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(54) **CALIBRATION METHOD AND ACTIVE ANTENNA**

(57) A calibration method and an active antenna are provided. The active antenna includes K antenna dipole arrays, 1st to Kth transceiver unit arrays corresponding to the antenna dipole arrays, 1st to Kth calibrators, a feature difference calculating unit, and baseband processing modules. The 1st to Kth calibrators are configured to obtain P feature difference values between P calibration signals passing through all calibration loops of the active antenna and an original calibration signal. The feature difference calculating unit is configured to calculate a feature difference value of a receiving channel and/or transmitting channel of each transceiver unit relative to a reference receiving channel and/or transmitting channel respectively. Each baseband processing module is configured to perform feature compensation on a service signal of the corresponding transceiver unit in a digital domain. Therefore, feature differences between all transceivers respectively disposed on a plurality of boards of the transceiver arrays can be calculated, so as to realize accurate calibration on transceiver arrays when the transceiver arrays are distributed on a plurality of boards.

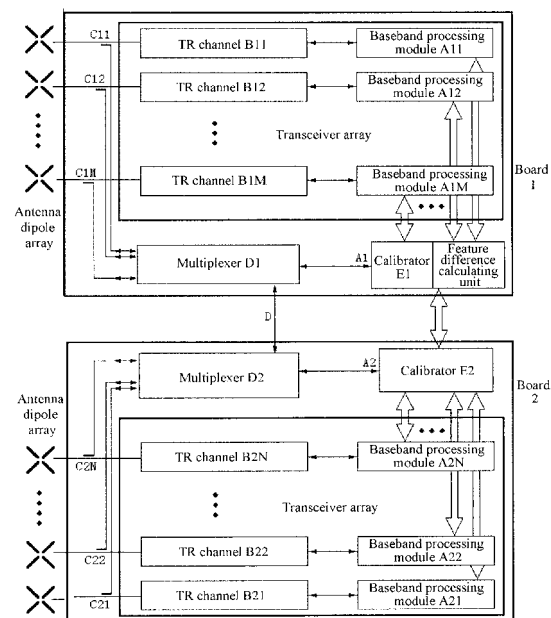


FIG. 1

Description**FIELD OF THE TECHNOLOGY**

5 **[0001]** The present invention relates to the field of communication technology, and more particularly to a calibration method and an active antenna.

BACKGROUND OF THE INVENTION

10 **[0002]** With the progress of technologies, transceivers have been developed towards the integration and low cost trends, which creates favorable conditions for the digital beam-forming (DBF) application. The DBF can be realized as long as each dipole is configured with a transceiver, so as to form transceiver arrays. A product in such a form is usually referred to as an active antenna.

15 **[0003]** In order to decrease fabrication and maintenance cost of the transceiver array and simplify the interconnection structure, the integration needs to be enhanced, that is, a printed circuit board (PCB, that is, a board) with a determined area shall be configured with transceiver units thereon as many as possible. However, a size of the PCB is limited by the fabrication and processing techniques. For example, as for conventional surface-mount technology (SMT) equipment, an allowed maximum length of a PCB is about 550 mm. Dipole units for forming an active antenna are arranged in a straight line and a spacing distance there-between is about 0.8 to 0.9 times of a wavelength. Each dipole unit is connected to a transceiver, so that the transceiver arrays need to be disposed on two or more boards at the same spacing distance. 20 For example, 8 transceiver arrays of an 18 dBi active antenna at 2GHz are evenly distributed within an interval between 900 mm and 1000 mm along a straight line, so that the 8 transceiver arrays need to be disposed on two same PCBs. In addition, the features (such as an amplitude, a phase, and a delay) of each transceiver unit are scattered. In order to realize the DBF, the transceiver arrays need to be calibrated.

25 **[0004]** In view of this situation, currently, when transceivers of transceiver arrays are disposed on different boards (that is, a plurality of PCBs), a solution for realizing calibration among the transceivers on different boards is urgently needed in this industry.

SUMMARY OF THE INVENTION

30 **[0005]** The present invention is directed to a calibration method and an active antenna, applicable to realize calibration of transceivers disposed on different boards.

35 **[0006]** In an embodiment, the present invention provides an active antenna, which includes: K antenna dipole arrays, 1st to Kth transceiver unit arrays corresponding to the antenna dipole arrays, 1st to Kth multiplexers, 1st to Kth calibrators, and a feature difference calculating unit. The 1st to Kth transceiver unit arrays are correspondingly disposed on 1st to Kth boards respectively. Each transceiver unit array includes a plurality of transceiver units. Each transceiver unit includes a receiving channel and/or a transmitting channel and a corresponding baseband processing module. The 1st to Kth multiplexers are correspondingly disposed on the 1st to Kth boards respectively. Each of the 1st to Kth multiplexers is configured to transmit calibration signals to multiplexers among the 1st to Kth multiplexers other than the current multiplexer 40 itself through multiplexers and electromagnetic connection between multiplexers. The 1st to Kth calibrators are correspondingly disposed on the 1st to Kth boards respectively and configured to obtain P feature difference values between P calibration signals that pass through all calibration loops of the active antenna and an original calibration signal. P equals to the number of all transceiver units of the 1st to Kth transceiver unit arrays. The feature difference calculating unit is configured to calculate a feature difference value of a receiving channel and/or transmitting channel of each transceiver unit in the active antenna relative to a reference receiving channel and/or transmitting channel respectively, 45 according to an association relation between a feature difference value and a feature of each calibration loop, and the P feature difference values obtained by each calibrator of the active antenna, where the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop of the active antenna and the original calibration signal. Each baseband processing module is configured to perform feature compensation on a service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding transceiver unit, in which K is a positive integer greater than or equal to 2.

50 **[0007]** The present invention further provides a calibration method, which is applied in an active antenna including 1st to Kth transceiver unit arrays, corresponding 1st to Kth multiplexers, and corresponding 1st to Kth calibrators correspondingly disposed on 1st to Kth boards respectively. K is a positive integer greater than or equal to 2. The method includes the following steps. The 1st to Kth calibrators obtain P feature difference values between P calibration signals passing through all calibration loops of the 1st to Kth boards of the active antenna and an original calibration signal. P equals to the number of all transceiver units of the 1st to Kth transceiver unit arrays. A feature difference value of a receiving 55

channel and/or transmitting channel of each transceiver unit of the active antenna relative to a reference receiving channel and/or transmitting channel respectively is calculated, according to an association relation between a feature difference value and a feature of each calibration loop, and the P feature difference values obtained by each calibrator of the active antenna, where the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop of the active antenna and the original calibration signal. Feature compensation is performed on a service signal of a corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding transceiver unit.

[0008] In the active antenna according to the embodiments of the present invention, each calibrator of the active antenna obtains P feature difference values between P calibration signals passing through all calibration loops of the active antenna and an original calibration signal. A feature difference value of a receiving channel and/or transmitting channel of each transceiver unit of the active antenna relative to a reference receiving channel and/or a reference transmitting channel is respectively calculated, according to an association relation between a feature difference value and a feature of each calibration loop, and the P feature difference values obtained by each of the calibrators of the active antenna, where the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop of the active antenna and the original calibration signal. In addition, each baseband processing module in the active antenna performs feature compensation on a service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding transceiver unit. Thus, accurate calibration of the transceiver arrays disposed on different boards is realized.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings are intended for better understanding of the present invention and constitute part of this application rather than limitation of the present invention.

FIG. 1 is a structural block diagram of an active antenna according to an embodiment of the present invention;

FIG. 2 is a schematic structural view of a passive link for connecting two boards according to an embodiment of the present invention;

FIG. 3 is a structural block diagram of another active antenna according to an embodiment of the present invention;

FIG. 4 is a structural block diagram of still another active antenna according to an embodiment of the present invention;

FIG. 5 is a peripheral block diagram of combiners when transceiver arrays in an active antenna are distributed at three boards according to an embodiment of the present invention;

FIG. 6 is a flow chart of a calibration method according to an embodiment of the present invention;

FIG. 7 is a flow chart of another calibration method according to an embodiment of the present invention; and

FIG. 8 is a flow chart of still another calibration method according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0010] In order to make the objectives, technical solutions, and merits of the present invention clearer, a detailed description of the present invention is hereinafter given with reference to accompanying drawings and some exemplary embodiments. The exemplary embodiments of the present invention and description thereof are intended for interpreting rather than limiting the present invention.

[0011] The present invention provides an active antenna and a calibration method for transceiver arrays, applicable to realize accurate calibration between transceivers disposed on different boards. It should be noted that, the calibration according to the embodiments of the present invention focuses on three features, that is, an amplitude, a phase, and a delay of the transceivers, and a unified feature variable is used to represent the three features. In addition, for the ease of illustration, in the accompanying drawings, a transmitting and receiving channel (briefly referred to as TR channel) is used to represent a receiving channel and/or a transmitting channel.

[0012] In an embodiment, the present invention provides an active antenna, which includes: K antenna dipole arrays, 1st to Kth transceiver unit arrays corresponding to the antenna dipole arrays, 1st to Kth multiplexers, 1st to Kth calibrators,

and a feature difference calculating unit.

[0013] The 1st to Kth transceiver unit arrays corresponding to the antenna dipole arrays are correspondingly disposed on 1st to Kth boards respectively. Each transceiver unit array includes a plurality of transceiver units. Each transceiver unit includes a receiving channel and/or a transmitting channel, and a corresponding baseband processing module.

[0014] The 1st to Kth multiplexers are correspondingly disposed on the 1st to Kth boards respectively. Each of the 1st to Kth multiplexers is configured to transmit calibration signals to multiplexers among the 1st to Kth multiplexers other than the current multiplexer itself through multiplexers and electromagnetic connection between multiplexers.

[0015] The 1st to Kth calibrators are correspondingly disposed on the 1st to Kth boards respectively and configured to obtain P feature difference values between P calibration signals passing through all calibration loops of the active antenna and an original calibration signal. P equals to the number of all transceiver units of the 1st to Kth transceiver unit arrays. It should be noted that, the calibration loops are formed by calibrators, multiplexers, couplers, TR channels, and baseband processing modules where the calibration signals are transmitted.

[0016] The feature difference calculating unit is configured to calculate a feature difference value of a receiving channel and/or transmitting channel of each transceiver unit of the active antenna relative to a reference receiving channel and/or transmitting channel respectively, according to an association relation between a feature difference value and a feature of each calibration loop, and P feature difference values obtained by each calibrator of the active antenna, where the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop of the active antenna and the original calibration signal.

[0017] Each baseband processing module is configured to perform feature compensation on a service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding transceiver unit, in which K is a positive integer greater than or equal to 2.

[0018] Furthermore, in an implementation, the feature difference calculating unit is a first feature difference calculating unit, configured to obtain a feature difference value of a receiving channel and/or transmitting channel of each transceiver unit disposed on each board relative to the reference receiving channel and/or transmitting channel respectively through a matrix operation of arrays according to P one-dimensional arrays corresponding to calibration loops where calibration signals pass through. The one-dimensional array represents features of each component where the signal is transmitted in the corresponding calibration loop and a feature difference value between the calibration signal passing through the calibration loop and the original calibration signal.

[0019] In an implementation, if the reception calibration of transceivers disposed on different boards is intended to be realized, each calibrator in the active antenna according to an embodiment of the present invention is specifically configured to send an original reception calibration signal. The original reception calibration signal is divided into a plurality of multiplexed signals through a multiplexer of the active antenna on the current board, and said a plurality of multiplexed signals enters reception calibration loops of the active antenna on the current board respectively. In addition, the original reception calibration signal is transferred to multiplexers among the K multiplexers and other than the current multiplexer through electromagnetic connection between multiplexers, and the original reception calibration signal is divided into a plurality of multiplexed signals by each of the other multiplexers, and then said a plurality of multiplexed signals enters reception calibration loops of the active antenna on each of the other boards respectively. The calibrator is further configured to receive P reception calibration signals passing through all reception calibration loops of the active antenna on the 1st to Kth boards, and then obtain P feature difference values between the P reception calibration signals and the sent original reception calibration signal through comparison.

[0020] In an implementation, if the transmission calibration of transceivers disposed on different boards is intended to be realized, the baseband processing module in the active antenna is further configured to send an original transmission calibration signal, where one baseband processing module carries out the sending after a predetermined delay interval that another baseband processing module carries out the sending. The original transmission calibration signal enters a corresponding transmitting channel according to a signal transmission direction.

[0021] Each calibrator in the active antenna according to an embodiment of the present invention is specifically configured to receive I transmission calibration signals passing through transmission calibration loops of the active antenna on the current board through corresponding multiplexers, in which I equals to the number of all transmitting channels of the active antenna on the current board. In addition, the calibrator is further configured to receive (P-I) transmission calibration signals transferred through electromagnetic connection between multiplexers, and obtain P feature difference values by comparing feature differences between the received P transmission calibration signals with the original transmission calibration signal sent by the corresponding baseband processing module.

[0022] In the active antenna according to an embodiment of the present invention, each multiplexer includes a switch matrix, a power splitter/combiner, a duplexer, or any combination thereof.

[0023] In an implementation, if the calibrators are classified into primary and secondary types, the feature difference calculating unit may be integrated with one calibrator to form an integral primary calibrator. Alternatively, in another implementation, the feature difference calculating unit may be integrated with one baseband processing module to form an integral module.

[0024] It can be seen from the above description that, in the active antenna according to an embodiment of the present invention, each transceiver unit array is corresponding to one calibrator. Each transceiver unit array is not only calibrated by the corresponding calibrator on the same board, but also calibrated by other calibrators disposed on other boards. That is, calibration signals are transferred to transceiver unit arrays and calibrators on other boards through multiplexers disposed on different boards and electromagnetic connection between multiplexers. Each calibrator of the active antenna obtains P feature difference values between P calibration signals passing through all calibration loops of the active antenna and an original calibration signal. In addition, the feature difference calculating unit calculates a feature difference value of a receiving channel and/or transmitting channel of each transceiver unit of the active antenna relative to a reference receiving channel and/or transmitting channel, according to an association relation between a feature difference value and a feature of each calibration loop, and the P feature difference values obtained by each of the calibrators of the active antenna, where the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop of the active antenna and the original calibration signal. In addition, each baseband processing module in the active antenna performs feature compensation on a service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding transceiver unit. Therefore, accurate calibration of the transceiver arrays disposed on different boards is realized.

First Embodiment

[0025] FIG. 1 is a principle block diagram of an active antenna according to a first embodiment of the present invention. In this embodiment, an example that transceiver arrays are distributed on two boards is cited for making detailed illustration. The active antenna includes two antenna dipole arrays, a transceiver unit array (corresponding to one of the antenna dipole arrays) disposed on a first board (that is, a board 1 in FIG. 1), a multiplexer D1, a calibrator E1, a transceiver unit array (corresponding to the other antenna dipole array) disposed on a second board (that is, a board 2 in FIG. 1), a multiplexer D2, and a calibrator E2. A digital signal connection is established between the calibrator E1 and the calibrator E2. A radio frequency (RF) signal connection is established between the multiplexer D1 and the multiplexer D2. The transceiver unit array on the first board includes M transceiver units (that is, TR channels B11 to B1M in FIG. 1). The transceiver unit array on the second board includes N transceiver units (that is, TR channels B21 to B2N in FIG. 1). Each transceiver unit includes a TR channel (a receiving channel and/or a transmitting channel) and a corresponding baseband processing module. $M \geq 2$ and $N \geq 2$.

[0026] The calibrator E1 is configured to obtain (M+N) feature difference values between (M+N) calibration signals passing through all calibration loops of the active antenna and an original calibration signal.

[0027] The calibrator E2 is configured to obtain (M+N) feature difference values between (M+N) calibration signals passing through all calibration loops of the active antenna and an original calibration signal.

[0028] The feature difference calculating unit is configured to calculate a feature difference value of a receiving channel and/or transmitting channel of each transceiver unit of the active antenna relative to a reference receiving channel and/or transmitting channel respectively, according to an association relation between a feature difference value and a feature of each calibration loop, and the (M+N) feature difference values obtained by each calibrator of the active antenna, where the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop of the active antenna and the original calibration signal. In the first embodiment, the feature difference calculating unit is integrated with the calibrator E1 (or integrated with the calibrator E2).

[0029] It should be noted that, each calibration loop includes at least a receiving channel or a transmitting channel. In other words, a receiving channel or a transmitting channel corresponds to one calibration loop.

[0030] Each baseband processing module (A11 to A1M, A21 to A2N) is configured to perform feature compensation on a service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding transceiver unit.

[0031] It should be noted that, the TR channels B11 to B1M and the TR channels B21 to B2N as shown in FIG. 1 have the same functions as that in the prior art, and couplers C11 to C1M and C21 to C2N have the same functions as that in the prior art, the description of which is thus omitted.

[0032] In order to realize the reception calibration on the transceiver arrays distributed on the first board and the second board, the specific description is given as follows.

[0033] The calibrator D1 is specifically configured to send an original reception calibration signal. The original reception calibration signal is divided into M multiplexed signals through the multiplexer D1. The M multiplexed signals enter M reception calibration loops of the active antenna on the first board respectively. The original reception calibration signal is transferred to the multiplexer D2 through the RF signal connection between the multiplexer D1 and the multiplexer D2 and is divided into N multiplexed signals through the multiplexer D2. The N multiplexed signals enter N reception calibration loops of the active antenna on the second board respectively. In addition, the calibrator E1 is configured to receive M reception calibration signals passing through the reception calibration loops of the active antenna on the first

board and N reception calibration signals passing through the reception calibration loops of the active antenna on the second board and that are transferred through the digital signal connection between the calibrator E1 and the calibrator E2, and obtain (M+N) feature difference values between the (M+N) reception calibration signals and the original reception calibration signal sent by the calibrator E1 through comparison, in which $M \geq 2$ and $N \geq 2$. M equals to the number of all receiving channels of the active antenna on the first board. N equals to the number of all receiving channels of the active antenna on the second board.

[0034] It should be noted that, the M reception calibration loops of the active antenna on the first board here are formed by the calibrator E1, the multiplexer D1, M receiving channels, and M corresponding baseband processing modules on the first board. The N reception calibration loops of the active antenna on the second board here are formed by the calibrator E1 and the multiplexer D1 on the first board and the multiplexer D2, N receiving channels, N corresponding baseband processing modules, and the calibrator E2 on the second board.

[0035] The calibrator E2 is specifically configured to send an original reception calibration signal. The original reception calibration signal is divided into N multiplexed signals through the multiplexer D2. The N multiplexed signals enter the N reception calibration loops of the active antenna on the second board respectively. The original reception calibration signal is transferred to the multiplexer D1 through the RF signal connection between the multiplexer D2 and the multiplexer D1 and is divided into M multiplexed signals through the multiplexer D1. The M multiplexed signals enter the M reception calibration loops of the active antenna on the first board respectively. In addition, the calibrator E2 is configured to receive N reception calibration signals passing through the reception calibration loops of the active antenna on the second board and M reception calibration signals passing through the reception calibration loops of the active antenna on the first board and that are transferred through the digital signal connection between the calibrator E1 and the calibrator E2, and obtain (M+N) feature difference values between the (M+N) reception calibration signals and the original reception calibration signal sent by the calibrator E2 through comparison.

[0036] It should be noted that, the N reception calibration loops of the active antenna on the second board here are formed by the calibrator E2, the multiplexer D2, N receiving channels, and N corresponding baseband processing modules on the second board. The M calibration loops of the active antenna on the first board here are formed by the calibrator E2 and the multiplexer D2 on the second board and the multiplexer D1, M receiving channels, M corresponding baseband processing modules, and the calibrator E1 on the first board.

[0037] The feature difference calculating unit is specifically configured to calculate a feature difference value of a receiving channel of each transceiver unit of the active antenna on the first and second boards relative to a reference receiving channel, according to an equivalent relation between a feature difference value and a feature of each reception calibration loop, according to the (M+N) feature difference values obtained by the calibrator E1, and according to the (M+N) feature difference values obtained by the calibrator E2, where the feature difference value is a value about the feature difference between the calibration signal passing through each reception calibration loop of the active antenna and the original calibration signal. In the first embodiment of the present invention, the feature difference calculating unit is integrated with the calibrator E1.

[0038] Specifically, the feature difference value of the receiving channel and/or transmitting channel of each transceiver unit of the active antenna relative to the reference receiving channel and/or transmitting channel is obtained through a matrix operation of arrays respectively, according to (M+N) one-dimensional arrays obtained by the calibrator E1 and (M+N) one-dimensional arrays obtained by the calibrator E2. It should be noted that, after the calibration signal finishes passing through one calibration loop, a one-dimensional array may be obtained. In the embodiment of the present invention, the (M+N) one-dimensional arrays are obtained after the calibration signal sent by the calibrator E1 finishes passing through the (M+N) calibration loops respectively. The (M+N) one-dimensional arrays are obtained after the calibration signal sent by the calibrator E2 finishes passing through the (M+N) calibration loops respectively. A plurality of one-dimensional arrays forms a two-dimensional array. Through the matrix operation, the feature difference value of each receiving channel relative to a certain receiving channel (a reference receiving channel, for example, a receiving channel in the TR channel 11) is obtained.

[0039] Each baseband processing module (A11 to A1M, A21 to A2N) is specifically configured to perform feature compensation on a reception service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel of the corresponding transceiver unit, so that each reception service signal may be coherently accumulated.

[0040] Specifically, the feature difference value of the receiving channel of each transceiver unit of the active antenna on the first and second boards relative to the reference receiving channel is provided for being invoked by (M+N) reception DBF modules located within the baseband processing modules respectively. The process includes the following steps. Post compensation for signal features (an amplitude, a phase, and a delay) is performed in a digital domain for each reception service signal after reception demodulation, so as to counteract differences of features (an amplitude, a phase, and a delay) of the receiving channel of each transceiver unit, so that features (an amplitude, a phase, and a delay) of baseband signals of all receiving channels are equal or distributed according to a certain rule, so as to realize the coherent accumulation of the (M+N) reception service signals, thereby forming a receiving direction diagram of the

antenna, and achieving a receiving sensitivity index of the whole antenna.

[0041] It should be noted that, in order to realize the reception calibration on the transceiver arrays distributed on the first board and the second board, in another implementation, the calibrator E1 is specifically configured to send an original reception calibration signal. The original reception calibration signal is divided into M multiplexed signals through the multiplexer D1. The M multiplexed signals enter M reception calibration loops of the active antenna on the first board respectively. The original reception calibration signal is transferred to the multiplexer D2 through the RF signal connection between the multiplexer D1 and the multiplexer D2 and is divided into N multiplexed signals through the multiplexer D2. The N multiplexed signals enter N reception calibration loops of the active antenna on the second board respectively. In addition, the calibrator E1 is configured to obtain features of M calibration signals passing through the reception calibration loops of the active antenna on the first board and features of N calibration signals passing through the reception calibration loops of the active antenna on the second board and that are transferred through the digital signal connection between the calibrator E1 and the calibrator E2, and obtain (M+N) feature difference values between the features of the (M+N) reception calibration signals and features of the sent original reception calibration signal through comparison.

[0042] The calibrator E2 is specifically configured to send an original reception calibration signal. The original reception calibration signal is divided into N multiplexed signals through the multiplexer D2. The N multiplexed signals enter the N reception calibration loops of the active antenna on the second board respectively. The original reception calibration signal is transferred to the multiplexer D1 through the RF signal connection between the multiplexer D2 and the multiplexer D1 and is divided into M multiplexed signals through the multiplexer D1. The M multiplexed signals enter the M reception calibration loops of the active antenna on the first board respectively. In addition, the calibrator E2 is configured to obtain features of N reception calibration signals passing through the reception calibration loops of the active antenna on the second board and features of M reception calibration signals passing through the reception calibration loops of the active antenna on the first board and that are transferred through the digital signal connection between the calibrator E1 and the calibrator E2, and obtain (M+N) feature difference values between the features of the (M+N) reception calibration signals and the features of the original reception calibration signal through comparison.

[0043] In order to realize the transmission calibration on the transceiver arrays distributed on the first board and the second board, specific description is given below.

[0044] The M baseband processing modules (A11 to AIM) are further configured to send M original transmission calibration signals, where the sending is carried out by the baseband processing modules in sequence one after another, and one baseband processing module carries out the sending after a predetermined delay interval that another baseband processing module carries out the sending. The original transmission calibration signals enter corresponding transmitting channels according to signal transmission directions (that is, the original transmission calibration signals enter transmission calibration loops).

[0045] The N baseband processing modules (A21 to A2N) are further configured to send N original transmission calibration signals, wherein the sending is carried out by the baseband processing modules in sequence one after another, and one baseband processing module carries out the sending after predetermined delay interval in sequence that another baseband processing module carries out the sending. The original transmission calibration signals enter corresponding transmitting channels according to signal transmission directions (that is, the original transmission calibration signals enter transmission calibration loops).

[0046] The calibrator E1 is specifically configured to receive M transmission calibration signals passing through transmission calibration loops of the active antenna on the first board, and N transmission calibration signals passing through transmission calibration loops of the active antenna on the second board and that are transferred through the RF signal connection between the multiplexer D1 and the multiplexer D2, and obtain (M+N) feature difference values between the transmission calibration signals and the (M+N) original transmission calibration signals respectively through comparison, in which $M \geq 2$ and $N \geq 2$. M equals to the number of all transmitting channels of the active antenna on the first board. N equals to the number of all transmitting channels of the active antenna on the second board.

[0047] The calibrator E2 is specifically configured to receive N transmission calibration signals passing through the transmission calibration loops of the active antenna on the second board, and M transmission calibration signals passing through the transmission calibration loops of the active antenna on the first board and that are transferred through the RF signal connection between the multiplexer D1 and the multiplexer D2, and obtain (M+N) feature difference values between the transmission calibration signals and the (M+N) original transmission calibration signals respectively through comparison.

[0048] It should be understood that, M transmission calibration loops may be formed by the M baseband processing modules, corresponding M TR channels (specifically, transmitting channels), the multiplexer D1, and the calibrator E1 on the first board. M transmission calibration loops may be formed by the M baseband processing modules, corresponding M TR channels (specifically, transmitting channels), and the multiplexer D1 on the first board, and the multiplexer D2 and the calibrator E2 on the second board.

[0049] It should be understood that, N transmission calibration loops may be formed by the N baseband processing modules, corresponding N TR channels (specifically, transmitting channels), the multiplexer D2, and the calibrator E2

on the second board. N transmission calibration loops may be formed by the N baseband processing modules, corresponding N TR channels (specifically, transmitting channels), the multiplexer D2 on the second board, the multiplexer D1, and the calibrator E1. It should be noted that, according to the transmission direction of signal streams, connection links or microstrip lines among the component units mentioned above are also components of calibration loops.

[0050] The feature difference calculating unit is specifically configured to calculate a feature difference value of a transmitting channel of each transceiver unit of the active antenna on the first and second boards relative to a reference transmitting channel, according to an equivalent relation between a feature difference value and a feature of each transmission calibration loop, according to the (M+N) feature difference values obtained by the calibrator E1, and according to the (M+N) feature difference values obtained by the calibrator E2 (in the first embodiment of the present invention, the feature difference calculating unit is integrated with the calibrator E1), where the feature difference value is a value about the feature difference between the transmission calibration signal passing through each transmission calibration loop of the active antenna and the original transmission calibration signals.

[0051] Each baseband processing module (A11 to A1M, A21 to A2N) is specifically configured to perform pre-compensation on features of a transmission service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the transmitting channel of the corresponding transceiver unit, so that features of each transmission service signal are distributed at the front end of the transceivers according to a certain rule.

[0052] Specifically, the feature difference value of the transmitting channel of each transceiver unit of the active antenna on the first and second boards relative to the reference transmitting channel is provided for being invoked by (M+N) transmission DBF modules located within the baseband processing modules respectively. The process includes the following steps. Pre-compensation for signal features (an amplitude, a phase, and a delay) is performed in a digital domain for each transmission baseband signal before transmission demodulation, so as to counteract differences of features (an amplitude, a phase, and a delay) of the transmitting channel of each transceiver unit, so that features (an amplitude, a phase, and a delay) of all transmission signals after being modulated and amplified by the transmitting channel are equal at the front end of the transceivers (between an antenna dipole and a duplexer) or distributed according to a certain rule. The transmission signals are converted into electromagnetic waves through the antenna dipole, and the vector composition occurs to the electromagnetic waves in the air, so as to form the required transmission direction diagram of the antenna.

[0053] Furthermore, in the embodiment of the present invention, an interconnection structure as shown in FIG. 2 may be adopted between the multiplexer D1 and the multiplexer D2. FIG. 2 is a schematic view of a passive link for connecting two boards according to an embodiment of the present invention. As shown in FIG. 2, the passive link includes coaxial connectors (female), coaxial connectors (male), and a coaxial cable. The coaxial connectors (male) are respectively disposed at two ends of the coaxial cable. The coaxial connectors (male) are respectively connected to the coaxial connectors (female) disposed on the board 1 and the board 2.

[0054] In another implementation, electromagnetic-wave signal connection may exist between the multiplexer D11 and multiplexer D2.

[0055] Two boards are taken as an example in the above description. It should be understood that, more boards may be adopted, which can be expanded in principle.

[0056] The embodiment of the present invention is applicable to realize calibration on transceiver arrays disposed on different boards. In the active antenna according to the embodiment of the present invention, a mapping relation exists between the calibration modules and the transceiver arrays. That is, each transceiver array corresponds to one calibration module. For example, a transceiver array on the first board corresponds to the calibrator E1, a transceiver array on the second board corresponds to the calibrator E2, ..., and a transceiver array M on the Mth board corresponds to the calibrator EM. Each transceiver array is not only calibrated by the calibrator corresponding to the current transceiver array, but also calibrated by the other (M-1) calibrators besides the calibrator corresponding to the current transceiver array.

[0057] It should be noted that, in the active antenna according to the embodiment of the present invention, the multiplexer D1 on the first board and the multiplexer D2 on the second board have the same structure, shape, and features, or have feature differences that are already known. During the following formula derivation, it is assumed that the multiplexers have the same features by default. The microstrip lines (or strip lines) from couplers C11, C12, ..., C1M to the multiplexer 1 have the same features as the microstrip lines (or strip lines) from C21, C22, ..., C2N to the multiplexer 2. The passive links from the couplers C11, C12, ..., C1M to an input end A1 of the calibrator 1 have the same features as the passive links from C21, C22, ..., C2N to an input end A2 of the calibrator 2. The passive links from the couplers C11, C12, ..., C1M to the input end A2 of the calibrator 2 have the same features as the passive links from C21, C22, ..., C2N to the input end A1 of the calibrator 1. All baseband processing modules on the board 1 and the board 2 are digital circuits and have the same features.

[0058] It can be seen from the above description that, in the active antenna according to the first embodiment of the present invention, a feature difference value of a receiving channel and/or a transmitting channel of each transceiver unit disposed on the first and second boards relative to a reference receiving channel and/transmitting channel is cal-

culated, according to an association relation between a feature difference value and a feature of each calibration loop, according to (M+N) feature difference values obtained by the calibrator E1, and according to (M+N) feature difference values obtained by the calibrator E2, where the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop and the original calibration signal. Then, feature compensation is performed on a service signal of the transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the transceiver unit. Therefore, accurate calibration between transceivers disposed on different boards is realized. That is, the features of a certain receiving channel or transmitting channel are taken as the reference, so as to counteract the feature differences of the receiving channels or transmitting channels of the transceiver units distributed on different boards. Thus, the features (an amplitude, a phase, and a delay) of the service signals of all the receiving channels are equal or distributed according to a certain rule, so as to realize coherent accumulation of the (M+N) reception service signals, thereby forming a required receiving direction diagram of the antenna, and achieving a receiving sensitivity index of the whole antenna. Furthermore, the features (an amplitude, a phase, and a delay) of all transmission signals after being modulated and amplified by the transmitting channel are enabled to become equal at the front end of the transceivers (between an antenna dipole and a duplexer in the TR channel), or distributed according to a certain rule. The transmission signals are converted into electromagnetic waves through the antenna dipole, and the vector composition occurs to the electromagnetic waves in the air, so as to form a required transmission direction diagram of the antenna.

Second Embodiment

[0059] FIG. 3 is a schematic structural view of an active antenna according to a second embodiment of the present invention. Referring to FIG. 3, the active antenna includes two antenna dipole arrays, a transceiver unit array (corresponding to one of the antenna dipole arrays) disposed on a board 1, combiners 1A, 1B, and 1C, and a calibrator F1, a transceiver unit array (corresponding to the other antenna dipole array) disposed on a board 2, combiners 2A, 2B, and 2C, and a calibrator F2. The calibrator F1 and the calibrator F2 are connected through digital signal connection. The combiner 1A and the combiner 1B are connected through a link B1. The combiner 1B and the combiner 1C are connected through a link E1. The combiner 1B and the combiner 2C are connected through a link D1. The combiner 2A and the combiner 2B are connected through a link B2. The combiner 2B and the combiner 2C are connected through a link E2. The combiner 2B and the combiner 1C are connected through a link D2. Structures of the links D1, D2 are the same as the passive links according to the first embodiment of the present invention (referring to FIG. 2).

[0060] Detailed illustration is provided in the following using an example of realizing the reception calibration on transceivers disposed on the board 1 and the board 2.

[0061] The calibrator F1 is configured to send an original reception calibration signal. The original reception calibration signal is divided into two multiplexed reception calibration signals through the combiner 1C. One reception calibration signal passes through the link E1, the combiner 1B, the link B1 and the combiner 1A in sequence according to a signal transmission direction, and then the reception calibration signal is divided into M multiplexed reception calibration signals through the combiner 1A. The M reception calibration signals enter front end positions of M transceiver units through corresponding couplers C11 to C1M respectively, pass through receiving channels and baseband processing modules of the corresponding transceiver units, and return to the calibrator F1. The other reception calibration signal passes through the link D2, the combiner 2B, the link B2, and the combiner 2A in sequence according to a signal transmission direction, and then the reception calibration signal is divided into N multiplexed reception calibration signals through the combiner 2A. The N reception calibration signals enter front end positions of N transceiver units through corresponding couplers C21 to C2N respectively, pass through receiving channels and baseband processing modules of the corresponding transceiver units, and return to the calibrator F2. The calibrator F2 transmits the N reception calibration signals to the calibrator F1 through the digital signal connection with the calibrator F1. Then, (M+N) feature difference values between the received (M+N) reception calibration signals passing through calibration loops and the original reception calibration signal are obtained through comparison. It should be noted that, the digital signal connection between the calibrator F1 and the calibrator F2 does not influence the amplitude and phase of the signals. However, the delay of the signals is influenced, but the influence is quite little and already known.

[0062] It should be understood that, M reception calibration loops are formed by the calibrator F1, the combiner 1C, the combiner 1B, the combiner 1A, M TR channels (specifically, receiving channels), and corresponding M baseband processing modules on the first board. N reception calibration loops are formed by the calibrator F1 and the combiner 1C on the first board, the combiner 2B, the combiner 2A, N TR channels (specifically, receiving channels), corresponding N baseband processing modules, and the calibrator F2 on the second board.

[0063] The calibrator F2 is configured to send an original reception calibration signal. The original reception calibration signal is divided into two multiplexed reception calibration signals through the combiner 2C. One reception calibration signal passes through the link E2, the combiner 2B, the link B2, and the combiner 2A in sequence according to a signal transmission direction, and then the reception calibration signal is divided into N multiplexed reception calibration signals

through the combiner 2A. The N reception calibration signals enter front end positions of N transceiver units through the corresponding couplers C21 to C2N respectively, pass through receiving channels and baseband processing modules of the corresponding transceiver units, and return to the calibrator F2. The other reception calibration signal passes through the link D1 the combiner 1B, the link B1 and the combiner 1A in sequence according to a signal transmission direction, and then the reception calibration signal is divided into M multiplexed reception calibration signals through the combiner 1A. The M reception calibration signals enter front end positions of M transceiver units through the corresponding couplers C11 to C1M respectively, pass through receiving channels and baseband processing modules of the corresponding transceiver units, and return to the calibrator F1. The calibrator F1 transmits the M reception calibration signals to the calibrator F2 through the digital signal connection with the calibrator F2. Then, (M+N) feature difference values between the received (M+N) reception calibration signals passing through calibration loops and the original reception calibration signal are obtained through comparison. It should be noted that, the digital signal connection between the calibrator F1 and the calibrator F2 does not influence the amplitude and phase of the signals. However, the delay of the signals is influenced, but the influence is quite little and already known.

[0064] It should be understood that, the N reception calibration loops are formed by the calibrator F2, the combiner 2C, the combiner 2B, the combiner 2A, N TR channels (specifically, receiving channels), and corresponding N baseband processing modules on the second board. The M reception calibration loops are formed by the calibrator F2 and the combiner 2C on the second board, the combiner 1B, the combiner 1A, M TR channels (specifically, receiving channels), corresponding M baseband processing modules, and the calibrator F1 on the first board. It should be noted that, the calibration loops indicate each component where the calibration signals pass through and connection links between the components.

[0065] The feature difference calculating unit is configured to calculate a feature difference value of a receiving channel of each transceiver unit of the active antenna on the first and second boards relative to a reference receiving channel, according to an equivalent relation between a feature difference value and a feature of each reception calibration loop, according to (M+N) feature difference values obtained by the calibrator F1, and according to (M+N) feature difference values obtained by the calibrator F2, where the feature difference value is a value about the feature difference between a calibration signal passing through each reception calibration loop of the active antenna and the original calibration signal. In the second embodiment of the present invention, the feature difference calculating unit is integrated with the calibrator F1 (the feature difference calculating unit may also be integrated with the calibrator F2).

[0066] Each baseband processing module (A11 to A1M, A21 to A2N) is configured to perform post feature compensation on a reception service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel of the corresponding transceiver unit, so that each reception service signal can be coherently accumulated, thereby forming a required receiving direction diagram of the antenna, and achieving a receiving sensitivity index of the whole antenna.

[0067] It should be noted that, in the active antenna according to the embodiment of the present invention, the combiners 1A, 1B and 1C on the first board and the combiners 2A, 2B, and 2C on the second board have the same structures and shapes. The links B1, B2 have the same features. The links E1, E2 have the same features. The microstrip lines (or strip lines) from the couplers C11, C12, ..., C1M to the combiner 1A have the same features as the microstrip lines (or strip lines) from C21, C22, ..., C2N to the combiner 2A. The links D1, D2 also have the same features. The passive links from the couplers C11, C12, ..., C1M to the input end A1 of the calibrator F1 have the same features as the passive links from C21, C22, ..., C2N to the input end A2 of the calibrator F2. The passive links from the couplers C11, C12, ..., C1M to the input end A2 of the calibrator F2 have the same features as the passive links from C21, C22, ..., C2N to the input end A1 of the calibrator F1. All the baseband processing modules on the board 1 and the board 2 have the same features.

[0068] In order to illustrate the functions of the feature difference calculating unit clearly, in the embodiment of the present invention, the calculation process thereof is illustrated as follows in detail.

1. The features of a TR channel B11, a TR channel B12, ..., a TR channel B1M on the board 1 are STR11, STR12, ..., STR1M respectively.

The features of a TR channel B21, a TR channel B22, ..., a TR channel B2N on the board 2 are STR21, STR22, ..., STR2N respectively (in which M and N may be the same or different, that is, the numbers of transceiver units on the two boards may be the same or different).

2. The combiners are passive. On different boards, as long as the combiners have the same structures and shapes, the features of the combiners are hardly scattered, which can be omitted. Therefore, the combiner 1A and the combiner 2A are considered as having the same features. Similarly, the rest combiners are considered in the same way.

[0069] Similarly, the links B1, B2 have the same features, and the links E1, E2 have the same features.

[0070] Similarly, the microstrip lines (or strip lines) from the couplers C11, C12, ..., C1M to the combiner 1A have the same features as the microstrip lines (or strip lines) from C21, C22, ..., C2N to the combiner 2A.

[0071] Both the links D1, D2 have the structures as shown in FIG. 2 and the cables have the same length. Therefore, the links D1, D2 also have the same features.

[0072] According to the addition and subtraction principles of the features such as an amplitude, a phase, and a delay, the following two aspects can be easily achieved.

[0073] The features SAC11 of the passive links from the couplers C11, C12, ..., C1M to the input end A1 of the calibrator F2 are the same as the features SAC22 of the passive links from C21, C22, ..., C2N to the input end A2 of the calibrator F2, which are set as SACC.

[0074] The features SAC12 of the passive links from the couplers C11, C12, ..., C1M to the input end A2 of the calibrator F2 are the same as the features SAC21 of the passive links from C21, C22, ..., C2N to the input end A1 of the calibrator F1, which are set as SACD.

3. The calibrators are shared. The feature of the calibrator F2 on the board 1 is SCAL1, and the feature of the calibrator F2 on the board 2 is SCAL2.

4. Each baseband processing module is a digital circuit. Therefore, the features of all the baseband processing modules on the board 1 and the board 2 are the same or already known, which are simply represented by SBB.

5. The calibrator F2 on the board 1 calibrates the transceiver units of the active antenna on the board 1 and the board 2 according to the embodiment of the present invention. It can be understood that, after the calibration signals finish passing through the calibration loops, the feature differences between the received (M+N) calibration signals and the sent original calibration signal are SE111, SE112, ..., SE11M, SE121, SE122, ..., SE12N respectively. The calibrator F2 on the board 2 calibrates the transceiver units of the active antenna on the board 1 and the board 2 according to the embodiment of the present invention. It can be understood that, after the calibration signals finish passing through the calibration loops, the feature differences between the received (M+N) calibration signals and the sent original calibration signal are SE211, SE212,SE21M, SE221, SE222, ..., SE22N respectively.

[0075] The calibrator F1 on the board 1 calibrates all the (M+N) transceiver units of the active antenna on the board 1 and the board 2 according to the embodiment of the present invention, and the following equations are listed.

$$\text{STR11} + \text{SACC} + \text{SCAL1} + \text{SBB} = \text{SE111}$$

$$\text{STR12} + \text{SACC} + \text{SCAL1} + \text{SBB} = \text{SE112}$$

.....

$$\text{STR1M} + \text{SACC} + \text{SCAL1} + \text{SBB} = \text{SE11M} \quad \text{.....Equation Set 1}$$

$$\text{STR21} + \text{SACD} + \text{SCAL1} + \text{SBB} = \text{SE121}$$

$$\text{STR22} + \text{SACD} + \text{SCAL1} + \text{SBB} = \text{SE122}$$

.....

$$\text{STR2N} + \text{SACD} + \text{SCAL1} + \text{SBB} = \text{SE12N} \quad \text{.....Equation Set 2}$$

[0076] Similarly, the calibrator F2 on the board 2 calibrates all the (M+N) transceiver units on the board 1 and the board 2, and the following equations are listed.

$$\text{STR11} + \text{SACD} + \text{SCAL2} + \text{SBB} = \text{SE211}$$

$$\text{STR12} + \text{SACD} + \text{SCAL2} + \text{SBB} = \text{SE212}$$

.....

$$\text{STR1M} + \text{SACD} + \text{SCAL2} + \text{SBB} = \text{SE21M} \quad \text{.....Equation Set 3}$$

$$\text{STR21} + \text{SACC} + \text{SCAL2} + \text{SBB} = \text{SE221}$$

$$\text{STR22} + \text{SACC} + \text{SCAL2} + \text{SBB} = \text{SE222}$$

.....

$$\text{STR2N} + \text{SACC} + \text{SCAL2} + \text{SBB} = \text{SE22N} \quad \text{.....Equation Set 4}$$

[0077] In the equation sets formed by the above $2*(M+N)$ equations, only the STR11, STR12, ..., STR1M, STR21, STR22, ..., STR2N, SACC, SACD, SCAL1 and SCAL2 are unknown, that is, totally $(M+N+4)$ unknowns. Therefore, the equation sets must have solutions (any board has at least two transceivers, $M \geq 2$ and $N \geq 2$, so that $2*(M+N) \geq M+N+4$, that is, the number of equations is greater than the number of the unknowns).

[0078] A plurality of methods may be adopted for solving the equation sets, as long as a difference of the features of each transceiver is acquired.

[0079] For example, in the embodiment of the present invention, the 1st equation in the Equation Set 1 is respectively subtracted from the 2nd, 3rd, ..., Mth equations in the Equation Set 1 to obtain an Equation Set 5.

$$\text{STR12} - \text{STR11} = \text{SE112} - \text{SE111}$$

.....

$$\text{STR1M} - \text{STR11} = \text{SE11M} - \text{SE111} \quad \text{.....Equation Set 5}$$

[0080] As seen from FIG. 1, the STR12 represents the feature of the TR channel 12 on the board 1, and the STR11 represents the feature of the TR channel 11 on the board 1.

[0081] The Equation Set 5 indicates that the calibrator F2 on the board 1 can calibrate all the M transceivers on the board 1.

[0082] The 1st equation in the Equation Set 1 is added with the 1st equation in the Equation Set 3 to obtain an Equation 6.

$$\text{STR11} + \text{SACC} + \text{SCAL1} + \text{SBB} + \text{STR11} + \text{SACD} + \text{SCAL2} + \text{SBB} = \text{SE111} + \text{SE211}$$

.....Equation 6

[0083] The 1st, 2nd, ..., Nth equations in the Equation Set 2 are added with the 1st, 2nd, ..., Nth equations in the Equation Set 4 respectively, so as to obtain an Equation Set 7.

$$\text{STR21} + \text{SACD} + \text{SCAL1} + \text{SBB} + \text{STR21} + \text{SACC} + \text{SCAL2} + \text{SBB} = \text{SE121} + \text{SE221}$$

$$\text{STR22} + \text{SACD} + \text{SCAL1} + \text{SBB} + \text{STR22} + \text{SACC} + \text{SCAL2} + \text{SBB} = \text{SE122} + \text{SE222}$$

.....

$$\text{STR2N} + \text{SACD} + \text{SCAL1} + \text{SBB} + \text{STR2N} + \text{SACC} + \text{SCAL2} + \text{SBB} = \text{SE12N} + \text{SE22N}$$

.....Equation Set 7

[0084] The Equation 6 is respectively subtracted from all the equations in the Equation Set 7 to obtain an Equation Set 8.

$$\text{STR21} - \text{STR11} = ((\text{SE221} + \text{SE121}) - (\text{SE211} + \text{SE111}))/2$$

$$\text{STR22} - \text{STR11} = ((\text{SE222} + \text{SE122}) - (\text{SE211} + \text{SE111}))/2$$

.....

$$\text{STR2N} - \text{STR11} = ((\text{SE22N} + \text{SE12N}) - (\text{SE211} + \text{SE111}))/2 \text{Equation Set 8}$$

[0085] As seen from FIG. 1, the STR21, STR22, ..., STR2N respectively represent the feature of the TR channel B21, TR channel B22, ..., TR channel B2N of the active antenna on the board 2 according to the embodiment of the present invention. The STR11 represents the feature of the TR channel B11 of the active antenna on the board 1 according to the embodiment of the present invention.

[0086] As seen from the above description, the Equation Set 5 and the Equation Set 8 represent that, by taking the features of the first transceiver of the active antenna on the board 1 according to the embodiment of the present invention as the reference, the features of all the other transceivers on the two boards can be obtained. Therefore, the cross calibration method according to the embodiment of the present invention can calibrate all the transceiver units of the transceiver arrays distributed on two boards, which are specifically receiving channels and/or transmitting channels of the transceiver units.

[0087] It should be noted that, the foregoing derivation process is illustrated by taking, for example, the features of the first transceiver of the active antenna on the board 1 as the reference. However, the present invention is not limited thereto. The features of the second transceiver of the active antenna on the board 1 may also be taken as the reference. Alternatively, the features of the first transceiver of the active antenna on the board 2 may be taken as the reference, and so forth. It should be understood that, if the calibration signal is a reception calibration signal, the feature difference of the receiving channel of each transceiver unit of the transceiver arrays distributed on the boards 1, 2 of the active antenna according to the embodiment of the present invention relative to the reference receiving channel is calculated. If the calibration signal is a transmission calibration signal, the feature difference of the transmitting channel of each transceiver unit of the transceiver arrays distributed on the boards 1, 2 of the active antenna according to the embodiment of the present invention relative to the reference transmitting channel is calculated.

[0088] Furthermore, in the embodiment of the present invention, not only the feature difference of the receiving channel and/or transmitting channel of each transceiver unit of the transceiver arrays distributed on the boards 1, 2 relative to the reference receiving channel and/or transmitting channel can be calculated, but also the feature difference between the calibrator F1 disposed on the board 1 and the calibrator F2 disposed on the board 2 can be calculated.

[0089] As known from the first equation in the Equation Set 1 and the first equation in the Equation Set 3, for example, when the TR channel B11 serves as a shared "calibrator" to calibrate the difference between the calibrator F1 and the calibrator F2, the feature difference between the link B1 (or B2) and the link D1 (or D2) is also mixed in the calibration.

[0090] Thus, the first equation in the Equation Set 2 and the first equation in the Equation Set 4 are further compared, that is, the TR channel B21 serves as the shared "calibrator" to calibrate the feature difference between the calibrator F1 and the calibrator F2 once again. Although the feature difference between the link B1 (or B2) and the link D1 (or D2) is mixed, the feature difference between the calibrator F1 and the calibrator F2 can be calculated as long as the four equations are made into simultaneous equations:

$$\text{SCAL1} - \text{SCAL2} = ((\text{SE111} + \text{SE121}) - (\text{SE211} + \text{SE221}))/2 \text{Equation Set 9}$$

[0091] It can be seen from the above description that, in the embodiment of the present invention, any TR channel may serve as a shared "calibrator" to calibrate the feature difference between the calibrator F1 and the calibrator F2.

[0092] As seen from the above description, in the active antenna according to the embodiment of the present invention, the feature difference values of receiving channels of all transceiver units of the active antenna on the first and second boards according to the embodiment of the present invention relative to any receiving channel of the active antenna on the first and second boards according to the embodiment of the present invention are calculated, according to an equivalent relation between a feature difference value and a feature of each calibration loop, according to (M+N) feature difference values obtained by the calibrator F1, and according to (M+N) feature difference values obtained by the calibrator F2, where the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop and the original calibration signal. According to the feature difference value of the receiving channel of each transceiver unit, post compensation for signal features is performed on a reception service signal of the corresponding transceiver unit. Therefore, accurate calibration between the transceivers disposed on different boards is realized. That is, the features of any receiving channel may be taken as the reference, so as to counteract the feature differences of receiving channels of all transceiver units distributed on different boards. Furthermore, the features (an amplitude, a phase, and a delay) of the service signals of all the receiving channels are made to be equal or distributed according to a certain rule, so as to realize coherent accumulation of (M+N) reception service signals, thereby forming a required receiving direction diagram of the antenna, and achieving a receiving sensitivity index of the whole antenna.

Third Embodiment

[0093] FIG. 4 is a schematic structural view of another active antenna according to a third embodiment of the present invention. Referring to FIG. 4, the differences between the third embodiment and the second embodiment lie in that, one combiner is omitted on each board, and a link D is provided between boards to realize interconnection (transmission) of calibration RF signals between the boards. Specifically, the active antenna includes two antenna dipole arrays, a transceiver unit array (corresponding to one of the antenna dipole arrays) disposed on a board 1, combiners 1A, 1B, a calibrator E1, a transceiver unit array (corresponding to the other antenna dipole array) disposed on a board 2, combiners 2A, 2B, and a calibrator E2. The calibrator E1 and the calibrator E2 are connected through digital signal connection. The combiner 1A and the combiner 1B are connected through a link B1. The combiner 1B and the calibrator E1 are connected. The combiner 1B and the combiner 2B are connected through a link D. The combiner 2A and the combiner 2B are connected through a link B2. The combiner 2B and the calibrator E2 are connected. The other connection relations are the same as that in the prior art, the description of which is omitted here. FIG. 2 is a schematic structural view of the link D.

[0094] Detailed illustration is provided in the following using an example of realizing the reception calibration on transceivers disposed on the board 1 and the board 2.

[0095] The calibrator E1 is configured to send an original reception calibration signal. The original reception calibration signal is divided into two multiplexed reception calibration signals through the combiner 1B. One reception calibration signal passes through the link B1 and the combiner 1A in sequence according to a signal transmission direction, and then the reception calibration signal is divided into M multiplexed reception calibration signals through the combiner 1A. The M reception calibration signals enter front end positions of M transceiver units through corresponding couplers C11 to C1M respectively, pass through receiving channels and baseband processing modules of the corresponding transceiver units, and return to the calibrator E1. The other reception calibration signal passes through the link D, the combiner 2B, the link B2, and the combiner 2A in sequence according to a signal transmission direction, and then the reception calibration signal is divided into N multiplexed reception calibration signals through the combiner 2A. The N reception calibration signals enter front end positions of N transceiver units through corresponding couplers C21 to C2N respectively, pass through receiving channels and baseband processing modules of the corresponding transceiver units, and return to the calibrator E2. The calibrator E2 transmits the N reception calibration signals to the calibrator E1 through the digital signal connection with the calibrator E1, and obtains (M+N) feature difference values between the received (M+N) reception calibration signals passing through calibration loops and the original reception calibration signal through comparison. It should be noted that, the digital signal connection between the calibrator E1 and the calibrator E2 does not influence the amplitude and phase of the signals. However, the delay of the signals is influenced, but the influence is quite little and already known.

[0096] It should be understood that, M reception calibration loops are formed by the calibrator E1, the combiner 1B, the combiner 1A, M TR channels (specifically, receiving channels), and corresponding M baseband processing modules on the first board. N reception calibration loops are formed by the calibrator E1 and the combiner 1B on the first board and the combiner 2B, the combiner 2A, N TR channels (specifically, receiving channels), corresponding N baseband processing modules, and the calibrator E2 on the second board.

[0097] The calibrator E2 is configured to send an original reception calibration signal. The original reception calibration

signal is divided into two multiplexed reception calibration signals through the combiner 2B. One reception calibration signal passes through the link B2 and the combiner 2A in sequence according to a signal transmission direction, and then the reception calibration signal is divided into N multiplexed reception calibration signals through the combiner 2A. The N reception calibration signals enter front end positions of the N transceiver units through the corresponding couplers C21 to C2N respectively, pass through the receiving channels and the baseband processing modules of the corresponding transceiver units, and return to the calibrator E2. The other reception calibration signal passes through the link D, the combiner 1B, the link B1, and the combiner 1A in sequence according to a signal transmission direction, and then the reception calibration signal is divided into M multiplexed reception calibration signals through the combiner 1A. The M reception calibration signals enter front end positions of the M transceiver units through the corresponding couplers C11 to C1M respectively, pass through the receiving channels and the baseband processing modules of the corresponding transceiver units, and return to the calibrator E1. The calibrator E1 transmits the M reception calibration signals to the calibrator E2 through the digital signal connection with the calibrator E2, and obtains (M+N) feature difference values between the received (M+N) reception calibration signals passing through calibration loops and the original reception calibration signal through comparison. It should be noted that, the digital signal connection between the calibrator E1 and the calibrator E2 does not influence the amplitude and phase of the signals. However, the delay of the signals is influenced, but the influence is quite little and already known.

[0098] It should be understood that, N reception calibration loops are formed by the calibrator E2, the combiner 2B, the combiner 2A, N TR channels (specifically, receiving channels), corresponding N baseband processing modules on the second board. M reception calibration loops are formed by the calibrator E2 and the combiner 2B on the second board, the combiner 1B, the combiner 1A, M TR channels (specifically, receiving channels), corresponding M baseband processing modules, and the calibrator E1 on the first board.

[0099] In the embodiment of the present invention, the calibrator E1 serves as a primary calibrator, and is further configured to calculate a feature difference value of a receiving channel of each transceiver unit of the active antenna on the first and second boards relative to a reference receiving channel, according to an equivalent relation between a feature difference value and a feature of each reception calibration loop, according to (M+N) feature difference values obtained by the calibrator E1, and according to (M+N) feature difference values obtained by the calibrator E2, where the feature difference value is a value about the feature difference between a reception calibration signal passing through each reception calibration loop of the active antenna and the original reception calibration signal.

[0100] Each of the (M+N) baseband processing modules (A11 to A1M, A21 to A2N) is configured to perform post feature compensation on a reception service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel of the corresponding transceiver unit, so that each reception service signal can be coherently accumulated, thereby forming a required receiving direction diagram of the antenna, and achieving a receiving sensitivity index of the whole antenna.

[0101] It should be noted that, in the active antenna according to the embodiment of the present invention, the combiners 1A, 1B on the first board and the combiners 2A, 2B on the second board have the same structures and shapes. The links B1, B2 have the same features. The microstrip lines (or strip lines) from the couplers C11, C12, ..., C1M to the combiner 1A have the same features as the microstrip lines (or strip lines) from C21, C22, ..., C2N to the combiner 2A. The passive links from the couplers C11, C12, ..., C1M to an input end A1 of the calibrator E1 have the same features as the passive links from C21, C22, ..., C2N to an input end A2 of the calibrator E2. The passive links from the couplers C11, C12, ..., C1M to the input end A2 of the calibrator E2 have the same features as the passive links from C21, C22, ..., C2N to the input end A1 of the calibrator E1. All the baseband processing modules on the board 1 and the board 2 have the same features.

[0102] Furthermore, in order to realize the transmission calibration on the transceiver arrays distributed on the first board and the second board, specific description is given below.

[0103] In the active antenna according to the embodiment of the present invention, the (M+N) baseband processing modules (A11 to A1M, A21 to A2N) are further configured to send (M+N) original transmission calibration signals (it should be noted that, each baseband processing module sends an original transmission calibration signal), where the sending is carried out by the baseband processing modules in sequence one after another, and one baseband processing module carries out the sending after a predetermined delay interval that another baseband processing module carries out the sending. The original transmission calibration signals enter corresponding transmitting channels (B11 to B1M, B21 to B2N) according to signal transmission directions and reach corresponding couplers (C11 to C1M, C21 to C2N). The M transmission calibration signals on the board 1 are combined into one transmission calibration signal through the combiner 1A. The transmission calibration signal is transmitted to the combiner 1B through the link B1 and is divided into two multiplexed transmission calibration signals through the combiner 1B. One of the two transmission calibration signals returns to the calibrator E1. The other transmission calibration signal reaches the combiner 2B through the link D and returns to the calibrator E2. The N transmission calibration signals on the board 2 are combined into one transmission calibration signal through the combiner 2A. The transmission calibration signal is transmitted to the combiner 2B through the link B2 and is divided into two multiplexed transmission calibration signals through the combiner 2B. One

of the two transmission calibration signals returns to the calibrator E2. The other transmission calibration signal reaches the combiner 1B through the link D and returns to the calibrator E1.

[0104] It should be understood that, M transmission calibration loops are formed by the M baseband processing modules, corresponding M TR channels (specifically, transmitting channels), the combiner 1A, the combiner 1B, and the calibrator E1 on the first board. M transmission calibration loops are formed by the M baseband processing modules, corresponding M TR channels (specifically, transmitting channels), the combiner 1A, and the combiner 1 B on the first board, the combiner 2B and the calibrator E2 on the second board.

[0105] It should be understood that, N transmission calibration loops are formed by the N baseband processing modules, corresponding N TR channels (specifically, transmitting channels), the combiner 2A, the combiner 2B, and the calibrator E2 on the second board. N transmission calibration loops are formed by the N baseband processing modules, corresponding N TR channels (specifically, transmitting channels), the combiner 2A, and the combiner 2B on the second board, the combiner 1B, and the calibrator E1. It should be noted that, according to the transmission direction of signal streams, connection links or microstrip lines among the component units mentioned above are also components of calibration loops.

[0106] The calibrator E1 is further configured to receive the M transmission calibration signals passing through transmission calibration loops of the active antenna on the first board, and the N transmission calibration signals passing through transmission calibration loops of the active antenna on the second board and that are transferred through the link D between the combiner 1B and the combiner 2B, and obtain (M+N) feature difference values between the transmission calibration signals and the (M+N) original transmission calibration signals respectively through comparison. M equals to the number of all transmitting channels of the active antenna on the first board. N equals to the number of all transmitting channels of the active antenna on the second board.

[0107] The calibrator E2 is further configured to receive the N transmission calibration signals passing through the transmission calibration loops of the active antenna on the second board, and the M transmission calibration signals passing through the transmission calibration loops of the active antenna on the first board and that are transferred through the link D between the combiner 1B and the combiner 2B, and obtain (M+N) feature difference values between the transmission calibration signals and the (M+N) original transmission calibration signals respectively through comparison.

[0108] In the embodiment of the present invention, the calibrator E1 serves as a primary calibrator, and is further configured to calculate a feature difference value of a transmitting channel of each transceiver unit of the active antenna on the first and second boards relative to a reference transmitting channel, according to an equivalent relation between a feature difference value and a feature of each transmission calibration loop, according to the (M+N) feature difference values obtained by the calibrator E1, and according to the (M+N) feature difference values obtained by the calibrator E2, where the feature difference value is a value about the feature difference between a transmission calibration signal passing through each transmission calibration loop of the active antenna and the original transmission calibration signal.

[0109] Each baseband processing module (A11 to A1M, A21 to A2N) is further configured to perform pre-compensation on features of a transmission service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the transmitting channel of the corresponding transceiver unit, so that the features of each transmission service signal are distributed at the front end of the transceivers according to a certain rule.

[0110] As seen in the above description, in the active antenna according to the embodiment of the present invention, the feature difference values of receiving channels and/or transmitting channels of all the transceiver units of the active antenna on the first and second boards according to the embodiment of the present invention relative to the reference receiving channel and/or transmitting channel are calculated, according to an equivalent relation between a feature difference value and a feature of each calibration loop, according to the (M+N) feature difference values obtained by the calibrator E1, and according to the (M+N) feature difference values obtained by the calibrator E2, where the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop and the original calibration signal. Then, feature compensation is performed on reception service signals and/or transmission service signals of the corresponding transceiver unit according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding transceiver unit. Therefore, accurate calibration between transceivers disposed on different boards is realized. That is, the features of any receiving channel may be taken as the reference, so as to counteract feature differences of the receiving channels and/or transmitting channels of all the transceiver units distributed on different boards. Thus, the features (an amplitude, a phase, and a delay) of the service signals of all the receiving channels are equal or distributed according to a certain rule, so as to realize coherent accumulation of (M+N) reception service signals, thereby forming a required receiving direction diagram of the antenna, and achieving a receiving sensitivity index of the whole antenna. Furthermore, the features (an amplitude, a phase, and a delay) of all transmission signals after being modulated and amplified by the transmitting channels are enabled to become equal at the front end of the transceivers (between an antenna dipole and a duplexer in the TR channel), or distributed according to a certain rule. The transmission signals are converted into electromagnetic waves through the antenna dipole, and the vector composition occurs to the electromagnetic waves in the air, so as to form a required

transmission direction diagram of the antenna.

[0111] Two boards are taken as an example in the above description. However, in the active antenna according to the embodiment of the present invention, the transceiver arrays may be distributed on a plurality of boards, for example, distributed on 1st to Kth (K is a positive integer greater than or equal to 2) boards.

[0112] FIG. 5 is a peripheral block diagram of combiners when transceiver arrays in an active antenna are distributed at three boards according to an embodiment of the present invention. It should be noted that, the combiner 1A, the combiner 1B, and the calibrator E1 are disposed on the first board. The combiner 2A, the combiner 2B, and the calibrator E2 are disposed on the second board. A combiner 3A, a combiner 3B, and a calibrator E3 are disposed on a third board. The other connection relations on the boards are the same as that in the foregoing embodiments, the description of which is omitted here.

[0113] As shown in FIG. 5, the combiner 1B disposed on the first board and the combiner 2B disposed on the second board are connected through a link D12, so as to transfer calibration signals between the boards. The combiner 1B disposed on the first board and the combiner 3B disposed on the third board are connected through a link D13, so as to transfer calibration signals between the boards. The combiner 2B disposed on the second board and the combiner 3B disposed on the third board are connected through a link D23, so as to transfer calibration signals between the boards. The calibrators disposed on the boards may be connected in pairs through signal lines CAL 12, CAL 13, and CAL 23.

[0114] In another implementation, as digital signals between the boards can be cascaded, the CAL 13 can be omitted, so that the calibrator E1 and the calibrator E3 are interconnected through the calibrator E2. It should be understood that, four or more boards may be used in the embodiments of the present invention. When the transceiver arrays in the active antenna are distributed on three boards according to the embodiment of the present invention, peripheral physical structures of the combiners are shown in FIG. 5. The calibration solution may be obtained with reference to this embodiment, the description of which is omitted.

Fourth Embodiment

[0115] Referring to FIG. 6, a calibration method is provided according to a fourth embodiment of the present invention, which is applied to an active antenna including 1st to Kth transceiver unit arrays, corresponding 1st to Kth multiplexers, and corresponding 1st to Kth calibrators correspondingly disposed on 1st to Kth boards respectively. K is a positive integer greater than or equal to 2. The method includes the following steps.

[0116] In step S601, the 1st to Kth calibrators obtain P feature difference values between P calibration signals passing through all calibration loops of the active antenna on the 1st to Kth boards and an original calibration signal. P equals to the number of all transceiver units of the 1st to Kth transceiver unit arrays.

[0117] In step S602, a feature difference value of a receiving channel and/or transmitting channel of each transceiver unit of the active antenna relative to a reference receiving channel and/or transmitting channel is calculated respectively, according to an association relation between a feature difference value and a feature of each calibration loop, and the P feature difference values obtained by each calibrator of the active antenna, where the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop of the active antenna and the original calibration signal.

[0118] The reference receiving channel and/or transmitting channel here is a receiving channel and/or transmitting channel of any transceiver unit included in the 1st to Kth transceiver unit arrays respectively.

[0119] The feature difference here is represented by three indexes, that is, an amplitude, a phase, and a delay of the transceiver unit (specifically, receiving channel and/or transmitting channel).

[0120] In step S603, feature compensation is performed on a service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding transceiver unit.

[0121] In the calibration method according to the embodiment of the present invention, if the calibration signal is a reception calibration signal, the method further includes the following steps. Each calibrator sends an original reception calibration signal. The original reception calibration signal is divided into a plurality of multiplexed signals through the multiplexer of the active antenna on the current board. Said a plurality of multiplexed signals enters reception calibration loops of the active antenna on the current board respectively. In addition, the original reception calibration signal is transferred to multiplexers among the K multiplexers and other than the current multiplexer itself through electromagnetic connection between multiplexers, and then the original reception calibration signal is divided into a plurality of multiplexed signals through each of the other multiplexers. Said a plurality of multiplexed signals enters reception calibration loops of the active antenna on each of the other boards respectively.

[0122] In an implementation, in step S601, the obtaining the P feature difference values between the P calibration signals passing through all the calibration loops of the active antenna on the 1st to Kth boards and the original calibration signal includes receiving P reception calibration signals passing through all reception calibration loops of the active antenna on the 1st to Kth boards and obtaining P feature difference values between the P reception calibration signals

and the original reception calibration signal through comparison.

[0123] In the calibration method according to the embodiment of the present invention, if the calibration signal is a transmission calibration signal, the method further includes the following steps. Each baseband processing module sends an original transmission calibration signal, where the sending is carried out by the baseband processing modules in sequence one after another, and one baseband processing module carries out the sending after a predetermined delay interval that another baseband processing module carries out the sending. Each original transmission calibration signal enters a corresponding transmitting channel according to a signal transmission direction.

[0124] In another implementation, in step S601, the obtaining the P feature difference values between the P calibration signals passing through all the calibration loops of the active antenna on the 1st to Kth boards and the original calibration signal includes: receiving I transmission calibration signals passing through transmission calibration loops of the active antenna on the current board, in which I equals to the number of all transmitting channels of the active antenna on the current board; receiving (P-I) transmission calibration signals transferred through electromagnetic connection between multiplexers; and comparing the P transmission calibration signals with the P original transmission calibration signals respectively to obtain P feature difference values.

[0125] In an implementation, step S602 includes the following steps.

[0126] The feature difference value of the receiving channel and/or transmitting channel of each transceiver unit disposed on each board relative to the reference receiving channel and/or transmitting channel is obtained through a matrix operation of arrays respectively, according to P one-dimensional arrays corresponding to all calibration loops where calibration signals pass through. The one-dimensional array represents features of each component in the corresponding calibration loop where the signal is transmitted, and the feature difference value between the calibration signal passing through the calibration loop and the original calibration signal. It should be understood that, the components here include multiplexers, TR channels, baseband processing modules, calibrators, and connection links between the foregoing components according to the transmission direction of signal streams.

[0127] Therefore, in the embodiment of the present invention, the feature difference value of the receiving channel and/or transmitting channel of each transceiver unit disposed on different boards relative to the reference receiving channel and/or transmitting channel is calculated, according to the association relation between the feature difference value and a feature of each calibration loop, where the feature difference value is a value about the feature difference between the calibration signal passing through each calibration loop and the original calibration signal. Then, the feature compensation is performed on a service signal of the corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding transceiver unit. Therefore, accurate calibration between transceivers disposed on different boards is realized. That is, the features of any receiving channel or transmitting channel may be taken as the reference, so as to counteract feature differences of the receiving channels or transmitting channels of the transceiver units distributed on different boards. Thus, the features (an amplitude, a phase, and a delay) of service signals of all the receiving channels are equal or distributed according to a certain rule, so as to realize coherent accumulation of (M+N) reception service signals, thereby forming a required receiving direction diagram of the antenna, and achieving a receiving sensitivity index of the whole antenna. Furthermore, the features (an amplitude, a phase, and a delay) of all transmission signals after being modulated and amplified by the transmitting channels are enabled to become equal at the front end of the transceivers (between an antenna dipole and a duplexer), or distributed according to a certain rule. The transmission signals are converted into electromagnetic waves through the antenna dipole, and the vector composition occurs to the electromagnetic waves in the air, so as to form a required transmission direction diagram of the antenna.

Fifth Embodiment

[0128] Detailed illustration is provided in the following using an example of realizing the reception calibration on transceiver arrays disposed on different boards.

[0129] FIG. 7 is a flow chart of a calibration method according to a fifth embodiment of the present invention. In the embodiment of the present invention, another calibration method is provided, which is applied in the active antenna as shown in FIG. 1. Referring to FIG. 7, the method includes the following steps.

[0130] In step S701, a calibrator E1 sends an original reception calibration signal.

[0131] In step S701', a calibrator E2 sends an original reception calibration signal.

[0132] In step S702, the original reception calibration signal passes through a multiplexer D 1 and M couplers on a board 1 and enters front end positions of M transceivers on the board 1 respectively. The original reception calibration signal enters front end positions of N transceivers on a board 2 respectively through the multiplexer D1, electromagnetic connection between the multiplexer D1 and a multiplexer D2, the multiplexer D2, and N couplers on the board 2.

[0133] In step S702', the original reception calibration signal passes through the multiplexer D2 and the N couplers on the board 2 and enters the front end positions of the N transceivers on the board 2 respectively. The original reception calibration signal enters the front end positions of the M transceivers on the board 1 respectively through the multiplexer

D2, the electromagnetic connection between the multiplexer D2 and the multiplexer D1, the multiplexer D1, and the M couplers on the board 1.

[0134] In step S703, the reception calibration signal passes through a receiving channel and a baseband processing module of each transceiver on the board 1 and the board 2, and reaches the calibrator E1.

[0135] In step S703', the reception calibration signal passes through a receiving channel and a baseband processing module of each transceiver on the board 1 and the board 2, and reaches the calibrator E2.

[0136] In step S704, the calibrator E1 obtains feature differences between the sent original reception calibration signal and the received reception calibration signals through comparison, so as to obtain (N+M) one-dimensional arrays.

[0137] In step S704', the calibrator E2 obtains feature differences between the sent original reception calibration signal and the received reception calibration signals through comparison, so as to obtain (N+M) one-dimensional arrays.

[0138] In step S705, feature difference values representing feature differences of receiving channels of all the transceiver units of the active antenna on the board 1 and the board 2 are obtained through a matrix operation of arrays according to the (N+M) one-dimensional arrays obtained in step S704 and the (N+M) one-dimensional arrays obtained in step S704'.

[0139] In step S706, each baseband processing module performs post compensation on features of reception service signals according to the feature difference values of the corresponding receiving channels respectively, so as to coherently accumulate each reception service signal.

[0140] In the fifth embodiment of the present invention, for ease of illustration, steps S701, S702, and S703 are illustrated as separate steps. It should be understood that, steps S701, S702, and S703 may be combined into one step. Similarly, steps S701', S702', and S703' may also be combined into one step.

[0141] It can be seen from the above description that, in the embodiment of the present invention, the feature difference value of the receiving channel of each transceiver unit disposed on each board relative to the reference receiving channel is obtained through a matrix operation of arrays respectively, according to a plurality of one-dimensional arrays corresponding to all the calibration loops where the reception calibration signals pass through. Then, the feature compensation is performed on a reception service signal of the corresponding transceiver unit according to the feature difference value of the receiving channel of the corresponding transceiver unit. Therefore, accurate calibration between transceivers disposed on different boards is realized. That is, the features of a certain receiving channel may be taken as the reference, so as to counteract feature differences of the receiving channels of the transceiver units distributed on different boards. Thus, the features (an amplitude, a phase, and a delay) of service signals of all the receiving channels are equal or distributed according to a certain rule, so as to realize coherent accumulation of (M+N) reception service signals, thereby forming a required receiving direction diagram of the antenna, and achieving a receiving sensitivity index of the whole antenna.

Sixth Embodiment

[0142] Detailed illustration is provided in the following using an example of realizing the transmission calibration on transceiver arrays disposed on different boards.

[0143] FIG. 8 is a flow chart of a calibration method according to an embodiment of the present invention. Still another calibration method is provided in the embodiment of the present invention, which is applied in the active antenna as shown in FIG. 1. Referring to FIG. 8, the method includes the following steps.

[0144] In step S801, all (M+N) baseband processing modules send (M+N) original transmission calibration signals, where the sending is carried out by the baseband processing modules in sequence one after another, one baseband processing module carries out the sending after a predetermined delay interval that another baseband processing module carries out the sending, and the (M+N) original transmission calibration signals pass through corresponding transmitting channels and reach corresponding couplers and corresponding multiplexers.

[0145] In step S802, the M transmission calibration signals on a board 1 return to a calibrator E1 through a multiplexer D1. The N transmission calibration signals on a board 2 return to the calibrator E1 through a multiplexer D2, electromagnetic connection between multiplexers, and the multiplexer D1.

[0146] In step S802', the N transmission calibration signals on the board 2 return to a calibrator E2 through the multiplexer D2. The M transmission calibration signals on the board 1 return to the calibrator E2 through the multiplexer D1, the electromagnetic connection between multiplexers, and the multiplexer D2.

[0147] In step S803, the calibrator E1 compares the received (M+N) transmission calibration signals with the (M+N) original transmission calibration signals sent by the baseband processing modules, so as to obtain (M+N) one-dimensional arrays.

[0148] In step S803', the calibrator E2 compares the received (M+N) transmission calibration signals with the (M+N) original transmission calibration signals sent by the baseband processing modules, so as to obtain (M+N) one-dimensional arrays.

[0149] In step S804, feature difference values representing feature differences of all transmitting channels of the active

antenna on the board 1 and the board 2 are obtained through a matrix operation of arrays according to the (M+N) one-dimensional arrays obtained in step S803 and the (M+N) one-dimensional arrays obtained in step S803'.

[0150] In step S805, each baseband processing module performs pre-compensation on features of transmission service signals according to the feature difference values of the corresponding transmitting channels respectively, so that the features of each transmission service signal are distributed at front ends of the transceivers according to a certain rule.

[0151] It can be seen from the above description that, in the embodiment of the present invention, the feature difference value of the transmitting channel of each transceiver unit disposed on each board relative to a reference transmitting channel is obtained through a matrix operation of arrays respectively, according to a plurality of one-dimensional arrays corresponding to all the calibration loops where the calibration signals pass through. Then, the feature compensation is performed on a transmission service signal of the corresponding transceiver unit according to the feature difference value of the transmitting channel of the corresponding transceiver unit. Therefore, accurate calibration between transceivers disposed on different boards is realized. That is, the features of a certain transmitting channel are taken as the reference, so as to counteract feature differences of the transmitting channels of the transceiver units distributed on different boards. Furthermore, the features (an amplitude, a phase, and a delay) of all transmission signals after being modulated and amplified by the transmitting channels are enabled to become equal at the front end of the transceivers (between an antenna dipole and a duplexer in the TR channel), or distributed according to a certain rule. The transmission signals are converted into electromagnetic waves through the antenna dipole, and the vector composition occurs to the electromagnetic waves in the air, so as to form a required transmission direction diagram of the antenna.

[0152] It should be understood that, a transceiver array A disposed on one board and a transceiver array B disposed on another board form a unified transceiver array C.

[0153] The calibration signal in the embodiment of the present invention includes a pseudo-random code or a single tone.

[0154] Persons of ordinary skill in the art may understand that all or part of the steps of the method according to the embodiments of the present invention may be implemented by a program instructing relevant hardware. The program may be stored in a computer readable storage medium. When the program runs, the steps of the method according to the embodiments of the present invention are performed. The storage medium may be a magnetic disk, a Compact Disk Read-Only Memory (CD-ROM), a Read-Only Memory (ROM) or a Random Access Memory (RAM).

[0155] Detailed above are the objectives, technical solution and merits of the present invention. It is understandable that the descriptions are merely some exemplary embodiments of the present invention, but not intended to limit the scope of the present invention. Any modification, equivalent replacement, or improvement made without departing from the spirit and principle of the present invention should fall within the scope of the present invention.

Claims

1. An active antenna, comprising K antenna dipole arrays, **characterized in that:** the active antenna further comprises:

1st to Kth transceiver unit arrays corresponding to the antenna dipole arrays, correspondingly disposed on 1st to Kth boards respectively, wherein each of the transceiver unit arrays comprises a plurality of transceiver units, and each of the transceiver units comprises a receiving channel and/or a transmitting channel, and a corresponding baseband processing module;

1st to Kth multiplexers, correspondingly disposed on the 1st to Kth boards respectively, wherein each of the 1st to Kth multiplexers is configured to transmit calibration signals to multiplexers among the 1st to Kth multiplexers and other than the current multiplexer itself through multiplexers and electromagnetic connection between the multiplexers;

1st to Kth calibrators, correspondingly disposed on the 1st to Kth boards respectively, and configured to obtain P feature difference values between P calibration signals passing through all calibration loops of the active antenna and an original calibration signal, wherein P equals to the number of all transceiver units of the 1st to Kth transceiver unit arrays; and

a feature difference calculating unit, configured to calculate a feature difference value of a receiving channel and/or transmitting channel of each of the transceiver units of the active antenna relative to a reference receiving channel and/or transmitting channel respectively, according to an association relation between a feature difference value and a feature of each calibration loop, and the P feature difference values obtained by each of the calibrators of the active antenna, wherein the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop of the active antenna and the original calibration signal; and

wherein each of the baseband processing modules is configured to perform feature compensation on a service

signal of a corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding transceiver unit, and K is a positive integer greater than or equal to 2.

2. The active antenna according to claim 1, wherein each of the calibrators is configured to send an original reception calibration signal; the original reception calibration signal is divided into a plurality of multiplexed signals through a multiplexer of the active antenna on the current board, and said a plurality of multiplexed signals enters reception calibration loops of the active antenna on the current board respectively; the original reception calibration signal is transferred to multiplexers among the K multiplexers and other than the current multiplexer through electromagnetic connection between multiplexers, and then the original reception calibration signal is divided into a plurality of multiplexed signals through each of the other multiplexers, and said a plurality of multiplexed signals enters reception calibration loops of the active antenna on each of the other boards respectively; and the each of the calibrators is further configured to receive P reception calibration signals passing through all reception calibration loops of the active antenna on the 1st to Kth boards and obtain P feature difference values between the P reception calibration signals and the sent original reception calibration signal through comparison.
3. The active antenna according to claim 1, wherein each of the baseband processing modules is further configured to send an original transmission calibration signal, wherein one baseband processing module carries out the sending after a predetermined delay interval that another baseband processing module carries out the sending, and the original transmission calibration signal enters a corresponding transmitting channel according to a signal transmission direction;
each of the calibrators is configured to receive I transmission calibration signals passing through transmission calibration loops of the active antenna on the current board through a corresponding multiplexer, wherein I equals to the number of all transmitting channels of the active antenna on the current board, and receive (P-I) transmission calibration signals transferred through electromagnetic connection between multiplexers, and compare feature differences between the received P transmission calibration signals and the original transmission calibration signal sent by the corresponding baseband processing module, so as to obtain P feature difference values.
4. The active antenna according to claim 1, wherein when K equals to 2, digital signal connection exists between a first calibrator and a second calibrator, and radio frequency (RF) signal connection exists between a first multiplexer and a second multiplexer,
the first calibrator is configured to send an original reception calibration signal; the original reception calibration signal is divided into M multiplexed signals through the first multiplexer, and the M multiplexed signals enter M reception calibration loops of the active antenna on a first board respectively; the original reception calibration signal is transferred to the second multiplexer through the RF signal connection between the first multiplexer and the second multiplexer, and then the original reception calibration signal is divided into N multiplexed signals through the second multiplexer, and the N multiplexed signals enter N reception calibration loops of the active antenna on a second board respectively; and the first calibrator is further configured to receive M reception calibration signals passing through the reception calibration loops of the active antenna on the first board and N reception calibration signals passing through the reception calibration loops of the active antenna on the second board and that are transferred through the digital signal connection between the first calibrator and the second calibrator, and obtain (M+N) feature difference values between the (M+N) reception calibration signals and the original reception calibration signal sent by the first calibrator through comparison, $M \geq 2$, $N \geq 2$, M equals to the number of all receiving channels of the active antenna on the first board, and N equals to the number of all receiving channels of the active antenna on the second board,
the second calibrator is configured to send an original reception calibration signal; the original reception calibration signal is divided into N multiplexed signals through the second multiplexer, and the N multiplexed signals enter the N reception calibration loops of the active antenna on the second board respectively; the original reception calibration signal is transferred to the first multiplexer through the RF signal connection between the second multiplexer and the first multiplexer, and then the original reception calibration signal is divided into M multiplexed signals through the first multiplexer, and the M multiplexed signals enter the M reception calibration loops of the active antenna on the first board respectively; and the second calibrator is further configured to receive N reception calibration signals passing through the reception calibration loops of the active antenna on the second board and M reception calibration signals passing through the reception calibration loops of the active antenna on the first board and that are transferred through the digital signal connection between the first calibrator and the second calibrator, and obtain (M+N) feature difference values between the (M+N) reception calibration signals and the original reception calibration signal sent by the second calibrator through comparison.

5. The active antenna according to claim 1, wherein when K equals to 2, digital signal connection exists between a first calibrator and a second calibrator, and RF signal connection exists between a first multiplexer and a second multiplexer,
 the first calibrator is configured to send an original reception calibration signal; the original reception calibration signal is divided into M multiplexed signals through the first multiplexer, and the M multiplexed signals enter M reception calibration loops of the active antenna on a first board respectively; the original reception calibration signal is transferred to the second multiplexer through the RF signal connection between the first multiplexer and the second multiplexer, and then the original reception calibration signal is divided into N multiplexed signals through the second multiplexer, and the N multiplexed signals enter N reception calibration loops of the active antenna on a second board respectively; and the first calibrator is further configured to obtain features of M reception calibration signals passing through the reception calibration loops of the active antenna on the first board and features of N reception calibration signals passing through the reception calibration loops of the active antenna on the second board and that are transferred through the digital signal connection between the first calibrator and the second calibrator, and obtain (M+N) feature difference values between features of the (M+N) reception calibration signals and features of the sent original reception calibration signal through comparison; and
 the second calibrator is configured to send an original reception calibration signal; the original reception calibration signal is divided into N multiplexed signals through the second multiplexer, and the N multiplexed signals enter the N reception calibration loops of the active antenna on the second board respectively; the original reception calibration signal is transferred to the first multiplexer through the RF signal connection between the second multiplexer and the first multiplexer, and then the original reception calibration signal is divided into M multiplexed signals through the first multiplexer, and the M multiplexed signals enter the M reception calibration loops of the active antenna on the first board respectively; and the second calibrator is further configured to obtain features of N reception calibration signals passing through the reception calibration loops of the active antenna on the second board and features of M reception calibration signals passing through the reception calibration loops of the active antenna on the first board and that are transferred through the digital signal connection between the first calibrator and the second calibrator, and obtain (M+N) feature difference values between features of the (M+N) reception calibration signals and feature of the original reception calibration signal through comparison.
6. The active antenna according to claim 1, wherein when K equals to 2, digital signal connection exists between a first calibrator and a second calibrator, and RF signal connection exists between a first multiplexer and a second multiplexer,
 M baseband processing modules are disposed on a first board and further configured to send M original transmission calibration signals, wherein the sending is carried out by the baseband processing modules in sequence one after another, one baseband processing module carries out the sending after a predetermined delay interval that another baseband processing module carries out the sending, and each of the original transmission calibration signals enters a corresponding transmitting channel according to a signal transmission direction;
 N baseband processing modules are disposed on a second board and further configured to send N original transmission calibration signals, wherein the sending is carried out by the baseband processing modules in sequence one after another, one baseband processing module carries out the sending after a predetermined delay interval that another baseband processing module carries out the sending, and each of the original transmission calibration signals enters a corresponding transmitting channel according to a signal transmission direction;
 the first calibrator is configured to receive M transmission calibration signals passing through transmission calibration loops of the active antenna on the first board, and N transmission calibration signals passing through transmission calibration loops of the active antenna on the second board and that are transferred through the RF signal connection between the first multiplexer and the second multiplexer, and compare the transmission calibration signals with the (M+N) original transmission calibration signals respectively, so as to obtain (M+N) feature difference values, $M \geq 2$, $N \geq 2$, M equals to the number of all transmitting channels of the active antenna on the first board, and N equals to the number of all transmitting channels of the active antenna on the second board; and
 the second calibrator is configured to receive N transmission calibration signals passing through the transmission calibration loops of the active antenna on the second board, and M transmission calibration signals passing through the transmission calibration loops of the active antenna on the first board and that are transferred through the RF signal connection between the first multiplexer and the second multiplexer, and compare the transmission calibration signals with the (M+N) original transmission calibration signals respectively, so as to obtain (M+N) feature difference values.
7. The active antenna according to claim 1, wherein the feature difference calculating unit is a first feature difference calculating unit, configured to obtain a feature difference value of a receiving channel and/or transmitting channel of each of the transceiver units disposed on each board relative to a reference receiving channel and/or transmitting

channel through a matrix operation of arrays respectively, according to P one-dimensional arrays corresponding to all the calibration loops where calibration signals pass through, and each of the one-dimensional arrays represents features of each component in a corresponding calibration loop where a signal is transmitted, and a feature difference value between a calibration signal passing through the calibration loop and an original calibration signal.

- 5 8. The active antenna according to claim 1, wherein the multiplexer comprises a switch matrix, a power splitter/combiner, a duplexer, or any combination thereof.
- 10 9. The active antenna according to claim 1, wherein if the calibrators are classified into primary calibrators and secondary calibrators, the feature difference calculating unit is integrated with one of the calibrators to form an integral primary calibrator, or the feature difference calculating unit is integrated with one of the baseband processing modules to form an integral module.
- 15 10. A calibration method, **characterized in that**, the method is applicable to an active antenna comprising 1st to Kth transceiver unit arrays, corresponding 1st to Kth multiplexers, and corresponding 1st to Kth calibrators correspondingly disposed on 1st to Kth boards respectively, wherein K is a positive integer greater than or equal to 2, the method comprising:

obtaining, by the 1st to Kth calibrators, P feature difference values between P calibration signals passing through all calibration loops of the active antenna on the 1st to Kth boards and an original calibration signal, wherein P equals to the number of all transceiver units of the 1st to Kth transceiver unit arrays;
calculating a feature difference value of a receiving channel and/or transmitting channel of each of the transceiver units of the active antenna relative to a reference receiving channel and/or transmitting channel respectively, according to an association relation between a feature difference value and a feature of each calibration loop,
25 and the P feature difference values obtained by each of the calibrators of the active antenna, wherein the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop of the active antenna and the original calibration signal; and
performing feature compensation on a service signal of a corresponding transceiver unit in a digital domain according to the feature difference value of the receiving channel and/or transmitting channel of the corresponding
30 transceiver unit.

11. The calibration method according to claim 10, wherein when the calibration signal is a reception calibration signal, the method further comprises:

35 sending, by each of the calibrators, an original reception calibration signal, wherein the original reception calibration signal is divided into a plurality of multiplexed signals through a multiplexer of the active antenna on a current board, and said a plurality of multiplexed signals enters reception calibration loops of the active antenna on the current board respectively; the original reception calibration signal is transferred to multiplexers among the K multiplexers other than a current multiplexer through electromagnetic connection between multiplexers,
40 and then the original reception calibration signal is divided into a plurality of multiplexed signals through each of the other multiplexers, and said a plurality of multiplexed signals enters reception calibration loops of the active antenna on each of the other boards respectively, and
the obtaining P feature difference values between P calibration signals passing through all calibration loops of the active antenna on the 1st to Kth boards and the original reception calibration signal comprises:

45 receiving P reception calibration signals passing through all reception calibration loops of the active antenna on the 1st to Kth boards, and obtaining P feature difference values between the P reception calibration signals and the original reception calibration signal through comparison.

- 50 12. The calibration method according to claim 10, wherein when the calibration signal is a transmission calibration signal, the method further comprises:

55 sending, by each baseband processing module, an original transmission calibration signal, wherein each of the original transmission calibration signals enters a corresponding transmitting channel according to a signal transmission direction, wherein the sending is carried out by the baseband processing modules in sequence one after another, and one baseband processing module carries out the sending after a predetermined delay interval that another baseband processing module carries out the sending; and
the obtaining P feature difference values between P transmission calibration signals passing through all cali-

bration loops of the active antenna on the 1st to Kth boards and the original transmission calibration signal, comprises:

receiving I transmission calibration signals passing through transmission calibration loops of the active antenna on a current board, wherein I equals to the number of all transmitting channels of the active antenna on the current board, and receiving (P-I) transmission calibration signals transferred through electromagnetic connection between multiplexers, and comparing the P transmission calibration signals with P original transmission calibration signals respectively to obtain P feature difference values.

13. The calibration method according to claim 10, wherein the calculating the feature difference value of the receiving channel and/or transmitting channel of each of the transceiver units of the active antenna relative to the reference receiving channel and/or transmitting channel respectively, according to the association relation between a feature difference value and a feature of each calibration loop, and the P feature difference values obtained by each of the calibrators of the active antenna, wherein the feature difference value is a value about the feature difference between a calibration signal passing through each calibration loop of the active antenna and the original calibration signal, comprises:

obtaining a feature difference value of the receiving channel and/or transmitting channel of each of the transceiver units disposed on each board relative to the reference receiving channel and/or transmitting channel through a matrix operation of arrays respectively, according to P one-dimensional arrays corresponding to all the calibration loops where calibration signals pass through, and each of the one-dimensional arrays represents features of each component in a corresponding calibration loop where a signal is transmitted, and a feature difference value between a calibration signal passing through the calibration loop and an original calibration signal.

14. The calibration method according to claim 10, wherein the reference receiving channel and/or transmitting channel is a receiving channel and/or transmitting channel of any transceiver unit in the 1st to Kth transceiver unit arrays respectively.

15. The calibration method according to any one of claims 10 to 14, wherein the feature is represented by an amplitude, a phase, and a delay.

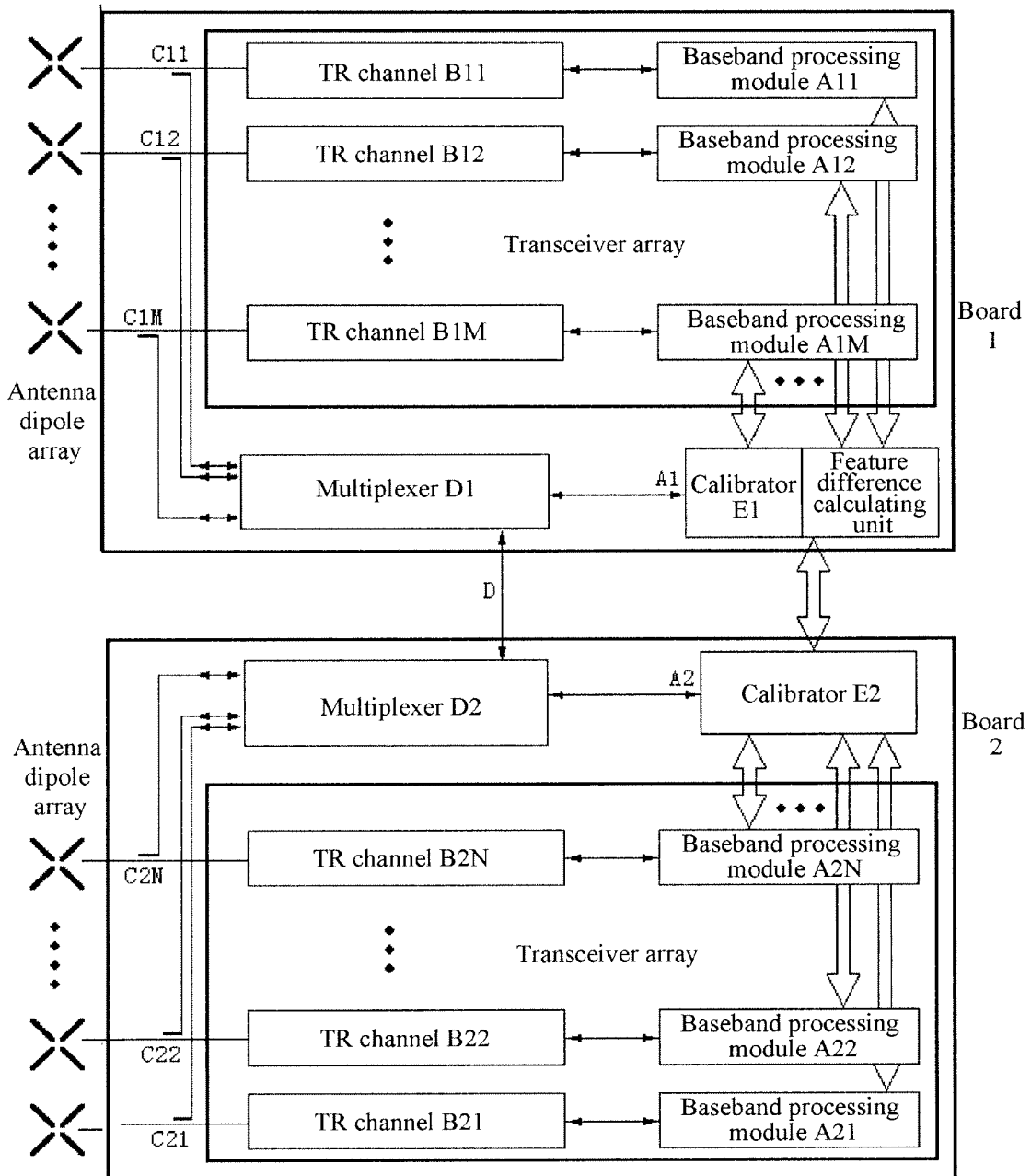


FIG. 1

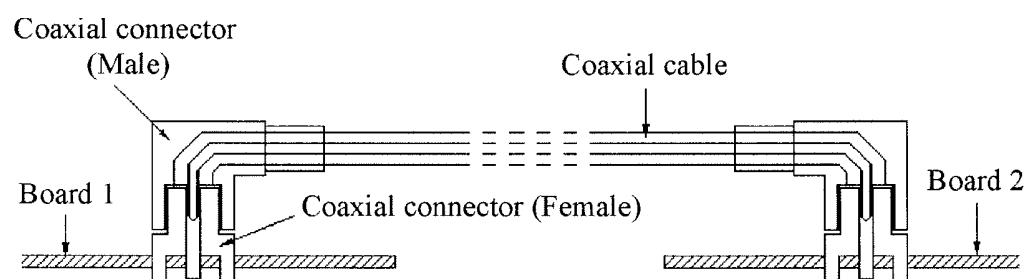


FIG. 2

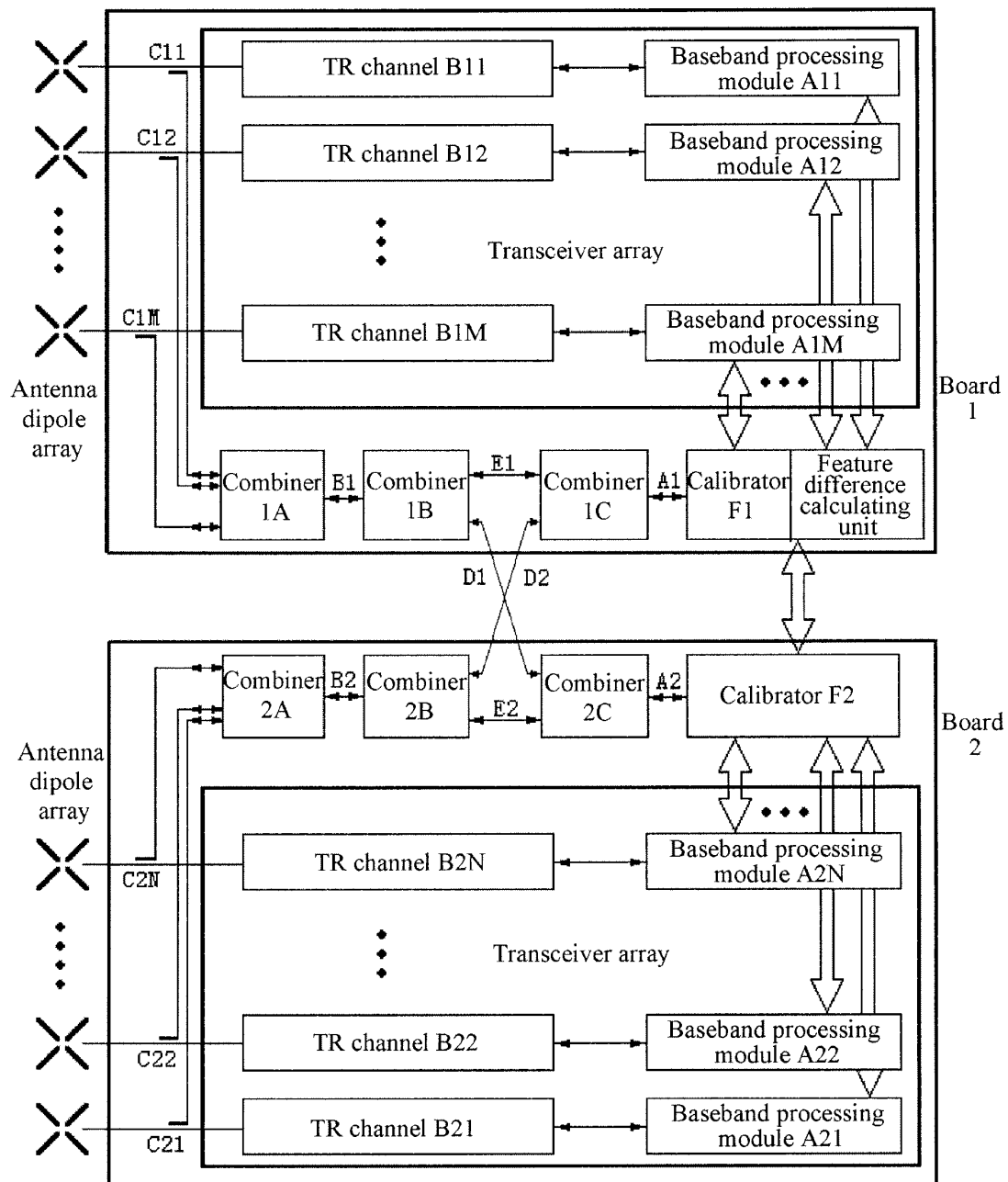


FIG. 3

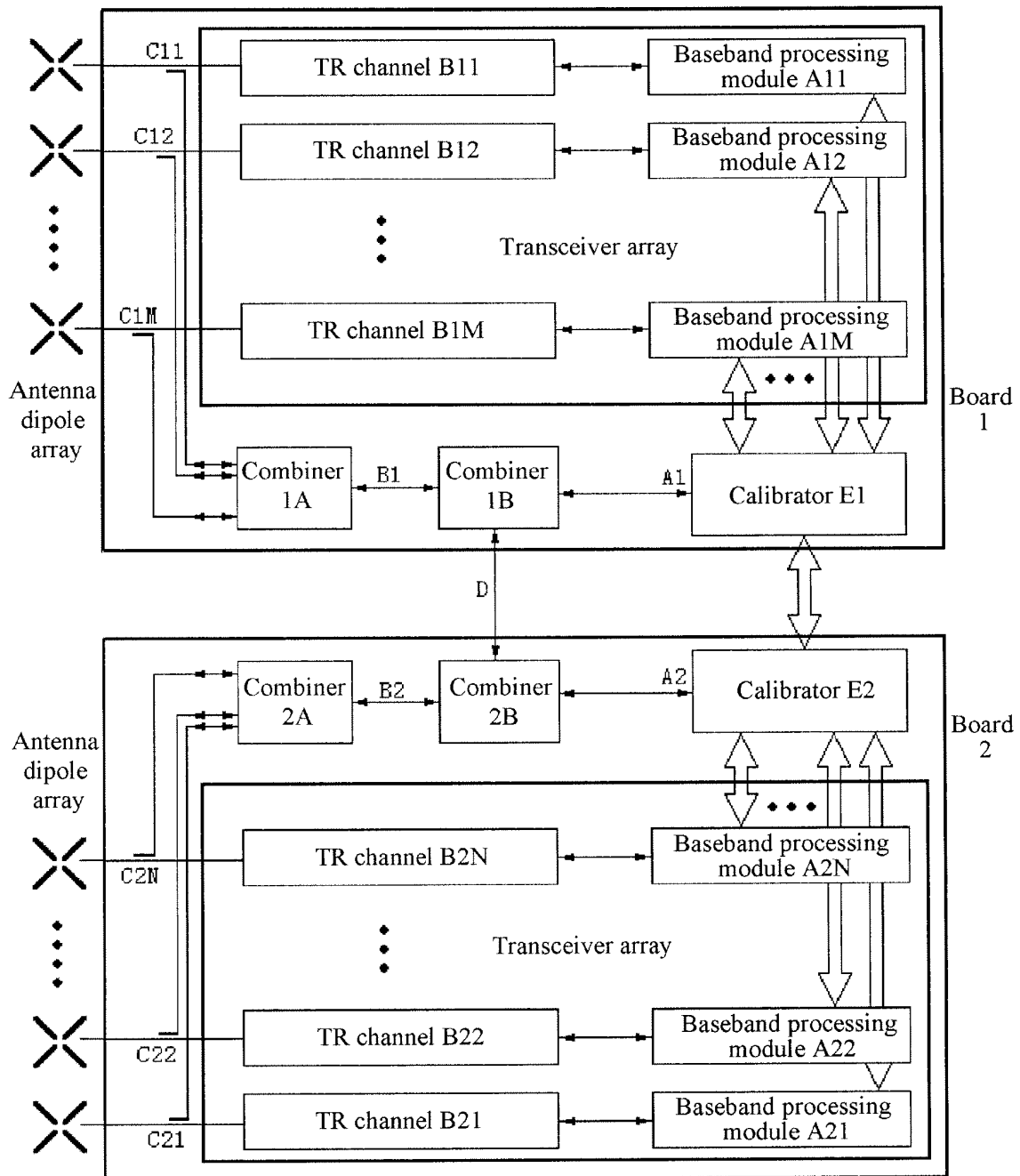


FIG. 4

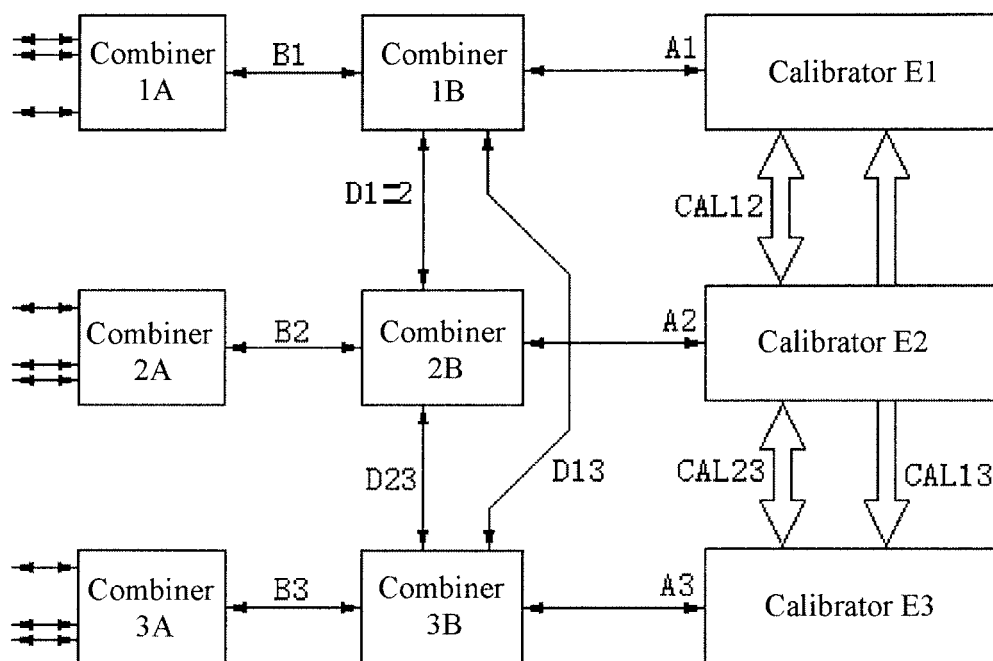


FIG. 5

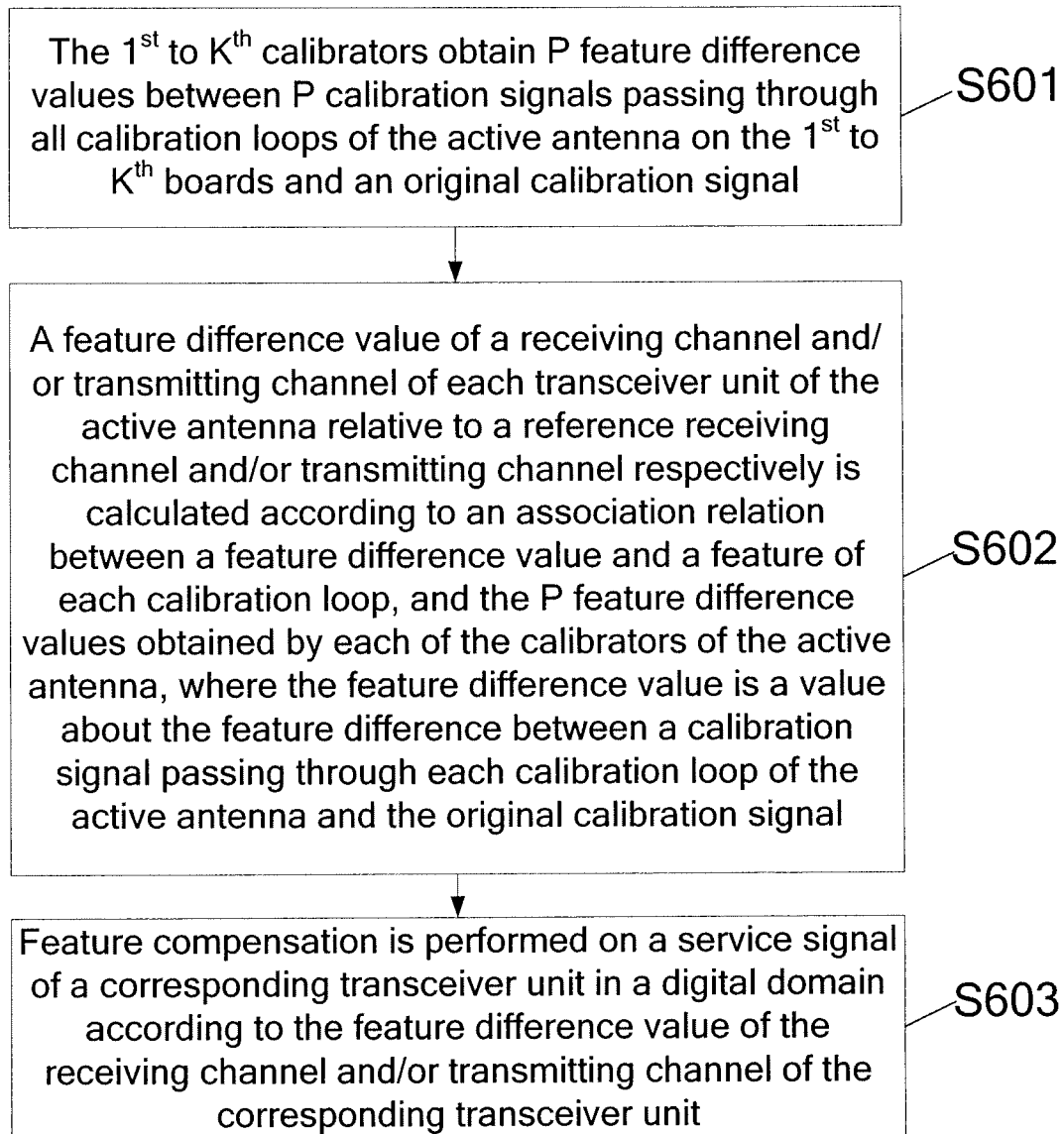


FIG. 6

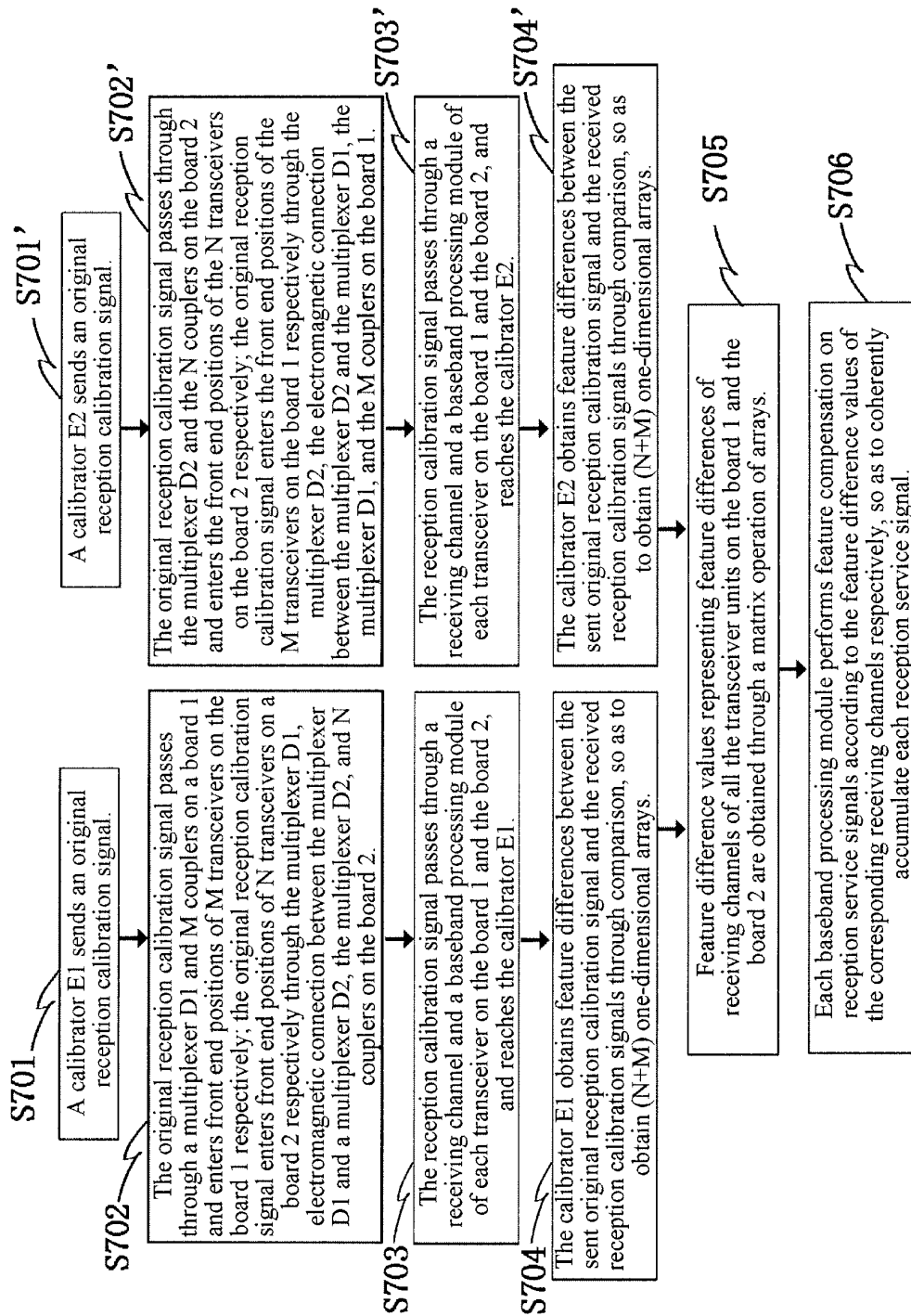


FIG. 7

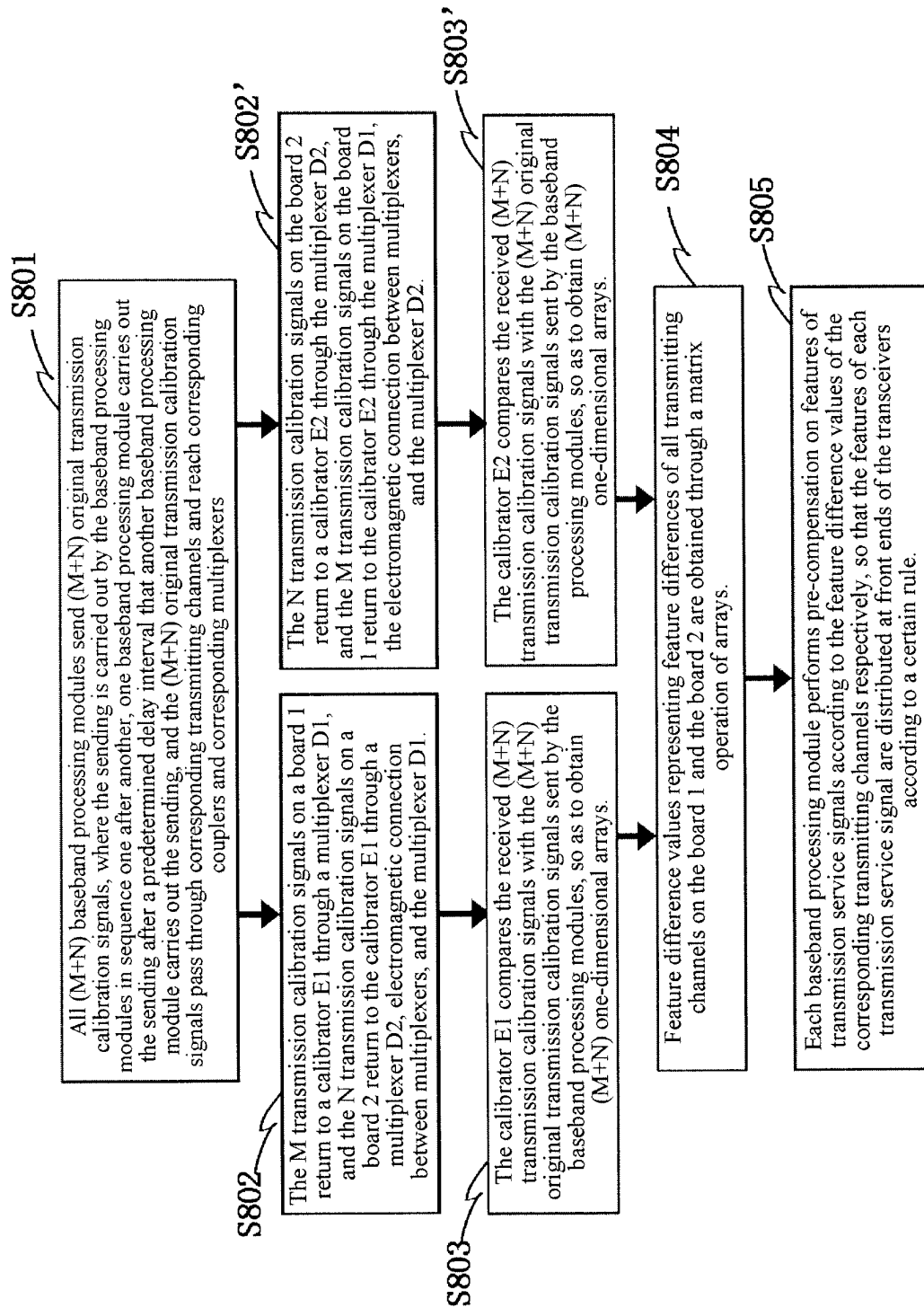


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2009/071412

A. CLASSIFICATION OF SUBJECT MATTER

H01Q3/26(2006.01)i

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: H01Q, G01S

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

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

WPI, EPODOC, CNKI, CNPAT: ANTENNA?, ARRAY, SMART, CALIBRAT+, RECEIV+, TRANSMIT+, SEND+, BOARD?, PCB?, PWB?

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN1535510A(NIPPON ELECTRIC CO) 06 Oct. 2004(06.10.2004) the whole document	1-15
A	CN1398124A(INST OF TELECOMM SCIENCE AND T) 19 Feb. 2003 (19.02.2003) the whole document	1-15
A	EP2040333 A1(ASTRUM GMBH) 25 Mar. 2009(25.03.2009) the whole document	1-15

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
18 Jan. 2010(18.01.2010)Date of mailing of the international search report
04 Feb. 2010 (04.02.2010)Name and mailing address of the ISA/CN
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2009/071412

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		AU2002309018A1	03.12.2002
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EP2040333A1	25.03.2009	WO2009040038A1	02.04.2009

Form PCT/ISA /210 (patent family annex) (July 2009)