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(54) **A DALI WIRELESS BUS**

(57) The invention relates to a bus signal adaptor for translating digital bus signals low and high from a wired bus into a wireless signal, the adaptor comprising two terminals for connecting two bus wires and means for

receiving/ transmitting wireless signals, further comprising a control unit, translating different logical states of the digital wired bus signal into different wireless transmitting frequencies and/or vice versa.

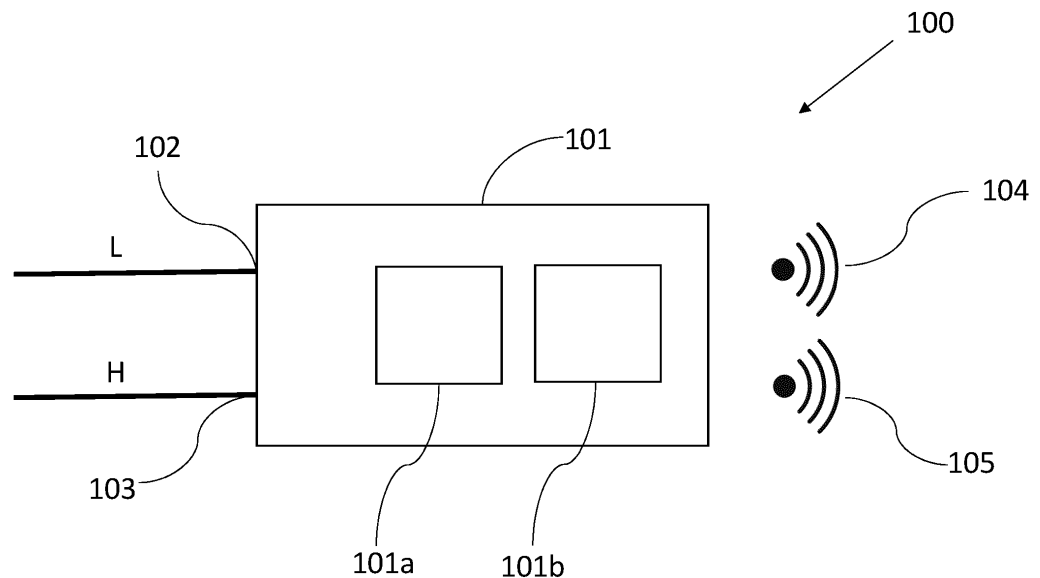


Fig. 1

Description

TECHNICAL FIELD OF THE INVENTION

[0001] The current invention relates to lighting control systems for homes, offices, commercial spaces, and public areas. More particularly, the present invention relates to incorporating wireless networks into the lighting control systems; more specifically to lighting control systems using digitally addressable lighting interface (DALI) command protocol.

BACKGROUND OF THE INVENTION

[0002] Lighting systems for homes, offices, commercial spaces, and public areas, which are centrally controlled, are well known in the art. The digital addressable lighting interface (DALI) belongs to such control systems. DALI is a digital protocol for lighting control devices. In particular, the two-wire physical network of DALI is a data bus. This data bus can connect up to 64 DALI lighting control devices, such as occupancy sensors, ballasts, switch panels and photo sensors, to one DALI controller via physical and electrical connections called also "ports". Ports are electrical and physical connections for the DALI controller, also denoted "master", and control devices, also denoted "slaves", to interconnect. The DALI controller can for example be a central computer or other control unit.

[0003] Standards for DALI protocol such as National Electronics Manufacturers Association LSD 53-2010 in the United States and DALI Manual by ZVEI-Division Leuchten of Frankfurt Germany are well known in the art.

[0004] In a wired configuration, a single DALI two-wire physical network is also called a "stream." A stream can contain only a single DALI control device or up to 64 DALI control devices, in addition to the DALI controller of the stream. Each DALI stream can be limited to one DALI controller which can be used as the bus master which initiates the DALI commands. Moreover, each of the DALI control devices can be given an address.

[0005] In a typical wired implementation of a DALI control system, a DALI stream can be defined as at least one DALI controller and at least one controlled device which are interconnected by a bus made of two wires. In order to improve the noise immunity of the bus, the two wires can be configured as a twisted pair.

[0006] DALI controllers and controlled devices can be connected in a star configuration or daisy chained configuration.

[0007] The DALI specification makes it possible for up to 64 controlled devices (ballasts, switches, sensors, etc.) to be connected to a common twisted pair bus. The bus can also need a DC voltage, which can be provided as a standalone power supply or the power supply function may be integrated into the physical package of a DALI controller or controlled device.

[0008] Therefore, a DALI stream can be seen as one

or more DALI controllers connected to one twisted pair bus comprising up to 64 DALI controlled devices. The stream can be supplied by a DC voltage provided by a standalone power supply or by a DALI device connected to the stream.

[0009] One DALI controller comprising a DALI port can be connected to one DALI stream having at least a single DALI controlled device via a wired data bus. A DALI controlled device is typically a DALI controllable ballast in a DALI controllable network. Moreover, the DALI specification NEMA LSD 53-2010 includes other controlled device types, such as switch device, slide dimmer, motion (occupancy) sensor, scheduler, gateways and so on.

[0010] DALI protocol by specification is designed to transmit data at 1,200 cycles per second (Hertz (Hz)), plus or minus 10 percent. The time duration of each cycle is nominally equal to 833.33 microseconds.

[0011] A DALI forward frame is defined as a command transmitted from the DALI controller and contains an address byte and one or two data bytes.

[0012] For example, a 2-bytes DALI forward frame, consisting of one address byte and a data byte, has 19-bits of data. A 3-bytes DALI forward frame, consisting of one address byte and two data bytes, has 27-bits of data.

[0013] A DALI back frame, defined as a reply responding to the immediate forward frame, consists of 11-bits of data.

[0014] DALI protocol makes use of Manchester encoding for serial data transmission. Manchester encoding requires two sampling intervals to decode a single data bit. DALI protocol refers to each sampling interval as "TE". The duration of each TE is one half of 833.33 microseconds.

[0015] Making use of a wireless network would be advantageous for several reasons, such as simplifying building renovation and reduced installation expense by elimination of communication wiring (i.e. long run communication wiring). An important disadvantage of wireless network based implementations (e.g. implementing ZigBee protocol) is that the communication between devices cannot be made sure to occur within the maximum response time of DALI specification.

[0016] The timing requirements of the DALI protocol are destined to communication media wherein a DALI controller and the connected DALI stream is hardwired in a manner that the delays or latency caused by the media are close to a zero value. This makes DALI incompatible with wireless communication media, wherein latency is non-deterministic and changes significantly depending on real-time network conditions, and can exceed the timing prescriptions of the DALI protocol.

[0017] When the DALI protocol is comprised inside a wireless networking scheme, such as ZigBee, the physical wires are removed, which limit one DALI physical port to a single DALI stream. If there is no one to one correspondence of a DALI port to a DALI stream, then one DALI controller could address multiple DALI streams via wireless connections. This would be advantageous

for a system where many DALI streams are sparsely populated as they could be grouped and controlled by one DALI physical port.

[0018] Unfortunately, the DALI protocol does not have a provision to allow multiple streams to be addressed over a single DALI port. Consequently, the advantages of using wireless connections, removing the physical limitation of the DALI network wires, could not be completely achieved.

[0019] Typical DALI deployments partition the light fixtures in a building on several separate DALI streams for reasons relating to bandwidth, maximum number of supported ballasts on a single stream, and the physical wiring and layout of the building. DALI controllers can have multiple physical DALI interfaces that allow more than a single stream to be connected to the controller.

[0020] A single ZigBee PAN can support hundreds of devices and provide enough bandwidth to support several DALI streams. A mechanism, which supports several streams on a single ZigBee PAN, would simplify deployment, reduce cost, and more optimally make possible to utilize constrained system resources.

[0021] A method to allow a wireless network to use the DALI protocol is to dedicate a ZigBee Personal Area Network (PAN) to a single physical DALI stream. However, this approach increases the number of separate wireless networks which are required, and, thus, increases complexity and costs, and increases potential of radio frequency interference between adjacent wireless PANs.

[0022] Thus, it is an object of the invention to provide for an improved DALI wireless communication system.

SUMMARY OF THE INVENTION

[0023] The object of the present invention is achieved by the solution provided in the enclosed independent claims. Advantageous implementations of the present invention are further defined in the dependent claims.

[0024] According to a first aspect, the invention relates to a bus signal adaptor for translating digital bus signals low and high from a wired bus into a wireless signal, the adaptor comprising two terminals for connecting two bus wires and means for receiving/ transmitting wireless signals, further comprising a control unit, translating different logical states of the digital wired bus signal into different wireless transmitting frequencies and/or vice versa.

[0025] According to an embodiment, different logical states are translated in a cyclic sequence of more than two different subsequent wireless transmission frequencies.

[0026] According to an embodiment, the cyclic sequence comprises at least: a first frequency for overriding a second frequency and causing a state of the bus signal to become low, and a third frequency for overriding the first frequency and causing the state of the bus signal to become high.

[0027] According to an embodiment, a time duration

of the different wireless transmitting frequencies corresponds to a time duration of the logical states of the digital wired bus signal.

[0028] According to an embodiment, the digital bus signals are DALI signals.

[0029] According to a second aspect, the invention relates to a mesh network having a plurality of nodes with an adaptor according to the first aspect.

[0030] According to an embodiment, each adaptor is designed to wirelessly retransmit a wirelessly received signal.

[0031] According to an embodiment, each adaptor is further configured to switch off a previously retransmitted frequency upon receipt of a new wireless transmitting frequency.

[0032] According to a third aspect, the invention relates to a method for translating digital bus signals low and high from a wired bus into a wireless signal, the method comprising the steps of connecting two bus wires, receiving / transmitting wireless signals, and translating different logical states of the digital wired bus signal into different wireless transmitting frequencies and/or vice versa.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] The invention will be explained in the followings together with the figures.

Fig. 1 shows an embodiment of a system comprising a bus signal adaptor according to an embodiment;

Fig. 2 shows a schematic representation of forward frames and backward frames in a DALI system according to an embodiment;

Fig. 3 shows a schematic representation of a DALI system according to an embodiment;

Fig. 4 shows a tabular representation of DALI frequencies in a DALI system according to an embodiment;

Fig. 5 shows a schematic representation of frequencies in a DALI system according to an embodiment;

Fig. 6 shows a schematic representation of frequencies in a DALI system according to an embodiment; and

Fig. 7 shows a first exemplary embodiment of a method for translating digital bus signals low and high from a wired bus into a wireless signal according to an embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0034] Aspects of the present invention are described herein in the context of a bus signal adaptor.

[0035] The present invention is described more fully hereinafter with reference to the accompanying drawings, in which various aspects of the present invention are shown. This invention however may be embodied in many different forms and should not be construed as limited to the various aspects of the present invention presented through this disclosure. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present invention to those skilled in the art. The various aspects of the present invention illustrated in the drawings may not be drawn to scale. Rather, the dimensions of the various features may be expanded or reduced for clarity. In addition, some of the drawings may be simplified for clarity. Thus, the drawings may not depict all of the components of a given apparatus.

[0036] Various aspects of a bus signal adaptor will be presented. However, as those skilled in the art will readily appreciate, these aspects may be extended to aspects of bus signal adaptors without departing from the invention.

[0037] Fig. 1 shows an embodiment of a system 100 comprising a bus signal adaptor 101 according to an embodiment.

[0038] The bus signal adaptor 101 is configured to translate digital bus signals low L and high H from a wired bus into a wireless signal. The adaptor 101 comprises two terminals 102, 103 for connecting two bus wires and means 101a for receiving/ transmitting wireless signals, further comprises a control unit 101b, translating different logical states of the digital wired bus signal into different wireless transmitting frequencies 104, 105 and/or vice versa.

[0039] According to one embodiment, the digital bus signals are DALI signals.

[0040] Moreover, a mesh network having a plurality of nodes can have each the adaptor 101, wherein each adaptor 101 is designed to wirelessly retransmit a wirelessly received signal. Moreover, each adaptor 101 can further be configured to switch off a previously retransmitted frequency upon receipt of a new wireless transmitting frequency 104, 105.

[0041] In general, the cost of wireless systems to some extent reflects their complexity. In order to replace a wired DALI system with a wireless system, a complex mesh network is envisaged. DALI protocol can be translated to a new digital format prior to being transmitted on the wireless mesh network. To reach receivers that are out of range, other receivers can be used in order to forward the message to the final destination, where the data will have to be translated again to a DALI protocol.

[0042] DALI protocol requires that, when a master sends a forward frame, the back frame is received within

a rigid time constraint, less than 22Te (9.17mS) (see Fig. 2).

[0043] A wireless mesh network would not practically allow for this to happen, so the memory can be added at the master wireless node that buffers the information stored at the final destination. This should be done for every possible destination, so for the mesh envisaged, around 200 devices. Complex IC's that integrate RF circuitry, microprocessors and memory can be considered.

[0044] DALI is a communication protocol that uses a pair of wires to communicate, therefore, an approach could be to simply switch an RF source ON and OFF to mimic this very simple situation.

[0045] First of all, if this was the situation, then the idle state would require that the RF transmitter was OFF as, otherwise, considerable power would be consumed by the transmitter. From this assumption, it follows that the active or low state of DALI would need to be transmission from the RF transmitter, allowing the idle state to be no RF transmission.

[0046] Fig. 3 shows this extremely simple case in a schematic representation.

[0047] In response to receiving what would be a DALI signal, just as if it had been transmitted on a wired bus, the DALI control gear would respond with a back frame according to the timing DALI specifies, which would be sent back through the wireless system with no loss of timing. The wireless system would not be doing any timing.

[0048] If this was feasible, it would be a wireless system that avoids translation of data, the inherent delays that would involve and the memory that would have to be added to circumvent those problems. It would be the equivalent of a set of wires, and the DALI master would be communicating directly with other DALI devices. The wireless system would require no intelligence, it would simply switch the RF signal on and off under the control of the DALI master and slave.

[0049] However, the first problem the above mentioned approach has deals with range. If the transmission range was exceeded, it is not clear how it would be extended. Repeating the signal seems like the obvious answer, but it is not obvious what would happen if this was done.

[0050] The DALI application controller 101b sends a forward frame. The start bit will immediately switch the RF ON. When a receiver receives this signal, it will also switch its transmitter ON so it can forward the signal. The application controller now switches its RF signal OFF for the second part of the start bit. The other device is already transmitting RF and stays ON with all other devices. The system has locked up and this would clearly not work.

[0051] The basic problem is that once a frequency is transmitting somewhere in the system, switching one transmitter off will leave the signal from the other transmitters. Therefore, the signal cannot be stopped and the system is locked up.

[0052] One solution to this problem could be the fol-

lowing.

[0053] In one embodiment, while it is important that the idle state should involve no transmission of RF, there could still be a frequency that would be associated as OFF, which is the idle state. If F0 causes the DALI bus to be pulled low, then F1 could override this and cause the DALI bus to go high, i.e. the idle state. However, F1 should be overridden. A cycle of frequencies would be a solution where simple logic decides that F1 will override F0 and cause the state to become high. F2 overrides F1 and causes the state to become low, just as with F0. F3 overrides F2 and causes the state to become high, just as with F1. Then the cycle would repeat with F0 overriding F3 to return the output to low. In this way, any frequency that is at present flooding the system can be removed by using another frequency that would switch it off (see Fig. 4).

[0054] In order for the cycle to be interrupted and the signal be switched off in order to allow a DALI idle state with no signal, according to an embodiment, a logic can be provided configured to ensure that frequencies F1 and F3 only remain active for some time period from the point when they were initiated. In this way, each RF circuit would first have been in a state when it was transmitting, for example F2. The circuits would receive F3, switch off F2 and start a timer. Even if F3 is still being received when the timer reaches the timeout, F3 would be terminated. The receipt of a signal at F3 or F1 would not re-trigger the sending of a high state frequency. A suitable timeout may be a time that was greater than $2 \times T_e$ from the timing diagram above.

[0055] Timeouts could also be applied to F0 and F2.

[0056] This approach should work for a single master DALI embodiment.

[0057] In a multi-master system instead, anti-collision should function. Drawing an analogy with the wired system, if the bus is pulled low by any device, the bus is pulled low regardless of whether other devices are signaling the bus to be high. Without the application of new rules, the present approach does not work.

[0058] According to an embodiment, the rules are:

F1 will stop F0;

F2 will stop F1; etc

[0059] Other additional rules are enumerated in the following according to an embodiment.

[0060] In one embodiment, if a master M1 expects to output a low signal, it will transmit either F0 or F2. If another master, M2 floods the system with F1, this would stop F0. M1 should replace F0 with F2 if it detects F1 on the system at a time when M1 is outputting a low on the bus. If M2 flooded the system with F3, this would have no effect on F0 and F0 should take priority in just the same way that a pulldown on the bus would take priority.

[0061] If M1 is producing F1 and M2 produces F2, F2 will stop F1. The next frequency in sequence for M1 would

be F2. Rather than staying with that sequence, M1 jumps to the next pull low frequency which in this case would be F0.

[0062] Applying these rules to the DALI waveforms shown in Fig. 5 gives the results shown in the same figure.

[0063] In the embodiment shown in Fig. 5, both masters start on the same frequency with the start bit. The bus waveform shows what a wired DALI bus would do. Applying the rules which have already been stated, when M1 outputs F2, F2 stops F1. F2 floods the system and all attached devices receive a low signal. DALI 2 protocol will detect this as a collision in M2. Continuing, the fact that F1 was stopped while M2 was attempting to output a high level causes the sequence to be changed, and rather than F2 being the next in sequence, it becomes F0. Now M1 can see a collision.

[0064] The diagram shows in Fig. 6 shows the same sequence of transmitted bits but on a system where M1 does not start with the same frequency as M2. Again, the rules allow the masters to detect collision.

[0065] In this case, multiple frequencies appear on the bus at the start when M1 starts with F0 and M2 starts with F2. Both have the same effect on the bus and neither stops the other.

[0066] The basic approach of using a sequence of frequencies to communicate appears to be allowing DALI communication over a very simple wireless network.

[0067] Fig. 7 shows a first exemplary embodiment of a method 700 for translating digital bus signals low and high from a wired bus into a wireless signal according to an embodiment.

[0068] The method 700 comprises the steps of:

- connecting 701 two bus wires;
- receiving / transmitting 702 wireless signals; and
- translating 703 different logical states of the digital wired bus signal into different wireless transmitting frequencies and/or vice versa.

[0069] All features of all embodiments described, shown and/or claimed herein can be combined with each other.

[0070] While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only and not limitation. Numerous changes to the disclosed embodiments can be made in accordance with the disclosure herein without departing from the spirit of scope of the invention. Thus, the breadth and scope of the present invention should not be limited by any of the above-described embodiments. Rather, the scope of the invention should be defined in accordance with the following claims and their equivalence.

[0071] Although the invention has been illustrated and described with respect to one or more implementations, equivalent alternations and modifications will occur to

those skilled in the art upon the reading of the understanding of the specification and the annexed drawings. In addition, while a particular feature of the invention may have been disclosed with respect to only of the several implementations, such features may be combined with one or more other features of the other implementations as may be desired and advantage for any given or particular application.

Claims

1. Bus signal adaptor (101) for translating digital bus signals low and high from a wired bus into a wireless signal, the adaptor (101) comprising two terminals (102, 103) for connecting two bus wires and means (101a) for receiving/ transmitting wireless signals, further comprising a control unit (101b), translating different logical states of the digital wired bus signal into different wireless transmitting frequencies and/or vice versa. 15
2. The bus signal adaptor (101) of claim 1, wherein different logical states are translated in a cyclic sequence of more than two different subsequent wireless transmission frequencies. 25
3. The bus signal adaptor (101) of claim 2, wherein the cyclic sequence comprises at least: 30
 - a first frequency for overriding a second frequency and causing a state of the bus signal to become low; and
 - a third frequency for overriding the first frequency and causing the state of the bus signal to become high. 35
4. The bus signal adaptor (101) of any one of the preceding claims, wherein a time duration of the different wireless transmitting frequencies corresponds to a time duration of the logical states of the digital wired bus signal. 40
5. The bus signal adaptor (101) of any one of the preceding claims, wherein the digital bus signals are DALI signals. 45
6. Mesh network having a plurality of nodes with an adaptor (101) according to any one of the preceding claims 1 to 5. 50
7. The mesh network of claim 6, wherein each adaptor (101) is designed to wirelessly retransmit a wirelessly received signal. 55
8. The mesh network of claim 6 or 7, wherein each adaptor (101) is further configured to switch off a previously retransmitted frequency upon receipt of

a new wireless transmitting frequency.

9. Method (700) for translating digital bus signals low and high from a wired bus into a wireless signal, the method (700) comprising the steps of:
 - connecting (701) two bus wires;
 - receiving / transmitting (702) wireless signals; and
 - translating (703) different logical states of the digital wired bus signal into different wireless transmitting frequencies and/or vice versa.

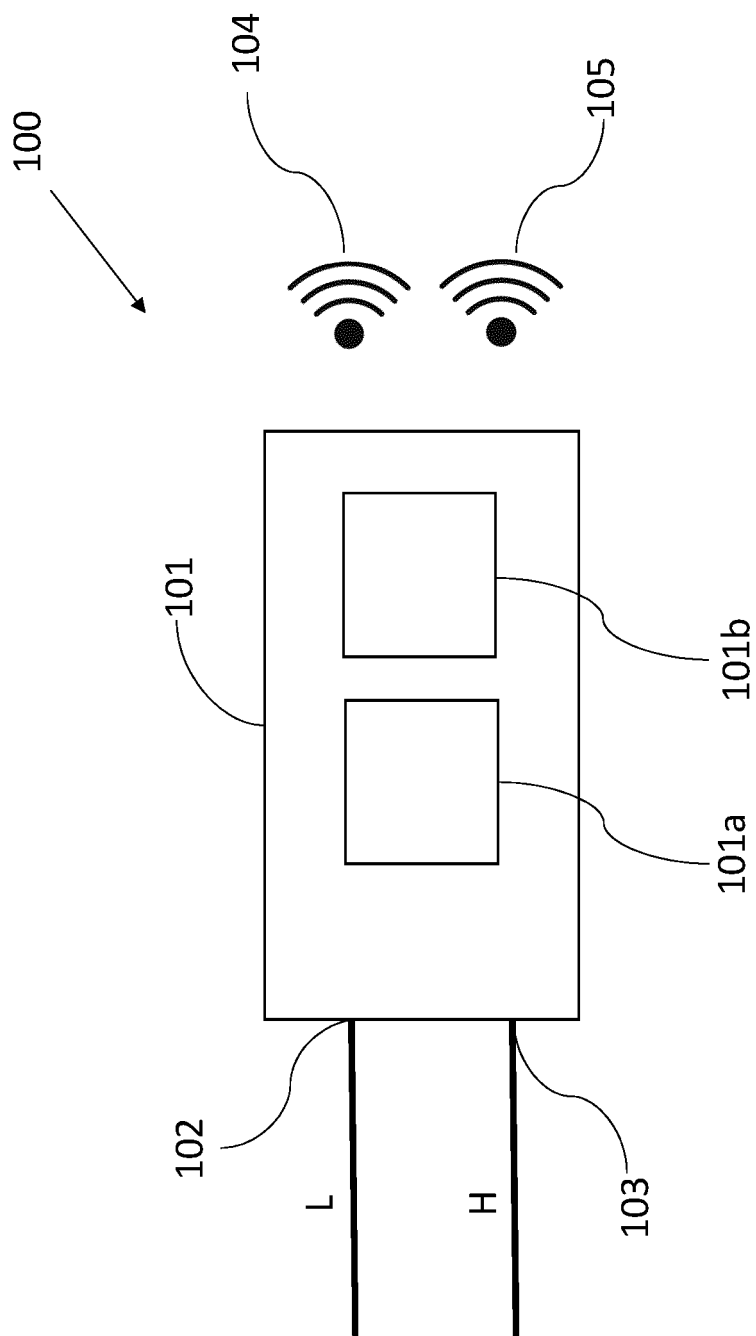


Fig. 1

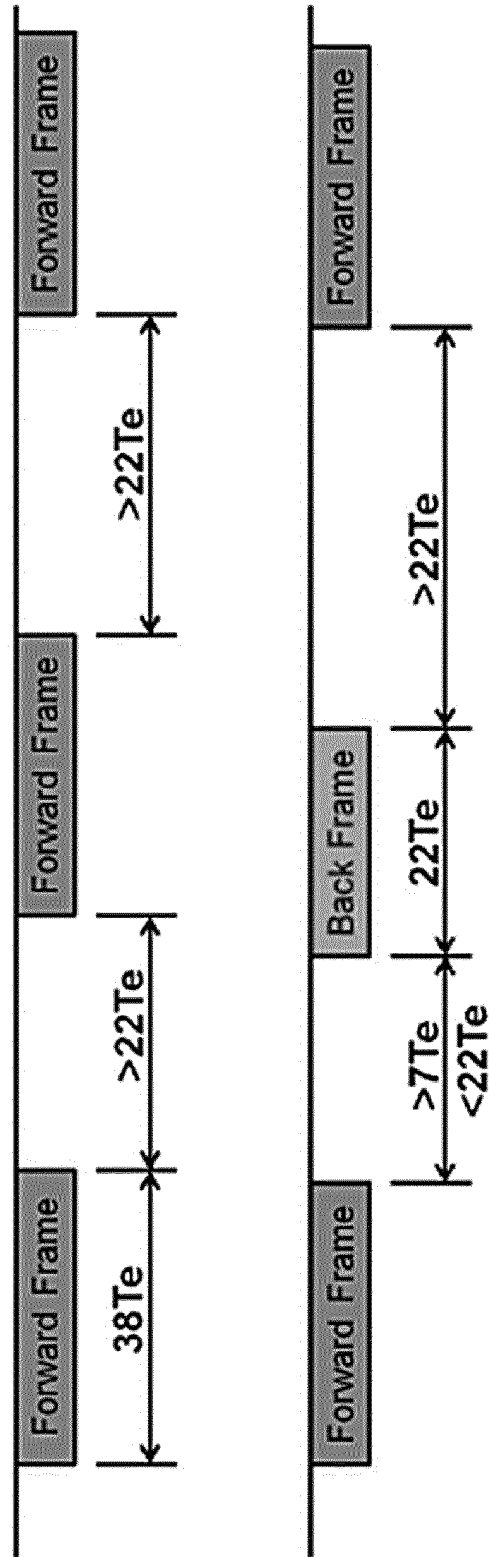


Fig. 2

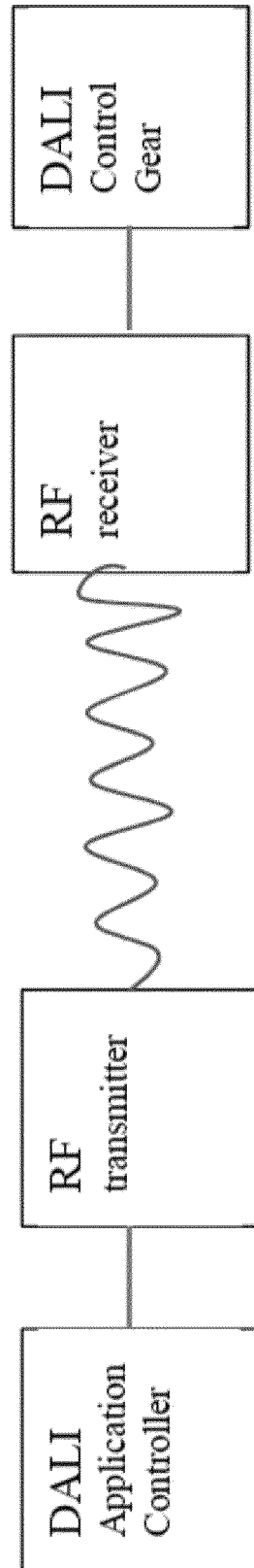


Fig. 3

	DALI state	Note
F0	Low	F1 will switch off F0
F1	High	F2 will switch off F1
F2	Low	F3 will switch off F2
F3	High	F0 will switch off F3
No signal	High	Idle state with no RF power

Fig. 4

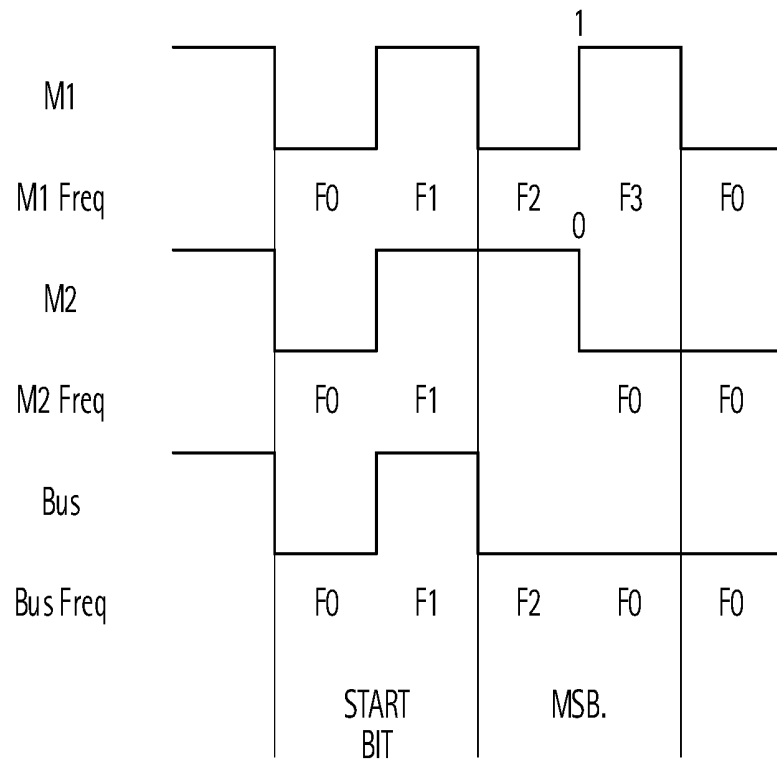


Fig. 5

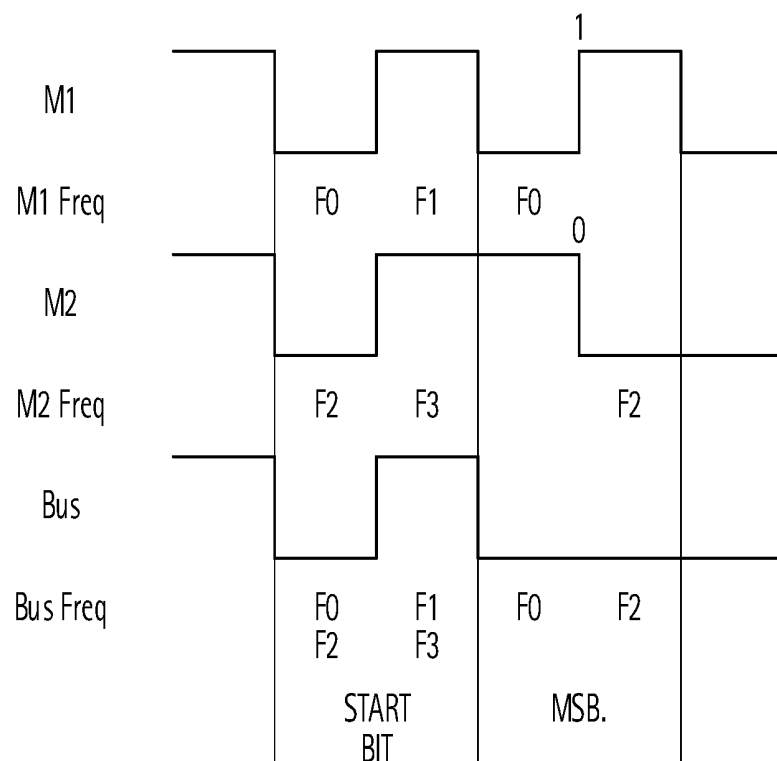
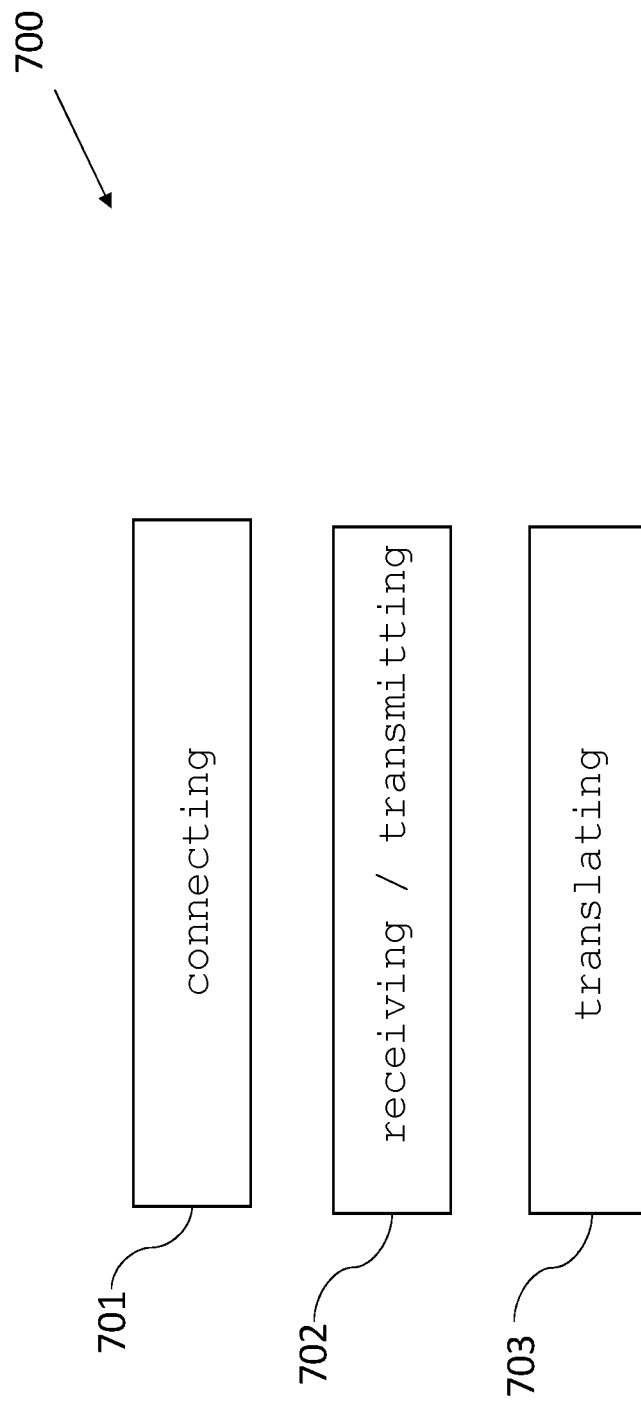


Fig. 6





EUROPEAN SEARCH REPORT

Application Number
EP 19 20 8421

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Y	* page 21, line 20 - line 24; figures 2,3 * * page 24, line 4 - line 7 * * page 7, line 11 - line 16 *	3	
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			H05B
Place of search		Date of completion of the search	Examiner
Munich		25 March 2020	Heiner, Christoph
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EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 19 20 8421

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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