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(54) **Title:** GNSS RECEIVER AND METHOD FOR SUPER-WIDEBAND RECEIVING OF GNSS SIGNALS

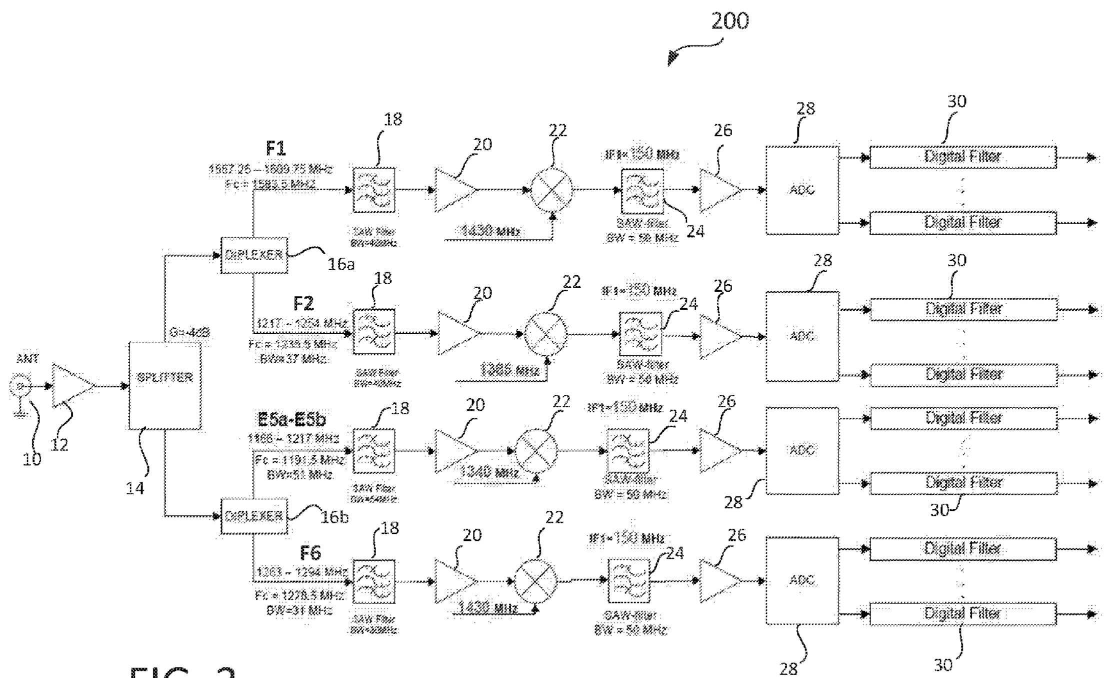

FIG. 3

(57) **Abstract:** A GNSS receiver (a) receives wideband GNSS signals including a first plurality of navigation signals from one or more satellite systems, each navigation signal having a respective frequency range, (b) separates the received GNSS signals, by filtration, into a second plurality of frequency bands, each frequency band including a group of navigation signals, (c) amplifies the group of navigation signals in each frequency band, (d) performs one or more frequency down-conversion onto the group of navigation signals in each frequency band into a group of intermediate frequency (IF) signals with a predetermined band width, (e) performs analog-to-digital conversion onto the group of IF signals to output a group of digitized IF signals, (f) digitally filters and separates the group of digitized IF signals into individual signals of the navigation systems, and (g) performs subsequent digital processing onto the separated individual signals of the navigation systems to generate solutions.

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[Continued on next page]

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GNSS RECEIVER AND METHOD FOR SUPER-WIDEBAND RECEIVING OF GNSS SIGNALS

CLAIM OF PRIORITY

[0001] This application claims priority to United States Provisional Patent Application No. 62/343,643, filed on May 31, 2016, which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to GNSS receivers. More specifically, the present invention relates to a super-wideband GNSS receiver and a method for receiving super-wideband GNSS signals.

2. Description of the Related Art

[0003] Global Navigation Satellite Systems (GNSS) available today or in the near future include United States Global Positioning System (GPS), Russian Global Orbiting Navigation Satellite System (GLONASS), European Union's Galileo, China's regional BeiDou Satellite Navigation System (BDS, formerly known as Compass), and Japanese Quasi-Zenith Satellite System (QZSS).

[0004] Thus, GNSS frequency bands are allocated to various satellite systems and their respective bands. For example, the GPS has L1 band (Center Frequency: 1575.42 MHz), L2 band (1227.60 MHz), and L5 band (1176.45 MHz). Similarly, the GLONASS has L1 (G1) band (1602 MHz), L2 (G2) band (1246 MHz), and L3 (G3) band (1202.025 MHz). The Galileo has E1 band (1575.42 MHz), E5 band (1191.795MHz) (E5a band (1176.45 MHz) + E5b band (1207.14 MHz)), and E6 band (1278.75 MHz). The BeiDou has B1 band (1561.098 MHz), B1-2 band (1589.74 MHz), B2 band (1207.14 MHz), and B3 band (1268.52 MHz). The QZSS has L1 band (1575.42 MHz), E6/LEX band (1278.75 MHz), L2 band (1227.60MHz), and L5 band (1176.45 MHz). The GNSS may have other frequency bands not mentioned above. FIG. 2 shows a table of some of the GNSS frequency bands.

[0005] Wideband GNSS receivers that support multiple GNSS systems have advantages to increase the number of satellites in view and thus to provide accuracy, continuity, availability, and reliability. Conventionally, this is done by providing parallel receiver paths for the different frequency bands. FIG. 2 schematically illustrates an example of a conventional super heterodyne wideband GNSS receiver which is adapted to receive two frequency bands. As shown in FIG. 2, a respective front-end is provided as a receiver path for each of the frequency bands, where each frequency band corresponds to one of the satellite signals. Thus, in order for a wideband GNSS to simultaneously receive and process the GNSS signals from multiple satellite systems, the GNSS receiver need to have the same number of multiple receiver paths (RF chips) as the number of the navigation signal frequency bands. However, such parallel receiver paths require increased hardware and power consumption.

BRIEF DESCRIPTION OF THE INVENTION

[0006] The embodiments of the present invention provide a method for receiving and processing GNSS signals in super-wide frequency band with lesser increase of hardware, and a GNSS receiver implementing the method.

[0007] The method includes (a) receiving wideband GNSS signals via an antenna, the GNSS signals including a first plurality of navigation signals from one or more satellite systems, each navigation signal having a respective frequency range, (b) separating the received GNSS signals, by filtration, into a second plurality of frequency bands, each frequency band including a group of navigation signals from among the first plurality of navigations signals, (c) amplifying the group of navigation signals in each frequency band, (d) performing one or more frequency down-conversion onto the group of navigation signals in each frequency band into a group of intermediate frequency (IF) signals with a predetermined band width, (e) performing analog-to-digital conversion onto the group of IF signals to output a group of digitized IF signals, (f) digital filtering and separating the group of digitized IF signals into individual signals of the navigation systems, and (g) performing subsequent digital processing onto the separated individual signals of the navigation systems to generate solutions.

[0008] The digital separating and filtering may be performed under software control, and this software may adaptively adjust frequency characteristics of digital filters that separate the group of digitized IF signals into the individual signals of navigation systems, thereby providing a high quality of navigation solution and a sufficient level of interference immunity.

[0009] The second plurality of frequency bands may be a full set or any subset of frequency bands selected from among the group consisting of approximately the following bands: 1560 to 1610 MHz (F1), 1165 to 1215 MHz (F5), 1215 to 1260 MHz (F2), and 1260 to1300 MHz (F6).

[0010] The performing one or more frequency down-conversion may include down-converting the frequency bands F1 and F6 to an intermediate frequency of approximately 150 MHz with a predetermined bandwidth, using a joint heterodyne.

[0011] The final stage of frequency down-conversion may transfer a signal spectrum of the group of signals to a final intermediate frequency, and the analog-to-digital conversion is performed in a single channel I-only processing. Alternatively, the final stage of frequency down-conversion is performed using a quadrature (I / Q) down-converter, and the analog-to-digital conversion is performed in a two-channel I and Q processing.

[0012] The first plurality may be equal to or greater than twelve (12), and the second plurality may be equal to or smaller than four (4), and a number of signals included in the group of signals may be equal to or smaller than four (4).

[0013] In accordance with one embodiment of the present invention, a GNSS receiver includes an antenna, a signal separator, a plurality of signal processing path, and a signal processing section. The antenna receives wideband GNSS signals including a first plurality of navigation signals from one or more satellite systems, each navigation signal having a respective frequency range. The signal separator separates, by filtration, the received GNSS signals into a second plurality of frequency bands, each frequency band including a group of navigation signals which are a subset of the first plurality of navigation signals. The plurality of signal processing paths are provided to process the second plurality of frequency bands.

[0014] Each signal processing path includes an amplifier, at least one frequency down-converter, an analog-to-digital convertor, and a set of digital filters. The amplifier receives corresponding one of the frequency bands and amplifies the group of navigation signals in the frequency band. The at least one frequency down-convertor is coupled to the amplifier, and converts the amplified navigation signals into a group of intermediate frequency (IF) signals. The analog-to-digital convertor is coupled to an output of the at least one frequency down-convertor, and generates digital signals including a group of digitized IF signals. The set of digital filters receive and separate the group of digitized IF signals into individual navigation signals of the satellite systems.

[0015] The signal processing section that performs subsequent digital processing onto the individual navigation signals of the satellite systems to generate solutions.

[0016] In accordance with one embodiment of the present invention, the signal separator may include a signal splitter, at least one diplexer coupled to the signal splitter, and at least two filters coupled to the diplexer.

[0017] The digital filters are implemented by software, and may be adaptive digital filters whose frequency characteristics are adjustable so as to provide a high quality of navigation solution and a sufficient level of interference immunity.

[0018] The second plurality of frequency bands may be a full set or any subset of frequency bands selected from among the group consisting of approximately the following bands: 1560 to 1610 MHz (F1), 1165 to 1215 MHz (F5), 1215 to 1260 MHz (F2), and 1260 to 1300 MHz (F6).

[0019] The at least one frequency down-convertor may include a final down-convertor to obtain an intermediate frequency of approximately 150 MHz with a predetermined bandwidth; and a local oscillator providing a down-conversion frequency to both of the frequency bands F1 and F6.

[0020] The at least one frequency down-convertor may transfer a signal spectrum of the group of signals to have a final intermediate frequency, and the analog-to-digital convertor performs a single-channel I-only processing. Alternatively, the at least one frequency down-converter may include a quadrature (I / Q) down-converter, and the analog-to-digital convertor performs a two-channel I and Q processing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

[0022] FIG. 1 is a table of some of the GNSS signal frequency bands.

[0023] FIG. 2 is a block diagram schematically illustrating a conventional super heterodyne wideband GNSS receiver.

[0024] FIG. 3 is a block diagram schematically illustrating a super-wideband GNSS receiver in accordance with one embodiment of the present invention.

[0025] FIG. 4 shows a table of example of navigation signals and corresponding signal frequency ranges, and divided frequency bands in accordance with one embedment of the present invention.

[0026] FIG. 5 is a diagram schematically illustrating an example of multi-stage frequency down-convertor.

[0027] FIG. 6 is a flow chart illustrating a process flow of a method for receiving GNSS signals in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0028] The present invention will now be described in detail with reference to a few preferred embodiments thereof as illustrated in the accompanying drawings. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art, that the present invention may be practiced without some or all of these specific details. In other instances, well known process steps and/or structures have not been described in detail in order to not unnecessarily obscure the present invention.

[0029] The present invention provides a super-wideband GNSS receiver and a method for receiving and processing GNSS signals. FIG. 3 schematically illustrates an example of a GNSS receiver 100 in accordance with one embodiment of the present invention. As shown in FIG. 3, the GNSS receiver 100 receives GNSS signals at an antenna 10. The GNSS receiver 100 is capable of receiving a super-wideband GNSS signals including a plurality of navigation signals from one or more satellite systems. For example, such satellite systems include GPS, GLONASS, Galileo, BeiDou, and QZSS. As mentioned above, each navigation signal has a respective frequency range allocated thereto. Since some of the navigation signals from different satellite systems use the same center frequency, the currently used or available navigation signals may be categorized into twelve (12) frequency ranges.

[0030] An example of such categorized frequency ranges is shown in a table in FIG. 4. FIG. 4 lists twelve navigation signals with respective notations (G1, B1-2, L1, B1, E6, B3, G2, L2, B2, G3, E5, and L5) and corresponding signal frequency ranges in MHz. It should be noted that the navigation signal of the same notation (for example, L1) may include signals from two or more satellite systems. It should also be noted that the total number of the frequency ranges does not have to be 12 or a specific number and may be increased or decreased in accordance with application.

[0031] Referring back to FIG. 3, the received GNSS signals are amplified by an amplifier 12 (typically a low noise amplifier) and then split by a signal splitter 14 into two signal channels. In each signal channel, the received GNSS signals are divided into a higher frequency part and a lower frequency part by filtration using a respective diplexer 16a, 16b. The divided signals are further filtered using respective SAW filters 18.

[0032] For example, the first diplexer 16a divides the received GNSS signals into a first frequency range F1 (1551 ~1610 MHz) with a center frequency 1583.5 MHz, and a second frequency range F2 (1218 ~1254 MHz) with a center frequency 1325.5 MHz. Similarly, the second diplexer 16b divides the received GNSS signals into a third frequency range F5 (1164 ~1217 MHz) with a center frequency 1191.5 MHz, and a fourth frequency range F6 (1259 ~1299 MHz) with a center frequency 1278.5 MHz. Accordingly, in this example, the received GNSS signals are separated into four frequency bands F1, F2, F5, and F6, which are also shown in the table of FIG. 4. In another example, the frequency ranges may be slightly different: with the first frequency range F1 of 1560 ~ 1610 MHz; the second frequency range F2 of 1215 ~ 1260 MHz; the third frequency range F5 of 1165 ~ 1215 MHz; and the fourth frequency range F6 of 1260 ~ 1300 MHz.

[0033] These frequency bands include a respective group of navigation signals which are a subset of the originally received (12, in this example) navigation signals. For example, the first frequency band F1 (with a band width 59 MHz) may include four navigation signals G1, B1-2, L1, and B1, as shown in FIG. 4. Similarly, the second frequency band F2 (with a band width 36 MHz) may include two navigation signals G2 and L2; the third frequency band F5 (with a band width 53 MHz) may include four navigation signals B2, G3, E5, and L5; and the fourth frequency band F6 (with a band width 40 MHz) may include two navigation signals E6 and B3, as shown in FIG. 4. It should be noted that a band gap is provided between the third frequency band F5 and fourth frequency band F6 when the second diplexer 16b divides these two frequency bands, since the second frequency band F2 therebetween is processed by the first diplexer 16a. Such a band gap facilitates clear separation of the two frequency bands F5 and F6 and reduces interference therebetween.

[0034] As shown in FIG. 3, four signal processing paths (channels) corresponding to the four frequency bands are provided in the GNSS receiver 100. Each signal processing path includes an amplifier 20, at least one frequency down-converter including a mixer 22 and a SAW filter 24, an amplifier 26, an analog-digital convertor 28, and a set of digital filters 30. The amplifier 20 receives one of the frequency bands (F1, F2, F5, or F6) and amplifies the group of navigation signals in the frequency band. The at least one frequency down-convertor (mixer) 22 is coupled to the amplifier 20, and converts the amplified navigation signals into a group of intermediate frequency (IF) signals. The IF singles are filtered by the SAW filter 24, and then amplified by the amplifier 26 before being input to the analog-to-digital converter 28.

[0035] In this example, the resulting IF signals have a center frequency of 150 MHz with a band width of 50 MHz. As is well understood by those of ordinary skill in the art, a suitable down-conversion frequency is supplied to each down-convertor (mixer) 22 from a local oscillator (not shown). It should be noted that by setting the IF at 150 MHz and dividing the GNSS signals into the frequency bands F1, F2, F5, and F6 as noted above, the same down-conversion frequency (1430 MHz) from the same local oscillator can be used for both first and fourth frequency bands F1 and F6, thereby reducing the number of local oscillators.

[0036] The analog-to-digital convertor 28 is coupled to the amplified output of the at least one frequency down-convertor, and generates a group of digitized IF signals corresponding to the multiple navigation signals from multiple satellite systems. The set of digital filters 30 receive the group of digitized IF signals and separate them into individual navigation signals of the multiple satellite systems. For example, for the frequency band F1, the digital filters 30 separate the digitized IF signals into the individual navigation signals of G1, B1-2, L1, and B1 based on their respective center frequencies. Similarly, for the frequency band F2, the digital filters 30 separate the digitized IF signals into the individual navigation signals G2 and L2 based on their respective center frequencies.

[0037] A signal processing section (not shown) performs subsequent digital processing onto the individual navigation signals of the satellite systems to generate solutions. Such digital processing includes, for example, obtaining the baseband signal, correlation, synchronization, obtaining time, calculating position, and the like.

[0038] In accordance with one embodiment of the present invention, the digital filters 30 are controlled by software. The digital filters 30 may be adaptive digital filters whose frequency characteristics are adjustable so as to provide a high quality of navigation solution and a sufficient level of interference immunity.

[0039] As mentioned above, a super wideband GNSS receiver needs to separate received multichannel/multiband GNSS signals into individual channels/frequency bands, and thus if the received GNSS signals include 12 different frequency ranges of navigation signals, there should be 12 arrays/cannels or receiver paths to simultaneously process the respective frequency ranges. However, in accordance with embodiments of the present invention, by dividing the full frequency range separation into a first-stage separation into broader frequency bands, and a second stage separation of each frequency band into individual frequency range, and by implementing the second-stage separation with software-based digital filters, it became possible to reduce the number of hardware-based signal processing channels/receiver paths. Such a two-stage frequency range separation reduces the size and cost for the hardware of the GNSS receiver, and the associated power consumption as well. Since the software-controlled digital filters are more flexible to configure and easier to fine-tune the filtering characteristics, they can be adjusted to obtain optimum conditions for the application, for example, signal strength, resolution, processing time, amount of interference, and the like. Furthermore, performing the frequency down-conversion before the digital filtering makes the software implementation it easier.

[0040] In this embodiment, the received GNSS signals are separated into four frequency bands: F1 band of approximately 1560 to 1610 MHz, F5 band of approximately 1165 to 1215 MHz, F2 band of approximately 1215 to 1260 MHz, and F6 band of approximately 1260 to 1300 MHz. That is, in accordance with this embodiment, the four frequency bands are received using one RF chip, compared with the conventional method in which four RF chips are necessary to receive four frequency bands.

[0041] However, the frequency bands are not limited to these four frequency bands, but any subset of these four frequency bands can be used. Thus, the number of the receiver paths (channel) may be 2, 3, or 4, depending on which signals are to be received and processed in a specific application of the GNSS receiver.

[0042] In addition, in case of three receiver paths, the frequency bands F6 and F2 (including four frequency ranges) may be processed in one hardware-based channel, and then the digital filters 30 may separate the combined frequency bands F6/F2 into the four individual frequency ranges E6, B3, G2, and L2 (see FIG. 4).

[0043] Furthermore, although only one frequency down-converter is used in the GNSS receiver shown in FIG. 3, the frequency down converter in each receiver path may be multi-staged, for example, such as a two-stage frequency down-convertor 220 shown in FIG. 5. The two-stage frequency down-convertor 220 uses two mixers 42 and 44 and corresponding two local oscillators.

[0044] The at least one frequency down-convertor may transfer a signal spectrum of the group of signals of the frequency band to have a final intermediate frequency (150 MHz in this example), and the analog-to-digital convertor 28 may perform a single-channel I-only processing. Alternatively, the at least one frequency down-converter may include a quadrature (I / Q) down-converter, and the analog-to-digital convertor 28 may perform a two-channel I and Q processing.

[0045] In accordance with one embodiment of the present invention, the GNSS signal receiving method separates the received GNSS signals into a plurality of frequency bands by filtration, such that each of the frequency bands includes signals of one or more satellite navigation systems. This first stage frequency band separation is performed by hardware-based receiver paths (channels). In each of the separated frequency bands, the signals are amplified and then one or more frequency down-conversion and analog-to-digital conversion of the signals are performed, which are also performed in the hardware-based receiver paths (channels). Subsequently, each of the individual frequency ranges of navigation signals from multiple satellite systems is separated using digital filtering. That is, the second stage frequency range separation is performed by the software-based digital filters. And then digital processing is performed on the each of the separated individual navigation signals.

[0046] Frequency characteristics of the digital filters that separate signals of the individual navigation systems can be adaptively adjusted to ensure the best quality of navigation solution and a sufficient level of interference immunity.

[0047] The frequency bands separated by filtering may represent the full set or any subset of the following frequency bands: approximately 1560 ~1610 MHz (F1), approximately 1165 ~ 1215 MHz (F5), approximately 1215 ~1260 MHz (F2), and approximately 1260 ~1300 MHz (F6). An intermediate frequency may be obtained if after-the-first-down-conversion frequency is equal to approximately 150 MHz, which allows the use of a joint heterodyne for down converting the frequency bands F1 and F6. However, other IF may also be used.

[0048] In each of the separated frequency bands, the last frequency down-conversion may transfer the signal spectrum to the last intermediate frequency, and then performs the single-channel analog-to-digital conversion (I-only processing). Alternatively, in each of the separated frequency bands the last frequency down-conversion may be performed using quadrature (I / Q) downconverter, and then performs the two-channel analog-to-digital conversion (I and Q processing).

[0049] FIG. 6 is a process flow chart of a method for receiving and processing GNSS signals in accordance with one embodiment of the present invention. This process may be performed with the GNSS receiver 100 described above.

[0050] Wideband GNSS signals is received via an antenna, where the GNSS signals include a first plurality (N1) of navigation signals from one or more satellite systems (Step 102). Each navigation signal has a respective frequency range, for example, as shown in the table in FIG. 4.

[0051] The received GNSS signals are separated by filtration into a second plurality (N2) of frequency bands (Step 104). For example, such frequency bands may be: F1 (1551 to 1610 MHz), F6 (1259 to 1299 MHz), F2 (1218 to 1254 MHz), and F5 (1164 to 1217 MHz), as shown in the table of FIG. 4. Each frequency band includes a corresponding group of navigation signals from among the first plurality (N1) of navigations signals. It should be noted the band width of each frequency band may be slightly wider or narrower (by a few MHz) so long as the frequency ranges of the corresponding group of navigation signals are included therein.

[0052] Each frequency band is processed through a corresponding receiver path (channel), and the group of navigation signals in each frequency band are amplified (Step 106). And one or more frequency down-conversion is performed onto the group of navigation signals in each frequency band so as to generate a group of intermediate frequency (IF) signals (Step 108). Each group of IF signals may have a center frequency of approximately 150 MHz and a band width of approximately 50 MHz after filtration.

[0053] Analog-to-digital conversion is performed onto the group of IF signals, thereby outputting a group of digitized IF signals (Step 110). Digital filtering is performed on the group of digitized IF signals so as to separate them into individual signals of the navigation systems (Step 112). For example, the digitized IF signals corresponding to the F1 frequency band are separated into the individual signals corresponding to the frequency ranges G1, B1-2, L1, and B1 in accordance with the respective center frequencies. Then, subsequent digital processing is performed onto the separated individual signals of the navigation systems (Step 114) so as to generate solutions (Step 116). The steps 104 through 112 are performed by hardware-based receiver paths (channels), while step 114 is performed by software-based digital filters. The digital filtering (Step 112) may include adaptively adjusting frequency characteristics of digital filters that separate the group of digitized IF signals into the individual signals of navigation systems, thereby providing a high quality of navigation solution and a sufficient level of interference immunity.

[0054] While this invention has been described in terms of several preferred embodiments, there are alterations, permutations, modifications, and various substitute equivalents, which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, permutations, and various substitute equivalents as fall within the true spirit and scope of the present invention.

CLAIMS

What is claimed is:

1. A method for receiving and processing GNSS signals, comprising:

receiving wideband GNSS signals via an antenna, the GNSS signals including a first plurality of navigation signals from one or more satellite systems, each navigation signal having a respective frequency range;

separating the received GNSS signals, by filtration, into a second plurality of frequency bands, each frequency band including a group of navigation signals from among the first plurality of navigations signals;

amplifying the group of navigation signals in each frequency band;

performing one or more frequency down-conversion onto the group of navigation signals in each frequency band into a group of intermediate frequency (IF) signals with a predetermined band width;

performing analog-to-digital conversion onto the group of IF signals to output a group of digitized IF signals;

digital filtering and separating the group of digitized IF signals into individual signals of the navigation systems; and

performing subsequent digital processing onto the separated individual signals of the navigation systems to generate solutions.

2. The method of claim 1, wherein the digital filtering includes:

adaptively adjusting frequency characteristics of digital filters that separate the group of digitized IF signals into the individual signals of navigation systems, thereby providing a high quality of navigation solution and a sufficient level of interference immunity.

3. The method of claim 1, wherein the second plurality of frequency bands are a full set or any subset of frequency bands selected from among the group consisting of: approximately 1560 to 1610 MHz (F1), approximately 1165 to 1215 MHz (F5), approximately 1215 to 1260 MHz (F2), and approximately 1260 to1300 MHz (F6).

4. The method of claim 3, wherein the performing one or more frequency down-conversion includes:

down-converting the frequency bands F1 and F6 to an intermediate frequency of approximately 150 MHz with a predetermined bandwidth, using a joint heterodyne.

5. The method of claim 1, wherein a final stage of frequency down-conversion transfers a signal spectrum of the group of signals to a final intermediate frequency, and the analog-to-digital conversion is performed in a single channel I-only processing.

6. The method of claim 1, wherein a final stage of frequency down-conversion is performed using a quadrature (I / Q) down-converter, and the analog-to-digital conversion is performed in a two-channel I and Q processing.

7. The method of claim 1, wherein the first plurality is equal to or greater than twelve (12), and the second plurality is equal to or smaller than four (4), and a number of signals included in the group of signals is equal to or smaller than four (4).

8. The method of claim 1, the digital separating and filtering is performed using software.

9. A GNSS receiver, comprising:

an antenna that receives wideband GNSS signals including a first plurality of navigation signals from one or more satellite systems, each navigation signal having a respective frequency range;

a signal separator that separates, by filtration, the received GNSS signals into a second plurality of frequency bands, each frequency band including a group of navigation signals which are a subset of the first plurality of navigation signals;

a same second plurality of signal processing paths correspondingly provided for the second plurality of frequency bands, each signal processing path including:

an amplifier that receives corresponding one of the frequency bands and amplifies the group of navigation signals in the frequency band;

at least one frequency down-convertor coupled to the amplifier, the frequency down-converter converting the amplified navigation signals into a group of intermediate frequency (IF) signals;

an analog-to-digital convertor coupled to an output of the at least one frequency down-convertor, the analog-to-digital converter generating digital signals including a group of digitized IF signals; and

a set of digital filters that receive and separate the group of digitized IF signals into individual navigation signals of the satellite systems; and

a signal processing section that performs subsequent digital processing onto the individual navigation signals of the satellite systems to generate solutions.

10. The GNSS receiver of claim 9, wherein the signal separator includes a signal splitter, at least one diplexer coupled to the signal splitter, and at least two filters coupled to the diplexer.

11. The GNSS receiver of claim 9, wherein in the digital filters are adaptive digital filters whose frequency characteristics are adjustable so as to provide a high quality of navigation solution and a sufficient level of interference immunity.

12. The GNSS receiver of claim 9, wherein the second plurality of frequency bands are a full set or any subset of frequency bands selected from among the group consisting of: approximately 1560 to 1610 MHz (F1), approximately 1165 to 1215 MHz (F5), approximately 1215 to 1260 MHz (F2), and approximately 1260 to 1300 MHz (F6).

13. The GNSS receiver of claim 9, wherein the at least one frequency down-convertor includes:

a final down-convertor to obtain an intermediate frequency of approximately 150 MHz with a predetermined bandwidth; and

a local oscillator providing a down-conversion frequency to both of the frequency bands F1 and F6.

14. The GNSS receiver of claim 9, wherein the at least one frequency down-convertor transfers a signal spectrum of the group of signals to have a final intermediate frequency, and the analog-to-digital convertor performs a single-channel I-only processing.

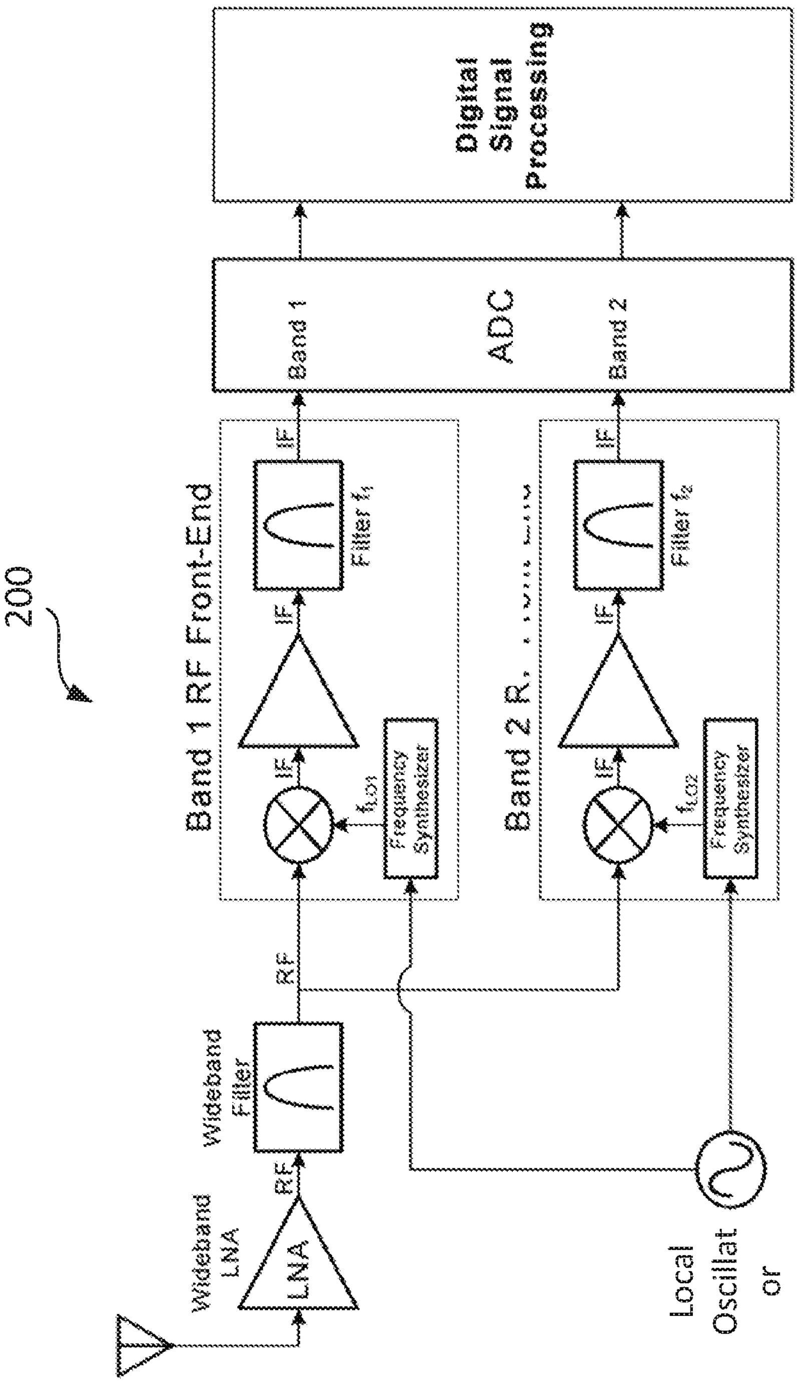
15. The GNSS receiver of claim 9, wherein the at least one frequency down-converter includes a quadrature (I / Q) down-converter, and the analog-to-digital convertor performs a two-channel I and Q processing.

16. The GNSS receiver of claim 9, wherein the first plurality is equal to or greater than twelve (12), and the second plurality is equal to or smaller than four (4), and a number of signals included in the group of signals is equal to or smaller than four (4).

17. The GNSS receiver of claim 9, wherein the set of digital filters are implemented by software.

System	Frequencies (MHz)				
	L1	L2	L3	L5/E5	E6
GPS	1563~1588	1215~1240	N/A	1164~1189	N/A
GLONASS	1592~1615	1237~1257	1194~1209	N/A	N/A
Galileo	1554~1596	N/A	N/A	1145~1238	1258~1300

FIG. 1



PRIOR ART

FIG. 2

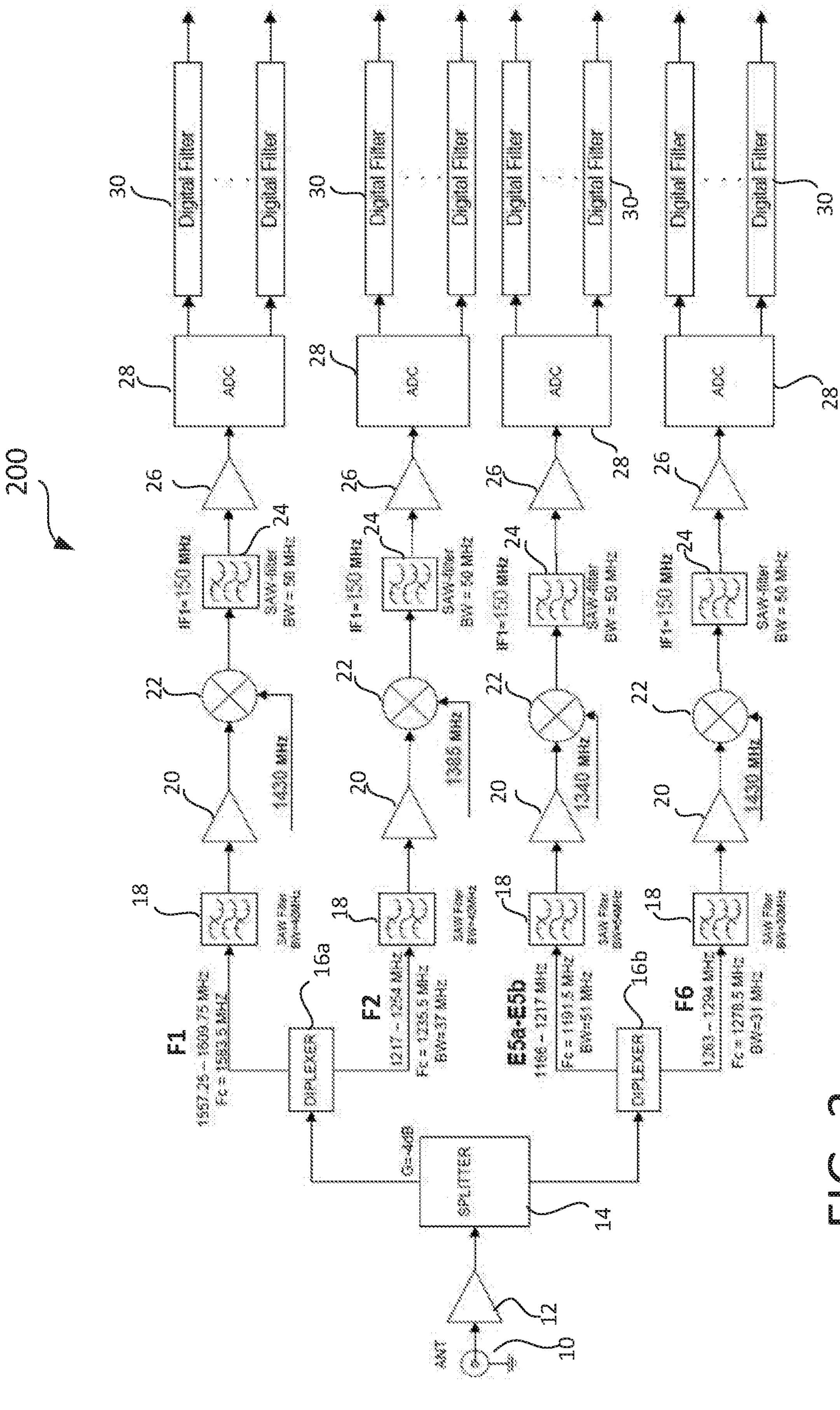

200
ANT
10
12
SPLITTER
G=-4dB
14
DIPLEXER
16a
16b
F1
1557.25 – 1609.75 MHz
Fc = 1583.5 MHz
F2
1217 – 1254 MHz
Fc = 1235.5 MHz
BW=37 MHz
E5a-E5b
1166 – 1217 MHz
Fc = 1191.5 MHz
BW=51 MHz
F6
1263 – 1294 MHz
Fc = 1278.5 MHz
BW=31 MHz
18
SAW Filter
20
22
1430 MHz
1365 MHz
1340 MHz
1430 MHz
24
IF1=150 MHz
SAW-filter
BW = 50 MHz
26
28
ADC
30
Digital Filter

FIG. 3

Signal	Notation	Signal Frequency Range, MHz	RF Chip Frequency Range, MHz
GLONASS L1	G1	1593 ~ 1610	F1 = 1551 ~ 1610 BW = 59 MHz
BeiDou B1-2	B1-2	1580 ~ 1600	
GPS L1, Galileo E1, QZSS L1	L1	1563 ~ 1587	
BeiDou B1	B1	1551 ~ 1571	
Galileo E6, QZSS LEX	E6	1259 ~ 1299	F6 = 1259 ~ 1299 BW = 40 MHz
BeiDou B3	B3	1259 ~ 1279	
GLONASS L2	G2	1238 ~ 1254	F2 = 1218 ~ 1254 BW = 36 MHz
GPS L2, QZSS L2	L2	1218 ~ 1238	
BeiDou B2	B2	1197 ~ 1217	F5 = 1164 ~ 1217 BW = 53 MHz
GLONASS L3	G3	1191 ~ 1211	
Galileo E5	E5	1167 ~ 1217	
GPS L5, QZSS L5	L5	1164 ~ 1188	

FIG. 4

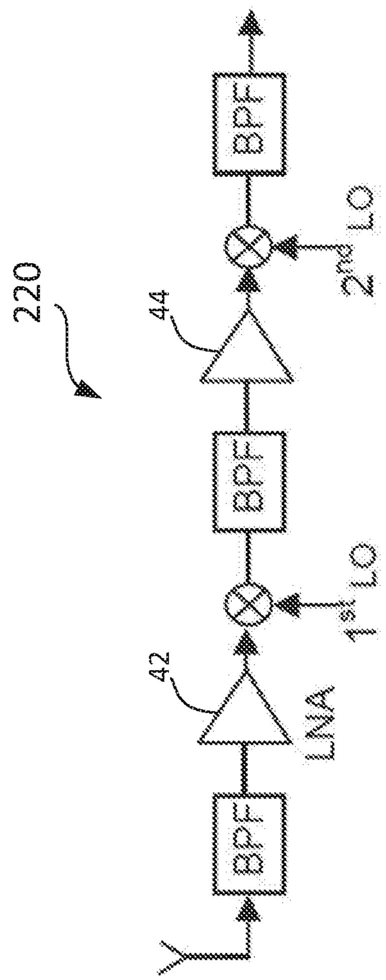


FIG. 5

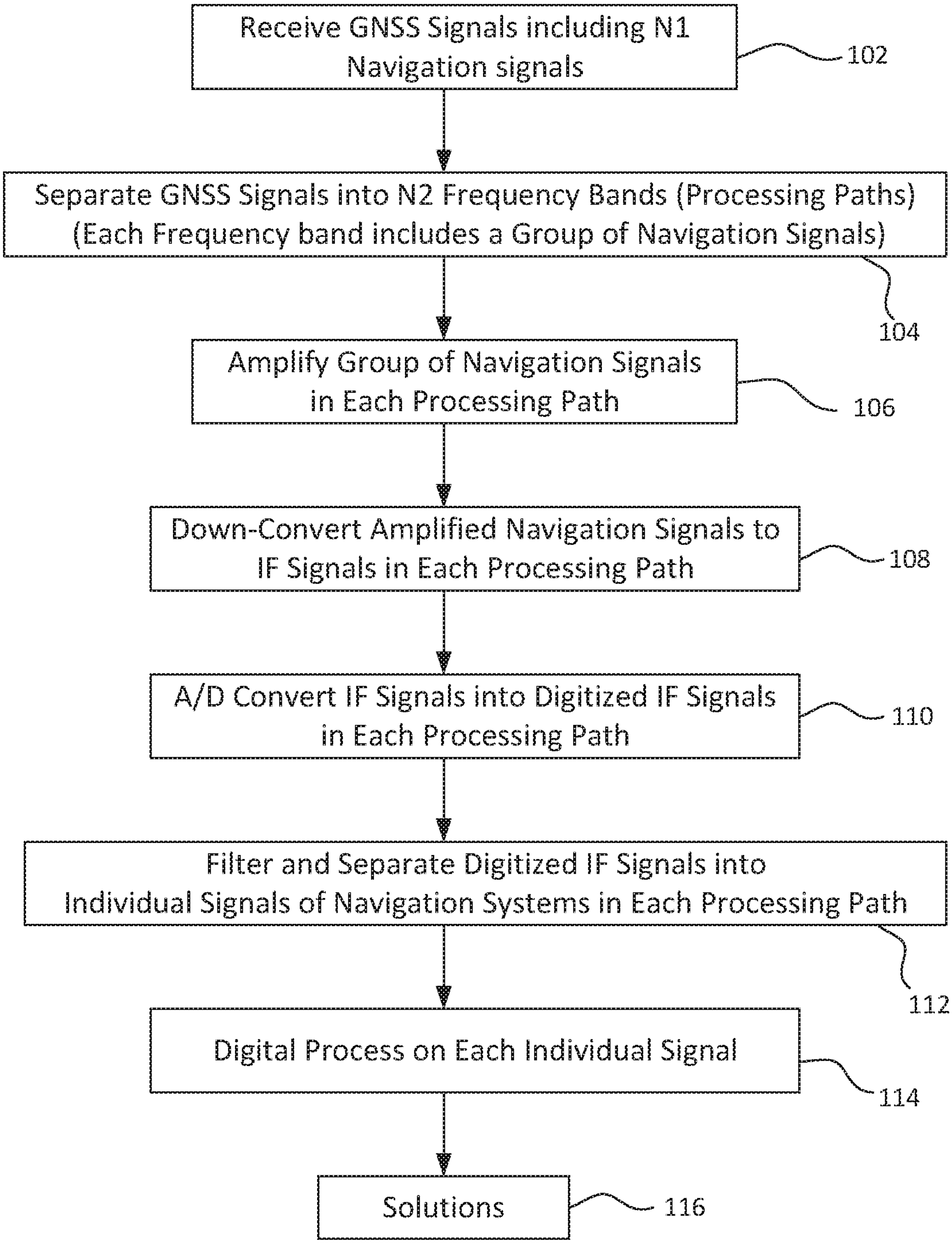

Receive GNSS Signals including N1 Navigation signals
102
Separate GNSS Signals into N2 Frequency Bands (Processing Paths) (Each Frequency band includes a Group of Navigation Signals)
104
Amplify Group of Navigation Signals in Each Processing Path
106
Down-Convert Amplified Navigation Signals to IF Signals in Each Processing Path
108
A/D Convert IF Signals into Digitized IF Signals in Each Processing Path
110
Filter and Separate Digitized IF Signals into Individual Signals of Navigation Systems in Each Processing Path
112
Digital Process on Each Individual Signal
114
Solutions
116

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/053187

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S19/33 G01S19/36
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)
G01S

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	US 2009/207075 A1 (RILEY STUART [US] ET AL) 20 August 2009 (2009-08-20) figures 3,5,8 table 1 paragraph [0037] - paragraph [0040] paragraph [0042] paragraph [0049] - paragraph [0050] paragraph [0070] -----	1-17
A	EP 1 988 407 A1 (SEPTENTRIO N V [BE]) 5 November 2008 (2008-11-05) figures 2,3,5 -----	1-17
A	US 2012/026039 A1 (GANESHAN SARAVANA KUMAR [IN] ET AL) 2 February 2012 (2012-02-02) the whole document ----- -/--	1-17

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

[X] See patent family annex.

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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
6 September 2017	13/09/2017

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	Hekmat, Taymoor

1

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/053187

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Form PCT/ISA/210 (continuation of second sheet) (April 2005)

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