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(54) **Title**: METHOD AND APPARATUS FOR SIMULTANEOUS SPECTRUM SENSING OF A PLURALITY OF WIRELESS CHANNELS USING CYCLOSTATIONARITY FEATURE DETECTION

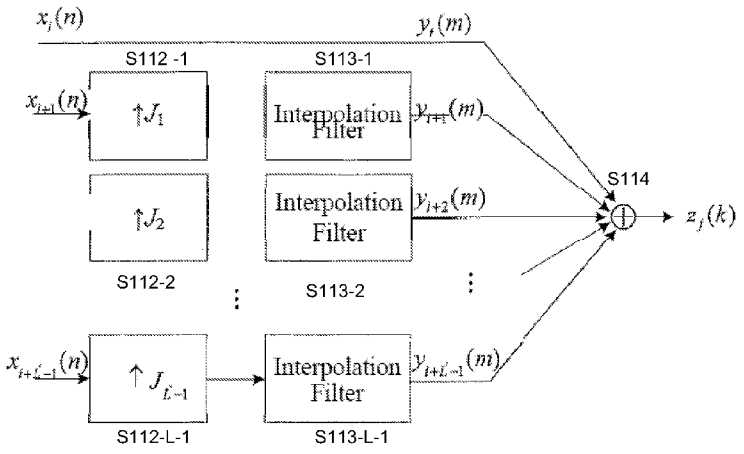


FIG. 5

(57) **Abstract**: A method and apparatus for determining the occupation of a plurality of radio - frequency channels, the method comprising: collecting baseband data streams from a plurality of L radio - frequency channels; performing upsampling on each data stream to modify a cyclo - stationarity parameter of each data stream; combining the upsampled data streams to generate a combined datastream; and performing cyclostationarity detection on the combined datastream to determine the occupation of the plurality of radio frequency channels.

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METHOD AND APPARATUS FOR SIMULTANEOUS SPECTRUM SENSING OF A PLURALITY OF WIRELESS CHANNELS USING CYCLOSTATIONARITY FEATURE DETECTION

Field of the Invention

The present invention relates in general to a method and apparatus for determining the occupation of a plurality of wireless channels. Particularly, but not exclusively the invention relates to spectrum sensing for cognitive radio systems.

Background of the Invention

Today's utilization of radio resources illustrates two absolutely contradictory phenomena. On the one hand, spectrum allocation for upcoming systems e.g. IMT-advanced, becomes difficult due to the scarcity of available spectrum. Indeed finding a paired spectrum for IMT-advanced FDD mode is said to be virtually unfeasible. On the other hand, cases of underutilization of licensed spectrum, e.g. large white space (or frequency holes) in TV bands, are subsequently reported in different countries, thereby motivating research and design to more efficient means of utilizing radio resources.

Cognitive radio (CR) is widely regarded as a promising solution to the current low usage of radio resources. It has the potential to utilize the large amount of unused licensed spectrum while swiftly vacating the occupied channel when a licensed user is detected. To make CR a reality, a series of techniques including spectrum sensing, real-time spectrum allocation, interference detection etc. are indispensable. Among these techniques, fast and reliable spectrum sensing is one of the most important elements for a CR system, since the first task of a CR terminal is to detect the unused frequency holes.

A large number of spectrum sensing algorithms have been reported in the literature. For example energy detector based spectrum sensing is described in the document by D. Cabric, et al., "Spectrum sensing measurements of pilot, energy, and collaborative detection" (Proc. IEEE Military Commun. Conf., 2006). This document describes a method of spectrum sensing by integrating the energy of the received signal and comparing the result with a threshold. Such an energy detector based approach is a popular way for spectrum sensing because of its low computational and implementation complexity. However, such energy-based

approaches always suffer from significant performance degradation when the signal-to-noise ratio (SNR) value decreases.

Waveform-based spectrum sensing for Chinese digital television terrestrial broadcasting system is described in the document by H. Chen, et al., "Spectrum sensing for DMB-T systems using PN" (Proc. IEEE Int. Conf. Commun., 2008). This document describes a method of spectrum sensing by correlating the received signal with the known pseudo noise (PN) sequence that is specified in the Chinese digital broadcasting standard. Such waveform-based approaches can be applied in a very low SNR situation, but they require that known patterns (e.g. a PN sequence in this case) should be inserted in the transmission signal which is not always satisfied in practical systems.

Cyclostationarity-based spectrum sensing is described in the document by A. V. Dandawate and G. B. Giannakis, "Statistical tests for presence of cyclostationarity" (IEEE Trans. Signal Process., Vol. 42, No.9, 1994), which proposes time-domain and frequency-domain optimal tests to detect the presence of cyclostationarity. Cyclostationarity-based spectrum sensing is also described in the document by H. Chen and W. Gao, "Apparatus and method for sensing a signal using cyclostationarity" (PCT patent, No.: WO 20081108797 Al), which proposes an Advanced Television Systems Committee (ATSC) signal detector by selecting one of a number of ATSC channels and determining the cyclostationary feature of the signal on the selected channel.

Cyclostationarity-based approach can be a good trade-off between performance and requirements on system's deployment, since it allows for detecting communication signals at low SNR regime while only assumes that parameter like symbol rate is known a priori.

Existing cyclostationarity-based methods, such as those described above are designed for detecting the occupation of a single channel, i.e., from an observation data stream $\mathbf{X} = [x(1)\ x(2)\ ...]$, computing the cyclic correlation or spectral correlation function (SCF) to infer whether or not the channel from which X was collected is occupied. However, in wireless systems such as ATSC, GSM and UMTS, a registered frequency band is composed of from several to several hundred channels (e.g. a GSM downlink band is divided into 120 channels and the bandwidth of a single channel is 200KHz). Employing the cyclostationarity based methods described above, the feasible way for a CR terminal that has to locate

the unused frequency spectrum is to detect the cyclostationarity of each channel one by one, which is inefficient as well as computationally intensive.

Summary of the Invention

Accordingly, it would be advantageous to provide a method of determining the occupation of a plurality of wireless channels which reduces the complexity or/and improves the efficiency of conventional cyclostationarity-based approaches when the occupation of multiple channels needs to be determined.

Accordingly, a first aspect of the invention provides a computer implemented method of determining the occupation of a plurality of radio-frequency channels, the method comprising: collecting baseband data streams from a plurality L of radio-frequency channels; performing a transformation on each data stream to modify a cyclo-stationary parameter of said each data stream; combining the transformed data streams to generate a combined datastream; and performing cyclostationarity detection on the combined datastream to determine the occupation of the plurality of radio frequency channels.

A second aspect of the invention provides an apparatus for determining the occupation of a plurality of radio-frequency channels, the apparatus comprising: data stream collection means for collecting baseband data streams from a plurality of L radio-frequency channels; transformation means for performing a transformation on each data stream to modify a cyclo-stationary parameter of the said data stream; combination means for combining the transformed data streams to generate a combined datastream; a cyclostationarity detection means for performing cyclostationarity detection on the combined datastream to determine the occupation of the plurality of radio frequency channels.

Since cyclostationarities of multiple channels are simultaneously detected using the single stream, complexity is significantly reduced.

- In embodiments of the method and the apparatus of the invention: the step of collecting baseband data streams comprises collecting the data streams in series at different time slots;
- each datastream is characterised by a central frequency and wherein each datastream is collected by tuning the frequency of a local oscillator of a receiving device receiving the datastream signals to the central frequency of each data stream sequentially.

- the step of collecting baseband data streams comprises collecting at least a portion of the data streams in parallel at the same time slot.
- the step of performing a transformation comprises upsampling, by an upsampling integer factor J, each sample of the respective data stream to derive transformed samples, and wherein (J-1) zeros are padded between every two samples of the data stream.
- the step of performing a transformation comprises upsampling on L' channels where L'=L/K and K is an integer; and wherein each datastream is upsampled by a different respective upsampling factor 1, J_1, J_2, ….$J_{L'-1}$ where ($1 < J_1, < J_2, < ….< J_{L'-1},$).
- the upsampling factor J_i (i=1,2, …, L'-1) may be a prime number or 4^n.
- the method further includes smoothing each upsampled signal by an interpolation filter.
- the step of combining the transformed data streams comprises linearly summing the data streams.
- the step of performing cyclostationarity detection on the combined datastream comprises: computing a discrete Fourier transform (FFT) on a segment of the combined data stream; correlating the discrete Fourier transformed segment for a plurality of RF channels; averaging the correlated segment; multiplying the averaged segment by a weighting factor; and comparing the weighted segment with a threshold parameter to determine occupation of the corresponding RF channel.
- the size N of the FFT is K x J_1 x J_2 x…. x$J_{L'-1}$,
- the step of correlation comprises computing the product $Z(f+\alpha)Z^*(f-\alpha)$ for $f= nf_{sample} / 2N$ ($n = 0, \pm1,.. ., \pm (N - l)$), wherein α is determined by the symbol rate of the signal.
- the step of averaging comprises averaging the output of the correlation step over Q datablocks by computing $1/Q \sum_{i=1}^{Q} Z_{(i)}(f+\alpha)Z^*_{(i)}(f-\alpha)$
- the step of multiplying the averaged segment by a weighting factor *w(f)* comprises computing according to the formula:

$$\sum_f \left| 1/Q \sum_{i=1}^{Q} Z_{(i)}(f+\alpha)Z^*_{(i)}(f-\alpha) \right|^2 w(f)$$

In embodiments of the invention the proposed method and system may jointly detect the cyclostationarity of multiple channels while keeping the computational complexity as low as that of a conventional cyclostationarity-based method when detecting only one channel thereby reducing the complexity and improving the efficiency.

At least part of the methods according to the invention may be computer implemented. The methods may be implemented in software on a programmable apparatus. They may also be implemented solely in hardware or in software, or in a combination thereof.

Since parts of the present invention can be implemented in software, the present invention can be embodied as computer readable code for provision to a programmable apparatus on any suitable carrier medium. A tangible carrier medium may comprise a storage medium such as a floppy disk, a CD-ROM, a hard disk drive, a magnetic tape device or a solid state memory device and the like. A transient carrier medium may include a signal such as an electrical signal, an electronic signal, an optical signal, an acoustic signal, a magnetic signal or an electromagnetic signal, e.g. a microwave or RF signal.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of example only, and with reference to the following drawings in which:-

Figure 1 is a flow chart of a method of determining occupation of a plurality of wireless channels according to a general embodiment of the invention;

Figure 2 is an apparatus for collecting datastreams according to an embodiment of the invention;

Figure 3 is an apparatus for collecting datastreams according to an alternative embodiment of the invention;

Figure 4 is an apparatus for upsampling datastreams according to an embodiment of the invention;

Figure 5 is an apparatus for performing datastream transformation according to an embodiment of the invention;

Figure 6 is an example of a SCF map of a signal with symbol rate f_s in which peaks corresponding to f_s $2f_s$ and $3f_s$ can be identified;

Figure 7 is an example of a SCF map according to an embodiment of the invention;

Figure 8 is an example of a SCF map according to an alternative embodiment of the invention;

Figure 9 is an apparatus for performing cyclostationarity for L' channels sharing a FFT module according to an embodiment of the invention; and

Figure 10 is an apparatus for performing cyclostationarity according to the prior art.

Detailed description

Embodiments of the invention will be described with reference to the Figures 1 to 9.

A method for determining occupation of multiple wireless radio frequency (RF) channels by jointly detecting the cyclostationarity of the multiple channels according to a general embodiment of the invention will be described with reference to Figure 1. The method comprises a number of main steps. Firstly in step S101, baseband data streams from a plurality of *L* channels x_1, $x_{2,\ldots}x_L$ are collected, where $x_i = [x_i(l), x_i(2)\ldots]$, i=1, 2,.....*L*. The data streams can be collected from the same RF front-end at different time slots or from different RF front-ends at the same time slot. Secondly in step S102 a signal transformation procedure such as, for example upsampling with carefully selected upsampling ratio is performed on L' channels (L' = L/K, where K is an integer). The purpose of this

operation is to enable different RF channels to have different symbol rates. Since cyclostationarity (e.g. correlated frequency) has a one to one mapping with the symbol rate, in a subsequent step, i.e. for cyclostationarity detection, different channels are resolvable because they have different symbol rates. In step S103 the L' transformed data streams are linearly combined (for example summed) to generate a single stream which can be referred to as an observation stream. Then a cyclostationarity test is performed on the observation stream in step S104 to determine the occupation of the L' channels. If K > 1, steps S102 to S104 are repeated K-1 times until the L channels are all detected. The advantage of the proposed method over conventional cyclostationarity-based methods is that complexity can be largely reduced.

The main steps of the proposed multi-channel spectrum sensing method are described in what follows. A number of embodiments are described for the implementation of each step . The input to a CR terminal is a RF signal containing a plurality of wireless RF channels which are characterized by their respective central frequency $f_1,\ldots..f_L$,

A first embodiment of an apparatus for implementing step S101 for collecting baseband data streams will be described with reference to Figure 2. Figure 2 is a schematic diagram of a RF-to-baseband module device 10, the main elements of which include an antenna 11 for receiving RF signals, a local oscillator (LO) 12, two down-converters 13-1, 13-2 and two analog-to-digital converters (ADC) 14-1, 14-2. In this embodiment data streams are collected using the same RF-to-baseband module 10 at different time slots by tuning the central frequency of the LO 12 to frequencies $f_1,\ldots..f_L$ sequentially.

A second embodiment of an apparatus for implementing step S101 for collecting baseband data streams will be described with reference to Figure 3. Figure 3 is a schematic diagram of a RF-to-baseband apparatus comprising an array of L RF-to-baseband modules 10 as illustrated in Figure 3. Data streams are collected using a plurality of RF-to-baseband modules but at the same time slot.

It will be appreciated that further embodiment of the apparatus can be easily derived by changing the number of element modules in the array, e.g. L/2, L/3 etc. The output of this module, i.e. datastreams $\mathbf{x}_1$, $\mathbf{x}_2$,... $\mathbf{x}_L$ are collected for further processing.

The objective of signal transformation step S102 is to change the cyclo-stationary feature of the original signal so that different signals may be resolved after linearly combining them to produce a single stream. In this particular embodiment of the invention, up-sampling by an integer factor is employed as the realization of signal transformation. It will however be appreciated that alternative transformations (e.g. rational up-sampling, integral down-sampling and rational down-sampling) that could also alter the cyclo-stationary feature may be applied within the scope of the invention.

The process of upsampling by a factor J is illustrated in Fig. 4. Firstly, in step S112 (J - 1) zeros are padded between every two samples of the original data sequence $x(n)$ to generate signal $v(m)$ which can be formulated as:

$$v(m)=\begin{cases} x(m/J) & m=nJ \\ 0 & otherwise \end{cases}$$

Then in step S113 signal $v(m)$is smoothed by an interpolation filter to produce the final output $y(m)$.

In the process of up-sampling and linearly combining according to an embodiment of the invention, originally received samples from L' channels i.e. $x_i(n)$, $x_{i+1}(n)$,… $x_{i+L'+1}(n)$ are respectively upsampled by different integer factors 1, J_1, J_2, …. $J_{L'-1}$ ($1 < J_1, < J_2, < ….< J_{L'-1},$) to derive the transformed samples $y_i(m)$, $y_{i+1}(n)$,… $y_{i+L'+1}(m)$ as illustrated in Fig. 5. The signal of the first channel $x_i(n)$is left unchanged and therefore the upsampling factor of the first branch is 1.

A proper choice of upsampling factor J_i's is essential to accurately identify the existence of multiple channels from the single linearly combined stream $z_j(k)$ due to the inter-signal inference in the spectral correlation domain, since peaks will appear at locations corresponding to $nf_s (n \in N)$ other than f_s, in the map of SCF as shown in Fig. 6, where f_s, is the symbol rate of the signal.

Two examples regarding the selection of J_i's are provided in the following. It will be appreciated that other choices which could avoid interference are also feasible and would also fall in the scope of this invention.

In the first example a prime number is employed as the upsampling factor, L'= 3, J_1 = 3, J_2 = 5 . The SCF map of the combined stream is shown in Fig. 7. Peaks at f_s / 5, f_s / 3 and f_s, can be identified, which respectively indicate the

presence of one channel. Since there is no integer *n* that satisfies *n* /5 f_s = *1* /3 f_s interference can be avoided.

In the second example the combination of prime number and 4^n as the upsampling factor L' = 4, J_1 = 3, J_2 = 4, J_3 = 7 is employed. The SCF map of the combined stream is shown in Fig. 8. In a similar way to the first example, peaks at f_s / 7, f_s / 4, f_s / 3 and f_s, can be identified and the occupation of four channels is indicated.

An embodiment of the apparatus implemented for the cyclostationarity detection for L' channels is depicted in Fig. 9, and comprises one N-point FFT module S115, L' correlating modules S116 , L' averaging modules S117 and L' feature detection modules S118. The N-point FFT module S115 computes the discrete Fourier transform on a segment of *z(k)* to derive *Z(m)*. According to the sampling property of FFT, i.e. only frequency component at nf_{sample} / 2*N* (*n = 0, ±1,.. ., ± (N - l)*) can be calculated, where f_{sample} is the sampling rate of the ADC and always a multiple of f_s, the FFT size *N* should be a number like K x J_1 x J_2 x.... x$J_{L'-1}$, where *K* is an integer.

Correlating module S116 computes the product

$Z(f+\alpha)Z^*(f-\alpha)$ for *f*= nf_{sample} / 2N (*n = 0, ±1,.. ., ± (N - l)*), where α is determined by the symbol rate of the signal.

Averaging module S117 averages the output of correlating module over Q consecutive data blocks, i.e. $\frac{1}{Q}\sum_{i=1}^{Q} Z_{(i)}(f+\alpha)Z_{(i)}^*(f-\alpha)$ to suppress the noise.

Feature detect module S118 adds the energy of the output of the averaging module multiplied by weighting factor

$$w(f), \text{ i.e. } \sum_f \left| \frac{1}{Q}\sum_{i=1}^{Q} Z_{(i)}(f+\alpha)Z_{(i)}^*(f-\alpha) \right|^2 w(f)$$

and compares the sum with a threshold to infer the occupation of the detected channel.

For comparison, the implementation of the conventional cyclostationarity detection method is also provided as shown in Fig.10, which includes an N-point FFT module, a correlating module, an averaging module and a feature detection module. From the two figures, it can be identified that the exemplary

implementation of the invention is made up of L' parallel branches, and each branch is part of the implementation of the conventional cyclostationarity detection method. Different than the parallel of L' conventional methods, the exemplary implementation employs only one FFT module which is the most computationally intensive component and shared among the L' branches. A rough estimation of the complexity reduction of the invention over the conventional method can be carried out as follows. For detecting L' channels, the invention needs Q FFTs while the conventional method needs L'Q FFTs. So the invention could save roughly $(L' - 1)Q / L'$ FFTs per channel detection.

Although the present invention has been described hereinabove with reference to specific embodiments, the present invention is not limited to the specific embodiments, and modifications will be apparent to a skilled person in the art which lie within the scope of the present invention. Many further modifications and variations will suggest themselves to those versed in the art upon making reference to the foregoing illustrative embodiments, which are given by way of example only and which are not intended to limit the scope of the invention, that being determined solely by the appended claims. In particular the different features from different embodiments may be interchanged, where appropriate.

In the claims, the word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality. The mere fact that different features are recited in mutually different dependent claims does not indicate that a combination of these features cannot be advantageously used. Any reference signs in the claims should not be construed as limiting the scope of the invention.

CLAIMS

1. A computer implemented method of determining the occupation of a plurality of radio-frequency channels, the method comprising:

collecting baseband data streams from a plurality of radio-frequency channels;

performing a transformation on each data stream to modify a cyclo-stationary parameter of said each data stream;

combining the transformed data streams to generate a combined datastream; and

performing cyclo-stationarity detection on the combined datastream to determine the occupation of the plurality of radio frequency channels.

2. A method according to claim 1, wherein the step of collecting baseband data streams comprises collecting the data streams in series at different time slots.

3. A method according to claim 2, wherein each datastream is characterised by a central frequency and wherein each datastream is collected by tuning the frequency of a local oscillator of a receiving device receiving the datastream signals to the central frequency of each data stream sequentially.

4. A method according to claim 1, wherein the step of collecting baseband data streams comprises collecting at least a portion of the data streams in parallel at the same time slot.

5. A method according to any one of the preceding claims, wherein the step of performing a transformation comprises upsampling, by an upsampling integer factor J, each sample of the respective data stream to derive transformed samples, and wherein (J-1) zeros are padded between every two samples of the data stream.

6. A method according to any one of claims 1 to 4, wherein baseband data streams are collected from L radio-frequency channels, and wherein the step of performing a transformation comprises:

upsampling on L' channels where L'=L/K and K is an integer; and wherein each datastream is upsampled by a different respective upsampling factor 1, J_1, J_2, ….$J_{L'-1}$ where (1 < J_1, < J_2, < ….<$J_{L'-1}$,).

7. A method according to claim 6, wherein the upsampling factor J_i (i=1,2, …, L'-1) is a prime number.

8. A method according to claim 6, wherein the upsampling factor J_i (i=1,2, …, L'-1) is a prime number or 4^n.

9. A method according to any one of claims 5 to 8, further comprising smoothing each upsampled signal by an interpolation filter.

10. A method according to any one of the preceding claims, wherein the step of combining the transformed data streams comprises linearly summing the data streams.

11. A method according to any one of the preceding claims, wherein the step of performing cyclostationarity detection on the combined datastream comprises:

computing a discrete Fourier transform (FFT) on a segment of the combined data stream;

correlating the discrete Fourier transformed segment for a plurality of RF channels;

averaging the correlated segment;

multiplying the averaged segment by a weighting factor; and

comparing the weighted segment with a threshold parameter to determine occupation of the corresponding RF channel.

12. A method according to claim 11, wherein the size N of the FFT is K x J_1 x J_2 x…. x$J_{L'-1}$,

13. A method according to claim 11 or 12, wherein the step of correlation comprises computing the product $Z(f+\alpha)Z^*(f-\alpha)$ for $f = nf_{sample} / 2N$ ($n = 0, \pm 1, .., \pm (N - l)$), wherein α is determined by the symbol rate of the signal.

14. A method according to any one of claims 11 to 13, wherein the step of averaging comprises averaging the output of the correlation step over Q datablocks by computing $1/Q \sum_{i=1}^{Q} Z_{(i)}(f+\alpha)Z^*_{(i)}(f-\alpha)$

15. A method according to any one of claims 11 to 14, wherein the step of multiplying the averaged segment by a weighting factor *w(f)* comprises computing according to the formula:

$$\sum_f \left| 1/Q \sum_{i=1}^{Q} Z_{(i)}(f+\alpha)Z^*_{(i)}(f-\alpha) \right|^2 w(f)$$

16. An apparatus for determining the occupation of a plurality of radio-frequency channels, the apparatus comprising:

data stream collection means for collecting baseband data streams from a plurality of L radio-frequency channels;

transformation means for performing a transformation on each data stream to modify a cyclo-stationary parameter of the said data stream;

combination means for combining the transformed data streams to generate a combined datastream; and

cyclostationarity detection means for performing cyclostationarity detection on the combined datastream to determine the occupation of the plurality of radio frequency channels.

17. A computer program product for a data-processing device, the computer program product comprising a set of instructions which, when loaded into the data-processing device, causes the device to perform the steps of the method as claimed in any of claims 1 to 15

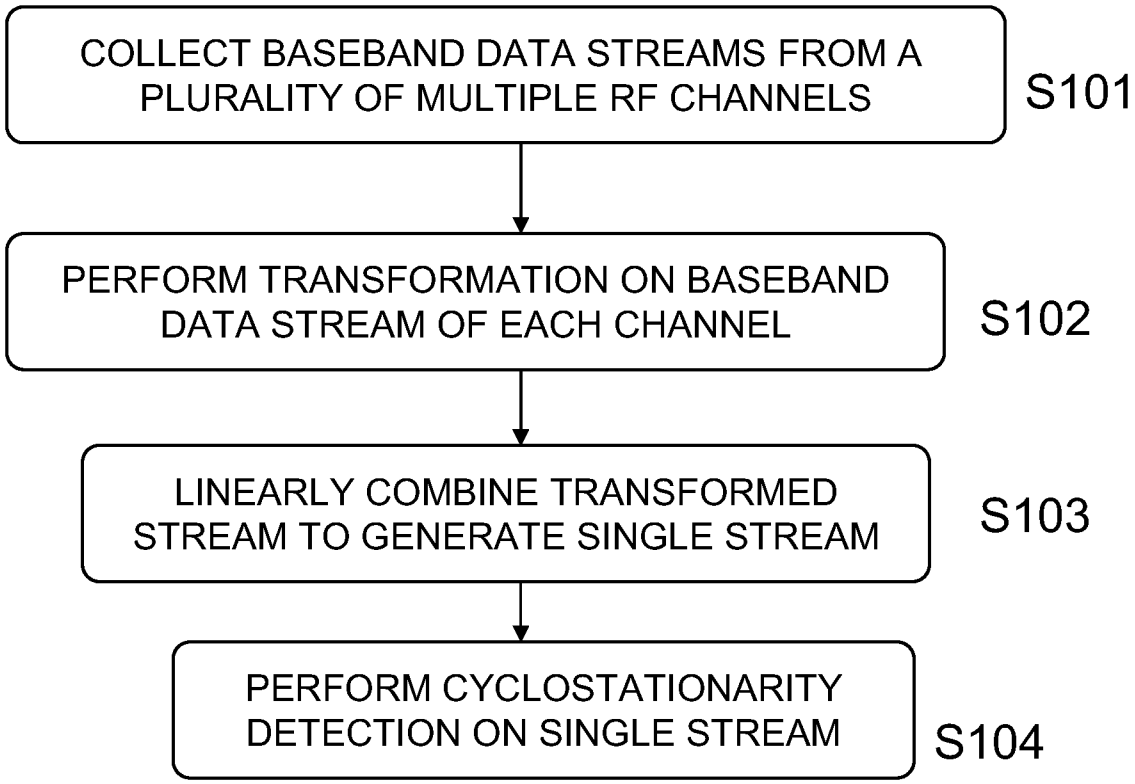

COLLECT BASEBAND DATA STREAMS FROM A PLURALITY OF MULTIPLE RF CHANNELS
S101
PERFORM TRANSFORMATION ON BASEBAND DATA STREAM OF EACH CHANNEL
S102
LINEARLY COMBINE TRANSFORMED STREAM TO GENERATE SINGLE STREAM
S103
PERFORM CYCLOSTATIONARITY DETECTION ON SINGLE STREAM
S104

FIG. 1

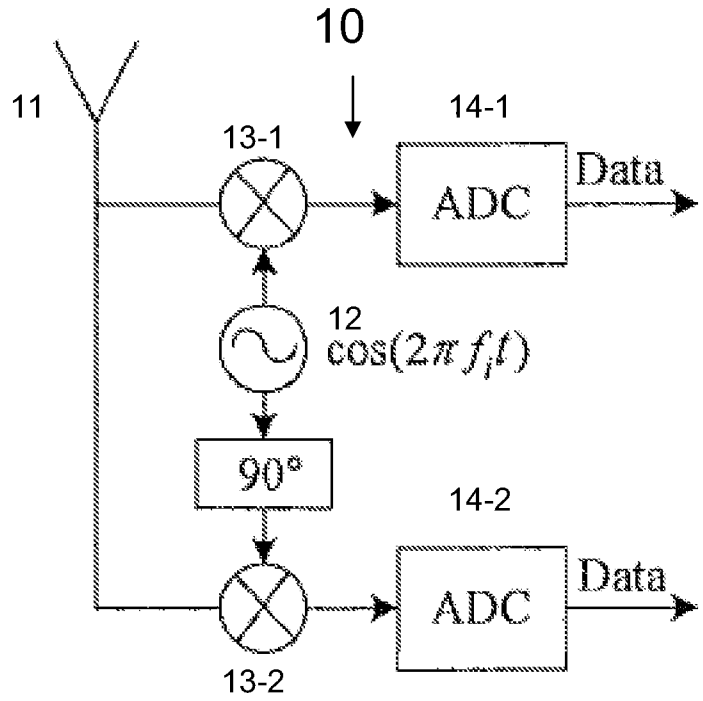

10
11
13-1
14-1
ADC
Data
12
$\cos(2\pi f_1 t)$
90°
14-2
ADC
Data
13-2

FIG. 2

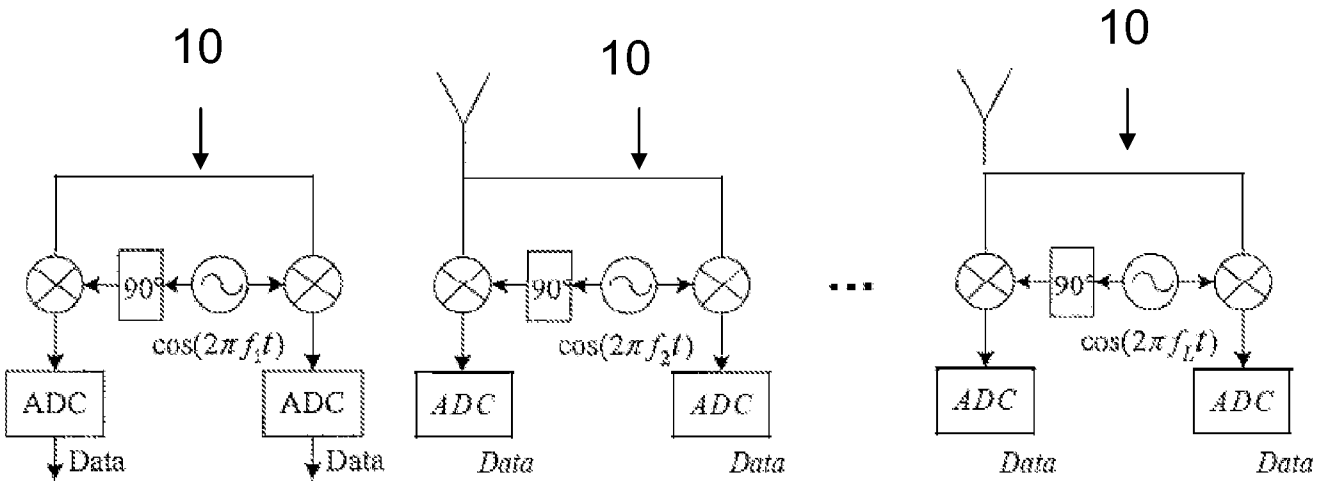

10
10
10
90
90
90
$\cos(2\pi f_1 t)$
$\cos(2\pi f_2 t)$
$\cos(2\pi f_1 t)$
ADC
ADC
ADC
ADC
ADC
ADC
Data
Data
Data
Data
Data
Data

FIG. 3

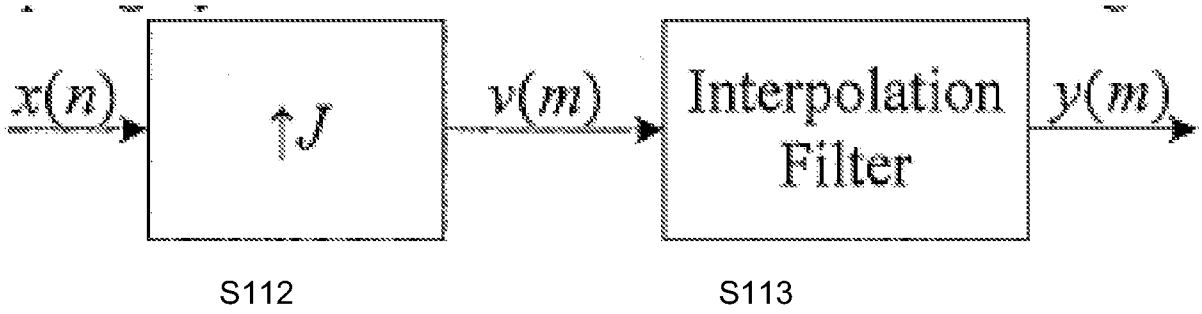

x(n)
↑J
v(m)
Interpolation Filter
y(m)
S112
S113

FIG. 4

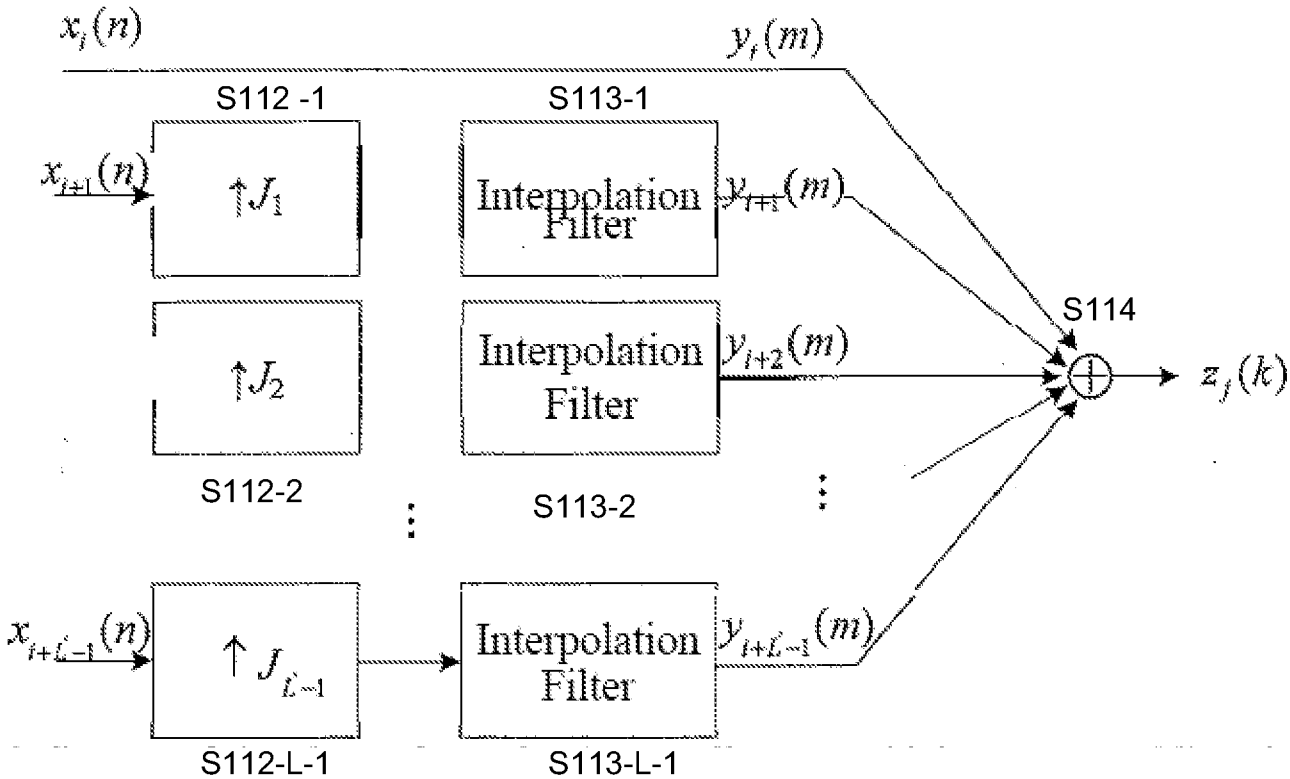

$x_i(n)$
$y_i(m)$
S112 -1
S113-1
$x_{i+1}(n)$
$\uparrow J_1$
Interpolation Filter
$y_{i+1}(m)$
S114
$\uparrow J_2$
Interpolation Filter
$y_{i+2}(m)$
$z_i(k)$
S112-2
S113-2
$x_{i+L-1}(n)$
$\uparrow J_{L-1}$
Interpolation Filter
$y_{i+L-1}(m)$
S112-L-1
S113-L-1

FIG. 5

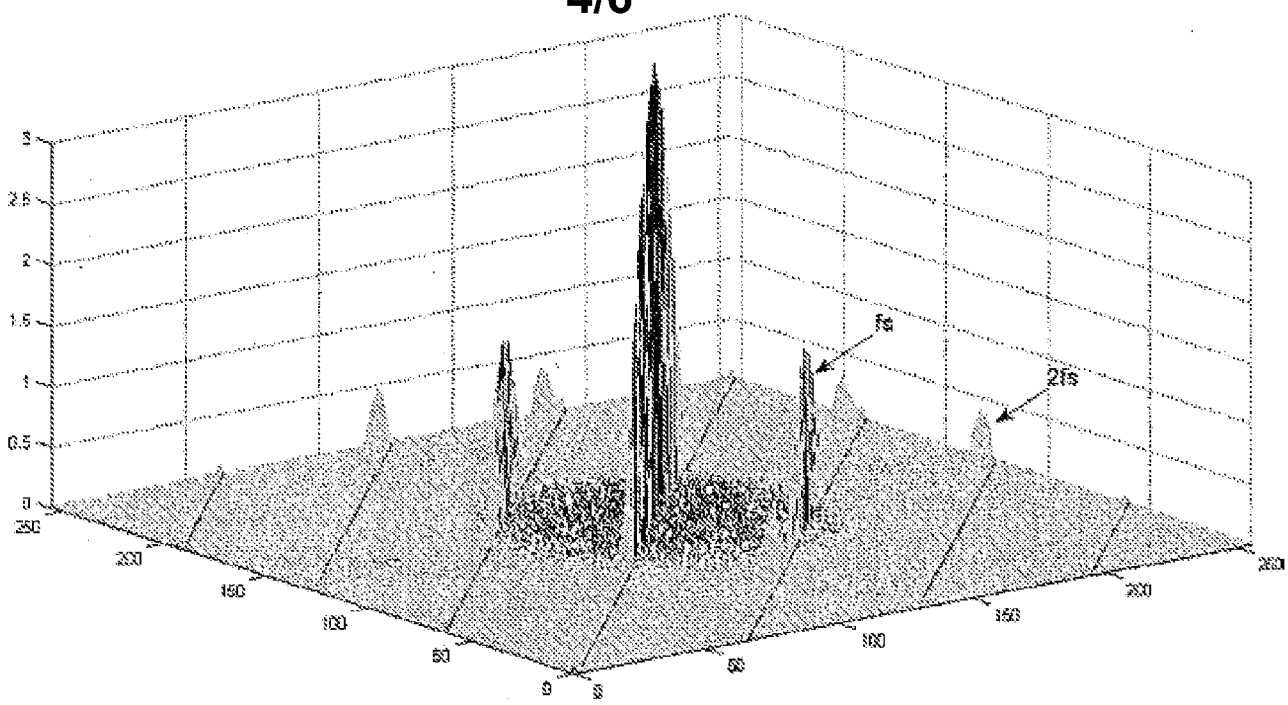
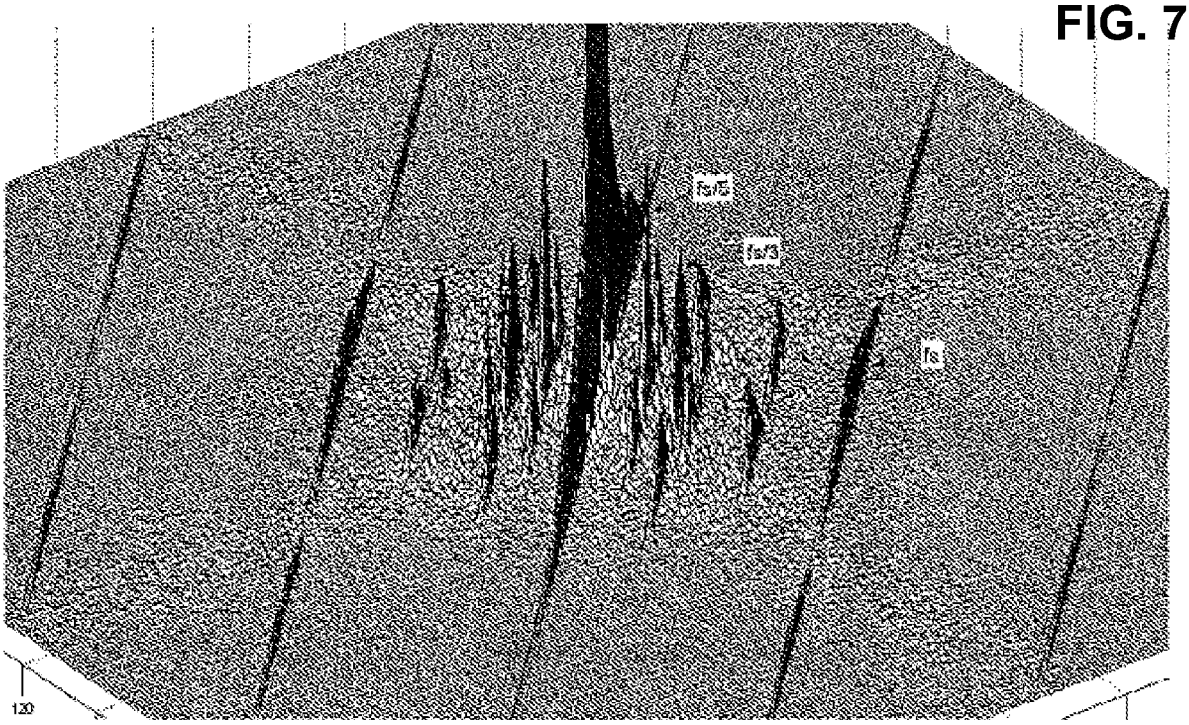


FIG. 6

FIG. 7



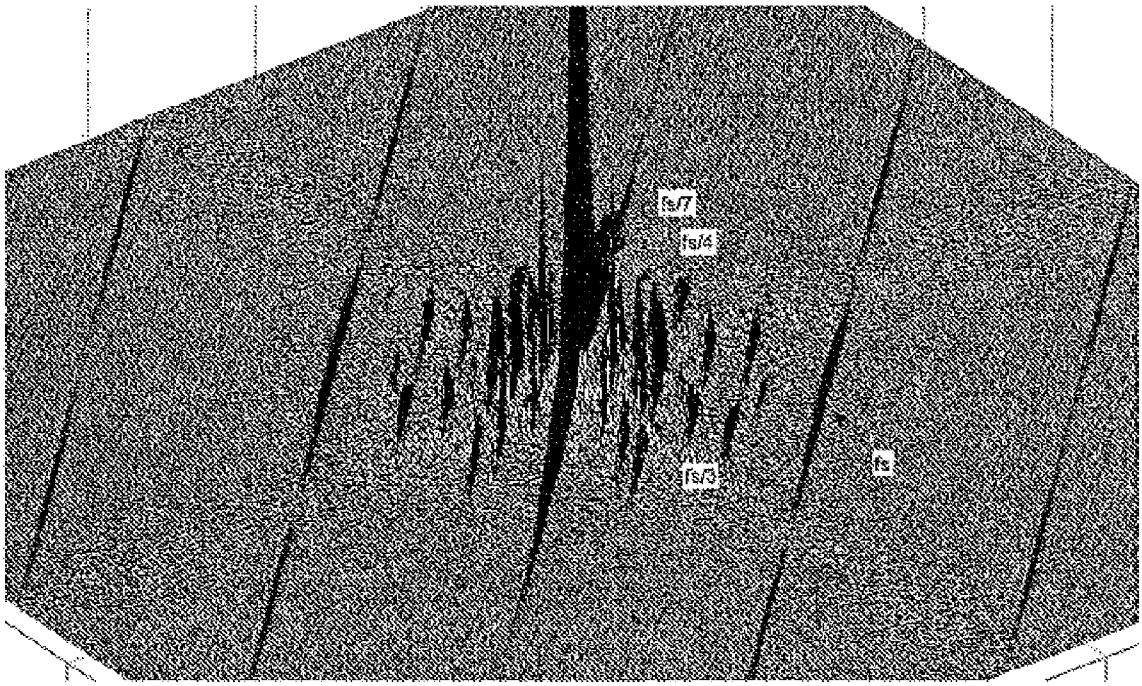

fs/7
fs/4
fs/3
fs

FIG.8

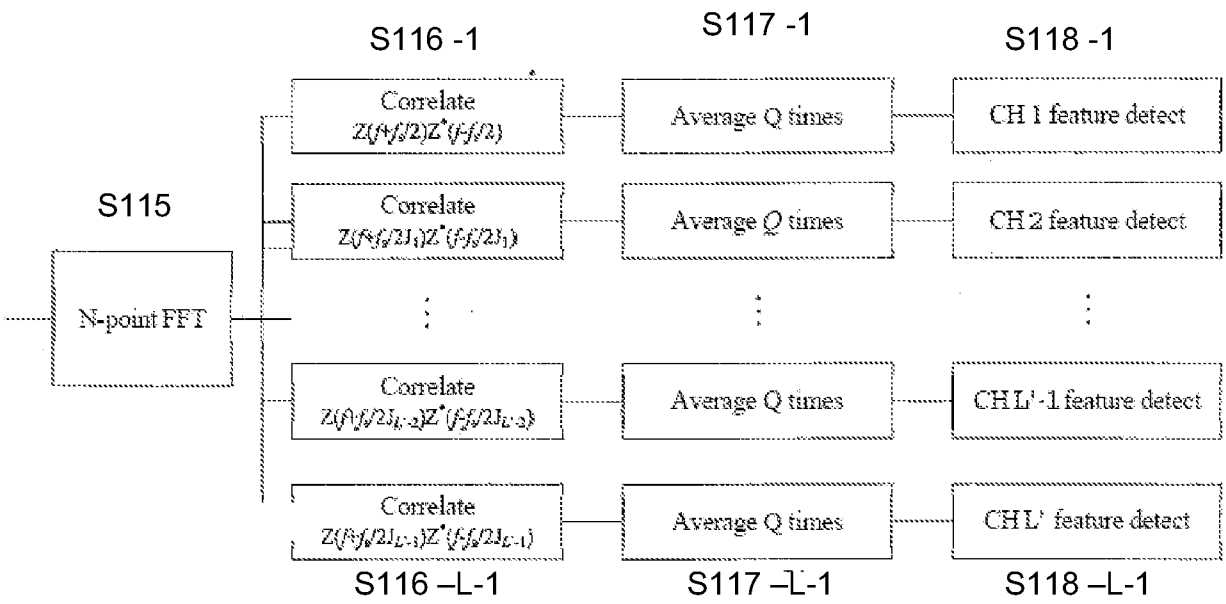

S116 -1
S117 -1
S118 -1
S115
Correlate
Average Q times
CH 1 feature detect
Correlate
Average Q times
CH 2 feature detect
N-point FFT
Correlate
Average Q times
CHL'-1 feature detect
Correlate
Average Q times
CHL' feature detect
S116 –L-1
S117 –L-1
S118 –L-1

FIG.9

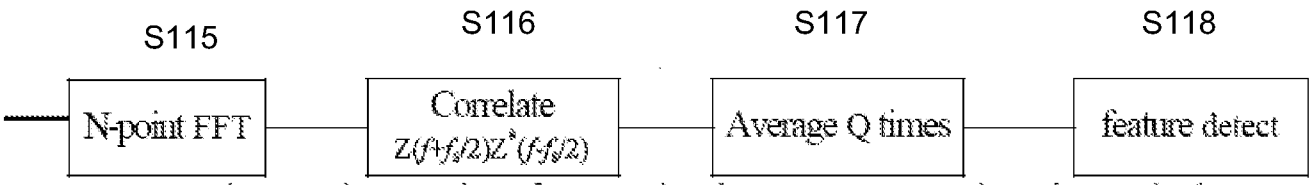

S115
S116
S117
S118
N-point FFT
Correlate
$Z(f+f_s/2)Z^*(f-f_s/2)$
Average Q times
feature detect

FIG.10

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2011/002706

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L27/00 H04L27/26
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	US 2008/165680 A1 (CHANG SOO-YOUNG [US]) 10 July 2008 (2008-07-10) abstract paragraph [0071] - paragraph [0076] figure 8	1-4,13, 14,16,17 5 6-12,15

Y A	WO 2007/083269 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; CHALLAPALI KIRAN [US]; DONG BIN []) 26 July 2007 (2007-07-26) abstract page 1 - page 6	5 1-4,6-17

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

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 February 2012	06/03/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Dhibi, Youssef

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2011/002706

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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