



METHOD OF OPTIMIZING THE MONITORING OR SCANNING OF SIGNALS BY A SENSOR

The invention relates to a method for optimizing the strategy for
5 scanning signals or for monitoring signals by sensors. It applies, for example,
for detecting and analysing electromagnetic emissions of communication or
radar type. The optimization requires the knowledge of the technical
parameters of the modes of emission which are held in a database dubbed a
technical repository.

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The problem posed in this field is to define the strategy for
scanning signals or "scanning strategy" of a sensor, adapted for monitoring,
intercepting, characterizing, identifying signals in a given context, that is to
say for frequently and temporally allocating the use of the sensor
15 instantaneous analysis band, or IAB, so as to cover all or part of the very
high frequency VHF, Ultra High Frequency, UHF or Supra High Frequency
SHF spectrum, while optimizing the probability of interception (POI) of the
objects to be monitored or radioelectric emissions belonging to the spectrum,
as well as the performance of the processing operations for identifying and
20 characterizing the emissions. The effectiveness of this allocation of resources
depends notably on the waveforms to be intercepted and, in particular, on the
technical characteristics relating to their modulation as well as their temporal
activity. These characteristics are held in a technical repository.

Figure 1 shows diagrammatically a scan model in a time-
25 frequency chart customarily used to poll signals. In this diagram it is seen
that the scan is performed in a linear and regular manner, in accordance with
a period $T_R(1/F_R)$, according to a sequence which lasts T_{seq} and while
varying the frequency F per listening frame or tier for an object. This
technique can lead to a degradation in identification/characterization
30 performance if the duration of listening is not adapted to the monitored
objects. Another limitation of this technique is the degradation in the



probability of interception POI if the revisit time, corresponding to the time gap between two listenings for one and the same object, is not adapted to the object. This is true, in particular, for objects whose emissions are of Frequency Evasion or FEV communication type, or frequency agility radars.

5 One of the problems unsolved by the prior art is of not having a scan strategy adapted to the objects to be monitored, which leads, notably, to an inability to identify or to characterize the objects for which the duration of listening or the revisit time is not adapted. Likewise, a need exists to have a method for optimizing the methods for scanning sensors intended to monitor
10 emitters.

 One of the objectives of the present invention is to define a method having a scan strategy adapted to the objects to be processed. The adaptation requires the knowledge of the technical parameters of the modes
15 of emission of the objects. These modes of emission are held in a database dubbed a technical referential : the optimization of the scan strategy is therefore indexed by the technical referential.

 The invention relates to a method for determining parameters for monitoring a set of instantaneous analysis bands IAB comprising at least two
20 objects to be monitored, characterized in that it comprises at least the following steps:

- slicing the "surveillance plan" into L instantaneous analysis bands IAB_j,
- determining the duration of listening $T_{Objecti}$ and the revisit time $TR_{Objecti}$
25 for each of the objects to be monitored by using waveform and network access information which is associated with the objects to be monitored,
- thereafter determining the duration of listening T_j and the revisit time TR_j which is optimal for each of the said instantaneous bands IAB_j by
30 using the values of the durations of listening $T_{Objecti}$, of the revisit times $TR_{Objecti}$ of the objects,

- determining at least one temporal scheduling of M instantaneous analysis bands with M greater than or equal to L , so as to obtain a temporal sequence T_{seq} of the instantaneous analysis bands which is adapted for satisfying at least the following points: the sequence comprises the set of L bands, the duration of the sequence T_{seq} is less than a duration T_{seqmax} .

The invention also relates to a method for determining parameters for monitoring a set of instantaneous analysis bands IAB_j in a system comprising at least two objects to be monitored and having in memory at least the characteristics of the modes of emission of the said object and at least one receiver adapted for receiving and analysing the signals received, characterized in that it comprises at least the following steps:

- a) slicing the "monitoring plan" or "surveillance plan" into L instantaneous analysis bands IAB_j ,
- b) determining the duration of listening $T_{Objecti}$ and the revisit time $TR_{Objecti}$ for each of the objects to be monitored by using waveform and network access information which is associated with the objects to be monitored and is contained in a technical repository,
- c) thereafter determining the duration of listening T_j and the revisit time TR_j which is optimal for each of the said instantaneous bands IAB_j by using the values of the durations of listening $T_{Objecti}$, of the revisit times $TR_{Objecti}$ of the objects,
- d) determining at least one temporal scheduling of M instantaneous analysis bands with M greater than or equal to L , so as to obtain a temporal sequence T_{seq} of the instantaneous analysis bands which is adapted for satisfying at least the following points: the sequence comprises the set of L bands, the duration of the sequence T_{seq} is less than a duration T_{seqmax} .

The revisit time TR_j of a band IAB_j is, for example, determined as a function of the associated priority of this band.

The duration T_{seq} can be greater than a maximum threshold value, in this case the method will decrease the priority of an instantaneous analysis band and the revisit time, and then it executes steps a) to d).

If the duration of the sequence T_{seq} is greater than the value
 5 T_{seqmax} , the method decreases the duration of listening of a band by removing an object to be monitored, and then it executes steps a) to d).

According to an implementation variant, it is possible to use a first reception pathway for determining a first temporal scheduling over the duration of listening, and a second reception pathway for determining a
 10 second temporal scheduling over the revisit time.

The invention also relates to a system comprising at least two objects to be monitored and having in memory at least the characteristics of the modes of emission of the said objects and at least one receiver adapted for receiving and analysing the signals received, characterized in that it
 15 comprises a processor adapted for executing the steps of the method according to the invention described hereinabove.

Other characteristics and advantages of the present invention will be more apparent on reading the description of an exemplary embodiment
 20 given by way of wholly nonlimiting illustration together with the figures which represent:

- Figure 1, an illustration of a regular scan model,
- Figure 2, a device diagram adapted for implementing the method according to the invention,
- 25 • Figure 3, a modelling of the scan strategy according to the invention,
- Figure 4, an illustration of an exemplary scan model according to the invention.

In the subsequent description, a technical repository corresponds
 30 to a set of data comprising, for an object to be monitored, at least its waveform (modulation used for the signals that it emits) and the type of

network access. The duration of a sequence T_{seq} corresponds to a fixed duration sufficient for a device, having the objective of monitoring a set of objects, to have had time to listen to the signals emitted by all the objects to be monitored. The duration of sequence obtained is less than the sum of the
 5 durations of listening T_i for each of the objects to be monitored.

Figure 2 represents an exemplary system allowing the implementation of the method according to the invention. The system 20 adapted for implementing the method according to the invention comprises, for example, a reception antenna 21, a reception pathway 25, a processor 22
 10 comprising a piece of software adapted for processing the signals or data received on this antenna, a database 23 storing the information on the objects to be monitored, or technical repository of radioelectric emissions.

The objects to be monitored 10, 11, 12 emit signals according to given frequency plans (frequency band set) which are known to the device
 15 according to the invention.

The processor 22 of the device according to the invention will carry out the slicing of the set of bands in which the N objects to be monitored emit into L adjoining sensor band, referred IAB (instantaneous analysis band).

20 The processor 22 will determine, a first parameter which is the duration of listening $T_{Objecti}$ for an object i . The processor also determines the revisit time $TR_{Objecti}$ which corresponds to the time interval between two listenings for an object i . Thus, the duration of listening $T_{Objecti}$ and the revisit time $T_{Objecti}$ necessary to intercept/identify/characterize the objects i
 25 belonging to an instantaneous analysis band IAB $_j$ are determined.

The processor 22 will accordingly utilize the characteristics of the waveform or modulation and of the type of network access of an object i which are contained in a technical repository stored in the database 23. The type of network access is for example, of FF, frequency evasion or FEV, time
 30 division multiple access or TDMA type, etc. An object i emits in a frequency band $[F_{min}, F_{max}]$, for example of 30 MHz to 88 MHz.

According to another variant embodiment, the system comprises a multipathway reception antenna for reception, for example two reception pathways (21, 25), (26, 27), which allow it to undertake processing operations in parallel.

5 The algorithm implemented by the processor 22 is adapted for executing at least the following steps:

1. A first step of the method consists of a slicing of the set of bands in which the N objects to be monitored emit into L adjoining sensor bands, IAB, a band comprises n ($n < N$) objects,
- 10 2. In the course of a second step, the processor 22 will calculate the duration of listening T_{Object} and the revisit time TR_{Object} for each of the N objects to be monitored, by utilizing at least the data stored in the technical repository and containing the characteristics of all the objects to be monitored,
- 15 3. In the course of a third step, the processor 22 will calculate the duration of listening and the revisit time for each of the instantaneous analysis bands as a function of the $n < N$ objects belonging to the band,
- 20 4. In the course of an optional fourth step, the processor will determine the priority of each of the instantaneous analysis bands as a function of a priority given to an object which corresponds to the fact that an object needs to be monitored at a more significant frequency than the other objects,
- 25 5. In the course of a fifth step the processor calculates the duration of listening T_j / revisit time TR_j optimal sequence for the set of instantaneous analysis bands,
6. Next a sixth step consists in validating this sequence.

30 The detail of the steps implemented by the method according to the invention is detailed hereinafter, for an example given by way of wholly nonlimiting illustration.

Cutting of the surveillance plan into IAB

The surveillance plan defines a certain number of objects to be intercepted and can be written in the form:

$$(1) \text{ SurveillancePlan} = \bigcup_{i=1}^N \text{Object}_i \text{ where } U \text{ is the union operator and } N$$

the number of objects to be intercepted.

- 5 To each object i there corresponds, for example, a frequency span $[F_{\min_i}, F_{\max_i}]$ or else a set of frequency spans. The surveillance plan can therefore be rewritten in the form:

$$(2) \text{ SurveillancePlan} = \bigcup_{i=1}^N [F_{\min_i}, F_{\max_i}].$$

This can be for example the union of the following 6 bands:

- 10 - band [30 MHz, 88 MHz] of a first object of military radio type,
 - band [133 MHz, 174 MHz] of a second object of type,
 - band [125 MHz, 250 MHz] of a third object of low-band radar type,
 - band [380 MHz, 470 MHz] of a fourth object of PMR (private mobile radio) type,
 15 - band [465 MHz, 467 MHz] of a fifth object of radio-messaging type,
 - band [1525 MHz, 1559 MHz] of a sixth object of satellite link type.

Knowing the instantaneous analysis band (IAB) of the sensor of the device according to the invention the surveillance plan or monitoring plan is translated into the form of a union of L instantaneous analysis bands IAB:

$$20 \quad (3) \text{ SurveillancePlan} = \bigcup_{i=1}^L \text{IAB}_i \text{ } U \text{ is the union operator and } L \text{ the}$$

number of instantaneous analysis Bands.

The steps described previously apply within the framework of fixed bandwidth or the case of variable bandwidth.

Determination of the duration of listening of the objects

- 25 For each object i of the surveillance plan, the optimal duration of listening $T_{\text{Object}i}$ is calculated so as to allow its identification.

This duration of listening $T_{\text{Object}i}$ is determined by the processor 22 on the basis of the table stored in the memory 23 of the device according to the invention, which gives as a function of the waveform of the object

(modulation and its technical parameters), and of the type of network access FF/FEV/TDMA/slot or burst, the necessary duration $T_{Objecti}$ required for the identification of the object i with a fixed probability, for example, of 95%. This table depends on the performance of the sensor used.

- 5 For example, in the case of an object with a waveform of linear modulation type under PSK8 modulation with modulation rate V , identification requires 500 symbols and therefore T_{Object} is equal to the ratio $500/V$. i.e. for a modulation rate of 24 kbauds, $T_{Object} = 20.83$ ms

 Generally, the duration of listening T_{Object} varies from 10 to
10 400 ms, these values being given by way of wholly nonlimiting illustration.

Determination of the object revisit time

 For each object i of the surveillance plan, the optimal duration of revisit is calculated so as to allow its interception with a given probability of interception POI as well as the characterization of the network access.

- 15 This duration of revisit $TR_{Objecti}$ is determined by the processor 22 on the basis of the table stored in the memory 23 of the device according to the invention.

 The minimum revisit time for an object depends on the type of the network access of the object and the temporal characteristics of this access.

- 20 The types of network access considered are the following: FF by alternation, slow FEV, TDMA/burst, fast FEV.

 By way of indication a scheme for calculating the revisit times in the case of the various types of network access:

- in the case of a network access of FF by alternation type, the object
25 revisit time typically corresponds to 20% of the duration of the alternation. This revisit time ensures a probability of interception of 100% as well as the measurement of the start and end time of the alternation;
- in the case of a network access of slow FEV type, the object revisit
30 time also corresponds to 20% of the duration of the tiers. This revisit time ensures a probability of interception of 100% on each tier as well

as the measurement of the start and end time of the tier;

- in the case of a network access of TDMA/burst type, the revisit time typically corresponds to the duration of the time slot or burst so as to ensure a POI of 100% on the burst (the POI is indeed given by the ratio Burst Duration/revisit Time);
- in the case of an access of fast FEV type, the revisit time typically corresponds to 10 times the duration of the tier so as to ensure a POI of 10% which is sufficient for the characterization of fast FEVs.

For example, in the case of an object whose access to the network is of slow FEV type (with the following technical characteristics: hop rate equal to 100 hops/s and with tier duration (D_p) equal to 90 ms), the revisit time TR_{Object} is equal to $0.2 \cdot D_p$ i.e. 18 ms.

Generally the duration of revisit typically varies between 10 ms and 100 ms. These values are given by way of wholly nonlimiting illustration.

Determination of the duration of listening of the IABs

The duration of listening T_j of an IAB must be adapted to the various objects belonging to this IAB. The adaptation consists in taking the maximum of the durations of listening of each object belonging to the IAB, and this may be written:

$$(4) T_j = \max_{Object} \{T_{Object}\} \text{ with } Object \subset IAB \text{ where } \{T_{Object}\} \text{ is the set of values of listening time adapted for all the objects of the surveillance plan.}$$

Determination of the revisit time of the IABs

The revisit time TR_j for an instantaneous analysis band IAB must be adapted to the various objects belonging to this IAB. The adaptation consists in taking the maximum of the revisit times of each object belonging to the IAB, and this may be written:

$$(5) TR_j = \max_{Object} \{TR_{Object}\} \text{ with } Object \subset IAB \text{ where } \{TR_{Object}\} \text{ is the set of revisit time values adapted for all the objects of the monitoring plan.}$$

Determination of the priorities of the IABs

The priority corresponds to the IAB revisit number over the

duration T_{SEQ} of the scan sequence.

The priority is therefore fixed so as to master the revisit number and therefore the mean revisit time equal to the ratio $T_{seq} / PRIO$. The minimum priority is 1 (1 revisit per sequence), maximum of 10 (10 revisits per sequence).

The priority depends on the type of network access of the object, a way of proceeding is described hereinafter:

- For a network access of FF by alternation type, for which the POI is 100% whatever the revisit number, the priority is a minimum and equals 1;
- For an access network of slow FEV type, the priority is also 1;
- For a network access of fast FEV type, the priority is calculated in such a way that FEV is returned to at least once every second;
- For a network access of burst type (emission in the form of time slots or "burst"), the priority is calculated in such a way that burst emission is returned to more than once a second.

The priority of a band must be adapted to the various objects belonging to this IAB. The adaptation consists in taking the maximum of the priorities of each object belonging to the IAB.

20 Determination of the optimal sequence

On completion of the previous steps, the method has a list of L analysis bands, IAB, and for each analysis band of the following parameters: the central frequency, the bandwidth, the duration of listening, the revisit time, the priority:

- 25 (6) $\{F_j, B_j, PRIO_j, T_j, TR_j\} j=1, L$ with for an analysis band IAB_j
- F_j the central frequency which is given by the slicing into sensor band,
 - B_j the bandwidth given by the sensor,
 - $PRIO_j$ the Priority of the IAB_j determined by the method
 - 30 according to the invention,
 - T_j the duration of listening determined by the method according

to the invention,

- TR_j the revisit time determined by the method according to the invention.

Thereafter one determines a temporal scheduling of M analysis
 5 bands IAB (M greater than or equal to L) so as to obtain an optimized IAB temporal sequence T_{seq} satisfying notably the following three points:

- The sequence comprises the set of elements of the list of analysis bands,
- The duration of the sequence T_{seq} is less than a duration $TSEQ_{Max}$,
- The bands are revisited as per the priority given by the technical
 10 repository.

The construction of this sequence calls upon conventional algorithms for optimal allocation of resources (lagrangian relaxation, heuristic, which are well known to the person skilled in the art).

As soon as the sum of the durations of listening is greater than
 15 one of the revisit times, a single sequence may not make it possible to comply with the setpoints for T_j and TR_j . Having regard to the orders of magnitude of the durations of listening and revisit times, this case is the general case.

Two sequences are therefore constructed, using the two reception
 20 pathways:

- An optimal sequence "from a point of view of the duration of listening": this sequence optimizes the identification performance,
- An optimal sequence "from a point of view of the revisit time": this sequence optimizes the POI performance and network access
 25 characterization performance.

Determination of the optimal sequence over the duration-of-listening parameter

A sequence which is simple to construct is the sequence composed of the succession of the L IABs: $SEQ = F_1, F_2, \dots, F_L$. On the
 30 other hand it does not satisfy the point about compliance with the priorities. To do this, each IAB must be repeated $Prio_i$ times in the sequence. The

sequence thus defined is denoted $S = F1(Prio_1), F2(Prio_2), F3(Prio_3)$. This sequence possesses the following characteristics:

- The number of element of the sequence is equal to $M = \sum_{j=1}^L prio_k$
- The duration of the sequence T_{seq} is equal to $\sum_{j=1}^L Pr io_i * T_i$
- 5 ○ Any permutation of the M elements of the sequence constitutes a sequence which also satisfies the stated points: there are therefore M! solutions.

Among these solutions, the solution chosen is that which will optimize the probability of interception of the objects. Without a priori
10 knowledge about the duration of the communications and the number of call, the optimal sequence must satisfy the following complementary point: the revisited frames must be equidistributed in the sequence, and this may be written: $TR_j = T_{seq} / Prio_j$ (the mean revisit time corresponds to the duration of the sequence divided by the priority).

- 15 For example, consider the K=10 bands with the following respective priorities = [1, 1, 2, 2, 3, 3, 2, 2, 1, 1] then the optimal sequence calculated by the previous algorithm has the length M=18 and may be written

Seq = F5, F6, F3, F4, F7, F8, F5, F6, F1, F2, F9, F10, F5, F6, F3, F4, F7, F8

Determination of the optimal sequence over the revisit-time parameter

- 20 The aim of this sequence being to optimize the POI, the duration of listening is then fixed with the minimum listening value allowed by the sensor. This minimum value is denoted T_{min} .

The construction of this sequence requires that the various revisit times be multiples. Indeed if the revisit times are not multiples, the sequence
25 constructed by the algorithm may show temporal overlaps of the instantaneous bands, this not being physically achievable.

To avoid overlaps between the listening frames or duration of listening T_j , the method carries out at input a projection of the revisit times of the L instantaneous bands onto a time base having the appropriate
30 properties for avoiding temporal overlaps. Accordingly the values of this time

base must be multiples of one another. This time base is therefore of the form $2^k \times T_{\min}$ with $k=1$ to K i.e. $2T_{\min}$, $4T_{\min}$, $8T_{\min}$,

For example in the case where $T_{\min}$ is equal to 1 ms, the time base is 2, 4, 8, 32, 64, 128 ms. A revisit time of 70 ms will be projected onto
 5 the immediately lower value of this base i.e. 64 ms in the case hereinabove

In the case of a goniometry method, the minimum duration of listening is given by the minimum duration of goniometry (T_{gon}) and the time base for determining the revisit times for each of the instantaneous bands corresponds to a multiple of T_{gon} and then, the revisit times TR_j are
 10 thereafter defined as multiples $2 \times T_{\text{gon}}$, $4 \times T_{\text{gon}}$, etc.

Validation of the sequence

The criterion for validating the sequence is its duration. The processor will compare the value of the duration of the sequence T_{seq} found with a predefined threshold value T_{seqmax} . If the value T_{seq} is greater than the
 15 threshold value, then, the method will:

- decrease the priority of a band and the associated revisit time, and/or
- decrease the duration of listening of a band, that is to say remove one of the objects of interest in the calculation of the duration of listening.

The deleted object is the most penalizing object in terms of duration of
 20 listening,

and then return to the previous steps.

The method and the device according to the invention offer notably the following advantages: an improvement in the probability of interception, an improvement in object characterization and identification
 25 performance due to the fact that the duration of listening and duration of revisit parameters are determined taking account of the objects to be monitored.

CLAIMS

- 1 – Method for determining parameters for monitoring a set of instantaneous analysis bands IAB_j in a system (20) comprising at least two objects to be monitored and having in memory (23) at least the characteristics of the modes of emission of the said object and at least one receiver (21) adapted for receiving and analysing the signals received, characterized in that it comprises at least the following steps:
- 10 a) slicing the "monitoring plan" into L instantaneous analysis bands IAB_j,
 - b) determining the duration of listening $T_{Objecti}$ and the revisit time $TR_{Objecti}$ for each of the objects to be monitored by using waveform and network access information which is associated with the
 - 15 objects to be monitored and is contained in a technical repository,
 - c) thereafter determining the duration of listening T_j and the revisit time TR_j which is optimal for each of the said instantaneous bands IAB_j by using the values of the durations of listening $T_{Objecti}$ of the revisit times $TR_{Objecti}$ of the objects,
 - 20 d) determining at least one temporal scheduling of M instantaneous analysis bands with M greater than or equal to L, so as to obtain a temporal sequence T_{seq} of the instantaneous analysis bands which is adapted for satisfying at least the following points: the sequence comprises the set of L bands, the duration of the sequence T_{seq} is
 - 25 less than a duration T_{seqmax} .
- 2 – Method according to Claim 1, characterized in that the revisit time TR_j of a band IAB_j is determined as a function of the priority associated with the said band.

3 – Method according to Claim 1, characterized in that if the duration of T_{seq} is greater than a maximum threshold value then the method will decrease the priority of an instantaneous analysis band and the revisit time, and then it executes steps a) to d).

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4 – Method according to Claim 1, characterized in that if the duration of the sequence T_{seq} is greater than the value T_{seqmax} , the method decreases the duration of listening of a band by removing an object to be monitored, and then it executes steps a) to d).

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5 – Method according to Claim 1, characterized in that use is made of a first reception pathway for determining a first temporal scheduling over the duration of listening, and of a second reception pathway for determining a second temporal scheduling over the revisit time.

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6 – System (20) comprising at least two objects to be monitored and having in memory (23) at least the characteristics of the modes of emission of the said objects and at least one receiver (21, 25) adapted for receiving and analysing the signals received, characterized in that it comprises a processor (22) adapted for executing the steps of the method according to one of the characteristics 1 to 5.

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