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

MM Docket No. 88-508

In the Matter of

Improved Methods for Calculating
Skywave Field Strength in the
AM Broadcast Band

REPORT AND ORDER
(Proceeding Terminated)

Adopted: April 12, 1990; Released: July 18, 1990

By the Commission:

INTRODUCTION

1. On October 13, 1988, the Commission adopted a *Notice of Proposed Rule Making* (" *Notice* ") in this proceeding, 3 FCC Rcd 6431 (1988), which proposed to adopt a new method of computing skywave signal strength in the AM Broadcast Service. This new skywave model would replace three sets of propagation curves (Figures 1a, 1b and 2 in §73.190) with more accurate equations that take into account the effects of the geomagnetic latitude of the propagation paths. The new model also proposed to use "slant distance" in lieu of the traditional "great circle distance" in making calculations. We also proposed that the new model be based on propagation conditions measured six hours after sunset ("SS+6") rather than two hours after sunset ("SS+2"). Lastly, because the new model yields results for 50% skywave field strength used in determining service contours, we proposed a geomagnetic latitude-based conversion factor for the 10% skywave signals used in predicting interference. With very few exceptions, the comments and reply comments filed in response to the *Notice* strongly supported the new skywave model and its underlying assumptions.[1] We now adopt the model essentially as proposed.

BACKGROUND

2. This proceeding is one of several AM improvement proceedings initiated in response to the MM Docket No. 87-267 *Notice of Inquiry* (" *Inquiry* "), 2 FCC Rcd 5014 (1987), which undertook a comprehensive review of AM broadcast assignment criteria and other technical standards. The *Inquiry* was begun in response to comments filed on the 1986 Mass Media Bureau Report on the Status of the AM Broadcast Rules (RM-5532), which discussed a number of AM broadcast technical, legal and policy issues. Extensive participation in that *Inquiry* and in the Region 2 Administrative Radio Conference by AM broadcasters, their consulting engineers and industry representatives has produced a general consensus about many of the new technical approaches needed for AM improvement, including the so-called "modified method" of calculating skywave field strength that, with minor revisions, is the heart of this proceeding.

3. Two of the skywave propagation curves set forth in the rules were empirically derived from observations of AM band propagation phenomena completed in 1935 (for Figure 1a) and 1944 (for figure 2). However, the Commission has continued to observe AM propagation phenomena in the ensuing decades and has been able to use its experience to develop a more accurate skywave signal prediction model. For example, we have learned that skywave signal strengths are more consistent when observed six hours after sunset rather than two. Also, skywave signal strength is reduced as the geomagnetic latitude of the signal path moves north. We have also learned that using the slant distance for a propagation path, rather than the great-circle path distance results in greater accuracy, particularly when the reception point is close to the transmitter. In short, years of additional observations and measurements have revealed deficiencies in the traditional skywave propagation curves that can no longer be tolerated if AM interference is to be reduced significantly as part of our AM improvement effort.

4. Thus, the *Notice* proposed a new skywave model based on the "modified method." Its use will serve the public interest because it is more accurate than the current propagation curves and because it is easily implemented on computers. Thus, its use will avoid disputes that may arise as a result of graphical interpretation of curve data. The enthusiastic support for the new model that was expressed in the comments and reply comments derives from the fact that the "modified method" has been given careful and widespread engineering scrutiny.

DISCUSSION

General comments on the new skywave model

5. General support for the new model was unanimous. Some commenters did, however, express concerns about unintended or potentially harmful effects that could result from its adoption.

6. For example, several commenters noted that the new model would depict smaller service areas than are now predicted for clear-channel stations in northern latitudes. 3-D Communications Corporation argued that because of the protection afforded to non-existent Class I station skywave service (i.e., the service area predicted to exist using the current propagation curves minus the service area calculated with the new model), Class II stations operating on clear channel frequencies are being deprived of the ability to serve their immediate areas during the heaviest nighttime listening period. The comments of Class II Station WJAG reflect a similar opinion. E. Harold Munn, Jr. & Associates, Inc. and R. Morgan Burrow, Jr. (both professional consulting engineers) indicate that there is no justification for protecting "fictional" (Munn) or "lost area" (Burrow) domestic service when it is actually receiving interference from foreign stations.

7. These opinions are countered by comments of Class I (clear channel) licensees, who argue that current skywave service areas, even if providing weaker signals than was formerly believed, should be protected. The Clear Channel Broadcasting Service ("CCBS") argues that clear channel stations provide the only nighttime service to over one-half the land area of the United States and offer

uch needed diversity within the AM band in those areas ıich have only one or two interference-free groundwave rvices at night. Thus, the CCBS concludes that during e night, clear channel stations anchor the AM band by aking available a service unique to AM. The Jefferson lot Broadcasting Co. urges the Commission not to im- ir nighttime skywave service for modest gains in oundwave service.

8. In another vein, the National Association of Broadsters ("NAB") and the CCBS request that the Commis- ɔn adopt a "safety factor" to insure that no new terference result from use of the new skywave propaga- ɔn model. How this "safety factor" should be deter- ined is left up to the Commission. However, NAB dicates that the safety factor should guarantee that inter- rence does not occur where it is predicted not to occur, ıd that if there is any statistical error in deriving an npirical formula from raw field strength measurements, e effects of any variances should occur below the reshold of signals causing interference. NAB adds that ıch a "safety factor" is appropriate in view the standards good engineering practice.

9. Concern about the protection afforded skywave ser- ce of Class I stations is outside the scope of this proceed- g. The new model will show that the service area of a ɔrthern Class I station may not be as large as formerly ıought. It will also show that the interfering contour of a ıuthern cochannel station may extend farther than pre- ously thought. Thus, as a general rule, licensees of ıuthern Class II stations operating on clear channels ıould not expect use of the new model to permit them obtain significant increases in their facilities. Converse- , the predicted interfering contour of a northern Class II ation may extend less than previously calculated. The ɛlationship between the service and interfering contours f any two cochannel stations will be latitude and path ɛpendent. Therefore, we can make no generalizations ɔout facility increases that may be made possible by use f the new skywave model.

10. Moreover, the new skywave model is only one ɔmponent used in depicting AM service. In MM Docket o. 88-511, 3 FCC Rcd 6448 (1988), the Commission had nder consideration new methods for calculating night- me protection for stations in the AM service. That dock- will shortly be terminated without action under uthority delegated to the Chief, Mass Media Bureau. lowever, we will continue to consider this question in IM Docket No. 87-267. *See Notice of Proposed Rule faking* adopted April 12, 1990. Predicted skywave signal rength is only one of several important factors used in etermining the permissibility of proposed facilities. Ana- ysis of its possible effects should also take into account ther pending changes in the AM technical standards.

11. We are adopting the new skywave model because it the most accurate and convenient method of predicting kywave signal strength ever developed. It simply reflects ur best estimate of signal strength and coverage. There- ɔre, we do not agree with the suggestion of NAB and CBS that it should be modified by some subjectively pplied "safety factor." If after considering the net effect f all the technical changes adopted in the AM improve- ıent proceedings we find that the service of Class I tations will be adversely affected, we can determine on a ɔlicy (rather than an engineering) basis whether the rotected contour for those stations should be changed. ut this issue is outside the scope of this proceeding.

12. The majority of commenters agree with our conclusions. Almost all of the commenters, while favoring ultimate use of the new skywave model, opposed its use unless it were part of a comprehensive AM improvement package. The Association for Broadcast and Engineering Standards ("ABES") argued that the implementation of the new model *not* be deferred so that the benefit of the higher degree of predictive accuracy would not be postponed. Karl D. Lahm and Associates ("Lahm") suggested that the new model be implemented in concert with the changes in RSS interference computation under consideration in MM Docket No. 88-511. However, Lahm indicated that it should not be implemented earlier than six months after its adoption in order to give consulting firms time to develop appropriate computer programs.

13. We agree with Lahm and the majority of commenters that implementation of the new model must be deferred at least until the matters at issue in MM Dockets No. 88-511 and 87-267 are resolved. Notwithstanding the merits of the new skywave model, we would not want a few licensees in potentially unique circumstances to be able to take advantage of short-term "loopholes" resulting from the implementation of new technical standards on a piecemeal basis. Such facility proposals, while permissible in the short-term, could require "grandfathering" in the long-term. We believe that implementing the skywave model at this time would only add to our application processing burden while potentially undermining our efforts to improve the AM service. Therefore, we will defer implementation of the new model until other related AM improvement matters have been resolved. At the same time, by adopting the new skywave model in principle at this time, we provide a technical basis for implementation and related technical proposals in the other AM improvement proceedings.

14. Several commenters noted some typographical errors and potential inconsistencies in the new skywave model as it was depicted in Appendix B of the *Notice*. For example, the term (2 Pi + 4.95 $\tan^2$ $Theta_M$) in Equation 1 in Appendix B of the *Notice* should have read (2 Pi + 4.95 $\tan^2$ Phi_M). This was corrected on November 15, 1988, by memorandum included in the docket file. H. R. Anderson and Associates, Inc. ("Anderson") believes the expression [cos $(69+b_M)$] in Equation 3 should be corrected to read [cos $(69-b_M)$].[2]

15. Anderson also questions the constant, 111.18, in Equation 4, arguing that the Handbook of Mathematical Functions by Abramowitz and Stegun (December, 1972) indicates that it should be 111.136. Anderson also notes that using a constant E layer of 100 km is inconsistent with departure angle formulas currently contained in §73.190, Figure 6a, and argues that either a single departure angle should be used for all situations (Anderson's preferred approach) or else the departure angle formula (2) in Appendix B must be corrected. Lahm expresses a similar concern, noting that a single angle is used in analyzing the impact of proposed Canadian and Mexican facilities. Lastly, du Treil, Lundin and Rackley, Inc. suggests that the results of all calculations made using the new skywave formulas be expressed to no more than three significant places so as to recognize natural limitations inherent in the technical data.

16. We appreciate the obviously close scrutiny given the proposed skywave model by the commenters and we concur with the recommendations summarized above. However, as Anderson notes elsewhere in its comments, the

onstant 111.18 in Equation 4 is referenced in the 1986 U.S.-Mexican AM Agreement. We note, too, the inconsistency of the new model (which is based on a fixed E-layer height of 100 km and thus by implication a fixed departure angle) with §73.190, Figure 6a (which depicts a range of departure angles based on different E-layer heights). Other commenters noted some of these problems and questioned how the new skywave model would be applied to certain "grandfathered" facilities.

17. The purpose of the *Notice* in this proceeding was simply to obtain general approval for future use of the new skywave model. Thus, Appendix B merely defined the new model without addressing how it would be applied to or used in conjunction with other relevant AM technical standards. Discussion of any minor adjustments to the model proposed in the *Notice* required to make it conform to international treaties and other matters pertaining to its implementation is premature. The action we are taking here is limited to adopting the model on a conceptual basis. We will resolve matters related to the timing and manner of its implementation in the *Notice of Proposed Rule Making* in MM Docket No. 87-267 which is also being adopted on this date. That *Notice* will include a detailed appendix presenting all of the interrelated AM improvement proposals in their proper context for review and comment.

Use of Slant Distance

18. The *Notice* proposed substituting slant distance for the traditional great circle distance in making skywave calculations. Whereas great circle distance is the length of an arc (the curvature of which is based on the earth's radius) between two points on the earth's surface, slant distance includes an additional element which takes into consideration the additional distance required for a signal to reflect off the E-layer while travelling along the arc. For long distances, slant distance and great circle distance converge, but for very short distances they can be very different. Thus, the *Notice* pointed out that the accuracy of calculations would be improved in cases for which the slant distance is large in relation to the great circle distance. It also noted that the Consultative Committee on International Radio ("CCIR") Recommendation 435 recommended the use of slant distance for all propagation paths.

19. All of the parties filing comments addressing this issue agreed that generally substitution of slant distance for great circle distance would improve the accuracy of the calculations. Thus, "slant distance" will be used in conjunction with the implementation of the new skywave propagation model for determining the skywave service of and interference to domestic AM facilities. Predicted interference to and from foreign AM facilities will continue to be determined consistent with applicable treaties until such time as those treaties may be revised.

Reference Hour

20. The skywave model described in Appendix B of the *Notice* was based on skywave propagation data measured roughly six hours after sunset ("SS+6"). These data were considered more appropriate than SS+2 data because phenomena affecting nighttime skywave signal propagation have become stable by that time and skywave propagation conditions are most favorable. Thus, calculation of skywave interference using SS+6 data will produce a worst case result, which is consistent with the use of a conservative interference prediction model. The Commission believes that use of such a model is essential if real reductions in AM skywave interference are to be achieved.

21. Most of the comments filed relating to reference hour supported the use of SS+6. All but one of the rest favored continued use of SS+2 (the current skywave propagation curves are based on SS+2 measurements). However, Robert A. Jones, P.E. ("Jones") suggested that SS+4 data might be a better choice, particularly in the case of the expanded band. Greater Media expressed the belief that SS+6 data would yield a more stable and uniform reference, freer of frequency effects and less sensitive to path direction. However, it noted SS+6 approximates the "graveyard shift" rather than the period of maximum evening radio listening. Greater Media concluded that some stations would be afforded more protection than was necessary using SS+6 but that this was preferable to increased interference levels. The Continental Broadcasting Company agreed that SS+6 better represented the "worst case" for interference calculations. Lahm noted that use of SS+6 would result in better protection of full-time stations' service areas and enhanced prediction of the skywave service of Class I stations. The Hearst Corporation observed that SS+2 appears to be outmoded, having as its genesis old-time family listening habits of 40 years ago.

22. However, the 3-D Communications Corporation ("3-D"), licensee of a Class II station, and Bonneville International Corporation ("Bonneville") expressed the view that SS+2 should be retained as the reference hour. 3-D opposed use of SS+6 because it maximizes protection to the service of Class I stations, according greater importance to Class I skywave service than to Class II station groundwave service. Use of SS+2 would reduce the predicted service areas of Class I stations and afford greater opportunity for Class II stations to increase their facilities. Thus, 3-D argues that at the least, the Commission should adopt a two step procedure whereby a Class II station would protect a Class I station's SS+2 contour until SS+6. It could then reduce power to protect the SS+6 contour. Bonneville argues that SS+2 is more appropriate because all stations' listenership is higher at that time, and because it believes SS+6 is meaningless as a reference point without identifying the season and latitude (*e.g.*, SS+6 in Alaska would be post-sunrise in the summertime).

23. 3-D's support of SS+2 clearly reflects a belief that Class I stations should no longer be protected as extensively as they have been. The protection afforded Class I skywave service is, however, a policy decision that is essentially unrelated to the technical merits of the new skywave propagation model. [3] Therefore, we do not wish to deal with it in this proceeding. It may be true, as Bonneville observes, that listenership levels peak at SS+2. A significant reduction in interference levels in the AM service could lead to increased listenership later in the evening. Because use of SS+2 would result in greater interference levels most of the night, we believe its use would be inconsistent with our desire to improve the quality of AM service. Because SS+6 measurements were obtained during winter months when the night at northern latitudes was very protracted, we find irrelevant the fact that SS+6 is latitude and season dependent. Winter data yield greater skywave coverage areas and concomitantly higher interference levels. Thus, their use reflects a

more conservative approach and would more effectively reduce overall interference levels. Because we believe that every possible means of reducing interference levels in the AM service should be pursued, we believe the public interest would best be served by use of the SS+6 measurement data. Therefore, we decline to modify the model to use SS+2 data instead of SS+6 measurement data.

Conversion factor for 10% skywave field strength

24. The *Notice* also proposed a formula (number eight in Appendix B) for calculating 10% skywave interference levels based upon the new model, noting that the correction factor varies from approximately 6 dB in southern latitudes to roughly 10 dB in northern latitudes.[4] However, the *Notice* described two possible alternatives to this approach. The first would simply be to use the average correction factor (8 dB) nationwide. The other would be to establish three zones based on latitude with different correction factors.

25. The majority of the comments favored using the formula proposed in the *Notice* although many commenters did not give a reason. However, Jones argued that the formula could be safely eliminated, because a standard conversion factor would overprotect all stations and use of an 8 dB correction factor would make the Commission's Rules consistent with those adopted at the 1981 Region 2 Conference. Bonneville likewise expressed the belief that use of an 8 dB correction factor was an acceptable compromise. However, Greater Media supported use of the formula, arguing that only by calculation can the best possible accuracy be obtained and noting that such calculations are readily and inexpensively performed using computers.

26. We disagree with Jones' opinion that a uniform 8 dB value would overprotect all stations. In fact, we find that it would tend to overprotect stations in southern latitudes and underprotect stations in northern latitudes. Thus, we continue to believe that because experience has provided us with the information needed to develop a highly accurate skywave signal strength prediction model, all components (such as the 10% skywave correction factor) of the model should be as accurate as possible. We agree with Greater Media that the effort required to implement the 10% skywave correction formula on computers is negligible and the calculation time minimal. Therefore, we are adopting the 10% skywave correction factor as proposed.

CONCLUSION

27. We conclude that no amendment of the skywave propagation model set forth in Appendix B of the *Notice* is necessary. Therefore, we adopt that model exactly as proposed. However, consistent with the discussion in paragraphs 12 and 13, *supra*, we will not incorporate the model into the rules at this time. Instead, in the MM Docket No. 87-267 AM improvement proceeding, we propose rules that will implement the new skywave model in conjunction with other related changes in the AM technical standards. Thus, interested parties have an opportunity to comment on the final effect of all of our recent AM improvement actions, including any minor refinements of the skywave model that may be necessary to conform it to domestic policy and international agreements. We also find that the purpose of this proceeding has been fulfilled and therefore conclude that it should be terminated.

FINAL REGULATORY FLEXIBILITY ANALYSIS

28. Pursuant to the Regulatory Flexibility Act of 1980, the Commission's final analysis is as follows:

I. Need and Purpose of this Action:

The Commission is replacing the AM skywave propagation curves with a new model based on a data developed over many decades which offer extensive information on skywave propagation characteristics. Use of the new skywave model will enable the Commission to more accurately predict skywave coverage and interference, and will provide us with an important means of potentially improving the quality of the AM service.

II. Summary of Issues Raised by the Public Comments in Response to the Initial Regulatory Flexibility Analysis :

No commenters addressed the Initial Regulatory Flexibility Analysis.

III. Significant Alternatives Considered and Rejected:

There are no alternatives to the action taken here that would accomplish the stated purpose.

29. The Secretary shall send a copy of this *Report and Order*, including the Final Regulatory Flexibility Analysis, to the Chief Counsel for Advocacy of the Small Business Administration in accordance with paragraph 603(a) of the Regulatory Flexibility Act (Pub. L. No. 96-354, 94 Stat. 1164, 5 U.S.C. Section 601 *et seq.*, (1981)).

PAPERWORK REDUCTION ACT STATEMENT

30. While a new skywave propagation model is being adopted in this action, its effective date is being deferred. Therefore, no rule changes are being implemented at this time, so no new or modified form, information collection, and/or record keeping, labeling, disclosure, or record retention requirements subject to the Paperwork Reduction Act of 1980 will result at this time. Neither will the burden hours placed upon the public be increased or decreased. We believe that implementation of the new skywave model will have little, if any impact on the Paperwork Reduction Act concerns listed above, except that the burden hours placed upon the public may be decreased through automation of skywave signal calculations on inexpensive and widely available computers.

ORDERING CLAUSES

31. Accordingly, IT IS ORDERED That pursuant to the authority contained in Sections 4(i) and 303(r) of the Communications Act of 1934, as amended, the skywave signal strength prediction model described by the formulas contained in Appendix A below IS ADOPTED. However, its implementation will be deferred pending action on related AM improvement proceedings.

32. IT IS FURTHER ORDERED that this proceeding IS TERMINATED.

FEDERAL COMMUNICATIONS COMMISSION

Donna R. Searcy
Secretary

APPENDIX A

Comments

3-D Communications Corporation
Association for Broadcast Engineering Standards, Inc.
Bonneville International Corporation
CBS, Inc.
Capital Cities/ABC, Inc.
Clear Channel Broadcasting Service
Continental Broadcasting
Cox Enterprises, Inc.
du Treil, Lundin & Rackley, Inc.
E. Harold Munn Jr., & Associates, Inc.
Empire Radio Partners, Ltd.
Greater Media, Inc.
H & C Communications, Inc.
H. R. Anderson & Associates, Inc.
Hearst Corporation
Karl D. Lahm & Associates
National Association of Broadcasters
Outlet Broadcasting, Inc.
Robert A. Jones, P.E.
Timothy C. Cutforth, P.E.

Reply Comments

Clear Channel Broadcasting Service
Eric Chandler Communications of San Diego, Inc.
Ex Parte Comments filed by R. Morgan Burrow, Jr., P.E.
Fisher Broadcasting, Inc.
Jefferson Pilot Broadcasting Company
Nolte Communications, Inc.

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APPENDIX B – CALCULATION OF SKYWAVE FIELD STRENGTH

The following formulas are to be used in place of the curves in Section 73.190 of the FCC Rules. The methods used to determine other factors such as radiation value, elevation angle, and f(θ) are unchanged and can be determined by referring to the appropriate section of the FCC Rules.

1. Skywave field strength, 50% of the time (at SS+6):

The skywave field strength, $F_e(50)$, for a characteristic field strength of 100 mV/m at 1 km is given by:

$$F_e(50) = (97.5 - 20\log D) - (2\pi + 4.95\tan^2\phi_M)\sqrt{(D/1000)} \ \text{dB}(\mu\text{V/m}) \quad (1)$$

The slant distance, D, is given by:

$$D = \sqrt{40{,}000 + d^2} \ \text{km} \quad (2)$$

The geomagnetic latitude of the midpoint of the path, ϕ_M, is given by:

$$\phi_M = \arcsin[\sin a_M \sin 78.5^\circ + \cos a_M \cos 78.5^\circ \cos(69 + b_M)] \ \text{degrees} \quad (3)$$

The short great-circle path distance, d, is given by:

$$d = 111.18 d^\circ \ \text{km} \quad (4)$$

Where:

$$d^\circ = \arccos[\sin a_T \sin a_R + \cos a_T \cos a_R \cos(b_R - b_T)] \ \text{degrees} \quad (5)$$

Where:
a_T is the geographic latitude of the transmitting terminal (degrees)
a_R is the geographic latitude of the receiving terminal (degrees)
b_T is the geographic longitude of the transmitting terminal (degrees)
b_R is the geographic longitude of the receiving terminal (degrees)
a_M is the geographic latitude of the midpoint of the great-circle path and is given by:

$$a_M = 90 - \arccos\left[\sin a_R \cos\left(\frac{d^\circ}{2}\right) + \cos a_R \sin\left(\frac{d^\circ}{2}\right)\left\{\frac{\sin a_T - \sin a_R \cos d^\circ}{\cos a_R \sin d^\circ}\right\}\right] \ \text{degrees} \quad (6)$$

b_M is the geographic longitude of the midpoint of the great-circle path and is given by:

$$b_M = b_R + k\left[\arccos\left(\frac{\cos\left(\frac{d^\circ}{2}\right) - \sin a_R \sin a_M}{\cos a_R \cos a_M}\right)\right] \ \text{degrees} \quad (7)$$

Note(1): If $|\phi_M|$ is greater than 60 degrees, equation (1) is evaluated for $|\phi_M| = 60$ degrees.
Note(2): North and east are considered positive; south and west negative.
Note(3): In equation (7), $k = -1$ if $b_R > b_T$, otherwise $k = 1$.

2. Skywave field strength, 10% of the time (at SS+6):

The skywave field strength, $F_e(10)$, is given by:

$$F_e(10) = F_e(50) + \Delta \ \text{dB}(\mu\text{V/m}) \quad (8)$$

Where:
$\Delta = 6$ when $|\phi_M| < 40$
$\Delta = 0.2|\phi_M| - 2$ when $40 \leq |\phi_M| \leq 60$
$\Delta = 10$ when $|\phi_M| > 60$

For the complete text of this revised CFR Section, See the Notice of Proposed Rule Making in MM Docket No. 87-267, FCC 90-136 at 55 FR

FOOTNOTES

[1] A list of parties filing comments and reply comments is given in Appendix A. A skywave signal is that portion of a station's transmitted signal that is reflected by the ionosphere back to the earth. The strength of the reflected signal is generally negligible during the day and increases gradually after sunset.

[2] However, we have verified that Equation 3 as depicted in Appendix B is correct. The negative term sought by Anderson would appear to follow from the convention indicated in Note 2, which states that western longitudes should be considered negative.

[3] *See* ¶¶ 10-12, *supra*.

[4] The correction factor is used to derive the 10% skywave interfering signal strength (or contour) from the 50% skywave service signal strength (or contour). The Commission traditionally uses 50% reliability signals or contours to define service and 10% reliability signals or contours to define interference.