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• **Weese, Kurt**
71254 Ditzingen (DE)

(74) Representative: **Dreiss**
Patentanwälte
Postfach 10 37 62
70032 Stuttgart (DE)

(71) Applicant: **Alcatel Lucent**
75007 Paris (FR)

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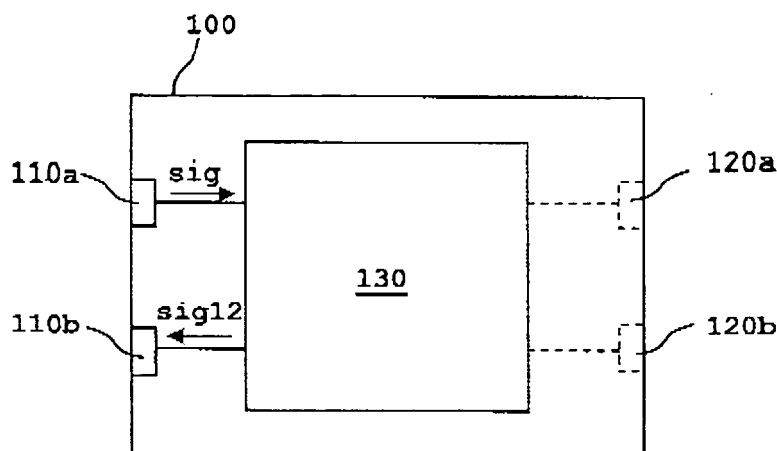
(72) Inventors:
• **Berndt, Peter**
70825 Korntal-Münchingen (DE)

(54) **Calibration device and method of operating a calibration device**

(57) The present invention relates to a calibration device (100) for calibrating a system (200) that is configured to process radio frequency, RF, signals, wherein said calibration device (100) comprises a plurality of input ports (110a, 110b) and a coupling structure (130) that is configured to receive a signal (sig) at at least one of said

input ports (110a, 110b) and to forward a portion (sig12) of said received signal (sig) to at least another one of said input ports (110a, 110b), wherein said portion (sig12) of said received signal (sig) comprises a predetermined delay and/or attenuation with respect to said received signal (sig).

Fig. 1



Description

FIELD OF INVENTION

[0001] The present invention relates to a calibration device for calibrating a system that is configured to process radio frequency, RF, signals.

[0002] The present invention further relates to a method of operating a calibration device.

BACKGROUND

[0003] RF systems such as e.g. antenna systems comprising a plurality of antenna elements which are supplied with RF signals via respective signal transmission lines and which are operated in a phase-controlled manner usually have to be calibrated regarding an electrical length of the signal transmission lines between a source of the RF signals and the antenna elements used for transmitting the RF signal. Up to now, no reliable solution for an efficient calibration is provided.

[0004] Thus, it is an object of the present invention to provide an improved calibration device and an improved method of operating a calibration device which enable a precise and efficient calibration of radio frequency processing systems.

SUMMARY

[0005] According to the present invention, regarding the above mentioned calibration device, this object is achieved by a calibration device comprising a plurality of input ports and a coupling structure that is configured to receive a signal at at least one of said input ports and to forward a portion of said received signal to at least another one of said input ports, wherein said portion of said received signal comprises a predetermined delay and/or attenuation with respect to said received signal.

[0006] Thus, the inventive calibration device advantageously provides a loop-back mechanism which enables to couple a reference signal that is received at a specific input port and is used for calibration purposes back to at least one further input port or preferably all other input ports of the calibration device. Said coupling of said received reference signal is advantageously performed so as to impart a predetermined delay and/or attenuation to the back coupled portion of the received reference signal, which is preferably also known by the source of the reference signal, thus enabling an analysis of signal delay and attenuation effected by other devices the reference signal is processed by prior to arriving at the signal source or analyzing means which are configured to assess said attenuation and/or delays.

[0007] Preferably, said predetermined delay and/or attenuation provided for by the calibration device is independent of external parameters such as environmental parameters of an environment the radio frequency signal is operated within.

[0008] Particularly, in contrast to conventional systems, wherein at best an unavoidable cross-coupling between existing antenna elements of an antenna system is used for establishing a loop-back-type coupling, the calibration device according to the embodiments may be provided in a closed and shielded casing, which prevents external influences such as temperature and/or dirt particles from affecting the predetermined coupling regarding delay and/or attenuation employed for the calibration process.

[0009] A particularly efficient calibration is enabled by a further advantageous embodiment of the calibration device, wherein said coupling structure is configured to forward a portion of said received signal to all other input ports of the calibration device, wherein said portion of said received signal comprises a predetermined delay and/or attenuation with respect to said received signal. Thus, by providing a reference signal to a single input port of the calibration device, all other input ports of the calibration device may simultaneously be employed as loop-back ports for returning a portion of the reference signal, said portions again having a predetermined delay and/or attenuation with respect to the reference signal supplied to the first input port. Thus, if there is an overall number of N many input ports provided at the calibration device, advantageously, N-1 input ports may simultaneously be used for the inventive calibration process thus providing a particularly efficient calibration.

[0010] According to a further preferred embodiment, said calibration device comprises a plurality of output ports, preferably as many output ports as there are input ports, wherein said coupling structure is configured to forward a signal received at a specific input port, or at least a portion thereof, to a specific output port. This configuration advantageously enables to also employ the calibration device according to the embodiment for forwarding signals received at specific input ports to respective specific output ports of the calibration device, thus looping through the signals supplied to the calibration device to a further device which may be connected to the output ports of the calibration device. This embodiment advantageously enables to leave the calibration device installed in the RF processing system even if no calibration has to be performed at a time. The calibration device according to the present embodiment rather forwards signals received at its input ports to a further system such as an antenna system connected to its output ports thus enabling a non-calibration type of operation of the RF system. Thus, advantageously, the calibration device is not required to be removed from the RF system during an ordinary operation of the RF system.

[0011] This is particularly advantageous when using the calibration device according to the embodiments for calibrating antenna systems of radio frequency communication systems such as cellular communication systems, because it is usually quite difficult for service technicians to reach antenna systems which are mounted on top of a building or a transmission tower.

[0012] According to a further advantageous embodiment, the coupling structure comprises a first coupling stage, said first coupling stage comprising at least one power splitter or a coupler, preferably a directional coupler, for forwarding a signal received at a specific input port to both a specific output port that is associated with said specific input port and a second coupling stage, wherein said second coupling stage is configured to distribute said signal to at least one further input port. The separation between a first coupling stage and a second coupling stage advantageously enables to choose specific power splitting or coupling components for the respective coupling stages. E.g., the first coupling stage may be optimised regarding minimization of a through power loss, i.e. insertion loss, between the input port and the output port thus not impeding an ordinary operation of the RF system comprising the calibration device. For example, by employing directional couplers at the first coupling stage, an insertion loss of a signal to be transmitted from the input port to the output port of the calibration device may amount to only about -0.1 dB. On the other hand, for the second coupling stage, identical or different coupling means as provided for by the first coupling stage may be used to optimise an operation of the second coupling stage.

[0013] According to a further advantageous embodiment, said coupling structure comprises a coupler, preferably a directional coupler, for coupling said portion of said received signal which comprises a predetermined delay and/or attenuation with respect to said received signal, back to an input port. Thus, an efficient coupling of said looped-back signal portion of the reference signal used for calibration is enabled.

[0014] According to a further advantageous embodiment, the coupling structure comprises at least one attenuation device for applying an attenuation to a signal processed by said coupling structure, whereby an aggregated attenuation to a signal processed by said coupling structure may be influenced, e.g. for establishing identical aggregated attenuations for a plurality of different signal paths within the coupling structure.

[0015] According to a further advantageous embodiment, signal paths provided by said coupling structure from a specific input port to any other input port each comprise a substantially identical electronic length and/or a substantially identical aggregated attenuation, whereby a particularly efficient calibration may be performed taking advantage of the symmetrical configuration.

[0016] According to a further particularly preferred embodiment, said coupling structure comprises an electrically conductive housing, a number of inner conductors each of which connects a specific input port with a respective output port, and shielding means at least partially arranged between neighbouring inner conductors to effect a coupling attenuation between said neighbouring inner conductors. The aforementioned configuration according to the embodiment advantageously provides

a coupling arrangement which is protected from external influences by the electrically conductive housing. Further, there is no requirement to provide lumped, i.e. discrete, coupling elements and attenuation elements, since a distributed coupling and coupling attenuation between the several inner conductors may be controlled by the geometry of the inner conductors with respect to the shielding means and the electrically conductive housing. For instance, an impedance of an inner conductor with respect to the electrically conductive housing may be tuned in a per se known manner by adjusting the distance between the inner conductor to the electrically conductive housing. Moreover, by altering the size and/or position of the shielding mean, the coupling attenuation between neighbouring inner conductors may be influenced.

[0017] According to a further preferred embodiment, said electrically conductive housing comprises a basically cylindrical shape with a circular cross-section, wherein said inner conductors are arranged substantially parallel to a longitudinal axis of said housing, and wherein said shielding means at least partially extend in a radially inward direction from a wall of said housing.

[0018] The calibration device according to the embodiments may advantageously be used in numerous radio frequency processing systems, for example in antenna systems.

[0019] A further solution to the object of the present invention is given by a method according to claim 12. The method of operating a calibration device according to claim 12 proposes: supplying a signal to said calibration device at a specific input port via a first transmission line, evaluating a signal portion that is output by said calibration device at at least one further input port via a second transmission line in reaction to said signal.

[0020] I.e., a loop-back configuration is achieved which enables to supply the calibration device according to the embodiments via the first transmission line and the first input port with the reference signal or calibration signal. The calibration device according to the embodiments returns a portion of the received calibration signal at at least one further input port and transmits this signal portion via the second transmission line back to the source of the reference signal or to evaluation means.

[0021] By evaluating a signal attenuation and/or a signal delay of the received signal portion with respect to the calibration signal, delay and/or attenuation properties of the first and second transmission lines may be determined since the calibration device itself has known properties regarding attenuation and signal delay.

[0022] Thus, an evaluation device connected to the first transmission line and the second transmission line may advantageously obtain information as to the signal attenuation and delay imparted on radio frequency signals in the course of transmission via the first and second transmission lines.

[0023] Thus, consequently, by applying per se known techniques of calibration, an operation of the antenna system connected to a radio frequency source via the

first and second transmission lines may be calibrated by employing the attenuation and delay properties of the first and second transmission lines as obtained by the steps according to the method according to the embodiments.

[0024] According to a further embodiment, said calibration device is preferably configured according to one of the claims 1 to 10, wherein said calibration device is used for transmitting radio frequency user signals from an RF source to an antenna system which is connected to the output ports of said calibration device.

[0025] According to a further advantageous embodiment, in a temporarily alternating fashion, user signals and calibration signals are supplied to said calibration device, whereby a periodical calibration of the transmission lines and further components processing the radio frequency signals associated with the transmission lines is achieved, and wherein, simultaneously, an ordinary operation (i.e. no calibration) may be effected during such phases where there is no calibration taking place. Thus, advantageously, the calibration device according to the embodiments is not required to be removed from the transmission lines to enable an ordinary operation of the RF system that is calibrated by means of the calibration device according to the embodiments.

[0026] The calibration device according to the embodiments may rather advantageously remain integrated into the RF processing system to enable calibration processes whenever required.

[0027] Particularly, by employing the calibration device according to the embodiments, no special reference path is required for the calibration process, in contrast to conventional systems that rely upon a dedicated RF transmission line for feedback purposes. By saving such a dedicated reference path, the manufacturing costs for a respective RF processing system may advantageously be reduced.

[0028] A further advantage of the calibration device according to the embodiments is that it operates independently of specific antenna systems or further RF processing components that may be attached thereto. Moreover, antennas to be used in combination with the calibration device according to the embodiments do not have to fulfil special requirements to enable the application of the calibration device according to the embodiments, except that - according to a particularly preferred embodiment - no additional relative delay should be inserted by the antennas or transmission lines connecting the antennas to the calibration device. Employing the calibration device according to the embodiments does not require to alter an existing antenna configuration. The calibration device according to the embodiments can rather be used with any existing antenna device.

BRIEF DESCRIPTION OF THE FIGURES

[0029] Further features, aspects and advantages of the present invention are given in the following detailed

description with reference to the drawings in which:

- FIG. 1 depicts a schematic block diagram of a calibration device according to an embodiment,
- FIG. 2 depicts a schematic block diagram of a radio frequency processing system including a calibration device according to an embodiment,
- FIG. 3 depicts a simplified block diagram of a calibration device according to a further embodiment,
- FIG. 4 depicts a simplified block diagram of a calibration device according to a further embodiment which employs directional couplers,
- FIG. 5a depicts a simplified coupling structure according to a further embodiment,
- FIG. 5b depicts a simplified coupling structure according to a further embodiment supporting three input and output ports,
- FIG. 5c depicts a simplified coupling structure according to a further embodiment which supports four input and output ports,
- FIG. 6a depicts a simplified front view of a coupling structure according to a further embodiment,
- FIG. 6b depicts a simplified front view of a coupling structure according to a further embodiment, and
- FIG. 6c schematically depicts a coupling structure according to FIG. 6b integrated into an RF processing system.
- [0030]** FIG. 1 schematically depicts a calibration device 100 according to a first embodiment. The calibration device 100 comprises a first input port 110a and a second input port 110b. Moreover, the calibration device 100 comprises a coupling structure 130. According to an embodiment, said coupling structure is configured to receive a signal at at least one of said input ports and to forward a portion of said received signal to at least another one of said input ports, wherein said portion of said received signal comprises a predetermined delay and/or attenuation with respect to said received signal. Thereby, a loop-back signal path may be established by means of the calibration device 100 which enables to return a portion of an input signal received at a first input port 110a to a remote device (not shown) via said second input port 110b.
- [0031]** For instance, an external device such as an RF transmitting device may provide a reference signal sig for calibration purposes to the first input port 110a of the

calibration device 100. Upon receiving said calibration signal sig, the calibration device 100 by means of its coupling structure 130 couples a signal portion sig12 from the input port 110a to the output port 110b, wherein said coupled signal portion sig12 comprises a predetermined delay and/or attenuation with respect to the received calibration signal sig.

[0032] Thus, a transmission line and further components which are arranged between the RF source and the calibration device 100 may be analysed as to their attenuation and/or delay properties. I.e., by doing so, the external RF source may determine the attenuation imparted on signals transmitted from the RF source to the calibration device 100 and vice versa. Related phase information is also obtainable by performing the above explained calibration method.

[0033] According to a further embodiment, the calibration device 100 may also comprise a number of output ports 120a, 120b, wherein said output ports 120a, 120b are also connected to the coupling structure 130.

[0034] Advantageously, the coupling structure 130 may also be configured to couple a portion of a signal received at an input port 110a to a specific output port 120a, which is associated with said input port 110a. Thus, a signal supplied to the calibration device 100 may advantageously be forwarded to the output port 120a. The same applies to other input ports 110b of the calibration device 100 which are assigned with respective output ports 120b.

[0035] Generally, the number of input ports and output ports of the calibration device 100 is arbitrary, wherein at least two input ports 110a, 110b are required to provide an efficient loop-back mechanism.

[0036] If the calibration device 100 also comprises output ports, preferably, the number of output ports 120a, 120b equals the number of input ports 110a, 110b, such that a one-by-one transmission of signals received at the respective input ports 110a, 110b through the calibration device 100 to the respective output ports 120a, 120b may be established.

[0037] Thus, advantageously, the calibration device 100 according to the embodiments is not required to be removed from a radio frequency system which is to be calibrated by using the calibration device 100. The calibration device 100 may rather remain installed in the radio frequency processing system after calibration, because the aforementioned transmission of signals from an input port 110a to a respective output port 120a is enabled.

[0038] Of course, if a calibration is to be performed, preferably only one specific input port 110a or 110b is supplied with a calibration signal sig, whereas the further input ports are not supplied with any signal to enable a precise determination of the looped-back signal portion sig12.

[0039] FIG. 2 depicts an RF processing system 200 which employs a calibration device 100 according to the embodiments.

[0040] In the present example, the RF processing system comprises an RF signal source 210, such as a base station of a cellular communications network or a remote radio head of a base station of a cellular communications network. The base station 210 comprises RF transceiver means 212 which are - in a per se known manner - configured to transmit and receive RF signals to be transmitted via the antenna system 220 to said antenna system 220 via the radio frequency transmission lines 210a, 210b, 210c, 210d, which have a first length 11. Preferably, due to simplicity, each of the transmission lines 210a, 210b, 210c, 210d has the same electrical length 11. However, according to a further embodiment, the transmission lines 210a, 210b, 210c, 210d may also have different electrical lengths, which can be recognized in the calibration process, because the transmission lines 210a, 210b, 210c, 210d are part of the feedback loop according to an embodiment.

[0041] In the current example, the antenna system 220 comprises four antenna elements, each of which is controlled by a specific RF signal transmitted to the antenna system 220 by one of the four transmission lines 210a, 210b, 210c, 210d. Such configuration may e.g. be employed for beam forming applications, where the antenna system 220 is controlled with different RF signals which are phase-shifted in relation to each other so as to enable a control of a spatial characteristic of the antenna system 220. For calibration purposes of the RF system 200 depicted by FIG. 2, the calibration device 100 according to the embodiments is provided and integrated into the transmission lines 210a, 210b, 210c, 210d connecting the transceiver 212 of the base station 210 with the antenna system 220.

[0042] More precisely, the input ports 110 of the calibration device 100 according to the embodiments are connected with the respective transmission lines 210a, 210b, 210c, 210d originating from the RF transceiver 212 of the base station 210.

[0043] Respective output ports 120 of the calibration device 100 according to the embodiments are connected via further transmission lines 210a', 210b', 210c', 210d' to the antenna system 220. The further transmission lines 210a', 210b', 210c', 210d' each have a second length 12. The electrical length of the further transmission lines 210a', 210b', 210c', 210d' is preferably identical, since they are not part of the feedback loop enabled by the calibration device 100. Thus, differences in the electrical length of the further transmission lines 210a', 210b', 210c', 210d', could not be detected by the calibration enabled by the calibration device 100.

[0044] The configuration as depicted by FIG. 2 advantageously enables to calibrate portions of the RF transceiver 212 and the transmission lines 210a, 210b, 210c, 210d connecting the transceiver 212 with the calibration device 100.

[0045] By transmitting a reference signal or a calibration signal used for calibration purposes via e.g. the first transmission line 210a from the transceiver 212 to the

calibration device 100, a loop-back test as already explained above with reference to FIG. 1 may be performed. The calibration device 100 according to the embodiments returns at its further input ports, which are associated with the transmission lines 210b, 210c, 210d, by means of the coupling structure 130, respective portions of the reference signals sent from the transceiver 212 via the first transmission line 210a to the first input port 110a (FIG. 1) of the calibration device 100. Thereby, i.e. by evaluating the received signal portions which have been returned from the further input ports 110b, 110c, 110d of the calibration device 100 via the transmission lines 210b, 210c, 210d to the transceiver 212, the transceiver 212 may evaluate attenuation properties and/or delay properties of the involved transmission lines 210a, 210b, 210c, 210d. Such measurement information may be considered for a future operation of the transceiver 212, i.e. an ordinary operation of the transceiver 212 and the base station 210, wherein user data signals are to be forwarded via the transmission lines 210a, 210b, 210c, 210d to the antenna system 220.

[0046] Obviously, it is advantageous to arrange the calibration device 100 according to the embodiments as close to the antenna system 220 as possible, thereby reducing a total length 12 of the transmission lines 210a', 210b', 210c', 210d' which cannot be calibrated by means of the calibration device 100 according to the embodiments due to the transmission line topology. Thus, preferably, the lengths 11, 12 are chosen according to 11 » 12.

[0047] As already explained above, since the coupling structure 130 of the calibration device 100 according to a preferred embodiment is also configured to forward a signal received at a specific input port to a specific output port, an ordinary operation of the RF system 200 is also enabled, wherein the transceiver 200 forwards RF user signals via the transmission lines 210a, 210b, 210c, 210d through the calibration device 100 and further via the further transmission lines 210a', 210b', 210c', 210d' to the antenna system 220. In order not to affect a transmission of (calibrated) user signals via the transmission lines 210a, 210b, 210c, 210d, 210a', 210b', 210c', 210d', of course, the internal signal paths of the calibration device 100 from the respective input ports 110 to the respective output ports 120 have to comprise an identical electrical length each so as not to introduce a relative phase shift between the signals transmitted via the four transmission lines 210a, 210b, 210c, 210d. According to an embodiment, this is also valid for the loop back of the calibration signal. The same applies to the attenuation of the four distinct signal paths as enabled by the coupling structure 130 of the calibration device according to the embodiments. That is, according to an ideal realization of an embodiment of the calibration device 100, a uniform attenuation and phase delay is applied to each of the four signal paths from the respective input ports 110 to the respective output ports 120 thus not affecting signal quality (in the sense of introducing unwanted relative phase

delays between the signal paths) as obtained at the antenna system 220. FIG. 3 depicts a schematic block diagram of a coupling structure 130 according to a further embodiment. The coupling structure 130 comprises a plurality of signal paths which are explained below in detail.

[0048] In addition to the coupling structure 130, FIG. 3 depicts four input ports 110a, 110b, 110c, 110d and four respective output ports 120a, 120b, 120c, 120d.

[0049] As such, the coupling structure 130 of FIG. 3 may e.g. be employed within the calibration device 100 according to FIG. 2, because it supports an overall number of four transmission lines.

[0050] As can be seen from FIG. 3, the coupling structure 130 comprises a first coupling stage 132, said first coupling stage 132 comprising power splitters 132a, 132b, 132c, 132d, each one of which is associated with a respective input port 110a, 110b, 110c, 110d of the coupling structure 130.

[0051] During a calibration operation, the first power splitter 132a, which is associated with the first input port 110a, receives a calibration signal sig supplied to the coupling structure 130 at the first input 110a and performs a per se known step of power splitting, wherein a signal portion of the input signal sig is forwarded from a first output of the power splitter 132a to the output port 120a, which is connected to the first output port of the power splitter 132a. A further signal portion of the input signal sig is forwarded from a second output of the power splitter 132a to a further power splitter 134a, which is comprised within a further coupling stage 134 of the coupling structure 130. The connection between the first output of the power splitter 132a and the output port 120a of the coupling structure 130 advantageously enables to forward a part of an input signal supplied to the input port 110a to the output port 120a for forwarding, e.g. to the antenna system 220 of FIG. 2. Thus, for an ordinary (i.e., non-calibrating) operation of the RF system 200 (FIG. 2), a seamless forwarding (apart from an insertion loss introduced by the power splitter 132a) of RF signals supplied to the input port 110a and to the output port 120a can be established.

[0052] Likewise, the further power splitters 132b, 132c, 132d extract a portion of a respective signal received at the associated input ports 110b, 110c, 110d for forwarding to a respective output port 120b, 120c, 120d.

[0053] According to a particularly preferred embodiment, the power splitters 132a, 132b, 132c, 132d of the first coupling stage 132 are power splitters of the 3-dB-type, which means that each power splitter 132a, 132b, 132c, 132d imposes an attenuation of 3 dB to a respective signal portion output at a first output and a second output of the power splitter, e.g. input signal power is equally distributed to both outputs of the power splitters 132a, 132b, 132c, 132d. The further power splitters 134a, 134b, 134c, 134d comprise an input port which is connected to a respective power splitter 132a, 132b, 132c, 132d of the first coupling stage 132. Each power splitter 134a, 134b,

134c, 134d of the second coupling stage 134 is, according to a preferred embodiment, designed as a 6 dB power splitter, e.g. at each of the four output ports of the power splitter 134a, an instance of the input signal input to the power splitter 134 is obtained which is attenuated by 6 dB with respect to the input signal. According to further embodiments, other types of splitters may be employed, e.g. 1-to-3-type splitters which effect an attenuation of about 5 dB, and the like.

[0054] Preferably, for the second coupling stage 134, the one-by-four power splitters as depicted by FIG. 3 are provided, because this configuration is a very common type and therefore, the power splitters 134a, 134b, 134c, 134d are comparatively inexpensive. The power splitter 134a of the second coupling stage 134 serves to forward an attenuated portion of its input signal to each of the further power splitters 134b, 134c, 134d, which, as well as the first power splitter 134a, also operate as power combiners in the reverse direction.

[0055] For example, if the input port 110a is supplied with a calibration signal sig, said calibration signal sig is attenuated by 3 dB by the first power splitter 132a of the first coupling stage 132 and forwarded to the further power splitter 134a of the second coupling stage 134. Again, the signal fed to the power splitter 134a, is attenuated by 6-dB by means of the power splitter 134a, whereby an attenuated signal is obtained at each of the four output ports of the power splitter 134a. As can be seen from FIG. 3, a second output port of the power splitter 134a is terminated by termination means 136a, because this output branch of the power splitter 134a is not required for the present configuration of the coupling structure 130. The further three output ports of the power splitter 134a are each connected with one of the further power splitters 134b, 134c, 134d of the same second coupling stage 134. Thus, an attenuated portion of the input calibration signal sig is fed from the first power splitter 134a of the second coupling stage 134 to the further power splitters 134b, 134c, 134d of the second coupling stage 134. At the further power splitters 134b, 134c, 134d, which also operate as power combiners in the reverse direction, the further attenuated input signal is forwarded to the further power splitters 132b, 132c, 132d of the first coupling stage 132, whereby, at an output of the power splitters 132b, 132c, 132d, which may also operate as power combiners in the reverse direction, attenuated signal portions sig12, sig13, sig14 are obtained.

[0056] As can be seen from FIG. 3, hence, the coupling structure 130 according to the embodiment generates a first coupled signal portion sig12 depending on the calibration signal sig input to the first input port 110a, wherein the first coupled signal portion sig12 is returned by the coupling structure 130 to the second input port 110b as a feedback signal.

[0057] In analogy thereto, further attenuated signal portions sig13, sig14 are provided by the coupling structure 130 depending on the calibration signal sig, whereby the further signal portions sig13, sig14 may be returned

to the transceiver 212, like the first attenuated signal portion sig12, for evaluation of attenuation and delay characteristics imposed on the signal sig and the fed back signal portion sig12, sig13, sig14, respectively, e.g. within the transmission lines 210a, 210b, ...

[0058] In a forward direction, i.e. in FIG. 3 from the left to the right, the second power splitter 134b of the second coupling stage 134 operates in the same fashion as the first power splitter 134a of the second coupling stage 134. The same holds true for the further power splitters 134c, 134d. I.e., each of the power splitters 134a, 134b, 134c, 134d of the second coupling stage 134 is configured to receive at its input an attenuated calibration signal which is further attenuated by the respective power splitters of the second coupling stage 134 and which is then forwarded to the further power splitters of the second coupling stage which, in turn, attenuate the received signals and forward them to the first coupling stage, where they are processed in the sense of the feedback signal portions sig12, sig13, sig14.

[0059] An aggregated attenuation of the signal portion sig12 may be calculated as follows: Firstly, on the first power splitter 132a of the first coupling stage 132, an attenuation of 3 dB is imparted on the input signal sig. By processing the so attenuated input signal within the further power splitter 134a, a further attenuation of an additional 6 dB is effected. I.e., at an output of the power splitter 134a, the calibration signal is already attenuated by 9 dB. In the signal path connecting an output of the power splitter 134a with the power splitter 134b, an attenuation device 138a is provided which effects a further attenuation of 8 dB to the signal, which results in an aggregated attenuation at an output of the attenuation device 138a of 17 dB. After processing within the power splitter 134b, which combines the signal obtained at an output of the attenuation device 138a, an overall attenuation of 23 dB is obtained.

[0060] After being processed by the power splitter 132b, which also operates in the sense of a power combiner in the direction from the right of FIG. 3 to the left, an aggregated attenuation of 26 dB is imparted on the portion sig12 of the calibration signal sig, which is obtained at the input port 110b, i.e. the loop-back signal sig12, which is forwarded from the input signal 110b to e.g. the transceiver 212 of the base station 210 (cf. FIG. 2) for analysis. Generally, for a proper calibration, it is important to know the specific attenuation for all paths to be calibrated, which, according to the symmetrical approach, should be the same for all paths. Of course, other values than 26 dB for an overall attenuation are also usable.

[0061] Likewise, the further signal paths for the signal portions sig13, sig14 and any other signal paths will yield a uniform aggregated attenuation of 26 dB thus offering a symmetry regarding signal attenuation regardless of the specific input port 110a, 110b, 110c, 110d chosen for supplying the calibration signal sig to the coupling structure 130 or the calibration device 100, respectively.

For this purpose, several further attenuation devices 138b, ..., 138f are provided as can be seen from FIG. 3. Moreover, a third output port of each 6 dB splitter 134a, 134b, 134c, 134d is terminated by appropriate termination devices 136a, 136b, 136c, 136d.

[0062] Thus, a particularly efficient calibration can be performed, because any signal path configuration comprises comparable attenuation characteristics.

[0063] Preferably, according to a further advantageous embodiment, the same holds true for a delay characteristic of the various signal paths within the coupling structure 130 between the different input ports 110a, 110b, 110c, 110d and/or output ports 120a, 120b, 120c, 120d. For this purpose, an effective electrical length of the respective signal paths has to be identical so that no relative phase delay for the various signal paths is attained.

[0064] FIG. 4 depicts a further embodiment 130a of a coupling structure according to an embodiment.

[0065] In contrast to the coupling structure 130 as depicted by FIG. 3, the coupling structure 130a of FIG. 4 primarily relies on directional couplers which are comprised within the coupling stages 133, 137. Only a further coupling stage 135 comprises power splitters comparable to the power splitters of the stages 132, 134 as depicted by FIG. 3.

[0066] The provisioning of directional couplers 133a, 133b, .. has a deciding advantage over power splitters, because an insertion loss of a signal supplied to the first input port 110a, which is to be transmitted to the first output port 120a, can be kept comparatively low as compared to the configuration depicted by FIG. 3.

[0067] For instance, the coupler 133a of the coupling structure 130a according to FIG. 4 may be designed as a 20 dB-type directional coupler, which outputs at its output a captured signal portion attenuated by 20 dB, whereas an effective insertion loss of the signal travelling from the input port 110a via the directional coupler 133a to the output port 120a is only about 0.1 dB. That is, the configuration according to FIG. 4 is particularly suited for an ordinary operation of the RF system (FIG. 2), because if no calibration is performed, a particularly low insertion loss is achieved for signals travelling from the input ports 110 to the output ports 120 (FIG. 2).

[0068] A signal portion coupled by means of the directional coupler 133a from the input port 110a is forwarded to the power splitter 135a which distributes the attenuated signal as obtained at its output ports to further power splitters or combiners 135b', 135c', 135d', each of said combiners 135b', 135c', 135d', forwards a further attenuated signal to the further directional couplers 137b, 137c, 137d. The further directional couplers 137b, 137c, 137d insert the signal they are supplied with into a signal line connected to the respective input ports 110b, 110c, 110d, whereby feedback signals may be returned on said input ports 110b, 110c, 110d to an external device 212 (FIG. 2), which has sent a corresponding calibration signal to the input port 110a of the coupling structure of FIG.

4.

[0069] The coupling structure 130a as depicted by FIG. 4 is symmetrical regarding its signal processing and the generation of feedback signals which are coupled to further input ports 110b, 110c, 110d. That means that, if a calibration signal is e.g. fed to a further input port, such as e.g. input port 110c, it is processed regarding delay and attenuation in the same way as it would be inserted to input port 110a of the coupling structure 130a.

[0070] I.e., at the further input ports 110a, 110b, 110c, 110d, respective loop-back signal portions are obtained, all of which have been imparted the same attenuation and phase delay.

[0071] For this purpose, the further power splitters 135b, 135c, 135d of the coupler stage 135, the combiners 135a', 135b', 135c', 135d' and the couplers 133a, 133b, 133c, 133d, 137a, 137b, 137c, 137d of the stages 133, 137 have to be configured identically.

[0072] Although this configuration is the basis for a particularly preferred embodiment, which - due to its symmetry - enables a simple and efficient calibration, it is also possible to provide different signal paths within the coupling structure 130, 130a with different attenuation and/or delay properties. However, these differences must be taken into consideration by the external device 212 which provides the calibration signal sig and which evaluates return signal portions sig12, sig13, sig14.

[0073] FIG. 5a depicts a further coupling structure 130b which comprises two input ports 110a, 110b and two output ports 120a, 120b.

[0074] The coupling structure 130b comprises a coupler 137e which enables to couple a portion of the calibration signal sig as supplied to the first input port 110a back to the second input port 110b in the form of the coupled signal portion sig12.

[0075] FIG. 5b shows a further coupling structure 130c which in sum comprises three different input ports 110a, 110b, 110c and three output ports 120a, 120b, 120c.

[0076] As can be seen from FIG. 5b, three couplers 137e, 137f, 137g are provided, which are connected to the input ports 110a, 110b, 110c via respective power splitters 135e, 135f, 135g and to the specific output ports 120a, 120b, 120c via respective power splitters or combiners, respectively, 139e, 139f, 139g.

[0077] The configuration depicted by FIG. 5b advantageously enables to couple a signal portion of a calibration signal e.g. received via input port 110a to both input ports 110b, 110c for feedback transmission to an external device such as the transceiver 212 (FIG. 2). Again, the coupling structure 130c is symmetrical regarding its inputs 110a, 110b, 110c, which means that a calibration signal may also be inserted into the further input ports 110b, 110c, and that at the further input ports, similar portions of the calibration signal are obtained.

[0078] The combiners 139e, 139f, 139g serve - in a per se known manner - to combine output signals obtained at an output of the respective couplers 137e, 137f, 137g and to provide the combined signal portions to the

outputs 120a, 120b, 120c, respectively.

[0079] FIG. 5c depicts a further coupling structure 130d, which comprises an overall number of four input ports 110a, 110b, 110c, 110d, and an overall number of four output ports 120a, 120b, 120c, 120d.

[0080] The operation of the coupling structure 130d is similar to the coupling structures 130b, 130c already explained above with reference to FIG. 5a, 5b.

[0081] The power splitters 135h, 135i, 135j, 135k split signals incoming in the various input ports 110a, 110b, 110c, 1110d for output to respective couplers 137h, 137i, 137j, 137k, 137l, 137m, whereas the power combiners 139h, 139i, 139j, 139k in a per se known manner combine signals received at their respective three input ports for output to the respective output ports 120a, 120b, 120c, 120d of the coupling structure 130d.

[0082] The aforescribed coupling structures may e.g. be realised by discrete coupling devices, by cables, or by printed circuits.

[0083] FIG. 6a depicts a front view of a particularly preferred embodiment of a coupling structure 130e that may be used within a coupling device according to the embodiments.

[0084] As can be gathered from FIG. 6a, the coupling structure 130e comprises an electrically conductive housing 131a which comprises a basically cylindrical shape with a circular cross-section. Three inner conductors 131d1, 131d2, 131d3 are arranged within said conductive housing 131a.

[0085] The electrically conductive housing 131a is preferably connected to an electric reference potential such as a ground potential 131b of the RF system 200 (FIG. 2).

[0086] The inner conductors 131d1, 131d2, 131d3 as such are not isolated, so that electric fields will propagate in a per se known manner from the inner conductors to the electrically conductive housing 131a as well as to the further inner conductors, whereby a mutual coupling 131e12, 131e13, .. between the inner conductors is achieved.

[0087] An impedance of a transmission line constituted by an inner conductor 131d1 and the electrically conductive housing 131a may in a per se known manner be tuned by changing the geometry of the inner conductor 131d1 and/or its distance to the conductive housing 131a.

[0088] Moreover, a mutual coupling attenuation between the inner conductors 131d1, 131d2, 131d3 may be influenced by the geometry and/or position of the shielding means 131c, which are connected to the conductive housing 131 in an electrically conductive manner and which extend radially inwards from said housing 131a.

[0089] Thus, a coupling attenuation between the various inner conductors 131d1, 131d2, 131d3 may be tuned.

[0090] The coupling structure 130e advantageously provides for a mutual coupling of the inner conductors,

whereby discrete or lumped couplers as depicted by the embodiments according to FIG. 3 to FIG. 5c are not required anymore. Instead, the mutual coupling between the inner conductors is advantageously employed to realize the coupling attenuation required by the coupling structure 130 according to the embodiments.

[0091] As such, the coupling structure 130e of FIG. 6a is comparable in function to the coupling structure 130c depicted by FIG. 5b.

[0092] FIG. 6b depicts a front view of a further coupling structure 130f which is similar to the configuration according to FIG. 6a but which provides an overall number of four input ports and four output ports each of which are interconnected by the inner conductors 131d1, 131d2, 131d3, 131d4.

[0093] Several shielding means 131c are provided within the electrically conductive housing to control the mutual coupling attenuation between the inner conductors. The coupling and impedance may i.a. be tuned by altering geometrical parameters 131d1', 131c'.

[0094] FIG. 6c depicts an RF system comprising a base station 210 and an antenna system 220. Advantageously, the coupling structure 130f which has been explained above with reference to FIG. 6b is integrated into the transmission lines between the base station 210 and the antenna system 220 thus enabling a particularly efficient calibration of those parts of the transmission lines which are arranged between the base station 210 and the coupling structure 130f. For a proper calibration of the system, the device 130f should be placed as close to the antenna system 220 as possible, thus minimizing the length of those signal paths to the antenna system 220 which cannot be calibrated since they do not form part of the calibration loop established according to the embodiments.

[0095] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

[0096] The functions of the various elements shown in the FIGs., including any functional blocks labeled as 'processors', may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared proc-

essor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term 'processor' or 'controller' should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing software, random access memory (RAM), and non volatile storage. Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the FIGS. are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically understood from the context.

[0097] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

Claims

1. Calibration device (100) for calibrating a system (200) that is configured to process radio frequency, RF, signals, wherein said calibration device (100) comprises a plurality of input ports (110a, 110b) and a coupling structure (130) that is configured to receive a signal (sig) at at least one of said input ports (110a, 110b) and to forward a portion (sig12) of said received signal (sig) to at least another one of said input ports (110a, 110b), wherein said portions (sig12) of said received signal (sig) comprises a predetermined delay and/or attenuation with respect to said received signal (sig).
2. Calibration device (100) according to claim 1, wherein said coupling structure (130) is configured to forward a portion (sig12, sig13, sig14) of said received signal (sig) to all other input ports (110b, 110c, 110d), wherein said portion (sig12, sig13, sig14) of said received signal (sig) comprises a predetermined delay and/or attenuation with respect to said received signal (sig).
3. calibration device (100) according to one of the preceding claims, wherein said calibration device (100) comprises a plurality of output ports (120a, 120b), preferably as many output ports (120a, 120b) as there are input ports (110a, 110b), and wherein said coupling structure (130) is configured to forward a signal received at a specific input port (110a) to a specific output port (120a).
4. Calibration device (100) according to claim 3, wherein said coupling structure (130) comprises a first coupling stage (132, 133), said first coupling stage (132, 133) comprising at least one power splitter (132a) or a coupler (133a), preferably a directional coupler, for forwarding a signal (sig) received at a specific input port (110a) to both a specific output port (120a) that is associated with said specific input port (110a) and a second coupling stage (134, 135), wherein said second coupling stage (134, 135) is configured to distribute said signal (sig) to at least one further input port (110b, 110c, 110d).
5. Calibration device (100) according to claim 4, wherein said first coupling stage (133) comprises a coupler (133a), preferably a directional coupler, for coupling said received signal (sig) to the second coupling stage (135).
6. Calibration device (100) according to one of the claims 4 to 5, wherein said coupling structure (130) comprises a coupler (137b), preferably a directional coupler, for coupling said portion (sig12) of said received signal (sig) which comprises a predetermined delay and/or attenuation with respect to said received signal (sig), back to an input port (110b).
7. Calibration device (100) according to one of the preceding claims, wherein said coupling structure (130) comprises at least one attenuation device (138a, ..., 138f) for applying an attenuation to a signal processed by said coupling structure (130).
8. Calibration device (100) according to one of the preceding claims, wherein signal paths provided by said coupling structure (130) from a specific input port (110a) to any other input port (110b, 110c, 110d) each comprise a substantially identical electronic length and/or a substantially identical aggregated attenuation.
9. Calibration device (100) according to one of the preceding claims, wherein said coupling structure (130e, 130f) comprises an electrically conductive housing (131a), a number of inner conductors (131d1, 131d2, 131d3, 131d4) each of which connects a specific input port (110a, 110b, 110c, 110d) with a respective output port (120a, 120b, 120c, 120d), and shielding means (131c) at least partially arranged between neighbouring inner conductors (131d1, 131d2, 131d3, 131d4) to effect a coupling attenuation between said neighbouring inner conductors (131d1, 131d2, 131d3, 131d4).

10. Calibration device (100) according to claim 9, wherein said electrically conductive housing (131a) comprises a basically cylindrical shape with a circular cross-section, wherein said inner conductors (131d1, 131d2, 131d3, 131d4) are arranged substantially parallel to a longitudinal axis of said housing (131a), and wherein said shielding means (131c) at least partially extend in a radially inward direction from a wall of said housing (131a). 5
11. Antenna system (220) of an RF processing system (200), wherein said antenna system (220) comprises at least one calibration device (100) according to one of the preceding claims. 10
12. Method of operating a calibration device (100), wherein said calibration device (100) comprises a plurality of input ports (110a, 110b) and a coupling structure (130) that is configured to receive a signal (sig) at at least one of said input ports (110a, 110b) and to forward a portion (sig12) of said received signal (sig) to at least another one of said input ports (110a, 110b), wherein said portion (sig12) of said received signal (sig) comprises a predetermined delay and/or attenuation with respect to said received signal (sig), said method comprising the following steps: supplying a signal (sig) to said calibration device (100) at a specific input port (110a) via a first transmission line (210a), evaluating a signal portion (sig12) that is output by said calibration device (100) at at least one further input port (110b) via a second transmission line (210b) in reaction to said signal (sig). 15 20 25 30
13. Method according to claim 12, wherein said calibration device (100) is preferably configured according to one of the claims 1 to 10, wherein said calibration device (100) is used for transmitting radio frequency, RF, user signals from an RF source (210) to an antenna system (220) which is connected to output ports (120a, 120b, 120c, 120d) of said calibration device (100). 35 40
14. Method according to claim 13, wherein, in a temporally alternating fashion, user signals and calibration signals (sig) are supplied to said calibration device (100). 45

Amended claims in accordance with Rule 137(2) EPC. 50

1. Calibration device (100) for calibrating a system (200) that is configured to process radio frequency, RF, signals, wherein said calibration device (100) comprises a plurality of input ports (110a, 110b) and a coupling structure (130) that is configured to receive a signal (sig) at at least one of said input ports 55

(110a, 110b) and to forward a portion (sig12) of said received signal (sig) to at least another one of said input ports (110a, 110b), wherein said portion (sig12) of said received signal (sig) comprises a predetermined delay and/or attenuation with respect to said received signal (sig), wherein signal paths provided by said coupling structure (130) from a specific input port (110a) to any other input port (110b, 110c, 110d) each comprise a substantially identical electronic length and/or a substantially identical aggregated attenuation.

2. Calibration device (100) according to claim 1, wherein said coupling structure (130) is configured to forward a portion (sig12, sig13, sig14) of said received signal (sig) to all other input ports (110b, 110c, 110d), wherein said portion (sig12, sig13, sig14) of said received signal (sig) comprises a predetermined delay and/or attenuation with respect to said received signal (sig).

3. Calibration device (100) according to one of the preceding claims, wherein said calibration device (100) comprises a plurality of output ports (120a, 120b), preferably as many output ports (120a, 120b) as there are input ports (110a, 110b), and wherein said coupling structure (130) is configured to forward a signal received at a specific input port (110a) to a specific output port (120a).

4. Calibration device (100) according to claim 3, wherein said coupling structure (130) comprises a first coupling stage (132, 133), said first coupling stage (132, 133) comprising at least one power splitter (132a) or a coupler (133a), preferably a directional coupler, for forwarding a signal (sig) received at a specific input port (110a) to both a specific output port (120a) that is associated with said specific input port (110a) and a second coupling stage (134, 135), wherein said second coupling stage (134, 135) is configured to distribute said signal (sig) to at least one further input port (110b, 110c, 110d).

5. Calibration device (100) according to claim 4, wherein said first coupling stage (133) comprises a coupler (133a), preferably a directional coupler, for coupling said received signal (sig) to the second coupling stage (135).

6. Calibration device (100) according to one of the claims 4 to 5, wherein said coupling structure (130) comprises a coupler (137b), preferably a directional coupler, for coupling said portion (sig12) of said received signal (sig) which comprises a predetermined delay and/or attenuation with respect to said received signal (sig), back to an input port (110b).

7. Calibration device (100) according to one of the

preceding claims, wherein said coupling structure (130) comprises at least one attenuation device (138a, ..., 138f) for applying an attenuation to a signal processed by said coupling structure (130).

8. Calibration device (100) according to one of the preceding claims, wherein said coupling structure (130e, 130f) comprises an electrically conductive housing (131a), a number of inner conductors (131d1, 131d2, 131d3, 131d4) each of which connects a specific input port (110a, 110b, 110c, 110d) with a respective output port (120a, 120b, 120c, 120d), and shielding means (131c) at least partially arranged between neighbouring inner conductors (131d1, 131d2, 131d3, 131d4) to effect a coupling attenuation between said neighbouring inner conductors (131d1, 131d2, 131d3, 131d4).

9. Calibration device (100) according to claim 8, wherein said electrically conductive housing (131a) comprises a basically cylindrical shape with a circular cross-section, wherein said inner conductors (131d1, 131d2, 131d3, 131d4) are arranged substantially parallel to a longitudinal axis of said housing (131a), and wherein said shielding means (131c) at least partially extend in a radially inward direction from a wall of said housing (131a).

10. Antenna system (220) of an RF processing system (200), wherein said antenna system (220) comprises at least one calibration device (100) according to one of the preceding claims.

11. Method of operating a calibration device (100), wherein said calibration device (100) comprises a plurality of input ports (110a, 110b) and a coupling structure (130) that is configured to receive a signal (sig) at at least one of said input ports (110a, 110b) and to forward a portion (sig12) of said received signal (sig) to at least another one of said input ports (110a, 110b), wherein said portion (sig12) of said received signal (sig) comprises a predetermined delay and/or attenuation with respect to said received signal (sig), said method comprising the following steps: supplying a signal (sig) to said calibration device (100) at a specific input port (110a) via a first transmission line (210a), evaluating a signal portion (sig12) that is output by said calibration device (100) at at least one further input port (110b) via a second transmission line (210b) in reaction to said signal (sig), wherein signal paths provided by said coupling structure (130) from a specific input port (110a) to any other input port (110b, 110c, 110d) each comprise a substantially identical electronic length and/or a substantially identical aggregated attenuation.

12. Method according to claim 11, wherein said cal-

ibration device (100) is preferably configured according to one of the claims 1 to 10, wherein said calibration device (100) is used for transmitting radio frequency, RF, user signals from an RF source (210) to an antenna system (220) which is connected to output ports (120a, 120b, 120c, 120d) of said calibration device (100).

13. Method according to claim 12, wherein, in a temporally alternating fashion, user signals and calibration signals (sig) are supplied to said calibration device (100).

Fig.1

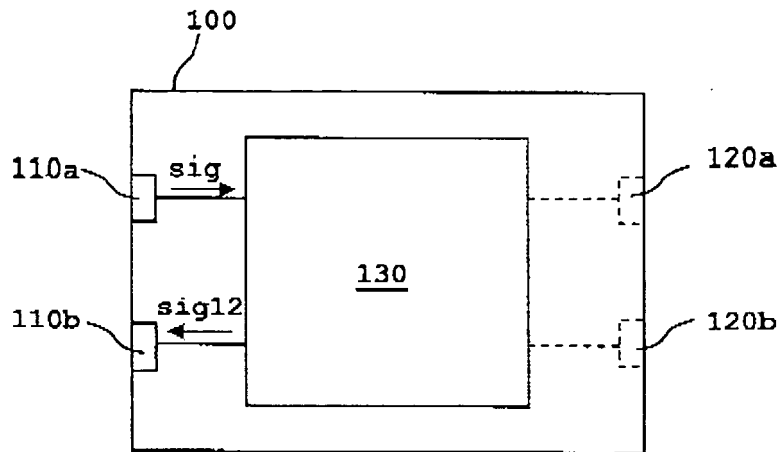


Fig.2

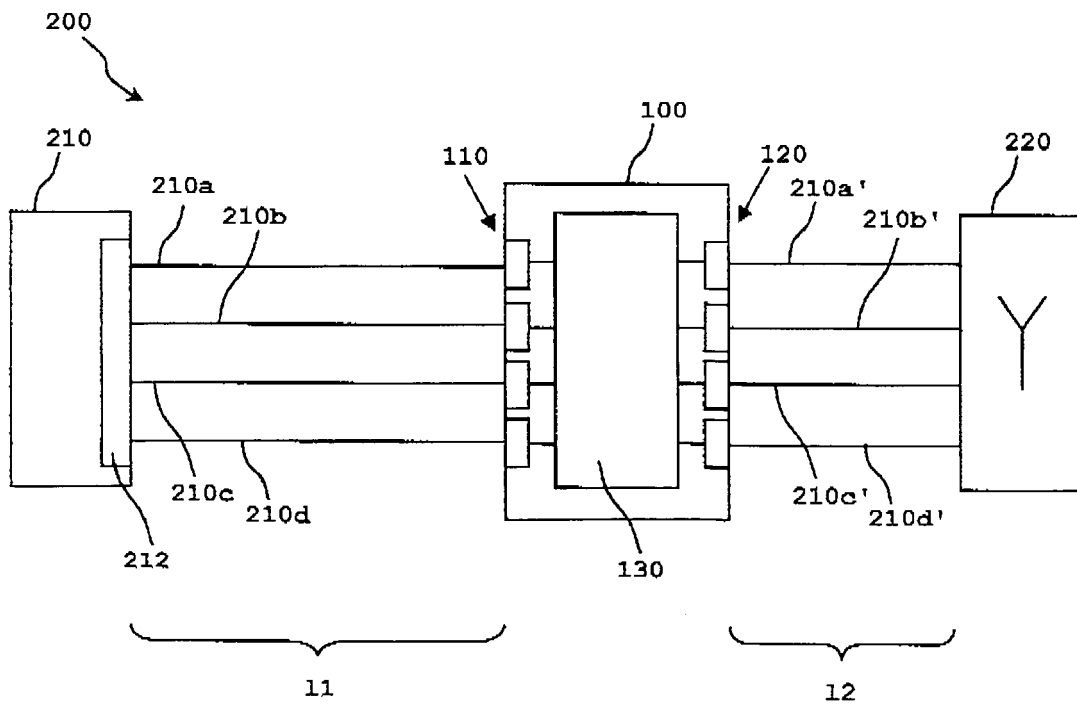


Fig. 3

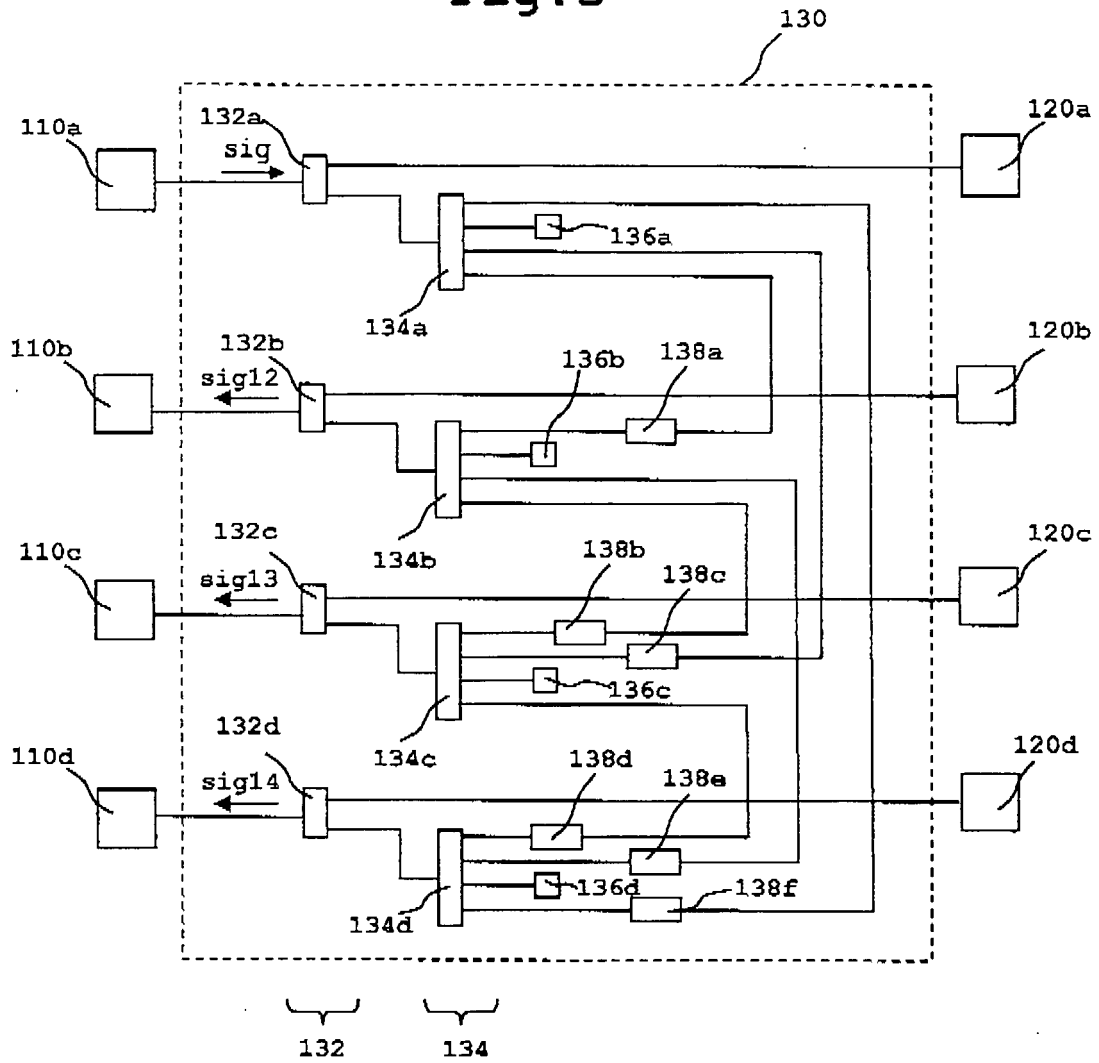


Fig. 4

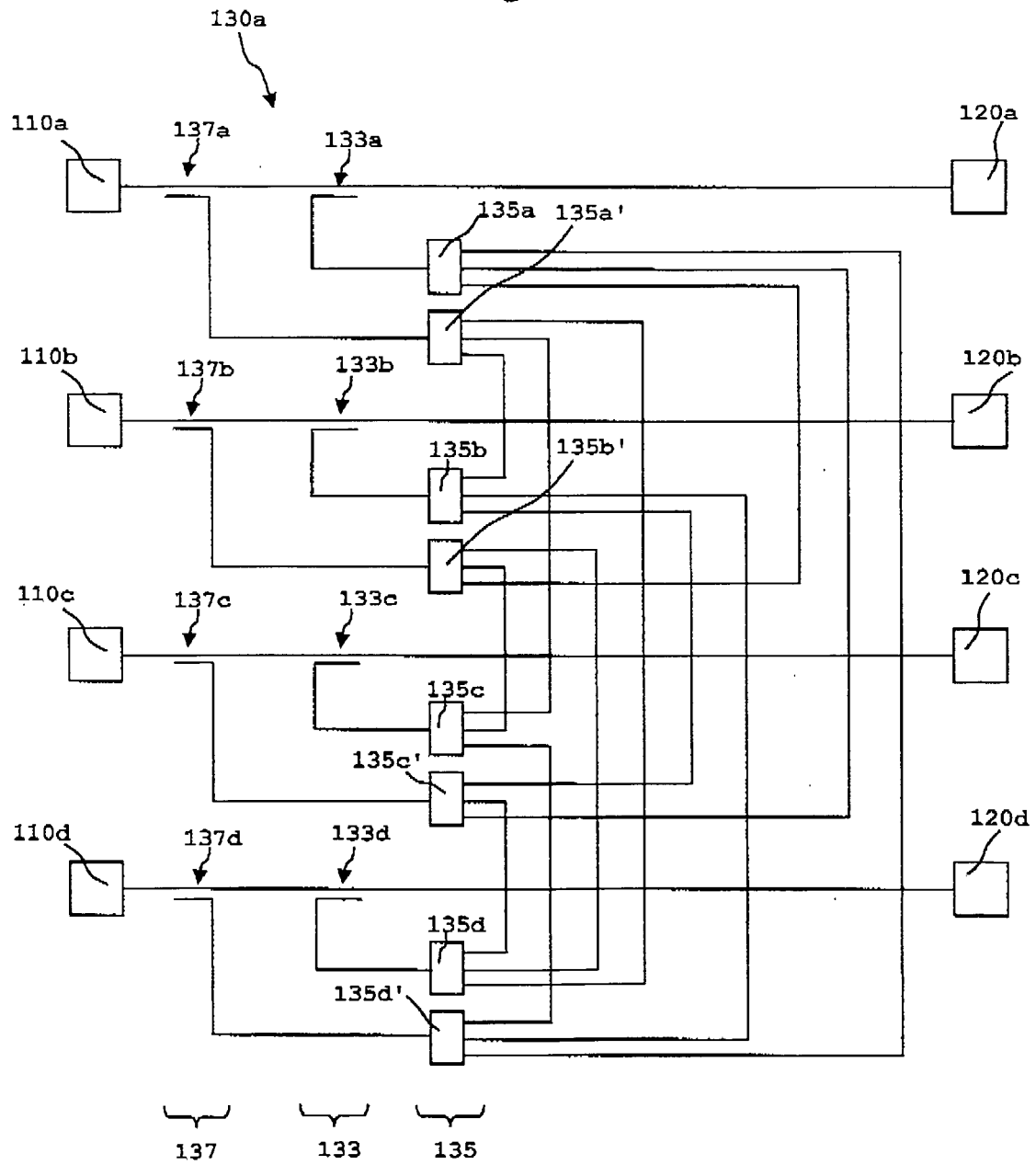


Fig. 5a

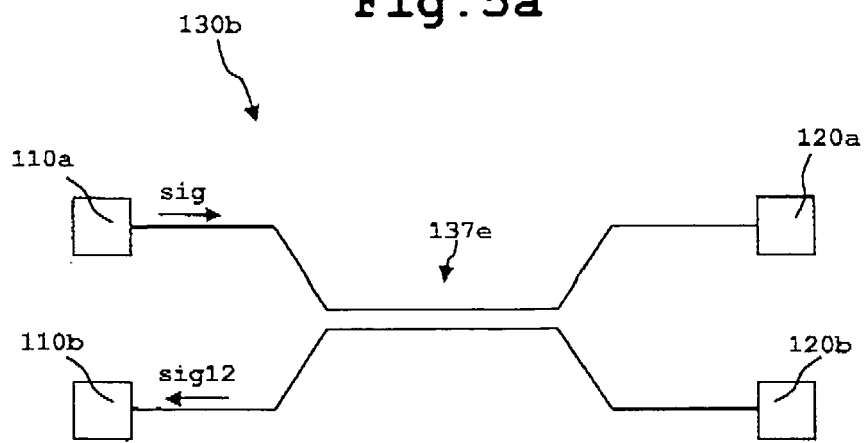


Fig. 5b

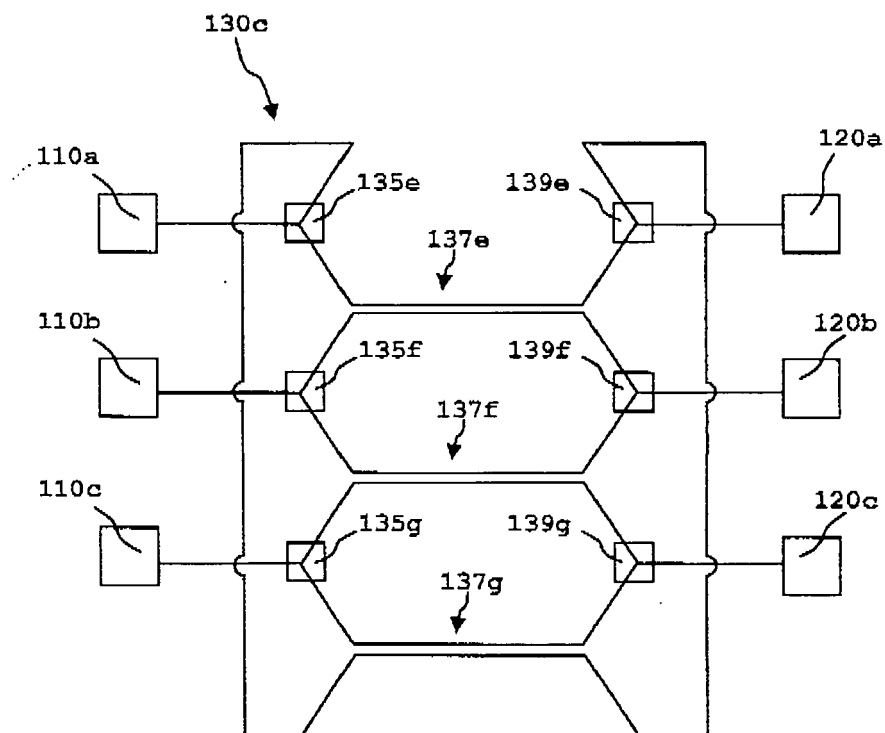


Fig. 5c

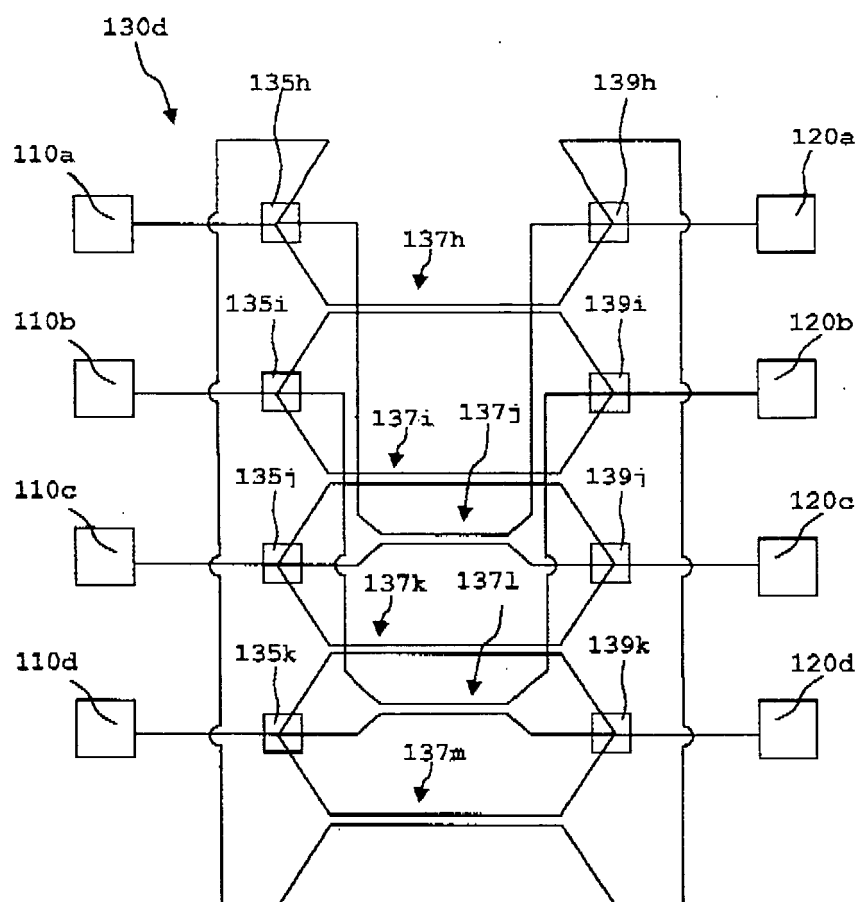


Fig. 6a

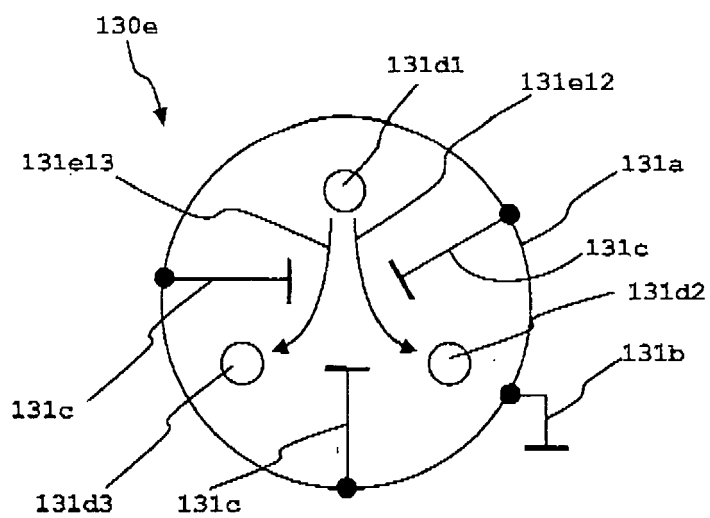


Fig. 6b

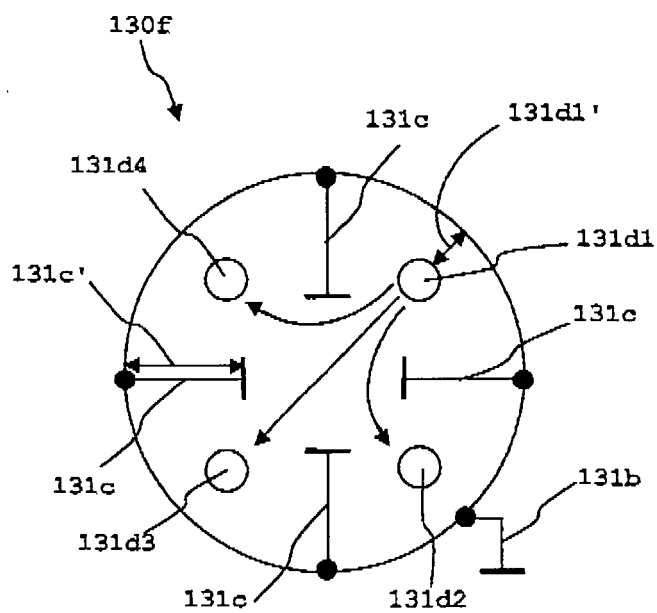
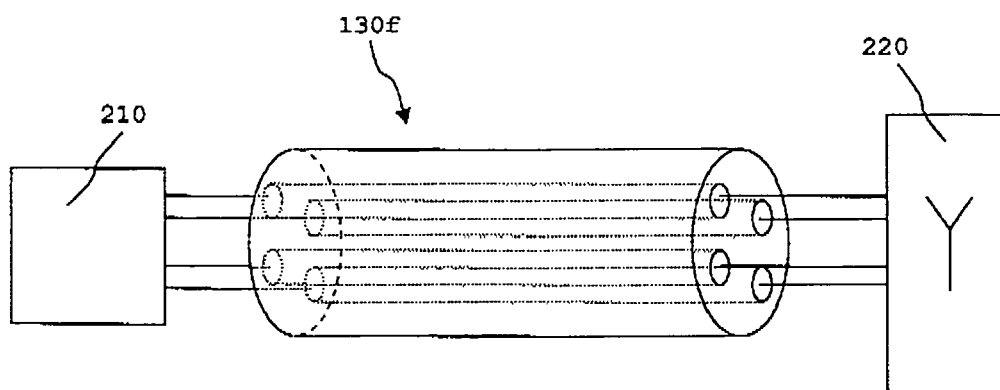


Fig. 6c





EUROPEAN SEARCH REPORT

Application Number
EP 11 29 0015

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Place of search		Date of completion of the search	Examiner
Munich		21 June 2011	Ribbe, Jonas
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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21-06-2011

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