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(54) **Beam forming for industrial system**

Strahlformung für Industrieanlage

Formation de faisceau pour système industriel

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Description

[0001] The present invention relates to a system for industrial application including a machine capable of changing its position and having machine communication means for wireless communication, and a controller designed for controlling the machine and having controller communication means for wireless communication with the machine communication means. Furthermore, the present invention relates to a method of preparing a wireless communication in an industrial system between machine communication means of a machine capable of changing its position and controller communication means of a controller designed for controlling the machine.

[0002] US 2011/0054690 A1 describes a double mast electro-mechanism for enhancing a performance of a bilateral robotic platform and a method of extending a capability of the bilateral robotic platform. If a change in attitude of an operational assembly is detected by an attitude sensor then masts are adjusted in order to counteract the change in attitude. When a command is received to change a mode then the attitude of the operational assembly is determined for example by the attitude sensor. An angle of masts is adjusted based on a feedback loop until performance is OK.

[0003] WO 95/11828 A1 describes an unmanned microwave powered aircraft system. A return tracking signal from an aircraft back down to a beaming antenna provides feedback to a ground control centre to aim and focus the beaming antenna in an optimum manner on the aircraft. A secondary tracking antenna may be utilized as a redundant system to track the position of the aircraft and relay tracking signals to the ground control centre. The ground control may transmit data from the primary tracking signal to the secondary communications antenna via a signal path. Providing position data acquired from the secondary tracking antenna speeds up the initial precise acquisition of the aircraft and may serve as redundancy.

[0004] US 2008/0316133 A1 refers to a remote control device for controlling the angle of inclination of the radiation diagram of an antenna. The device permits remote actuation on the slope angle of an antenna consisting of two units, one electric and one mechanical, physically separated and connected forming a single arrangement, in which each of the units is provided with its own casing. The mechanical unit supports an electro-motor coil positioning sensors, a driving gear, and a gear wheel engaged with the pinion. The electronic unit is provided with supply and communication connection terminals, an electronic circuit, a sensor for reading initial reference positioning and a casing. Both are connected by means of a cable and connector. Due to the independent manner in which the mechanical and electrical units are arranged, it is possible to obtain a watertight electronic unit protected from damp, independent replacement in a simple manner of both units, and the visualisation of the indicator rod's position and movement.

[0005] JP 2007 002429 A refers to a self-propelled working machine remote-operated by a remote controller having GPS with a GPS antenna and a GPS receiver installed on a vehicle body, and moving while sequentially transmitting the position detected result of the GPS antenna.

[0006] JP H 11 303146 A describes a wireless remote control system. The system comprises a moving type working machine which can be made to do work movably in a working site through wireless control by use of a first wireless device and a remote controller which controls the wireless moving type working machine by use of a second wireless device. The first and second wireless devices are constructed as fixed wireless devices equipped with respective conical scan antennas and electric wave reflecting mechanisms.

[0007] The field of the invention concerns wireless industrial control. In this context, the normal wired connection between a machine and its controller implemented, for example, using Profinet is replaced by a bi-directional wireless connection. Such an approach has advantages in flexibility of operation and re-configuration.

[0008] The required bandwidth for wired industrial communications is increased all the time. Furthermore, in a wireless context, it may often be advantageous to implement a star/broadcast topology using TDMA where one controller controls several machines over a common air interface. Together these aspirations lead to increasing requirements for RF bandwidth. The bandwidth must be provided under the constraints of limited available spectrum and limited link budget to achieve the desired operating range.

[0009] An advantageous technology for providing additional bandwidth and range is beam forming. This is closely related to the choice of operating frequency. Considerably more spectrum is available at higher frequencies (e.g. 60 GHz). However, path loss between omnidirectional antennas is prohibitively high. Thus, beam forming is needed to achieve acceptable range performance. Fortunately, because antenna elements are small at high frequencies, the array of antenna elements required to achieve the necessary beam forming typically has practical size.

[0010] Ideally, a wireless communication link is provided by arranging for the antenna arrays at both ends of the link to point their beam in the direction of the other end of the link. However, if the link budget requires correct alignment of the antenna array beams to achieve communication, then it is not clear how to align the beams in the first place.

[0011] The conventional solution to this problem is initially to establish a communication channel between the end points of the link, whose bit rate is low enough to allow reliable communications with unaligned beams. A reduced bit rate link can be achieved in one of a number of ways:

- Reduce the occupied bandwidth of the transmitted signal - in this case the noise power will reduce in direct proportion to the occupied bandwidth.
- Reduce the modulation constellation size - for example, if the normal modulation was 64 QAM (constellation size = 64), this could be reduced to BPSK (constellation size = 2). The minimum acceptable signal to noise ratio for the smaller constellation size modulation would be lower than for the larger constellation size.
- Use spread spectrum - this provides a processing gain so that the minimum acceptable signal to noise ratio is further reduced, typically to values less than unity.

[0012] Once such a channel is available, adjustments can be made in the beam direction at either end of the link and the impact on the received signal level observed. For example, one approach could be to provide each link end with a table of antenna element weightings to provide a set of overlapped beams. Each entry in the table is tested in turn and the entry providing the highest signal level is selected. Once this process is completed, a further beam scan can be performed but with finer granularity of angle until the most favourable antenna pattern has been obtained.

[0013] This process can be performed at both ends of the link but in a coordinated fashion to avoid confusing signal level changes caused by antenna pattern changes at the opposite end of the link. For example, operation is effective if the transmitting end is able to establish an omni-directional pattern, perhaps using a single antenna element, while the receiving end is adjusting its beam.

[0014] In a wireless industrial control application, either or both of the ends of the link, typically the machine, can be mobile so it will be necessary to provide a capability to maintain alignment of the beams at both ends of the link as the machine moves. One approach to achieving this is to dither the pointing angle of the beam by a small amount to either side of its nominal pointing angle. When the dithering in a particular direction causes the received signal strength to exceed the level for the nominal direction, the nominal pointing angle is shifted to that direction. Again, coordination is required between the dithering at both ends of the link to avoid confusion of measurement. Dithering in one angular dimension is all that is required for a linear (one dimensional) array. If the array is two dimensional (azimuth and elevation), then dithering will be required in both of these dimensions.

[0015] The above approach is effective where the time required to align the ends of the links is acceptably small and where the rate of change of angle due to motion can be accommodated by the dither algorithm. While such algorithms are generally reliable, the level of reliability required for wireless industrial control is extremely demanding. Typically, the minimum acceptable mean time between corrupted messages is of the order of days or even months.

[0016] In view of that, it is the object of the present invention to provide a system for industrial application, where effective wireless communication is possible even if a machine changes its position dynamically. Furthermore, a corresponding method of preparing a wireless communication in such an industrial system shall be provided.

[0017] According to the present invention, this object is solved by a system for industrial application including the features according claim 1. This solution includes a machine capable of changing its position and having machine communication means for wireless communication and a controller designed for controlling the machine and having controller communication means for wireless communication with the machine communication means, wherein the controller is capable of aligning the machine communication means and/or the controller communication means to each other on the basis of an instruction from the controller to the machine to change its position.

[0018] Since the controller gives instructions to the machine to change its position, the new position or movement is known or inherently contained in the instruction. Thus, the movement or new position of the machine can be predicted with the content of the instruction. Consequently, the communication means of the wireless communication can be aligned dynamically due to the available instructions of the controller.

[0019] Preferably, the machine communication means includes a machine antenna being designed for aligning to the controller communication means by control of the controller. Such antenna may be an antenna array, the beam of which can be formed electronically.

[0020] Similarly, the controller communication means may include a controller antenna being designed for aligning to the machine communications means by control of the controller. The controller antenna may also be designed as array antenna for electronic beam forming.

[0021] In one embodiment, each of the machine communication means and the controller communication means includes a transceiver for bidirectional communication. For such constellation, it is advantageous to align the beams in both communication directions.

[0022] The above object is also solved by a method according claim 5.

[0023] This method has the same advantage as the above described system, specifically the alignment of the communication means can be anticipated by the instructions of the controller.

[0024] In a further development the controller may give several instructions to the machine, each to change its position, in a first calibration phase, one or both of the communication means are automatically aligned to one another at each position, and alignment values for each position are stored in a table. Thus, a first calibration can be performed over the range of movement of the machine.

[0025] A first table contains alignment values of the controller and is stored in the controller. Thus, the alignment of the communication means can be performed with (nearly) no delay.

[0026] Furthermore, a second table contains alignment values of the machine and may be stored in the machine. Thus, the machine itself can evaluate alignment data from the instructions received from the controller. Thus, the wireless link is not stressed with the transmission of alignment data.

[0027] According to another preferred aspect, the controller gives several instructions to the machine, each to change its position, in a second calibration phase, one or both of the communication means are automatically aligned, where line of sight directions are excluded, and alignment values for each position are stored in an additional table. Such second calibration phase has the advantage that the wireless communication link is not limited to line of sight communication. Rather, additional communication paths can be used alternatively if the line of sight communication is not possible or disrupted.

[0028] During the first and/or second calibration phase, an omni-directional signal may be transmitted and the receiving one of the machine communication means or controller communication means may scan an angle region for a strongest signal. Thus, first and second calibration can be performed fully automatically.

[0029] The above features related to the method can also be used to further develop the inventive system and vice versa, where the respective functions are not limited to the means described.

[0030] The present invention will now be described in more detail in connection with FIG 1 showing a principal block diagram of an inventive industrial system. The claimed method can also be gathered from this figure.

[0031] The following described embodiments represent preferred examples of the present invention.

[0032] The proposed solution to the beam alignment problem is to make use of known position or known movements of the machines that carry antennas or antenna arrays (in the following for simplification only "antenna arrays"). The proposal is based on the assumption that means can be provided to locate the controller antenna array (part of controller communication means) and the machine antenna array (part of machine communication means) in two or three dimensions as required (the additional dimension in the case of three dimensions being height above the floor).

[0033] Since typically an antenna array that is connected to a controller will be fixed, it would be relatively straightforward to determine its position through surveying. For many machines whose position changes, each movement is a direct result of an instruction from the controller. Thus, the controller can anticipate the movement that the machine will make in response to its instruction and adjust the antenna beam direction accordingly.

[0034] Even without surveying, the movement-related beam pointing requirements can be determined through a calibration phase. The controller can instruct the machine to move over its available movement space in slow time. The beam can be aligned using an existing algorithm such as those described earlier. Next, the beam pointing information can be stored in two tables with entries corresponding to every position of the machine. In one embodiment, one table would reside in the wireless transceiver associated with the controller for the purposes of setting the controller beam angle(s) as a function of machine position and the other would reside in the wireless transceiver associated with the machine for the purposes of setting the machine beam angle(s) as a function of machine position.

[0035] The above approach will be most reliable where there is a line of sight path between the two ends of the link. Under some circumstances, another machine might occasionally move into position that causes it to block the line of sight path. In principle, it might then be possible to find an alternative path via a reflective surface. However, if a standard prior art solution were used, this path could take considerable time to find, which would probably be unacceptable for a high reliability, low latency industrial application. It would be highly advantageous if a good alternative path were already available.

[0036] A further aspect of this invention is for a second calibration phase to search for non line of sight paths. One proposed way of doing this would be, having found the direction of the line sight path at both ends of the link, to perform a calibration run that excludes the line of sight direction and angles around it. In this case, if the transmitting end establishes a single null in the main path direction, this will assist the receiving end in finding the direction of a reflected component by attenuating the line of sight path.

[0037] A concrete embodiment of the present invention is shown in the block diagram of FIG 1. It shows a system for realizing wireless industrial control. A controller C shall control machine M. The controller C includes a controller core CC, controller communication means CCM and controller storage means CSM. The controller communication means CCM comprises a controller transceiver CT, a controller antenna array CA and an angle scan controller CAS. The controller core CC is in bidirectional communication with the controller transceiver CT. The controller transceiver CT in turn has a bidirectional multichannel connection with the controller antenna array CA. The angle scan controller CAS of the controller C controls the character of the controller antenna or controller antenna array CA, respectively. For example, the angle scan controller CAS controls the controller antenna array CA such that the controller antenna array CA scans a pregiven angle region for finding the strongest signal during the first or second calibration phase. Additionally, the angle scan controller CAS may control the controller antenna array CA such that the reception or transmission beam is directed to a specific direction.

[0038] In the present example, a position look-up table is stored in the controller storage means CSM. Such table is established during a calibration phase by the angle scan controller CAS. An instruction for moving the machine M will also be passed to the position look-up table in order to obtain the actual angle for the controller antenna array CA, which is transmitted via the angle scan controller CAS and the controller transceiver CT.

[0039] In the present example, the wireless communication is performed in the RF region. However, other frequencies may be used.

[0040] The structure of the machine M is symmetrical to that of the controller C. This means that the machine M includes a machine core MC (i.e. the classical machine), machine communication means MCM and machine storage means MSM. The machine communication means MCM comprises a machine transceiver MT, a machine antenna array MA and an angle scan controller MAS. The functionality of the components of the machine M corresponds to the functionality of the components of the controller C. Thus, it is referred to the above description of the controller C.

[0041] During operation and calibration in one stage the controller C may act as transmitter and the machine M as receiver, whereas in another stage the machine may act as transmitter and the controller as receiver. Beam forming is accomplished if at least one of the antennas or antenna arrays CA and MA are directed to the other one. In such situation we simply say the one communications means is directed to the other communication means.

[0042] The functions involved in capturing the data for generating the table data are shown in FIG 1. The controller C enforces a range of movements onto the machine M over a low data rate channel to the machine M. For each position of the machine M the controller core CC first instructs the transceiver MT associated with the machine M to transmit using an omni-directional antenna, where the machine antenna array MA has an omni-directional characteristic. The controller core CC then instructs its transceiver CT to scan the angle of its antenna array CA and search for the angle that gives the strongest received signal. Once this is found, the controller C associates the angle with the position in its position look-up table in the controller storage means CSM and then instructs its transceiver CT to transmit using the best angle just found and uses the low data rate channel to instruct the transceiver MT associated with the machine M to scan the angle of its antenna array MA and search for the strongest signal. Once this is found, the machine M associates the angle with the position in its position look-up table in the machine storage means MSM. The controller C then repeats the process for the next position and so on.

[0043] The above process relies on the machine M always returning to the same position when instructed to do so. This may involve a measure of "dead reckoning". Where this is the case, there could be a build up of errors as the machine M moves many times over its available area/volume. In that event, the table would be updated for every re-visit to the same controller-specified position using the position obtained from a fine-tracking algorithm (using narrow angle dither).

[0044] The advantages of the present invention are as follows:

- More reliable wireless communications are guaranteed.
- Ability to use narrower beams is provided, allowing greater operation range/higher bandwidth.
- Potential for high bandwidth communications is provided even where line of sight may not always be available.

Claims

1. System for industrial application including

- a machine (M) capable of changing its position and having machine communication means (MCM) for wireless communication and
- a controller (C) designed for controlling the machine and having controller communication means (CCM) for wireless communication with the machine communication means (MCM),
- wherein the controller (C) is provided to give an instruction to the machine (M) to change its position, thus the new position or movement is known or inherently contained in the instruction so that the movement or new position of the machine can be predicted with the content of the instruction and
- as a consequence the controller communication means (CCM) and the machine communication means (MCM) are dynamically aligned to each other due to the available instructions of the controller,
- wherein a first table stored in the controller (C) contains alignment values of the controller (C),
- wherein a second table stored in the machine (M) contains alignment values of the machine (M) and
- wherein the alignment values are alignment values for each position of the machine (M).

2. System according to claim 1, wherein the machine communication means (MCM) includes a machine antenna (MA) being designed for aligning to the controller communication means (CCM) by control of the controller (C).

3. System according to one of the preceding claims, wherein the controller communication means (CCM) includes a controller antenna (CA) being designed for aligning to the machine communication means (MCM) by control of the controller (C).

4. System according to one of the preceding claims, wherein each of the machine communication means (MCM) and the controller communication means (CCM) includes a transceiver (MT, CT) for bidirectional communication.

5. Method of

- preparing a wireless communication in an industrial system between machine communication means (MCM) of a machine (M) capable of changing its position and controller communication means (CCM) of a controller (C) designed for controlling the machine (M),
- wherein the controller (C) gives an instruction to the machine (M) to change its position, thus the new position or movement is known or inherently contained in the instruction so that the movement or new position of the machine can be predicted with the content of the instruction and
- as a consequence the controller communication means (CCM) and the machine communication means (MCM) are dynamically aligned to each other due to the available instructions of the controller,
- wherein the controller (C) gives several instructions to the machine (M), each to change its position, in a first calibration phase, one or both of the communication means (CCM, MCM) are automatically aligned to one another at each position,
- wherein a first table stored in the controller (C) contains alignment values of the controller (C),
- wherein a second table stored in the machine (M) contains alignment values of the machine (M) and
- wherein the alignment values are alignment values for each position of the machine (M).

6. Method according to claims 5, wherein the controller (C) gives several instructions to the machine (M), each to change its position, in a second calibration phase, one or both of the communication means (CCM, MCM) are automatically aligned, where line of sight directions are excluded, and alignment values for each position are stored in an additional table.

7. Method according to one of the claims 5 or 6, wherein during the first and/or second calibration phase an omni-directional signal is transmitted and the receiving one of the machine communication means (MCM) or controller communication means (CCM) scans an angle region for a strongest signal.

Patentansprüche

1. System zur industriellen Anwendung, das Folgendes enthält:

eine Maschine (M), die ihre Position ändern kann und Maschinenkommunikationsmittel (MCM) zur drahtlosen Kommunikation aufweist, und
eine Steuereinheit (C), die zum Steuern der Maschine konstruiert ist und Steuereinheitskommunikationsmittel (CCM) zur drahtlosen Kommunikation mit den Maschinenkommunikationsmitteln (MCM) aufweist,
wobei die Steuereinheit (C) vorgesehen ist, der Maschine (M) eine Anweisung zu erteilen, ihre Position zu ändern, und somit die neue Position oder Bewegung bekannt oder inhärent in der Anweisung enthalten ist, so dass die Bewegung oder die neue Position der Maschine mit dem Inhalt der Anweisung vorhergesagt werden kann, und
als eine Konsequenz die Steuereinheitskommunikationsmittel (CCM) und die Maschinenkommunikationsmittel (MCM) aufgrund der verfügbaren Anweisungen der Steuereinheit dynamisch aneinander angepasst werden,
wobei eine erste in der Steuereinheit (C) gespeicherte Tabelle Anpassungswerte der Steuereinheit (C) beinhaltet,
wobei eine zweite in der Maschine (M) gespeicherte Tabelle Anpassungswerte der Maschine (M) beinhaltet, und
wobei die Anpassungswerte Anpassungswerte für jede Position der Maschine (M) sind.

2. System nach Anspruch 1, wobei die Maschinenkommunikationsmittel (MCM) eine Maschinenantenne (MA) enthalten, die zum Anpassen an die Steuereinheitskommunikationsmittel (CCM) durch Steuern der Steuereinheit (C) konstruiert ist.

3. System nach einem der vorhergehenden Ansprüche, wobei die Steuereinheitskommunikationsmittel (CCM) eine Steuereinheitsantenne (CA) enthalten, die zum Anpassen an die Maschinenkommunikationsmittel (MCM) durch Steuerung der Steuereinheit (C) konstruiert ist.

4. System nach einem der vorhergehenden Ansprüche, wobei sowohl die Maschinenkommunikationsmittel (MCM) als auch die Steuereinheitskommunikationsmittel (CCM) einen Sender/Empfänger (MT, CT) zur bidirektionalen Kommunikation enthalten.

5. Verfahren zum
Vorbereiten einer drahtlosen Kommunikation in einem industriellen System zwischen Maschinenkommunikationsmitteln (MCM) einer Maschine (M), die zum Ändern ihrer Position fähig ist, und Steuereinheitskommunikationsmittel (CCM) einer Steuerein-

heit, die zum Steuern der Maschine (M) konstruiert ist,

wobei die Steuereinheit (C) der Maschine (M) eine Anweisung erteilt, ihre Position zu ändern, und somit die neue Position oder Bewegung bekannt oder inhärent in der Anweisung enthalten ist, so dass die Bewegung oder die neue Position der Maschine mit dem Inhalt der Anweisung vorhergesagt werden kann, und

als eine Konsequenz die Steuereinheitskommunikationsmittel (CCM) und die Maschinenkommunikationsmittel (MCM) aufgrund der verfügbaren Anweisungen der Steuereinheit dynamisch aneinander angepasst werden,

wobei die Steuereinheit (C) der Maschine (M) mehrere Anweisungen erteilt, jede zum Ändern ihrer Position, in einer ersten Kalibrierungsphase, wobei eines der oder beide Kommunikationsmittel (CCM, MCM) in jeder Position automatisch aneinander angepasst werden,

wobei eine erste in der Steuereinheit (C) gespeicherte Tabelle Anpassungswerte der Steuereinheit (C) beinhaltet,

wobei eine zweite in der Maschine (M) gespeicherte Tabelle Anpassungswerte der Maschine (M) beinhaltet, und

wobei die Anpassungswerte Anpassungswerte für jede Position der Maschine (M) sind).

6. Verfahren nach Anspruch 5, wobei die Steuereinheit (C) der Maschine (M) mehrere Anweisungen erteilt, jede zum Ändern ihrer Position, in einer zweiten Kalibrierungsphase, wobei eines der oder beide Kommunikationsmittel (CCM, MCM) automatisch angepasst werden, wobei Sichtlinienrichtungen ausgeschlossen und Anpassungswerte für jede Position in einer zusätzlichen Tabelle gespeichert sind.

7. Verfahren nach einem der Ansprüche 5 oder 6, wobei während der ersten und/oder der zweiten Kalibrierungsphase ein omnidirektionales Signal gesendet wird und die empfangenden aus den Maschinenkommunikationsmitteln (MCM) oder den Steuereinheitskommunikationsmitteln (CCM) einen Winkelbereich nach einem stärksten Signal abtasten.

Revendications

1. Système pour application industrielle, comprenant

- une machine (M) capable de changer sa position et ayant des moyens (MCM) de communication de machine pour communication sans fil et
- une unité (C) de commande conçue pour commander la machine et ayant des moyens (CCM) de communication d'unité de commande pour communication sans fil avec les moyens (MCM) de communication de la machine,
- dans lequel l'unité (C) de commande est prévue pour donner une instruction à la machine (M) de changer sa position, la position nouvelle ou le déplacement étant ainsi connu ou contenu de manière inhérente dans l'instruction, de manière à ce que le déplacement ou la position nouvelle de la machine puisse être prédit par le contenu de l'instruction et
- en conséquence, les moyens (CCM) de communication de l'unité de commande et les moyens (MCM) de communication de la machine sont alignés dynamiquement l'un sur l'autre en raison des instructions disponibles de l'unité de commande,
- dans lequel une première table mise en mémoire dans l'unité (C) de commande contient des valeurs d'alignement de l'unité (C) de commande,
- dans lequel une deuxième table mise en mémoire dans la machine (M) contient des valeurs d'alignement de la machine (M) et
- dans lequel les valeurs d'alignement sont des valeurs d'alignement pour chaque position de la machine (M).

2. Système suivant la revendication 1, dans lequel les moyens (MCM) de communication de la machine comprennent une antenne (MA) de machine conçue pour s'aligner aux moyens (CCM) de communication de l'unité de commande par commande de l'unité (C) de commande.

3. Système suivant l'une des revendications précédentes, dans lequel les moyens (CCM) de communication de l'unité de commande comprennent une antenne (CA) d'unité de commande conçue pour s'aligner sur les moyens (MCM) de communication de la machine par commande de l'unité (C) de commande.

4. Système suivant l'une des revendications précédentes, dans lequel chacun des moyens (MCM) de communication de la machine et des moyens (CCM) de communication de l'unité de commande comprennent un émetteur-récepteur (MT, CT) de communication bidirectionnelle.

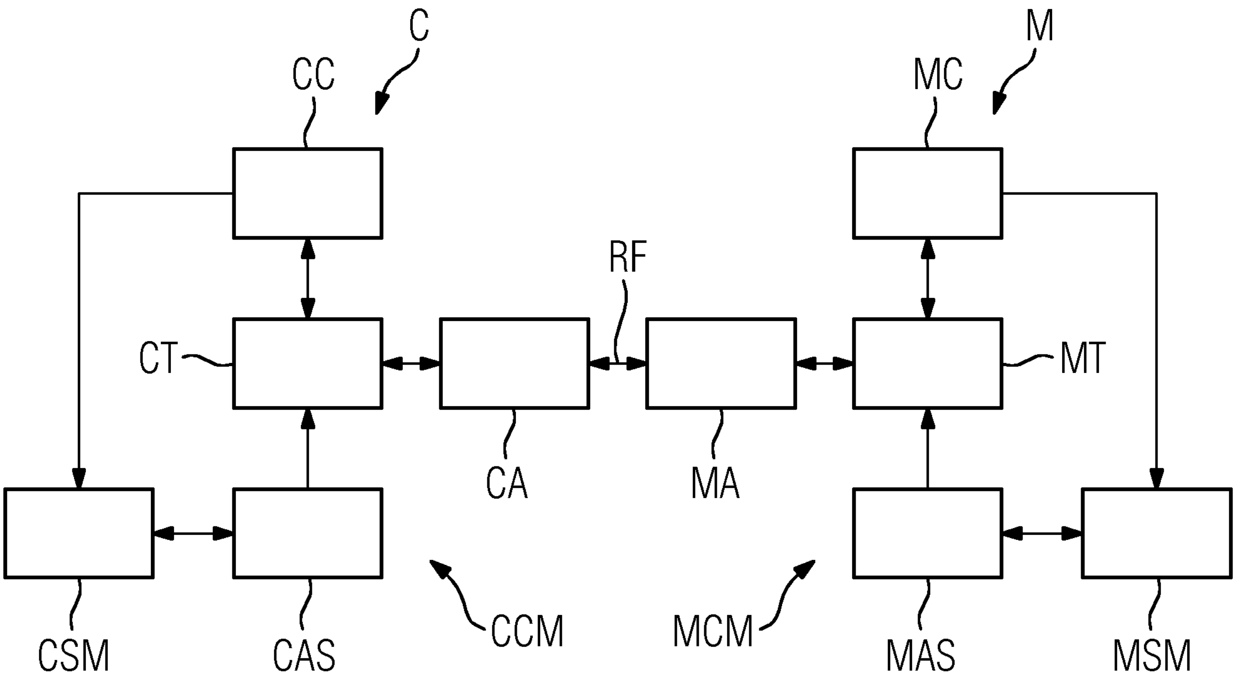
5. Procédé dans lequel

- on prépare une communication sans fil dans un système industriel entre des moyens (MCM) de communication de machine d'une machine (M) capable de changer sa position et des moyens (CCM) de communication de l'unité de commande d'une unité (C) de commande conçue pour commander la machine (M),

- dans lequel l'unité (C) de commande donne une instruction à la machine (M) de changer sa position, la position nouvelle ou le déplacement étant ainsi connu ou contenu de manière inhérente dans l'instruction, de manière à ce que le déplacement ou la position nouvelle de la machine puisse être prédit par le contenu de l'instruction et
- en conséquence, les moyens (CCM) de communication de l'unité de commande et les moyens (MCM) de communication de la machine sont alignés dynamiquement l'un sur l'autre en raison des instructions disponibles de l'unité de commande,
- dans lequel l'unité (C) de commande donne plusieurs instructions à la machine (M), chacune pour changer sa position dans une première phase d'étalonnage, les uns ou les deux des moyens (CCM, MCM) de communication étant alignés automatiquement l'un sur l'autre à chaque position,
- dans lequel une première table mise en mémoire dans l'unité (C) de commande contient des valeurs d'alignement de l'unité (C) de commande,
- dans lequel une deuxième table mise en mémoire dans la machine (M) contient des valeurs d'alignement de la machine (M) et
- dans lequel les valeurs d'alignement sont des valeurs d'alignement pour chaque position de la machine (M).

6. Procédé suivant la revendication 5, dans lequel l'unité (C) de commande donne plusieurs instructions à la machine (M), chacune pour changer sa position, dans une deuxième phase d'étalonnage, les uns ou les deux des moyens (CCM, MCM) de communication sont alignés automatiquement, des directions de ligne de vue étant exclues et des valeurs d'alignement pour chaque position sont mises en mémoire dans une table supplémentaire.

7. Procédé suivant l'une des revendications 5 ou 6, dans lequel pendant la première et/ou la deuxième phases d'étalonnage, un signal omnidirectionnel est transmis et ce récepteur des moyens (MCM) de communication de la machine ou des moyens (CCM) de communication de l'unité de commande balaie une région angulaire pour un signal plus fort.


C
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REFERENCES CITED IN THE DESCRIPTION

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