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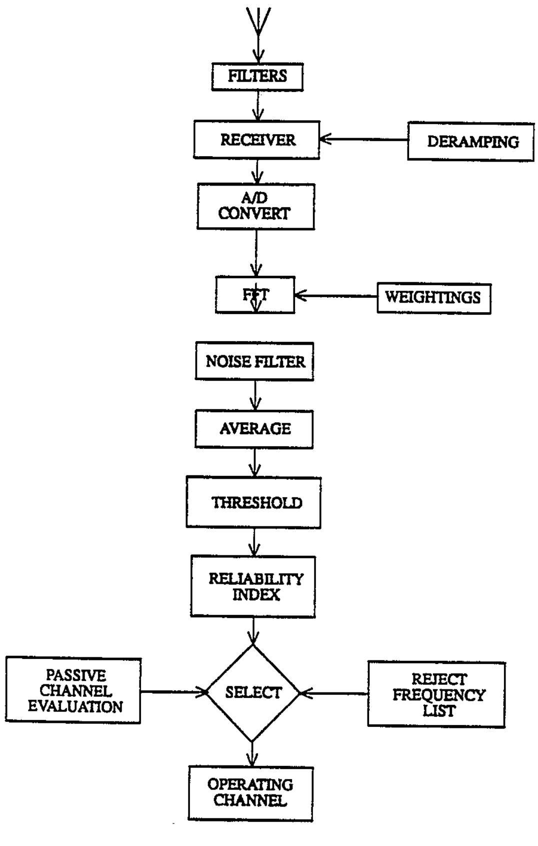
(54) Title: OPERATIONAL CHANNEL SELECTION

(57) Abstract

A method of selecting suitable channels for operation in a frequency band comprising the steps of obtaining real time channel occupancy from a frequency surveillance system, applying a threshold to determine those channels which are occupied, determining a reliability index for each channel, forming a list of available channels, sorting and selecting available channels from the list of available channels based on operational requirements, evaluating the selected channels to determine the best channel in which to operate and operating on the determined channel. The reliability index is defined by $R_j = [\mu C_j + \Delta(1-\mu)C_{j-1}]C_j$ where C_j is an occupancy factor and is either 0 for an occupied channel or 1 for an unoccupied channel, ∝ is a weighting factor and Δ is a data lifetime factor.



OPERATIONAL CHANNEL SELECTION

This invention relates to radio frequency surveillance systems and in particular to a method and apparatus for monitoring the occupancy of a range of channels in an operating band and utilizing an adaptive reliability index to aid in the selection of clear channels. In addition the invention relates to a system of selecting an appropriate operating frequency to minimise the effects of interference.

It is well known by communicators using the high frequency (HF) bands that performance depends largely on frequency selection. This is due in large part to the vagaries of the ionosphere. For HF skywave radars, or Over-the-Horizon Radars (OTHR), it is particularly important that the optimum frequency is chosen for the task at hand. This leads to a requirement for real-time frequency advice on a continuous basis.

The problem is that the high frequency band from 5 to 45 MHz can be particularly congested from both man-made and natural sources. At frequencies below about 10 MHz lightning discharges distributed around the earth generate noise which inhibits use of this region of the HF spectrum. This is particularly true at night when ionospheric conditions support propagation over long distances. By contrast the noise above 20 MHz is almost entirely galactic in origin and displays little temporal variation.

In addition to the broad environmental noise there is narrow band congestion caused by other HF radio transmissions. These transmissions will generally be random in nature and of varying duration. Some transmissions will however be regular, occuring at say 1700 hours every day and lasting for a well defined period.

An HF system will normally consist of one or more antennas connected to one or more receivers. The antennas may be omnidirectional or may be physically arranged to have a degree of directionality. In addition, various analogue techniques can be used to form receiver beams having a defined direction and width. The signals from the antennas are often subjected to some degree of analogue filtering before reaching the receiver. The receiver output can be converted from analogue to digital form before undergoing further processing and analysis. Once in digital form phase weighting techniques can be used to form multiple receiver beams.

It is an object of this invention to provide a method and apparatus for monitoring a frequency band and providing an indication of clear channels suitable for HF communication or radar operations. It is a further object of this invention to provide a technique that will provide real time advice on clear channels available for use and a reliability index which indicates the likelihood of the channel remaining clear for an extended period of time.

The invention operates in two parts. Firstly the frequency surveillance system operates in a channel occupancy mode to monitor activity across the HF spectrum and identify unoccupied channels. A database of unoccupied channels is maintained. Secondly, a clear channel method selects suitable operating channels from the database of unoccupied channels. The clear channel method uses a reliability index to aid in this selection. The background atmospheric noise level is measured in selected unoccupied channels.

In the channel occupancy mode the system scans the entire band to determine the occupancy of each channel. In the past the occupancy of channels in a frequency band has been determined by using narrow band filters and directly measuring the power received through the filter. The problem with this method is that it is limited by the fidelity of the filters and it is inflexible. Furthermore, use of a narrow band filter limits the rate at which the system can be swept across the HF band.

It is desirable to operate any HF system at the optimum signal to noise ratio. For an OTHR which relies on backscattered signals this translates to a requirement to select an operating frequency with an acceptable clutter to noise ratio. Clutter refers to the signal backscattered from the earth's surface.

A number of sub-systems such as sounders provide information for determining the optimum operating frequency band for a given combination of ionospheric conditions. Once a frequency band has been selected however, an unoccupied channel must be chosen in which to operate. This invention is designed to aid in this choice.

Therefore, in one form of the invention there is proposed a method of identifying suitable channels for operation in a frequency band consisting of a plurality of frequency channels comprising the steps of:
accumulating analogue signals from a plurality of scans over the frequency band;
transforming the signals;
averaging the transformed signals of a number of the scans;
scaling the averaged transformed signals to absolute signals;
determining the amplitude of the absolute signal in a frequency channel; and
displaying the signal amplitude against frequency on a visual display means.

In preference the step of transforming the signals includes converting the analogue signals to digital signals and applying a Fourier transform to the digital signals to produce transformed signals.

In preference a fast Fourier transform is used to transform the digital signals into a plurality of signals at a desired resolution across a receiver bandwidth.

In preference each scan is checked for the effect of impulsive noise and effected signals are excluded. The remaining signals in a number of scans are averaged. In preference the number of scans that are averaged is ten.

In preference signals are checked for the effects of impulsive noise by comparing the amplitude of signals at a given frequency from a number of scans. Signals which occur in a small minority of the scans are assumed to be due to impulsive noise and are therefore removed.

The resulting digital signal amplitudes provide a measure of the level of occupancy in each channel across a frequency band. The amplitudes are displayed graphically with frequency as the independent variable.

In a further form of the invention there is proposed a method of selecting clear channels for operation in a frequency band consisting of a plurality of frequency channels comprising the steps of:
identifying suitable channels for operation;
determining a reliability index for each channel;
forming a list of available channels;
sorting and selecting available channels from the list of available channels based on operational requirements;

evaluating the selected channels to determine the best channel in which to operate and operating on the determined channel.

In a still further form of this invention there is proposed a method of selecting clear channels in a frequency band comprising the steps of:
obtaining real time channel occupancy and background noise data from a frequency surveillance system;
applying a threshold to determine those channels which are occupied;
determining a reliability index for each channel;
forming a list of available channels;
sorting and selecting available channels from the list of available channels based on operational requirements;
evaluating the selected channels to determine the best channel in which to operate and operating on the determined channel.

In preference the threshold can be set by an operator or may be set by an expert system.

In preference a reject frequency list is maintained and referred to when selecting appropriate operating frequencies.

The reject frequency list contains two types of frequencies. Firstly there are those frequencies which are always prohibited due to designation as international distress frequencies or due to constant use by other HF operators. Secondly there are those frequencies which are generally occupied a high percentage of the time or always occupied at certain times. The aim of the reject frequency list is to prevent operation at frequencies which have a high probability of suffering radio frequency interference. Thus if a channel is known to be occupied at a certain time each day it will not be selected at that time, even if all other considerations identify it as the best channel.

In preference a passive channel evaluation method is used to evaluate the selected channels. The passive channel evaluation method utilizes an antenna and receiver to look at the selected channels at higher resolution than the frequency surveillence system and thereby may select between two channels which appear equivalent from all other considerations.

On a continual basis channel histories are established by determining a reliability index R_j defined as:

$$R_j = [\mu C_j + \Delta(1-\mu)C_{j-1}]C_j$$

where C_j is the occupancy factor and is either 0 for an occupied channel or 1 for an unoccupied channel, ∝ is a weighting factor and Δ is a data lifetime factor.

The reliability index will be zero for a channel which is considered to be occupied and will approach unity for a channel which has been unoccupied for an extended period, the rate of transition being determined by the weighting factor ∝. In effect, ∝ is a time constant which can be set to change the time that a channel must remain unoccupied to be considered as reliable.

The data lifetime factor Δ sets the relative weight given to data collected during a recent radar operation compared to an earlier operation and will be a function of time.

The radar tasking system determines the optimum operating frequency for the ionospheric conditions and the desired task. Suitable channels are selected from the list determined by the clear channel method and a passive radar is used to evaluate each of the possible channels and to select the most appropriate channel.

In a still further form of this invention there is provided a frequency surveillance apparatus consisting of a plurality of omnidirectional antennas, a plurality of directional antennas, a reference noise source for providing a signal for calibration, a radio frequency receiver input unit for selecting input from an appropriate antenna, a filter unit to reduce the effects of radio frequency interference, a receiver unit for tuning across the frequency band, an analogue to digital conversion unit and a processor unit to transform and average digitised signals.

In preference the apparatus may also have a local oscillator unit which supplies a signal to the receiver for use in deramping the received signal.

In preference the reference noise source provides a calibration signal of -170 dBW/Hz.

For a better understanding of this invention a preferred embodiment will now be described with reference to the attached drawings in which:

FIG. 1 is a schematic view of a surveillance system,

FIG. 2 is a flow chart of the method of selecting an operating channel,

FIG. 3 is an example of one output of the method, and

FIG. 4 shows a hypothetical graph of the variation of a reliability index with time.

The invention will be described with reference to a known Over-the-Horizon Radar system, although it will be appreciated that the invention is in no ways limited to this application.

The surveillance system is shown in FIG. 1 and consists of a receiver input unit which is able to select an input from any one of eight beams via a beam select unit, from either of two omnidirectional.antennas, a reference noise source or a diagnostic test signal generator. The receiver input unit is connected via suitable filters to a single receiver. The method only utilizes one of the omnidirectional antennas and the reference noise source for calibration.

The receiver has a bandwidth of 20 kHz and the output is digitised at a sampling rate of 51.2 kHz. Data is acquired over an interval of 5 ms and subjected to spectral analysis, leading to a fundamental frequency resolution of 200 Hz. The gain and frequency of the receiver are under direct computer control and the entire data acquisition process is coded in such a manner that it maximises the effective rate at which data can be acquired.

To calibrate the data a noise signal is injected into the receiver at a known level (-170 dBW/Hz) at the beginning of each set of observations. Noise signal samples are acquired over a 5 msec interval as above and a fast Fourier transform is used to transform the data to a power spectrum. To remove the effects of passband fluctuations this process is repeated a number of times and the average is taken. The resultant power spectrum is an absolute calibration of the response characteristics of the receiver system and is therefore used to scale all subsequent spectral estimates.

A flowchart of the method is shown in FIG. 2. Signal levels are measured in all 2 kHz channels by stepping the receiver in 20 kHz steps across the spectrum with the receiver connected to an omnidirectional antenna. Data is acquired for 5 msec in each 20 kHz band, converted to digital form and transformed using a fast Fourier transform to give power at 200 Hz resolution. Ten adjacent 200 Hz spectral estimates are averaged to provide power estimates at 2 kHz resolution in order to reduce variance. Ten scans are made across the HF spectrum from 4 to 30 MHz with all 130000 spectral estimates stored in a multiport memory. The 10 scans for each 20 kHz step are examined in order to identify any scans which have been effected by impulsive noise and these are rejected. The remaining scans are averaged in order to further reduce the variance in the estimates.

FIG. 3 shows a typical signal level display measured over the 11 to 12 MHz band. It is clear from the display those channels that are occupied and those that are clear.

A threshold is applied to the data to classify each channel as occupied or unoccupied and the appropriate occupancy factor is associated with each channel. A reliability index is calculated for each channel. Channels with the highest reliability index are checked against the reject frequency list and if not rejected are chosen for operation since they are known to have been unoccupied for an extended period of time.

The temporal behaviour of the reliability index is shown in FIG. 4. The horizontal axis 1 represents time and the vertical axis 2 represents R_j which varies between zero when the channel is occupied 3 and one. When the channel is detected as being unoccupied the reliability index takes on a non-zero value. As time progresses and the channel remains unoccupied the index will increase at a rate determined by the value of $\propto$ until it asymptotes to one. The solid line 4 represents the change in reliability index over time for a weighting factor of $\propto = 0.3$ and the dashed line 5 is for $\propto = 0.5$.

Throughout this specification the purpose has been to illustrate the invention and not to limit this.

CLAIMS:

1. A method of identifying suitable channels for operation in a frequency band consisting of a plurality of frequency channels comprising the steps of:
accumulating analogue signals from a plurality of scans over the frequency band;
transforming the signals;
averaging the transformed signals of a number of the scans;
scaling the averaged transformed signals to absolute signals;
determining the amplitude of the absolute signal in a frequency channel and displaying the signal amplitude against frequency on a visual display means.

2. The method of claim 1 in which the step of transforming the signals includes converting the analogue signals to digital signals and applying a Fourier transform to the digital signals to produce transformed signals.

3. The method of claim 1 in which the averaged transformed signals are scaled by comparison with signals received from a reference noise source.

4. The method of claim 3 in which the reference noise source provides noise at a magnitude of -170 dBW/Hz.

5. The method of claim 1 in which each scan is checked for the effect of impulsive noise prior to the step of averaging the transformed signals and affected signals are excluded.

6. A method of selecting clear channels for operation in a frequency band consisting of a plurality of frequency channels comprising the steps of:
identifying suitable channels for operation;
determining a reliability index for each channel;
forming a list of available channels;
sorting and selecting available channels from the list of available channels based on operational requirements;
evaluating the selected channels to determine the best channel in which to operate and operating on the determined channel.

7. The method of claim 6 in which the step of identifying suitable channels for operation includes:
accumulating analogue signals from a plurality of scans over a frequency band;

transforming the signals;
averaging the transformed signals of a number of the scans;
scaling the averaged transformed signals to absolute signals;
determining the amplitude of the absolute signal in each frequency channel; and
applying a threshold to determine those channels which are occupied.

8. The method of claim 6 in which the reliability index, R_j, is determined from

$$R_j = [\mu C_j + \Delta \ (1-\mu) C_{j-1}] C_j$$

where C_j is an occupancy factor being either 0 for an occupied channel or 1 for an unoccupied channel, $\propto$ is a weighting factor and Δ is a data lifetime factor.

9. The method of claim 6 further characterized in that the list of available channels is determined by reference to the reliability index and a reject frequency list.

10. The method of claim 6 in which the selected channels are evaluated by a passive channel evaluation method.

11. The method of claim 7 in which the passive channel evaluation method utilizes an antenna and receiver to analyse the selected channels at higher resolution.

12. A frequency surveillance apparatus for selecting clear channels for operation in a frequency band consisting of a plurality of frequency channels, consisting of:
an omnidirectional antenna;
a reference noise source adapted to provide a signal for calibration;
a radio frequency receiver input unit adapted to select input from either the antenna or the reference noise source;
a filter unit adapted to reduce the effects of radio frequency interference;
a receiver unit adapted to tune across the frequency band and receive analague signals from the input selected by the receiver input unit;
an analogue to digital conversion unit adapted to convert the analogue signals received by the receiver to digital signals;

a processor unit adapted to transform digital signals, calculate a reliability index and select a clear channel for operation; and
a visual display means to display the output from the processor unit.

13. The apparatus of claim 12 having a local oscillator unit adapted to supply a signal to the receiver unit for use in deramping the received signal.

14. The apparatus of claim 12 in which the reference noise source provides a calibration signal of -170 dBW/Hz.

15. The apparatus of claim 12 in which the processor unit is adapted to:
transform digital signals by applying a Fourier transform;
average the transformed signals;
scale the averaged transformed signals to absolute signals;
determine the amplitude of the absolute signal in each frequency channel; and
apply a threshold to determine those channels which are occupied.

16. The apparatus of claim 12 further characterised in that the processor unit is adapted to :
calculate a reliability index, R_j, of the form

$$R_j = [\mu C_j + \Delta \ (1-\mu) C_{j-1}] C_j$$

where C_j is an occupancy factor being either 0 for an occupied channel or 1 for an unoccupied channel, $\propto$ is a weighting factor and Δ is a data lifetime factor;
utilize the reliability index to select an operating channel; and
provide as output to the visual display means an indication of the selected channel.

17. A method of selecting clear channels in a frequency band comprising the steps of:
obtaining real time channel occupancy and background noise data from a frequency surveillance system;
applying a threshold to determine those channels which are occupied;
determining a reliability index for each channel;
forming a list of available channels;
sorting and selecting available channels from the list of available channels

based on operational requirements;
evaluating the selected channels to determine the best channel in which to operate and operating on the determined channel.

18. A method as herein described with reference to the attached figures.

19. An apparatus as herein described with reference to the attached figures.

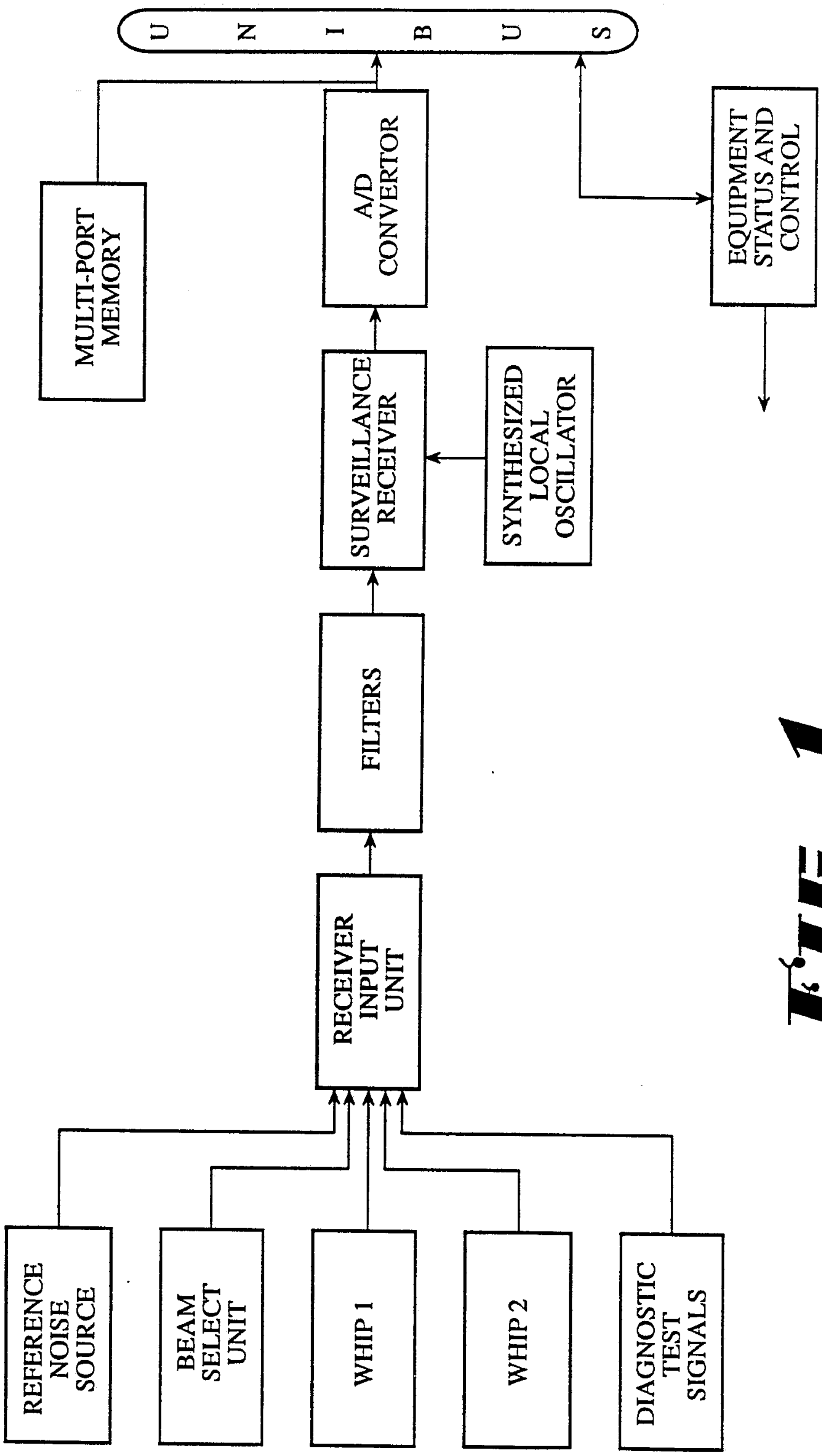

UNIBUS
MULTI-PORT MEMORY
A/D CONVERTOR
EQUIPMENT STATUS AND CONTROL
SURVEILLANCE RECEIVER
SYNTHESIZED LOCAL OSCILLATOR
FILTERS
RECEIVER INPUT UNIT
REFERENCE NOISE SOURCE
BEAM SELECT UNIT
WHIP 1
WHIP 2
DIAGNOSTIC TEST SIGNALS

FIG 1

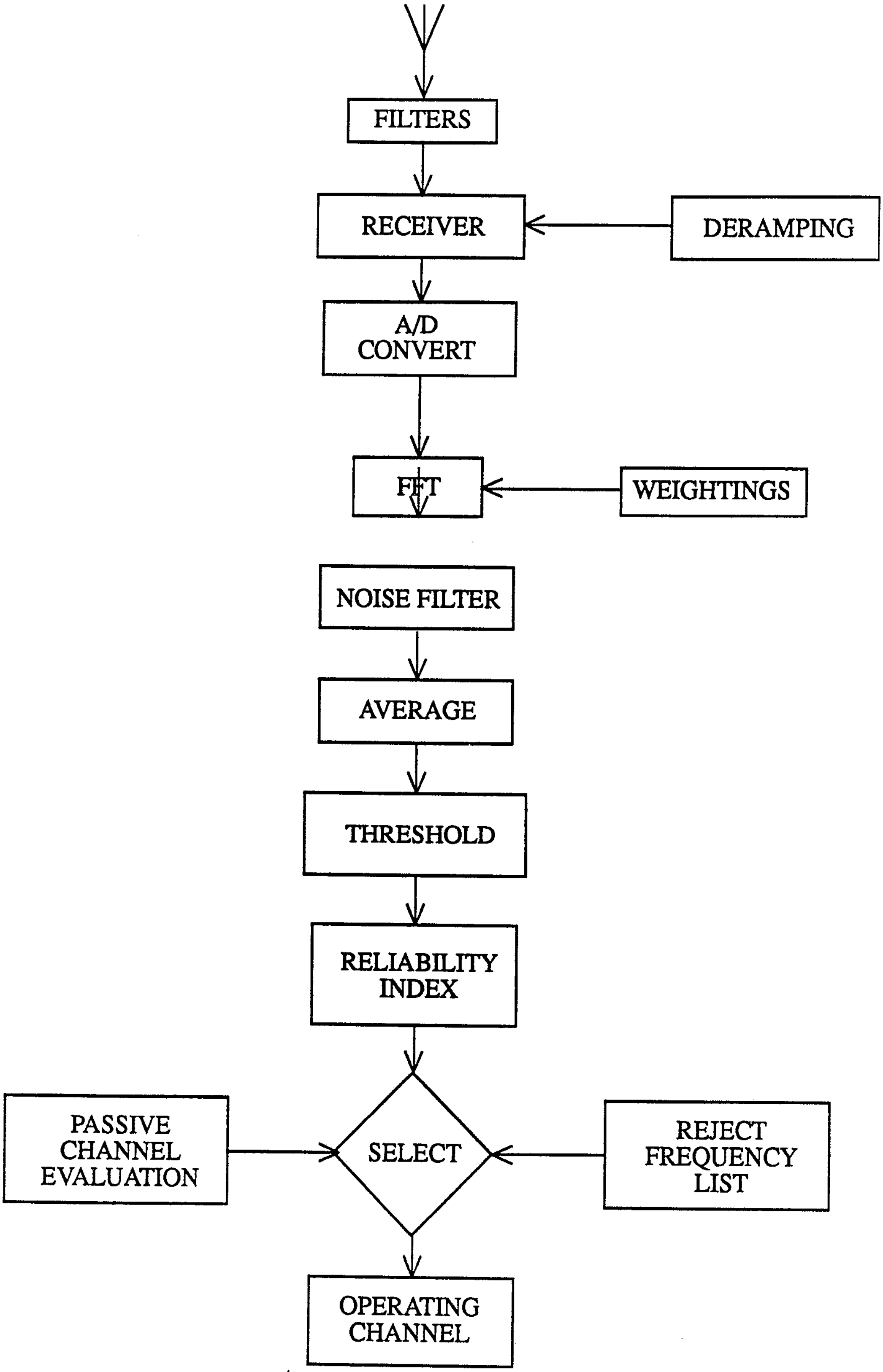

FILTERS
RECEIVER
DERAMPING
A/D CONVERT
FFT
WEIGHTINGS
NOISE FILTER
AVERAGE
THRESHOLD
RELIABILITY INDEX
PASSIVE CHANNEL EVALUATION
SELECT
REJECT FREQUENCY LIST
OPERATING CHANNEL

FIG 2

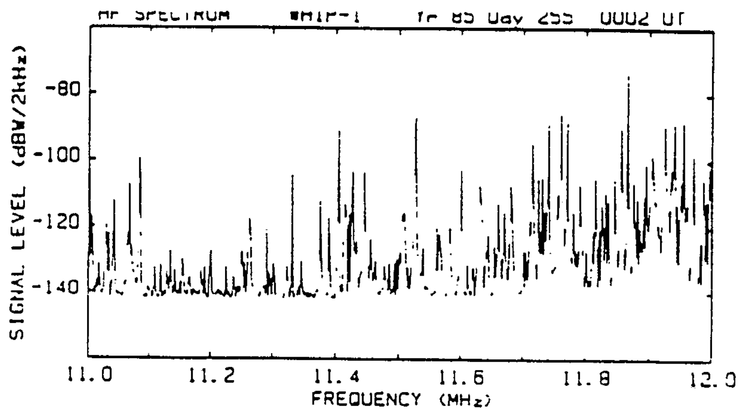

SIGNAL LEVEL (dBW/2kHz)
-80
-100
-120
-140
11.0
11.2
11.4
11.6
11.8
12.0
FREQUENCY (MHz)

FIG 1

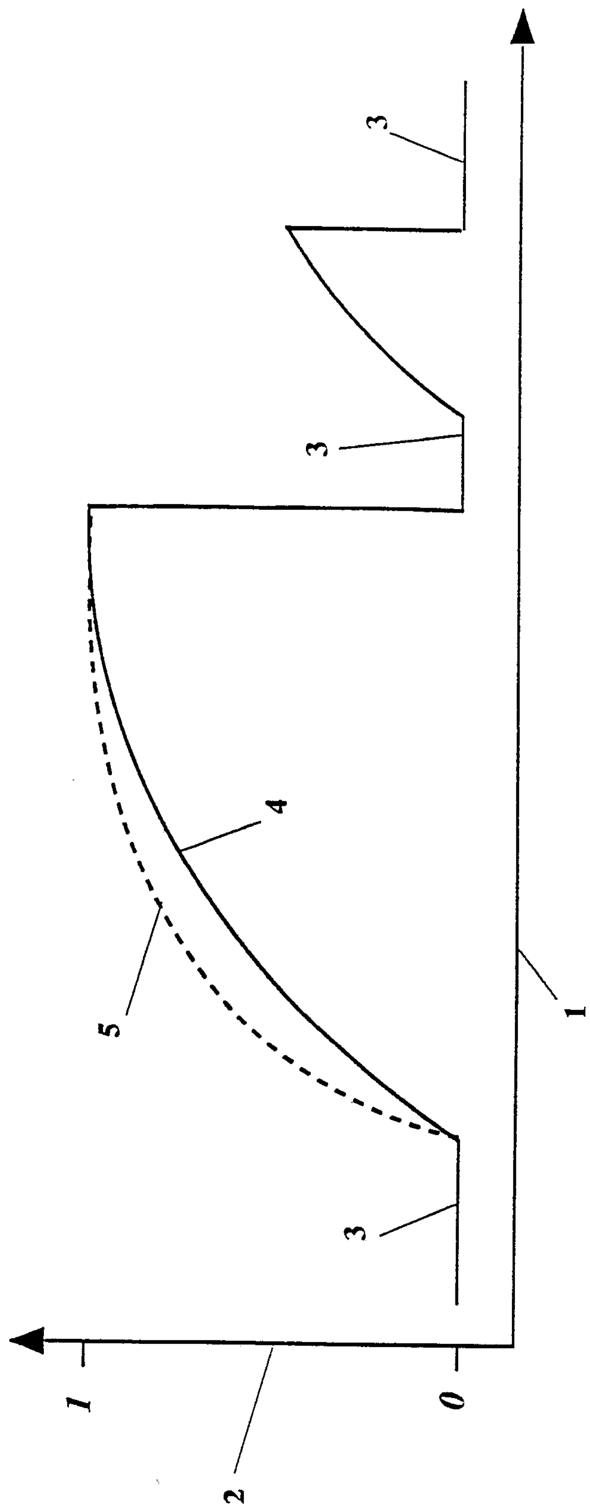


FIG 4

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^5. G01S 7/295, 7/40; H04B 7/00; H04Q 7/00

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)
IPC G01S 7/295, 7/40, 7/44; G01R 23/16; H04B 7/00; H04Q 7/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above.

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
A	Patent Abstracts of Japan, P-279, page 63, JP,A, 59-30068 (NIPPON DENSHIN DENWA KOSHA) 17 February 1992 (17.02.92)	
A	Patent Abstract of Japan E-382, page 16, JP,A, 60-197033 (TOSHIBA K.K.) 5 October 1985 (05.10.85)	
A	Patent Abstract of Japan, P-1007, page 79, JP,A, 1-296169 (SONY CORP) 29 November 1989 (29.11.89)	
	Continued	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 August 1992 (12.08.92)	21 Aug 1992 (21.08.92)

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indixation, where appropriate of the relevant passages	Relevant to Claim No.
A	Patent Abstract of Japan, P-1125, page 20, JP,A, 2-205790 (NEC CORP) 15 August 1990 (15.08.90)	
A	DE,A, 2402562 (TEKADE FELTEN & GUILLEAUME FERNMELDEANLAGEN GMBH) 24 July 1975 (24.07.75)	
A	EP,A, 413951 (HUGHES AIRCRAFT COMPANY) 27 February 1991 (27.02.91)	
A	US,A, 4603331 (WEHNER) 29 July 1986 (29.07.86)	
A	US,A, 4649394 (MINKER et al.) 10 March 1987 (10.03.87)	
P,A	US,A, 5056051 (TKALCEVIC) 8 October 1991 (8.10.91)	
P,A	WO,A, 91/10300 (MOTOROLA INC) 11 July 1991 (11.07.91)	

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL APPLICATION NO. PCT/AU 92/00201

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Member		
EP 413951	JP 3089188		
US 4649394	DE 3213430	FR 2524983	GB 2122449
	DE 3223565	DE 3223566	

END OF ANNEX