Regional Administrative MF

Broadcasting Conference (Region 2)

First Session, Buenos Aires, 1980

REPORT TO THE SECOND SESSION OF THE CONFERENCE

(See Resolution B)

General Secretariat
of the
International
Telecommunication Union
Geneva, 1980

Corrigendum No. 1-E
4 September 1980

Original : French/
English

Canada

Regional Administrative MF Broadcasting Conference (Region 2)

First Session, Buenos Aires, 1980

REPORT TO THE SECOND SESSION OF THE CONFERENCE

As agreed at the First Session of the Regional Administrative MF Broadcasting Conference, the Canadian Administration has revised Annex A* to the Report for the Second Session of the Conference to bring it into line with the use of the sky-wave curve 50 % of the time for interference calculations.

The attached texts and the new Figure 4 are the result of this revision.

Annex : 4 pages

* Annex B to the Report submitted to the Conference.

ANNEX A

PLANNING METHOD

1. On pages 52, 53 and 54, replace points 6.1 to 6.6 by the new texts given below.

2. On page 65, replace Figure 4 by the new figure attached.

6.1 Below we give an example of the method described in this annex. The map in Figure 3 (page 64) shows the stations to be protected by a proposed station to serve the City P on frequency 1000 kHz. Azimuths are referred to true North.

Also on 1000 kHz are :

- Station 1 at 3,000 km, azimuth 30°, Class A
- Station 2 at 1,000 km, azimuth 170°, Class B
- Station 3 at 1,500 km, azimuth 120°, Class C
- Station 4 at 400 km, azimuth 350°, Class B, day only

On 990 kHz are :

- Station 5 at 300 km, azimuth 60°, Class C
- Station 6 at 500 km, azimuth 270°, Class B

On 1010 kHz is :

- Station 7 at 600 km, azimuth 300°, Class A

On 980 kHz is :

- Station 8 at 205 km, azimuth 110°, Class B

6.2 These stations produce the following limitations on the proposed station. The calculations pertain to noise zone 1, but the method is applicable to the other zones with appropriate corrections.

Station 1 - The simplified method for calculating skywave interference to Class A stations described in paragraph 6.8 is used. At station 1, the contribution from station 2 is 165 μV/m and from station 3 is 56 μV/m. The latter is eliminated by the 50 % exclusion rule. Two protection points are then established between 1 and P (called 1.P) and between 1 and 2 (called 1.2).

At 1.2 the contribution from station 2 is 392 μV/m, thus the permissible contribution is $\sqrt{500^2 - 392^2} = 310$ μV/m.

At 1.P the contribution from station 2 is 377 μV/m, thus the permissible contribution is $\sqrt{500^2 - 377^2} = 328$ μV/m.

The permissible radiation towards 1.2 (37.5°) is $460 \times \frac{310}{500} = 285$ mV/m.

The permissible radiation towards 1.P (30°) is $444 \times \frac{328}{500} = 291$ mV/m.

Station 2 - At 170° azimuth and 9.3° vertical angle, from Curve 3 of Figure 1 : 452 mV/m

Station 3 - At 120° azimuth and 4.0° vertical angle, from Curve 4 of Figure 1 : 1870 mV/m

These three stations are too far away to limit daytime radiation.

Station 4 - Assuming typical class B station (see section 7) the radiation is $307 \times \sqrt{10} = 971$ mV/m at 1 km. From the 15 mS/m curve of Figure 2 the protected contour lies at a distance from station 4 of 180 km. Thus the distance to the protected contour from the proposed station is : 400 - 180 = 220 km from the 15 mS/m curve and the multiplying factor table the permissible radiation at 350° is : 1530 x 0.05 = 76.5 mV/m.

Station 5 - Assuming a typical Class C station (see section 7) the radiation is $307 \times \sqrt{0.5} = 217$ mV/m at 1 km. Thus, from the 15 mS/m curve, the protected contour lies at a distance from station 5 of 96 km. The distance to the protected contour from the proposed station is : 300 - 96 = 204 km. The permissible radiation at 60° is : 1300 mV/m.

Station 6 - As for station 4, the radiation is 971 mV/m at 1 km. From the 5 mS/m curve, the protected contour lies at a distance from station 6 of 100 km. From the 15 mS/m curve, the distance to the protected contour from the proposed station is ; 500 - 100 = 400 km. The permissible radiation at 270° is ; 11500 mV/m. These values are too large to be of significance.

Station 7 - Assuming a typical Class A station (see section 7) the radiation is $385 \times \sqrt{50} = 2722$ mV/m. From the 5 mS/m curve the protected contour lies at a distance from station 7 of : 150 km. The distance to the protected contour from the proposed station is : 600 - 150 = 450 km. As for station 6, the permissible radiation is too large to cause a restriction.

Station 8 - As for station 4, the protected contour lies at a distance from Station 8 of : 180 km. The distance to the protected contour from the proposed station is : 205 - 180 = 25 km. The permissible radiation at 110° is : 19.6 x 30 = 588 mV/m.

6.3 In view of these limitations, it is apparent that, unless a power level of less than 100 watts is suitable for daytime service needs, a directional antenna system is required. Hence it would be practical to determine the arcs of protection. The simplified method is to take the arc-sine of the distance to the protected contour divided by the station-to-station distance.

For station 1, the arc of protection has already been established as 30° to 37.5° using the Appendix to Chapter 6.

For station 2 the arc-sine is : 50/1000 = 3°.

For station 3 no refinement needed.

For station 4 the arc-sine is : 180/400 = 26.7°.

6.4 At the extremities of this arc, the protected contour is at : 357 km and the permissible radiation is : 7800 x .05 = 390 mV/m.

Station 5 - no refinement needed.

For station 8, the arc-sine is : 180/205 = 61.4°.

At the extremities of this arc, the distance is : 98 km and the permissible radiation is : 230 x 30 = 6900 mV/m.

At 30° from the station-to-station azimuth, the distance is : 30 km and the permissible radiation is : 25.5 x 30 = 765 mV/m.

6.5 Station design

The pattern limitations require a wide null to the north and a narrow null to the south, with modest restrictions at 110° and 250° if a station power of 5 kW or greater is required. The minimum radiation requirements for service should be added to Figure 4 and a pattern determined to meet these and the protection requirements. For maximum service, a daytime pattern which need not consider protections to stations 1, 2 and 3 and a night-time pattern which need not protect station 4 could be designed. As shown below a 50 kilowatt station with maximum daytime service over a wide arc to the south and maximum night-time service over a fairly wide arc to the north-west using six vertical radiators is feasible.

6.6 Pattern design

The permissible radiation is tightly limited over relatively wide arcs in the northerly and north easterly directions for day and night services respectively. Other limitations are not as restrictive but must be considered if powers over 1 kW are contemplated.

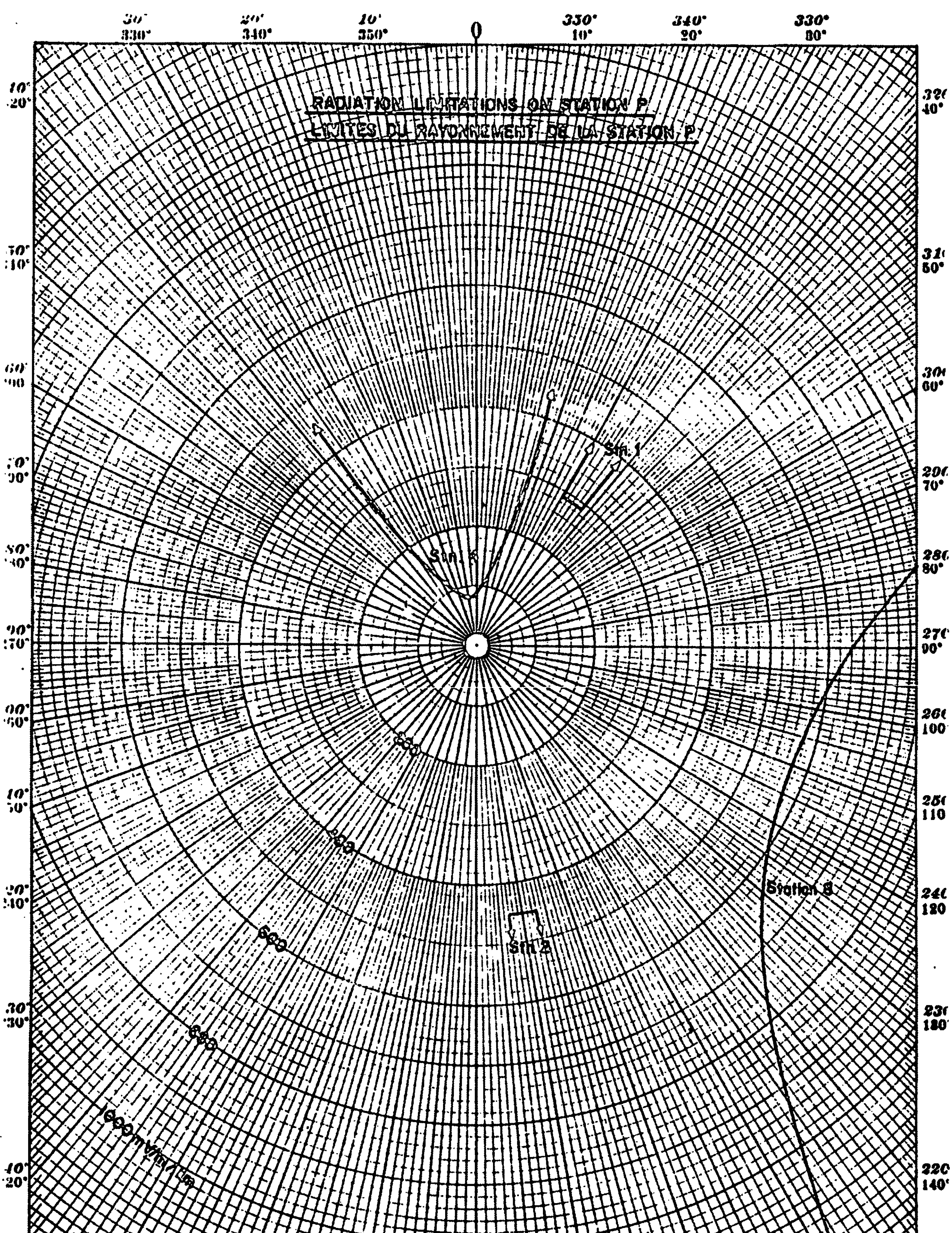
RADIATION LIMITATIONS ON STATION P
LIMITES DU RAYONNEMENT DE LA STATION P
Stn 1
Stn K
Stn 2
Station B
1000mV/m/1km

FIGURE 4

Regional Administrative MF
Broadcasting Conference (Region 2)
First Session, Buenos Aires, 1980

REPORT TO THE SECOND SESSION OF THE CONFERENCE

(See Resolution B)

General Secretariat
of the
International
Telecommunication Union
Geneva, 1980

FIRST SESSION OF THE
REGIONAL ADMINISTRATIVE MF
BROADCASTING CONFERENCE (REGION 2),
BUENOS AIRES, 1980

Buenos Aires, 28 March 1980

The Chairman of the Second
Session of the Regional
Administrative MF
Broadcasting Conference

Dear Sir,

In accordance with the provisions of Resolution B adopted at the First Session of the Regional Administrative MF Broadcasting Conference (Buenos Aires, 1980), I enclose the Report on the First Session for transmission to the Second Session of the Conference.

R. J. P. SEVERINI

Chairman of the First Session

Annex referred to

TABLE OF CONTENTS

* Not published in the present Report

CHAPTER 1

DEFINITIONS AND SYMBOLS

1. DEFINITIONS

In addition to the definitions given in the Radio Regulations, the following apply to the Plan for Region 2.

1.1 Broadcasting channel (in AM)

A part of the frequency spectrum, equal to the necessary bandwidth of AM sound broadcasting stations, and characterized by the nominal value of the carrier frequency located at its centre.

1.2 Class A station

A station intended to provide coverage over extensive primary and secondary service areas, and which is protected against interference accordingly.

1.3 Class B station

A station intended to provide coverage over one or more population centres and the contiguous rural areas located in its primary service area, and which is protected against interference accordingly.

1.4 Class C station

A station intended to provide coverage over a city or town and the contiguous suburban areas located in its primary service area, and which is protected against interference accordingly.

1.5 Station power

Unmodulated carrier power supplied to the antenna system.

1.6 Characteristic field strength (E_c)

The field strength, at a reference distance of 1 km in a horizontal direction, of the ground-wave signal propagated along perfectly conducting ground for 1 kW fed to the antenna, taking into account losses in a real antenna.

Note : a) The gain (G) of the transmitting antenna relative to an ideal short vertical antenna is given in dB by the following equation :

$$G = 20 \log \frac{E_c}{300}$$

where E_c is in units of mV/m.

b) The equivalent monopole radiated power (e.m.r.p.) is given in dB(1 kW) by the following equation :

$$\text{e.m.r.p.} = 10 \log P_t + G$$

where P_t is the transmitter power in kW.

1.7 Protected contour

Continuous line that determines the area of primary or secondary service which is protected from objectionable interference.

1.8 Audio-frequency (AF) protection ratio

Agreed minimum value of the audio-frequency signal-to-interference ratio corresponding to a subjectively defined reception quality. This ratio may have different values according to the type of service desired.

1.9 Radio-frequency protection ratio

The desired radio-frequency signal-to-interference ratio which, in well-defined conditions, makes it possible to obtain the audio-frequency protection ratio at the output of a receiver. These specified conditions include various parameters such as the frequency separation between the desired carrier and the interfering carrier, the emission characteristics (type and percent modulation etc.) levels of input and output of the receiver and its characteristics (selectivity, sensitivity to intermodulation, etc.).

1.10 Nominal usable field strength (E_{nom})

Agreed minimum value of the field strength required to provide satisfactory reception, under specified conditions, in the presence of natural noise, industrial noise and interference from other transmitters. The value of nominal usable field strength is that employed as the reference for planning.

1.11 Usable field strength (E_u)

Minimum value of the field strength required to provide satisfactory reception, under specified conditions in the presence of natural noise, industrial noise, and interference in a real situation (or resulting from a frequency assignment plan).

1.12 Ground-wave

Electromagnetic wave which is propagated along the surface of the Earth or near it and which has not been reflected by the ionosphere.

1.13 Sky-wave

Electromagnetic wave which has been reflected by the ionosphere.

1.14 Primary service area

Service area delimited by the contour within which the calculated level of the ground-wave field strength is equal to or greater than the nominal usable field strength.

1.15 Secondary service area

Service area delimited by the contour within which the calculated level of the field strength due to the sky-wave 50 % of the time is equal to or greater than the nominal usable field strength.

1.16 Objectionable interference

Interference caused by a signal exceeding the maximum permissible field strength within the protected contour according to the terms of an agreement.

1.17 Daytime operation

Operation between the times of local sunrise and local sunset.

1.18 Night-time operation

Operation between the times of local sunset and local sunrise.

1.19 Sky-wave field strength, 10 % of the time

The median sky-wave field strength during the reference hour which is not exceeded for more than 10 % of the nights of the year. The reference hour is the period of one hour beginning one and a half hours after sunset and ending two and a half hours after sunset at the mid-point of the great-circle path.

1.20 Sky-wave field strength, 50 % of the time

The median sky-wave field strength during the reference hour which is not exceeded for more than 50 % of the nights of the year. The reference hour is the period of one hour beginning one and a half hours after sunset and ending two and a half hours after sunset at the mid-point of the great-circle path.

1.21 Synchronized network

Two or more broadcasting stations whose carrier frequencies are identical (in practice they may differ slightly, usually by a fraction of a hertz) and which broadcast the same programme simultaneously.

2. SYMBOLS

Hz	:	hertz
kHz	:	kilohertz
W	:	watt
kW	:	kilowatt
mV/m	:	millivolt/metre
μV/m	:	microvolt/metre
dB	:	decibel
dB (μV/m)	:	decibels with respect to 1 μV/m
mS/m	:	millisiemens/metre

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CHAPTER 2

PLANNING

2.1 Planning principles

The Second Session of the Regional Administrative MF Broadcasting Conference shall establish a frequency assignment plan for Region 2 in the band 535 - 1 605 kHz.

The Plan shall be based on the principle of equal rights for all countries large or small. It should also make provision for the requirements of administrations as defined in Chapter 7 of this Report and ensure satisfactory reception conditions for all countries, allowing for the different situations which arise in the countries of Region 2.

Planning shall be based on the use of three classes of stations, namely Classes A, B and C. The primary and secondary service areas of Class A stations shall be protected. For Class B and Class C stations, only the primary service area shall be protected. The Plan shall be based on the power of stations as notified to the IFRB for the establishment of the basic inventory. Modifications to the basic inventory, as well as modifications to the Plan to be prepared by the Second Session of the Conference, shall be subject to power limitations.

The Plan shall be established using a uniform channel spacing. The IFRB shall undertake a comparative study of 9 kHz and 10 kHz channel spacing and prepare a report on this question to the Second Session, which shall adopt the appropriate channel spacing to be used in planning.

In planning, the Second Session shall take account of the interference from stations in Regions 1 and 3 which are recorded in the Master Register. The interfering field strength of such stations shall be calculated in accordance with the criteria defined in the present Report. Appropriate protection shall also be afforded to stations in Regions 1 and 3 recorded in the Master Register on the understanding that, between the stations in Regions 1 and 3 on the one hand, and Region 2 on the other hand, the provisions of Article 12 of the Radio Regulations shall apply.

2.2 Planning methods

2.2.1 The Plan shall be established in accordance with the above planning principles, but account must also be taken of the following facts :

- the available frequency spectrum is limited, as are capital and human resources;
- the problem of providing a fair and rational allocation of channels and adequate powers is particularly difficult in those areas where there are a large number of countries or population groups in relatively close proximity.

A rational planning method is needed to maximize the number of programmes and to optimize the coverage that is provided to the listener. An approach for determining basic station parameters is given in Annex A. Planning methods for determining the assignment capacity around a Class A and a Class B station are also given in Annex A.

2.2.2 When planning, it is necessary to observe the following basic considerations :

- the use of identical carrier frequencies, with uniform channel spacing, throughout Region 2;
- the retention of the coverage of existing broadcasting stations and, to the maximum extent possible, the resolution of cases of interference within that coverage, having regard to the requirements of countries;
- the minimization of changes in those frequencies presently in use;
- the endeavour to meet, to the maximum extent possible, the requirements of administrations for the broadcasting service;
- the technical parameters adopted by the First Session of the Conference;
- the specific needs of certain countries which lack sufficient alternative means in other frequency bands (for example VHF-FM), noting that the MF band is particularly suitable and economical for mass communication over large areas.

2.3 Planning criteria

2.3.1 Percentage of time

In calculating the field strength of the interfering sky-wave signal, the sky-wave field strength 50 % of the time shall be used*.

2.3.2 Station power

The Plan shall be established on the basis of the requirements communicated to the IFRB as described in Chapter 7 of this Report. The stations appearing in the basic inventory shall be entered in the Plan with the power given in the inventory.

If the Second Session of the Conference should adopt a procedure permitting modification of the Plan after its entry into force, the following conditions shall apply :

2.3.2.1 Class A

- the power of any Class A station exceeding 100 kW day/50 kW night shall not be increased;
- the power of any Class A station not exceeding 100 kW day/50 kW night may be increased but shall not exceed those values;
- any new Class A station shall have a power not exceeding 100 kW day/50 kW night.

2.3.2.2 Class B

The maximum station power shall be 50 kW.

2.3.2.3 Class C

During night-time, the maximum station power shall be 1 kW.

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* See Annex B

During daytime, the maximum station power shall be :

- 1 kW in noise zone 1
- 5 kW in noise zone 2
- 10 kW in noise zone 3

provided that the protection criteria given in paragraph 4.5 of Chapter 4 are met.

2.3.3 Application of protection criteria

2.3.3.1 Value of protected contours

Inside the national boundary of a country, the protected contour shall be determined by using the appropriate value of nominal usable field strength*.

2.3.3.2 Co-channel protection

The protection ratio shall be applied at the protected contours from interfering daytime ground-wave and night-time sky-wave signals.

In the case of daytime ground-wave protection for all classes of stations, and in the case of night-time sky-wave protection for Class A stations when interfering field strength for 10 % of the time is applied; the protection ratio shall be applied separately to each interfering signal; the presence of interference from existing stations in excess of the level allowed will not reduce the requirement to limit interference from proposed stations.

Interference to a Class A station is determined using the root sum square (RSS) calculation on a site-to-contour basis to the protected contour, except when the 10 % interfering field strength is applied. The result of such calculations shall be compared with the nominal usable field strength to determine if there is an incompatibility. The results of this comparison may be used as a basis for discussions between administrations. See paragraph 6.8 (Chapter 6) for a simplified method for such calculations.

2.3.3.3 Adjacent channel protection

For Class A stations, the protection ratios specified in paragraph 4.5 (Chapter 4) shall be applied only to interfering ground-wave signals at the ground-wave contour corresponding to the nominal usable field strength.

For Class B and C stations, the protection ratios specified in paragraph 4.5 (Chapter 4) shall be applied for both daytime and night-time operation at the ground-wave protected contour determined on the basis of daytime nominal usable field strength from interfering ground-wave signals.

2.3.4 Protection outside national boundaries

2.3.4.1 No station which has the right to be protected beyond the boundary of the country in which the station is established, except when otherwise specified in a bilateral or multilateral agreement.

2.3.4.2 No broadcasting station shall be assigned a frequency with a separation of 10 kHz or 9 kHz or less from that of a station in another country if the 2 500 μV/m contours overlap.

* See Annex B

No broadcasting station shall be assigned a frequency with a separation of 20 kHz or 18 kHz from that of a station in another country if the 10 000 μV/m contours overlap.

No broadcasting station shall be assigned a frequency with a separation of 30 kHz or 27 kHz from that of a station in another country if the 25 000 μV/m contours overlap.

2.3.4.3 In addition to the conditions described in paragraph 2.3.4.2, when the protected contour extends beyond the boundary of the country in which the station is located, the calculated field strength along the boundary shall be protected on the basis of the ratios specified in paragraph 4.5.2 (Chapter 4).

2.3.4.4 For protection purposes, the boundary of a country shall be deemed to encompass only its land area including islands.

CHAPTER 3

PROPAGATION

3.1 Ground-wave propagation

3.1.1 Ground conductivity

3.1.1.1 Annex C is an atlas of ground conductivity*. Administrations should examine the data carefully and advise the Brazilian Administration by 31 May 1980 of any corrections to be made to the information.

3.1.1.2 The Administration of Brazil is requested to send updated maps to the administrations concerned and to the ITU, if possible during June 1980. Within thirty days of receiving the maps, administrations should notify the ITU whether they agree or disagree with the updated maps. A copy of this notification should also be sent to the Brazilian Administration for information.

3.1.1.3 These maps will be used in the planning exercise which the IFRB is to perform before May 1981. Later conductivity information should be sent directly to the ITU for publication and distribution as well as for updating the data bank. (See also Recommendation A.)

3.1.2 Field-strength curves for ground-wave propagation

The curves shown in Annex D are to be used for the prediction of ground-wave propagation.

It should be noticed that these graphs are valid for the following frequency ranges :

Graph No.	kHz
1	530 - 565
2	566 - 595
3	596 - 625
4	626 - 655
5	656 - 685
6	686 - 715
7	716 - 765
8	766 - 815
9	816 - 865
10	866 - 915
11	916 - 965
12	966 - 1 035
13	1 036 - 1 105
14	1 106 - 1 175
15	1 176 - 1 245
16	1 246 - 1 335
17	1 336 - 1 425
18	1 426 - 1 515
19	1 516 - 1 615

* Not reproduced in the present Report; this atlas was distributed at the First Session to delegations present.

3.1.3 Calculation of ground-wave field strength

3.1.3.1 Homogeneous paths

The vertical component of the electric field strength for a homogeneous path is represented in these graphs as a function of distance, for various values of ground conductivity.

The distance in kilometres is shown on a logarithmic scale on the abscissa. The electric field strength is shown on a linear scale on the ordinate in decibels above 1 μV/m. Graphs 1 to 19 are standardized for a characteristic field strength of 100 mV/m at 1 km corresponding to an equivalent monopole radiated power (e.m.r.p.) of -9.5 dB relative to 1 kW. The straight line marked "100 mV/m at 1 km" is the field strength on the assumption that the antenna is erected on a surface of perfect conductivity.

For omnidirectional antenna systems having a different characteristic field strength, corrections must be made according to the following formulae :

$$E = E_0 \times \frac{E_c}{100} \times \sqrt{P}$$

if field strengths are expressed in mV/m

$$E = E_0 + E_c - 100 + 10 \log P$$

if field strengths are expressed in dB(μV/m).

For directional antenna systems, the correction must be made according to the following formulae :

$$E = E_0 \times \frac{E_R}{100}$$

if field strengths are expressed in mV/m

$$E = E_0 + E_R - 100$$

if field strengths are expressed in dB (μV/m)

where E : resulting electric field strength

E_0 : electric field strength read from graphs 1 to 19

E_R : actual radiated field strength at a particular azimuth at 1 km

E_c : characteristic field strength at 1 km

P : station power in kW

Graph 20 consists of three pairs of scales to be used with the other graphs of Annex D. Each pair contains one scale labelled in decibels and another in millivolts per metre. Each pair can be cut out and trimmed as a unit to be used as sliding ordinate scales. The scales allow graphical conversion between decibels and millivolts per metre, and are used to make graphical determinations of field strength. Alternate methods of making calculations on graphs 1 to 19 may be used, including the use of dividers to adjust for values of E_R that differ from 100 mV/m at 1 km. However, any method used will follow steps similar to those discussed below.

For both omnidirectional and directional antenna systems the value of E_R must be found. For omnidirectional systems E_R can be determined by using the following formulae :

$$E_R = E_c \sqrt{P}$$

if field strengths are expressed in mV/m

$$E_R = E_c + 10 \log P$$

if field strengths are expressed in dB(μV/m).

To determine the field strength at a given distance the scale is placed at the given distance with the 100 dB(μV/m) point of the scale resting on the applicable conductivity curve. The value of E_R is then found on the scale; the point on the underlying graph (which lies underneath the E_R point of the scale) yields the field strength at the given distance.

To determine the distance at a given field strength, the E_R value is found on the sliding scale and that point is placed directly at the level of the given field strength on the appropriate graph. The scale is then moved horizontally until the 100 dB(μV/m) point of the scale coincides with the applicable conductivity curve. The distance may then be read from the abscissa of the underlying graph.

The mathematical discussion for the calculation of ground-wave curves is set out in Annex E. The corresponding computer programme is at the disposal of the IFRB.

3.1.3.2 Examples of field strength calculations for homogeneous paths

a) Determination of the electric field strength at a certain distance from a station.

Consider a station with a power of 5 kW at 1 240 kHz. The antenna has a characteristic field strength for 1 kW of 306 mV/m at one kilometre.

The electrical field strength at a distance of 40 km is to be determined, for a conductivity of 4 mS/m throughout the path.

From graph 15 (1 176 - 1 245 kHz) we obtain a field strength of 45.5 dB(μV/m) which corresponds to 188 μV/m from the curve corresponding to 4 mS/m.

Therefore

$$E = E_0 \frac{E_c}{100} \sqrt{P} = \frac{188 \times 306}{100} \sqrt{5} = 1\ 286\ \mu V/m \text{ or } 62.2\ dB(\mu V/m)$$

b) Determination of the distance at which a certain electric field strength is obtained.

On the basis of the data from the preceding example, at what distance can a field strength of 500 μV/m or 54 dB(μV/m) be obtained ?

Since the antenna involved has a characteristic field strength for 1 kW of 306 mV/m at one kilometre and the station power is 5 kW, i.e. conditions different from those of graphs 1 to 19 (100 mV/m at 1 km), the field strength value must be determined before referring to the corresponding figure.

The calculated value is

$$E_0 = \frac{100\ E}{E_c \sqrt{P}} = \frac{100 \times 500}{306 \times \sqrt{5}} = 73.1\ \mu V/m \text{ or } 37.3\ dB(\mu V/m)$$

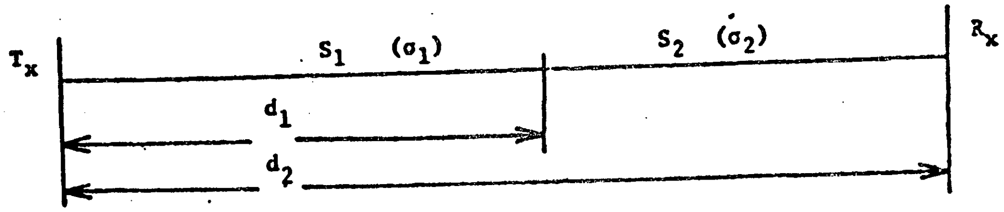
Taking the corresponding curve at 4 mS/m in graph 15, we arrive at 37.3 dB(μV/m) at 62 km.

3.1.3.3 Non-homogeneous paths

The equivalent distance or Kirke method is to be used. (The US Administration will supply the ITU with a computer programme.) Details of the method are given below.

Graphs 1 to 20 can be used to determine the field strength in mixed conductivity paths by the equivalent distance or Kirke method.

Consider a path whose sections S_1 and S_2 have endpoint distances corresponding to d_1 and d_2, and conductivities σ_1 and σ_2 respectively, as shown on the following figure :



The method is applied as follows :

a) Taking section S_1 first, we read the field strength corresponding to conductivity c_1 at distance d_1 on the graph corresponding to the operational frequency (Annex D).

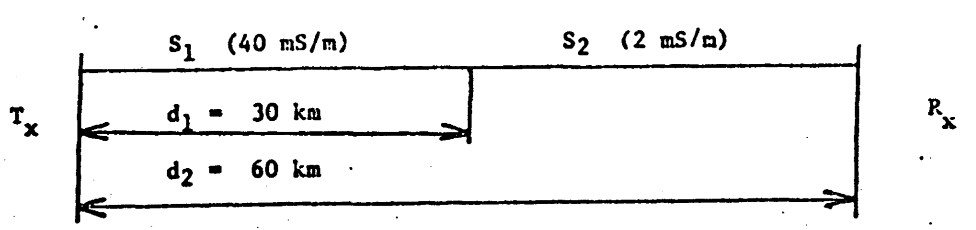
b) As the electric field strength remains constant at the soil discontinuity, the value immediately after the point of discontinuity must be equal to that obtained in a) above. As the conductivity of the second section is σ_2, the curve corresponding to conductivity σ_2 gives the equivalent distance to that which would be obtained at the same electric field strength arrived at in a). This equivalent distance is d. Distance d is larger than d_1 when σ_2 is larger than σ_1. Otherwise d is less than d_1.

c) The electric field strength at the real distance d_2 is determined by taking note of the corresponding curve for conductivity σ_2 similar to that obtained at equivalent distance $d + (d_2 - d_1)$.

d) For successive paths with different conductivities, procedures b) and c) are repeated.

Example :

Consider the following path :



For a 25 kW station at 1 000 kHz and an antenna with a characteristic field strength of 100 mV/m, what field strength is obtained at 60 km ?

- In graph 12 we obtain on the 40 mS/m curve a field strength of 69 dB(μV/m) or 2.8 mV/m at the point of discontinuity (30 km).

- We obtain the same field strength at 9.5 km (d = 9.5 km) on the 2 mS/m curve.

- The equivalent distance, for d_2 = 60 km, is $d + (d_2 - d_1) = 9.5 + (60 - 30) = 39.5$ km.

From the 2 mS/m curve we obtain a field of 43 dB(μV/m) or 141 μV/m at 39.5 km.

Lastly, we calculate the field strength :

$$E = E_o \times \frac{E_c}{100} \sqrt{P} = 141 \times \frac{100}{100} \times \sqrt{25} = 705 \ \mu V/m.$$

Taking the preceding example, at what distance will the 500 µV/m contour be ?

First we determine the electric field strength :

$$E_o = \frac{100E}{E_c\sqrt{P}} = \frac{100}{100\sqrt{25}} \times 500 = 100\ \mu V/m$$

Following the 40 mS/m curve of graph 12, we note that at 30 km the electric field strength is 69 dB(µV/m) or 2.8 mV/m. This value is higher than the one we seek (0.1 mV/m), therefore, we shall have a distance greater than 30 km. The equivalent distance for a 2 mS/m conductivity is 9.5 km.

Following the 2 mS/m curve, we find the 100 µV/m or 40 dB(µV/m) contour at 46 km giving us the equivalent distance. The true distance is 46 + (30 - 9.5) km = 66.5 km.

3.2 Sky-wave propagation

The method of calculation of sky-wave field strength described in the following pages is to be used.

3.2.1 List of symbols

- d : short great-circle path distance (km)
- E_c : characteristic field strength, mV/m at 1 km for 1 kW
- $f(\theta)$: radiation in percent of value at theta = 0
- f : frequency (kHz)
- F_b : basic sky-wave field strength (annual median in the absence of sea gain and excess polarization coupling loss) (dB(µV/m))
- F_c : field strength read from Figure 4 and Table III (dB(µV/m)) for a characteristic field strength of 100 mV/m at 1 km
- $F(50)$: predicted annual median sky-wave field strength (dB(µV/m))
- $F(10)$: predicted sky-wave field strength exceeded for 10 % of the nights of the year (dB(µV/m))
- I : magnetic dip angle (degrees)
- L_p : excess polarization coupling loss (dB)
- P : power (kW)
- β : direction of propagation relative to magnetic East-West (degrees)
- θ : angle of departure from the horizontal (degrees)

3.3.2 General procedure

3.2.2.1 Radiation in the horizontal plane of an omnidirectional antenna fed with 1 kW (characteristic field strength, E_c) is known either from design data or, if the actual design data is not available, from Figure 1 of Chapter 3.

3.2.2.2 Angle of departure, θ, is given by

$$\theta = \tan^{-1} \left(0.00752 \operatorname{cotg} \frac{d}{444.54}\right) - \frac{d}{444.54} \text{ degrees} \qquad (1)$$

$$0 \leqslant \theta \leqslant 90^\circ$$

Alternatively, Table I and Figure 2 may be used.

It is assumed that the Earth is a smooth sphere with an effective radius of 6 367.6 km, and that reflections occur from an ionospheric height of 96.5 km.

3.2.2.3 The radiation $f(\theta)$ expressed in percent of value at $\theta = 0°$ at a pertinent angle of departure θ, can be determined from Figure 3 or Table II.

3.2.2.4 The product $E_c f(\theta)\sqrt{P}$ is thus determined for an omnidirectional antenna. For a directional antenna, $E_c f(\theta)\sqrt{P}$ can be determined from the antenna radiation pattern. $E_c f(\theta)\sqrt{P}$ is the field strength at 1 km at the appropriate angle of departure and azimuth.

3.2.2.5 The basic sky-wave field strength F_b is given by :

$$F_b = F_c + 20 \log \frac{E_c f(\theta)\sqrt{P}}{100} \quad (\text{dB}(\mu\text{V/m})) \qquad (2)$$

where F_c is the direct reading from the field strength curve in Figure 4 or Table III.

Note : Values of F_c in Figure 4 and Table III are normalized to 100 mV/m at 1 km corresponding to an equivalent monopole radiated power (e.m.r.p.) of - 9.5 dB(kW).

For distances greater than 4 250 km, it should be noted that F_c can be expressed by :

$$F_c = \frac{231}{3 + d/1000} - 35.5 \text{ dB}(\mu\text{V/m}) \qquad (3)$$

for $d > 4\,250$ km

3.2.2.6 Sea gain

For planning purposes, sea gain is assumed to be zero.

3.2.2.7 Excess polarization coupling loss

L_p is the excess polarization coupling loss. At low latitudes, for $|I| < 45°$, the following formula applies for each terminal :

$$L_p = 180\ (36 + \beta^2 + I^2)^{-\frac{1}{2}} - 2 \qquad \text{dB} \qquad (4)$$

where I is the magnetic dip in degrees at the terminal and β is the path azimuth measured in degrees from the magnetic E-W direction, such that $|\beta| \leq 90°$. For $|I| > 45°$, $L_p = 0$.

L_p should be evaluated separately for the two terminals, because of the different β and I that may apply, and the two L_p values added. The most accurate available values of magnetic dip and declination should be used in determining β and I (see Figures 6, 7 and 8).

The excess polarization coupling loss, L_p, is less than 3.1 dB when either β or $|I|$ is greater than 35° (see equation 4). This small loss may be ignored in many sky-wave calculations.

Therefore, L_p need be calculated for a terminal only when either β is less than or equal to 35°, or the terminal is located in South America between latitudes 5° N and 40° S.

3.2.2.8 The calculated annual median sky-wave field strength is given by :

$$F(50) = F_b - L_p \qquad \text{dB}(\mu\text{V/m}) \qquad (5)$$

3.2.2.9 The sky-wave field strength exceeded for 10 % of the time is given by :

$$F(10) = F(50) + 8 \qquad \text{dB}(\mu\text{V/m}) \qquad (6)$$

3.2.2.10 The nocturnal variation of sky-wave field strength

Hourly median sky-wave field strengths vary during the night and at sunrise and sunset. Figure 9 showns the average variation referred to the value at 2 hours after sunset at the path midpoint. This variation applies to field strengths occurring for both 50 % and 10 % of the nights.

3.2.2.11 Sunrise and sunset time

To facilitate the determination of the local time of sunrise and sunset, Figure 10 gives the times for various geographic latitudes (see 3.2.2.12 below) and for each month of the year. The time is the local meridian time at the point concerned and should be converted to the appropriate standard time.

3.2.2.12 Path parameters

If a_T and b_T respectively are the latitude and longitude of the transmitting terminal, and a_R and b_R are those of the receiving terminal, then the path parameters may be calculated as follows North and East are considered positive; South and West negative. These parameters apply to the calculation of the short great-circle path.

- Great-circle path distance

$$d = 111.18 \times d^o \quad \text{km}$$

where

$$d^o = \text{arc cos} \left[\sin a_T \sin a_R + \cos a_T \cos a_R \cos (b_R - b_T) \right]$$

- Geographic azimuth of the path from either terminal

For the transmitting terminal, for example,

$$\alpha_T = \text{arc cos} \frac{\sin a_R - \cos d^o \sin a_T}{\sin d^o \cos a_T}$$

determined such that $0^o \leqslant \alpha < 180^o$. The geographic bearing in degrees East of North to the receiving terminal is α_T if $\sin (b_R - b_T) \geqslant 0$ or is $(360^o - \alpha_T)$ if $\sin (b_R - b_T) < 0$. The same equation, with the latitudes reversed, is used for the receiving terminal.

- Direction of propagation at either terminal relative to magnetic East-West

$$\beta = \left| 90^o + \delta - \alpha \right|$$

where δ is the magnetic declination at the terminal, as determined from Figure 8, considered positive for East declination.

- Path midpoint latitude

$$a = \text{arc sin} \left[\sin a_T \cos (d^o/2) + \cos a_T \sin (d^o/2) \cos \alpha_T \right]$$

- Path midpoint longitude

$$b = b_T + \text{arc cos} \left[\frac{\cos (d^o/2) - \sin a_T \sin a}{\cos a_T \cos a} \right]$$

Note that the transmitting location was used in these equations for a and b, but alternatively the receiving location may be used.

3.2.2.13 Calculation of inter-regional interference

For planning purposes in the interim period prior to the Second Session of the Conference, the procedure for calculating interference shall be as follows :

- when the midpoint of the path falls within Region 1 or Region 3, the Region 1 or Region 3 method of calculation shall be used;
- when the midpoint of the path falls within Region 2, the method described in this paragraph 3.2.2 shall be used, but will include sea gain factors at both terminals in accordance with CCIR Recommendation 435-3.

In both cases, the sunspot number will be taken as zero.

This procedure shall also be applied for calculating interference from stations in Region 2 to stations in the U.S.S.R.

The CCIR has been requested to examine the situation and to suggest the best method for calculating inter-regional interference for consideration at the Second Session of the Conference and for subsequent planning (see Recommendation B).

Note 1 : In sea gain calculations, the presence of small islands or channels along the great circle path between the points concerned shall be ignored.

Note 2 : Sea gain calculations shall be made along the contour to be protected.

Note 3 : For economy, the calculations of sea gain need only be done for cases in which the interference calculated without sea gain is within 20 dB of the critical level (the maximum sea gain contribution is 20 dB).

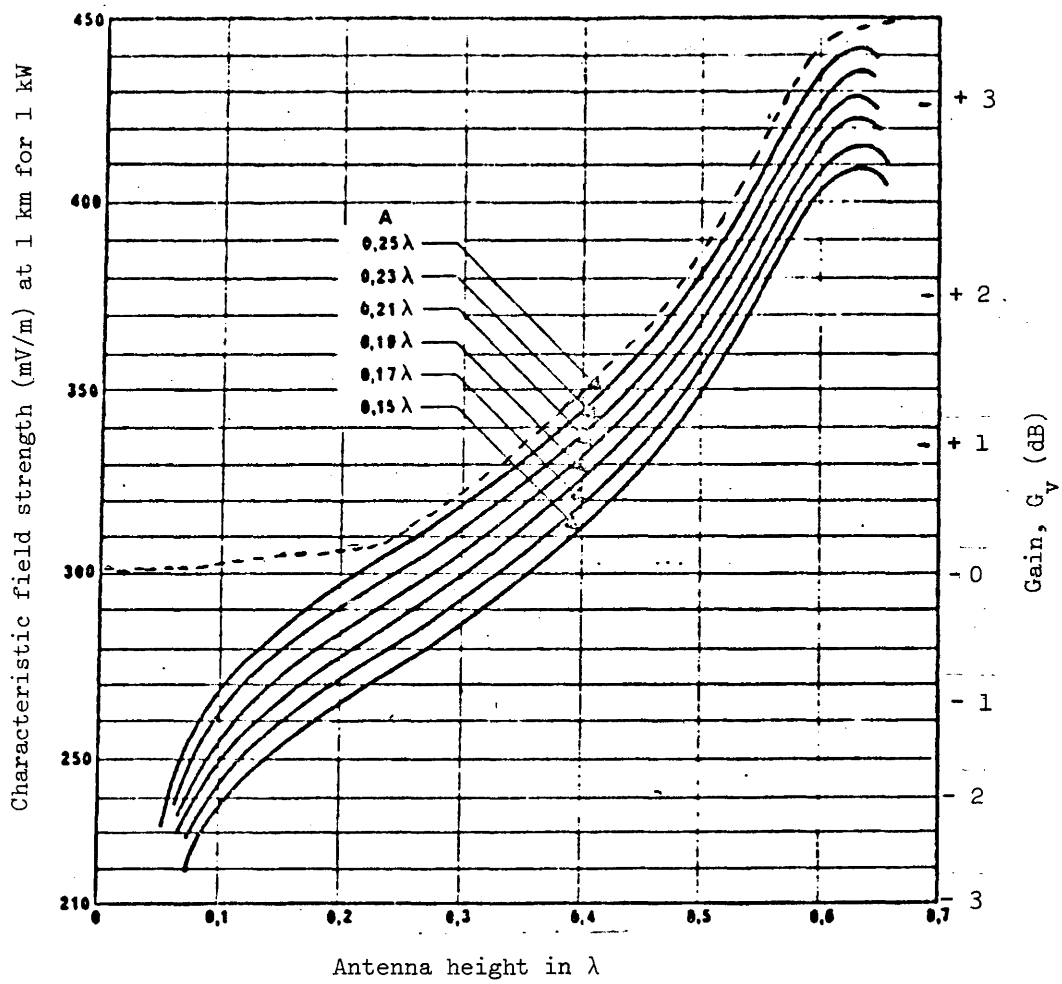


FIGURE 1 - Characteristic field strengths for vertical omnidirectional radiators, using 120-radial ground systems

A : radius of ground system

Full lines : real antenna correctly designed

Dashed line : ideal antenna on a perfectly conducting ground

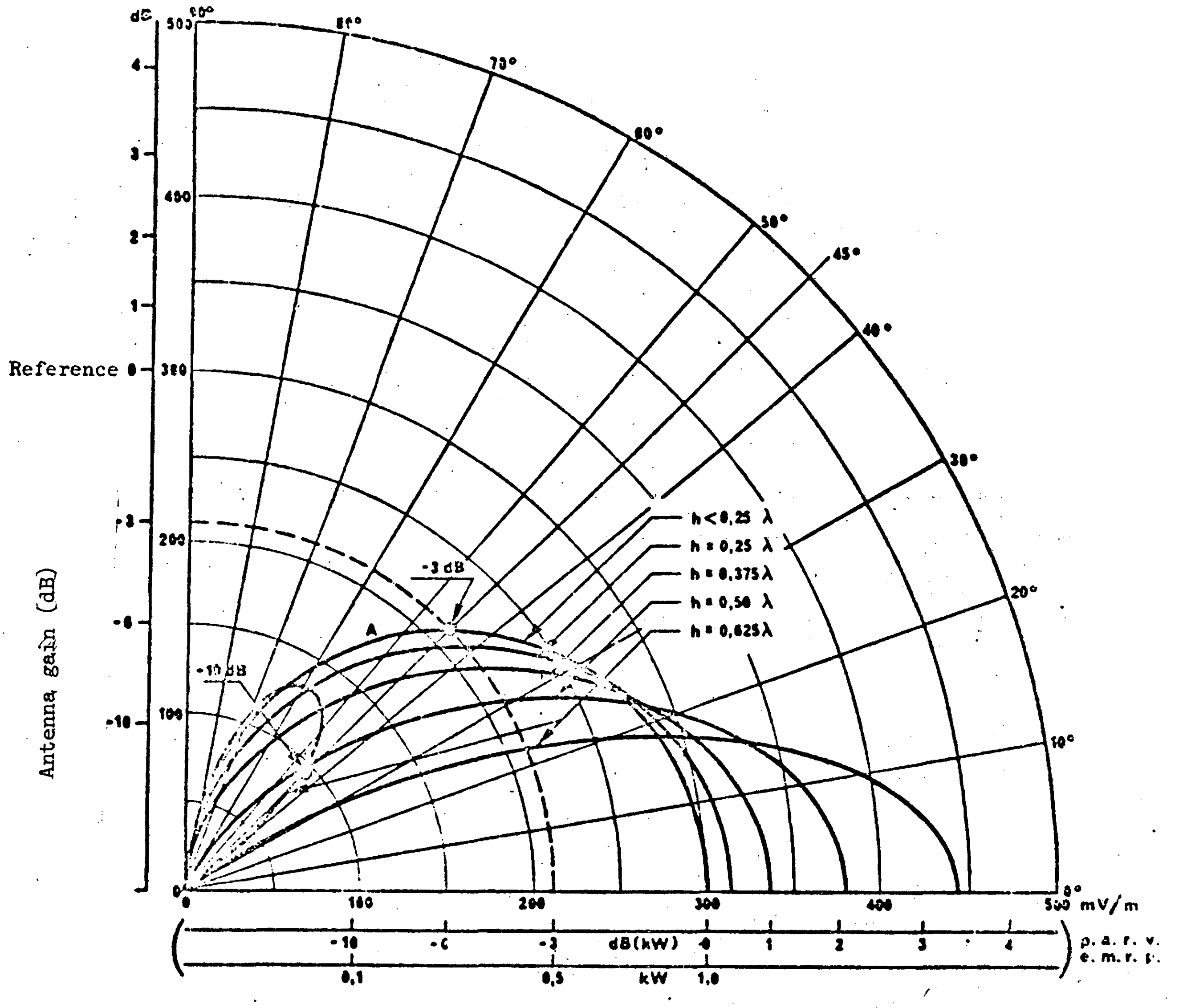


FIGURE 1a - Equivalent monopole radiated power (e.m.r.p.) and field strength at a distance of 1 km as a function of elevation angle, for different heights of vertical antennae assuming a transmitter power of 1 kW

A : short vertical antenna

TABLE I - Angle of departure vs distance

Distance (km)	Angle of departure (degrees)
50	75.3
100	62.2
150	51.6
200	43.3
250	36.9
300	31.9
350	27.9
400	24.7
450	22.0
500	19.8
550	18.0
600	16.3
650	14.9
700	13.7
750	12.6
800	11.7
850	10.8
900	10.0
950	9.3
1000	8.6
1050	8.0
1100	7.4
1150	6.9
1200	6.4
1250	5.9
1300	5.4
1350	5.0
1400	4.6
1450	4.3
1500	3.9
1550	3.5
1600	3.2
1650	2.9
1700	2.6
1750	2.3
1800	2.0
1850	1.7
1900	1.5
1950	1.2
2000	1.0
2050	0.7
2100	0.5
2150	0.2
2200	0.0
2250	0.0
2300	0.0
2350	0.0
2400	0.0

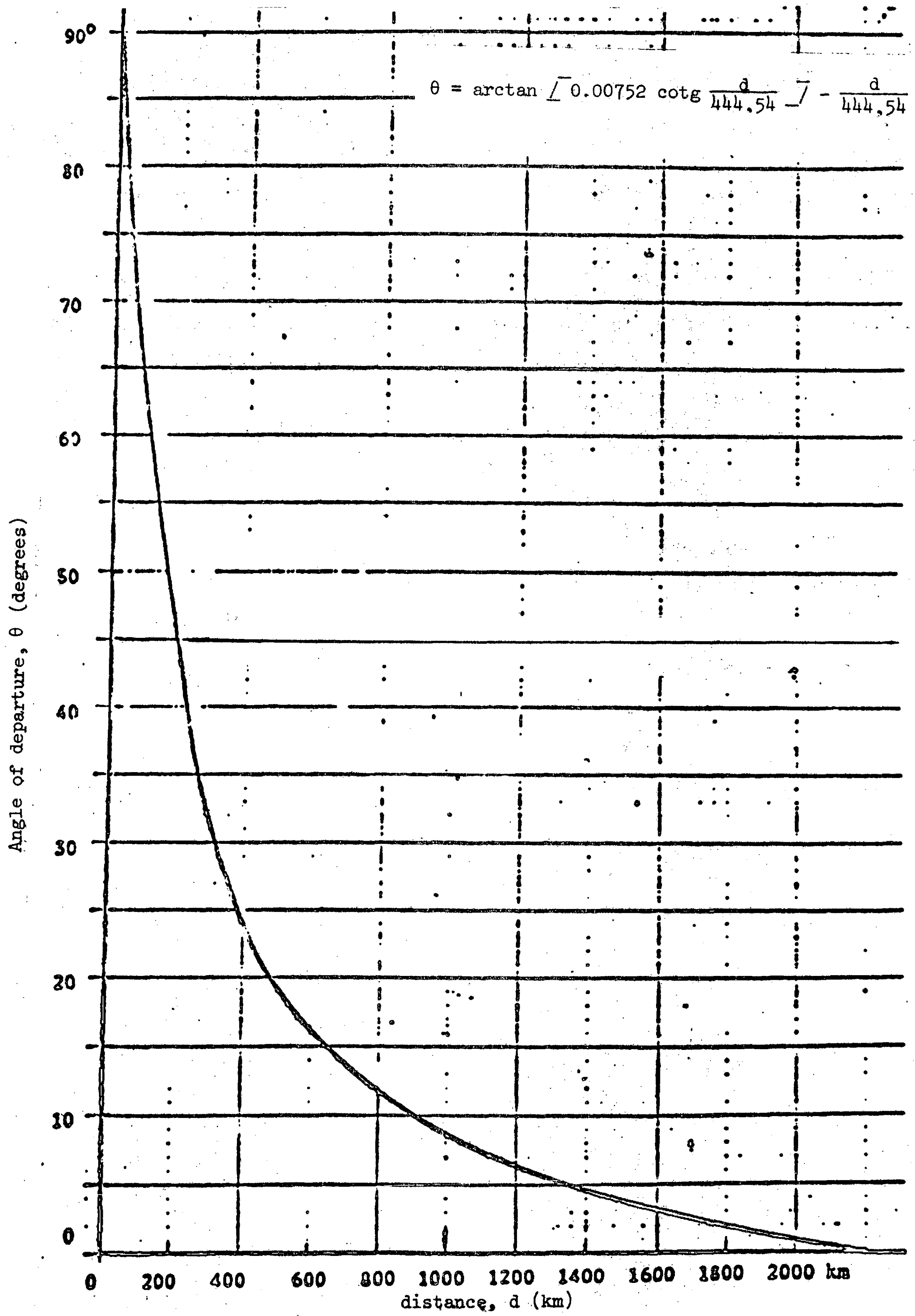


FIGURE 2 - Angle of departure vs distance

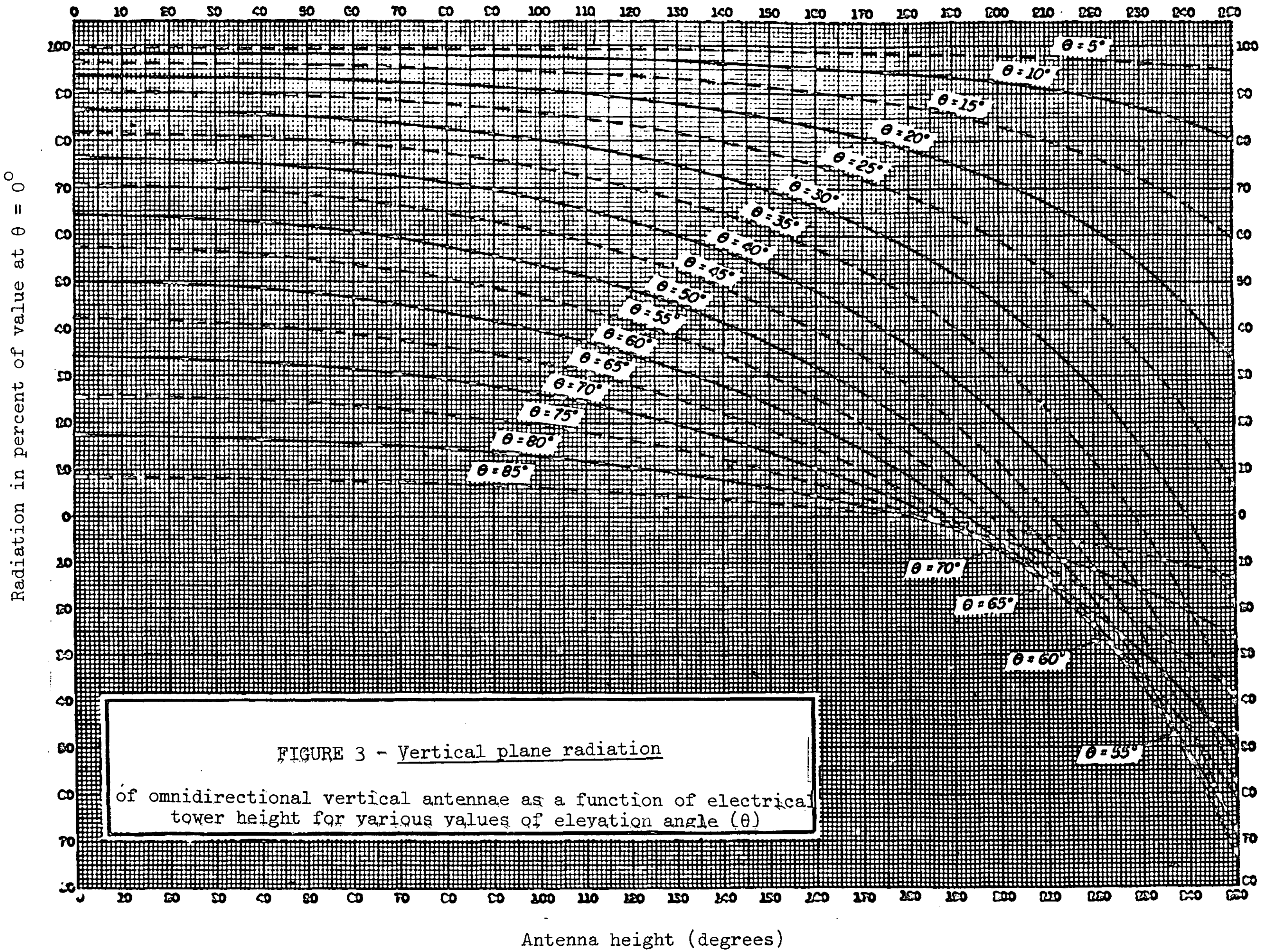


FIGURE 3 - Vertical plane radiation

of omnidirectional vertical antennae as a function of electrical tower height for various values of elevation angle (θ)

TABLE II - f(θ) values for vertical monopoles

Angle of departure (degrees)	f (θ)					
	0,11λ	0,13λ	0,15λ	0,17λ	0,19λ	0,21λ
0	1,000	1,000	1,000	1,000	1,000	1,000
1	1,000	1,000	1,000	1,000	1,000	1,000
2	0,999	0,999	0,999	0,999	0,999	0,999
3	0,999	0,998	0,998	0,998	0,998	0,998
4	0,997	0,997	0,997	0,997	0,997	0,997
5	0,996	0,996	0,996	0,995	0,995	0,995
6	0,994	0,994	0,994	0,993	0,993	0,993
7	0,992	0,992	0,991	0,991	0,991	0,990
8	0,989	0,989	0,989	0,988	0,988	0,987
9	0,987	0,986	0,986	0,985	0,985	0,984
10	0,984	0,983	0,983	0,982	0,981	0,980
11	0,980	0,980	0,979	0,978	0,977	0,976
12	0,976	0,976	0,975	0,974	0,973	0,971
13	0,972	0,972	0,971	0,969	0,968	0,967
14	0,968	0,967	0,966	0.965	0,963	0,961
15	0,963	0,962	0,961	0,959	0,958	0,956
16	0,958	0,957	0,956	0,954	0,952	0,950
17	0,953	0,952	0,950	0,948	0,945	0,943
18	0,947	0,946	0,944	0,942	0,940	0,937
19	0,941	0,940	0,938	0,935	0,933	0,930
20	0,935	0,933	0,931	0,929	0,926	0,922
22	0,922	0,920	0,917	0,914	0,911	0,907
24	0,907	0,905	0,902	0,898	0,894	0,890
26	0,892	0,889	0,885	0,882	0,877	0,872
28	0,875	0,872	0,868	0,864	0,858	0,852
30	0,857	0,854	0,849	0,844	0,839	0,832
32	0,838	0,834	0,830	0,824	0,818	0,811
34	0,819	0,814	0,809	0,803	0,796	0,789
36	0,798	0,793	0,788	0,781	0,774	0,766
38	0,776	0,771	0,765	0,758	0,751	0,742
40	0,753	0,748	0,742	0,735	0,726	0,717
42	0,730	0,724	0,718	0,710	0,702	0,692
44	0,705	0,700	0,693	0,685	0,676	0,666
46	0,680	0,674	0,667	0,659	0,650	0,639
48	0,654	0,648	0,641	0,633	0,623	0,612
50	0,628	0,621	0,614	0,606	0,596	0,585
52	0,600	0,594	0,587	0,578	0,568	0,557
54	0,572	0,565	0,559	0,550	0,540	0,529
56	0,544	0,537	0,530	0,521	0,512	0.501
58	0,515	0,508	0,501	0,493	0,483	0,472
60	0,485	0,479	0,472	0,463	0,454	0,443

Note : When the negative sign (-) appears in the Table, it signifies only the existence of a secondary lobe having the opposite electrical phase from the principal lobe, in the vertical radiation pattern. In order to perform the calculation, ignore the negative (-) and use only the absolute value of f(θ) from the Table.

TABLE II (continued) - f(θ) values for vertical monopoles

Angle of departure (degrees)	f(θ)					
	0,23λ	0,25λ	0,27λ	0,29λ	0,311λ	0,35λ
0	1,000	1,000	1,000	1,000	1,000	1,000
1	1,000	1,000	1,000	1,000	1,000	1,000
2	0,999	0,999	0,999	0,999	0,999	0,999
3	0,998	0,998	0,998	0,998	0,998	0,997
4	0,997	0,996	0,996	0,996	0,996	0,995
5	0,995	0,994	0,994	0,994	0,993	0,992
6	0,992	0,992	0,991	0,991	0,990	0,989
7	0,990	0,989	0,988	0,988	0,987	0,985
8	0,987	0,986	0,985	0,984	0,983	0,980
9	0,983	0,982	0,981	0,980	0,973	0,975
10	0,979	0,978	0,977	0,975	0,973	0,969
11	0,975	0,973	0,972	0,970	0,966	0,963
12	0,970	0,968	0,966	0,964	0,962	0,956
13	0,965	0,963	0,961	0,958	0,955	0,949
14	0,959	0,957	0,955	0,952	0,948	0,941
15	0,953	0,951	0,948	0,945	0,941	0,932
16	0,947	0,944	0,941	0,937	0,933	0,924
17	0,941	0,937	0,934	0,930	0,925	0,914
18	0,934	0,930	0,926	0,921	0,916	0,904
19	0,926	0,922	0,918	0,913	0,907	0,894
20	0,919	0,914	0,909	0,904	0,898	0,883
22	0,902	0,897	0,891	0,885	0,877	0,851
24	0,885	0,879	0,872	0,865	0,856	0,837
26	0,866	0,859	0,852	0,843	0,833	0,811
28	0,846	0,838	0,830	0,820	0,309	0,795
30	0,825	0,816	0,807	0,797	0,784	0,758
32	0,803	0,794	0,784	0,772	0,759	0,729
34	0,780	0,770	0,759	0,747	0,732	0,701
36	0,756	0,746	0,734	0,721	0,705	0,671
38	0,732	0,720	0,708	0,694	0,677	0,642
40	0,706	0,695	0,681	0,667	0,649	0,612
42	0,681	0,668	0,654	0,539	0,621	0,582
44	0,654	0,641	0,627	0,611	0,593	0,552
46	0,628	0,614	0,600	0,583	0,564	0,523
48	0,600	0,587	0,572	0,555	0,536	0,494
50	0,573	0,559	0,544	0,527	0,507	0,465
52	0,545	0,531	0,516	0,498	0,479	0,436
54	0,517	0,503	0,487	0,470	0,451	0,408
56	0,488	0,474	0,459	0,442	0,423	0,381
58	0,460	0,446	0,431	0,414	0,395	0,354
60	0,431	0,418	0,403	0,387	0,368	0,328

See Note on page 22

TABLE II (continued) - f(θ) values for vertical monopoles

Angle of departure (degrees)	f(θ)					
	0,40λ	0,45λ	0,50λ	0,523λ	0,55λ	0,625λ
0	1,000	1,000	1,000	1,000	1,000	1,000
1	1,000	1,000	0,999	0,999	0,999	0,999
2	0,998	0,998	0,998	0,997	0,997	0,995
3	0,997	0,996	0,995	0,994	0,993	0,989
4	0,994	0,992	0,990	0,989	0,988	0,981
5	0,991	0,988	0,985	0,983	0,981	0,970
6	0,986	0,983	0,979	0,975	0,972	0,957
7	0,982	0,977	0,971	0,967	0,962	0,941
8	0,976	0,970	0,962	0,957	0,951	0,924
9	0,970	0,963	0,953	0,945	0,938	0,904
10	0,963	0,954	0,942	0,933	0,924	0,882
11	0,955	0,945	0,930	0,919	0,909	0,859
12	0,947	0,934	0,917	0,905	0,893	0,834
13	0,938	0,923	0,903	0,889	0,875	0,807
14	0,929	0,912	0,889	0,872	0,857	0,773
15	0,918	0,899	0,873	0,855	0,837	0,748
16	0,908	0,886	0,857	0,836	0,816	0,717
17	0,897	0,873	0,840	0,817	0,795	0,684
18	0,885	0,859	0,823	0,797	0,772	0,651
19	0,873	0,844	0,804	0,776	0,749	0,617
20	0,860	0,828	0,785	0,755	0,726	0,582
22	0,833	0,795	0,746	0,710	0,677	0,510
24	0,805	0,763	0,705	0,665	0,625	0,436
26	0,775	0,728	0,653	0,618	0,574	0,363
28	0,745	0,692	0,621	0,570	0,522	0,290
30	0,714	0,655	0,577	0,522	0,470	0,219
32	0,682	0,619	0,534	0,475	0,419	0,151
34	0,649	0,582	0,492	0,428	0,369	0,085
36	0,617	0,545	0,450	0,383	0,321	0,025
38	0,584	0,509	0,409	0,340	0,273	-0,031
40	0,552	0,473	0,370	0,293	0,231	-0,083
42	0,519	0,438	0,332	0,258	0,190	-0,129
44	0,488	0,405	0,296	0,221	0,152	-0,170
46	0,457	0,372	0,262	0,187	0,117	-0,205
48	0,427	0,341	0,230	0,155	0,085	-0,235
50	0,397	0,311	0,201	0,126	0,056	-0,259
52	0,369	0,283	0,174	0,099	0,031	-0,278
54	0,341	0,257	0,149	0,076	0,009	-0,291
56	0,315	0,232	0,126	0,055	-0,010	-0,300
58	0,289	0,208	0,105	0,037	-0,026	-0,304
60	0,265	0,186	0,087	0,021	-0,039	-0,304
62				0,003	-0,049	-0,300
64				-0,003	-0,056	-0,292
66				-0,011	-0,062	-0,281
68				-0,017	-0,064	-0,257
70				-0,022	-0,065	-0,250
72				-0,025	-0,064	-0,231
74				-0,025	-0,061	-0,210
76				-0,026	-0,056	-0,138
78				-0,024	-0,051	-0,163
80				-0,022	-0,044	-0,13[illegible]

See Note on page 22

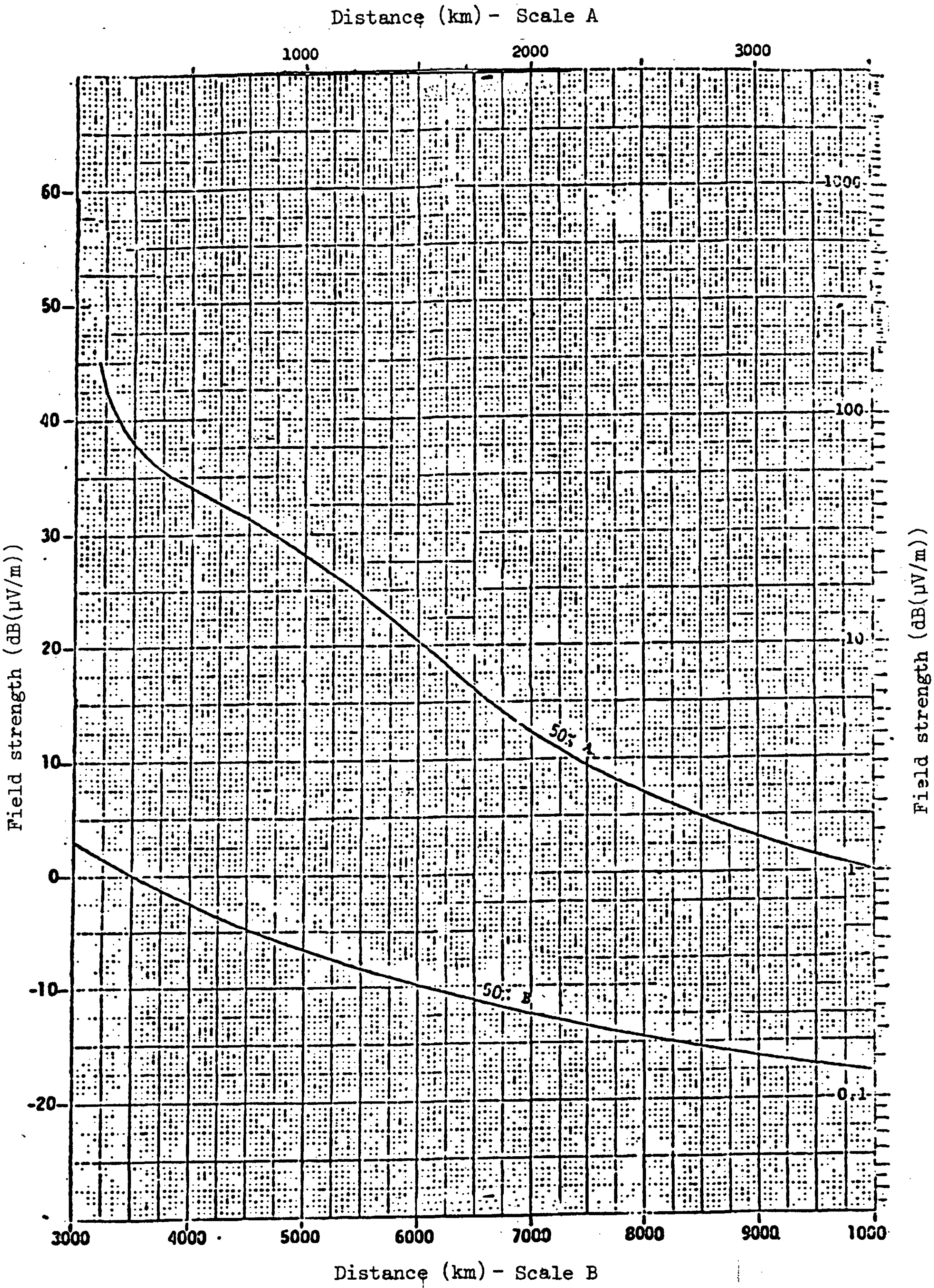


FIGURE 4 - Sky-wave field strength vs distance for a characteristic field strength of 100 mV/m at 1 km

TABLE III - Sky-wave field strength for distances from 100 to 10 000 km

d(km)	E (dB(µV/m)) 50 %	e (µV/m) 50 %
100	45,06	179,11
150	41,38	117,18
200	39,28	92,06
250	37,79	77,54
300	36,75	68,82
350	35,86	62,06
400	35,13	57,08
450	34,46	52,86
500	33,92	49,[illegible]5
550	33,40	46,78
600	32,94	44,36
650	32,45	41,95
700	31,94	39,54
750	31,32	36,81
800	30,73	34,40
850	30,18	32,30
900	29,51	29,89
950	28,83	27,63
1000	28,14	25,54
1050	27,44	23,56
1100	26,79	21,84
1150	25,98	19,91
1200	25,25	18,30
1250	24,50	16,78
1300	23,71	15,32
1350	22,90	13,97
1400	22,08	12,71
1450	21,25	11,55
1500	20,42	10,50
1550	19,59	9,53
1600	18,66	8,57
1650	17,75	7,72
1700	16,87	6,98
1750	16,04	6,34
1800	15,28	5,80
1850	14,52	5,32
1900	13,78	4,89
1950	13,05	4,49
2000	12,34	4,14
2100	11,15	3,61
2200	10,05	3,18
2300	8,92	2,79
2400	8,13	2,55
2500	7,09	2,26
2600	6,16	2,03
2700	5,32	1,85
2800	4,58	1,69
2900	3,81	1,55

TABLE III (continued)

d(km)	E (dB(µV/m)) 50 %	e (µV/m) 50 %
3000	3,11	1,43
3100	2,45	1,33
3200	1,78	1,23
3300	1,18	1,15
3400	0,57	1,07
3500	0,02	1,00
3600	-0,53	0,94
3700	-1,08	0,88
3800	-1,59	0,83
3900	-2,03	0,79
4000	-2,52	0,75
4100	-3,01	0,71
4200	-3,46	0,67
4300	-3,90	0,64
4400	-4,33	0,61
4500	-4,74	0,58
4600	-5,15	0,55
4700	-5,54	0,53
4800	-5,93	0,51
4900	-6,30	0,48
5000	-6,67	0,46
5100	-7,02	0,45
5200	-7,37	0,43
5300	-7,71	0,41
5400	-8,04	0,40
5500	-8,37	0,38
5600	-8,68	0,37
5700	-8,99	0,36
5800	-9,29	0,34
5900	-9,59	0,33
6000	-9,83	0,32
6200	-10,43	0,30
6400	-10,97	0,28
6600	-11,48	0,27
6800	-11,97	0,25
7000	-12,44	0,24
7200	-12,90	0,23
7400	-13,33	0,22
7600	-13,75	0,21
7800	-14,15	0,20
8000	-14,54	0,19
8200	-14,92	0,18
8400	-15,28	0,17
8600	-15,63	0,17
8800	-15,97	0,16
9000	-16,29	0,15
9200	-16,61	0,15
9400	-16,91	0,14
9600	-17,21	0,14
9800	-17,50	0,13
10000	-17,77	0,13

FIGURE 5

(A figure numbered 5 was not retained for Chapter 3)

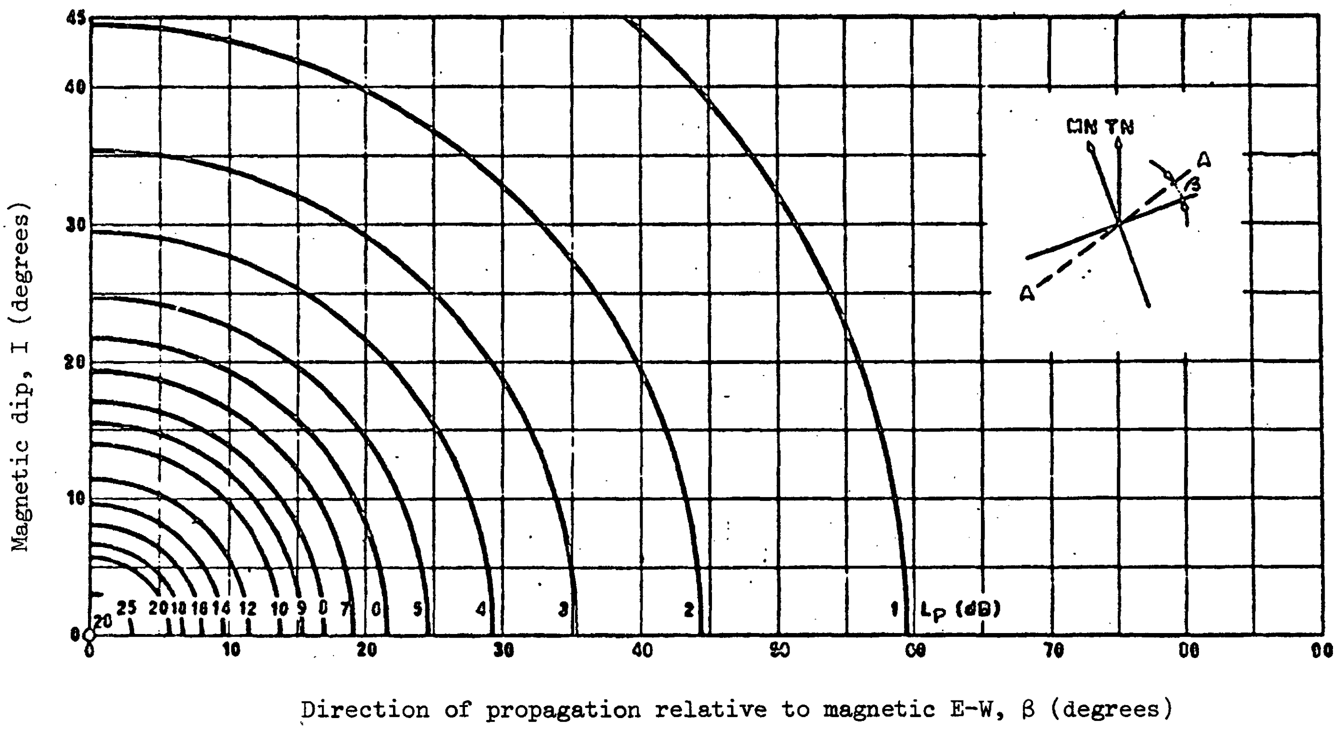


FIGURE 6 - Excess polarization coupling loss L_p for a single terminal

$$L_p = 180\,(36 + \beta^2 + I^2)^{-\frac{1}{2}} - 2$$

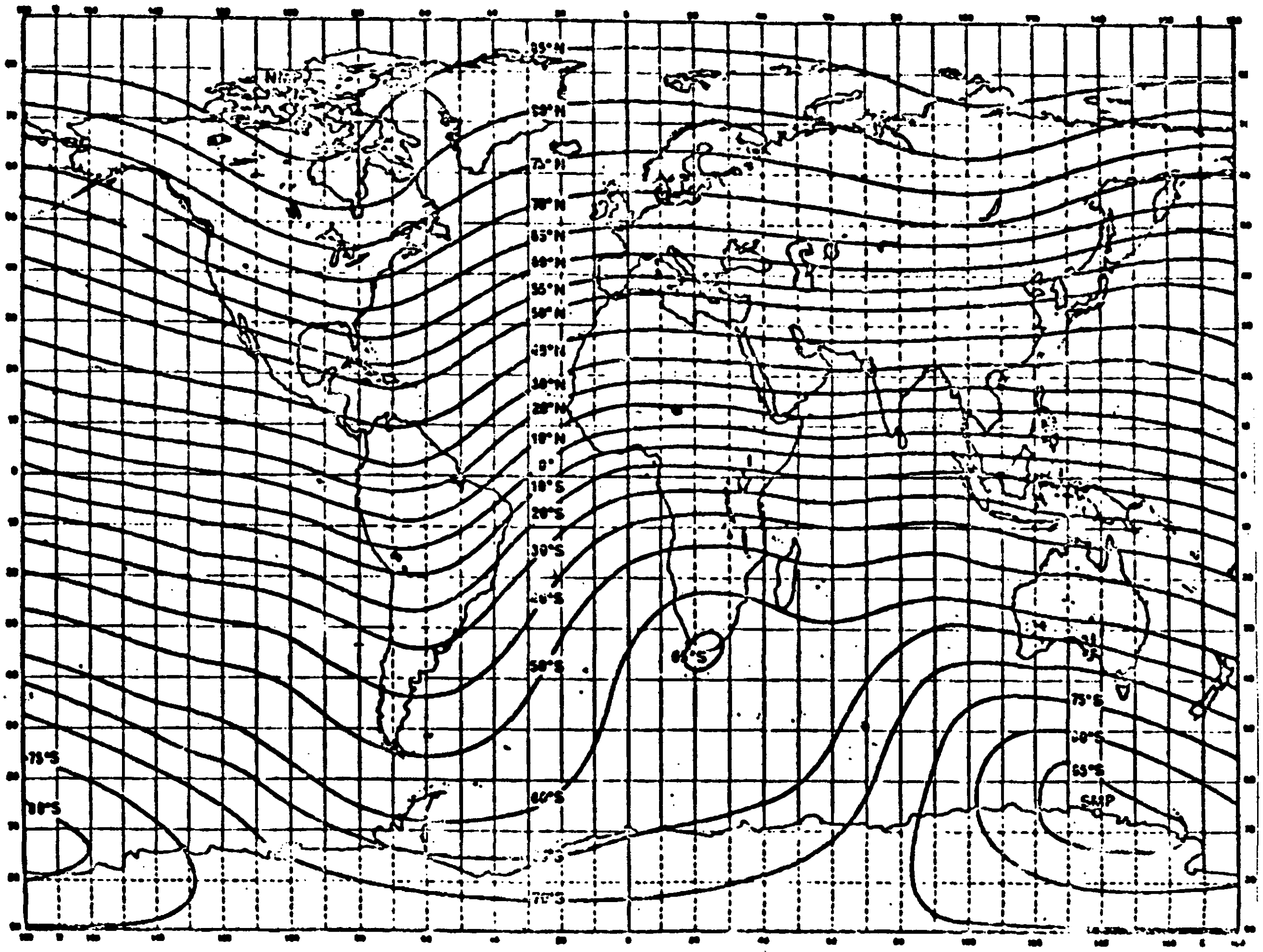


FIGURE 7 - Map of magnetic dip

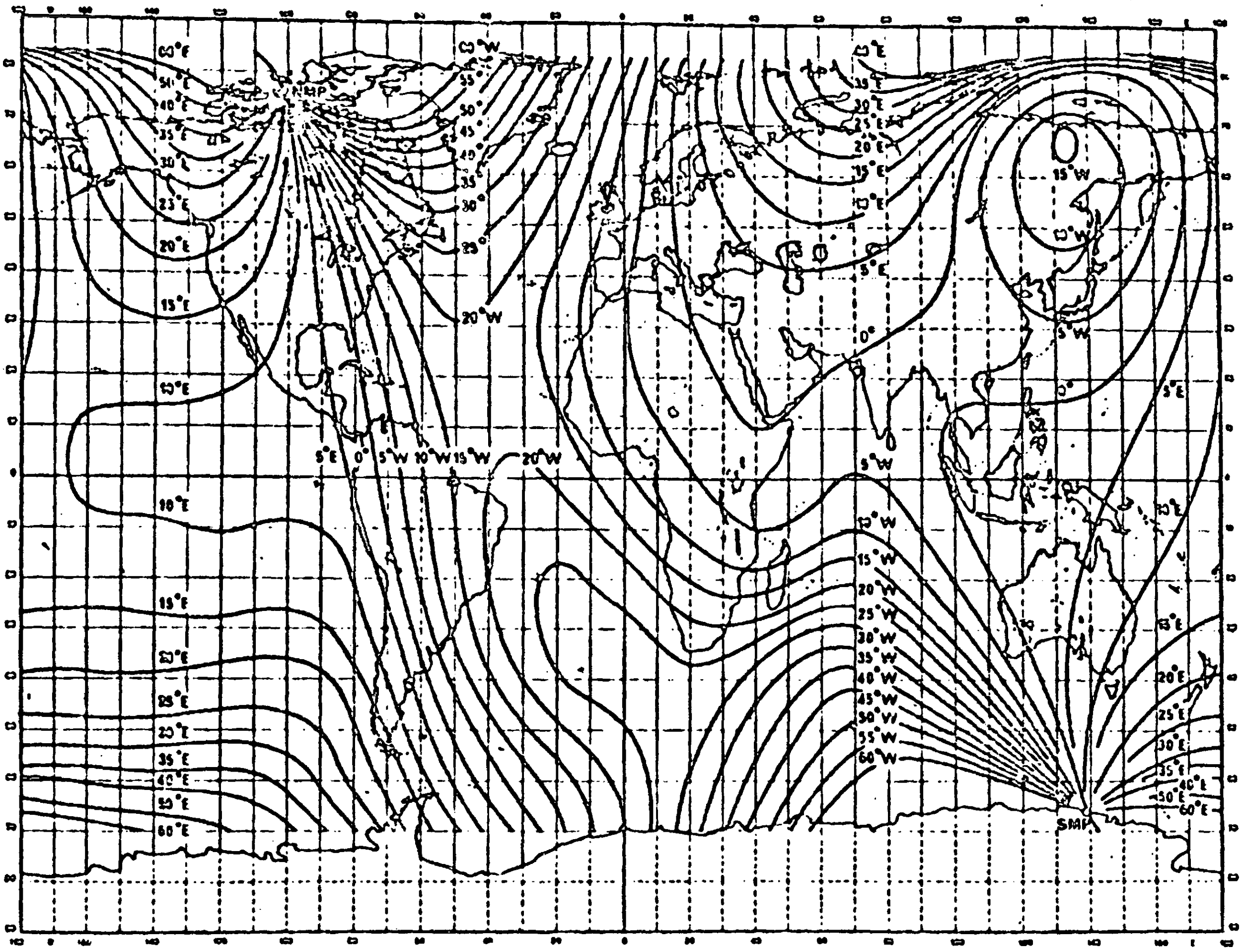


FIGURE 8 - Map of magnetic declination (dotted curves east declination, continuous curves west declination)

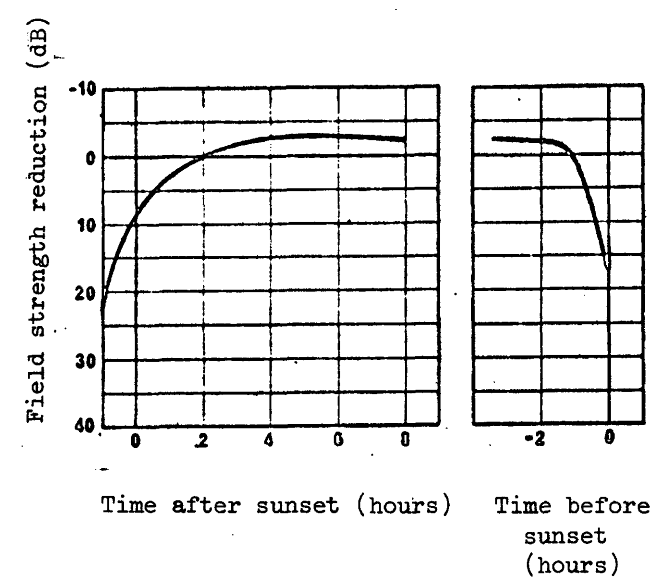


FIGURE 9 - Field strength variation during the night

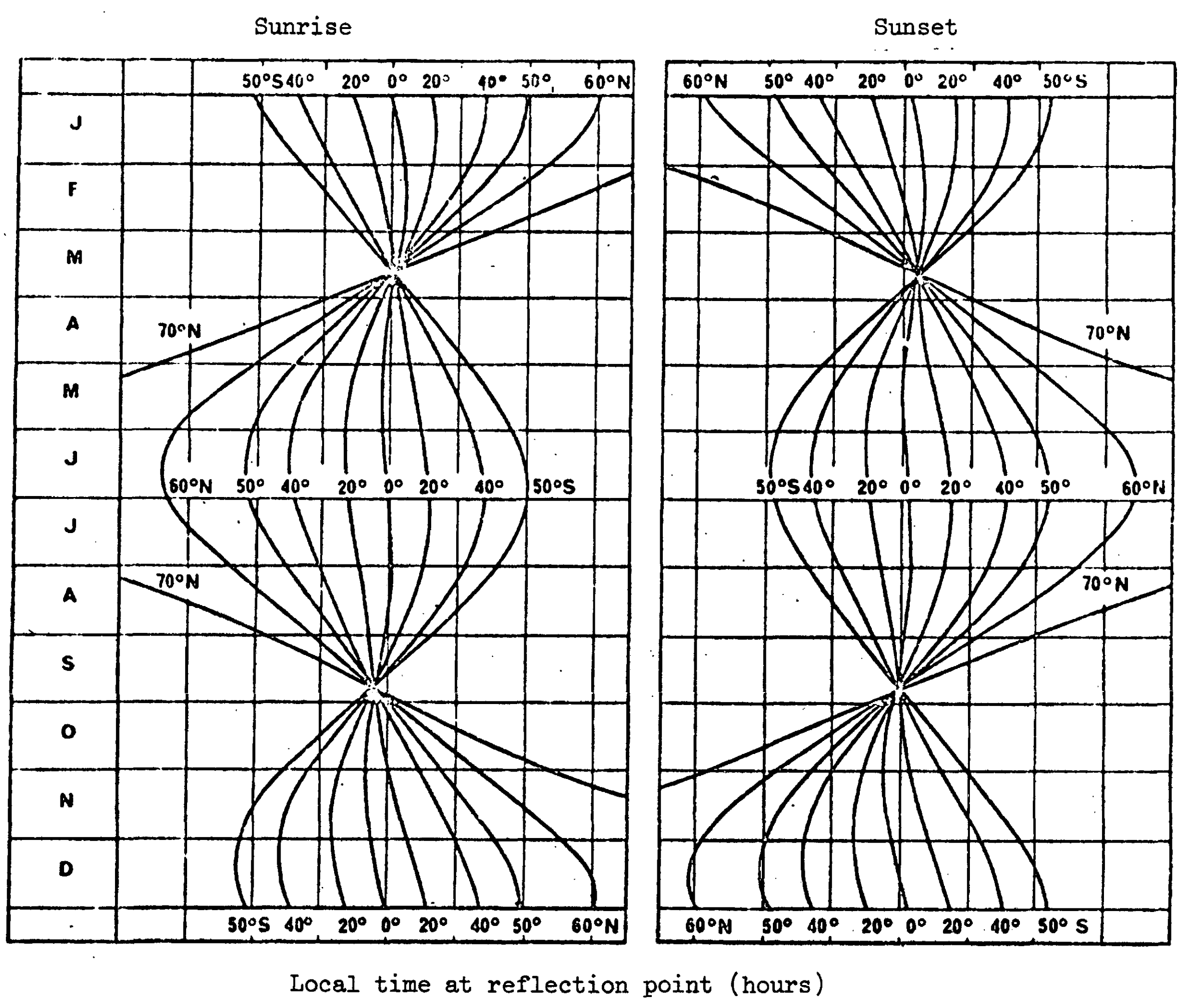


FIGURE 10 - Times of sunrise and sunset for various months and geographical latitudes

CHAPTER 4

BROADCASTING STANDARDS AND TRANSMISSION CHARACTERISTICS

4.1 Channel spacing and carrier frequencies

Consensus could not be reached on this topic during the First Session of the Regional Broadcasting Conference, Buenos Aires, 1980. The matter has therefore been referred to the IFRB and to a Panel of Experts, in order that an appropriate comparative report on 9 kHz and 10 kHz channel spacings be prepared for submission to the Second Session (see Resolution A).

4.2 Class of emission

The Plan will be established with double sideband amplitude modulation with full carrier (A3)*.

Classes of emission other than A3*, for instance to accommodate stereophonic systems, could also be used on condition that the energy level outside the necessary bandwidth does not exceed that normally expected in A3* emission and that the emission be receivable by conventional receivers employing envelope detectors without increasing appreciably the level of distortion.

4.3 Bandwidth of emission

4.3.1 For 9 kHz channel separation

The Plan will be drawn for a necessary bandwidth of 9 kHz. For 9 kHz necessary bandwidth, only 4.5 kHz audio bandwidth could be obtained. While this might be an appropriate value for some administrations, others which employ or wish to employ more sophisticated or wider bandwidth systems may use occupied bandwidths of the order of 20 kHz (approximately 10 kHz audio frequency bandwidth). Any administration whose station is adversely affected by such operation may require the modification of the interfering station's emissions in order to eliminate the interference.

4.3.2 For 10 kHz channel separation

The Plan will be drawn for a necessary bandwidth of 10 kHz. For 10 kHz necessary bandwidth, only 5 kHz audio bandwidth could be obtained. While this might be an appropriate value for some administrations, others which employ or wish to employ more sophisticated or wider bandwidth systems may use occupied bandwidths of the order of 20 kHz (approximately 10 kHz audio frequency bandwidth). Any administration whose station is adversely affected by such operation may require the modification of the interfering station's emissions in order to eliminate the interference.

* On 1 January 1982 when the new Radio Regulations (1979) come into effect, this classification changes to A3E.

4.4 TABLE IV - Nominal usable field strength[1][2]

	NOISE ZONE 1[3]	NOISE ZONE 2	NOISE ZONE 3
4.4.1	Class A station [4] Ground-wave Daytime : co-channel 100µV/m adjacent channel } 500µV/m Night-time: 500µV/m Sky-wave 500µV/m for 50% of time	Class A station [4] Ground-wave Daytime : co-channel 250µV/m adjacent channel } 500µV/m Night-time: 1250µV/m Sky-wave 1250µV/m for 50% of time	Class A station [4] Ground-wave Daytime : co-channel 750µV/m adjacent channel } 750µV/m Night-time: 1400µV/m Sky-wave 1400 µV/m for 50% of time
4.4.2	Class B station[5] Ground-wave Daytime : 500µV/m Night-time :2500µV/m	Class B station[5] Ground-wave Daytime 1250µV/m Night-time :6500µV/m	Class B station[5] Ground-wave Daytime :2800µV/m Night-time :7000µV/m
4.4.3	Class C station [5] Ground-wave Daytime : 500µV/m Night-time :4000µV/m	Class C station [5] Ground-wave Daytime :1250µV/m Night-time :10,000µV/m	Class C station [5] Ground-wave Daytime :2800µV/m Night-time :11,000µV/m

Notes : See the following page

Note 1 : The field strength values shown in the Table are used as the reference for planning (see definition in Chapter 1, paragraph 1.10).

Note 2 : Higher values than those shown in the Table may be adopted in order to satisfy noise limitations or particular agreements between two or more administrations.

Note 3 : The following nominal usable field strength values are adopted for Class A stations by the countries of Central America :

Ground-wave :

Daytime :	co-channel	500 μV/m
	adjacent channel	500 μV/m
Night-time :		1000 μV/m

Sky-wave : 1000 μV/m for 50 % of the time

These values will apply only within the sub-region referred to.

Note 4 : The night-time contour, ground-wave or sky-wave, whichever is the more distant, is to be protected in the case of Class A stations.

Note 5 : After the effective date of the Plan, the protected contour during night-time operation for Class B and C stations shall be the higher of the ground-wave contour in paragraphs 4.4.2 and 4.4.3 respectively, or the ground-wave contour corresponding to the RSS usable field strength of the station as defined in Chapter 6. The RSS method shall also be used to resolve incompatibilities that arise as a result of the initial planning phase.

4.4.4 Definition of noise zones

Noise zone 1

Includes the whole of Region 2 with the exception of noise zones 2 and 3.

Noise zone 2

Covers the area within the line defined by the coordinates 20° S - 45° W, the meridian 45° W to the coordinates 20° N - 45° W, the parallel 20° N to the coordinates 20° N - 80° W, the meridian 80° W, the north-eastern coast of Panama, the frontier between Panama and Columbia, the south-east coast of Panama and the meridian 82° W to the parallel 20° S, with the exception of noise zone 3, Chile and Paraguay; Bolivia is entirely included in noise zone 2 as are the islands belonging to Columbia.

Noise zone 3

Comprises the following : Ecuador, Colombia, Venezuela, Trinidad and Tobago.

The limits of the three noise zones are given in the map (Figure 1) which follows.

National borders close to the delimitation of noise zones may be used to define the high noise area if desired by the administration concerned.

4.5 Channel protection ratios

4.5.1 Co-channel protection ratio

The Plan will be based on a co-channel protection ratio of 26 dB.

4.5.2 Adjacent channel protection ratios

4.5.2.1 For 9 kHz channel separation

- protection ratio for the first adjacent channel : 5 dB*
- protection ratio for the second adjacent channel : -29.5 dB

4.5.5.2 For 10 kHz channel separation

- protection ratio for the first adjacent channel : 0 dB
- protection ratio for the second adjacent channel : -29.5 dB

4.5.3 Protection ratio for stations belonging to a synchronized network

The Plan will be based on a value of 8 dB.

* Smaller values for the first adjacent channel protection ratio, such as 0 dB, may be used, subject to agreement between the countries concerned or affected.

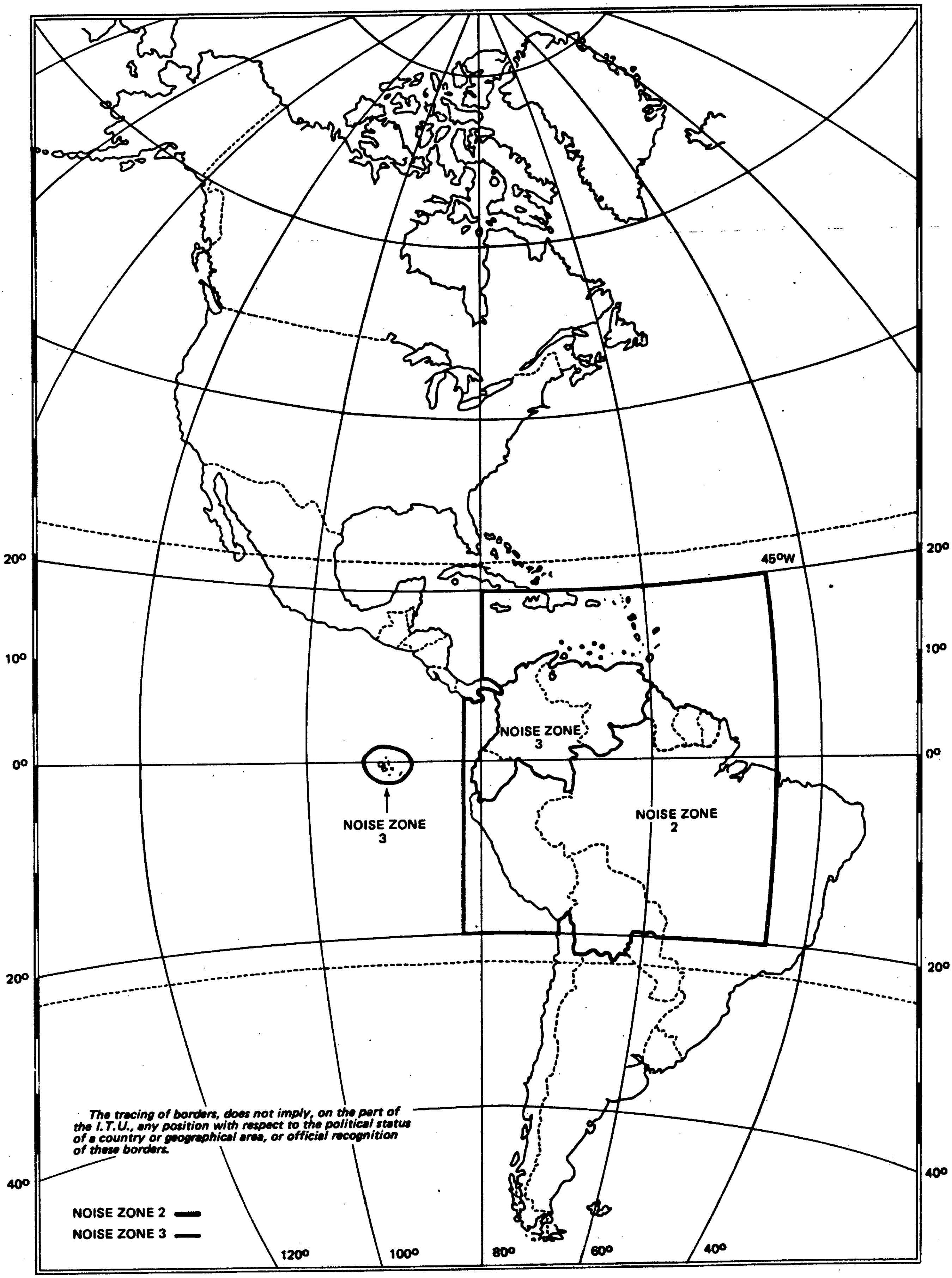


FIGURE 1 - Map showing the limits of the three noise zones

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CHAPTER 5

RADIATION CHARACTERISTICS OF TRANSMITTING ANTENNAE

5.1 Omnidirectional antennae

Figure 1 of Chapter 3 shows the characteristic field of a simple vertical antenna as functions of its length, and of the radius of the ground system. The characteristic field of an antenna with a loss-less ground system is also shown for comparison.

It is clear that the characteristic field strength increases as the loss in the ground system is reduced to zero and as the antenna height is increased up to 0.625λ. For planning purposes only the 0.25λ curve of Figure 1 of Chapter 3 need be used.

The increased characteristic field strength for antenna lengths up to 0.625λ is obtained at the expense of radiation at high angles as shown graphically in Figure 1a of Chapter 3 and numerically in Table II of Chapter 3.

5.2 Consideration of the radiation patterns of directional antennae

5.2.1 Information concerning the radiation patterns of transmitting antennae is given in both the CCIR Handbook of "Antenna Diagrams" (Geneva 1978) and in "Theory and Design of Directional Antennas", Carl E. Smith (1959). Additional information and a calculation procedure based on the latter are given in Annex F.

5.2.2 Several studies have been carried out to determine whether or not the method given in Annex F and the method used by the CCIR result in the same radiation patterns. These studies revealed that, on the assumption of no loss, there is no difference between the theoretical directional patterns obtained by the two methods.

The CCIR Handbook includes correction factors for three types of soil (poor, average and good) by means of graphs and equations. These CCIR correction factors are used in conjunction with the radiation patterns. Since normally a radial ground system is installed beneath a directional array, the method given in Annex F does not take into account such correction factors.

5.2.3 The examples given in the CCIR Handbook are limited to a maximum of four towers and the CCIR method is restricted to cases where the towers are of equal height. The method described here, on the other hand, provides data that can be expanded for calculating an array with any desired number of towers and can include the cases where unequal tower heights are involved. Many stations in North America presently use arrays employing more than four towers as well as arrays with towers of unequal length.

5.2.4 Adequate ground systems should be used together with a standard loss resistance of one ohm unless otherwise specified. Also the "Format for Notifying MF Broadcasting Stations" calls for a value of theoretical r.m.s. as well as a value of maximum radiation. The efficiency of an antenna system can therefore be easily determined.

5.2.5 The method described in Annex F gives the characteristic field strength in any direction from the antenna, and includes the effect of the antenna input power. The pattern diagrams shown in Annex F are for 1 kW radiated power.

It should be noted that the CCIR Antenna Handbook gives the radiation pattern of each antenna array described, referred to an e.m.r.p. of 1 kW (a characteristic field strength of 300 mV/m at 1 km) in the direction of maximum radiation. Each chart also gives the maximum gain of the antenna (G_V) and the characteristic field strength (F_{cs} in the Handbook).

5.3 Method to be used for calculating directional antenna patterns

5.3.1 In order for all the required studies to be performed on the multi-tower systems within the time constraints, the IFRB shall use computer programmes based on the method described in Annex F and modify them for their computer. These programmes are immediately available.

5.3.2 In those cases where the information required is not available for the calculation procedures described in Annex F, all particulars relating to the gain for different azimuths and angles of elevation should be provided by the responsible administration. The azimuths and the elevation angles for which the information shall be provided may be determined by the notifying administration. The accuracy with which the protected contour for a station with a highly directional antenna system shall be calculated may sometimes require that the antenna gain be known for intervals of five degrees or less in the horizontal plane, with a similar precision in the vertical plane.

5.3.3 When the administrations are not able to provide the data on the radiation characteristics as proposed in paragraph 5.3.2, the same information may be provided in the form of graphs on which the antenna gain is shown as a function of the azimuth and the angle of elevation. In this event care should be taken to mention, without any ambiguity the value used as reference for drawing the graph.

CHAPTER 6

ROOT SUM SQUARE (RSS) ADDITION OF WEIGHTED INTERFERENCE CONTRIBUTIONS TO DETERMINE USABLE FIELD STRENGTH

6.1 General

The overall usable field strength E_u due to two or more individual interference contributions is calculated on an RSS basis, using the expression

$$E_u = \sqrt{(a_1 E_1)^2 + (a_2 E_2)^2 + \ldots\ldots. (a_i E_i)^2 \ldots\ldots.} \qquad (1)$$

where :

E_i is the field strength of the ith interfering transmitter (in µV/m) ·

a_i is the radio frequency protection ratio associated with the ith interfering transmitter (see Figure 1) and expressed as a numerical ratio of field strengths.

Since each individual usable field strength contribution is, by definition, equal to the individual interfering field strength weighted by the associated protection ratio, the overall E_u calculated on an RSS basis takes into account the effect of frequency offsets between each interfering carrier and the wanted carrier.

6.2 50 % exclusion principle

The 50 % exclusion principle allows a significant reduction in the number of calculations.

With this method, the values of the individual usable field strength contributions are arranged in descending order of magnitude. If the second value is less than 50 % of the first value, the second value and all subsequent values are neglected. If the second value is not less than 50 % of the first, an RSS value is calculated for the first and second values. The calculated RSS value is then compared to the third value in the same manner by which the first value was compared to the second and a new RSS value is calculated if required. The process is continued until the next value to be compared is less than 50 % of the last calculated RSS. At that point the last calculated RSS value is considered to be the usable field strength E_u.

For planning purposes, if the contribution of a new station is greater than the smallest value considered in calculating the RSS value, the contribution of the new station is unacceptable even if it is less than 50 % of the RSS value. However, the new contribution is acceptable if the RSS value determined by inserting the contribution of the new station into the list of contributors is smaller than the nominal usable field strength E_{nom}.

6.3 Calculation of sky-wave interference to Class A stations

Interference to a Class A station is determined using the RSS calculation on site-to-contour basis (from the interfering transmitter to the protected contour) except when the 10 % interfering field strength is applied. The result of such calculations shall be compared with the nominal usable field strength to determine if there is an incompatibility. The results of this comparison may be used as a basis for discussions between administrations. See paragraph 6.8 (Chapter 6) for simplified method for such calculations.

6.4 Calculation of sky-wave interference to Class B or C stations

For a Class B or C station, the RSS of the interference shall be calculated site-to-site and the resulting protected contour shall be determined using the ground-wave method in Chapter 3.

6.5 Inter-regional heterodyne interference

The heterodyne beat effect due to interference from stations when carriers are separated by 1 or several kilohertz is dependent on the extent of compression used by the affected station and the characteristics of the receiver.

It is recommended that Figure 1 be used to produce a table of protection ratios to be applied for the calculation of heterodyne interference.

Any administration which considers that a curve of Figure 1 other than curve A should be used in determining the effect of heterodyne interference on the usable field strength of its stations should advise the IFRB before 31 May 1980.

6.6 Examples

The following examples illustrate the use of the RSS method and 50 % exclusion principle. The first example applies to the case where the interfering carriers are co-channel with the wanted carrier. In the second example, one of the interfering carriers is offset from the wanted carrier by 3 kHz while a second interfering carrier is offset by 5 kHz. The remaining interfering carriers are co-channel with the wanted carrier, as in the first example.

6.6.1 Example 1 : All interfering signals are co-channel with the wanted signals

Interfering signal (1)	Interfering signal field strength		Protection ratio (dB)	Individual usable field strength contribution (UFS)		Calculated RSS		Remarks
	(μV/m)	(dB(μV/m))		dB(μV/m)	μV/m	dB(μV/m)	μV/m	
A	140	42.9	26	68.9	2800			
C	130	42.3	26	68.3	2600	71.6	3812	$\sqrt{A^2 + C^2}$
B	125	41.9	26	67.9	2500	73.2	4555	Individual UFS greater than 50% of $\sqrt{A^2 + C^2}$ therefore $\sqrt{A^2 + C^2 + B^2}$.
D	65	36.3	26	62.3	1300			Individual UFS less than 50% of $\sqrt{A^2 + C^2 + B^2}$ therefore disregard
E	52	34.3	26	60.3	1040			idem

(1) in descending order of individual usable field strength contribution (UFS)

6.6.2 Example 2 : Interfering signals A, B and C are co-channel with the wanted signal; interfering signal D' is 3 kHz offset; interfering signal E' is 5 kHz offset

Interfering signal (1)	Interfering signal field strength		Protection ratio	Individual usable field strength contribution (UFS)		Calculated RSS		Remarks
	(μV/m)	(dB(μV/m))	(dB)	(dB(μV/m))	(μV/m)	(dB(μV/m))	(μV/m)	
D' (3 kHz offset)	65	36.3	40	76.3	6500			
A	140	42.9	26	68.9	2800	-	-	Individual UFS less than 50% of D', therefore disregard
C	130	42.3	26	68.3	2600			idem
B	125	41.9	26	67.9	2500			idem
E' (5 kHz offset)	52	34.3	30	64.3	1644			idem

(1) in descending order of individual usable field strength contribution (UFS)

6.7 Radio-frequency protection ratio curves

The curves in Figure 1 below may be applied as follows :

- curve A is used when a limited degree of modulation compression is applied at the transmitter input, such as in good quality transmissions, and when the bandwidth of the audio-frequency modulating signal is of the order of 10 kHz;
- curve B is used when a high degree of modulation compression (at least 10 dB greater than in the preceding case) is applied by means of an automatic device and when the bandwidth of the audio-frequency modulation signal is of the order of 10 kHz;
- curve C is used when a limited degree of modulation compression (as in the case of curve A) is applied and when the bandwidth of the audio-frequency modulating signal is of the order of 4.5 kHz;
- curve D is used when a high degree of modulation compression (as in the case of curve B) is applied by means of an automatic device and when the bandwidth of the audio-frequency modulating signal is of the order of 4.5 kHz.

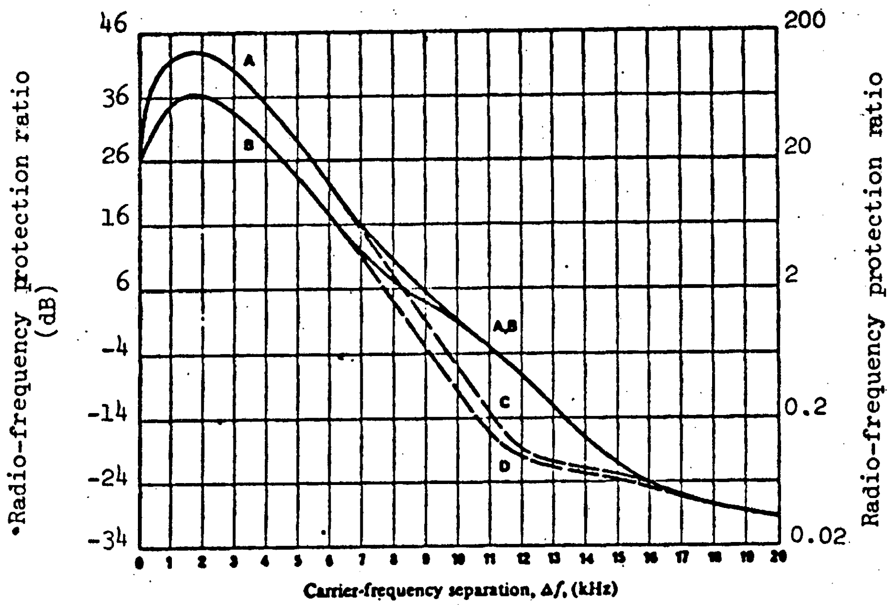

FIGURE 1 - Radio-frequency protection ratio as a function of the carrier-frequency separation

6.8 Simplified method for calculating sky-wave interference to Class A stations

The determination of interference to a Class A station using the RSS calculation on a site-to-contour basis can be simplified in the following way :

1) The site-to-site RSS usable field strength for the station to be protected is determined. The contributors to the RSS are identified. (The number of contributions are limited mathematically by the 50 % exclusion rule to a maximum of 5, these being the most significant).

2) For each contributor to the RSS, a protection point at the intersection of the sky-wave protected contour and the great circle line between the protected transmitter site and the contributor transmitter site is identified. (When only non-directional stations are involved this would be the worst case point for site-to-contour protection.)

3) Where directional stations are involved, the interfering signal is calculated on a site-to-site basis, using the one or more radiation maxima in the arc towards the protected contour. If one or more signals prove to be contributors to the previously established RSS usable field strength in point 1 above, protection points shall be identified at the intersections of the protected contour and the great circle lines along the azimuths corresponding to these radiation maxima.

4) To determine protection to Class A stations in accordance with this procedure, for each contributor to the site-to-site RSS as defined above, a calculation is made of the usable field strength contribution at each protection point. The results of such calculations are to be employed as in paragraph 6.3 (Chapter 6).

Should a more complex approach be deemed necessary by any affected administration, further consultations leading to agreement between all administrations concerned shall be undertaken on a case-by-case basis.

CHAPTER 7

BASIC INVENTORY OF THE REQUIREMENTS OF ADMINISTRATIONS

7.1 General

Having adopted the appropriate channel spacing, the Second Session of the Conference shall establish a Plan based on the basic inventory as modified in accordance with paragraph 7.3 below. In a second stage the Second Session of the Conference shall include in the Plan the requirements notified to the IFRB in accordance with paragraph 7.4 below concerning stations to be authorized in the period between 1 January 1983 and 31 December 1987.

The Second Session is requested to determine the circumstances under which assignments in the Plan may be deleted if they have not been authorized by administrations to be put into operation within a specified period after the Plan comes into force. In this regard, the Second Session is requested to establish appropriate procedures.

At the Second Session of the Conference, planning shall be based on the following material :

- basic inventory
- modifications to the basic inventory
- stations to be authorized in the period between 1 January 1983 and 31 December 1987
- any other modification or addition which the Second Session of the Conference may decide to take into consideration.

7.2 Basic inventory

The basic inventory consists of the data supplied to the Board in reply to its Circular-letter No. 441 of 24 August 1979 sent to administrations pursuant to Administrative Council Resolution No. 836. It contains the characteristics of existing broadcasting stations and those authorized by the end of 1982, as notified to the Board by 25 March 1980. However, administrations may make corrections to their requirements until 31 May 1980 with the condition that, for an increase in power of a Class A station or an addition of a new Class A station, the power shall not exceed 50 kW.

The Board will send a reminder to each administration which has failed to reply to Circular-letter No. 441, requesting it to submit its requirements as soon as possible and not later than 31 May 1980, and informing it that the power of its Class A stations must under no circumstances exceed 100 kW. If the Board has received no reply from an administration by 31 May 1980, it will include in the basic inventory the characteristics of that administration's stations as listed in Annex G of the present Report. Annex G may be modified or updated at any time by the Board prior to 31 May 1980 if it obtains more exact data from any source.

7.3 Modifications to the basic inventory

Between 1 June 1980 and the date of the first day of the Second Session of the Conference, administrations may notify the Board of the modifications to their requirements in the basic inventory. In so doing, administrations shall not increase the power of their Class A stations. However, a Class A station which is already listed in the basic inventory with a power less than 50 kW may increase that power so that it will not exceed 50 kW. This limit shall also apply to new stations.

Administrations shall use the form appearing in Annex H of this Report to notify the Board of these modifications.

7.4 Notification to the IFRB

Administrations shall notify to the IFRB, using the form in Annex H, their requirements concerning stations intended to be authorized in the period between 1 January 1983 and 31 December 1987, except the indication of the channels which will be determined by the Second Session of the Conference on the basis of the adopted channel spacing. Such communication shall reach the Board not later than 31 May 1981.

CHAPTER 8

PROCEDURE TO BE FOLLOWED BY THE BOARD IN PREPARING FOR THE SECOND SESSION OF THE CONFERENCE

8.1 The Board will prepare for publication as soon as possible the basic inventory containing the data of every administration. A copy will be distributed to each administration. Subsequent modifications will be published and distributed on a monthly basis. All this information will be made available in computer-readable as well as in printed form.

8.2 With the cooperation of the Panel of Experts mentioned in Resolution A, the Board will study the basic inventory with the modifications supplied in accordance with Chapter 7. For this study it will use the technical criteria adopted by the First Session of the Conference, and will develop computer programmes to calculate, for example :

- shape of the directional antenna pattern for an array containing up to 15 towers;
- scale factor of a directional antenna pattern;
- mixed path propagation loss due to different ground conductivities;
- ground-wave interference;
- sky-wave interference, taking into account propagation conditions and RSS night-time limitations;
- interference between stations in different Regions;
- service area of each station;
- sub-programmes related to the above programmes, for example digitized geographical and conductivity maps, and digitized ground-wave and sky-wave propagation curves.

Those administrations which have developed any of the above programmes are requested to make them available to the Board and to offer the assistance of experts in order to facilitate the adaptation of such programmes.

8.3 The study mentioned above will also allow the Board to provide assistance to administrations in determining :

- when requested by an administration, the frequency to be assigned to a station and the related technical parameters needed to satisfy new requirements;
- incompatibilities between all new requirements.

8.4 In accordance with Resolution A, the Board will undertake the above study for both 9 and 10 kHz channel separation, and will prepare for the Second Session of the Conference a report indicating the comparative results.

To this effect, stations will be examined in the following order :

- stations in the basic inventory as defined in paragraph 7.2 (Chapter 7);
- modifications to the basic inventory (see paragraph 7.3 (Chapter 7)).

8.5 The IFRB shall prepare for consideration by the Conference the list of requirements received in application of paragraph 7.4 (Chapter 7).

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ANNEX A

PLANNING METHOD

A. AN APPROACH TO DETERMINING BASIC STATION PARAMETERS

1. Introduction

The method outlined in this Annex is for use in the design phase of the planning procedure where new medium frequency (MF) stations are being introduced into an existing congested MF environment. This method does not supersede the formal frequency assignment procedure, as it uses an approximation to the propagation models employed in that procedure.

The method constitutes a simple way of determining available frequencies and permissible radiation levels between a proposed station and existing protected stations. It is an iterative procedure for determining the basic daytime and night-time radiation constraints on the radiation patterns of each new station. New stations should be considered in turn in order of their national priority - with each new station protecting all existing stations and any new stations with a higher priority.

This simplified method allows for treatment of directional as well as omnidirectional stations and refers to other optional refinements which can be included at the user's discretion. In many cases this method provides the permissible radiation levels to within 10 % of the rigorously calculated required protection levels.

2. Objective of the procedure

This procedure presupposes :

1) that areas requiring new MF services have already been determined;

2) that each proposed new service has been assigned a station class (A, B or C) and a priority which ranks it among the needs for all new services on a national basis.

Applying the above assumptions, the objectives of this Annex is to develop a simple procedure which can be adapted for use on a computer or a programmable calculator. It determines the best frequency, the assignment constraints and the basic technical parameters for a large number of new stations, one by one, according to their class and priority ranking. It is further assumed that these new stations will operate in a specified geographic area in an already congested MF environment.

3. Overview of the planning process

In general due to the large existing Region 2 MF station inventory, planning from a zero base is impractical.

As the first stage in the planning process, each administration should determine its additional MF radio station needs; define the general location and coverage requirement and assign a priority to each need. Following initial studies, if incompatibilities are determined, administrations should meet to resolve these situations, using as a basis the more rigorous criteria defined in Chapters 3, 4, 5 and 6 of this Report. These stages are outside the scope of this Annex which covers only preliminary and intermediate design stages.

The final objective of a planning process is to make the most efficient use of the frequency spectrum to obtain the desired coverage while protecting other stations. It is essential that stations operate within the agreed power limits while meeting the technical criteria for protection to other stations.

3.1 Selection of the appropriate frequency

The procedure commences with a predetermined list giving the class and priority ranking of the required additional stations. It is then necessary to determine, for the station under consideration, the frequency channel or channels where existing interference is minimum. This search may require examination of all or part of the MF band depending on the particular case. Frequently, several channels might be appropriate for use at the site considered, because their various interference levels do not differ substantially.

In view of the many possible frequencies that may be employed at each transmitter site, it might be useful to start the selection of frequency assignments at the site believed to have the lowest number of choices and continue in the order of increasing number of choices. Before an assignment has been fixed, however, it is necessary to verify whether or not this frequency prohibits other proposed assignments still to be considered. The frequency selected should be that having the least effect on the remaining assignments.

The greatest difficulty will arise when selecting Class A stations; therefore, they should be given priority. Class B and then Class C stations should be dealt with subsequently.

3.2 Determination of permissible radiation

Once a potentially suitable frequency has been found at the site selected for a new station, a calculation is then made of permissible radiation in each direction to protect other existing stations from both night and daytime interference caused by the new station. The permissible radiation in each direction will then determine the shape of a directional pattern or the maximum radiation of an omnidirectional antenna which should be used to provide the required protection to these other stations.

4. Outline of proposed method

The method provides an estimate of the permissible radiation level from a new proposed station at a specified location operating on a given frequency. Protection must be provided to existing stations at their protected contours. In general, several different contours must be considered :

- daytime ground-wave
- night-time ground-wave, and
- for Class A stations, night-time sky-wave.

For a first approximation, the assumptions given in the next section are adequate. Better estimates can be developed which will recognize specific station parameters such as more precise conductivity values, polarization coupling loss, etc.; however, a much greater effort is required to develop these estimates.

The appropriate protection ratio (summarized in section 9) is applied at the protected contour to determine the permissible signal level from the proposed station (ground-wave in the daytime, sky-wave at night). The signal levels have been used in developing the appended curves shown in Figures 1 and 2 from which permissible radiations at the pertinent azimuths can be read directly.

5. Method

5.1 Explanation of curves*

5.1.1 Figure 1 - Sky-wave curves

Curves 1, 3 and 4 of Figure 1 indicate the permissible radiation at a given distance between a proposed station and any protected (existing or proposed) station. Curve 2 indicates the permissible radiation at given distances from the protected contour. When a Class B or C station is protected using the 50 % root sum square (RSS) method (see Chapter 6), the RSS value in mV/m of usable field strength is used as a multiplying factor on the value from curve 2 to give the permissible radiation. This planning method uses 50 % sky-wave propagation curves, and a 26 dB co-channel protection ratio. This permits a realistic assessment of the service area that is protected from night-time interference.

5.1.2 Figure 2 - Ground-wave curves

The four curves shown indicate the permissible radiation at a given distance between a proposed station on 1 000 kHz and a protected contour of 500 μV/m for different average values of conductivity over the path. To improve precision there could be a separate figure for each frequency range on the propagation curves and further curves for other conductivity values. This improvement in precision would not unduly increase the effort needed to use this method.

The curves were drawn to cover a first adjacent channel protection of 0 dB at the 500 μV/m contour and hence can also be used directly to determine the distance to the protected 500 μV/m contour when the radiation value is known. For other protection requirements, the permissible radiation value given by the curves should be multiplied by the appropriate factors taken from the Table at the bottom of Figure 2.

5.2 The assumptions applied in determining distance to protected contours in curves 1, 3 and 4 of Figure 1 are listed in section 7.

5.3 Application of method

5.3.1 Sky-wave

From Figure 1 choose the appropriate curve (curve 1, 3 or 4 depending on whether the protected station is Class A, B or C respectively). Using the station-to-station distance along the horizontal axis, read the permissible radiation from the vertical axis. Permissible radiations are at the pertinent range of vertical angles of departure as determined from Table I of Chapter 3.

Record the permissible radiation and, if a directional antenna is proposed, the pertinent azimuth (a polar plot is suggested).

Repeat the previous two steps for any other co-channel station whose protection may affect the operating parameters of the proposed station.

* Since Annex A was written, a new method has been accepted by the Conference for providing night-time protection to a Class A station. However, the method given in Annex A for protecting a Class B or C station remains valid.

Therefore, for a Class A station, in Figure 1, curve 2 should now be used instead of curve 1. Furthermore, the RSS calculation needs to be made in accordance with paragraph 6.3 of Chapter 6.

The Canadian Administration will undertake to update the calculation contained in the example shown in this Annex, before the Second Session.

5.3.2 Ground-wave

For overland paths, determine the weighted mean conductivity over the path from the proposed station to the protected contour as follows :

$$C_{mean} = \frac{C_1 d_1 + C_2 d_2 + \ldots + C_n d_n}{d_1 + d_2 + \ldots + d_n}$$

where the path is broken down into segments of distance d_1 to d_n and conductivities C_1 to C_n.

When part of the path is over sea, determine a weighted mean conductivity for the land sections by the above procedure and use the mixed path method given in Chapter 5 for the land/sea calculation.

On the graph for the appropriate frequency range (Figure 2 is based on 1 000 kHz) use the curve nearest the mean conductivity determined above, at the distance corresponding to the denominator above, along the vertical axis and read permissible radiation from the horizontal axis.

Apply the appropriate multiplying factor as described in paragraph 5.1.2 above and record the permissible radiation and, if a directional antenna is proposed, the pertinent azimuth.

Repeat the above three steps for any other station whose ground-wave protection might affect the operating parameters of the proposed station.

5.3.3 Determination of station parameters

For an omnidirectional system, divide the lowest value of permissible radiation recorded by the characteristic radiation for the antenna height and ground system proposed (as read from Figure 1, Chapter 3), and square this division to get the permissible station power in kilowatts.

For a directional antenna system, the recorded values of permissible radiation and azimuths provide the outer limits for the antenna pattern. A simple refinement to define protection requirements over the protected contour is to extend the permissible radiation over the arc from the proposed station to the limits of the protected contour. The protected contour can be approximated from the values in section 7 or determined from the appropriate propagation curves depending on the degree of accuracy needed.

Daytime and night-time limitations can be either combined or separated, depending on service requirements or economic limitations. The easiest type of directional system to construct and maintain uses only one pattern. Next in ease of construction and maintenance, and often superior in service, is the directional-by-night/omnidirectional-by-day system. A two pattern system is the most complex but allows optimum service in a highly populated area with many stations.

6. Examples

6.1 The following shows an example of the method described above. The appended map (Figure 3) shows the stations to be protected by a proposed station to serve City P on frequency 1 000 kHz. Azimuths are referred to true North.

Also on 1 000 kHz are :

- Station 1 at 3 000 km, azimuth 30°, Class A
- Station 2 at 1 000 km, azimuth 170°, Class B
- Station 3 at 1 500 km, azimuth 120°, Class C
- Station 4 at 400 km, azimuth 350°, Class B, day only.

On 990 kHz are :

- Station 5 at 300 km, azimuth 60°, Class C
- Station 6 at 500 km, azimuth 270°, Class B.

On 1 010 kHz is :

- Station 7 at 600 km, azimuth 300°, Class A.

On 980 kHz is :

- Station 8 at 205 km, azimuth 110°, Class B.

6.2 These stations produce the following limitations on the proposed station. The calculations pertain to noise zone 1, but the method is applicable to the other zones with appropriate corrections.

Station 1 - At 30° azimuth and 1.5° vertical angle (from Table 1 of Chapter 3) from curve 1 of Figure 1 : 454 mV/m.

Station 2 - At 170° azimuth and 9.3° vertical angle, from curve 3 of Figure 1 : 452 mV/m.

Station 3 - At 120° azimuth and 4.0° vertical angle, from curve 4 of Figure 1 : 1 870 mV/m.

These three stations are too far away to limit daytime radiation.

Station 4 - Assuming a typical Class B station (see section 7) the radiation is 307 x $\sqrt{10}$ = 971 mV/m at 1 km. From the 15 mS/m curve of Figure 2 the protected contour lies at a distance from station 4 of : 180 km. Thus the distance to the protected contour from the proposed station is : 400 - 180 = 220 km. From the 15 mS/m curve and the multiplying factor table the permissible radiation at 350° is : 1 530 x 0.05 = 76.5 mV/m.

Station 5 - Assuming a typical Class C station (see section 7) the radiation is 307 x $\sqrt{0.5}$ = 217 mV/m at 1 km. Thus from the 15 mS/m curve, the protected contour lies at a distance from station 5 of : 96 km. The distance to the protected contour from the proposed station is : 300 - 96 = 204 km. The permissible radiation at 60° is 1 300 mV/m.

Station 6 - As for station 4, the radiation is 971 mV/m at 1 km. From the 5 mS/m curve, the protected contour lies at a distance from station 6 of : 100 km. From the 15 mS/m curve, the distance to the protected contour from the proposed station is : 500 - 107 = 393 km. The permissible radiation at 270° is : 11 500 mV/m. These values are too large to be significant.

Station 7 - Assuming a typical Class A station (see section 7) the radiation is 385 x $\sqrt{50}$ = 2 722 mV/m. From the 5 mS/m curve, the protected contour lies at a distance from station 7 of : 150 km. The distance to the protected contour from the proposed station is : 600 - 150 = 450 km. As for station 6, the permissible radiation is too large to cause a restriction.

Station 8 - As for station 4, the protected contour lies at a distance from station 8 of : 180 km. The distance to the protected contour from the proposed station is : 205 - 180 = 25 km. The permissible radiation at 110° is : 19.6 x 30 = 588 mV/m.

6.3 In view of these limitations, it is apparent that, unless a power level of less than 100 W is suitable for daytime service needs a directional antenna system is required. Hence it would be practical to determine the arcs of protection. The simplified method is to take the arc-sine of the distance to the protected contour divided by the station-to-station distance. For station 1 the arc-sine is : 1170/3000 = 23°.

6.4 A further refinement for determining the permissible radiation at the contour extremes might also be useful. In this case, the distance to the protected contour becomes : 2 760 km.

From curve 2 of Figure 1 the permissible radiation is : 1 430 mV/m at 1 km.

For station 2 the arc-sine is : 50/1000 = 3°.

For station 3 no refinement is needed.

For station 4 the arc-sine is : 180/400 = 26.7°.

At the extremities of this arc the protected contour is at : 357 km and the permissible radiation is : 7 800 x 0.05 = 390 mV/m.

For station 5 no refinement is needed.

For station 8 the arc-sine is : 180/205 = 61.4°.

At the extremities of this arc the distance is : 98 km and the permissible radiation is : 230 x 30 = 6 900 mV/m.

At 30° from the station-to-station azimuth, the distance is : 30 km and the permissible radiation is 25.5 x 30 = 765 mV/m.

6.5 Station design

The pattern limitations require a wide null to the north and a narrow null to the south, with modest restrictions at 110° and 250° if a station power of 5 kW or greater is required. The minimum radiation requirements for service should be added to Figure 4 and a pattern determined to meet these and the protection requirements. For maximum service, a daytime pattern which need not consider protections to stations 1, 2 and 3 and a night-time pattern which need not protect station 4 could be designed. As shown below, a 50 kW station with maximum daytime service over a wide arc to the south and maximum night-time service over a fairly wide arc to the north-west using six vertical radiators is feasible.

6.6 Pattern design

The permissible radiation is tightly limited over relatively wide arcs in the northerly and north-easterly directions for day and night services respectively. Other limitations are not as restrictive but must be considered if powers over 1 kW are contemplated.

If powers of 50 kW are desired for both night-time and daytime operation, patterns have been calculated and are shown in Figures 5 and 6, based on the use of the same six towers for the two patterns.

If powers of 5 or 10 kW were considered, the number of towers could be reduced. For omnidirectional operation powers would be limited to around 100 W in daytime and about 500 W at night-time.

6.7 Further flexibility with RSS calculations

With the RSS method of determining usable field strength incorporating the 50 % exclusion rule described in Chapter 6, it is often possible to increase radiation without noticeably increasing interference. Let us assume that there is another Class B station 800 km south of station 2 (which we ignored because we would automatically be protecting it while protecting station 2) which has a directional 10 kW operation and radiates 800 mV/m towards station 2. This situation would cause a signal level at station 2 of : 0.275 mV/m. The signal strength caused by stations 1 and 3 is less than 50 % of this value. Therefore, the RSS usable field strength for station 2 is : 0.275 x 20 = 5.5 mV/m.

From curve 2 of Figure 1 the permissible radiation toward station 2 is : 97.9 x 4.12 = 538 mV/m.

This would allow better service to the south, and possibly a decrease in the number of required radiators.

7. Assumptions used to determine distances to protected contours

For Class A stations

- The night-time protected contour corresponds to 500 μV/m sky-wave 50 % of the time.
- The protected station operates with a station power of 50 kW.
- The protected station uses an omnidirectional antenna of height 0.5 λ and a ground system of radius 0.25 λ. From Chapter 3, Figure 1, the characteristic field strength of the station is 385 mV/m at 1 km.
- The distance to the 500 μV/m contour using these assumptions is 1 170 km from Chapter 3, Figure 4.

For Class B stations

- The protected contour is the nominal usable field strength for a Class B station, i.e. the 2 500 μV/m ground-wave contour (night-time) or the 500 μV/m ground-wave contour (daytime).
- The protected station operates with a station power of 10 kW.
- The protected station uses an antenna of height 0.25 λ and a ground system of radius 0.25 λ. From Chapter 3, Figure 1, the characteristic field strength of the station is 307 mV/m at 1 km.
- The ground conductivity is 5 mS/m and the frequency is 1 000 kHz.
- The distance to the 2 500 μV/m contour using these assumptions is 54 km and to the 500 μV/m contour is 107 km from Annex D, graph 12.

For Class C stations

- The night-time protected contour is the nominal usable field for a Class C station, i.e. 4 000 μV/m ground-wave contour.
- The protected station operates with a station power of 500 W.
- The protected station uses an antenna of height 0.25 λ and a ground system of radius 0.25 λ. From Chapter 3, Figure 1, the characteristic field strength of the station is 307 mV/m at 1 km.

- The ground conductivity is 5 mS/m and the frequency is 1 000 kHz.
- The distance to the 4 000 µV/m contour using these assumptions is 20 km from Chapter 3, Annex D, graph 12.

8. Additional ground-wave protection considerations

8.1 Introduction

In the initial evaluation of the frequency most appropriate for use by a new station, the considerations below should be applied, since they minimize the possibilities for interference created by the characteristics of receivers within the service contours of stations in the same area.

However, in areas where usable channels are scarce administrations may wish to implement assignments despite the described constraints.

8.2 Receiver oscillator radiation constraint

The mechanism which causes this constraint is the radiation of the local oscillator in receivers. A receiver tuned to frequency f will radiate in its vicinity at a frequency of f plus the intermediate frequency (IF). Therefore, any radio station assigned to this higher frequency f + IF would suffer interference to its reception in the same community from the receivers of listeners tuned to the station at frequency f.

Protection against this form of interference requires a 0 dB protection ratio at the ground-wave 500 µV/m contour between the protected station and the signal of any new proposed station. This is identical to the protection levels required for the first adjacent channel.

8.3 Receiver image constraint

The mechanism which causes this constraint is the lack of image frequency rejection in most common receivers. A receiver tuned to frequency f will also receive a signal at f plus twice the intermediate frequency.

Protection against this interference mechanism requires the same level of protection as for the first adjacent channel or the receiver oscillator radiation constraint.

This material is also noted in section 9.

9. Summary of ground-wave protection requirements

TABLE V

	Protected contour[1] (Nominal usable field strength) (µV/m)	Protection ratio (dB)	Level of interfering signal (uV/m)[1]
Co-channel Daytime Class A	100	26	5
Co-channel Daytime Class B and C	500	26	25
Daytime and night-time First adjacent channel Receiver oscillator radiation constraint[2] Receiver image constraint[3]			
10 kHz	500	0	500
9 kHz	500	5	280
Daytime and night-time Second adjacent channel	500	-29.5	15,000
Daytime and night-time Third adjacent channel	25 000	0	25 000

1) These values are valid for noise zone 1 but can be altered to be appropriate for noise zones 2 and 3 using the table of nominal usable field strengths (see Chapter 4, section 4.4).

2) Frequency plus or minus 450 or 460 kHz.

3) Frequency plus or minus 910, 920 or 930 kHz.

10. Guidelines for assigning a class to a station

The following guidelines offer a method of deciding the class that is appropriate for each station. The method closely follows the definition of each class of station, and thus yields a result that is both logical and defensible.

Class A

A Class A station is intended to provide coverage over extensive primary and secondary service areas and is protected against interference accordingly. Therefore, a Class A station should have a transmitter power of 10 kW or more and should have a secondary service area that is protected against sky-wave interference.

Class B

A Class B station is intended to provide coverage over one or more population centres and the rural areas contiguous to them, located in its primary service area, and is protected against interference accordingly. Therefore a Class B station would have a transmitter power greater than 1 kW and up to 50 kW, and would not have a secondary service area that is protected against sky-wave interference. A station having a transmitter power of 1 kW or less would also qualify as Class B provided its RSS night-time limitation is less than 2 000 µV/m.

Class C

A Class C station is intended to provide coverage over a city or town and the contiguous suburban areas located in its primary service area, and is protected against interference accordingly. Therefore, a Class C station must have a power in accordance with Chapter 2 of the Report.

B. ASSIGNMENT CAPACITY AROUND A STATION

1. Assignment capacity around a Class A station

1.1 Positioning of Class B or C stations around a Class A station

Assuming that the Class A station operates omnidirectionally, the 500 µV/m sky-wave night-time contour 50 % of the time will be found, according to power, at the following distances :

50 kW	1 125 km
100 kW	1 325 km
200 kW	1 500 km

An interfering station may have a sky-wave field strength of 25 µV/m at any point on the protected contour. This means a distance of 1 500 km measured from an interfering station with a power of 1 kW to the protected contour of the Class A station.

Figure 7 shows the distances in question for the case of a 200 kW Class A station.

The distance x = 1 950 km is that which ensures a field strength from station 2 which satisfies the 50 % exclusion rule at point 1'. The same should be true for a signal from station 1 which reaches point 2'. It remains to calculate the angle α, substended by the Class A station, in order to satisfy the above condition.

From the cosine theorem, we have :

$$x^2 = (R + d)^2 + R^2 - 2(R + d) \cdot R \cos \alpha$$

We then have :

$$\cos \alpha = \frac{(R + d)^2 + R^2 - x^2}{2(R + d) R}$$

In the example, the result is :

$$\cos \alpha = 0.8275, \text{ hence } \alpha = 34.15^\circ$$

The same calculation can be used for 50 kW and 100 kW stations; the results are shown in the table below :

P (kW)	R (km)	d (km)	x (km)	α (o)
50	1125	1500	1950	42.52
100	1325	1500	1950	37.57
200	1500	1500	1950	34.15

In the worst case, the angle does not exceed 45°.

Therefore, this value can be taken to re-calculate the distance x and the field strengths at 1' or 2'. The calculations are summarized in the table below :

P (kW)	R (km)	d (km)	α (°)	x (km)	E(dB(μV/m))
50	1125	1500	45	2005	20
100	1325	1500	45	2120	18,5
200	1500	1500	45	2225	17,5

The values for E correspond to a Class C station which radiates 1 kW to the Class A station with a characteristic field strength of 240 mV/m at 1 km.

It is also necessary to check the interference from the Class A station to the Class C stations. Here it will be necessary to calculate the distance at which the Class A station has a sky-wave field strength of 200 μV/m.

The results are shown below :

P (kW)	200 μV/m	(R + d) km
50	1625	2625
100	1800	2825
200	2000	3000

If we compare the third column with the second, we note that the spacing between stations (R + d) is greater than the distance at which we have a value of 200 μV/m. Therefore, the reciprocal case is also true.

It remains to be seen whether between 1 kW stations the minimum separation requirement is complied with. Here, it will be necessary to use (R + d) for each power level and the cosine theorem.

Thus we have :

P (kW)	R + d (km)	S (km)	200 μV/m
50	2625	2033	1625
100	2825	2188	1800
200	3000	2324	2000

The values for S are greater than the corresponding values at 200 μV/m.

Conclusion

It is possible to accommodate eight stations around one Class A station without exceeding the 50 % exclusion rule at any point. Such stations will be Class C.

If we accept a difference of about 1 dB between the stations set up around the Class A stations, such stations could be Class B.

1.2 Positioning of Class A stations around another Class A station

Carrying out an analysis similar to the preceding one, and given the position of a specific station to which an assignment has been made, it is found that non-directional stations may be positioned in the following numbers and angular positions :

Assigned station	Stations around it		
200 kW	200 kW	100 kW	50 kW
Angular position	120°	72°	60°
Quantity	3	5	6
Distance (km)	6250	6075	5875

Assigned station	Stations around it		
50 kW	200 kW	100 kW	50 kW
Angular position	180°	120°	90°
Quantity	2	3	4
Distance (km)	5875	5225	4625

Conclusion

It can be seen from the foregoing tables that the best utilization was achieved with 50 kW stations. This enables a single channel to be used in three zones of the Americas with Class A stations, for instance in North, Central and South America.

2. Assignment capacity around a Class B station

The 50 % exclusion rule can be satisfied as follows : assume there are two 5 kW assignments and the distance between them is 1 120 km.

A third station may be positioned at a distance enabling this rule to be satisfied but its power should be 1.25 kW. Figure 8 shows the maximum capacity of assignments around the first station without affecting the quality of the service in the zone under consideration.

The values at each point correspond to the field strengths produced at each station by the others.

The RSS value of the field strengths reaching the first station is :

$$RSS = (125^2 + 4 \times 62.5^2)^{\frac{1}{2}} = 176.7 \ \mu V/m$$

This interference value is equal to that produced by two 5 kW stations at the location of the first station, since

$$RSS = (125^2 + 125^2)^{\frac{1}{2}} = 176.7 \ \mu V/m$$

Hence Figure 8 may be replaced by an equilateral triangle (Figure 9) and the effect of two stations on the third is still the same.

If we consider two 10 kW stations, the results are similar, but in this case the field strength of the third station at the first will be 6 dB less than the interfering signal from the second 10 kW station.

Thus the power of the other stations can be 6 dB less than that of the first and second stations; in other words, they can have a power of 2.5 kW.

Moreover, the exclusion rule establishes two conditions for the RSS value not to be increased, i.e. :

1. The new signal must be less than half the RSS value already calculated.
2. The new signal must not be greater than the minimum value already included in the calculation.

Consequently, if the interfering field strengths are designated u and all their values are the same, we have for five values :

$$RSS = (5 \ u^2)^{\frac{1}{2}}$$

To meet the first condition, the following inequality must be met :

$$\frac{(5 \ u^2)^{\frac{1}{2}}}{2} > u$$

This result means that if we consider only five values, the sixth meets the first condition.

The second condition will be met when the sixth value is not higher than the fifth. As we have assumed equal field strengths, this condition is also met.

It is possible that when the five larger values of interfering signals are unequal, the fifth might be negligible.

In conclusion, we can reduce the number of interfering field strengths to the first five values on the assumption that they are listed in decreasing order.

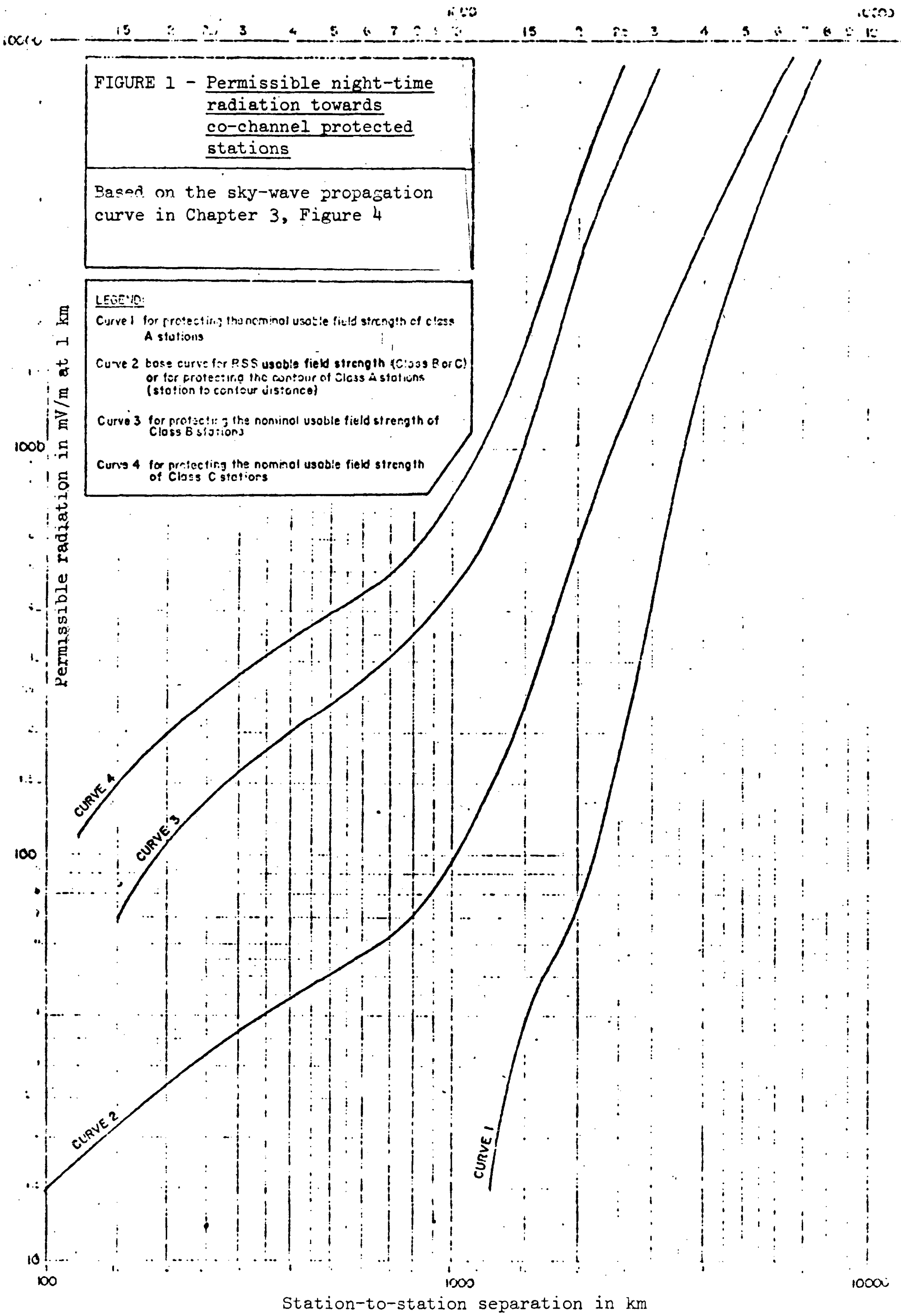
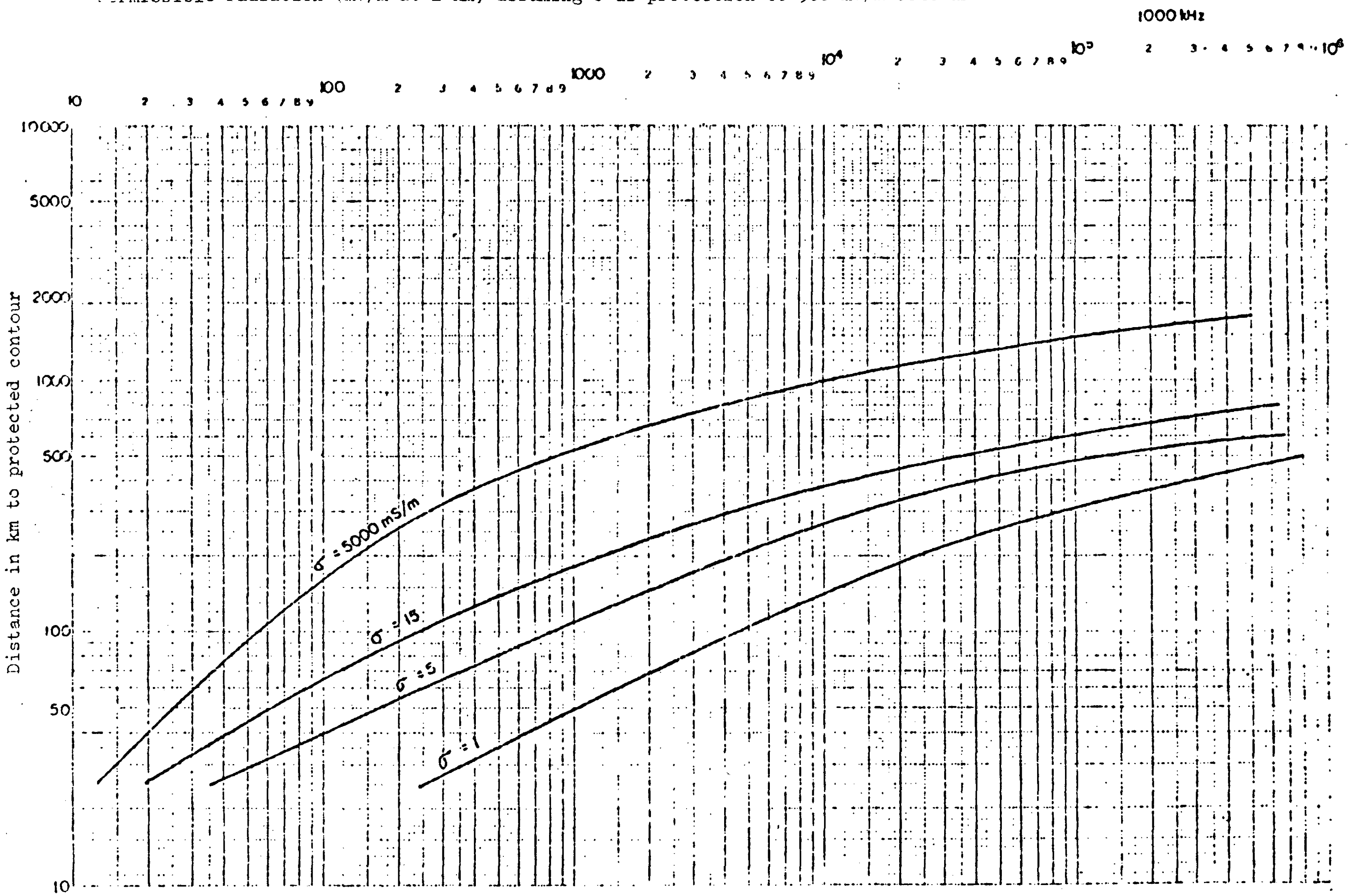


FIGURE 1 - Permissible night-time radiation towards co-channel protected stations

Based on the sky-wave propagation curve in Chapter 3, Figure 4

Permissible radiation (mV/m at 1 km) assuming 0 dB protection to 500 mV/m contour



Multiplying factors for other protection requirements

Protected contour	Protection ratio	Factor
0.1 mV/m	26 dB	0.01
0.5 mV/m	26 dB	0.05
0.5 mV/m	5 dB	0.56
0.5 mV/m	-29.5 dB	30
25 mV/m	0	50

FIGURE 2 - Permissible radiation based on ground-wave propagation curves contained in Annex D, graph 12

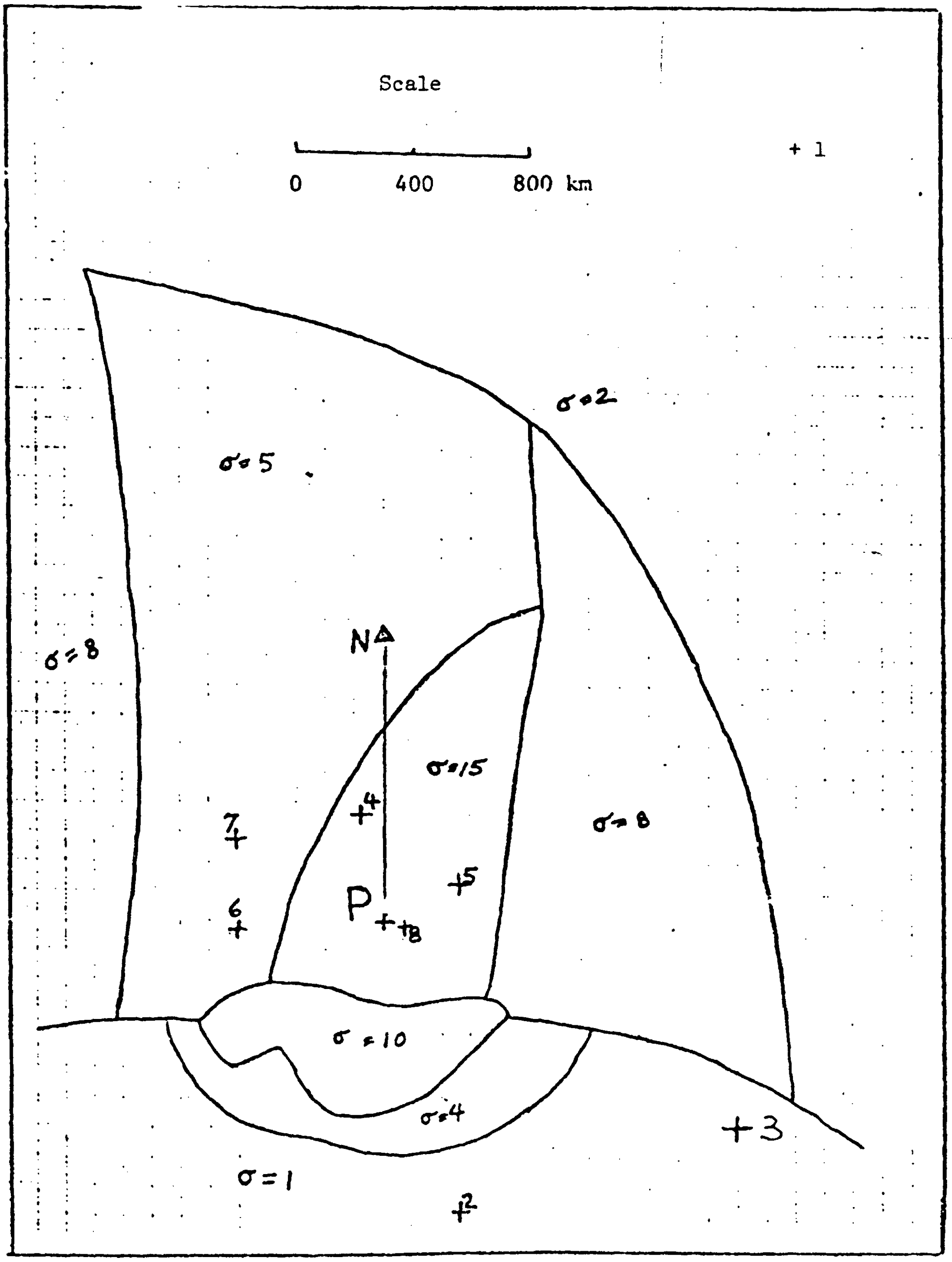


FIGURE 3 - Map of station locations and ground conductivities

Legend : σ = conductivity mS/m
$+_n$ = location of station n

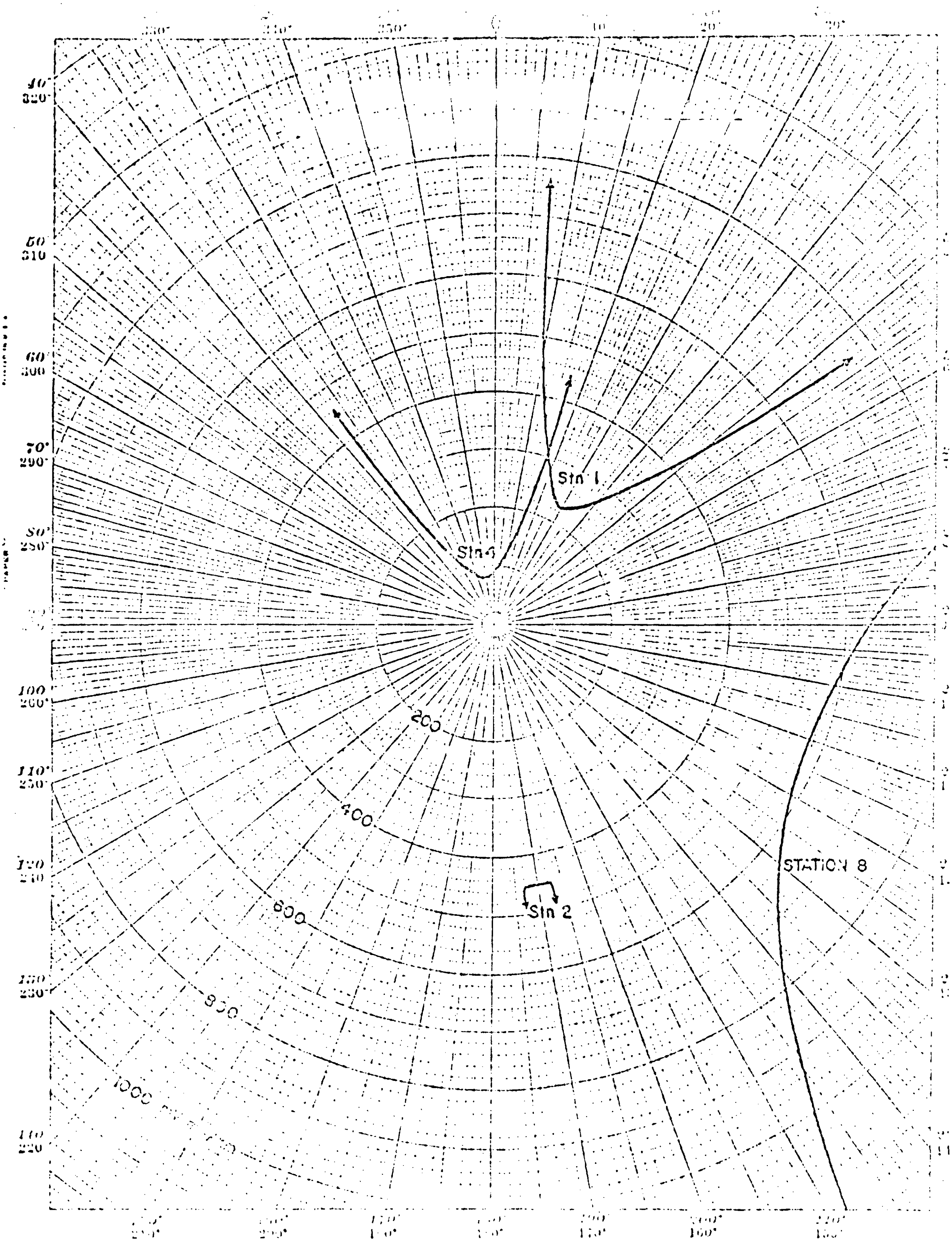


FIGURE 4 - Radiation constraints on station P

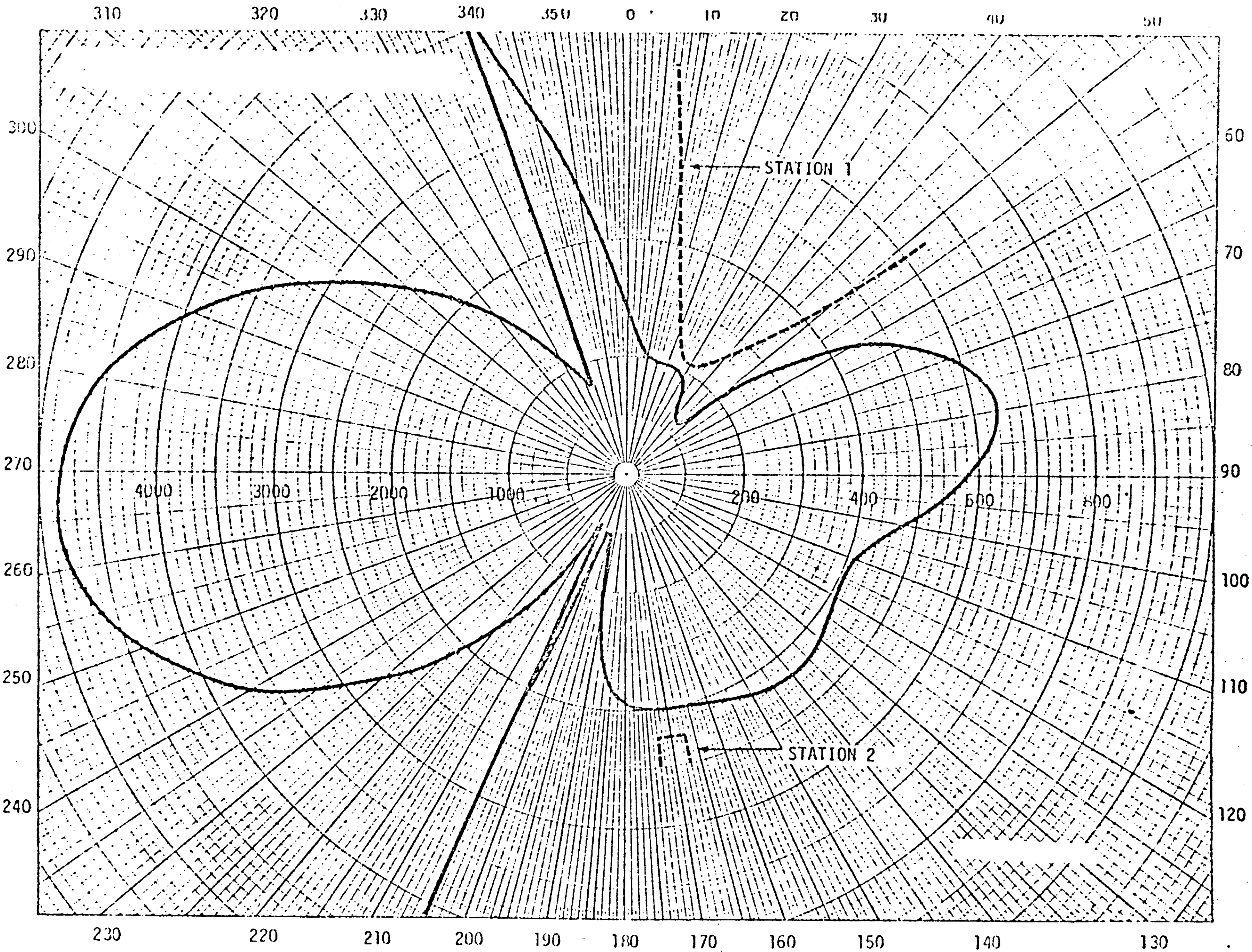


FIGURE 5 - Night pattern

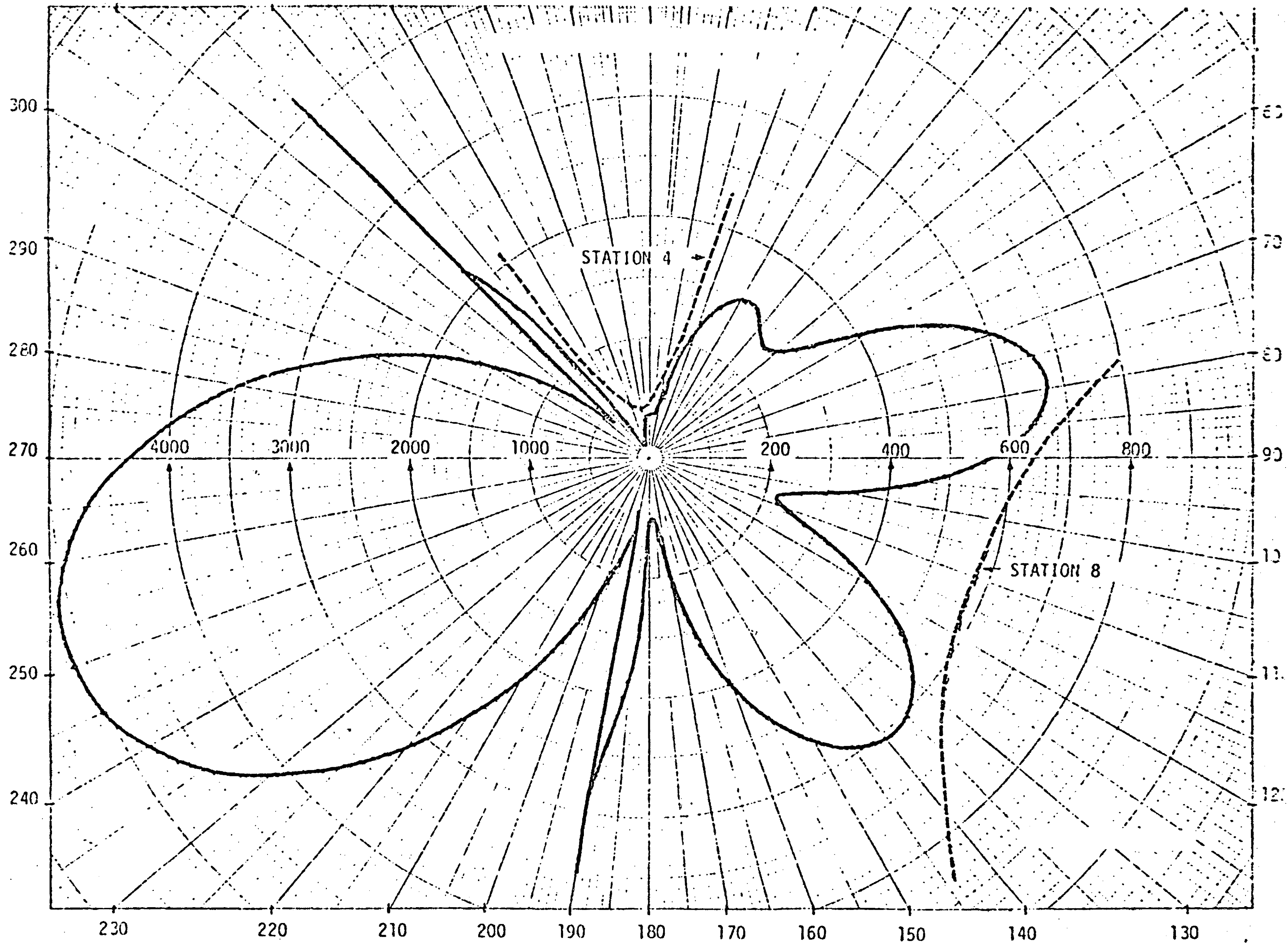


FIGURE 6 - Daytime pattern

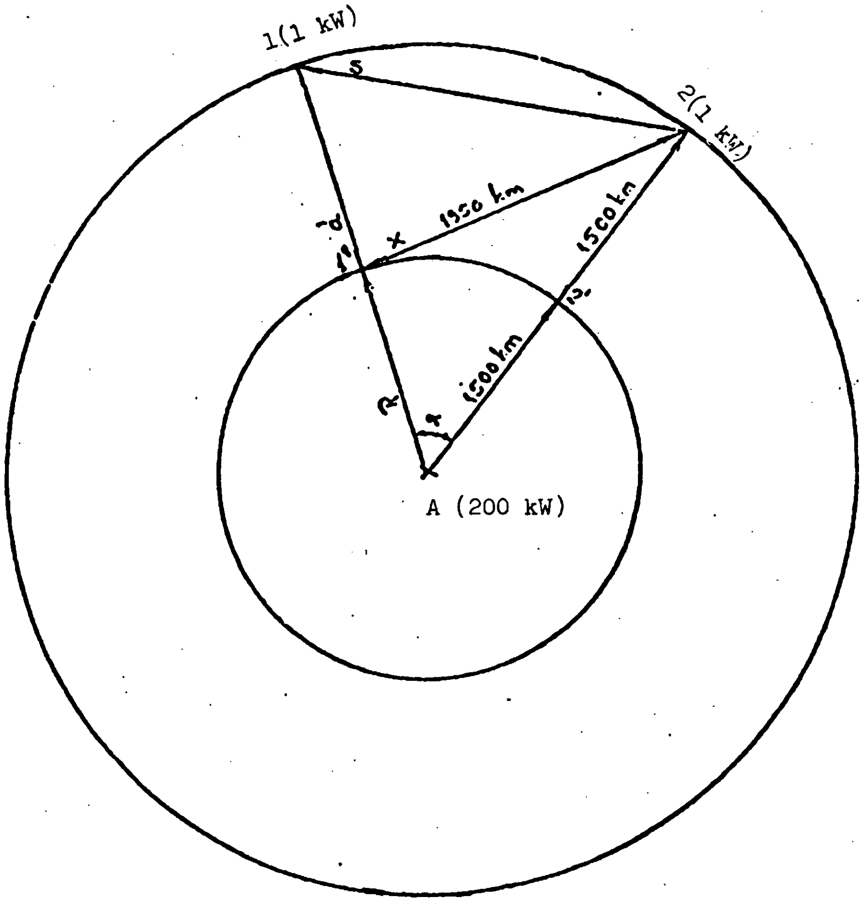


FIGURE 7

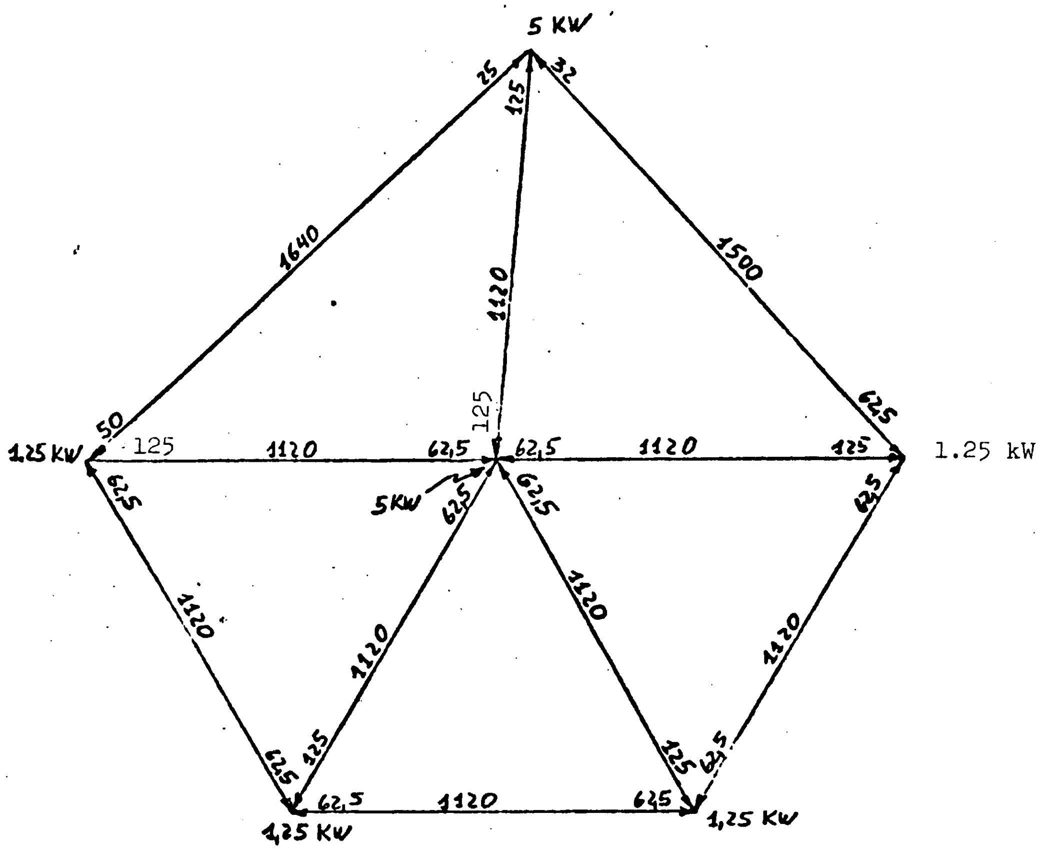


FIGURE 8 - Maximum capacity around the first station

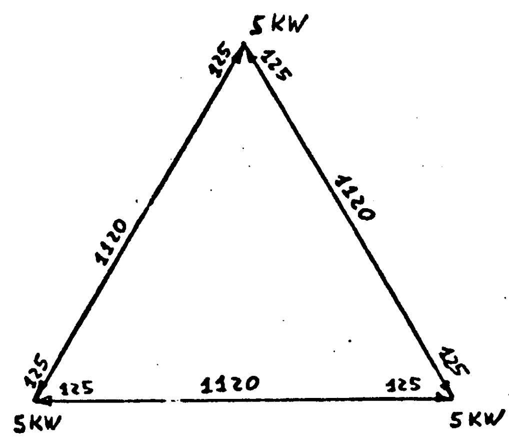


FIGURE 9 - Showing three 5 kW stations

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ANNEX B

NOTES

(see Chapter 2)

2.3.1 Canada, Denmark (for Greenland), French Department of Saint Pierre and Miquelon, Mexico and the United States of America will calculate the value of interfering sky-wave signals that each receives from Canada, Greenland, Saint Pierre and Miquelon, Mexico and the United States of America for Class A, B and C stations on the basis of sky-wave field strength 10 % of the time. Accordingly, the IFRB will calculate these interfering signals on that basis. Otherwise, the sky-wave field strength, 50 % of the time will be used.

2.3.3.1 In lieu of protecting normally protected contours for Class A stations, countries with specific service requirements beyond the normally protected contours for such stations may establish, through bi-lateral, or multi-lateral agreements with concerned or affected countries, additional protection criteria for one or more existing broadcasting stations.

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ANNEX C

ATLAS OF GROUND CONDUCTIVITY

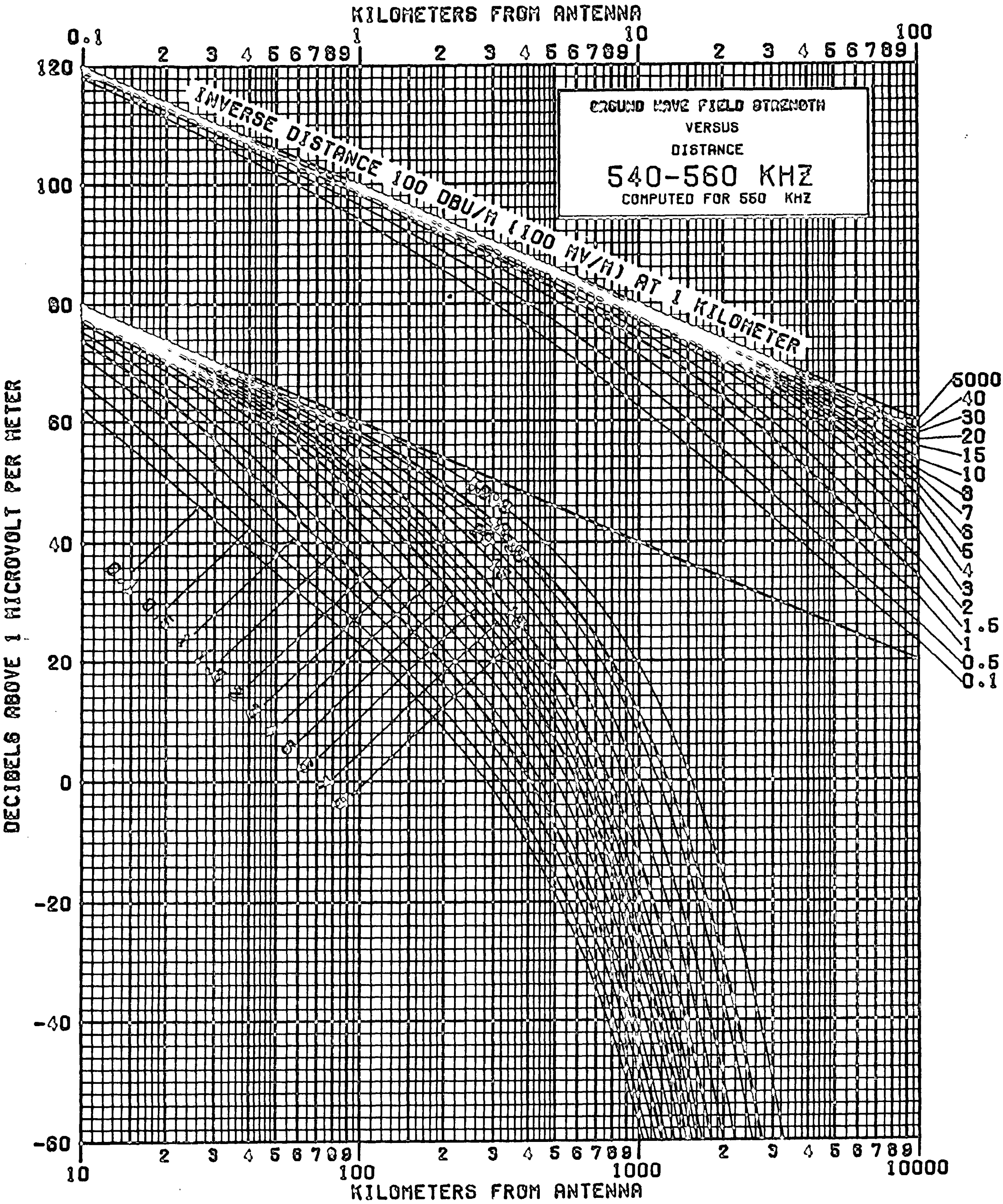
Note by the General Secretariat

This atlas was distributed at the First Session of the Conference.

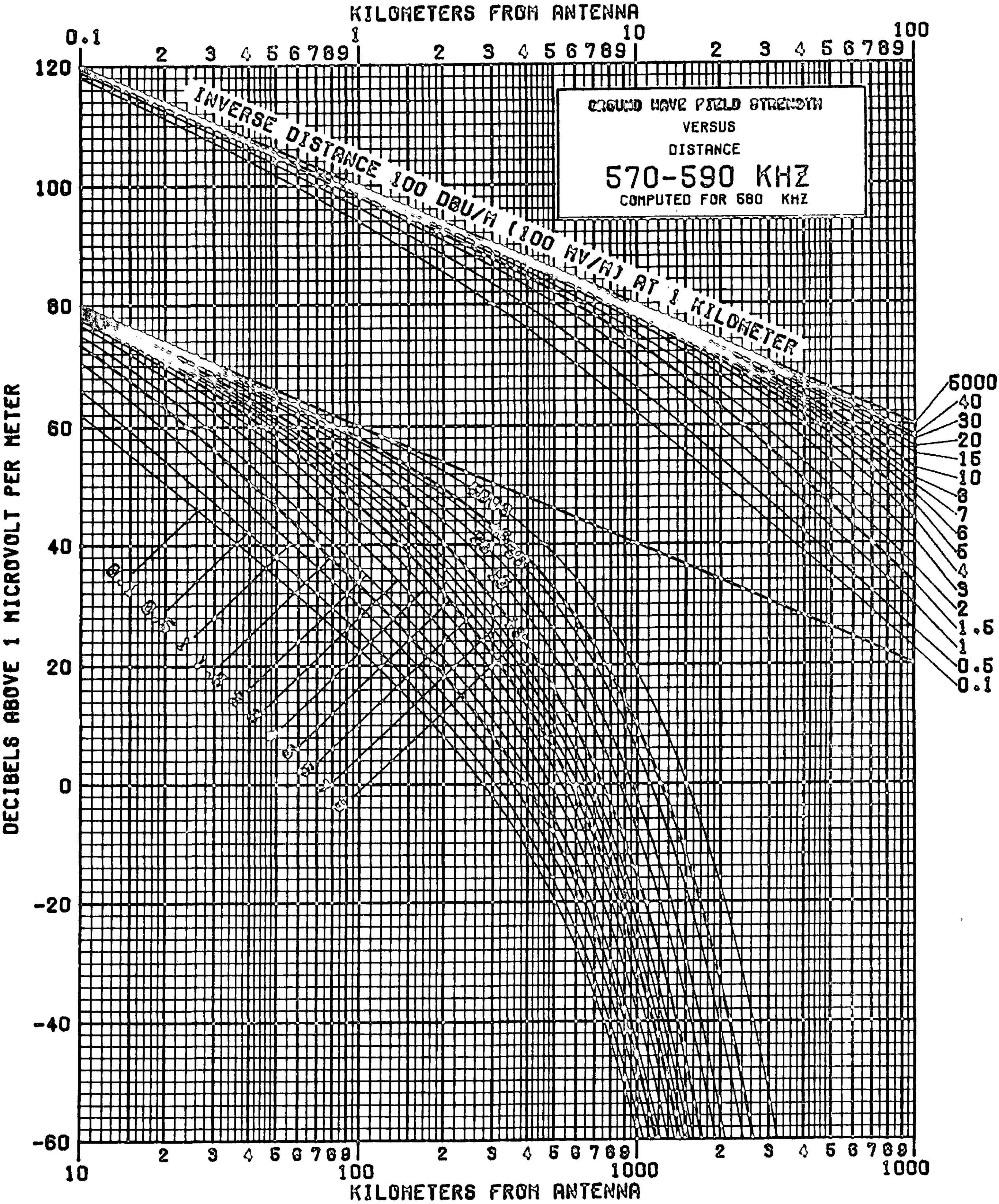
ANNEX D

FIELD-STRENGTH CURVES FOR GROUND-WAVE PROPAGATION

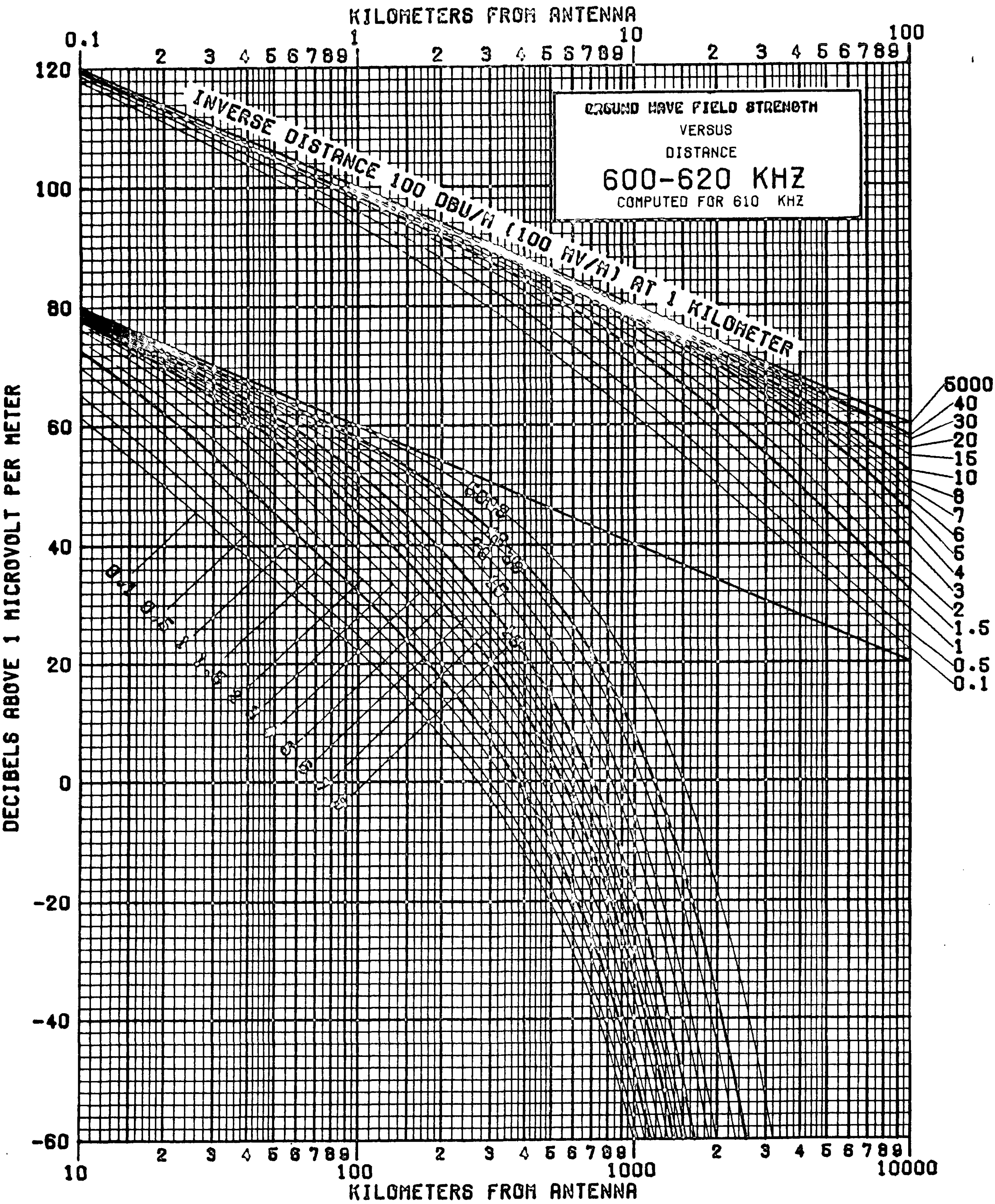
The curves are labelled with the ground conductivities in millisiemens/metre. All curves except the 5 000 mS/m (sea water) curve are derived for a relative dielectric constant of 15. The sea water curve is derived for a dielectric constant of 80.


KILOMETERS FROM ANTENNA
0.1
1
10
100
120
100
80
60
40
20
0
-20
-40
-60
DECIBELS ABOVE 1 MICROVOLT PER METER
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
540-560 KHZ
COMPUTED FOR 550 KHZ
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
10
100
1000
10000
KILOMETERS FROM ANTENNA

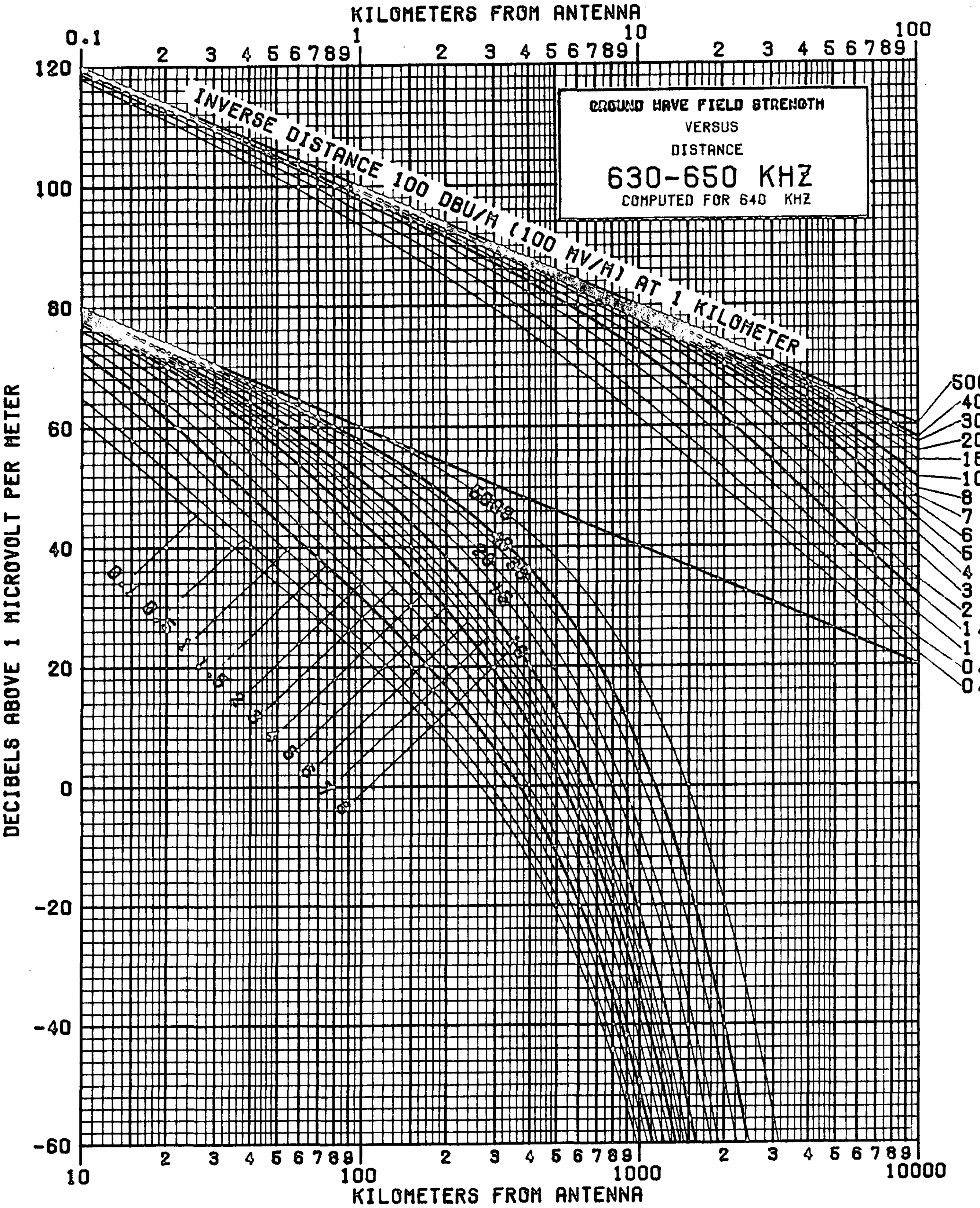
GRAPH 1


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
570-590 KHZ
COMPUTED FOR 580 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

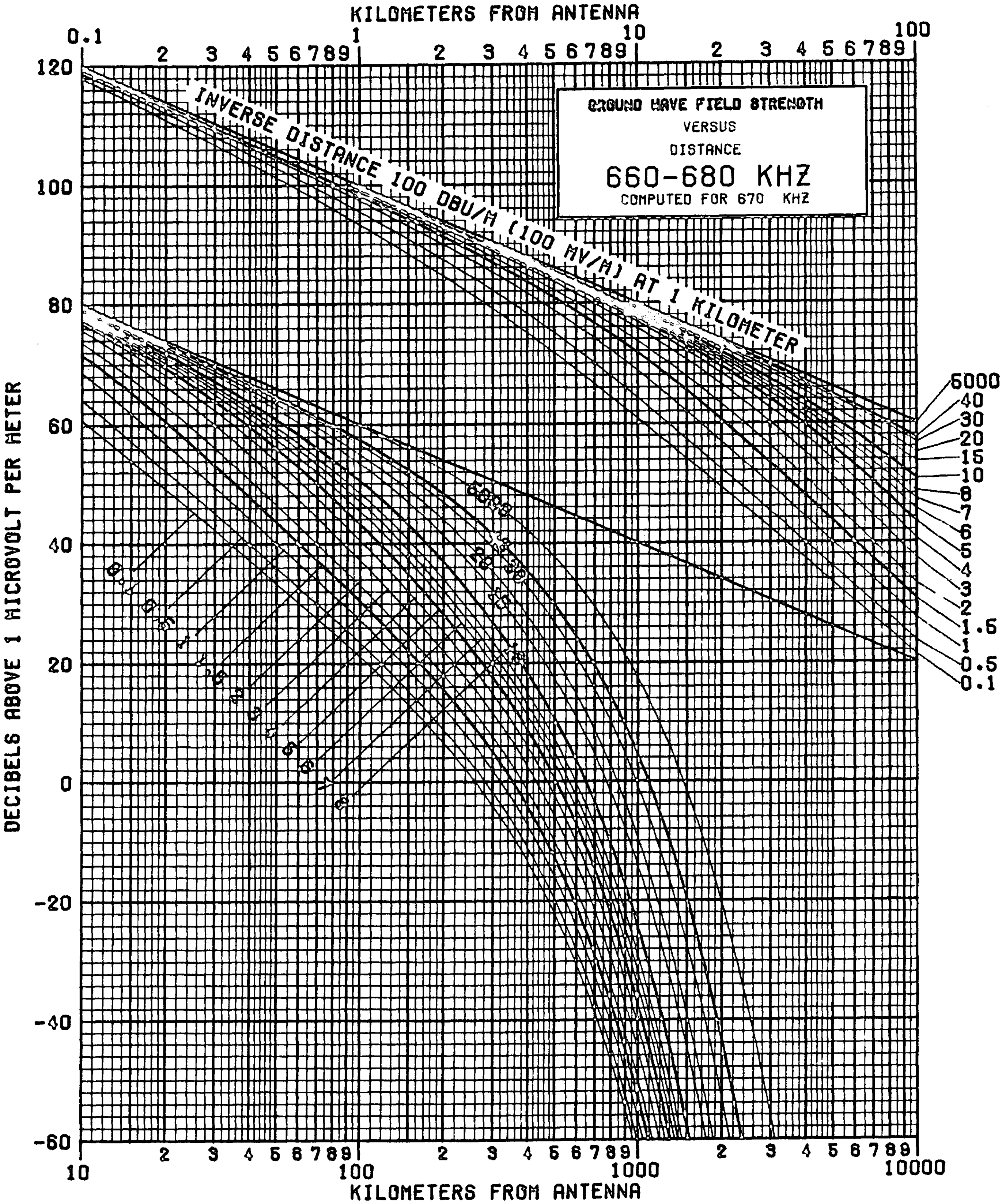
GRAPH 2


KILOMETERS FROM ANTENNA
0.1
1
10
100
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
600-620 KHZ
COMPUTED FOR 610 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
120
100
80
60
40
20
0
-20
-40
-60
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
10
100
1000
10000
KILOMETERS FROM ANTENNA

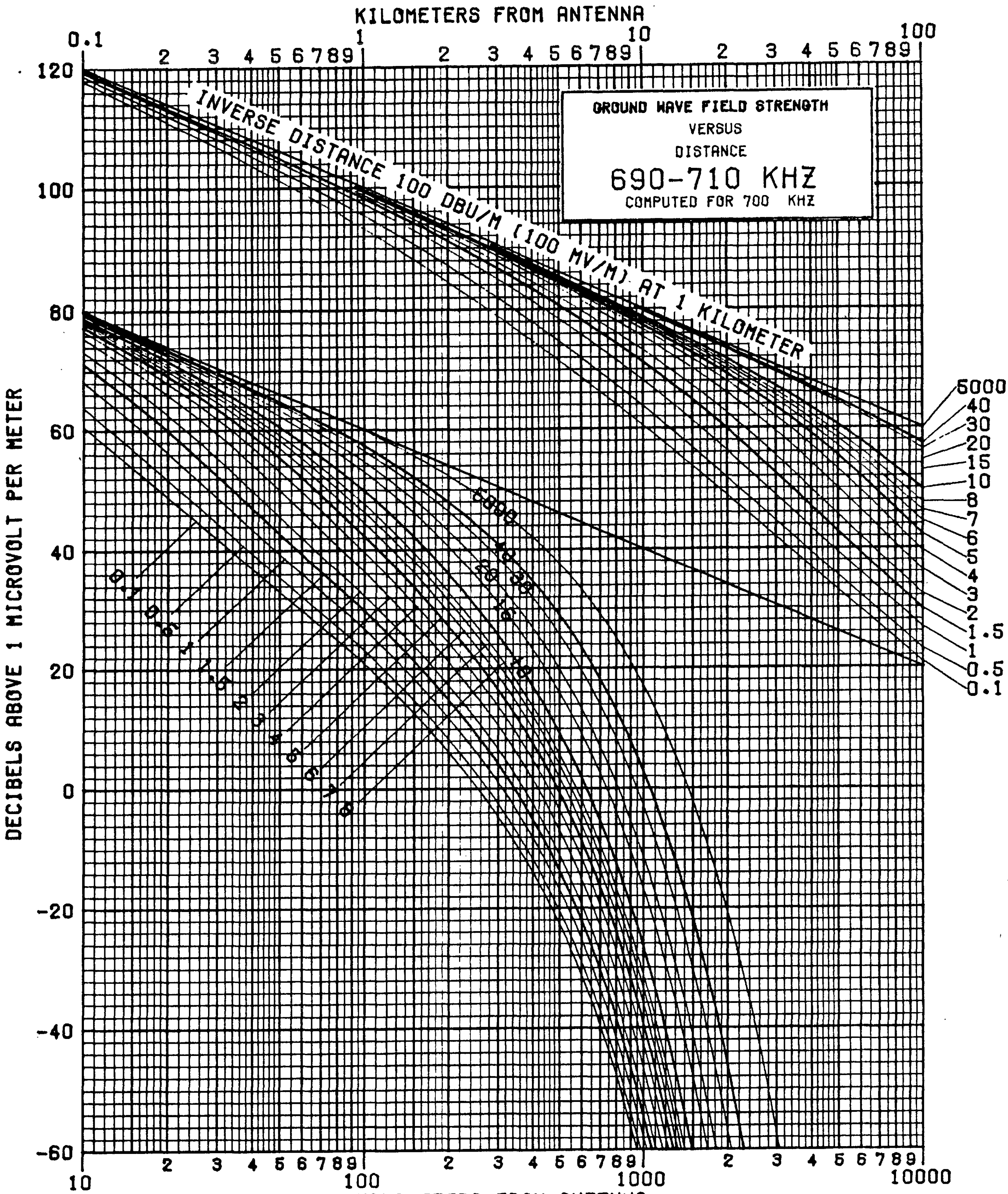
GRAPH 3


KILOMETERS FROM ANTENNA
0.1
1
10
100
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
630-650 KHZ
COMPUTED FOR 640 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
120
100
80
60
40
20
0
-20
-40
-60
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
10
100
1000
10000
KILOMETERS FROM ANTENNA

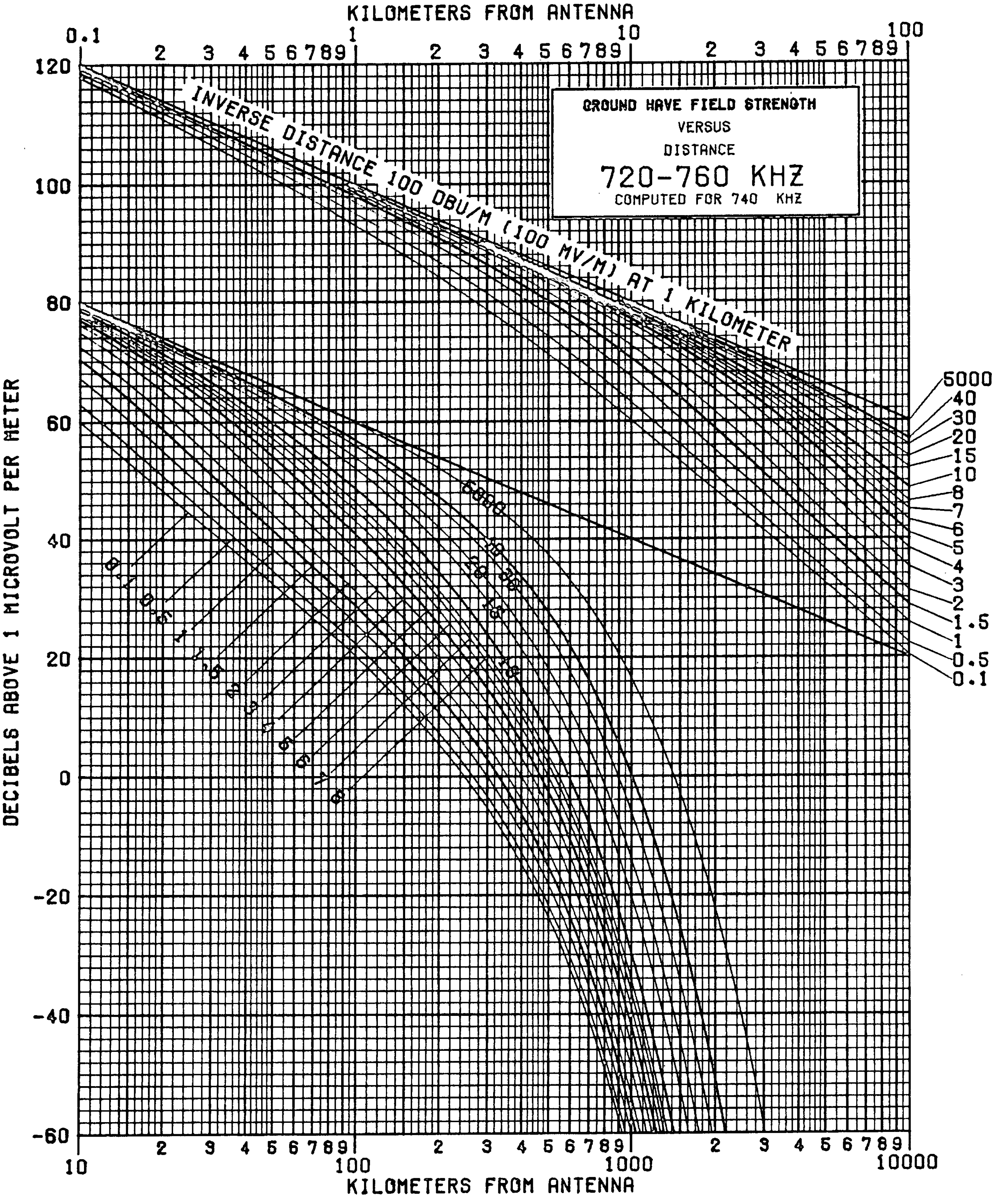
GRAPH 4


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
660-680 KHZ
COMPUTED FOR 670 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

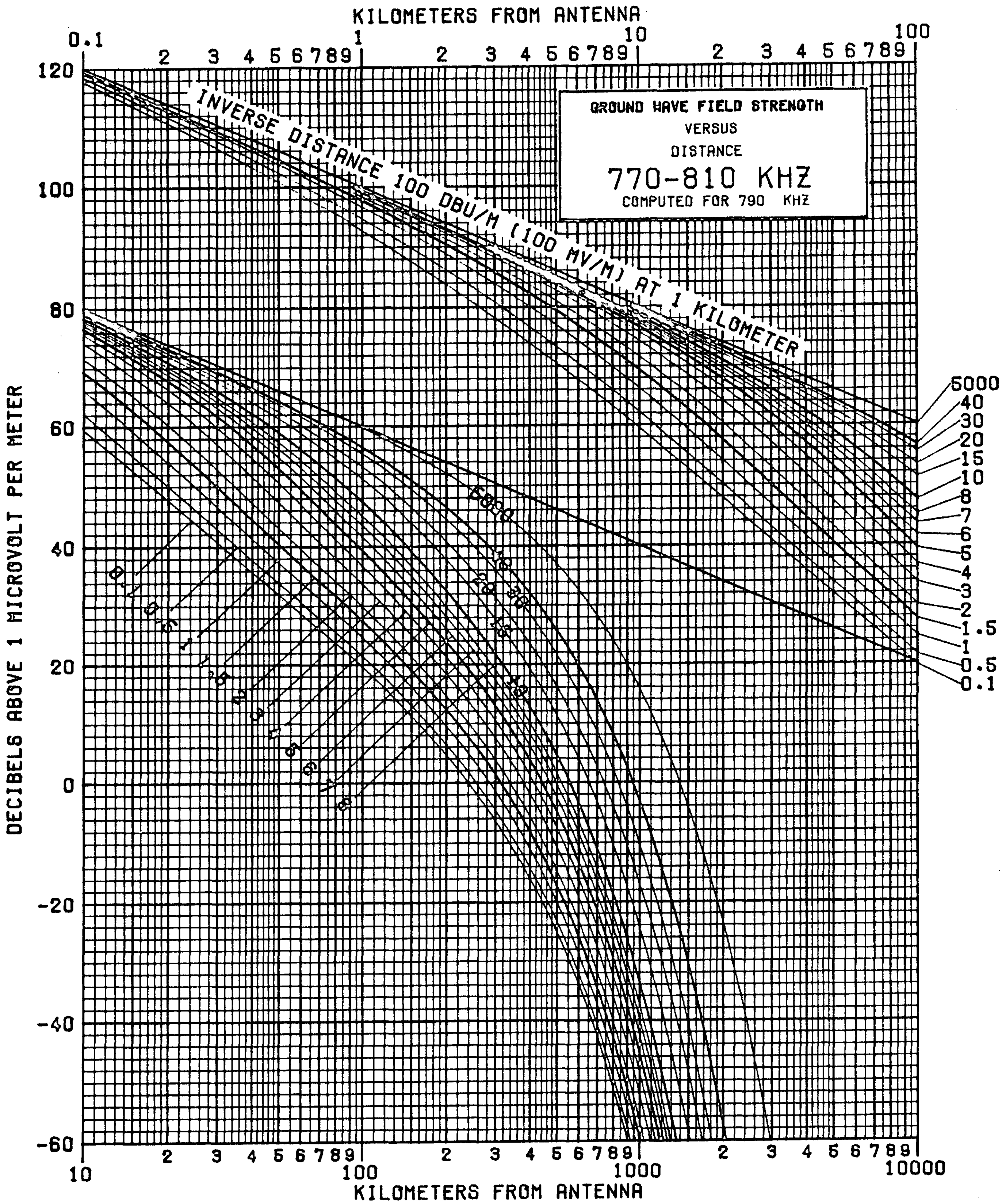
GRAPH 5


KILOMETERS FROM ANTENNA
0.1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 10 2 3 4 5 6 7 8 9 100
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
690-710 KHZ
COMPUTED FOR 700 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
120
100
80
60
40
20
0
-20
-40
-60
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
10 2 3 4 5 6 7 8 9 100 2 3 4 5 6 7 8 9 1000 2 3 4 5 6 7 8 9 10000
KILOMETERS FROM ANTENNA

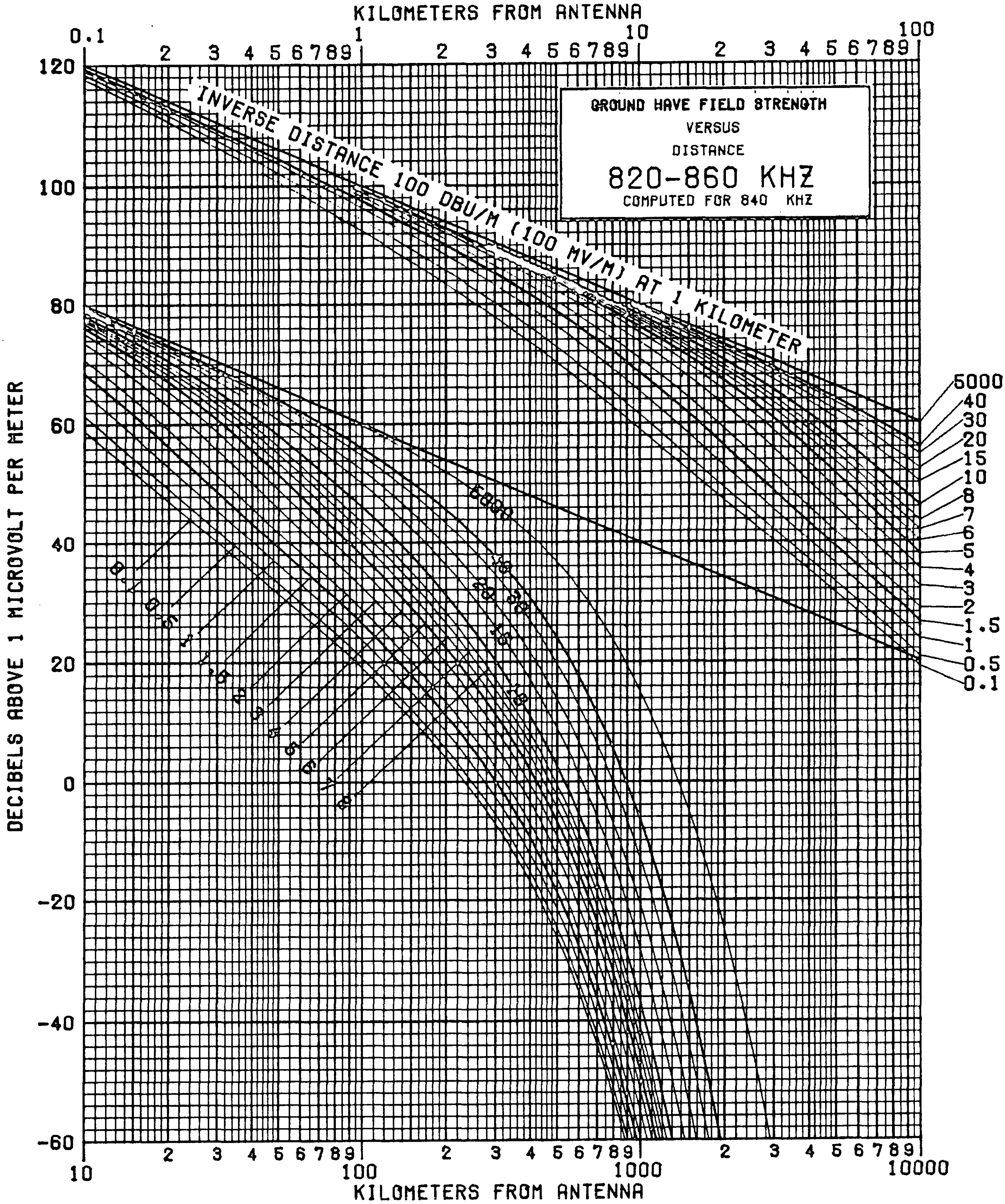
GRAPH 6


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
720-760 KHZ
COMPUTED FOR 740 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

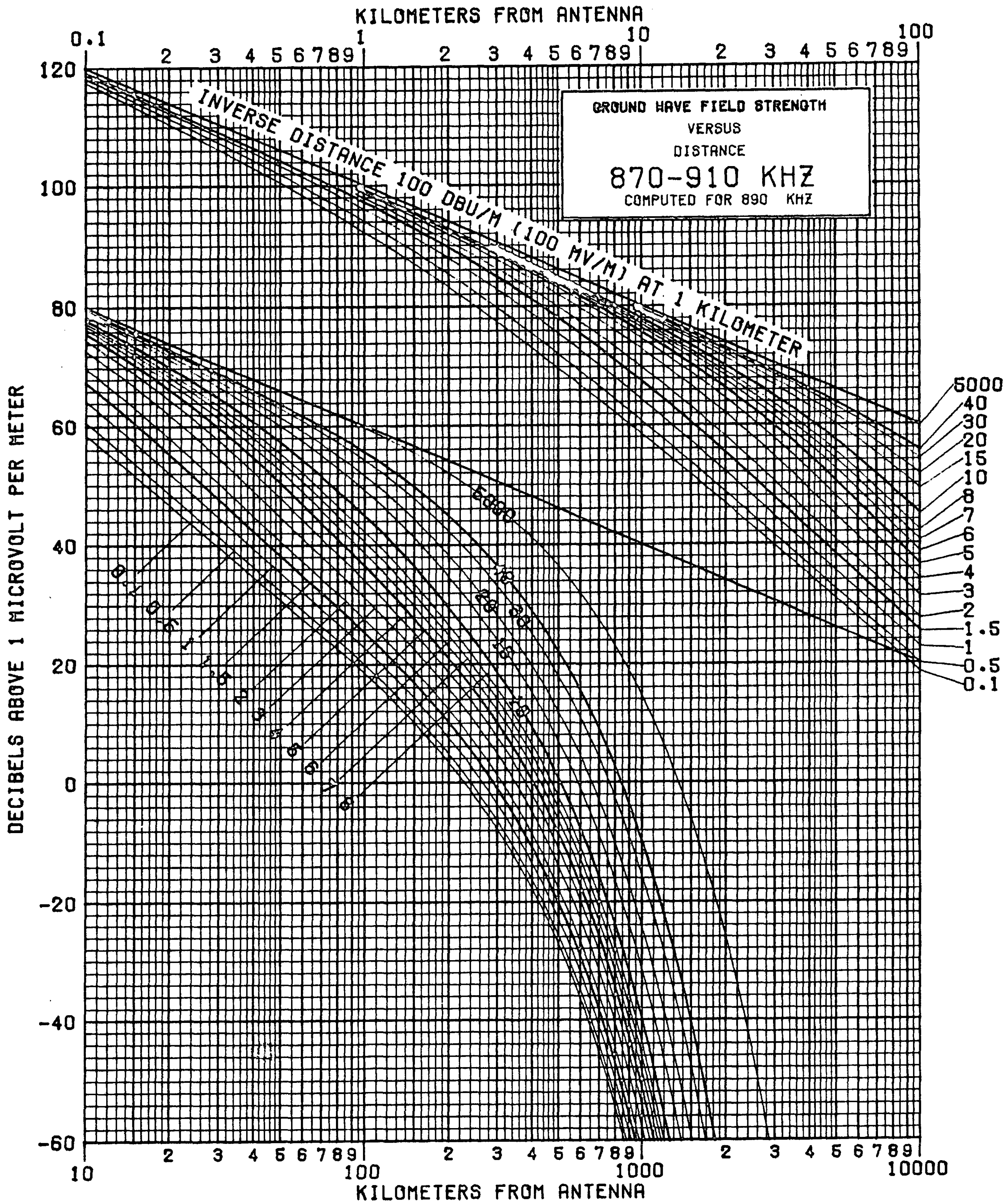
GRAPH 7


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
770-810 KHZ
COMPUTED FOR 790 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

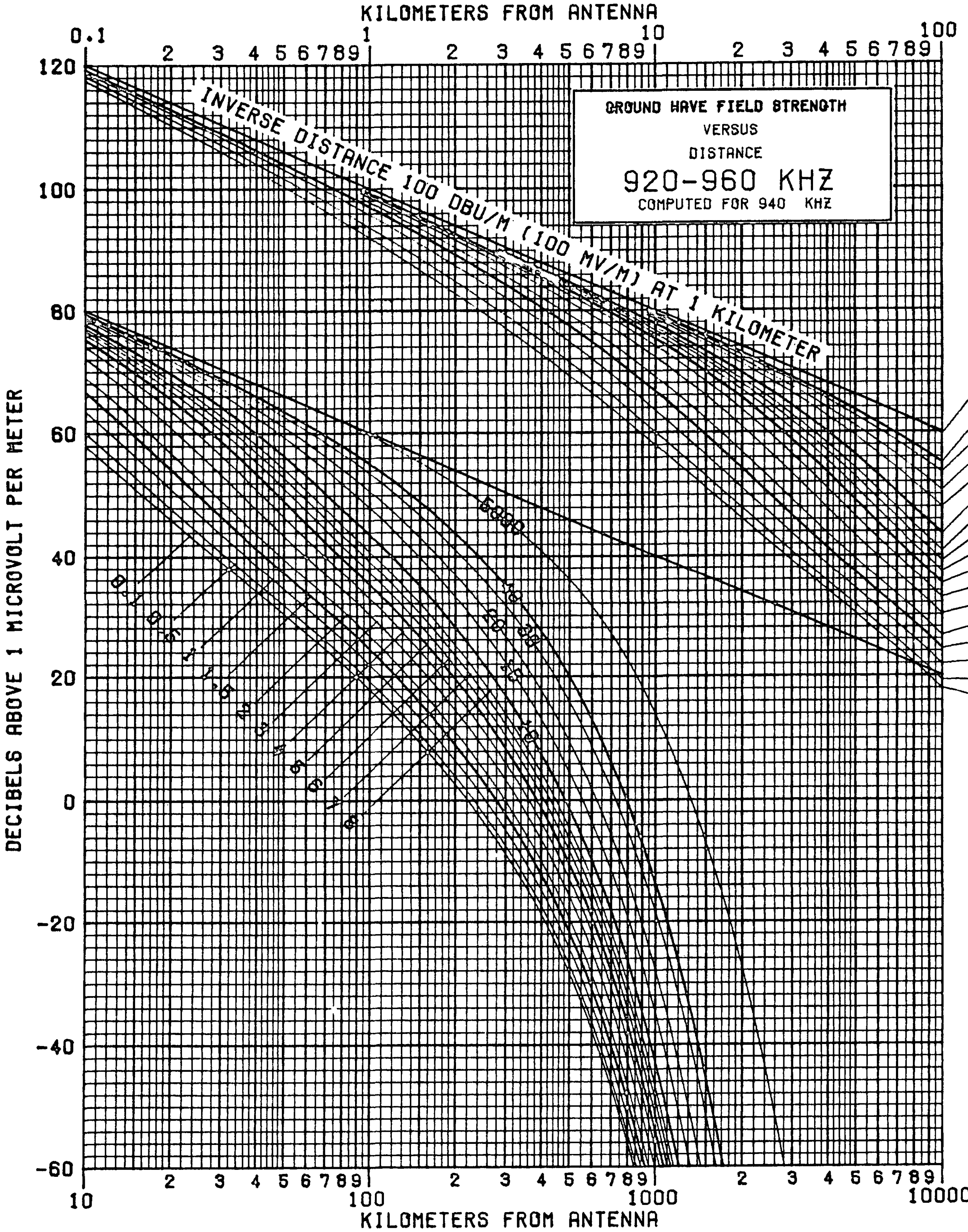
GRAPH 8


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
820-860 KHZ
COMPUTED FOR 840 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

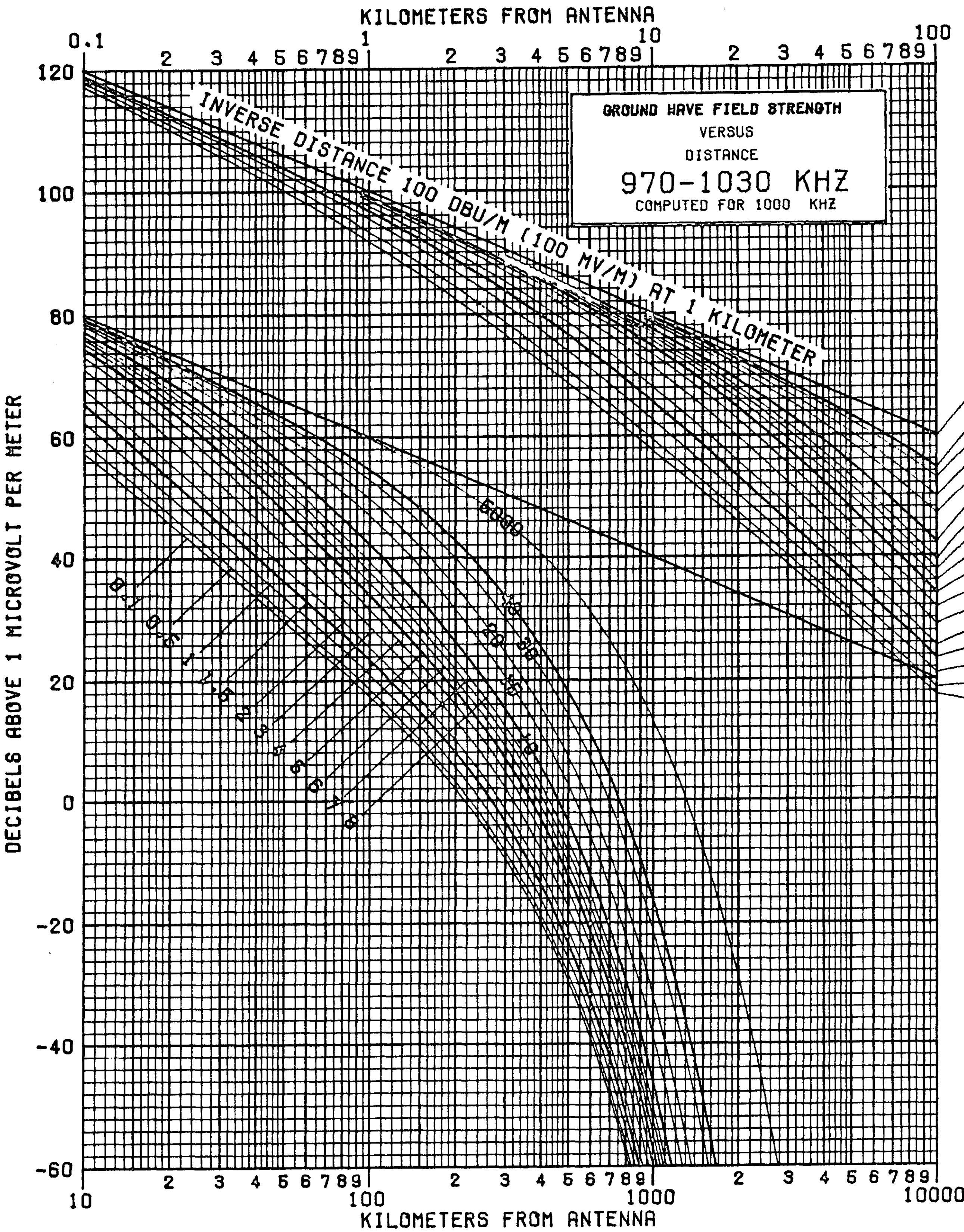
GRAPH 9


KILOMETERS FROM ANTENNA
0.1
1
10
100
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
870-910 KHZ
COMPUTED FOR 890 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
120
100
80
60
40
20
0
-20
-40
-60
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
10
100
1000
10000
KILOMETERS FROM ANTENNA

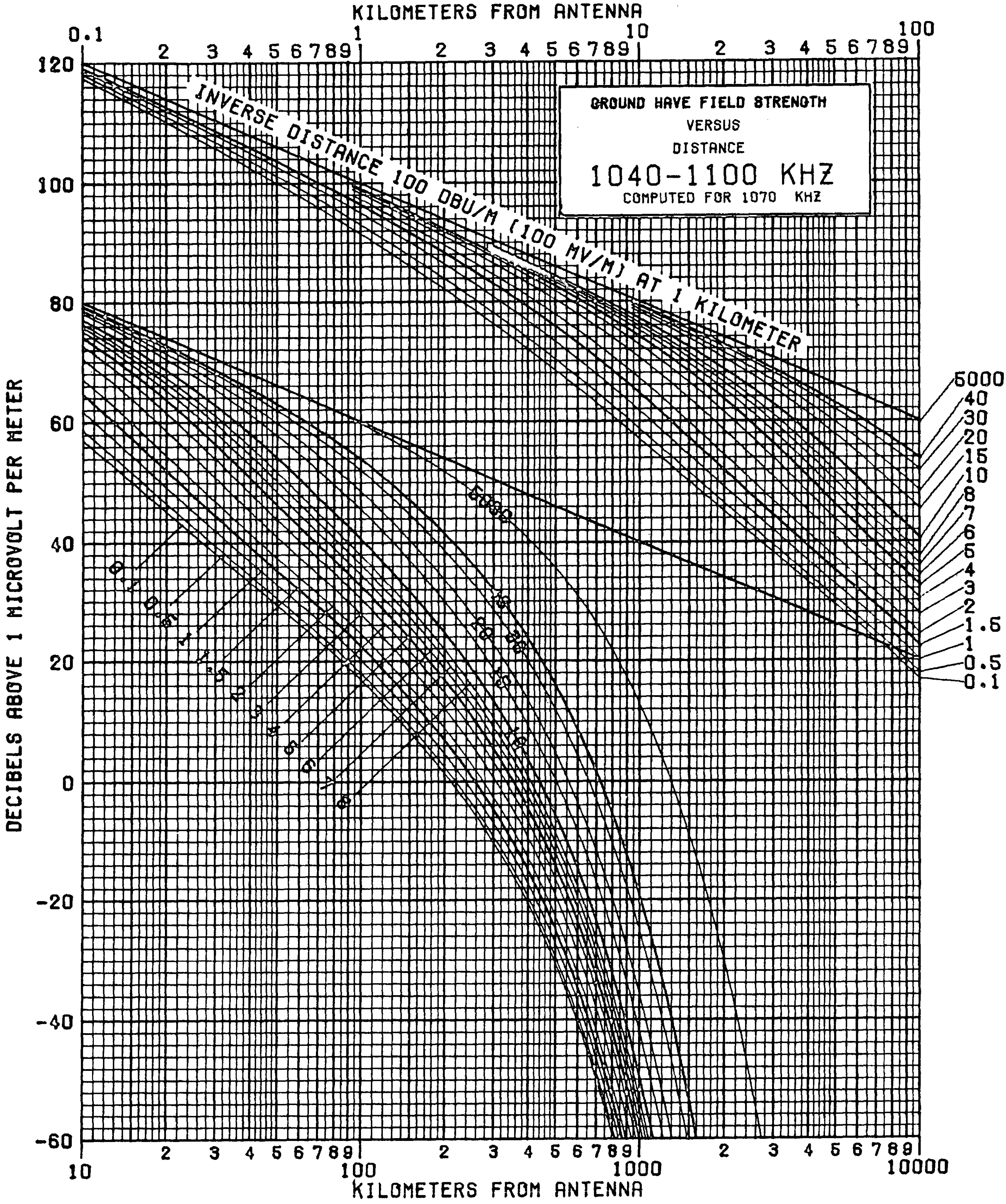
GRAPH 10


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
920-960 KHZ
COMPUTED FOR 940 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

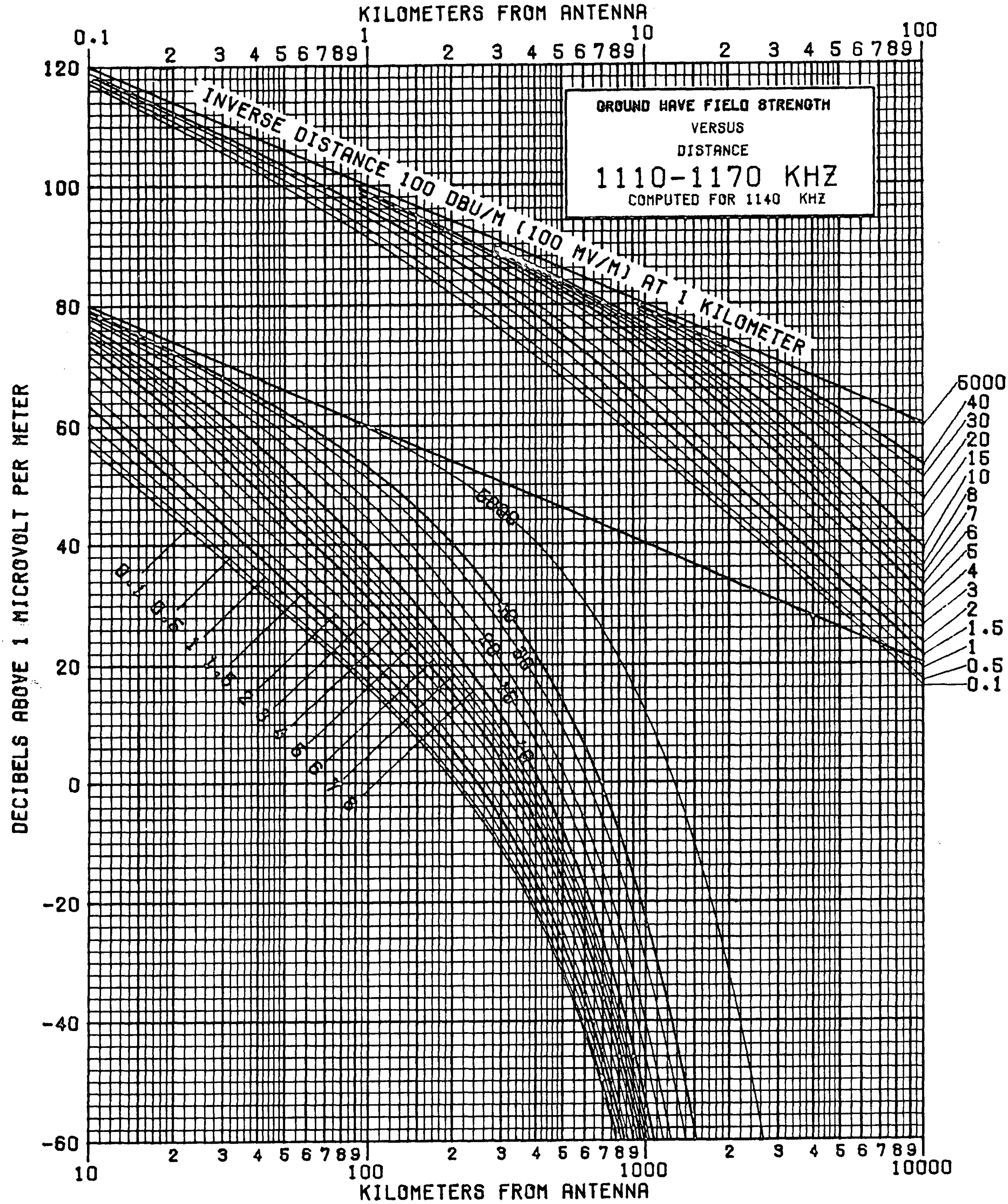
GRAPH 11


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
970-1030 KHZ
COMPUTED FOR 1000 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

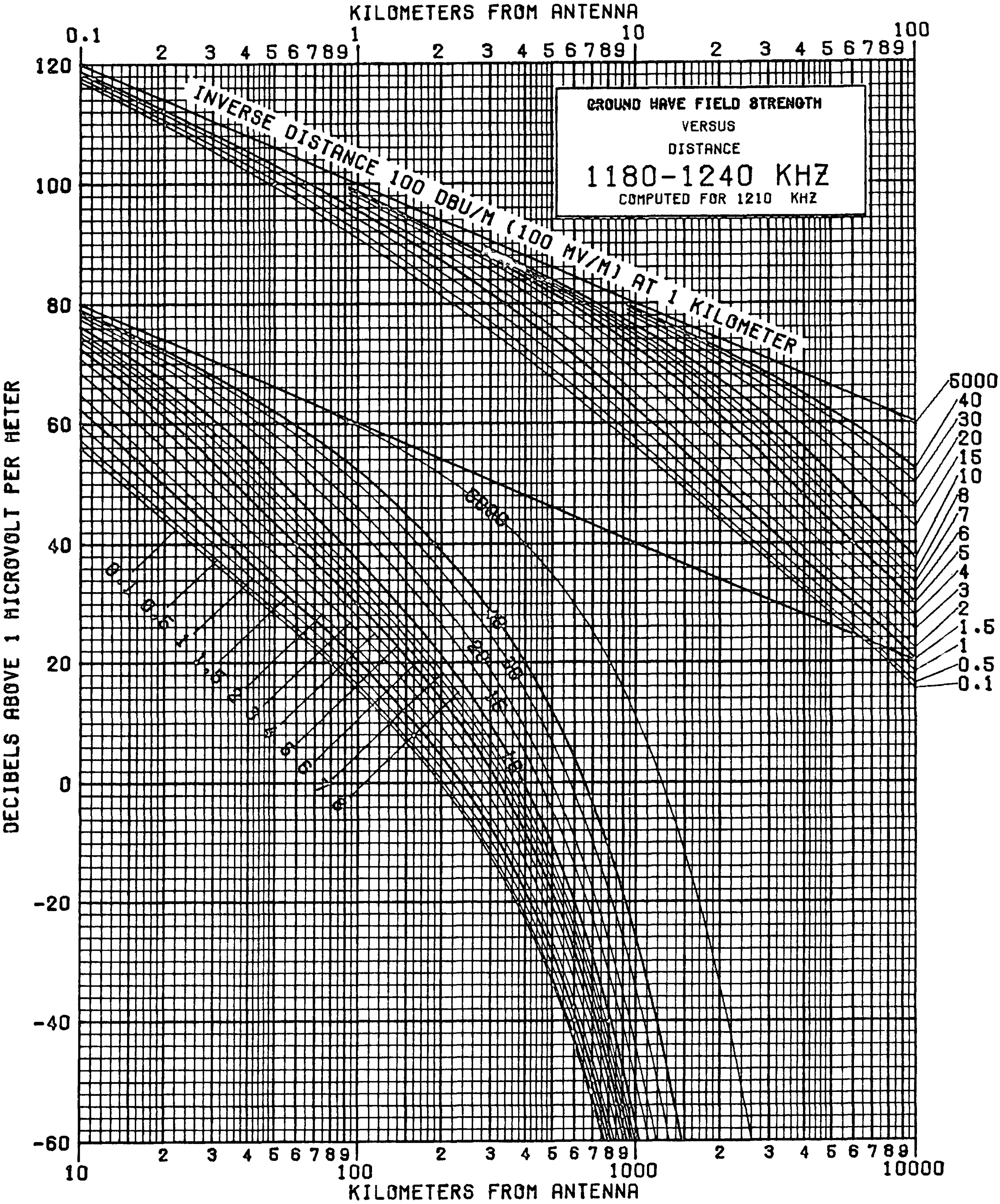
GRAPH 12


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
1040-1100 KHZ
COMPUTED FOR 1070 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

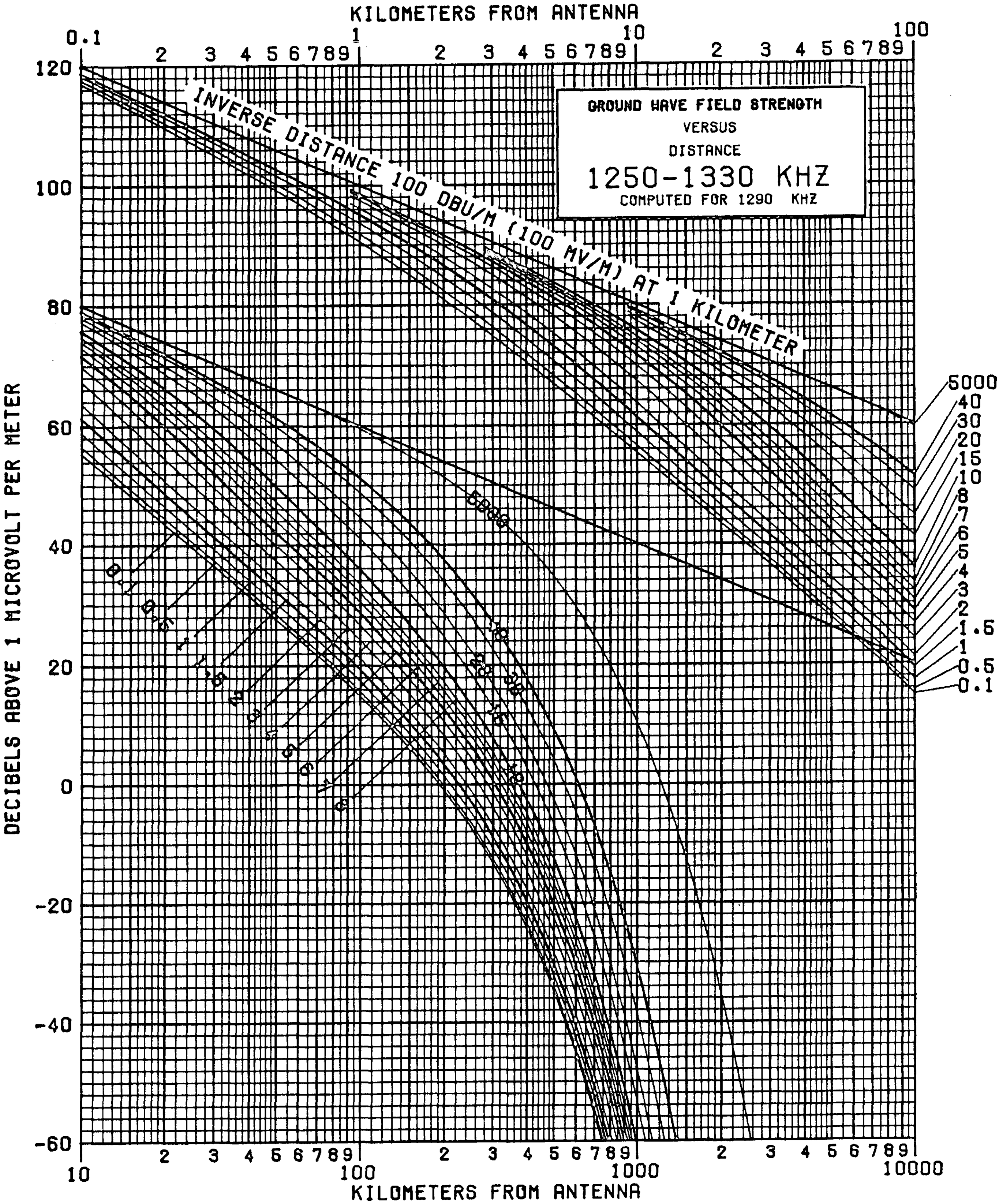
GRAPH 13


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
1110-1170 KHZ
COMPUTED FOR 1140 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
KILOMETERS FROM ANTENNA

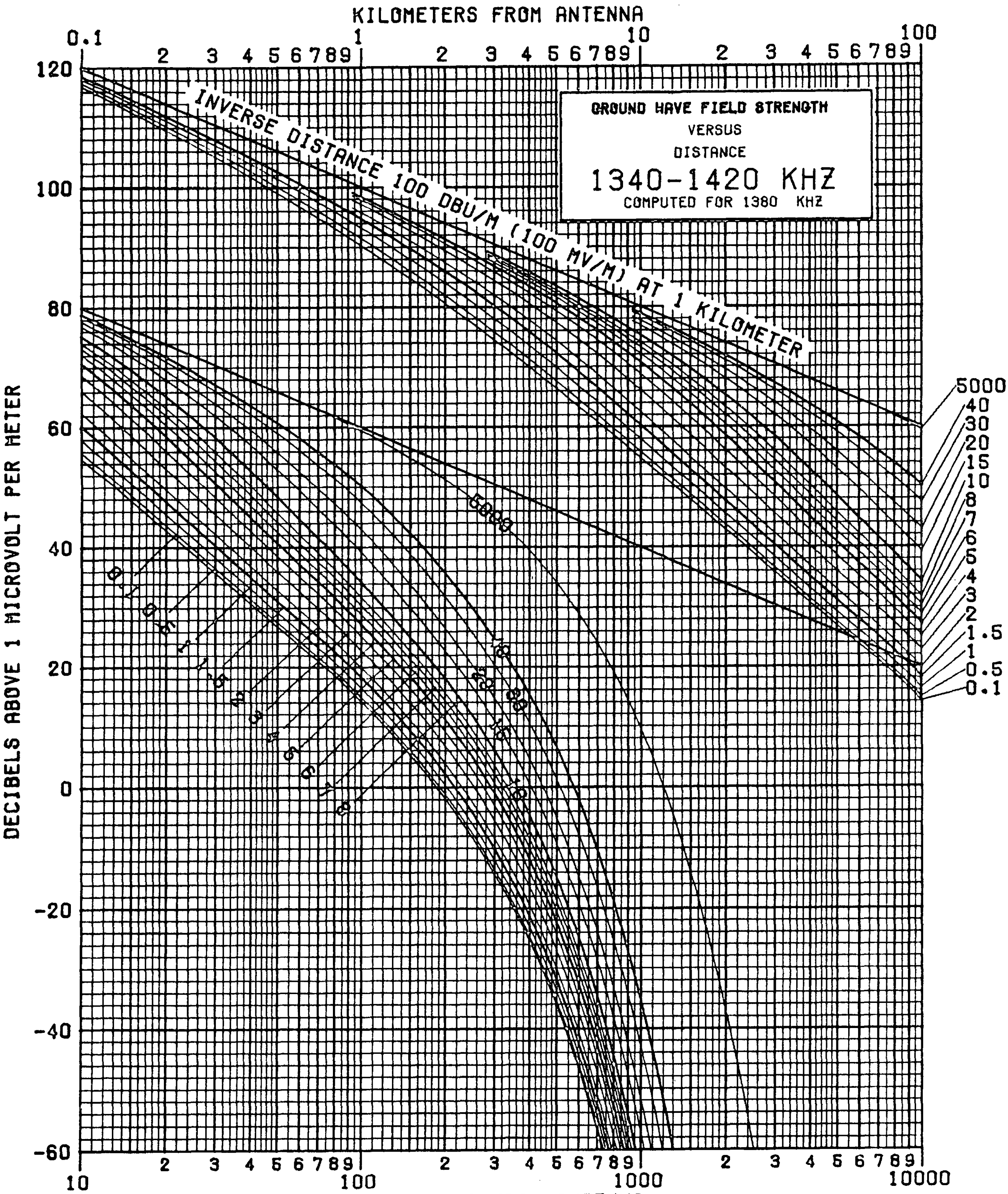
GRAPH 14


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
1180-1240 KHZ
COMPUTED FOR 1210 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

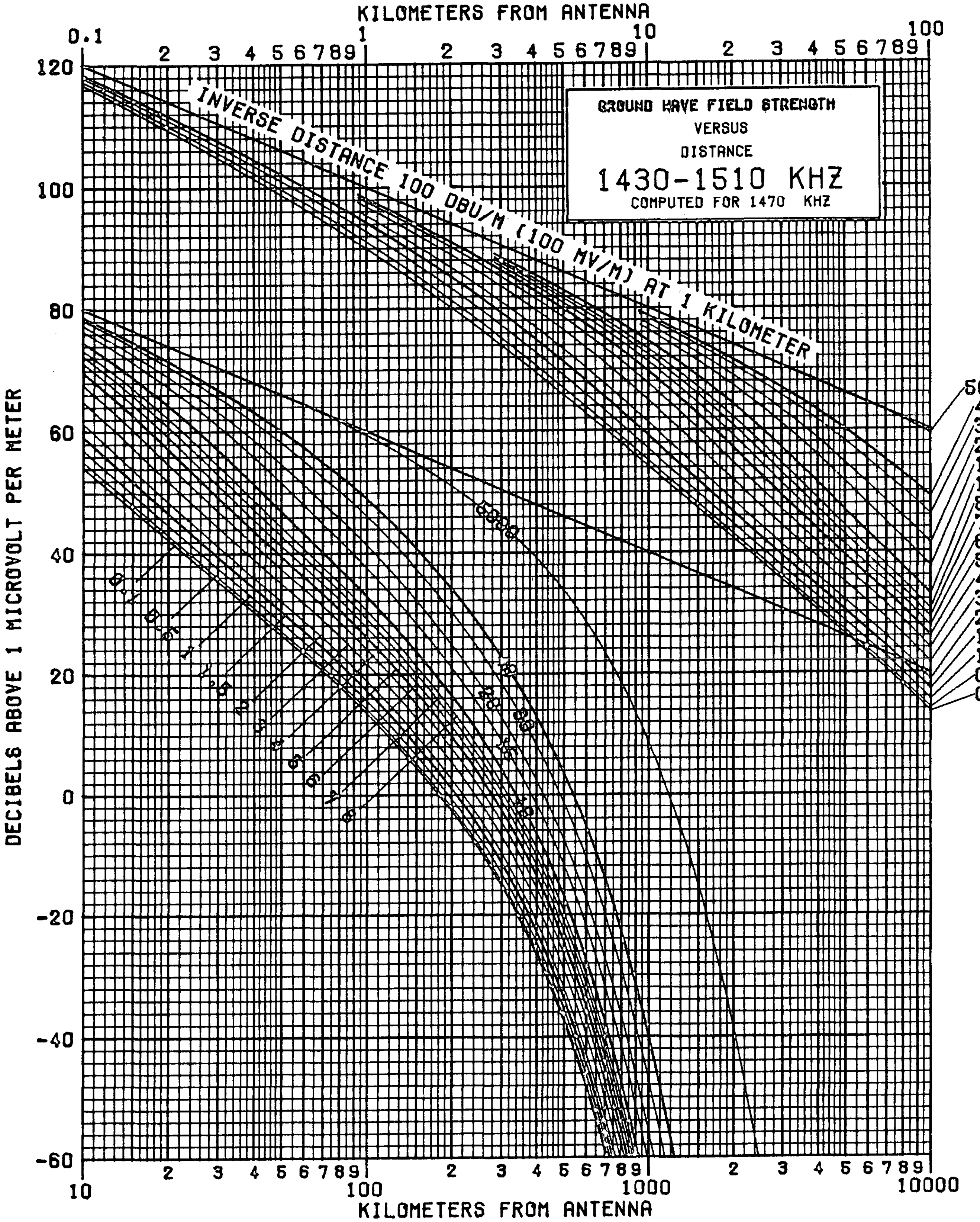
GRAPH 15


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
1250-1330 KHZ
COMPUTED FOR 1290 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

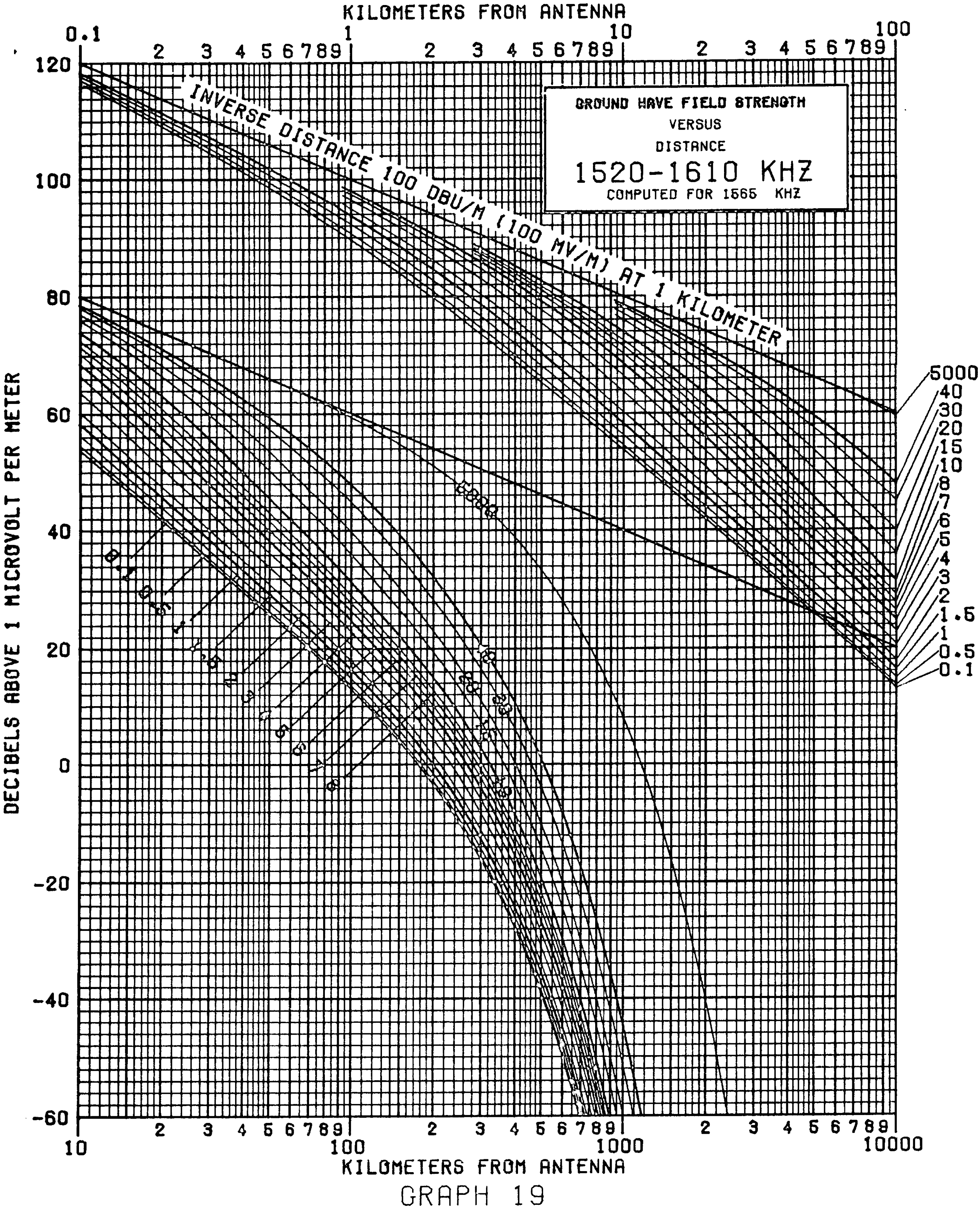
GRAPH 16


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
1340-1420 KHZ
COMPUTED FOR 1380 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

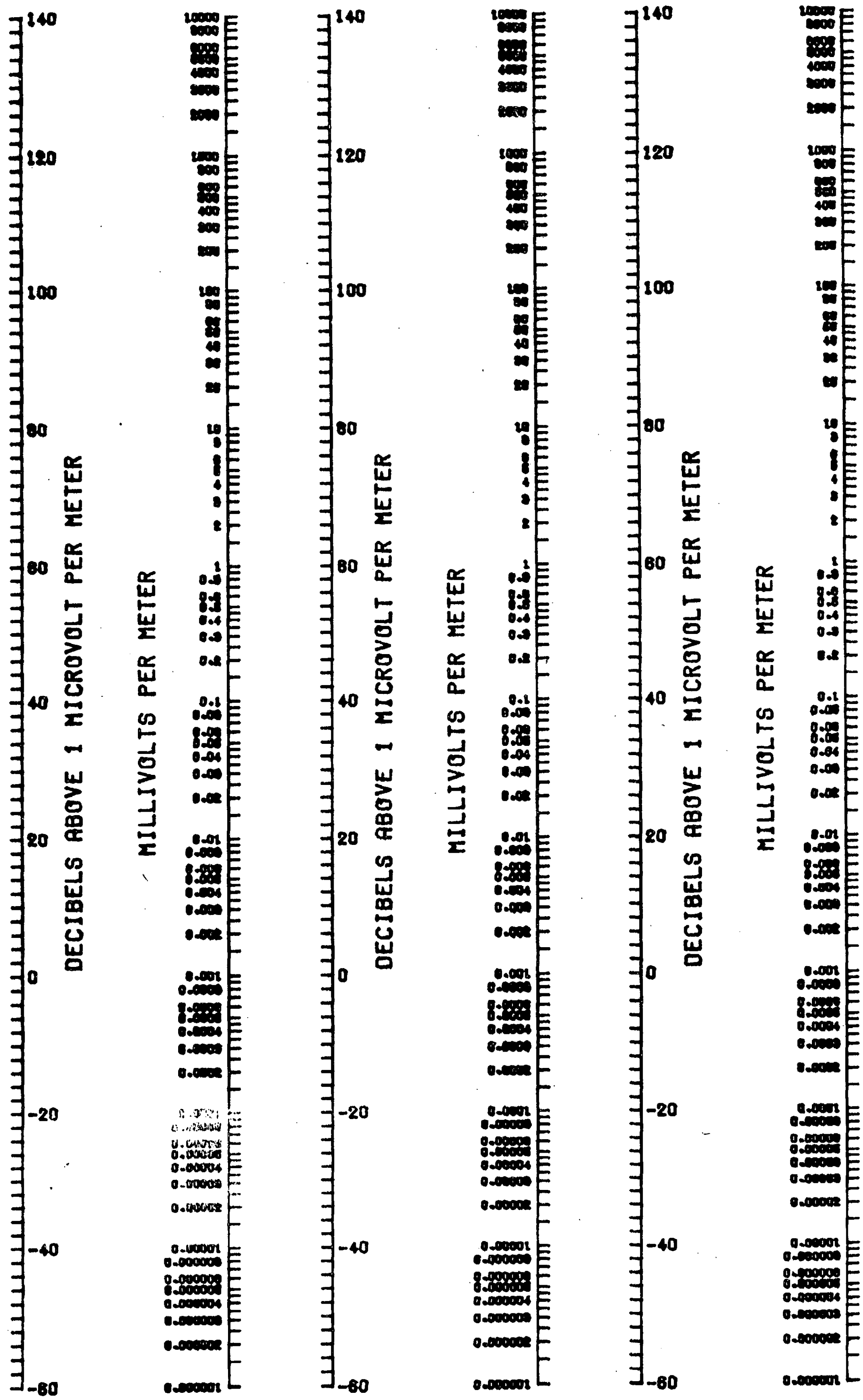
GRAPH 17


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
1430-1510 KHZ
COMPUTED FOR 1470 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

GRAPH 18


KILOMETERS FROM ANTENNA
GROUND WAVE FIELD STRENGTH
VERSUS
DISTANCE
1520-1610 KHZ
COMPUTED FOR 1565 KHZ
INVERSE DISTANCE 100 DBU/M (100 MV/M) AT 1 KILOMETER
DECIBELS ABOVE 1 MICROVOLT PER METER
5000
40
30
20
15
10
8
7
6
5
4
3
2
1.5
1
0.5
0.1
KILOMETERS FROM ANTENNA

GRAPH 19



GRAPH 20

SCALE FOR USE WITH GROUND WAVE
FIELD STRENGTH GRAPHS 1-19

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ANNEX E

MATHEMATICAL DISCUSSION AND COMPUTER PROGRAMME FOR GROUND-WAVE CURVES

Introduction

A computer programme has been written to calculate ground-wave field strengths at metric distances (McMahon, 1979) using the Norton surface wave equation (Norton, 1936) at distances within the radio horizon, and using the Bremmer residue series (Bremmer, 1949) for distances beyond the radio horizon.

Field strength curves calculated by the Norton equation and by the Bremmer residue series are parallel for a considerable distance on either side of the horizon. However, the values of field strength calculated by the two methods differ by as much as ten percent in this region. The method used in the computer programme to merge the Norton field strengths and the Bremmer field strengths into a smooth continuous curve is to normalize the Bremmer fields to the Norton fields at the horizon by calculating a factor which when multiplied by the Bremmer field makes the product equal to the Norton field at the horizon. This same factor is then used to adjust the Bremmer field strengths at greater distances. This factor is calculated for each change in frequency, or in ground constants.

This Report includes a section giving information on the mathematical methods used to calculate the field strengths using the Norton surface wave equation and the Bremmer residue series. The Report also contains a description of the various sub-routines used in the computer programme and a Fortran of the programme.

Mathematical discussion

I. Norton surface wave equation

Norton gives the following equation for A, the surface wave attenuation factor :

$$A = \left| 1 + i\sqrt{\pi p_1}\, e^{-p_1} \operatorname{erfc}(-i\sqrt{p_1}) \right| \qquad \text{(Norton, 1936)}$$

P_1 is the complex numerical distance which is calculated from the following factors :

$$X = 17.9731 \text{ Sigma}/F$$

$$b_1 = \tan^{-1}((E-1)/X)$$

$$b_2 = \tan^{-1}(E/X)$$

$$b = 2b_1 - b_2$$

$$p = \pi D \overline{\cos(b_2)}^2 / X\lambda \cos(b_1)$$

$$p_1 = p\, e^{ib}$$

where :

Sigma is the ground conductivity in milli-Siemens per metre

E is the relative dielectric constant of the the ground

F is the frequency in MHz

λ is the wavelength in metres

D is the distance from the antenna in kilometres

The erfc $(-i\sqrt{p_1})$ is defined as :

$$\mathrm{erfc}(-i\sqrt{p_1}) = (2/\sqrt{\pi}) \cdot \int_{-i\sqrt{p_1}}^{\infty} e^{-t^2}\,dt \qquad \text{(Abramowitz, 1970) p. 297, 7.1.2}$$

This function cannot be evaluated in closed form and most of the labour in calculating A lies in obtaining suitable series to evaluate erfc$(-i\sqrt{p_1})$ for the full ranges of possible values in p and b.

Mathematical discussion

I. Computer programme evaluation of Norton surface wave equation

Field strengths out to distances of (80.467 / (cube root of the frequency in MHz)) kilometres are calculated in the computer programme using the Norton surface wave equation. The programme uses five different methods of calculation depending upon the values of p, the numerical distance, and b, the angle of p.

1) p less, or equal to, 0.65 b any value

For this range of numerical distances the computer programme uses the w(z) function. (Abramowitz, 1970), equations 7.13, 7.18, page 297.

$$w(z) = e^{-z^2} \cdot \mathrm{erfc}(-iz) = \sum_{n=o}^{\infty} (iz)^n / \Gamma(n/2+1)$$

where $\Gamma(n/2 + 1)$ is a Gamma function which is evaluated by the formulae in (Abramowitz, 1970), Chapter VI.

If the substitution $\sqrt{p_1} = z$ is made in the w(z) summation :

$$A = |1 + i\sqrt{\pi p_1} \cdot w(\sqrt{p_1})|$$

2) p between 0.65 and 5, b less than $\pi/2$

For this range of p and b, the computer programme uses the infinite 2p series given by Norton. (Norton, 1936), page 1386.

$$A = |u + iv|$$

where :

$$u + 1 - 2p\cos(b) + (2p)^2\cos(2b)/1 . 3 - (2p)^3\cos(3b)/1 . 3 . 5 \ldots$$

$$+\sqrt{\pi p} \cdot e^{-p\cos(b)} \cdot \sin(p\sin(b) - b/2)$$

$$v = -2p\sin(b) + (2p)^2 / 1 . 3 - (2p)^3\sin(3b) / 1 . 3 . 5 \ldots$$

$$+\sqrt{\pi p} \cdot e^{-p\cos(b)} \cdot \cos(p\sin(b) - b/2)$$

3) p between 5 and 20, b less than $\pi/4$

For this range of p and b, the programme calculates A using the following equations :

$\mathrm{erfc}(z) = 1 - \mathrm{erf}(z)$ (Abramowitz, 1970) 7.1.2, p. 297.

$\mathrm{erf}(\bar{z}) = \overline{\mathrm{erf}(z)}$ (Abramowitz, 1970) 7.1.10, p. 297.

$$\mathrm{erf}(x + iy) = \mathrm{erf}(x) + (e^{-x^2} / 2\pi x). (1 - \cos(2xy) - i\sin(2xy)) +$$

$$(2 /\pi . e^{-x^2} . \sum_{n=1}^{\infty} ((e^{-.25n^2}) / (n^2 + 4x^2)) . (f_n (x,y) + ig_n (x,y))$$

$$f_n (x,y) = 2x - 2x \cosh(ny) \cos(2xy) + n \sinh(ny) \sin(2xy)$$

$$g_n (x,y) = 2x \cosh(ny) \sin(2xy) + n \sinh(ny) \cos(2xy)$$
(Abramowitz, 1970) 7.1.29, p. 299

$$\mathrm{erf}(x) = 1 - (a_1t + a_2t^2 + a_3t^3 + a_4t^4 + a_5t^5) . e^{-x^2}$$
(Abramowitz, 1970) 7.1.26, p. 299

$t = 1 / (1+ px)$ $p = .3275911$

$a_1 = .254829592$ $a_2 = -.284496736$ $a_3 = 1.421413741$

$a_4 = -1.453152027$ $a_5 = 1.061405429$

Solution of the preceding equations yields $\mathrm{erfc}(-i\sqrt{p_1})$

$$A = |1 + i\sqrt{\pi p_1}\ e^{-p_1}\ \mathrm{erfc}(i\sqrt{p_1})|$$

4) p between 5 and 20, b greater, or equal to $\pi/4$ or p between 0.65 and 20, b greater than $\pi/2$

In this range the computer programme uses the following identity to calculate A :

$$2 e^{z^2} \int_z^{\infty} e^{-t^2} dt = \frac{1}{z+} \frac{1/2}{z+} \frac{1}{z+} \frac{3/2}{z+} \frac{2}{z+} \ldots$$
(Abramowitz, 1970) 7.1.14, p. 298

If z is set equal to $-i\sqrt{p_1}$, the continued fraction (C.F.) equals,

$e^{-p_1}\sqrt{\pi}\ \mathrm{erfc}(-i\sqrt{p_1})$ and, $A = |1 + i\sqrt{p_1}\ .(\mathrm{C.F.})|$

5) p greater than 20, b any value

In this range of parameter values, the computer programme calculates the w(z) function from the following polynominal equation :

$$w(z) = iz(.4613135 / (z^2 - .1901635) + .9999216 / (z^2 - 1.7844297) +$$

$$.002883894 / (z^2 - 5.5253437))$$ (Abramowitz, 1970) bottom page 328

As in (1) previously, the substitution $\sqrt{p_1} = z$ is made, and:

$$A = |1 + i\sqrt{\pi p_1} \cdot w (\sqrt{p_1})|.$$

Mathematical discussion

II. Bremmer residue series

Bremmer (Bremmer, 1949) defines the attenuation factor for the ground-wave over the radio horizon as follows :

$$A_1 = \sqrt{2\pi\chi} \sum_{s=0}^{\infty} e^{iT_s\chi} / (2T_s - 1/\delta_e^2)$$

A_1 is the additional attenuation above the inverse distance attenuation. T_s are terms of the Bremmer residue series.

As defined by Bremmer :

$$X = (2\pi a \; / \lambda_{km})^{1/3} \; . \; D_0 \; o-$$

Bremmer used 6 370 km for the radius of the Earth. This is the actual average radius of the Earth. In the computer programme, a radius of 8 493 km (4/3 x 6370) was used for a. This change was made to conform to the usual practice to account for diffraction and because fields calculated by the Bremmer series with this larger radius were found to correspond more nearly to those given by the existing FCC ground-wave curves and to CCIR ground-wave curves. 5)

With this change and using the relationship between λ, the wavelength and F, the frequency in MHz.

$$X \text{ (Chi)} = 0.006635 \; . \; F^{1/3} \; . \; D$$

where D is the distance from the antenna in km.

If X is defined as previously given by Norton 2),

$$X = 17.9731 \; . \; SIG \; / \; F$$

where SIG in milli-Siemens metre is the ground conductivity. Then using E for the relative ground dielectric constant, the following parameters used by Bremmer may be calculated :

$$\Psi_e = \mathrm{Tan}^{-1} \; (E \; / \; X) -.5 \; . \; \mathrm{Tan}^{-1} \; ((E-1/ \; X)$$

$$K_e = 0{,}01957\sqrt{E^2 + X^2} \;) \; / \; (\; 4\sqrt{(E-1)^2 + X^2} \; .F^{1/3})$$

$$\delta_e = Ke. \; e^{\,i(2{,}356- \Psi e)} \quad (\Psi_e \text{ in radians })$$

The residue series given by Bremmer 3) is as follows :

When K_e is small (Ψ_e in degrees)

$$\mathrm{Im}\, T_0 = 1{,}607 - K_e \sin (45^0 + \Psi_e) -1{,}237 \; K_e^{\;3} \sin(75^o + 3\Psi_e) +$$
$$0{,}5 \; K_e^4 \sin(4\Psi_e) -2{,}755 \sin(75^o - \Psi_e)$$

$$\mathrm{Im}\, T_1 = 2{,}810 - K_c \sin(45^o + \Psi_e) -2{,}163 \; K_e^{\;3} \sin(75^o +3\Psi_e) +$$
$$0{,}5 K_e^{\;4} \sin(4 \; \Psi_e) -8{,}422 \; K_e^5 \sin(75^o - 5\Psi_e)$$

$$\mathrm{Im}\, T_2 = 3{,}795 - K_c \sin(45^o + \Psi e) -2{,}921 \; K_e^3 \sin(75^o + 3\Psi e) +$$
$$0{,}5 \; K_e^4 \sin(4\Psi_e) - 15{,}36 \; K_e^5 \sin(75^o - 5\Psi_e)$$

$$\mathrm{Re}\, T_0 = 0{,}928 + K_e \cos(45^o + \Psi_e) + 1{,}237 \; K_e^3 \cos(75^o +3\Psi_e) -$$
$$0{,}5 K_e^{\;4} \cos(4\Psi_e) - 2{,}755 \; K_e^{\;5} \cos(75^o -5\Psi_c)$$

$$\mathrm{Re}\, T_1 = 1{,}622 + K_e \cos (45^O + \Psi_e) + 2{,}163 \; K_c^3 \cos (75^o + 3\Psi_e) -$$
$$0{,}5 K_e^{\;4} \cos (4\Psi_e) -8{,}422 \; K_e \; 5 \cos (75^O - 5\Psi_e)$$

$$Re\,T_2 = 2{,}191 + K_e \cos(45^o + e) + 2{,}921\, K_e^{\;3} \cos(75^o + 3\Psi e) -$$
$$0{,}5\, K_e^{\;4} \cos(4\Psi e) - 15{,}36\, K_e^{\;5} \cos(75^o - 5\Psi_e)$$

When K_e is large (Ψ_e in degrees)

$$Im\,T_0 = 0{,}7003 - 0{,}6183 \sin(15^o - \Psi_e)/K_e + 0{,}2364 \cos(2\Psi_e)/K_e^{2} -$$
$$0{,}0533 \sin(15^o + 3\Psi_e)/K_e^{\;3} - 0{,}00226 \sin(60^o - 4\Psi_e)/K_e^{4}$$

$$Im\,T_1 = 2{,}232 - .1940 \sin(15^o - \Psi_e)/K_e + 0{,}0073 \cos(2\Psi_e)/K_e^{\;2} +$$
$$0{,}0120 \sin(15^o + 3\Psi e)/K_e^{\;3} + 0{,}00160 \sin(60^o - 4\Psi_e)/K_e^{4}$$

$$Re\,T_0 = 0{,}4043 + 0{,}6183 \cos(15^o - \Psi_e)/K_e - 0{,}2364 \sin(2\Psi_e)/K_e^{2} -$$
$$0{,}0533 \cos(15^o + 3\Psi_e)/K_e^{3} + 0{,}00226 \cos(60^o - 4\Psi_e)/K_e^{4}$$

$$Re\,T_1 = 1{,}288 + .1940 \cos(15^o - \Psi_e)/Ke - 0{,}0073 \sin(2\Psi_e)/K_e^{2} +$$
$$0{,}0120 \cos(15^o + 3\Psi_e)/K_e^{3} - 0{,}00160 \cos(60^o - 4\Psi_e)/K_e^{4}$$

To improve convergence of the series for distances near the radio horizon, the number of terms in each series has been increased to eight in the computer programme. The additional terms have been calculated by the methods given by Bremmer 3), pages 44 and 45. In this section, Bremmer lists the first six zeroes of each series according to the Hankel approximation. The remaining two additional terms were calculated by the tangent approximation.

For K_e small, in the tangent approximation, the zeroes are given as follows :

$$T_{s,0} = 1/2 \quad (3\pi(S + 3/4))^{2/3}\, e^{i\pi/3}$$

where T_s is the term number starting at zero.

For K_e large :

$$T_{s,\infty} = 1/2\ (3\pi\,(S + 1/4))^{\,2/3}\ e^{\,i\pi/3}$$

Each series term was then calculated from these equations given by Bremmer (Bremmer, 1949) page 45 :

K_e small

$$T_s = T_{s,o} - \delta - 2/3T_{s,0}\,\delta^3 + 1/2\,\delta^4 - 4/5\,T_{s,0}^{\;2}\,\delta^5 \ldots$$

K_e large

$$T_s = T_{s,\infty} - 1/(2T_{s,\infty} \cdot \delta) - 1/(8T_{s,\infty}^{\;3} \cdot \delta^2) -$$
$$(1 + 3/4T_{s,\infty}^{\;3})/(12T_{s,\infty}^{\;2} \cdot \delta^3) -$$
$$(1/32T_{s,\infty}^{\;3}) \cdot (7/3 + 5/4T_{s,\infty}^{\;3}) \cdot (1/\delta^4)$$

where $\delta = \delta_e$, as previously defined.

Mathematical discussion

Problems in calculation of ground-wave field strengths

One of the most time-consuming operations connected with the development of the ground-wave field strength computer programme was to find suitable methods of obtaining calculations for the Norton surface wave attenuation factor for the ranges of parameters to be used. The present ranges of use for each series or other calculation method for the attenuation factor were determined experimentally by requiring each method of calculation to give consistent values with the adjacent calculation methods. From time to time during programme development, as more field strength values were calculated for the standard broadcast band for the required range of ground constants, it would be found that for a narrow range of values of p and b, a particular series, or calculation method would give one, or several values of field strength at variance with values on either side of the inconsistent values. To the maximum extent possible such regions have been eliminated by proper choice of ranges for each calculation method. The continued fraction solution was introduced into the computer programme to cover a range where none of the other solution methods gave consistent values.

The Bremmer residue series was also found to contain such a region of inconsistency where neither K_e small or K_e large series gave consistent values. This region occurred for K_e values between 0.45 and 0.55. The problem was eliminated by linearly interpolating between each small and large series term prior to the Bremmer summation procedure.

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ANNEX F

AN INTRODUCTION TO DIRECTIONAL ANTENNA PATTERN CALCULATION

CONTENTS

Introduction

This Annex describes directional antenna calculation methods employed in the United States and Canada. Two-element directional patterns are presented for use as building blocks for more complicated patterns. Practical aspects of antenna calculation are discussed and a computer programme for a handheld calculator is given.

1. General equations

The theoretical directional antenna radiation pattern is calculated employing the following equation which sums the field strengths from the elements in the array :

$$E(\phi,\theta)_{th} = \left| K \sum_{i=1}^{n} F_i \, f_i(\theta) \; \underline{/\Psi_i + S_i \cos\theta \cos(\phi_i - \phi)} \right|^{*} \qquad (1)$$

$E(\phi,\theta)_{th}$ is the theoretical inverse distance field strength at one kilometre in mV/m for the given azimuth and elevation

K is the multiplying constant in mV/m which determines the basic pattern size (see paragraph 4.1 of this Annex for derivation of K)

n is the number of elements (towers) in the directional array

i is the ith element in the array

F_i represents the field ratio of the ith element in the array

θ is the vertical elevation angle, in degrees, measured from the horizontal plane

$f_i(\theta)$ is the vertical plane distribution factor of the ith element. For a typical vertical antenna, with sinusoidal current distribution

$$f(\theta) = \frac{\cos(G \sin\theta) - \cos G}{(1 - \cos G)\cos\theta} \qquad (2)$$

G is the electrical height of the element (tower) in degrees

S_i is the electrical spacing of the ith element from the reference point, in degrees

ϕ_i is the orientation of the ith element from the reference element (with respect to True North), in degrees

ϕ is the azimuth with respect to True North, in degrees

Ψ_i is the electrical phase angle of the current in the ith element (with respect to the reference element), in degrees.

The equation employed in the calculation of directional antenna patterns assumes that :

- the currents in the elements are sinusoidal,
- there are no losses in the elements or in the ground (see paragraph 3.3 of this Annex concerning ground systems),
- the antenna elements are fed at their base, and
- the distance to the computation point is large in relation to the directional array spacing.

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* $X\underline{/Y}$ indicates a complex number with an amplitude X and a phase Y in degrees.

2. Directional pattern examples

All examples in this section are based on antenna elements 90° in height and power input of 1 000 W. Unless otherwise specified, pattern values are theoretical values employing a multiplying constant which assumes no loss in the antenna system.

2.1 Two-element (tower) patterns

Complex directional patterns can be designed employing two-element directional patterns as building blocks.

For a two-element array, the null locations in the horizontal plane may be determined by the equation :

$$\phi_N = \text{arc cos} \left\{\frac{\pm 180 - \Psi}{S}\right\} \qquad (3)$$

where :

ϕ_N is the azimuth angle from the line of towers. (For simplicity, the elements are assumed to be on a line bearing True North with the reference tower (No. 1) to the south.)

Ψ is the phase of the current (at the current maxima) with respect to the reference (south) element, in degrees

S is the spacing between towers, in degrees.

For example, if two towers are spaced 90° apart, determine the phase angle needed to produce a null at ± 20° from the line of towers. Using equation (3),

$$\Psi = \pm 180^\circ - S \cos\phi_N$$

$$\Psi = \pm 180^\circ - 90^\circ \cos 20^\circ \qquad (4)$$

$$\Psi = 95.4^\circ$$

If the field strength from each tower is equal, complete cancellation of fields takes place at azimuths of 20° and 340°. If equal height elements are employed, the current ratio and field strength ratio are identical. Decreasing the current ratio or field ratio between towers causes the field strength in the minima to increase. A field strength ratio of 1:1 produces "zero" nulls. Conversely, a ratio of 1:0 implies use of only one tower since the current in the second tower is zero, thereby producing no radiation.

Figure 1 is a polar plot of a two-element directional antenna with nulls at azimuths ± 30° from True North. The pattern is shown with a 1:1 current ratio (solid line) and 1:0.7 current ratio (dashed line). The phase angle was determined by use of equation (4), as follows :

$$\Psi = \pm 180^\circ - 90^\circ \cos 30^\circ$$

$$\Psi = 102^\circ$$

The pattern which employs a 1:1 field strength ratio was calculated using equation (1) as follows :

$$E_{(\phi)} = K \left\{ (1\underline{/0^\circ}) + (1\underline{/102^\circ + 90^\circ \cos\phi}) \right\} \qquad (5)$$

where :

K = 235.9 mV/m at 1 km as determined by computer calculations (see paragraph 4.1 of this Annex).

The term for the elevation angle θ is not shown since only the horizontal plane pattern was computed.

The equation for the same pattern but with 1:0.7 field ratio is :

$$E_{(\phi)} = \left\{ K \quad \underline{1/0^\circ} + 0.7\underline{/102^\circ + 90^\circ \cos\phi} \right\} \qquad (6)$$

where :

K = 272.3 mV/m.

The two-element patterns shown in Figures 1 to 4 were calculated employing the following parameters :

Figure number	Null location (degrees)	Tower No. 2 field	Tower No. 2 phase (degrees)	Spacing (degrees)	Orientation (degrees)	Antenna height (degrees)	K (mV/m)
1 ——	± 30	1.0	102	90	0	90	235.9
1 ---	± 30	0.7	102	90	0	90	272.3
2 ——	± 60	1.0	135	90	0	90	285.0
2 ---	± 60	0.7	135	90	0	90	324.0
3 ——	± 90	1.0	180	90	0	90	333.5
3 ---	± 90	0.7	180	90	0	90	372.4
4 ——	± 40	1.0	42	180	0	90	237.4

Figures 1 to 3 are for towers spaced 90° apart and with nulls at ± 30°, ± 60° and ± 90°. The pattern of Figure 4 uses a spacing of 180° and nulls at ± 40°.

2.2 Three-element (tower) patterns

Figure 5 is a three-element array which combines the two-tower pattern shown in Figure 1 with the two-tower pattern shown in Figure 2. The "pairs" of elements are combined by vector multiplication. The pattern of Figure 1 is assumed to have parameters of $1\underline{/0}$ and $F_2\underline{/\Psi_2}$. The pattern of Figure 2 is assumed to have parameters of $1\underline{/0}$ and $F_3\underline{/\Psi_3}$. By vector multiplication, the resulting parameters for the three-element array are :

Tower number	Field and phase
3 (north)	$F_2F_3\underline{/\Psi_2 + \Psi_3}$
2 (centre)	$F_2\underline{/\Psi_2} + F_3\underline{/\Psi_3}$
1 (south)	$1.0\underline{/0^\circ}$

Using 1:1 ratios for the two pairs, the parameters are :

No. 3 $(1)(1)\underline{/102^\circ + 135^\circ} = 1.0\underline{/237^\circ}$

No. 2 $1\underline{/102^\circ} + 1\underline{/135^\circ} = 1.92\underline{/118.5^\circ}$

No. 1 $1.0\underline{/0^\circ} = 1.0\underline{/0^\circ}$

Using the 1:0.7 ratios for the two pairs, the parameters are :

No. 3 $(0.7)(0.7)\underline{/102° + 135°} = 0.49\underline{/237°}$

No. 2 $0.7\underline{/102°} + 0.7\underline{/135°} = 1.34\underline{/118.5°}$

No. 3 $1.0\underline{/0°} = 1.0\underline{/0°}$.

The pattern computed using 1:1 ratios is shown on Figure 5 as a solid line. The pattern using 1:0.7 ratios is a dashed line.

2.3 Four-element (tower) patterns

If the two-element pattern shown in Figure 3 is combined with the three-element pattern shown in Figure 5, a four-element pattern is obtained. The four-element pattern is thereby composed of the three patterns shown on Figures 1, 2 and 3.

By vector multiplication, the parameters for the four towers using two-element pairs of

$1\underline{/0°}$ $F_2\underline{/\psi_2}$

$1\underline{/0°}$ $F_3\underline{/\psi_3}$

$1\underline{/0°}$ $F_4\underline{/\psi_4}$ are:

Tower number	Field and phase
4 (north)	$F_2F_3F_4\underline{/\psi_2 + \psi_3 + \psi_4}$
3	$F_2F_3\underline{/\psi_2 + \psi_3} + F_2F_4\underline{/\psi_2 + \psi_4} + F_3F_4\underline{/\psi_3 + \psi_4}$
2	$F_2\underline{/\psi_2} + F_3\underline{/\psi_3} + F_4\underline{/\psi_4}$
1 (south)	$1\underline{/0°}$.

For the pairs having 1:1 ratio, the parameters for the pattern of Figure 6 are :

No. 4 $(1)(1)(1)\underline{/102° + 135° + 180°} = 1.0\underline{/57°}$

No. 3 $(1)(1)\underline{/102° + 135°} + (1)(1)\underline{/102° + 180°}$
$+ (1)(1)\underline{/135° + 180°} = 2.55\underline{/-82°}$

No. 2 $1\underline{/102°} + 1\underline{/135°} + 1\underline{/180°} = 2.55\underline{/139°}$

No. 1 $1\underline{/0°} = 1\underline{/0°}$.

In a similar manner, the parameters for the four-tower array with the three pairs using 1:0.7 field ratio are :

No. 4 $0.34\underline{/57°}$

No. 3 $1.25\underline{/-82°}$

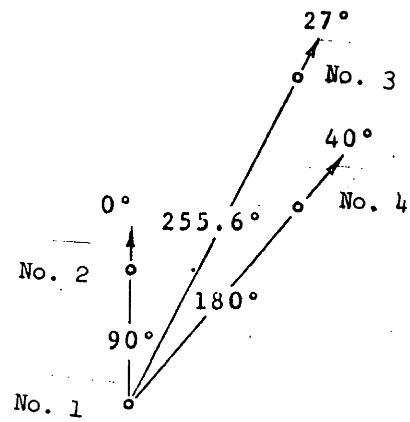
No. 2 $1.79\underline{/139°}$

No. 1 $1\underline{/0°}$.

2.4 Asymmetrical directional patterns

The two-, three- and four-tower directional patterns discussed have elements which are "in-line" and therefore produce patterns which are symmetrical about the line of towers. Depending on the amount of asymmetry desired, it is often possible to employ a three-or four-tower in-line pattern for the basic design shape and by offsetting one tower a few degrees, to produce asymmetry. The results of this method are difficult to predict and are time-consuming, unless done by computer.

A four-tower (or more) parallelogram allows excellent control of pattern shape in a more predictable manner. Consider, for example, combining the pattern of Figure 1 and the pattern of Figure 4 to produce the asymmetrical pattern shown on Figure 7. In this example, the Figure 4 pattern is rotated 40° clockwise from True North. A sketch of the tower layout follows :



The azimuth angle and distance to Tower No. 3 can be determined employing basic trigonometric equations.

Parameters for a four-tower parallelogram made up of pairs

$1/\underline{0}$ $F_2/\underline{\varphi_2}$

$1/\underline{0}$ $F_4/\underline{\varphi_4}$ are:

No. 4 $F_4/\underline{\varphi_4}$

No. 3 $F_2 F_4/\underline{\varphi_2 + \varphi_4}$

No. 2 $F_2/\underline{\varphi_2}$

No. 1 $1/\underline{0^\circ}$.

For the example of Figure 7, the parameters are :

No. 4 $1/\underline{42^\circ}$

No. 3 $(1)(1)/\underline{42^\circ + 102^\circ} = 1/\underline{144^\circ}$

No. 2 $1/\underline{102^\circ}$

No. 1 $1/\underline{0^\circ}$.

The equation for the pattern shown on Figure 7, using general equation (1) is :

$$E = K \{1\underline{/0^\circ} + 1\underline{/102^\circ + 90^\circ\cos(0 - \phi)^\circ} + 1\underline{/144^\circ + 255.6^\circ\cos(27 - \phi)^\circ} + 1\underline{/42^\circ + 180^\circ\cos(40 - \phi)^\circ}\} \quad (7)$$

where :

K = 99.8 mV/m as calculated by computer programme.

Figure 7 also shows a "standard" pattern for the same antenna parameters. The method used in a standard pattern calculation is detailed in paragraph 4.6 of this Annex. The standard pattern constitutes a pattern envelope which is slightly larger than the theoretical pattern calculated with no loss. The standard pattern is easily computerized and provides reasonable assurance that a measured or adjusted directional pattern will not exceed standard pattern values. A theoretical pattern is exceeded on occasion for one or more of the following reasons :

- re-radiation from nearby metallic objects,
- terrain irregularities,
- nonsinusoidal tower current distribution,
- ground system irregularities, and
- the physical inability to "prove" patterns with "zero" nulls.

The standard pattern shown on Figure 7 has a theoretical r.m.s. and RSS (root sum square) values of 290 mV/m and 317 mV/m, respectively. The RSS/r.m.s. ratio is slightly over unity, an indication of good "quality" antenna system (see paragraph 3.4 of this Annex).

3. Practical pattern calculation

Although it is possible to design directional antenna patterns which have short elements (generally less than 70°) or close spacing (generally less than 80°), practical considerations limit their usefulness because of radiation inefficiency and instability. Some practical aspects are discussed in this section.

3.1 Element (tower) height

The heights of towers employed in directional arrays are selected on the basis of :

- pattern design considerations (achieving proper vertical radiation characteristics and array efficiency),
- adequate driving point impedances,
- aeronautical safety,
- cost.

It may be desirable, for example, when a short tower must be used, to consider "top-loading" by addition of a capacitive "top-hat" or employing the uppermost guy wires for top loading where a guyed tower is employed. Top loading has the effect of making a short tower electrically taller. However, depending on the physical height of the structure, usually only 10° to 15° of electrical height can be achieved with the "guy wire" method. Guy wire top loading is achieved by connecting the top guy wires to the tower and placing an insulator in the guy at a particular distance from the top. Using top loading also requires modification of the equation for the antenna vertical characteristic, $f(\theta)$, (equation (2)).

3.2 Spacing between directional array elements

Generally, spacing of less than 80° should be avoided. The mutual impedance between closely spaced towers becomes large as the spacing is decreased, causing the antenna driving point resistance to approach zero or become negative (a negative driving point implies that the mutual impedance(s) is/are larger than the element self-impedance, so that the negative tower actually returns power to the system combining point). A tower with a large negative driving point resistance can be controlled, whereas a tower with very low resistance can result in losses in the system and can be difficult to control. Consider two simple cases; a single antenna element with input power of 1 000 W, loss resistance, R_L of one ohm, and radiation resistance in one case of 10 ohms and 50 ohms in the second case.

Antenna current is given by the following equation :

$$I = \left(\frac{P}{R_L + R_R}\right)^{\frac{1}{2}} \qquad (8)$$

where :

I is the current, amperes

P is the input power, Watts

R_L is the loss in the system, ohms

R_R is the radiation resistance, ohms.

For 1 000 W, the antenna current for the first case is

$$I = \left(\frac{1000}{1 + 10}\right)^{\frac{1}{2}} = 9.53 \text{ A}$$

the power loss is I^2R_L or 91 W.

In the second case, the antenna current is

$$I = \left(\frac{1000}{1 + 50}\right)^{\frac{1}{2}} = 4.43 \text{ A}$$

and the loss is I^2R_L or 20 W.

Generally, a directional array is expected to exhibit a loss resitance of at least one ohm per element, with the resistance assumed to be in series with the base of each element in the array.

3.3 Antenna ground system

For directional antennae, a ground system of adequate size is important so as to minimize ground losses, to provide for a stable operating system and to produce a predictable radiation pattern. Copper wire radials, for example 120 in number, each 90° in length (one-quarter wavelength) equally spaced around each tower are considered adequate in most instances. Where radials between adjacent towers would overlap, they are bonded together or welded to a 10 cm wide copper strap, having thickness of about 0.8 mm. Where high base voltages are expected, usually in towers having heights near 0.4 λ (144°), an expanded copper mesh screen, approximately 7 x 7 m^2, is employed at the tower base. The copper wire radials are then bonded to the copper screen at its periphery. The copper wires are usually buried 10 to 15 cm to protect them from damage.

The importance of an adequate ground system cannot be overemphasized since directional array calculations depend on predictable antenna characteristics which are realized only with an adequate ground system.

3.4 RSS/r.m.s. ratio

Paragraphs 4.1 and 4.6 of this Annex give a method for determining the r.m.s. and RSS for a directional pattern. The ratio of RSS/r.m.s. provides a number which implies a "quality" for a particular directional array. When the RSS/r.m.s. ratio is near unity, the array is considered to be excellent. When the ratio exceeds 2, caution must be exercised in its use. An array with an RSS/r.m.s. ratio greater than 3.0 should be avoided if possible.

3.5 Antenna monitoring

The magnitude and phase of the current in each element can be monitored by employing a device at the tower feed point or on the tower which samples the current in the element. Either a toroidal pickup at the tower base or a loop antenna on the tower may be used (naturally, a loop on the tower requires isolation as it crosses the base insulator if used at tower potential). The current samples are returned to the antenna monitor by means of a small diameter coaxial cable. The cables are usually of equal length, which allows for a direct phase reading to be made between towers. The antenna monitor, which compares current and phase in each element with those in the reference tower, is generally located near the transmitter or the equipment employed to divide the power between towers.

3.6 Pattern calculations

Handheld calculators are easily programmed to calculate directional patterns. Figure 8 gives a programme to compute an array of six elements or less. This programme was written for a TI-59 programmable calculator, but can be modified for use with other handheld calculators.

The programme is used as follows :

Step	Press
Enter number of towers (six maximum)	A
Prepare registers for data	B
For each tower enter : current ratio	R/S
phase	R/S
spacing	R/S
orientation	R/S
tower weight	R/S
Multiplying constant, K	C
Vertical angle, θ	D
Azimuth (from True North), ϕ	E
Pattern value is displayed in MV/M at 1 km for θ and ϕ	
A new ϕ or θ can be entered and the pattern recalculated	E

If the calculator has an associated printer, the programme can be modified to automatically print ϕ and θ at predetermined intervals, and the calculated values at those intervals.

4. Determination of important values and constants

4.1 Determination of the multiplying constant, K, for an array

The multiplying constant, K, for the loss-free case may be computed by integrating the power flow over the hemisphere, deriving an r.m.s. field strength, and comparing the result with the case where the power is radiated uniformly in all directions over the hemisphere.

Thus

$$K = \frac{E_s\sqrt{P}}{r.m.s._h} \qquad \text{mV/m}$$

where

K : no loss multiplying constant

E_s : reference level for uniform radiation over a hemisphere and is 244.95*

P : antenna input power (kW)

$r.m.s._h$: root-mean-square effective field intensity over the hemisphere (based on a multiplying constant of unity) which may be obtained by integrating the r.m.s. at each vertical angle over the hemisphere. The integration can be made using the trapozoidal method of approximation.

$$r.m.s._h = \left\{ \frac{\pi\Delta}{180} \left[\frac{r.m.s.^2(\theta = 0^\circ)}{2} + \sum_{m=1}^{L} r.m.s._{m\Delta}^2 \cos m\Delta \right] \right\}^{\frac{1}{2}} \qquad (9)$$

where

Δ : the interval, in degrees, between the equally spaced sampling points at the different elevation angles θ

m : an integer from 1 to L, which gives the elevation angle θ in degrees when multiplied by Δ

L : one less than the number of intervals

L : $90/\Delta - 1$

$r.m.s._\theta$: the root mean square field strength at the specified elevation angle θ

$$r.m.s._\theta : \left[\sum_{i=1}^{n} \sum_{j=1}^{n} F_i\, f_i(\theta)\, F_j\, f_j(\theta) \cos\Psi_{ij} J_0(S_{ij} \cos\theta) \right]^{\frac{1}{2}} \qquad (10)$$

where

i : the ith element

j : the jth element

n : the number of elements in the array

F_i : the field strength ratio of the ith element

*

$$E_s = \left[\frac{120\pi \times 1\,000 \times P}{2\,\pi\, r^2} \right]^{\frac{1}{2}} \times 10^3 \qquad \text{mV/m}$$

where r is the distance from the antenna in km. For 1 kW uniformly radiated over a hemisphere, the value E_s at 1 km is 244.95 mV/m.

$f_i(\theta)$: the vertical plane distribution factor of the ith element (see equation (2))

F_j : the field strength ratio of the jth element

$f_j(\theta)$: the vertical plane distribution factor of the jth element

Ψ_{ij} : the difference in electrical phase angles of the currents in the ith and jth elements in the array

S_{ij} : the spacing in degrees between the ith and jth elements in the array

$J_0(S_{ij}\cos\theta)$: the Bessel function of the first kind and zero order of the apparent spacing between the ith and jth towers.

4.2 Relationship of field strength to antenna current

The field strength resulting from a current flowing in a vertical antenna element is :

$$E = \frac{R_c\ I[\cos(G\ \sin\theta) - \cos G]}{2\pi r\ \cos\theta} \times 10^3 \quad \text{mV/m} \qquad (11)$$

where

E : the field strength in mV/m

R_c : the resistivity of free space, 120π ohms

I : the current at the current loop, in amperes

G : the electrical height of the element, in degrees

r : the distance from the antenna, in metres

θ : the vertical elevation angle, in degrees.

At one kilometre and in the horizontal plane ($\theta = 0^\circ$) :

$$E = \frac{120\ \pi\ I[1 - \cos G]}{2\pi\ (1\ 000)} \times 10^3 \quad \text{mV/m} \qquad (12)$$

$$E = 60\ I[1 - \cos G] \quad \text{mV/m} \qquad (13)$$

4.3 Determination of no-loss loop current

For a uniform cross-section tower or a similar type of directional array element, the no-loss loop current (the current at the current maximum) is :

$$I_i = \frac{KF_i}{60\ (1 - \cos G_i)} \qquad (14)$$

where

I_i : the loop current in amperes in the ith element

K : the no-loss multiplying constant computed as shown in paragraph 4.1 of this Annex

F_i : the field strength ratio for the ith element

G_i : the electrical height of the ith element, degrees

If the tower is less than 90 electrical degrees in height, the base current is computed by multiplying the loop current by sin G.

4.4 Array power loss

Power is lost in a directional antenna system for various reasons, including ground losses, antenna coupling losses, etc. The loss resistance for the array may be assumed to be in series with the element base resistances to account for all losses. The power loss is :

$$P_{loss} = \frac{1}{1\,000} \sum_{i = n}^{n} R_i \, I_i^2 \qquad (15)$$

where

P_{loss} : the total power loss in kilowatts

i : the ith element

n : the number of elements in the array

R_i : the assumed loss resistance in ohms (one ohm, unless otherwise notifed) for the ith tower

I_i : the loop current (or base current if element is less than 90 electrical degrees in height) for the ith tower

4.5 Determination of an adjusted multiplying constant

The multiplying constant, K, can be modified to account for power loss in the antenna system as follows :

$$K_{loss} = K\left(\frac{P}{P + P_{loss}}\right)^{\frac{1}{2}} \qquad (16)$$

where

K_{loss} : the multiplying constant after adjustment for the assumed loss resistance

K : the no-loss multiplying constant computed in paragraph 4.1 of this Annex

P : the array input power

P_{loss} : the total power loss in kilowatts

4.6 Determination of standard pattern values

Although a standard pattern is not proposed for Region 2, the United States and Canada employ a method for computing directional patterns that will produce an envelope larger than the theoretical directional pattern. This provides a reasonable degree of assurance that the actual directional array will not produce measured values higher than the standard pattern value. (The FCC also has a method to handle the infrequent occurrence of a measured pattern value exceeding a standard pattern by use of an augmented or modified standard pattern.) The standard pattern is easily computer generated.

The standard pattern is determined as follows :

$$E(\phi, \theta)_{std} = 1.05\left[\left\{E(\phi, \theta)_{th}\right\}^2 + Q^2\right]^{\frac{1}{2}} \qquad (17)$$

where

$E(\phi, \theta)_{std}$: the inverse distance field strength at one kilometre which is assumed to be produced by the directional antenna

$E(\phi, \theta)_{th}$: the theoretical inverse distance fields strengths at one kilometre as computed with equation (1), except that the multiplying constant, K, is determined assuming a lumped loss resistance of one ohm at the current loop of each element of the array (or at the base if the tower is less than 90°). The computation of K_{loss} is detailed in paragraph 4.5 of this Annex.

Q is the greater of the following quantities :

$$0.025\ f(\theta)E_{RSS}$$

or

$$10.0\ f(\theta)\sqrt{P}$$

where

f(θ) : the vertical plane distribution factor, for the shortest element in the array (see equation (2))

E_{RSS} : the root-sum-square of the amplitudes of the inverse field strengths of the elements of the array in the horizontal plane, and is computed as follows :

$$E_{RSS} = K_{loss}\left[\sum_{i=1}^{n} F_i^{\,2}\right]^{\frac{1}{2}} \qquad (18)$$

where

P : the array input power in kilowatts and must not be less than 1.

(The ratio of RSS to r.m.s. in a particular antenna array has design and stability significance. Refer to paragraph 3.4 of this Annex for additional information.)

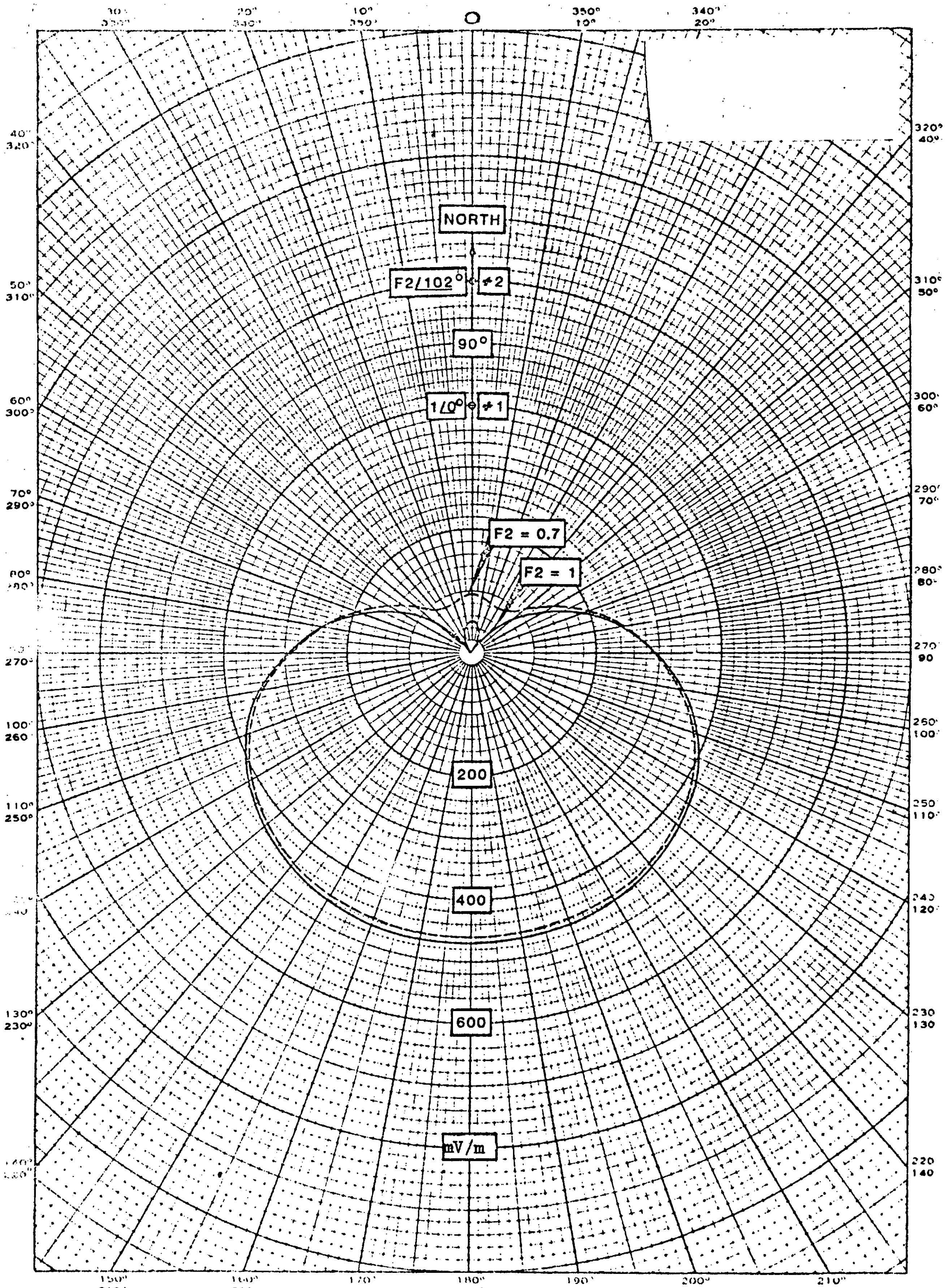


FIGURE 1 - Two-element patterns

P = 1 kW G = 90° nulls ± 30°

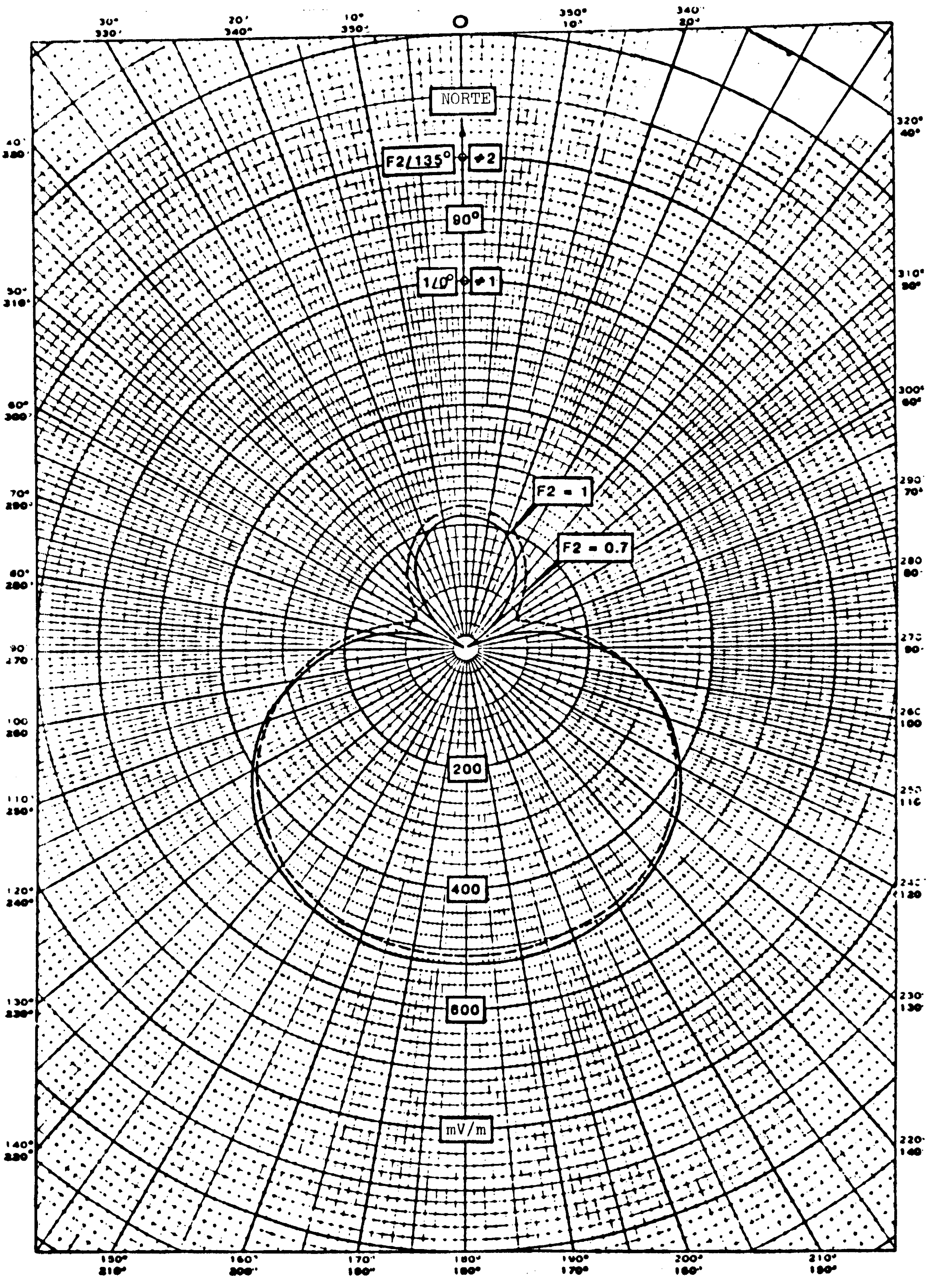


FIGURE 2 - Two-element patterns

P = 1 kW G = 90° nulls ± 60°

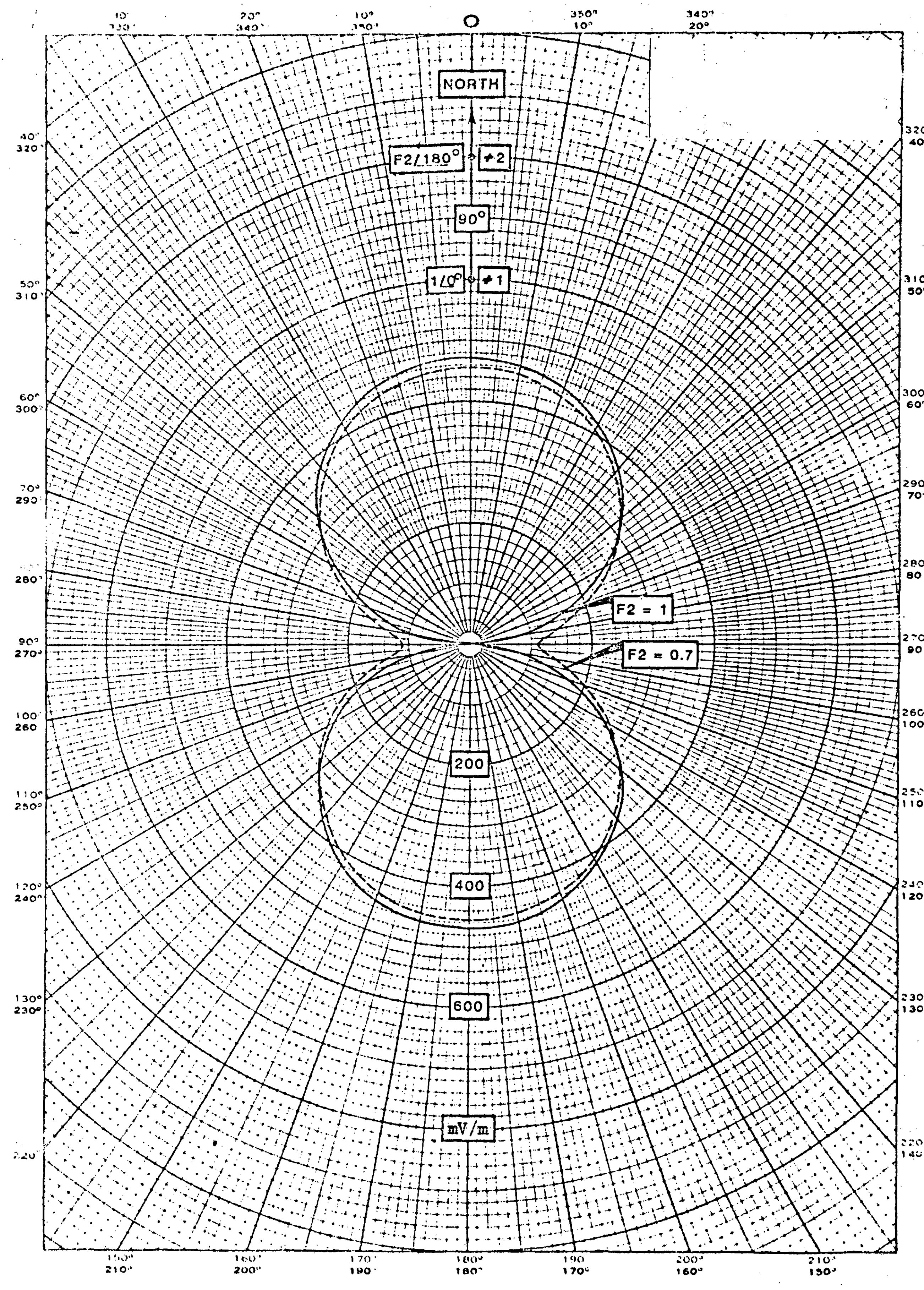


FIGURE 3 - Two-element patterns

P = 1 kW G = 90° nulls ± 90°

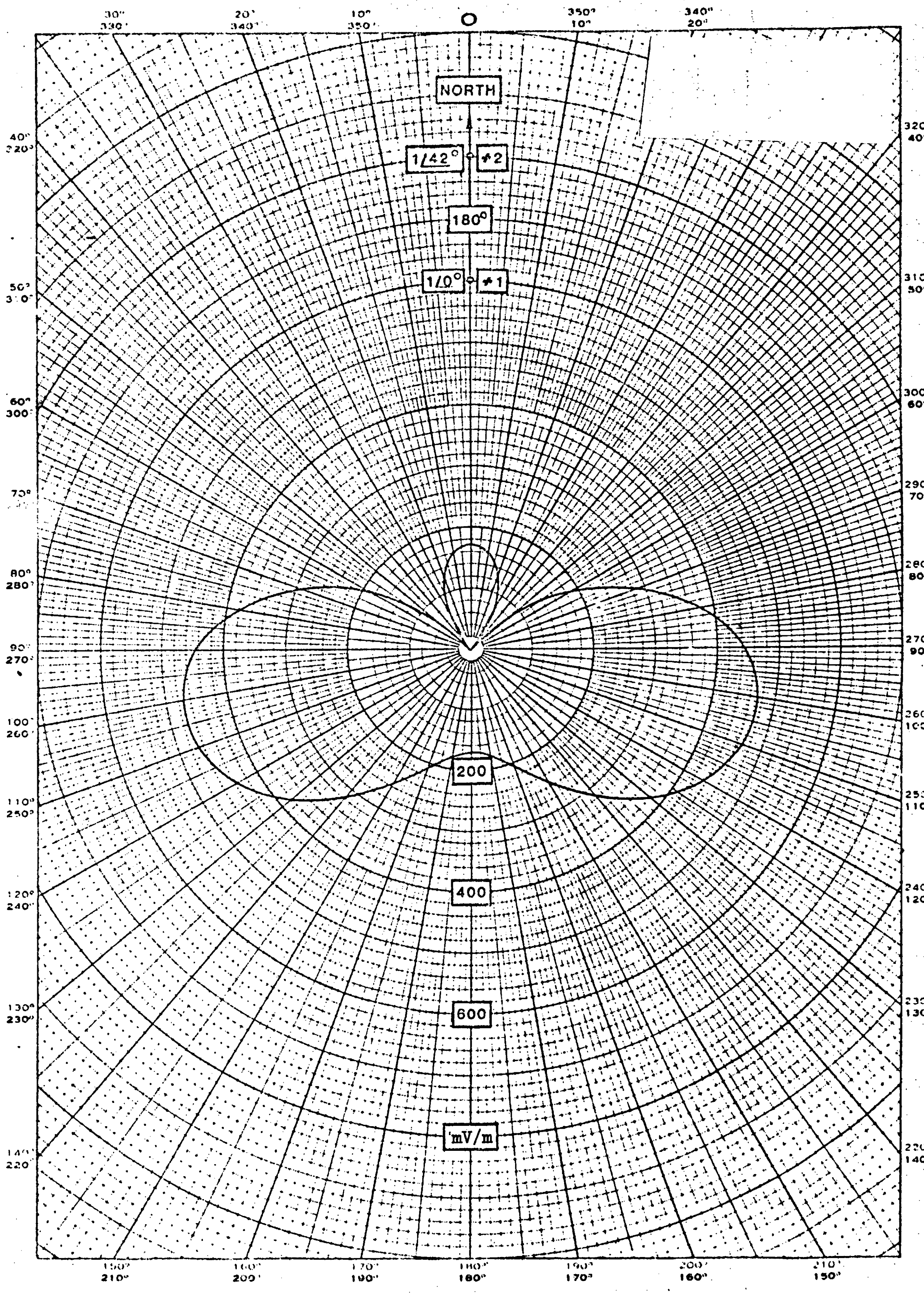


FIGURE 4 - Two-element patterns

P = 1 kW G = 90° nulls ± 40°

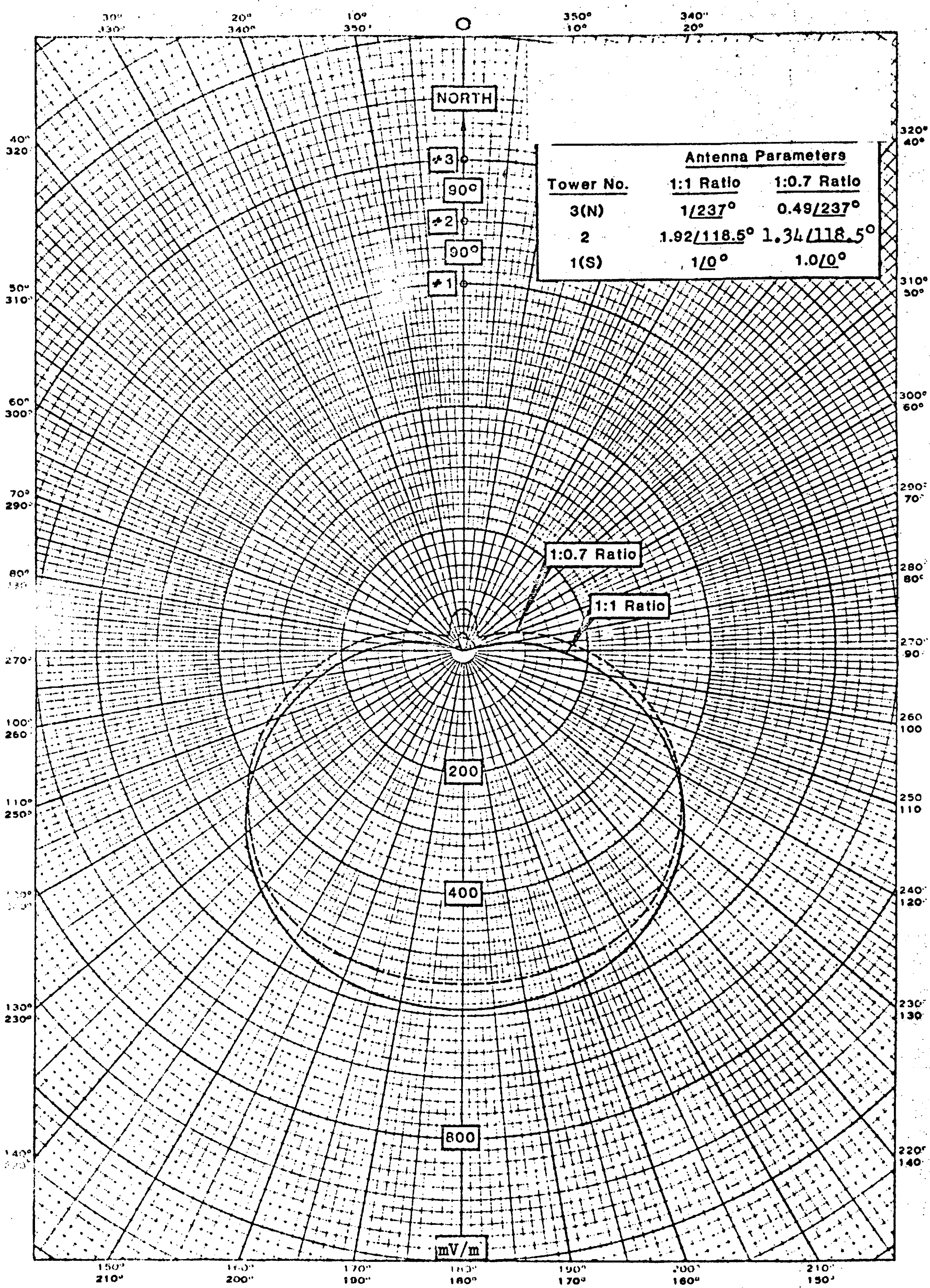


FIGURE 5 - Three-element patterns

P = 1 kW G = 90° nulls ± 30°, ± 60°

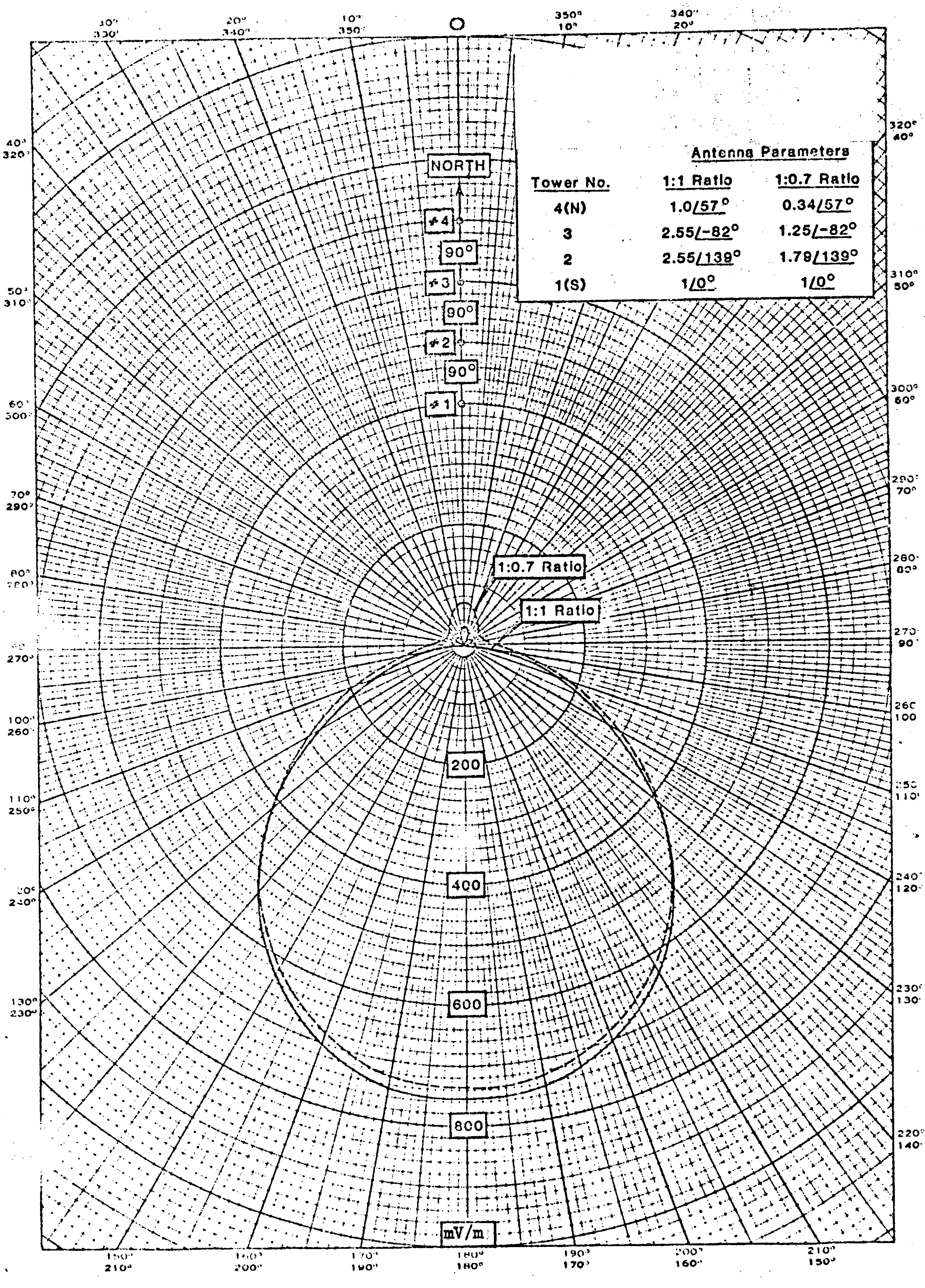
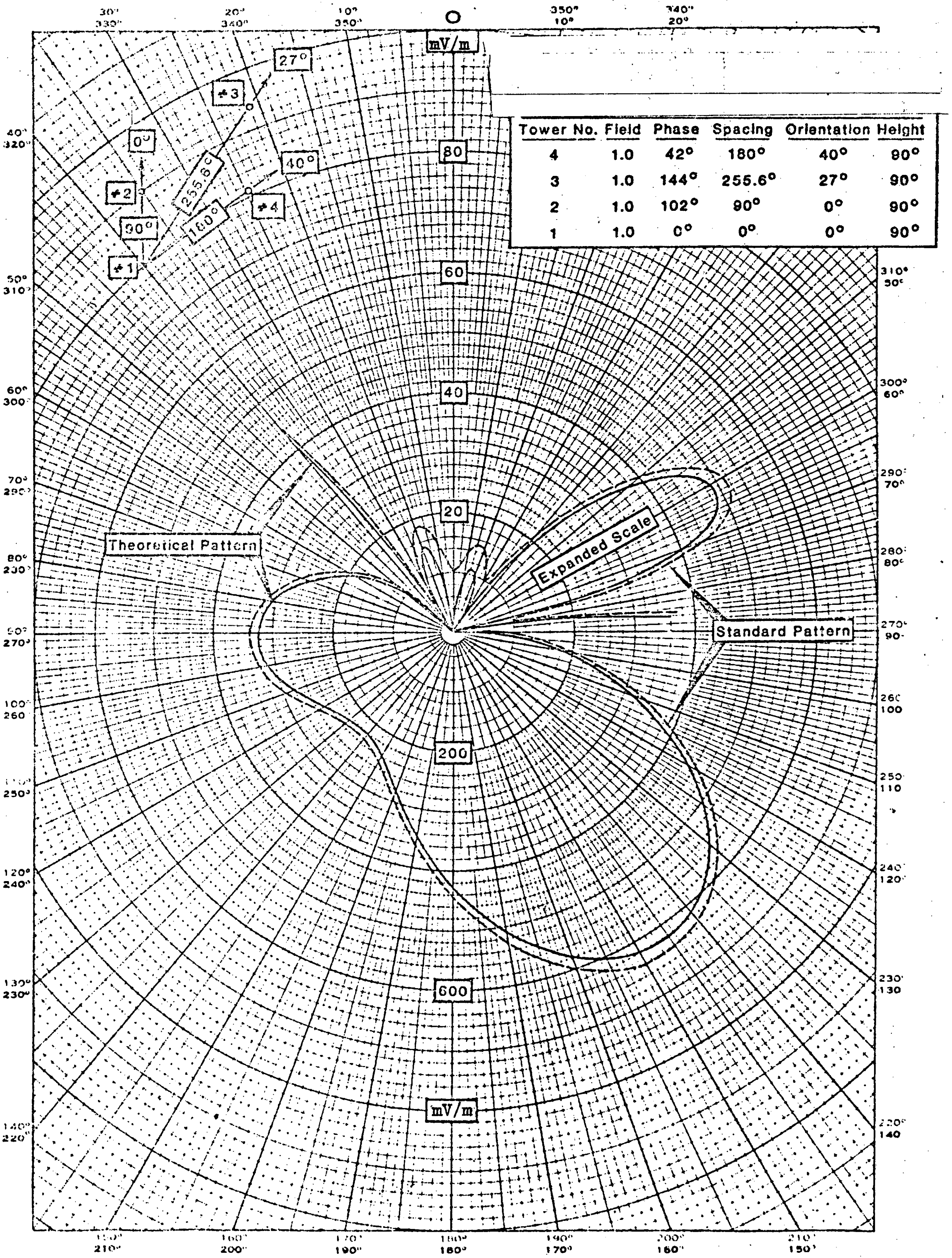


FIGURE 6 - Four-element patterns

P = 1 kW G = 90° nulls ± 30°, ± 60°, ± 90°



Tower No.	Field	Phase	Spacing	Orientation	Height
4	1.0	42°	180°	40°	90°
3	1.0	144°	255.6°	27°	90°
2	1.0	102°	90°	0°	90°
1	1.0	0°	0°	0°	90°

FIGURE 7 - Four-element non-symmetrical patterns (theoretical and standard patterns)

P = 1 kW G = 90°

000	76	LBL									
001	11	A	058	72	ST*	115	42	STO	172	43	RCL
002	42	STO	059	01	01	116	37	37	173	40	40
003	00	00	060	69	OP	117	42	STO	174	67	EQ
004	32	X:T	061	31	31	118	38	38	175	79	x̄
005	43	RCL	062	91	R/S	119	42	STO	176	61	GTO
006	00	00	063	72	ST*	120	40	40	177	33	X²
007	85	+	064	02	02	121	76	LBL	178	76	LBL
008	06	6	065	69	OP	122	33	X²	179	79	x̄
009	95	=	066	32	32	123	01	1	180	43	RCL
010	42	STO	067	91	R/S	124	44	SUM	181	37	37
011	01	01	068	72	ST*	125	40	40	182	32	X:T
012	43	RCL	069	03	03	126	73	RC*	183	43	RCL
013	00	00	070	69	OP	127	04	04	184	38	38
014	85	+	071	33	33	128	69	OP	185	22	INV
015	01	1	072	91	R/S	129	34	34	186	37	P/R
016	02	2	073	72	ST*	130	94	+/-	187	32	X:T
017	95	=	074	04	04	131	85	+	188	65	×
018	42	STO	075	69	OP	132	43	RCL	189	43	RCL
019	02	02	076	34	34	133	06	06	190	39	39
020	43	RCL	077	91	R/S	134	95	=	191	95	=
021	00	00	078	72	ST*	135	39	COS	192	58	FIX
022	85	+	079	05	05	136	65	×	193	02	02
023	01	1	080	69	OP	137	43	RCL	194	91	R/S
024	08	8	081	35	35	138	50	50	195	76	LBL
025	95	=	082	43	RCL	139	39	COS	196	52	EE
026	42	STO	083	45	45	140	95	=	197	73	RC*
027	03	03	084	67	EQ	141	65	×	198	05	05
028	43	RCL	085	89	π	142	73	RC*	199	69	OP
029	00	00	086	61	GTO	143	03	03	200	35	35
030	85	+	087	12	B	144	69	OP	201	42	STO
031	02	2	088	76	LBL	145	33	33	202	41	41
032	04	4	089	89	π	146	95	=	203	65	×
033	95	=	090	00	0	147	85	+	204	43	RCL
034	42	STO	091	91	R/S	148	73	RC*	205	50	50
035	04	04	092	76	LBL	149	02	02	206	38	SIN
036	43	RCL	093	13	C	150	69	OP	207	95	=
037	00	00	094	42	STO	151	32	32	208	39	COS
038	85	+	095	39	39	152	95	=	209	75	−
039	03	3	096	91	R/S	153	32	X:T	210	43	RCL
040	00	0	097	76	LBL	154	71	SBR	211	41	41
041	95	=	098	14	D	155	52	EE	212	39	COS
042	42	STO	099	42	STO	156	65	×	213	95	=
043	05	05	100	50	50	157	73	RC*	214	55	÷
044	00	0	101	91	R/S	158	01	01	215	53	(
045	42	STO	102	76	LBL	159	69	OP	216	53	(
046	45	45	103	15	E	160	31	31	217	01	1
047	43	RCL	104	42	STO	161	95	=	218	75	−
048	00	00	105	06	06	162	32	X:T	219	43	RCL
049	92	RTN	106	43	RCL	163	37	P/R	220	41	41
050	76	LBL	107	00	00	164	44	SUM	221	39	COS
051	12	B	108	71	SBR	165	38	38	222	54	)
052	01	1	109	11	A	166	32	X:T	223	65	×
053	44	SUM	110	61	GTO	167	44	SUM	224	43	RCL
054	45	45	111	42	STO	168	37	37	225	50	50
055	43	RCL	112	76	LBL	169	43	RCL	226	39	COS
056	45	45	113	42	STO	170	00	00	227	95	=
057	91	R/S	114	00	0	171	32	X:T	228	92	RTN

FIGURE 8 - Directional pattern programme for TI-59 programmable calculator

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ANNEXE G

CARACTERISTIQUES DES STATIONS DES ADMINISTRATIONS N'AYANT PAS REPONDU A LA LETTRE-CIRCULAIRE N° 441 DE L'IFRB

(voir paragraphe 7.1, chapitre 7)

ANNEX G

CHARACTERISTICS OF STATIONS OF ADMINISTRATIONS WHICH HAVE NOT REPLIED TO IFRB CIRCULAR-LETTER N° 441

(see paragraph 7.1, chapter 7)

ANEXO G

CARACTERISTICAS DE LAS ESTACIONES DE LAS ADMINISTRACIONES QUE NO HAN RESPONDIDO A LA CARTA-CIRCULAR N° 441 DE LA IFRB

(véase el párrafo 7.1, capítulo 7)

Administration Administration Administración	**Fréquence** Frequency Frecuencia (kHz)	**Puissance de la porteuse** Carrier Power Potencia de la portadora (kW)	**Emplacement** Location Ubicación
1	2	3	4
BAHAMAS	810	1	FREEPORT
	1240	1	FREEPORT
	1540	20	FREEPORT
BARBADE/BARBADOS/ BARBADOS	900	10	BRIDGETOWN
COSTA RICA	525	0.25	CARTAGO
	550	10	SAN JOSE
	575	30	SAN JOSE
	600	3.5	SAN JOSE
	625	12	SAN JOSE
	650	10	SAN JOSE
	675	12	SAN JOSE
	700	10	SAN JOSE
	725	10	SAN JOSE
	750	3	SAN JOSE

1	2	3	4
COSTA RICA (suite/cont.)	775	10	SAN JOSE
	800	5	SAN JOSE
	825	20	SAN JOSE
	850	1	SAN PEDRO DE MONTES DE OCA
	850	1	LIBERIA
	875	1	LIBERIA
	900	5	SAN JOSE
	925	1	SAN JOSE
	950	2	SAN JOSE
	975	10	SAN JOSE
	1000	10	SAN JOSE
	1025	10	SAN JOSE
	1050	1	PUNTARENAS
	1075	5	SAN JOSE
	1100	1	SAN ISIDRO
	1120	5	SAN JOSE
	1130	1	SAN CARLOS
	1160	1	EL ROBLE
	1200	14	SAN JOSE
	1180	1	LIMON
	1220	5	SAN FRANCISCO
	1240	1	NICOYA
	1260	1	SAN VITO
	1280	1	ALAJUELA
	1300	2.5	CARTAGO
	1320	1	LIMON
	1340	1	SAN RAMON
	1360	1	LIMON
	1380	1	LIBERIA
	1400	5	SAN ISIDRO
	1420	1	NICOYA
	1460	1	CIUDAD QUESADA
	1463	1	SAN CARLOS
	1480	1	PUNTARENAS
	1500	2	CIUDAD QUESADA
	1520	1	TURRIALBA
	1540	1	SAN JOSE
DOMINICAINE (Rép.) DOMINICAN Rep. DOMINICANA (Rep.)	540	5	STO. DOMINGO
	560	5	SANTIAGO
	570	5	STO. DOMINGO

1	2	3	4
DOMINICAINE (Rép.) DOMINICAN Rep. DOMINICANA (Rep.) (suite/cont.)	590	5	LA VEGA
	620	10	STO. DOMINGO
	630	1	MONTE CRISTI
	650	5	STO. DOMINGO
	660	2	SANTIAGO
	680	3	SANTIAGO RODRIGUEZ
	690	5	STO. DOMINGO
	700	1	VALVERDE
	720	5	SANTIAGO
	730	5	STO. DOMINGO
	750	5	SANTIAGO
	770	0.5	TAMBORIL
	780	1	CONSTANZA
	790	5	STO. DOMINGO
	820	5	SANTIAGO
	830	10	STO. DOMINGO
	840	1	PTO. PLATA
	850	1	SANTIAGO
	880	1	VALVERDE
	890	5	STO. DOMINGO
	900	1	PUERTO PLATA
	910	0.5	SAN FRANCISCO
	920	5	STO. DOMINGO
	940	5	SANTIAGO
	950	1	STO. DOMINGO
	960	1	PTO. PLATA
	980	1	SANTIAGO
	1000	1	DAJABON
	1010	10	STO. DOMINGO
	1030	5	LA VEGA
	1040	1	STO. DOMINGO
	1050	1	SANTIAGO
	1060	1	SAN PEDRO
	1070	5	SAN FRANCISCO
	1080	0.5	STO. DOMINGO
	1090	3	SANTIAGO
	1100	1	SAN PEDRO
	1100	5	NAGUA
	1110	0.5	JARABACOA
	1120	5	STO. DOMINGO

1	2	3	4
DOMINICAINE (Rép.) DOMINICAN Rep. DOMINICANA (Rep.) (suite/cont.)	1130	1	SANTIAGO
	1150	1	STO. DOMINGO
	1160	5	SANTIAGO
	1180	10	STO. DOMINGO
	1190	1.5	VILLA TAPIA
	1200	1	SAN PEDRO
	1200	1	AZUA
	1210	5	SAN FRANCISCO
	1220	10	STO. DOMINGO
	1230	1	MOCA
	1240	3	PTO. PLATA
	1240	1	BARAHONA
	1250	1	SAN FRANCISCO
	1260	1	STO. DOMINGO
	1270	1	SANTIAGO
	1270	1	BANI
	1290	1	BONAO
	1290	0.5	JANICO
	1300	1	SANTO DOMINGO
	1310	0.5	LA VEGA
	1310	1	EL SEIBO
	1320	1	BANI
	1320	0.5	BOYA
	1330	5	MOCA
	1340	0.25	OCOA
	1340	1	MAGUANA
	1350	1	SANTO DOMINGO
	1360	1	LA ROMANA
	1360	1	LA VEGA
	1360	1	MONTE CRISTI
	1370	1	BARAHONA
	1380	5	SANTO DOMINGO
	1380	5	SANTIAGO
	1400	1	LA VEGA
	1410	0.25	PEDERNALES
	1410	5	SANTO DOMINGO
	1410	3	HIGUEY
	1415	1	DAJABON
	1410	0.5	BARAHONA
	1420	0.25	COTUI
	1430		LA VEGA
	1440	1	NAGUA

1	2	3	4
DOMINICAINE (Rép.) DOMINICAN Rep. DOMINICANA (Rep.) (suite/cont.)	1440	1	SAN JUAN
	1440	0.5	SANTO DOMINGO
	1440	1	HIGUEY
	1450	0.5	SAN CRISTOBAL
	1450	0.25	SALCEDO
	1460	0.5	HATO MAYOR
	1470	5	SANTIAGO
	1480	1	SANTO DOMINGO
	1490	1	AZUA
	1490	1	EL SEIBO
	1490	1	PTO. PLATA
	1500	0.5	MOCA
	1510	10	SANTO DOMINGO
	1525	1	NEYBA
	1540	1	LA ROMANA
	1540	1	SANTO DOMINGO
	1550	1	SANTIAGO
	1560	0.5	PEDERNALES
	1570	1	SANTO DOMINGO
	1570	1	LA ROMANA
	1580	0.5	SAMANA
	1590	3	SANTIAGO
	1600	5	SANTO DOMINGO
EQUATEUR ECUADOR ECUADOR	540	25	GUAYAQUIL
	550	10	QUITO
	560	50	MAMBO
	570	1	QUITO
	580	0.5	GUAYAQUIL
	590	1	QUITO
	605	10	GUAYAQUIL
	615	10	QUITO
	635	5	QUEVEDO
	640	50	QUITO
	650	10	MANTA
	660	10	GUAYAQUIL
	660	1.2	QUITO
	665	0.45	VENTANAS
	675	10	GUAYAQUIL
	690	5	PORTO VIEJO
	690	30	QUITO

1	2	3	4
EQUATEUR **ECUADOR** **ECUADOR** **(suite/cont.)**	695	50	GUAYAQUIL
	715	1.5	PORTO VIEJO
	720	5	QUITO
	730	10	GUAYAQUIL
	740	2	CHONE
	735	10	QUITO
	750	10	GUAYAQUIL
	760	25	QUITO
	770	1	GUAYAQUIL
	780	0.5	MANTA
	785	0.5	QUITO
	795	2	PORTO VIEJO
	800	10	GUAYAQUIL
	805	1	QUITO
	810	0.3	EL MILAGRO
	820	1	PORTO VIEJO
	825	2	SANTO DOMINGO
	830	0.5	RIOBAMBA
	835	1	QUITO
	840	1	PORTO VIEJO
	845	0.8	AMBATO
	850	1	GUAYAQUIL
	855	0.5	PUYO
	860	10	QUITO
	865	0.4	PILLARO
	870	20	GUAYAQUIL
	880	1	QUITO
	890	1	RIOBAMBA
	900	0.5	QUITO
	900	3	CUENCA
	900	2	CHONE
	910	1	GUAYAQUIL
	910	0.5	RIOBAMBA
	915	1	MACHALA
	925	1	GUAYAQUIL
	930	1	QUITO
	930	1	IBARRA
	935	0.25	COLTA
	940	0.15	QUITO
	945	10	GUAYAQUIL
	955	1	BANOS

1	2	3	4
EQUATEUR ECUADOR ECUADOR (suite/cont.	955	0.25	QUEVEDO
	960	1	QUITO
	965	10	STO.DOMINGO
	970	0.25	IBARRA
	970	1	CUENCA
	975	10	GUAYAQUIL
	980	0.5	RIOBAMBA
	985	0.5	CUENCA
	990	3	QUITO
	1010	3	SANTA ROSA
	1010	0.7	MANTA
	1010	5	AMBATO
	1015	0.75	GUARANDA
	1015	1.5	CUENCA
	1020	0.6	QUITO
	1025	0.25	COLTA
	1027	1	GUAYAQUIL
	1030	1	CHONE
	1040	0.7	MACHACHI
	1045	0.5	AMBATO
	1045	0.25	RIOBAMBA
	1050	5	GUAYAQUIL
	1060	0.75	SAQUISILI
	1065	2	VILCABAMBA
	1070	0.5	STO.DOMINGO
	1070	0.5	QUITO
	1080	10	GUAYAQUIL
	1085	1	MANTA
	1090	0.25	QUITO
	1095	0.4	LATACUNGA
	1100	3	GUAYAQUIL
	1100	0.25	CUENCA
	1105	0.5	PELILEO
	1110	1	QUITO
	1115	0.5	GUAYAQUIL
	1120	1	SAN GABRIEL
	1120	1	CUENCA
	1125	0.5	POMASQUI
	1125	0.3	AMBATO
	1130	2	IBARRA
	1140	0.25	CUENCA
	1140	0.5	GUAYAQUIL

1	2	3	4
EQUATEUR ECUADOR ECUADOR (suite/cont.)	1150	0.5	RIOBAMBA
	1155	0.5	PORTOVIEJO
	1160	1	QUITO
	1160	2	MACHALA
	1165	0.25	LATACUNGA
	1170	0.5	RIOBAMBA
	1175	0.3	CUENCA
	1180	0.3	MIRA
	1180	1	PORTO VIEJO
	1190	0.3	GUAYAQUIL
	1195	0.5	SANGOLGUI
	1195	0.25	PUJILI
	1200	2	CUENCA
	1205	0.25	QUEVEDO
	1210	1	QUITO
	1210	0.5	SANTA ANA
	1220	1	GUAYAQUIL
	1225	0.35	QUITO
	1230	0.25	ESMERALDA
	1230	0.22	IBARRA
	1235	0.5	CUENCA
	1235	0.4	SAQUISILI
	1240	0.5	RIOBAMBA
	1245	1	QUITO
	1250	1	BAHIA
	1250	1	GUAYAQUIL
	1255	2	TULCAN
	1260	0.5	AMBATO
	1260	1.5	SANTO DOMINGO
	1265	0.2	CUENCA
	1270	0.17	GUAMOTE
	1270	0.2	LATACUNGA
	1270	0.25	GUAYAQUIL
	1280	1	QUITO
	1280	1	RIOBAMBA
	1285	1	JIPÑAPA
	1290	0.5	CUENCA
	1295	1	ATUNTAGUI
	1295	0.5	SANTO DOMINGO
	1295	0.5	LATACUNGA
	1300	1	GUAYAQUIL
	1315	0.25	PASAJE

1	2	3	4
EQUATEUR ECUADOR ECUADOR (suite/cont.)	1320	0.4	AMBATO
	1325	0.25	BABAHOYO
	1330	0.45	CUENCA
	1335	1.5	MACHALA
	1335	0.5	QUITO
	1340	1	CARAGUEZ
	1340	1	CAJABAMBA
	1345	3	AMBATO
	1350	0.3	TULCAN
	1350	0.3	GUAYAQUIL
	1350	1	LAGO AGRIO
	1360	0.5	RIOBAMBA
	1370	1	LOJAS
	1370	1	PINAS
	1370	0.25	ZAMORA
	1370	2	PINAMPINO
	1375	3	AMBATO
	1375	0.5	MILAGRO
	1380	0.5	QUITO
	1390	0.4	LATACUNGA
	1390	0.75	URLUGUI
	1390	0.25	SARAGURO
	1390	0.4	CUENCA
	1395	0.3	ESMERALDES
	1400	0.2	GUAYAQUIL
	1400	0.3	MANTA
	1400	1	TENA
	1410	0.5	QUITO
	1410	0.5	GUANO
	1410	5	S. CRISTOBAL
	1420	0.3	SALCEDO
	1425	0.5	GUAYAQUIL
	1440	10	QUITO
	1440	1	AZOGUES
	1440	0.6	IBARRA
	1445	0.5	RIOBAMBA
	1450	0.75	LOJA
	1450	5	QUEVEDO
	1465	0.25	ESMERALDAS
	1465	0.25	LATACUNGA
	1470	0.36	CAYAMBE
	1470	0.25	BABAHOYO

1	2	3	4
EQUATEUR ECUADOR ECUADOR (suite/cont.)	1475	1	PASAJE
	1480	1	JIPIJAPA
	1480	0,5	BREZA
	1490	0.5	ESMERALDAS
	1490	1	QUITO
	1490	0.5	TRIUNFO
	1490	0.2	TENA
	1495	0.5	VINCES
	1495	0.5	RIOBAMBA
	1500	0.2	OTAVALO
	1500	0,5	EL CARMEN
	1500	0,35	JUNIN
	1500	0.7	SANTA ROSA
	1505	0,2	LOJA
	1510	1	GUAYAQUIL
	1520	0.35	MANTA
	1520	3	QUEVEDO
	1520	0.15	GUAMOTE
	1530	1	PEN. LA LIBERTAD
	1530	0.5	PELILEO
	1530	0.25	SAN LORENZO
	1530	0.25	AZOGUES
	1530	5	MACHALA
	1535	0.5	LATACUNGA
	1540	1	SUCUA
	1545	0.36	QUITO
	1550	1	SANTA ISABEL
	1550	0.25	EL TRIUNFO
	1560	0.5	AMBATO
	1555	2	EL GUABO
	1560	0.5	DAULE
	1560	1.5	URCUGUI
	1560	0.25	CANAR
	1570	1	QUITO
	1570	0.5	PASAJE
	1580	0.25	CATACOCHA
	1580	1	GIRON
	1580	1.5	ESMERALDAS
	1590	1	TABACUNDO
	1590	0.35	LIBERTAD
	1595	0.3	QUERO
	1600	2	EMPALME

ANNEX H

FORM FOR NOTIFYING CHARACTERISTICS OF REGION 2 BROADCASTING STATIONS IN THE BAND 535 - 1 605 kHz

I.F.R.B.

I.F.R.B. Serial No. (to be filled in by the I.F.R.B.)

PART I GENERAL INFORMATION

(01) Administration

Sheet No.

Assigned frequency (kHz)		(02)
Transmitting station	Name of the station	(03)
	Call sign	(04)
	Additional Identification	(05)
	Station class	(06)
	Operational Status	(07)
Country		(08)
Geographical coordinates of the transmitting station		(09) E/W N/S

DAYTIME OPERATION

Station power (kW)	Radiation characteristics of transmitting antenna: Maximum radiation (dB)	Azimuth(s) maximum radiation (degrees)	Sector(s) of limited radiation (degrees)	Maximum radiation in limited sector(s) (dB)	Antenna type	Simple vertical antenna, electrical height (degrees)
(21)	(22)	(23)	(24)	(25)	(26)	(27)

NIGHT-TIME OPERATION

Station power (kW)	Radiation characteristics of transmitting antenna: Maximum radiation (dB)	Azimuth(s) maximum radiation (degrees)	Sector(s) of limited radiation (degrees)	Maximum radiation in limited sector(s) (dB)	Antenna type	Simple vertical antenna, electrical height (degrees)
(31)	(32)	(33)	(34)	(35)	(36)	(37)

Hours of operation (GMT) (42)

REMARKS (44)

I.F.R.B.

FORM FOR NOTIFYING CHARACTERISTICS OF REGION 2 BROADCASTING STATIONS IN THE BAND 535 - 1 605 kHz

I.F.R.B. Serial No.

(to be filled in by the I.F.R.B.

PART II

Description of the directional antenna consisting of vertical conductors *)

(01) Name of transmitting station (02) Country **Sheet No.** **(03) Hours of operation** **(04) Total number of towers**

(05) Tower No.	(06) Tower current ratio	(07) Current phase difference (± degrees)	(08) Electrical tower spacing (degrees)	(09) Angular tower orientation (degrees)	(10) Reference tower indicator	(11) Electrical height of tower (degrees)	(12) Tower structure
01							
02							
03							
04							
05							
06							
07							
08							
09							
10							
11							
12							
13							
14							
15							

(13) SUPPLEMENTARY INFORMATION

(14) Theoretical r.m.s value (mV/m)

*) This information would permit the calculation of the theoretical radiation pattern.

INSTRUCTIONS FOR COMPLETING THE FORM

The Form is divided into two parts :

PART I : General information : basic characteristics of the transmitting station

PART II : Description of the directional antenna : this part of the Form need not be filled in when the transmitting antenna is a simple vertical antenna.

PART I

Where the changes in the characteristics of the station are based on hours of operation other than the "daytime" and "night-time", use a separate sheet to describe the characteristics for each time period shown in Box No. 42.

Box No.

01 Administration

Give the name of your Administration and your reference number in the Form.

02 Assigned frequency (kHz)

03 Name of the transmitting station

Indicate the name of the locality by which the station is known. Limit the number of letters and numerals to a total of 14.

04 Call sign

This information is optional. Limit the number of letters and numerals to a total of 7.

05 Additional identification

Give any additional information which may be considered essential for complete identification. Where no such information is required this box may be left blank.

06 Station Class (A, B or C)

Insert A, B or C in accordance with the station class as defined in Chapter 1.

07 Operational status

Indicate the status of operation of the station by entering Φ for a station which is already in operation and by entering P for a station which is planned to be brought into operation.

08 Country

Indicate the name of the country in which the station is located. Use the symbols in Table 1 of the Preface to the International Frequency List.

09 Geographical coordinates of the transmitting station

Indicate the geographical coordinates (longitude and latitude) of the transmitting antenna site in degrees, minutes and seconds. Seconds need to be entered only if available. Cross out letters E, W, N, S which do not apply.

Box No.

DAYTIME OPERATION

21 Station power (kW)

Indicate the carrier power supplied to the antenna transmission line by the transmitter for daytime operation. Two decimal positions are provided indicating powers less than 1 kW.

Radiation characteristics of transmitting antenna

22 Maximum radiation (dB)

Indicate maximum radiation in dB relative to an equivalent monopole radiated power (e.m.r.p.) of 1 kW, for daytime operation. This value is obtained by adding the carrier power of the transmitter (in dB) to the gain of the antenna in dB. In the case of more than one maximum of radiation, values corresponding to up to four maxima may be indicated. When Part II is used, this box may be left blank.

23 Azimuth(s) of maximum radiation

When a directional antenna is used, indicate the azimuth of maximum radiation in the horizontal plane in degrees (clockwise) from True North, for daytime operation. Where appropriate, values of up to four azimuths of radiation may be indicated. In the case of a simple vertical antenna or when Part II is used, this box may be left blank.

24 Sector(s) of limited radiation (degrees)

When a directional antenna is used, indicate here the azimuths defining the sector of limited radiation, for daytime operation. The purpose of this information is to indicate the directions in which the radiation is significantly below the maximum radiation. Space is provided for information up to a maximum of four sectors. When Part II is used, this box may be left blank.

25 Maximum radiation in limited sector(s) (dB)

Indicate here the maximum radiation, in dB, in the sectors defined in Box No. 24. When Part II is used, this box may be left blank.

Antenna

26 Antenna type

Indicate here the type of antenna used for daytime operation. In the case of a simple vertical antenna, insert here the symbol A. In the case of an antenna other than a simple vertical antenna, insert here the symbol B.

27 Simple vertical antenna electrical height

Indicate here the electrical height, in degrees, for a simple vertical antenna in use during daytime operation. In the case of a B type antenna, this box should be left blank.

NIGHT-TIME OPERATION

31 - 37 (see DAYTIME OPERATION)

Box No.

42 Hours of operation (GMT) *

Indicate the daily hours of operation in GMT, to the nearest hour. Symbols "HJ" for daytime operation and "HN" for night-time operation may also be used.

44 Remarks

Indicate here any necessary additional information, such as, if appropriate, the identification of the corresponding synchronized network.

PART II

DESCRIPTION OF THE DIRECTIONAL ANTENNA

Radiation characteristics of the transmitting antenna other than the simple vertical base-fed antenna

1. For the purpose of the calculations generally required for establishing a Plan, the antenna gain in the horizontal and vertical planes should be known.

2. The Administrations are invited to use Part II of the Form to furnish the electrical characteristics of the antenna. From the information thus furnished, the IFRB will determine the radiation pattern.

3. Part II of the Form does not necessarily cover all the types of antennae that may be in use. Administrations faced with difficulty in using the Form (Part II), such as when it is not suitable for describing the antenna in question, may communicate the particulars of the antenna on a separate sheet, taking care that all the parameters necessary for the calculation of the radiation diagram have been included.

4. Radiation diagrams shall be used only when the information requested in Part II is not available. See also Chapter 5.

Box No.

01 Indicate the name of the transmitting station.

02 Country

Indicate the country in which the station is located. Use the symbols in Table 1 of the Preface to the International Frequency List.

03 Indicate the hours of operation for which the given characteristics of the antenna are applicable. The symbols HJ for daytime operation and HN for night-time operation may also be used.

04 Indicate the total number of towers constituting the array.

Column No.

05 This column shows the serial number of towers, as they will be described in columns 06 to 12.

06 Indicate here the ratio of the tower current to the current in the reference tower.

* On the date of the entry into force of the Final Acts of the World Administrative Radio Conference, Geneva, 1979, i.e., on 1 January 1982, the abbreviation "GMT" will be replaced by the abbreviation "UTC".

Column No.

07 Indicate here, in degrees, the positive or negative difference in the phase angle of the current in the tower with respect to the current in the reference tower (tower No. 01). In the case of a passive tower, leave this column blank.

08 Indicate in degrees the electrical spacing of the tower from the reference tower, which is shown in Column 10.

09 Indicate here, in degrees referred to True North, the angular orientation of the tower from the reference tower indicated in Column 10.

10 Indicate the reference tower as follows:

0 = where the spacing and orientation have previously been shown with reference to tower No. 01;

1 = where the spacing and orientation have been shown with respect to the previous tower.

11 Indicate the electrical height (degrees) of the tower under consideration.

12 Indicate the tower structure as follows:

0 = simple vertical monopole

1 = top loaded

2 = sectionalized

13 Indicate here any additional information which is considered essential for describing the antenna in question. The schematic diagram of the antenna layout, if appropriate, may be included here.

14 Indicate here the theoretical root mean square (r.m.s.) radiation in mV/m.

RESOLUTION A

CHANNEL SPACING

The Regional Administrative MF Broadcasting Conference (Region 2), First Session, Buenos Aires, 1980,

considering

a) that the use of a uniform channel spacing throughout Region 2 is of the utmost importance for the efficient use of the medium frequency band between 535 and 1 605 kHz and for planning that band;

b) that the channel spacing to be used for the planning should be acceptable to all the countries of the Region;

c) that a consensus could not be reached regarding channel spacing for planning purposes;

d) that the present Session of the Conference has adopted technical standards for 9 kHz as well as 10 kHz channel spacing, which is generally used in the Region;

e) that the adoption of a particular channel spacing has technical, operational, social and economic implications;

f) that the problem of inter-Regional interference must be examined for both 9 and 10 kHz channel spacing;

g) that a comparative study of the two channel spacings is required;

resolves

1. that with a view to reaching a consensus on the channel spacing during the Second Session of the Conference, the IFRB shall undertake the study referred to in paragraphs 8.2 and 8.4 of Chapter 8 of the Report of the First Session of the Conference for the two channel spacings of 9 kHz and 10 kHz and shall prepare a comparative report for submission to the Second Session.

2. that, if needed, the IFRB, in conducting the study, may consider a change of carrier frequencies of more than 4 kHz subject to the agreement of the administrations concerned;

3. that a Panel of Experts from Argentina, Brazil, Canada, Cuba, United States of America, Mexico, Peru and Uruguay will assist the IFRB with the analysis of the results in accordance with the Annex to the present Resolution;

invites the Administrative Council

to provide sufficient resources for the IFRB and the Panel of Experts to complete the study in a timely manner.

ANNEX TO RESOLUTION A

BASIC PRINCIPLES TO BE APPLIED FOR THE COMPARATIVE STUDY OF CHANNEL SPACING

1. The study shall take account of the following:

a) For 10 kHz channel spacing, broadcasting stations generally would only have to change frequency to resolve incompatibilities;

b) For 9 kHz channel spacing, since most broadcasting stations would be required to change frequency, the change should be made according to a rearrangement of the channels so as to optimize the use of the spectrum, while bearing in mind the relevant technical, operational and economic factors (see paragraph 5 below).

2. The stations to be included in this study will be those contained in the basic inventory as modified in accordance with Chapter 7 of the Report of this Conference.

3. The study on 10 kHz channel spacing shall determine the usable field strength. Where there are incompatibilities which cause a serious degradation of the usable field strength, recommendations shall be made whenever possible to solve the problem.

4. The study on 9 kHz channel spacing shall determine the usable field strength using the following approach:

a) initially to choose a channel rearrangement that minimizes the frequency changes for stations with directional antennae and which provides, in turn, appropriate relief to areas with frequency congestion;

b) subsequently, to apply the method described in Annex A of the Report of this Conference.

5. For 9 kHz channel spacing, every effort shall be made to minimize the frequency change to be made by any particular station, but it may be necessary for some administrations to change carrier frequencies of some stations by more than 4 kHz in order to derive the maximum number of new assignments. In such cases, consultations shall be undertaken with the administrations concerned in accordance with resolves 2 of Resolution A.

6. The criteria on which administrations could base their decision on optimum channel spacing include the following:

a) the extent to which the service areas of stations could be extended;

b) the number of new frequency assignments that would be available in all countries of Region 2 where new requirements are identified;

and also,

c) to the extent possible, other relevant factors such as economic and operational implications.

7. With reference to the 10 kHz study, the IFRB shall communicate to the administrations concerned the results of calculations concerning stations whose service areas would be significantly reduced.

8. A report shall be prepared for the Second Session in a format which will be adopted in consultation with the Panel of Experts. The report will include the criteria in paragraph 6 above and shall be sent to administrations no later than two months before the Second Session.

RESOLUTION B

REPORT OF THE FIRST SESSION

The Regional Administrative MF Broadcasting Conference (Region 2), First Session, Buenos Aires, 1980

considering

that, pursuant to Administrative Council Resolution No. 835, the First Session is responsible for establishing the necessary basis for the preparation, by the Second Session of the Conference, of a frequency assignment plan for the MF broadcasting band in Region 2 (535 - 1605 kHz);

resolves

1. to approve the Report of the First Session of the Conference;

2. that the Second Session apply the criteria established in said Report as the basis for the Agreement and the associated Frequency Assignment plan for the MF broadcasting band in Region 2 (535 - 1605 kHz), subject to the consideration of the comparative report on the choice of channel spacing (See Resolution A);

instructs

1. the Chairman of the Conference to transmit under his signature the Report of the First Session to the Second Session of the Conference;

2. the Secretary-General to transmit the Report of the First Session to all administrations of Region 2 as well as to the administrations of the other Regions and to the international organizations which have participated in the First Session of the Conference.

RESOLUTION C

APPOINTMENT OF THE MEMBERS OF THE PANEL OF EXPERTS

The Regional Administrative MF Broadcasting Conference (Region 2), First Session, Buenos Aires, 1980,

considering

a) that the Conference has adopted Resolution A providing inter alia for the establishment of a Panel of Experts to assist the IFRB in the preparation of a comparative report on 9 and 10 kHz channel spacing and to assist in the analysis of results;

b) that the Panel of Experts has been also invited to assist in connection with certain other aspects of the work in preparation for the Second Session of the Conference as provided for in Chapter 8 of the Report;

c) that the above tasks of the Panel of Experts will also cover assistance to the IFRB with respect to the adaptation of computer programs (referred to in Chapter 8 of the Report) to the technical criteria adopted by the First Session of the Conference, as well as to the computer facilities of the ITU;

invites

those administrations which have developed any of the computer programs relevant to the studies required and listed, as examples, in paragraph 8.2 of Chapter 8 of the Report to make such programs available;

invites also

the following countries to provide experts to meet the differing requirements mentioned in a), b), and c) above: Argentina, Brazil, Canada, Cuba, United States of America, Mexico , Peru and Uruguay;

requests the Administrative Council

to provide the necessary resources to enable the Panel of Experts (equivalent to one expert per country and phase) to carry out their tasks in the inter-sessional preparations for the Second Session of the Conference.

requests also

the Chairman of the IFRB to convene the first meeting of the Panel.

RECOMMENDATION A

GROUND CONDUCTIVITY MAPS

The Regional Administrative MF Broadcasting Conference (Region 2), First Session, Buenos Aires, 1980,

considering

a) that the maps of ground conductivity for Region 2 compiled by CITEL and coordinated by the Brazilian Administration provide detailed data for the Region based upon the best available information;

b) that the maps represent a major extension of the information previously available;

c) that the CCIR is conducting a study (Decision 3-2) leading to the preparation of a World Atlas of ground conductivity;

invites the CCIR

to take account of these data in the CCIR World Atlas of ground conductivity;

and urges administrations

to submit any additional or updated information to the CCIR for subsequent inclusion in the Atlas.

RECOMMENDATION B

INTER-REGIONAL SKY-WAVE PROPAGATION PREDICTION

The Regional Administrative MF Broadcasting Conference (Region 2), First Session, Buenos Aires, 1980,

considering

a) that inter-Regional sky-wave interference may affect MF broadcasting in Region 2, particularly for some channel spacings;

b) that, so far, studies that take account of all the available measured propagation data for long night-time paths have been insufficient;

c) that a detailed study is required which will consider all such available data and which will analyse these measurements using the most appropriate model;

noting

that for paths with terminals in different Regions the method used could be that which applies at the midpoint of the great-circle path;

invites the CCIR

1. to undertake a study of the most suitable method for predicting sky-wave propagation for inter-Regional planning purposes, taking account of all available data;

2. to complete the study as soon as practicable and in particular invites Study Group 6 to make the information available for consideration at the Second Session of the Conference;

and urges administrations

to submit any relevant data to the CCIR for use in the study.

RECOMMENDATION C

PREDICTION OF SEA GAIN ON SKY-WAVE PROPAGATION PATHS AT MEDIUM FREQUENCIES

The Regional Administrative MF Broadcasting Conference (Region 2), First Session, Buenos Aires, 1980,

considering

a) that interference to a broadcasting service in the band 535-1605 kHz should be determined at all azimuths around the service area;

b) that reception points at the limit of the service area may be at a considerable distance from the transmitter;

c) that the calculation of sea gain for coastal reception points requires the compilation of a substantial data bank of coastline details and may be difficult, particularly for complicated coastlines;

invites the CCIR

to examine the procedure for the sea gain calculation given in Recommendation 435-3 and to consider simplified methods which may be appropriate for planning purposes.

RECOMMENDATION D

POSSIBLE INTER-REGIONAL INTERFERENCE

The Regional Administrative MF Broadcasting Conference (Region 2), First Session, Buenos Aires, 1980,

recognizing

a) Article 35 of the International Telecommunication Convention (Malaga-Torremolinos, 1973),

b) Number 114 of the Radio Regulations,

considering

a) that, according to paragraph 576 of the Radio Regulations, broadcasting stations in Region 2 operating in the band between 535 and 1605 kHz are listed in the IFRB Master Register for information only;

b) that, according to Resolution 501 of the 1979 World Administrative Radio Conference, this situation will be modified only with the coming into force of the Final Acts of the present Conference;

c) that the frequency assignment plan for Regions 1 and 3 is based on a channel spacing of 9 kHz while currently broadcasting stations in Region 2 are generally spaced 10 kHz apart;

d) that, in certain areas of Region 2, operating broadcasting stations may be affected by inter-regional interference;

e) that, inter-regional interference problems can be reduced by coordination of the technical and operational parameters of those stations that are either subject to or causing interference;

recommends

1. to the Administrations of Region 2, that upon reception of IFRB weekly circulars indicating that stations in Regions 1 and 3 will be put into service, they assess the possibility of inter-regional interference to their stations;

2 that, in those cases where possible inter-regional interference is expected, the administrations forward immediately their concerns to the IFRB and to the Administration responsible for the notified station in order that the necessary steps be taken to remove the interference in accordance with Articles 12 and 15 of the Radio Regulations.

RECOMMENDATION E

AGENDA AND DURATION FOR THE SECOND SESSION OF THE CONFERENCE

The Regional Administrative MF Broadcasting Conference (Region 2), First Session, Buenos Aires, 1980,

considering

a) that the Administrative Council in consultation with the Members of Region 2 has established the Agenda of the Second Session of the Conference "to draw up an agreement and an associated frequency plan of assignments in the MF broadcasting band in Region 2 (535 - 1 605 kHz);

b) that the Second Session of the Conference shall be convened in November 1981 for a duration of approximately four weeks;

c) that the First Session has decided that a panel of experts will assist the IFRB to undertake an inter-sessional study for a comparative report on the two channel spacings of 9 kHz and 10 kHz and to analyze the results (see Resolution A);

d) that the Second Session will need to review the comparative report as well as certain technical criteria to be furnished to the Second Session through considerations in the CCIR;

e) that the Administrative Council has not yet considered the precise date and duration of the Second Session;

recommends to the Administrative Council

1. to modify the Agenda of the Second Session in an appropriate manner, in order to take account of the foregoing inter-sessional studies, and

2. to provide for at least four weeks' duration for the Second Session of the Conference.

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LIST OF MEMBERS WHICH PARTICIPATED IN THE FIRST SESSION

1. Members of Region 2

Argentine Republic

Bolivia (Republic of)

Brazil (Federative Republic of)

Canada

Chile

Colombia (Republic of)

Costa Rica

Cuba

Denmark

Dominican Republic

El Salvador (Republic of)

Ecuador

United States of America

France

Guatemala (Republic of)

Guyana

Haiti (Republic of)

Jamaica

Mexico

Nicaragua

Panama (Republic of)

Paraguay (Republic of)

Netherlands (Kingdom of the)

Peru

United Kingdom of Great Britain and Northern Ireland

Uruguay (Oriental Republic of)

Venezuela (Republic of)

2. Observers from Regions 1 and 3

Saudi Arabia (Kingdom of)

Union of Soviet Socialist Republics

Printed in Switzerland