REPORT 28
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AUSTRALIAN BROADCASTING CONTROL BOARD

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TECHNICAL SERVICES DIVISION

REPORT NO. 28 + Addendum

TITLE: Medium Frequency Sky-Wave Field Strength Predictions for Australia.

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TECHNICAL REPORT NO 28

TITLE: Medium Frequency Sky-Wave Field Strength Predictions for Australia.

Prepared by : J.M. DIXON,

October, 1965

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Acting Director.
Technical Services Division

Medium Frequency Sky-Wave Field Strength Predictions for Australia.

by J.M. DIXON.

Prepared from a very large number of measurements made at Melbourne, Brisbane and Perth; these predictions are intended for use in broadcast service planning to estimate the extent of secondary service areas and the extent of sky-wave limited primary service areas, where such a limitation is not self imposed. In terms of the chosen statistics, the accuracy of measurement exceeded that required for planning purposes.

Figures 1, 2 and 3 show the hourly median field strength exceeded on 50% and 10% of the nights of a year at the second hour after sunset for an unattenuated field strength of 100mV/m at 1 mile in the direction of propagation and at the pertinent angle of departure for one hop E propagation.

The corresponding field strength exceeded for 10% of the time over a period of one hour ($^{E}10$), sometimes referred to as the hourly 10% quasi maximum, may be obtained by adding 5db to the hourly median value ($^{E}50$).

Figure 1 relates to the period of low sunspot activity (annual mean Zurich sunspot number 10) for paths which are predominately north-south. Figure 2 relates to the period of high sunspot activity (annual mean Zurich sunspot number 180) for paths which are predominately north-south. Figure 3 relates to the period of low sunspot activity (annual mean Zurich sunspot number 20) for paths which are predominately east-west.

Corrections given in figure 3 should be applied to field strength predictions from figures 1 and 2, to compensate for the transmitting aerial vertical radiation pattern. A further factor is required for the unattenuated

..2/..

E.d which will depend upon the transmitting aerial input power, height, efficiency, and any variation in the horizontal polar pattern. Typical values for non-directional aerials are given in tables 1, 2 and 3.

The variation of sky-wave field strength over a complete sunspot cycle is not known precisely. Sky-wave field strength recordings[1] made in Australia over an appreciable proportion of one sunspot cycle show a minimum at $R \simeq 100$. The relation between sky-wave field strength and sunspot number is therefore not necessarily linear. It is not known whether sky-wave field strength variations are the same from one sunspot cycle to another.

According to the data from which these predictions are prepared, there is no discernible variation of field strength with frequency within the medium frequency band. However, fading characteristics vary appreciably with frequency, distance and time. As a general rule, the fading rate increases with increase in frequency and decreases with increase in distance. On rare occasions, particularly rapid and deep fading has been observed on short paths (less than 600 miles) for frequencies above about 1000Kc/s. This type of fading may persist for several hours at a time. Figure 6 shows the median fading rate as determined from recordings made during three months in 1964. These values do not include the low amplitude rapid fading sometimes evident in recordings.

Interpretation of Predictions

When applied to individual cases these predictions may be in error for the following reasons -

1. The random variation from night to night which produces a

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1 J.M. DIXON "Some Medium Frequency Sky-Wave Measurements", Proc. I.R.E. Australia, June, 1960.

standard deviation of 2db over a period of one month for measurements made at a particular time of night.

2. The variation which occurs from hour to hour throughout the night.

3. The seasonal variation which produces a standard deviation of 2.5db for measurements made at the second hour after sunset.

4. The variation which occurs from site to site in the one locality. For reception in an urban area, this variation can be negligible at one frequency and up to ±6db at another frequency. Predictions in figure 1 were developed from measurements processed in such a way that this variation was eliminated. Figure 1 therefore refers to the field strength exceeded at 50% of locations. An additional increase in field strength of 6db may occur where the receiving aerial is in very close proximity to domestic electric wiring.

   Predictions in this report are not applicable to reception sites with sea water in the foreground.

5. The variation between sunspot minimum and sunspot maximum.

6. All other variations. These produce a standard deviation in annual median values of 1db.

The type of variation mentioned in items 2 and 3 above can be seen in figure 5 which shows the hourly median field strength exceeded at 50% of locations on 50% of the nights of a month in db relative to the hourly median field strength exceeded at 50% of locations on 50% of the nights of a year (April 1964 - March 1965) at the second hour after sunset. Figure 5 may

..4/..

be used in conjunction with the predictions given in figure 1 to determine the field strength at any time of night and in any month during the period of low sunspot activity. When figures 1 and 5 are used in this manner, the predictions will be more accurate for a distance of 430 miles than for a distance of 1000 miles.

Apparently the seasonal variation is not completely consistent for year to year. Field strength troughs and peaks are repeated from one year to the next but the month of appearance is not necessarily the same. Consequently a much better correlation exists between the results from two stations measured over the same path in one year than between the results for a single station from one year to the next.

Except for the periods of rapid increase in field strength after sunset and rapid fall in field strength before sunrise, the standard error of field strength contours in figure 5 is 0.7db.

Figure 1 has been prepared from annual median values corrected from R=27 to R=10 in accordance with measurements of 2UW and 2GB made during the period March 1963 - March 1965. It may therefore be necessary to modify figure 1 slightly when all the recordings made in 1964 and 1965 are analysed. Figure 5 should also be regarded as being tentative with respect to frequencies and distances other than those for which it is strictly correct (1110Kc/s, 870Kc/s and 430 miles).

DEFINITIONS

Hourly median field strength - The field strength exceeded for 50% of the time during a continuous period of one hour.

Unattenuated E.d - The product of field strength and distance in the absence of ground losses for that section of the path beyond half a wavelength from the transmitting aerial. If field strength measurements are made close to the transmitting aerial (between 0.5 and 4.0 miles) and the product of field strength and distance is plotted against distance, points so obtained will be found to fall around an appropriate ground wave x distance curve which when projected back to zero distance gives the unattenuated E.d.

Second hour after sunset - Two hours after ground level sunset at the path midpoint. In the case of long east-west paths involving a dominant two hop mode, the time referred to is two hours after ground level sunset at the western control point. Field strengths referred to in this report are those for a period of one hour centred on the time indicated except during periods of rapid change immediately following sunset and preceding sunrise when a quarter hour interval is more appropriate.

Fading rate - The number of times an increasing field strength passes through the median value over a period of one hour.

LEGEND TO FIGURES

Figure 1 Hourly median field strength exceeded at 50% of locations on 50% and 10% of the nights of a year, at the second hour after sunset.

Unattenuated E.d = 100mV/m.mile.

North - south paths.

Annual mean Zurich sunspot number 10.

Figure 2 Hourly median field strength exceeded on 50% and 10% of the nights of a year at the second hour after sunset.

Unattenuated E.d = 100mV/m.mile.

North - south paths.

Annual mean Zurich sunspot number 180.

Figure 3 Hourly median field strength exceeded on 50% and 10% of the nights of a year at the second hour after sunset. The number of paths investigated was not sufficient to obtain an accurate prediction over the dashed section.

Unattenuated E.d = 100mV/m.mile.

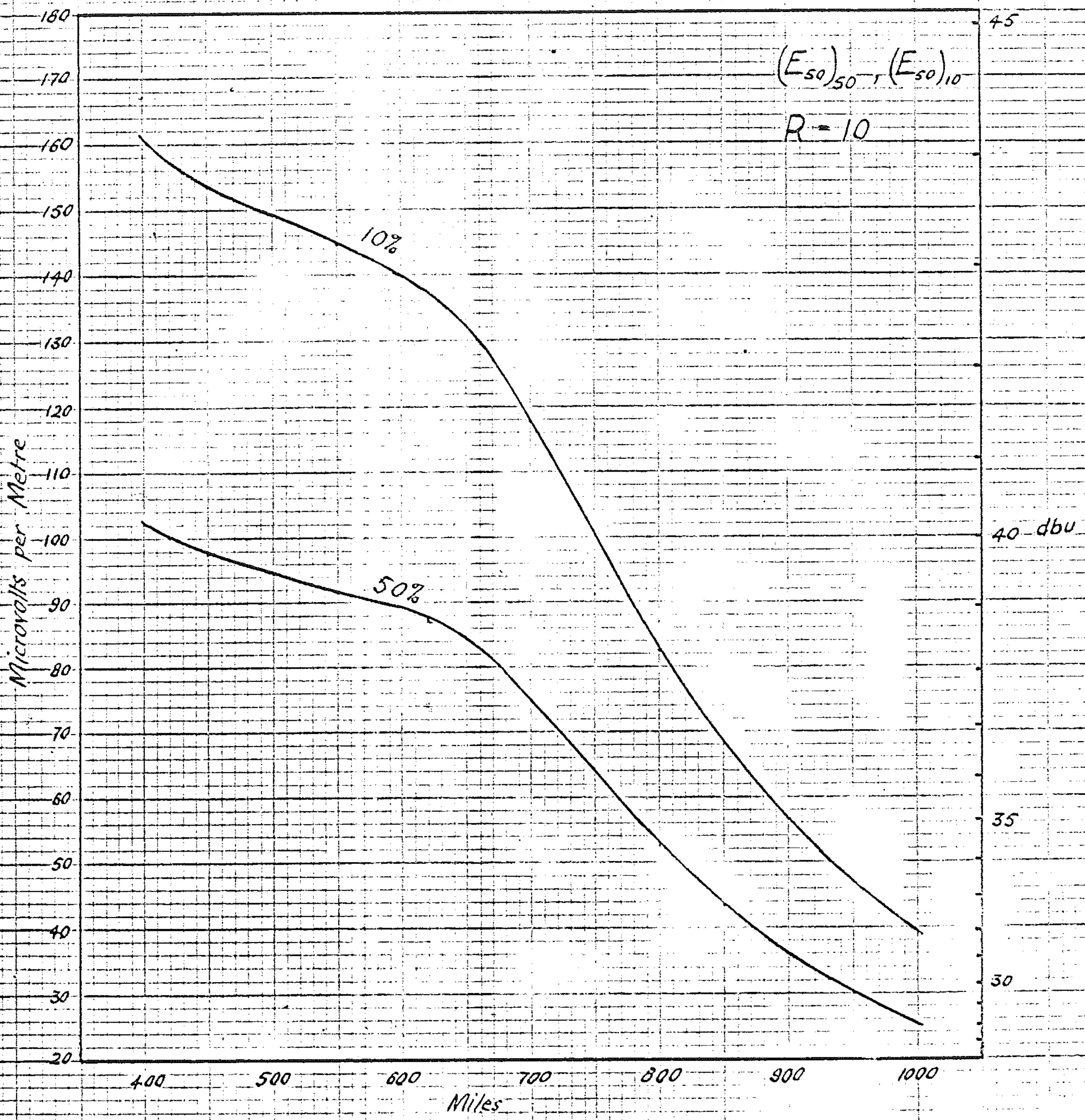
East - west paths.

Annual mean Zurich sunspot number 20.

Figure 4 Correction factors to compensate for the vertical radiation pattern of the transmitting aerial. These factors should be applied to the field strength predicted in figures 1 and 2.

Figure 5 Field strength variation with time of night and month of the year. Contours show the hourly median field strength exceeded at 50% of locations on 50% of the nights of a month, in db above the hourly median field strength exceeded at 50% of locations on 50% of the nights of a year (April 1964-March 1965) at the second hour after sunset. The values shown are accurate for quasi longitudinal transmission on a path of 430 miles for transmission frequencies in the range 800 Kc/s to 1200Kc/s. Dashed lines show the times of sunset and sunrise.

Figure 6 Median fading rate (per hour) determined from recordings made in 1964.



$(E_{50})_{50}$, $(E_{50})_{10}$
R = 10
10%
50%
Microvolts per Metre
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
45
40 dbu
35
30
400
500
600
700
800
900
1000
Miles

FIGURE 1

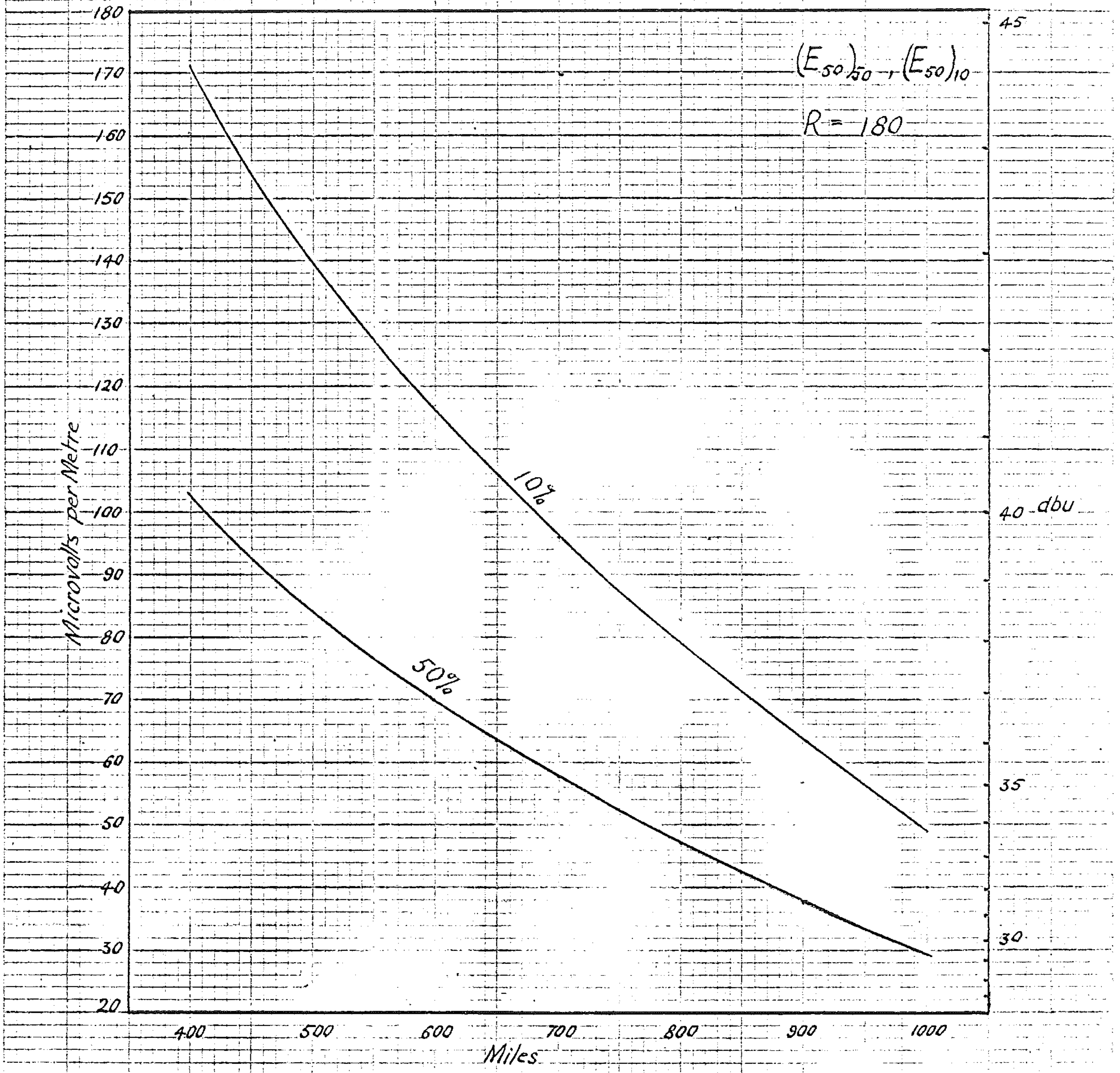
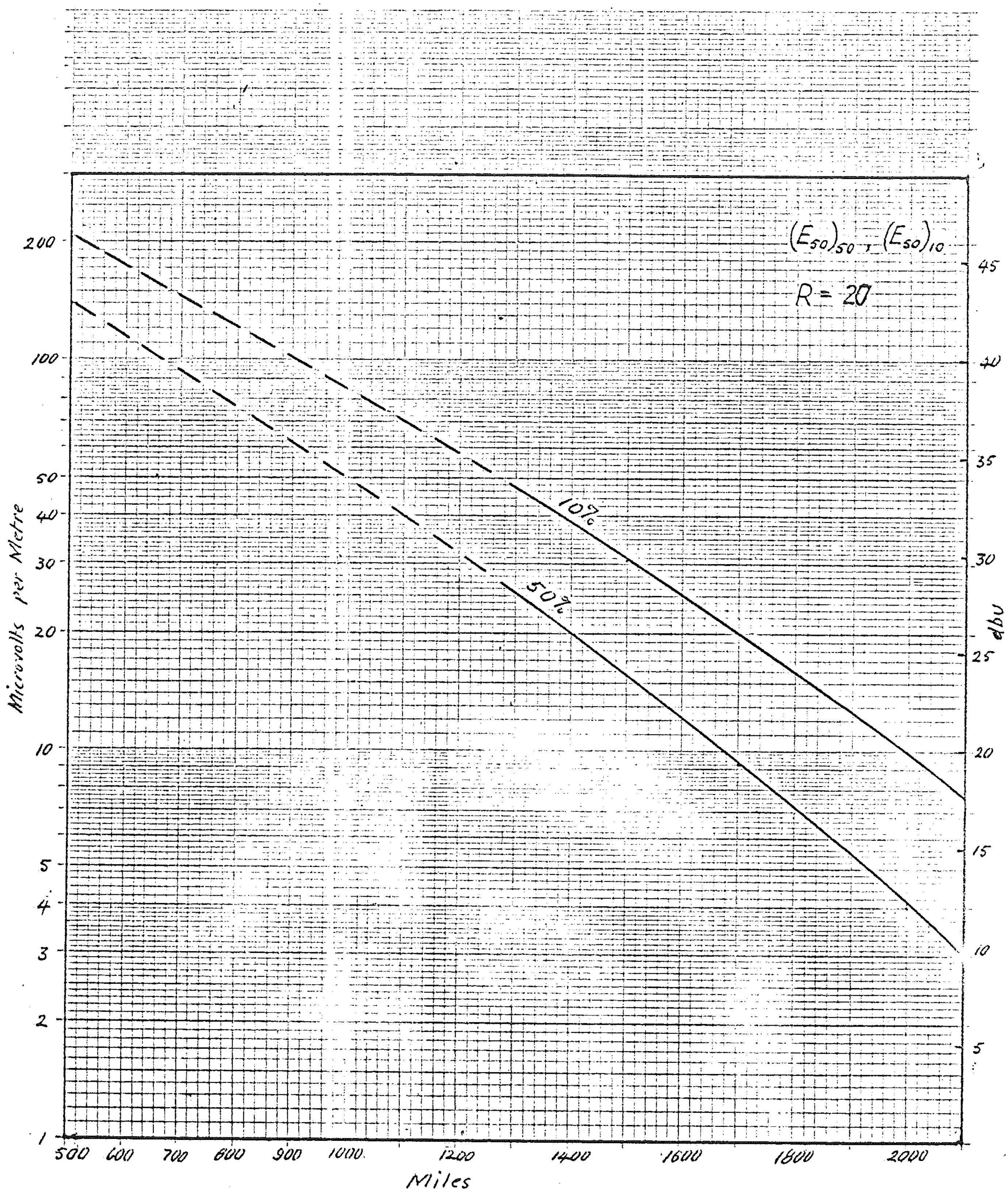

(E50)50 , (E50)10
R = 180
10%
50%
Microvolts per Metre
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
45
40 dbu
35
30
400
500
600
700
800
900
1000
Miles

FIGURE 2



$(E_{50})_{50}$; $(E_{50})_{10}$
R = 20
10%
50%
Microvolts per Metre
200
100
50
40
30
20
10
5
4
3
2
1
dbu
45
40
35
30
25
20
15
10
5
500
600
700
800
900
1000
1200
1400
1600
1800
2000
Miles

FIGURE 3

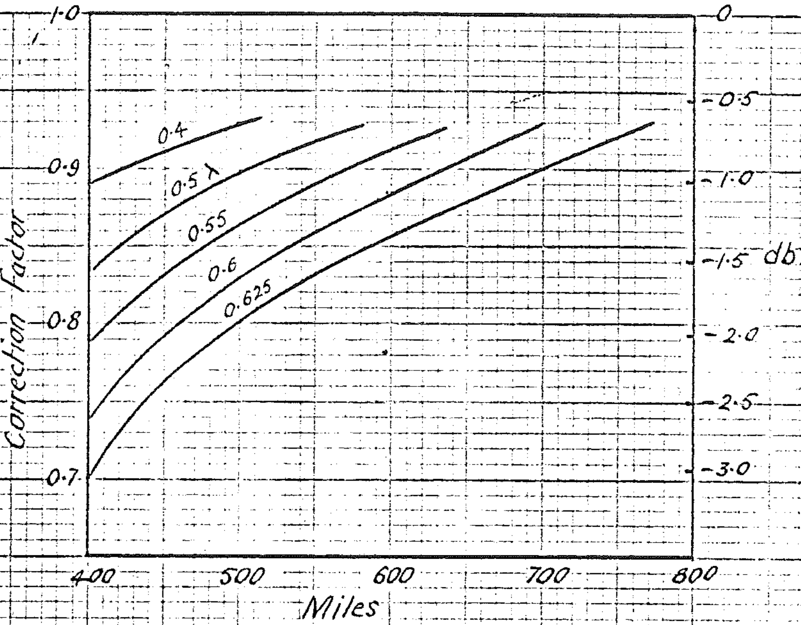


FIGURE 4

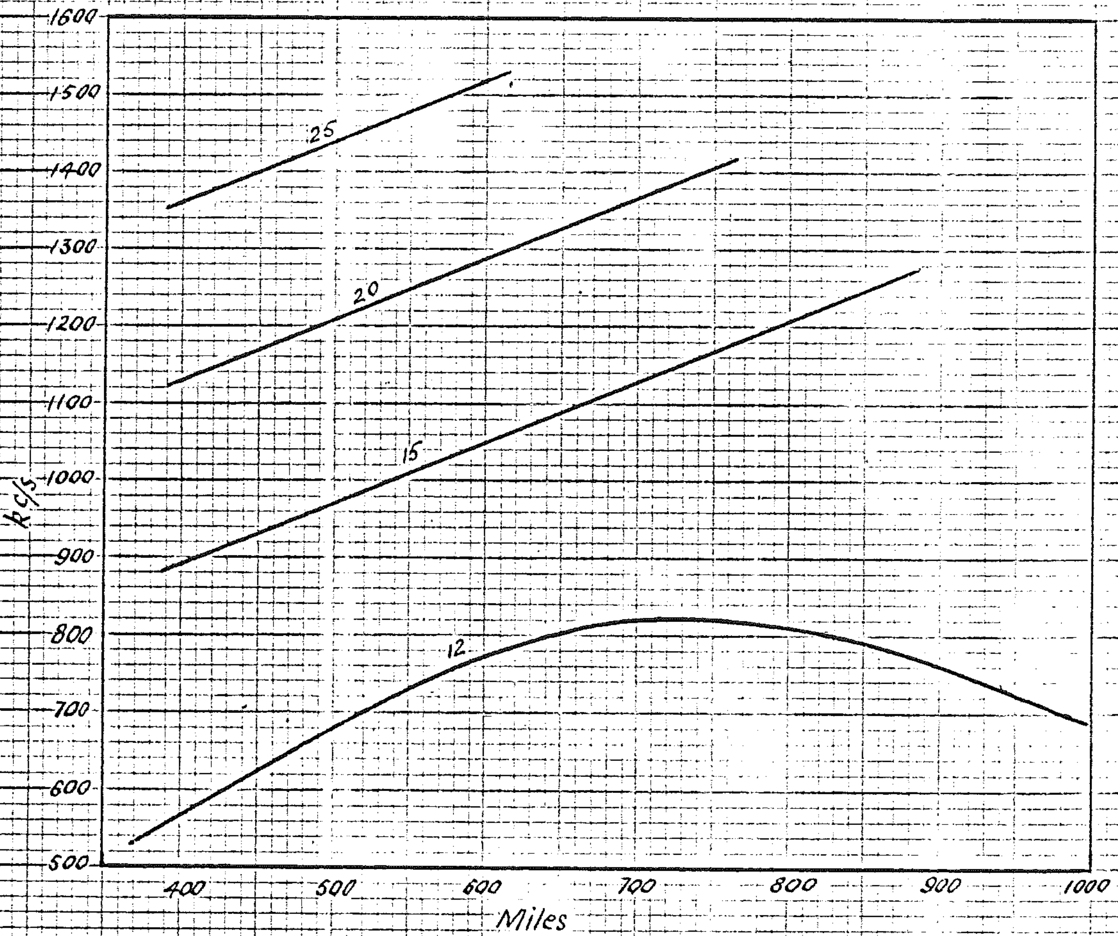


FIGURE 6

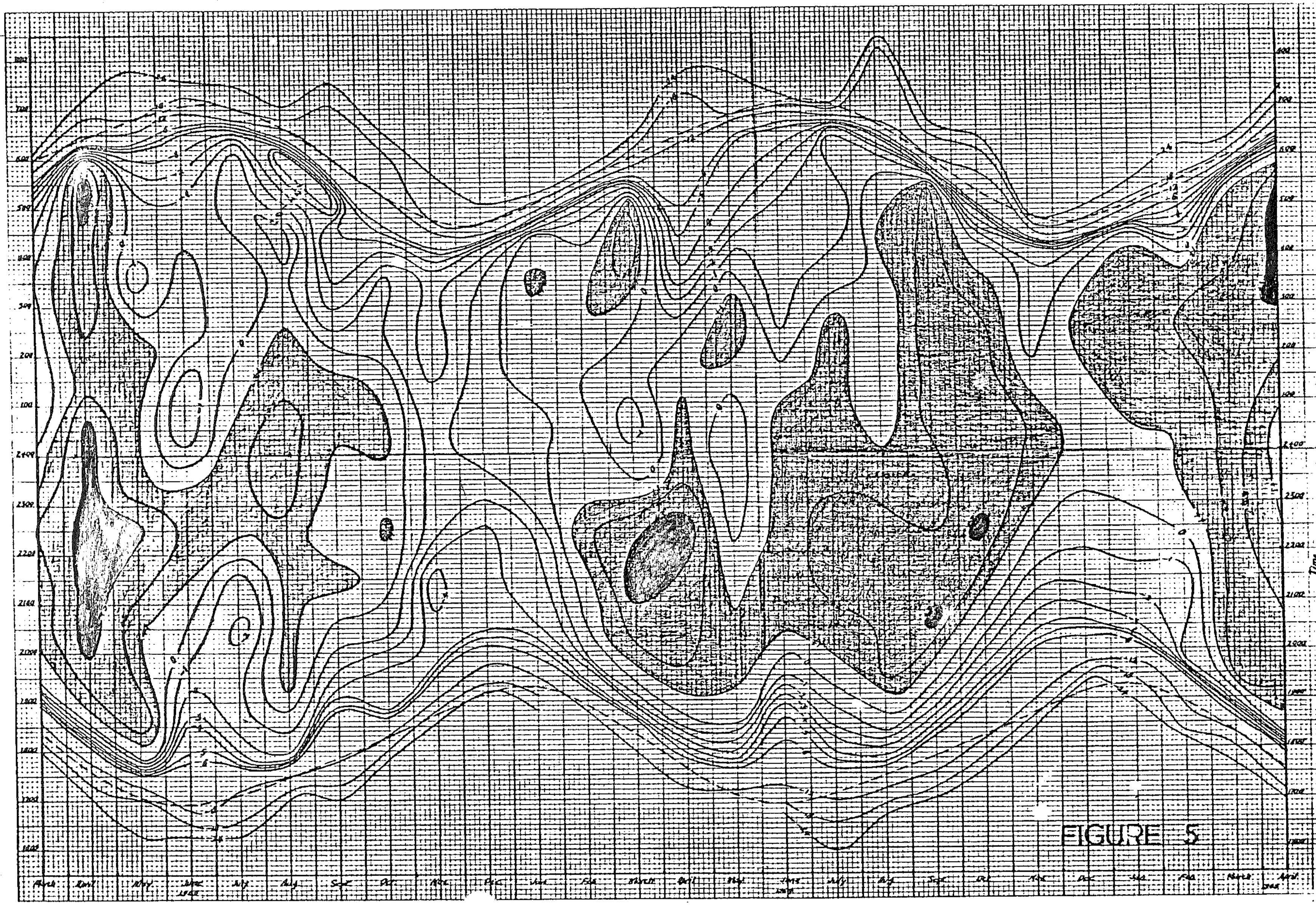


FIGURE 5

TABLE 1

Input data from which the predictions in figure 1 are derived.

Station	Location	Frequency Kc/s	Power kw	Distance Miles	Unattenuated E.d mV/m. mile	Aerial effective height	$\frac{(E_{50})_{50}}{E_{ID}}$ Two hours after sunset *	Recorded at	Period
4BH	Brisbane	1390	2	852	425		0.30	Melbourne	April 1963–March 1964
4BK	Brisbane	1300	2	845	250	0.25	0.26	"	" "
4AK	Oakey	1220	2	818	272	0.24	0.40	"	" "
4BC	Brisbane	1120	2	842	275	0.25	0.245	"	" "
4RK	Rockhampton	840	10	1042	780		0.25	"	" "
4QG	Brisbane	790	10	860	726	0.56	0.33	"	" "
2NR	Grafton	700	50	740	1800	0.53	0.46	"	" "
2NA	Newcastle	1510	10	508	420	0.55	0.43	"	" "
2NX	Bolwarra	1360	2	525	292	0.56	0.42	"	" "
2NC	Newcastle	1230	10	508	700		0.47	"	" "
2HD	Newcastle	1140	2	507	273	0.25	0.35	"	" "
2GL	Glen Innes	820	10	673	810	0.58	0.55	"	" "
2KP	Kempsey	680	10	650	820	0.53	0.475	"	" "
2BS	Bathurst	1500	2	406	352	0.52	0.43	"	" "
2DU	Dubbo	1250	2	434	297	0.56	0.42	"	" "
2UW	Sydney	1110	5	433	597	0.56	0.33	"	" "
2UW	"	"	"	"	"	"	0.37	"	April 1964 – March 1965
2GZ	Orange	990	2	387	292	0.27	0.42	"	April 1963 – March 1964
2GB	Sydney	870	5	434	590	0.57	0.33	"	" "

2GB	Sydney	870	5	434	590	0.57	0.37	Melbourne	April 1964-March 1965
2BL	Syndey	740	50	426	1720	0.60	0.35	"	April 1963-March 1964
2CR	Orange	550	50	395	1850	0.56	0.39	"	" "

* Annual median of hourly median field strength exceeded at 50% of locations/the inverse distance value.

These values have been corrected for aerial height (the reciprical of corrections given in figure 4).

TABLE 2

Input data from which the predictions in figure 2 are derived.

Station	Location	Frequency Kc/s	Power kw	Distance Miles	Unattenuated E.d mV/m. mile	Aerial effective height	$\frac{(E_{10})_{50}}{E_{ID}}$ Two hours after sunset *	Recorded at	Period
2TM	Tamworth	1300	2	562	240, 300	0.24	0.70	Melbourne	June 1958–June 1959
4AK	Oakey	1220	2	820	272	0.24	0.52	"	" "
2GZ	Orange	990	2	392	245	0.27	0.64	"	" "
4QB	Pialba	910	2	974	269	0.25	0.65	"	" "
2BL	Sydney	740	10	430	700	0.55	0.83	"	" "
2KP	Kempsey	680	10	645	360		0.71	"	" "
2CR	Orange	550	10	400	600	0.56	0.58	"	" "
2NX	Bolwarra	1360	2	390	315	0.56	0.87	Brisbane	" "
2CA	Canberra	1050	2	605	256	0.25	0.71	"	" "
3DB	Melbourne	1030	5	860	525	0.45	0.67	"	" "
2CY	Canberra	850	10	605	800	0.53	0.94	"	" "
3AR	Melbourne	620	10	870	720	0.44	0.62	"	" "

* Annual median of hourly 10% field strength/the inverse distance value.

These values have been corrected for aerial height (the reciprical of corrections given in figure 4).

TABLE 3

Input data from which the predictions in figure 3 are derived.

Station	Location	Frequency Kc/s	Power kw	Distance Miles	Unattenuated E.d. mV/m. mile	$\frac{(E_{50})_{50}}{E_{ID}}$ 2 hours after sunset	Recorded at	Period
2NA	Newcastle	1510	10	2072	740	0.073	Perth	July 1963-July 1964
2NC	Newcastle	1230	10	2072	720	0.06	"	" "
5CL	Adelaide	730	50	1308	1610	0.33	"	" "
3AR	Melbourne	620	50	1679	1565	0.19	"	" "
2FC	Sydney	610	50	2017	1675	0.079	"	" "
5CL	Adelaide	730	50	413	1580	0.67	Melbourne	March 1963-March 1964

<u>References</u>

1. T.L. Eckersley and G. Millington, "The Limiting Polarisation of Medium Waves Reflected from the Ionosphere". Proceeding of the Physical Society, Vol.51, Part 1, 1939.

2. J.A. Ratcliffe, The Magneto-ionic Theory and its Applications to the Ionosphere, Cambridge University Press 1959.

3. K.G. Buddan, Radio Waves in the Ionosphere, Cambridge University Press 1961.

4. G.J. Phillips, "Effects of Polarisation on a Medium Frequency Sky-Wave Service at Low Latitude", BBC Engineering Division Research Department Report No.G-083 June, 1962.

5. G.J. Phillips, "Effects of Polarisation on a Medium Frequency Sky-Wave Service, Including the Case of Multi-Hop Paths". BBC Engineering Division Research Department Report No. G-083/2, January, 1964.

6. K. Davies, "The Importance of Wave Polarisation on the Propagation of Medium Frequencies in Low Latitudes" (A contribution to the work of C.C.I.R. Working Party VI/4 by the United States of America).

7. A.F. Barghansen, "Some Characteristics of Medium Frequency Propagation in Equatorial Latitudes" (A contribution to the work of C.C.I.R. Working Party VI/4 by the United States of America.)

8. W.D. Parkinson and R.G. Curedale, "Isomagnetic Maps of Australian for the Epoch 1957.5" Commonwealth of Australia, Department of National Development, Bureau of Mineral Resources, Geology and Geophysics Report No.55, 1960 and 62, 1961.

Addendum to

Australian Broadcasting Control Board Technical Report No.28

Australian Broadcasting Control Board Technical Report No.28 was prepared when the analysis of field strength recordings made between April 1964 and April 1965 was incomplete. Consequently figure 1 of that report was regarded as being tentative, and is now replaced by figure 1A which has been prepared after considering field strength data for the period April 1963-April 1965. The (E50)50 curve of figure 1 has not been altered, as the additional annual median values were dispersed around this curve. The (E50)10 curve of figure 1 has been altered in accordance with results obtained in the period April 1964-April 1965. A significant reduction in the variance of hourly median field strength values occurred from sunspot maximum to sunspot minimum for measurements made at the second hour after sunset, with samples taken over a period of one year. Alterations to the (E50)10 curve of figure 1 were necessary due to the continued reduction in the dispersion of measurements.

Figure 1B shows the hourly median field strength exceeded on 50% and 10% of the nights of a year at 2330 hours for an unattenuated field strength of 100 mv/m at 1 mile in the direction of propagation and at the pertinent angle of departure for one hop E propagation.

Figures 1A and 1B relate to the period of low sunspot activity (annual mean Zurich sunspot number 10) for paths which are predominately north-south. Annual median values (E50)50 for 2330 hours display a variation with frequency which is not present in the early evening results. It is now realised that the general variation of field strength throughout the night is a function of season, transmission frequency and distance. The determination of this variation will complete the statistical analysis of recordings made in the 1963-1965 measurement campaign.

Corrections given in figure 4 of Technical Report No.28 should be applied to field strength predictions from figures 1A and 1B, to compensate for the transmitting aerial vertical radiation pattern. The inverse of this correction was applied to measured field strengths from which the basic prediction values were derived. Corrections in figure 4 are considered to be adequate for this purpose except where the transmitting aerial environment departs significantly from that of the stations used in the sky-wave measurement campaigns. Most of these transmitting sites have a ground conductivity between 5×10^{-14} e.m.u. and 10×10^{-14} e.m.u.

Legend to Figures

Figure 1A. Hourly median field strength exceeded at 50% of locations on 50% and 10% of the nights of a year, at the second hour after sunset.

Unattenuated E. d = 100 mV/m. mile.

North-south paths.

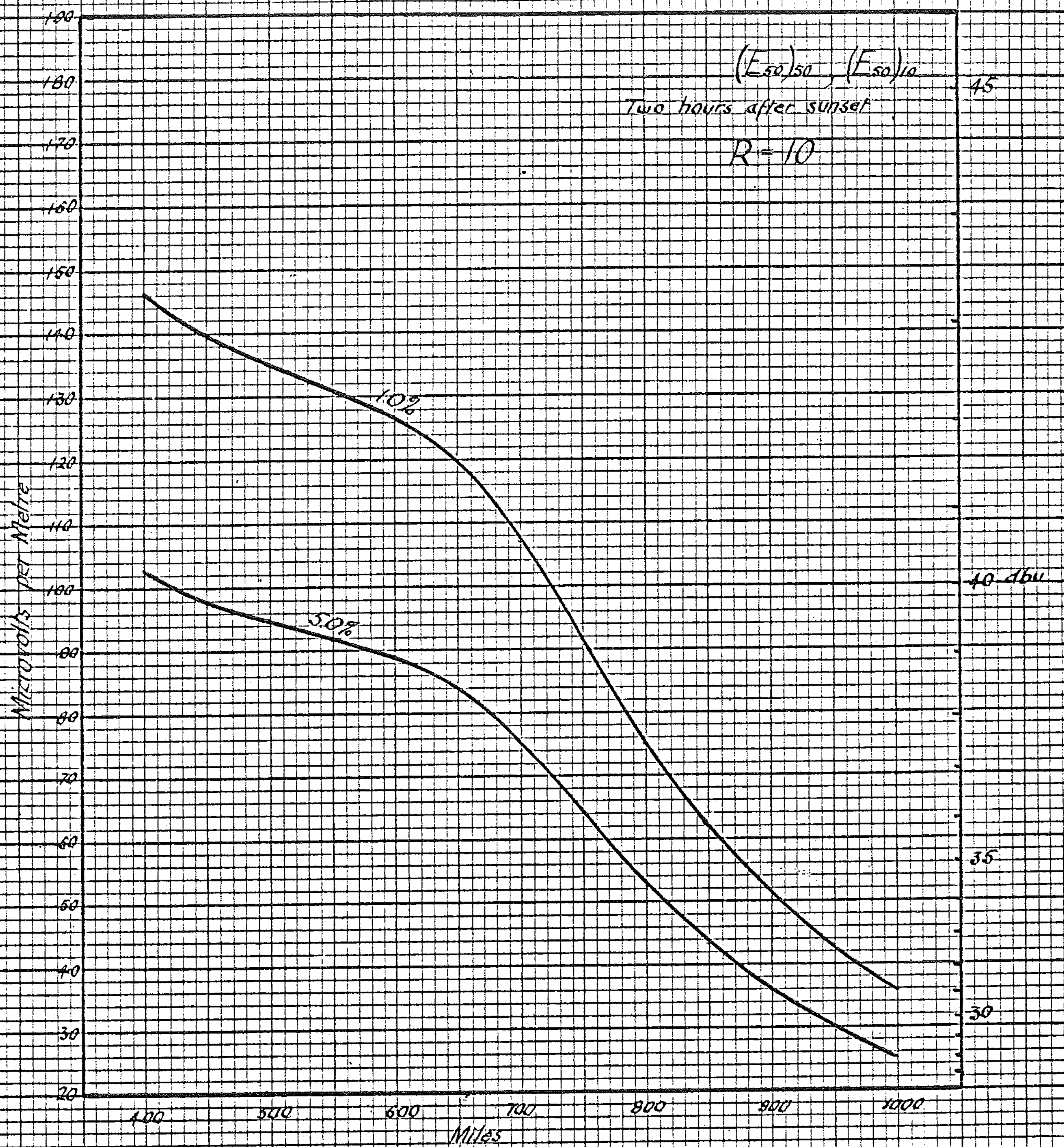
Annual mean Zurich sunspot number 10.

Figure 1B. Hourly median field strength exceeded at 50% of locations on 50% and 10% of the nights of a year, at 2330 hours.

Unattenuated E. d = 100 mV/m. mile.

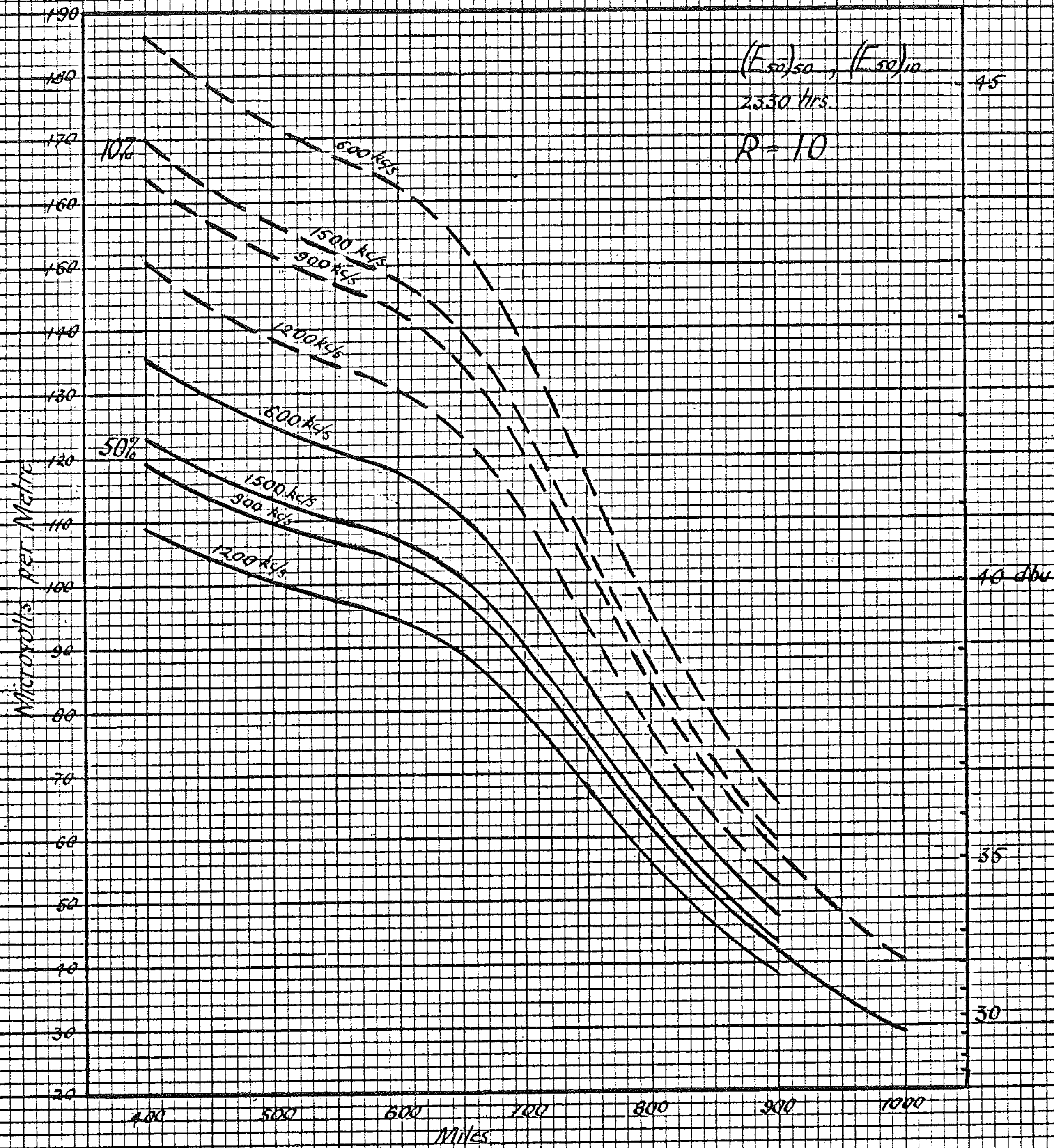
North-south paths.

Annual mean Zurich sunspot number 10.



(E50)50 , (E50)10
Two hours after sunset
R = 10
10%
50%
Microvolts per Metre
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
45
40 dbu
35
30
400
500
600
700
800
900
1000
Miles

FIGURE 1A



$(E_{50})_{50}$, $(E_{50})_{10}$
2330 hrs.
R = 10
10%
50%
600 kc/s
1500 kc/s
900 kc/s
1200 kc/s
Microvolts per Metre
Miles
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
400
500
600
700
800
900
1000
45
40 dbu
35
30

FIGURE 1B

TABLE 4

Input data from which the predictions in figures 1A and 1B are derived

Station	Location	Frequency kc/s	Power kw	Distance miles	Unattenuated E.d.mV/m	Aerial effective height	(E50)50* / EID: Two hours after sunset	(E50)50* / EID: 2330 hours	Recorded at	Period
4BH	Brisbane	1390	2	852	425		0.365	0.40	Melbourne	April 64-April 65
4AK	Oakey	1220	2	818	272	0.24	0.45	0.44**	"	" " " "
4RK	Rockhampton	840	10	1042	780		0.26	0.305	"	" " " "
4QG	Brisbane	790	10	860	726	0.56	0.385	0.505	"	" " " "
2NA	Newcastle	1510	10	508	420	0.55	0.51	0.63	"	" " " "
2NC	Newcastle	1230	10	508	700		0.51	0.53	"	" " " "
2GL	Glen Innes	820	10	673	810	0.58	0.595	0.665	"	" " " "
2KP	Kempsey	680	10	650	820	0.53	0.50	0.615	"	" " " "
2BS	Bathurst	1500	2	406	352	0.52	0.45	0.56	"	" " " "
2UW	Sydney	1110	5	433	597	0.56	0.37	0.41	"	" " " "
2GZ	Orange	990	2	387	292	0.27	0.43	0.515	"	" " " "
2GB	Sydney	870	5	434	590	0.57	0.37	0.415	"	" " " "
2BL	Sydney	740	50	426	1720	0.60	0.38	0.48	"	" " " "
2CR	Orange	550	50	395	1850	0.56	0.505	0.675	"	" " " "

* Site correction factors are included in both sets of figures. These values were therefore exceeded at 50% of locations within a radius of at least 2 miles and in some cases extending to 4 miles from the reception site.

** In the case of 4AK the figure given refers to field strength recordings made between 2200 hours and 2300 hours.

These values have been corrected for aerial height (the reciprocal of corrections given in figure 4).

Basic prediction values prepared
from the data contained in table 1,
table 4 and the dispersion of
measured values.

	A	B	C				D
Distance	$\left[\frac{(E_{50})_{50}}{E_{ID}}\right]$ 2H, R=10 North-south propagation.	$\left[\frac{(E_{50})_{10}}{E_{ID}}\right]$ 2H, R=10	$\left[\frac{(E_{50})_{50}}{E_{ID}}\right]$ 2330 hrs. R=10				$\left[\frac{(E_{50})_{10}}{E_{ID}}\right]$ 2330 hrs. R=10
			600kc/s	900kc/s	1200kc/s	1500kc/s	
400	.41	Multiply the values in column A by 1.425	Axl.32	Axl.16	Axl.06	Axl.20	Multiply the values in column C by 1.38
450	.44						
500	.475						
550	.505						
600	.535						
650	.55						
700	.535						
750	.48						
800	.42						
850	.37						
900	.325						
950	.285						
1000	.252						
1050	.223						

Basic prediction values prepared from the data contained in table 2 and the dispersion of measured values.

Distance miles	$\left[\frac{(E_{50})_{50}}{E_{ID}}\right]_{2H}$, R = 180 North-south propagation.	$\left[\frac{(E_{50})_{10}}{E_{ID}}\right]_{2H}$, R = 180
400	0.41	Multiply values in the first column by 1.675.
450	0.415	
500	0.42	
550	0.42	
600	0.42	
650	0.415	
700	0.405	
750	0.39	
800	0.375	
850	0.36	
900	0.34	
950	0.32	
1000	0.295	