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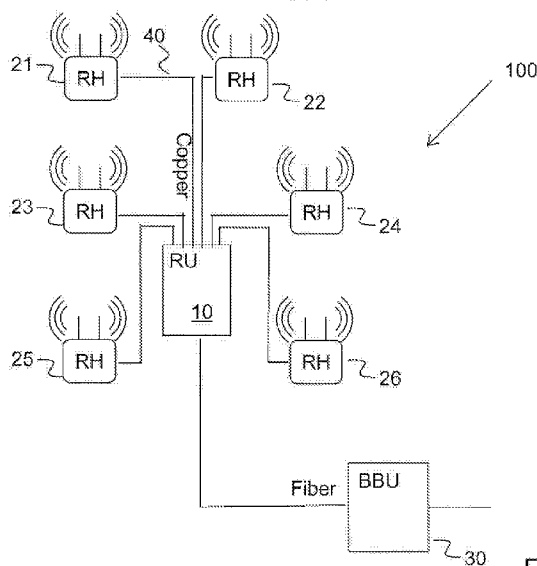


Fig. 1

(57) Abstract: Disclosed is a radio unit, RU, (10) operable in a base station system of a wireless communication system, and arranged for transmitting down-link signals. The base station system comprises a baseband unit, BBU, (30) the RU (10) and a plurality of radio heads, RHs, (21-26). The RU is arranged to be connected to the plurality of RHs via a plurality of metallic conductors (40). The RU (10) comprises: an input port (202, 302) for receiving a baseband signal from the BBU and a frequency shifting unit (206, 306) for shifting the baseband signal to an intermediate frequency, IF, signal having a frequency suitable for transmission over the metallic conductors. The RU further comprises a plurality of output ports (214, 314) for connecting to the plurality of metallic conductors; and an IF distribution unit (208, 308) for distributing the IF signal to the plurality of output ports.

A RADIO UNIT OPERABLE IN A BASE STATION SYSTEM OF A WIRELESS COMMUNICATION SYSTEM AND METHOD PERFORMED BY THE RADIO UNIT

Technical field

[0001] The present disclosure relates generally to a radio unit operable in a base station system of a wireless communication system, the base station system comprising a baseband unit, the radio unit and a plurality of radio heads, wherein the radio unit is arranged to be connected to the plurality of radio heads via a plurality of metallic conductors. The disclosure also relates to a corresponding computer program and method performed by a radio unit.

Background

[0002] Wireless communication networks have evolved from pure voice networks to high-speed data networks. The 4th generation radio network - long-term evolution, LTE, is able to provide capacities exceeding 100 Mbit/s in an ultra-dense small-cell installation. As most of the traffic in the wireless communication networks will be generated in-doors, ultra-dense small-cell indoor network solutions are required. Different approaches have been taken to provide network architectures able to cost-efficiently and reliably meet the run on high mobile capacity.

[0003] Beside scalable light-weight radio base station, RBS, products, such as pico base stations and femto base stations, passive/active distributed-antenna system, DAS, technology in combination with conventional or main-remote architectures or WIFI, active radio signal distribution over low-cost Ethernet and coaxial cabling appears to be promising alternatives.

[0004] Classically, a radio unit, RU, generates high-power, RF radio signals from the base-band data generated by a baseband unit, BBU, also called a digital-unit, which RF radio signals are to be transmitted by a single antenna or a passive DAS antenna cluster.

[0005] In a future scenario, it is of interest to use copper cables, e.g. existing cables in buildings in such ultra-dense small-cell networks. If a BBU would deliver RF signals onto the copper cables for transmission by remotely arranged antennas at the other end of the copper cables there would be high transmission losses in the copper cables. Consequently, there is a need for a solution of how to deliver signals from a baseband unit over copper cables, or other metallic conductors, to antennas at the other end of the copper cable without high transmission losses occurring in the metallic conductors.

[0006] It is an object to achieve a communication over a metallic conductor between a baseband unit of a base station and an antenna of the base station, which communication has at least one of the following advantages: high transmission capacity, low transmission losses, low latency and low cost.

Summary

[0007] It is an object of the invention to address at least some of the problems and issues outlined above. It is possible to achieve these objects and others by using a method and an apparatus as defined in the attached independent claims.

[0008] According to a first aspect, a radio unit, RU, operable in a base station system of a wireless communication system is provided. The RU, is arranged for transmitting downlink signals. The base station system comprises a baseband unit, BBU, the said RU and a plurality of radio heads, RHs. The RU is arranged to be connected to the plurality of RHs via a plurality of metallic conductors. The RU comprises an input port for receiving a baseband signal from the BBU and a frequency shifting unit for shifting the baseband signal to an intermediate frequency, IF, signal having a frequency suitable for transmission over the metallic conductors. The RU further comprises a plurality of output ports for connecting to the plurality of metallic conductors; and an IF distribution unit for distributing the IF signal to the plurality of output ports.

[0009] According to a second aspect, a method is provided performed by a radio unit operable in a base station system for transmitting downlink signals. The base station system comprises a baseband unit, BBU, the said RU and a plurality of

radio heads, RHs. The RU is connected to the plurality of RHs via a plurality of metallic conductors. The method comprises receiving a baseband signal from the BBU and shifting the baseband signal to an intermediate frequency, IF, signal having a frequency suitable for transmission over the metallic conductors. The method further comprises distributing the IF signal to the plurality of metallic conductors.

[00010] According to a third aspect, a computer program is provided comprising computer readable code means. The code means can run in a radio unit operable in a base station system for transmitting downlink signals. The base station system comprises a baseband unit, BBU, the RU and a plurality of radio heads, RHs. The RU is connected to the plurality of RHs via a plurality of metallic conductors. When run in such a radio unit, the computer readable code means causes the radio unit to perform the following steps: receiving a baseband signal from the BBU; shifting the baseband signal to an intermediate frequency, IF, signal having a frequency suitable for transmission over the metallic conductors; and distributing the IF signal to the plurality of metallic conductors.

[00011] Further possible features and benefits of this solution will become apparent from the detailed description below.

Brief description of drawings

[00012] The solution will now be described in more detail by means of exemplary embodiments and with reference to the accompanying drawings, in which:

[00013] Fig. 1 describes a schematic block diagram of a base station system according to an embodiment.

[00014] Fig. 2 is a schematic block diagram of a possible geographical area covered by a number of radio heads.

[00015] Figs. 3-6 are schematic block diagrams of radio units according to possible embodiments.

[00016] Fig. 7 is a schematic block diagram of a radio unit and radio heads and cells covered by the radio heads according to a possible implementation scenario.

[00017] Figs. 8 is a schematic block diagram of a radio unit according to a possible embodiment.

[00018] Figs. 9a-9d are schematic diagrams illustrating possible different allocations of carriers to radio heads.

[00019] Figs. 10-11 are schematic block diagrams of radio units according to possible embodiments.

[00020] Figs. 12-14 are schematic block diagrams of a radio unit and radio heads and cells covered by the radio heads according to possible implementation scenarios.

[00021] Figs. 15-16 are flow charts illustrating methods according to embodiment.

[00022] Fig. 17 is a schematic block diagram illustrating an arrangement in more detail, according to further possible embodiments.

Detailed description

[00023] Fig. 1 shows an architecture of a base station system 100 according to an embodiment of the invention for connecting antennas to a baseband unit 30 over metallic conductors 40, e.g. copper cables. The base station system 100 comprises a baseband unit 30 arranged to treat signals in a baseband frequency region, typically in a low frequency region. The base station system 100 further comprises a radio unit 10 connected to the baseband unit 30 via e.g. an optical fiber. The radio unit, RU, 10 is arranged for generating downlink, DL, radio signals in a low intermediate frequency, IF, band from downlink baseband signals received from the baseband unit 30. A number of downlink baseband signals may be sent as a single digital signal from the BBU to the RU, over the optical fiber, e.g. using Common Public Radio Interface, CPRI. The base station system 100 further comprises a number of remote radio heads 21-26 connected to the radio unit 10 via metallic conductors 40, e.g. of copper. The radio heads may be

connected to the radio unit via separate conductors, one conductor to one radio head. The radio unit 10 is further arranged to send the DL IF radio signals to the radio heads via the metallic conductors. A radio head 21-26 is arranged for picking up the analog IF radio signals from the metallic conductor to which it is connected and convert the IF signals to the actual radio frequency, RF, to be transmitted over the air from the antenna(s) of the radio head. A radio frequency region may be e.g. 400 MHz to 6 GHz. The radio head comprises at least one antenna element for transmitting the DL signal to UEs.

[00024] Fig. 2 shows a schematic view of an example of how the radio heads 21-26 of fig. 1 may be positioned to cover a geographical area. Each radio head 21-26 covers a geographical area 51-56. A mobile station 60 that is situated in e.g. geographical area 54 will be connected to radio head 24 and receive DL RF signals over the air from radio head 24. Even though fig. 2 shows circular geographical areas, so called omniscells, any other type of geographical area may be covered, such as an angular section, a part of a building floor etc. The radio heads may be arranged in a building, e.g. on different floors of the building.

[00025] In the uplink direction, the RH 21-26 is arranged to receive RF radio signals, mix the RF signal to an IF frequency to be transported towards the RU 10 for further processing, such as further down-converting to a baseband frequency for further transmission to the BBU 30. Uplink and downlink IF signals may be transported over the metallic conductors 40 via frequency duplexing for FDD radios, and/or time duplexing for TDD radios. In the following, the description will be concentrated on downlink communication but the invention is similarly applicable in the uplink as in the downlink.

[00026] Such an architecture as described in fig. 1 makes it possible to send data over metallic conductors in a base station system from a baseband unit to antennas of the base station with low transmission losses and high transmission capacity. For realizing such an architecture, a number of changes have to be performed in the radio unit 10, compared to an existing prior art radio unit generating RF radio signals, which is designed for a main-remote deployment scenario in radio networks. For example, the RU 10 has to be changed to provide

a multitude of metallic-conductor-based ports on which radio heads may be connected point-to-point, e.g. in a star distribution from the RU. The radio heads may also be called active antenna elements, AAE. The RU can be seen to act like an intermediate-frequency hub, IF-HUB.

[00027] In short, the high-power, highly linear RF part of the prior art RU has to be replaced with a number of low-power IF ports. The low-power IF ports may support, in the data plane, one or more of the following: radio signal generation on IF; IF signal distribution via a network; copper analog front end, AFE, containing bandpass filters, variable gain amplifiers, equalizers, duplex filters, line drivers, transformers, connectors, etc. The low-power IF ports may support, in the control and management plane, one or more of the following: control channel for Automatic Gain Control, AGC; frequency setup; gain control and supervision; line testing tools, e.g. testing cable loss, noise level, flexible IF-features, etc. The low-power IF ports may support, in the power plane, one or more of the following: remote powering devices based on Power over Ethernet, PoE, power sourcing equipment.

[00028] Fig. 3 and fig. 4 each shows a radio unit, RU, 10 according to exemplary embodiments operable in a base station system 100 of a wireless communication system. The base station system comprises a baseband unit, BBU, 30 the RU 10 and a plurality of radio heads, RHs, 21-26. The RU is arranged to be connected to the plurality of RHs via a plurality of metallic conductors 40. The RU 10 comprises an input port 202, 302 for receiving a baseband signal from the BBU. The RU 10 further comprises a frequency shifting unit 206, 306 for shifting the baseband signal to an intermediate frequency, IF, signal having a frequency suitable for transmission over the metallic conductors. The RU 10 further comprises a plurality of output ports 214, 314 for connecting to the plurality of metallic conductors. The RU 10 further comprises an IF distribution unit 208, 308 for distributing the IF signal to the plurality of output ports connected to the plurality of metallic conductors.

[00029] A frequency suitable for being transmitted over a metallic conductor is a frequency that experiences low attenuation and/or low noise over metallic

conductors. Such a frequency may typically be in the IF frequency spectrum of e.g. 30 to 300 MHz. One output port may be connected to one metallic conductor. A metallic conductor is a conductor leading to an RH, e.g. a coaxial cable or a pair of conductors (twisted-pair cable). One output port may be connected to one output of the IF distribution unit. The metallic conductors receiving distributed IF signals from the distribution unit may not be all metallic conductors connected to the RU 10. In some use cases it may happen that some of the metallic conductors, and consequently the RHs connected to these metallic conductors, are not to receive any IF signals at all., e.g. for maintenance, testing or energy saving purposes.

[00030] By such an RU it is realized to distribute a plurality of IF signals over a plurality of metallic conductors to a plurality of RHs for further treatment at an RF frequency level at the RHs and for DL wireless transmission to UEs in communication with the RHs. Also, existing metallic conductors, such as twisted pair copper cables already existing in a building, may be re-used. By the RU shifting from baseband to IF frequency, data may be transmitted over the metallic conductors with a rather low transmission loss.

[00031] According to an embodiment, The RU further comprises a digital to analog, DA, converter 204, 304 for converting the received signal, either in IF or baseband, from digital to analogue form.

[00032] According to the embodiment of fig. 3, which shows an analog embodiment, the DA converter 204 is positioned before the frequency shifting unit 206 and the IF distribution unit 208, when going from the input port 202 to the output port 204.

[00033] According to the embodiment of fig. 4, which shows a digital embodiment, the DA converter 304 is positioned after the frequency shifting unit 306 and the IF distribution unit 308, when going from the input port 302 to the output port 304.

[00034] According to an embodiment, the baseband signal comprises a number of subsignals, each subsignal having a frequency subrange of a frequency range

of the baseband signal. The radio unit 10 further comprises a subsignal extraction unit 210, 310 arranged to extract from the received signal, either in IF or baseband, at least some of the number of subsignals. Further, the IF distribution unit 208, 308 is arranged for distributing the at least some of the number of subsignals to the plurality of RHs.

[00035] A subsignal of the received signal is a signal in a sub-frequency range of the whole frequency range of the received signal, for example a sub-signal of the baseband signal in a sub-frequency range of the baseband signal. As an example, the received signal may have a frequency range of 80 MHz, comprising four subsignals each having a frequency range of 20 MHz. The received signal may be a carrier signal comprising a number of carriers, or sub-carriers, as sub-signals. Each subsignal may corresponds to one or more Antenna-Carrier signals. One Antenna-Carrier signal contains one carrier of radio signal with certain amount of bandwidth for one antenna transmission and reception. For example, for a 20 MHz carrier radio network, one Antenna-Carrier signal is a 20 MHz signal dedicated for one antenna.

[00036] By extracting the subsignals from the received signal before distributing the subsignals to the RHs, it is possible to allow for more sectors or cells. Also, by extracting the subsignals at the RU instead of at the RHs, less bandwidth has to be transmitted over each metallic conductor. The concept "sector" is in this disclosure to be interpreted as both comprising cell and sector. For example, two radio heads using the same subsignal would belong to one sector and two other radio heads using another subsignal would belong to another sector. In each sector the same baseband resources are used. Frequency use within the sector may have to be planned to avoid interference within the sector for TDMA-based systems like GSM. In recent 3G/4G systems, the same frequencies (meaning one carrier) are usually used in all the sectors in the whole network. The subsignal extracting unit may be realized as a filter unit, filtering out a requested frequency subrange.

[00037] The subsignal extraction unit 210, 310 may either be arranged before the frequency shifting unit (as shown in fig. 3 and 4) or after the frequency shifting unit

(not shown), in a direction from the input port 202, 302 to the output port 214, 314. In case the subsignal extraction unit 210, 310 is arranged before the frequency shifting unit, the frequency shifting unit 206, 306 may be arranged for separately frequency shifting the at least some of the number of extracted subsignals.

[00038] According to an embodiment, the subsignal extracting unit 310 is a digital subsignal extracting unit for extracting the subsignals in digital form, and the IF distribution unit 308 is a digital IF distribution unit. Further, the DA converter 304 is connected between the plurality of output ports 314 and the IF distribution unit 308.

[00039] The DA converter 304 may comprise a plurality of DA converter subunits, one for each output port, to enable each of the distributed signals to be converted to analog form. A digital solution has the advantage of being possible to implement in software. Further, the implementation is rather easy to perform.

[00040] According to another embodiment, the subsignal extraction unit 210 is arranged as an analog filter for extracting the sub-signals in analog form. The subsignal extraction unit 210 is further arranged to receive an analog signal from the DA unit 204. This analog implementation has the benefit of only needing one DA converter per RX/TX branch. Further, it is possible to reuse parts of already existing Remote Radio Unit (RRU) designs, which typically have CPRI input and RF output

[00041] According to another embodiment, the IF distribution unit 208, 308 is arranged to distribute the number of subsignals onto the plurality of output ports according to a defined plan. The IF distribution unit 208, 308 may distribute the subsignals to the plurality of output ports, and further to the plurality of RHs via the plurality of metallic conductors according to a defined plan for e.g. increasing network throughput. I.e. the subsignals may be dynamically distributed e.g. based on different traffic load at the different RHs, or more statically distributed based on e.g. cell planning reasons regarding which RH that should belong to the same sector.

[00042] According to another embodiment, the frequency shifting unit 206, 306 is arranged for shifting the at least some of the number of subsignals individually or for shifting the baseband signal as a whole. When shifting the subsignals individually, the frequency separation between the subsignals may be changed.

[00043] According to an embodiment, the radio unit 10 further comprises an amplifier 212, 312 connected between the IF distribution unit 208, 308 and the plurality of output port 214, 314, the amplifier 212, 312 being capable of amplifying the distributed IF signal independently for the output ports. Thereby, a suitable signal level can be achieved at each RH irrespective of different characteristics for the transmission between the RU and the different RHs, for example depending on different lengths of the different metallic conductors being connected to the different output ports. This may be implemented by having one amplifier section connected to one output port, each output port having one amplifier section. The amplification level of each output port may be independently adjusted.

[00044] The radio unit 10 of fig. 4 may further comprise one or more storage units or memories 320. The frequency shifting unit 306, the IF distribution unit 308 and the subsignal extraction unit 310 may be arranged in an arrangement 301. The arrangement 301 could be implemented e.g. by one or more of: a processor or a micro processor and adequate software and storage therefore, a Programmable Logic Device (PLD) or other electronic component(s)/processing circuit(s) configured to perform the actions, or methods, mentioned further down in this disclosure.

[00045] According to another aspect, the invention may also relate to a base station system 100 comprising a baseband unit 30, a plurality of radio heads 21-26 and a radio unit 10 as described in any of the embodiments of this disclosure.

[00046] Fig. 5 shows another embodiment of a radio unit 10 (or IF Hub). The radio unit 10 comprises an IQ flow extractor 502 that receives a CPRI signal from a BBU. The IQ flow extractor 502 is arranged to extract the IQ flows, i.e. the subsignals of the baseband signal received from the BBU into separate subsignals. The RU 10 further comprises TX units 506 performing frequency shift

from baseband to IF on signals to be transmitted downlink. The number of TX units may equal the number of sub-signals. The RU further comprises RX units 508 performing frequency shift from IF to baseband on signals received uplink. The number of RX units may equal the number of sub-signals. The RU 10 further comprises an IF distribution unit/IF combining unit 510, in which the IF distribution part of the unit distributes the incoming DL signal to the output ports 214 and the IF combining part combines the incoming UL signal from the output ports to a common signal for further treatment in the RX boxes. The RU further comprises amplifiers for amplifying the distributed signals and for putting the downlink and uplink signals intended for the same RH on the same output port. The RU further comprises transformers and connectors. There are also a number of control units for controlling signal distribution through the RU, such as gain control and supervision, RH power supply and supervision, cable loss measurement and synchronization. Note that there are two TRX branches (branch A and B, i.e. TX A, TX B, RX A, RX B) assumed here. The invention may also support more than two branches.

[00047] The inventive RU supports a number of radio head connections, thereby providing sufficient reach and dynamic capacity for indoor small-cell deployments.

[00048] According to an embodiment, an RF front-end of an existing RU is replaced with an IF-distribution interface according to embodiments, providing several output ports, e.g. Ethernet-like ports. In detail, at a border from legacy digital to analog domain (DA Converter at DL, AD Converter at UL), an RF transmit portion (DL), comprising RF modulator, amplifier, linearization, circulator, power measurement, duplexers, antenna port, and an RF receive portion (UL), comprising duplexer, tunable LNA chain, RF mixer, are detached and replaced with an IF distribution interface having several output ports allowing to haul radio signals to several, for example 8, 12, 16, radio-heads, via for example a star-like copper-based distribution cable plant. Several physical layers may be provided such as support for Ethernet Category-x cabling (CAT5e, CAT6, CAT6a, CAT7) or coaxial cabling. CAT-cables can be unshielded or shielded.

[00049] According to an embodiment, called a static RU embodiment, the subsignal extraction unit of fig. 3 and fig. 4 is neglected. Instead, the IF distribution unit 208, 308 is arranged to split the IF signal into a number of branches, which number may be equal to the number RHs 21-26 and, consequently, the number of metallic conductors that are to be connected to the output ports 214. The splitting may be the same as copying the IF signal, with a loss in signal power similar to the number of branches the signal is split into. This kind of splitting usually referred to as power splitting. For example, an incoming IF signal of 80 MHz may be split into 8 branches, each containing the same IF signal of 80 MHz. Each branch may have an individual amplifier (or line driver) for amplifying the individual split signal. Correspondingly, in the uplink, the signals received at the output port 314 on a metallic-conductor-compliant IF frequency are combined from the number of output ports, e.g. 8, into one IF signal.

[00050] The static RU embodiment is also shown in figure 6. Line drivers, duplex-filters, transformers if needed, over-voltage protection, OVP, and connectors such as RJ45 connectors may constitute a remainder of analog copper front-end, AFE. A typical CAT5e or better cable contains 4 twisted pairs, which means that Multiple Input Multiple Output, MIMO, can be supported on different cable pairs of said cable. The second branch of TX/RX ports, i.e. B-branch, also has 8 amplifier pairs and duplex-filters attached to drive a second pair in the cable. In fig. 6 the IF distribution unit is a simple IF splitting network 608, in the DL direction, or IF combiner network, in the UL direction. The output ports 214 are shown to the right in the figures. Fig. 6 further shows an input unit 602 for receiving a CPRI signal from the BBU. The CPRI signal comprises the received signal in the baseband. The input unit 602 distributes the received signal to the transmitter units TXA, TXB where the signal digital to analog converted and frequency shifted to IF.

[00051] Fig. 6 also contains a couple of control-plane functions that may be needed to operate remote RHs. One such control-plane function is Power over Ethernet, PoE. The PoE may comprise a multi-port power sourcing equipment, PSE, in accordance with IEEE 802.3at/af, to provide power to remote RHs containing powered-device, PD, circuits. The PSE may be controlled by a

microprocessor. Another such control-plane function is Gain control/Supervision, which controls gain of the amplifiers (gain setting per direction). This can either be done statically or automatically via an Automatic Gain Control, AGC. A purpose of gain control here is to improve the UL dynamic range. Another such control-plane function is Media-dependent functions which takes into consideration cable characterization like cable length, cable loss and transfer function measurements. As depicted in Fig. 6 this can be done by in-build physical layer, PHY, functions, (like Ethernet PHY, ETH PHY, xDSL or SELT) or in a proprietary way. Another such control-plane function is Sync transfer, for example synchronization of FDD reference clock or TDD sync (direction switch). This can be accomplished either by Ethernet SyncE, xDSL NTR, IEEE1588, or in a proprietary way.

[00052] Another such control-plane function is a control channel control plane function, which comprises a basic digital channel for data exchange between the RU and the RHs. This may be e.g. Ethernet-based, xDSL-based, RS422-based, i.e. Antenna Interface Standards Group, AISG, etc.

[00053] A typical carrier/sector configuration possible with this static design is shown in fig. 7. Basically, the same signals are provided to each RH, which means that all RHs constitute a single sector, i.e. uses the same IQ data, equal base-band signal. In the example of fig. 7, a maximum of four 20 MHz carriers C1-C4 are generated per TX branch and transmitted over individual cables 40, e.g. CAT cables, from the RU 10 to the RHs, AAE1-AAE8, on equal IF frequencies. As there are two TX branches, 2x2 MIMO is supported. RX branches work in an analog way. S stands for Sector, and S1 for sector 1 etc.

[00054] To make it possible to have more than one sector from one RU, the IF splitting/combiner network 608 of fig. 6 may be replaced with a frequency selection portion as shown in fig. 8, showing another embodiment, called a dynamic RU embodiment. The frequency selection portion comprises a filter bank 810 and a switch 808. The filter bank 810 is arranged to filter out the different sub-signals or carriers from the carrier signal. The filter bank 810 may be seen as an implementation of the subsignal extraction units 210, 310 of fig. 2 and 3, respectively. The switch 808 is arranged to distribute the different sub-signals to

the RHs. The switch may be seen as an implementation of the IF distribution unit 208, 308 of fig. 2 and 3, respectively. The switch may distribute the subsignals, or carriers, according to a defined plan. In fig. 8, the frequency shifting from baseband to IF has been performed before the DL signal is received at the filter bank, similar to the embodiment of fig. 6. In this case, the frequency shift, and possibly also the DA conversion, may be performed in an input unit 802. However, the frequency shift may alternatively be performed after the filter bank and before the switch.

[00055] Fig. 8 further comprises control plane functions, which may be similar to the control plane functions of fig. 6.

[00056] The concept of the frequency selection portion is described in the following, with reference to fig. 9a-d showing different possible ways of switching extracted carrier frequencies to different RHs. In DL, the input unit 802 may produce an exemplary 80 MHz IF bandwidth on two branches, one branch going to TX-A (see also in fig. 8) and one branch going to TX-B. The 80 MHz IF bandwidth may comprise of 4 sectors with the same carrier of 20 MHz signal, 2 sectors with 2 carriers of 20 MHz signal each, 1 sector with 4 carriers of 20 MHz signal each or any combination of different number of sectors and carriers. Focusing on TX-A, the filter bank 810 extracts the signals for the desired combination of sector and carriers to be directed to individual RH, or output, ports 214. As an example, shown in fig. 9a, the sector-carrier signal S1C1A is extracted by a dedicated filter of the filter bank, and switched in the switch to one output port. The extracted sector-carrier signal S1C1A in IF is then transmitted on the cable connected to the selected output port to RH1. The RH1 connected to the other side of the cable extracts the IF signal S1C1A from the cable and modulates it into the RF domain given its configuration.

[00057] Given that 80 MHz IF bandwidth is available per branch and 2 branches are available, A and B, 8 RH can be provided with one carrier each, e.g. 20 MHz. This scenario corresponds to a single input single output, SISO, or single input multiple output, SIMO scenario supporting 8 sectors, which scenario is shown in fig. 9a. If 2x2 MIMO is needed in the same scenario, 2 RHs have to be within the

same sector. This scenario is shown in fig. 9b. As shown in the example of fig. 9b, RH1 and RH5 are in the same MIMO sectors, i.e. use the same IF signals, i.e. S1C1A and S1C1B. Figures 9c and 9d assume that the RHs are required to have an IF bandwidth of 40 MHz (illustrated as two carriers to each RH, but if a carrier is designed as 40 MHz instead of 20 MHz, only one carrier per band would have sufficed), which basically reduces the number of possible sectors to 4 for SISO/SIMO and 2 for MIMO. Fig. 9c shows a SISO/SIMO scenario with 4 sectors and 40 MHz to each RH, one sector for two RHs. Fig. 9d shows a MIMO scenario with two sectors and 40 MHz to each RH, one sector for four RHs.

[00058] Fig. 10 shows another embodiment of a dynamic RU, in a schematic illustration. This RU comprises an input unit 1102 receiving a CPRI signal from the BBU. The RU further comprises, in the DL (or TX) branch, a DA converter 1104 for converting the received baseband signal to analog form. The RU further comprises a filter bank 1110 for extracting subsignals of the received signals, e.g. each filter extracting the bandwidth of a subsignal or carrier. The RU further comprises a mixer bank 1106 for frequency shifting each of the extracted subsignals to an IF frequency suitable for transmitting over a metallic conductor. The RU further comprises a switch 1108 for distributing the extracted subsignals in the IF frequency domain to the output ports to which the RHs are individually connected. As shown there is an input port called "SEL" to the switch 1108 which input port may provide signals for controlling the distribution of the subsignals to the RHs according to a defined plan. The switch may be a N*M non-blocking switch.. The RU further comprises an amplifier bank 1112, which comprises individual amplifiers in each branch. The individual amplifiers may be programmable gain amplifiers. Fig. 10 further shows a similar RX-branch for treating UL signals. The shown switch in the RX branch may also contain some switching functionality in order to perform some more advanced combining.

[00059] The mentioned filters may be fixed in a center frequency and pass-band filter, e.g. SAW filters. If such filters are used they may dictate the maximum RH-bandwidth per system. In case of a fully flexible IF bandwidth, BW, generation is needed, a different embodiment of this invention may foresee a digital filter, also

called a digital fork, based on e.g. individual spatial low-speed DA converter/AD converter (DAC/ADC) branches for each sub-signal. An example of this digital embodiment is shown in fig. 11. This RU comprises an input unit 1202 receiving a CPRI signal from the BBU. The input unit may be arranged with the digital filter to extract the sub-signals. The RU further comprises, in the DL (or TX) branch, a frequency shifter 1206 for frequency shifting each of the extracted subsignals to an IF frequency suitable for transmitting over a metallic conductor. The RU further comprises a switch 1208 for distributing the extracted digital subsignals to individual DA converters 1204. One DA converter may be arranged to one output port. Thereby the DA converters produce individually a portion of the total RU IF BW with flexible bandwidth (10 MHz, 20MHz, 40MHz, 80MHz,...). An optional numerically controlled oscillator, NCO, that may be built-in in the DAC, allows to shift each individual package to the right IF frequency position. The uplink is analog with individual mixers (which may be as a separate mixer bank or as an integrated part of the ADCs) and low-speed ADCs. Analog mixers can be avoided if the ADCs can perform bandpass sampling, i.e. sample in different Nyquist zones.

[00060] Typical carrier/sector configurations possible with the dynamic design is shown in figs. 12-14. In the figures, "S" is used for sector addressing. In the examples shown in fig. 12 and 13, each carrier has a bandwidth of up to 20 MHz. There are 8 DL carriers and 8 UL carriers with a total bandwidth of up to 160 MHz. Fig. 12 shows a 4 sector. S1 – S4, configuration with one carrier, C1, to two separate TX/RX branches, A and B, enabling 2x2 MIMO. Fig. 13 shows a 2 sector configuration, S1 – S2, with two carriers C1, C2 to two separate TX/RX branches, also enabling 2*2 MIMO. Fig. 14 shows an 8-sector configuration with 8 UL and DL carriers, each on up to 5 MHz, enabling 2*2 MIMO. Total bandwidth in this example is up to 80 MHz.

[00061] Even though only these three use cases are shown, any combination of carrier frequencies, or sub-signals at the different RHs may be assumed.

[00062] Figs. 15 and 16 each shows a method performed by a radio unit 10 operable in a base station system for transmitting downlink signals. The base

station system comprises a BBU 30, the said RU 10 and a plurality of RHs 21-26. The RU is connected to the plurality of RHs via a plurality of metallic conductors 40. The method comprises receiving 1602; 1702 a baseband signal from the BBU and shifting 1606; 1706 the baseband signal to an IF signal having a frequency suitable for transmission over the metallic conductors. The method further comprises distributing 1608; 1708 the IF signal to the plurality of metallic conductors.

[00063] According to an embodiment, the method further comprises converting 1604; 1704 the received signal, either in IF or baseband, from digital to analogue form. Fig. 15 shows an analog implementation in which the conversion is performed early in the transmission method such that most of the method steps are performed in the analog domain. Fig. 16 shows a digital implementation in which the conversion is performed late in the transmission method such that most of the steps in are performed in the digital domain.

[00064] According to another embodiment, the baseband signal comprises a number of subsignals, each subsignal having a frequency subrange of a frequency range of the baseband signal. The method further comprises extracting 1610; 1710 from the received signal, either in IF or baseband, at least some of the number of subsignals. The distributing 1608; 1708 of the IF signal to the plurality of metallic conductors comprises distributing the at least some of the number of subsignals to the plurality of RHs.

[00065] According to another embodiment, shown in fig. 16, the extracting 1710 from the received signal, of at least some of the number of subsignals, is performed in digital form. Further, the conversion 1704 of the received signal from digital to analog form is performed after the distribution of the IF signal.

[00066] According to another embodiment, shown in fig. 15, the extracting 1610 from the received signal, of at least some of the number of subsignals, is performed in analog form. Further, the conversion 1604 of the received signal from digital to analog form is performed before the distribution of the IF signal.

[00067] According to another embodiment, the distribution 1608; 1708 of the number of subsignals onto the plurality of output ports is performed according to a defined plan.

[00068] According to another embodiment, the shifting 1606; 1706 of the baseband signal to an IF signal comprises shifting the at least some of the number of subsignals individually or shifting the baseband signal as a whole.

[00069] According to another embodiment, the method further comprises amplifying 1612; 1712 the individually distributed IF signals independently.

[00070] Figure 17 schematically shows an embodiment of an arrangement 1800 for use in a radio unit 10, which also can be an alternative way of disclosing an embodiment of the arrangement 301 in a radio unit 10 illustrated in figure 4. Comprised in the arrangement 1800 is a processing unit 1806, e.g. with a Digital Signal Processor (DSP). The processing unit 1806 may be a single unit or a plurality of units to perform different actions of procedures described herein. The arrangement 1800 may also comprise an input unit 1802 for receiving signals from other entities, and an output unit 1804 for providing signal(s) to other entities. The input unit 1802 and the output unit 1804 may be arranged as an integrated entity.

[00071] Furthermore, the arrangement 1800 comprises at least one computer program product 1808 in the form of a non-volatile or volatile memory, e.g. an Electrically Erasable Programmable Read-only Memory (EEPROM), a flash memory, a disk drive or a Random-access memory (RAM). The computer program product 1808 comprises a computer program 1810, which comprises code means, which when executed in the processing unit 1806 in the arrangement 1800 causes the arrangement 1800 and/or the radio unit 10 to perform the actions of any of the procedures described earlier in conjunction with figs. 15 and/or 16.

[00072] The computer program 1810 may be configured as a computer program code structured in computer program modules. Hence, in an exemplifying embodiment, the code means in the computer program 1810 of the arrangement 1800 comprises a receiving module 1810a for receiving a baseband signal from

the BBU, a shifting module 1810b for shifting the baseband signal to an intermediate frequency, IF, signal having a frequency suitable for transmission over the metallic conductors, and a distributing module 1810c for distributing the IF signal to the plurality of metallic conductors.

[00073] The acts which have above been described as being implemented or executed by a processor may be performed by any suitable machine. The machine may take the form of electronic circuitry in the form of a computer implementation platform or a hardware circuit platform. A computer implementation of the machine platform may be realized by or implemented as one or more computer processors or controllers as those terms are herein expansively defined, and which may execute instructions stored on non-transient computer-readable storage media. In such a computer implementation the machine platform may comprise, in addition to a processor(s), a memory section, which in turn can comprise random access memory; read only memory; an application memory, a non-transitory computer readable medium which stores, e.g., coded non instructions which can be executed by the processor to perform acts described herein; and any other memory such as cache memory, for example. Another example platform suitable is that of a hardware circuit, e.g., an application specific integrated circuit, ASIC, wherein circuit elements are structured and operated to perform the various acts described herein.

[00074] The above described inventive solutions, which are based on sending radio over existing metallic conductors, has one or more of the following advantages: High performance, which is RBS 3GPP specification compliant; enables a modular system hardware/software licensing structure; high utilization of system resources; enables customized customer offerings within buildings; enables rapid installation and possible with automatic configuration; low power consumption; enables full network supervision; competitive price and quality; controlled Quality of Service/ effective interference mitigation; flexible spectrum utilization/high aggregation; cost efficient deployment; excellent scalability; high security; public damage protected; future proof; platform for new applications and radio functionality

[00075] At least parts of this description are focusing on the downlink part of the RU. However, the invention is equally applicable in the uplink. Even though the description above contains a plurality of specificities, these should not be construed as limiting the scope of the concept described herein but as merely providing illustrations of some exemplifying embodiments of the described concept. It will be appreciated that the scope of the presently described concept fully encompasses other embodiments which may become obvious to those skilled in the art, and that the scope of the presently described concept is accordingly not to be limited. Reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." All structural and functional equivalents to the elements of the above-described embodiments that are known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed hereby. Moreover, it is not necessary for an apparatus or method to address each and every problem sought to be solved by the presently described concept, for it to be encompassed hereby.

CLAIMS

1. A radio unit, RU, (10) operable in a base station system of a wireless communication system, and arranged for transmitting downlink signals, the base station system comprising a baseband unit, BBU, (30) the RU (10) and a plurality of radio heads, RHs, (21-26) wherein the RU is arranged to be connected to the plurality of RHs via a plurality of metallic conductors (40), the RU (10) comprising:
 - an input port (202, 302) for receiving a baseband signal from the BBU,
 - a frequency shifting unit (206, 306) for shifting the baseband signal to an intermediate frequency, IF, signal having a frequency suitable for transmission over the metallic conductors;
 - a plurality of output ports (214, 314) for connecting to the plurality of metallic conductors; and
 - an IF distribution unit (208, 308) for distributing the IF signal to the plurality of output ports.
2. Radio unit according to claim 1, further comprising:
 - a digital to analog DA, converter (204, 304) for converting the received signal, either in IF or baseband, from digital to analogue form.
3. Radio unit according to claim 1 or 2, wherein the baseband signal comprises a number of subsignals, each subsignal having a frequency subrange of a frequency range of the baseband signal, and wherein the radio unit (10) further comprises:
 - A subsignal extraction unit (210, 310) arranged to extract from the received signal, either in IF or baseband, at least some of the number of subsignals,
 - and wherein the IF distribution unit (208, 308) is arranged for distributing the at least some of the number of subsignals to the plurality of RHs.
4. Radio unit according to claim 2 and 3, wherein the subsignal extracting unit (310) is a digital subsignal extracting unit for extracting the subsignals in digital form, and the IF distribution unit (308) is a digital IF distribution unit and

wherein the DA converter (304) is connected between the plurality of output ports (314) and the IF distribution unit (308).

5. Radio unit according to claim 2 and 3, wherein the subsignal extraction unit (210) is arranged as an analog filter for extracting the sub-signals in analog form, the subsignal extraction unit being arranged to receive an analog signal from the DA unit (204).

6. Radio unit according to any of claims 3-5, wherein the IF distribution unit (208, 308) is arranged to distribute the number of subsignals onto the plurality of output ports according to a defined plan.

7. Radio unit according to any of claims 3-6, wherein the frequency shifting unit (206, 306) is arranged for shifting the at least some of the number of subsignals individually or shifting the baseband signal as a whole.

8. Radio unit according to any of the preceding claims, further comprising an amplifier (212, 312) connected between the IF distribution unit (208, 308) and the plurality of output ports (214, 314), the amplifier (212, 312) being capable of amplifying the individually distributed IF signals independently.

9. A base station system (100) comprising a baseband unit (30), a plurality of radio heads (21-26) and a radio unit (10) according to any of claims 1-7.

10. A method performed by a radio unit (10) operable in a base station system for transmitting downlink signals, the base station system comprising a baseband unit, BBU, (30) the RU (10) and a plurality of radio heads, RHs, (21-26) wherein the RU is connected to the plurality of RHs via a plurality of metallic conductors (40), the method comprises:

receiving (1602; 1702) a baseband signal from the BBU,

shifting (1606; 1706) the baseband signal to an intermediate frequency, IF, signal having a frequency suitable for transmission over the metallic conductors,

distributing (1608; 1708) the IF signal to the plurality of metallic conductors.

11. Method according to claim 10, further comprising:
converting (1604; 1704) the received signal, either in IF or baseband, from digital to analogue form.
12. Method according to claim 10 or 11, wherein the baseband signal comprises a number of subsignals, each subsignal having a frequency subrange of a frequency range of the baseband signal, and wherein the method further comprises:
extracting (1610, 1710) from the received signal, either in IF or baseband, at least some of the number of subsignals,
and wherein the distributing (1608; 1708) of the IF signal to the plurality of metallic conductors comprises distributing the at least some of the number of subsignals to the plurality of RHs.
13. Method according to claim 11 and 12, wherein the extracting (1710) from the received signal, of at least some of the number of subsignals, is performed in digital form, and wherein the conversion (1704) of the received signal from digital to analog form is performed after the distribution of the IF signal.
14. Method according to claim 11 and 12, wherein the extracting (1610) from the received signal, of at least some of the number of subsignals, is performed in analog form, and wherein the conversion (1604) of the received signal from digital to analog form is performed before the distribution of the IF signal.
15. Method according to any of claims 12-14, wherein the distribution (1608; 1708) of the number of subsignals onto the plurality of output ports is performed according to a defined plan.
16. Method according to any of claims 12-15, wherein the shifting (1606; 1706) of the baseband signal to an intermediate frequency, IF, signal comprises shifting the at least some of the number of subsignals individually or shifting the baseband signal as a whole.
17. Method according to any of claims 10-16, further comprising

amplifying (1612; 1712) the individually distributed IF signals independently

18. A computer program (1810) comprising computer readable code means, which when run in a radio unit (10) operable in a base station system for transmitting downlink signals, the base station system comprising a baseband unit, BBU, (30) the RU (10) and a plurality of radio heads, RHs, (21-26) wherein the RU is connected to the plurality of RHs via a plurality of metallic conductors (40), the computer readable code means causes the radio unit (10) to perform the following steps:

receiving a baseband signal from the BBU,
shifting the baseband signal to an intermediate frequency, IF, signal having a frequency suitable for transmission over the metallic conductors,
distributing the IF signal to the plurality of metallic conductors.

19. A computer program product (1808), comprising computer readable medium and a computer program (1810) according to claim 18 stored on the computer readable medium.

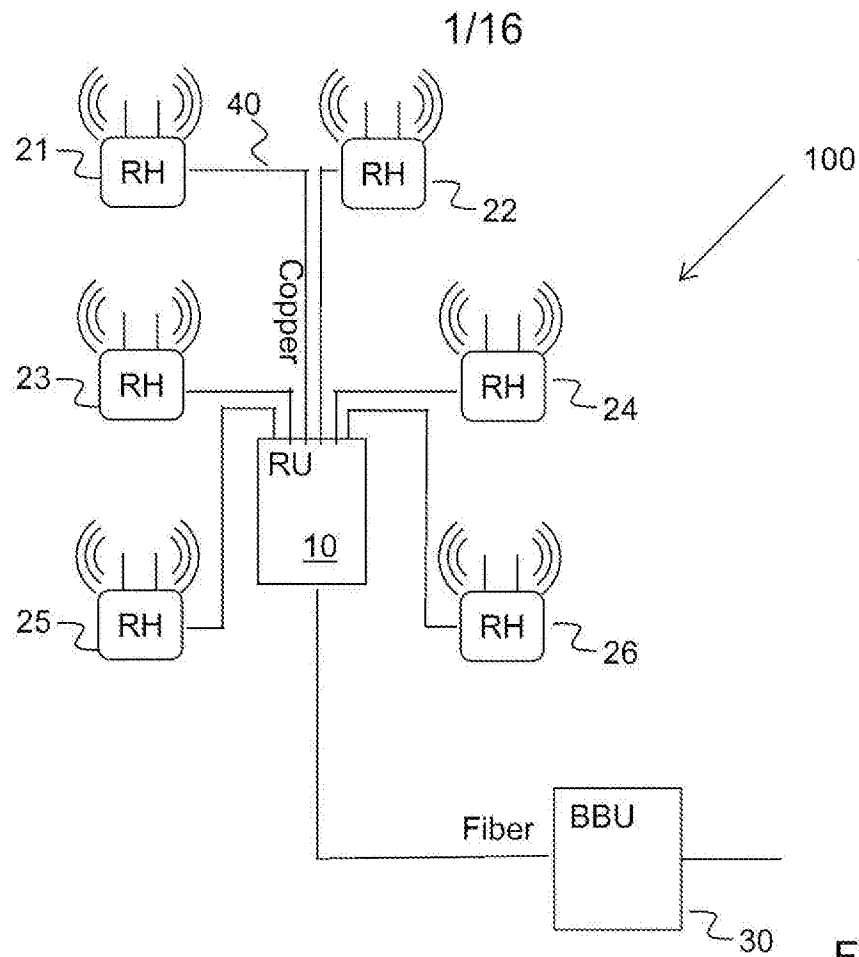


Fig. 1

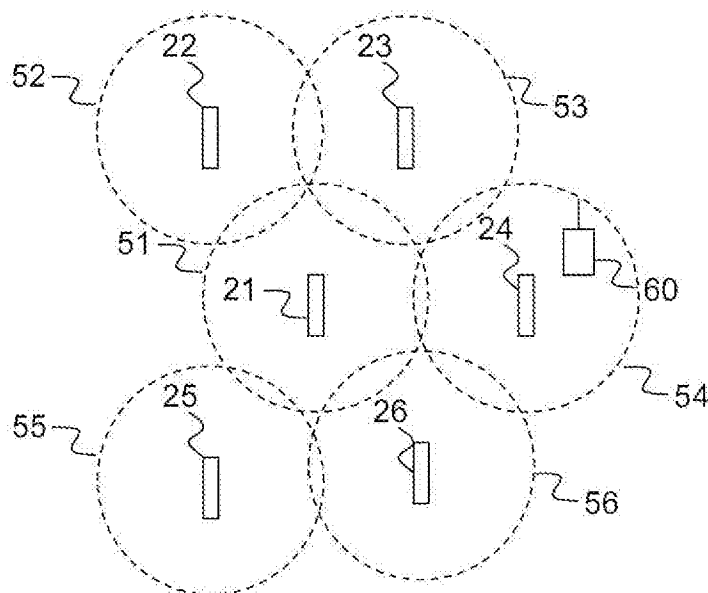


Fig. 2

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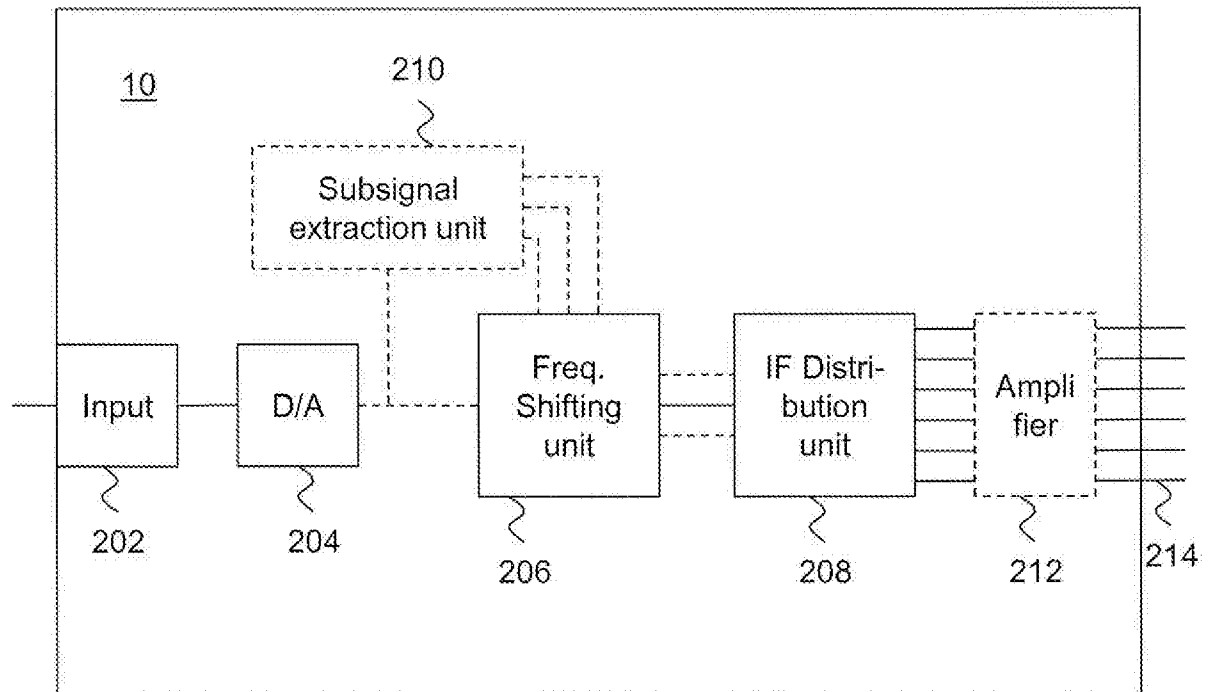


Fig. 3

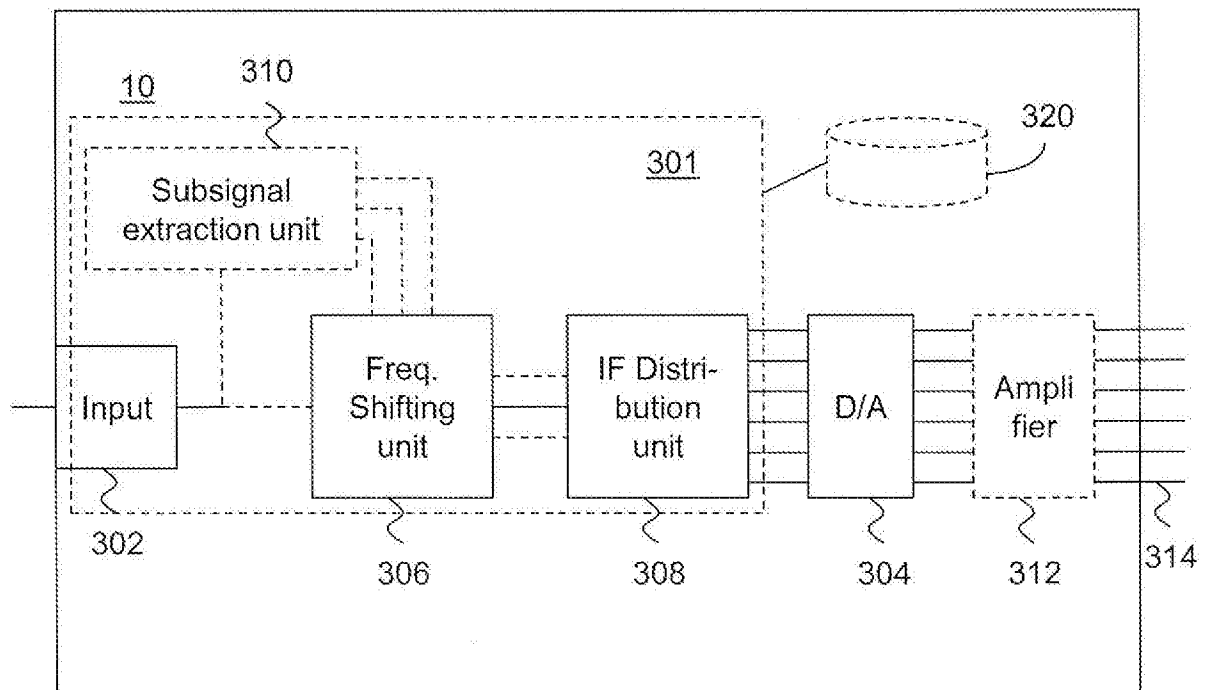


Fig. 4

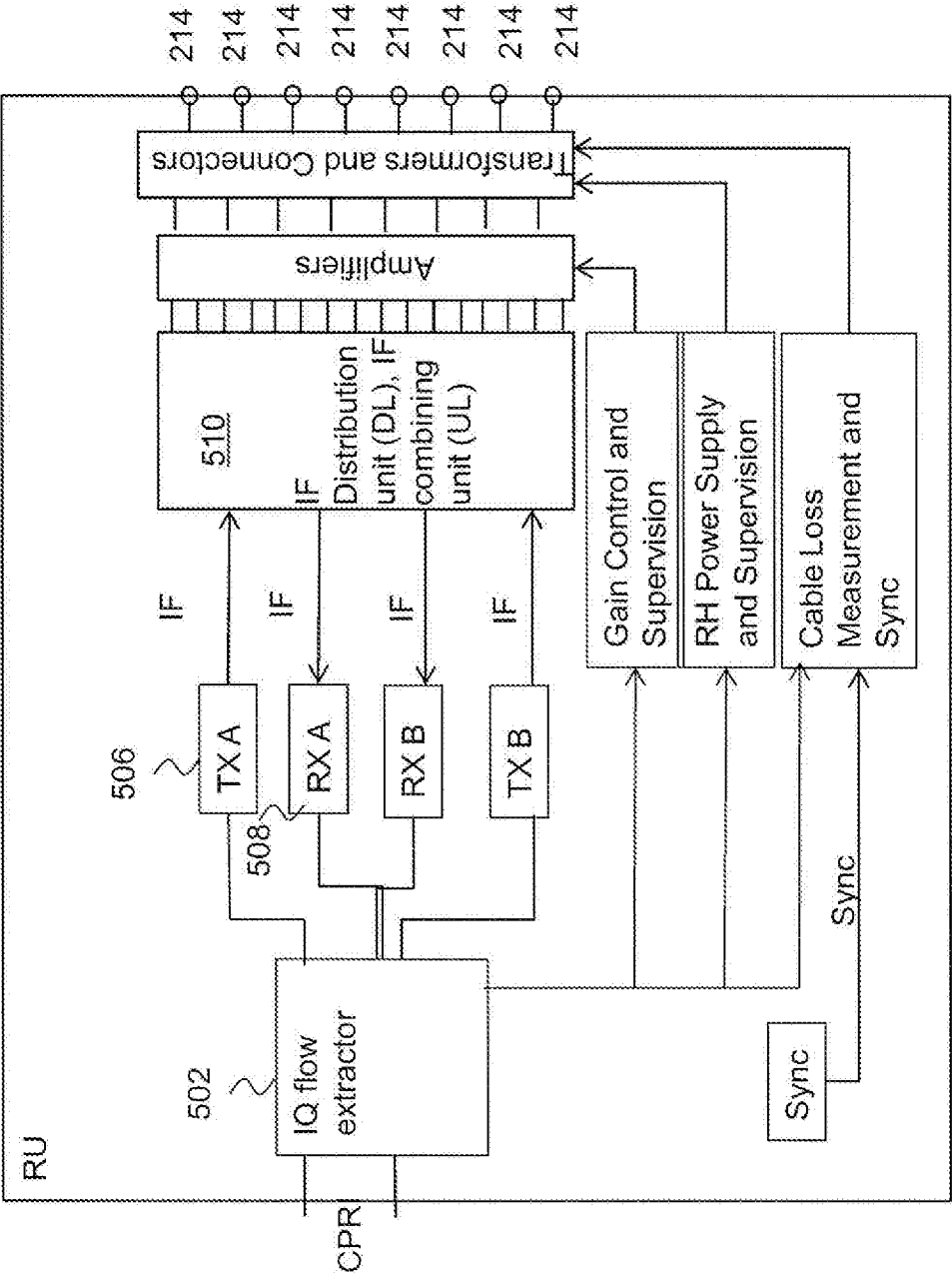
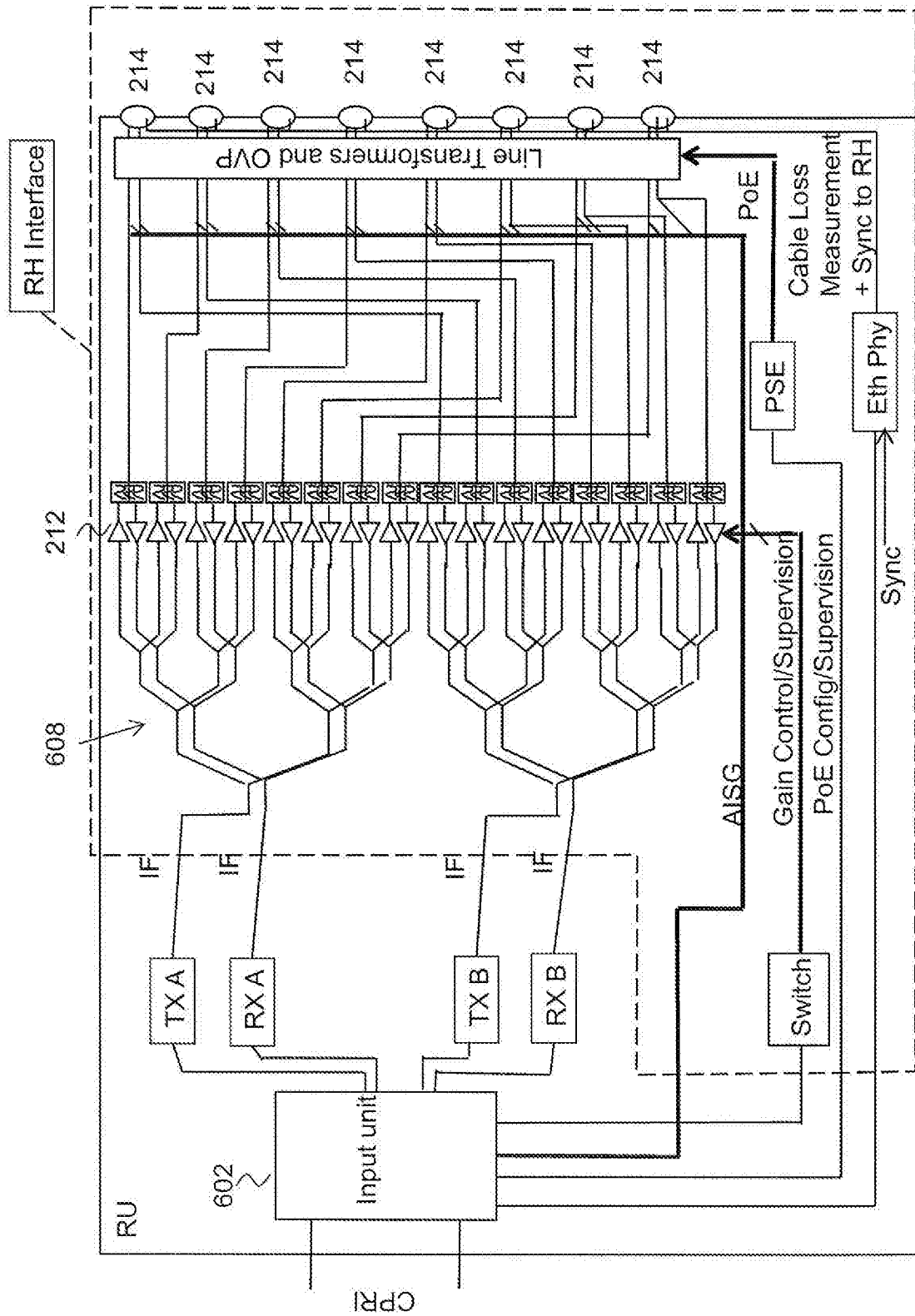


Fig. 5



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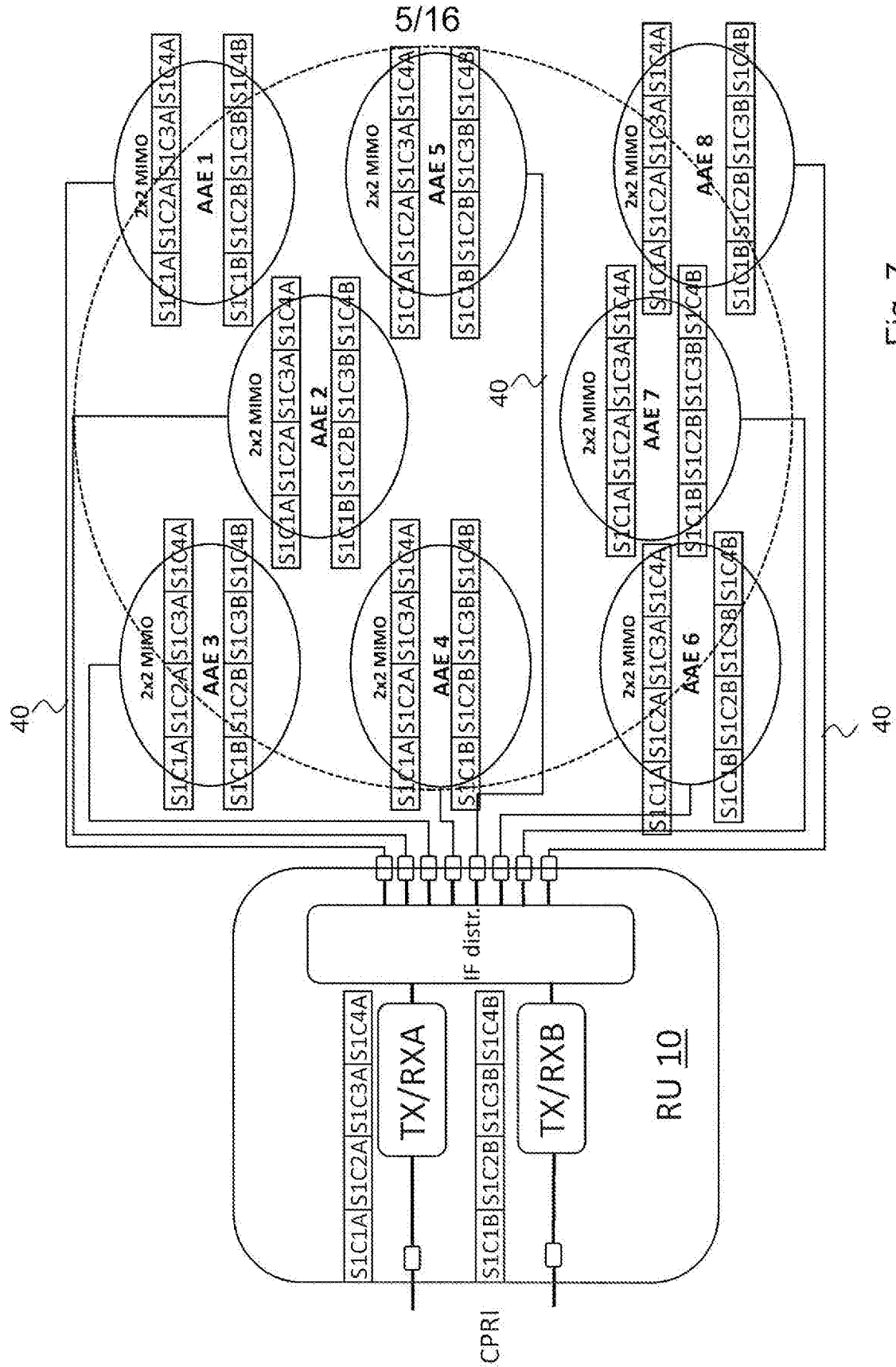


Fig. 7

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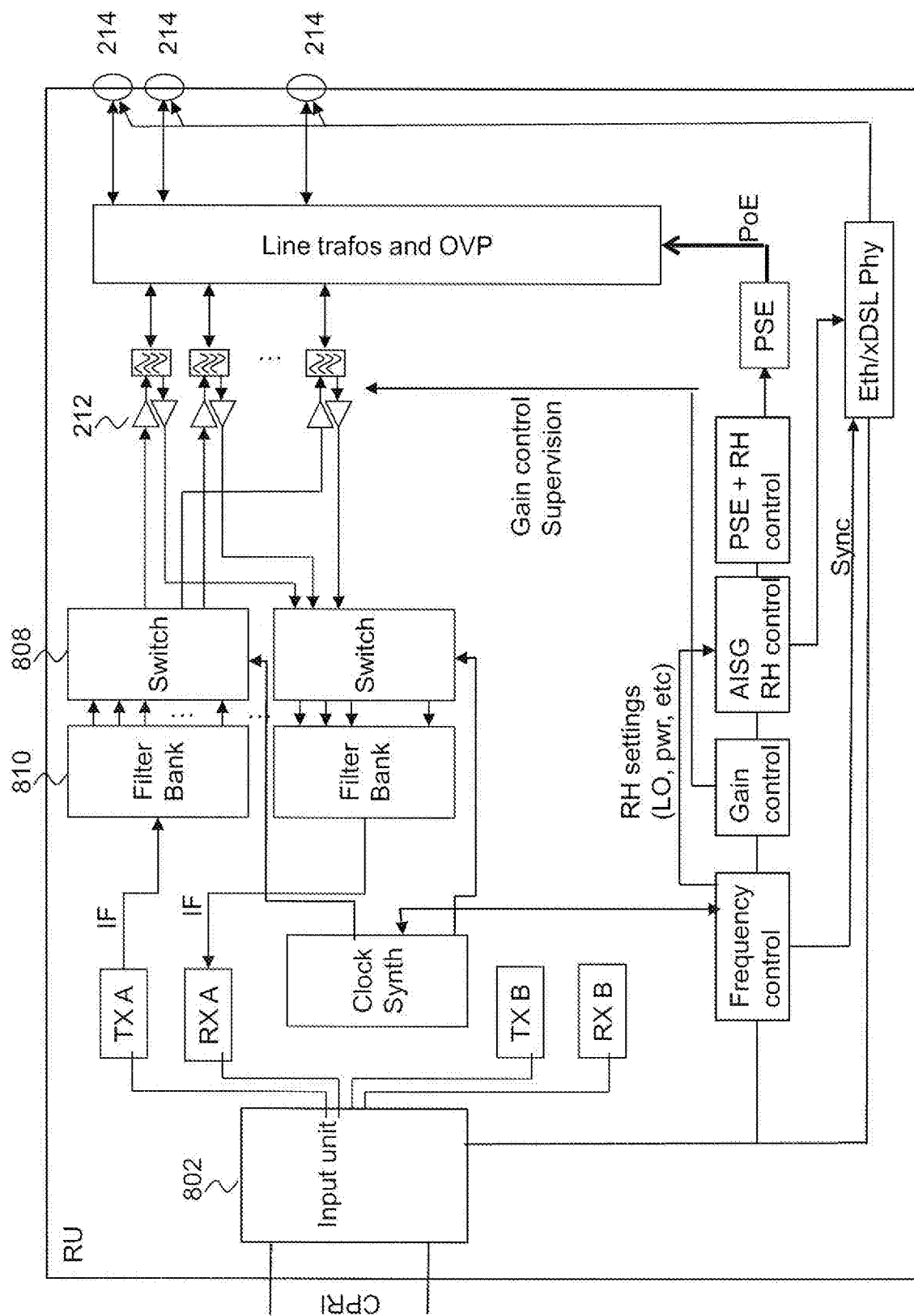


Fig. 8

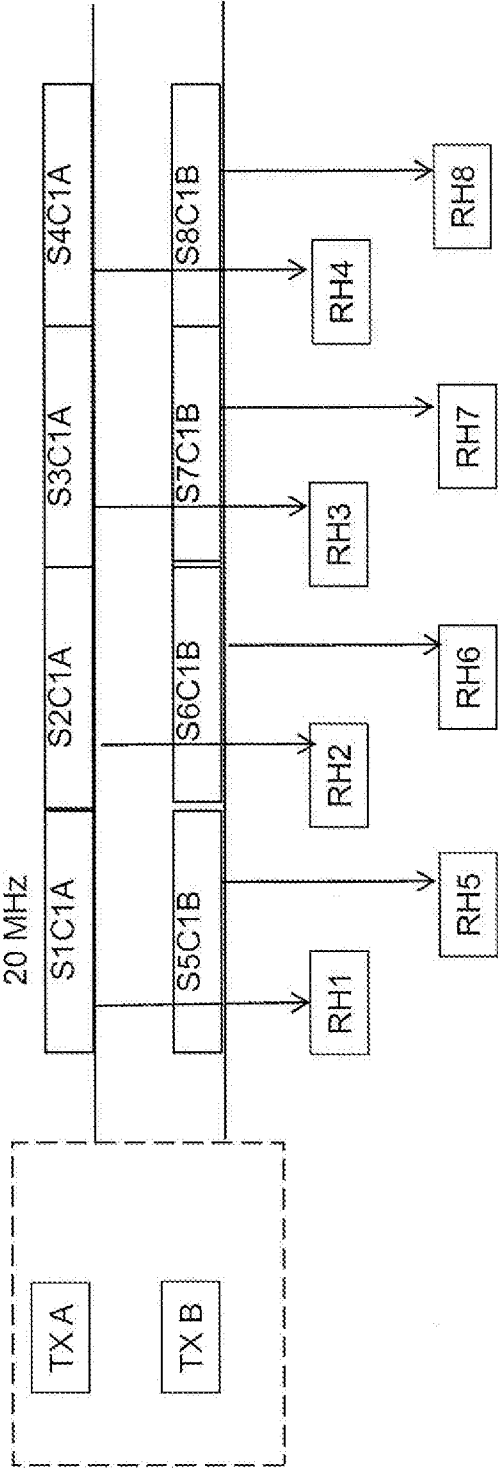


Fig. 9a

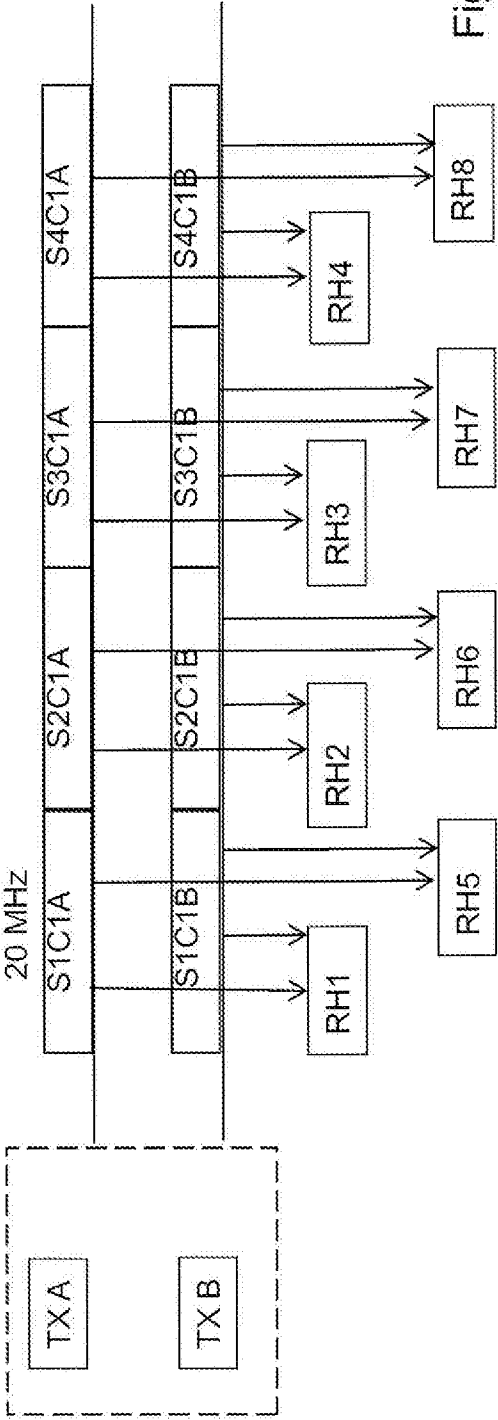


Fig. 9b

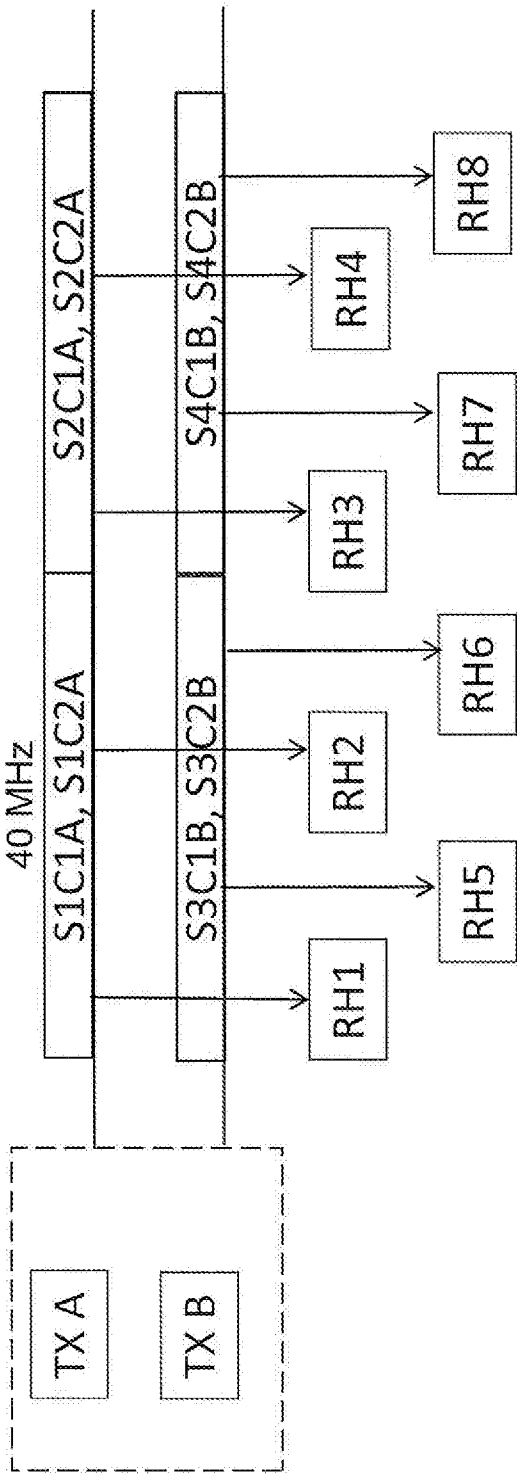


Fig. 9c

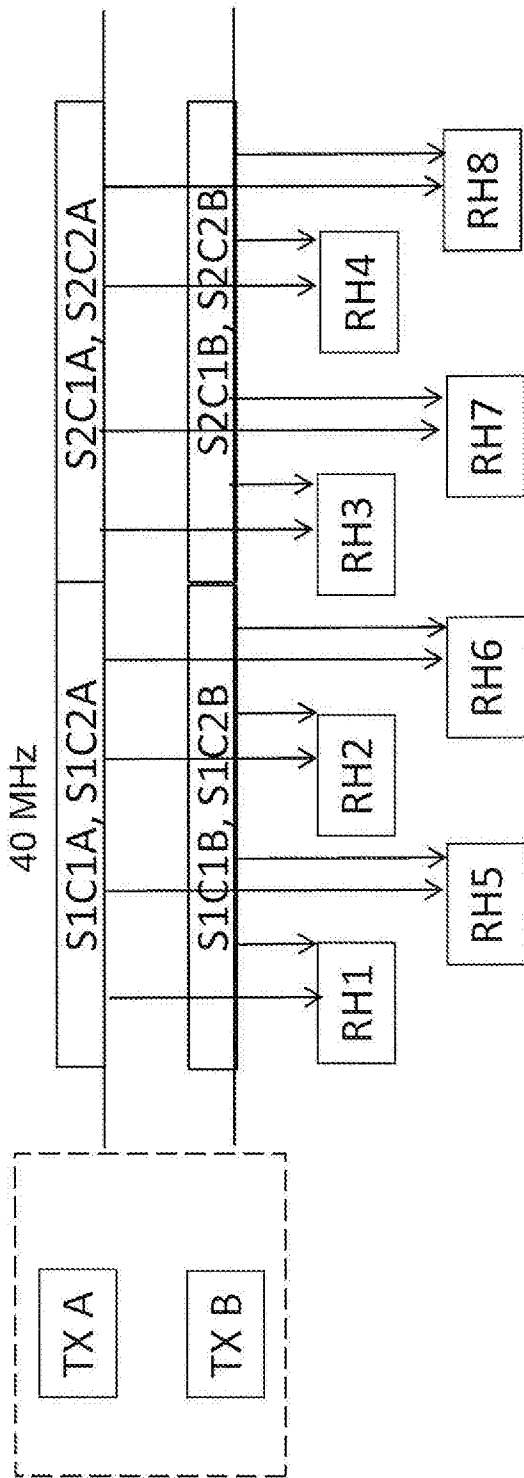


Fig. 9d

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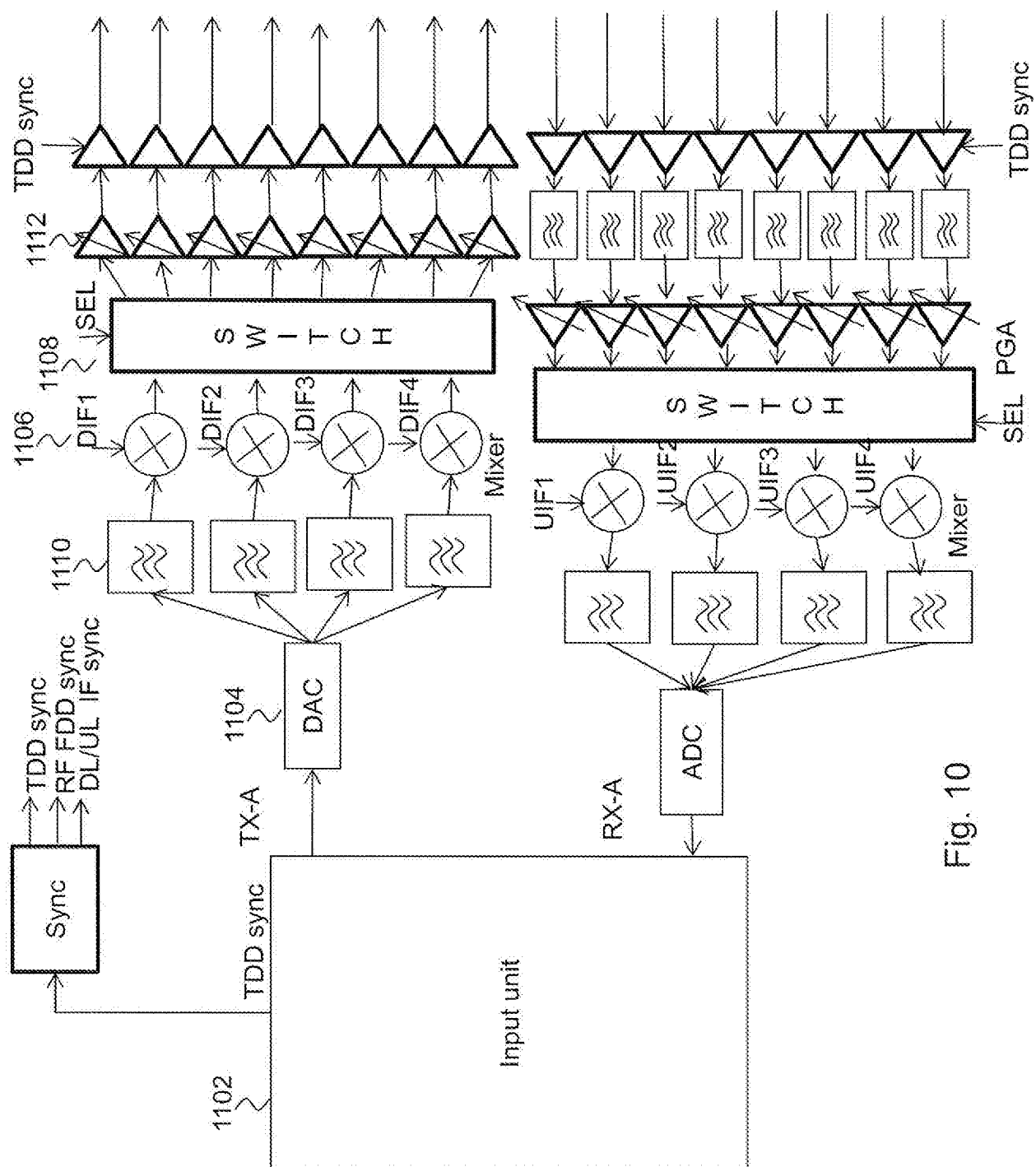


Fig. 10

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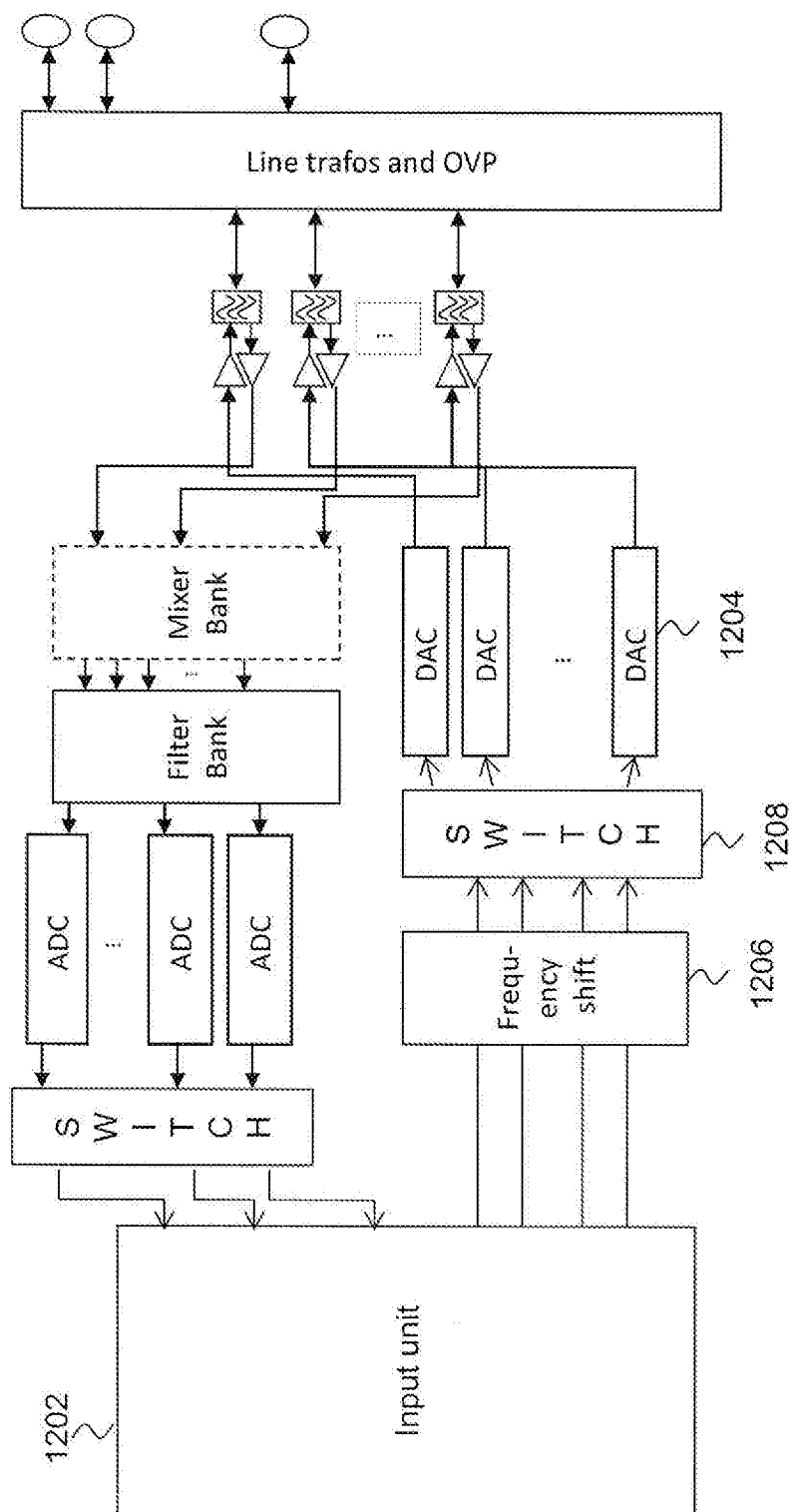


Fig. 11

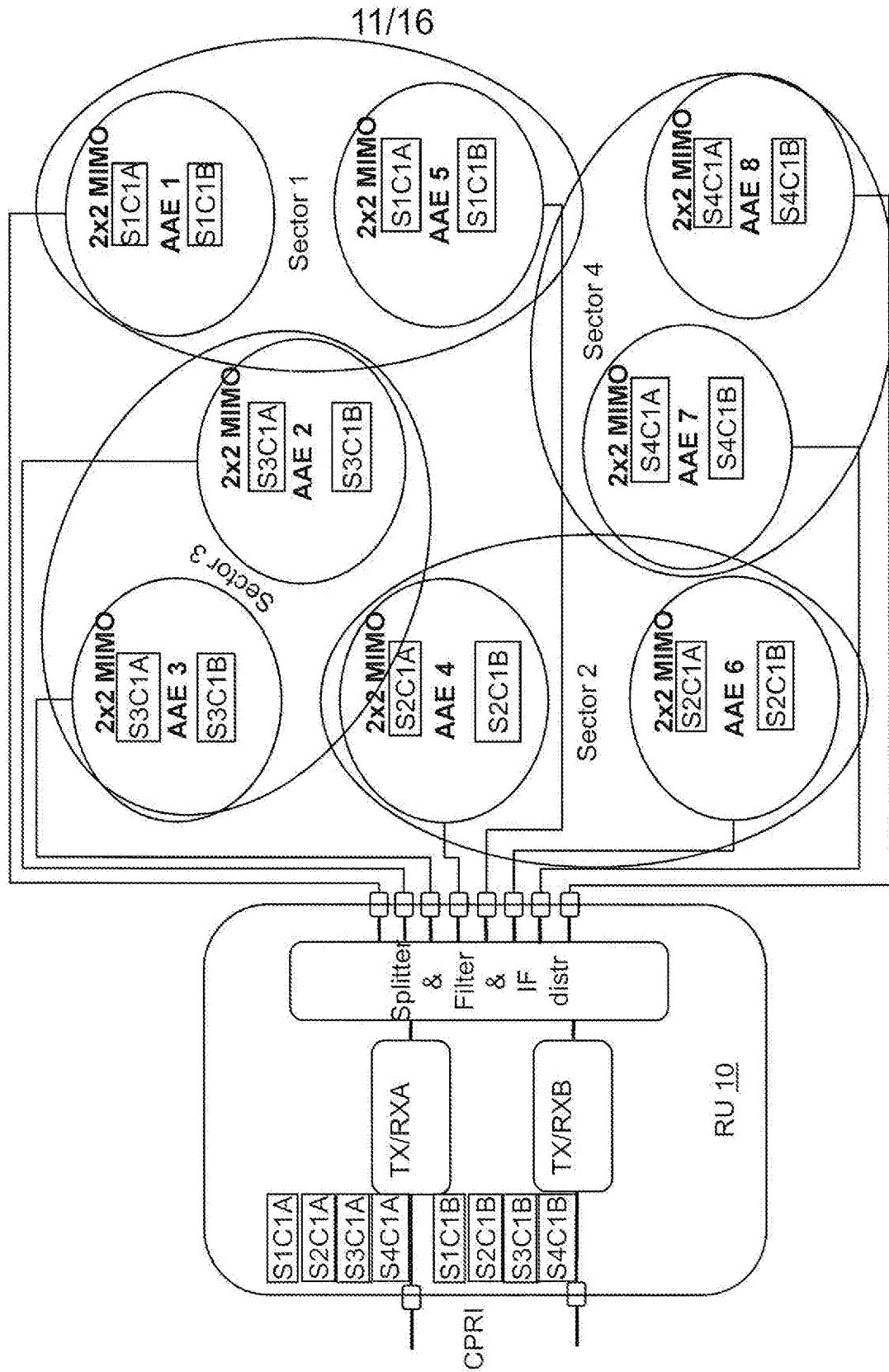


Fig. 12

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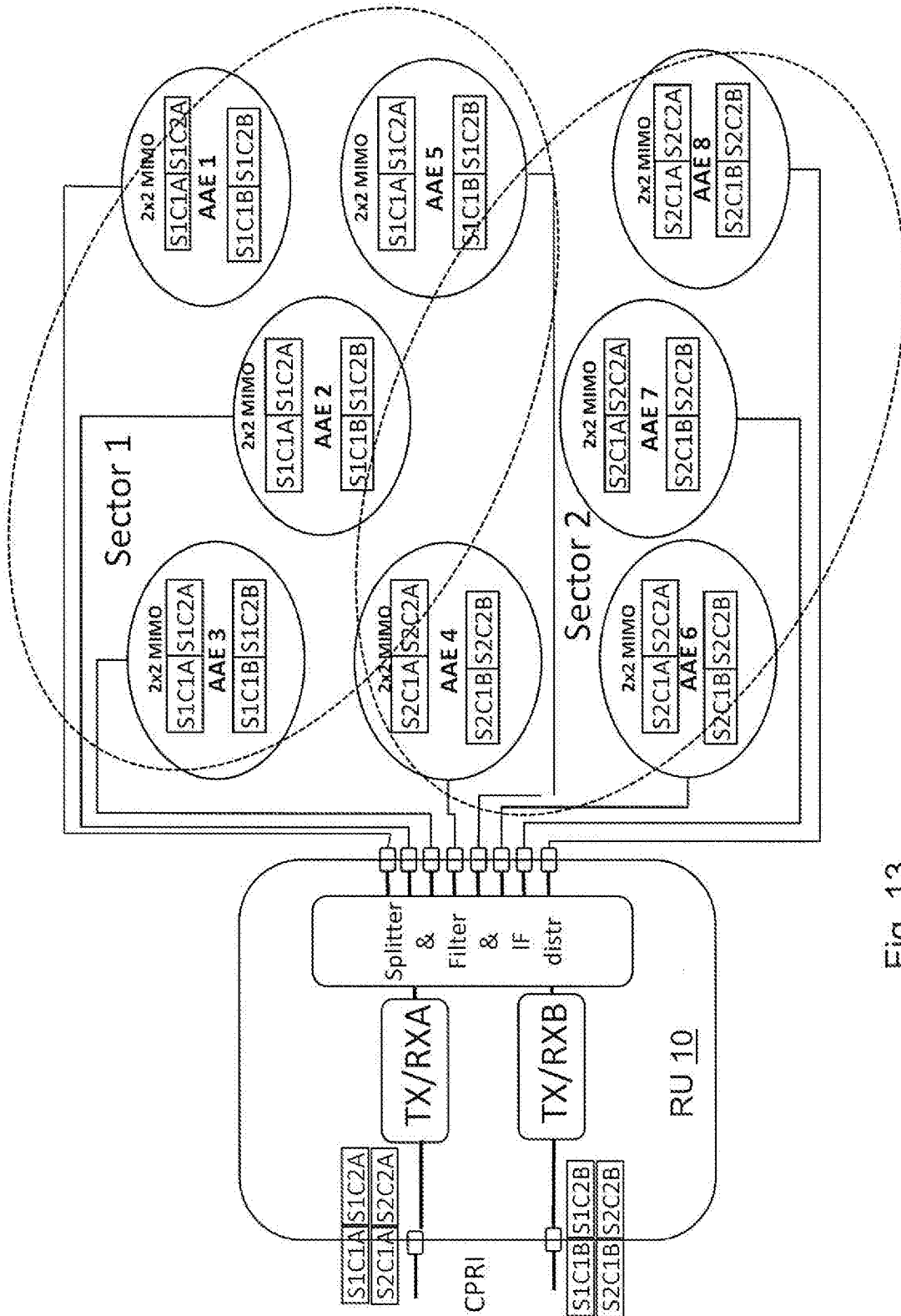


Fig. 13

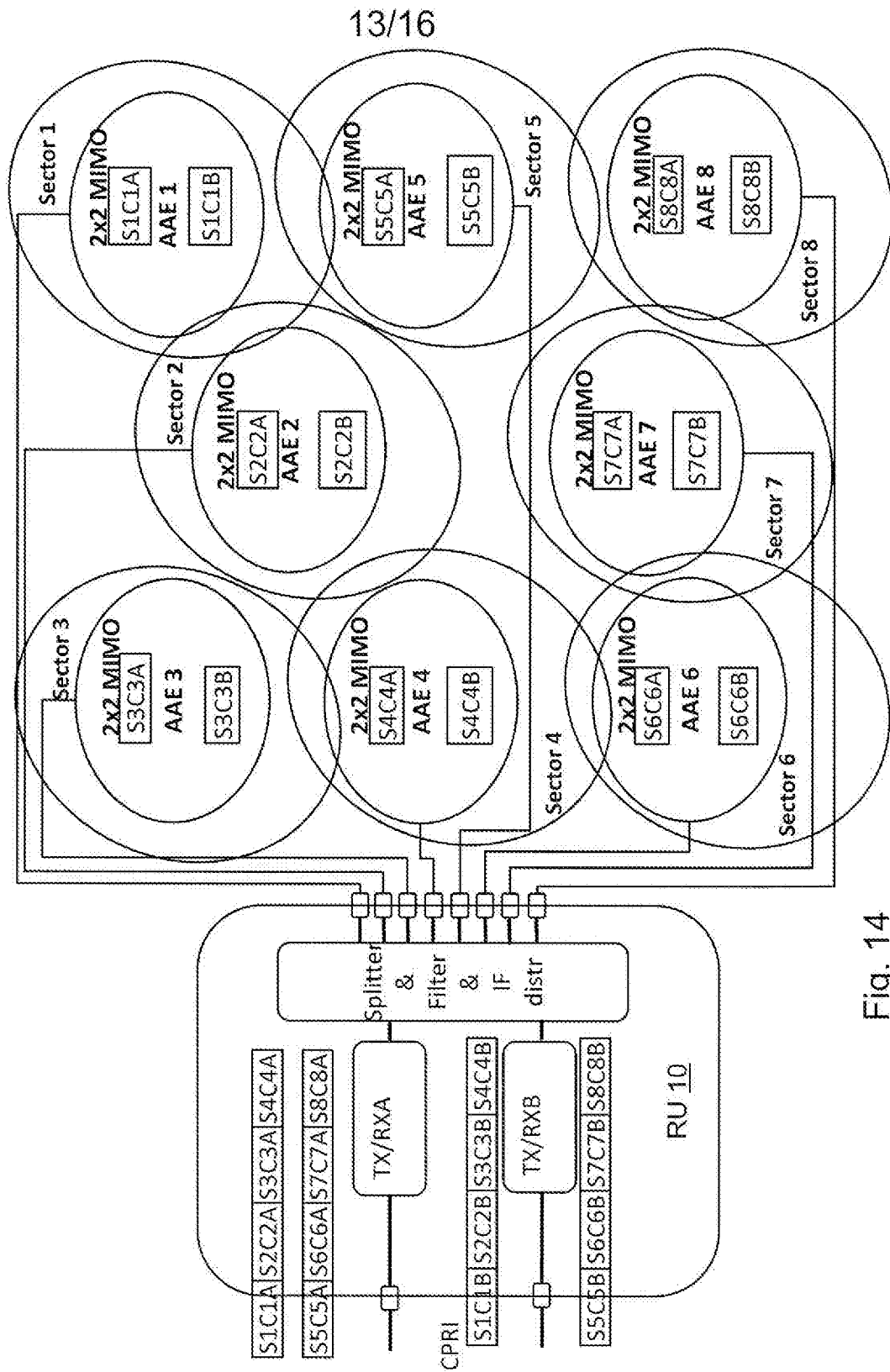


Fig. 14

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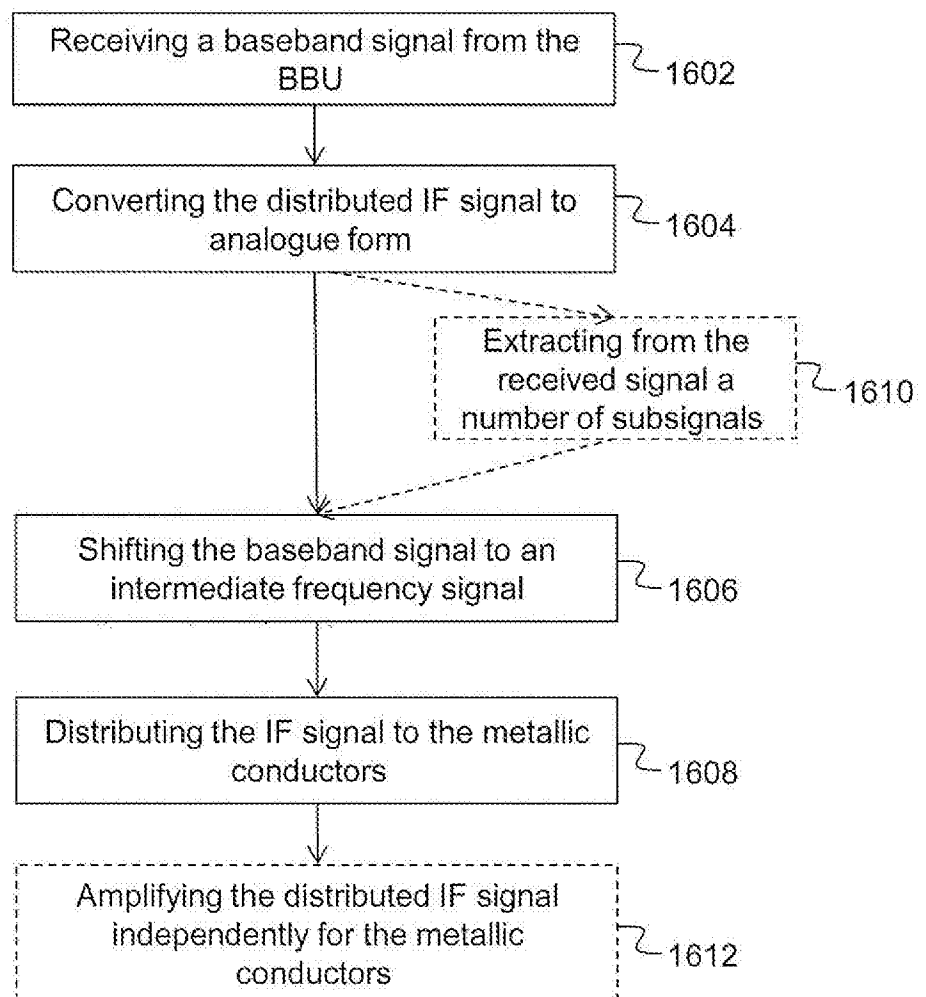


Fig. 15

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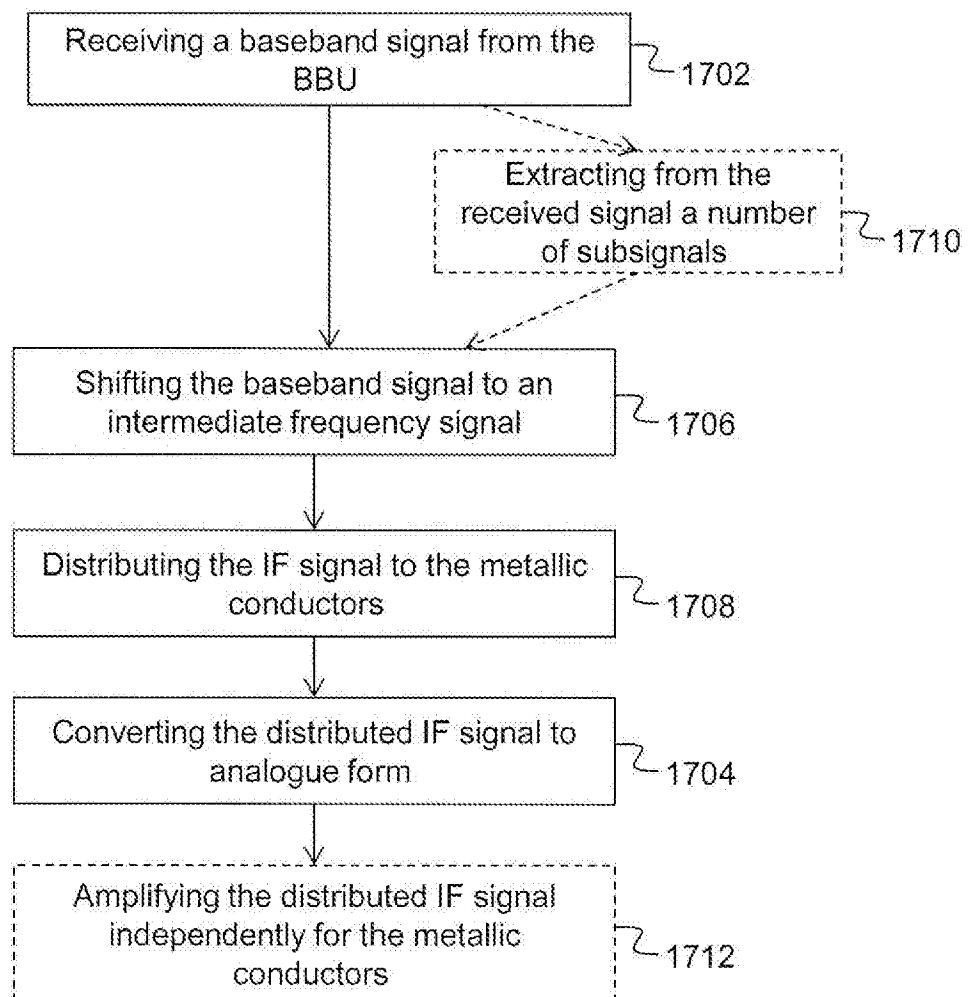


Fig. 16

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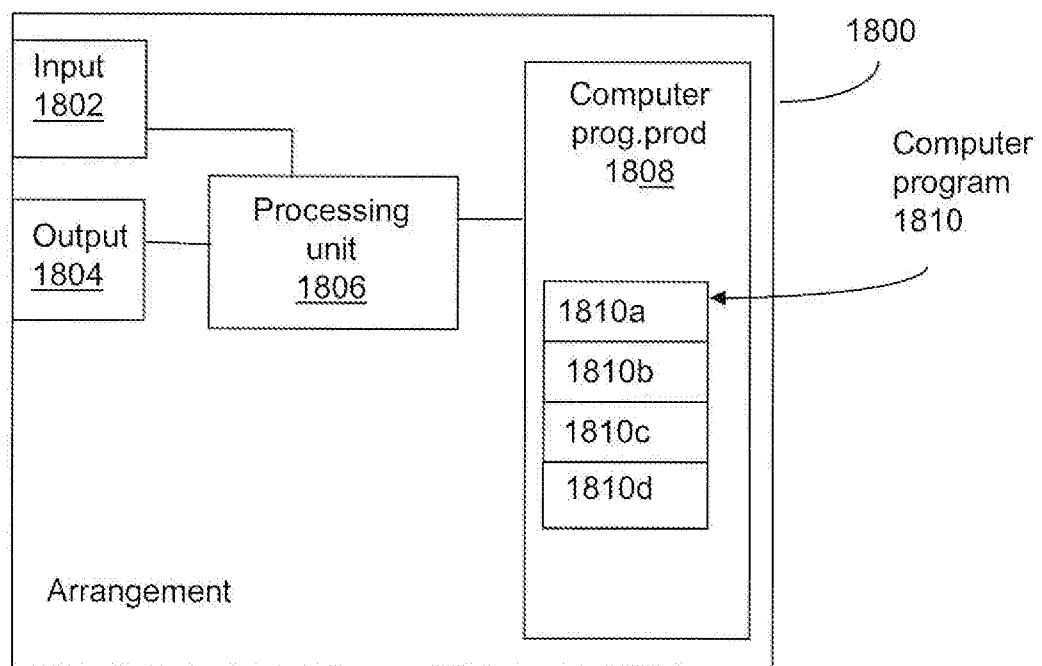


Fig. 17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/050549

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: H04B, H04L, H04W

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, PAJ, WPI data, COMPENDEX, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	--	5, 14
Y	WO 9708840 A2 (NORTHROP GRUMMAN CORP), 6 March 1997 (1997-03-06); page 21, line 3 - page 21, line 13; figures 1-3	5, 14
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

15-11-2013

Date of mailing of the international search report

15-11-2013

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INTERNATIONAL SEARCH REPORT

 International application No.
 PCT/SE2013/050549

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Continuation of: second sheet**International Patent Classification (IPC)***H04W 88/08* (2009.01)*H04B 7/04* (2006.01)*H04W 92/12* (2009.01)*H04L 12/44* (2006.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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