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A SYSTEM AND METHOD FOR OBJECT TRACKING

FIELD OF INVENTION

The present invention relates to a system and method for object tracking. More
5 specifically, the present invention relates to a system and method for object tracking
using radio signal.

BACKGROUND OF THE INVENTION

Radio tracking is a type of positioning system using radio frequency. Radio
10 tracking is often used to determine the location of various inanimate or animate
objects. One of the solutions for radio tracking is by tagging an object that a user
wants to track with a tag. Usually, this tag is a radio transmitter which can be
detected by a radio receiver. By using a single radio receiver, the information that
the user may receive from the tag is the signal strength of a radio signal, which can
15 be used to estimate the direction and distance of the tag from the radio receiver.
However, depending only on the signal strength received by one radio receiver is
not practical especially in a building. The presence of walls and furniture disturb and
alter the signal strength of the radio signal. As a result, it is difficult to estimate the
location of a tagged object with good accuracy.

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To overcome the limitations of a single radio transmitter and a single emitter,
many object tracking systems utilise a plurality of transmitters and emitters. An
example of a positioning system utilising a plurality of transmitters and emitters was
developed by Dong, Mengjiao, and Wenjuan (2017). The system utilises wireless
25 signal pattern matching, also known as signal fingerprinting, to determine the
location of an object. Using a plurality of fixed emitters and a mobile receiver, a map
of signal strength received by the mobile receiver from the plurality of fixed emitters
is produced by associating the signal strength of each emitter with a known
coordinate of the receiver during the time the fixed emitters emit a radio signal. The
30 map of signal strength is populated with signal strength measurements from a
plurality of coordinates. In operation, the location of the receiver is estimated by
matching the signal strength received by the receiver with the map of signal strength.
The location on the map with similar signal strength received by the receiver is
estimated to be the most likely position of the receiver.

A United States Patent Publication No. 2005/0261004 A1 disclosed a system for estimating the location of wireless nodes in a radio frequency environment. The system comprises a plurality of radio transceivers which transmit and receive radio signal and a wireless node which only receives radio signal. In calibration mode, the system constructs a coverage map. The coverage map is constructed by associating the signal strength with the location data of the wireless node. The location of a wireless node is determined by matching the signal strength received by the wireless node with the coverage map.

Although there are many known systems and methods for object tracking, most system that computes a fingerprint or coverage map does the computation on the tracked device. The computation for the fingerprint or coverage maps is usually complex and demanding. Therefore, a device with limited computation capacity may not be able to compute the fingerprint or coverage maps. Furthermore, the accuracy of most system and method for radio positioning depends on the quality of the radio signal that is being exchanged between a transmitter and a receiver. Inconsistent quality of radio signal results in an inaccurate positioning estimation. Therefore, there is a need for a system and method for object tracking that can solve the aforementioned problems.

SUMMARY OF INVENTION

The invention relates to a system (1000) and method for object tracking. The system (1000) comprising at least one emitter (1001) configured to emit radio signal, a plurality of listeners (1002) configured to receive the radio signal from the at least one emitter (1001), a Signal Harvester (1003) configured to assign a timestamp to radio signal data, a Signal Batcher (1005) configured to convert the radio signal data into time batch data, an Offline Fingerprint Database (1008) configured to store signal fingerprint for the at least one emitter (1001) tagged with location data, an Online Fingerprint Database (1009) configured to store signal fingerprint for the at least one emitter (1001), and a Signal Fingerprint Matcher (1010) configured to compare signal fingerprint from the Online Fingerprint Database (1009) with signal fingerprint from the Offline Fingerprint Database (1008). The system (1000) further comprising a Signal Fingerprint Generator (1007) configured to generate a signal fingerprint for the at least one emitter (1001) by compiling radio signal received by the plurality of listeners (1002) from the at least one emitter (1001) based on detection of a predetermined number of

emitters (**1001**) within a predefined period with a predetermined signal strength value by the plurality of listeners (**1002**). The Signal Fingerprint Generator (**1007**) is connected to the Offline Fingerprint Database (**1008**) and the Online Fingerprint Database (**1009**). The Signal Harvester (**1003**) is connected to the plurality of listeners
5 (**1002**). The Signal Fingerprint Matcher (**1010**) is connected to the Offline Fingerprint Database (**1008**) and the Online Fingerprint Database (**1009**)

Preferably, the signal strength values include maximum, mean, minimum and standard deviation values of the signal strength.

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Preferably, the system (**1000**) further comprising a time-series signal database (**1004**) configured to store the time-series data from the Signal Harvester (**1003**). The time-series database (**1004**) is connected to the Signal Harvester (**1003**) and the Signal Batcher (**1005**).

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Preferably, the system (**1000**) further comprising a time batch signal database (**1006**) configured to store the time batch data. The time batch signal database (**1006**) is connected to the Signal Batcher (**1005**) and the Signal Fingerprint Generator (**1007**).

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Preferably, the system (**1000**) further comprising a location database (**1011**) configured to store the coordinates of the at least one emitter (**1001**) being located. The location database (**1010**) is connected to the Signal Fingerprint Matcher (**1010**).

The method for object tracking comprising the steps of emitting radio signal by
25 at least one emitter (**1001**), receiving a radio signal from the at least one emitter (**1001**) by a plurality of listener (**1002**), acquiring radio signal data from the plurality of listeners (**1002**) by a Signal Harvester (**1003**), assigning a timestamp to the radio signal data by the Signal Harvester (**1003**), storing the radio signal data from the Signal Harvester (**1003**) on a Time-Series Signal Database (**1004**), converting radio signal data into time
30 batch signal data by a Signal Batcher (**1005**), storing time batch signal data on a Time Batch Signal Database (**1006**), generating a signal fingerprint by the Signal Fingerprint Generator (**1007**), determining the operation mode of the system by a Signal Fingerprint Generator (**1000**), storing the signal fingerprint with location tag on an Offline Fingerprint Database (**1008**) if the system is in calibration mode, storing the
35 signal fingerprint on an Online Fingerprint Database (**1009**) if the system (**1000**) is in

tracking mode, comparing signal fingerprint from the Online Fingerprint Database (1009) with a signal fingerprint from the Offline Fingerprint Database (1008) by a Signal Fingerprint Matcher (1010), and storing the coordinates of the at least one emitter (1001) on a Location Database (1011). The step of generating the signal fingerprint by the Signal Fingerprint Generator (1007) further comprises the sub-steps of filtering the radio signals received by the plurality of listeners (1002) based on the number of unique emitters detected by each listener (1002) within a predefined period, filtering the radio signals received by the plurality of listeners (1002) based on a predetermined signal strength values of the radio signal from the emitter (1001) received by the listeners (1002), and converting the time batch signal data from emitter-per-listener to listener-per-emitter.

Preferably, if the number of unique emitters (1001) during the predefined period is less than a predetermined number of emitters (1001), the radio signals received by the plurality of listeners (1002) from the emitters (1001) within the predefined period are filtered out.

Preferably, if any particular listener (1002) receives at least one radio signal with a signal strength of less than predetermined signal strength values, all radio signals received by the particular listener (1002) are filtered out.

Preferably, the signal strength values include maximum, mean, minimum and standard deviation values of the signal strength.

25 BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

30 **FIG. 1** illustrates a system (1000) for object tracking according to an embodiment of the present invention.

FIGS. 2a and **2b** illustrate flow charts of a method for object tracking according to an embodiment of the present invention.

FIG. 3 illustrates a flow chart of sub-steps of generating fingerprint data by a Signal Fingerprint Generator (**1007**) of the method of **FIGS. 2a** and **2b**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

5 A preferred embodiment of the present invention will be described hereinbelow with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure the description with unnecessary detail.

10 An initial reference is made to **FIG. 1** which illustrates a system (**1000**) for object tracking according to an embodiment of the present invention. The system (**1000**) comprises at least one emitter (**1001**), a plurality of listeners (**1002**), a Signal Harvester (**1003**), a Time Series Signal Database (**1004**), a Signal Batcher (**1005**), a Time Batch Signal Database (**1006**), a Signal Fingerprint Generator (**1007**), an Offline Fingerprint
15 Database (**1008**), an Online Fingerprint Database (**1009**), a Signal Fingerprint Matcher (**1010**), and a Location Database (**1011**). The system (**1000**) utilises the emitter (**1001**) and the listeners (**1002**) to build a radio signal map of an area in a calibration stage. Then, during a positioning stage, the system (**1000**) utilises the radio signal map to predict the location of the emitter (**1001**). The system (**1000**) may be implemented
20 using various wireless technology including but not limited to Wi-Fi, Bluetooth Low Energy, Ultra-wideband, and Radio Frequency Identification.

The emitter (**1001**) emits a radio signal. The radio signal carries identification information of the emitter (**1001**). The identification information includes but not limited
25 to a hardware identification number and MAC address. Preferably, the emitter (**1001**) is either powered by a battery or passively powered. The emitter (**1001**) is attached to an object that is being tracked.

The listeners (**1002**) receive the radio signal emitted by the emitter (**1001**). The
30 listeners (**1002**) are always powered on to be able to receive the radio signal periodically emitted by the emitter (**1001**). Each listener (**1002**) is placed on a fixed location within an area of interest. The area of interest is an area within the range of the at least one listener (**1002**). The object attached with the emitter (**1001**) is expected to be only within the area of interest. The listeners (**1002**) are electrically connected to

the Signal Harvester (1003). The listeners (1002) convert the radio signal into an electrical signal and transmits the electrical signal to the Signal Harvester (1003).

The Signal Harvester (1003) is configured to receive the electrical signal from the listeners (1002). The Signal Harvester (1003) interprets the electrical signal into the identification information of the emitter (1001). The Signal Harvester (1003) assigns the identification information of the emitter (1001) with a timestamp which indicates the time of receipt of the identification information. The Signal Harvester (1003) also measures a signal strength of the radio signal. The signal strength of the radio signal is preferably quantified as Received Signal Strength Indicator, RSSI. The Signal Harvester (1003) is connected to the Time Series Signal Database (1004). The Signal Harvester (1003) stores the identification information and the signal strength of the emitter (1001) inside the Time Series Signal Database (1004). The Signal Harvester (1003) compiles the identification information and the signal strength of each emitter (1001) in an emitter-per-listener format. In the emitter-per-listener format, the identification information and the signal strength from a plurality of emitters (1001) received by a listener (1002) are compiled. For each listener (1002), the identification information and the signal strength of each emitter (1001) are compiled and separated based on the timestamp of the identification information.

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The Time Series Signal Database (1004) stores the identification information and the signal strength of the emitter (1001) which has been assigned with the timestamp. The Time Series Signal Database (1004) is connected to the Signal Batcher (1005).

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The Signal Batcher (1005) retrieves the identification information and the signal strength of each emitter (1001) from the Time Series Signal Database (1004). The Signal Batcher (1005) runs statistical analysis on the signal strength of each emitter (1001) for some predetermined periods, for example, 30 seconds, 1 minute, or 5 minutes. The statistical analysis produces information including but not limited to a maximum, a minimum, a mean, and a standard deviation value of the signal strength of each emitter (1001) detected by each listener (1002) within the predetermined period. Each information within the predetermined period is called a time batch data. The Signal Batcher (1005) is connected to the Time Batch Signal Database (1006). The time batch data in the Time Batch Signal Database (1006) is stored in the emitter-

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per-listener format. The time batch data is compiled according to the time period assigned for each time batch data. For example, all time batch data collected over a period of 30 seconds are separated from time batch data collected over a period of 1 minute.

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The Time Batch Signal Database (1006) stores the time batch data produced by the Signal Batcher (1005). The Time Batch Signal Database (1006) is connected to the Signal Fingerprint Generator (1007).

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The Signal Fingerprint Generator (1007) retrieves time batch data from the Time Batch Signal Database (1006) to generate a signal fingerprint for each emitter (1001). The signal fingerprint is a signal strength value received by a plurality of listeners (1002) for an emitter (1001). Preferably, the signal fingerprint for the emitter (1001) comprises the mean, maximum, minimum and standard deviation value of the signal strength received by the listeners (1002).

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For example, if there are five listeners (1002) that received the radio signal from the emitter (1001) for a period of 30 seconds, the mean, maximum, minimum and standard deviation value of the signal strength received by each listener (1002) is compiled. This compilation of signal strength information collected by the listeners (1002) is assigned as the signal fingerprint for the emitter (1001) for a similar time period.

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To generate the signal fingerprint for the emitter (1001), the Signal Fingerprint Generator (1007) compiles radio signals received by the listener (1002) only if the listener (1002) receives a radio signal from a predetermined minimum number of emitters (1001) within a predefined period. The radio signals received by each listener (1002) are stored as time batch data, whereby the radio signals that are received within the predefined period are compiled together. For example, all radio signals received over a period of 30 seconds are compiled in a group, while the radio signals received over the next 30 seconds are compiled in another group. If the number of unique emitters (1001) during the predefined period is less than a predetermined number of unique emitters (1001), the radio signals received by the listener (1002) from the emitters (1001) for the predefined period are not compiled. For example, assuming the predetermined number of unique emitters (1001) is 2, the radio signals received by the

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listener (1002) from only one emitter (1001) during the 30 seconds period are not compiled.

5 The value of the predetermined number of unique emitter affects the performance of the system (1000). A higher value of the predetermined number of unique emitters (1001) may reduce computation time but results in reduced accuracy of positioning. On the other hand, a lower value of the predetermined number of unique emitters (1001) may increase positioning accuracy at the expense of higher computational load.

10

The Signal Fingerprint Generator (1007) also compiles radio signal received by the listener (1002) only if the listener (1002) receives a radio signal of a predetermined mean, maximum, minimum, and standard deviation value of signal strength from the emitter (1001). For example, if a predetermined mean value of signal strength of a
15 radio signal is -50 dBm, the Signal Fingerprint Generator (1007) only compiles the radio signal received by the listeners (1002) with a mean value of signal strength of at least -50 dBm.

20 The Signal Fingerprint Generator (1007) transforms the time batch data from the emitter-per-listener format into a listener-per-emitter format. In the listener-per-emitter format, the identification information and the signal strength from the emitter (1001) received by the plurality of listeners (1002) are compiled. A compilation of maximum, minimum, mean, and standard deviation values of signal strength is unique to an emitter (1001) at a distinct location for a distinct period. The compilation is used
25 as a signal fingerprint for the emitter (1001).

The Signal Fingerprint Generator (1007) also collects other information such as the listener (1002) that measures the highest signal strength from the emitter (1001) and the last listener (1002) that receives the radio signal from the emitter (1001). The
30 information allows the system (1000) to infer an approximate location before a more accurate location is pinpointed.

The Signal Fingerprint Generator (1007) is connected to the Offline Fingerprint Database (1008) and the Online Fingerprint Database (1009). If the system (1000) is
35 set up for calibration mode, the signal fingerprint for the emitter (1001) is tagged with

a known location of the emitter (**1001**), preferably with a 3-dimensional Cartesian coordinate and is stored in the Offline Fingerprint Database (**1008**). In contrast, if the system (**1000**) is set up for tracking mode, the signal fingerprint for the emitter (**1001**) is stored in the Online Fingerprint Database (**1009**).

5

The Signal Fingerprint Matcher (**1010**) compares a signal fingerprint from the Online Fingerprint Database (**1009**) with the signal fingerprints from the Offline Fingerprint Database (**1008**). The signal fingerprint from the Offline Fingerprint Database (**1008**) which has the best or closest match to the Online Fingerprint Database (**1009**) is regarded as having the same position as the detected emitter (**1001**). The matching process uses an algorithm such as but not limited to k-nearest neighbour, Bayesian Classifier, Support Vector Machine, and Deep Learning for matching the signal fingerprints. The Signal Fingerprint Matcher (**1010**) is connected to the Location Database (**1011**).

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The Location Database (**1011**) stores the location of a detected emitter (**1001**). The Location Database (**1011**) allows the user to identify the last known location of the emitter (**1001**).

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Reference is now made to **FIGS. 2a** and **2b** which illustrate flow charts of a method for tracking an object according to an embodiment of the present invention. Initially, the radio signal is emitted periodically by the emitter (**1001**) as in step **2001**. The radio signal carries the identification information of the emitter (**1001**). The identification information includes but not limited to the hardware identification number and MAC address.

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Then, the radio signal is received by the listeners (**1002**) as in step **2002**. The listener (**1002**) converts the radio signal into the electrical signal.

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Afterwards, the electrical signal from the listeners (**1002**) is acquired by the Signal Harvester (**1003**) as in step **2003**. The Signal Harvester (**1003**) interprets the electrical signal into the identification information of the emitter (**1001**).

The identification information of the emitter (**1001**) is then assigned with a timestamp as in step **2004**. The timestamp indicates the time of receipt of the identification information by the Signal Harvester (**1003**). The Signal Harvester (**1003**)

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also measures a signal strength of the radio signal. The Signal Harvester (1003) compiles the identification information and the signal strength of each emitter (1001) in an emitter-per-listener format. In the emitter-per-listener format, the identification information and the signal strength from a plurality of emitters (1001) received by a listener (1002) are compiled. For each listener (1002), the identification information and the signal strength of each emitter (1001) are compiled and separated based on the timestamp of the identification information.

Furthermore, the identification information and the signal strength of the emitter (1001) is stored inside the Time Series Signal Database (1003) as in step 2005. If there is more than one emitter (1001), the Signal Harvester (1004) compiles the identification information and the signal strength of each emitter (1001) with respect to the receiving listener (1002) inside the Time Series Signal Database (1004).

The identification information and the signal strength of the emitter (1001) are then converted into time batches by the Signal Batcher (1005) as in step 2006. The Signal Batcher (1005) runs statistical analysis on the signal strength of each emitter (1001) for some predetermined periods of time, for example, 30 seconds, 1 minute, or 5 minutes. The statistical analysis produces information including but not limited to a maximum, a minimum, a mean, and a standard deviation value of the signal strength of each emitter (1001) detected by each listener (1002) within the predetermined period. Each information within the predetermined period is called a time batch data.

Subsequently, the time batch data stored in the Time Batch Signal Database (1006) as in step 2007. The time batch data stored in the Time Batch Signal Database (1006) is grouped according to the time period assigned for each time batch data. The time batch data in the Time Batch Signal Database (1006) is stored in the emitter-per-listener format. The time batch data is compiled according to the time period assigned for each time batch data. For example, all time batch data collected over a period of 30 seconds are assigned in a group, while time batch data collected over a period of 1 minute are assigned in another group.

Afterwards, the signal fingerprint is generated by the Signal Fingerprint Generator (1007) as in step 2008. The signal fingerprint comprises the mean, maximum, minimum and standard deviation value of the signal strength received by

the listeners (**1002**) for each emitter (**1001**). The sub-steps for generating signal fingerprint by a Signal Fingerprint Generator (**1007**) are further explained in relation to **FIG. 3**.

5 The Signal Fingerprint Generator (**1007**) then determines the operation mode of the system as in decision **2009**. There are two modes of operation, which are calibration mode and tracking mode. If the system (**1000**) is set up for calibration mode, the signal fingerprint for the emitter (**1001**) is tagged with the known location of the emitter (**1001**), preferably with a 3-dimensional Cartesian coordinate. The tagged
10 signal fingerprint is then stored in the Offline Fingerprint Database (**1008**) as in step **2010a**.

 In contrast, if the system (**1000**) is set up for tracking mode, the signal fingerprint for the emitter (**1001**) is directly stored in the Online Fingerprint Database
15 (**1009**) without any tagging as in step **2010b**.

 In tracking mode, the signal fingerprint from the Online Fingerprint Database (**1009**) is compared with the signal fingerprint from the Offline Fingerprint Database (**1010**) by the Signal Fingerprint Matcher as in step **2011**.

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 Finally, the coordinates of the emitter (**1001**) are then stored in the Location Database (**1011**) as in step **2012**. The user is able to identify the last known position of the emitter (**1001**) by referring to the Location Database (**1011**).

25 Reference is now made to **FIG. 3** which illustrates a flow chart of sub-steps of generating a signal fingerprint by the Signal Fingerprint Generator (**1007**) of the method of **FIG. 2a** and **2b**. Initially, the radio signals received by the plurality of listeners (**1002**) are filtered based on the number of unique emitters detected by each listener (**1002**) within a predefined period as in sub-step **2101**. The radio signals received by
30 each listener (**1002**) are stored as time batch data, whereby the radio signals that are received within the predefined period are compiled together. For example, all radio signals received over a period of 30 seconds are compiled in a group, while the radio signals received over the next 30 seconds are compiled in another group. If the number of unique emitters (**1001**) during the predefined period is less than a predetermined
35 number of unique emitters (**1001**), the radio signals received by the listener (**1002**)

from the emitters (1001) for the predefined period are filtered out. For example, assuming the predetermined number of unique emitters (1001) is 2, the radio signals received by the listener (1002) from only one emitter (1001) during the 30 seconds period are filtered out.

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Subsequently, the radio signals received by the listeners (1002) are filtered based on the signal strength of the emitters (1001) received by the listeners (1002) as in step 2102. If any particular listener (1002) receives at least one radio signal with a signal strength of less than predetermined mean, maximum, minimum, and standard deviation values of signal strength, all radio signals received by the particular listener (1002) are filtered out. For example, if the predetermined mean value of signal strength of the radio signal is -50 dBm, the Signal Fingerprint Generator (1007) filters out the radio signals received by the listeners (1002) which receives any radio signal with mean values of signal strength of less than -50 dBm. The predetermined value of the signal strength used in the present invention depends on the technology being used and the situation of the location.

Afterwards, the time batch data is converted from the emitter-per-listener format into a listener-per-emitter format as in step 2103. In the listener-per-emitter format, the identification information and the signal strength from the emitter (1001) received by the plurality of listeners (1002) are compiled. A compilation of maximum, minimum, mean, and standard deviation values of signal strength detected by a plurality of listeners (1002) is unique to an emitter (1001) at a distinct location for a distinct period. The compilation is used as a signal fingerprint for the emitter (1001).

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While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specifications are words of description rather than limitation and various changes may be made without departing from the scope of the invention.

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REFERENCE

- [1] Dong, Z., Mengjiao, C. and Wenjuan, L. (2017). Implementation of Indoor Fingerprint Positioning Based on ZigBee. In: *2017 29th Chinese Control and Decision Conference (CCDC)*. IEEE, pp.2654-2659.

CLAIMS

1. A system (**1000**) for object tracking comprising:
- a) at least one emitter (**1001**) configured to emit radio signal;
 - b) a plurality of listeners (**1002**) configured to receive the radio signal from the at least one emitter (**1001**);
 - c) a Signal Harvester (**1003**) configured to assign a timestamp to radio signal data, wherein the Signal Harvester (**1003**) is connected to the plurality of listeners (**1002**);
 - d) a Signal Batcher (**1005**) configured to convert the radio signal data into time batch data;
 - e) an Offline Fingerprint Database (**1008**) configured to store signal fingerprint for the at least one emitter (**1001**) tagged with location data;
 - f) an Online Fingerprint Database (**1009**) configured to store signal fingerprint for the at least one emitter (**1001**); and
 - g) a Signal Fingerprint Matcher (**1010**) configured to compare signal fingerprint from the Online Fingerprint Database (**1009**) with the signal fingerprint from the Offline Fingerprint Database (**1008**), wherein the Signal Fingerprint Matcher (**1010**) is connected to the Offline Fingerprint Database (**1008**) and the Online Fingerprint Database (**1009**),
- characterised in that the system (**1000**) further comprising:
- h) a Signal Fingerprint Generator (**1007**) configured to generate a signal fingerprint for the at least one emitter (**1001**) by compiling radio signal received by the plurality of listeners (**1002**) from the at least one emitter (**1001**) based on detection of a predetermined number of emitters (**1001**) within a predefined period with a predetermined signal strength value by the plurality of listeners (**1002**), wherein the Signal Fingerprint Generator (**1007**) is connected to the Offline Fingerprint Database (**1008**) and the Online Fingerprint Database (**1009**).
2. The system (**1000**) as claimed in claim 1, wherein the signal strength values include maximum, mean, minimum and standard deviation values of the signal strength.
3. The system (**1000**) as claimed in claim 1, wherein the system (**1000**) further comprising a time-series signal database (**1004**) configured to store the time-

series data from the Signal Harvester (1003), wherein the time-series database (1004) is connected to the Signal Harvester (1003) and the Signal Batcher (1005).

- 5 4. The system (1000) as claimed in claim 1, wherein the system (1000) further comprising a time batch signal database (1006) configured to store the time batch data, wherein the time batch signal database (1006) is connected to the Signal Batcher (1005) and the Signal Fingerprint Generator (1007).

- 10 5. The system (1000) as claimed in claim 1, wherein the system (1000) further comprising a location database (1011) configured to store coordinates of the at least one emitter (1001) being located, wherein the location database (1010) is connected to the Signal Fingerprint Matcher (1010).

- 15 6. A method for object tracking comprising the steps of:
 - a) emitting radio signal by at least one emitter (1001);
 - b) receiving a radio signal from the at least one emitter (1001) by a plurality of listener (1002);
 - c) acquiring radio signal data from the plurality of listeners (1002) by a
 - 20 Signal Harvester (1003);
 - d) assigning a timestamp to the radio signal data by the Signal Harvester (1003);
 - e) storing the radio signal data from the Signal Harvester (1003) on a Time-Series Signal Database (1004);
 - 25 f) converting the radio signal data into time batch signal data by a Signal Batcher (1005);
 - g) storing time batch signal data in a Time Batch Signal Database (1006);
 - h) generating a signal fingerprint by a Signal Fingerprint Generator (1007);
 - i) determining the operation mode of the system by the Signal Fingerprint
 - 30 Generator (1007);
 - j) storing the signal fingerprint with location tag in an Offline Fingerprint Database (1008) if the system is in calibration mode;
 - k) storing the signal fingerprint in an Online Fingerprint Database (1009) if the system (1000) is in tracking mode;

l) comparing signal fingerprint from the Online Fingerprint Database (1009) with the signal fingerprint from the Offline Fingerprint Database (1008) by a Signal Fingerprint Matcher (1010); and

m) storing coordinates of the at least one emitter (1001) on a Location Database (1011),

characterised in that the step of generating the signal fingerprint by the Signal Fingerprint Generator (1007) further comprises the steps of:

a) filtering the radio signals received by the plurality of listeners (1002) based on number of unique emitters detected by each listener (1002) within a predefined period;

b) filtering the radio signals received by the plurality of listeners (1002) based on a predetermined signal strength value of the radio signal from the emitter (1001) received by the listeners (1002); and

c) converting the time batch signal data from emitter-per-listener to listener-per-emitter.

7. The method as claimed in claim 6, wherein if the number of unique emitters (1001) during the predefined period is less than a predetermined number of emitters (1001), the radio signals received by the plurality of listeners (1002) from the emitters (1001) within the predefined period are filtered out.

8. The method as claimed in claim 6, wherein if any particular listener (1002) receives at least one radio signal with a signal strength of less than predetermined signal strength values, all radio signals received by the particular listener (1002) are filtered out.

9. The method as claimed in claims 8, wherein the signal strength values include maximum, mean, minimum and standard deviation values of the signal strength.

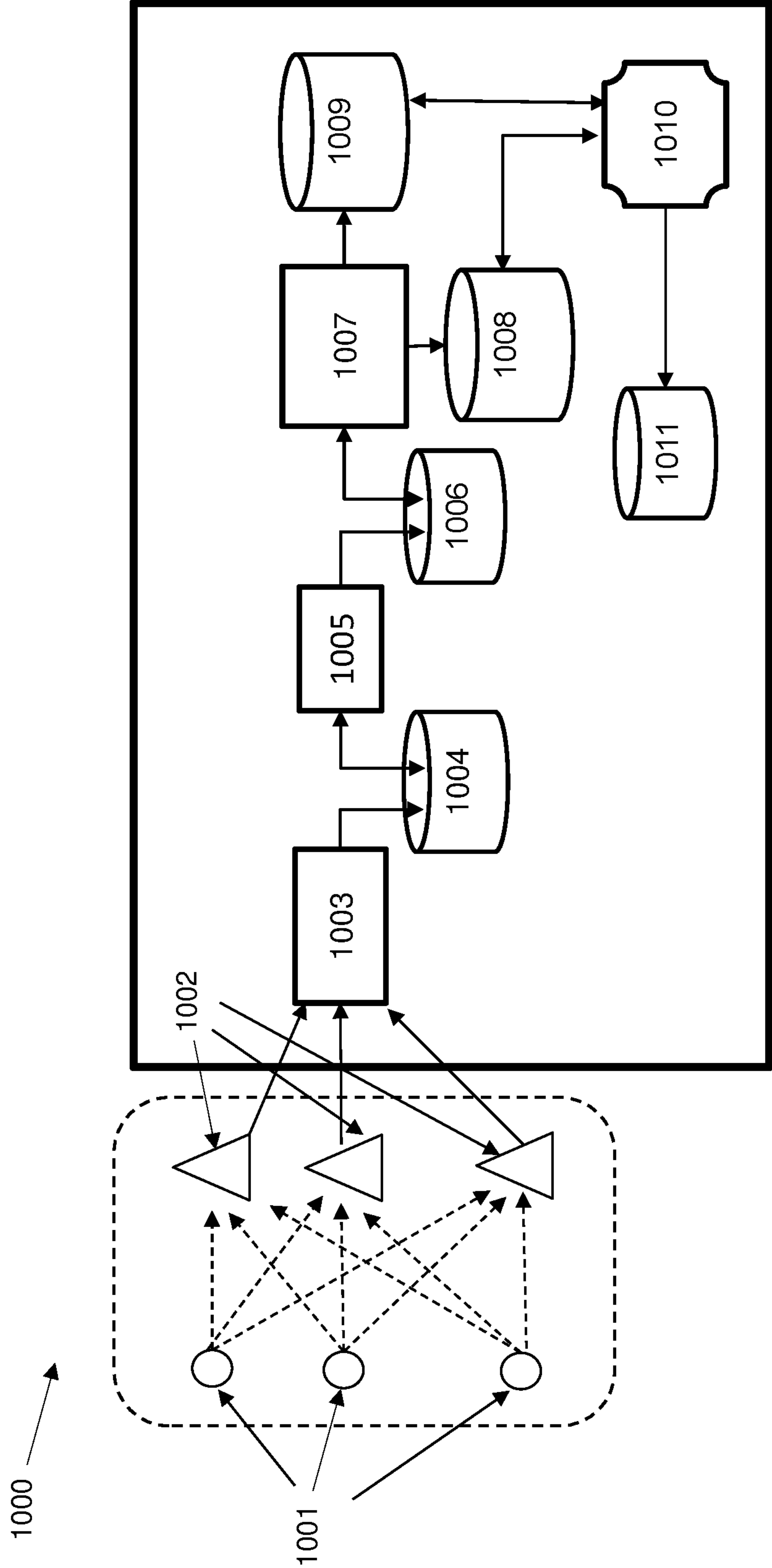


FIG. 1

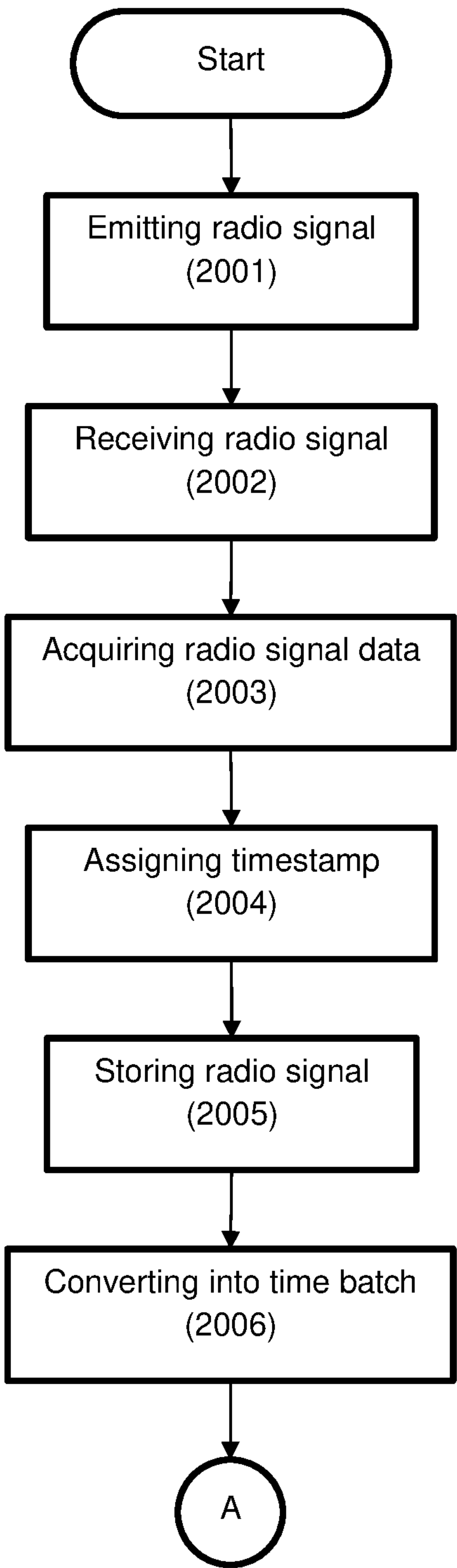


FIG. 2a

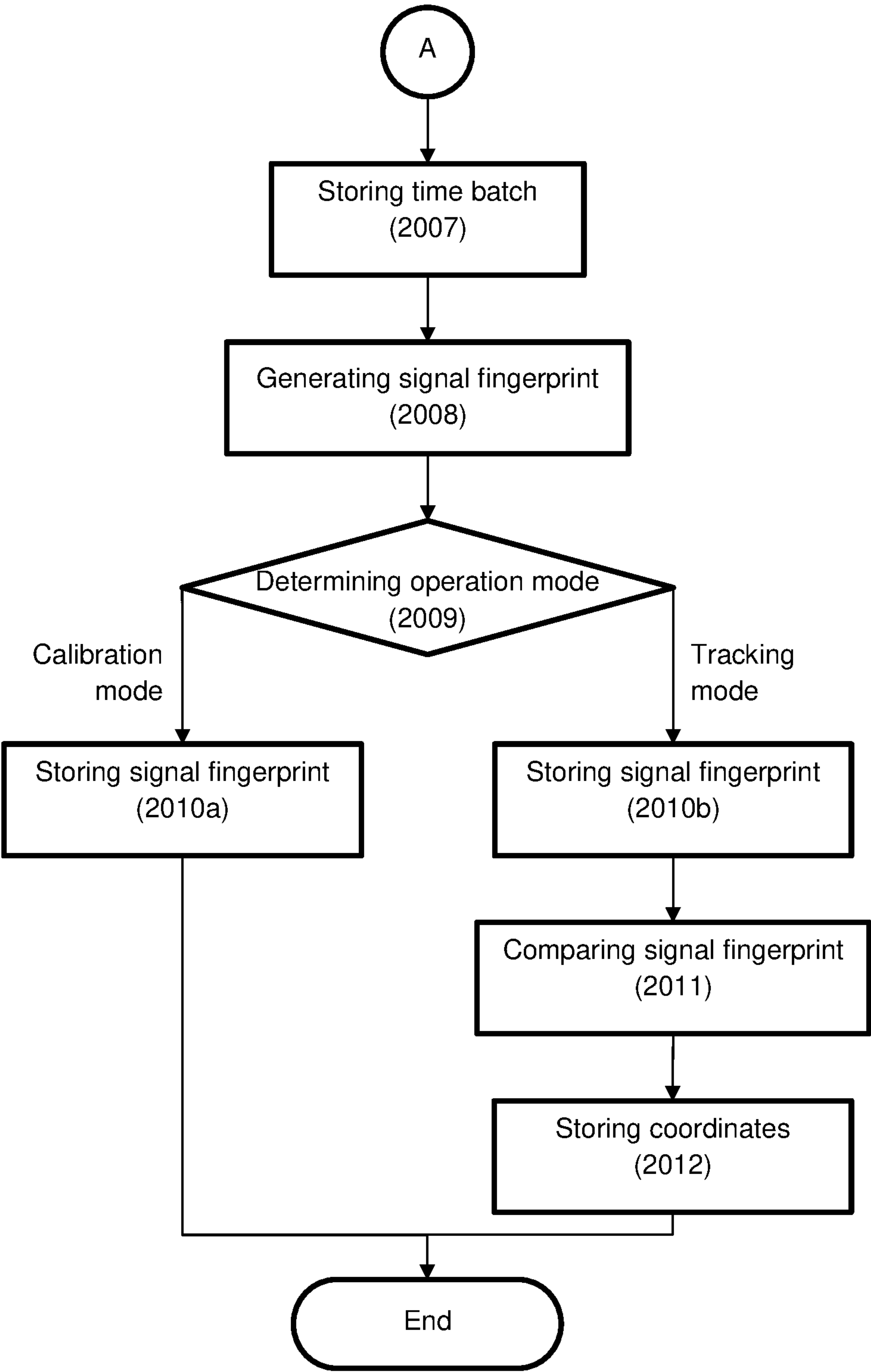


FIG. 2b

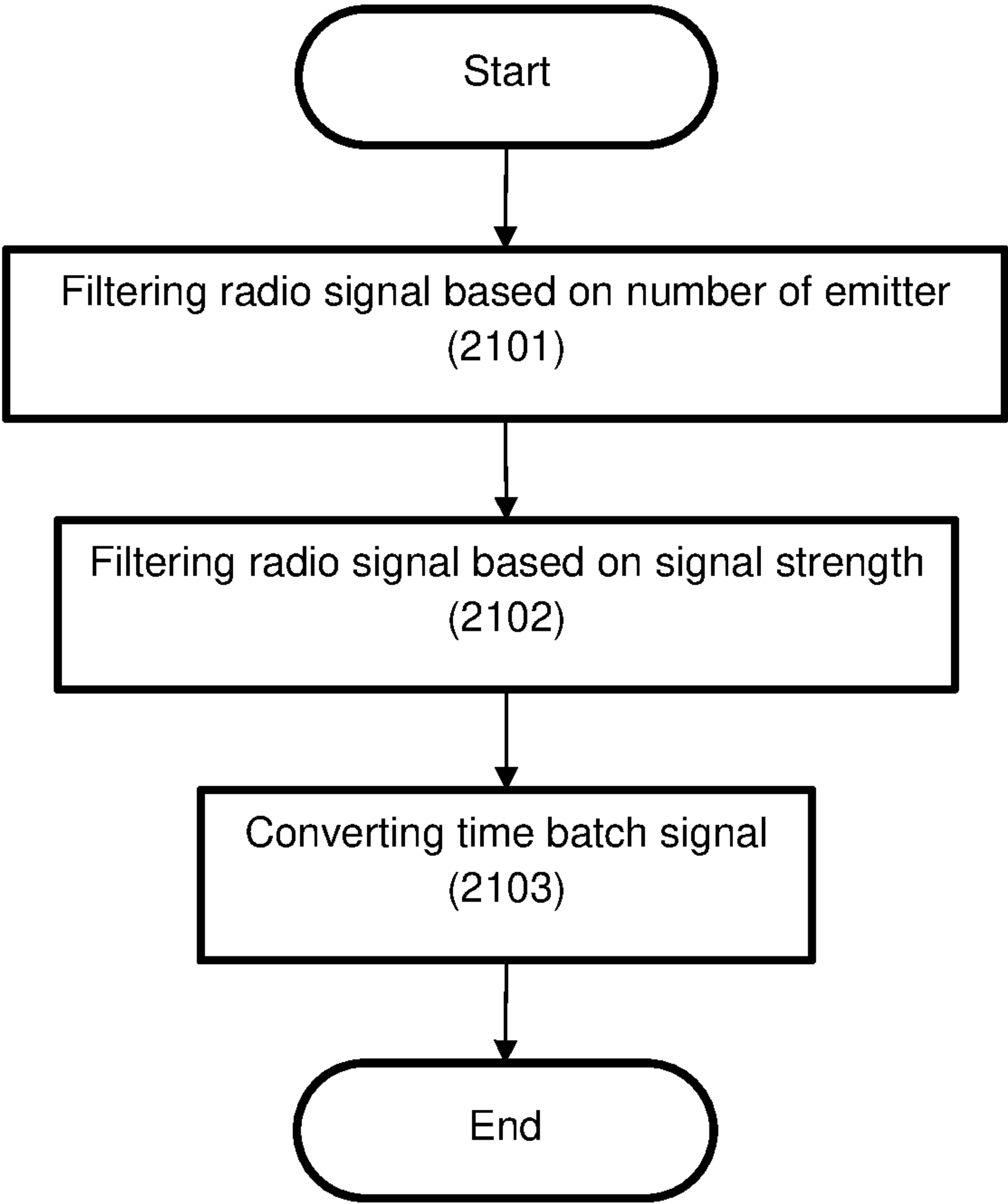


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/MY2020/050102

A. CLASSIFICATION OF SUBJECT MATTER

G01S 5/02(2010.01)i
FI: G01S5/02 Z

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01S5/00-5/14, H04B7/24-7/26, H04W4/00-99/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2021
Registered utility model specifications of Japan 1996-2021
Published registered utility model applications of Japan 1994-2021

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

JSTPlus/JST7580 (JDreamIII)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/0323149 A1 (THE MOREY CORPORATION) 30 October 2014 (2014-10-30) paragraphs [0017]-[0037], Figs. 1-4	1-9
A	CN 105588566 A (CHONGQING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS) 18 May 2016 (2016-05-18) paragraphs [0054]-[0172], Figs. 1-3	1-9
A	CN 106792554 A (CHANG'AN UNIVERSITY) 31 May 2017 (2017-05-31) paragraphs [0033]-[0073], Figs. 1-3	1-9
A	CN 106851573 A (XI'AN JIAOTONG UNIVERSITY) 13 June 2017 (2017-06-13) paragraphs [0048]-[0102], Figs. 1-3	1-9
A	WO 2013/021552 A1 (PANASONIC CORPORATION) 14 February 2013 (2013-02-14) paragraphs [0002]-[0018], Fig. 1	1-9

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

- “A” document defining the general state of the art which is not considered to be of particular relevance
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- “O” document referring to an oral disclosure, use, exhibition or other means
- “P” document published prior to the international filing date but later than the priority date claimed

- “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- “&” document member of the same patent family

Date of the actual completion of the international search

12 January 2021

Date of mailing of the international search report

26 January 2021

Name and mailing address of the ISA/JP

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/MY2020/050102

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US	2014/0323149	A1	30 October 2014	WO 2014/176494 A2	
CN	105588566	A	18 May 2016	(Family: none)	
CN	106792554	A	31 May 2017	(Family: none)	
CN	106851573	A	13 June 2017	(Family: none)	
WO	2013/021552	A1	14 February 2013	US 2014/0228048 A1 paragraphs [0002]-[0017], Fig. 1	
				EP 2741099 A1	