BASE STATION AND METHOD FOR FACILITATING CALIBRATION OF RADIO OVER FIBER TRANSCEIVERS

TECHNICAL FIELD

The present disclosure generally relates to radio frequency (RF) technology, and more particularly, to a base station and a method for facilitating calibration of Radio over Fiber (ROF) transceivers.

BACKGROUND

A base station, known as evolved NodeB (eNB) in Long Term Evolution (LTE) or gNB in New Radio (NR), can be divided into a Radio Unit (RU), which may be known as Remote Radio Unit (RRU), radio header (RH) or remote radio head (RRH), and a Base Band Unit (BBU).

Fig. 1 shows an illustrative structure of a base station including a BBU and a RU. The BBU may include base band functionality for Layer 1 (L1), Layer 2 (L2) and higher layers. The RU may include radio functionality such as radio Digital Front-End (DFE), RF signal processing and antennas. Conventionally, a Common Public Radio Interface (CPRI) can be used between the BBU and the RU, as shown in Fig. 1.

However, with the development of multi-antenna techniques, the CPRI may not be optimal, particularly for Massive MIMO (i.e. Multiple Input Multiple Output) which provides significant improvements in both throughput and energy efficiency through the use of a large number of service antennas in combination of simultaneous scheduling of a large number of terminal devices.

In general, the design of the interface between the BBU and the RU should consider the following factors:

- RF bandwidth has become wider and multi-band, multi-antenna systems have become more popular;
- Bitrate capacity is a big challenge to face for wide-band or multi-band applications;
- Thermal problem is now a very hot topic in radio design. Power transistors are not the bottle neck, but digital chips;

- Radio may cover the full band (not frequency dependent); and
- Radio capacity increases quickly and becomes comparable with DU.

In order to meet the above requirements, an ROF technique can be adopted. An ROF transceiver includes an ROF transmitter and an ROF receiver connected via an optical fiber. In the ROF transmitter, an RF signal is inputted to a transmitting module that adapts impedance of an RF circuit (typically 50 Ohms) to a driving laser circuit for converting the RF signal into light. In the ROF receiver module, a modulated laser light is converted into RF and output impedance is adapted as required (typically 50 Ohms).

However, in order to utilize the ROF technique in the base station, there is a need for a solution for calibration of ROF transceivers.

SUMMARY

It is an object of the present disclosure to provide a base station and a method for facilitating calibration of ROF transceivers.

According to a first aspect of the present disclosure, a base station is provided. The bases station comprises a first unit and a second unit. The first unit comprises a measurement transceiver connected to the second unit and selectively coupled to a first Radio over Fiber (ROF) transceiver or a second ROF transceiver. The first ROF transceiver comprises a first ROF receiver at the first unit and a first ROF transmitter at the second unit connected with each other via a first optical fiber. The second ROF transceiver comprises a second ROF transmitter at the first unit and a second ROF receiver at the second unit connected with each other via a second optical fiber. The measurement transceiver is configured to: receive from the first ROF receiver a first analog signal, convert the first analog signal into a first digital signal and transmit the first digital signal to the second unit for calibration of the first ROF transceiver, and/or receive from the second unit a second digital reference signal, convert the second digital reference signal into a second analog reference signal and transmit the second analog reference signal to the second ROF transmitter for transmission to the second unit for calibration of the second ROF transceiver.

In an embodiment, the first analog signal is resulted from a first digital reference signal originated and digital-to-analog converted at the second unit being transmitted through the first ROF transceiver.

In an embodiment, the second analog reference signal is transmitted through the second ROF transceiver and analog-to-digital converted at the second unit, resulting in a second digital signal for calibration of the second ROF transceiver.

In an embodiment, the measurement transceiver is further coupled to a third ROF transceiver comprising a third ROF transmitter at the first unit and a third ROF receiver at the second unit connected with each other via a third optical fiber, and configured to receive from the second unit a third digital reference signal, convert the third digital reference signal into a third analog reference signal and transmit the third analog reference signal to the third ROF transmitter for transmission to the second unit for calibration of the third ROF transceiver.

In an embodiment, the third ROF transmitter is connected to a Low Noise Amplifier (LNA) coupled to an output of a Power Amplifier (PA) connected to the first ROF transceiver.

In an embodiment, the measurement transceiver is further coupled to an output of a Power Amplifier (PA) connected to the first ROF receiver, and configured to receive a fourth analog signal from the output of the PA, convert the fourth analog signal into a fourth digital signal and transmit the fourth digital signal to the second unit for calibration of the PA.

In an embodiment, the base station further comprises: a digital controller connected to the measurement transceiver and the second unit, and configured to provide synchronization and/or signal format conversion between the measurement transceiver and the second unit.

In an embodiment, the first unit comprises radio functionality and the second unit comprises base band and/or digital functionality.

In an embodiment, the measurement transceiver is connected to the second unit via a digital over fiber interface.

According to a second aspect of the present disclosure, a method in a base station for facilitating calibration of Radio over Fiber (ROF) transceiver. The base station comprises a first unit and a second unit. The first unit comprises a measurement transceiver connected to the second unit and selectively coupled to a first ROF transceiver or a second ROF transceiver. The first ROF transceiver comprises a first ROF receiver at the first unit and a first ROF transmitter at the second unit connected with each other via a first optical fiber. The second ROF transceiver comprises a second ROF transmitter at the first unit and a second ROF receiver at the second unit connected with each other via a second optical fiber. The method comprises, at the measurement transceiver: receiving from the first ROF receiver a first analog signal, converting the first analog signal into a first digital signal and transmitting the first digital signal to the second unit for calibration of the first ROF transceiver, and/or receiving from the second unit a second digital reference signal, converting the second digital reference signal into a second analog reference signal and transmitting the second analog reference signal to the second ROF transmitter for transmission to the second unit for calibration of the second ROF transceiver.

In an embodiment, the first analog signal is resulted from a first digital reference signal originated and digital-to-analog converted at the second unit being transmitted through the first ROF transceiver.

In an embodiment, the second analog reference signal is transmitted through the second ROF transceiver and analog-to-digital converted at the second unit, resulting in a second digital signal for calibration of the second ROF transceiver.

In an embodiment, the measurement transceiver is further coupled to a third ROF transceiver comprising a third ROF transmitter at the first unit and a third ROF receiver at the second unit connected with each other via a third optical fiber. The method further comprises, at the measurement transceiver: receiving from the second unit a third digital reference signal, converting the third digital reference signal into a third analog reference signal and transmitting the third analog reference signal to the third ROF transmitter for transmission to the second unit for calibration of the third ROF transceiver.

In an embodiment, the third ROF transmitter is connected to a Low Noise Amplifier (LNA) coupled to an output of a Power Amplifier (PA) connected to the first ROF transceiver.

In an embodiment, the measurement transceiver is further coupled to an output of a Power Amplifier (PA) connected to the first ROF receiver. The method further comprises, at the measurement transceiver: receiving a fourth analog signal from the output of the PA, converting the fourth analog signal into a fourth digital signal and transmitting the fourth digital signal to the second unit for calibration of the PA.

In an embodiment, the first unit further comprises a digital controller connected to the measurement transceiver and the second unit. The method further comprises, at the digital controller: providing synchronization and/or signal format conversion between the measurement transceiver and the second unit.

In an embodiment, the first unit comprises radio functionality and the second unit comprises base band and/or digital functionality.

In an embodiment, the measurement transceiver is connected to the second unit via a digital over fiber interface.

With the embodiments of the present disclosure, a measurement transceiver can be provided at a first unit of a base station and connected to a second unit of the base station. The measurement transceiver is selectively coupled to a first ROF transceiver or a second ROF transceiver. The first ROF transceiver includes a first ROF receiver at the first unit and a first ROF transmitter at the second unit connected with each other via a first optical fiber. The second ROF transceiver includes a second ROF transmitter at the first unit and a second ROF receiver at the second unit connected with each other via a second optical fiber. The measurement transceiver can receive from the first ROF receiver a first analog signal, convert the first analog signal into a first digital signal and transmit the first digital signal to the second unit for calibration of the first ROF transceiver. Alternatively or additionally, the measurement transceiver can receive from the second unit a second digital reference signal, convert the second digital reference signal into a second analog reference signal and transmit the second analog reference signal to the second ROF transmitter for transmission to the second unit for calibration of the second ROF transceiver. In this way, the first and/or second ROF transceiver can be calibrated and imperfections such as non-linearity and uncertainty due to introduction of the ROF transceivers can be compensated for.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages will be more apparent from the following description of embodiments with reference to the figures, in which:

Fig. 1 is a schematic diagram showing a structure of a base station with a CPRI interface between a BBU and an RU;

Fig. 2 is a schematic diagram showing a structure of a base station in which the ROF technique is applied;

Fig. 3 is a schematic diagram showing an example of a specific structure of the base station in Fig. 2;

Fig. 4 is a schematic diagram showing a structure of a base station according to an embodiment of the present disclosure;

Fig. 5 is a schematic diagram showing an example of a signal flow in the base station in Fig. 4;

Fig. 6 is a schematic diagram showing another example of a signal flow in the base station in Fig. 4;

Fig. 7 is a schematic diagram showing yet another example of a signal flow in the base station in Fig. 4;

Fig. 8 is a schematic diagram showing a structure of a base station according to another embodiment of the present disclosure;

Fig. 9 is a schematic diagram showing a structure of a base station according to yet another embodiment of the present disclosure; and

Fig. 10 is a flowchart illustrating a method for facilitating calibration of ROF transceiver according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

The embodiments of the disclosure will be detailed below with reference to the drawings. It should be appreciated that the following embodiments are illustrative only, rather than limiting the scope of the disclosure.

As used herein, the term "base station" refers to a device in a wireless communication network via which a terminal device accesses the network and receives services therefrom. The base station may be, for example, a Node B (NodeB or NB), an evolved NodeB (eNodeB or eNB), or gNB. More generally, however, the base station may represent any suitable device (or group of devices) capable, configured, arranged, and/or operable to enable and/or provide a terminal device access to the wireless communication network or to provide some service to a terminal device that has accessed the wireless communication network.

Fig. 2 shows an illustrative structure of a base station in which the ROF technique can be applied. As shown, the RF signal processing functionality in Fig. 1 is split into two portions. Some of the RF signal processing functionality, for example including Analog-to-Digital Converter (ADC), Digital-to-Analog Converter (DAC) and small signal processing, along with the radio DFE functionality, can be moved to the BBU, while some large signal processing, e.g. Power Amplifier (PA), Low Noise Amplifier (LNA), Filter Unit (FU) and antennas remain in the RU. As used herein, the unit providing the remaining functionality of the RU is referred to as a “first unit” and the unit incorporating the functionality of the BBU and some of the functionality of the RU is referred to as a “second unit”.

Fig. 3 shows an example of a specific structure of the base station in Fig. 2. As shown, the base station 300 includes a first unit 310 and a second unit 320. The second unit 320 includes a BBU 310 and a DFE 340. In this example, the base station 300 includes five branches for transmitter, Transmitter Observation Receiver (TOR), receiver, antenna calibration transmitter and antenna calibration receiver, respectively. The transmitter branch includes a DAC 351, a mixer 352, an ROF transceiver 353, a PA 354, a circulator 355, an FU 356 and an antenna 357. The TOR branch includes an ADC 361, a mixer 362, an ROF transceiver 363 and an LNA 364 coupled to the output of the PA 354 via a coupler 365. The receiver branch includes an ADC 371, a mixer 372, an ROF transceiver 373, a PA 374, the circulator 355 connected to the PA 374 via a switch 375, the FU 356 and the antenna 357. The antenna calibration transmitter branch includes a measurement transceiver 380 and an ROF transceiver 382 coupled to the antenna 357 via a coupler 393. The antenna calibration receiver branch includes the measurement transceiver 380 and an ROF transceiver 383 coupled to the antenna 357 via the coupler 393. Two switches 391 and 392 are provided for switching between transmitter calibration and receiver calibration.

It can be seen from Fig. 3 that each of the ROF transceiver 353, 363, 373, 382 and 383 includes an ROF transmitter (TX) and an ROF receiver (RX) connected with each other via an optical fiber. There may be only one optical fiber between the first unit and the second unit and signals transmitted between the respective pairs of ROF transmitter and ROF receiver can be multiplexed onto the optical fiber.

Each of the ROF transceivers here can be treated as an analog component which requires calibration in order to be applied in the base station of Fig. 3. Various factors or parameters associated with non-linearity, gain and phase need to be considered for the ROF transceivers, such as:

- Amplitude/phase ripple,
- Gain adjustment range,
- Noise figure,
- Noise floor,
- 3rd order intermodulation product (IM3),
- 3rd order intercept point (IIP3),
- 1dB compression point (P1dB),
- Amplitude/phase flatness, and

- Time alignment error/phase impact.

In practice, the modules in the first unit and the modules in the second unit, including the ROF transmitters, fiber(s) and ROF receivers, may be ordered separately and have not been paired before on-site installation. Even if they are paired in advance, it is very likely that various errors may be introduced during installation. However, it is very difficult, or even impossible, to perform on-site calibration after installation, as it requires expensive test equipment as well as a huge cost in time and efforts.

Moreover, it can be seen from Fig. 3 that, for transmitter calibration, a signal has to travel through the ROF transceiver 353 and the ROF transceiver 383 and, for receiver calibration, a signal has to travel through the ROF transceiver 382 and the ROF transceiver 373. Due to presence of two ROF transceivers in the signal path, the calibration algorithm will be extremely complicated.

Fig. 4 is a schematic diagram showing a structure of a base station 400 according to an embodiment of the present disclosure. The DAC 451, mixer 452, PA 454, circulator 455, FU 456, antenna 457, ADC 461, mixer 462, LNA 464, coupler 465, ADC 471, mixer 472, PA 474, switch 475 and coupler 493 in the base station 400 are substantially the same as the DAC 351, mixer 352, PA 354, circulator 355, FU 356, antenna 357, ADC 361, mixer 362, LNA 364, coupler 365, ADC 371, mixer 372, PA 374, switch 375 and coupler 393 in the base station 300 shown in Fig. 3, and details thereof will be omitted here. As shown, the base station 400 includes a first unit 410 and a second unit 420. The second unit 420 includes a BBU 430 and a DFE 440. A measurement transceiver 480 is provided at the first unit 410 and connected to second unit 420 (in particular, the DFE 440) via e.g., a digital over fiber interface. The measurement transceiver 480 includes a DAC 481 and an LNA 482 for its measurement transmitter part, and an ADC 483 and an LNA 484 for its measurement receiver part. With switches 491 and 492, the measurement transceiver 480 can be selectively coupled to an ROF transceiver 453 or an ROF transceiver 473. The ROF transceiver 453 includes an ROF receiver 4532 at the first unit 410 and an ROF transmitter 4531 at the second unit 420 connected with each other via an optical fiber. The ROF transceiver 473 includes an ROF transmitter 4731 at the first unit 410 and an ROF receiver 4732 at the second unit 420 connected with each other via an optical fiber. Fig. 4 also shows an optional TOR branch including an ROF transceiver 463. The ROF transceiver 463 includes an ROF transmitter 4631 at the first unit 410 and an ROF receiver 4632 at the second unit 420 connected with each other via an optical fiber. It is to be noted here that one single optical fiber can be provided between the first unit 410 and the second unit 420 and signals transmitted between the respective pairs of ROF transmitter and ROF receiver can be multiplexed onto the optical fiber.

In the following, the operations of the base station 400 for calibration of the ROF transceivers will be described in detail.

Fig. 5 is a schematic diagram showing an example of a signal flow in the base station 400 for calibration of the ROF transceiver 453.

In this example, the measurement transceiver 480 can receive from the ROF receiver 453 an analog signal, convert the analog signal into a digital signal and transmit the digital signal to the second unit 420 for calibration of the ROF transceiver 453. The analog signal can be resulted from a digital reference signal originated and digital-to-analog converted at the second unit 420 being transmitted through the ROF transceiver 453.

In particular, the signal flow is shown in the bold line in Fig. 5. As shown, the DFE 440 can include a signal generator 441 which generates a digital reference signal. The digital reference signal is digital-to-analog converted by the DAC 451, mixed by the mixer 452 and then transmitted from the ROF transmitter 4531 to the ROF receiver 4532 via an optical fiber, resulting in an analog signal to be received by the measurement transceiver 480 via the switches 491 and 492. In the measurement transceiver 480, the analog signal is amplified by the LNA 484 and converted by the ADC 483 into a digital signal, which is then transmitted via the digital interface to the DFE 440. The DFE 440 includes a calibrator 442 which receives the digital signal and calibrates the ROF transceiver 453 based on the digital signal and the digital reference signal. The calibration can be carried out in the digital domain and can be associated with one or more of:

- Non-linear mitigation in the fiber;
- Digital pre-distortion;
- RF calibration, which is similar to antenna calibration; and

- Timing alignment.

Fig. 6 is a schematic diagram showing an example of a signal flow in the base station 400 for calibration of the ROF transceiver 473.

In this example, the measurement transceiver 480 can receive from the second unit 420 a second digital reference signal, convert the second digital reference signal into a second analog reference signal and transmit the second analog reference signal to the ROF transmitter 4731 for transmission to the second unit 420 for calibration of the ROF transceiver 473. The second analog reference signal is transmitted through the ROF transceiver 473 and analog-to-digital converted at the second unit 420, resulting in a second digital signal for calibration of the ROF transceiver 473.

In particular, the signal flow is shown in the bold line in Fig. 6. As shown, the DFE 440 can include a signal generator 441 which generates a digital reference signal. The digital reference signal is digital-to-analog converted by the DAC 481, amplified by the LNA 482 and then transmitted from the ROF transmitter 4731 to the ROF receiver 4732 via an optical fiber. The signal received by the ROF receiver 4732 is then mixed by the mixer 472 and analog-to-digital converted by the ADC 471, resulting in a digital signal to be received by the DFE 440. The DFE 440 includes a calibrator 442 which receives the digital signal and calibrates the ROF transceiver 473 based on the digital signal and the digital reference signal. Accordingly, the calibration can be carried out in the digital domain and can be associated with one or more of: non-linear mitigation in the fiber, digital pre-distortion, RF calibration and timing alignment.

Fig. 7 is a schematic diagram showing an example of a signal flow in the base station 400 for calibration of the ROF transceiver 463 in the TOR branch.

In this example, the measurement transceiver 480 can further be coupled to the ROF transceiver 463 (in particular, the ROF transmitter 4631). The measurement transceiver 480 can receive from the second unit 420 a third digital reference signal, convert the third digital reference signal into a third analog reference signal and transmit the third analog reference signal to the ROF transmitter 4631 for transmission to the second unit 420 for calibration of the ROF transceiver 463.

The ROF transmitter 4631 is connected to the LNA 464 coupled, via the coupler 465, to an output of the PA 454 connected to the ROF transceiver 453 (in particular, the ROF receiver 4532).

In particular, the signal flow is shown in the bold line in Fig. 7. As shown, the DFE 440 can include a signal generator 441 which generates a digital reference signal. The digital reference signal is digital-to-analog converted by the DAC 481, amplified by the LNA 482 and then transmitted from the ROF transmitter 4631 to the ROF receiver 4632 via an optical fiber. The signal received by the ROF receiver 4632 is then mixed by the mixer 462 and analog-to-digital converted by the ADC 461, resulting in a digital signal to be received by the DFE 440. The DFE 440 includes a calibrator 442 which receives the digital signal and calibrates the ROF transceiver 463 based on the digital signal and the digital reference signal. Accordingly, the calibration can be carried out in the digital domain and can be associated with one or more of: non-linear mitigation in the fiber, digital pre-distortion, RF calibration and timing alignment.

Fig. 8 is a schematic diagram showing a structure of a base station 800 according to another embodiment of the present disclosure. The base station 800 differs from the base station 400 shown in Figs. 4-7 in that ROF transceiver 463 for the TOR branch is omitted. In order to provide the TOR function, the measurement transceiver 480 can further be coupled to an output of the PA 454 connected to the ROF receiver 4532. The measurement transceiver 480 can receive a fourth analog signal from the output of the PA 465, convert the fourth analog signal into a fourth digital signal and transmit the fourth digital signal to the second unit 420 for calibration of the PA 454.

In particular, the signal flow is shown in the bold line in Fig. 8. As shown, the DFE 440 can include a signal generator 441 which generates a digital reference signal. The digital reference signal is digital-to-analog converted by the DAC 451, mixed by the mixer 452, transmitted from the ROF transmitter 4531 to the ROF receiver 4532 via an optical fiber and amplified by the PA 454. The signal outputted from the PA 454 is coupled to the measurement transceiver 480 via the switches 491 and 492. In the measurement transceiver 480, the signal is amplified by the LNA 484 and converted by the ADC 483 into a digital signal, which is then transmitted via the digital interface to the DFE 440. The DFE 440 includes a calibrator 442 which receives the digital signal and calibrates the ROF transceiver 453 and the PA 454 based on the digital signal and the digital reference signal. In this way, the base station 800 can provide the same TOR function as the base station 400 shown in Fig. 7.

Fig. 9 is a schematic diagram showing a structure of a base station 900 according to another embodiment of the present disclosure. The base station 900 differs from the base station 400 shown in Figs. 4-7 in that a digital controller 910 is provided. The digital controller 910 can be connected to the measurement transceiver 480 and the second unit 420 (in particular, the DFE 400). The digital controller 910 can provide synchronization and/or signal format conversion between the measurement transceiver 480 and the second unit 420. The digital controller 910 can be connected to a Local Timing Unit (LTU) 920 to obtain clock information for synchronization.

The digital controller 910 and the LTU 920 can also be provided in the base station 800 shown in Fig. 8.

Fig. 10 is a flowchart illustrating a method 1000 for facilitating calibration of ROF transceiver according to an embodiment of the present disclosure. The method can be applied in the base station 400, 800 or 900 as described above. The base station includes a first unit and a second unit. The first unit includes a measurement transceiver connected to the second unit and selectively coupled to a first ROF transceiver or a second ROF transceiver. The first ROF transceiver includes a first ROF receiver at the first unit and a first ROF transmitter at the second unit connected with each other via a first optical fiber. The second ROF transceiver includes a second ROF transmitter at the first unit and a second ROF receiver at the second unit connected with each other via a second optical fiber.

At block 1010, the measurement transceiver receives from the first ROF receiver a first analog signal, converts the first analog signal into a first digital signal and transmits the first digital signal to the second unit for calibration of the first ROF transceiver.

Alternatively or additionally, the measurement transceiver can receive from the second unit a second digital reference signal, convert the second digital reference signal into a second analog reference signal and transmit the second analog reference signal to the second ROF transmitter for transmission to the second unit for calibration of the second ROF transceiver.

In an embodiment, the first analog signal is resulted from a first digital reference signal originated and digital-to-analog converted at the second unit being transmitted through the first ROF transceiver.

In an embodiment, the second analog reference signal is transmitted through the second ROF transceiver and analog-to-digital converted at the second unit, resulting in a second digital signal for calibration of the second ROF transceiver.

In an embodiment, the measurement transceiver is further coupled to a third ROF transceiver comprising a third ROF transmitter at the first unit and a third ROF receiver at the second unit connected with each other via a third optical fiber. The method 1000 can further include, at the measurement transceiver: receiving from the second unit a third digital reference signal, converting the third digital reference signal into a third analog reference signal and transmitting the third analog reference signal to the third ROF transmitter for transmission to the second unit for calibration of the third ROF transceiver.

In an embodiment, the third ROF transmitter is connected to a Low Noise Amplifier (LNA) coupled to an output of a Power Amplifier (PA) connected to the first ROF transceiver.

In an embodiment, the measurement transceiver is further coupled to an output of a Power Amplifier (PA) connected to the first ROF receiver. The method 1000 can further include, at the measurement transceiver: receiving a fourth analog signal from the output of the PA, converting the fourth analog signal into a fourth digital signal and transmitting the fourth digital signal to the second unit for calibration of the PA.

In an embodiment, the first unit can further include a digital controller connected to the measurement transceiver and the second unit. The method 1000 can further include, at the digital controller: providing synchronization and/or signal format conversion between the measurement transceiver and the second unit.

In an embodiment, the first unit includes radio functionality and the second unit includes base band and/or digital functionality.

In an embodiment, the measurement transceiver is connected to the second unit via a digital over fiber interface.

All the aspects and features as described above in connection with Figs. 4-9 also apply to the method 1000.

With the embodiments of the present disclosure, each ROF transceiver in the base station can be calibrated separately and imperfections such as non-linearity and uncertainty due to introduction of the ROF transceivers can be compensated for.

The disclosure has been described above with reference to embodiments thereof. It should be understood that various modifications, alternations and additions can be made by those skilled in the art without departing from the spirits and scope of the disclosure. Therefore, the scope of the disclosure is not limited to the above particular embodiments but only defined by the claims as attached.

CLAIMS

1. A base station (400, 800, 900), comprising a first unit (410) and a second unit (420), the first unit (410) comprising a measurement transceiver (480) connected to the second unit (420) and selectively coupled to a first Radio over Fiber, ROF, transceiver (453) or a second ROF transceiver (473), the first ROF transceiver (453) comprising a first ROF receiver (4532) at the first unit (410) and a first ROF transmitter (4531) at the second unit (420) connected with each other via a first optical fiber, and the second ROF transceiver (473) comprising a second ROF transmitter (4731) at the first unit (410) and a second ROF receiver (4732) at the second unit (420) connected with each other via a second optical fiber,

wherein the measurement transceiver (480) is configured to:

receive from the first ROF receiver (4532) a first analog signal, convert the first analog signal into a first digital signal and transmit the first digital signal to the second unit (420) for calibration of the first ROF transceiver (453), and/or

receive from the second unit (420) a second digital reference signal, convert the second digital reference signal into a second analog reference signal and transmit the second analog reference signal to the second ROF transmitter (4731) for transmission to the second unit (420) for calibration of the second ROF transceiver (473).

2. The base station (400, 800, 900) of claim 1, wherein the first analog signal is resulted from a first digital reference signal originated and digital-to-analog converted at the second unit (420) being transmitted through the first ROF transceiver (453).

3. The base station (400, 800, 900) of claim 1 or 2, wherein the second analog reference signal is transmitted through the second ROF transceiver (473) and analog-to-digital converted at the second unit (420), resulting in a second digital signal for

calibration of the second ROF transceiver (473).

4. The base station (400) of any of claims 1-3, wherein the measurement transceiver (480) is further coupled to a third ROF transceiver (463) comprising a third ROF transmitter (4631) at the first unit (410) and a third ROF receiver (4632) at the second unit (420) connected with each other via a third optical fiber, and configured to receive from the second unit (420) a third digital reference signal, convert the third digital reference signal into a third analog reference signal and transmit the third analog reference signal to the third ROF transmitter (4631) for transmission to the second unit (420) for calibration of the third ROF transceiver (463).

5. The base station (400) of claim 4, wherein the third ROF transmitter (463) is connected to a Low Noise Amplifier, LNA, (464) coupled to an output of a Power Amplifier, PA, (454) connected to the first ROF transceiver (453).

6. The base station (800) of any of claims 1-3, wherein the measurement transceiver (480) is further coupled to an output of a Power Amplifier, PA, (454) connected to the first ROF receiver (4532), and configured to receive a fourth analog signal from the output of the PA (454), convert the fourth analog signal into a fourth digital signal and transmit the fourth digital signal to the second unit (420) for calibration of the PA (454).

7. The base station (900) of any of claims 1-6, further comprising:
- a digital controller (910) connected to the measurement transceiver (480) and the second unit (420), and configured to provide synchronization and/or signal format conversion between the measurement transceiver (480) and the second unit (420).

8. The base station (400, 800, 900) of any of claims 1-7, wherein the first unit (410) comprises radio functionality and the second unit (420) comprises base band and/or digital functionality.

9. The base station (400, 800, 900) of any of claims 1-8, wherein the measurement transceiver (480) is connected to the second unit (420) via a digital over fiber interface.

10. A method (1000) in a base station for facilitating calibration of Radio over Fiber, ROF, transceiver, the base station comprising a first unit and a second unit, the first unit comprising a measurement transceiver connected to the second unit and selectively coupled to a first ROF transceiver or a second ROF transceiver, the first ROF transceiver comprising a first ROF receiver at the first unit and a first ROF transmitter at the second unit connected with each other via a first optical fiber, and the second ROF transceiver comprising a second ROF transmitter at the first unit and a second ROF receiver at the second unit connected with each other via a second optical fiber, the method comprising, at the measurement transceiver:

- receiving (1010) from the first ROF receiver a first analog signal, converting the first analog signal into a first digital signal and transmitting the first digital signal to the second unit for calibration of the first ROF transceiver, and/or
- receiving (1010) from the second unit a second digital reference signal, converting the second digital reference signal into a second analog reference signal and transmitting the second analog reference signal to the second ROF transmitter for transmission to the second unit for calibration of the second ROF transceiver.

11. The method (1000) of claim 10, wherein the first analog signal is resulted from a first digital reference signal originated and digital-to-analog converted at the second unit being transmitted through the first ROF transceiver.

12. The method (1000) of claim 10 or 11, wherein the second analog reference signal is transmitted through the second ROF transceiver and analog-to-digital converted at the second unit,

resulting in a second digital signal for calibration of the second ROF transceiver.

13. The method (1000) of any of claims 10-12, wherein the measurement transceiver is further coupled to a third ROF transceiver comprising a third ROF transmitter at the first unit and a third ROF receiver at the second unit connected with each other via a third optical fiber, and the method (1000) further comprises, at the measurement transceiver:

- receiving from the second unit a third digital reference signal, converting the third digital reference signal into a third analog reference signal and transmitting the third analog reference signal to the third ROF transmitter for transmission to the second unit for calibration of the third ROF transceiver.

14. The method (1000) of claim 13, wherein the third ROF transmitter is connected to a Low Noise Amplifier, LNA, coupled to an output of a Power Amplifier, PA, connected to the first ROF transceiver.

15. The method (1000) of any of claims 10-12, wherein the measurement transceiver is further coupled to an output of a Power Amplifier, PA, connected to the first ROF receiver, and the method (1000) further comprises, at the measurement transceiver:

- receiving a fourth analog signal from the output of the PA, converting the fourth analog signal into a fourth digital signal and transmitting the fourth digital signal to the second unit for calibration of the PA.

16. The method (1000) of any of claims 10-15, wherein the first unit further comprises a digital controller connected to the measurement transceiver and the second unit, and the method (1000) further comprises, at the digital controller:

- providing synchronization and/or signal format conversion between the measurement transceiver and the second unit .

17. The method (1000) of any of claims 10-16, wherein the first unit comprises radio functionality and the second unit comprises base band and/or digital functionality.

18. The method (1000) of any of claims 10-17, wherein the measurement transceiver is connected to the second unit via a digital over fiber interface.

ABSTRACT

The present disclosure provides a base station (400, 800, 900). The base station includes a first unit (410) and a second unit (420). The first unit (410) includes a measurement transceiver (480) connected to the second unit (420) and selectively coupled to a first ROF transceiver (453) or a second ROF transceiver (473). The measurement transceiver (480) is configured to: receive from a first ROF receiver (4532) a first analog signal, convert the first analog signal into a first digital signal and transmit the first digital signal to the second unit (420) for calibration of the first ROF transceiver (453), and/or receive from the second unit (420) a second digital reference signal, convert the second digital reference signal into a second analog reference signal and transmit the second analog reference signal to a second ROF transmitter (4731) for transmission to the second unit (420) for calibration of the second ROF transceiver (473).

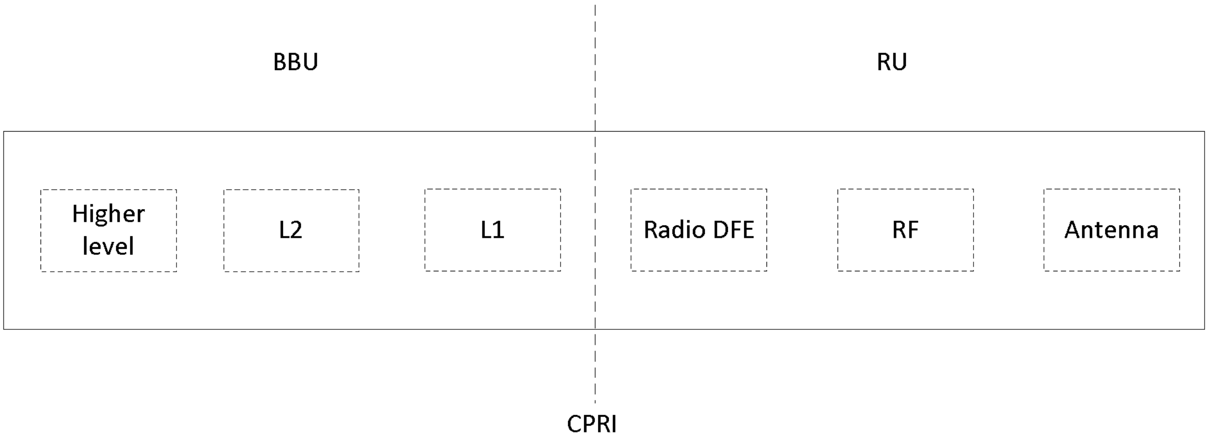

BBU
RU
Higher level
L2
L1
Radio DFE
RF
Antenna
CPRI

Fig. 1

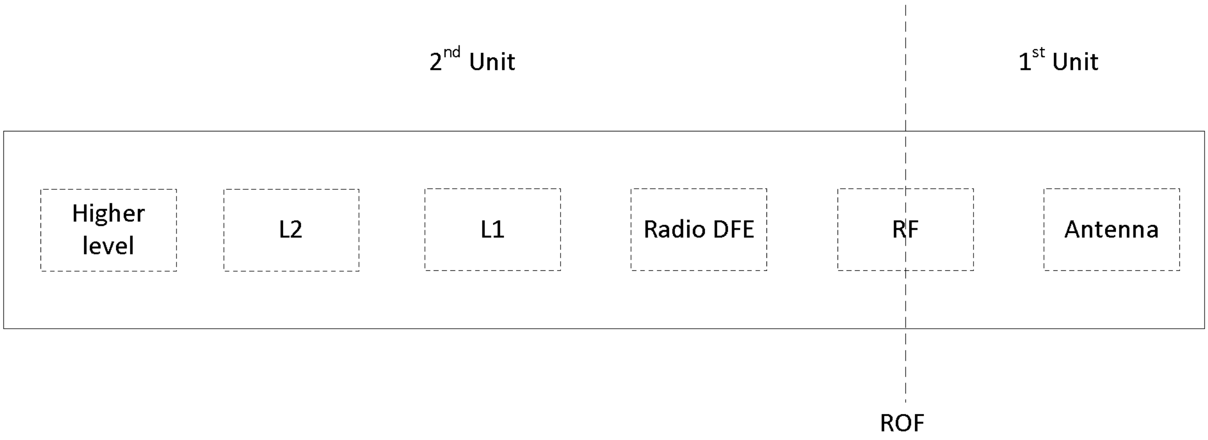

2nd Unit
1st Unit
Higher level
L2
L1
Radio DFE
RF
Antenna
ROF

Fig. 2

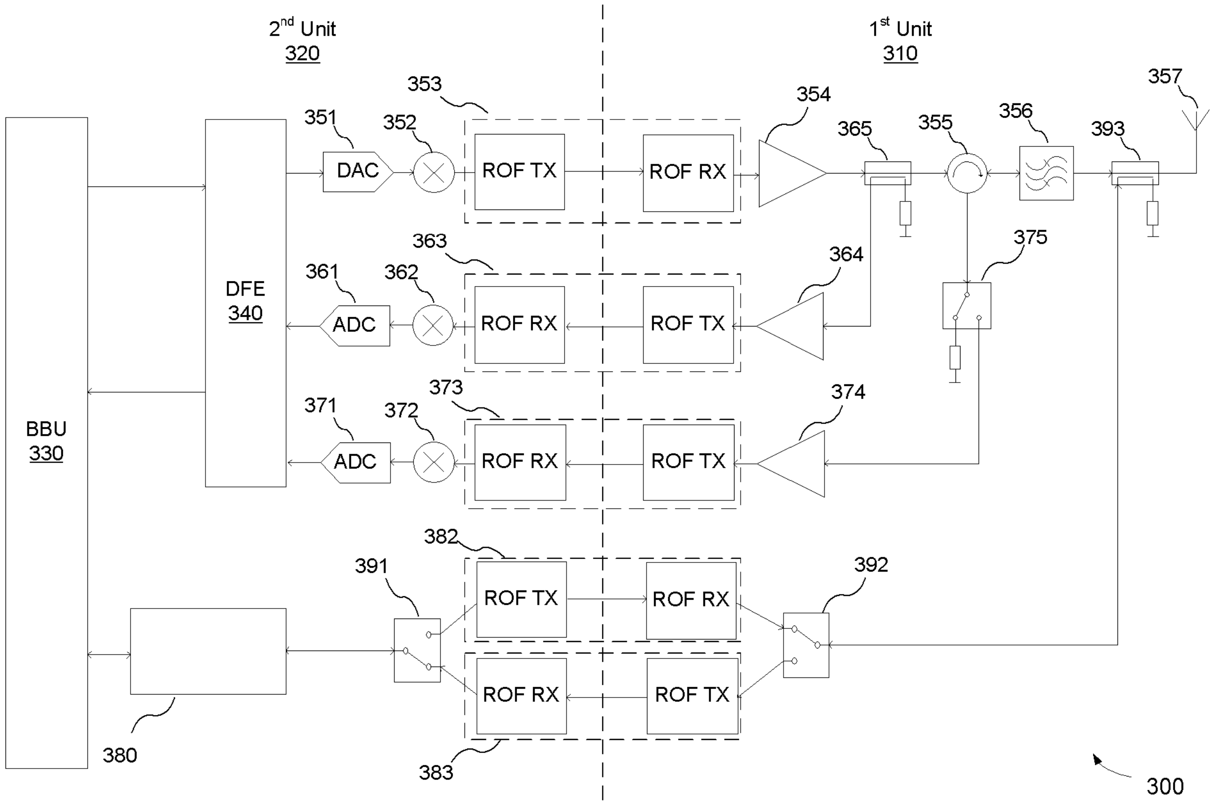

2nd Unit
320
1st Unit
310
BBU
330
DFE
340
DAC
ADC
ADC
ROF TX
ROF RX
ROF RX
ROF TX
ROF RX
ROF TX
ROF TX
ROF RX
ROF RX
ROF TX
351
352
353
354
355
356
357
361
362
363
364
365
371
372
373
374
375
380
382
383
391
392
393
300

Fig. 3

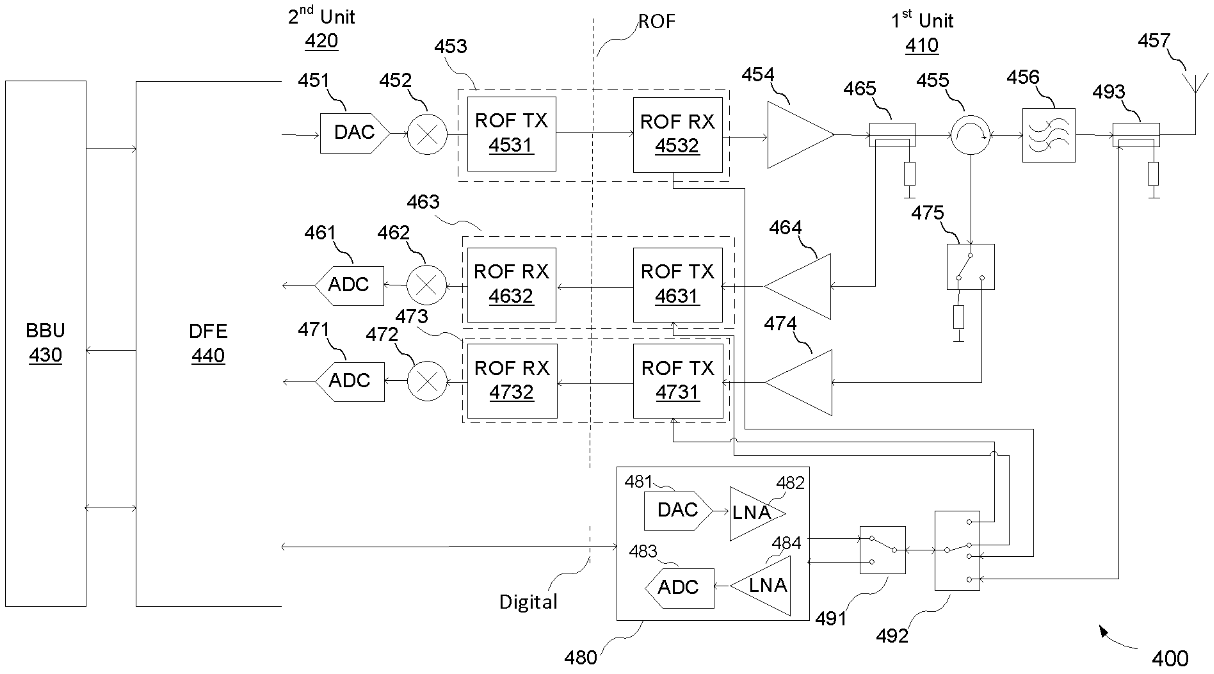

2nd Unit
420
ROF
1st Unit
410
453
451
452
454
465
455
456
457
493
DAC
ROF TX
4531
ROF RX
4532
463
461
462
475
464
ADC
ROF RX
4632
ROF TX
4631
BBU
430
DFE
440
471
472
473
474
ADC
ROF RX
4732
ROF TX
4731
481
482
DAC
LNA
483
484
ADC
LNA
Digital
491
492
480
400

Fig. 4

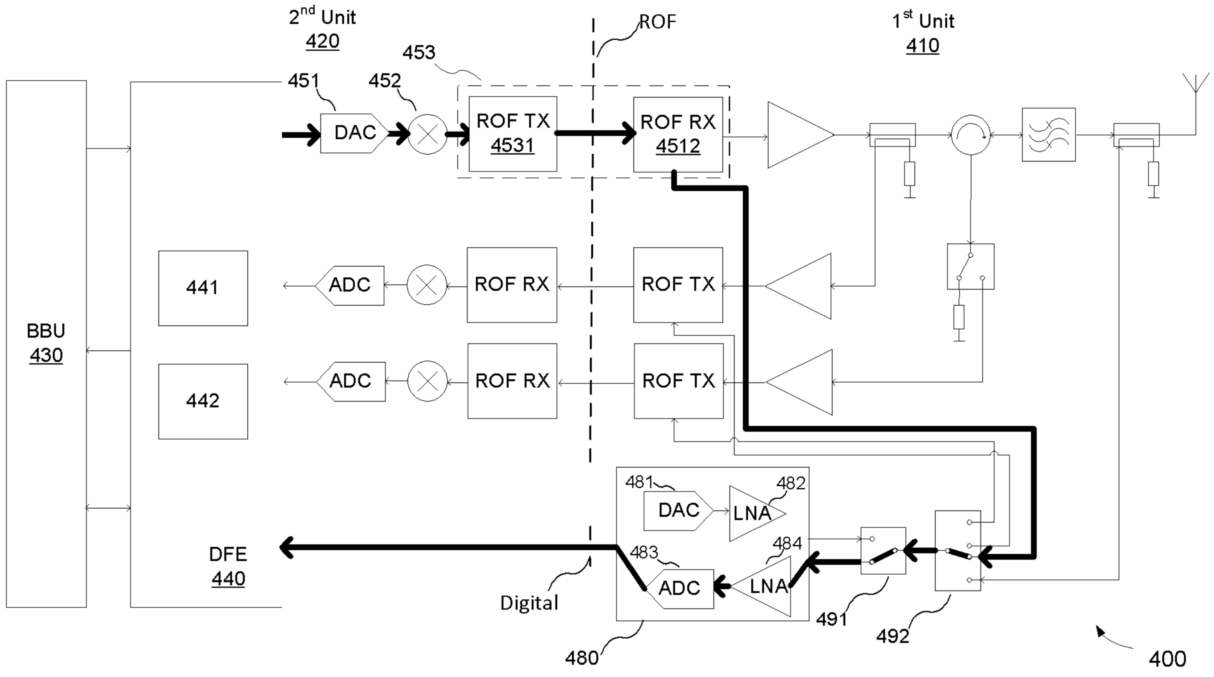

2nd Unit
420
ROF
1st Unit
410
453
451
452
DAC
ROF TX
4531
ROF RX
4512
441
ADC
ROF RX
ROF TX
BBU
430
442
ADC
ROF RX
ROF TX
481
482
DAC
LNA
DFE
440
483
484
ADC
LNA
Digital
491
492
480
400

Fig. 5

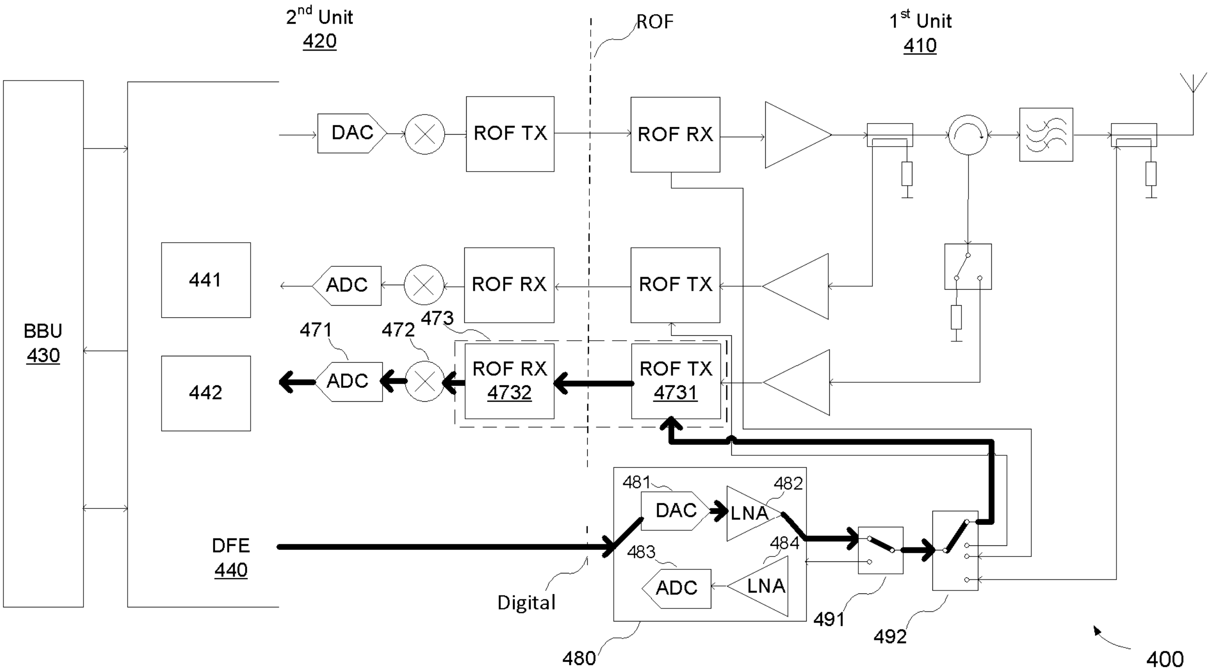

2nd Unit
420
ROF
1st Unit
410
BBU
430
DAC
ROF TX
ROF RX
441
ADC
ROF RX
ROF TX
471
472
473
442
ADC
ROF RX
4732
ROF TX
4731
481
DAC
LNA
482
DFE
440
483
484
ADC
LNA
Digital
491
492
480
400

Fig. 6

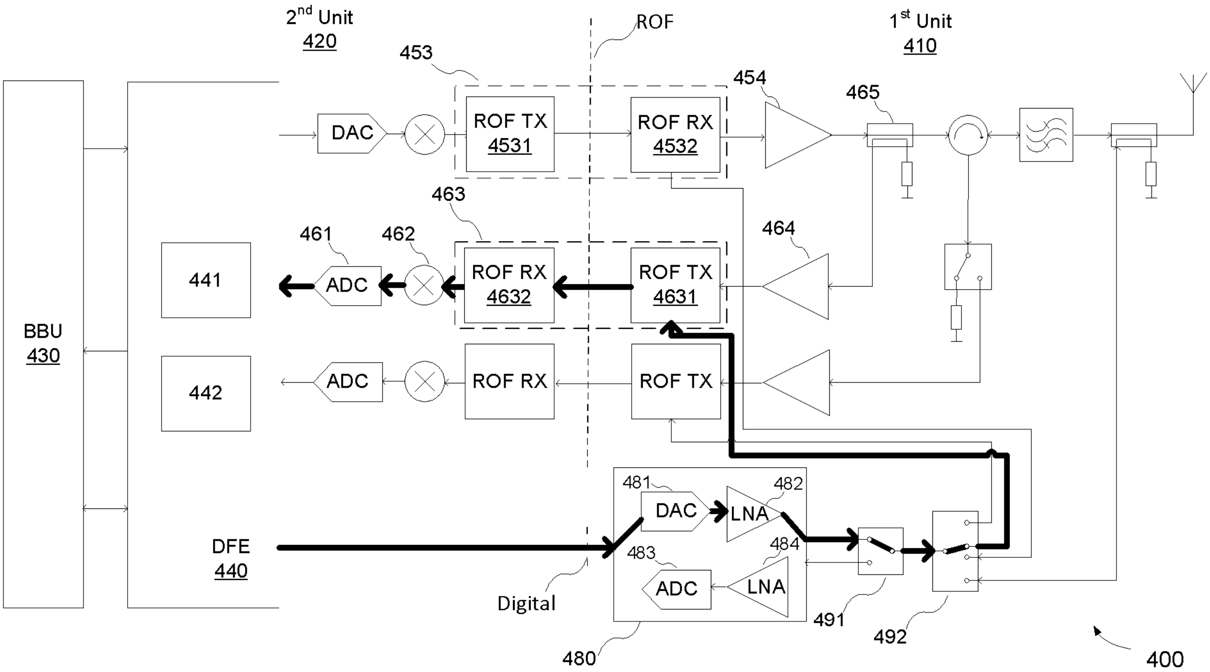

2nd Unit
420
ROF
1st Unit
410
453
454
465
BBU
430
DAC
ROF TX
4531
ROF RX
4532
463
461
462
464
441
ADC
ROF RX
4632
ROF TX
4631
442
ADC
ROF RX
ROF TX
481
DAC
LNA
482
DFE
440
483
484
ADC
LNA
Digital
491
492
480
400

Fig. 7

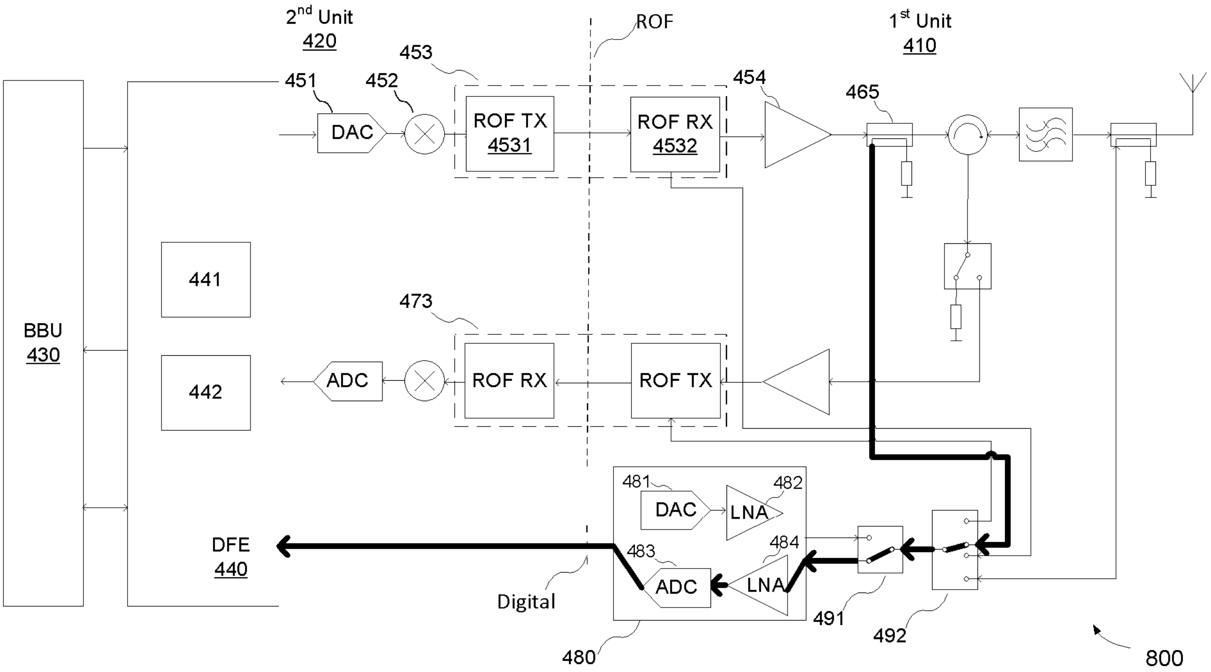

2nd Unit
420
ROF
1st Unit
410
453
451
452
DAC
ROF TX
4531
ROF RX
4532
454
465
BBU
430
441
442
473
ADC
ROF RX
ROF TX
481
DAC
LNA
482
483
ADC
484
LNA
DFE
440
Digital
491
492
480
800

Fig. 8

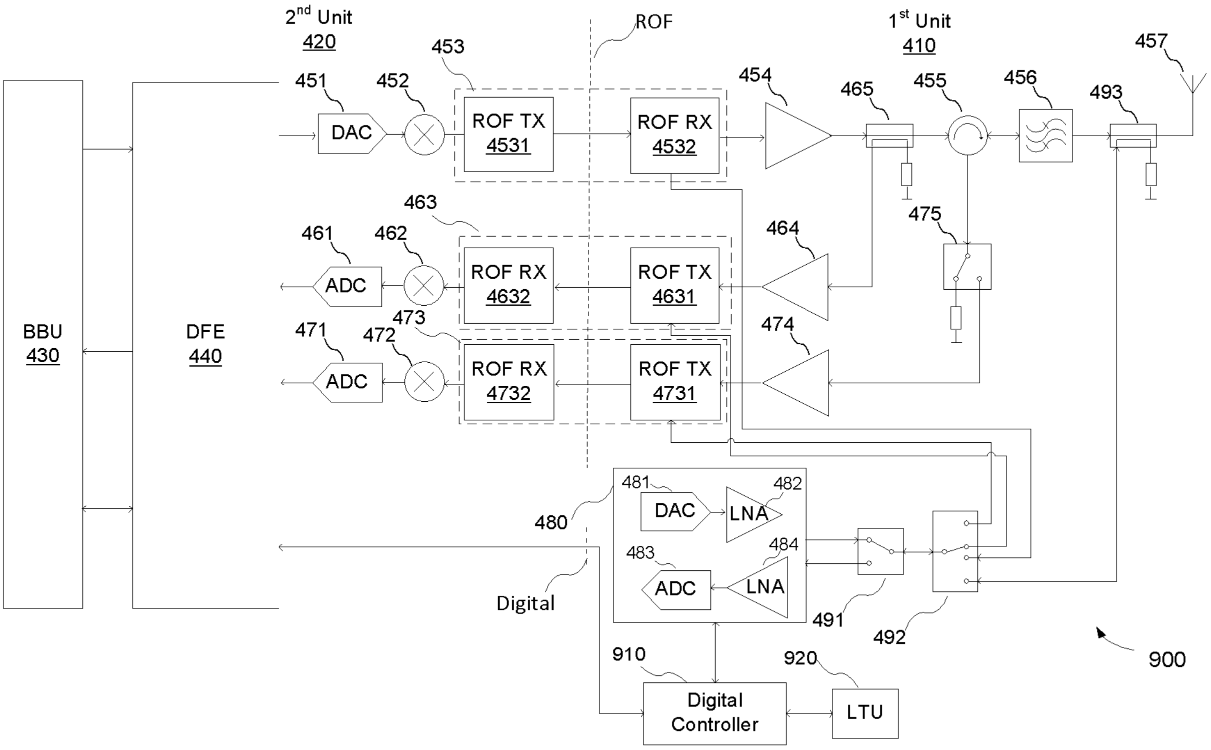
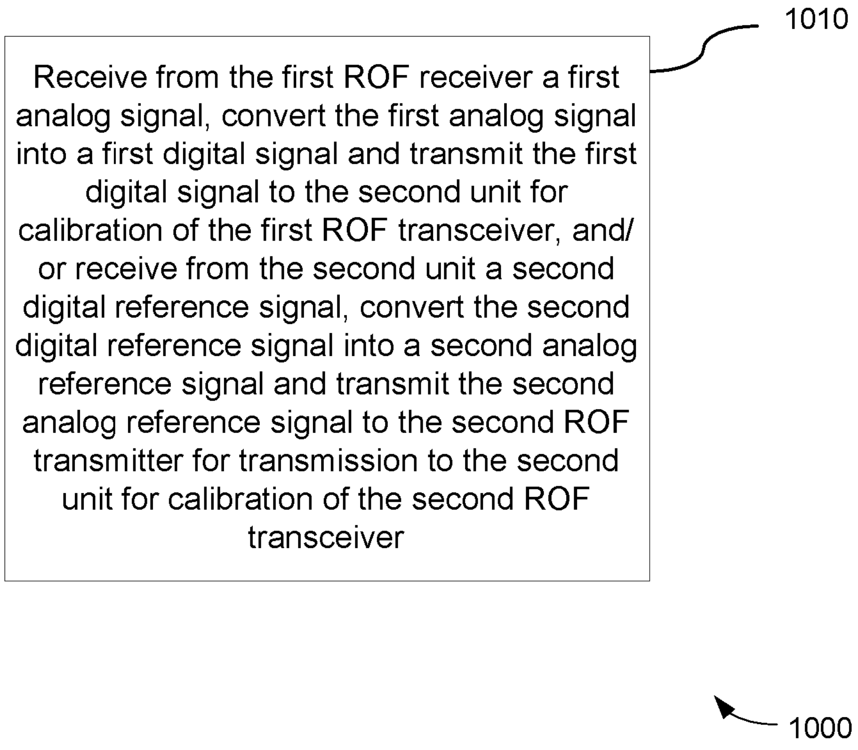

2nd Unit
420
ROF
1st Unit
410
457
453
451
452
454
465
455
456
493
DAC
ROF TX
4531
ROF RX
4532
463
461
462
464
475
ADC
ROF RX
4632
ROF TX
4631
473
471
472
474
ADC
ROF RX
4732
ROF TX
4731
BBU
430
DFE
440
481
482
DAC
LNA
480
483
484
ADC
LNA
Digital
491
492
900
910
920
Digital
Controller
LTU

Fig. 9



Receive from the first ROF receiver a first analog signal, convert the first analog signal into a first digital signal and transmit the first digital signal to the second unit for calibration of the first ROF transceiver, and/or receive from the second unit a second digital reference signal, convert the second digital reference signal into a second analog reference signal and transmit the second analog reference signal to the second ROF transmitter for transmission to the second unit for calibration of the second ROF transceiver

Fig. 10