Before the
Federal Communications Commission
Washington, D.C. 20554

MM Docket No. 87-267

In the Matter of

Review of Technical Assignment Criteria for the AM Broadcast Service

NOTICE OF INQUIRY

Adopted: July 16, 1987; Released: August 17, 1987

By the Commission:

INTRODUCTION

1. The Commission is initiating this *Notice of Inquiry (Inquiry)* for the purpose of providing a comprehensive review of the technical principles pertaining to AM broadcast assignment criteria and related issues. The goal of the FCC in taking this action is to identify any needed changes to its technical rules which would permit AM stations to improve their service to the public and enhance their ability to compete in the market place.

2. This *Inquiry* is an outgrowth of the Mass Media Bureau's *Report on the Status of the AM Broadcast Rules*, RM-5532, *(Report)* released April 3, 1986. The *Report* addressed a large number of technical, legal, and policy issues, and sought to identify opportunities to change or remove existing rules in order to allow AM broadcasters to meet the competitive challenges facing them and thereby to enhance their service to the public. Comments received in response to the *Report* have provided guidance to the Commission in identifying technical issues appropriate for further study in this *Inquiry*.[1]

3. All interested parties are invited to comment on these issues and to provide detailed analysis and exhibits in support of suggested changes to the FCC rules and to assess the benefits to the industry and public that would result from such changes.[2] Many questions arise as a result of the discussions in the following Sections of this *Inquiry*.[3] Several of the matters discussed would require extensive studies if they are ultimately deemed necessary. Recognizing limitations on the availability of FCC resources for such studies, recommendations on alternative approaches for conducting such studies are also requested. Finally, it is the intent of the Commission to issue subsequent rule making actions where the record developed herein supports such action.

DISCUSSION

4. The AM broadcast service is the oldest broadcasting service, but it still remains today one of the most technically complex to administer. This is due in large part to the propagation conditions that exist in the AM broadcasting band. In contrast to the other frequency bands where broadcast services are authorized, the propagation characteristics of the AM band vary with the time of day. During daytime hours, signal propagation of an AM station is predominantly by groundwave signals. Groundwave signals travel along the surface of the earth and are thus affected by the characteristics of soil conductivity along the propagation path. During nighttime hours, however, the reach of skywave signals from an AM station becomes significantly greater than the reach of its groundwave signals. Skywave signals are reflected from the ionosphere and can be propagated many hundreds of miles from the transmitter location. As a consequence, co-channel stations may be located reasonably close to one another without interference during daylight hours. The enhanced nighttime propagation has both positive and negative implications. On the one hand nighttime skywave can be employed to provide skywave service many hundreds of miles distant from the transmitter, whereas, on the other hand such enhanced conditions increase the interference possibilities of stations over distances of hundreds of miles.

5. The technical AM broadcast assignment principles currently set out in the FCC rules evolved over many decades during which AM broadcasting was undergoing considerable growth. Section 307(b) of the Communications Act of 1934 has provided a foundation for development of these principles, by requiring that there be a fair, efficient and equitable distribution of radio services to the States and communities. To accomplish this, the 107 AM channels were subdivided into three classes of channels, clear channels, regional channels, and local channels. In addition, four basic classes of stations evolved, Class I, Class II, Class III, and Class IV, that are permitted to operate on the three classes of channels. Assignment principles and technical criteria consistent with Section 307(b) of the Act were also developed which regulate the manner in which assignments are made and which ensure levels of protection from interference for each class of station.

6. Class I and Class II stations operate on Clear channels. Class I stations provide extensive primary (groundwave) service during the day and night, as well as skywave service during nighttime hours generally extending out to 750 miles or more. Class II stations normally render primary service only, the area of which depends on the station location, power, and frequency. Class III stations operate on regional channels and provide primary service to larger cities and the surrounding rural areas, whereas, Class IV stations operate on local channels and provide primary service to a community and contiguous suburban or rural areas.

7. The AM broadcasting service has significantly matured since those earlier years of rapid growth and there are approximately 4,900 AM stations currently authorized. Opportunities for new stations are now limited, except in the more remote areas of the United States. Moreover, there are now approximately 5,200 FM stations authorized in the United States which have significantly added to the availability and choices of aural broadcast service available to the public. Television has also become an important source of information and entertainment, particularly during evening hours. These developments have dramatically altered the listening habits of the public over the past two decades, generally resulting in significant changes in the economic position of AM stations. As a result, the burden and responsibility previously placed solely upon the AM service in regard to provision of a national aural broadcast service is now shared with the FM radio service.

8. In view of these significant changes that have occurred, we believe that it is now appropriate to reassess the policies and technical criteria related to AM station assignments and interference protection that have been applied through the years. Depending upon the nature of changes ultimately made, we believe that service to the public may be enhanced in several respects. For example, if existing stations are given greater flexibility through a redefinition of protected contours they could increase their transmitter power in order to overcome the undesirable effects of atmospheric and man-made noise; protection ratios could be improved in order to reduce interference between stations on adjacent channels as well as reflect the degree of protection necessary to be consistent with improved AM receivers; greater accuracy in calculating the interference between AM assignments would help ensure against unintended interference; and greater flexibility in choosing the type of antenna system most appropriate for a given set of circumstances could help enable a station to employ a transmitter site that best serves the public. It must be recognized, however, that many of these types of changes are unlikely to occur unless affected parties accept the trade-offs that are necessary to reach a balance between quality of service and extent of service. In view of the congestion in the AM band today, without accepting such trade-offs AM broadcast stations essentially will remain "locked-in" with the current quality of service because opportunities for improvements will be foreclosed to a large extent.

9. The Commission is aware that an effort is already underway within the industry to study and develop technical improvements in AM broadcasting. The National Radio Systems Committee (NRSC) has recently studied a number of AM technical issues and has adopted interim voluntary standards for transmission pre-emphasis, receiver de-emphasis, and 10 kHz transmission bandwidth. The National Association of Broadcasters is also sponsoring a project to test new antenna designs developed by industry engineers that show promise of reduced skywave interference. The FCC encourages such efforts and through this *Inquiry* hopes to promote even broader support for technical studies.

I. TECHNICAL ASSIGNMENT PRINCIPLES

10. The AM technical assignment principles are complex and interrelated to a large extent, and there are many permutations in the technical changes that are possible. This makes it necessary to assess these interrelationships and the overall effect upon AM service resulting from any single technical change or combination of changes that may be under consideration. In order to better focus on these technical principles, this section of the *Inquiry* will address the key ingredients underlying the technical assignment principles. These are: field strength values for the protected contours of AM stations, minimum usable field strength, the effects of atmospheric and man-made noise, and radio-frequency protection ratios.

A. PROTECTED CONTOURS

11. The technical assignment principles contained in the FCC Rules are based upon a system of "protected contours". Section 73.182 of the FCC Rules, 47 CFR ' 73.182,[4] prescribes the station contours for each of the four classes of AM stations that are to be protected from interference. Field strength values of these contours vary depending upon the channel relationship between the protected station and the interfering station, whether it is day or night, and the class of station. The field strength values defining these protected contours are often referred to as the nominal usable field strength (Enom).[5] Additionally, section 73.37(a) and (b) of the Rules contain a series of proscriptions relating to prohibited overlap between the contours of protected and interfering stations. These form part of the so called "go/no-go" rules adopted by the Commission during the early 1960's.[6]

12. Factors considered in the derivation of the protected contours relate to both technical and policy issues. Technical factors include minimum usable field strength (Emin)[7] for day or night and radio-frequency protection ratios.[8] Policy factors considered are those discussed, *supra*, relating to Section 307(b) of the Communications Act. As a practical matter, Enom should not be less than Emin, otherwise, protection to substandard service would result. Thus, the policy question is how much in excess of Emin should Enom be? It is important to reassess this policy issue, along with the technical factors, when considering any adjustments to the values of Enom.

13. As noted, *supra*, the significantly increased availability and choices of aural broadcast service (i.e., AM and FM) during the past two decades have resulted in dramatic changes in the listening habits of the public. The normally protected contours that are currently specified in the FCC rules were developed during an earlier period consistent with policies based upon service needs of the public perceived at that time. With the changes that have occurred to the aural service, we have reason to believe that these normally protected contours may not be appropriate in today's radio marketplace. For example, the normally protected contour during daytime hours is typically 0.5 mV/m. This was adopted at a time when there were far fewer aural broadcast stations and there was public dependence upon service within this contour. Such a low field strength, however, is more subject to interference from atmospheric and man-made noise than service provided at greater field strength. As a consequence, do listeners continue to rely upon reception of the 0.5 mV/m daytime contour to the same degree as in the past, or do listeners tend to select aural service having stronger field strength? It is important to establish those field strength contours upon which the listening public depends today which, presumably, are of economic value to the broadcast stations.

14. There is a penalty if we unnecessarily continue protection to the contours currently specified in the FCC rules. For example: such protection can prevent stations from increasing power in order to enable them to better overcome the effects of atmospheric and man-made noise; flexibility is limited for modifications to station facilities; and opportunities for new AM broadcast stations are precluded that otherwise might be possible.

15. QUESTIONS:

A. Taking into account today's listener habits, are the field strength values of the normally protected contours currently in the FCC rules still appropriate?

B. If it is believed that the normally protected contours should be modified, what field strength values should be substituted?

C. What are the benefits and costs to the broadcasting industry and to the public that would result from changing or not changing the field strength values of the protected contours?

B. MINIMUM USABLE FIELD STRENGTH

16. Factors which affect the determination of Emin are both technical and subjective. Technical factors include receiver characteristics and the presence of atmospheric and man-made noise. Subjective factors include listener satisfaction with quality of service, and the type of programming (voice or music). The International Radio Consultative Committee (CCIR) recommends a ratio of signal to atmospheric noise of 40 dB (100/1), whereas, measurements performed in the United States during the Clear Channel Hearings in the late 1940's, FCC Docket 6741, indicated that a ratio of signal to atmospheric noise of 46 dB (200/1) was needed in order to satisfy 67% of listeners for a variety of voice and music programming.

17. The effect of atmospheric noise power varies directly with receiver bandwidth.[9] As a consequence, if the bandwidth of receivers in general use by the public were to be doubled, the noise power would be doubled (3 dB increase), and the Emin would be effectively increased by 3 dB for such receivers. For example, if the Emin for a narrow band receiver is 0.5 mV/m, then the Emin would be 0.707 mV/m for an improved receiver having twice the bandwidth. This is an important factor when considering the effect upon the appropriate value of Enom that would result from a new generation of receivers that provide significantly increased bandwidth over that possessed by typical receivers in use today or in the past.

18. In order to re-evaluate the field strength values, Enom, applied to the normally protected contours, it would be necessary to recalculate the values of Emin that occur throughout the United States. Atmospheric noise would be considered as discussed in the following section of this *Inquiry*. It would also be necessary to identify the receiver characteristics that should be employed during the computations.

19. QUESTIONS:

A. Are additional subjective listener measurements necessary to determine listener satisfaction? If so, what measurement procedures are recommended for such measurements?

B. If additional subjective listener measurements are not necessary, what ratio of signal to atmospheric noise should be used for calculations?

C. What receiver characteristics should be employed for determination of Emin?

D. What reference level of listener satisfaction should be used for determining Emin?

C. ATMOSPHERIC AND MAN - MADE NOISE

20. As noted above, atmospheric and man-made noise is a technical factor that must be considered in the determination of Emin. Atmospheric radio noise is produced mainly by lightning discharges in thunderstorms.[10] Man-made noise occurs primarily in populous areas and arises from a number of sources such as power lines, industrial machinery, ignition systems, appliances, etc., with widely varying noise characteristics.

21. Atmospheric radio noise obeys the same propagation laws as communication signals. It travels up to several thousands of kilometers away from the source via skywave. Atmospheric noise level thus varies with time of day, season of the year, weather, geographical location, and frequency. Multiple paths with various reflections and scattering are very common, resulting in continuous noise. In general, atmospheric noise level is the highest:

when the receiver is located near a thunderstorm;

during local summer;

during the night;

when the frequency is low.

22. Propagation of man-made noise occurs principally over power lines and by groundwave. Thus, man-made noise is relatively unaffected by diurnal or seasonal changes in the ionosphere.[11]

23. There are three major thunderstorm (hence, noise) centers in the world: the Caribbean, equatorial Africa and Southeast Asia. Maps showing the atmospheric noise levels for different parts of the world corresponding to different seasons of the year and different hours of the day have been developed by the CCIR since 1964. These maps are contained in CCIR Report 322, which was revised extensively in 1986. These maps may be used to determine the distribution of atmospheric noise throughout the United States and the corresponding values of Emin.[12]

24. These maps show that southern latitudes in the United States have higher levels of atmospheric noise than do northern latitudes. As a consequence, values for Emin will be higher in the southern latitudes. This raises the issue as to whether the United States should continue to be treated as a single noise zone or whether two or more noise zones should be created that could ultimately result in different values of protected contours being adopted for the different noise zones.

25. QUESTIONS:

A. What source of data should be used in determining noise levels in the United States? If a source other than CCIR Report 332 is recommended, please explain the rationale for such recommendation.

B. Should the U.S. be divided into noise zones with different standards applied to each zone, or should the noise conditions for the U.S. be averaged and uniformly applied? Similarly, should noise values for the worst time of the year or the most favorable time of the year be used, or should seasonal data be averaged throughout the year?

C. If separate domestic noise zones are established, what should be the basis for drawing the boundaries (i.e., how many zones should be created and at what noise levels)?

D. Recognizing that noise level decreases with increasing frequency, should values of Emin be uniformly applied to all frequencies or should different values be established for different frequency ranges?

D. CO - CHANNEL AND ADJACENT CHANNEL PROTECTION RATIOS

26. Radio-frequency protection ratios are standards which define the maximum permissible interference from one station to another. Co-channel and adjacent channel protection ratios are prescribed in Section 73.182(t) of the FCC rules, which establish the minimum ratio of a desired signal to an undesired signal (D/U) for interference free service. These are critical parameters which affect the minimum quality of service within the protected contours of AM broadcast stations.

27. Under the FCC Rules, the protection ratios are applied at the normally protected contour of AM stations. When changes are considered to the field strength values of protected contours of stations, it is necessary also to re-evaluate the level of protection that is desired at the new contours being proposed. Moreover, because of changes over time in the receivers being employed by the public, changes in transmission characteristics and program formats, and expectations by the public in the quality of service received, there may be an additional need to reassess the protection ratios contained in the rules.

28. Measurements to establish radio-frequency protection ratios are difficult because they include both technical and non-technical factors. Important technical factors that must be considered include: the frequency spacing between the desired and undesired signals; emission characteristics (i.e., percentage of modulation, dynamic range compression, bandwidth of emission, etc.); and receiver characteristics such as selectivity. Non-technical factors involve subjective evaluation by listeners as to what degree of interference is judged acceptable, the type of programming being employed (voice or music),[13] and stability of the desired and undesired signals (i.e., are they groundwave or skywave).

29. A common procedure used in establishing protection ratios is to measure initially the co-channel protection ratio, through listener tests, which achieves a subjectively defined reception quality. This establishes the reference to be used in determining the relative adjacent channel radio-frequency protection ratios. Several approaches may be used to determine the co-channel protection ratio. One approach is to measure subjectively the audio-frequency protection ratio which achieves the defined reception quality. In effect, these measurements are performed at the audio baseband, using audio signals having the desired characteristics. Alternatively, the co-channel protection ratio may be measured through subjective tests directly at radio frequencies (RF) by employing the appropriate reference receiver and signal transmission equipment.[14]

30. Once a co-channel protection ratio is determined through one of these procedures, relative adjacent channel protection ratios can be measured using a reference receiver having desired characteristics. Selection of a reference receiver is critical, and it is usually selected based on the fact that it possesses either characteristics representative of receivers generally in use or characteristics of a receiver that would permit a desired quality of broadcast service. Objective measurement procedures may be used to facilitate measurements of relative protection ratios.[15]

31. Radio-frequency protection ratios used within the United States are based largely upon subjective tests performed with large groups of listeners. Some of the most definitive subjective information collected was that developed during the 1940's in the Clear Channel Hearings (FCC Docket No. 6741). During these hearings, listener tests were conducted using program formats of music and voice in order to determine the relationship between interference perceived to be objectionable and the type of program material broadcast. These tests showed, for example, that for a variety of programs (both voice and music) a co-channel protection ratio of 15/1 (desired to undesired) satisfied approximately 40% of the listeners participating in the tests, 20/1 satisfied 67%, and 27/1 satisfied 75%. It was further noted that some types of programming require higher protection ratios than do other types in order to provide the same degree of listener satisfaction. For example, when speech is present on both the desired and undesired signals a protection ratio of 37/1 is needed to satisfy 67% of listeners, whereas, when music only is employed, a co-channel protection ratio of 15/1 satisfied 67% of the listeners.

32. The CCIR recommends a co-channel protection ratio of 40 dB (100/1)(D/U) for high quality broadcast service where both signals are groundwave. Such a high level of protection can significantly restrict the number of stations permitted to use the spectrum in a given area. Thus, CCIR recognizes that for practical reasons a lower ratio may be needed in actual practice in order to achieve a desired use of the broadcast spectrum. No recommendation is made by CCIR related to protection ratios for desired skywave service, although it is considered that lower values of protection ratios should be applied as compared to groundwave service. The following table exemplifies the protection ratios employed in the Western Hemishpere:

CURRENT PROTECTION RATIOS (D/U)
GROUNDWAVE TO GROUNDWAVE

SOURCE	CO-CHANNEL	1ST ADJ CHANNEL	2ND ADJ CHANNEL
NARBA	20/1	2/1	1/30
REGION 2	20/1	1/1	1/30
U.S./CAN	20/1	1/1	1/30
U.S./MEX	20/1	1/1	1/30
FCC RULES	20/1	1/1	*

* Current FCC rules do not specify a protection ratio for 2nd adjacent channels.

33. As shown in the above table, the FCC rules do not specify a protection ratio for second adjacent channels, but Section 73.37(a) of the FCC rules prohibit overlap of 2 mV/m and 25 mV/m contours of stations on these channels. These overlap restrictions, which relate in large part to interference susceptibility characteristics of receivers, are not directly related to a specifically identified second adjacent channel ratio. A second adjacent channel protection ratio of 1/30 (D/U) would be required in order to provide a level of protection consistent with that protection required by the FCC rules for the co-channel and first adjacent channels. This degree of second adjacent channel is not provided by the overlap restriction prescribed in the Rules.

34. In light of the substantial effort now underway in the industry to develop improved AM broadcast standards and AM receivers, there is the need to reassess the protec-

tion ratios contained in the FCC rules in order to determine whether they are consistent with the improvements in AM radio service being sought.[16] If it is determined that changes to the protection ratios are warranted, measurements will be required, but there are issues, as set forth below, that must be resolved before actual measurement programs can be undertaken.

35. QUESTIONS:

A. What changes to the protection ratios are needed? Commenting parties should provide analysis in their comments.

B. What percentage of listeners should we seek to satisfy during measurements of protection ratios (for example, 67% of listener satisfaction or some other percentage)? It is recognized that a final decision on this issue may have to await the results of measurements, if performed, in order to permit the trade-offs between alternative choices to be assessed.

C. Are additional subjective listening tests needed, or is sufficient information available to establish the appropriate co-channel protection ratio?

E. What bandwidth characteristics should be used for the reference receiver if measurements are performed? Full receiver de-emphasis characteristics should be described (RF, IF and AF). Also, comments should address whether any receiver characteristics related to AM stereo should be included.

F. What emission characteristics should be used for desired and undesired signals during measurements (i.e., audio bandwidth, pre-emphasis, and audio processing), and the types of program formats that should be employed (voice, music, etc.)? Also, comments should address whether any transmission characteristics related to AM stereo should be included.

G. What protection ratios should be measured (co-channel, and 1st, 2nd and 3rd adjacent channels)? In addition, consideration should be given to whether measurements should also be made to determine whether different protection ratios should be applied for groundwave and skywave propagation modes.

H. What are the recommended measurement procedures and alternatives for effectuating measurements if they are deemed appropriate?

II. ADDITIONAL ASSIGNMENT CONSIDERATIONS

36. In addition to the considerations pertaining to the technical assignment principles that were discussed in earlier sections, additional considerations have been identified which could increase flexibility to AM stations regarding station assignments. These are discussed below.

A. INTERFERENCE CAUSED

37. Before the so called "go/no-go" rules were adopted in the early 1960's, numerous instances occurred where AM broadcast stations were permitted to cause interference to each other. Under the procedures that existed before then, trade-offs between new service that would be provided by a proposed new or modified station and service lost by existing stations were compared during hearings to determine if the gains outweighed the losses. Many stations in the U.S. today still receive interference within their normally protected contours that result from the earlier procedures.

38. Since adoption of the "go/no-go" rules, such interference has not been permitted by proposed new or modified assignments. Section 73.37(a) of the FCC Rules sets out proscriptions on overlap of contours between protected and interfering stations. For example, the 0.025 mV/m contour of a proposed new station is not permitted to overlap the 0.5 mV/m contour of any co-channel station. This rule not only prevents new interference from being caused, it also has expedited the processing of applications by minimizing the number of hearing cases that result.

39. Section 73.37(a) makes no provision for those instances where interference already occurs within a station's normally protected contour resulting from stations licensed before Section 73.37(a) of the Rules was adopted. Prohibiting the interfering contour of other stations from overlapping the normally protected contour of a station in areas where interference to the normally protected contour already exists could result in occurences of over-protection. As a consequence, instances may occur where new stations or modifications to improve existing stations are unnecessarily precluded by rules that require protection to be afforded where interference already occurs.

40. It would be possible to avoid such over-protection by amending the rules to specify that protection shall be afforded to the interference limited contour of the protected station in instances where interference already exists within the normally protected contour.[17] The interference limited contour to be protected would be calculated using the applicable protection ratios prescribed by the rules. Calculation of interference limited contours was a complex and lengthy process at the time that Section 73.37(a) was adopted. Today, this is much easier due to the wide-spread availability of computer facilities to perform such calculations.

41. QUESTIONS:

A. Should Section 73.182 be amended to specify that in those instances where the normally protected contour receives interference from existing stations, the normally protected contour is the interference limited contour in those areas where interference is received? What are the advantages and disadvantages to the public and to the efficient use of the broadcast spectrum that would result from such an amendment?

B. How should the interference limited contour be computed if the rule is amended?

C. Are there special circumstances where protection to the interference limited contour would not be appropriate?

B. INTERFERENCE RECEIVED

42. The proscriptions of Section 73.37(a) of the FCC Rules notwithstanding, Section 73.37(b) permits a proposed new or modified daytime facility to receive interference overlap up to its 1.0 mV/m contour under certain circumstances.[18] The basic intent of the Rule is to provide additional flexibility for provision of service to communities and areas lacking it. Modification of Section 73.37(b) to permit its general application to all AM stations would appear to have the potential for creating additional opportunities for new and improved service to the public, while still providing full protection to other co-channel and adjacent channel stations.

43. As noted earlier, the "go/no-go" rules were adopted to insure, among other things, that the remaining opportunities for new stations or modifications to existing stations were spectrum efficient. Considering how use of the AM broadcast band has now matured, however, there now appears to be merit for expanding opportunities for applications for new or modified assignments even though interference would be received by the applicant assignment. This would permit new and improved service into areas and communities that otherwise could not be achieved. Whether the interference that would be received outweigh the gains of the new or modified facility appears to be a matter best left to the discretion of the broadcast applicant.

44. Although we believe that there is merit in considering amendment of the FCC rules as discussed, *supra*, there is at least one administrative problem that should be addressed. If Section 73.37(a) and (b) of the FCC rules are amended to generally permit received overlap to occur, it could become difficult to determine when co-pending applications are mutually exclusive. Under the prohibited overlap criteria currently contained in Section 73.37(a) of the FCC rules this problem does not occur because there is reciprocity (mutuality) between overlap caused and overlap received. If the rules are amended to generally permit received overlap, however, clear reciprocity would not exist because one station would be causing prohibited overlap, whereas, the other station would not be receiving prohibited overlap. Thus, this would not appear to be a mutually exclusive situation since the preclusion is in one direction only. In such circumstances it would appear that both applications generally could be granted. However, there could be circumstances where the station receiving the overlap would not, in fact, wish to accept the received interference because it occurs within an area that the station desires to serve.

45. One possible solution to this problem could be the amendment of Section 73.37(a) in a manner that would essentially maintain the rule in its current form in relation to co-pending applications. In this manner, co-pending applications could be identified as being mutually exclusive in the same manner as today. If it were subsequently determined that the station receiving the interference did not object to the received interference, both applications could be granted. Applications filed that result in received overlap from existing stations and which were not affected by co-pending applications would not be affected by such a procedure.

46. QUESTIONS:

A. Should Section 73.37(b) be amended to permit any applicant station to receive interfering overlap of its normally protected contour? What are the advantages and disadvantages to the public and to the efficient use of the broadcast spectrum by making such an amendment? Stations that are permitted to receive interference have the potential for precluding new stations and modifications to existing stations. In this regard, commenters are asked to weigh the the impact of such preclusion on the efficient use of the spectrum.

B. Should there be a restriction on the degree of received overlap that should be permitted, or should this be left to the discretion of the applicant station?

C. Are there any special circumstances where received overlap should not be permitted?

D. What procedures should be considered to permit applications that are mutually exclusive to be properly identified?

C. NEGOTIATION OF INTERFERENCE RIGHTS

47. The earlier discussions have focused on specific protection criteria applicable to the AM broadcast service. This has included both the standards themselves as well as how they were derived. Beyond these matters lies another area to be examined, one involving the possible application of a more decentralized decision making framework for addressing the subject of AM protection. Essentially, the question to be addressed is whether (and if so, to what extent) the public would benefit from interference rights and responsibilities being resolved through negotiations among the various affected parties to resolve interference issues.

48. Our decision to examine this subject derives principally from two factors. Although we apply a single set of protection criteria to all stations, it may well be that interference should not be handled in such a manner. Many factors could affect the optimal level of interference protection for a particular station, and this level may vary widely from that provided under our rules. It is entirely possible that reliance on a uniformly applied set of protection criteria may be producing inefficiencies which are adversely affecting listeners.

49. There is another factor which supports our decision to consider a fundamentally different approach to interference protection. That is the change which has taken place affecting FCC's responsibilities regarding interference protection. Initially, the Commission focused on the protection of the service areas of AM stations against undue interference from other stations. Proposals for new stations or for changes in existing stations had to establish that the proposal would not cause or receive excessive interference as defined by the Commission's rules. In effect, by virtue of the protection they provided, these interference standards defined the station's coverage area. Some waivers were granted, but for the most part, these rules were applied on an across-the-board basis. This approach was well suited to the early days of broadcasting when large numbers of stations were to be established throughout the country. It was important to ensure that the station would have an established service area that would be protected from interference.

50. Now, the situation has changed drastically. Virtually all of the United States receives one or more radio services. Equally important, the opportunities for establishing new stations is limited, particularly in AM. Even in the areas where such opportunities might exist, the current interference standards place severe additional restrictions. In view of the vast changes which have taken place in AM radio, it is no longer clear that the current approach should be continued. Instead, it may be appropriate to consider whether it would be desirable to give to AM station licensees the opportunity, through mutual agreement, to adjust the amount of interference to be permitted.

51. Under the present system, some possible improvements or additions to AM service are precluded because they would result in prohibited interference to areas defined by calculated service contours of protected stations. This is the case even though they may have relatively little relevance to the actualities of service needs.

For example, protection is afforded to some areas where the protected station does not in any case reach, or which have little population, or where the protected station has few listeners. Interference protection involves limitations upon broadcast radiation that, if less restricted, would enable the "interfering" stations to provide improved or extended service.[19] Thus, the rigid application of generally applicable rules of interference protection operates in some situations to block service and thereby waste valuable spectrum. Likewise, there may be instances where a licensee would find it desirable to obtain greater interference protection so as to more effectively compete with other stations or to provide service to newly populated areas.

52. It would be impossible as well as entirely inappropriate for the Commission to attempt an administrative remedy for these situations. This was amply demonstrated during the period preceding the shift to the present "go/no-go" basis for interference control, under which the overlap of signals of prescribed field strengths is rigidly proscribed. This system provided sorely needed relief from the system it replaced, which involved minute scrutiny--often in expensive, lengthy administrative hearings--of claims that proposed new or changed station facilities would render service that would more than offset service losses from resulting interference to existing stations. Long and unfavorable experience with laborious case-by-case adjudications demonstrated that such a procedure would not be a desirable way to reintroduce flexibility into the station assignment process.

53. Inasmuch as governmental consideration of the gains and losses of changes in coverage and interference is itself costly, we wish to examine the relative advantages of allowing these matters to be resolved through private agreements to the mutual satisfaction of the affected broadcasters. Current rules make no provision for this situation and ignore the fact that the two broadcasters involved might be able to reach an accommodation. Thus, introducing a marketplace mechanism would allow broadcasters to reach an understanding between themselves on how to quantify the transaction. Such an understanding on how to value this trade-off between service and interference could far better respond to the need of the listeners than does the current arrangement. Likewise, it could help remove impediments to the ability of AM stations to compete more effectively with FM stations by stressing their service advantages. This very idea was advanced by Group W in its comments in response to the *AM Report*. There it suggested that the Commission should allow stations to purchase "grandfathered" interference rights, thereby reducing interference being received and extending station coverage.

54. Two related points also need to be mentioned. First, there may be implications for other broadcast stations not involved in the negotiations. That is to say that under our current methods of defining interference (principally the 50% exclusion/RSS provisions), stations could conceivably "free ride" on arrangements to which they are not a party. If substantial "free ride" effects could discourage the consumation of otherwise useful arrangements, we, therefore, ask commenters to address the significance of the "free ride" problem and whether these effects could be reduced by modification of the 50% exclusion rule. Likewise, it must be recognized that there are international implications involved in these transactions. Thus, for example, if a station's level of interference was increased as a result of negotiations, it would be that higher level of interference that would be used for international interference calculations, thus permitting foreign stations to direct increased radiation toward U.S. stations. Similarly, it would not be possible to require increased protection from foreign stations in cases where the station has obtained additional domestic protection. While in some cases the effect of these international matters will be significant, this may not be the case generally. We request that commenters address the significance of international operations.

55. There may also be some legal issues raised in the context of this proposal. As a general matter, the Communications Act provides the Commission with substantial discretion in the establishment of methods that provide interference protection. It is our tentative view that allowing AM licensees to transfer their interference would promote the public interest.[20] We request that commenters address this matter.

56. There may also be concerns relating to Section 307(b) of the Communications Act. That Section requires the Commission to foster a fair, efficient and equitable distribution of radio facilities, a goal that we believe can be fostered by the approach we have described. Thus, it is our tentative view that this approach is consistent with the mandate of Section 307(b), so that at least in general terms it could be adopted consistent with current statutory authority.

57. Because it is a new concept, the possibility of allowing the negotiation of interference rights raises a wide variety of questions. Some deal with the concept itself and whether it should be followed. Others deal with specific aspects, particularly as to its applicability in various interference situations. Thus, it should be understood that the following questions are intended solely as examples and are not intended to cover all possible aspects of such an approach. Comment on the full range of these issues is welcomed.

58. QUESTIONS:

A. What are the public interest gains and losses of giving licensees greater discretion in determining the levels of interference they wish to tolerate?

A-1. Under what circumstances would application by the Commission of a uniform interference protection policy be adverse to the aggregate best interests of listeners?

A-2. Under what circumstances would an arrangement beneficial to all affected licensees be, nonetheless, adverse to the best interests of all affected listeners?

A-3. What is the possibility that contracts or negotiated agreements would result in the practice of excluding less desirable demographic areas from receiving service?

A-4. Should a distinction be made between interference caused and interference received?

A-5. Should there be a limit on the amount of interference protection that could be the subject of negotiation?

A-6. Should co-channel cases be treated differently from adjacent channel cases?

B. With regard to the Commission's legal authority:

B-1. To what degree, if any, is implementation of the concepts discussed above dependent upon additional statutory authority?

B-2. Are contracts or private licensee agreements for levels of interference inconsistent with Section 307(b) of the Communications Act?

C. The facilities changes which would result from private interference agreements would require license modification. In light of this:

C-1. To what extent would the Commission be required under Section 309 of the Communications Act to review and approve the specifics of the arrangement?

C-2. What criteria should the Commission consider in making such an evaluation? Should the agreements be maintained in licensees' files at the Commission? Should any technical record of these arrangements be kept in our engineering data base other than the parameters of the facilities involved?

D. How would contracts or negotiated agreements for alternative interference levels be treated relative to the term of a license?

D-1. Under what circumstances would an agreement terminate at transfer? At renewal? If these events do not trigger termination, should petitions to deny based on dissatisfaction with the alteration of service resulting from the interference arrangement be accepted?

D-2. Should the terms for the duration of such agreements be prescribed by the Commission?

E. Should licensees be required to maintain copies of interference agreements in their public file?

F. The level of interference is a function of interfering stations' facilities. Operation of unauthorized facilities can result in increases in interference levels, and these instances are now investigated and enforced by Commission personnel.

F-1. If interference contracts are permitted and a breach occurs, should the present procedure continue, or should remedy be provided through contract litigation?

F-2. If it is found that, as a result of such a breach, the public is adversely affected, should the Commission entertain petitions to reimpose its interference standards until the dispute is resolved?

F-3. Should the Commission accept petitions to deny license renewal based upon breaches of interference contracts?

G. Under what circumstances should there be a basis for the Commission to reassert its authority to decide such issues?

H. To what degree do the present methods of defining interference (*e.g.*, the 50% exclusion policy) provide benefits to stations not party to an agreement (*i.e.*, that is free ride)? If the possibility of free riding reduces the expected efficiency effects of providing for transferral of interference rights, how should the rules be altered to prevent parties that are not part of the agreement from benefiting from these changes when planning modifications to their own facilities?

III. RELATED TECHNICAL ISSUES

59. There are additional important technical issues related to the assignment principles discussed in earlier sections of this *Inquiry* that also warrant reassessment. These issues are emission limitations, skywave and groundwave propagation curves, conductivity data, calculation methodologies, and AM antennas. The accuracy and application of the technical criteria prescribed in the FCC rules related to these matters affect both the degree of interference that may actually occur at the protected contour of an AM station and the flexibility in making new station assignments or modifications to existing assignments. These issues are discussed below.

A. EMISSION LIMITATIONS

60. Section 73.44 of the FCC Rules prescribes the emission limitations (modulation products and spurious) that must be met by AM broadcast stations. In effect, the rules specify a "mask" of minimum required attenuation of emissions below the unmodulated transmitter carrier level for various frequency ranges removed from the carrier by 15 kHz or more.[21] There are no limitations placed on emissions falling on frequencies within 15 kHz of the transmitter carrier. In theory, this permits stations to transmit audio frequencies up to nearly 15 kHz. In actual practice, however, stations often install low-pass filters that "roll-off" high-end audio frequencies in order to ensure that their emissions do not exceed 25 dB at 15 kHz, particularly when audio processing is employed to "boost higher audio frequencies.

61. As noted in a preceding section, radio-frequency protection ratios are affected by the emission characteristics permitted by the rules. In particular, the transmitted audio frequencies that are permitted up to 15 kHz can influence 1st and 2nd adjacent channel protection ratios. These unattenuated emissions are not only permitted to overlap the emissions of stations operating on 1st adjacent channels, but they are also permitted to extend into the emissions of stations operating on 2nd adjacent channels. Moreover, the interference effects of this overlap is exacerbated by many stations that "boost" their higher audio frequencies in order to overcome the selectivity characteristics of receivers typically in use today. We believe that the resulting adjacent channel interference that is permitted by the rules has contributed to the reluctance of receiver manufacturers to design and market AM receivers possessing wide selectivity characteristics needed for improved fidelity.

62. Another technical issue that warrants review regarding emission limitations relates to amplitude modulation. Section 73.1570(b)(1) of the FCC Rules limits amplitude modulation of the carrier to a maximum of 100% on negative peaks and 125% on positive peaks. It has long been understood that overmodulation and heavy clipping on negative peaks to prevent overmodulation creates spur-

ious emissions capable of causing interference to stations operating on adjacent channels. This subject was recently addressed in a publication issued by the National Association of Broadcasters.[22] The report contained both theoretical calculations and tests performed on station transmitters which showed the effects of excessive negative modulation or heavy clipping on negative peaks performed to prevent overmodulation. It was demonstrated that the effects of heavy clipping on negative peaks produces spurious modulation products into adjacent channel frequencies similar in magnitude to those produced from overmodulation on negative peaks. Moreover, although these spurious products have significant potential for causing interference to listeners on adjacent channels, in most instances the spurious modulation products, either from clipping or from overmodulation, met the current FCC restrictions on emission limitations. This suggests that spurious modulation products should be further restricted.

63. QUESTIONS:

A. Should unattenuated transmitted audio frequencies be further restricted in order to reduce 1st and 2nd adjacent channel interference, and if so, by how much? Indications are that "roll-off" of the audio bandwidth between 10 kHz and 12 kHz could significantly reduce adjacent channel interference. If it is determined that measurements for protection ratios are required, the interrelationship between the limitations should be considered in parallel with those measurements.

B. Should the amount of attenuation prescribed in the FCC rules be increased to reduce further interference from spurious emissions, such as those from undesired modulation products? What attenuation levels are appropriate and feasible in actual practice to achieve the desired improvements?

B. SKYWAVE PROPAGATION

64. There are three sets of skywave curves contained in Section 73.190 of the FCC Rules. The first set, Figure 1a, was derived from short-term recordings taken in the spring of 1935, a relatively low solar activity period. Figure 1a is used primarily for determining service areas of clear-channel stations; hence they are sometimes called the FCC clear-channel curves. A version of Figure 1a was adopted by the Region 2 Administrative Radio Conference, Rio de Janeiro, 1981.

65. A second set of curves, Figure 2, was subsequently developed as a result of an extensive long-term skywave field strength measurement program initiated by the FCC in 1939.[23] Soon after this program began, it became clear that skywave field strength is a function of many factors, including latitude and sunspot number. Figure 2 was developed from data acquired for the year 1944. Minimum solar activity occurred in 1944 and, therefore, that year presented the highest skywave field strengths and represented the worst case for determining interference levels and service areas. Figure 2 differs from Figure 1a in one major respect, namely, by giving weight to the effects of geographic latitude.[24] Recordings were made on more than 40 paths ranging from 165 to 4176 km with transmitting frequencies ranging from 540 to 1530 kHz. The mid-point geomagnetic latitudes of these paths are between 40 and 54 degrees, north.

66. The FCC measurement program initiated in 1939 continued for a full 11 year solar activity cycle. Data corresponding to the second hour after sunset (SS+2, the traditional reference hour adopted by administrations in ITU Region 2, the Americas) at path midpoint for 26 propagation paths were released in 1971 and have been studied by a number of researchers from different parts of the world.[25] Among other things, it has been found that the effects of latitude are so great that the 1944 FCC data, which represents only a narrow range of latitudes, is inadequate. Consequently, in order to collect supplemental data, the Commission in 1980 initiated a low-latitude skywave measurement project (Central America to southern U.S.) and in 1981 initiated a high-latitude measurement project (coterminous U.S. to Alaska).[26] Furthermore, in preparation for the Region 2 Administrative Radio Conference for the band 535 - 1605 kHz, the CCIR adopted a number of Study Programs and established Interim Working Party 6/4. This Interim Working Party has remained active since that Conference in order to provide support during preparations for the Region 2 Administrative Radio Conference for the band 1605 - 1705 kHz ("Expanded Band RARC").[27] A number of administrations (e.g., Brazil, Mexico) have contributed a sizable amount of data from the low-latitude areas.

67. The high-latitude field strength measurement program contributed to the development of Figure 1b, the third set of curves in Section 73.190 of the FCC rules. Figure 1b depicts interim curves for use in performing all skywave calculations involving one or more stations in Alaska regardless of class. In adopting Figure 1b, it was anticipated that upon conclusion of the measurement program a final set of curves would be developed.

68. Based on new data and an improved understanding of skywave propagation, we have identified certain shortcomings of the FCC skywave curves. The importance of these shortcomings is magnified by the increasing demand for spectrum. For example, we now know that skywave attenuation increases by about 1 dB per degree of latitude in a year of low sunspot activity as radio path midpoint is moved further north. This means that a station located in a low-latitude area, such as Texas, that would radiate a signal level of 0.5 mV/m per meter at distances 800 miles from the transmitter would radiate 0.5 mV/m only 500 miles if it were located in a high-latitude area, such as Minnesota. Section 73.190, Figure 2, is appropriate in its approach because it treats interference levels as a function of geographic latitude. We now know, however, that geomagnetic latitude rather than geographic latitude is the more determinative factor.

69. Figures 1a and 2 of Section 73.190 of the FCC Rules cover a range of distances from approximately 160 to 4250 km (100 to 2600 miles). Figure 1b of Section 73.190 extends from 250 to 7500 km (155 to 4660 miles). There is a need to extend the curves by some means to distances less than 160 km (100 miles). Since there is virtually no data from short propagation paths some assumptions must be made. It has been recommended (CCIR Recommendation 435) that in calculating skywave field strengths for short paths, the slant distance (earth-to-sky-to-earth) is most appropriate and should be used.

70. Medium waves are usually reflected by the E layer of the ionosphere, which spans the altitude range of approximately 90 to 130 km. In the FCC Rules, the average height of the E layer is assumed to be 96.5 km (60 miles). Thus, even for a receiving point only 1 km away from the

transmitter, the skywave may travel 193 km to reach its destination. An increase between the transmitting and receiving points, within a certain range, will not result in a significant change in the slant distance. For example, if the distance between the two points is increased to 100 km, the actual slant distance is only 217 km. In this case, the horizontal distance has increased by 100 times while the slant distance has only increased 12%. Therefore, the skywave must travel nearly as far to reach a receiver near the transmitter as it does to reach a receiver several hundred kilometers away. Thus it can be concluded that when great-circle distances are sufficiently small, slant distances are, more or less, constant, and skywave field strengths increase very little with decreasing distance. We now believe that use of slant distance is the proper procedure for calculating skywave field strength for distances less than those for which Figures 1a, 1b, and 2 are applicable.

71. Work by FCC staff has continued in efforts to develop an improved skywave propagation model. In preparation for the Expanded Band RARC, the Commission staff developed a latitude-dependent skywave model.[28] It is referred to as the "modified method" and adopted by the First Session of the Expanded Band RARC for calculating inter-regional interference. Studies performed by FCC staff indicates that this "modified method" is more accurate than Figures 1a, 1b, and 2 of Section 73.190. Therefore, we believe that there is merit to its adoption as a single propagation model for all calculations.

> The modified method is easy to use. Predictions can be calculated from formulas using a hand-held calculator or the prediction can be read from graphs.
>
> The modified method is fully compatible with the existing methods described in the Rules (and the Rio Final Acts). Computer programs can be changed easily.
>
> The modified method takes into account the effect of geomagnetic latitude. Determination of the average geomagnetic latitude of path is straightforward.
>
> The curve corresponding to the geomagnetic latitude of 45 degrees is similar to the current FCC Figure 1a. Likewise, the curve corresponding to 59 degrees is very similar to the interim curve for use between Alaska and the lower states.

72. Another issue that merits consideration is use of geomagnetic mid-point correction for all skywave field strength calculations, including those performed on clear channel frequencies. This would result in more accurate depiction of skywave service contours as well as interference calculations on these channels.[29] A final issue that merits review pertains to the additional protection requirements imposed upon Class II stations during the daytime hours referred to as "critical hours".[30] Generally, Section 73.187 of the FCC rules limits the level of daytime radiation for Class II stations that is permitted toward the daytime 0.1 mV/m contour of Class I stations. Figures 9-11 of Section 73.190 of the FCC rules depict curves used in performing these calculations. If the skywave propagation curves are changed as discussed, *supra*, it would be necessary to revise the procedures and curves used in calculating permissible daytime radiation for Class II stations as well.

73. **QUESTIONS:**

A. Should the Commission adopt the "modified method" for domestic applications?

B. If so, should the "modified method" be used in determining protected contours as well as in calculating interference levels?

C. If the "modified method" is to be used in determining service contours for Class I stations, should the geomagnetic mid-point latitude on each calculation azimuth be used, or, for simplicity, should the geomagnetic latitude of the transmitter site be used for calculating all azimuths?

D. The difference between field strengths exceeded for 10% and 50% of the time is a function of geomagnetic latitude. It varies more or less linearly with geomagnetic latitude from about 6 dB in Mexico to more than 10 dB in Alaska. The CCIR recommends that a fixed figure of 8 dB be used at all latitudes. If the modified method is adopted domestically, should a single value be used? In that case, is 8 dB acceptable?

E. The Commission established two hours after sunset as the reference hour many years ago. Since then, many administrations in Region 2 have adopted the same convention. It was thought that the ionosphere would be stabilized and field strength maximized at two hours after sunset. Recent studies, however, show that skywave field strength does not reach a maximum at two hours after sunset.[31] This is an important issue since data suggests that field strength of a skywave signal relative to SS+2 may increase by more than 2.5 dB at a reference hour taken at midnight. Therefore, should the reference hour for the FCC skywave propagation curves be changed?

F. When calculating skywave field strength for great-circle distances less than 200 km, should the slant distance be used in lieu of the great-circle distance? Alternatively, should the great-circle distance be used in conjunction with the field strength from the curves at 200 km? In effect, the second alternative would apply the field strength values depicted at 200 km for all distances less than 200 km. Figure 1b of Section 73.190 of the FCC rules is currently applied similarly except that 250 km was adopted. Moreover, this approach has been endorsed by the First Session of the Expanded Band RARC and can be applied in the band 535-1605 kHz as well.

G. Figures 1a and 1b of Section 73.190 of the FCC rules include formulas to permit skywave field strength to be calculated at distances greater than 4250 km, but such formulas have not been included in the FCC rules for Figure 2. If the current skywave propagation curves are to be maintained, should such formulas be developed?

H. If Figure 1a of Section 73.190 of the FCC rules is changed, what changes to Section 73.187 and Figures 9-11 of Section 73.190 of the FCC rules are required?

C. CALCULATION METHODOLOGIES

74. In order to assess the cumulative effects of skyway interference to Class II and Class III stations licensed within the United States, Section 73.182 of the FCC rules requires calculations to be based upon the root-sum-square (RSS) of the multiple interfering signals.[32] In order to limit the number of interfering signals that must be taken into account during calculations, this Rule requires application of the "50 exclusion method". This method provides a procedure for determining at what point interfering signals can be disregarded. Ignoring insubstan-

tial sources of interference facilitates the implementation of new or modified nighttime operations and minimizes the number of calculations required.[33]

75. Calculation of a station's RSS using the 50% exclusion method does not in actual practice result in the true RSS (i.e., the RSS calculated using all interfering contributions) for the station because this method excludes some interference contributions from the RSS calculations. In effect, the 50% exclusion method ignores the effect of interfering contributions that in actuality can raise the RSS of an AM station by as much as approximately 1 dB. As a result, over time as new stations are added or existing stations make modifications the cumulative effects of the excluded interference contributions can substantially increase the disparity between the true RSS of stations and the RSS calculated using the 50% exclusion method.

76. Additionally, there is a basic inconsistency in the application of the 50% exclusion method. For example, a new station can be placed on the air as long as its interference contribution to other stations is sufficiently low as to be ignored by the 50% exclusion method. However, an existing station whose interfering contribution to the same protected station is sufficiently strong as to already require its inclusion in the protected station's calculated RSS would not be permitted to increase interference by any amount, even though the interfering effect of nearly 1 dB would be the same as that caused by the new station. This inconsistency appears to restrict unnecessarily the flexibility of existing stations in modifying their facilities to improve service.

77. A possible alternative that could eliminate this inconsistency as well as providing a more accurate calculation of the RSS is to replace the 50% exclusion method with a rule that would permit any new or existing station to increase interference to another station up to a specified amount. However, the degree of increased interference that would be permitted is an issue that would need resolution if such an approach is considered desirable. For example, increased interference relative to the existing RSS could be restricted to 1 dB or 0.5 dB. In considering such a change to the FCC rules it would be necessary to weigh the gains versus losses in service that would generally accrue. As a practical matter, it would still be possible to limit the number of interfering contributors used in calculating the RSS to a reasonable number such as, for example, 10 contributors. Although such changes would add to the complexity of calculations, they are practical today through use of computers and would result in increased precision and consistency.

78. It is recognized that the alternative procedure discussed, *supra*, raises certain policy issues. One issue relates to the procedure that would be applied to prevent stations from submitting successive applications to increase interference by the maximum permitted. For example, if a maximum increase in interference of 1 dB is permitted, a station could, in effect, double its power by submitting three successive applications, each of which increased interference by 1 dB.

79. An additional alternative that would at least minimize the cumulative effect of new or changed interference contributions would be to change the 50% exclusion method by specifying a smaller reference, such as 25%, above which new interference contributions would not be permitted. This would not, however, resolve the inconsistency discussed, *supra*.

80. Another issue concerning calculation methodologies relates to adjacent channel skywave interference. Section 73.182(n) of the FCC rules limits the amount of interference that is permitted at the normally protected contour of a station resulting from the groundwave signal of an adjacent channel interfering station. Where two or more interfering stations are operating on the same adjacent channel, the RSS of the interfering stations is used to determine requisite protection. No provision is made for also considering the effect of adjacent channel skywave interference, and there have been indications that adjacent channel skywave interference can cause significant interference. If further study provides support for developing changes to the rules to take into account such skywave interference there appear to be at least two alternatives for treating the matter. One alternative would be to amend Section 73.182 of the FCC rules to require inclusion of skywave signals in the calculation of the adjacent channel RSS. Another approach could be the inclusion of adjacent channel skywave signals in the RSS calculations of stations, after appropriate adjustment to account for the adjacent channel protection ratio.

81. QUESTIONS :

A. Should the current procedure for calculating RSS and use of the 50% exclusion method be maintained? If not, what replacement procedure should be considered?

B. Should adjacent channel skywave signals be included in the RSS of groundwave signals on the same channel? If so, should 50 or 10% skywave signals be used?

C. Alternatively, should adjacent channel skywave signals be included in the RSS calculations of stations?

D. GROUNDWAVE PROPAGATION

82. Refinements to the FCC rules for calculating groundwave field strength contours may be appropriate in order to facilitate improvements in AM broadcast service. Groundwave field strength calculations are performed in accordance with Section 73.183 of the FCC rules. These procedures make use of the groundwave propagation curves contained in Section 73.184 as well as FCC Figure M3. Procedures are also included for performing field strength measurements for use in lieu of Figure M3.

83. Simplifications and shortcoming in the procedures presently used for AM broadcast propagation prediction in FCC matters include:

1. The ground conductivity map, "M3", is known to be a very imperfect guide. There have been recommendations for projects to revise the map dating from the time it was first published. It does not give conductivity information for Alaska, Hawaii, or U.S. territories.[34]

2. The groundwave propagation curves, Graphs 1 to 19 of Section 73.184, are not completely consistent with the formulas in engineering texts.

3. FCC Rules do not identify a suitable modern method for computations for estimating the earth dielectric constant in situations where this quantity differs from 15.0, the standard value. Section 73.184,

Graph 20, "Ground Wave Field Intensity versus Numerical Distance of a Plane Earth," is intended to serve this purpose. However, it is still in English units (miles) and therefore unwieldy.

4. The Rules do not recognize earth surface conditions affecting propagation except those conditions that can be described by dielectric constant and conductivity. It is known, however, that situations in which the earth has a layered structure can only be described accurately by the resulting surface impedance. Surface impedance is the more general concept. It can be calculated from given ground conductivity and dielectric constants, but the computation cannot, in general, be reversed.

5. Another propagation factor not considered in the present framework is terrain. The U.S. Army recognizes terrain effects in field communications, and is supporting research with the goal of producing antenna siting guidelines for groundwave radio.[35] The methods being used in this research may be adaptable for use in FCC matters, and in fact the Department of Commerce provides on-line computer services that make MF groundwave propagation predictions for mixed conductivity over irregular terrain paths.[36]

84. The present FCC groundwave propagation curves are sufficiently accurate for most practical purposes. However, they are not directly applicable in all situations and when interpolated may give results inconsistent with alternative methods of analysis. To the extent that AM broadcast service improvements require difficult decisions sometimes involving considerable engineering detail, the discrepancies may make the decisions unnecessarily difficult or inappropriately bias the decisions. There may be merit, therefore, to consider further work in the future to refine the groundwave curves so that they are fully consistent with the general formulas.

85. Advances of great practical significance were made in groundwave propagation theory in the late 1930s, and graphs representing that theory have been part of the FCC rules since 1940. Whereas these graphs were the only practical means of propagation prediction before computers, computations can now be made readily from formulas representing the theory.

86. A recent FCC report included a history of FCC groundwave curves and provided background in the supporting mathematical theory.[37] The original 1940 curves were drawn using exact computations for the field strength out to approximately 80 kilometers and also at much greater distances. It was necessary to use freehand drawing to complete the curves at intermediate distances because the required computations for this region were much too difficult. Additional curves were added to the original curves in 1954 for very low conductivity. When the low-conductivity curves were added, freehand drawing was still necessary to estimate the field strength values at intermediate distances.

87. The curves adopted in the rules in 1940 and improved in 1954 were considered satisfactory for regulatory purposes until it became necessary to convert to metric units. In a 1979 FCC report, several methods were described for recalculating the curves in order to convert to metric units.[38] It was recommended that the method found in a 1949 text by H. Bremmer[39] be used, and a computer program was developed. This program was subsequently used to produce new FCC curves in 1985[40] which agree within about 1 or 2 decibels over the range of the previous curves in the rules. However, the computer program developed to produce the curves did not overcome the difficulties previously encountered in determining field strength values for intermediate distances, and, as a result, the great-distance values it computes are shifted upward to force a match in the intermediate range.

88. Curves drawn for the Expanded Band RARC are the most recent. They are the result of precise calculations of field strength over the full range of distances of interest, including the previously troublesome intermediate distances. These were adopted at the First Session of the Conference, Geneva, 1986, and presumably they could be added to the FCC rules during domestic implementation of the band.

89. Radio scientists have continued to improve groundwave radio propagation prediction methods. Advances in numerical methods applicable to intermediate distances have provided the formulas that can now replace or supplement prediction curves. Additional refinements applicable to FCC matters have been made with regard to mixed paths[41], stratified earth[42], irregular terrain[43], and the effects of a troposphere whose refractive index varies exponentially with height.[44] It is generally desirable to use propagation prediction methods compatible with these refinements to facilitate treating the more complex aspects when necessary.

90. Section 73.183(e) of the FCC rules prescribes the procedure to be used when calculating groundwave field strength over paths containing more than one groundwave conductivity value. This is referred to as the equivalent distance method or "Kirke method" after H. L. Kirke who described several calculation methodologies and compared results with actual measurements in 1949. One of the methods described by Kirke as possibly too complicated for general use is that of Millington. Millington's theoretical account of mixed path phenomena is now well established.[45] Predictions by the Kirke method are known to be imperfect in that they do not satisfy the reciprocity condition, that is, results obtained by interchanging the receiver and transmitter do not agree in general. We believe that it is desirable to reassess the methodology that is currently prescribed by the FCC rules in order to determine if another method, such as the "Millington method", would provide greater accuracy in predicting groundwave field strength contours in actual practice.

91. In addition to refinements in the theory, a great wealth of earth conductivity data has accumulated from site selection studies and construction of AM broadcast antenna systems. Revision of FCC Figure M3 to reflect these data may warrant consideration.[46] The existing Figure M3 is inaccurate and provides only what may be termed "default" conditions supporting the formal development of groundwave contours in cases in which the actual contours will not be in dispute. It is further possible that the ground conductivity measurements on file at the FCC can be correlated with data collected by satellite sensors.

92. Other government agencies have also been performing tasks related to collection of groundwave conductivity data. The Federal Aviation Administration has been collecting ground conductivity data in connection with aviation use of low frequency beacons. Station engineering data on file at the FCC would be of value for general

geological mapping purposes, and an effort to extract systematically these data may be justified in connection with improving the AM broadcast service. The Federal Aviation Administration's ground conductivity collection activities have produced maps with considerably more detail than FCC Figure M3.[47] The FAA data is for frequencies lower than those used in MF broadcasting, but there is reason to believe that ground conductivities are not much different.[48] Thus, it may be appropriate to consider use of the FAA maps in areas of the U.S. where Figure M3 data have repeatedly been questioned.

93. QUESTIONS:

A. Should the Commission revise Graphs 1 through 19 to agree more closely with the theory presented in FCC report FCC/OET R86-1?

B. Should a metric-units version of Graph 20, "Ground Wave Field Intensity versus Numerical Distance over a Plane Earth," be constructed and included in FCC rules?

C. Should the Commission undertake a program to improve the accuracy of the ground conductivity map, FCC Figure M3?

D. If an accurate map becomes available, will it then be acceptable to define protected and interfering contours to be those determined by standard calculations based on the revised Figure M3 map, and to dispense with interference studies that establish unique contours by actual field measurements?

E. Do the Commission's rules in their present form inhibit the submission of engineering data or propagation analyses in ways detrimental to high quality AM broadcast service or in ways that unnecessarily limit engineering design choices important to providing such service? If so, how may the rules be improved?

F. The FAA ground conductivity maps found in Report FAA-RD-78-103 have considerably more detail than FCC Figure M3. Are there portions of the U.S. where Figure M3 should be replaced by the FAA data?

G. Should alternate calculation methods be considered for the prediction of groundwave field strength in the case of mixed paths, that is, for paths with sections of different ground conductivity? If so, what methods are recommended for consideration?

IV. ANTENNA SYSTEMS

94. The broadcast antenna is one of the most critical components of an AM station. The efficiency and effectiveness of the transmitting antenna significantly affects the service area of a station and the level of interference caused to other co-channel and adjacent channel stations.

95. During the "early" days of development of the AM broadcast service, antennas were relatively simple in design. These early antennas were non-directional because spectrum congestion was relatively low and it had not yet become necessary to tailor service areas through use of directional antennas. Moreover, the scientific community's understanding of radio propagational phenomena, particularly during nighttime hours, was still undergoing development. Such propagational knowledge was a necessary ingredient in the development of directional antenna design criteria.

96. Over the years the AM band has become congested, and increasingly it has become necessary for AM stations to use directional antenna systems to avoid interference to other AM stations and to tailor their service areas to the communities and population centers targeted for service. However, stations have increasingly encountered difficulty in installing the types of antennas needed for their respective circumstances. Such difficulties include lack of adequate sites for constructing antennas and problems involving FAA clearance for antenna towers. As a consequence, studies need to be continued to identify or develop antenna designs not in common use today which could overcome these difficulties.

97. There is some evidence that unique antenna designs have been effectively discouraged because of a likelihood that their approval would be delayed. There is also reason to believe that the vertical radiation pattern of many antennas, a critical consideration in assessing skywave interference potential, differs substantially from the pattern that is calculated using standard procedures recognized by the FCC rules. These procedures are based on assumptions that the antenna consists of very thin wire segments, rather than towers, and that the system of such wires is isolated from other structures such as power line towers, buildings and highway bridges.

98. Special antenna designs are valuable for their potential for overcoming local siting problems, increasing signal quality, and extending service areas. Problems of importance that might be relieved by new antenna designs include:

1. In recent years, AM broadcast antennas that have enjoyed a location central to the community served are being required to move because the relatively large pieces of real estate occupied are too valuable to be dedicated to such single use. The choice of a new site is often difficult and may require very close engineering studies of candidate antenna designs. In some cases, otherwise acceptable antenna sites have severe FAA tower height restrictions.

2. The effective power radiated to provide groundwave service is greatly limited because of the interference potential resulting from undesirable radiation at higher radiation angles. Anti-skywave antennas are being designed and tested to overcome this problem.

3. Signal fading within (especially near the boundaries of) the groundwave coverage region is often caused by self-induced skywave interference. This interference can substantially limit the actual service area.

4. Unexpected secondary interference is often caused by alterations in antenna patterns when new structures are erected near existing MF antennas. The new structures may passively scatter radiation, or they may resonate and drastically affect the desired radiation pattern.

99. It has become relatively easy to investigate antenna radiation patterns using a type of analysis called "method-of-moments".[49] This method of analysis makes the usual simplifying assumptions unnecessary. In particular, the horizontal cross section of towers can be taken into consideration rather than assuming that the towers are thin wires. In addition, the influence of other nearby structures can be estimated. Application of the method-

of-moments has recently been made to evaluating signal fading found near the boundaries of groundwave service areas.[50]

100. Anti-skywave antennas are being designed and tested in program supported by the National Association of Broadcasters. This is a significant effort that may lead to geographically extended nighttime groundwave service without increase in interference potential to distant stations. The tests are not complete, but it is not too early to consider the types of changes, if any, that may have to be made in FCC rules to accommodate anti-skywave antennas.

101. Interest has also been shown in other types of antennas. One such antenna is the "perimeter current antenna" (PARAN). This antenna has the advantage of being electrically short while still possessing reasonable antenna efficiency. It would appear that such an antenna would have application where there are severe FAA tower height restrictions. Renewed interest has also been expressed related to use of directional antennas that comprise passive radiating elements in lieu of active radiating elements as is the common design approach today. In fact, there have been articles published through the years concerning use of a simple passive radiator which is composed of one of the guy wires of the antenna.[51]

102. Finally, there are additional technical issues related to antennas that could be given consideration. For example, elimination of antenna efficiency requirements could be considered. In lieu thereof, the rules could be amended to specify a minimum radiated RMS. Thus, in circumstances where use of short towers is needed that comply with the minimum antenna efficiency currently specified in the FCC rules, the power to the antenna could be increased in order to meet the minimum RMS.

103. QUESTIONS:

A. What can the Commission do to ease problems arising when centrally located AM broadcast antenna is forced to relocate?

B. Are there ways in which FCC rules could be modified to encourage fuller use of antenna pattern measurement data? For example, if the measured groundwave field is higher than predicted, FCC rules require a corresponding power reduction under the supposition that the various potential interference conditions are also higher than has been predicted. But it might be possible to demonstrate that interference potential has actually been reduced by the same special conditions that have increased the groundwave.

C. Should "method-of-moments" analyses be accepted to support claims of special characteristics of proposed antennas? If so, under what conditions and in what form should the analyses be presented? It should be noted that the results achieved using this method may have ramifications pertaining to international agreements.

D. What changes to the rules are desirable to encourage use of types of antennas not in common use today, such as the PARAN antenna and directional antennas that use passive radiating elements?

E. Should the requirements in the FCC rules related to minimum antenna efficiency be eliminated and replaced with a requirement specifying only minimum radiated RMS?

ADMINISTRATIVE MATTERS

104. In order to establish a comprehensive record in this proceeding that will assist the Commission to develop rule proposals, we invite comment from all interested parties on the issues discussed in this *Inquiry*. If commenters wish to address issues we have not identified, we encourage them to do so.

105. Pursuant to applicable procedures set forth in Sections 1.415 and 1.419 of the Commission's Rules, interested parties may file comments on or before **October 5, 1987** and reply comments on or before **October 20, 1987.** All relevant and timely comments will be considered by the Commission before final action is taken in this proceeding. To file formally in this proceeding, participants must file an original and five copies of all comments, reply comments and supporting comments. If participants want each Commissioner to receive a personal copy of their comments, an original and nine copies must be filed. Comments and reply comments should be sent to Office of the Secretary, Federal Communications Commission, Washington, D.C. 20554. Comments and reply comments will be available for public inspection during regular business hours in the Dockets Reference room (Rm. 239) of the Federal Communications Commission, 1919 M Street, N.W., Washington, D.C. 20554.

AUTHORITY

106. Authority for issuance of this *Inquiry* is contained in Sections 4(i), 303(r) and 403 of the Communications Act of 1934, as amended.

107. For information concerning this proceeding contact Wilson A. La Follette at (202) 632-5414.

FEDERAL COMMUNICATIONS COMMISSION

William J. Tricarico
Secretary

APPENDIX

The Modified Method for Calculating Skywave Field Strength

10 IEEE TRANSACTIONS ON BROADCASTING, VOL. BC-31, NO. 1, MARCH 1985

A SKYWAVE PROPAGATION STUDY IN PREPARATION FOR THE 1605-1705 kHz BROADCASTING CONFERENCE

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1. INTRODUCTION

The 1979 World Administrative Radio Conference allocated the band 1605 - 1705 kHz for broadcasting in Region 2 (the Americas), while fixed services elsewhere will continue to use this band. A planning conference has been scheduled for April 1986, in Geneva. One of the most important topics will be the selection of a method for predicting skywave field strengths. This calls for a study of MF skywave propagation with emphasis on interference. In addition to administrations, a number of international organizations, such as the International Radio Consultative Committee (CCIR) and the Inter-American Conference on Telecommunications (CITEL), have begun a concerted technical study. The author is fortunate to be involved in this international endeavor. The purpose of this paper is to present some of the progress that has been made.

2. AVAILABLE PREDICTION METHODS

2.1 The FCC Curves

Two sets of MF skywave field-strength curves are contained in Part 73 of the FCC Rules and Regulations.[1] The first set is based on short-term measurements taken in the spring of 1935. They are applicable to clear-channel stations in the United States.

In 1939, an extensive measurement program was initiated by the FCC. The measurements were continued for a full sunspot cycle, and portions of the results were released in 1972.[2] Soon after this program was initiated, it became apparent that the skywave field strengths were functions of many factors. Consequently, the 1944 data were used to develop a second set of curves. The second set differs from the first set in one respect: it gives some weight to the effects of geographic latitude. This set of curves was adopted by the Commission primarily for calculating interference levels. The FCC (clear-channel) curves have been regarded as a conservative and safe method when applied to most of the continental United States.

2.2 The Cairo Curves

Under the auspices of the CCIR, some short-term measurements between North and South America, between North America and Europe, etc., were carried out by several administrations in the late 1930s. A working group under the leadership of Dr. B. van der Pol (Holland) was established to study the results. This working group developed two separate curves: one for propagation paths distant from the earth's magnetic poles (i.e., low-latitude paths), and one for propagation paths that pass near the earth's magnetic poles (i.e., high-latitude paths). The former is better known as the Cairo north-south curve because it was derived from measurements made on transequatorial paths; the latter is better known as the Cairo east-west curve because it was derived from measurements made across the Atlantic. These curves were officially adopted by the CCIR at the 1938 meeting held in Cairo; hence, they are collectively called the Cairo curves.[3]

The 1975 LF/MF Conference adopted the Cairo north-south curve for official use in Asia. Field-strength measurements conducted by the Asia-Pacific Broadcasting Union (ABU) indicate that the Cairo curve is preferable for that part (i.e., low geomagnetic latitude) of the world. It has also been reported that, for very long paths, the Cairo curve, in general, yields the highest prediction.[4]

2.3 The CCIR Method

Recognizing the needs for a simple field-strength prediction method for worldwide application, the CCIR in 1966 established an ad hoc working group known as the Interim Working Party (IWP) 6/4. In 1974, under the leadership of Dr. P. Knight (UK), IWP 6/4 adopted the USSR method with modifications (e.g., UK sea-gain term). The method is recommended by the CCIR for "provisional use."[5] The 1975 LF/MF Conference adopted this method for official use in Region 1 and part of Region 3 (with modifications).[6]

When compared with measured data from different parts of Region 2, the CCIR method shows better overall results than the FCC curves. However, qualitatively, certain limitations became apparent.[7] Briefly stated, they are:

2.3.1 The method has a tendency to underestimate field-strength levels in low-latitude areas and to overestimate in high-latitude areas.

2.3.2 Measurements taken in North America suggest that when other factors are equal, the field strength of a higher-frequency path tends to be stronger. The frequency-dependence term of the CCIR formula is of the opposite sense.

2.3.3 For very long paths, this method has a strong tendency to underestimate field-strength levels.

*Views and opinions expressed in this paper are those of the author and should not be interpreted as official FCC policy.

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2.4 The Simplified CCIR Method for Planning Purposes in Region 2

In preparation for the 1980 Regional Administrative Broadcasting Conference (Region 2), IWP 6/4 of the CCIR held a special meeting in Geneva (October 1979). A set of modifications to the CCIR method was adopted.[8] These modifications, which were derived from a paper by Wang[9], are believed to simplify the CCIR method while improving its accuracy when applied to Region 2. The modifications are:

2.4.1 In using the CCIR formula for skywave field strength, 1000 kHz is used regardless of frequency. This not only simplifies the calculation but also reconciles the differences in frequency dependence as observed in different regions.

2.4.2 A loss factor (k) of the CCIR method was modified in such a way that the accuracy in the high-latitude areas and the low-latitude areas is improved without affecting the prediction in the average-latitude areas.

2.4.3 For planning purposes, sunspot number is assumed to be zero.

2.4.4 It should be emphasized that these modifications are derived from studies of data collected in different parts of Region 2.

2.5 The Region 2 Method (535-1605 kHz)

The first session of the Regional Administrative Broadcasting Conference for Region 2 (Buenos Aires, March 1980) considered all the available methods and decided that:

2.5.1 The metric version of the FCC (clear-channel) curve, normalized to a characteristic field strength of 100 mV/m at 1 km, is to be used for paths up to 4,250 km in length.

2.5.2 For paths greater than 4,250 km in length, the Cairo north-south curve, converted to 100 mV/m at 1 km and "lowered" by 5.4 dB, is to be used. This lowering allows the Cairo and the FCC curves to intersect with each other smoothly at 4,250 km. This composite FCC/Cairo curve was originally adopted by the Permanent Technical Committee II, Inter-American Conference on Telecommunications (PTC II/CITEL) at a meeting held in Brasilia, Brazil (July 1979; C. Romero, Peru, Chairman).

2.5.3 The first session decided against the adoption of the sea-gain factor. Instead, it invited the CCIR to carry out further studies. The polarization coupling loss factor from the CCIR method was adopted by the first session but deleted by the second session (Rio de Janeiro, November-December 1981) for reasons of simplicity. Furthermore, the second session of the conference also decided that in calculating interregional interference, the arithmetic mean of the signal strengths calculated both by the Region 2 method and the method described in CCIR Recommendation 435-3 is to be used. Details of the Region 2 method can be found in reference 10.

2.6 Other Methods

A number of other methods have been developed; see for example, references 4 and 7.

3. FACTORS AFFECTING PROPAGATION AND INTERFERENCE

3.1 Effects of Frequency

Extensive data in the 535-1605 kHz band collected by the FCC conclusively show that skywave field strengths for transition hours are highly frequency dependent.[11] For example, at sunset (or sunrise), signals of a 1530 kHz station are consistently about 15 dB stronger than those of a 700 kHz station. As the evening goes on, frequency dependence diminishes. At about two hours after sunset, field strengths of a higher-frequency station are typically 3 to 5 dB stronger than those of a lower-frequency station. At midnight, frequency dependence is so slight (typically 1 to 3 dB, in favor of the higher-frequency station) that it may be neglected entirely. Because the study[12] is so extensive, it seems to be safe to say that at nighttime (from 2 hours after sunset and on), skywave propagation conditions at 1.7 MHz and at 1.6 MHz are very similar. During transition hours, however, signals of stations in the new band are expected to be significantly stronger than those in the lower band.

3.2 Effects of Latitude

A major drawback of the current method for Region 2 (535-1605 kHz) is that the method does not take into account the effects of latitude, which happens to be a very, if not the most, influential factor. Furthermore, the populated areas of Region 2 cover a range of geomagnetic latitude of more than 120 degrees, wider than any other Region of the ITU. Thus, latitudinal effects are particularly important for the current study.

MF skywave field strength decreases with increasing geomagnetic latitude. This correlation can be described[5] by the squared tangent function of the latitude. Extensive data collected in the mid-latitude areas of Region 2 show a more or less similar latitude dependence. Data from the high-latitude areas of Region 2 show that measured field strengths are usually weaker than those predicted by any of the prediction methods available. Data collected in the low-latitude areas show a strong opposite trend. It should be mentioned that data from the high-latitude and the low-latitude areas of Region 2 cannot be considered extensive. Additional data are being collected by the FCC at Kingsville, Texas and Fairbanks, Alaska. Results from these studies may become available soon.

3.3 Daytime Skywave Propagation

It is difficult to collect daytime skywave field strengths for a number of reasons. Nevertheless, the FCC did manage to collect a considerable amount of daytime skywave data representing different levels of solar activity. Before analyzing daytime data, some stringent tests were performed to make sure that the data collected were actually skywave. Measurements of eight paths are believed to be skywave and have been studied. An analysis of the FCC daytime skywave data shows that:[12]

3.3.1 The annual median value of skywave field strength at noon is about 45 dB lower than the corresponding value at midnight. This agrees quite well with data collected in Japan and Europe. If one considers the winter season alone, however, the picture can be quite different. In the high-latitude areas where nighttime winter anomaly is pronounced, the difference between daytime and nighttime field strengths can be drastically smaller. For example, during the period of November 1, 1941, to January 31, 1942, signals of WLW (700 kHz, Cincinnati, Ohio) were detected in Portland, Oregon (path length = 3192 km, midpoint geomagnetic latitude = 53.2 degrees N) regularly around noon with a median value of 6 dB above 1 μV/m. The corresponding nighttime (6 hours after sunset) value was only 17.3 dB above 1 μV/m. The difference was only about 11 dB. The typical difference between nighttime and daytime field strengths for the winter months, as observed in the United States, is usually between 25 and 30 dB.

3.3.2 Day-to-day fluctuation of midday field strengths is more pronounced with signals in the upper end of the MF band than in the lower end of the band.

3.3.3 Daytime skywave field strengths vary with solar activity in a similar manner as that of nighttime.

3.3.4 The seasonal variation of the median value of daytime field strengths is very apparent. Field strengths are strongest in the winter months.

3.4. Effects of Solar and Magnetic Activity

Solar activity reduces MF nighttime skywave field strengths. An analysis of data collected in Region 2 suggests that the reduction is a function of geomagnetic latitude, frequency, distance and sunspot number.[7]

Evidence based on some U.S.-Canada paths shows that another dominant factor in reducing MF nighttime skywave field strength is the magnetic-activity-related absorption.[13] Short-term effects of magnetic storms have been studied recently.[12] Storm-related absorption, particularly during the first 5 to 10 days immediately following the onset of a storm, increases with increasing frequency. For example, when monitored in Grand Island, Nebraska, the signal of KSTP (1500 kHz, Minneapolis, Minnesota) decreased by 33 dB while the signal of WCCO (830 kHz, St. Paul, Minnesota) decreased by only 19 dB when a magnetic storm struck the world (March 19, 1950; Ap = 84). Storm-related absorption is usually less severe in tropical latitudes.

It should also be mentioned that at MF storm-related absorption has no diurnal variation to speak of. Storms affect daytime field strength and nighttime field strength in a similar manner.

3.5 Field Strengths Exceeded for Different Percentages of Time

Based on extensive data collected in Region 2, it has been observed that during a year of low-solar activity:

3.5.1 In the low-latitude areas, (40 degrees or less, geomagnetic) field strength exceeded for 1% of the time is about 9.5 dB greater than the annual median value. This difference increases to about 15 dB in the high-latitude areas (60 degrees or greater).

3.5.2 In the low-latitude areas, field strength exceeded for 10% of the time is about 6 dB greater than the median value. This difference increases to about 10 dB in the high-latitude areas.

3.5.3 For simplicity, 12.25 dB and 8 dB may be added to the median value in order to determine the top-percentile and upper-decile values, respectively.

3.5.4 For a year of high solar activity, these figures may be considerably larger.

3.6 Seasonal Variation

Nighttime field strength measurement made in the low-latitude areas of Region 2 (e.g., Mexico, the Caribbean) show very little seasonal variation.[14] Measurements made in the mid-latitude areas of the Region show only a slight minimum in the summer months, typically 5 or 6 dB. Measurements made in Europe show a more pronounced minimum in the summer together with maxima in spring and autumn.[15]

Daytime skywave field strengths show a strong maximum in the winter months.

3.7 Field Strengths at Two Hours and Six Hours after Sunset

Different reference hours are being used by different administrations in different Regions of ITU. In Region 2, two hours after sunset (SS+ 2) at the midpoint of a path has been adopted as the reference hour. In Region 1, six hours after sunset (SS+ 6) has been in use. In Australia, midnight has been the traditional reference hour. CCIR Recommendation 435-4 suggests that field strength at six hours after sunset is 2.5 dB stronger than that at two hours after sunset. A study of Region 2 data reveals that:

3.7.1 The CCIR-recommended figure of 2.5 dB is most accurate for short paths (i.e., one hop) regardless of direction.

3.7.2 This figure is also accurate for north-south paths regardless of path length.

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3.7.3 For multi-hop east-west paths, the difference between field strengths at six and two hours after sunset can be considerably larger than 2.5 dB.

3.8 General Characteristics of the Band 1605-1705 kHz

The high MF band is expected to be characterized by wide short-term fluctuation in skywave field strengths. Nighttime field strengths particularly in the high-latitude areas (e.g., northern USA, Canada, Greenland), where magnetic storms are frequent and winter anomaly is pronounced, fluctuation of more than 40 dB is to be expected. Storm-related absorption increases with increasing frequency. It should be noted that short-term fluctuation of daytime field strengths also increases with increasing frequency.

4. HOW TO IMPROVE THE FCC METHOD

Recognizing the basic limitations with the current FCC (hence, the Region 2) method, and in preparation for the forthcoming 1605-1705 kHz conference, a new latitude-dependent term has been developed by this author (see Appendix 1). This term, when used in conjunction with the method for Region 2 decribed in reference 10, has the following features:

4.1 The modified method is simple to use. A hand-held calculator would suffice. In many cases, a pencil and a straight edge would be all that is needed. A computer is not necessary.

4.2 The modified method is fully compatible with the existing model. Computer programs being used by the administrations and the IFRB can be changed very easily.

4.3 The modified method takes into account the effects of latitude by utilizing the average geomagnetic latitude (Φ) of a path involved. Conversion from geographic to geomagnetic coordinates is straightforward.[5,16]

4.4 The curve corresponding to $\Phi = 35^{\circ}$ is extremely close to the Cairo north-south curve. The difference is about 1.5 dB, on the rms basis.

4.5 The curve corresponding to $\Phi = 45^{\circ}$ is similar to the current curve for Region 2, which is the metric version of the FCC curve. At this stage, it should be mentioned that there is a "hump" on the FCC curve at distances near 1,000 km. The presence of this hump has prevented engineers from developing a simple, descriptive mathematical equation. The author has reexamined some of the earlier work done by FCC engineers. It was found that several stations in Texas were monitored at Grand Island, Nebraska, with path lengths varying between 900 and 1,100 km. Ground conductivities along these paths are considerably higher than average. High conductivity enhances groundwave and, to a lesser degree, skywave signals. Later measurements of station WFAA (Dallas, Texas) at Grand Island taken around noon strongly suggest that the groundwave component is appreciable (about 3 µV/m). Thus, the hump may have resulted from the presence of groundwave components. It is believed that the hump can be smoothed without losing accuracy. With the hump, the Region 2 curve and the new modified curve for $\Phi = 45^{\circ}$ are about 2.5 dB apart, on the rms basis. If the hump is smoothed, the difference is narrowed to less than 2 dB.

4.6 The curve for $\Phi = 59^{\circ}$ (with minor refinements) has been adopted by the FCC (Docket 83-807) for use between Alaska and the lower 48 states of the United States.

4.7 The modified method is fully flexible. Additional terms can be included easily.

4.8 While the modified method has been developed in preparation for the 1986 conference that will deal with the band 1605-1705 kHz, it can be applied to the existing band for standard broadcasting as well.

5. A COMPARISON OF PREDICTED AND MEASURED FIELD STRENGTHS

Data from a large number of propagation paths have been studied. Region 2 data have been divided into three groups according to geomagnetic latitudes. In the mid-latitude and high-latitude cases, only measured field strengths for a year of low solar activity (i.e., the worst-case data) were studied. Table 1 summarizes prediction errors of the different prediction methods. In this study, an error is defined as the difference, in dB, between the calculated field strength and the measured field strength.

TABLE 1 - PREDICTION ERRORS

CASE	RMS ERRORS FOR DIFFERENT METHODS			
	A	B	C	D
0°-44.9°	9.8	7.8	7.6	8.9
45°-52.5°	4.7	6.0	4.1	5.8
$> 52.5^{\circ}$	11.1	13.4	4.6	6.8
SUB-TOTAL	8.1	8.7	5.4	7.0
INTER-REGIONAL	13.6	17.2	11.1	8.9*
TOTAL	10.97	13.96	8.51	8.0*

All figures are in dB.
* Preliminary results

A = The Region 2 Method
B = The Cairo Curve
C = The Simplified CCIR Method
D = The Modified FCC Method

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A careful study of the results of this comparative study and results of previous work suggests that:[7,14]

5.1 As expected, the Region 2 method works well in the mid-latitude areas of the region. When used in the low-latitude areas, however, it usually underpredicts field strength levels. When used in the high-latitude areas, on the other hand, it almost always overpredicts. From a frequency management point of view, it means that in the low-latitude areas, skywave contours for a given signal level, calculated by the Region 2 method, are usually considerably smaller than the actual ones. The calculated contours in the high-latitude areas, on the other hand, are usually much larger than the actual ones. Much the same can be said about the Cairo curve.

.2 The simplified CCIR method for planning purposes in Region 2 yields promising results. When compared to measured data collected in Region 2, it offers closer agreement with observations than the other methods. When compared to measurements made over inter-regional paths, it offers reasonable overall results too. However, it has been reported that when applied to paths longer than, say, 4000 km, this method has a tendency of underestimating.[8]

.3 Like the simplified CCIR method, the modified FCC method contains a latitude-dependent term. Unlike the simplified CCIR method, the modified FCC method seems to work well for long paths as well as short paths.

6. CONCLUSIONS

Based on the latest study on frequency dependence, the Region 2 method, as described in the Rio Final Acts, for calculating nighttime skywave field strengths in the band 535 - 1605 kHz can be extended to 1705 kHz without introducing significant additional errors.

If administrations in Region 2 prefer a somewhat more advanced approach to improve the accuracy of prediction, two alternative methods deserve careful consideration: the simplified CCIR method for planning purposes in Region 2 and the modified FCC method.

TABLE 2 - LIST OF SYMBOLS

	short great-circle path distance (km)
c	characteristic field strength, mV/m at 1 km for 1 kW
(θ)	radiation as a fraction of the value θ = 0 (when θ = 0, f(θ) = 1)
	annual median skywave field strength, in dB (μv/m)
c	field strength for a characteristic field strength of 100 mV/m
G	antenna gain at the appropriate elevation angle and azimuth, with respect to an ideal small vertical antenna, in dB
P	station power (kW)
θ	elevation angle from the horizon (degrees)
ϕ	arithmetic mean of the geomagnetic latitude of the transmitter (ϕ_T) and that of the receiving site (ϕ_R) of a path. Northern latitudes are considered positive, southern latitudes negative

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8. ACKNOWLEDGEMENTS

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APPENDIX 1

The Official Method for Calculating Skywave Field Strengths in Region 2 and the Suggested Modifications

According to Chapter 3 of reference 10, nighttime (2 hours after sunset) skywave field strength, 50% of the time, is given by:

$$F = F_c + 20 \log \frac{E_c f(\theta) \sqrt{P}}{100} \quad (1)$$

(all equations are in dB [µV/m])

For distances less than 4,250 km, F_c is the direct reading from Figure 4 of reference 10; no equation is available. For greater distances, F_c can be expressed by:

$$F_c = \frac{231}{3 + d/1000} - 35.5 \quad (2)$$

It is suggested that, for all distances greater than 250 km, F_c be given by:

$$F_c = (95-20 \log d) - (2\pi + 4.95 \tan^2 \phi)(d/1000)^{\frac{1}{2}} \quad (3)$$

If $|\phi|$ is greater than 60°, equation (3) is evaluated for $\phi = 60°$. If d is less than 250 km, F_c is evaluated for d = 250 km. However, the actual value of d is to be used in determining angle of departure.

Figure 1 shows F_c for selected latitudes. For those who prefer antenna gain over characteristic field strength, equation (1) can be rewritten as:

$$F = F_c + 10 \log P + G + 9.54 \quad (1A)$$

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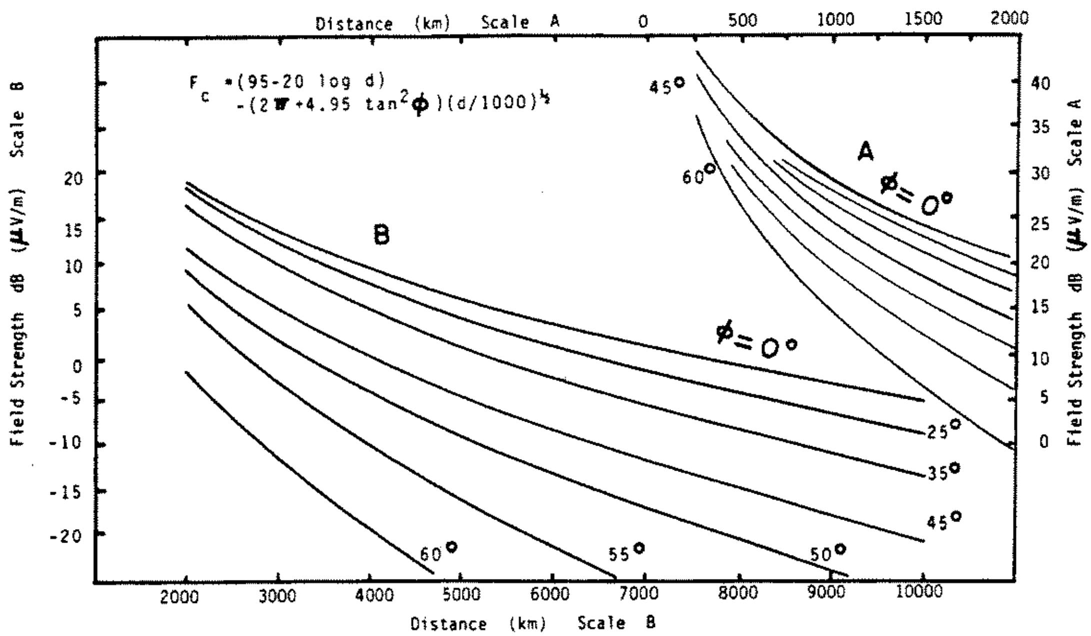
FIGURE 1 Skywave field strength vs distance (100 mV/m at 1 km, 50 %, 2 hours after sunset)



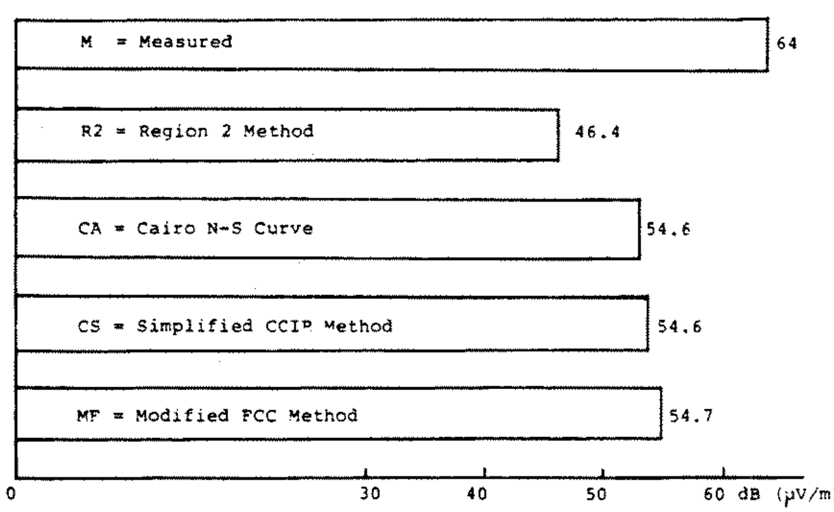


FIGURE 2 A graphical comparison of predicted field strengths by using different methods (Bonaire to Florida, 800 kHz, 2195 km, 31 deg N)

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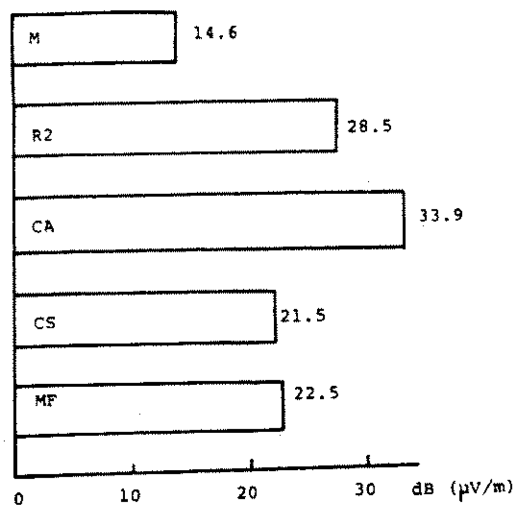

FIGURE 3 A graphical comparison of predicted field strengths by using different methods (Atlanta to Portland, 750 kHz, 3498 km, 51 deg N)

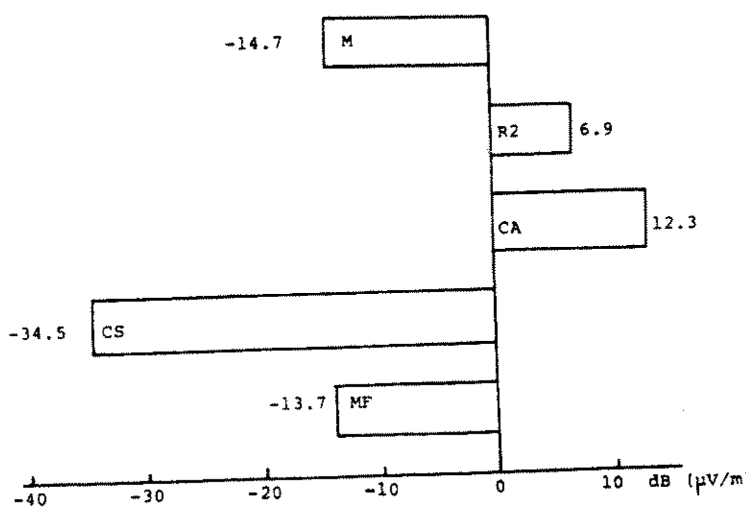

FIGURE 4 A graphical comparison of predicted field strengths by using different methods (N. Ireland to Ottawa, 977 kHz, 4797 km, 64 deg N)

ANNEX TO RECOMMENDATION No. 5

Calculation of the skywave field strength to evaluate interregional interference

1. List of symbols (see also Chapter 2)

a_T: geographical latitude of the transmitting terminal (degrees)

a_R: geographical latitude of the receiving terminal (degrees)

b_T: geographical longitude of the transmitting terminal (degrees)

b_R: geographical longitude of the receiving terminal (degrees)

Φ_T: geomagnetic latitude of the transmitting terminal (degrees)

Φ_R: geomagnetic latitude of the receiving terminal (degrees)

Φ: average geomagnetic latitude of a path under study (degrees)

Note - North and east are considered positive, south and west negative.

2. General procedure

The general procedure for calculation of skywave field strength to evaluate interregional interference is similar to that described in Chapter 2 with the following exception.

The unadjusted skywave field strength F is given by:

$$F = F_c + 20 \log \frac{E_c \, f(\theta) \sqrt{P}}{100} \quad dB(\mu V/m) \qquad (1)$$

F_c is given by:

$$F_c = (95 - 20 \log d) - (6.28 + 4.95 \tan^2 \Phi)(d/1000)^{1/2} \, dB(\mu V/m) \qquad (2)$$

Figure 1 and Table I show F_c for selected latitudes. If $|\Phi|$ is greater than degrees, equation (2) is evaluated for $|\Phi| = 60$ degrees. If d is less than 200 km, quation (2) is evaluated for d = 200 km. However, the actual great-circle distance is o be used in determining elevation angle. See section 4 for calculation of great-circle istance and conversion from geographical latitude to geomagnetic latitude.

ote - Values of F_c are normalized to 100 mV/m at 1 km corresponding to an ffective monopole radiated power (e.m.r.p.) of -9.54 dB(kW).

Skywave field strength, 50% of the time

This is given by:

$$F(50) = F \quad dB(\mu V/m) \qquad (3)$$

4. Path parameters

Refer to section 1. The great-circle distance d (km) is given by:

$$d = 111.18 \text{ arc cos } [\sin a_T \sin a_R + \cos a_T \cos a_R \cos (b_R - b_T)] \quad (4)$$

The geomagnetic latitude of the transmitting terminal, ϕ_T, is given by:

$$\phi_T = \text{arc sin } [\sin a_T \sin 78.5^\circ + \cos a_T \cos 78.5^\circ \cos (69^\circ + b_T)] \quad (5)$$

ϕ_R can be determined in a similar manner. And,

$$\phi = {}^1/_2 \, (\phi_T + \phi_R) \quad (6)$$

Alternatively, Figure 2 may be used.

FOOTNOTES

[1] In an earlier action, the Commission issued a *Notice of Inquiry* addressing issues relating to operation of synchronous transmitters. *See Notice of Inquiry* released March 3, 1987 in MM Docket 87-6, FCC 87-27, 52 FR 8085 (1987). This *Inquiry* is not intended to duplicate the issues addressed in that proceeding.

[2] The Technical Subgroup of the FCC Radio Advisory Committee is also being invited to develop data and recommendations on these issues.

[3] In order to facilitate the analyses of comments and information received in response to the many specific questions raised in this *Inquiry*, commenting parties are requested to identify the paragraph number and associated question to which the comments are directed.

[4] All references to FCC rules in this *Inquiry* are contained in Part 47 of the Code of Federal Regulations bearing the same section number as the FCC rule.

[5] Enom is the field strength that provides satisfactory reception in the presence of atmospheric noise, man-made noise, and interference from other transmitters. Values for Enom are determined administratively by taking into account technical and non-technical factors.

[6] This process began with a "freeze" on the acceptance of AM applications (FCC 62-516; 23 RR 1545, 1962) and the issuance of a *Notice of Proposed Rule Making* in Docket No. 15084 (FCC 63-468). This in turn led to the *Report and Order* 45 FCC 1515; 2 RR 2d 1658 (1964); *recon.* 45 FCC 2092; 4 RR 2d 1567 (1965).

[7] The minimum usable field strength, Emin, is the minimum value of field strength necessary to permit a desired reception quality in the presence of atmospheric and man-made noise. *See* Recommendation 499-2, Volume X - Part 1 of the International Radio Consultative Committee (CCIR).

[8] Minimum usable field strength and radio-frequency protection ratios are in turn related to subjective and technical factors. These are discussed in the following section.

[9] Receiver bandwidth refers to the combined effects of the radio-frequency and audio-frequency bandwidths of the receiver.

[10] There are about 50,000 thunderstorms per annum world wide, producing 100 lightning flashes per second. Each lightning flash yields two discharges. The flash discharge current varies between 10 and 100 kiloamperes (kA). Discharge takes place between 2 and 4 kilometers above ground. The power released is substantially typically greater than 10 gigawatts (gW). Armel Picquenard, "Radio Wave Propagation", Wiley and Sons, New York, 1974.

[11] *See* CCIR Report 322.

[12] During the Clear Channel Hearings, Docket 6741, noise maps were also prepared.

[13] There are four combinations possible with voice and music: voice to voice, music to music, voice to music, and music to voice.

[14] This latter procedure is considered to be more difficult due to the greater number of parameters that must be taken into account.

[15] *See*, CCIR Recommendation 559-1, Volume X, Recommendations and Reports of the CCIR.

[16] As noted in an earlier section of this *Inquiry*, a voluntary standard pertaining to receiver de-emphasis has already been adopted by the NRSC. It is anticipated that receiver manufacturers will begin manufacturing receivers meeting this standard. AM stereophonic receivers are also being manufactured that possess significantly improved performance characteristics.

[17] The field strength of a contour which is limited by interference is often referred to as the usable field strength, Eu.

[18] Among other things, the applicant facility must be the first AM broadcast facility in a community of any size wholly outside of an urbanized area or the first AM broadcast facility in a community of 25,000 or more population wholly or partly within an urbanized area, or where the facilities proposed would provide a first primary service to at least 25 percent of the interference-free area within the proposed 0.5 mV/m contour.

[19] Recently, the Commission denied a waiver request from AM station KCBQ in San Diego, California. After some years of operation under a Special Temporary Authority (STA), KCBQ was unable to adjust its nighttime array in accordance with its authorization. As a result, the station sought to regularize its STA operation, but the Commission rejected the request because of interference to station KVOO, Tulsa, Oklahoma. KCBQ had argued that it should not be forced to reduce power since there had been no interference complaints against its operation. Although the Commission applied its traditional approach in denying the request for waiver, the outcome might well have been different if the two stations could have negotiated a resolution to the interference problem.

[20] In a number of previous instances, we have provided similar flexibility for licensees in other services with positive results. In the satellite and point-to-point microwave services, for example, licensees are permitted to accept varying degrees of interference. It is common for licensees to employ highly directional antennas, or innovative encoding/modulation systems in those instances where congestion is high. Our experience here suggests that if given the opportunity and encouragement, licensees will respond by making effective and efficient use of the spectrum. We would expect a similar outcome in the AM broadcast service.

[21] Any emissions appearing on a frequency removed from the carrier between 15 kHz and 30 kHz, inclusive, and by more than 30 kHz up to 75 kHz must be attenuated at least 25 dB and 35 dB, respectively. Emission limitations also apply to frequencies above 75 kHz.

[22] Harrison J. Klein, P.E., "Modulation, Overmodulation, and Occupied Bandwidth; Recommendations for the AM Broadcast Industry", September 1986.

[23] Figure 2 is used for performing interference calculations on regional channels.

[24] Figure 2 depicts a family of curves ranging from 36 degrees to 50 degrees latitude.

[25] The reference hour used in propagation models developed within the CCIR is midnight, the time when nighttime propagation is greatest.

[26] This high-latitude field strength measurement program is expected to be completed during 1987.

[27] The Expanded Band RARC is a two session conference to plan the use of the expanded AM band, 1605 - 1705 kHz, in Region 2 (the americas). The First Session of the Conference was held in Geneva during April, 1986, to develop the technical standards to be employed in the expanded band as well as the planning methodology. The Second Session will be held in early 1988 to adopt an agreement and associated plan.

[28] *See* "A Skywave Propagation Study in Preparation for the 1605-1705 kHz Broadcasting Conference" by J. Wang, *IEEE Transactions on Broadcasting*, Vol. BC-31, No. 1, pp. 10-17, March 1985. (For a step-by-step procedure, see the Report to the Second Session of the Expanded Band RARC, pp. 80-91). Both of these sources are included in the Appendix to this *Inquiry*.

29 At one time the calculation of service contours using such a procedure was laborious, but the wide-spread availability of computers today facilitates such calculations.

30 The critical hours periods are the two hours after sunrise and the two hours before sunset during which skywave propagation is undergoing transition from nighttime hours to daytime hours. The two periods of critical hours are the daytime hours during which daytime skywave signals are most likely to cause interference to co-channel Class I stations.

31 *See* "A Skywave propagation Study in Preparation for the 1605 - 1705 kHz Broadcasting Conference" by J. Wang, *IEEE Transactions on Broadcasting*, Vol. BC-31, No. 1, pg. 12, March 1985.

32 The RSS is a mathmatical procedure which involves taking the square-root of the sum of the squares of interfering signals. This is often referred to as the Eu for the subject station. The FCC rules require that the normally protected contour, Enom, or the Eu be protected from interference, whichever is greater.

33 This was an important consideration at the time of the rule's adoption when computers were not available to perform interference calculations.

34 Such data was developed by the technical subgroup of the Radio Advisory Committee for the Region 2 Administrative Radio Conference, Rio de Janeiro, 1981. However, it has not been formally adopted for domestic applications.

35 R. M. Bevansee, G. J. Burke and R. J. King, "Relative Communication Effectiveness (RCE) of Antennas for Groundwave Generation", paper prepared for the Radio Science Journal reporting research at Lawrence Livermore National Laboratory, Livermore, CA, July 1986.

36 N. Deminco, "Ground-wave Analysis Model for MF Broadcast Systems", NTIA Report 86-203 (work sponsored by the Voice of America), September 1986. N. Deminco, "Automated Performance Analysis Model for Ground-wave Communications Systems", NTIA Report 96-209 (work sponsored by the U.S. Army), December 1986.

37 R. P. Eckert, "Modern Methods for Calculating Ground-wave Field Strength over a Smooth Spherical Earth", Report FCC/OET R86-1, February 1986.

38 J. H. McMahon, "Investigation of Methods for Converting the FCC Ground Wave Field Intensity Curves to the Metric System," FCC/OCE Report RS79-01, January 1979.

39 H. Bremmer, "Terrestrial Radio Waves," Elsevier Publishing Co., 1949.

40 FCC MM Docket No. 84.752, *Report and Order* "In the Matter of Changes in AM Technical Rules to Reflect New International Agreements," published in the *Federal Register* May 2, 1985 (50 FR 18818). The computer program used for calculating these curves was subsequently released to the public for use in lieu of drawn curves for calculating groundwave field strength.

41 G. Millington, "Ground Wave Propagation over an Inhomogeneous Smooth Earth," *Proc. of the Institution of Electrical Engineers* (London), Part III, Vol. 96, pp. 53-64, January 1949; H. L. Kirke, "Calculation of Ground-wave Field Strength over a Composite Land and Sea path," *Proceedings of the IRE*, Vol. 37, May 1949, pp. 489-496; J. R. Wait, "Recent Analytical Investigations of Electromagnetic Ground Wave Propagation over Inhomogeneous Earth Models, *Proceedings of the IEEE*, Vol. 62, pp. 1061-1072, August 1974.

42 J. R. Wait, and W. C. G. Fraser, "Radiation from a Vertical Dipole over a Stratified Ground (Part II)," *IRE Transactions on Antennas and Propagation*, Vol. AP-3, pp. 144-146, Oct. 1954.

43 R. H. Ott, L. E. Volger, and G. A. Hufford, "Ground Wave Propagation over Irregular, Inhomogeneous Terrain: Comparisons of Calculations and Measurements," NTIA Report 79-20, U.S. Department of Commerce. Copies obtainable from the National Technical Information Service, Springfield, VA (accession No. PB-298-668).

44 S. Rotheram, "Ground-wave Propagation. Part I - Theory for Short Distances; Part II - Theory for Medium and Long Distances and Reference Propagation Curves", *Proc. of the Institution of Electrical Engineers*, Part F, Vol. 128, October 1981.

45 Ray J. King and James R. Wait, in "Electromagnetic Groundwave Propagation Theory and Experiment", Volume XVIII of the Symposia Mathematica published by the Istituto Nationale di Alta Mathematica, Bologna, 1976, state the following, "Millington was the first to explain the now familiar recovery effect for propagation over a boundary separating two media using a semi-empirical graphical technique and reciprocity arguments. An impressive set of confirming experiments over a wide range of frequencies immediately followed as well as theoretical confirmation. This effect has also been measured on a number of occasions using microwave frequency models.

46 On December 15, 1980, the FCC released a *Notice of Inquiry* in BC Docket No. 80-757, In the Matter of Amendment of the Rules concerning Automation of the use of Measurement Data for AM Broadcast Stations. This proceeding which has not yet been closed, solicited comments concerning development of a data base containing, in some form, all outstanding measurement data to be considered in allocation studies. Included in the considerations was development of a digitized conductivity map based on the measurement data.

47 S. A. Arcone and A. J. Delaney, "Electrical Ground Impedance Measurements in the U.S. between 200 and 415 kHz", Report No. FAA-RD-78-103, 1978.

48 CCIR, "Electrical Characteristics of the Surface of the Earth", Recommendations and Reports of the CCIR, Recommendation 527-1, Dubrovnik, 1986.

49 The "method of moments" is a mathematical procedure wherein the radiation from the component parts of a broadcast tower are individuallycalculated. The results of these incremental calculations are integrated to provide the resultant radiation characteristics of the tower.

50 Harry R. Anderson and David J. Ponion, "Short Range Skywave Field Strengths from Tall AM Broadcast Towers", *IEEE Trans. Broadcast*, Vol. BC-32, No. 3, September 1986.

51 *See*, e.g., "An Economical Directional Antenna for AM Stations", 1987 NAB Engineering Conference Proceedings, by Grant W. Bingeman.