Australian Broadcasting Control Board

TECHNICAL SERVICES DIVISION

Report No. 20

Title: Temporal Variation of Medium Frequency Ground Wave Field Strength

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Temporal Variation of Medium Frequency Ground Wave Field Strength

1. Introduction

Observations of medium frequency ground wave signal levels in Europe and North America revealed a temporal variation of field strength with maximum levels in winter and minimum levels in summer, the ratio reaching 2:1 in some cases. In view of the large variations reported and the fact that no completely satisfactory explanation could be given, it was decided to observe the variation in signal level under Australian conditions. Tests began in 1953 and were completed by 1956 when a variety of path conductivity and frequency combinations had shown the effect to be negligible.

2. Ground Wave Propagation

Vertically polarised medium frequency radio waves propagated over the earth's surface are attenuated by the spread of energy with distance and by energy dissipation in the earth. Waves incident at a boundary of air and earth are reflected and refracted due to a complex relative refractive index -

$$n = \left(k - 1.8 \frac{\sigma}{f} 10^{15} j\right)^{\frac{1}{2}} \qquad \ldots\ldots\ldots\ldots(1)$$

where k = dielectric constant of the earth (air = 1)

σ = conductivity in e.m.u.

f = frequency in Mc/s

The refracted wave is propagated almost vertically and attenuated rapidly due to the earth's conductivity. The resulting field at the earth's surface has a horizontal component producing forward tilt and its attenuation is given by the general equation developed by Norton,(2) which depicts a resultant surface wave determined by the surface attenuation factor f (P,B), a complex quantity depending on ground conductivity, dielectric constant, frequency and distance.

$$E = \frac{E_0}{d}\left[\cos^3\psi_1\, e^{\frac{2\pi r_1}{\lambda}j} + R\cos^3\psi_2\, e^{\frac{2\pi r_2}{\lambda}j} + (1-R)\, f(P,B)\cos^2\psi_2\, e^{\left(\frac{2\pi r_2}{\lambda}+\phi\right)j}\right] \qquad \ldots\ldots\ldots\ldots(2)$$

$$E = \frac{2E_0}{d} f(P,B)\, e^{j\phi} \qquad \text{when } \psi_1 \simeq \psi_2 \simeq 0$$

..2/.

Only a limited region below the earth's surface is effective in determining the attenuation factor. This is conveniently taken as the depth at which the current density is reduced to $\frac{1}{e}$ times the surface value. Variations in conductivity over a large proportion of this depth would therefore be expected to influence the received field. Moisture content is likely to be the most important factor, but significant changes in moisture content are probably restricted to the first few feet below the surface. Temperature changes are also restricted to a surface region but little information is available on the variation with depth and the influence of covering foliage.

Figure 1 shows medium frequency penetration depths in soil conductivities ranging from 10^{-14} e.m.u. to 40×10^{-14} e.m.u. (dielectric constant 15). The penetration in very poor conductivity soil is deep (80 feet) and almost independent of frequency, while the penetration in good conductivity soil is shallow and dependent on frequency. However even at the highest frequency and conductivity to be considered (1600 kc/s, 40×10^{-14} e.m.u.), the depth of penetration is still 6 feet.

Variations in field strength caused by moisture variations in the first few feet of soil are therefore expected to be small.

3. Ground wave field strength measurements

Field strength measurements of eight Victorian stations were made each week at noon near Melbourne during the period March '53 to April '54. Similar measurements of three Queensland stations were made near Brisbane from July '54 to May '56. Steady signal levels were usually observed except for one or two occasions when skywave propagation was evident.

Table 1 gives details of the stations and propagation paths which include combinations of high frequency - high conductivity and low frequency - high conductivity. Levels exceeded by 10%, 50% and 90% of the results are shown and the dispersion of the distribution ($E10\%/E90\%$) has been plotted against average path conductivity in figure 2. These distributions include variations from all causes including that of transmitted power (figure 3).

An outstanding feature of these results is the small variation in level indicated by the ratio $E10\%/E90\%$ which did not exceed 3 db, most of the ratios being less than 2 db. Paths with high conductivity show the expected trend of increasing variation with increase in frequency but larger variations occurred on low conductivity paths. No significant correlation would be established between rainfall and signal level for the 3CV path or for 4IP except that the signal level of all three Queensland stations increased after very heavy rainfall in March '55. Four stations show some sign of a season trend but no two trends are similar (fig. 4 & 5).

..3/.

Paths to 3CV and 3BO are sufficiently close for a comparison of effective conductivities obtained from field strength measurements. In this case the conductivity changes from 8×10^{-14} e.m.u. at 960 kc/s to 17×10^{-14} e.m.u. at 1440 kc/s, indicating that a greater depth of penetration has resulted in a lower effective conductivity.

4. Comparison with measurements made in Europe and North America

Australian results are significantly different from those obtained in Europe and North America[4,5] since no common seasonal trend has been observed, no correlation is obtained with temperature and in general the variation in level is small. Ratios of the maximum to minimum monthly mean field strength in Europe vary from 1.37 to 1.80 compared with 1.06 to 1.35 for Australian observations. Changes in soil conductivity due to changes in temperature or changes in moisture content and absorption due to foliage have been suggested as probable explanations of the observed results in Europe. In view of the Australian results the latter explanation would appear to be favoured, since Australian eucalypts are not deciduous.

5. Conclusion

The variation in medium frequency ground wave field strength measurements made at noon has been found to be small. In most cases 80% of the results for any one path are within ± 1 db of the median for that path.

In good conductivity soil the results show a trend towards more stable conditions with decrease in frequency which corresponds to an increase in penetration.

Table 1

Station	Frequency kc/s	Power k.w.	Ed mV/m mile	Distance Miles	Conductivity e.m.u. x 10^{14}	E50 Median Field Strength	$\frac{E_{10}}{E_{50}}$ db	$\frac{E_{90}}{E_{50}}$ db	$\frac{E_{10}}{E_{90}}$ db	Remarks
3CV	1440	1	220	82	17	160 uV/m	1.3	-1.2	2.5	Timber on 10% of path, 30% rough.
3SR	1260	1.6	248	98	18	160 uV/m	1.0	-0.8	1.8	Timber on 17% of path, 50% rough.
3HA	1000	2	258	160	19	110 uV/m	0.8	-0.8	1.6	Scattered timber on 8% of path, 15% rough.
3BO	960	1	162	78	8	160 uV/m	1.0	-0.6	1.6	Timber on 5% of path, 25% rough
3UL	880	1	200	54	5	330 uV/m	0.7	-0.7	1.4	Heavy timber on 13% of path, 60% rough.
3GI	830	7	600	115	6.5	225 uV/m	0.6	-1.5	2.1	Heavy timber on 50% of path, 80% rough
3LO	770	10	712	12	20	50 mV/m	0.4	-0.7	1.1	Urban path
3WV	580	10	712	164	8	480 uV/m	0.4	-0.8	1.2	Timber on 23% of path, 30% rough
4IP	1010	1	140	25	2.9	410 uV/m	1.4	-1.5	2.9	Mostly scattered timber
4GR	860	2	233	76	4.3	168 uV/m	1.1	-1.5	2.6	Scattered timber on 40% of path
4QS	750	10	830	110	8	425 uV/m	0.5	-1.2	1.7	Scattered to heavy timber on 35% of path.

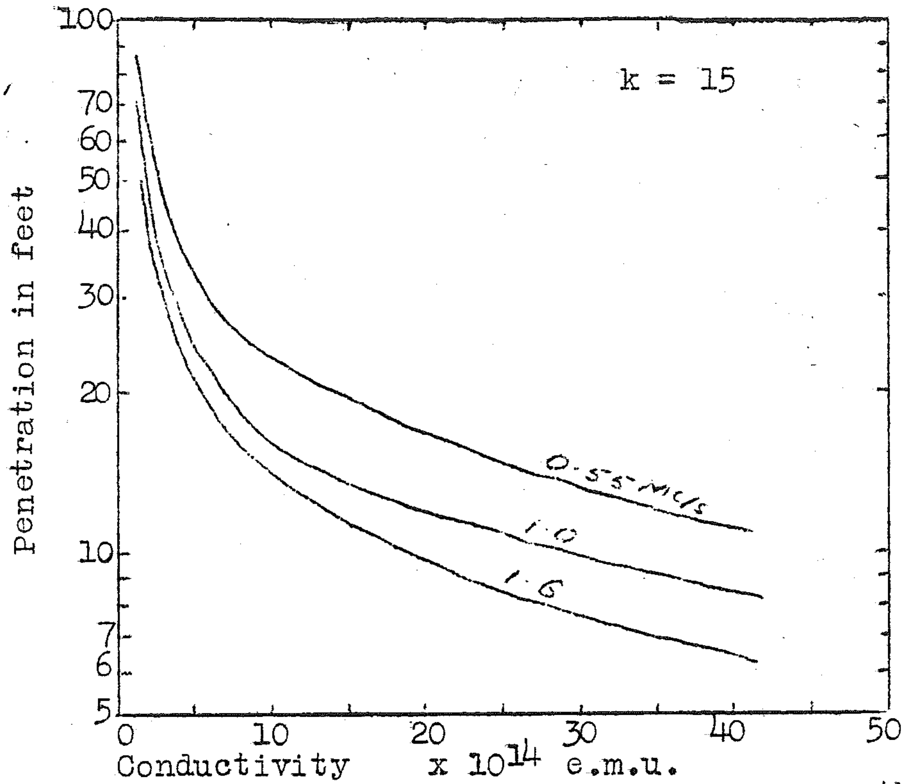

Figure 1 - Depth of penetration in a homogeneous earth as a function of conductivity with frequency as a parameter.

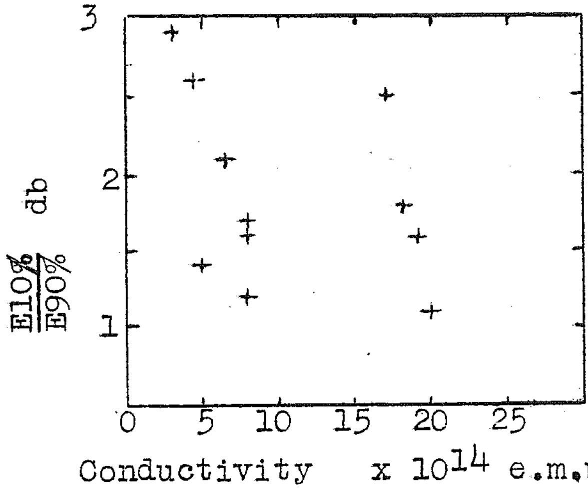

Figure 2 - Ratio of field strength exceeded by 10% of the results to that exceeded by 90% of the results plotted against median conductivity.

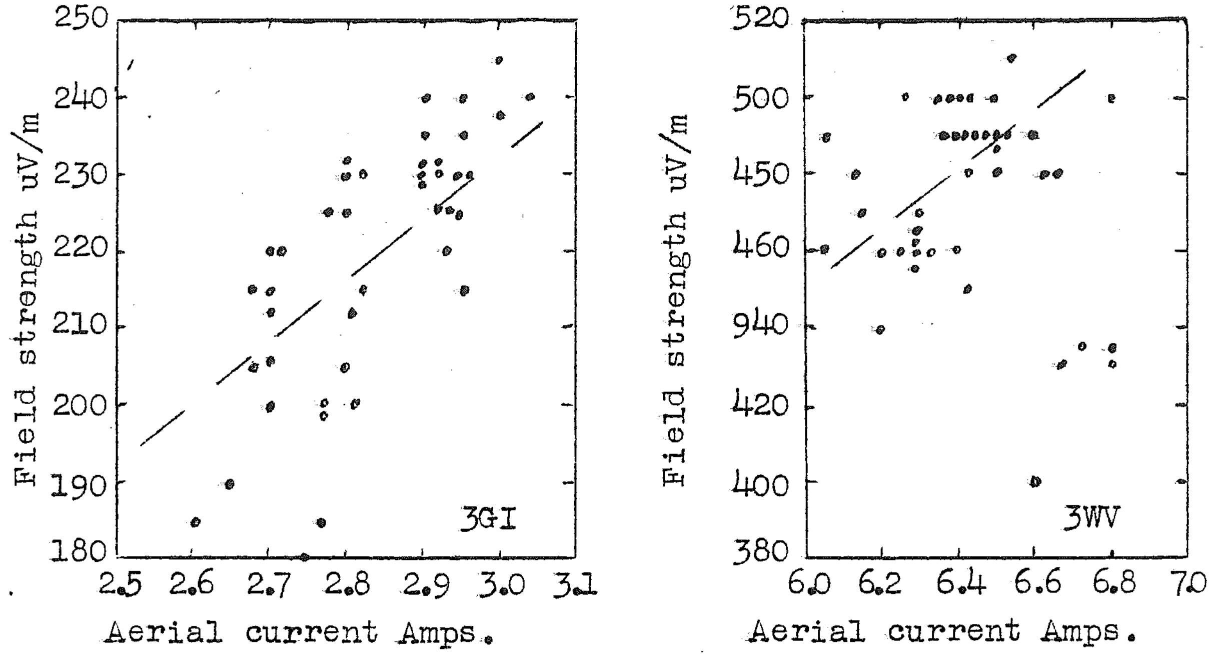

Figure 3 - Field strength plotted against aerial current.

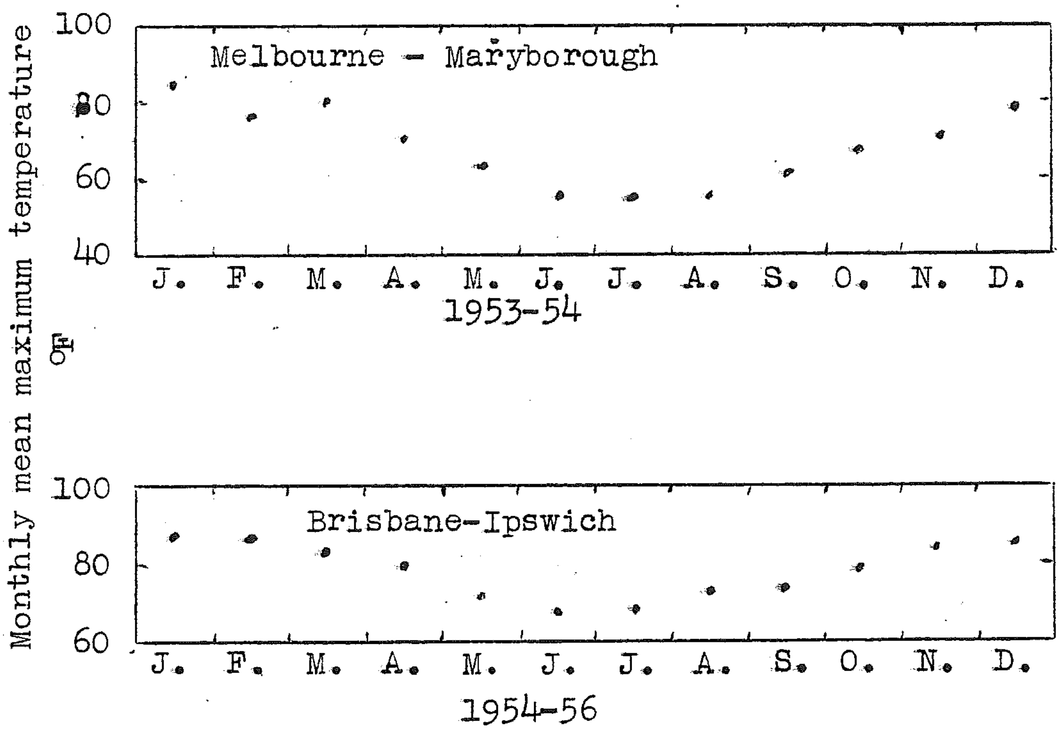

Figure 4 - Typical temperature variations.

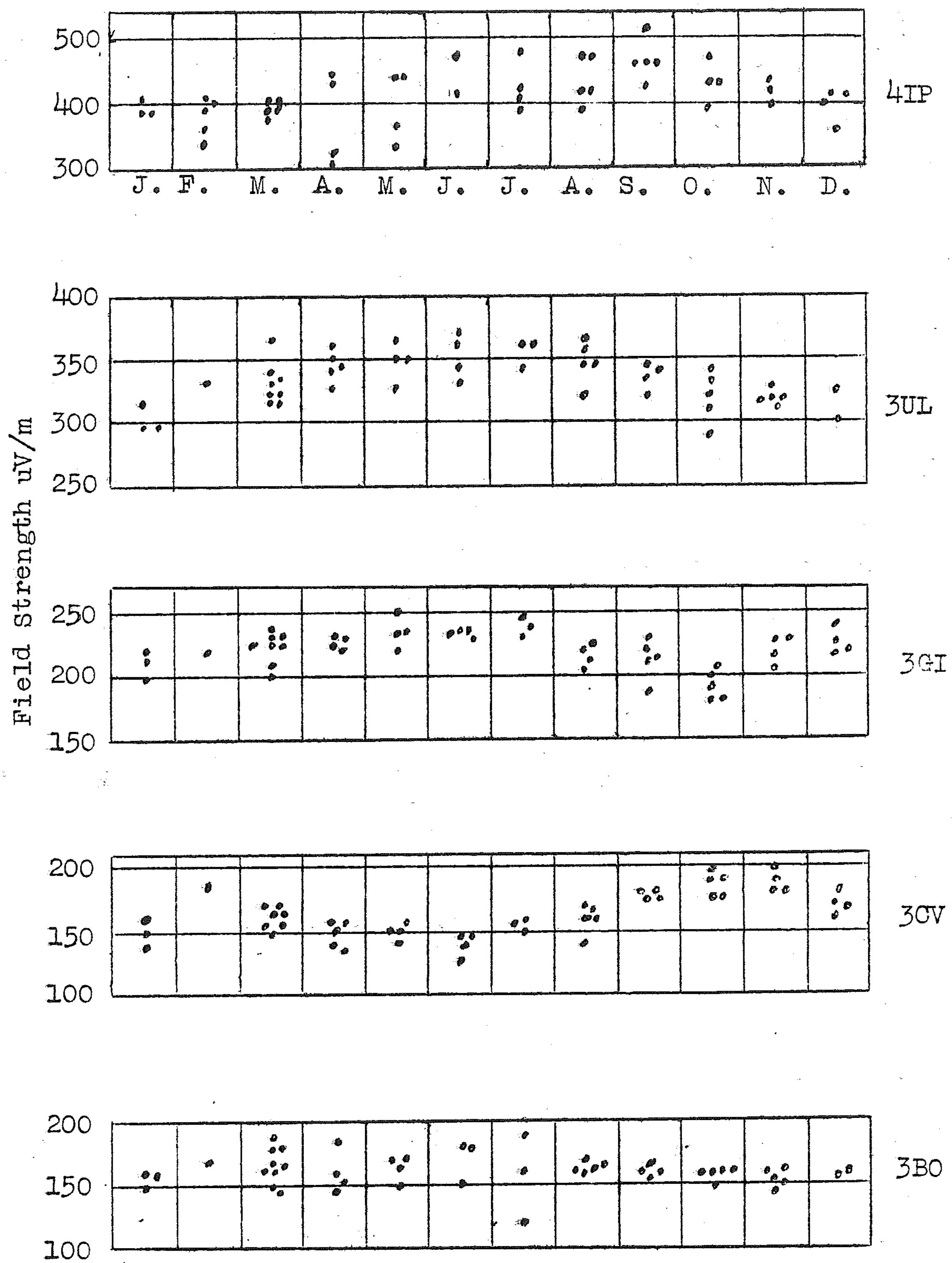

Figure 5 - Seasonal variation observed on four paths. Most paths studied showed no seasonal trend.

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