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PLANNING FOR FREQUENCY CONTINUITY IN HF BROADCASTING

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PLANNING FOR FREQUENCY CONTINUITY IN HF BROADCASTING

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The Second Session of the High Frequency Broadcasting Conference held in Geneva, Switzerland, in February 1987, resolved a need for an improved system to plan the radio frequencies allocated exclusively to the HF broadcasting service. The Final Acts of the Conference represented a compromise between reverting to the broadcast notification procedure under Article 17 of the ITU's Radio Regulations and adopting an <u>a priori</u> planning system for HF broadcasting. The IFRB was charged to implement and test the procedures adopted by the Conference and report the result of their studies to the next conference on HF broadcast planning.

The compromise included the adoption of several new procedures while trying to adhere to the already adopted planning principles. The procedures that would have the greatest impact on United States HF broadcasters would be the division of the broadcast bands into planned portions and consulted portions, appropriate band selection, transferring broadcast requirements from the planned portion of the spectrum to the consulted portion, and overall frequency continuity of broadcasts. Issues raised by the procedures are discussed.

Key words: broadcast reliability; broadcast requirement; HF spectrum utilization model; HF propagation prediction; IFRB; WARC for HF Broadcasting

1. **INTRODUCTION**

The Second Session of the Conference for Planning the Frequencies Allocated to the High Frequency Broadcasting Service [HFBC(87)] was held in Geneva, Switzerland, from February 2, 1987

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to March 8, 1987. This Conference reviewed a broadcast planning system that was implemented and tested by the IFRB under instructions of an earlier conference (Rush, et al., 1988b). The results showed that for most seasons and solar cycle conditions, more than half of the broadcast requirements in the world would not be satisfied at a level ensuring a high quality service. HFBC(87) developed new criteria to try to combine planning along with consultation. The planning is to be used in the expanded portions of the HF broadcast bands plus a small portion of the pre-WARC-1979 HF broadcast bands. A new improved consultation procedure will be used in the remainder of the pre-WARC bands (ITU, 1987). These criteria are to be implemented and tested by the IFRB and the results presented before a third HF broadcasting conference currently scheduled for the first quarter of 1993.

In addition to the partitioning of the bands, HFBC(87) made the following decisions that directly affect planning in the HF bands:

(1) No requirement would be suspended and those that could not possibly fit in the new planned portions would be transferred to a consulted portion.

(2) Frequency continuity would be ensured to the extent possible even if an administration chose to reduce the levels of protection it requires for its services.

(3) Co-channel protection ratios of 27 dB, used in the planned portions of the bands for compatibility analyses, are to be lowered to 17 dB under stringent rules before a requirement is transferred (also under stringent rules) to the consulted portions.

The United States has already undertaken preparations for the third session of the HF broadcasting conference to assure that a high quality, technically-viable service will be available to U.S. HF broadcasters. This is because HF broadcasting is a key element in implementing the policy of the United States to provide for the free flow of information across national borders that cannot be compromised.

The United States is following the work of the IFRB very closely during this inter-conference period as it interprets and implements the decisions of the HFBC(87). Particular attention is being paid by the Institute for Telecommunications Sciences to assure that all U.S. broadcast requirements will be satisfied and that the improved planning system does not compromise the U.S. broadcast service performance.

To assist in this effort, ITS developed a comprehensive computer model to determine the effect of a priori planning of HF broadcasting requirements on U. S. broadcasting objectives. The computer model followed the decisions made at the First Session of the HF Broadcasting Conference as contained in the report to the Second Session (ITU, 1984) and described by Washburn, et al (1987). Currently this model has been expanded to incorporate the decisions taken at the HFBC(87), in so far as the IFRB has interpreted the implementation of those decisions, and for planning and spectrum studies for all services that are allocated to the HF bands. The model, since named the high frequency spectrum utilization model (HFSUM), provides a powerful tool to numerically simulate the performance of high-frequency sky wave systems operating in both noise-limited and interference-limited environments. A description of the basic elements of HFSUM along with examples of frequency assignment applications, interleaving requirements to improve spectrum efficiency, and studies to optimize double sideband and single sideband operations can be found in Rush, et al (1988a).

Continuity in the use of a frequency (frequency continuity) provides consistency to the service area and is important for both the broadcaster and the listener. Ideally, a broadcaster would like to have the same frequency for the duration of a broadcast from day to day and season to season. This usually is not possible because of the changing nature of the earth's ionospheric reflector which enables HF radio wave propagation; the temporal, spatial, and seasonal nature of atmospheric noise which affects HF radio wave reception; and the interference caused by other services and requirements operating in the high frequency band. Further, limitations on frequency use may be imposed on some administrations because of constraints on transmitting equipment, thereby forcing continuous operations on the same frequency.

This report is confined to the decisions of HFBC(87) that directly affect frequency continuity in HF broadcast planning. The ensuing material details how appropriate bands are selected for broadcast requirements, how requirements come to be transferred from the planned portions of the bands to the consulted portions, how frequencies come to be assigned, and how frequency continuity is maintained in what is called the improved planning system (ITU(1987); IFRB(1989)). The sections of this report cover these topics in order and then discuss frequency continuity issues.

Certain conventions will be followed in the report concerning physical units. Any variables related to field strength will be expressed in decibels above a μVolt/m, denoted dBu, and any ratio between such variables will be expressed in decibels, denoted dB.

2. APPROPRIATE BAND SELECTION BY HOUR

The decisions of HFBC(87) provided portions of the HF bands for use under a planning procedure and the remainder for use under an improved consultation procedure. The entire process was labeled the improved planning system and is documented as stated above. Under this improved planning system, administrations can specify if a requirement is to be considered for the planned portion or should be placed in the consulted portion. There is the possibility that a requirement designated for the planned portion to not be assigned a frequency there, but rather to be transferred to a consulted portion of an HF band and assigned a frequency there. Figure 1 depicts the distribution of the HF bands allocated for the broadcasting service along with the corresponding planned and consulted portions. This figure shows what spectrum was assigned exclusively for the HF broadcasting services before and after the WARC-1979. This WARC decided to expand the spectrum for this service. Figure 1 also shows the portions of the spectrum allocated for planning and consultation as resolved by the HFBC(87).

As an aside, 8.6% of the 27 MHz that makes up the HF band is currently allocated for HF broadcasting. Including the expanded bands, authorized by the WARC-79 but awaiting implementation by a future competent HF WARC, the amount of spectrum allocated for HF broadcasting will become approximately 11.6% of the HF band. To test the improved planning system, the current bands plus the expansion bands will be used with approximately 60% designated for the consulted procedure and approximately 40% designated for the planning procedure. This translates to a total spectrum of 1880 kHz for the consulted portion and 1250 kHz for the planned portion. The limited Reallocation Conference (ITU, 1989) scheduled for the first quarter of 1992, will have an effect on the spectrum allocated exclusively to the HF broadcast bands and the actual spectrum proportions are likely to change for the purposes of testing.

The noise-limited portion of HFSUM assesses a broadcast requirement's chance of success in its service area. An algorithm decides which band or bands would provide the greatest reliability for the time period that the requirement must operate. This algorithm is called the appropriate band selection algorithm.

The expression "appropriate band" grew out of ambiguities written in the Report to the Second Session (ITU, 1984), which used the expression several places, but never defined the concept. As a result of the HFBC(87), the expression

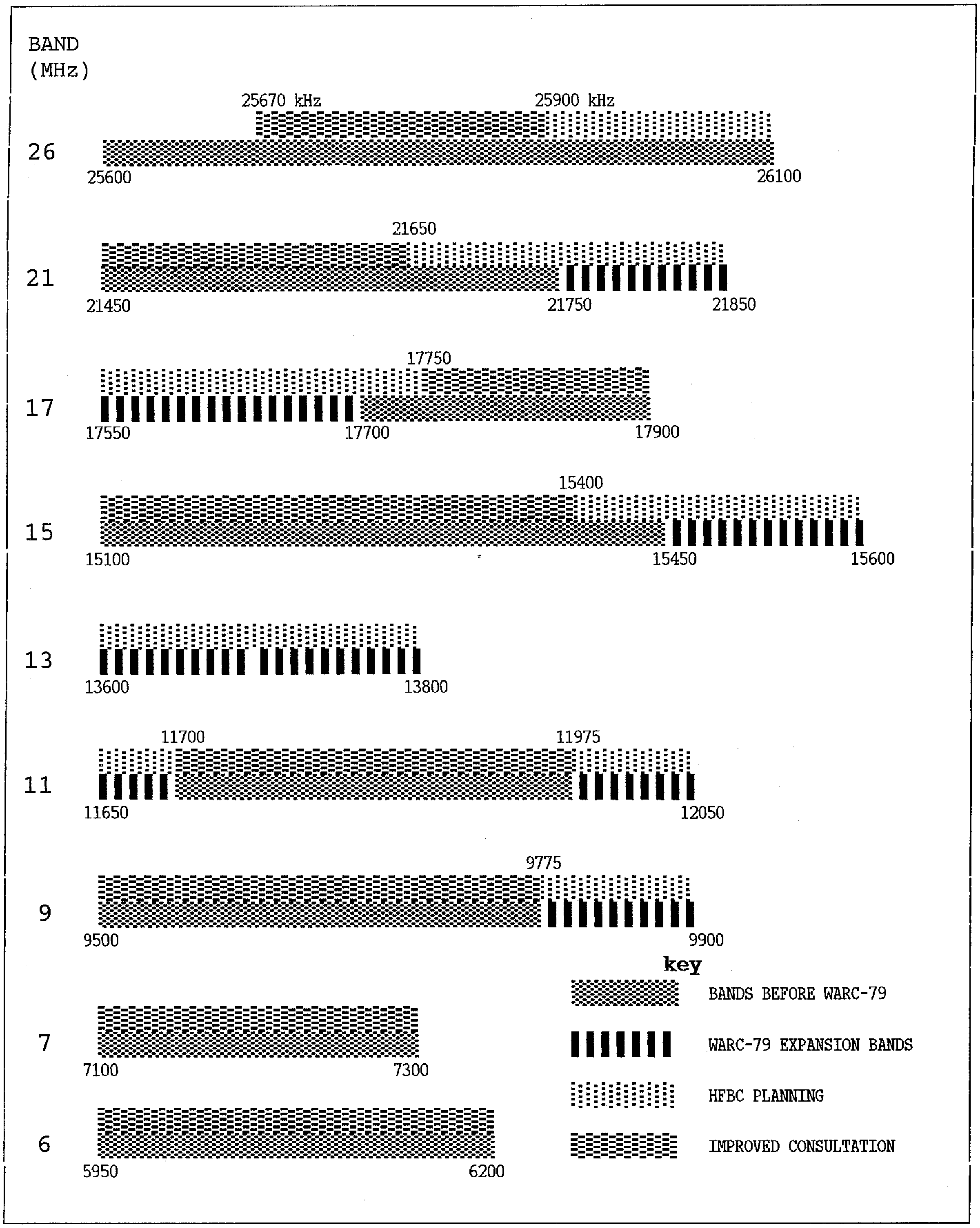

Figure 1. Current division of bands for testing (from Leinwoll, 1988)

"appropriate band" came to have a specific meaning, namely "The appropriate band for a requirement is the band which will ensure the continuity of use of the same frequency during the longest possible period of operation, with the best possible values of basic broadcast reliability (BBR), taking account of propagation conditions, operational limitations, and equipment availability and constraints" (IFRB, 1989).

This definition makes sense provided one knows what is meant by frequency continuity, BBR, propagation conditions, operational limitations, and equipment availability and constraints. The Final Acts of HFBC(87) (ITU,1987) define these concepts and for the sake of completeness these definitions will be repeated here as the concepts are used.

Administrations have the choice of submitting requirements either for the planned portion or the consulted portion of the HF broadcast bands. There is a good possibility that not every requirement designated for the planned portion will be assigned a frequency there. Usually there are more requirements than spectrum to accommodate them. As a result some requirements will have to be transferred to the consulted portions. Thus, those either transferred to, or designated for, the consulted portion will be assigned there, but those designated for the planned portion will only be assigned there <u>to the extent possible</u>. HFSUM is used to determine the "extent possible" for those designated for the planned portion.

Initially, for the requirements designated for planning, HFSUM calculates the propagation conditions for which a plan is to be generated and determines the band or bands the requirement would be suitable for in the presence of atmospheric noise and equipment limitations. One sees from Figure 1 that the actual bands available for planning are portions of the 9, 11, 15, 17, 21, and 26 MHz bands and all of the 13 MHz band. HFSUM determines from the information about the requirement which bands are available to it and calculates a measure of broadcast success into the desired service area called the basic broadcast reliability (BBR), accounting for all transmitted frequencies (possibly, up to three). The qualifications for these additional frequencies are discussed below.

The requirements submitted for the planning process provide information about the administrations' transmission capability. It provides information about the desired service area, frequency or band preference, usable bands, antenna, power, transmitter location, and broadcast times. From this information the basic circuit reliability (BCR) can be calculated for each service area test point and for each band the administration declared it could operate in. The BCR is the probability that the predicted signal's median field strength will exceed some nominal median value. This nominal value is the minimum field strength required for the signal to achieve "good" reception at a test point in the service area and is called "Emin." Emin has factored into it a protection ratio against the predicted median effects of atmospheric, man-made, and intrinsic receiver noise.

The BCR's at each of the service area test points for the hour-band are ranked greatest to least. The BCR at the test point that is exceeded in value by 80% of the BCR's at the other test points in the service area is the BBR for that hour-band.

Band types are assigned on the basis of median field-strength (Ep) in dBu compared to minimum required field-strength values (Emin) in dBu at each test point. Type-A bands are those where the (Ep-Emin) are greater than or equal to 0 dB at all service area test points. Type-B bands have this same characteristic at some, but not all, of the test points. Type-C bands have (Ep-Emin) less than 0 dB at all test points but at some of these, possibly one, (Ep-Emin) is greater than or equal to -10 dB. Finally, Type-D bands have their (Ep-Emin) values less than -10 dB at all test points.

Selection of an appropriate band for a requirement starts with the selection of an appropriate band for each operational hour of the requirement. The first case for choosing the appropriate band for the hour under consideration occurs if the BBR is greater than 80% in one or more bands. The band types can be only A and B. Given the choice between these, choose the type-A band. If there are 2 or more bands of the same type choose the band with the greatest BBR. If this results in identical BBR values (a tie) choose the higher band.

Case 2 occurs when the BBR is greater than or equal to 50% and less than 80% in one or more bands. This is also the case when such a requirement may qualify for additional frequency bands so that it may broadcast simultaneously on two or three frequencies to improve its signals to its service area. If such is the case then the band with the greatest BBR will be taken as the primary appropriate band. In case of a tie, choose the higher band (additional individual frequency-band qualifications are given below).

Case 3 occurs when the BBR is less than 50% in all bands. If one or more of these bands is type-B, then choose the band with the most test-points that have (Ep-Emin) greater than 0 dB. Otherwise, if one or more bands is of type-C, choose the band with the most test-points that have (Ep-Emin) greater than or equal to -10 dB. The only remaining possibility is that all the bands available to the requirement are of type-D. In this last case, choose the band with the greatest BBR, and in case of ties, choose the higher band.

Table 1 provides the steps to determine if the requirement qualifies for additional frequency bands, by hour. If the requirement does qualify then the primary band and the additional individual bands are considered to be the requirement's appropriate bands for the hour.

Table 2 summarizes the appropriate band selection rules for each band-hour. Modifications to the appropriate band selection for the entire operational period of the requirement will be discussed in the Section 3 on frequency continuity.

In IFRB (1989) a statement is found that could have made a profound impact on the planning system. That statement is found in Chapter 4, Section 5 and has to do with the preferred frequency band; i.e., "...the preference of the administration

Table 1. Rules for Additional Frequency Bands

Step No.		Process
1	*	Choose the test points whose BCR's are < or = to BBR of the primary band.
2	*	Choose minimum value of BCR at each of the above test points in each of the other available bands.
3	*	Choose band with highest value of BCR (in 2 above) as candidate for second frequency band (in case of ties choose the highest band).
4	*	Calculate[º] Y = 30 + 0.75 x BBR of primary band and determine the BBR of the primary and candidate bands (in 3 above). If BBR of both bands is greater than the value Y the requirement qualifies for the second frequency band If the BBR of the primary and candidate bands is not greater than the value Y then the requirement does not qualify for the additional band.
5	*	If the requirement qualifies for the additional band and the BBR of the primary and secondary bands is still less than 80% then the requirement can be tested for a third band. For each of the remaining available bands the individual BBR values are determined and that band having the highest value of BBR is selected as a candidate for the third band.
6	*	Determine the BBR of the three bands in question and compare this value to Z = 30 + 0.75 x BBR of primary and secondary bands. If the BBR of the three bands is greater than the value of Z then the requirement qualifies for the third band. If the BBR of the three bands is not greater than the value Z the requirement does not qualify for a third band.

º Note: See IFRB (1989) Chapter 4, Section 4 for details on calculating BBR's for one or two additional frequency bands.

takes priority over the appropriate frequency band." The IFRB recognized that by implementing this "priority" they could have impaired a requirements' transmitting effectiveness in lieu of technical soundness and therefore, in spite of the statement, the preferred band will be selected if and only if it can qualify as the appropriate band. The preference of the administration is factored into appropriate band selection under conditions to be discussed in Section 4 on appropriate band selection by requirement.

Table 2. Appropriate Band Selection for Each Hour

Step No.	Process
1.	* Determine individual BBR's and band types for each usable band.
2.	* If the BBR is greater than 80% in at least one band, given the choice, choose the type-A band with the highest BBR as the appropriate one. If no type-A bands exist then choose the type-B band with the highest BBR (In case of ties choose the highest band). * Otherwise, continue with step 3.
3.	* If 50% <=BBR< 80% for at least one band, then choose the band with the greatest BBR as the appropriate band (this band also becomes the primary band used to investigate the possibility for the requirement to qualify for additional bands). In case of ties choose the highest band. * Otherwise, go on to step 4.
4.	* BBR's are all < 50%. Choose the type-B band with the most test points having (Ep-Emin)>0 dB. If no type-B bands exist choose the type-C band with the most test points with (Ep-Emin)>=-10 dB. * Otherwise, continue with step 5.
5.	* Only type-D bands exist for this requirement. Choose the band with the greatest BBR. In case of ties choose the highest band.

3. FREQUENCY CONTINUITY

As stated earlier continuity in the use of a frequency is an important matter for both the broadcaster and the listener. The desirable aim is that frequency change should be limited to those necessitated by variations in propagation conditions. As a result of this, HFBC(87) provided details as to types of frequency continuity and their application. Table 3 provides a list of the types of frequency continuity that have to be considered in the planning process. These apply to the consulted portion of the HF bands as well. However, type-1 frequency continuity is the only type of continuity that must be considered in testing the improved planning system. The other types of continuity will be granted to the extent the appropriate bands of one requirement become the appropriate bands of the other.

Table 3. Frequency Continuity Types

Frequency continuity Type	Definition
1.	Continuity of use of the same frequency within an hour or from one hour to the following hour for one requirement.
2.	Continuity of use of same frequency in the same season when passing from one requirement to another or one time block to another.
3.	Continuity of the use of the same frequency for the requirement in two consecutive seasons.
4.	Continuity of use of the same frequency for the requirement in two consecutive equinoctial seasons.
5.	Continuity of use of the same frequency for the same requirement in the same season in two consecutive years.

The specific rules for the application of frequency continuity are deduced from ITU (1987) and IFRB (1989), and are linked to the requirement's appropriate band.

The IFRB has had to interpret the HFBC(87)'s stipulations for type-1 frequency continuity. It has attempted to determine the appropriate frequency band which will provide the same frequency over the longest possible period of operation where the BBR in each of the contiguous hours of operation is not less than 80%. Many cases arise in choosing the appropriate band. In cases where an administration wants continuity over longer periods of operation it may specify a BBR reference value lower than 80%. Throughout the period of operation for a requirement the number of frequencies permitted to be used simultaneously could vary from 1 to 3 depending on propagation conditions. Frequency continuity for these additional frequencies will be applied if, and only if, these frequencies are permitted.

Special cases arise from the application of the appropriate band concept. Preset frequencies imply the appropriate bands can only be in the bands where these frequencies are located. Likewise, if an administration can only use its facilities in a given band, this band will be considered to be the appropriate band. Whenever two or more frequency bands are available for use and one of them is a preferred frequency band, the appropriate frequency band may not coincide with this preferred band. In such a case the preference of the administration takes priority over the appropriate frequency band and the system will attempt to select a frequency in the preferred band. If several values of power are available, the appropriate frequency band shall be that band which ensures the achievement of the desired BBR reference value with the single lowest value of power. Lastly, the appropriate frequency band shall be the band in which the available antenna can operate.

The relationship between frequency continuity and appropriate bands is summarized in the following six HFBC(87) considerations (IFRB, 1989) and each is explained by using an example. The general case of the actual appropriate band selection algorithm is more complex and will be discussed in Section 4.

1) When a single frequency is sufficient to provide a BBR greater than or equal to the BBR reference value (nominally set at 80%) the appropriate band is determined by using the type-1 frequency continuity rule. As an example, suppose a broadcast requirement needed two contiguous hours as shown in Figure 2(a). Further suppose bands 9, 11, and 13 had BBR's of 90, 80,and 76% respectively in hour 1 and correspondingly 74, 80, and 83% in hour 2. The appropriate band selection based on the hour alone would be to select band 9 for hour 1 and band 13 for hour 2. Applying type-1 continuity to the requirement the appropriate band would be band 11 since it had achieved a BBR of at least 80% in both hours.

2) Administrations may choose to extend frequency continuity at the expense of BBR and can indicate this by specifying a lower reference value of BBR to be used. For example, using the Figure 2(b) where the BBR values remain the same as the previous example but the administration has indicated it would accept a BBR value of 70% to extend frequency continuity. In this case the appropriate band for the duration of the requirement would be band 9. Note all the bands in the example are type-A and because a lower BBR reference is acceptable the algorithm would choose the appropriate band as the one with the highest average BBR.

3) In the application of frequency continuity with the reduced BBR reference value, additional frequencies are allowed. But they are allowed only to the extent they will not exceed the number of additional frequencies in the original appropriate bands calculated for the hour. For example, using the BBR values

(a) Single band only in any hour

Appropriate bands by hour alone, BBR ref = 80%

band/hour	01	02
09	90A*	74A
11	80A	80A
13	76A	83A*

Appropriate band with type-1 continuity

band/hour	01	02
09	90A	74A
11	80A*	80A*
13	76A	83A

key

A,B band types
* appropriate band for the hour
+ not allowed as third band

(b) Single band only in any hour

Appropriate band with type-1 continuity, BBR ref = 70%

band/hour	01	02
09	90A*	74A*
11	80A	80A
13	76A	83A

(c) Multiple bands allowed in any hour

Appropriate bands by hour, BBR ref = 80%

band/hour	01	02	03	04
09	90A*	74A	76B*	58B
11	80A	80A	76B*	60B*
13	76A	83A*	75B	58B*
15	73B	75A	75B*	56B*

Appropriate bands with type-1 continuity, BBR ref = 75%

band/hour	01	02	03	04
09	90A	74A	76B	55B
11	80A	80A	76B	60B*
13	76A*	83A*	75B*	58B*
15	73B	75A	75B	56B*

(d) Single band only in any hour

Appropriate band with type-1 continuity, BBR ref = 70%

band/hour	01	02	03	04	05
09	66A	66A	67B*	48B	71B
11	80A	70A	66B	44B	64A
13	70A*	83A*	65B	50B*	70B*
15	63B	65A	65B	46B	55B

(e) Multiple bands allowed in any hour

Appropriate band with type-1 continuity, BBR ref = 75%

band/hour	01	02	03	04	05
09	66A	66A	75B*	68B*	71B
11	70A	70A	66B+	44B	64A
13	80A*	83A*	65B*	76B*	75B*
15	63B	65A	65B	66B*	55B

(f) Multiple bands allowed in any hour

Appropriate band with type-1 continuity, BBR ref = 80%

band/hour	01	02	03	04	05
09	66A	66A	70B*	68B*	71B*
11	80A*	70A	66B*	44B	64A
13	70A	83A*	65B	70B*	70B
15	63B	65A	65B	66B*	55B

Figure 2. Examples of appropriate band selection.

shown in Figure 2(c), hour 3 qualifies for additional frequencies. But by invoking frequency continuity, band 13 in this hour is chosen the appropriate band. This was not one of the bands designated as the hourly appropriate band. Since hour 3 used a reduced BBR reference value to achieve frequency continuity it is not allowed the use of other frequencies.

4) If an administration indicates it can only operate on a single frequency at one time and the BBR is less than 80% in some of the hours, continuity of use of this single operating frequency will be assured within the lower BBR reference value indicated by the administration. For example, in Figure 2(d) one sees that only one frequency band is available in any one hour and the BBR values are below 80% in some hours. Assume the administration indicated a BBR of 70% would be tolerable to assure frequency continuity. Note, continuity in one band is held as long as possible within the lower value of the BBR in the selection of the appropriate band.

5) If an administration can operate on more than one frequency the use of a lower BBR reference value shall not allow the use of a third frequency. For example, observe Figure 2(e) and note additional bands are allowed for hours 3 and 4. Also note that to achieve continuity the administration's lower BBR reference value of 75% has to be invoked for hour 3. As a result of step 5) only one additional frequency can be used instead of the two additional bands it initially qualified for in hour 3.

6) If a requirement qualifies for additional frequencies frequency continuity shall apply to these frequencies in the same manner as for the first frequency. For example, in Figure 2(f) one observes that in each of the hours the requirement qualifies for additional frequencies, e.g. hours 3 and 4, the continuity of the additional bands are preserved where possible.

4. APPROPRIATE BAND SELECTION BY REQUIREMENT

The details for choosing appropriate bands for one hour are given in Table 2 and the rules to determine additional frequencies were given in Table 1, but Section 3 shows that appropriate band selection is much more complex when the stipulations for type-1 frequency continuity have to be incorporated. The Final Acts of HFBC(87) (ITU, 1987) did specify that the IFRB was to determine an exact methodology for appropriate band selection. The IFRB has done so based on its interpretations of these Final Acts. This procedure is extremely complicated and will be explained here in general terms. The major steps of the procedure are given in Table 4 and the actual flow chart and computer code for appropriate band selection used by the IFRB appears in Appendix A for those interested in the details of this procedure.

The general procedure for determining the appropriate band is presented here as an heuristic exercise using an example created by the IFRB. Figure 3 shows the matrix of hourly BBR values for a fictitious requirement which has 4 available bands. The requirement requires 8 hours of operation, not necessarily contiguous in time but contiguous in the matrix, and there is no specified preferred band. What considerations are now given to determine the appropriate band for this requirement? Note the hourly appropriate bands were determined from Table 2 and are designated by the "^" symbol. The greatest number of contiguous hours with BBR's exceeding the BBR reference value of 80% is determined for each band, then the next lowest number of contiguous hours with BBR's exceeding this reference is determined and so forth until all bands and all hours are processed. Next the results are sorted by band and ordered greatest to least with the results in this case shown in Table 5. The number of columns in this table is simply the number of possible hour-pairs allowing for a wrap around from the last hour

Table 4. Outline of the Appropriate Band Selection Algorithm

1. Initialize by arranging the matrix of hourly BBR values (available bands vs hours).

2. Determine the hours for which BBR >= BBREF (the BBR reference value) by band. If none, take the bands with the highest BBR for all the remaining hours as the appropriate band(s). Ties are resolved by noting the appropriate band should have a minimum number of band changes, the most type A bands and the highest average of BBR's >= 80% . For this case the appropriate band(s) has been selected, otherwise, proceed with the next step.

3. For each band determine the number(s) (NMAX) of consecutive hours where BBR >= BBREF and order these by the NMAX(s) greatest to least.

4. Select the band with the largest NMAX and proceed to section A. If equality exists among the NMAX's go to section B1.

Section A (Store appropriate band by hour block, determine next action)

5. For the hours involved in NMAX store the appropriate band and remove these hours from further consideration.

5a. Examine the best BBR's remaining. If some or all are < 80% select the band(s) for which the BBR is the best and store appropriately. In any case proceed to section E. If none are remaining, the appropriate band selection is complete for this requirement.

Section B1 (Equality among the NMAX's)

6. Examine the best BBR's in adjacent hours to the equal NMAX's. Determine from the mix of BBR's if the appropriate band selection can be extended (return to section A), preferred frequency band can be invoked (return to section A), if another level of ties occurs among the new set of NMAX's (proceed with section C), or if the number of unresolved ties needs further organization into separate plans (proceed with section B2).

Section B2 (Organizes the separate possible outcomes)

7. Analyze the plans to determine the greatest number of type A bands within an NMAX, if none take the best BBR's for the remaining hours as the appropriate band and the selection is complete. Otherwise, break ties, if any, by averaging type A band BBR's and choosing the highest band as the appropriate band. In any case return to section A.

Section C (Tracks progress on the possible outcomes)

8. Determines the total number of parallel plans this algorithm has to deal with (proceed with section D) and keeps track of the branches of the plans taken (returns to section A)

Section D (Provides the record keeping for the possible outcomes)

9. Does the actual ordering of the bands by hour in the various plans and creates a matrix from which decisions can be made. Once done for each plan proceeds with section E.

Section E (Finalizes the selection of the appropriate band(s))

10. Assures analysis is proceeding on all plans and distributes results to the proper section.

to the first. To arrive at this number divide the number of available requirement hours by 2, truncate to the nearest integer, then and add 1. In this case, [(8/2)+1] = 5.

An inspection of the table shows there is an equality between bands 9 and 11; therefore, it is necessary to investigate further assuming each of these bands in turn as the appropriate band to see what impact each would have on the final selection. Each path is termed a "plan." Remove the hours involved in each band that are included in the greatest number of contiguous

HOUR:	1	2	3	4	5	6	7	8
BAND	BBR *	BBR *	BBR *	BBR *	BBR *	BBR *	BBR *	BBR *
6								
7								
9	82+B2	81+B2	73 B4	76 A3	84+B3	81+B3	83+A2	84+B3
11	^85 A1	^85 A1	76 A3	81 A2	86 A2	85 A2	^86 A1	73 A4
13								
15	-- C	70 B3	^85 A1	48 B4	60 B4	^88 A1	77 B4	82^A1
17								
21	-- D	-- C	80+A2	^87+A1	^90 A1	70 B4	80 A3	92 B2
26								

* Note: letter - band-type for the hour
number - ranking for appropriate band within the hour
^ - appropriate band selection within the hour
\+ - appropriate band selection applying frequency continuity rules

Figure 3. Finding the appropriate band by requirement.

hours, i.e., 4. The number of subsequent sets of contiguous blocks to consider is 3, i.e., [[(8-4)/2]+1]. Table 6(a) depicts the result of applying the search for BBR's exceeding the BBR reference in the remaining contiguous hours in each band and ordering the findings. Note, once again, the equality found in bands 9 and 11. So once again the hours representing the biggest block are removed from analysis and the remaining hours are subjected to the search in their respective cases or plans. In this latter case the number of search sets becomes 2, i.e., [(8-6)/2+1]. Table 6(b) shows the result.

Table 5. Ordered Number of Contiguous Time Blocks Exceeding BBR Reference

BAND	Ordered Numbers				
9	4	2	0	0	0
11	4	2	0	0	0
15	1	1	1	0	0

Table 6. Final Processing of Ordered Number of Contiguous Hour Blocks

(a) First Comparison

BAND	Ordered No. (Plan 1)			Ordered No. (Plan 2)		
9	2	0	0	2	1	0
11	2	1	0	2	0	0
15	1	0	0	1	1	0
21	2	0	0	1	1	0

(b) Final Comparison

BAND	Ordered No. (Plan 1)		Ordered No. (Plan 2)	
9	0	0	1	0
11	1	0	0	0
15	1	0	1	1

At this point the plan that shows the fewest number of band changes is chosen as the best plan. The fewest band changes are determined by counting the actual number of times the bands change first for plan 1 and then for plan 2. In this example plan 1 shows the fewest changes and is chosen which implies band 9 would be the appropriate band for hours 1, 2, and 5 through 8 with band 21 being the appropriate band for hours 3 and 4. A "+" symbol in the hourly matrix of BBR's in Figure 3 indicates the appropriate band selection for the requirement.

This example shows some of the complexity involved in selecting the appropriate band for a requirement. In general if equality does exist at various levels of analysis, the preferred frequency band, if designated, is given the preference at that level for the consecutive hours involved. It is conceivable that equality of selection could exist among two or more bands with no preferential frequency band indicated. At this point, individual plans would be generated based on the choices presented between equal possibilities and the alternative plans tabulated. The selection of the best plan would be based on the final outcomes of the alternate plans. First consideration would be based on the number of band changes, fewer being the choice. If equality still exists, selection would be based on the number of type-A bands in the last outcome of the alternate plans, the greater number being choice. If equality still exists, the band with the highest average of BBR's greater than or equal to 80% is chosen as the appropriate band. At this point, if equality still exists, the higher band is chosen.

5. TRANSFER RULES

With the determination of the appropriate bands for each requirement in the planned portions of the HF band, some analysis is necessary to determine which requirements can occupy these bands in cases of congestion. Congestion occurs if the number of required channels exceeds the number of available channels. The quantitative analysis required to determine this congestion is detailed in IFRB (1989) and will be outlined here.

First some analysis is required to determine for a given hour-band the signal-to-interference ratios (S/I's) for all of the requirements competing for a channel. Essentially, each requirement is taken as wanted in turn and the remainder are considered as unwanted interferers in the wanted requirement's service area. On a protected (or partially protected) test-point-by-test-point basis the median field strength of the wanted requirement's signal is compared to the RSS (root-sum-square) of the interferers' median field strengths. The resultant ratios of signal to interference at each test point are ordered greatest to least and that ratio exceeded by 80% of the others is taken as the S/I value for entry in the S/I matrix. The wanted requirements, in order, are the rows and the interferers, in the same order, are the columns of this S/I matrix. This composes a square matrix where the diagonal elements are zero. This matrix is not necessarily symmetric because interference between any two given requirements is not necessarily reciprocal.

On the basis of the S/I matrix for all pairs of requirements in a given hour-band, an incompatibility matrix is created by associating with each element of the S/I matrix a corresponding element in the constraint matrix. The constraint matrix element value depends on whether the two requirements are co-, first-, second-, or possibly third-channel compatible. Table 7 provides an explanation of the values used for these elements. In case the transposed elements of the constraint matrix are different, the greater value replaces the lesser in this matrix, and the constraint matrix so obtained is symmetric.

This constraint matrix is further analyzed by finding the largest group of incompatible requirements within it. This group, or groups (for it may not be unique), consists of all requirements which are incompatible with each other. The number of entries in this group represents a lower bound on the number of channels required to satisfy the requirements in the constraint matrix. If this number is greater than the available number of channels then congestion exists and will have to be resolved. In this case the disparity between the required number of channels and those available is called the deficit and is denoted here as "d." HFBC(87) provided mechanisms to reduce congestion.

The incompatibility matrix with the greatest difference between the number of required and available channels is identified among the various hours and bands where congestion occurs. This matrix corresponds to the most congested hour and band. Of all the groups of incompatible requirements in this matrix the largest is chosen and is called the greatest group of incompatible requirements (GGIR). This GGIR may not be unique so all the elements which appear at least once in a GGIR are placed in a set called the maximal group of incompatible requirements (MGIR). The method for selecting the GGIR's is a near optimal approximation to a method that is NP-hard (Garey and Johnson, 1979) and is used because of its speed of computation.

HFBC(87) stated the improved planning system will endeavor to satisfy the requirements with a minimal co-channel RF protection ratio of 17 dB without taking account of the fading allowances and multiple interference entries. In cases of congestion this ratio may be lowered until the congestion is resolved. This caveat is accounted for in the establishment of the S/I matrices since the assessment of congestion is based on a 27 dB co-channel protection ratio.

Having identified the MGIR of the most congested hour and band, a first attempt to reduce congestion can be made by lowering by 3 dB the RF protection ratio of all requirements in this MGIR. This process is applied as required until congestion is resolved or until it is impossible to find a solution with the co-channel RF protection ratio of 17 dB. However, each time the protection ratio is lowered, a new MGIR is found and a further reduction of the protection ratio is only applied to the members of the latest MGIR. Note, that requirements not members of any MGIR retain their original RF protection ratio.

Table 7. Elements of the Constraint Matrix

Constraint Matrix Element	X = (S/I Matrix Element-Protection Ratio)	
	10 kHz channel-spacing	5 kHz channel-spacing
0	0dB < X	0dB < X
1	-35dB <= X < 0dB	-3dB <= X < 0dB
2	X < -35dB	-35dB <= X < -3dB
3	-	X < -35dB

Where: 0 - co-channel compatible
1 - first adjacent channel compatible
2 - second adjacent channel compatible
3 - third adjacent channel compatible

If the congestion is not resolved by the above step, then HFBC(87) provided a set of transfer rules to equitably transfer requirements to the consulted portions of the HF bands. These rules are summarized in Table 8.

In theory, requirements are to be transferred one at a time in the hope that the congestion will be relieved and frequency assignment can begin. This would require, of course, after each transfer recomputing the GGIR's and the MGIR if the deficit "d" remained positive. In practice something else is done. An heuristic value of "d+1" requirements are all transferred at one time to reduce congestion and minimize computation time. The identification of the requirements to transfer is based on an algorithm which applies the transfer rules as necessary to transfer the "d+1" requirements. This process will allow for fewer iterations. During the process of applying rules N1, N2, or N3, there may be a need to decide which of two or more candidates for transfer from the same administration should be transferred. The decision can be made on the basis, in sequence, of the greatest number of incompatibilities, the smallest requested transmission period, and lastly the lowest BBR value.

If after application of the transfer rules congestion still exists, then a protection ratio reduction of 3 dB is made to each requirement in the new MGIR until the congestion is relieved. Note that after each 3 dB reduction a new MGIR is computed. It

Table 8. Summary of the Transfer Rules

Rule # -Name	Action
N1 -Identical Service Area	-(1)Sort rqs in MGIR by ad, by service area, (2)transfer rq from most populous to consultation procedure, (3) repeat as necessary to reduce congestion.
N2 -Identical Unit of Service Area	-(1)Sort rqs in MGIR by ad, by unit of service area, (2) transfer rq from most populous, (3)repeat as necessary to reduce congestion.
N3 -Identical Unit of Service Area in Other Bands	-(1)Sort rqs in MGIR by ad, by unit of service area in other bands, (2) transfer rq from most populous, (3)repeat as necessary to reduce congestion.
N4 -Rqs with Additional Frequencies	-(1)Sort rqs in MGIR by ad, by additional bands, (2) transfer rq if BBR is lowest, (3) repeat as necessary to reduce congestion.

If congestion still exists use 3 dB reductions of the RF protection ratio of all requirements in the MGIR to eliminate congestion.

Note: Abbreviations used solely in this table are rq - requirement; ad - administration.

is possible that some requirements will be protected below the 17 db floor set by HFBC(87), in this case the administrations so affected will be notified by the IFRB if they have so designated on the requirements form.

Another important item to consider is the necessity to provide frequency continuity for the largest possible period of operation. Therefore, if a requirement is transferred to the consulted portion of its appropriate band during the transfer process, even only for one hour of a contiguous block of hours, then it is transferred in all of the hours in that contiguous block.

6. FREQUENCY CONTINUITY FOR THE IMPROVED PLANNING SYSTEM

After the application of the transfer rules to reduce the congested hour-bands, two sets of files of requirements exist for processing by the frequency assignment algorithms. The first set consists of the resolved requirements in the planned portions of the HF bands and the second consists of the requirements transferred to the consulted portions of the HF bands. This latter file may also consist of requirements transferred on request of the administration concerned because their RF protection ratio was less than 17 dB. This file also contains portions of requirements that were transferred in order to ensure frequency continuity with respect to other portions of requirements to which the transfer rules applied.

A specific frequency assignment algorithm is applied to the file of resolved requirements and a different one is applied to the file of transferred requirements which exist for each hour-band. While assigning frequencies to requirements in the bands where the planning procedure applies, four constraints have to be considered. These are frequency continuity, preset frequencies, preferred frequencies, and synchronized requirements. Each of these has an impact on decreasing the efficiency of any frequency assignment algorithm.

The approach taken to assign frequencies under the consultation procedure is based on "least adversely affecting" (IFRB, 1989) those already assigned frequencies as a result of notification or previous assignment. In case of transferred requirements with a period of operation exceeding one hour, the frequency to be selected, which ensures continuity, will be the one causing the least amount of degradation to existing requirements over the entire period of operation.

HFBC(87) was very specific in insisting on ensuring frequency continuity. Having assigned a frequency to a specific requirement in a given hour-band, the same frequency will be assigned to the same requirement in all its hour blocks for which the appropriate band remains the same. This is the application of type-1 frequency continuity of Table 3. The other continuity types will be ensured to the extent the respective appropriate bands of the requirements involved are the same.

Preset frequencies, another constraint to frequency assignment, are allowed when an administration so indicates on its requirements form, denoting the impossibility of operating its transmitter on any other frequency in a band. If the preset frequency is in the only available band to the requirement then the requirement will be assigned that frequency. On the other hand, if there are other available bands to the requirement outside of the band of the preset frequency, then the requirement will be assigned a frequency in its appropriate band. Incompatible preset frequencies from different administrations will be referred to the administrations involved. It is not possible to transfer requirements with preset frequencies into the consulted portion of a band. These cases, where requirements qualify to be transferred but cannot because of the preset frequency, will be referred to the administration involved.

The next constraint to the assignment of a frequency to a requirement is in the category of preferred frequencies. When an administration indicates a preferred frequency, the band in which it is located is considered to be a preferred band for the purposes of determining the appropriate band. To the extent possible this is done. In the application of the frequency assignment method an attempt is made to assign any preferred frequencies present in the hour-band under consideration. If this results in difficulties or inefficiencies in assigning frequencies to other requirements, the preferred frequency will be disregarded and other frequencies in the same band will be assigned.

The last constraint in assigning frequencies applies to those designated as synchronized requirements. These are the requirements which broadcast simultaneously from different locations to overlapping service areas. For the purposes of the improved planning system, synchronized requirements are considered as one requirement and the same frequency will be assigned to the individual synchronized requirements.

The frequency assignment procedure tries to assign frequencies so that no unacceptable interference is caused to any of the requirements. This procedure is applied sequentially for each hour-band, starting with the most compatible hour. The plan obtained becomes the basis for the next incremental hour and permits the carry-over of assignments to the next hour as required. This approach ensures frequency continuity.

As stated earlier, the establishment of the GGIR's were based on approximate methods because of practical considerations. The order of this group represents a lower bound on the number of required channels. Thus any deficit "d" between the required number of channels and the available number may not be precise in terms of what is exactly needed. In some cases, then, the frequency assignments are not given to all requirements. This situation warns that the congestion was not totally resolved for the hour-band in question and it is necessary to return to the application of the transfer rules with the corrected deficit "d", transfer the necessary number of requirements, and restart the frequency assignment process. This iterative process is repeated until the frequencies are assigned to all requirements.

7. SUMMARY

This report discusses the decisions of the HFBC(87) relating to appropriate band selection and frequency continuity in HF broadcast planning under the "improved planning system." The discussion details the appropriate band selection process and the relationship between this selection and assigning frequencies to HF broadcast requirements.

The report points out that achieving acceptable reception quality and having as few frequency changes as possible during an HF broadcast are important considerations for both the broadcaster and the listener. The improved planning system calls for frequency changes only when propagation conditions necessitate. It follows that the selection of the appropriate band is critical in determining frequency continuity for a broadcast requirement. As is shown, appropriate band selection is a complex matter which takes into consideration a requirement's band type, its BBR value in each band-hour, the BBR's relative values by band-hour, and the administration's willingness to reduce the BBR reference value for the sake of frequency continuity.

Further, the report points out that frequency continuity is applied to both the planned and consulted portions of the HF broadcast bands under the improved planning system. Since all requirements will be included in a seasonal broadcast plan there may be a transfer of requirements originally requested for the planned portion to the consulted portion. The interference conditions under which a requirement may come to be transferred are detailed as well as the actual transfer rules.

The frequency assignment process comes when all requirements are in place in their appropriate band in either the planned portion or the consulted portion of the HF bands under the improved planning system. Those requirements in the planned portion are then assigned frequencies by an algorithm (IFRB, 1989). It is shown that the transfer and frequency assignment processes are interrelated because of the imprecise manner in which the deficit "d" is determined. This may result in iterations of the two processes. The frequency assignments in the consulted portion are based first on notification and then on a least interference basis for the transferred requirements. These requirements are assigned frequencies on a first-transferred first-assigned basis.

8. DISCUSSION

The planning procedure presented to the HFBC(87) Conference proved to be inadequate. The main failures of that procedure were to permanently suspend some requirements and to not fully provide frequency continuity for requirements remaining in the plan. The Final Acts of HFBC(87) [ITU (1987)] noted that the changes to the proposed planning system would be a hybrid arrangement between an improved planning system and the consultation procedures under the existing Article 17 of the ITU Radio Regulations. These changes were incorporated by the Conference to try to save <u>a priori</u> planning in the use of spectrum allocated exclusively to the HF broadcasting service. As a result the Final Acts stated that <u>all</u> requirements would be included in the seasonal plans and that frequency continuity was to be incorporated to the extent possible. This latter caveat called for an elaborate algorithm to determine, as we have seen, the appropriate band for each requirement. Many cases for appropriate band selection were discussed -- from requirements with preset frequencies in one available band to those with many available bands requiring additional frequencies.

Many factors will influence the final outcome of the tests of the improved planning system. The outcome of the tests will influence the next HF broadcast conference scheduled now for 1993 [denoted here as HFBC(93)]. The first factor will be the final acts of the limited reallocation conference to be held early in 1992 (ITU, 1989) to determine if and when the bands allocated exclusively for the HF broadcasting service will be expanded. This outcome will affect the HFBC(93) preparations in order to give administrations time to adequately prepare requirements for submission to the IFRB for analysis under the improved planning system.

Other factors influencing the final outcome are related to the ambiguities in the Final Acts of HFBC(87) (ITU, 1987). The IFRB's interpretation of these Final Acts may, in fact, have changed some of the intentions of HFBC(87). The discussion here is directed to those interpretations which have an impact on planning for frequency continuity in HF broadcasting.

The Improved Planning System (Chapter 2, IFRB, 1989) discusses the potential problems in the identification of the appropriate bands for the consulted portions of the HF bands. The IFRB can identify these appropriate bands only if the proper information is supplied on the requirement form. If only a frequency is supplied, its band will be considered the appropriate one by the Board. If information about other bands is supplied then the appropriate band analysis can be performed. The **issue** here is that the IFRB's development of the capability to specify appropriate bands for administrations where historically the IFRB has only registered their broadcast frequencies. It can be argued that the IFRB only does this upon request or by default, nevertheless this establishes the precedent for IFRB-assigned bands and frequencies under the consultation procedure.

Since all requirements are to be assigned a frequency, administrations may want to give careful consideration as to where their requirements most likely will be assigned. Requirements transferred from the planned portions of the bands must be placed in the consulted portions. In cases where frequency continuity is to be applied in all circumstances for the requirement, if the requirement is transferred to the consulted portion from the planned portion, for even one hour, it is transferred in its entirety. Type-1 frequency continuity is mandatory for a BBR reference value of 80% or lower if the administration indicates it will accept a lower reference value. The **issue** here is where the administration really wants to apply for its requirement. If by the improved planning system a requirement qualifies for the planned portion of the HF bands in all but a minority of hours where it is transferred to the consulted portion, then the entire requirement is transferred to the consulted portion, a potentially more congested place than the planned portion. But if the administration designates its requirement for a preset frequency for the planned portion, it will get it. If the preset frequency is in the consulted portion, then it will be among the first assigned frequencies. All other transferred requirements will be assigned frequencies on a least interfering, first-transferred-first-served basis. The advantage is clearly with preset frequencies under either procedure.

The IFRB has considered interrelated questions with respect to the transfer process. These questions are:

(1) To which bands shall the requirement be transferred?

(2) In the case of a band with both planned and consulted portions should a requirement be transferred from the planned to its own consulted portion?

3) What happens when the requirement is transferred from the entirely-planned 13 MHz band?

4) How is the destination band selected when there are choices of available bands?

5) How are requirements handled in the transfer process when they are entitled to multiple frequencies?

The IFRB offers the following guidelines to solve cases that arise corresponding to the above questions.

1) To ensure continued operation in their appropriate band, requirements transferred out of the planned portion will be transferred to the consulted portion of the same band.

2) Requirements transferred from the 13 MHz band will be transferred to the available band which ensures the greatest service quality.

3) The transferred requirements are to be assigned frequencies which least adversely affect (IFRB, 1989) the assignments already present.

4) A transferred requirement which qualifies for additional frequencies in a given hour block will be transferred to the available bands where the consultation procedure applies provided that at most one frequency is assigned per band.

The **issues** raised by these guidelines are many. A requirement designated for the planned portions runs the risk of getting transferred to the consulted portions for a variety of reasons. The consulted portions will most probably be subjected to greater interference than planned requirements because of the catch-all nature of the consulted portion of the bands. The consulted portion in the same band may, in fact, not offer the best service quality in the presence of interference among the bands available to the requirement.

Also, requirements designated for transfer from the 13 MHz band may have nowhere to go in case this is their only available band. This becomes problematic because the requirement, unsuitable to remain in the band, will have to stay in this band; otherwise, this requirement will not be satisfied in the plan, a contradiction to the planning principles. The IFRB recognizing this has indicated it will request the administration involved to take appropriate action should this case occur.

The last guideline (number 4 above) gives no specifics as to how this process is to be accomplished since it may well be that the only available bands are those already designated.

The U.S. should question the IFRB and its HFBC team either publicly or privately in order to clarify the issues enumerated above. Because of the evolving nature of the IFRB HFBC planning activities, and hence those of NTIA/ITS in its related planning activities it is incumbent that NTIA/ITS maintain public and private contact with the IFRB (and its HFBC team) on these and future issues.

9. REFERENCES

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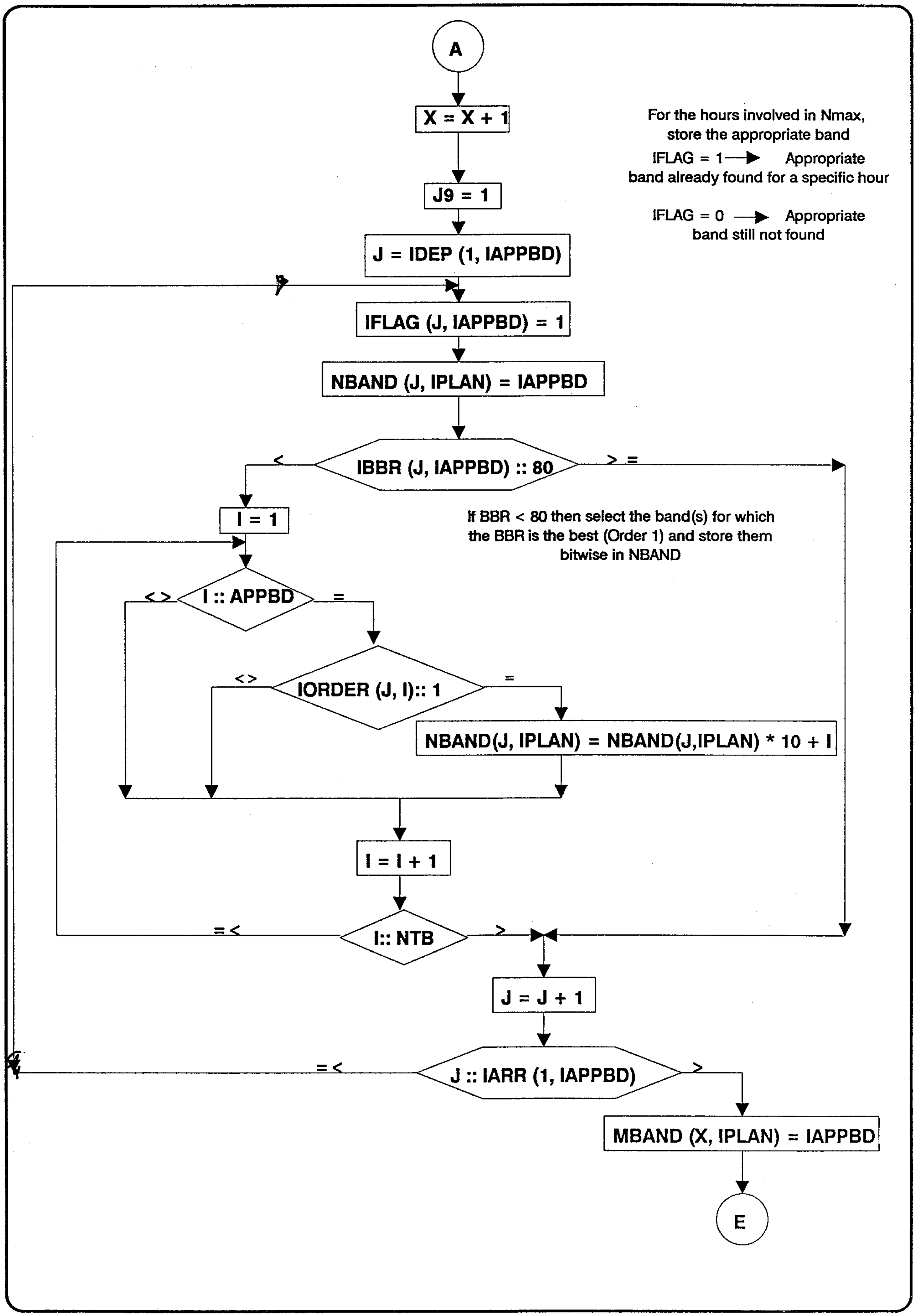
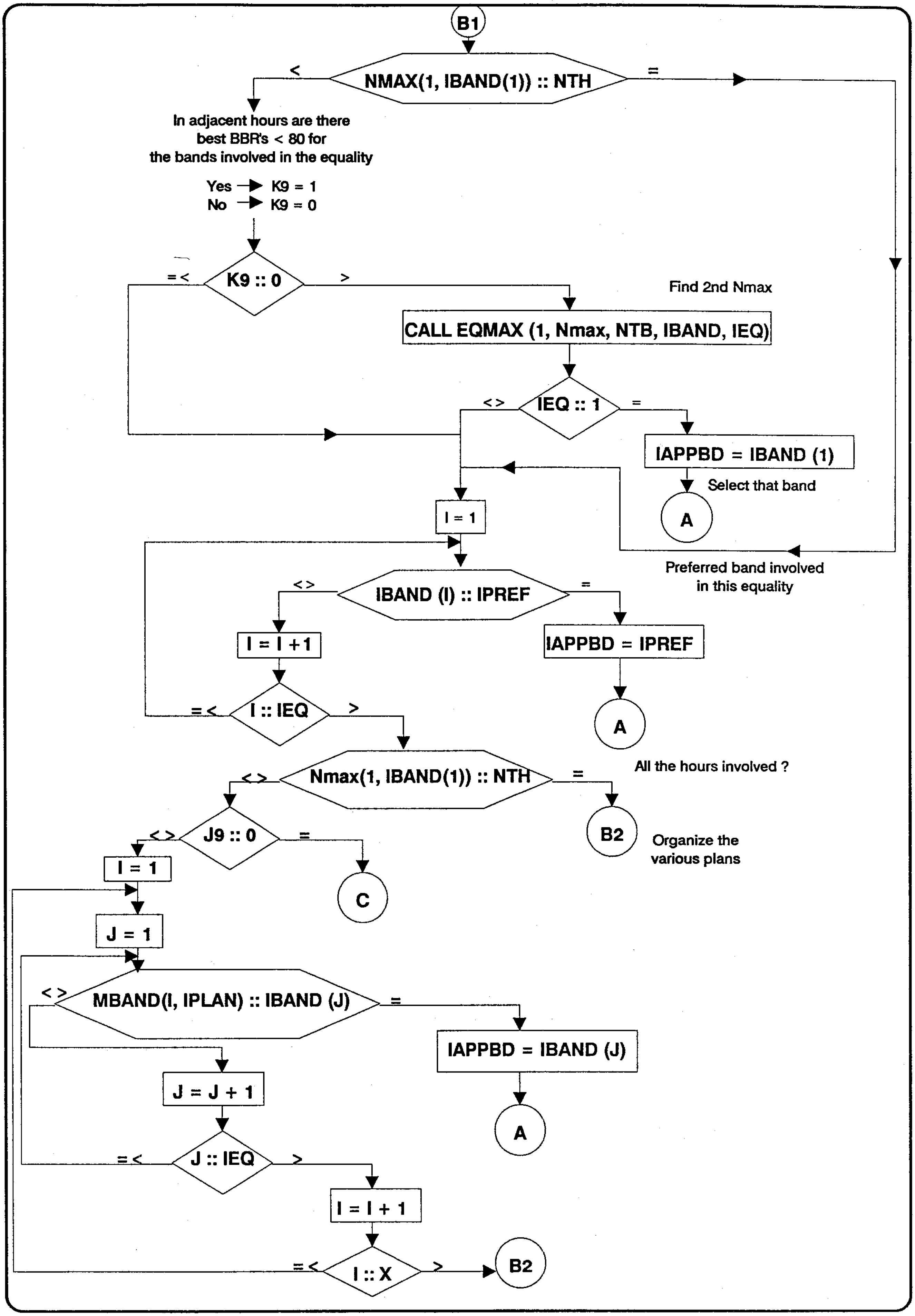
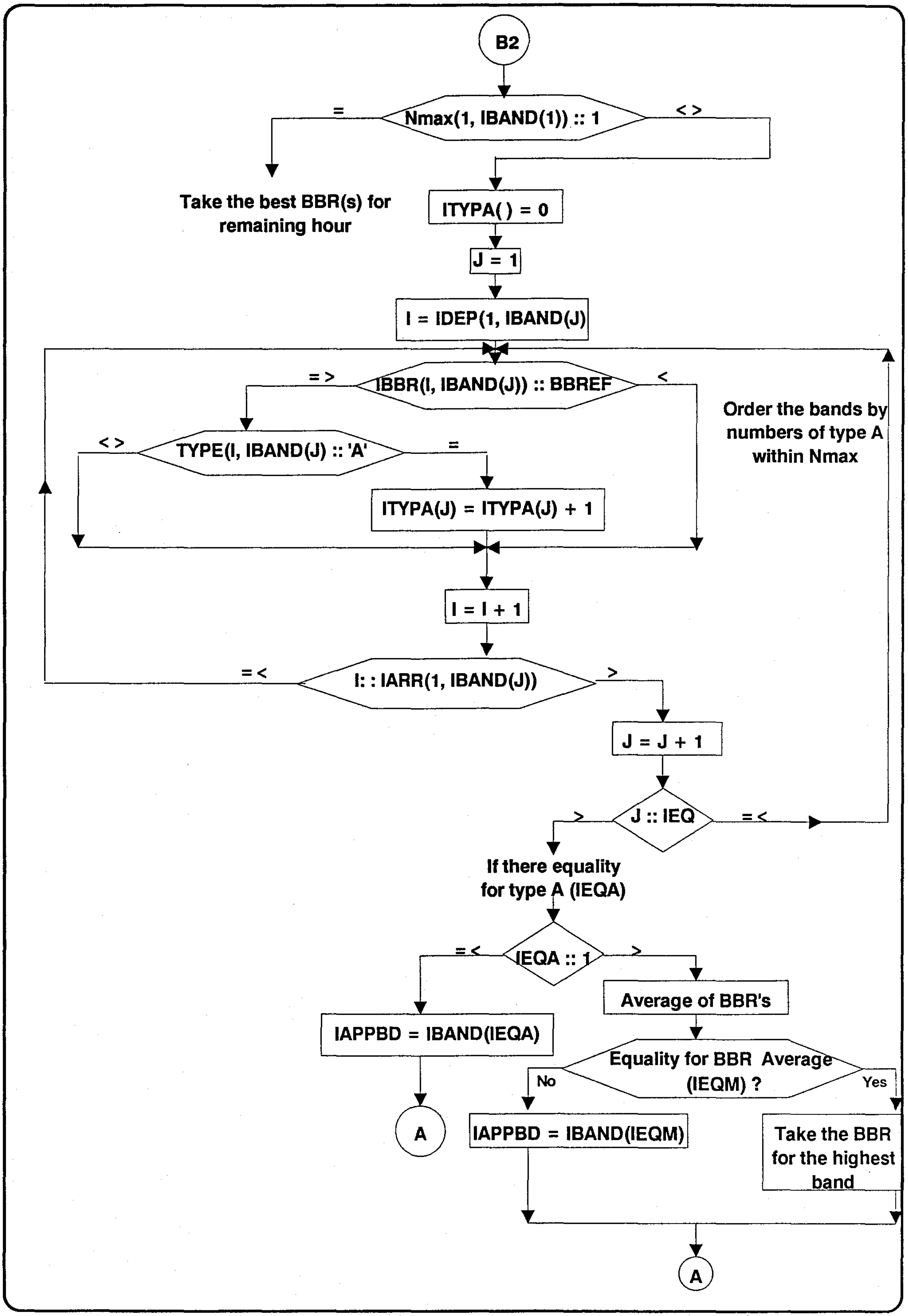
*** National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

APPENDIX: ALGORITHM FOR APPROPRIATE BAND SELECTION (FLOW CHARTS AND FORTRAN LISTING)

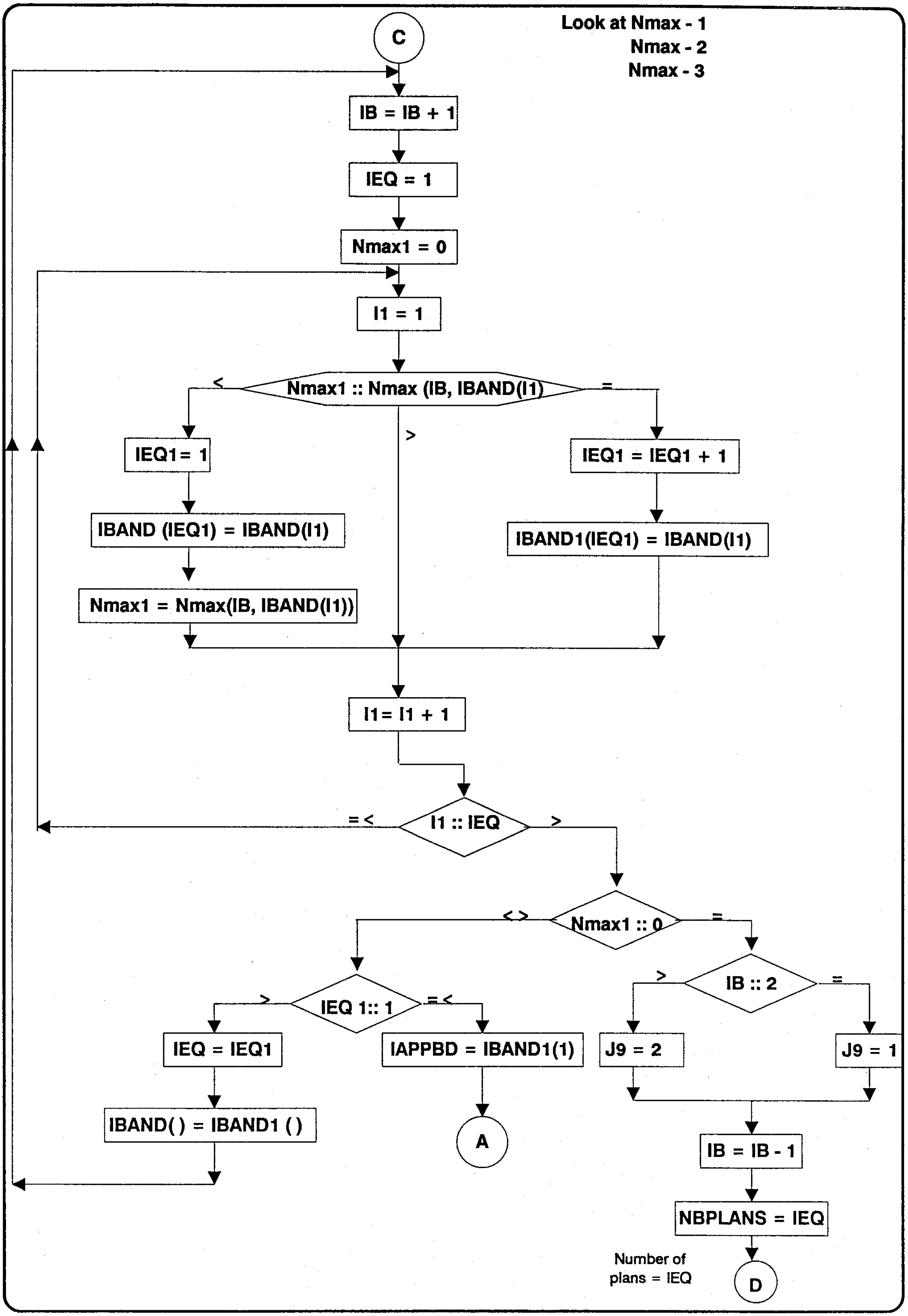


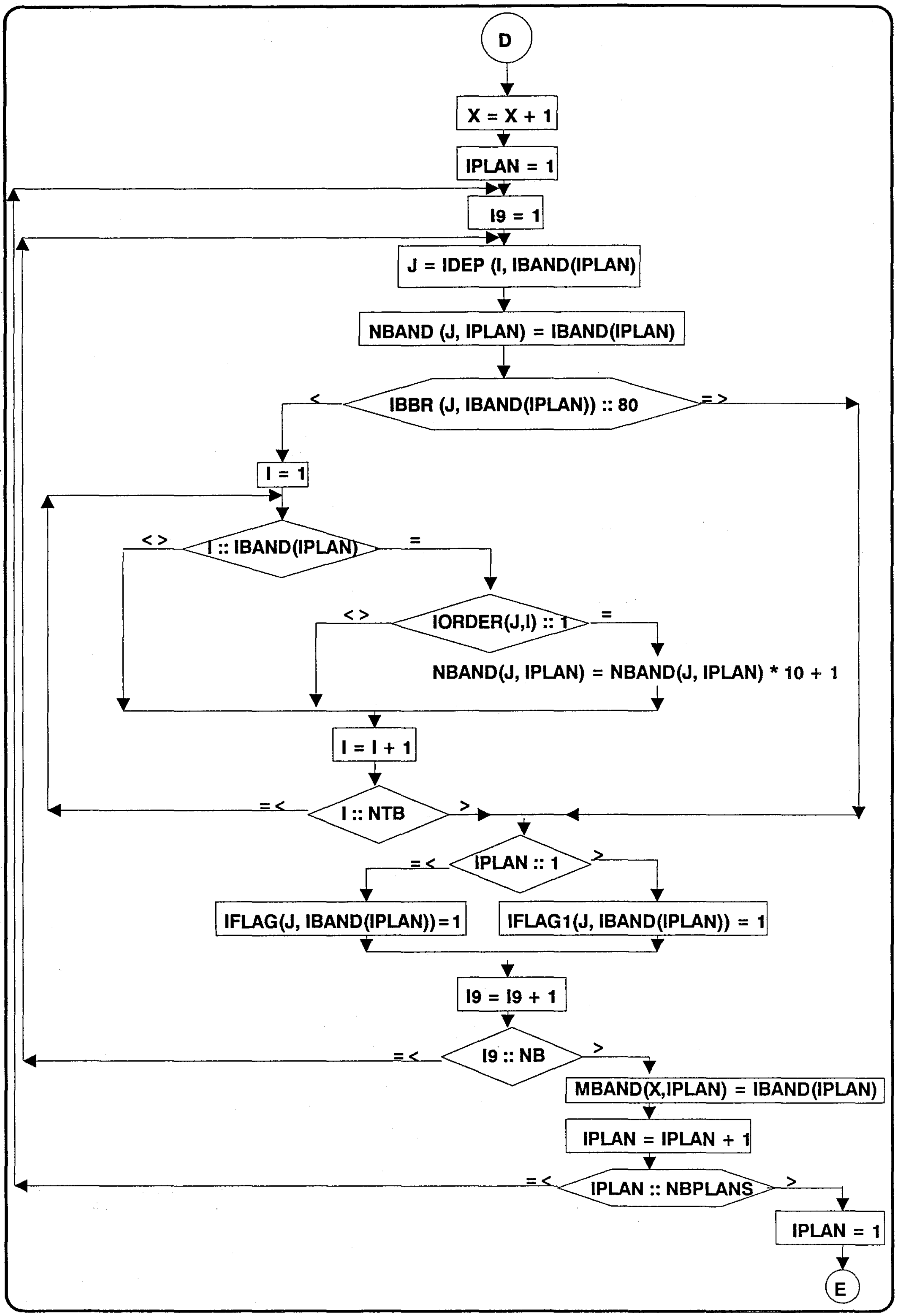
A
X = X + 1
J9 = 1
J = IDEP (1, IAPPBD)
For the hours involved in Nmax, store the appropriate band
IFLAG = 1 → Appropriate band already found for a specific hour
IFLAG = 0 → Appropriate band still not found
IFLAG (J, IAPPBD) = 1
NBAND (J, IPLAN) = IAPPBD
IBBR (J, IAPPBD) :: 80
<
> =
I = 1
If BBR < 80 then select the band(s) for which the BBR is the best (Order 1) and store them bitwise in NBAND
I :: APPBD
<>
=
IORDER (J, I):: 1
<>
=
NBAND(J, IPLAN) = NBAND(J,IPLAN) * 10 + I
I = I + 1
I:: NTB
=<
>
J = J + 1
J :: IARR (1, IAPPBD)
=<
>
MBAND (X, IPLAN) = IAPPBD
E

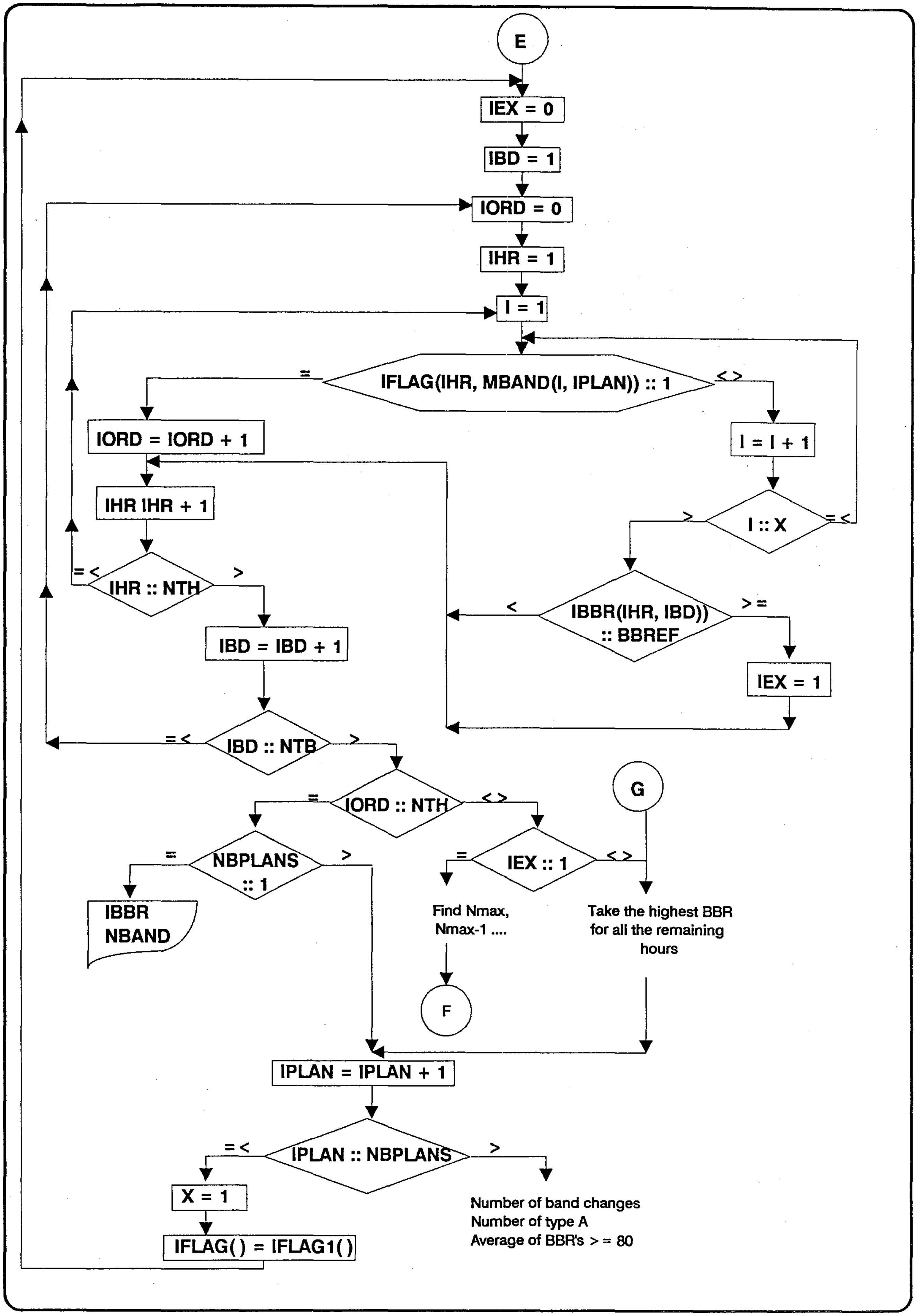

B1
NMAX(1, IBAND(1)) :: NTH
<
=
In adjacent hours are there
best BBR's < 80 for
the bands involved in the equality
Yes → K9 = 1
No → K9 = 0
K9 :: 0
=<
>
Find 2nd Nmax
CALL EQMAX (1, Nmax, NTB, IBAND, IEQ)
IEQ :: 1
<>
=
IAPPBD = IBAND (1)
Select that band
A
I = 1
Preferred band involved
in this equality
IBAND (I) :: IPREF
<>
=
I = I +1
IAPPBD = IPREF
I :: IEQ
=<
>
A
All the hours involved ?
Nmax(1, IBAND(1)) :: NTH
<>
=
B2
Organize the
various plans
J9 :: 0
<>
=
I = 1
C
J = 1
MBAND(I, IPLAN) :: IBAND (J)
<>
=
IAPPBD = IBAND (J)
J = J + 1
A
J :: IEQ
=<
>
I = I + 1
I :: X
=<
>
B2



B2
Nmax(1, IBAND(1)) :: 1
=
< >
Take the best BBR(s) for remaining hour
ITYPA( ) = 0
J = 1
I = IDEP(1, IBAND(J)
IBBR(I, IBAND(J)) :: BBREF
= >
<
TYPE(I, IBAND(J) :: 'A'
< >
=
ITYPA(J) = ITYPA(J) + 1
Order the bands by numbers of type A within Nmax
I = I + 1
I: : IARR(1, IBAND(J))
= <
>
J = J + 1
J :: IEQ
>
= <
If there equality for type A (IEQA)
IEQA :: 1
= <
>
Average of BBR's
IAPPBD = IBAND(IEQA)
Equality for BBR Average (IEQM) ?
No
Yes
A
IAPPBD = IBAND(IEQM)
Take the BBR for the highest band
A


Look at Nmax - 1
Nmax - 2
Nmax - 3
C
IB = IB + 1
IEQ = 1
Nmax1 = 0
I1 = 1
Nmax1 :: Nmax (IB, IBAND(I1)
<
=
>
IEQ1= 1
IBAND (IEQ1) = IBAND(I1)
Nmax1 = Nmax(IB, IBAND(I1))
IEQ1 = IEQ1 + 1
IBAND1(IEQ1) = IBAND(I1)
I1= I1 + 1
I1 :: IEQ
=<
>
Nmax1 :: 0
<>
=
IEQ 1:: 1
>
=<
IEQ = IEQ1
IBAND( ) = IBAND1 ( )
IAPPBD = IBAND1(1)
A
IB :: 2
>
=
J9 = 2
J9 = 1
IB = IB - 1
NBPLANS = IEQ
Number of
plans = IEQ
D


D
X = X + 1
IPLAN = 1
I9 = 1
J = IDEP (I, IBAND(IPLAN)
NBAND (J, IPLAN) = IBAND(IPLAN)
IBBR (J, IBAND(IPLAN)) :: 80
I = 1
I :: IBAND(IPLAN)
IORDER(J,I) :: 1
NBAND(J, IPLAN) = NBAND(J, IPLAN) * 10 + 1
I = I + 1
I :: NTB
IPLAN :: 1
IFLAG(J, IBAND(IPLAN))=1
IFLAG1(J, IBAND(IPLAN)) = 1
I9 = I9 + 1
I9 :: NB
MBAND(X,IPLAN) = IBAND(IPLAN)
IPLAN = IPLAN + 1
IPLAN :: NBPLANS
IPLAN = 1
E


E
IEX = 0
IBD = 1
IORD = 0
IHR = 1
I = 1
IFLAG(IHR, MBAND(I, IPLAN)) :: 1
=
< >
IORD = IORD + 1
I = I + 1
IHR IHR + 1
I :: X
>
= <
IHR :: NTH
= <
>
IBBR(IHR, IBD)) :: BBREF
<
> =
IBD = IBD + 1
IEX = 1
IBD :: NTB
= <
>
IORD :: NTH
=
< >
G
NBPLANS :: 1
=
>
IEX :: 1
=
< >
IBBR
NBAND
Find Nmax, Nmax-1 ....
Take the highest BBR for all the remaining hours
F
IPLAN = IPLAN + 1
IPLAN :: NBPLANS
= <
>
X = 1
IFLAG( ) = IFLAG1( )
Number of band changes
Number of type A
Average of BBR's > = 80

APPROPRIATE BAND ALGORITHM

```
      program app
      integer*2 x,iflag(96,9),n9(9),bbref
      integer*2 nmax(49,9),idep(49,9),iarr(49,9),iband(9),iband1(9)
      integer*2 itypa(9),nband(96,9),mband(96,9)
      integer*2 iflag1(96,9),jband(3),iapb,iusb
c..............................................................
      integer*2 ifrb1,rig1
      integer*2 rt1,numh1,hrop(96),ipref1,hbid1(24),bbrg1(24)
      integer*2 numb1(24),bdid1(9,24),prp1(9,24),bbrbd1(9,24)
      integer*2 bdtyp1(9,24),ior1(9,24),igrflg1(9,24)
c..............................................................
      integer*2 ifrb(96),rig(96)
      integer*2 numh(96),ipref,hbid(24,96),bbrg(24,96)
      integer*2 numb(24,96),bdid(9,24,96),prp(9,24,96),bbrbd(9,24,96)
      integer*2 bdtype(9,24,96),iord(9,24,96),iflg(9,24,96)
      integer*2 ibbr(96,9),itype(96,9),iorder(96,9)
      integer*2 hropw(96)
      integer*2 typ7389,heure(96),recnb(96),iapp(3,24,96)
      integer*2 iusbd(8,24,96),j5(96),rt(96)
      character bandtype*1
c..............................................................
      dimension min(9),bbr3(9)
c............... open ...........................................
      luin=5
      luout=6
c..................initializations...............................
      typ7389=0
13    do 15 i=1,49
      do 15 j=1,9
      nmax(i,j)=0
      idep(i,j)=0
      iarr(i,j)=0
15    continue
      do 14 i=1,9
      bbr3(i)=0
      min(i)=0
      n9(i)=0
      iband(i)=0
      iband1(i)=0
      itypa(i)=0
14    continue
      do 17 i=1,3
      jband(i)=0
17    continue
      do 11 i=1,96
      hropw(i)=0
      ifrb(i)=0
      numh(i)=0
      rig(i)=0
      heure(i)=0
      j5(i)=0
      rt(i)=0
      recnb(i)=0
11    continue
      do 2 i=1,96
      do 2 j=1,9
      ibbr(i,j)=0
      itype(i,j)=0
      iorder(i,j)=0
2     continue
      do 174 i=1,96
      do 174 j=1,9
      iflag(i,j)=0
      iflag1(i,j)=0
      nband(i,j)=0
      mband(i,j)=0
174   continue
      do 170 i=1,96
      do 170 j=1,24
      hbid(j,i)=0
      bbrg(j,i)=0
      do 171 k=1,9
      bdid(k,j,i)=0
      prp(k,j,i)=0
      bbrbd(k,j,i)=0
      bdtype(k,j,i)=0
      iord(k,j,i)=0
```

```
      iflg(k,j,i)=0
171   continue
      do 172 k=1,3
172   iapp(k,j,i)=0
      do 173 k=1,8
173   iusbd(k,j,i)=0
170   continue
      idep1=0
      iarr1=0
      x=0
c.................................................................
      ilbl=1
      if(typ7389.eq.0) go to 10
      typ7389=0
      go to 35
10    irn9=irn9+1
      read(luin,*,end=41) ifrb1,rig1,rt1,numh1,numbands,ipref1,bbref
      do 1011 i=1,96
1011  hrop(i)=0
      do 1015 i=1,numh1
      read(luin,*) hbid1(i),bbrg1(i)
      idx=(hbid1(i)-1)*4
      hrop(idx+1)=1
      hrop(idx+2)=1
      hrop(idx+3)=1
      hrop(idx+4)=1
      numb1(i)=numbands
      do 1015 j=1,numbands
      read(luin,1014) bdid1(j,i),prp1(j,i),bbrbd1(j,i),bandtype,
     +                ior1(j,i),igrflg1(j,i)
1014  format(5x,2i2,i3,a1,i1,i2)
1015  bdtyp1(j,i)=ibtype(bandtype)
c.................................................................
35    if(rt1.eq.7 .or. typ7389.ne.0) go to 189
      do 30 i=1,96
30    if(hrop(i).eq.1) hropw(i)=ilbl
      ifrb(1)=ifrb1
      rig(1)=rig1
      rt(1)=rt1
      numh(1)=numh1
      ipref=ipref1
      do 270 j=1,numh1
      hbid(j,1)=hbid1(j)
      bbrg(hbid1(j),1)=bbrg1(j)
      numb(hbid1(j),1)=numb1(j)
      do 270 k=1,numb1(j)
      bdid(k,hbid1(j),1)=bdid1(k,j)
      prp(k,hbid1(j),1)=prp1(k,j)
      bbrbd(k,hbid1(j),1)=bbrbd1(k,j)
      bdtype(k,hbid1(j),1)=bdtyp1(k,j)
      iord(k,hbid1(j),1)=ior1(k,j)
      iflg(k,hbid1(j),1)=igrflg1(k,j)
270   continue
      if(numh1.gt.1) go to 40
c......treatment of a one hour requirement .................
      write(luout,'("One hour requirement")')
       iapb=0
       iusb=0
       if(bbrg1(1).eq.0) go to 181
       do 180 i=1,numb1(1)
       if(igrflg1(i,1).eq.1) then
         iapb=iapb+1
         iapp(iapb,hbid1(1),1)=i
       else
         iusb=iusb+1
         iusbd(iusb,hbid1(1),1)=i
       end if
180    continue
       go to 186
181    if(ipref1.eq.0) go to 186
        do 185 i=1,numb1(1)
         if(bdid1(i,1).eq.ipref1 .and. bbrbd1(i,1).ge.bbref) then
          iapb=1
          iapp(iapb,hbid1(1),1)=i
         else
          iusb=iusb+1
          iusbd(iusb,hbid1(1),1)=i
```

```
         end if
185     continue
c***************************************
186     if(ipref1.ne.0 .and. iapb.ne.0) go to 188
        iapb=0
        iusb=0
        do 187 i=1,numb1(1)
          if(ior1(i,1).eq.1)then
           iapb=1
           iapp(iapb,hbid1(1),1)=i
          else
           iusb=iusb+1
           iusbd(iusb,hbid1(1),1)=i
          end if
187    continue
c***************************************
188    continue
       write(luout,911) 1,ifrb1,rig1,rt1,numh1
       j=hbid1(1)
       write(luout,912) j,numb1(1),iapb,bbrg1(1)
       do 193 int=1,iapb
       k=iapp(int,j,1)
193    write(luout,914) bdid1(k,1),bbrbd1(k,1),prp1(k,1)
        go to 13
c***************************************
189    typ7389=7
       if(ilbl.eq.1 .or. rig(ilbl-1).eq.rig1) go to 190
           ilbl=ilbl-1
           go to 40
190    do 36 i=1,96
36     if(hrop(i).eq.1) hropw(i)=ilbl
       ifrb(ilbl)=ifrb1
       rig(ilbl)=rig1
       rt(ilbl)=rt1
       numh(ilbl)=numh1
       ipref=ipref1
       do 275 j=1,numh1
       hbid(j,ilbl)=hbid1(j)
       bbrg(hbid1(j),ilbl)=bbrg1(j)
       numb(hbid1(j),ilbl)=numb1(j)
       do 275 k=1,numb1(j)
       bdid(k,hbid1(j),ilbl)=bdid1(k,j)
       prp(k,hbid1(j),ilbl)=prp1(k,j)
       bbrbd(k,hbid1(j),ilbl)=bbrbd1(k,j)
       bdtype(k,hbid1(j),ilbl)=bdtyp1(k,j)
       iord(k,hbid1(j),ilbl)=ior1(k,j)
275    iflg(k,hbid1(j),ilbl)=igrflg1(k,j)
           ilbl=ilbl+1
           go to 10
c**********************************************************************
c.....build the matrix ibbr in case of continuity between hours 24 & 1
41     iend=1
       ilbl=ilbl-1
40     iflag2=0
       do 37 i=1,96
37     if(hropw(i).eq.0)iflag2=1
       if(iflag2.eq.1.and.hropw(1).ne.0.and.hropw(96).ne.0) then
         i=95
31       if(hropw(i).eq.0) then
           idep1=i+1
         else
           i=i-1
           go to 31
         end if
         i=2
32       if(hropw(i).ne.0)iarr1=i
         i=i+1
         if(i.ne.idep1)go to 32
       else
         if(iflag2.eq.1) then
           do 33 i=1,96
           if(hropw(i).ne.0.and.idep1.eq.0)idep1=i
           if(hropw(i).ne.0.and.idep1.ne.0)iarr1=i
33         continue
         else
           idep1=1
           iarr1=96
```

```
        end if
      end if
c-----------------------------------------------------------------------
      nth=0
      if(idep1.le.iarr1) then
        do 50 i=idep1,iarr1
        ihbp=(i-2)/4+1
        ihb=(i-1)/4+1
        if(i.ne.idep1.and.hropw(i-1).eq.hropw(i).and.ihbp.eq.ihb.or.
     *  hropw(i).eq.0)go to 50
        if(numb(ihb,hropw(i)).eq.0)go to 50
        nth=nth+1
        do 70 jbd=1,numb(ihb,hropw(i))
        ibbr(nth,bdid(jbd,ihb,hropw(i)))=bbrbd(jbd,ihb,hropw(i))
        itype(nth,bdid(jbd,ihb,hropw(i)))=bdtype(jbd,ihb,hropw(i))
        if((iord(jbd,ihb,hropw(i)).eq.1.and.bbrg(ihb,hropw(i)).eq.0)
     *  .or.(iflg(jbd,ihb,hropw(i)).eq.1)) then
        iorder(nth,bdid(jbd,ihb,hropw(i)))=1
        heure(nth)=ihb
        recnb(nth)=hropw(i)
        end if
70      continue
50      continue
        else
        do 55 i=idep1,96
        ihbp=(i-2)/4+1
        ihb=(i-1)/4+1
        if(i.ne.idep1.and.hropw(i-1).eq.hropw(i).and.ihbp.eq.ihb.or.
     *  hropw(i).eq.0)go to 55
        if(numb(ihb,hropw(i)).eq.0)go to 55
        nth=nth+1
        do 57 jbd=1,numb(ihb,hropw(i))
        ibbr(nth,bdid(jbd,ihb,hropw(i)))=bbrbd(jbd,ihb,hropw(i))
        itype(nth,bdid(jbd,ihb,hropw(i)))=bdtype(jbd,ihb,hropw(i))
        if((iord(jbd,ihb,hropw(i)).eq.1.and.bbrg(ihb,hropw(i)).eq.0)
     *  .or.(iflg(jbd,ihb,hropw(i)).eq.1)) then
        iorder(nth,bdid(jbd,ihb,hropw(i)))=1
        heure(nth)=ihb
        recnb(nth)=hropw(i)
        end if
57      continue
55      continue
        do 75 i=1,iarr1
        ihbp=(i-2)/4+1
        ihb=(i-1)/4+1
        if(i.ne.1.and.hropw(i-1).eq.hropw(i).and.ihbp.eq.ihb.or.
     *  hropw(i).eq.0)go to 75
        if(numb(ihb,hropw(i)).eq.0)go to 75
        nth=nth+1
        do 77 jbd=1,numb(ihb,hropw(i))
        ibbr(nth,bdid(jbd,ihb,hropw(i)))=bbrbd(jbd,ihb,hropw(i))
        itype(nth,bdid(jbd,ihb,hropw(i)))=bdtype(jbd,ihb,hropw(i))
        if((iord(jbd,ihb,hropw(i)).eq.1.and.bbrg(ihb,hropw(i)).eq.0)
     *  .or.(iflg(jbd,ihb,hropw(i)).eq.1)) then
        iorder(nth,bdid(jbd,ihb,hropw(i)))=1
        heure(nth)=ihb
        recnb(nth)=hropw(i)
        end if
77      continue
75      continue
      end if
c-----------------------------------------------------------------------
       nbplans=1
       j9=0
       iplan=1
       ncol=(nth/2)+1
c.....is there at least 1 hour where bbr>=bbref in at least 1 band
       i=1
       j=1
18    if(ibbr(i,j).ge.bbref.and.iflag(i,j).eq.0) go to 16
       i=i+1
      if(i.gt.nth) then
        i=1
        j=j+1
        if(j.gt.9)go to 600
      end if
      go to 18
```

```
c.....look for nmax,nmax-1,nmax-2,......
16    do 51 ibd=1,9
      nmax1=0
      k=1
      do 60 ihr=1,nth
      if(ibbr(ihr,ibd).ge.bbref.and.iflag(ihr,ibd).eq.0) then
        nmax1=nmax1+1
        nmax(k,ibd)=nmax1
        idep(k,ibd)=ihr-nmax1+1
        iarr(k,ibd)=ihr
      else
        if(nmax1.gt.0) k=k+1
        nmax1=0
      end if
60    continue
51    continue
c.....sort the matrix nmax
450    ib=1
      do 71 ibd=1,9
      do 80 i=1,ncol-1
       j=i
85     l=j+1
       if(nmax(j,ibd).ge.nmax(l,ibd)) go to 80
       i1=nmax(j,ibd)
       nmax(j,ibd)=nmax(l,ibd)
       nmax(l,ibd)=i1
       i1=idep(j,ibd)
       idep(j,ibd)=idep(l,ibd)
       idep(l,ibd)=i1
       i1=iarr(j,ibd)
       iarr(j,ibd)=iarr(l,ibd)
       iarr(l,ibd)=i1
       j=j-1
       if(j.gt.0) go to 85
80    continue
71    continue
c.....equality in nmax ?
c.....recherche du plus grand nmax
      iappbd=0
      call eqmax(1,nmax,iband,ieq)
c.....if ieq>1 there is a conflict else select the band with the biggest
c.....nmax
      if(ieq.eq.1) then
        iappbd=iband(1)
        go to 800
      end if
      if(nmax(1,iband(1)).eq.nth) go to 140
c.....in adjacent hours are there best bbr less than 80
      k9=0
      do 120 i9=1,ieq
      ialpha=0
      if(idep(1,iband(i9)).eq.1)go to 130
      k=idep(1,iband(i9))-1
135   if(ibbr(k,iband(i9)).lt.bbref.and.iorder(k,iband(i9)).eq.1
     *.and.iflag(k,iband(i9)).ne.1)then
        k9=1
        ialpha=ialpha+1
        idep(1,iband(i9))=k
        k=k-1
        if(k.lt.1)go to 130
        go to 135
      end if
130   if(iarr(1,iband(i9)).eq.nth)go to 141
      k=iarr(1,iband(i9))+1
138   if(ibbr(k,iband(i9)).lt.bbref.and.iorder(k,iband(i9)).eq.1
     *.and.iflag(k,iband(i9)).ne.1)then
        k9=1
        ialpha=ialpha+1
        iarr(1,iband(i9))=k
        k=k+1
        if(k.le.nth)go to 138
      end if
141   nmax(1,iband(i9))=nmax(1,iband(i9))+ialpha
120   continue
      if(k9)140,140,145
c.....equality in nmax ?
145   call eqmax(1,nmax,iband,ieq)
```

```
c.....if ieq=1 there is a conflict else select the band with the biggest
c.....nmax
      if(ieq.eq.1) then
        iappbd=iband(1)
        go to 800
      end if
c.....500 => no equality
c.....140 => there is still equality . is the preferred band involved
c.....in this equality ?
140   do 142 i=1,ieq
      if(iband(i).eq.ipref) then
c.....select that band
        iappbd=ipref
        go to 800
      end if
142   continue
      if(nmax(1,iband(1)).eq.nth)go to 200
      if(j9.eq.0)go to 150
      do 143 i=1,x
      do 143 j=1,ieq
      if(mband(i,iplan).eq.iband(j)) then
        iappbd=iband(j)
        go to 800
      end if
143   continue
200   if(nmax(1,iband(1)).eq.1) then
        go to 600
      else
       do 147 j=1,ieq
147    itypa(j)=0
       do 144 j=1,ieq
       do 144 i=idep(1,iband(j)),iarr(1,iband(j))
       if(ibbr(i,iband(j)).lt.bbref) go to 144
       if(itype(i,iband(j)).eq.1)itypa(j)=itypa(j)+1
144    continue
c.....is there equality for type a
       ieqa=1
       maxa=itypa(1)
       do 300 i=2,ieq
       if(maxa.lt.itypa(i)) then
         ieqa=1
         iband(ieqa)=iband(i)
         maxa=itypa(i)
       else
        if(maxa.eq.itypa(i)) then
          ieqa=ieqa+1
          iband(ieqa)=iband(i)
        end if
       end if
300   continue
c.....average of bbr >= bbref
      if(ieqa.gt.1) then
        ieq=ieqa
        do 320 i=1,ieq
        ibbr2=0
        i2=0
        do 321 i1=1,ncol
        if(idep(i1,iband(i)).eq.0)go to 321
        do 330 j=idep(1,iband(i)),iarr(1,iband(i))
        if(ibbr(j,iband(i)).lt.bbref)go to 330
        i2=i2+1
        ibbr2=ibbr2+ibbr(j,iband(i))
330     continue
321     continue
        bbr3(i)=float(ibbr2)/i2
320     continue
c.....is there equality for bbr average
        ieqm=1
        amaxm=bbr3(1)
        do 310 i=2,ieq
        if(amaxm.lt.bbr3(i)) then
          ieqm=1
          iband(ieqm)=iband(i)
          amaxm=bbr3(i)
        else
          if(amaxm.eq.bbr3(i)) then
            ieqm=ieqm+1
```

```
            iband(ieqm)=iband(i)
          end if
        end if
310     continue
      else
        iappbd=iband(ieqa)
        go to 800
      end if
        iappbd=iband(ieqm)
        go to 800
      end if
c.....look at nmax-1,nmax-2,nmax-3......
150   ib=ib+1
c....................................
      ieq1=1
      nmax1=0
      do 166 i1=1,ieq
      if(nmax1.lt.nmax(ib,iband(i1))) then
        ieq1=1
        iband1(ieq1)=iband(i1)
        nmax1=nmax(ib,iband(i1))
      else
        if(nmax1.eq.nmax(ib,iband(i1))) then
          ieq1=ieq1+1
          iband1(ieq1)=iband(i1)
        end if
      end if
166   continue
      if(nmax1.eq.0)then
        if(ib.eq.2) j9=1
        if(ib.gt.2) j9=2
        ib=ib-1
        nbplans=ieq
        go to 700
      end if
c....................................
      if(ieq1.gt.1) then
        ieq=ieq1
        do 167 i=1,ieq
167     iband(i)=iband1(i)
        j9=2
        go to 150
      else
        iappbd=iband1(1)
        go to 800
      end if
c..................................................................
700   x=x+1
      do 720 iplan=1,nbplans
      do 710 i9=1,ib
      do 710 j=idep(i9,iband(iplan)),iarr(i9,iband(iplan))
      nband(j,iplan)=2**(iband(iplan)-1)
      if(ibbr(j,iband(iplan)).lt.bbref) then
        do 340 i=1,9
        if(i.eq.iband(iplan)) go to 340
        if(iorder(j,i).eq.1)nband(j,iplan)=nband(j,iplan)+2**(i-1)
340     continue
      end if
      if(iplan.le.1) then
        iflag(j,iband(iplan))=1
      else
        iflag1(j,iband(iplan))=1
      end if
710   continue
      mband(x,iplan)=iband(iplan)
720   continue
      iplan=1
      go to 2005
c..................................................................
800   x=x+1
      if(j9.eq.0)j9=1
      do 810 j=idep(1,iappbd),iarr(1,iappbd)
      iflag(j,iappbd)=1
      nband(j,iplan)=2**(iappbd-1)
      if(ibbr(j,iappbd).lt.bbref) then
        do 350 i=1,9
        if(i.eq.iappbd) go to 350
```

```
        if(iorder(j,i).eq.1)nband(j,iplan)=nband(j,iplan)+2**(i-1)
350     continue
      end if
810   continue
      mband(x,iplan)=iappbd
c...................................................................
2005  iex=0
      do 2000 ibd=1,9
      iord1=0
      do 2000 ihr=1,nth
      do 2010 i=1,x
      if(iflag(ihr,mband(i,iplan)).eq.1) then
        iord1=iord1+1
        go to 2000
      end if
2010  continue
      if(ibbr(ihr,ibd).ge.bbref) iex=1
2000  continue
      if(iord1.eq.nth) then
        if(nbplans.le.1)then
          ires=1
          go to 9999
        else
          go to 650
        end if
      end if
      if(iex.eq.1) then
c.....at least 1 bbr >= bbref
c.....look for nmax,nmax-1,nmax-2,......
        do 2061 i=1,ncol
        do 2061 j=1,9
        nmax(i,j)=0
        idep(i,j)=0
2061    iarr(i,j)=0
        do 2060 ibd=1,9
        nmax1=0
        k=1
        do 2070 ihr=1,nth
        iord1=0
        do 2080 i=1,x
        if(iflag(ihr,mband(i,iplan)).eq.1) then
          if(nmax(k,ibd).ne.0) then
            nmax1=0
            k=k+1
          end if
          iord1=iord1+1
        end if
2080    continue
        if(iord1.ne.0) go to 2070
        if(ibbr(ihr,ibd).ge.bbref) then
          nmax1=nmax1+1
          nmax(k,ibd)=nmax1
          idep(k,ibd)=ihr-nmax1+1
          iarr(k,ibd)=ihr
        else
          if(nmax1.ne.0) k=k+1
          nmax1=0
        end if
2070    continue
2060    continue
        go to 450
      end if
600   do 2030 ihr=1,nth
      ibd=1
      iord1=0
      do 2040 i=1,x
2040  if(iflag(ihr,mband(i,iplan)).eq.1) iord1=iord1+1
      if(iord1.ne.0) go to 2030
2041  if(iorder(ihr,ibd).eq.1) then
        nband(ihr,iplan)=nband(ihr,iplan)+2**(ibd-1)
        x=x+1
        mband(x,iplan)=ibd
        iflag(ihr,ibd)=1
      end if
      ibd=ibd+1
      if(ibd.le.9) go to 2041
2030  continue
```

```
c..................................................................
650   iplan=iplan+1
      if(iplan.le.nbplans) then
      x=1
      do 660 i=1,9
      if(i.eq.mband(x,iplan)) then
      do 662 j=1,nth
662   iflag(j,i)=iflag1(j,i)
      else
      do 661 j=1,nth
661   iflag(j,i)=0
      end if
660   continue
      go to 2005
      else
c.....take the least number of band changes..........................
      do 670 i=1,nbplans
      n9(i)=0
      do 670 j=1,nth-1
670   if(iand(nband(j,i),nband(j+1,i)).eq.0) n9(i)=n9(i)+1
c.....is there equality ?  .........................................
      ieq=0
      imin=110
      do 680 i=1,nbplans
      if(imin.eq.n9(i)) then
      ieq=ieq+1
      min(ieq)=i
      end if
      if(imin.gt.n9(i)) then
      imin=n9(i)
      ieq=1
      min(ieq)=i
      end if
680   continue
      if(ieq.eq.1) then
      ires=min(1)
      go to 9999
      end if
c..... find number of types a ...............
      do 684 j=1,ieq
684   itypa(j)=0
      do 685 j=1,ieq
      do 685 ihr=1,nth
        call band(nband(ihr,min(j)),jband,j5)
        if(jband(1).eq.0.or.jband(2).gt.0) go to 685
        if(ibbr(ihr,jband(1)).lt.bbref)go to 685
        if(itype(ihr,jband(1)).eq.1)itypa(j)=itypa(j)+1
685   continue
c.....is there equality for type a
      ieqa=1
      mina=itypa(1)
      do 690 i=2,ieq
      if(mina.lt.itypa(i)) then
      ieqa=1
      min(ieqa)=min(i)
      mina=itypa(i)
      else
      if(mina.eq.itypa(i)) then
      ieqa=ieqa+1
      min(ieqa)=min(i)
      end if
      end if
690   continue
c.....average of bbr >= bbref
      if(ieqa.gt.1) then
      ieq=ieqa
      do 696 i=1,ieq
      i2=0
      ibbr2=0
      do 695 ihr=1,nth
        call band(nband(ihr,min(i)),jband,j5)
        if(jband(1).eq.0.or.jband(2).gt.0) go to 695
        if(ibbr(ihr,jband(1)).lt.bbref)go to 695
        i2=i2+1
        ibbr2=ibbr2+ibbr(ihr,jband(1))
695   continue
      if(i2.eq.0) go to 696
```

```
      bbr3(i)=float(ibbr2)/i2
696   continue
c.....is there equality for bbr average
      ieqm=1
      amaxm=bbr3(1)
      do 698 i=2,ieq
      if(amaxm.lt.bbr3(i)) then
        ieqm=1
        min(ieqm)=min(i)
        amaxm=bbr3(i)
      else
        if(amaxm.eq.bbr3(i)) then
          ieqm=ieqm+1
          min(ieqm)=min(i)
        end if
      end if
698   continue
      else
      ires=min(ieqa)
      go to 9999
      end if
      ires=min(ieqm)
      end if
c.....................................................................
c... update of the appropriate band file ..............................
9999  do 900 label=1,ilbl
      do 910 i1=1,numh(label)
      do 910 i=1,nth
      if(heure(i).ne.hbid(i1,label) .or. recnb(i).ne.label) go to 910
        call band(nband(i,ires),jband,j5(i1))
        ius=0
        iapb=0
        do 920 jb=1,numb(hbid(i1,label),label)
        if(bdid(jb,hbid(i1,label),label).eq.jband(1).or.
     *  bdid(jb,hbid(i1,label),label).eq.jband(2).or.
     *  bdid(jb,hbid(i1,label),label).eq.jband(3))then
          iapb=iapb+1
          iapp(iapb,hbid(i1,label),label)=jb
        else
          ius=ius+1
          iusbd(ius,hbid(i1,label),label)=jb
        end if
920     continue
910   continue
c     write(luout,911)label,ifrb(label),rig(label),rt(label),numh(label)
911   format(i5,1h=,4i5," hours")
      do 919 i=1,numh(label)
      j=hbid(i,label)
c     write(luout,912) j,numb(j,label),j5(i),bbrg(j,label)
912   format(10x,4i5)
      do 913 int=1,j5(i)
      k=iapp(int,j,label)
c     write(luout,914) bdid(k,j,label),bbrbd(k,j,label),prp(k,j,label)
913   continue
914   format(10x,"app ",3i5)
c      do 915 int=1,numb(j,label)-j5(i)
c      k=iusbd(int,j,label)
c915   write(luout,916) bdid(k,j,label),bbrbd(k,j,label),prp(k,j,label)
c916   format(10x,"usbd",3i5)
919   continue
      call dumpprt(luout,numh(label),numb(1,label),hbid(1,label),
     +            bdid(1,1,label),bbrbd(1,1,label),bdtype(1,1,label),
     +            iapp(1,1,label),j5)
c.....................................................................
900   continue
      if(iend.eq.0)go to 13
      end
c---------------------------------------------------------------------
      subroutine eqmax(ib,nmax,iband,ieq)
      integer*2 nmax(49,9),iband(9)
      ieq=1
      iband(ieq)=1
      nmax1=nmax(ib,1)
      do 50 i1=2,9
c                                 <   =   >
      if(nmax1 - nmax(ib,i1)) 10 , 30 , 50
10    do 15 i=1,ieq                   !  nmax1 < nmax(ib,i1)
```

```
15    iband(i)=0
      ieq=1
      iband(ieq)=i1
      nmax1=nmax(ib,i1)
      go to 50
30    ieq=ieq+1                     !  nmax1 = nmax(ib,i1)
      iband(ieq)=i1
50    continue
      return
      end
c-----------------------------------------------------------------------
      subroutine band(nband1,jband,j5)
      integer*2 jband(3),j5
      integer*2 nband1,mask(9)
      data mask/1,2,4,8,16,32,64,128,256/
      j5=0
      do 20 i5=1,3
20    jband(i5)=0
      do 40 i5=1,9
      if(iand(nband1,mask(i5)).ne.mask(i5)) go to 40
        j5=j5+1
        jband(j5)=i5
40    continue
      return
      end
c-----------------------------------------------------------------------
      function ibtype(bandtype)
      character bandtype*1
      ibtype=4
      if(bandtype.eq.'A') ibtype=1
      if(bandtype.eq.'B') ibtype=2
      if(bandtype.eq.'C') ibtype=3
      if(bandtype.eq.'D') ibtype=4
      if(bandtype.eq.'a') ibtype=1
      if(bandtype.eq.'b') ibtype=2
      if(bandtype.eq.'c') ibtype=3
      if(bandtype.eq.'d') ibtype=4
      return
      end
c-----------------------------------------------------------------------
      subroutine dumpprt(luout,nhour,nband,hbid,bdid,bbrbd,bdtype,
     +                  iapp,j5)
      integer*2 nhour,nband(24),hbid(24),iapp(3,24),j5(1)
      integer*2 bbrbd(9,24),bdtype(9,24),bdid(9,24)
      character bandt(4)*1,band(9)*2,appbnd(24,9)*1
      data bandt/'A','B','C','D'/
      data band/'06','07','09','11','13','15','17','21','26'/
      istart=hbid(1)
      do 10 ib=1,9
      do 10 ih=1,24
10    appbnd(ih,ib)=' '
      do 20 ih=1,nhour
      jh=hbid(ih)
c      write(luout,11) ih,jh,j5(ih),(iapp(int,jh),int=1,j5(ih))
c11    format(i3,1h=,i3,1h=,i3,1h=,10i4)
      do 20 int=1,j5(ih)
      ib=iapp(int,jh)
      kb=bdid(ib,istart)
20    appbnd(jh,kb)='*'
c
      write(luout,2) (istart+i-1,i=1,nhour)
2     format(" band",i4,23i5)
      do 50 ib=1,nband(istart)
      kb=bdid(ib,istart)
      write(luout,1) band(kb),
     + (bbrbd(ib,istart+i-1),bandt(bdtype(ib,istart+i-1)),
     +  appbnd(istart+i-1,kb),i=1,nhour)
1     format(2x,a2,1x,24(i3,a1,a1))
50    continue
      return
      end
c-----------------------------------------------------------------------
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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The Second Session of the High Frequency Broadcasting Conference held in Geneva, Switzerland, in February 1987, resolved there was a need for an improved system to plan for the radio frequencies allocated exclusively for the high frequency broadcasting service. The final acts of the Conference represented a compromise between those who wished to revert to the broadcast notification procedure under Article 17 of the ITU's Radio Regulations and those who wanted a priority planning system for their broadcasting requirements. The IFRB was charged to implement and test the procedures adopted by the Conference and report the results of their studies to the next conference on HF broadcast planning.

(Continued)

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Broadcast reliabilities; broadcast requirement; HF spectrum utilization model; HF propagation prediction; IFRB; World Administrative Radio Conference for HF Broadcasting.

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The compromise included the adoption of several new procedures while trying to adhere to the planning principles adopted by the First Session of the High Frequency Broadcast Conference. Among the procedures that would have the greatest impact on the use of the HF broadcast spectrum by United States broadcasters would be the division of the broadcast bands into planned portions and consulted portions, appropriate band selection, transferring broadcast requirements from the planned portion of the spectrum to the consulted portion, and over all frequency continuity of broadcasts. These procedures are discussed in this report in terms of the high frequency spectrum utilization model developed for this work by NTIA's Institute for Telecommunication Sciences (ITS).

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