

## **METHOD AND SYSTEM FOR THE DISTRIBUTED PhDOA, PwDOA LOCATION OF EMITTER SOURCES**

The invention relates to a method and to a system for detecting  
5 one or more electromagnetic emissions emitted in a given area, using a distributed sensor architecture including at least two antennae.

Hereinafter, the term 'sensor' will be applied to any system capable of digitizing an electromagnetic signal and that is equipped with a processor for processing the digitized signal and with a digital emission  
10 system. A sensor may be a software-defined radio receiver, for example. The invention is notably used in the field of radio monitoring.

Locating electromagnetic sources is a significant problem in the field of monitoring authorized or unauthorized emissions in a given space.

In order to detect electromagnetic emissions, it is known, from the prior art, to use the principle of blind detection, which may be implemented  
15 using several techniques.

It is thus possible, in order to locate one or more emitter sources, to estimate the time difference of arrival (TDOA) and the hyperbolic location in accordance with a method described in patent US2005/0073459.  
20 However, the main drawback of the location technique using the TDOA is that of having to transmit, on the radiocommunication emissions, the digitized signal of each detected emission to the unit performing the intercorrelations between the signals from the various sensors in order to estimate the time difference of arrival, and then the position of the emitter. The location  
25 performance depends on the product band factor×signal time (i.e. on the number of samples), this meaning that, in order to achieve good performance, a large number of samples have to be exchanged and therefore a high communication throughput of the sensors is necessary. The limitation on the throughputs does not allow all of the emissions to be  
30 systematically located.

Another technique consists in estimating the angle of arrival (AOA) of the emissions and the MAOA (multiple angle of arrival) triangulation using a moving sensor or with a plurality of sensors. One example is given in the publication by Don J. Torrieri, entitled 'Statistical Theory of Passive Location Systems', IEEE 1984. MAOA location techniques implement unambiguous networks of antennae and have complex antenna networks having more than two antennae. These networks may prove difficult to integrate into a carrier, in particular for the low frequencies imposed by networks of large size, given the wavelengths and the angular precision required.

MAOA location techniques implement PhDOA (phase difference of arrival) goniometry, allowing location ambiguities to be removed by utilizing the measurements performed by the sensor during the trajectory of the carrier.

This multichannel location technique leads to ambiguous estimations of directions of arrival, whose ambiguities are not able to be resolved if the sensor is static or if the periods of the emissions that are observed are too short in terms of the time necessary to move the sensor so as to remove the ambiguities.

Patent US8248210 describes the use of two antennae and the calculation of the differential phase in order to estimate angles of arrival, with ambiguities, of a plurality of RFID (radiofrequency identification) identification tags so as to distinguish them spatially. These tags are distinguished spatially by calculating the phase differences linked to each of the RFID tags (SD-PDOA for space division - phase difference of arrival technique).

Patent USH2224H1 uses the calculation of the phase difference of arrival, or PhDOA, of the TDOA and of the frequency difference of arrival FDOA between two single-channel receivers to locate the emitter.

Another way consists in estimating the power difference of arrival or PwDOA. However, this location technique has the drawback of having location performance linked to the propagation models. With the propagation channel not being able to be estimated in a blind location system, the

location performance is uncertain and is often unacceptable, in particular in an urban environment or in a wet environment.

For example, patent US9316719 uses a PwDOA technique to estimate the position of an emitter using a mobile sensor and measurements  
5 of the power difference of arrival.

Patent application WO98/47019 presents a location system in which the cellular network through which the emitters communicate will locate the latter.

The various techniques from the prior art do not make it possible,  
10 in particular and at the same time, to solve the following problems:

- The short emission periods of the emitters to be located (TDOA, PhDOA with moving MAOA and unambiguous AOA, moving MAOA),
- Systematic location of all of the communications intercepted by  
15 sensors with wide-band instantaneous reception (TDOA),
- Radiometry networks of antennae that are complex and difficult to integrate (AOA),
- Fixed-position emitters to be located and fixed-position sensors (FDOA),
- 20 • Good-performance operation of the blind location (estimation of the propagation channel for the PwDOA or order to force the emitters to emit),
- Using the same software-defined radio (SDR) reception means to observe the emissions to be located and receive information  
25 from the other sensors contributing to the location,
- Separating co-channel emission situations (multipath or a plurality of sources in the same channel) from single-signal situations (PwDOA, PhDOA and TDOA).

In the remainder of the description, the letter  $P_i$  denotes a power  
30 value and  $\hat{P}_i$  denotes an estimated value.

The invention relates to a method for locating at least one electromagnetic source  $S$  within a communication network comprising at least two sensors  $R_1, R_2$ , said sensors being separated by a given distance, each sensor comprising a network of antennae comprising at least two reception antennae  $A_1, A_2$ , characterized in that it comprises at least the following steps:

- For each sensor  $R_1, R_2$ ,
  - Estimating the powers  $P_1$  and  $P_2$  of the received signal  $S_r$  coming from a source  $S$  and received at the sensors  $R_1, R_2$ ,
- For the signal  $S_r$  arriving at each of the two reception antennae, measuring the phase difference  $\Delta\varphi$  on the basis of the value of the phase difference  $\Delta\varphi$  and of information on the position and the orientation of the network of antennae  $A_1, A_2$ , determining a set of potential directions of arrival DOA for a given source  $S$ , and then
- Merging the power values  $\hat{P}_1, \hat{P}_2$  received at the sensors  $R_1$  and  $R_2$ , the potential direction of arrival DOA values and the geographical coordinates of the networks of antennae of the sensors  $R_1$  and  $R_2$ , in order to calculate the coordinates of the emission source by executing the following steps:
  - On the basis of the power values  $\hat{P}_1, \hat{P}_2$  estimated by the two sensors  $R_1, R_2$ , of a propagation model and of the value of the ratio of these powers  $\hat{P}_1 / \hat{P}_2$ , defining, for each ratio value, an elementary location area  $Z_e$  in which the source is present, and then a potential location area  $Z_s$  corresponding to the intersection of the various elementary location areas for an emission source  $S$ ,
  - On the basis of the geographical coordinates of the sensors and of the possible directions of arrival, calculating the possible half-lines of sight and their points of intersection  $P(D_k)$ ,
  - Retaining only those points of intersection  $P(D_k)$  of the half-lines of sight that belong to the potential location area  $Z_s$ ,

- Selecting the points of intersection  $P(D_k)$  for which the geographical density is highest, and determining the coordinates of the emission source on the basis of these points of intersection.

The step of merging the data, estimated power values, directions  
5 of arrival DOA and coordinates of the networks of antennae is executed in the processor of each sensor of the communication network.

According to another variant embodiment, the step of merging the data is executed in a centralized processing device communicating with the sensors that are present in the communication network.

10 The method may comprise a step of auto-calibration of the network of antennae of each sensor by using the known position of the other sensors while they are being used in emission mode.

The method comprises, for example, a step of time segmentation and frequency segmentation of the signal received at the antennae, and a  
15 step of detecting the number of sources present by calculating the covariance matrix of the signal at each time/frequency cell and by comparing the two eigenvalues of the covariance matrix with the noise level.

The propagation model used to determine an elementary location area of the source on the basis of the estimated power values is a 'free  
20 space' propagation model.

The measurement periods on the signal received (detection, various estimations known under the term 'sensing') from the sensors use the time division multiple access (TDMA) method, and a specific TSLT slot is used to execute the steps of the method according to the invention.

25 The invention also relates to a system for locating at least one emission source in a communication network comprising at least two sensors  $R_1$ ,  $R_2$  communicating with one another by way of a radio link, each sensor comprising a network of antennae comprising at least two reception antennae  $A_1$ ,  $A_2$ , a sensor comprising a processor designed to process the  
30 received signals so as to determine the power values of the signal received at the antennae, the potential directions of arrival and the phase offset value

of the signal received at the two antennae, the location system comprising a processor designed to execute the following steps:

- Merging the power values received and estimated at the sensors, the potential direction of arrival values and the coordinates of the network of antennae, in order to calculate the coordinates of the emission source by executing the following steps:
  - On the basis of the power values  $\hat{P}_1$ ,  $\hat{P}_2$  estimated by the two sensors  $R_1$ ,  $R_2$ , of a propagation model and of the value of the ratio of these powers  $\hat{P}_1 / \hat{P}_2$ , defining, for each ratio value, an elementary location area  $Z_e$  in which the source is present, and then a potential location area  $Z_s$  corresponding to the intersection of the various elementary location areas for an emission source  $S$ ,
  - On the basis of the geographical coordinates of the sensors and of the possible directions of arrival, calculating the possible half-lines of sight and their points of intersection  $P(D_k)$ ,
  - Retaining only those points of intersection  $P(D_k)$  of the half-lines of sight that belong to the potential location area  $Z_s$ ,
  - Selecting the points of intersection for which the geographical density is highest, and determining the coordinates of the emission source on the basis of these points.

The invention is applied to a method and to a system implementing software-defined radio receivers.

Other features and advantages of the present invention will become more clearly apparent on reading the description of exemplary embodiments alongside the figures, in which:

- Figure 1 shows an example of a system according to the invention,
- Figure 2 and Figure 3 show an example of the steps implemented by the method according to the invention,
- Figure 4 shows a depiction of the arrival of a wavefront at two antennae,

- Figure 5 and Figure 6 show two depictions of the definition of a possible location area,
- Figure 7 shows a three-dimensional histogram of the number of instances of intersections of the lines of sight as a function of their abscissae and ordinates,
- Figure 8 shows an exemplary application in the case of a communication using the TDMA waveform.

To facilitate understanding of the subject matter of the invention, an example is given for a communication network comprising two sensors  $R_1$ ,  $R_2$ , communicating by virtue of radiofrequency links.

Each sensor  $R_k$ ,  $R_1$ ,  $R_2$  comprises at least two antennae  $A_1$  and  $A_2$ , each linked to a reception channel and comprising an acquisition system. The two sensors are positioned at a given distance with respect to one another. These two acquisition channels 10, 11 have to be synchronous. The samples acquired (corresponding in particular to the signal emitted by the source to be located) are sent to a processing module 12, such as a processor. Each sensor also comprises a geolocation system 14, giving its geographical position and its orientation, as well as a wireless communication module 15 that allows the sensors  $R_k$  that are present in the communication network to exchange data with one another. The sensors do not have to be collocated, but there is not a minimum distance to be complied with.

Without departing from the scope of the invention, the system could comprise a remote centralized processing module that is not a sensor involved in the communication system.

In the example, each sensor comprises two antennae, but could comprise a number  $M$  of antennae greater than two. The processing of the data that is explained hereinafter will then be carried out, for example, considering the antennae in pairs.

Figure 2 and Figure 3 detail the steps implemented by the invention. The steps described in Figure 2 are performed in each sensor. In

the example that will be described in Figure 3, the steps that are outlined are performed by each sensor, but could, without departing from the scope of the invention, be executed by a processing device separate from the N sensors of the system, which will receive the various measurements carried out by  
 5 each of the sensors.

In Figure 2, each sensor  $R_1$ ,  $R_2$  receives the signals on the instantaneous band to be listened to, and samples the band on its two synchronous reception channels 10, 11 (Figure 1), 201. The sampling step is performed by each sensor, in accordance with a principle known to those  
 10 skilled in the art. The received signal  $S_r$ , corresponding to the two signals  $S_{r1}$ ,  $S_{r2}$  received at each antenna  $A_1$ ,  $A_2$ , is time-segmented and frequency-segmented, for example using a bank of polyphase filters, 202.

For each time/frequency cell, 203, the processor of the sensor enumerates the number of co-channel sources contained in the received  
 15 signal  $S_r$ . From the two reception channels, the processor will determine the number of sources that are potentially present in the signal: zero sources, one source or more than one source.

If there are zero sources or more than one source, 204, the processing of the time/frequency cell stops there, and the method continues  
 20 to process the following time/frequency cells, 205.

If just one source  $S$  has been detected, 206, the processor of the sensor will execute the following steps:

- It estimates the received power  $P(S)$  of the source  $S$ , 207,
- It estimates the differential phase  $\Delta\varphi$  of the signal  $S_r$  between the two  
 25 reception channels of the sensor (between the two antennae) using a technique known under the abbreviation PhDOA ('phase difference of arrival'), 208,
- On the basis of the differential phase  $\Delta\varphi$  estimated in the previous step and of information on the position and the orientation of the  
 30 network of antennae, the processor estimates the potential directions of arrival (DOA), 209. Among these directions of arrival are the

direction of arrival DOA corresponding to the source S to be located and one or more ambiguities, 210. The higher the ratio  $d/\lambda$ , the higher the number of ambiguities, where  $d$  corresponds to the distance between the two reception antennae and  $\lambda$  corresponds to the wavelength of the processed signal,

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- The sensor will then transmit, 300, the following data to the other sensors:
  - the estimation of the power that it has received,
  - the estimations of the potential directions of arrival, DOA,
  - 10 • its location coordinates (longitude, latitude) and the orientation of its network of antennae, which data are known for example by virtue of a navigation system 211,
- These data (powers, directions of arrival, coordinates and orientation of the network of antennae) are merged (combined), by the processor
- 15 of the sensor, with the data calculated in the other sensors that are present in the system, in the example given a second sensor, and thus allow calculation of the locations of the radio emitter(s) using the steps described in Figure 3.

These data are transmitted by virtue of the wireless communication module  
20 of each sensor.

In the example, the steps of Figure 3 are executed in each of the two sensors. Without departing from the scope of the invention, these steps could be executed in a device (external to the sensors) whose role would be to centralize the processing of the data.

25 The sensor  $R_1$  recovers the data associated with the second sensor  $R_2$  (the value of the estimated received power  $\hat{P}_2$  and the measured directions of arrival DOA, 301, that were obtained by executing the steps described for the sensor  $R_2$ ). Reciprocally, the sensor  $R_2$  recovers the data associated with the sensor  $R_1$ .

30 On the basis of the first power value  $P_1$  estimated  $\hat{P}_1$  by the first sensor  $R_1$  and of the second power value  $P_2$  estimated  $\hat{P}_2$  by the second sensor  $R_2$ , of a

propagation model and of the value of the ratio of these two powers,  $R_1/R_2$ , the processor determines an elementary location area  $Z_e$  and then deduces from this a potential location area  $Z_s$  of the emission source  $S$  ( $Z_s$  is the intersection of all of the elementary areas  $Z_e$  determined by taking all of the possible pairs of sensors. In the case, in the example, where there are only two sensors,  $Z_s=Z_e$ ). The processor calculates the intersections of half-lines of sight, 303, on the basis of the possible direction of arrival values and of the latitude and longitude of the antenna network of the sensors  $R_1$  and  $R_2$ .

The following step consists in eliminating the intersections of the half-lines that are not located in the location area  $Z_s$ , 304, so as to eliminate some of the points of intersection  $P(D_k)$  corresponding to ambiguous lines of sight.

Next, the processor 12 will determine the densest cloud of points, 305, and calculate, for example, the barycentre of the intersections in the cloud in question, 306. This barycentre corresponds to an estimation of the location of the emitter source, 307.

These steps are executed in each sensor of the communication system, so that each sensor is able to locate the emitter source  $S$ .

The steps that have just been described may, without departing from the scope of the invention, be performed in a centralized device (external to the sensors) that receives the aforementioned data from each of the sensors, and that processes said data in a similar way so as to locate the electromagnetic source(s).

The broadcasting of the measurements and of the measurement results may be performed in multicast mode so as to distribute the data to all of the sensors that are present in the system and allow each of them to estimate the position of one or more electromagnetic sources locally.

If the measurements performed in the first processing phase are transmitted to a centralized processing device, it is the latter that will estimate the position of the electromagnetic source or sources that is or are present in an area.

In order to determine whether the signal received at a sensor and processed by the latter corresponds to a single emission source, the processor of this sensor calculates for example the matrix of covariance of the received signal  $\mathbf{R}_{xx}$  ( $2 \times 2$  matrix) on each time/frequency cell obtained at the end of the time/frequency division step. The two eigenvalues of  $\mathbf{R}_{xx}$  are then calculated and compared with the noise level in order to deduce therefrom whether there are zero, one or more than one source(s). The noise level is estimated using statistics regarding the eigenvalues of all of the channels on the instantaneous band processed, using a principle known to those skilled in the art. Next, the processor deduces the eigenvalues of the matrix  $\mathbf{R}_{xx}$  by using methods known to those skilled in the art.

The differential phase between the two channels or antennae is deduced directly from the eigenvector associated with the eigenvalue corresponding to the signal (the eigenvalue that is detached from the noise level).

Using the conventions of Figure 4, the phase difference between the two antennae of a sensor has the value  $\Delta\varphi = \frac{2\pi d}{\lambda} \cdot \sin(\theta)$ . It is then possible to deduce therefrom the possible directions of arrival or DOA. Specifically, two signals coming from two directions  $\theta_1$  and  $\theta_2$  give the same phase difference if

$$\frac{2\pi d}{\lambda} \cdot \sin(\theta_1) = \frac{2\pi d}{\lambda} \cdot \sin(\theta_2) + 2k\pi, \text{ with } k \in \mathbb{Z}$$

The ambiguity  $\theta_1 = \pi - \theta_2$  is therefore still present, corresponding to the case  $k = 0$ .

This ambiguity is added to by the ambiguities  $\sin(\theta_1) = \sin(\theta_2) + \frac{k\lambda}{d}$ , the number of these ambiguities depending on the value of  $d/\lambda$ .

To define the potential location area, the method may execute the steps detailed hereinafter. For each pair of sensors, an area  $Z_e$  (which will be called elementary area), in which the emitter source  $S$  is present, is

estimated. The potential location area  $Z_s$  is the intersection of all of the elementary areas  $Z_e$ .

An elementary area  $Z_e$  is obtained on the basis of the estimation of the power  $P_1$  ( $\hat{P}_1$ ) and  $P_2$  ( $\hat{P}_2$ ) of the emitter source by the two sensors. On the basis of the value of the ratio of these powers  $\hat{P}_1/\hat{P}_2$ , the elementary location area  $Z_e$  of the source is deduced by taking, as propagation model, for example, a 'free space' model with an attenuation proportional to the inverse distance squared. If this model were to be exact, the elementary area  $Z_e$  would be a circle.  $\varepsilon_p$  is the upper bound of the error applied to the estimation of the power ratio  $P_1/P_2$ . This means that:

$$\frac{P_1}{P_2} \in \left[ \frac{\hat{P}_1}{\hat{P}_2} - \varepsilon_p, \frac{\hat{P}_1}{\hat{P}_2} + \varepsilon_p \right]$$

where  $\hat{P}_1$  and  $\hat{P}_2$  are, respectively, the estimations of  $P_1$  and  $P_2$ .

The value of  $\varepsilon_p$  is chosen to be high, so as to ensure that an upper bound of the error is indeed involved, regardless of the actual propagation model compared to the chosen propagation model.

The propagation model under consideration may also be a propagation model that takes obstacles and the terrain into account. In any case, the propagation model is known to those skilled in the art, and will not be detailed.

Two circles  $C_1$ ,  $C_2$ , respectively corresponding to  $\frac{\hat{P}_1}{\hat{P}_2} - \varepsilon_p$  and to  $\frac{\hat{P}_1}{\hat{P}_2} + \varepsilon_p$ , are thus defined. The elementary area  $Z_e$  is then the area contained between these two circles, outside the circle defined by  $\frac{\hat{P}_1}{\hat{P}_2} - \varepsilon_p$  and inside the circle defined by  $\frac{\hat{P}_1}{\hat{P}_2} + \varepsilon_p$ , as indicated in Figure 5. In this case, the elementary area  $Z_e$  is a finite area.

Depending on the position of the two sensors and on the value of  $\varepsilon_p$ , there are cases where the elementary area  $Z_e$  is outside the circle defined

by  $\frac{\widehat{P}_1}{\widehat{P}_2} - \varepsilon_p$  and outside the circle defined by  $\frac{\widehat{P}_1}{\widehat{P}_2} + \varepsilon_p$ , as indicated in Figure 6.

In this case, the elementary area is an infinite area.

The PwDOA algorithm determines whether the elementary area is inside or outside the circle defined by  $\frac{\widehat{P}_1}{\widehat{P}_2} + \varepsilon_p$ . To this end, it observes  
 5 whether or not the centres  $C_{r1}$ ,  $C_{r2}$  of the two circles  $C_1$ ,  $C_2$  are situated on the same side of the two sensors (the centres of the circles are to the right of the rightmost sensor or the two centres of the circles are to the left of the leftmost sensor).

In practice, to determine the location area  $Z_s$ , the geographical  
 10 area in which the sensors are moving is covered by a grid defined in an abscissa and ordinate reference frame. For each pair of sensors  $R_1$ ,  $R_2$ , the cells of the grid are contained within the elementary area  $Z_e$  when at least one of their four corners is in the elementary area  $Z_e$ . The location area  $Z_s$  corresponds to the cells that are in all of the elementary areas  $Z_e$  (that is to say in as many elementary areas as there are pairs of sensors).  
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This principle may be extended, without departing from the scope of the invention, to other propagation models, such as for example propagation models utilizing a digital terrain model, in order to reduce uncertainties and therefore the potential location areas.

20 To calculate the intersections of the half-lines of sight (actual ones and ambiguities), the processor of a sensor considers the geographical coordinates of the sensors and the estimation of the possible directions of arrival DOA. The equations for the half-lines of sight (half-line starting at the sensor and pointing in the direction of the DOA) are calculated, followed by  
 25 all of the intersections of these half-lines.

In order to locate the emission source(s), the method will detect the densest cloud of points (area with the highest concentration of points of intersection). In order to detect the area where the density of points is highest, histograms with two variables (abscissae and ordinates of the points  
 30 of intersection) are calculated using a method known to those skilled in the

art. The bins of the histogram are therefore rectangular parallelepipeds whose height corresponds to the number of points of intersection contained in the area defined by the area of the parallelepiped. The cloud of points in question corresponds to the points in the highest bin of the histogram and in the adjacent bins (so as to dispense with the problem of the centre of the bins). The width of the bins is adaptive. The algorithm starts with a very fine pitch and increases iteratively until the height of the bins is close to the height expected in theory (number of times that  $N$  straight lines intersect,  $N$  being the number of sensors).

Finally, to estimate the location of the emitter source, the processor will consider, for example, the barycentre of the points of the densest cloud.

Figure 8 shows two exemplary implementations of the method according to the invention when the sensors are of software-defined radio receiver type. The reception of the signals on the band to be monitored may be performed in specially allocated TDMA time slots 'TS', TS1 to TS5. Pseudorandom offsetting of the time slot(s) makes it possible in particular to avoid a stroboscopic effect on the observation of the communication system that has the same TDMA frame period as the device of the invention. Other ways of proceeding may be contemplated, such as using the period between the increments of emissions with frequency hops.

The power of arrival (POA) and the differential phase (PhDOA) are calculated and estimated by detecting situations of single-signal emission through calculation of the eigenvalues of the intercorrelation matrix on the two channels of each sensor. The eigenvector associated with the signal is then used for the calculation of the differential phase. These estimations may be performed over short periods of the order of  $160\text{ }\mu\text{s}$  for a division of the instantaneous reception band into channels of 25 kHz. This short TSLT (time slot look through) observation period, and the synthetic data that it gives (PhDOA and PwDOA), make it possible to obtain an amount of information to be transmitted by sensor and thus to systematically locate all of the

intercepted emissions. This short observation period makes it possible to combine the 'sensing' function with the radiocommunication function necessary for the communication service, ensuring the exchanges of data for the benefit of the 'sensing' function and the communication needs of the  
5 users.

According to one variant embodiment, the method makes it possible to carry out automatic calibration of the two antennae of a sensor by using the known position of the other sensors that are present in the communication system and that are considered to be emitter sensors. The  
10 processor of a sensor then determines the calibration correction to be applied during the processing of the data.

The steps that have just been described apply to a system in which the sensors are software-defined radio receivers.

The method and the system according to the invention perform a distributed location of one or more radio wave-emitting sources. They make it possible in particular:  
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- to dispense with the ambiguities of dual-channel differential-phase goniometry,
- to locate emitters with short observation periods and small volumes of  
20 data to be exchanged between sensors, thus enabling systematic location of the intercepted emissions and a 'simultaneous' service formed of the 'sensing' service and of the radiocommunication service.

The implementation of the invention does not require any scenario involving stationarity of the position of the emitters and of the sensors. The invention  
25 may be implemented in existing software-defined radio receivers having two synchronous channels (MIMO or multiple input multiple output capability). The invention makes it possible to facilitate integration into a carrier by utilizing a network of two reception antennae having spatial reception diversity (antennae spaced apart by between less than one wavelength and  
30 several wavelengths).

## CLAIMS

- 1 - Method for locating at least one electromagnetic source S within a communication network comprising at least two sensors  $R_1$ ,  $R_2$ , said sensors  
 5 being separated by a given distance, each sensor comprising a network of antennae comprising at least two reception antennae  $A_1$ ,  $A_2$ , characterized in that it comprises at least the following steps:
- For each sensor  $R_1$ ,  $R_2$ ,
    - Estimating the powers  $P_1$  and  $P_2$  of the received signal  $S_r$  coming from  
 10 a source S and received at the sensors  $R_1$ ,  $R_2$ ,
    - For the signal  $S_r$  arriving at each of the two reception antennae, measuring the phase difference  $\Delta\varphi$  on the basis of the value of the phase difference  $\Delta\varphi$  and of information on the position and the orientation of the network of antennae  $A_1$ ,  $A_2$ , determining a set of  
 15 potential directions of arrival DOA for a given source S, and then
  - Merging the estimated power values  $\hat{P}_1$ ,  $\hat{P}_2$  received at the sensors  $R_1$  and  $R_2$ , the potential direction of arrival DOA values and the geographical coordinates of the networks of antennae of the sensors  $R_1$  and  $R_2$ , in order to calculate the coordinates of the emission source by executing  
 20 the following steps:
    - On the basis of the power values  $\hat{P}_1$ ,  $\hat{P}_2$  estimated by the two sensors  $R_1$ ,  $R_2$ , of a propagation model and of the value of the ratio of these powers  $\hat{P}_1$ ,  $\hat{P}_2$ , defining, for each ratio value, an elementary location area  $Z_e$  in which the source is present, and then a potential location  
 25 area  $Z_s$  corresponding to the intersection of the various elementary location areas for an emission source S,
    - On the basis of the geographical coordinates of the sensors and of the possible directions of arrival, calculating the possible half-lines of sight and their points of intersection  $P(Dk)$ ,
    - Retaining only those points of intersection  $P(Dk)$  of the half-lines of  
 30 sight that belong to the potential location area  $Z_s$ ,

- Selecting the points of intersection  $P(D_k)$  for which the geographical density is highest, and determining the coordinates of the emission source on the basis of these points of intersection.

- 5     2 - Method according to Claim 1, characterized in that the step of merging the data, estimated power values, direction of arrival DOA and coordinates of the antennae is executed in the processor (12) of each sensor of the communication network.
  
- 10    3 - Method according to Claim 1, characterized in that the step of merging the data is executed in a centralized processing device communicating with the sensors that are present in the communication network.
  
- 15    4 - Method according to Claim 1, characterized in that it comprises a step of automatically calibrating the network of antennae of each sensor by using the known position of the other sensors while they are being used in emission mode.
  
- 20    5 - Method according to one of the preceding claims, characterized in that it comprises a step (202) of time segmentation and frequency segmentation of the signal received at the antennae, and a step (203) of detecting the number of sources present by calculating the covariance matrix of the signal at each time/frequency cell and by comparing the two eigenvalues of the covariance matrix with the noise level.
  
- 25    6 - Method according to one of the preceding claims, characterized in that it uses, as propagation model to determine an elementary location area of the source on the basis of the estimated power values, a 'free space' propagation model.

7 - Method according to one of the preceding claims, characterized in that the measurement periods on the signal received from the sensors use the TDMA access method, and in that a specific TSLT slot is used to execute the steps of the method according to the invention.

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8 - System for locating at least one emission source in a communication network comprising at least two sensors  $R_1$ ,  $R_2$  communicating with one another by way of a radio link, each sensor comprising a network of antennae comprising at least two reception antennae  $A_1$ ,  $A_2$ , a sensor  
10 comprising a processor (12) designed at least to process the received signals so as to determine the power values of the signal received at the antennae, the potential directions of arrival and the phase offset value of the signal received at the two antennae, the location system comprising a processor designed to execute the following steps:

- 15 • Merging the power values received at the sensors, the potential direction of arrival values and the coordinates of the network of antennae, in order to calculate the coordinates of the emission source by executing the following steps:
- On the basis of the power values  $\hat{P}_1$ ,  $\hat{P}_2$  estimated by the two sensors  $R_1$ ,  
20  $R_2$ , of a propagation model and of the value of the ratio of these powers  $\hat{P}_1$ ,  $\hat{P}_2$ , defining, for each ratio value, an elementary location area  $Z_e$  in which the source is present, and then a potential location area  $Z_s$  corresponding to the intersection of the various elementary location areas for an emission source  $S$ ,
- 25 • On the basis of the geographical coordinates of the sensors and of the possible directions of arrival, calculating the possible half-lines of sight and their points of intersection  $P(Dk)$ ,
- Retaining only those points of intersection  $P(Dk)$  of the half-lines of sight that belong to the potential location area  $Z_s$ ,

- Selecting the points of intersection for which the geographical density is highest, and determining the coordinates of the emission source on the basis of these points.
- 5 9 - Location system according to Claim 8, characterized in that a sensor is a software-defined radio receiver.