



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
28.09.2022 Bulletin 2022/39

(51) International Patent Classification (IPC):
H04K 3/00 (2006.01)

(21) Application number: **21164510.6**

(52) Cooperative Patent Classification (CPC):
H04K 3/45; H04K 3/41; H04K 2203/34

(22) Date of filing: **24.03.2021**

(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:
KH MA MD TN

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(54) **JAMMING SYSTEM AS WELL AS METHOD OF OPERATING JAMMING SYSTEM**

(57) The invention relates to a jamming system with at least two responsive jammers (12, 14). Each responsive jammer (12, 14) comprises a detector (18) and an exciter (20). The respective detector (18) is configured to receive a radio frequency signal. The respective exciter (20) is configured to generate a jamming signal that disturbs the radio frequency signal received. Each of the

responsive jammers (12, 14) comprises a state machine (22) that is configured to define a detection phase and a jamming phase of the respective responsive jammer (12, 14). The state machines (22) of the responsive jammers (12, 14) are synchronized with each other. Further, a method of operating a jamming system (10) is described.

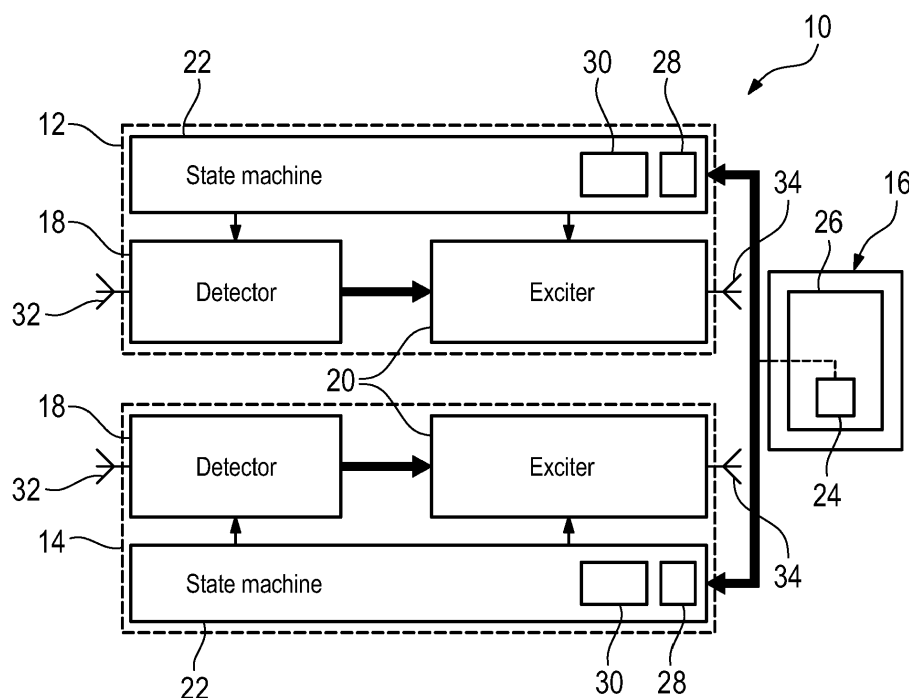


Fig. 1

Description

[0001] The invention relates to a jamming system with at least two responsive jammers. Further, the invention relates to a method of operating a jamming system with at least two responsive jammers.

[0002] In the state of the art, it is known to use a responsive jammer, which is also called reactive jammer, in order to jam/disturb a radio frequency (RF) signal. The responsive jammers detect the radio frequency signal such that characteristics of the radio frequency signal are determined which in turn are used to generate a jamming signal for disturbing/jamming the radio frequency signal detected. The radio frequency signal detected may relate to a frequency-agile radio frequency signal, e.g. a frequency-varying radio frequency signal.

[0003] Generally, the responsive jammers are configured to gather information from the RF signal detected and to process this information gathered in order to generate the jamming signal in a fast manner. This ensures that the RF signal has not changed its respective characteristics when the jamming signal is transmitted by the responsive jammer. Accordingly, the jamming signal is transmitted at the same frequency with as little delay as possible. This is especially important for frequency-agile radio frequency signals to be disturbed.

[0004] Typically, the operating area of a responsive jammer is limited. However, it is not possible to extend the operating area by using several responsive jammers, as one of the several responsive jammers may detect a jamming signal of another responsive jammer, thereby reacting on the jamming signal of the other responsive jammer rather than the RF signal to be disturbed/jammed.

[0005] Accordingly, there is need for a jamming system as well as a method of operating a jamming system which provide a large operating area in an effective manner.

[0006] The invention provides a jamming system with at least two responsive jammers. Each responsive jammer comprises a detector and an exciter. The respective detector is configured to receive a radio frequency signal (RF signal). The respective exciter is configured to generate a jamming signal that disturbs or rather jams the radio frequency signal received. Each of the responsive jammers also comprises a state machine that is configured to define a detection phase and a jamming phase of the respective responsive jammer. The state machines of the responsive jammers are synchronized with each other.

[0007] Further, the invention provides a method of operating a jamming system with at least two responsive jammers. Each responsive jammer comprises a detector and an exciter wherein the respective detector is configured to receive a radio frequency signal. The respective exciter is configured to generate a jamming signal that disturbs or rather jams the radio frequency signal received. A detection phase and a jamming phase of the responsive jammer are defined by means of a state ma-

chine of the respective responsive jammer. The state machines of the responsive jammers are synchronized with each other.

[0008] Accordingly, it is possible to operate more than one responsive jammer within a certain operational area, as the responsive jammers are controlled by means of their state machines that define the allocation of detection phases and jamming phases appropriately. The responsive jammers in the jamming system are operated due to their synchronization, particularly the synchronization of their state machines, such that they do not disturb each other, thereby ensuring that the jamming signal of one responsive jammer is not detected by the other one. Accordingly, it is avoided that the responsive jammers react on each other.

[0009] Hence, the operational area of the jamming system can be extended since several responsive jammers may be located in proximity of each other, particularly in the individual operational areas of neighbored responsive jammers. The individual operational areas of neighbored responsive jammers may at least partly overlap, thereby creating an entire operational area of the jamming system that is extended with respect to the individual operational area of a single responsive jammer. In other words, each of the responsive jammers provided has its own operational area, wherein the operational areas of the responsive jammers partially overlap, thereby establishing a common operational area of the jamming system. In addition, the partial overlap ensures that no areas are provided that are not covered by the jamming system. Furthermore, redundancy of the overall jamming system is ensured when providing more than one responsive jammer in a certain area.

[0010] In any case, the responsive jammers do not react on each other as they are controlled by means of the synchronized state machines, which define the detection phases and the jamming phases of the responsive jammers. Accordingly, the state machines each allocate a certain time for the respective responsive jammer that can be used for detecting the RF signal, also called detection phase or rather detection period, as well as a certain time that can be used by the respective responsive jammer for jamming the RF signal detected, also called jamming phase or rather jamming period.

[0011] In general, each of the responsive jammers comprises at least one antenna that is connected with the detector and/or the exciter. The detector and the exciter of each responsive jammer may share a common antenna that can be used for receiving RF signals to be disturbed/jammed as well as transmitting RF signals, particularly the jamming signals provided by the exciter.

[0012] Alternatively, each of the responsive jammers comprises two antennas that are assigned to the detector and the exciter, respectively. In other words, one of the two antennas is used for receiving radio frequency signals, whereas the other antenna is used for transmitting radio frequency signals, namely the jamming signals.

[0013] Generally, the detector is configured to receive

the RF signal, to process the RF signal and to detect characteristics of the RF signal, thereby gathering information of the RF signal received. Thus, the detector receives the respective RF signal over-the-air by means of the (receiving) antenna and analyzes the RF signal in order to gather the information concerning the RF signal. The detector may comprise a receiving module for receiving the RF signal and a monitoring module for processing and monitoring a characteristic of the RF signal received, e.g. frequency. Thus, the monitoring module may relate to a frequency monitoring module that is configured to gather the information concerning the frequency of the RF signal received.

[0014] Generally, the information gathered can be used for controlling the exciter. In fact, the exciter is controlled based on the information provided by the detector.

[0015] For instance, the detector controls the exciter at least partly, particularly by controlling the settings of the exciter to generate the jamming signal, e.g. controlling its characteristics like frequency and/or amplitude.

[0016] The exciter is configured to generate and provide the jamming signal, particularly based on information and/or the control signal received from the detector. Hence, the detector may directly control the exciter or rather the detector may forward information to the detector, particularly a jamming control of the exciter, which processes the information obtained in order to control the exciter appropriately, particularly its components.

[0017] For instance, the exciter may comprise an analog synthesizer or a direct digital synthesis (DDS) module that uses a fixed signal for creating arbitrary waveforms, e.g. a single, fixed-frequency reference clock signal.

[0018] The exciter may have a frequency reference, e.g. an oscillator, a numerically controlled oscillator (NCO) and a digital-to-analog converter (DAC), which are controlled such that the desired jamming signal is generated.

[0019] In any case, the exciter is configured to provide a wideband RF signal.

[0020] Generally, each of the responsive jammers comprises a combined wideband detector and exciter, thereby enabling the responsive jammer to jam regular and frequency-hopping radio frequency signals with high hop rates, e.g. so-called frequency-agile radio frequency signals.

[0021] Moreover, each of the state machine comprises an input for receiving a signal used for synchronizing purposes as well as at least one output for controlling components of the respective responsive jammer, e.g. the detector and the exciter. In other words, the state machine receives the signal in order to synchronize itself with a reference time, for instance a global time. After the synchronization, the state machine controls the associated detector and exciter, thereby defining the detection phase and the jamming phase in a temporal manner while defining the time spans for the different phases.

[0022] Since both state machines are synchronized

with the same reference time, it is ensured that both state machines control the respective detectors and the respective exciters in a synchronized manner.

[0023] Hence, the state machines may also be called clock state machines as they are used to provide a (common) clock signal for the respective responsive jammers.

[0024] The state machines each define a starting point in time for the respective detection phase and/or the jamming phase. Since the state machines are synchronized, it is ensured that the starting points of the respective phases are also synchronized in time.

[0025] An aspect provides that the individual detection phases and jamming phases of the at least two responsive jammers are defined such that different kinds of phases do not overlap with each other. Put differently, the first responsive jammer is operated in its detection phase, whereas the second responsive jammer is not operated in the jamming phase at the same time. The second responsive jammer is either also operated in the detection phase or the second responsive jammer is not operated.

[0026] The responsive jammers may be operated commonly in their detection phases or jamming phases. This means that the responsive jammers both are operated in the detection phase or rather the jamming phase at the same time.

[0027] Alternatively, the responsive jammers are operated in a subsequent manner. Thus, the first responsive jammer is operated in the detection phase, wherein the second responsive jammer is not operated at that time. Once the first responsive jammer is not operated in its detection phase anymore, the second responsive jammer may be operated, for instance in its detection phase or its jamming phase.

[0028] However, the jamming system can be operated in an efficient way when the responsive jammers are operated commonly, namely commonly in the detection phases or rather commonly in the jamming phases.

[0029] Another aspect provides that the state machines are configured to receive a signal from an external global navigation satellite system (GNSS), thereby synchronizing themselves. For instance, the GNSS may relate to GPS, GLONASS, Beidou or Galileo. In general, the global navigation satellite system provides a clock time that can be used by the respective responsive jammers, particularly their state machines, in order to synchronize themselves to the clock time of the global navigation satellite system, thereby ensuring that the responsive jammers can be operated in a synchronized manner.

[0030] The synchronization generally ensures that an absolute time is provided that is used by the responsive jammers, as they are operated with respect to the absolute time.

[0031] Further, the state machines may be configured to synchronize themselves by receiving a clock signal from an external clock. The external clock may be provided by a cellular network, an external device that can be connected with a respective responsive jammer in a

wireless manner or by wire. The responsive jammer, particularly the state machine integrated, may comprise a reception module that is configured to receive a signal from the external clock providing the external clock signal, e.g. the clock signal. The external clock may be synchronized with the external global navigation satellite system, thereby ensuring that the clock signal provided by the external clock is a globally synchronized one.

[0032] According to a further aspect, a guard time is provided between the detection phase the jamming phase. The guard time, also called dead time, ensures that a respective responsive jammer is not directly switched from one of the phases into the other phase due to the guard time that is applied between the respective phases.

[0033] For instance, each state machine may be configured to provide a settable guard time. The guard time may be set automatically or rather manually. In any case, the guard time can be set such that the guard time is adapted to the respective jamming system, particularly any characteristics of the jamming system. For instance, the guard time may be adapted once the jamming system is extended by a further responsive jammer.

[0034] For instance, the guard time may be set such that the guard time corresponds to the maximum runtime of the jamming signal generated by the respective exciter to the detector of another responsive jammer in the jamming system. This ensures that the different responsive jammers do not disturb each other, as each responsive jammer is switched from its jamming phase into the detection phase once the guard time has expired. This ensures that the responsive jammers do not detect a jamming signal issued by another responsive jammer within the jamming system.

[0035] Furthermore, the radio frequency signal received may be a frequency-agile radio frequency signal. The responsive jammers are generally configured to react to the frequency-agile radio frequency signal directly by adapting its settings and/or characteristics of the jamming signal generated.

[0036] Therein and in the following, the term "module" is understood to describe suitable hardware, suitable software, or a combination of hardware and software that is configured to have a certain functionality. The hardware may, inter alia, comprise a CPU, a GPU, an FPGA, an ASIC, or other types of electronic circuitry.

[0037] Further aspects and advantages of the claimed subject matter will become more readily appreciated, as the same become better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings. In the drawings,

- Figure 1 schematically shows an overview of a jamming system according to the invention, and
- Figure 2 schematically shows an overview that illustrates the operation of the jamming system according to the invention.

[0038] The detailed description set forth below in connection with the appended drawings, where like numerals reference like elements, is intended as a description of various embodiments of the disclosed subject matter and is not intended to represent the only embodiments. Each embodiment described in this disclosure is provided merely as an example or illustration and should not be construed as preferred or advantageous over other embodiments. The illustrative examples provided herein are not intended to be exhaustive or to limit the claimed subject matter to the precise forms disclosed.

[0039] For the purposes of the present disclosure, the phrase "at least one of A, B, and C", for example, means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B, and C), including all further possible permutations when more than three elements are listed. In other words, the term "at least one of A and B" generally means "A and/or B", namely "A" alone, "B" alone or "A and B".

[0040] In Figure 1 a jamming system 10 is shown that comprises two different responsive jammers, namely a first responsive jammer 12 and a second responsive jammer 14.

[0041] In addition, the jamming system 10 comprises an external system 16 that communicates with both responsive jammers 12, 14 as will be explained later in more detail. In fact, the external system 16 provides a signal that is received by the responsive jammers 12, 14 as explained later in more detail.

[0042] Each of the responsive jammers 12, 14 comprises a detector 18 as well as an exciter 20. The detector 18 and the exciter 20 are connected with each other in a signal-transmitting manner such that the detector 18 is enabled to forward signals/information to the exciter 20.

[0043] In addition, both responsive jammers 12, 14 have (integrated) state machines 22 that are configured to receive a signal from the external system 16, thereby receiving a reference time from the external system 16. The reference time is used to synchronize the responsive jammers 12, 14 in a temporal manner, e.g. the state machines 22.

[0044] The external system 16 has an external clock 24 that provides an external clock signal to which the state machines 22 synchronize themselves when receiving the time reference from the external system 16 such that the responsive jammers 12, 14 are synchronized with the time reference. This also ensures that the responsive jammers 12, 14 are synchronized with each other, as they are synchronized with the same reference time that is provided by the external system 16.

[0045] The external system 16 may relate to an external global navigation satellite system 26, e.g. GPS, GLO-NASS, Beidou or Galileo.

[0046] Alternatively, the external system 16 may relate to an external device, a cellular network or any other module that uses a clock signal, e.g. the one provided by the external clock 24.

[0047] The state machines 22 comprises an input 28 associated with a reception module 28 that is configured

to receive a signal from the external clock 24, e.g. the reference time or rather the clock signal.

[0048] In addition, the state machines 22 are configured to control the detector 18 and the exciter 20 of the responsive jammers 12, 14 appropriately such that the responsive jammers 12, 14 are operated in a detection phase, also called look-through phase, and a jamming phase in a defined manner.

[0049] In fact, the starting points of the respective phases can be defined in an absolute synchronized manner due to the fact that the state machines 22 synchronized themselves with the reference time previously, namely the clock signal provided by the external clock 24.

[0050] This ensures that the responsive jammers 12, 14 do not disturb each other, as shown in Figure 2 that illustrates the respective detection phases and jamming phases of both responsive jammers 12, 14 over time t.

[0051] Since the state machines 22 of both responsive jammers 12, 14 are synchronized with the external clock 24, it can be ensured that the detectors 18 as well as the exciters 20 are operated in a synchronized manner.

[0052] Therefore, both responsive jammers 12, 14 may be operated in the respective detection phases at the same time as shown in Figure 2. Further, both responsive jammers 12, 14 are also operated in the respective jamming phases simultaneously.

[0053] Between the different phases of each responsive jammer 12, 14, a guard time or rather dead time is provided, which ensures that the detection phase does not directly cross over into the jamming phase and vice versa.

[0054] In general, the guard time can be set by an operator of the jamming system 10. Alternatively, the guard time is set automatically, for instance based on characteristics of the jamming system 10 such as number of responsive jammers 12, 14 within the jamming system 10, their respective relative distances and/or operational areas.

[0055] Hence, the guard time can be set such that it is optimized with respect to the jamming system 10. The guard time ensures that a jamming signal issued by one of the exciters 20 within the jamming phase is not received or rather detected by the other responsive jammer 12, 14, particularly its detector 18, in a subsequent detection phase.

[0056] Therefore, the guard time lasts at least as long as the run-time of the jamming signal generated by one of the responsive jammers 12, 14 to the other responsive jammers 12, 14.

[0057] As shown in Figure 2, the individual detection phases and jamming phases of the responsive jammers 12, 14 are defined or rather scheduled such that different kinds of phases do not overlap with each other.

[0058] In the embodiment shown in Figure 2, the responsive jammers 12, 14 are commonly operated in the respective detection and jamming phases.

[0059] Alternatively, the responsive jammers 12, 14 may be operated in a subsequent manner such that only

one of the responsive jammers 12, 14 is operated, whereas the other one is not operated at the same time. Thus, the responsive jammers 12, 14 do not overlap during their operation.

[0060] Figure 1 shows that the detectors 18 are associated with an antenna 32, e.g. a receiving antenna, that is used to receive an RF signal. The detectors 18 process the RF signal received, thereby gathering information concerning the RF signal received, for instance information concerning the frequency of the RF signal.

[0061] Based on this information, the exciters 20 are controlled in order to generate a jamming signal that is used to disturb/jam the RF signal received while being transmitted via transmission antennas 34. The exciters 20 may be controlled directly by the corresponding detectors 18. Alternatively, the detectors 18 forward the information gathered to the corresponding exciters 20 that process the information, thereby generating the jamming signal.

[0062] Furthermore, the state machines 22 synchronized with the external clock 24 control the detectors 18 and the exciters 20 accordingly, particularly their activation while defining the starting times, e.g. the detection phases and the jamming phases, in a global manner.

[0063] Accordingly, the external clock 24, for instance the external system 16, ensures that the state machines 22 of the responsive jammers 12, 14 are synchronized with the reference time and, therefore, the state machines 22 are synchronized with each other.

[0064] Accordingly, the jamming system 10 as well as its operation ensures that two or more responsive jammers 12, 14 can be operated simultaneously within the same operational area or rather at least in an overlapping operational area.

[0065] In other words, each of the responsive jammers 12, 14 has its own operational area, wherein the own operational areas of the responsive jammers 12, 14 at least overlap with each other partially, thereby creating an extended operational area of the entire jamming system 10. Due to the synchronization of the state machines 22 that control the detectors 18 and the exciters 20 of the responsive jammers 12, 14, it is also ensured that the responsive jammers 12, 14 of the jamming system 10 do not disturb each other while detecting jamming signals issued by the jamming system 10 itself.

[0066] Certain embodiments disclosed herein, particularly the respective module(s), utilize circuitry (e.g., one or more circuits) in order to implement standards, protocols, methodologies or technologies disclosed herein, operably couple two or more components, generate information, process information, analyze information, generate signals, encode/decode signals, convert signals, transmit and/or receive signals, control other devices, etc. Circuitry of any type can be used.

[0067] In an embodiment, circuitry includes, among other things, one or more computing devices such as a processor (e.g., a microprocessor), a central processing unit (CPU), a digital signal processor (DSP), an applica-

tion-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a system on a chip (SoC), or the like, or any combinations thereof, and can include discrete digital or analog circuit elements or electronics, or combinations thereof. In an embodiment, circuitry includes hardware circuit implementations (e.g., implementations in analog circuitry, implementations in digital circuitry, and the like, and combinations thereof).

[0068] In an embodiment, circuitry includes combinations of circuits and computer program products having software or firmware instructions stored on one or more computer readable memories that work together to cause a device to perform one or more protocols, methodologies or technologies described herein. In an embodiment, circuitry includes circuits, such as, for example, microprocessors or portions of microprocessor, that require software, firmware, and the like for operation. In an embodiment, circuitry includes one or more processors or portions thereof and accompanying software, firmware, hardware, and the like.

[0069] The present application may reference quantities and numbers. Unless specifically stated, such quantities and numbers are not to be considered restrictive, but exemplary of the possible quantities or numbers associated with the present application. Also in this regard, the present application may use the term "plurality" to reference a quantity or number. In this regard, the term "plurality" is meant to be any number that is more than one, for example, two, three, four, five, etc. The terms "about", "approximately", "near" etc., mean plus or minus 5% of the stated value.

Claims

1. A jamming system with at least two responsive jammers (12, 14), wherein each responsive jammer (12, 14) comprises a detector (18) and an exciter (20), wherein the respective detector (18) is configured to receive a radio frequency signal, and wherein the respective exciter (20) is configured to generate a jamming signal that disturbs the radio frequency signal received, **characterized in that** each of the responsive jammers (12, 14) comprises a state machine (22) that is configured to define a detection phase and a jamming phase of the respective responsive jammer (12, 14), and wherein the state machines (22) of the responsive jammers (12, 14) are synchronized with each other.
2. The jamming system according to claim 1, wherein the individual detection phases and jamming phases of the at least two responsive jammers are defined such that different kinds of phases do not overlap with each other.
3. The jamming system according to claim 1 or 2, wherein the responsive jammers (12, 14) are oper-

ated commonly in their detection phases or jamming phases or wherein the responsive jammers are operated in a subsequent manner.

4. The jamming system according to any of the preceding claims, wherein the state machines (22) are configured to receive a signal from an external global navigation satellite system (26), thereby synchronizing themselves.
5. The jamming system according to any of the preceding claims, wherein the state machines (22) are configured to synchronize themselves by receiving a clock signal from an external clock (24).
6. The jamming system according to any of the preceding claims, wherein a guard time is provided between the detection phase and the jamming phase.
7. The jamming system according to any of the preceding claims, wherein each state machine (22) is configured to provide a settable guard time.
8. The jamming system according to any of the preceding claims, wherein the radio frequency signal received is a frequency-agile radio frequency signal.
9. A method of operating a jamming system (10) with at least two responsive jammers (12, 14), wherein each responsive jammer (12, 14) comprises a detector (18) and an exciter (20), wherein the respective detector (18) is configured to receive a radio frequency signal, and wherein the respective exciter (20) is configured to generate a jamming signal that disturbs the radio frequency signal received, wherein a detection phase and a jamming phase of the responsive jammer (12, 14) are defined by means of a state machine (22) of the respective responsive jammer (12, 14), and wherein the state machines (22) of the responsive jammers (12, 14) are synchronized with each other.
10. The method according to claim 9, wherein the individual detection phases and jamming phases of the at least two responsive jammers (12, 14) are defined such that different kinds of phases do not overlap with each other.
11. The method according to claim 9 or 10, wherein the state machines (22) receive a signal from an external global navigation satellite system (26), thereby synchronizing themselves.
12. The method according to any of the claims 9 to 11, wherein the state machines (22) synchronize themselves by receiving a clock signal from an external clock (24).

13. The method according to any of the claims 9 to 12, wherein each of the state machines (22) has a guard time between the detection phase and the jamming phase.
14. The method according to claim 13, wherein the respective guard time is settable.
15. The method according to claim 13 or 14, wherein the guard time is set such that the guard time corresponds to the maximum run-time of the jamming signal generated by the respective exciter (20) of one responsive jammer (12, 14) to the detector (18) of another responsive jammer (12, 14) in the jamming system (10).

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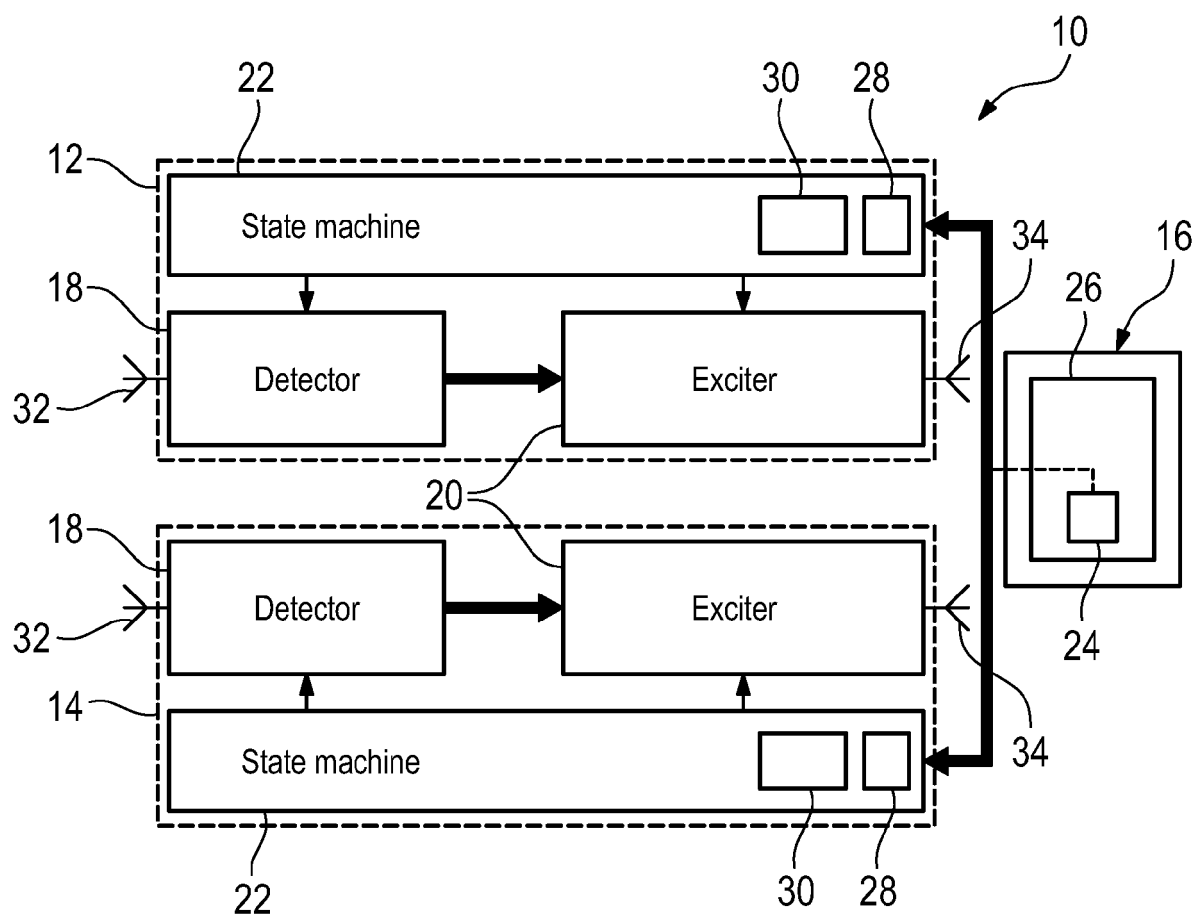


Fig. 1

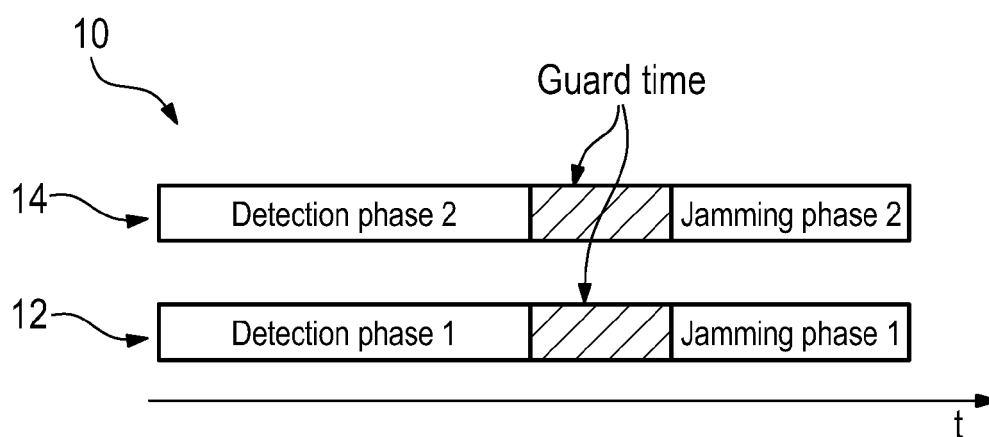


Fig. 2



EUROPEAN SEARCH REPORT

Application Number
EP 21 16 4510

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 22 July 2021	Examiner Dujardin, Corinne
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 21 16 4510

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