(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 393 212 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
24.10.2018 Bulletin 2018/43

(51) Int Cl.:
H05B 37/02 *(2006.01)*

(21) Application number: **17166891.6**

(22) Date of filing: **18.04.2017**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(71) Applicant: **GRP Iluminacion, S.A.**
28108 Alcobendas (Madrid) (ES)

(72) Inventor: **BELLIDO BÁREZ, Daniel**
28108 Alcobendas (Madrid) (ES)

(74) Representative: **Lins, Martina**
Gramm, Lins & Partner
Patent- und Rechtsanwälte PartGmbB
Theodor-Heuss-Strasse 1
38122 Braunschweig (DE)

(54) A METHOD FOR CONTROLLING AN AIRPORT NAVIGATION LIGHTS SYSTEM

(57) The invention relates to a method for controlling an airport navigation lights system (22), comprising
(a) a power source (24) for producing an AC current (I);
(b) a plurality of lamp units (26) that
- are powered by the power source (24) via a cable (25) and
- comprise a receiver;

(c) at least one aeronautical ground light (14.1); and
(d) a control unit (30) that
- is connected to the cable (25) and
- is arranged for sending messages to the lamp units (26) and receiving messages from the lamp units (26) via the cable (25),

the method comprising the following steps:
(i) determining a noise level for a plurality of time slots (S) along the period of the AC current (I);
(ii) determining low-noise time slots during which the noise level is below a noise threshold;
(iii) sending a low-information message (M_{low}) encoding the timing of at least some of the low-noise time slots relative to the period via the cable; and
(iv) sending high-information messages encoding control commands during these low-noise time slots.

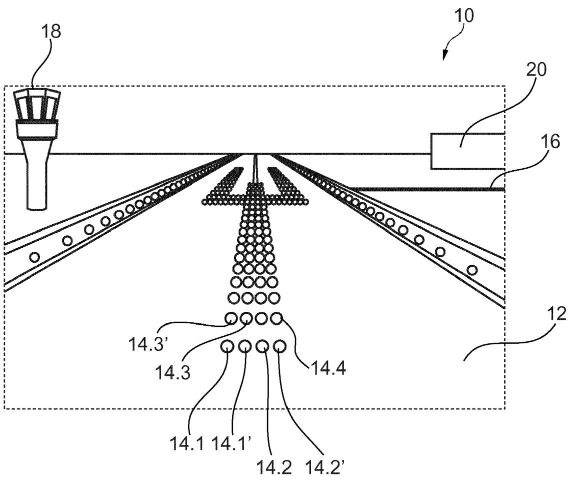


Fig. 1

EP 3 393 212 A1

Description

[0001] The invention relates to a method for controlling an airport navigation lights system, comprising (a) a power source for producing an AC current, the AC current having a period; (b) a plurality of lamp units that are powered by the power source via a cable and comprise a receiver and at least one aeronautical ground light; and (c) a control unit that is connected to the cable and arranged for sending messages to the lamp units and receiving messages from the lamp units via the cable. According to a second aspect, the invention relates to such an airport navigation lights system.

[0002] Airport navigation lights systems are used for lighting traffic ways of an airport, e.g. its runway or taxiways. The lamps of the airport navigation light system, which may also be called aeronautical ground lights, must be checked regularly in order to make sure they function properly. Furthermore, it is an advantage to be able to communicate with each of those lights so that they may be used as signals for pilots.

[0003] Some airport navigation light systems use unshielded cables for powering the lamp units that each control at least one aeronautical ground light. These existing systems can be upgraded for communication with the lamp units. However, the number of aeronautical ground lights that can be addressed individually by these systems is rather limited.

[0004] It would be possible to connect all aeronautical ground lights and all lamp units to a network of shielded data cables. This would lead to a safe, reliable and versatile system, but requires a completely new communication system.

[0005] The invention aims at improving an airport navigation lights systems, in particular existing airport navigation lights systems.

[0006] The invention solves this problem by means of a method with the features of claim 1. In particular, the method comprises the following steps: (i) determining a noise level for a plurality of time slots along the period of the AC current; (ii) determining low-noise time slots during which the noise level is below a. e.g. pre-determined, noise threshold; (iii) sending a low-information message encoding the timing of at least some of the low-noise time slots, in particular all time slots, relative to the period via the cable; and (iv) sending high-information messages encoding control commands during these low-noise time slots.

[0007] According to a second aspect, the invention solves the problem by an airport navigation lights system according as described above, wherein the control unit is set up to automatically perform the steps (i) to (iv).

[0008] It is an advantage of the invention that many aeronautical ground lights can be controlled. Tests have shown that more than 500 and up to 990 lights can be addressed within less than 5 seconds per available frequency channel. As a consequence, the airport navigation lights systems of relatively large airports can be retrofitted.

[0009] It is a further advantage that the error rate is low. As only low-noise time slots are used, frequency multiplexing is possible, and errors in the data transmission are unlikely.

[0010] It is a further advantage that repeaters are usually not needed. As several time slots can be used, the maximum frequency can be chosen to be lower than e. g. 30 kilohertz. The inventors have found that the attenuation of signals at higher frequency is particularly high. As lower frequency can be used, the attenuation is reasonably low so that repeaters are usually not necessary.

[0011] As a consequence, no shielding is required for the cable. The invention is applicable to almost all existing airport navigation lights systems.

[0012] It is a further advantage of the present system that it is robust. As the lamp units and/or the control unit only use low-noise time channels, the communication electronics can, according to a preferred embodiment, be switched off or be set up for automatically switching off during high-noise time slots. Consequently, they are not affected by possible voltage peaks.

[0013] In this description, the noise level is in particular intended to mean the amount of current and/or voltage fluctuations that are not intended.

[0014] The noise threshold is in particular intended to mean a fixed value that has been chosen such that noise below that threshold does not interfere with the data transmission. The noise threshold may be pre-determined. In other words, the noise threshold may be stored in e.g. a digital storage before the noise levels are being determined. This noise threshold is chosen as high as possible, but low enough to ensure reliable communication.

[0015] Alternatively, the noise threshold may be implicit. For example, it is possible that the method comprises the steps of (a) determining the number N_a of time slots that are needed in order to be able to obtain status information from the aeronautical ground lights within a preset time interval of e.g. 2 seconds or 5 seconds and (b) choosing the first with the lowest noise level. In this case, the noise threshold is above the noise level of the N_a-th time slots with the lowest noise level and the time slot with the (N_a+1) lowest noise level.

The phrase "along the period" is intended to mean a position relative to the repeating pattern of the AC current. Instead of the phrase "along the period" the phrase "along the waveform of the AC current" or "relative to the waveform of the AC current" could be used. The AC current can be described as $I(t)=I_0 \cdot \sin(\omega t+\varphi_0)$ + noise(t). In other words, the AC current is a periodic function of the time t. The phrase "along the period" refers to the time modulo 2π.

[0016] Each lamp unit is connected to at least one aeronautical ground light. It is possible, but not necessary, that the number of aeronautical ground lights a lamp unit is connected with is constant for all lamp units.

[0017] Preferably, the low-information message encodes less than two bits per half period, e. g. one bit per half period. Such a low data rate makes the data transmission very robust and little error-prone.

[0018] Preferably, the high-information message contains at least 12 bits per half-period, for example 17, 18 or 19 bit per half-period.

[0019] The widths of the time slot is preferably at least 300 microseconds and/or at most 600 microseconds. There may be at least 20 time slots, in particular at least 30 time slots, per period. Preferably, there are less than 60 time slots, in particular less than 50 time slots, per period. The number of bits per active low-noise time slot is preferably at least one, but several frequency channels are possible and advantageous. In particular, more than two, three or four frequency channels can be used. It has turned out that more than 9 frequency channels are possible, but usually not required.

[0020] Preferably, the cable in unshielded. The invention could of course be used for shielded cables as well. However, it is an advantage that it can be used with unshielded cables as well.

[0021] Step (iii) may comprise sending a low-noise time slot mask. This is a sequence of consecutive bits, wherein each bit encodes whether or not a time slot is low-noise and active or not. It is possible to encode the time slots of the low-noise time slots in a different way, but this is a very efficient way of doing it. It should be noted that encoding the low-noise time slots can also be achieved by encoding the inactive or high-noise time slots, e.g. those time slots that are either low-noise, but unused or not low-noise. In this case, the communication takes place only in those time slots that are not marked as inactive or high-noise.

[0022] The low-noise time slots that are used for sending high-information messages are called active time slots. It is possible, but not necessary, that all low-noise time slots are active time slots. If not all low-noise time slots are necessary for the communication with the lamp units, it is advantageous that the least noisy time slots are used as active time slots.

[0023] According to a preferred embodiment, the bit values for each time slot and for each frequency channel are frequency-encoded or phase-encoded. If the bit values are frequency encoded, the bit value 0 is represented by a first frequency and the bit value 1 is represented by a second frequency distinct from the first frequency. If the bit values are phase-encoded, the bit value 0 is represented by a first phase of the frequency and the bit value 1 is represented by a second phase relative to the first phase of the frequency. In particular, the second phase is 180°.

[0024] The first channel may be used encode time-critical information, e.g. whether or not a lamp unit is operational, inactive or defect. The second channel may be used to encode non time-critical information, e.g. electrical parameters of the lamp units such as voltage or current. Preferably, the first channel uses a frequency that has a lower attenuation and/or noise level than the other channels.

[0025] If the bit values are frequency encoded, the frequencies are preferably sampled in the middle of each time slot e.g. by the control unit and/or the lamp units. The phrase "in the middle of a time slot" is in particular intended to mean a time interval around the center of the time slot, wherein this interval has interval length that does not exceed a tenth of the widths of the time slot.

[0026] Preferably, the frequencies do not exceed 30 kilohertz. As pointed out above, higher frequencies can lead to a significant amount of attenuation, thus requiring repeaters.

[0027] According to a preferred embodiment, for each time slot at least four, in particular at least six, frequency channels are used. It has turned out that for most airport navigation light systems at least up to ten frequency channels are possible, which leads to a high data rate.

[0028] According to a preferred embodiment, at least some of the high information messages encode switching information for selectively switching at least one lamp unit on or off. The switching information may contain a point of time at which the respective lamp unit has to switch on or off. This point of time may refer to an internal time or system time that is distributed by the control unit, e.g. via a reference point setting signal as discussed below.

[0029] The steps (i) to (iv) are preferably carried out automatically by the control unit. Preferably, at least a majority of the lamp units automatically carries out a method comprising the following steps: (i) receiving the low-information message encoding the timing of the low-noise time slots and (ii) sending at least one status message in at least one low-noise time slot. Of course, the lamp units usually receive and send these kinds of messages regularly.

[0030] The steps (i) to (iv) may be carried out after a start of the airport navigation lights system. These steps may also be carried out after pre-determined time intervals, e.g. once a day.

[0031] Preferably, the steps (i) and (ii) of claim 1 are carried out repeatedly after preset time interval and if the noise level in one low-noise time slots exceeds the noise threshold and this low-noise time slot is an active low-noise time slot used for sending high-information messages, a new low-information message encoding the timing of at least some of the low-noise time slots relative to the period is sent. If the noise level in one of the high-noise time slots falls below the noise threshold and an active low-noise time slot has a higher-noise level than this (formerly high-noise) time slot, a new low-information message encoding the timing of at least some of the low-noise time slots relative to the period may be sent. In other words, the active low-noise time slots will be changed, if necessary and/or advantageous.

[0032] The AC current’s waveform may be a phase-cut sine wave or sine wave, i.e. a complete sine wave, and has a least one current edge, in particular precisely two current edges, per period, wherein the timing of the time slots is determined relative to the current edge. This timing of the time slots is carried out by the lamp units and/or the control unit. The current edge may be a point of time along the period of the AC current that can be detected with the highest accuracy. Thus, a timing miss match between the control unit and lamp units or between two lamp units is small. As a consequence, relatively small time slots can be used.

[0033] If the AC current's waveform is a phase-cut sine wave, the current edges are the steep incline when the phase cut ends and the steep decline when the phase cut starts. If the AC current's waveform is a sine wave, the current edges occur when the first derivative with respect to time has its maximum or its minimum.

[0034] As an alternative, the AC current's waveform is a sine wave. Of course, a cosine wave equals a sine wave, as they only differ in phase. The timing of the time slots may than determined relative to the phase of the sine wave.

[0035] The method may comprise the steps of determining the timing of the time slots by means of a clock of a lamp unit, by sending a reference point setting signal, e.g. by means of the control unit; and by synchronizing the clock with the phase of the AC current based on the reference point setting signal. This reference point setting signal may comprise (i) a first set of at least one bit of a first value, (e.g. 0) immediately followed by (ii) one marker bit of not the first value, (e.g. 1), and (iii) a second set of at least one bit that is the first value, (e.g. 0). The lamp units preferably determine the sampling point of time for a time slot relative to the marker bit point of time of the marker bit. In other words, the point of time at which the marker bit is received by the lamp unit is regarded as the significant point of time that is used to synchronize the internal clock of the lamp unit to the AC current. The first set preferably comprises at least two consecutive equal bits. The second set preferably comprises at least two consecutive equal bits that are the first value.

[0036] An *independent aspect of the present invention* is a method for controlling an airport navigation lights system comprising (a) a power source for producing an AC current, the AC current having a period, (b) a plurality of lamp units that are powered by the power source by means of a cable, and comprise a receiver and a clock, (c) a control unit that is connected to the cable and is arranged for sending messages to the lamp units and receiving messages from the lamp units via the cable, the method comprising the following steps: (i) sending messages in time slots by means of at least one of the lamp units; a timing of the time slots being determined by means of the clock; (ii) sending a reference point setting signal (e.g. by means of the control unit) and synchronizing the clock with the AC current based on the reference point setting signal.

[0037] An *independent aspect of the present invention* is also an airport navigation lights system comprising (a) a power source for producing an AC current, the AC current having a period, (b) a plurality of lamp units that are powered by the power source by means of a cable, and comprise a receiver and a clock, (c) a control unit that is connected to the cable and is arranged for sending messages to the lamp units and receiving messages from the lamp units via the cable, wherein (d) the lamp units are set up to automatically send messages in time slots, wherein a timing of the time slots being determined by means of the clock; and wherein (e) the control unit is set up to automatically send a reference point setting signal and wherein (f) lamp units are set up to automatically synchronizing the clock with the AC current (I) based on the reference point setting signal.

[0038] The method and the airport navigation lights system, which may be part of an airport, may or may not have the features described with respect to the other aspect of the invention, and vice versa.

[0039] The airport navigation lights system may comprise a filter unit between the power source and the lamp units. The filter unit is set-up such that for frequencies a first cut-off frequency, e.g. 32 kHz, and above a second cut-off frequency (that is smaller than the first frequency, e.g. 2 kHz,) the filter unit acts as short-circuit. The filter unit may also be set-up such that for frequencies above the second cut-off frequency are prevented from entering into the power source..

[0040] The voltage of the power source is preferably at least 4 kilovolt and preferably does not exceed 8 kilovolt.

[0041] Each lamp unit may comprise a transformer, a receiver, a sender, and a processor.

[0042] According to a preferred embodiment, the lamp unit is connected to the cable via an isolation transformer. The failure of one lamp unit will not interrupt the whole system. Very high frequencies are prevented from entering the lamp unit. Should one of the lamp units get short circuited to ground, this does not affect the other lamp units.

[0043] Preferably, there is a clock for each lamp unit. The clock comprises a frequency generator that is synchronized to the AC current. It is advantageous, but not necessary, that each lamp unit has its own clock. As an alternative, two or more lamp units could share one clock.

[0044] The clock may comprise a phase-lock loop having a low-pass filter characteristics, e.g. a PI (proportional and integral terms) controller. The timing of the current edge usually show a jitter with respect to the sine envelope of the AC current. The low-pass filter characteristics may have a cut-off frequency that is chosen to eliminate the jitter, but to allow the clock to follow the drift of the current edge of the AC current relative to the frequency generator. In other words, the clock is synchronized following the drift of the current edge, but not its jitter. The current edge may be determined e.g. by determining the point of time in which the increase of the AC current with time (i.e. the first derivative of the current) exceeds a pre-set threshold. The low-pass filter in the phase-lock loop has the effect that the clock will run faster if the frequency of the AC current increases. The cut-off frequency may be 10 Hertz, in particular below 1 Hertz.

[0045] According to a preferred embodiment, the airport navigation lights system has a number of aeronautical ground lights that is chosen small enough so such that the status of all lamp units is retrievable within two seconds. An airport may comprise more than one airport navigation light system according to the invention so that the total number of aeronautical ground lights that can be checked within two seconds can be larger.

[0046] The invention also solves the problem by means of an airport comprising an airport navigation light system as described above and a taxiway and a runway, wherein the aeronautical ground lights are installed in the taxiway and/or the runway. According to a preferred embodiment this airport comprises a second airport navigation lights system as described above, wherein the frequencies of their frequency channels in the first airport navigation lights system differ from the frequencies in the frequency channels in the second airport navigation lights system so that cross-talk between the two airport navigation lights systems is minimized.

[0047] It should be noted that the airport may comprise two groups of lamp units. The first group may be safety relevant and may need to be checkable within e.g. two seconds. The second group may not be safety relevant and may be checked only within a longer time period, e.g. five seconds.

[0048] The airport may comprise (i) a second airport navigation lights system according to the invention, wherein (ii) the control unit of the first airport navigation lights system is synchronized with a second control unit of the second airport navigation lights system. At least one of the frequencies of one of the frequency channels in the first airport navigation lights system corresponds to one of the frequencies of one of the frequency channels in the second airport navigation lights system. As a consequence, cross-talk could occur. To avoid cross-talk, each lamp unit has a digital storage in which a timing of a sending time frame is stored, wherein the sending time frames for all lamp units of the first airport navigation lights system and the second airport navigation lights system are different. Thus, the communication is undisturbed even if there is cross-talk between the cable of the first airport navigation lights system and the cable of the second airport navigation lights system.

The invention will now be described in further detail with reference to the attached drawings, in which

figure 1 shows a schematic view of an airport according to the present invention,

figure 2 depicts a circuit diagram of an airport navigation lights system that is part of the airport according to figure 1,

figure 3 is an illustration of the time slots used for sending high-information messages and

figure 4 shows a diagram for explaining the encoding of the timing of the active low-noise time slots and the reference point setting signal.

[0049] Figure 1 shows an airport 10 according to the present invention. The airport 10 comprises a runway 12 and a plurality of aeronautical ground lights 14.1, 14.2, ... that may be used for the runway or for a taxiway 16 or another part of the airport's infrastructure. The airport 10 may also comprise a tower 18 and at least one terminal 20.

[0050] Figure 2 shows an airport navigation lights system 22 comprising a power source 24 for producing an AC current that powers lamp units 26.1, 26.2, ..., 26.N via a cable 25. The voltage U is for example 5 kV and the frequency f_{AC} = 50 Hz or f_{AC} = 60 Hz. A filter 28 is arranged between the power source 24 and the lamp unit 26.i (=1,2, ... , N).

[0051] The filter unit 28 acts as short-circuit between a first end E1 and a second end E2 of the cable 25 for frequencies a first cut-off frequency f_{co1} = 32 kHz and above a second cut-off frequency f_{co2} = 2 kHz. The filter unit 28 strongly damps frequencies above f_{co1}. Frequencies below f_{co2} can almost not pass through the filter from the first end E1 to the second end E2. The filter unit 28 also prevents frequencies above f_{co2} from entering into the power source 24.

[0052] The airport navigation lights system 22 also comprises a control unit 30 that is connected to the cable 25 via an isolation transformer 32. The control unit 30 may have a terminal or another human-machine interface so that a human operator can use the control unit 30 to communicate with the lamp units 26.i.

[0053] Each lamp unit 26.i is connected to the cable 25 by means of an isolation transformer 34.i and is connected to at least one aeronautical ground light 14.i, e.g. 14.1. No aeronautical ground light 14.i is connected to more than one lamp unit 26.i. Figure 2 shows these Elements for i = 1. All lamp units 26.i have the same structure. Each lamp unit 26.i and the at least one aeronautical ground light 14.i that is connected to the lamp unit 26.i are part of a lamp system 36.i.

[0054] The lamp unit 26.i comprises a first frequency filter F1 that is used to filter out all frequencies that are lower than a first frequency $f_{1.1}$ and higher than a second frequency $f_{1.2}$ (with $f_{1.1} < f_{1.2}$). The lamp unit 26.i may comprises further frequency filters Fj (j = 2, ..., n) that are used to filter out all frequencies that are lower than a third frequency $f_{j.1}$ and higher than a second frequency $f_{j.2}$ (with $f_{j.1} < f_{j.2}$). For each frequency filter Fj, its respective input is connected to a receiver 39.i. The receiver 39.i is connected to the respective isolation transformer 34.i. The output of frequency filter FJ is connected to a demodulator DEMj (j = 1, ..., N_C). N_C is the number of frequency channels that can be used.

[0055] The demodulators DEMj are set-up for determining as to whether or not the first frequency $f_{j.1}$ (which may equal to a bit value 0) or the second frequency $f_{j.2}$ (which may equal to a bit value 1) is present.

[0056] The receiver 39.i is, via at least one of the frequency filters Fj, connected to a clock 41.i (in figure 2: 41.1). The clock comprises a frequency generator or oscillator 38.i, e.g. a quartz oscillator and a phase-lock loop (PLL) 40.i. The clock 41.i thus receives the frequency f_{AC} of the AC current in the cable 25.i a. The oscillator 38.i is therefore synchronized to the AC frequency f_{AC}.

[0057] All the demodulators DEM 1, ...DEMNc are connected to a processor 42.1 (in figure 2: 42.1). The processor 42.i may contain a fpga device (fpga, field programmable gate array). The processor 42.i is connected to the respective aeronautical ground light 14.i (in the present case: the aeronautical ground light 14.1) e.g. for switching it on and off.

[0058] The processor 42.i is also used to check the voltage and the electric current through the aeronautical ground light 14.i in order to check whether or not the aeronautical ground light 14.i is working properly.

[0059] The processor 42 is programmed so as to automatically decode messages sent by the control unit 30. For example the control unit 30 may send high-information messages M_{high} encoding an address of the respective aeronautical ground light 14.i and encoding a command that the respective aeronautical ground light 14.i has to perform. For example, one of the high-information messages M_{high} may encode the information that a specific aeronautical ground light 14.i be switched on or off. Alternatively or in addition, the high information message may encode the command that the status of a specific aeronautical ground light 14.i be sent by the respective controller. For that purpose, the processor is connected to a sender 44 for sending messages via the cable 25. The high-information messages M_{high} may also encode the time slot that has to be used for the answer to M_{high}.

[0060] Figure 2 shows that the airport may comprise a second airport navigation lights system 22'. It should be noted that the airport 10 may comprise two, three or more aeronautical ground light systems, wherein no aeronautical ground light is connected to two or more airport navigation lights systems at a given time.

[0061] A switch 43.1 is connected to the processor 42.1 that can open and close the switch 43.1.

[0062] Figure 3 is a diagram for explaining a method according to the present invention. Figure 3a shows the AC current I from the power source 24 (cf. figure 2). In this example, the AC frequency f_{AC} is 50 Hz. Figure 3a shows that the waveform of the AC current I(t) is a phase-cut sine wave. It comprises a current edge 46 at the point of time t_{edge1} along the period of the AC current.

[0063] Figure 3b shows the noise level noise $I_{eff}(t)$ that may be measured in form of the effective value I_{eff} of the noise current. It can be seen that the noise level I_{eff} exceeds a noise threshold $I_{eff,thr}$ immediately after the current edge at t_{edge1}. The time interval between the current edge 46 and a second current edge 46' may be called a frame or time frame and is divided into e.g. 20 time slots. A time slot is a time interval relative to the current edge point of time t_{edge1} relative to the period. In the present case, all time slots have the same width, i.e. duration. This is advantageous, but not necessary.

[0064] In the present example, the noise I_{eff} exceeds the noise threshold $I_{eff,thr}$ in the time slots S_1, S_{10} and S_{11}. As a consequence, they are not used for communication.

[0065] Figure 3c shows schematically, that within one time slot, e.g. time slot S_2, a plurality of frequencies can be used for encoding bit values. This is the well-known frequency multiplexing.

[0066] As shown in figure 3b, the time slots S_2, S_3, .. , S_9, S_{12}, ..., S_{20} may be used for communication, as the noise level is below the noise threshold $I_{eff,thr}$. Here, the time slot S_{20} is not used. The steps of determining the noise level and the determining of the time slots S_j for which the noise level is below the noise threshold is done by the control unit 30.

[0067] Figure 4 shows the structure of a low-information message M_{low} that is sent by the control unit 30 (cf. figure 2). The low-information message M_{low} comprises a code word that may have 13 bits. As can be seen, the low-information message M_{low} encodes one bit for each frame or half period, which equals to two bits per period. The code word encodes the fact that the message sent is the low-information message.

[0068] The code word is followed by an active time slot mask. This is a sequence of bit values indicating whether or not a time slot S_j is active or not. An active time slot is a low-noise time slot that is used for communication. Usually, all low-noise time slots are active time slots. As, in the present example, S_1 is a high-noise time slot, the respective bit value is 0. As S_2 is a low-noise time slot, the bit value is 1. Of course, it would also be possible to assign the bit values the other way around.

[0069] In the present example, only 19 of the 20 time slots S_j are used. As a consequence, the active time slot mask has 19 bits. The fact that only 19 out of the 20 possible time slots are used is stored in e.g. a digital storage 21.i of the processor 42.i (cf. figure 2) and a respective digital storage of the control unit 30.

[0070] In the digital storage 21.i, a digital address is stored. This digital address codifies a sending time frame for the lamp unit 26.i. The sending time frame is a time frame in which only the respective lamp unit 26.i is allowed to (and will) send data.

[0071] After the active time slot mask, a reference point setting signal is sent. This reference point setting signal uses the time slots as shown in figure 3. The reference point setting signal comprises a first set R1 comprising at least 1 bit, in the present case 4 bits of consecutive equal bits, e.g. 0. The first set R1 is immediately followed by a marker bit B. Here, B is represented by the value 1. The marker bit B is immediately followed by a second set R2 of at least 1 bit of the first value, i.e. 0 in this example. The number of bits in the first set and in the second set may be pre-determined. As an alternative, the low-information message may comprise further component that may be sent immediately after the active time slot mask and which encodes the time slot in which the marker bit will be sent.

[0072] As the marker bit has a different bit value than the first set and the second set, the peak of the respective signal determines with high accuracy the time position of the time slot (in this example: S_6) along the period of the AC signal. The processor 42 (cf. figure 2) measures the time at which it detects the marker bit relative to its internal clock 38 and calculates a time shift Δt between the time of the clock 38 and the point of time at which the marker bit was received. The processor 42 calculates the middle of each time slot S_j by means of the time that is composed of the clocks time and the time shift.

[0073] Figure 2 shows that an airport may comprise the second airport navigation lights system 22' having the same structure as the first airport navigation lights system 22. Its control unit 30' is synchronized with the control unit 30. The frequencies used in the second airport navigation lights system 22' are the same as in the first airport navigation lights system 22. In other words, all of the frequency channels in the first airport navigation lights system 22 correspond to the respective frequencies of the frequency channels in the second airport navigation lights system 22'.

[0074] All lamp units 26.i of the first airport navigation lights system 22 and all lamp units 26.i' of the second airport navigation lights system 22' have different sending time frames. This ensures that at any given time at maximum one lamp unit 26.i sends data.

[0075] Figure 1 shows that the aeronautical ground lights 14.i of the first airport navigation lights system 22 and the aeronautical ground lights 14.i' of the second airport navigation lights system 22' are arranged in a complementary manner. In other words, they are arranged such that e.g. the runway 12 and/or the taxiway can still be used even if one of the airport navigation lights systems 22, 22' fails.

List of reference numerals

10	airport	f_{AC}	AC frequency
12	runway	F1	first frequency filter
14	aeronautical ground light	F2	second frequency filter
16	taxiway	F3	third frequency filter
18	tower		
		i, j	running index
20	terminal	I	AC current
21	digital storage	I_{eff}	effective value of noise current
22	airport navigation lights system	$I_{eff,thr}$	noise theshold
24	power source	m_{atsm}	active time slot mask
25	cable		
26	lamp unit	m_{rpss}	reference point setting signal
28	filter	M_{high}	high-information message
		M_{low}	low-information message
30	control unit	N	number of lamp units
32	isolation transformer	Nc	number of frequency channels
34	isolation transformer		
36	lamp system	R1	first set
38	frequency generator, oscillator	R2	second set
39	receiver	S	time slot
		t	time
40	PLL	t_B	marker bit point of time
41	clock	U	AC voltage
42	processor		
43	switch	PL/ne-be	
44	sender		
46	current edge		
B	marker bit		
DEM	demodulator		
E1	first end of cable		
E2	second end of cable		
$f_{1.1}$	first frequency		
$f_{1.2}$	second frequency		

Claims

1. A method for controlling an airport navigation lights system (22), comprising

    (a) a power source (24) for producing an AC current (I);
    (b) a plurality of lamp units (26) that

    - are powered by the power source (24) via a cable (25) and
    - comprise a receiver;

    (c) at least one aeronautical ground light (14.1); and
    (d) a control unit (30) that

    - is connected to the cable (25) and
    - is arranged for sending messages to the lamp units (26) and receiving messages from the lamp units (26) via the cable (25),

    the method comprising the following steps:

    (i) determining a noise level for a plurality of time slots (S) along the period of the AC current (I);
    (ii) determining low-noise time slots during which the noise level is below a noise threshold;
    (iii) sending a low-information message (M_{low}) encoding the timing of at least some of the low-noise time slots relative to the period via the cable; and
    (iv) sending high-information messages encoding control commands during these low-noise time slots.

2. The method according to claim 1, **characterized in that** for each time slot (S) and for each frequency channel

    (a) the bit values are frequency encoded or
    (b) the bit values are phase encoded.

3. The method according to one of the above claims, **characterized in that** at least some of the high-information messages (M_{high}) encode switching information for selectively switching at least one lamp unit on or off.

4. The method according to one of the above claims, **characterized in that**

    (a) the steps (i) to (iv) are carried out automatically by the control unit (30) and
    (b) at least a majority of the lamp units (26) automatically carries out a method comprising the following steps:

    (i) receiving the low-information message (M_{low}) encoding the timing of the low-noise time slots and
    (ii) sending at least one status message in at least one low-noise time slot.

5. The method according to one of the above claims, **characterized in that**

    (a) the steps (i) and (ii) are carried out repeatedly after a respective preset time interval and
    (b) if the noise level in one of the low-noise time slots exceeds the noise threshold and this low-noise time slot is an active low-noise time slot used for sending high-information messages, a new a low-information message (M_{low}) encoding the timing of at least some of the low-noise time slots relative to the period is sent and/or
    (c) if the noise level in one of the high-noise time slot falls below the noise threshold ($I_{eff,thr}$) and an active low-noise time slot has a higher noise level than this time slot, a new low-information message (M_{low}) encoding the timing of at least some of the low-noise time slots relative to the period is sent.

6. The method according to one of the above claims, **characterized in that**

    - the AC current's waveform is a phase-cut sine wave or a sine wave and has at least one current edge (46, 46') per period and that
    - the timing of the time slots is determined relative to the current edge (46, 46').

7. The method according to one of the above claims, **characterized in that** the method comprises the steps:

- determining the timing of the time slots by means of a clock (41) of a lamp unit (26);
- sending a reference point setting signal (m_{rpss}); and
- synchronizing the clock (41) with the phase of the AC current (I) based on the reference point setting signal (m_{rpss}).

8. The method according to one of the above claims, **characterized in that**

(a) the low-information message (M_{low}) comprises

(i) a code word encoding the information that the message is the low-information message (M_{low}),
(ii) after the code word an active time slot mask encoding the active low-noise time slots and
(iii) a reference point setting signal and that

(b) the lamp units (26) determine the sampling point of time for sampling the bit value based on the reference point setting signal.

9. The method according to claim 8, **characterized in that**

(a) the reference point setting signal comprises

- a first set (R1) of at least one bit of a first value immediately followed by
- one marker bit (B) of not the first value and
- a second set (R2) of at least one bit that is the first value and that

(b) the lamp units (26) determine the sampling point of time in a time slot (S) relative to the marker bit point of time (t_B) of the marker bit (B).

10. A method for controlling an airport navigation lights system (22), comprising

(a) a power source (24) for producing an AC current (I), the AC current (I) having a period
(b) a plurality of lamp units (26) that

- are powered by the power source (24) by means of a cable (25), and
- comprise a receiver and
- a clock,

(c) a control unit that

- is connected to the cable (25) and
- is arranged for sending messages to the lamp units (26) and receiving messages from the lamp units (26) via the cable (25),

the method comprising the following steps:

(i) sending messages in time slots by means of at least one of the lamp units (26); a timing of the time slots being determined by means of the clock;
(ii) sending a reference point setting signal and
synchronizing the clock with the AC current (I) based on the reference point setting signal.

11. An airport navigation lights system (22) comprising:

(a) a power source (24) for producing an AC current (I), the AC current (I) having a period;
(b) a plurality of lamp units (26) that

- are powered by the power source (26) via a cable and
- comprise a receiver;

(c) at least one aeronautical ground light (14); and
(d) a control unit (30) that

- is connected to the cable (25) and
- is arranged for sending messages (M_{high}, M_{low}) to the lamp units (26) and receiving messages from the lamp units (26) via the cable (25)

characterized in that
(e) the control unit (30) is set up to automatically perform a method comprising the steps (i) to (iv) of claim 1.

12. The airport navigation lights system (22) according to claim 11, **characterized in that** each lamp unit (26) is connected to the cable (25) by means of an isolation transformer (32).

13. The airport navigation lights system (22) according to claim 11 or 12
characterized in that

- for each lamp unit (26) exists a clock (41),
- the clock (41) comprising a frequency generator (38) that is phase-locked to the AC current (I).

14. An airport (10) comprising

(i) an airport navigation lights system (22) according to one of the preceding claims and
(ii) a taxiway (16) and a runway (12)
(iii) wherein the aeronautical ground lights (14) are installed in the taxiway (16) or the runway (12).

15. An airport according to claim 14, comprising

(i) a second airport navigation lights system (221) according to one of the preceding claims
(ii) frequencies of the frequency channels in the first airport navigation lights (22) system differ from the frequencies of the frequency channels in the second airport navigation lights system (22).

16. An airport according to claim 14 or 15, comprising

(i) a second airport navigation lights system (22') according to one of the preceding claims,
(ii) the control unit (30) of the first airport navigation lights system (22) being synchronized with a second control unit (30') of the second airport navigation lights system (22'),
(iii) wherein at least one of the frequencies of one of the frequency channels in the first airport navigation lights system (22) corresponds to one of the frequencies of one of the frequency channels in the second airport navigation lights system (22') and
(iv) wherein each lamp unit (26.i) has a digital storage (21.i) in which a timing of a sending time frame is stored, wherein the sending time frames for all lamp units (26) of the first airport navigation lights system (22) and the second airport navigation lights system (22') are different.

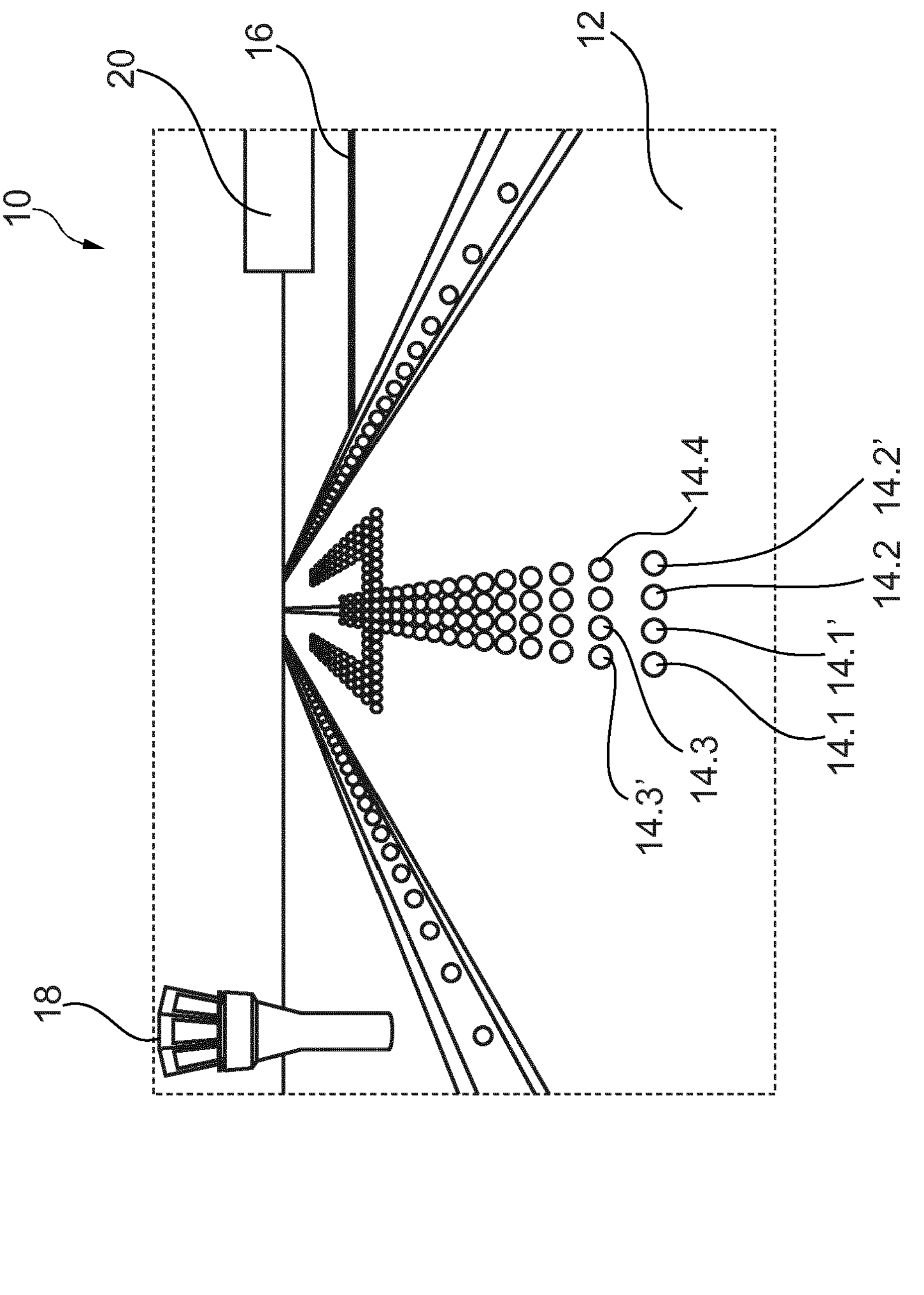


Fig. 1

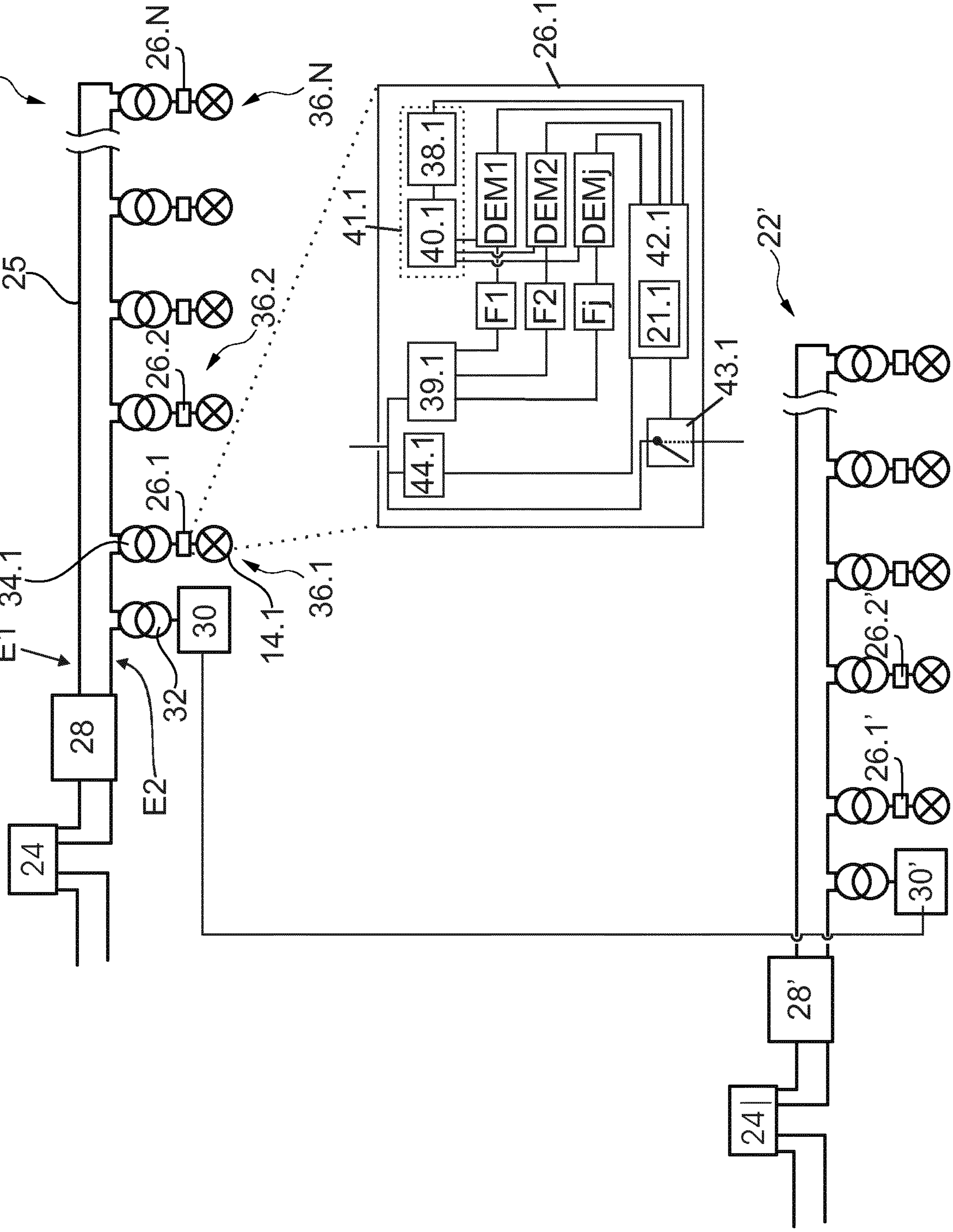
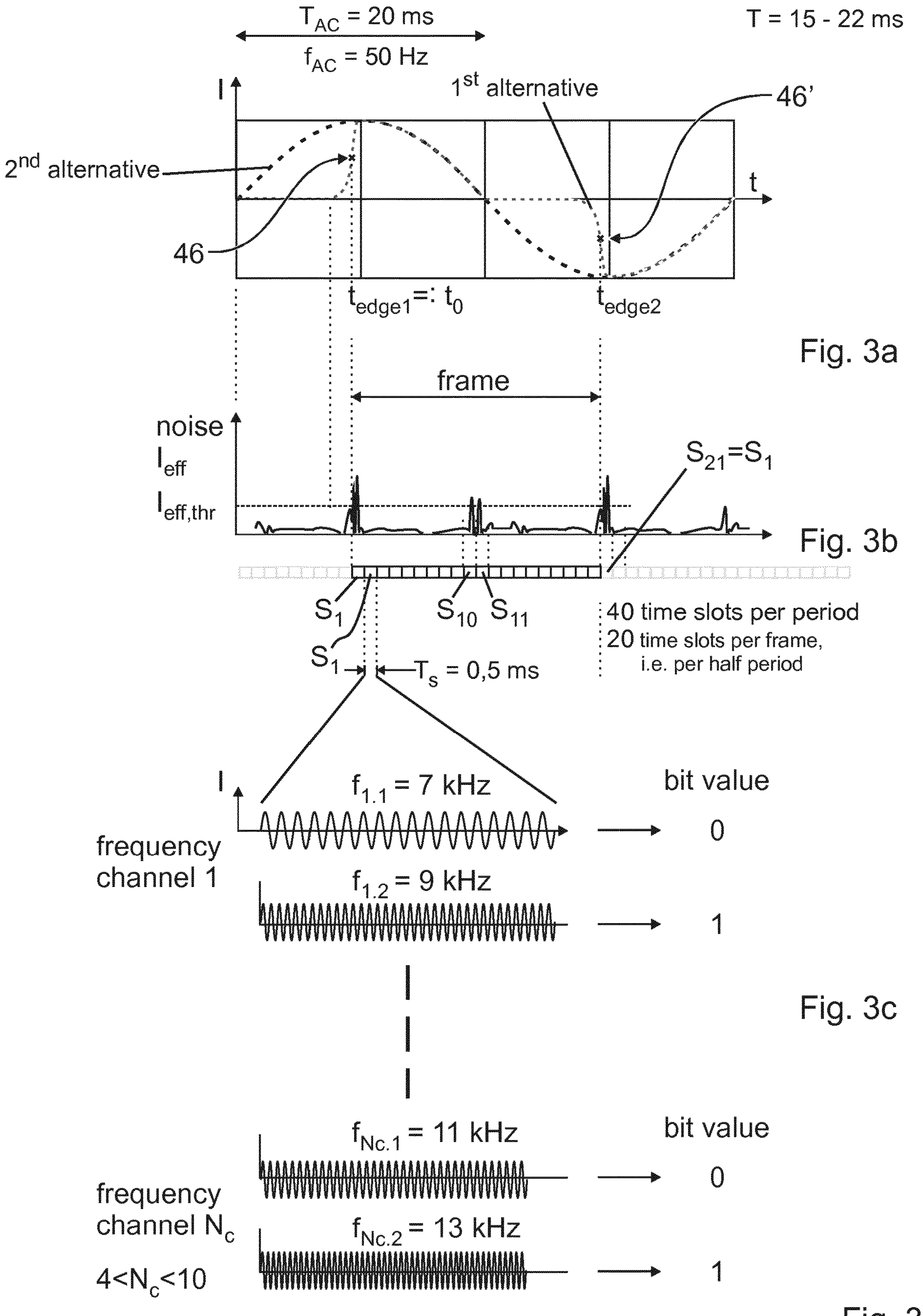

22
25
26.N
36.N
26.2
36.2
26.1
34.1
E1
24
28
E2
32
30
14.1
36.1
41.1
38.1
40.1
DEM1
DEM2
DEMj
F1
F2
Fj
39.1
44.1
42.1
21.1
43.1
22'
26.2'
26.1'
30'
28'
24'

Fig. 2



T_AC = 20 ms
f_AC = 50 Hz
T = 15 - 22 ms
I
1st alternative
46'
2nd alternative
t
46
t_edge1 =: t_0
t_edge2
Fig. 3a
frame
noise
I_eff
I_eff,thr
S21=S1
Fig. 3b
S1
S10
S11
40 time slots per period
20 time slots per frame, i.e. per half period
S1
T_s = 0,5 ms
I
f1.1 = 7 kHz
bit value
frequency channel 1
0
f1.2 = 9 kHz
1
Fig. 3c
fNc.1 = 11 kHz
bit value
0
frequency channel Nc
fNc.2 = 13 kHz
4<Nc<10
1

Fig. 3

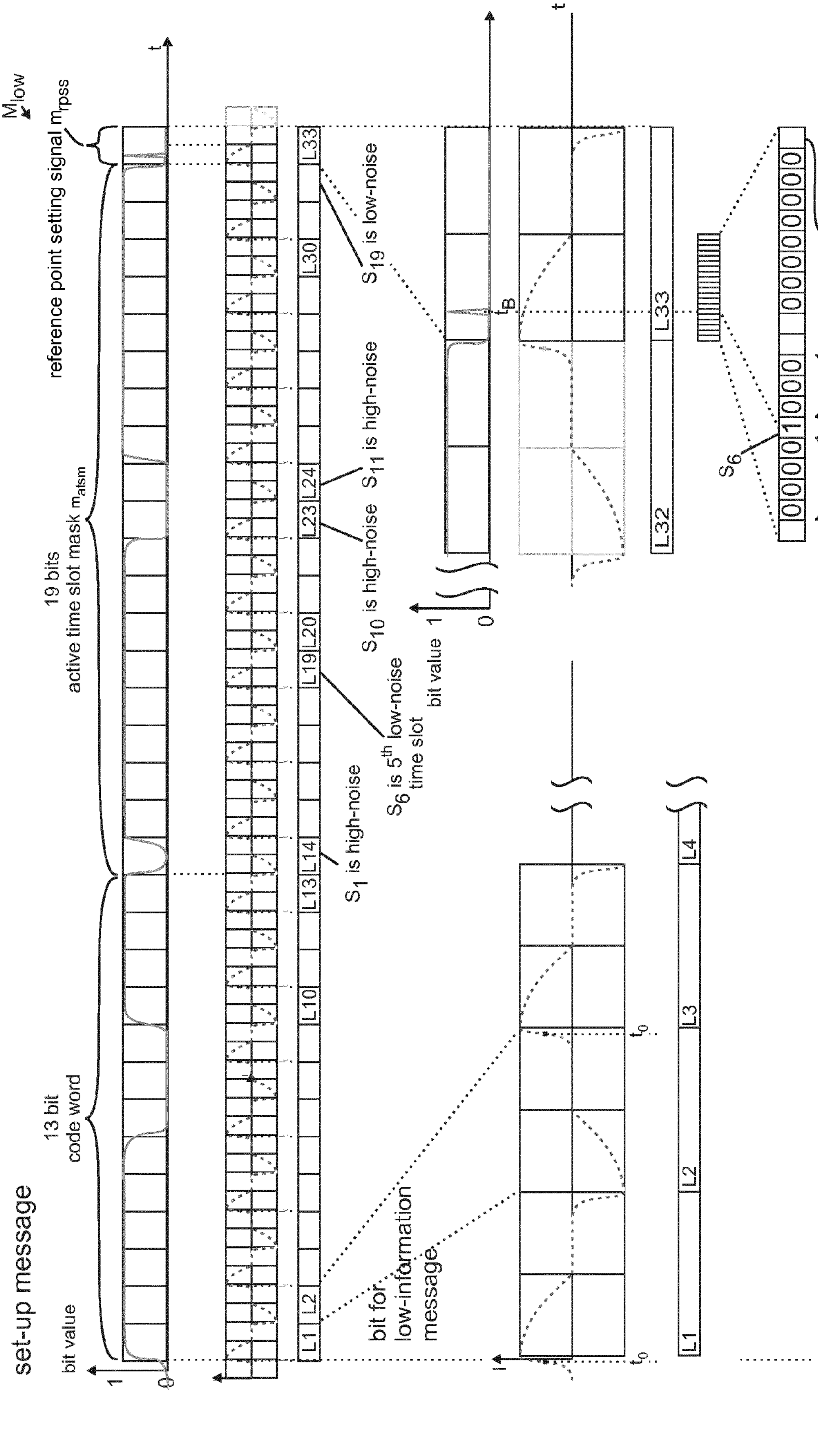

set-up message
bit value
1
0
13 bit
code word
19 bits
active time slot mask m_atsm
reference point setting signal m_rpss
M_low
t
L1
L2
L10
L13
L14
L19
L20
L23
L24
L30
L33
S1 is high-noise
S6 is 5th low-noise time slot
S10 is high-noise
S11 is high-noise
S19 is low-noise
bit for low-information message
t0
L3
L4
bit value
t_B
L32
L33
S6
0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
R1
B
R2
S20 unused

Fig. 4

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 16 6891

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y A	FR 2 865 871 A1 (AUGIER S A [FR]) 5 August 2005 (2005-08-05) * page 10, line 6 - page 11, line 6; figures 1, 3, 4 *	1-9, 11-13 10,14-16	INV. H05B37/02
Y	US 2008/304577 A1 (KOGA HISAO [JP] ET AL) 11 December 2008 (2008-12-11) * paragraphs [0113], [0144] - [0145]; figures 5, 10, 20-21 *	1-9, 11-16	
X Y	WO 95/24820 A1 (AIRPORT TECH SCANDINAVIA [SE]; MILLGAARD LARS [SE]; LIDSTROEM KJELL [S) 14 September 1995 (1995-09-14) * pages 1, 4, 11-12; figures 1-3, 5-7, 11 *	10 1-9, 11-13	
Y A	WO 2008/073321 A2 (COOPER TECHNOLOGIES CO [US]; THAT DANIEL A [US]; MITSCH JAMES M [US]) 19 June 2008 (2008-06-19) * paragraphs [0020], [0025] - [0026]; figures 1,4 *	14-16 1-13	TECHNICAL FIELDS SEARCHED (IPC)
A	DICHMANN G ET AL: "DIGITAL SIGNAL PROCESSING FOR MULTI-CARRIER DATA TRANSMISSION ON PHASE-CONTROLLED POWER LINES WITH NONLINEARITIES", 1995 IEEE INTERNATIONAL SYMPOSIUM ON CIRCUITS AND SYSTEMS (ISCAS). SEATTLE, APR. 30 - MAY 3, 1995; [INTERNATIONAL SYMPOSIUM ON CIRCUITS AND SYSTEMS (ISCAS)], NEW YORK, IEEE, US, 30 April 1995 (1995-04-30), pages 889-892, XP000558825, ISBN: 978-0-7803-2571-5 * the whole document *	1-16	H05B

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	9 October 2017	Erskine, Andrew

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

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 16 6891

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

09-10-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2865871 A1	05-08-2005	FR 2865871 A1	05-08-2005
		WO 2005083963 A1	09-09-2005
US 2008304577 A1	11-12-2008	BR PI0812133 A2	18-11-2014
		CN 101682368 A	24-03-2010
		EP 2165423 A1	24-03-2010
		ES 2548012 T3	13-10-2015
		JP 5448359 B2	19-03-2014
		JP 2009010929 A	15-01-2009
		US 2008304577 A1	11-12-2008
		WO 2008149956 A1	11-12-2008
WO 9524820 A1	14-09-1995	AT 218788 T	15-06-2002
		AU 2088995 A	25-09-1995
		DE 69526932 D1	11-07-2002
		DE 69526932 T2	19-12-2002
		EP 0749672 A1	27-12-1996
		ES 2177639 T3	16-12-2002
		WO 9524820 A1	14-09-1995
WO 2008073321 A2	19-06-2008	WO 2008073321 A2	19-06-2008
		WO 2008073322 A1	19-06-2008

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82