectively;
- determine a third and fourth forward Fast Fourier Transform (FFT_{B1} , FFT_{B2}) of the same block length (B)
- 10 in dependence on the third and fourth ingress sample stream $(k_0, \dots, k_{B-1}, l_0, \dots, l_{B-1})$, respectively;
- determine a third and fourth egress sample stream $(n_0, \dots, n_{M-1}, o_0, \dots, o_{P-1})$ in dependence on the first and second forward Fast Fourier Transform (FFT_{B1} , FFT_{B2}),
- 15 respectively; and
- determine first and second control or payload data in dependence on the third and fourth egress sample stream $(n_0, \dots, n_{M-1}, o_0, \dots, o_{P-1})$, respectively.
7. A radio device (UE) for operating in a radio
- 20 communications network (RCN), wherein the radio device (UE) comprises the OFDM-demodulator (2000) according to one of the preceding claims, wherein the radio device (UE) comprises a radio module (R2) and an antenna (A2) being configured to:
- 25
- receive a radio signal from a radio channel (ch2);
 - down-convert the radio signal to the sample stream $(h_0, \dots, h_{A-1}, \dots)$.
8. A method to operate an OFDM-demodulator (2000) for
- operating in a device (BS; UE) of a radio
- 30 communications network (RCN), wherein the method comprises:
- receiving a down-converted sample stream $(h_0, \dots, h_{B-1}, \dots)$;
 - determining at least a first and second ingress

5 sample stream $(k_0, \dots, k_{B-1}, l_0, \dots, l_{B-1})$ of the down-converted sample stream $(h_0, \dots, h_{B-1}, \dots)$ of same block length (B) and of different frequency offsets ($\Delta fs1, \Delta fs2$), respectively;

- determining a first and second forward Fast Fourier Transform (FFT_{B1}, FFT_{B2}) of the same block length (B) in dependence on the first and second ingress sample stream $(k_0, \dots, k_{B-1}, l_0, \dots, l_{B-1})$, respectively;

10 - determining a third and fourth egress sample stream $(n_0, \dots, n_{M-1}, o_0, \dots, o_{P-1})$ in dependence on the first and second forward Fast Fourier Transform (FFT_{B1}, FFT_{B2}), respectively; and

15 - determining a synchronization sequence (SS) in dependence on the first and second egress sample stream $(n_0, \dots, n_{M-1}, o_0, \dots, o_{P-1})$.

20

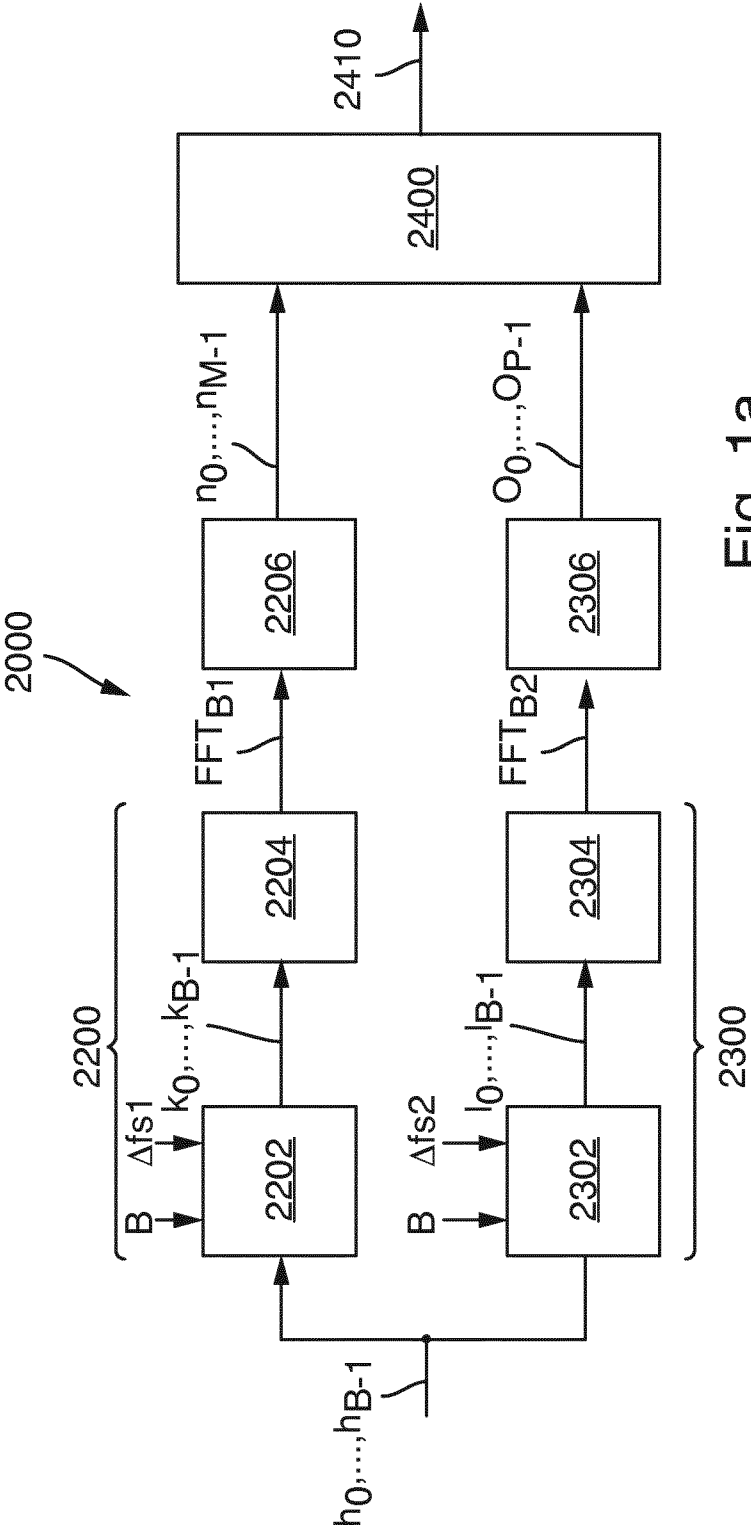


Fig. 1a

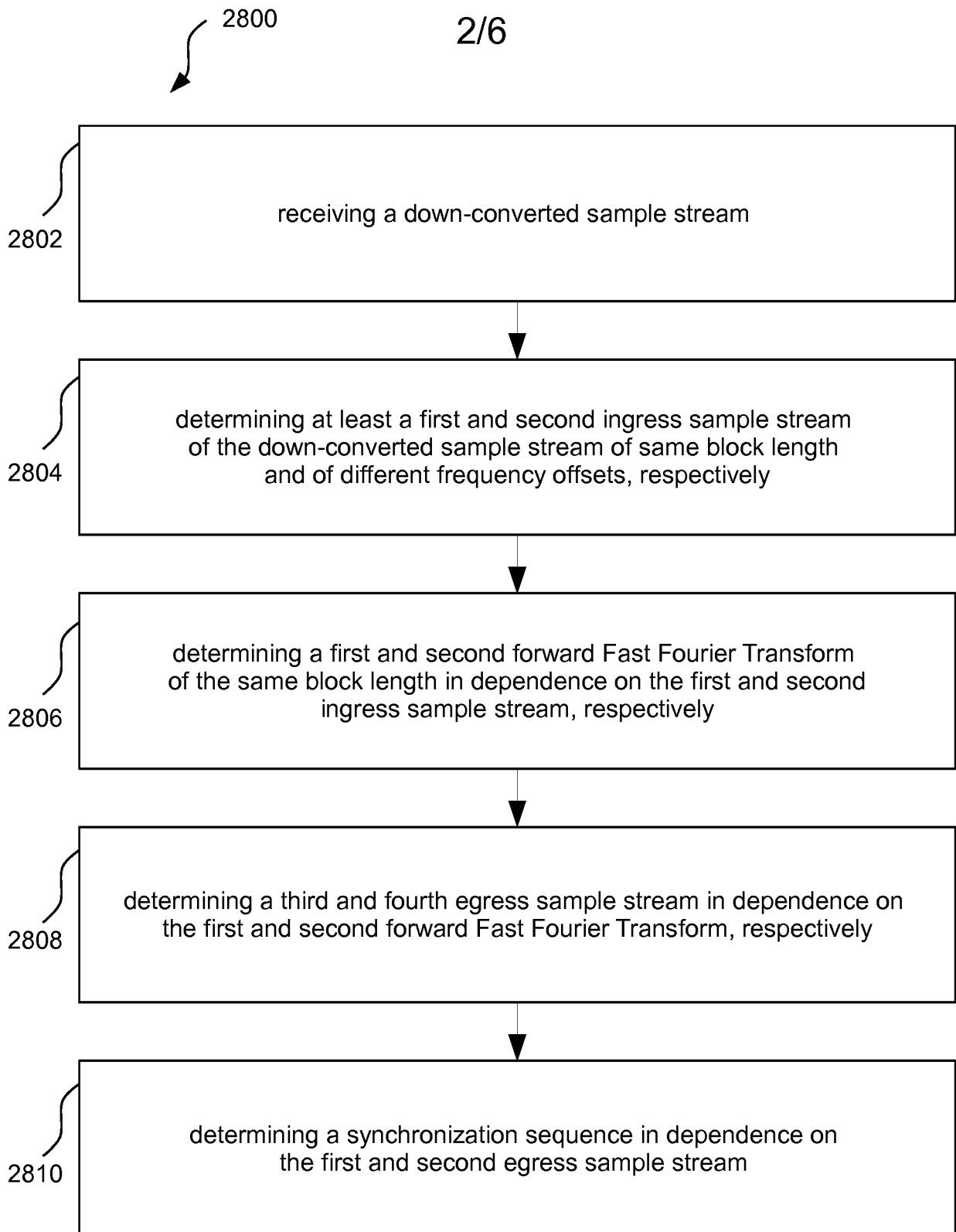


Fig. 1b

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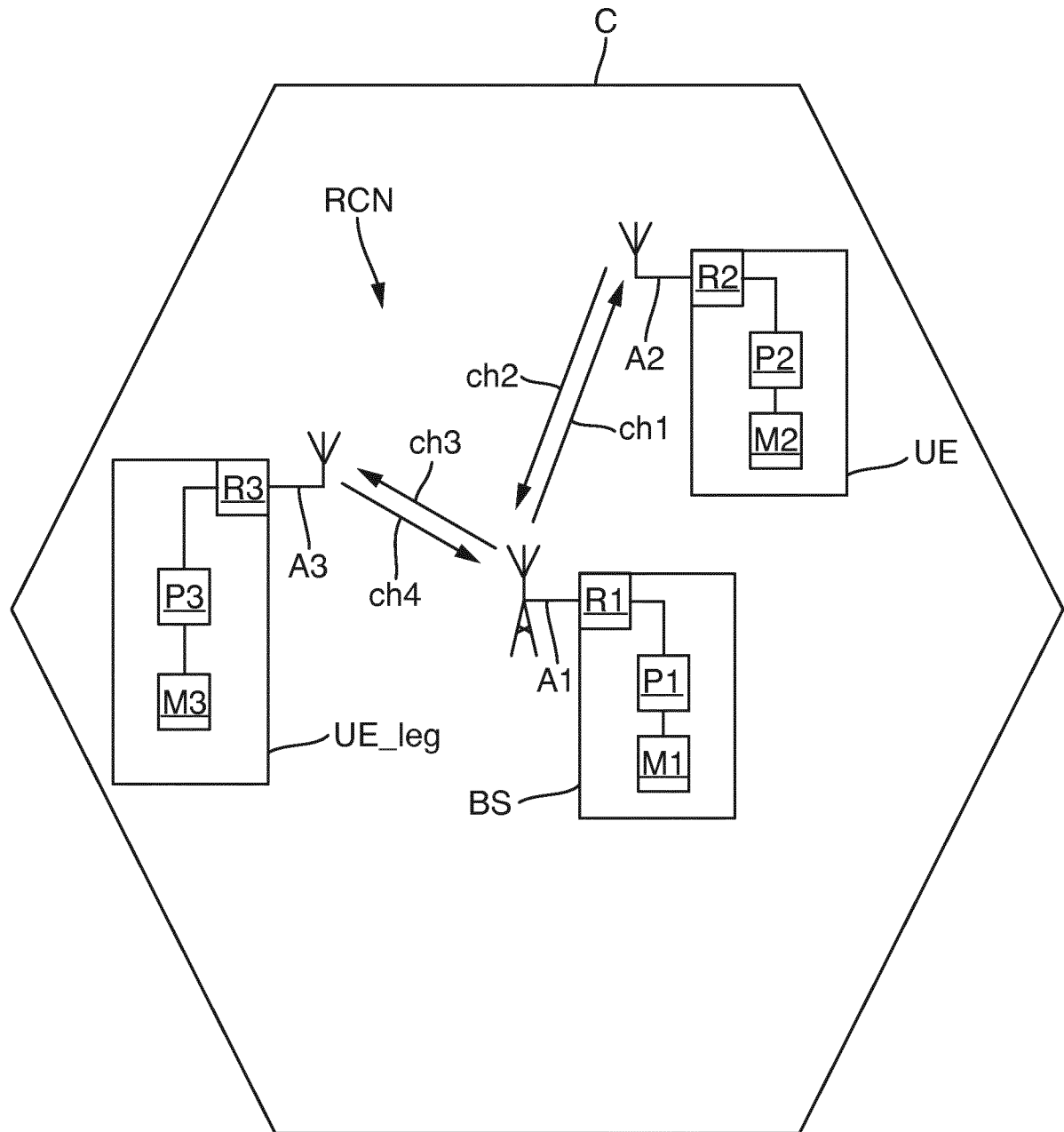


Fig. 2

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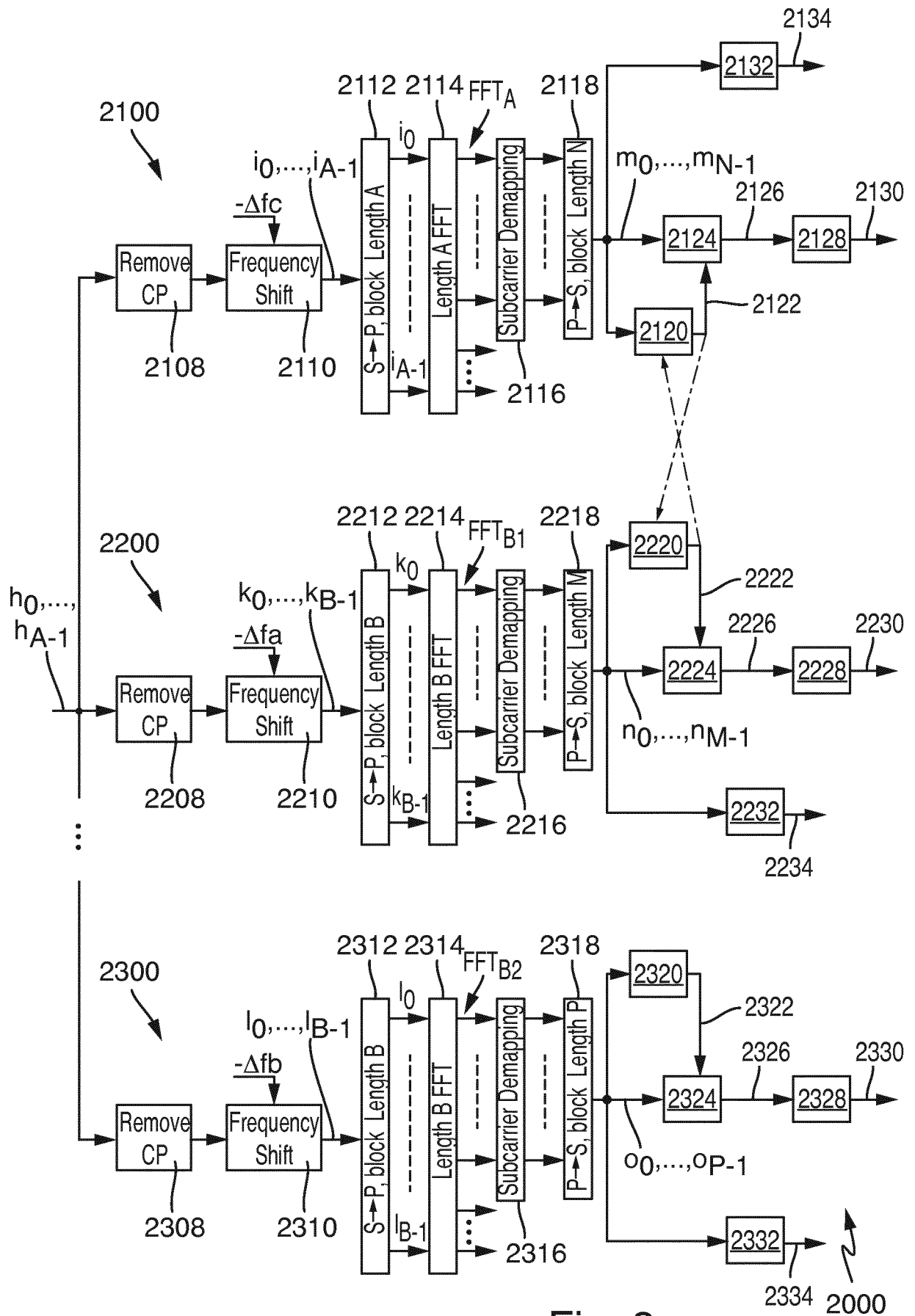


Fig. 3

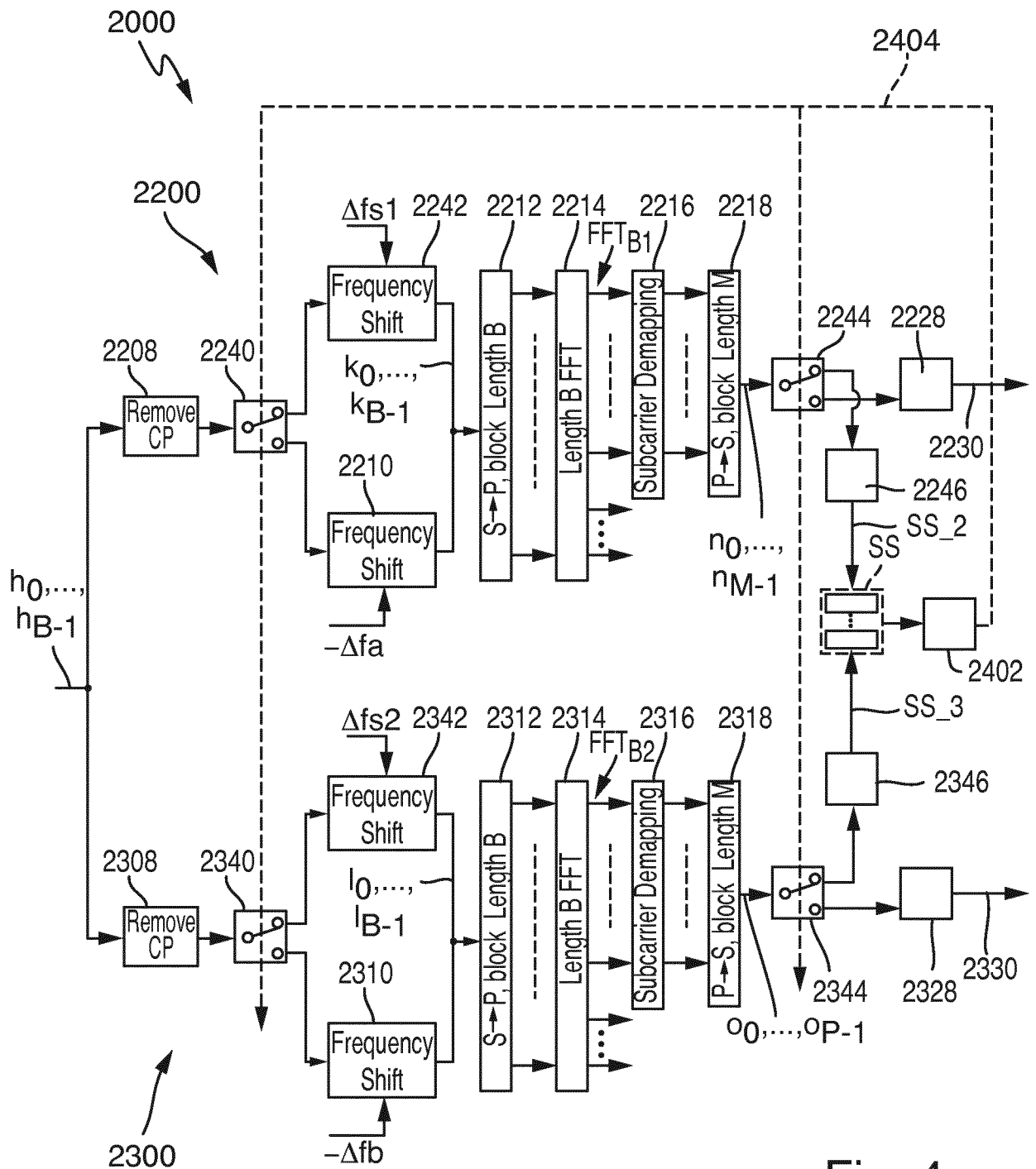


Fig. 4

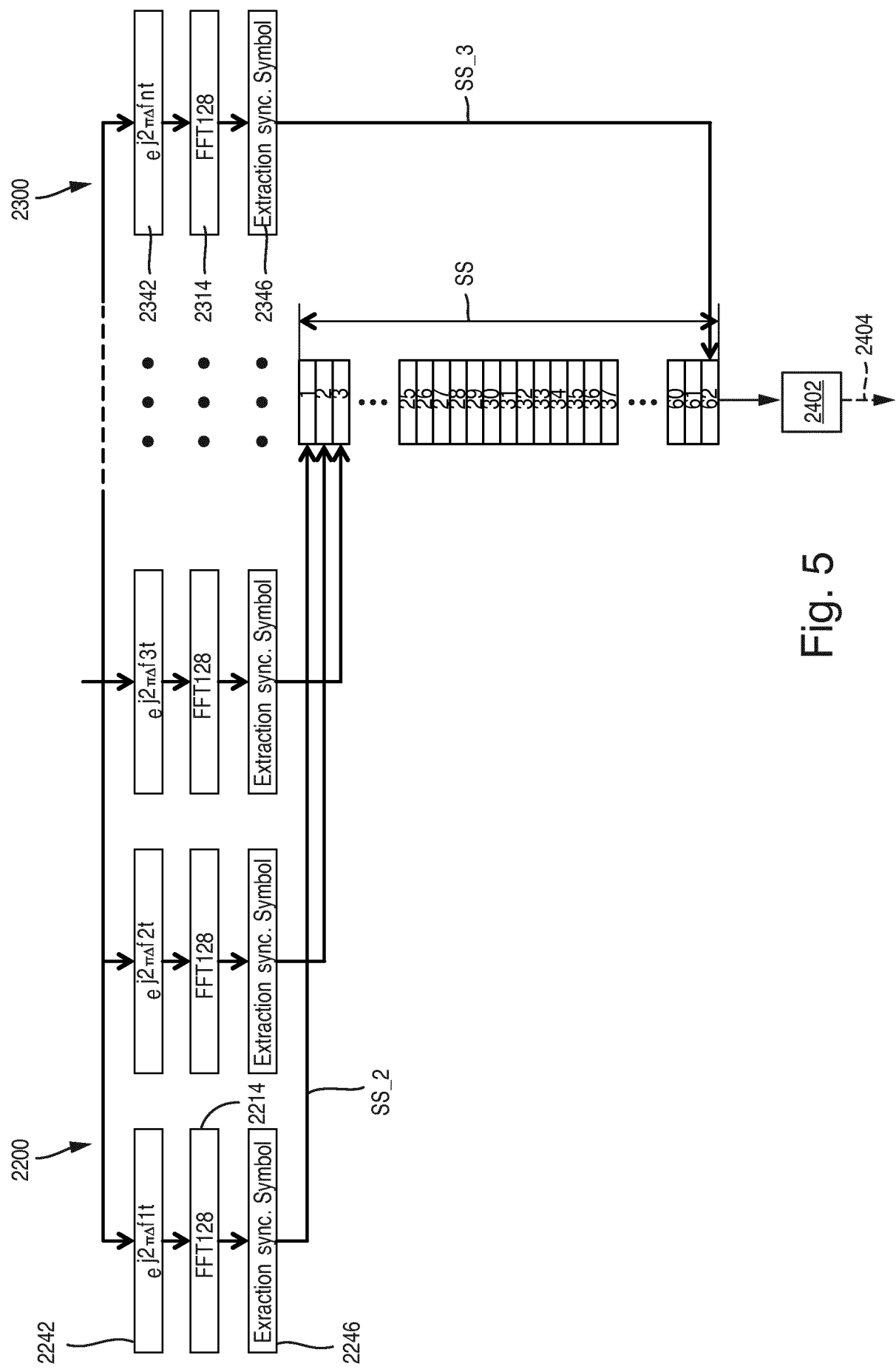


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/082418A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L27/26
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Fabrizio Tomatis ET AL: "7. Synchronization and Cell Search" In: "LTE- The UMTS Long Term Evolution", 17 February 2009 (2009-02-17), John Wiley & Sons, Ltd, Chichester, UK, XP055064038, ISBN: 978-0-47-069716-0 pages 142-157, DOI: 10.1002/9780470742891.ch7, page 144 ----- -/--	1-8



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

1 February 2018

Date of mailing of the international search report

09/02/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Douglas, Ian

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2017/082418

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Stefania Sesia ET AL: "19. Random Access" In: "LTE - the UMTS long term evolution : from theory to practice ; [Including release 10 for LTE-advanced]", 17 February 2009 (2009-02-17), Wiley, Chichester, XP055329751, ISBN: 978-0-470-66025-6 pages 371-406, DOI: 10.1002/9780470978504.ch17, paragraph [19.5.2.1] -----	1-8