

CONFINED LINEAR DETECTION AND LOCATION METHOD AND DEVICE

The subject of the invention relates to a method and a device for
5 confined detection and localization, using a linear aerial and means of
detection and of localization adapted for detecting and localizing radio
systems whose operation is not authorized within a given closed or semi-
open prohibition area.

The invention is applicable within confined locations, in particular
10 in an indoor environment, such as prisons, examination centers, schools,
embassies, military premises and, more generally, sensitive sites.

In certain aforementioned environments such as prisons,
examination centers, etc., the use of radio communications devices, such as
mobile telephones, is prohibited. One of the problems posed today is to
15 detect all the unauthorized radio communications within an enclosed volume
by monitoring the confinement in order to avoid any intrusion into or
interference with the communications of users not concerned by the
prohibition.

The prior art known to the applicant describes detection systems
20 and systems which detect illicit radio communications and localize the
terminals that use these radio communications with conventional radio
antennas, and sometimes emit a scrambling signal in response. In a confined
indoor environment and in a semi-open space, these devices exhibit
numerous drawbacks, and this is due to the nature of the radiating pattern of
25 conventional antennas of the point-like type or with a reduced geometrical
extension and to the nature of the $-20 \cdot \log_{10}(R)$ propagation losses of the
power radiated from a terminal to such a conventional antenna (R being the
distance from the terminal to the phase center of the antenna). Conventional
aerials and the systems that use them are unsuitable in terms of efficiency
30 and of coverage since the $-20 \cdot \log_{10}(R)$ propagation losses characteristic
renders it difficult to guarantee coverage and to monitor the confinement of

the detection. The sensitivity of the system must be increased in order to guarantee the coverage of the area, but then the confinement is not sufficient, neither in order to avoid a large number of false alarms, nor in order to guarantee the absence of indiscretions with regard to external users and operators not concerned by the emission prohibition. Thus, these conventional systems are not only tricky to install and to maintain, but also often costly as soon as significant coverages need to be obtained.

The document entitled "Revealing System of GSM Mobile Phone Operations Aboard Aircraft" discloses a method for detection of cellular telephones potentially present within an aircraft.

The patent application US 2008/042864 discloses a method for localizing a transmitter by measuring the differences in phase and in amplitude between the signals received in a cable at several locations within the cable.

The patent application DE 10 2011 107164 discloses the use of a cable for localizing a mobile unit.

The document DE 10 2007 037723 discloses a method for localizing a mobile telephone using a linear cable.

One of the problems not solved by the prior art is the implementation of a complete and reliable detection and localization for coverage of an enclosed or semi-open space (also referred to as indoor space), with confined effect and controlled confinement.

There therefore currently exists a need for a method and for a device allowing radio communications devices, whose use is prohibited, to be detected and localized, the device being applicable inside of an indoor space in general, with a reliable efficiency, a controlled coverage, confined effect and controlled confinement. The expression "illicit or prohibited terminal" denotes a terminal, a radio communication device, which does not have the authorization to operate within a given perimeter and to communicate with the outside of this perimeter.

The expressions "linear element" or "linear aerial" will be used interchangeably to denote the same element of linear type.

The subject of the invention is notably based on the use of one or more aerials with a linear geometry associated with devices for reception via
5 matched couplers, switches and connectors. The employment of these receiving devices and the linear geometry of the aerial provides all of the following:

- a reliable coverage for the detection,
- a reliable estimation of localization of the sources of emission detected,
- 10 • control of the confinement of the detection and of the localization,
- identification of the nature of the emissions by a adapted processing, while simultaneously addressing a large number of frequency intervals and a large number of radio communications systems whose frequency ranges are included within these intervals.

15 The invention relates to a device for detecting and localizing in a confined manner one or more radio devices possibly present in an enclosed or semi-open area of prohibition, characterized in that it comprises at least the following elements: at least one linear aerial comprising several orifices O_i designed to allow the capture of the signals emitted by the prohibited radio
20 device or devices, then their transmission via the linear aerial to a receiving device connected to the linear aerial via a connector, the receiving device being adapted to process the signals sensed by the linear aerial in order to detect the presence of prohibited devices in said area and designed to reject the detections of the authorized devices outside of said area.

25 The receiving device comprises, for example, at least two detection thresholds $Seuil_{j,f}$ and $Seuil'_{j,f}$; the value of the threshold $Seuil_{j,f}$ is adapted so that the value of the power received $P(r,l)_{j,f}$ at the detection device is such that the ratio $P(r,l)_{j,f}/N_{j,f}$ is higher than the detection threshold $Seuil_{j,f}$ for the carriers employed by the transmitters of the illicit devices
30 considered at the points $M(r,l)$ inside of the area of prohibition, with

$$10.\log_{10}(P_{0,j,f}) - C(r_0) - P' \cdot (l - l_0) - 10.\log_{10}(r/r_0) - 10.\log_{10}(N_{j,f}) \geq 10.\log_{10}(\text{Seuil}_{j,f}) + \eta$$

where

- . r, l , are the radial and linear coordinates of a point M ,
- . l_0 denotes a reference linear distance,
- 5 . r_0 denotes a reference radial distance to the linear element,
- . P' denotes the rate of the linear losses along the radiating aerial starting from the distance l_0 ,
- . $-C(r_0)$ denotes the coupling losses in the band $B_{j,f}$ at the reference radial distance,
- 10 . $N_{j,f}$ denotes the receiver noise in the band $B_{j,f}$,
- . $P_{0,j,f}$ denotes the power radiated at the point $M(r, l)$ in the band $B_{j,f}$,
- . $\text{Seuil}_{j,f}$ represents the sensitivity threshold of the receiving device in the band $B_{j,f}$, adjusted in order to obtain the confinement of the detection,
- 15 . η represents a certain safety margin for taking into account the additional attenuations of the signal when it propagates from the prohibited terminal to the aerial, and

the value of $\text{Seuil}'_{j,f}$ is such that:

$$10.\log_{10}(P_{S,j,f}) - 20.\log_{10}(R) - 10.\log_{10}(N_{j,f}) \leq 10.\log_{10}(\text{Seuil}'_{j,f}) - \eta' \quad \text{where}$$

- 20 . R is the distance from the point M (outside of the area of prohibition) to the phase center of the linear aerial, Real distance/phase center,
- . $P_{S,j,f}$ denotes the power radiated at the point $M(R)$ by the permissible terminals outside of the area of prohibition, in the band $B_{j,f}$,
- . $\text{Seuil}'_{j,f}$ represents a non-detection threshold of the receiving device
- 25 in the band $B_{j,f}$, adjusted according to the gain of the linear element in order to obtain the confinement of the detection to the area of prohibition,
- . η' represents a certain safety margin for taking into account the excesses of power at transmission which can notably come from
- 30 fluctuations in the traffic and the fluctuations in the propagation characteristics for the points outside of the area of prohibition.

The device may comprise a first receiving device disposed at a first end of the linear aerial and a second receiving device disposed at a second end of the linear aerial, the first and the second receiving device being synchronized by means of a module adapted in order to receive the same signal to be detected at the two ends of the linear aerial.

The module, adapted for synchronizing the first and the second receiving device, may comprise a module for estimating localization:

- based on the values of amplitudes A_1 , A_2 measured on the signals received on each receiving device,
- 10 • and/or based on the measured ratio (A_1/A_2) of these amplitudes after propagation, and/or
- based on the propagation times τ_1 , τ_2 measured on the signals received on each receiving device, and/or
- based on the measured difference ($\tau_1 - \tau_2$) of these propagation times, and/or
- 15 • based on the measured propagation phases φ_1 , φ_2 of the signals received on each receiving device, and/or
- based on the measured difference ($\varphi_1 - \varphi_2$) of these propagation phases.

20 At least one of the receiving devices may be a generic wideband receiver.

According to one variant, the receiving device is composed of an assembly of dedicated receivers, having specifically adapted filtering and thresholding amplification modules, whose input signals come from a switch connected to the linear aerial.

The receiving device may comprise filtering modules selective in frequency and adapted to excise the received signal.

The device comprises, for example, a means designed to couple the signals at the output of two different linear aerials and to inject the resulting signal into a single receiving device.

The device comprises, for example, a system of baffles designed to locally optimize the confinement of the signal, such as grids for the passage of electrical cables with reversed mounting, or nettings with various meshes and geometries.

5 The invention also relates to a method for detecting and localizing in a confined manner one or more radio devices potentially present in an enclosed or semi-open prohibited area, characterized in that it comprises at least the following steps:

- use a linear aerial comprising several orifices O_i designed to allow the
10 passage of the signals emitted by the radio device or devices via the linear aerial to a receiving device connected to the linear aerial,
- process the received signals in order to detect the presence of unauthorized devices within said area and to reject the detections of the authorized devices outside of said area.

15 The method uses for example a first threshold $Seuil_{j,f}$ verifying

$$10.\log_{10}(P_{0,j,f}) - C(r_0) - P' \cdot (l - l_0) - 10.\log_{10}(r/r_0) - 10.\log_{10}(N_{j,f}) \geq 10.\log_{10}(Seuil_{j,f}) + \eta$$

where

- . r, l , are the radial and linear coordinates of a point M ,
- . l_0 denotes a reference linear distance,
- 20 . r_0 denotes a reference radial distance to the linear element,
- . P' denotes the rate of the linear losses along the radiating aerial starting from the distance l_0 ,
- . $-C(r_0)$ denotes the coupling losses in the band $B_{j,f}$ at the reference radial distance,
- 25 . $N_{j,f}$ denotes the receiver noise in the band $B_{j,f}$,
- . $P_{0,j,f}$ denotes the power radiated at the point $M(r,l)$ within the area of prohibition, in the band $B_{j,f}$,
- . $Seuil_{j,f}$ represents the sensitivity threshold of the receiving device in the band $B_{j,f}$, adjusted in order to obtain the confinement of the
30 detection,

. η represents a certain safety margin for taking into account additional attenuations of the signal when it propagates from the prohibited terminal to the aerial, and

a second rejection threshold $\text{Seuil}'_{j,f}$ verifying:

$$5 \quad 10.\log_{10}(P_{S,j,f}) - 20.\log_{10}(R) - 10.\log_{10}(N_{j,f}) \leq 10.\log_{10}(\text{Seuil}'_{j,f}) - \eta' \text{ where}$$

. R is the distance from the point M (outside of the area of prohibition) to the phase center of the linear aerial,

. $P_{S,j,f}$ denotes the power radiated at the point $M(r,l)$ by the permissible terminals outside of the area of prohibition, in the band $B_{j,f}$,

10 . $\text{Seuil}'_{j,f}$ represents a non-detection threshold of the receiving device in the band $B_{j,f}$, adjusted according to the gain of the linear element in order to obtain the confinement of the detection,

. η' represents a certain safety margin for taking into account excesses of radiated power at transmission that can notably come from
15 fluctuations in the traffic and the fluctuations of the propagation characteristics for the points outside of the area of prohibition.

According to one variant of the method, the threshold levels for detection $\text{Seuil}_{j,f}$ and rejection $\text{Seuil}'_{j,f}$ are determined by taking into account one or more of the following parameters:

- 20 - the measurements of the levels of the marker, control and traffic signals coming from transmitters present in the external networks and capable of entering into communication with the illicit devices,
 - the rate P' of linear losses within the linear aerial,
 - the coupling losses $C(r_0)$ of the linear aerial,
- 25 - margins η intended to compensate for the additional attenuations of various natures which may affect the scrambling signal J when it propagates from the linear aerial to the device to be scrambled,
- margins η' intended to compensate for the excesses of radiated power at transmission which can notably come from non-stationarities in the traffic and
30 the fluctuations of the propagation characteristics for the points outside of the area of prohibition.

Other features and advantages of the method and of the device according to the invention will become more clearly apparent upon reading the description that follows of one exemplary embodiment presented by way of non-limiting illustration with appended figures which show:

- 5 • figure 1, one example of a device according to the invention comprising a linear element equipped with receiving means adapted to capture and to receive radio signals emitted by devices located within an area to be monitored,
- figure 2, a detail of a linear element,
- 10 • figure 3a, one example of arrangement of a linear element having, at each of its ends, a receiving device and implemented in a space with a predominant direction,
- figure 3b, one possible example of arrangement of several linear elements for the implementation of the method in an enclosed space
- 15 of rectangular or square shape, of which the linear elements define the perimeter, in which the signal to be detected, received on two receiving devices present at the ends of a diagonal, is distributed within each semi-perimeter, and
- figure 4, one possible example of arrangement of two receiving
- 20 devices on the same linear aerial.

For a better understanding of the subject of the invention, the description that follows is presented by way of non-limiting illustration for the detection and the localization (and potentially the characterization) of one or more mobile telephones present within a volume and whose use is, in theory,

25 prohibited in this volume. The explanations that will follow may be applied for all the radio communications devices whose operation is not authorized within a given indoor space.

Figure 1 shows schematically a first exemplary embodiment of the device according to the invention comprising an aerial with linear geometry 1,

30 associated via a connector 3 with a receiving device 2 adapted to receive

radio signals emitted by devices whose operation is not authorized within a given area, itself linked with processing means 8, such as a processor.

The receiving device 2 is, for example, composed of:

- one or more receivers 5, 5' of the signals in the ranges of frequencies corresponding to the illicit radio communications, linked with the signal processing device 8,
- one or more modules 6, 6' for filtering and for amplification of the signals emitted by the aforementioned illicit transmission devices, which filtering and amplification modules allow any frequency-dispersive propagation losses within the linear aerial to be compensated for, and allow fine adjustment of the sub-bands, the carriers, and the levels of sensitivity at reception,
- a potential switch 7 between frequency bands allowing the signal effectively sensed by the linear aerial 1 to be received via the connector 3 and allowing it to be injected toward the receivers 2 dedicated to each frequency band.

The receiving device may also be composed of a wideband receiver equipped with adapted filtering and processing means in each of the sub-bands corresponding to the illicit transmissions. In this case, all of the components 5, 5', 6, 6' and 7 constituting the receiving device 2 in figure 1 are directly integrated into a single wideband receiving component 2.

Such arrangements allow multiple illicit signals to be received, over the appropriate frequency bands and on the appropriate carriers in given areas where prohibited terminals 4 that it is sought to detect are potentially located, with adapted sensitivity thresholds.

The processing means 8 are notably adapted:

- to carry out a selective detection of signals in the sub-bands and on the carriers concerning the potential illicit communications, by methods known to those skilled in the art such as:
 - radiometry on the wideband signals,
 - radiometry applied in parallel to the filtered carriers,
 - the adapted filtering of the signals received by the preambles, learning sequences, pilot codes, guard spaces, etc., applied in parallel to the

filtered carriers, these preambles, learning sequences, pilot codes, guard spaces, etc., being known to those skilled in the art by consultation of the standards describing the radio communication systems prohibited within the area,

- 5 • the cyclical autocorrelation of the signals, applied in parallel to the filtered carriers,

- etc.,

- to perform spectral analyses and characterizations of the nature of the communications detected, by means of the aforementioned detection processing operations (adapted filtering, cyclical autocorrelation), or even
10 where appropriate, the identification of the subscriber by decoding the control and access signaling messages specific to the communication, thus precluding a blocking decision in a reactive system,

- to carry out measurements of amplitude A , of synchronization τ , of phase ϕ ,
15 on the received signals, either in wideband mode, or on each filtered carrier, by means of the methods known to those skilled in the art such as:

- radiometry in wideband mode or radiometry on filtered carriers (estimation of amplitude),
- the recovery of symbol synchronization by estimation of timing and
20 eye diagram (measurement of synchronization τ and of phase ϕ on the linear modulations),
- the adapted filtering of the received signals by the preambles, the learning sequences, pilot codes, guard spaces, etc., applied in parallel to the filtered carriers (measurement of amplitude A , of
25 synchronization τ and of phase ϕ on all the standardized digital modulations),

- to carry out, when two receiving devices are connected to the same linear aerial such as in figure 4,

- estimations of localization by exploiting the value of the ratio A_2/A_1 of
30 the amplitudes of the signals received on each receiver after

propagation to each end of the linear aerial, and a prior calibration or modeling of the linear losses by propagation in the linear aerial,

- estimations of localization by exploiting the difference in synchronization $\tau_1 - \tau_2$ of the signals received after propagation to each end of the linear aerial, and a prior calibration or modeling of the propagation times in the linear aerial,
- estimations of localization by difference in phase $\phi_1 - \phi_2$ of the signals received after propagation to each end of the linear aerial, and a prior calibration or modeling of the phase shifts due to the propagation in the linear aerial.

Figure 2 is a detail of a linear cable comprising several orifices arranged in such a manner as to allow the passage of the waves emitted by the illicit terminals potentially located in the area to be monitored. The linear aerial 1 comprises several orifices O_i distributed along the element according to the desired application; the orifices are separated by sections 21 which do not allow the passage of the signals emitted by the unauthorized mobile telephone; the orifices O_i will concentrate the signals emitted in their neighborhood.

More generally, an aerial with linear geometry such as shown in figure 1 exhibits, for example, characteristics which, combined with adapted receiving devices such as described hereinabove, allow the radio signals emitted by the unauthorized mobile telephones to be selectively sensed, by controlling the coverage, the sensitivity and the confinement of this sensing.

More precisely, the power received $P(l, r)$ by the aerial, in a band B , emanating from a point $M(r, l)$ located by the linear distance l and the radial distance r , is given in decibels (dB) by the "cylindrical" propagation losses characteristic expressed by the following formula:

$$10 \cdot \log_{10}(P(l, r)) = 10 \cdot \log_{10}(P_0) - C(r_0) - P' \cdot (l - l_0) - 10 \cdot \log_{10}(r/r_0) \quad (1)$$

. l denoting the linear distance,

. r denoting the radial distance to the linear element,

- . l_0 denoting a reference linear distance (in practice, those skilled in the art consider l_0 as zero or very small, and for example make l_0 correspond to the input of the coupler 7),
 - . P_0 denoting the power radiated at the point $M(r,l)$ in the band B,
 - 5 . P' denoting the rate of the linear losses along the radiating aerial (assumed, in order to simplify the expression but without limiting the generality, constant in the band B, itself assumed to be sufficiently narrow); this value is in general a manufacturer's data value or a quantity matched by the measurement in each of the bands B; this value is a few dB per 100 m of
 - 10 propagation in the aerial, or more if attenuators are added,
 - . r_0 denoting a reference radial distance (in general, those skilled in the art consider $r_0=2m$),
 - . $-C(r_0)$ denoting the coupling losses in the band B at the reference radial distance r_0 , uniform over the length of the aerial. $-C(r_0)$ is generally a
 - 15 manufacturer's data value, which may be matched by measurement, being a value of the order of -55 dB to -70 dB at a reference radial distance $r_0= 2m$,
 - $P(l, r)$ is the power received in the band B of the signal coming from the point $M(r,l)$. In the case where there is an emission over several sub-bands simultaneously, the power P considered is global and can correspond to
 - 20 several of the sub-bands.
- In the equation (1) hereinabove:
- the rate P' of the linear losses by propagation in the aerial is low, a fact which guarantees a gain of the aerial that is uniform over the lengths targeted by the invention, the linear distance being $l \in [l_0, L]$; $L \leq 100$ m,
 - 25 - the cylindrical characteristic (expressed in dB by $-10 \cdot \log_{10}(r/r_0)$ in the formula(1)) of the propagation losses by radiation is linearly dependent on the inverse of the radial distance r to the linear aerial rather than quadratically dependent on the inverse of the absolute distance R to the phase center of the aerial as in the case of the conventional systems with a point-like type
 - 30 antenna or with a limited surface area described in the prior art.

The dimensions of the linear aerial element, its diameter Φ , its length L and its orientation with respect to the geometry of the area to be covered, together with the distribution of the orifices O_i allowing the reception of the signals, and the positioning of potential baffles in order to facilitate the confinement, are chosen notably depending on the radio communication devices that it is desired to detect, and on the geometry of the area in which they might be found.

When the area to be covered has predominant directions (corridors, alleyways) such as in figure 3a, the orientation of the linear elements is set for example tangentially to these predominant directions. When the area to be covered is an enclosed volume without a predominant direction, such as in figure 3b, the aeriels are disposed for example tangentially to the edges of this volume.

The levels of sensitivity (threshold levels) of the receiving devices are adjusted, for example, by taking into account one or more of the following elements:

- the proximity of the transmitters 9, 10, 11, 12, nearby in the external networks and capable of entering into communication with the illicit terminals that it is desired to detect and localize, and/or
- the position in frequency of the marker and access channels of the transmitters 9, 10, 11, 12, nearby in the external networks and capable of entering into communication with the illicit terminals that it is desired to detect and localize, and/or
- the characteristic of linear losses expressed by the formula (1) hereinabove, and/or
- margins η and η' designed to compensate for the additional attenuations and fluctuations of diverse natures which may affect the signal to be detected when it propagates from the place of emission 4 to the linear aerial 1 (walls, doors, human bodies, etc.) and during its emission.

It will be sought to obtain a detection signal with a level higher than a threshold, $Seuil_j$, adjusted for the access or control channels employed on

the carriers f (carrier of band denoted $B_{j,f}$) within each band B_j $j = 1 \dots J$, which corresponds to the illicit transmitters within a given area. The idea is to adjust things such that the power received $P(l,r)_{i,f}$ at the detection device is such that:

- 5 • for the carriers employed by the illicit transmitters considered at the positions $M(l,r)$ in the prohibited area, the ratio $P(l,r)_{i,f}/N_{j,f}$ is greater than a detection threshold $Seuil_{j,f}$,
- for the carriers employed by the transmitters considered outside of the prohibited area at the distance R measured with respect to the phase
10 center of the linear element, the ratio $P(R)_{i,f}/N_{j,f}$ is below an appropriate rejection threshold,

$N_{j,f}$ being the level of the receiver noise in the band $B_{j,f}$. $N_{j,f}$ and $B_{j,f}$ are known to those skilled in the art for each radio communications network and for each type of access or control carrier to be detected f by consulting the
15 standards for these networks.

Considering the location of the illicit terminal $M(r,l)$, within the prohibited area, the detection condition is written in decibels in the band $B_{i,f}$ of the carrier f :

$$10.\log_{10}(P(l,r)_{j,f}) - 10.\log_{10}(N_{j,f}) \geq 10.\log_{10}(Seuil_{j,f}) \quad (1')$$

20 Still considering the location of the illicit terminal $M(r,l)$, the average radiated power $P_{0,j,f}$ of the signal emitted at the point M in the band $B_{j,f}$ of each carrier f , the thresholding on a signal received via the linear aerial 1 and the connector 3 must therefore verify, for the band $B_{j,f}$ of each carrier f :

$$10.\log_{10}(P_{0,j,f}) - C(r_0) - P' \cdot (l - l_0) - 10.\log_{10}(r/r_0) - 10.\log_{10}(N_{j,f}) \geq 10.\log_{10}(Seuil_{j,f}) + \eta \quad (2)$$

25 where η represents a safety margin for taking into account additional attenuations of the scrambling signal when it propagates from the aerial to the prohibited terminal 4.

Since this condition expressed in the formula (2) must be verified for an area defined by a radius $r_0 \leq r \leq r_{\max}$, $l_0 \leq l \leq L_{\max}$, a sufficient condition is, for example,
30 to verify it for $P_{0,j,f} = (P_{0,\min})$, $r = r_{\max}$, $l = L_{\max}$, $\eta = \eta_{\max}$, $\text{Max}_{j,f}(N_{j,f}) = N_{\max}$, $\text{Max}_{j,f}(Seuil_{j,f})$, $Seuil_{\max}$

$$10.\log_{10}(P_{0,\min}) - C(r_0) - P' \cdot (L_{\max} - l_0) - 10.\log_{10}(r_{\max}/r_0) - 10.\log_{10}(N_{\max}) \\ \geq 10.\log_{10}(\text{Seuil}_{\max}) + \eta_{\max} \quad (3)$$

- For points $M(R)$ far away from the area of prohibition, at the distance R (real distance/phase center) measured with respect to the phase center of the linear element, the idea is to receive via the linear aerial a value of received signal power $P(R)_{i,f}$, in the band $B_{i,f}$ of each carrier, that is sufficiently low for its detection to be rejected. A value of threshold $\text{Seuil}'_{j,f}$ and the following rejection condition in decibels in the band $B_{i,f}$ of the carrier f are used:
- 10 $10.\log_{10}(P_{S,j,f}) - 20.\log_{10}(R) - 10.\log_{10}(N_{j,f}) \leq 10.\log_{10}(\text{Seuil}'_{j,f}) - \eta' \quad (2')$ where
- . $P_{S,j,f}$ denotes the average power radiated at the point $M(r,l)$ by the permissible terminals outside of the prohibited area, in the band $B_{j,f}$,
 - . $\text{Seuil}'_{j,f}$ represents a rejection threshold for the detections by the receiving device in the band $B_{j,f}$, adjusted according to the gain of the
 - 15 linear element in order to obtain the confinement of the detection,
 - . η' represents a certain safety margin for taking into account the excesses of radiated power at transmission which can notably come from fluctuations in the traffic and the fluctuations of the propagation characteristics for the points far away from the area of prohibition,
 - 20 . R is the distance from the point M to the phase center of the linear aerial, assumed to be sufficiently large for the characteristic of spherical $20.\log_{10}(R)$ propagation losses varying as to apply; for that, the margin η' and the lengths of aerial L are adapted according to the wavelength λ of the detected emissions in such a manner that R is
 - 25 greater than the Fraunhofer distance $2.L^2/\lambda$ for the points far away from the area of prohibition.

Figure 3a shows schematically one variant embodiment of the invention in an enclosed volume with a predominant direction of the corridor type, in which a single element 301 is installed on a ceiling and two effectors

30 305, 306 are installed at opposite ends of the element, according to the description hereinabove. The orifices of the linear element allow signals

emitted by the mobile telephone 4 located within the area of coverage of the linear element to be received.

Figure 3b shows schematically one variant embodiment of the invention in a volume not having any predominant direction, in which four
 5 linear elements 311, 312, 313, 314, of length respectively L_2 , L_1 , L_2 , L_1 , have been installed on the walls (not shown) of a room with square geometry to be monitored and two effectors 315, 316 have been installed at opposite ends of one of the diagonals of the room, according to the description hereinabove. The effector 315 is connected according to an arrangement described in
 10 figure 1 to the two linear elements 311, 312, and the effector 316 is linked to the linear elements 313, 314. The thresholding and margin parameters will notably be chosen as a function of the square arrangement of the linear elements.

Figure 4 shows schematically one variant embodiment in which
 15 two receiving devices are connected to the same linear aerial 41 in order to receive the signal to be detected at each of its ends, the first receiving device 42a at a first end 41a of the linear aerial 41 via a first connector 43a, and the second receiving device 42b at the second end 41b of the linear aerial 41 via a second connector 43b. In this case, the first and the second receiving
 20 device exhibit characteristics that are substantially identical (same frequency bands, same thresholdings, same margins). They are synchronized, or their synchronization is matched and maintained in a module 44 according to techniques known to those skilled in the art in order to allow measurements of delay times and of phase-shifts on the signals propagating in the linear
 25 aerial, these measurements being carried out, where relevant, in the module 44. The module 44 comprises, for example, a synchronization module and a processing algorithm common to the two systems for reception, detection, and analysis of the signals, for estimation of localization and known to those skilled in the art designed to obtain:
 30 - synchronized detections,

- estimations of localization by exploiting the ratio A_2/A_1 of the amplitudes of the signals received at the ends of the linear aerial, A_1 corresponding to the amplitude of the signal detected by the first detector and A_2 corresponding to the amplitude detected on the second detector, A_2 and A_1 being measured according to synchronized detections according to the methods known to those skilled in the art, and exploiting, for example, a prior calibration or modeling of the linear losses by propagation in the linear aerial,
- estimations of localization by difference of propagation times $\tau_1 - \tau_2$ of the signals received at the ends of the aerial after linear propagation, the delays τ_1 and τ_2 being measured according to synchronized detections, according to the methods known to those skilled in the art, and a prior calibration or modeling of the propagation times in the linear aerial,
- estimations of localization by difference of phase of propagation $\varphi_1 - \varphi_2$ of the signals received at the ends of the aerial after linear propagation, the phases φ_1 and φ_2 being measured according to synchronized detections, according to the aforementioned methods known to those skilled in the art, and a prior calibration or a modeling of the phase-shifts due to the propagation in the linear aerial.

In one sub-variant of the implementation in figure 4, the signals received at each end of the linear aerial Sig_1 and Sig_2 are directly routed to the common processing module 44, and the ratio of amplitude $\Delta A = A_1/A_2$, the difference in propagation times $\Delta \tau = \tau_1 - \tau_2$, and the difference in phase $\Delta \varphi = \varphi_1 - \varphi_2$ are directly estimated by normalized inter-correlation of the signals Sig_1 and Sig_2 according to methods known to those skilled in the art.

Without straying from the scope of the invention, other variant implementations of the invention are possible.

For example, it is possible to add to the system one or more baffles for locally optimizing the confinement of the detection. For the nature, the shape and the size of the baffles, the following may be used: grids for the passage of electrical cables (frequencies > 900 MHz) with reversed mounting, nettings with various meshes and geometries. The example of a

plane rectangular netting with opening $\geq (\lambda/2)^2$ (λ : wavelength of the scrambling emission) leads to a directivity of around 120 and a ratio Forward/Back of the order of 10 to 15 dB). This facilitates the confinement of the detection during installation in a “semi-open environment”, for example
 5 for prison windows or examination/conference room windows, or when there are diffraction problems (metal conduits or others).

Another variant consists in adding a metrology in the installation/maintenance phase which allows the installation and the adjustment of the system to be facilitated. For this purpose, tracking
 10 terminals or propagation channel probes well known to those skilled in the art may be used.

According to another variant embodiment, a “supernet” of authorized wired communications, or else a “supernet” of communications using power line transmissions, etc. may be used

15 According to another variant embodiment, a “supernet” of “à la carte” authorized radio communication may be added, by means of the following elements:

- choice of carrier frequencies according to a prior sampling of the frequency assignment plans for the external networks according to
 20 methods known to those skilled in the art,
- where appropriate, frequency excision of the authorized carriers within the receiving device (band-rejection filtering) or in the detection processing and in its exploitation,
- installation of a local micro-network using the authorized carriers and
 25 relay to an external network.

Examples of components usable on the carriers which would be authorized for such a supernet are DECT (Digital Enhanced Cordless Telephone) wireless access points, pico/femto-cells of the UMTS (Universal Mobile Telecommunications System) third generation system or of the LTE
 30 (Long Term Evolution) standard, Wifi or WiFi Direct access points, UMTS

“device-to-device” terminals or MANET (Release 12 and 13 standard) LTE terminals known to those skilled in the art, etc.

The method and the system according to the invention notably offer the following advantages:

- 5 • the possibility of selectively localizing and detecting 0.3-3 GHz radio communicationss devices, where appropriate with a single system of large linear extension,
- confinement of the detection to a given area with no impact on the external environment nor risks of indiscretion or of intrusion, by virtue
10 of the linear nature of the aerial and of the resulting cylindrical loss characteristic according to the equation (1),
- flexibility of installation, with a deployment of “à la carte” systems, thanks to an adaptation of the architecture of the device according to the geometry of the area being monitored,
- 15 • ease of maintenance,
- numerous possibilities for extension in terms of added functions and in terms of services.

CLAIMS

1 – A device for detecting and localizing in a confined manner one or more radio devices which might be present in an enclosed or semi-open area of prohibition,
 5 characterized in that it comprises at least the following elements:

at least one linear aerial comprising several orifices O_i designed to allow the capture of signals emitted by prohibited radio devices then their transmission via the linear aerial to one or more receiving devices connected to the linear aerial via a connector, the one or more receiving devices being
 10 adapted to process the signals sensed by the linear aerial in order to detect the presence of prohibited devices in said area and to reject the detections of authorized devices outside of said area, and in that each of the one or more receiving devices comprises at least two detection thresholds $Seuil_{j,f}$ and $Seuil'_{j,f}$, the value of the threshold $Seuil_{j,f}$ is adapted so that the value of the
 15 power received $P(r,l)_{j,f}$ at the device for detecting is such that the ratio $P(r,l)_{j,f}/N_{j,f}$ is higher than the detection threshold $Seuil_{j,f}$ for carriers employed by transmitters of the prohibited devices considered at the points $M(r,l)$ inside of the area of prohibition, with

$$10.\log_{10}(P_{0,j,f}) - C(r_0) - P' \cdot (l - l_0) - 10.\log_{10}(r/r_0) - 10.\log_{10}(N_{j,f}) \geq 10.\log_{10}(Seuil_{j,f}) + \eta \text{ where}$$

- 20 . r, l , are the radial and linear coordinates of a point M ,
- . l_0 denotes a reference linear distance,
- . r_0 denotes a reference radial distance to the linear element,
- . P' denotes the rate of the linear losses along the radiating aerial starting from the distance l_0 ,
- 25 . $-C(r_0)$ denotes the coupling losses in the band $B_{j,f}$ at the reference radial distance,
- . $N_{j,f}$ denotes the receiver noise in the band $B_{j,f}$,
- . $P_{0,j,f}$ denotes the power radiated at the point $M(r,l)$ in the band $B_{j,f}$,
- . $Seuil_{j,f}$ represents the sensitivity threshold of the receiving device in the
 30 band $B_{j,f}$, adjusted in order to obtain the confinement of the detection,

η represents a safety margin taking into account the additional attenuations of the signal when it propagates from the prohibited devices to the aerial, and

the value of the threshold $\text{Seuil}'_{j,f}$ is such that:

$$5 \quad 10.\log_{10}(P_{S,j,f}) - 20.\log_{10}(R) - 10.\log_{10}(N_{j,f}) \leq 10.\log_{10}(\text{Seuil}'_{j,f}) - \eta' \quad \text{where}$$

. R is the distance from the point M , outside of the area of prohibition, to the phase center of the linear aerial,

. $P_{S,j,f}$ denotes the power radiated at the point $M(R)$ by the authorized devices outside of the area of prohibition, in the band $B_{j,f}$,

10 . $\text{Seuil}'_{j,f}$ represents a non-detection threshold of the receiving device in the band $B_{j,f}$, adjusted according to the gain of the linear element in order to obtain the confinement of the detection to the area of prohibition,

η' represents a safety margin taking into account excesses of power at transmission.

15

2 – The device as claimed in claim 1, characterized in that it comprises a first receiving device disposed at a first end of the linear aerial and a second receiving device disposed at a second end of the linear aerial, the first and the second receiving device being synchronized by means of a module in order to
20 receive the same signal to be detected at the two ends of the linear aerial.

3 – The device as claimed in claim 2, characterized in that the module comprises a module for estimating localization:

- based on the values of amplitudes A_1 , A_2 measured on the signals
25 received on each receiving device, and/or
- based on the measured ratio (A_1/A_2) of these amplitudes after propagation, and/or
- based on the propagation times τ_1 , τ_2 measured on the signals received on each receiving device, and/or based on the measured difference ($\tau_1 - \tau_2$) of these propagation times, and/or
30

- based on the measured propagation phases φ_1 , φ_2 of the signals received on each receiving device, and/or based on the measured difference ($\varphi_1 - \varphi_2$) of these propagation phases.

5 4 – The device as claimed in one of the preceding claims, characterized in that at least one of the one or more receiving devices is a generic wideband receiver.

10 5 – The device as claimed in one of the preceding claims, characterized in that the receiving device is composed of an assembly of dedicated receivers, having specifically adapted filtering and thresholding amplification modules, whose input signals come from a switch (7) connected to the linear aerial.

15 6 – The device as claimed in one of the preceding claims, characterized in that the receiving device comprises filtering modules selective in frequency and adapted to excise the received signal.

20 7 – The device as claimed in one of the preceding claims, characterized in that it comprises a means designed to couple the signals at the output of two different linear aerials and to inject the resulting signal into a single receiving device.

25 8 – The device as claimed in one of the preceding claims, characterized in that it comprises a system of baffles designed to locally optimize the confinement of the signal.

9 – The device as claimed in claim 8, characterized in that the system of baffles comprises grids for the passage of electrical cables with reversed mounting, or nettings with various meshes and geometries.

10 – A method for detecting and localizing in a confined manner one or more radio devices present in an enclosed or semi-open prohibited area, characterized in that it comprises at least the following steps:

- use a linear aerial comprising several orifices O_i designed to allow the passage of the signals emitted by the one or more radio devices via the linear aerial to a receiving device connected to the linear aerial,
- process the received signals in order to detect the presence of unauthorized devices within said area and to reject the detections of authorized devices outside of said area.

11 – The method as claimed in claim 10, characterized in that it uses a first threshold $Seuil_{j,f}$ such that:

$$10.\log_{10}(P_{0,j,f}) - C(r_0) - P' \cdot (l - l_0) - 10.\log_{10}(r/r_0) - 10.\log_{10}(N_{j,f}) \geq 10.\log_{10}(Seuil_{j,f}) + \eta \text{ where}$$

. r , l , are the radial and linear coordinates of a point M ,

. l_0 denotes a reference linear distance,

. r_0 denotes a reference radial distance to the linear element,

. P' denotes the rate of the linear losses along the radiating aerial starting from the distance l_0 ,

. $-C(r_0)$ denotes the coupling losses in the band $B_{j,f}$ at the reference radial distance,

. $N_{j,f}$ denotes the receiver noise in the band $B_{j,f}$,

. $P_{0,j,f}$ denotes the power radiated at the point $M(r,l)$ in the band $B_{j,f}$,

. $Seuil_{j,f}$ represents the sensitivity threshold of the receiving device in the band $B_{j,f}$, adjusted in order to obtain the confinement of the detection,

η represents a certain safety margin for taking into account additional attenuations of the signal when it propagates from the unauthorized devices to the aerial, and

a second rejection threshold $Seuil'_{j,f}$ such that

$$10.\log_{10}(P_{S,j,f}) - 20.\log_{10}(R) - 10.\log_{10}(N_{j,f}) \leq 10.\log_{10}(Seuil'_{j,f}) - \eta' \text{ where}$$

. R is the distance from the point M (outside of the area of prohibition) to the phase center of the linear aerial,

. $P_{S,j,f}$ denotes the power radiated at the point $M(R)$ by the authorized devices outside of the area of prohibition, in the band $B_{j,f}$,

. $Seuil'_{j,f}$ represents a non-detection threshold of the receiving device in the band $B_{j,f}$, adjusted according to the gain of the linear element in order to obtain the confinement of the detection,

5

η' represents a safety margin taking into account excesses of radiated power at transmission.

12 – The method as claimed in claim 11 characterized in that the threshold levels for detection $Seuil_{j,f}$ and rejection $Seuil'_{j,f}$ are determined by taking into account one or more of the following parameters:

10

- the measurements of the levels of marker, control and traffic signals coming from transmitters (9, 10, 11, 12) present in external networks and capable of entering into communication with the unauthorized devices,

15

- the rate P' of linear losses within the linear aerial,

- the coupling losses $C(r_0)$ of the linear aerial,

- margins η intended to compensate for the additional attenuations of various natures which may affect a scrambling signal J when it propagates from the linear aerial to the device to be scrambled,

20

- margins η' intended to compensate for the excesses of radiated power at transmission.