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(71) Applicant: SINGAPORE TELECOM MOBILE PTE LTD. [SG/SG]; Comcentre, 31 Exeter Road, Singapore 239732 (SG).

(72) Inventors: LIM, Chuen, Kheng; Comcentre, 31 Exeter Road, Singapore 239732 (SG). CHIN, Ivan, Chee, Hoong; Comcentre, 31 Exeter Road, Singapore 239732 (SG). KANG, Aik, Siang; Comcentre, 31 Exeter Road, Singapore 239732 (SG). SI, Cheng, Choon; Comcentre, 31 Exeter Road, Singapore 239732 (SG).

(74) Agent: SACHITHANANTHAN, Madelene; Allen & Gledhill, #18–01 City House, 36 Robinson Road, Singapore 068877 (SG).

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(57) Abstract

The mobile phone usage within a specific area is measured so as to identify a potential hotspot for installing a microcellular transmitter. This hotspot measurement is applicable to digital cellular communication systems utilising time division multiple access (TDMA) technology. The hotspot measurements are performed in real time, and the signals transmitted by all mobile phones within a specific area are received by a spectrum analyser. The spectrum analyser is set to zero frequency span, so that the signals are captured in the time domain. The analysis of data is performed after the data collection so as not to reduce the speed of the data collection process. This method provides a more realistic measurement as only the mobile phone users that are utilising the system are considered. By varying the threshold level, the number of mobile phone users within areas of different sizes can be determined.

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MEASURING USAGE OF CELLULAR MOBILE TELEPHONES

The present invention relates to the measurement of the usage of cellular mobile telephones and has particular application to cellular mobile telephone systems employing time division multiple access (TDMA) radio technology.

During the setting-up of a cellular network for mobile telephones, it is important to provide maximum coverage in the minimum time. To achieve this, large omnidirectional cells, approximately 3 to 5 km in radius, termed "macrocells" are deployed, since these can provide coverage over an extensive geographical area and can meet the communications requirements of the subscriber base, which will initially be small. However, as the number of users increases, the traffic demand in populated places such as cities or other urban areas will become high, and the communications network can then become congested. This will result in a degradation of service quality, resulting in dropped calls which will in turn lead to user dissatisfaction and a resulting loss in revenue.

Such areas of high traffic demand are termed "hotspots", and various solutions have been suggested to address the problems associated with these. For example, cell sectorisation, cell splitting, half rate coding/dual rate, dual band operation and multilayer networks, such as those incorporating microcellular and picocellular underlays, have been suggested, since these all add capacity in such hotspots. However, only cell sectorisation and multilayer networks have the capability of providing coverage as well as capacity for hotspot areas.

In cell sectorisation, the network operator can improve the capacity and coverage by the restricting the coverage area of each cell to a sector of 60 to 120 degrees. This method gives increased control of coverage and interference, enabling frequency re-use over smaller distances and increasing the overall network capacity. However, it is still not possible to focus this increase to specific areas.

The most effective solution to the problem of providing focused capacity and coverage is by the implementation of a microcellular network. Microcell antennas are typically installed three or four stories high. These can provide focused coverage (approximately 200 to 300 m in radius) over concentrated traffic areas such as shopping malls. Such microcellular transmitters normally transmit at a much lower power and, with the use of directional antennas, enables coverage to be precisely focused on the traffic hotspots.

However, it is not an easy task to identify a traffic hotspot. This is due to the fact that TDMA radio technology is used in the GSM and PCN systems. Each channel is divided into 8 time slots, and a digitised portion of each subscriber's channel is broadcast in a different time slot. It is therefore not possible to monitor the signals transmitted by the mobile phone in the frequency domain. The traffic channels have to be monitored in the time domain so that all the time slots in each channel can be studied. It would therefore be desirable to measure the traffic with a specific area so as to determine the number of mobile phones in use within that area.

In an existing system, a test transmitter is installed at a location, and the mobile stations within the vicinity of this transmitter are caused to register with it. A counter inside the test transmitter is thus able to count the number of mobile phones within the area. However, this method will count all the mobile phones that are switched on, and this will give a much higher result, since not all the mobile phones that are switched on are utilising the system. Furthermore, this method causes temporary disruption to the mobile phone users.

In accordance with the present invention, there is provided a method of measuring the usage of cellular mobile telephones employing time division multiple access (TDMA) within a predetermined area, the method comprising counting the number of occupied time slots within a TDMA frame.

In a preferred embodiment of the present invention, the number of occupied time slots is counted by using a spectrum analyser.

The location chosen for conducting the hotspot measurement is ideally the place where the traffic is suspected to be high and where the microcell transmitter is desired to be placed. The directional antenna of the spectrum analyser should be placed at the location where the microcellular transmitter is likely to be placed. Only those channels that are in the sector are selected. This method provides a real-time measurement of the instantaneous traffic, and the result obtained from this measurement should reflect the actual traffic within the hotspot area. Based on the results obtained from hotspot measurements at different locations, a decision can be made as to which is the ideal location to install the microcell transmitter.

The hotspot measurement enables the network operator to determine the traffic usage within a specific area. In the ETAC and AMPS communications systems, frequency division multiple access (FDMA) is used. Therefore, by simply monitoring the traffic channels, traffic usage within an area can be determined. However, in the GSM and PCN systems, time division multiple access (TDMA) is used. Thus it becomes relatively difficult to compute the traffic usage by monitoring the traffic channels. This is because there can be up to 8 mobile phone users accessing the same channel at any one time.

The invention will now be described with reference to the accompanying drawings, in which:

Figure 1 illustrates the rising edge of a signal detected to determine the presence of a telephone call;

Figure 2 illustrates the counting of occupied time slots using three windows;

Figures 3 to 5 illustrate situations arising which require repeated counting using additional windows;

Figure 6 is a graph of percentage occupancy vs. time; and

Figures 7 to 10 are flowcharts illustrating the methods of determining occupancy in accordance with preferred embodiments of the present invention.

In this hotspot measurement for the GSM and PCN systems, a spectrum analyser and a portable computer are used. The spectrum analyser is used to receive signals transmitted by all the mobile phones within the specific area, and the portable computer is used to store the data from the spectrum analyser. The measurement process is divided into two parts, namely the collection of data and the processing of the data. The data collection is conducted at the location where the traffic is suspected to be high. The collection of data is performed automatically by the software which remotely controls the spectrum analyser and transfers the data to the computer via a serial interfacing cable, such as RS 232 standard cable. During this process, the spectrum analyser is set to zero frequency span (i.e. to operate in the time domain). The processing involves studying the time slots of each channel. The computation of traffic usage can be performed by considering the users in all of the channels.

Time Slot Computation

In this measurement, an Advantest spectrum analyser, model U4941, is used, in which there are a total of 701 data points for a single sweep, and each data point has a maximum magnitude of 340 (in ASCII value). This maximum magnitude corresponds to the reference level of the spectrum analyser. In order to determine the number of users at any instant in a particular channel, the spectrum analyser is set to the zero frequency span where the signal is captured in the time domain rather than the frequency domain. The channels monitored are the Broadcast Control channel (BCCH) and the Traffic channel (TCH). For BCCH, the time slots 0 and 1 are used for signalling purposes. Only time slots 2 to 7 are used for traffic. In TCH, all the time slots are used for traffic.

In this hotspot measurement, only the uplink (i.e. mobile station to base station) frequencies are used, even though the downlink (base station to mobile station) frequencies can also reflect the same number of users. This is because the hotspot detector works by considering the signal strength received by the spectrum analyser. If a mobile phone station is far away from the receiver antenna of the spectrum analyser, then the received signal will be weak (due to path loss). Similarly, if a mobile station is near to the antenna of the spectrum analyser, the signal will be high. However, if the line of sight of the mobile phone and the base transmitter is blocked, the mobile phone will be controlled to transmit at a higher power by the base station. With variation of signal strength, one can set a threshold level below which any signal strength will not be considered as a "nearby" mobile phone user. On the other hand, if downlink frequencies were used, then the signal strength transmitted by the base transmitter would be the same irrespective of the distance between the mobile phone and the spectrum analyser, as the transmitted location is fixed with respect to the antenna of the spectrum analyser. In this way, it is impossible to estimate the distance of the mobile phone users from the spectrum analyser. This arises from the fact that, at present, the mobile phone has power control whereas the base transmitter does not.

The sweep time of the spectrum analyser is set to 50 ms by the software. This value is chosen as being particularly advantageous, and, with this sweep time, the spectrum analyser is able to capture approximately 10 TDMA frames (one TDMA frame has 8 time slots) in one sweep. These 10 TDMA frames are just sufficient for determining the number of users (or number of time slots) in a particular channel. If the spectrum analyser is set at a much higher sweep time, more TDMA frames can be captured, but the resolution may not be sufficient to determine the number of users (or the number of time slots). As the spectrum analyser used has a resolution of 700 data points in the x axis. This means that when the sweep time is set to 50 ms, the interval between two data points will be 50/100 = 71.428 μs. Since each time slot lasts 577 μs, one time slot will be represented by 577/71.4285 data points = 8 data points, and 8 time slots (one TDMA frame) will be represented by 64 data points.

In order to count the number of users or time slots in a particular channel, a "window" programming method is adopted. This method is very efficient in terms of processing speed as well as accuracy. This window has a fixed width of 8 time slots, i.e. one TDMA frame. The window is formed by detecting rising edges of the signal (see Figure 1).

A rising edge is detected when the following conditions are fulfilled:

1. The magnitude of a data point must be at least 10 points (in ASCII value) greater than the previous data point.

2. The data point must be greater than the specified threshold level.

The above conditions ensure that the rising edge detected is not due to fluctuation of noise present in the signal.

The first rising edge is ignored, and a second rising edge is detected using the same method. With the second rising edge determined, a window having a width of 8 time slots is formed (see Figure 2). Based on this window, the number of data points with a magnitude (in ASCII value) above the threshold level is counted.

In the software program used in the method, as illustrated in the flowchart shown in Figure 7, the threshold level, which is set by the user, is expressed in dbm or a normalised value. However, the data collected is in terms of an ASCII value. Therefore, a conversion is required, and the following two formulas are used to convert the threshold level from dbm or the normalised value to the ASCII value respectively.

$$\text{ASCII value} = \frac{100 - [\text{abs(dbm value)} - \text{abs(reference level)}]}{100/340}$$

$$\text{ASCII value} = \text{noise base} + (\text{maximum value} - \text{noise base}) \times (\text{normalised input})$$

where maximum value is the highest value throughout the whole data record and noise base is the noise level of the signal. Both of these two values are expressed in ASCII.

The number of time slots above the threshold level can be computed by dividing the total number of data points which are above the threshold level by the number of data points for one time slot. As mentioned above there are approximately 8 data points for one time slot. This can be expressed mathematically as:

$$N_{OCC} = N_{TOT} \div 8$$

where N_{OCC} is the number of occupied time slots and N_{TOT} the total number of data points having a magnitude above the threshold level.

With the number of occupied time slots determined for the first window, second and third windows are formed directly next to one another (see Figure 2), and the numbers of occupied time slots in these windows are also determined. A comparison is then made between the numbers of occupied time slots counted in these three windows. The number of occupied time slots occurring in two or three of the windows is taken as the actual number of occupied time slots (i.e. the number of mobile phone users) at that instant. If the three windows have three different numbers of occupied time slots (see Figure 3), or the actual number of occupied time slots computed is not the highest of the three (see Figure 4), then another three windows will be formed using the same method. This process will be repeated until a satisfactory result is obtained or when no more windows can be formed within the scan due to the data points having been exhausted, since a single sweep contains only 700 data points which is equivalent to 10 TDMA frames (see Figure 5). In this case, the number of occupied time slots that occurs the most often in all of the windows will be taken as the actual number of occupied time slots for that channel. These method steps are illustrated in the flowchart of Figure 8.

The purpose of adopting the above method for determining the number of time slots is to ensure accuracy of the result. This is because the software is unable to identify the time slot number. This means that the first window may be formed in any one of the time slots. For example, if the window is in time slot 2 of a TDMA frame, then it will end in time slot 1 of the next TDMA frame. Therefore, even if the user is occupying time slot 5 of a TDMA frame, the window is able to "capture" it as time slot 3, with respect to the window formed. The actual time slot number is not significant and plays no part in the analysis.

When the channel is a Broadcast Control Channel, then time slots 0 and 1 are unoccupied most of the time unless some control signal is being transmitted by a mobile phone due to call initialisation. This is because additional control signals may be captured in the time slot 0 of the TDMA frames. In this case, the time slot computation is different. The first rising edge is detected using the above method. From this first rising edge, a window of one TDMA frame size is formed. A check is made to ensure that there are sufficient data points to form the window. This process is repeated until no more windows can be formed. The number of occupied time slots for each window is determined as discussed above. The time slot occupation numbers are then compared in order to determine the actual number of occupied time slots for the Broadcast Control Channel. The comparison is effected by first storing all the time slots of the windows in an array. Next, a comparison is made to determine the highest number of time slot occurrence. The numbers of time slots that are greater than 4, and which occur the most often, will be taken to be the actual number of occupied time slots for the Broadcast Control Channel. In case the number of occupied time slots computed is greater than 6, then the number of occupied time slots is taken to be 6. These method steps are illustrated in the flowchart of Figure 9.

In this hotspot measurement, frequency hopping and discontinuous transmission are preferably deactivated. If frequency hopping is not deactivated, then a time slot within one channel may hop to another channel (due to frequency hopping), and two mobile phone users will be detected, although there is only one. With discontinuous transmission, no signal will be sent by the mobile phone if the user is not talking. Thus no time slot will be detected even though the user is on the line but no talking. In this case, this will not reflect the actual mobile phone users within the vicinity.

Channel Occupancy Calculation

Channel occupancy refers to the total number of users in all the channels at any time. This is an important parameter for the network operator, since its permits determination of the period with the highest instantaneous traffic. The channel occupancy is calculated by adding all the occupied time slots in all the channels that are being monitored. However, this value will not give the exact instantaneous traffic for all of the channels, because of hardware limitations. The process of transferring the data from the spectrum analyser to the computer, such as a laptop computer, and storing it on the hard disc requires approximately 2.6s. Thus a total of (2.6 x n)s is required to scan through n channels. Therefore, the results obtained using the above processes, as illustrated in Figure 6, may not reflect the instantaneous traffic of all the channels.

Erlangs Calculation

During the early days of telephone manual switchboards, it was observed that the telephones were used only occasionally, and providing separate connections for all the telephone extensions is neither necessary nor efficient.

In order to determine how well a communications system is operating, the relationship between the offered (input) load to the system and the carried (output) load is required. This relationship is determined theoretically. One method of carrying out such a determination involves the measurement of the traffic intensity. Traffic intensity is a dimensionless ratio used for determining the congestion or occupancy of a unit. It is measured in erlangs (E). When a unit under study (line to line) is fully occupied for an hour, it is said to have a traffic intensity of 1 erlang of traffic. Thus a communication line that is occupied for 30 minutes for each hour has an intensity of 0.5 E.

Another way of approaching the definition of erlangs is as follows. If a total of n calls are made during a period of observation of T seconds, and the durations of the calls are h_1, h_2, h_3 ...,h_n seconds respectively, then the total use of the system by the users in the period T is

$$\sum_{i=1}^{i=n} h_i \text{ call-seconds.}$$

This is sometimes called the amount of traffic or traffic volume for the period T. The average traffic, that is the amount of traffic per unit time, can be defined as:

$$E = \frac{\sum_{i=1}^{i=n} h_i}{T} \text{ (in erlangs)}$$

In the hotspot measurement, it is assumed, when calculating the erlangs volume, that all the calls detected by the spectrum analyser, for a particular channel, will continue until the channel is monitored again. This is because the spectrum analyser, which is set to the time domain, can monitor only one frequency (RF channel) at a time. If a particular sector of a communications system (e.g. GSM) has four channels, then the spectrum analyser has to scan for the other three frequencies before returning to the same channel. During this interval, some users may terminate their calls and, similarly, new calls may be established. For example, a channel may have five users initially and, after scanning the other three channels, only two users remain. It will then be assumed that the five users used the system for the period of that scanning cycle (4 channels). If the spectrum analyser required h seconds to scan and transfer data to the hard disc of the computer, then it will take the spectrum analyser 4 x h seconds to scan through all the channels and return to the same channel. Therefore, in the previous example, the fiver users will be assumed to continue their calls for 4 x h users will be assumed to continue their calls for 4 x h seconds. Similarly, the next two users will be assumed to continue their calls for 4 x h seconds.

Thus, the amount of traffic for the period T is equal to the total number of users per channel multiplied by the number of channels being monitored multiplied by h, where h is the time required for scanning through all the channels that are being monitored, and

$$E = \frac{\text{Amount of traffic for the period T}}{T}$$

In the software used in the method, the erlangs value is calculated by first computing the erlangs value for one channel and then adding the erlangs values of the subsequent channels.

A major advantage of this measuring technique is that the result obtained reflects the actual traffic usage within a specific location. This hotspot measurement is required to be conducted only once for a given location, and the size of the hotspot area can be varied simply by changing the threshold level. Thus, different traffic usage can be analysed by conducting only one measurement for each location. Furthermore, this hotspot measurement does not require any sophisticated or bulky equipment. All that is required is a conventional spectrum analyser and a portable computer. Furthermore, there is no disruption to the system during the measurement.

CLAIMS

1. A method of measuring usage of cellular mobile telephones employing time division multiple access (TDMA) within a predetermined area, the method comprising counting the number of occupied time slots within a TDMA frame.

2. A method as claimed in claim 1, further comprising counting the number of occupied time slots within a TDMA frame for each one of a plurality of channels and adding together the respective count values so as to derive the total number of mobile telephones being used within said predetermined area.

3. A method as claimed in claim 1 or claim 2 in which a spectrum analyser set to zero frequency is used to count the said number of occupied time slots.

4. A method as claimed in any preceding claim employing a threshold value for determining whether or not a given time slot is occupied.

5. A method as claimed in any preceding claim comprising monitoring transmissions from mobile telephones to a base station.

6. A method as claimed in any preceding claim, wherein the step of counting comprises forming a time window having a time width equal to that of a TDMA frame and counting the number of occupied time slots within said time window.

7. A method as claimed in claim 6, wherein three consecutive time windows are employed and the number of occupied time slots within each of said three windows is counted to produce a count value for each of said windows.

8. A method as claimed in claim 7, further comprising forming three further windows in the event that the count

values associated with the first three windows are not related in a predetermined manner.

9. A method as claimed in claim 8, wherein said predetermined manner comprises the three count values being equal.

10. A method as claimed in claim 8 or claim 9, wherein said predetermined manner comprises two of said count values being identical and greater than the other count value.

11. A method as claimed in any preceding claim, further comprising controlling a base station associated with the cellular mobile telephones being monitored to disable frequency hopping during the measurement.

12. A method as claimed in any preceding claim, further comprising controlling a or the base station associated with said cellular mobile telephones so as to prevent discontinuous transmission during the usage measurement.

13. A method substantially as hereinbefore described with reference to the accompanying drawings.

FIG. 1

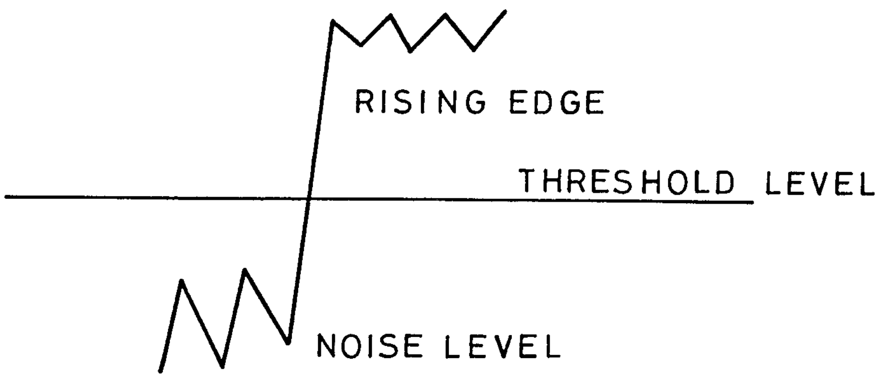


FIG. 2

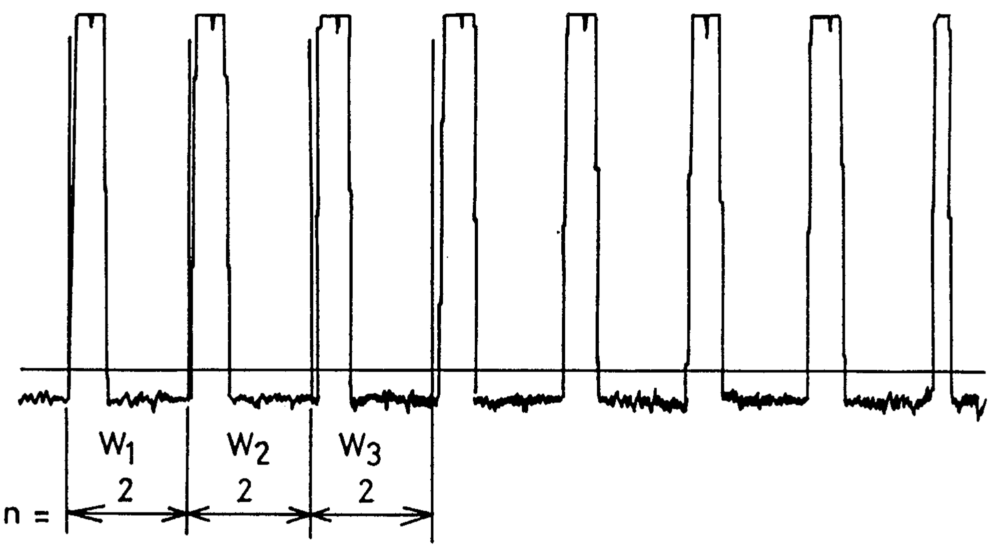


FIG. 3

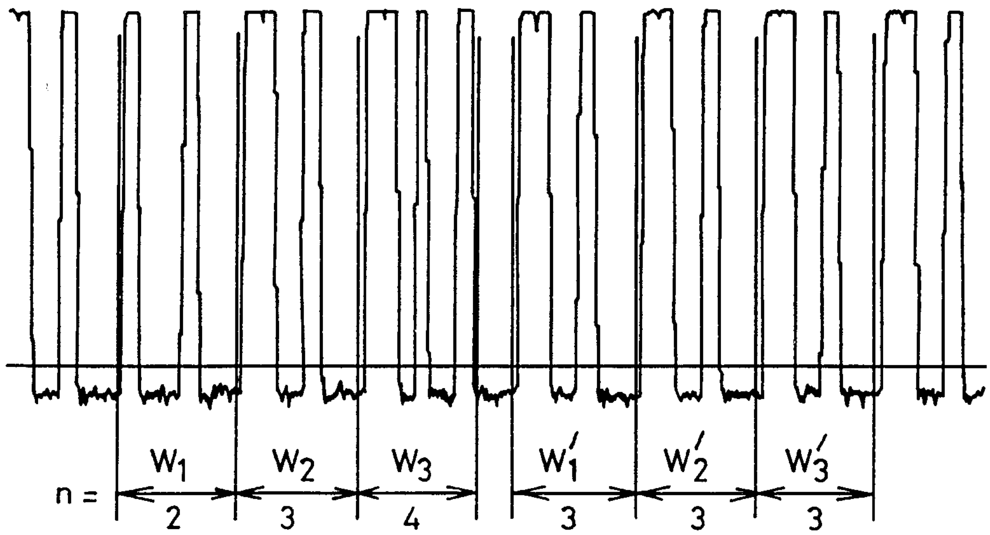


FIG. 4

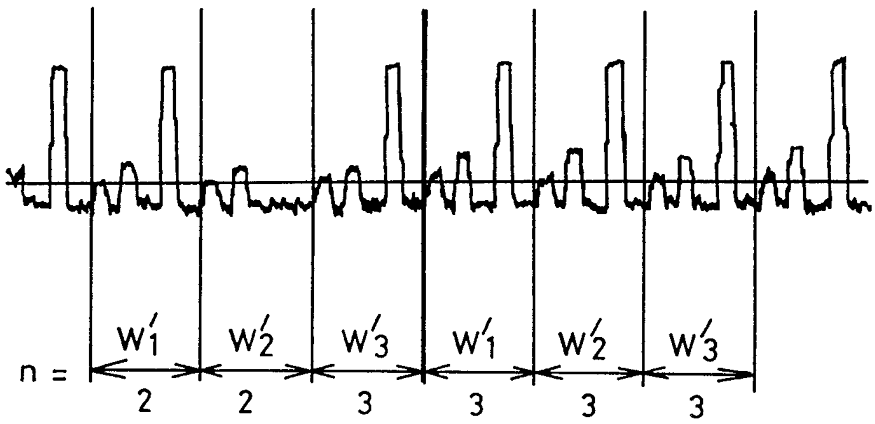


FIG. 5

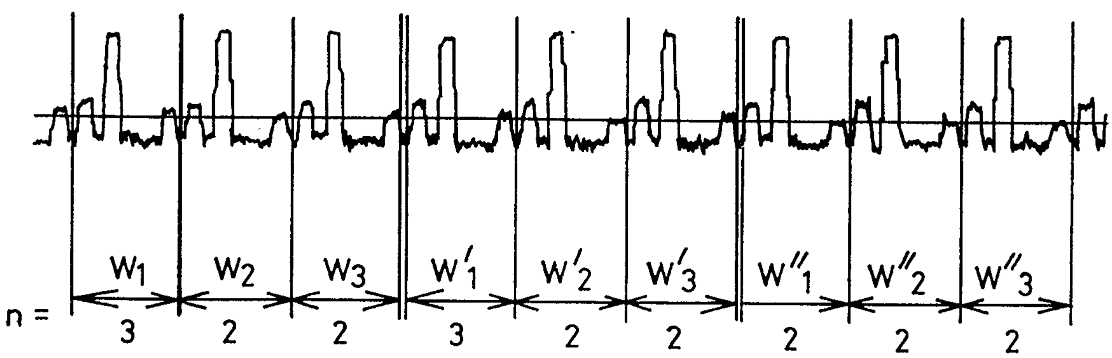
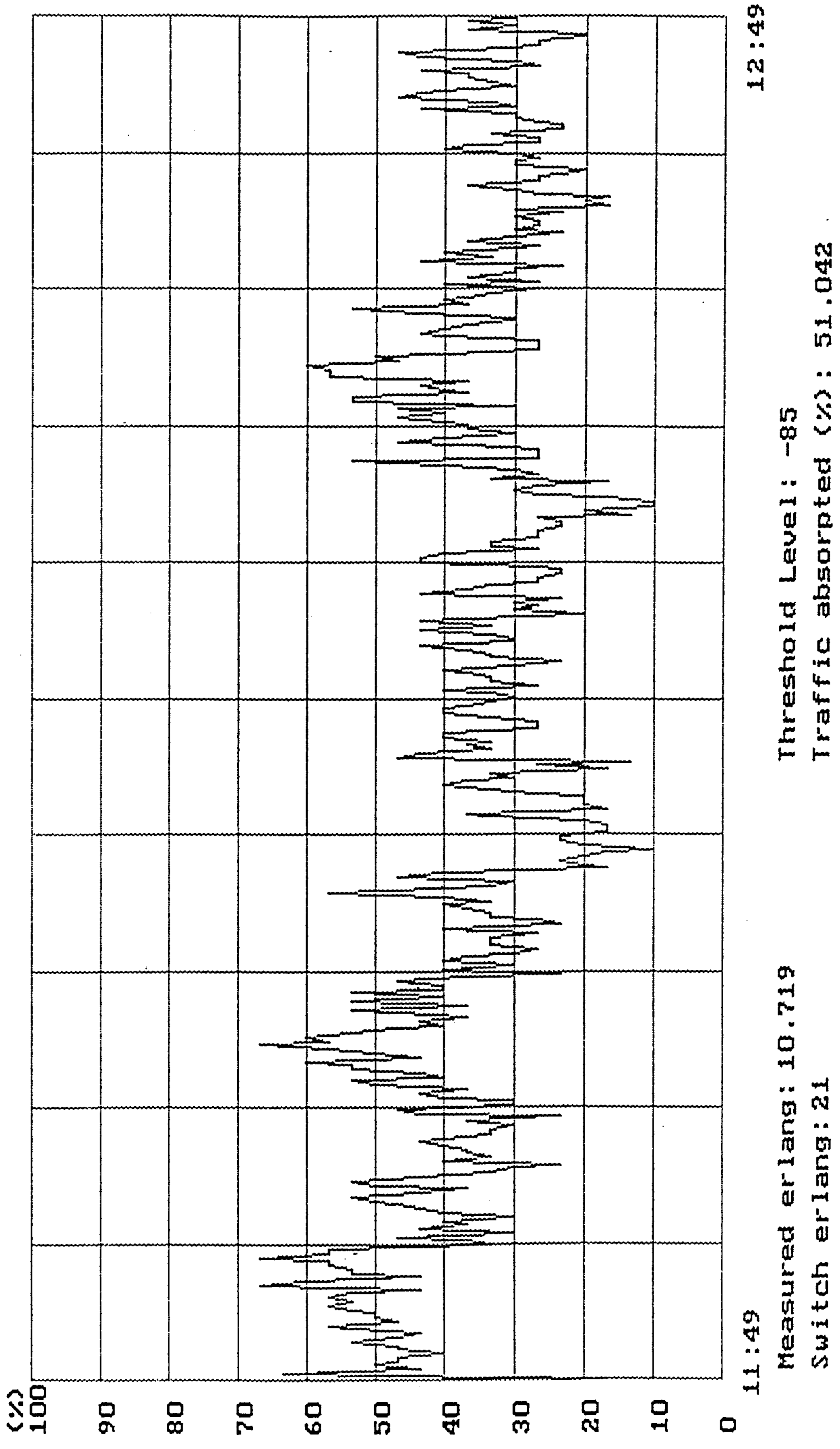


FIG. 6


(%)
100
90
80
70
60
50
40
30
20
10
0
11:49
12:49
Measured erlang: 10.719
Switch erlang: 21
Threshold Level: -85
Traffic absorpted (%): 51.042

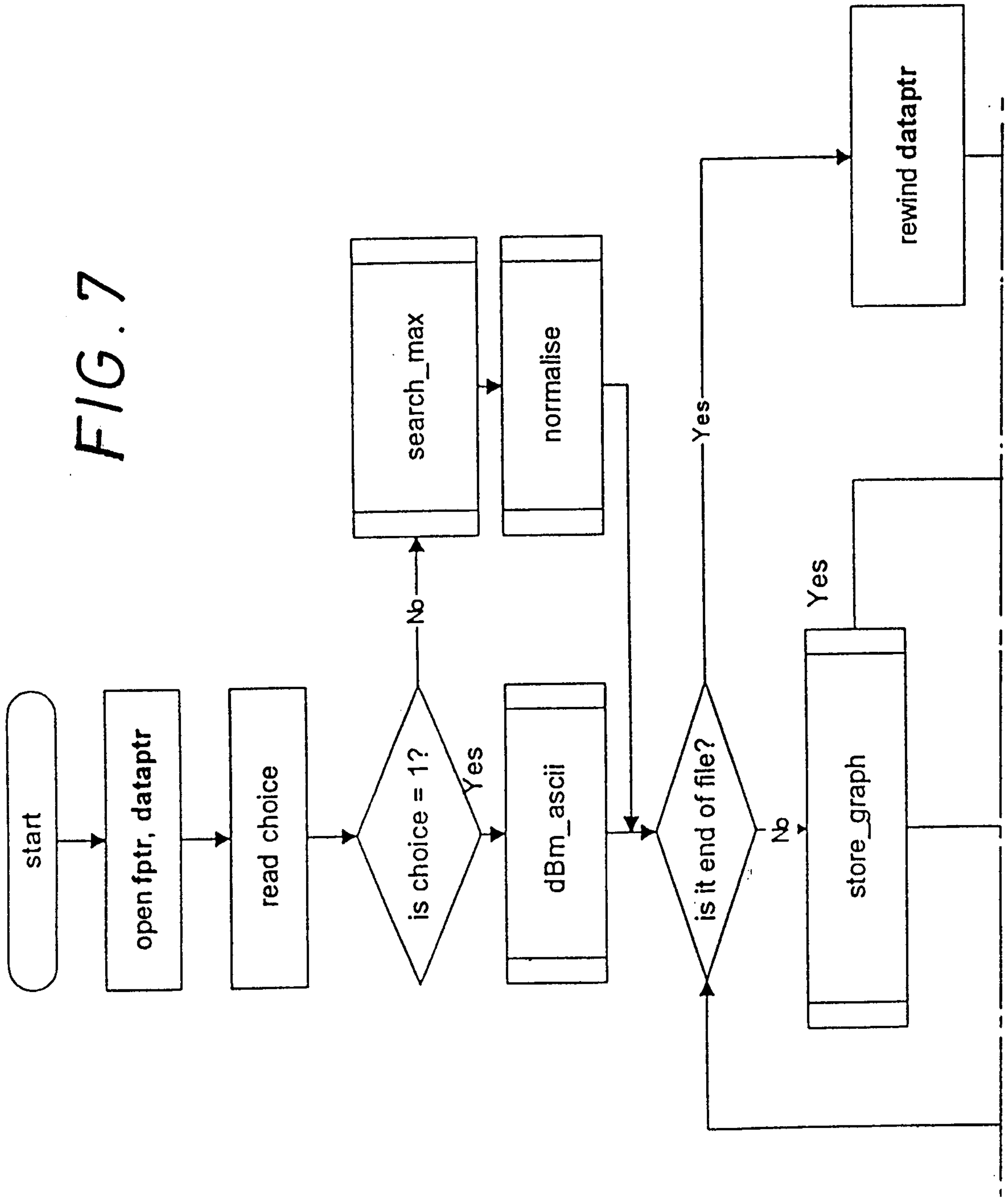

start
open fptr, dataptr
read choice
is choice = 1?
Yes
No
search_max
normalise
dBm_ascii
is it end of file?
Yes
No
rewind dataptr
store_graph
Yes

FIG. 7

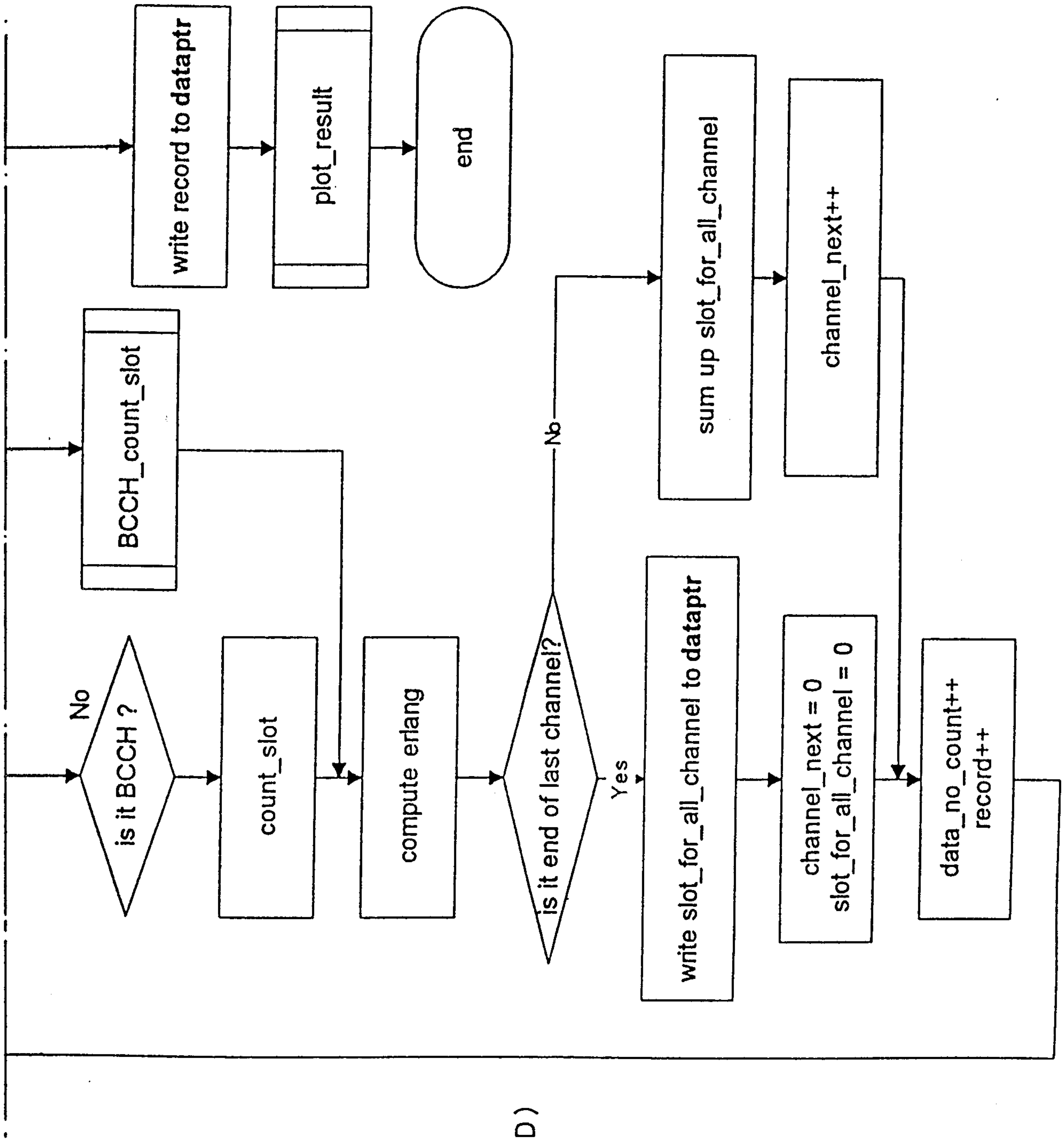
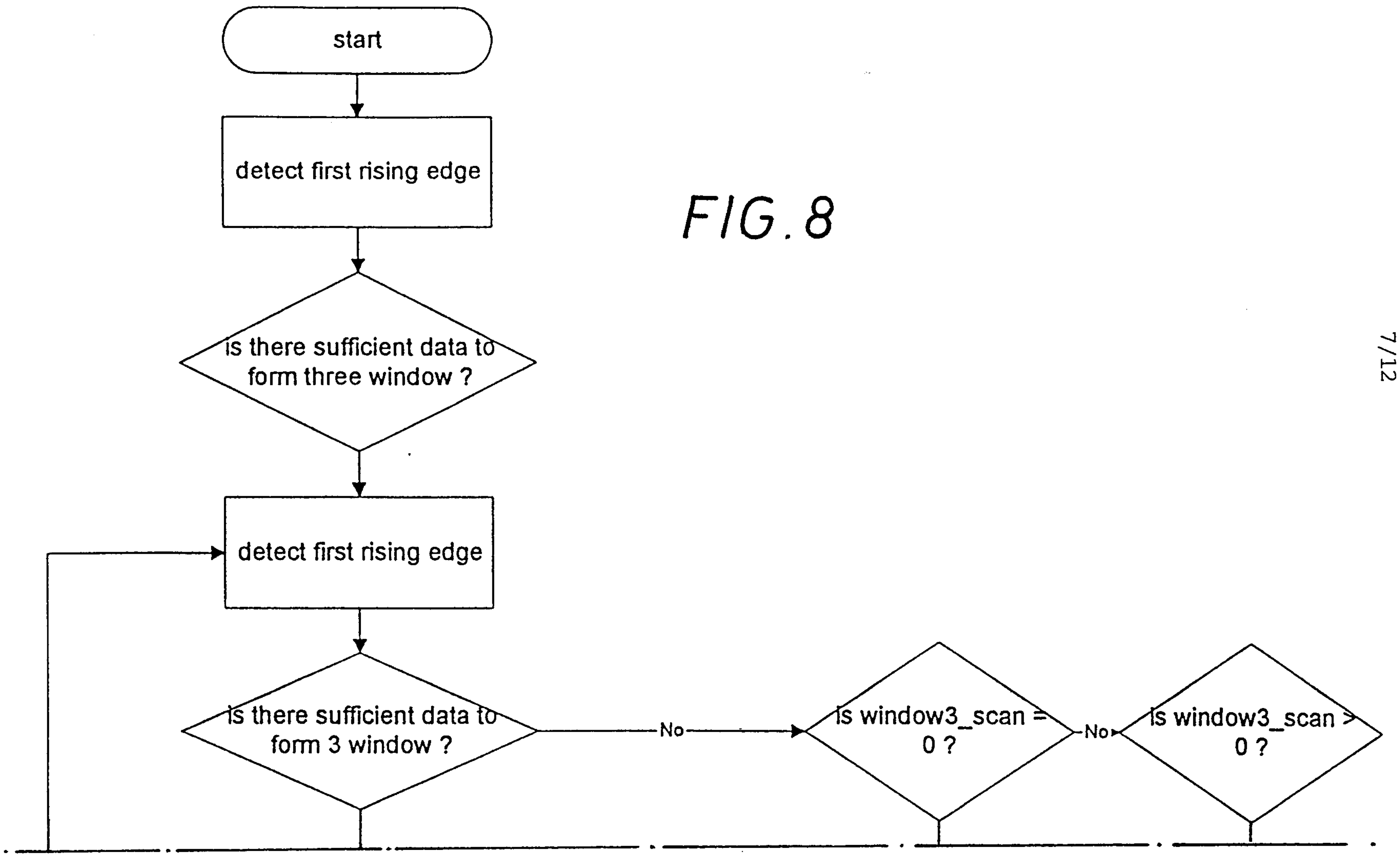

No
is it BCCH ?
count_slot
BCCH_count_slot
compute erlang
is it end of last channel?
Yes
No
write slot_for_all_channel to dataptr
sum up slot_for_all_channel
channel_next = 0
slot_for_all_channel = 0
channel_next++
data_no_count++
record++
write record to dataptr
plot_result
end

FIG. 7 (CONTD)

FIG. 8


start
detect first rising edge
is there sufficient data to form three window ?
detect first rising edge
is there sufficient data to form 3 window ?
No
is window3_scan = 0 ?
No
is window3_scan > 0 ?

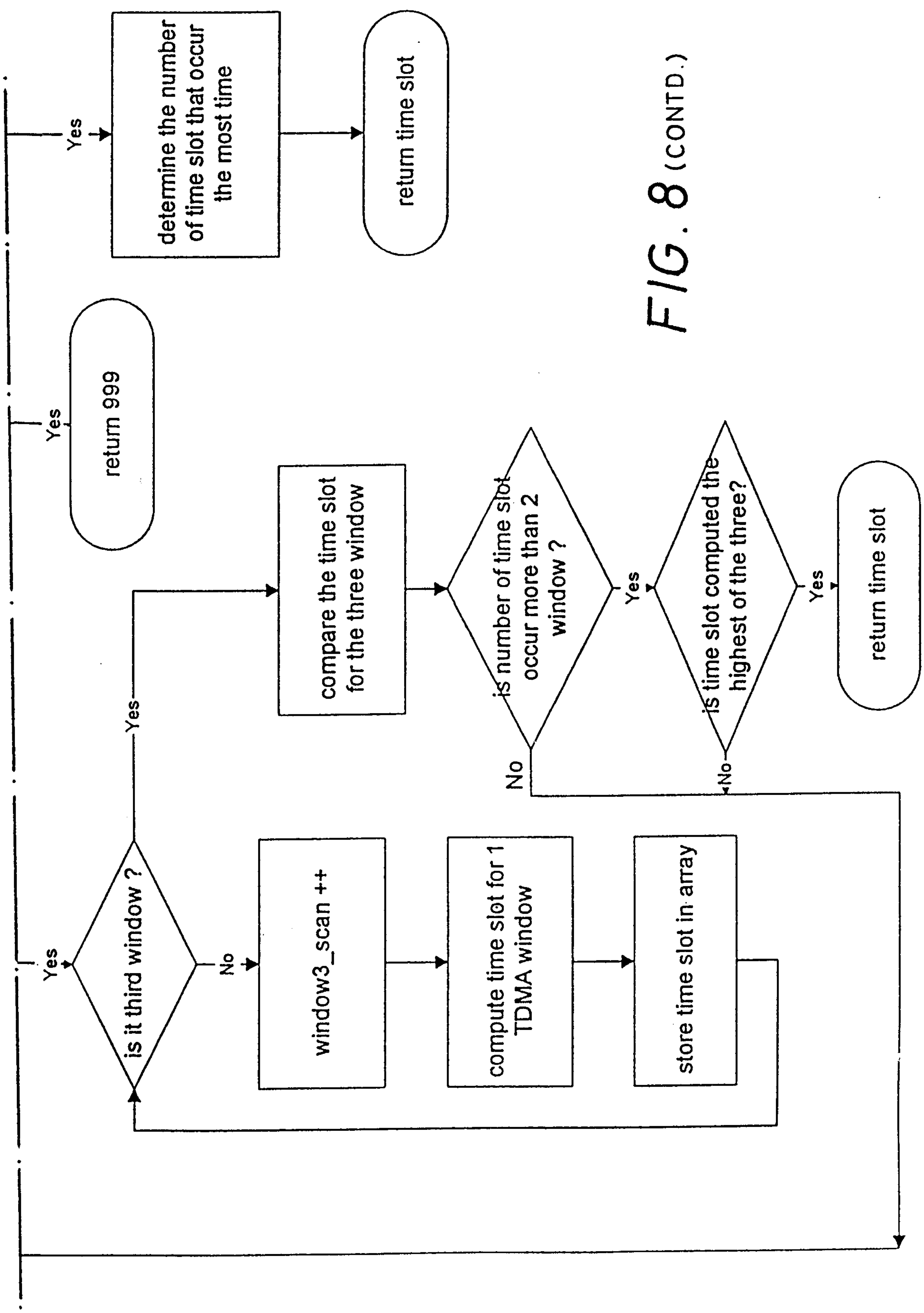

Yes
determine the number of time slot that occur the most time
return time slot
Yes
return 999
Yes
is it third window ?
No
window3_scan ++
compute time slot for 1 TDMA window
store time slot in array
Yes
compare the time slot for the three window
is number of time slot occur more than 2 window ?
Yes
No
is time slot computed the highest of the three?
Yes
No
return time slot

FIG. 8 (CONTD.)

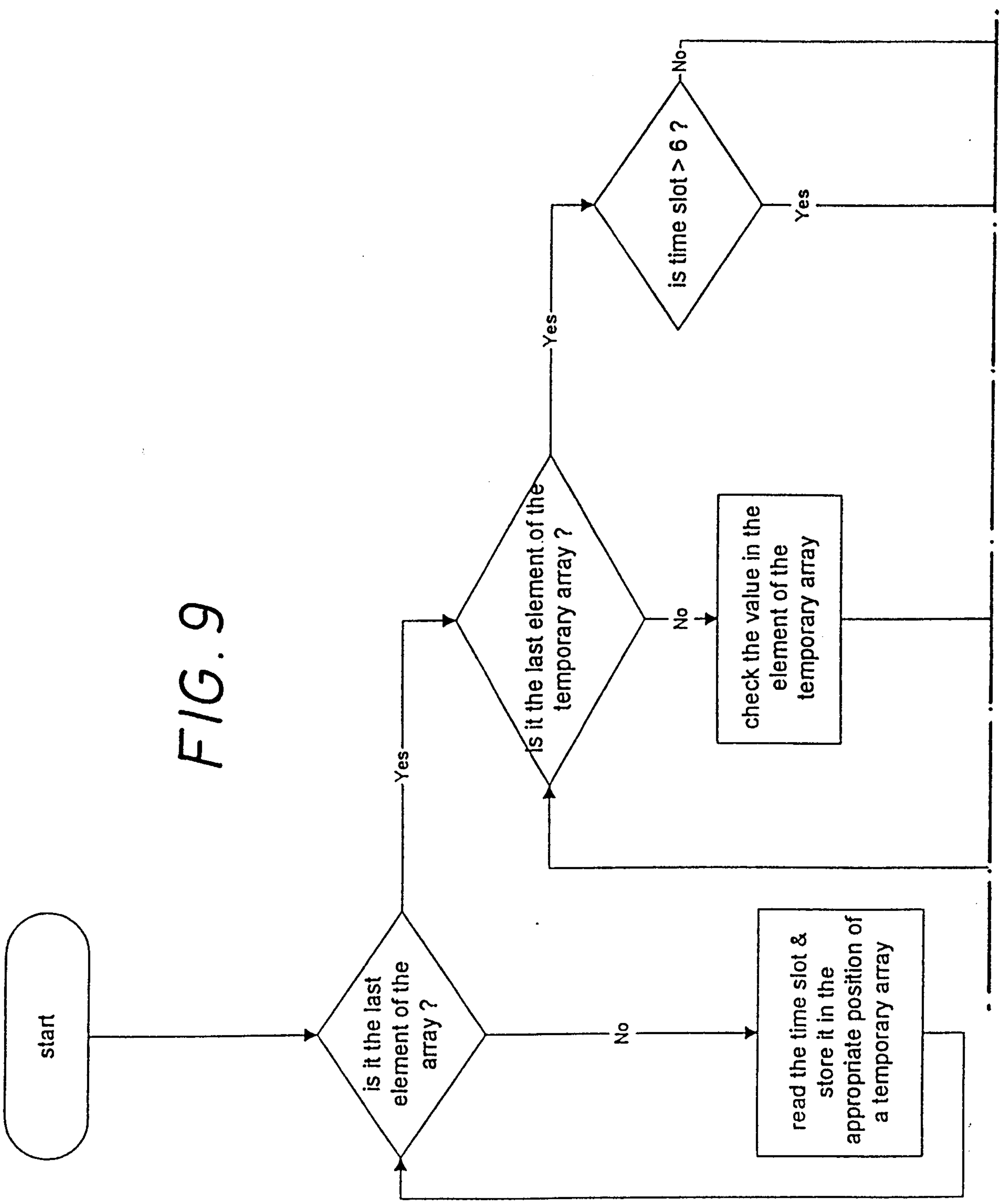

start
is it the last element of the array ?
No
Yes
read the time slot & store it in the appropriate position of a temporary array
is it the last element of the temporary array ?
No
Yes
check the value in the element of the temporary array
is time slot > 6 ?
No
Yes

FIG. 9

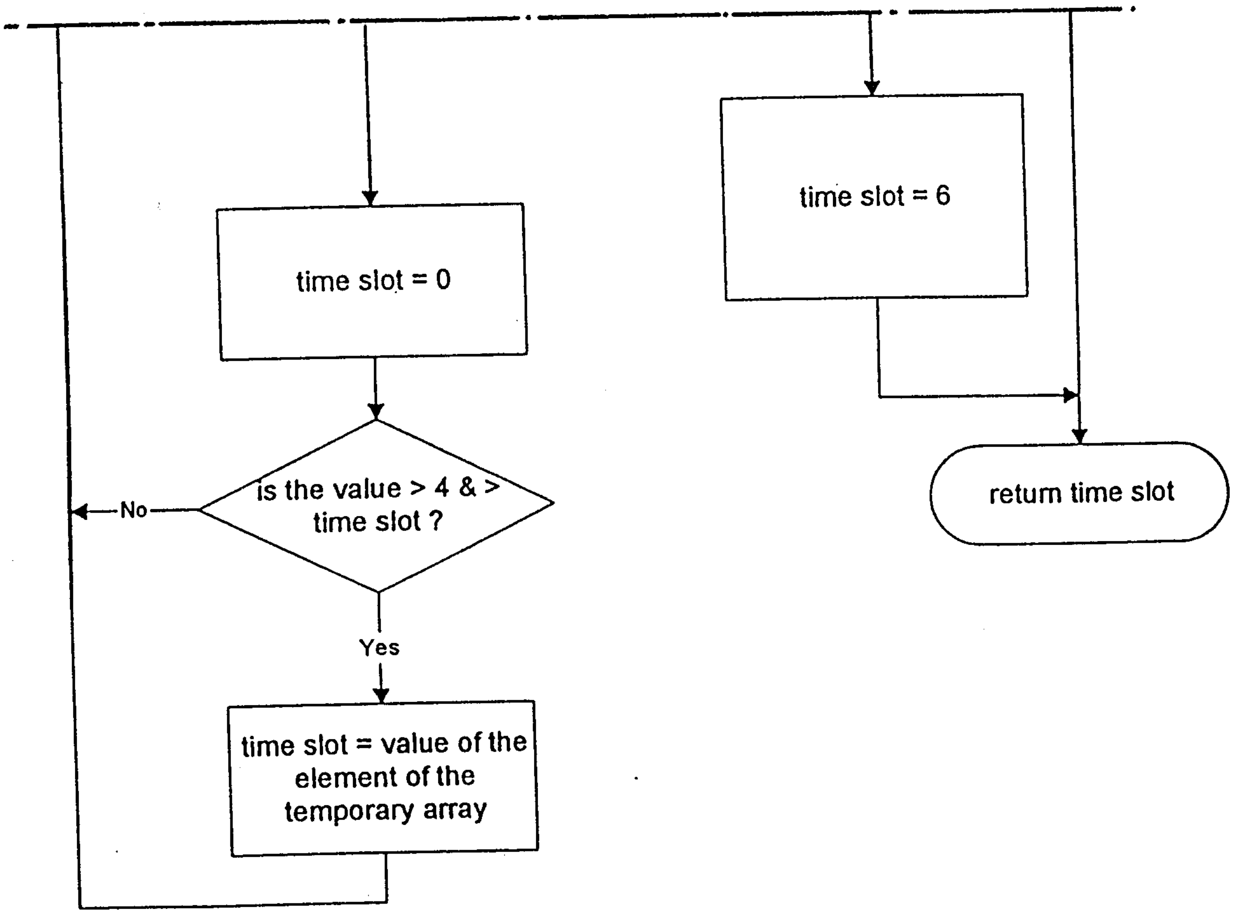

time slot = 0
is the value > 4 & > time slot ?
No
Yes
time slot = value of the element of the temporary array
time slot = 6
return time slot

FIG. 9 (CONTD.)

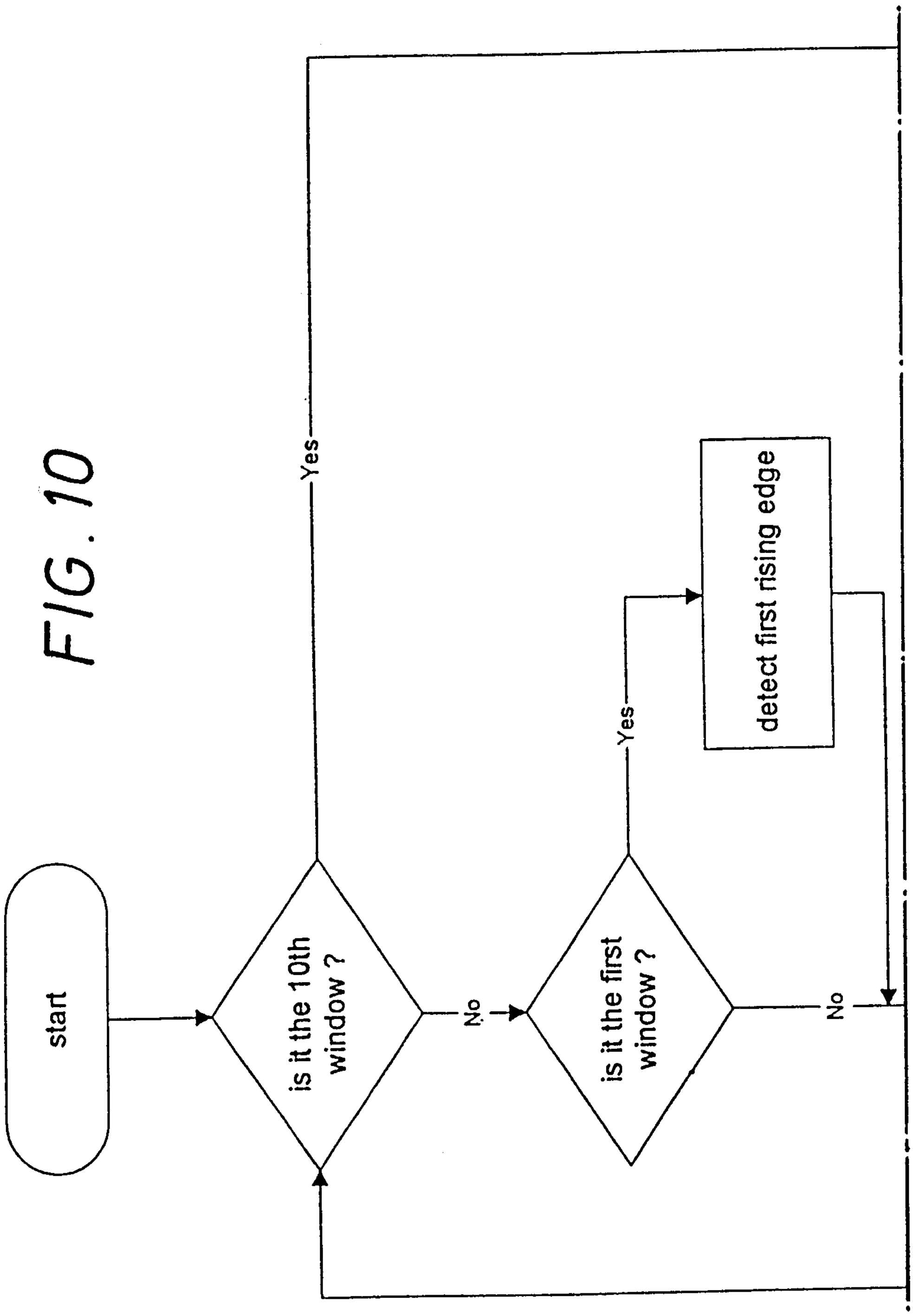

start
is it the 10th window ?
Yes
No
is it the first window ?
Yes
No
detect first rising edge

FIG. 10

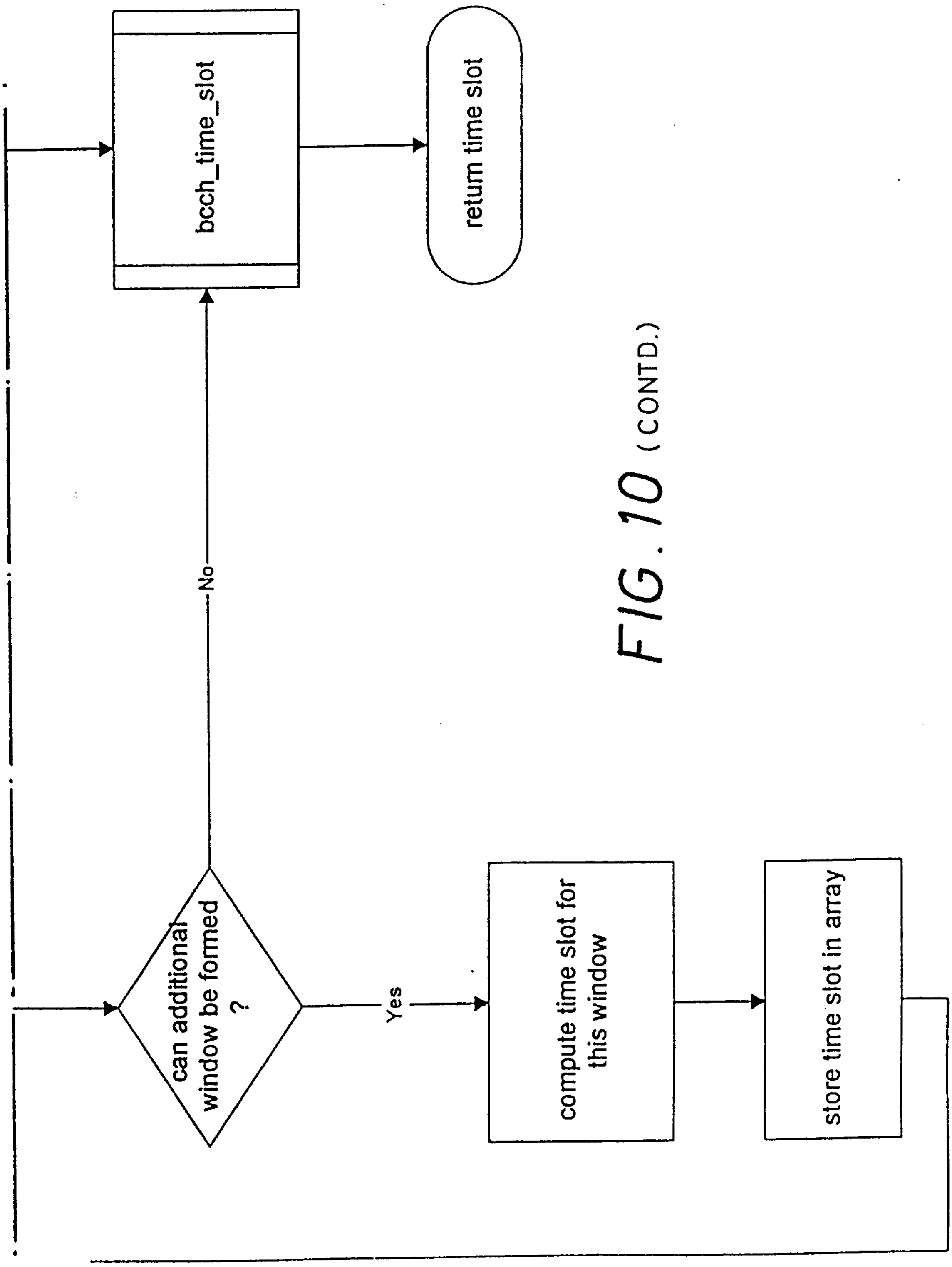

bcch_time_slot
retum time slot
No
can additional window be formed ?
Yes
compute time slot for this window
store time slot in array

FIG. 10 (CONTD.)

INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/SG 97/00003

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/34

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 6 H04Q

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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 44 13 484 A (ROHDE & SCHWARZ) 26 October 1995	1,5
Y	see column 2, line 47 - column 3, line 57 see column 4, line 43 - line 57; figure 2	3
Y	US 5 303 262 A (JOHNSON MATTHEW) 12 April 1994 see column 1, line 60 - column 2, line 14; claim 4	3
A	KAM C: "MOBILFUNK HF-MESSUNGEN AN GSM-SENDERN" FUNKSCHAU, vol. 62, no. 23, 2 November 1990, page 54, 55, 58, 59 XP000170666 see page 58, middle column, line 8 - right-hand column, line 23	1,11

-/--

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

[X] Patent family members are listed in 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

1 Date of the actual completion of the international search
10 March 1998

Date of mailing of the international search report
17/03/1998

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer
Gerling, J.C.J.

Form PCT/ISA/210 (second sheet) (July 1992)

Inte. onal Application No
PCT/SG 97/00003

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 96 31988 A (ERICSSON TELEFON AB L M) 10 October 1996 see page 6, line 19 - line 29 see page 9, line 16 - line 27 ---	1,12
A	WO 96 35305 A (ERICSSON TELEFON AB L M) 7 November 1996 ---	
A	RASINGER J ET AL: "A RECEIVER FOR THE REGISTRATION OF MOBILE COMMUNICATIONS TRAFFIC" VEHICULAR TECHNOLOGY CONFERENCE, ORLANDO, MAY 6 - 9, 1990, no. CONF. 40, 6 May 1990, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 675-679, XP000204192 -----	

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte onal Application No
PCT/SG 97/00003

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 5303262 A	12-04-94	NONE	
WO 9631988 A	10-10-96	AU 5291996 A	23-10-96
		EP 0819361 A	21-01-98
WO 9635305 A	07-11-96	US 5613217 A	18-03-97
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		EP 0824839 A	25-02-98