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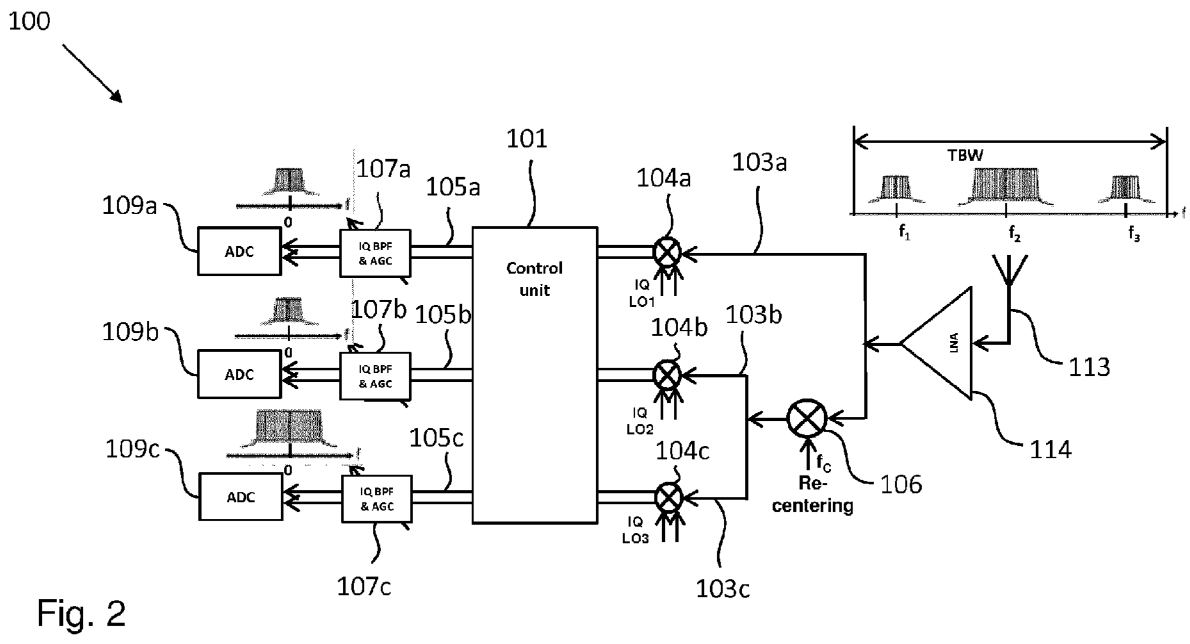

Fig. 2

(57) Abstract: The invention relates to a receiver (100) for a RF-signal comprising: a control unit (101) configured to operate the receiver (100) in a first operation mode and a second operation mode; a plurality of RF-channels (103a-m) for RF-processing configured as input of the control unit (101); and a plurality of BB-channels (105a-n) for BB-processing configured as output of the control unit (101); wherein in the first operation mode the control unit (101) is configured to relate a first RF-channel (103a) with a first BB-channel (105a) and a second RF-channel (103b) with a second BB-channel (105b), and wherein in the second operation mode the control unit (101) is configured to relate the transfer characteristics of the second BB-channel (105b) to the first BB-channel (105a).

WO 2017/186268 A1

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DESCRIPTION

A RECEIVER AND A METHOD FOR RECEIVING A CARRIER AGGREGATED RF SIGNAL

TECHNICAL FIELD

In general, the present invention relates to the field of wireless communications. More specifically, the present invention relates to a receiver and a method for receiving a radio frequency (RF) signal.

BACKGROUND

Carrier aggregation (CA) in wireless communications is becoming a key approach for increasing the bandwidth and data rate as well as optimally utilizing the generally fragmented spectra available in wireless communications (e.g., LTE, Wi-Fi). Generally, the following types of CA are supported in modern wireless communications standards: (i) intra-band contiguous CA; (ii) intra-band non-contiguous (NC) CA; and (iii) inter-band CA. The aggregated component carriers may all be of a different bandwidth and each may be transmitted using a different power level.

It would be desirable to have a flexible receiver that can support several of the above CA types. However, these different CA types pose somewhat different technical challenges. A receiver supporting, for instance, non-contiguous carrier aggregation (NC CA) should meet the following technical challenges: (i) a wide bandwidth (BW) and high EVM (Error Vector Module) are imperative and (ii) a trade-off exists between the dynamic range of the analog-to-digital converter (ADC) and the BW, limiting the adoption pace of wider BW base band channels and ADCs. Moreover, CA and simultaneous multi-standard reception must consider blockers (in-band and out of band), different amplitudes and bandwidths for different component carriers or standards and frequency spacing with high variability between component carriers or standards received.

For supporting CA receivers are known from the prior art, including receivers with a single local oscillator (LO) as well as receivers with multiple LOs. Although a single LO receiver has the advantage of requiring only one LO synthesizer circuitry without LO pulling and/or coupling risks, it might not be capable of efficiently handling more complex CA scenarios.

Thus, in light of the above there is a need for a more flexible receiver and method, allowing handling different CA scenarios in a more flexible manner.

SUMMARY

It is an object of the invention to provide for a more flexible receiver and a method, to allow handling of different CA scenarios in a more flexible manner.

The foregoing and other objects are achieved by the subject matter of the independent claims. Further implementation forms are apparent from the dependent claims, the description and the figures.

According to a first aspect, the invention relates to a receiver for a radio frequency signal (RF-signal) comprising: a control unit configured to operate the receiver in a first operation mode and a second operation mode; a plurality of RF-channels for RF-processing configured as input of the control unit; and a plurality of baseband channels (BB-channels) for BB-processing configured as output of the control unit; wherein in the first operation mode the control unit is configured to relate a first RF-channel with a first BB-channel and a second RF-channel with a second BB-channel, and wherein in the second operation mode the control unit is configured to relate the transfer characteristics of the second BB-channel to the first BB-channel.

Thus, a more flexible receiver is provided allowing handling different CA scenarios in a more flexible manner, including intra-band contiguous and non-contiguous as well as inter-band and multi-standard channel aggregation.

In an implementation form, the control unit can relate in the second operation mode the transfer characteristics of the second BB-channel to the first BB-channel by shunting the second BB-channel to the first BB-channel over an impedance inverter. In an implementation form the control unit can relate in the first operation mode the first RF-channel with the first BB-channel and the second RF-channel with the second BB-channel by connecting the first RF-channel with the first BB-channel and the second RF-channel with the second BB-channel, respectively.

In a first possible implementation form of the receiver according to the first aspect as such, the receiver further comprises a third RF-channel and a third BB-channel. In an implementation form the receiver can comprise more than three RF-channels and/or more than three BB-channels. In an implementation form the number of BB-channels is equal to or larger than the number of RF-channels.

Having more than two RF-channels and/or more than two BB-channels further increases the flexibility of the receiver and allows processing additional frequency channels.

In a second possible implementation form of the receiver according to the first implementation form of the first aspect, the control unit is further configured to operate the receiver in a third operation mode, wherein in the third operation mode the control unit is configured to relate the first RF-channel to the first BB-channel, to relate the second RF-channel to the second BB-channel and to relate the transfer characteristics of the third BB-channel to the second BB-channel.

Thus, the receiver can be operated in a third operation mode, which is a mix of the first operation mode and the second operation mode, thereby further increasing the flexibility of the receiver for adapting to different CA scenarios.

In a third possible implementation form of the receiver according to the first or second implementation form of the first aspect, each RF-channel comprises a demodulator configured to generate a respective baseband signal on the basis of the RF-signal.

Using a respective demodulator each RF-channel can effectively demodulate the RF-signal, i.e. generate a respective baseband signal to be further processed by the respective BB-channels.

In a fourth possible implementation form of the receiver according to the third implementation form of the first aspect, the second RF-channel and the third RF-channel further comprise a re-centering mixer upstream of the demodulator of the second RF-channel and the demodulator of the third RF-channel, wherein the re-centering mixer is configured to re-center the RF-signal on the basis of a predefined re-centering frequency f_C around a first frequency $f_{RF}+f_C$ and around a second frequency $f_{RF}-f_C$, wherein f_{RF} is a central frequency associated with the RF-signal.

Thus, the receiver can shift a spectral region of interest of the original RF-signal to the frequencies $f_{RF} + f_C$ and $f_{RF} – f_C$ and, thus, allows further processing of the spectral region of interest at these two distant frequencies without LO pulling.

In a fifth possible implementation form of the receiver according to the fourth implementation form of the first aspect, the demodulator of the second RF-channel is configured to demodulate the re-centered RF-signal on the basis of the first frequency $f_{RF}+f_C$ and wherein the demodulator of the third RF-channel is configured to demodulate the re-centered RF-signal on the basis of the second frequency $f_{RF}-f_C$.

In a sixth possible implementation form of the receiver according to any one of the first to fifth implementation form of the first aspect, in the first operation mode the control unit is further configured to relate the third RF-channel to the third BB-channel. In an implementation form the control unit can in the first operation mode relate the third RF-channel to the third BB-channel by connecting the third RF-channel to the third BB-channel.

In a seventh possible implementation form of the receiver according to any one of the first to sixth implementation form of the first aspect, in the second operation mode the control unit is configured to relate the first RF-channel to the first BB-channel and to relate the transfer characteristics of the second BB-channel to the first BB-channel and to relate the transfer characteristics of the third BB-channel to the second BB-channel. In an implementation form the control unit in the second operation mode can relate the first RF-channel to the first BB-channel by connecting the first RF-channel to the first BB-channel. In an implementation form the control unit in the second operation mode can relate the transfer characteristics of the second BB-channel to the first BB-channel and the transfer characteristics of the third BB-channel to the second BB-channel by shunting the second BB-channel to the first BB-channel over an impedance inverter and by shunting the third BB-channel to the second BB-channel over an impedance inverter.

In an eighth possible implementation form of the receiver according to the second implementation form of the first aspect, the demodulator of the first RF-channel is configured to demodulate the RF signal on the basis of a central frequency f_{RF} associated with the RF-signal.

In a ninth possible implementation form of the receiver according to the third implementation form of the first aspect, each demodulator of each RF-channel comprises a mixer and a local oscillator.

In a tenth possible implementation form of the receiver according to the first aspect as such or any one of the first to ninth implementation form thereof, the control unit comprises a plurality of switches, wherein the plurality of switches are configured to connect the plurality of BB-channels in parallel, in particular the first BB-channel with the second BB-channel in parallel.

In an eleventh possible implementation form of the receiver according to the first aspect as such or any one of the first to tenth implementation form thereof, each BB-channel comprises a frequency selective filter.

In a twelfth possible implementation form of the receiver according to the eleventh implementation form of the first aspect, each frequency-selective filter of each BB-channel is a band-pass filter having an adjustable bandwidth and/or an adjustable center frequency.

In a thirteenth possible implementation form of the receiver according to the twelfth implementation form of the first aspect, the control unit further comprises at least one impedance inverter and wherein the control unit is configured to relate the transfer characteristics of the second BB-channel to the first BB-channel by shunting the second BB-channel to the first BB-channel over the impedance inverter.

In a fourteenth possible implementation form of the receiver according to the eleventh implementation form of the first aspect, the frequency-selective filter of the first BB-channel is a band-pass filter having an adjustable bandwidth and/or an adjustable center frequency and the frequency-selective filter of the second BB-channel is a band-stop filter having an adjustable bandwidth and/or an adjustable center frequency.

According to a second aspect the invention relates to a method of operating a receiver for a RF signal, the method comprising: operating the receiver in a first operation mode or a second operation mode using a control unit, wherein the receiver comprises a plurality of RF-channels for RF-processing configured as input of a control unit of the receiver and wherein the receiver further comprises a plurality of BB-channels for BB-processing configured as output of the control unit; in the first operation mode, relating a first RF-channel to a first BB-channel and a second RF-channel to a second BB-channel; and in the second operation mode, relating the transfer characteristics of the second BB-channel to the first BB-channel.

The method according to the second aspect of the invention can be performed by the receiver according to the first aspect of the invention. Further features of the method according to the second aspect of the invention result directly from the functionality of the receiver according to the first aspect of the invention and its different implementation forms.

According to a third aspect the invention relates to a computer program comprising program code for performing the method according to the second aspect of the invention when executed on a computer.

The invention can be implemented in hardware and/or software.

BRIEF DESCRIPTION OF THE DRAWINGS

Further embodiments of the invention will be described with respect to the following figures, wherein:

Fig. 1 shows a schematic diagram of a receiver according to an embodiment;

Fig. 2 shows a schematic diagram of a receiver according to an embodiment operating in a first operation mode;

Fig. 3 shows a schematic diagram of a receiver according to an embodiment operating in a second operation mode;

Fig. 4 shows a schematic diagram of a receiver according to an embodiment operating in a third operation mode;

Figs. 5a-c show schematic diagrams illustrating different aspects of the present invention;

Figs. 6a-d show schematic diagrams illustrating exemplary carrier aggregation scenarios that can be handled by a receiver according to an embodiment;

Fig. 7 shows a schematic diagram illustrating the processing of a RF-signal by a receiver according to an embodiment in a first operation mode;

Fig. 8 shows a schematic diagram illustrating the processing of a demodulated RF-signal by a receiver according to an embodiment in a second operation mode; and

Fig. 9 shows a schematic diagram illustrating a method for operating a receiver for a RF-signal according to an embodiment.

In the various figures, identical reference signs will be used for identical or at least functionally equivalent features.

DETAILED DESCRIPTION OF EMBODIMENTS

In the following description, reference is made to the accompanying drawings, which form part of the disclosure, and in which are shown, by way of illustration, specific aspects in which the present invention may be placed. It will be appreciated that other aspects may be utilized and structural or logical changes may be made without departing from the scope of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense, as the scope of the present invention is defined by the appended claims.

For instance, it will be appreciated that a disclosure in connection with a described method may also hold true for a corresponding device or system configured to perform the method and vice versa. For example, if a specific method step is described, a corresponding device may include a unit to perform the described method step, even if such unit is not explicitly described or illustrated in the figures.

Moreover, in the following detailed description as well as in the claims embodiments with different functional blocks or processing units are described, which are connected with each other or exchange signals. It will be appreciated that the present invention covers embodiments as well, which include additional functional blocks or processing units that are arranged between the functional blocks or processing units of the embodiments described below.

Finally, it is understood that the features of the various exemplary aspects described herein may be combined with each other, unless specifically noted otherwise.

Figure 1 shows a schematic diagram of a receiver 100 for a radio frequency signal (RF-signal) according to an embodiment. The RF-signal can comprise a plurality of frequency channels, i.e. carriers.

The receiver 100 comprises a control unit 101 configured to operate the receiver 100 in a plurality of operation modes. Moreover, the receiver 100 comprises a plurality of RF processing channels 103a-m (hereinafter referred to as RF-channels 103a-m) and a plurality of baseband processing channels 105a-n (hereinafter referred to as BB-channels) in communication with the control unit 101. In an embodiment, the number of BB-channels 105a-n is equal to or larger than the number of RF-channels 103a-m, i.e. $n \geq m$.

Figure 2 shows a schematic diagram of the receiver 100 according to an embodiment operating in a first operation mode. In the embodiment shown in figure 2, the exemplary RF-signal comprises three frequency channels or carriers spread over a total bandwidth (TBW) and centered at frequencies f_1, f_2 and f_3, respectively.

In the embodiment shown in figure 2, the receiver 100 comprises an antenna 113 for receiving the RF-signal. For amplifying the RF-signal received by the antenna 113 the receiver 100 can further comprise a low noise amplifier (LNA) 114.

In the embodiment shown in figure 2, the receiver comprises three RF-channels 103a-c and three BB-channels 105a-c in respective communication with the control unit 101. Each RF-channel 103a-c can comprise a respective demodulator 104a-c for generating a respective BB-signal on the basis of the RF-signal. In an embodiment, each demodulator 104a-c can comprise a mixer, in particular an IQ mixer, and a local oscillator.

In the embodiment shown in figure 2, the RF-signal provided by the LNA 114 is directly fed into the demodulator 104a of the first RF-channel 103a. The second RF-channel 103b and the third RF-channel 103c can comprise a re-centering mixer 106 upstream of the demodulator 104b of the second RF-channel 103b and the demodulator 104c of the third

RF-channel 103c. In embodiments of the receiver 100 without the re-centering mixer 106 the second RF-channel 103b and the third RF-channel 103c can be configured essentially identical to the first RF-channel 103a, i.e. the first, second and third RF-channel 103a-c process the RF-signal provided by the LNA 114 in parallel with the demodulators 104a-c of the first, second and third RF-channel 103a-c being operated with different demodulation frequencies. In an embodiment, the re-centering mixer 106 is configured to re-center the RF-signal provided by the LNA 114 on the basis of a predefined re-centering frequency f_C around a first frequency $f_{RF}+f_C$ and around a second frequency $f_{RF}-f_C$, wherein f_{RF} is a central frequency associated with the RF-signal. For the exemplary RF-signal shown in figure 2 this central frequency f_C can be close to or identical to the frequency f_2.

As illustrated in figure 2, the respective demodulator or mixer 104a-c can demodulate an incoming signal on the basis of a signal provided by a local oscillator having an adjustable frequency of LO1, LO2 and LO3, respectively. In an embodiment, the demodulator 104b of the second RF-channel 103b is configured to demodulate the re-centered RF-signal on the basis of the first frequency $LO2=f_{RF}+f_C$ and the demodulator 104c of the third RF-channel 103c is configured to demodulate the re-centered RF-signal on the basis of the second frequency $LO3=f_{RF}-f_C$. In an embodiment, the demodulator 104a of the first RF-channel 103a is configured to demodulate the RF-signal on the basis of the central frequency f_{RF} associated with the RF-signal, i.e. $LO1=f_{RF}$.

As already mentioned above, in the embodiment shown in figure 2 the control unit 101 is configured to operate the receiver in a first operation mode. In this first operation mode the control unit is configured to relate, i.e. connect, the first RF-channel 103a, the second RF-channel 103b and the third RF-channel 103c with a first BB-channel 105a, a second BB-channel 105b and a third BB-channel 105c, respectively. In other words, in the first operation mode the control unit 101 is configured to supply the respective demodulated RF-signal (i.e. respective baseband signal) provided by the respective demodulator 104a-c of the RF-channels 103a-c to the first BB-channel 105a, the second BB-channel 105b and the third BB-channel 105c, respectively.

In the embodiment shown in figure 2, each BB-channel 105a-c comprises a frequency selective filter 107a-c configured to generate a respective filtered baseband signal on the basis of the respective baseband signal provided by the respective demodulator 104a-c of the RF-channels 103a-c via the control unit 101. In an embodiment, the frequency selective filters 107a-c can be bandpass or bandstop filters having an adjustable bandwidth and/or an adjustable center frequency, as will described in more detail in the context of figures 3 and 4 further below. In an embodiment, each BB-channel 105a-c can comprise in addition to the frequency selective filter 107a-c an automatic gain control (AGC). In the embodiment shown in figure 2, each BB-channel 105a-c further comprises an analog-to-digital converter (ADC) 109a-c for transferring the filtered baseband signals provided by the frequency selective filters 107a-c into the digital domain.

As indicated in figure 2, the receiver 100 operating in the first operation mode allows distributing the three frequency channels or carriers of the exemplary RF-signal shown in figure 2 over the three BB-channels 109a-c, which, in turn, allows a separate further processing of these three frequency channels or carriers.

Figure 3 shows a schematic diagram of the receiver 100 according to an embodiment operating in a second operation mode. In the embodiment shown in figure 3, the exemplary RF-signal comprises three frequency channels or carriers, which in comparison to the exemplary RF-signal shown in figure 2 are spread only over a fraction of the total available bandwidth (TBW) and centered at frequencies f_1, f_{LO1} and f_3, respectively.

In the second operation mode the control unit 101 of the receiver 100 shown in figure 3 is configured to relate, i.e. connect, the first RF-channel 103a with the first BB-channel 105a, to relate the transfer characteristics of the second BB-channel 105b to the first BB-channel 105a and to relate the transfer characteristics of the third BB-channel 105c to the transfer characteristics of the second BB-channel 105b. In other words, in the second operation mode the control unit 101 can be configured to modify a frequency response of the frequency-selective filter 107a of the first BB-channel 105a by coupling the frequency-selective filter 107b of the second BB-channel 105b to the frequency-selective filter 107a of the first BB-channel 105a and by coupling the frequency-selective filter 107c of the third BB-channel 105c to the frequency-selective filter 107b of the second BB-channel 105b.

To this end, the control unit 101 can comprise a plurality of switches 111a-d, in particular multiport switches 111a-d, as well as two impedance inverters 112a,b. The plurality of switches 111a-d can be addressed by the control unit 101 and are configured to connect the plurality of BB-channels 105a-c in parallel. The control unit 101 is configured to relate the transfer characteristics of the second BB-channel 105b to the first BB-channel 105a by shunting the second BB-channel 105b to the first BB-channel 105a over the impedance inverter 112a using the switches 111a and 111b and to relate the transfer characteristics of the third BB-channel 105c to the second BB-channel 105b by shunting the third BB-channel 105c to the second BB-channel 105b over the impedance inverter 112b using the switches 111c and 111d.

As indicated in figure 3, the receiver 100 operating in the second operation mode allows selecting each of the three frequency channels or carriers of the exemplary RF-signal shown in figure 3 on the first BB-channels 109 by appropriately adjusting the bandpass filters 109a-c. In this second operation mode there is no processing of the RF-signal along the RF-channels 103b and 103c as indicated in figure 3 by the cross. Thus, in an embodiment of the receiver 100, where the demodulators 104a-c comprise a mixer and a local oscillator, only one mixer and local oscillator will be active, namely the mixer and the local oscillator of the first RF-channel 103a.

Figure 4 shows a schematic diagram of the receiver 100 according to an embodiment operating in a third operation mode. In the embodiment shown in figure 4, the exemplary RF-signal comprises three frequency channels or carriers spread over a total bandwidth (TBW) and centered at frequencies f_1, f_2 and f_3, respectively, wherein two of the carriers, namely the carriers centered at frequencies f_1 and f_2, are located very close to each other.

The third operation mode of the receiver 100 can be considered to be a mix of the first operation mode shown in figure 2 and the second operation mode shown in figure 3. This is because in the third operation mode the control unit 101 is configured such that the first RF-channel 103a and the first BB-channel 105a operate as in the first operation mode, whereas the second RF-channel 103b, the second BB-channel 105b and the third BB-channel 105c operate as the first RF-channel 103a, the first BB-channel 105a and the second BB-channel 105b in the second operation mode. In other words, in the third operation mode the control unit 101 is configured on the one hand to relate, i.e. connect, the first RF-channel 103a with the first BB-channel 105a and to relate, i.e. connect, the second RF-channel 103b with the second BB-channel 105b and on the other hand to relate the transfer characteristics of the third BB-channel 105c to the transfer characteristics of the second BB-channel 105b. In an embodiment, the control unit 101 is configured in the third operation mode to relate the transfer characteristics of the third BB-channel 105c to the second BB-channel 105b by shunting the third BB-channel 105c to the second BB-channel 105b over the impedance inverter 112b using the switches 111c and 111d. In the third operation mode there is due to an appropriate setting of the switches 111a and 111b (which for the sake of clarity have been omitted in figure 4) no parallel connection between the first BB-channel 105a and the second BB-channel 105b.

As indicated in figure 4, the receiver 100 operating in the third operation mode allows distributing the frequency channel or carrier of the RF-signal centred at frequency f_3 to the first BB-channel 105a and the two neighbouring frequency channels or carriers centred at frequencies f_1 and f_2 to the second BB-channel 105b. By appropriately adjusting the bandpass filter 109b of the second BB-channel 105b and/or the bandpass filter 109c of the third BB-channel 105c each of the two neighbouring frequency channels or carriers centred at frequencies f_1 and f_2 can be selected, i.e. filtered, on the second BB-channel 105b for further processing. In this third operation mode there is no processing of the RF-signal along the third RF-channels 103c as indicated in figure 4 by the cross.

For describing how the receiver 100 can be operated in different operation modes adapted to different CA scenarios the following definitions will be used, which are illustrated in figures 5a, 5b and 5c.

Figure 5a illustrates an exemplary total wireless BW (TBW) allocated by a wireless communication standard. For a wireless communication standard such as Wi-Fi the TBW may be rather larger, such as the 5170 – 5835 MHz BW for 5 GHz Wi-Fi. In addition to three exemplary CA channels, i.e. CH1, CH2 and CH3, blocker signals may exist within this TBW, such as other 5 GHz Wi-Fi or LTE carriers to be assigned in the future.

For each wireless communication standard the maximal instantaneous BW in the baseband is primarily determined by engineering considerations and trade-offs concerning the specific implementation of the analog-to-digital converter (ADC) 109a-c of each of the BB-channels 105a-c. Figure 5b illustrates an exemplary maximum BB channel processing BW, which is denoted as B. Currently, for 5GHz 802.11ac Wi-Fi, the maximum baseband channel processing BW, i.e. B, is 80 MHz. Next generation communication standards are targeting B to be 160MHz.

Figure 5c illustrates an exemplary minimum BB channel processing BW, which is defined as B/n, wherein n is a power of 2. Currently, for 5GHz 802.11ac Wi-Fi the minimum BB channel processing BW is B/n = 20 MHz with n=4.

Figure 6a illustrates a first exemplary CA scenario for intra-band CA, wherein three frequency blocks of width B are spread over a total wireless BW (TBW) and are centered at frequencies f_1, f_2 and f_3, respectively. As already described above, such a scenario can be advantageously handled by the receiver 100 operating in the first operation mode, wherein in this first operation mode all demodulators or mixers 104a-c are active, i.e. are being used.

Figure 6b illustrates a second exemplary CA scenario with two carriers having a minimum CA processing BW. In this case it is difficult to process the two "distant" channels within one BB-channel 105a-c so that also this scenario can be handled in a more efficient way by the receiver 100 operating in the first operation mode, i.e. when more than one of the demodulators or mixers 104a-c is being used.

Figure 6c illustrates a third exemplary CA scenario with two carriers having a minimum CA processing BW and allocated within B. Such a scenario can be handled by the receiver 100 being operated in the first operation mode or the second operation mode.

Figure 6d illustrates a fourth exemplary CA scenario with three carriers having a minimum CA processing BW, such as 3x20MHz for 802.11ac, and allocated within B. Such a scenario can be handled by the receiver 100 being operated in the first operation mode or the second operation mode.

Figure 7 shows a schematic diagram illustrating the processing of an exemplary RF-signal by the RF-channels 103a-c of the receiver 100 according to an embodiment being operated in the first operation mode. As can be taken from figure 7, the receiver 100 being operated in the first operation mode can provide for a sufficient separation between the local oscillator frequencies LO1, LO2 and LO3 for demodulating the exemplary frequency channels "ch1", "ch2" and "ch3" so that essentially no or only very little LO pulling and minimized coupling occurs between the local oscillator frequencies f_{LO1}, f_{LO2} and f_{LO3}, which is mainly due to the re-centering mixer 106. For more details about embodiments of the receiver 100, which in the first operation mode can process a RF-signal by the RF-channels 103a-c thereof in the manner illustrated in figure 7 reference is made to the published patent application PCT/EP2015/059859 , which is hereby incorporated by reference.

Figure 8 shows a schematic diagram illustrating the processing of a demodulated RF-signal by the BB-channels 105a-c of the receiver 100 according to an embodiment being operated in the second operation mode. As can be taken from figure 8, the transfer characteristics of the first BB-channel 105a are determined by the three bandpass filters 107a-c shunted by the impedance inverters 112a and 112b. The bandwidth of the three bandpass filters 107a-c narrows from 107a to 107b, and then further to 107c. Thus, the transfer function of the first BB-channel 105a has three passbands for Ch1, Ch2 and Ch3 respectively. For more details about the processing of a demodulated RF-signal by the BB-channels 105a-c of the receiver 100 being operated in the second operation mode reference is made to the published patent application PCT/EP2015/070339, which is hereby incorporated by reference.

Figure 9 shows a schematic diagram illustrating a method 900 for operating the receiver 100 according to an embodiment. The method 900 comprises the step 901 of operating the receiver 100 in the first operation mode or the second operation mode using the control unit 101, wherein the receiver 100 comprises the plurality of RF-channels 103a-m for RF-processing configured as input of the control unit 101 and wherein the receiver 100 further comprises the plurality of BB-channels 105a-n for BB-processing configured as output of the control unit 101. In the first operation mode the method 900 comprises the further step 901a of relating the first RF-channel 103a to the first BB-channel 105a and the second RF-channel 103b to the second BB-channel 105b. In the second operation mode the method comprises the further step 901b of relating the transfer characteristics of the second BB-channel 105b to the first BB-channel 105a.

While a particular feature or aspect of the disclosure may have been disclosed with respect to only one of several implementations or embodiments, such feature or aspect may be combined with one or more other features or aspects of the other implementations or embodiments as may be desired and advantageous for any given or particular application. Furthermore, to the extent that the terms "include", "have", "with", or other variants thereof are used in either the detailed description or the claims, such terms are intended to be inclusive in a manner similar to the term "comprise". Also, the terms "exemplary", "for example" and "e.g." are merely meant as an example, rather than the best or optimal. The terms “coupled” and “connected”, along with derivatives may have been used. It should be understood that these terms may have been used to indicate that two elements cooperate or interact with each other regardless whether they are in direct physical or electrical contact, or they are not in direct contact with each other.

Although specific aspects have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific aspects shown and described without departing from the scope of the present disclosure. This application is intended to cover any adaptations or variations of the specific aspects discussed herein.

Although the elements in the following claims are recited in a particular sequence with corresponding labeling, unless the claim recitations otherwise imply a particular sequence for implementing some or all of those elements, those elements are not necessarily intended to be limited to being implemented in that particular sequence.

Many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the above teachings. Of course, those skilled in the art readily recognize that there are numerous applications of the invention beyond those described herein. While the present invention has been described with reference to one or more particular embodiments, those skilled in the art recognize that many changes may be made thereto without departing from the scope of the present invention. It is therefore to be understood that within the scope of the appended claims and their equivalents, the invention may be practiced otherwise than as specifically described herein.

CLAIMS

1. A receiver (100) for a radio frequency, RF,-signal comprising:

a control unit (101) configured to operate the receiver in a first operation mode and a second operation mode;

a plurality of RF-channels (103a-m) for RF-processing configured as input of the control unit (101); and

a plurality of baseband, BB,-channels (105a-n) for BB-processing configured as output of the control unit (101);

wherein in the first operation mode the control unit (101) is configured to relate a first RF-channel (103a) to a first BB-channel (105a) and a second RF-channel (103b) to a second BB-channel (105b), and

wherein in the second operation mode the control unit (101) is configured to relate transfer characteristics of the second BB-channel (105b) to the first BB-channel (105a).

2. The receiver (100) of claim 1, wherein the receiver (100) further comprises a third RF-channel (103c) and a third BB-channel (105c).

3. The receiver (100) of claim 2, wherein the control unit (101) is further configured to operate the receiver (100) in a third operation mode, wherein in the third operation mode the control unit (101) is configured to relate the first RF-channel (103a) to the first BB-channel (105a), to relate the second RF-channel (103b) to the second BB-channel (105b) and to relate the transfer characteristics of the third BB-channel (105c) to the second BB-channel (105b).

4. The receiver (100) of claim 2 or 3, wherein each RF-channel (103a-c) comprises a demodulator (104a-c) configured to generate a respective baseband signal on the basis of the RF-signal.

5. The receiver (100) of claim 4, wherein the second RF-channel (103b) and the third RF-channel (103c) comprise a re-centering mixer (106), wherein the re-centering mixer (106) is configured to re-center the RF-signal on the basis of a predefined re-centering frequency f_C around a first frequency $f_{RF}+f_C$ and around a second frequency $f_{RF}-f_C$, wherein f_{RF} is a central frequency associated with the RF-signal.

6. The receiver (100) of claim 5, wherein the demodulator (104b) of the second RF-channel (103b) is configured to demodulate the re-centered RF-signal on the basis of the first frequency $f_{RF}+f_C$ and wherein the demodulator (104c) of the third RF-channel (103c) is configured to demodulate the re-centered RF-signal on the basis of the second frequency $f_{RF}-f_C$.

7. The receiver (100) of any one of claims 2 to 6, wherein in the first operation mode the control unit (101) is further configured to relate the third RF-channel (103c) to the third BB-channel (105c).

8. The receiver (100) of any one of claims 2 to 7, wherein in the second operation mode the control unit (101) is configured to relate the first RF-channel (103a) to the first BB-channel (105a) and to relate the transfer characteristics of the second BB-channel (105b) to the first BB-channel (105a) and to relate the transfer characteristics of the third BB-channel (105c) to the second BB-channel (105b).

9. The receiver (100) of claim 3, wherein the demodulator (104a) of the first RF-channel (103a) is configured to demodulate the RF signal on the basis of a central frequency f_{RF} associated with the RF-signal.

10. The receiver (100) of claim 4, wherein each demodulator (104a-c) of each RF-channel (103a-c) comprises a mixer and a local oscillator.

11. The receiver (100) of any one of the preceding claims, wherein the control unit (101) comprises a plurality of switches (111a-d), wherein the plurality of switches (111a-d) are configured to connect the plurality of BB-channels (105a-c) in parallel, in particular the first BB-channel (105a) with the second BB-channel (105b) in parallel.

12. The receiver (100) of any one of the preceding claims, wherein each BB-channel (105a-c) comprises a frequency selective filter (107a-c).

13. The receiver (100) of claim 12, wherein each frequency-selective filter (107a-c) of each BB-channel (105a-c) is a band-pass filter (107a-c) having an adjustable bandwidth and/or an adjustable center frequency.

14. The receiver (100) of claim 13, wherein the control unit (101) further comprises at least one impedance inverter (112a,b) and wherein the control unit (101) is configured to relate the transfer characteristics of the second BB-channel (105b) to the first BB-channel (105a) by shunting the second BB-channel (105b) to the first BB-channel (105a) over the impedance inverter (112a).

15. The receiver (100) of claim 12, wherein the frequency-selective filter (107a) of the first BB-channel (105a) is a band-pass filter having an adjustable bandwidth and/or an adjustable center frequency and the frequency-selective filter (107b) of the second BB-channel (105b) is a band-stop filter having an adjustable bandwidth and/or an adjustable center frequency.

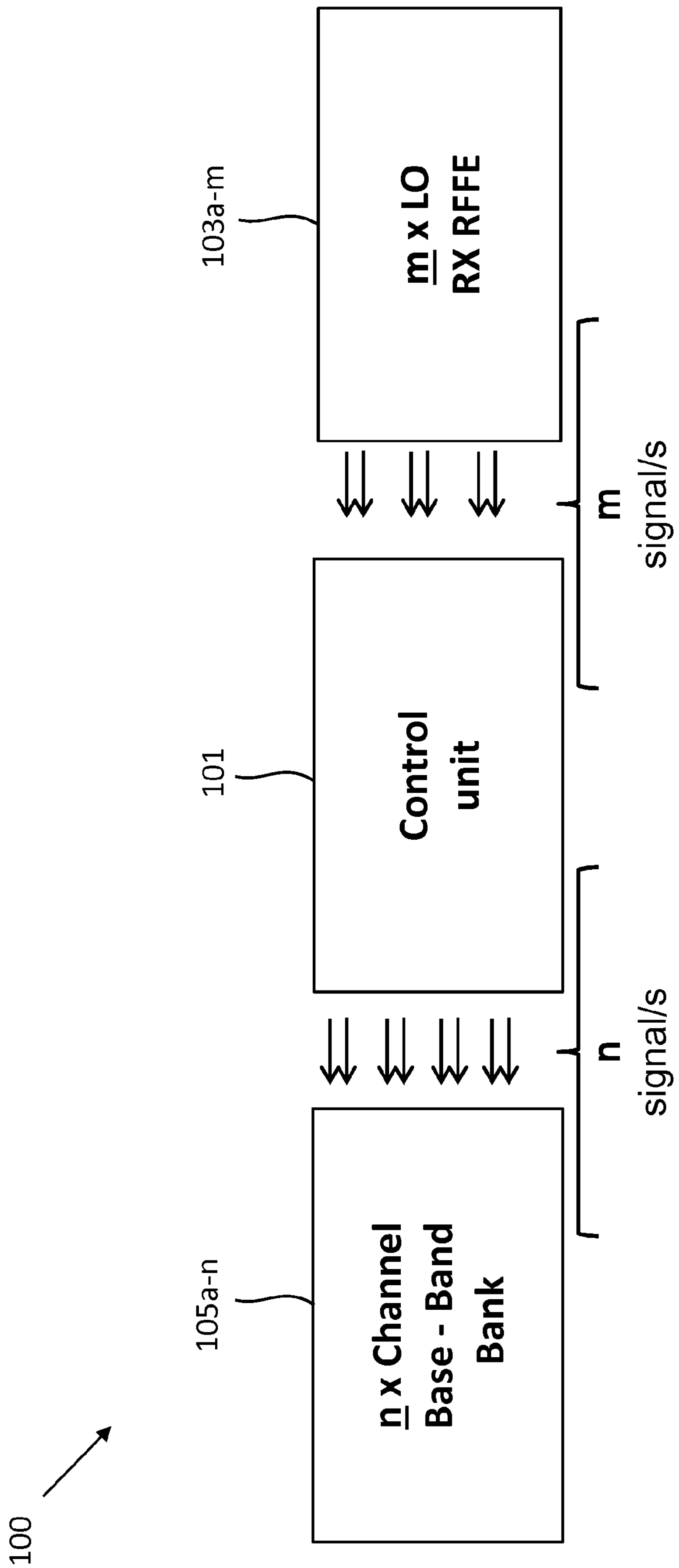
16. A method (900) of operating a receiver (100) for a RF signal, the method (900) comprising:

operating (901) the receiver (100) in a first operation mode or a second operation mode using a control unit (101), wherein the receiver (100) comprises a plurality of RF-channels (103a-m) for RF-processing configured as input of the control unit (101) and wherein the receiver (100) further comprises a plurality of BB-channels (105a-n) for BB-processing configured as output of the control unit (101);

in the first operation mode, relating (901a) a first RF-channel (103a) to a first BB-channel (105a) and a second RF-channel (103b) to a second BB-channel (105b); or

in the second operation mode, relating (901b) the transfer characteristics of the second BB-channel (105b) to the first BB-channel (105a).

17. A computer program comprising program code for performing the method (900) of claim 16 when executed on a computer.



103a-m
m x LO
RX RFFE
m
signal/s
101
Control
unit
n
signal/s
105a-n
n x Channel
Base - Band
Bank
100

Fig. 1

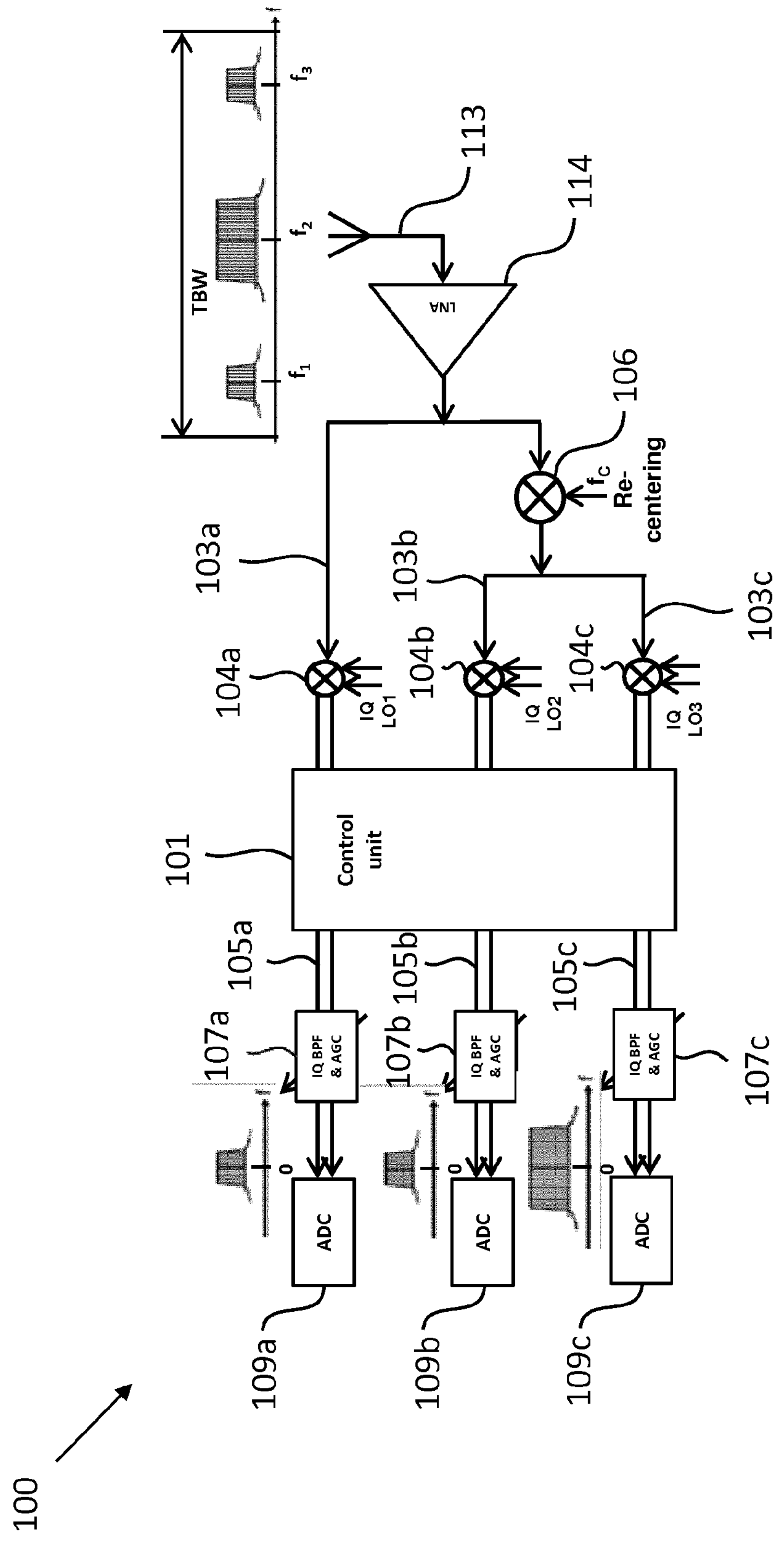

TBW
f1
f2
f3
f
113
114
LNA
106
fC
Re-centering
103a
103b
103c
104a
104b
104c
IQ LO1
IQ LO2
IQ LO3
101
Control unit
105a
105b
105c
107a
107b
107c
IQ BPF & AGC
0
ADC
109a
109b
109c
100

Fig. 2

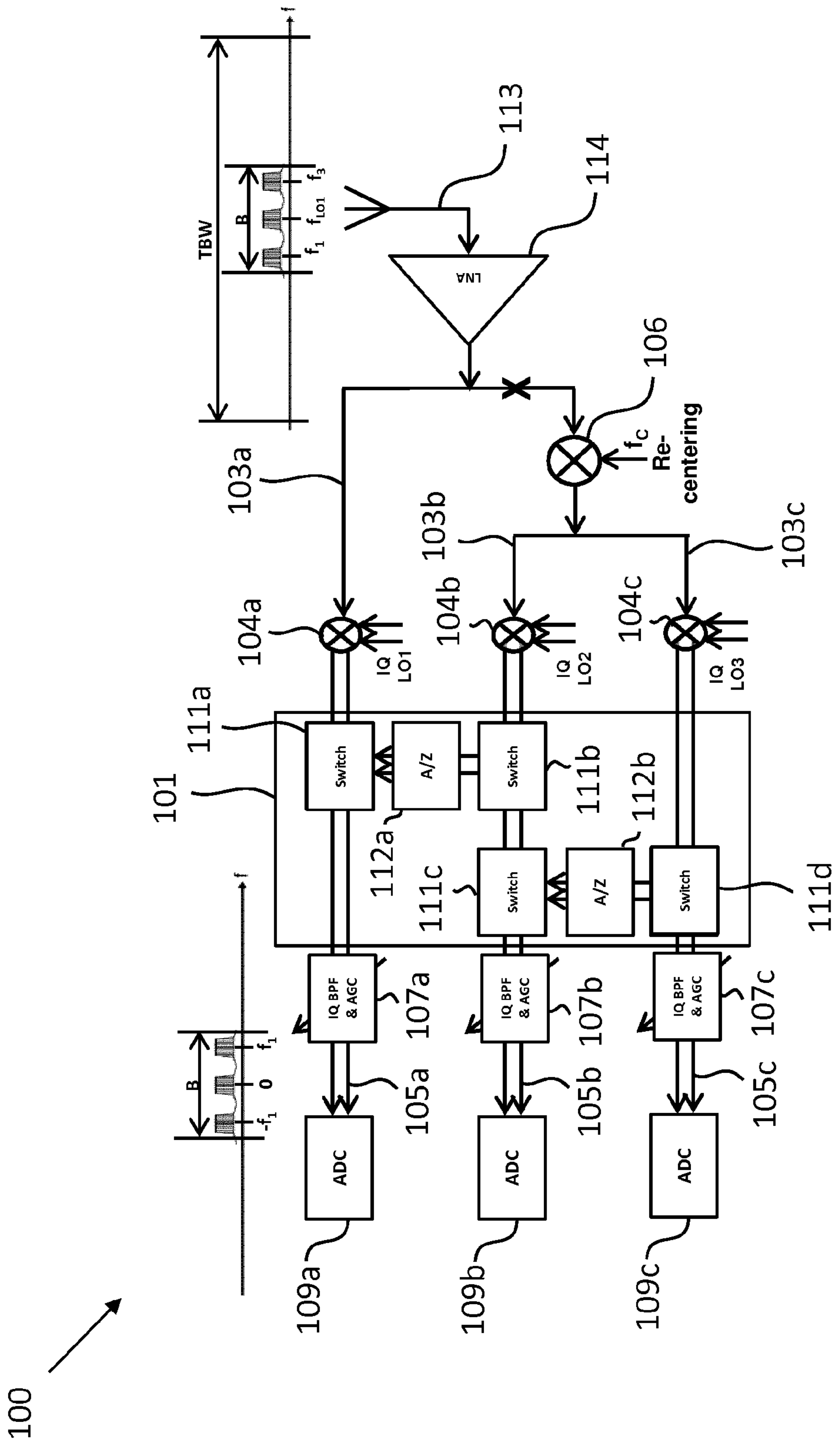

100
TBW
B
f
f_1
f_{LO1}
f_3
113
114
LNA
106
f_C
Re-centering
103a
103b
103c
104a
104b
104c
IQ LO1
IQ LO2
IQ LO3
101
111a
111b
111c
111d
112a
112b
Switch
A/Z
IQ BPF & AGC
107a
107b
107c
105a
105b
105c
ADC
109a
109b
109c
$-f_1$
0

Fig. 3

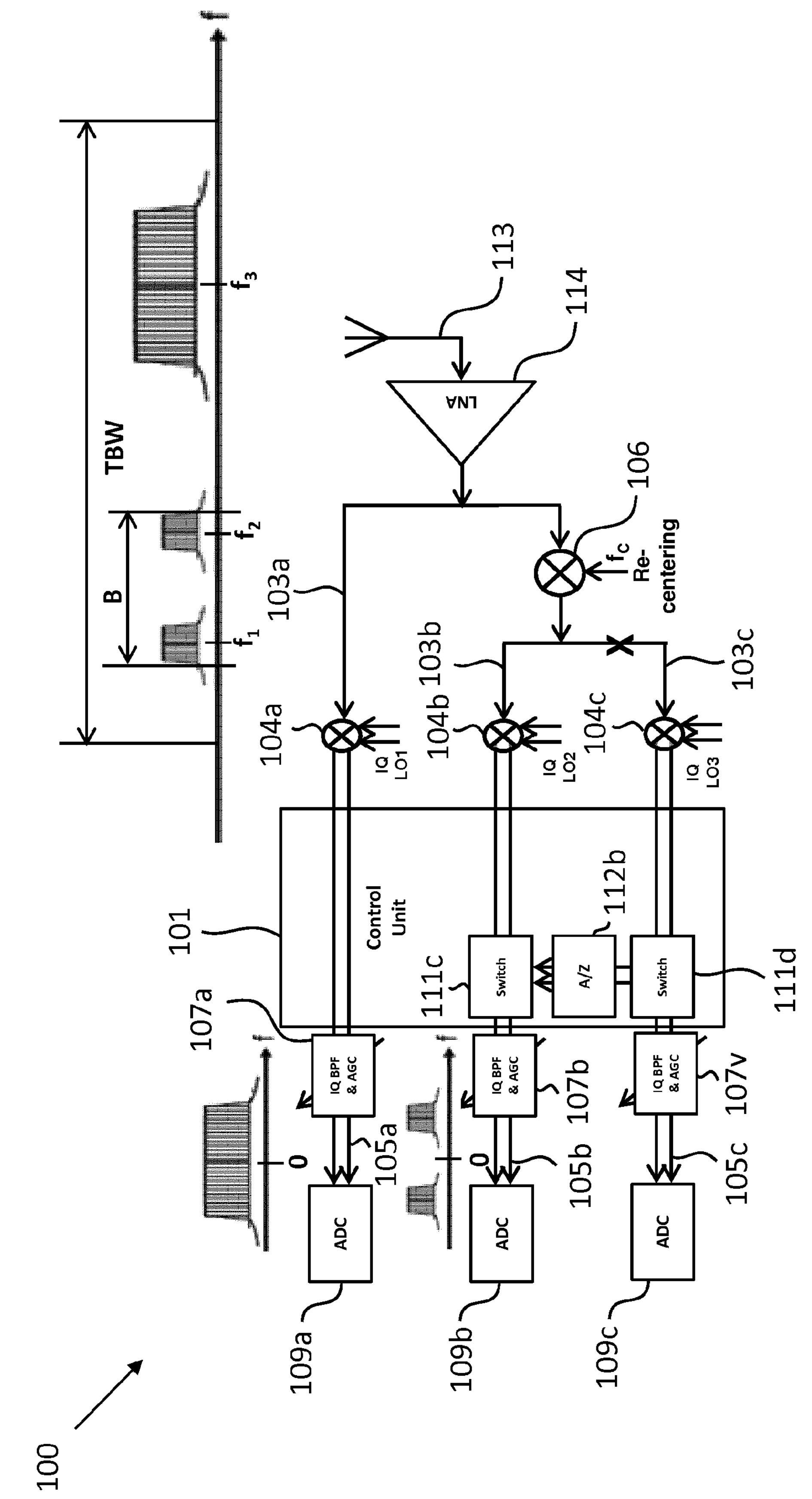

f
TBW
B
f_1
f_2
f_3
113
114
LNA
106
f_c
Re-centering
103a
103b
103c
104a
104b
104c
IQ LO1
IQ LO2
IQ LO3
101
Control Unit
Switch
A/Z
112b
111c
111d
107a
107b
107v
IQ BPF & AGC
0
105a
105b
105c
ADC
109a
109b
109c
100

Fig. 4

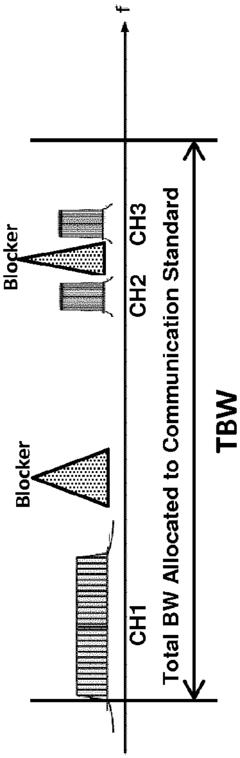


Fig. 5a

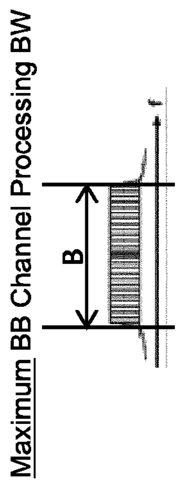


Fig. 5b

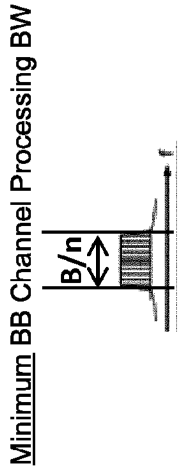


Fig. 5c

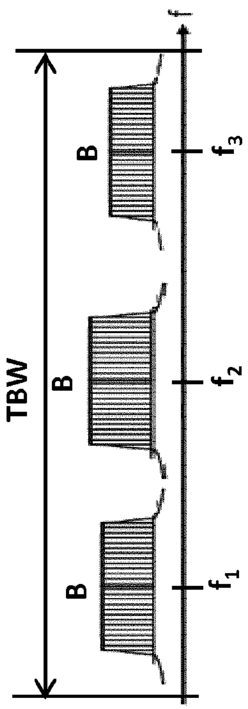


Fig. 6a

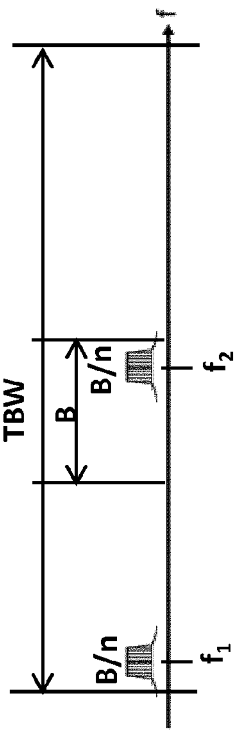


Fig. 6b

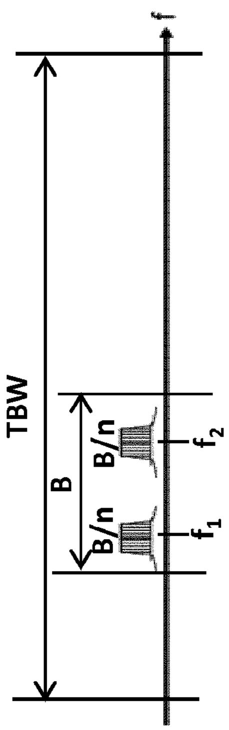


Fig. 6c

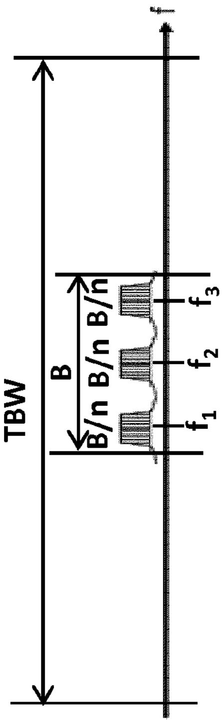


Fig. 6d

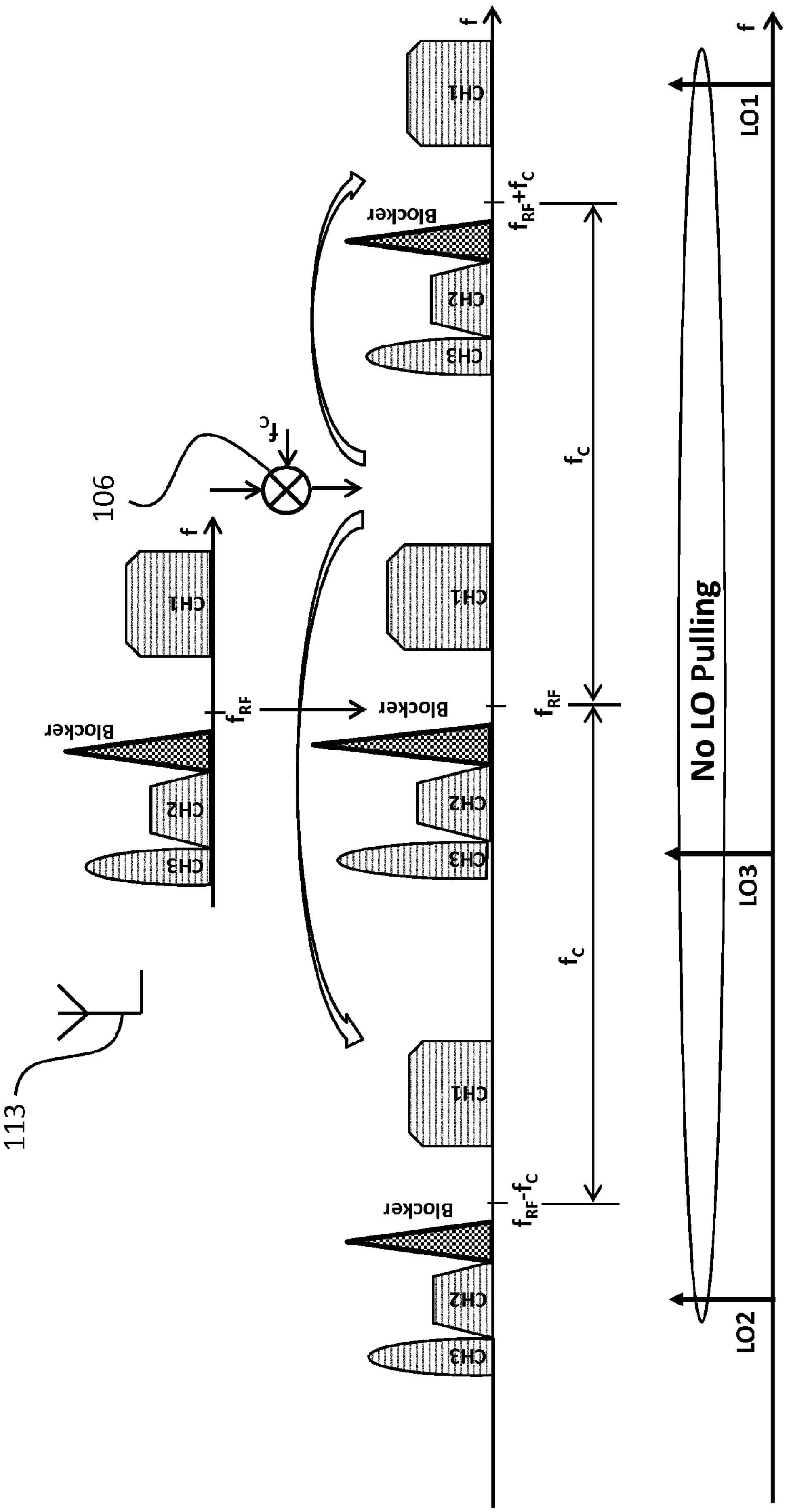

106
113
CH1
CH2
CH3
Blocker
f
f_{RF}
f_C
$f_{RF}+f_C$
$f_{RF}-f_C$
LO1
LO2
LO3
No LO Pulling

Fig. 7

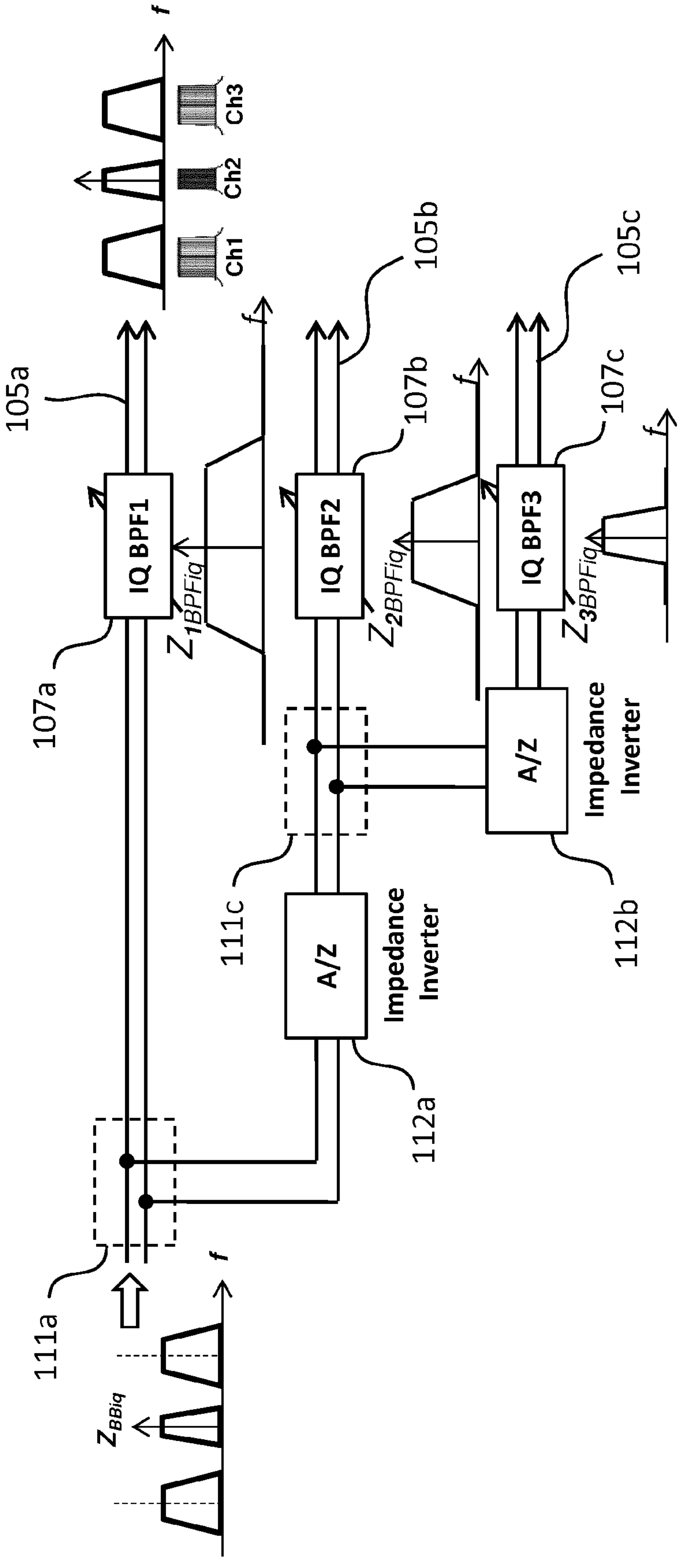

f
Ch1
Ch2
Ch3
105a
105b
105c
107a
107b
107c
IQ BPF1
IQ BPF2
IQ BPF3
Z_{1BPFiq}
Z_{2BPFiq}
Z_{3BPFiq}
A/Z
Impedance Inverter
A/Z
Impedance Inverter
111a
111c
112a
112b
Z_{BBiq}

Fig. 8

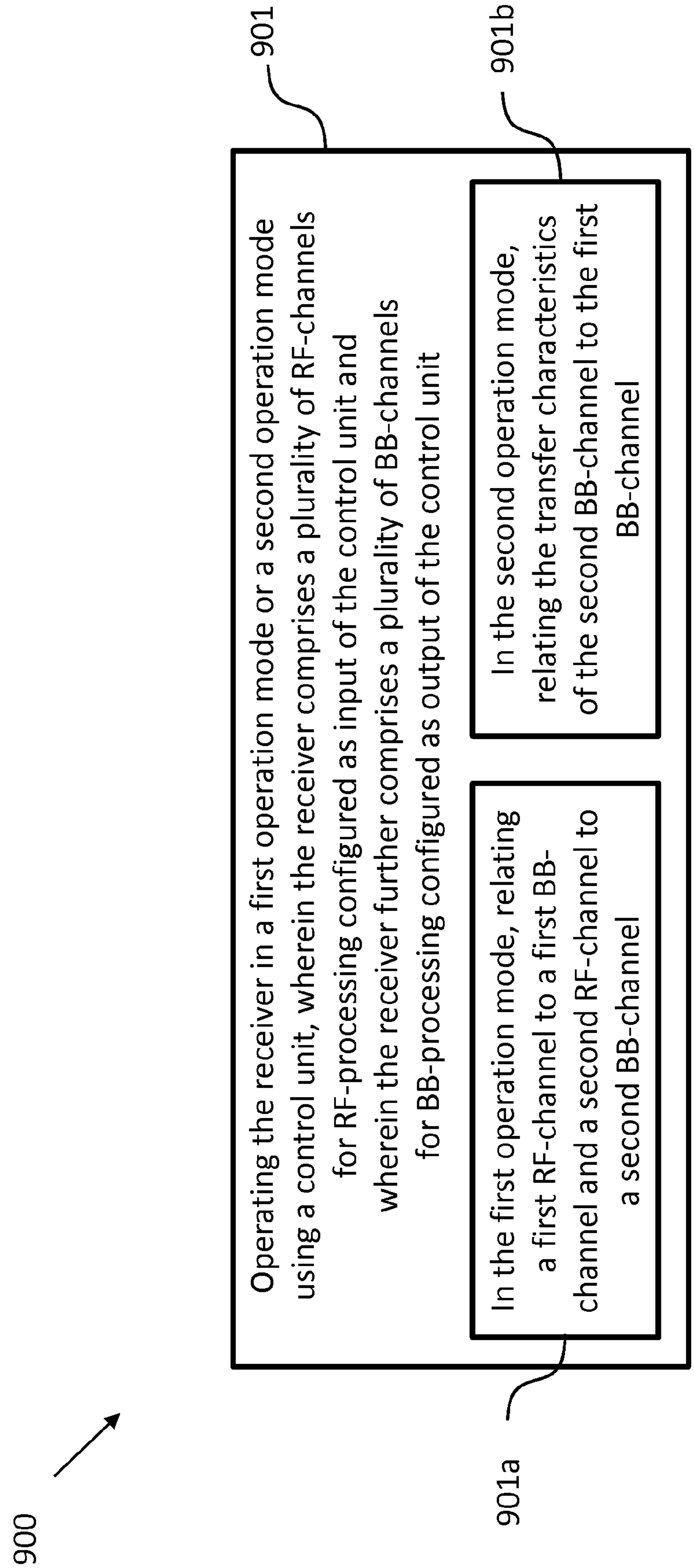

900
901
Operating the receiver in a first operation mode or a second operation mode using a control unit, wherein the receiver comprises a plurality of RF-channels for RF-processing configured as input of the control unit and wherein the receiver further comprises a plurality of BB-channels for BB-processing configured as output of the control unit
901a
In the first operation mode, relating a first RF-channel to a first BB-channel and a second RF-channel to a second BB-channel
901b
In the second operation mode, relating the transfer characteristics of the second BB-channel to the first BB-channel

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/059245

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B1/00
ADD. H04L27/26

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)
H04B 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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2016/043822 A1 (YI MIN [CN] ET AL) 11 February 2016 (2016-02-11) figure 4 figure 8a figure 9a figure 7 figures 10-11 paragraph [0079] - paragraph [0081] paragraph [0077] paragraph [0082] - paragraph [0094] -----	1-4,7-17 5,6
X A	US 2015/236887 A1 (KAUKOVUORI JOUNI KRISTIAN [FI] ET AL) 20 August 2015 (2015-08-20) figures 8,13,14 paragraph [0072] - paragraph [0086] paragraph [0106] - paragraph [0121] ----- -/--	1-4,7-17 5,6

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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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	Date of mailing of the international search report
17 January 2017	24/01/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hanus, Pavol

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PARK CHESTER ET AL: "Carrier aggregation for LTE-advanced: design challenges of terminals", IEEE COMMUNICATIONS MAGAZINE, IEEE SERVICE CENTER, PISCATAWAY, US, vol. 51, no. 12, 1 December 2013 (2013-12-01), pages 76-84, XP011534261, ISSN: 0163-6804, DOI: 10.1109/MCOM.2013.6685761 [retrieved on 2013-12-16] figure 3 page 79 - page 81 -----	1-17

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2016/059245

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		EP 2885876 A1	24-06-2015
		GB 2504973 A	19-02-2014
		HK 1209918 A1	08-04-2016
		US 2015236887 A1	20-08-2015
		WO 2014027232 A1	20-02-2014