Associated File No. [illegible]

REPORT No. 7

<u>TITLE</u>: Synchronized Broadcast Stations.

Report on investigations carried out by J.H. Dixon for Director, Technical Services, to determine populations served by one synchronised transmitter in each capital city of the Commonwealth except Hobart.

R. McDonald

Director of Technical Services.

<u>Date of Issue.</u>

28/7/53

Synchronized Broadcast Stations.

1. Introduction.

The purpose of this report is to explore the possibilities of providing a third programme in each capital city in the Commonwealth, except Hobart, using one channel in the frequency range 1500 to 1600 kC/sec.

The use of 10 K.W. transmitters with anti-fading radiators located at the sites of existing national stations is considered.

It is considered unlikely that synchronized operation, throughout the whole of the time of operation, would prove practicable to the Australian Broadcasting Commission, and on occasions the stations would almost certainly radiate individual programmes.

The operation of the transmitters under the two conditions

(a) shared channel basis.

(b) synchronized.

has therefore been considered.

2. Shared Channel Operation.

In this case different programmes may be used in each capital. Primary service area limits in the daytime are set at

(a) the 0.5 mV/m. contour.

(b) 20:1 ratio of ground wave field strength required to R.S.S. of undesired ground wave field strength.

whichever contour falls nearest to the transmitter.

In all cases considered here the separation and conductivities are such that the 0.5 mV/m. contour sets the limit of service.

The service area at night is set at the 0.5 mV/m. contour, the 50% fading boundary or the 20:1 ratio of ground wave desired to R.S.S. of the 10% quasimaximum field strength.

In all cases considered here the latter boundary gives the service area. Populations within these boundaries are given in table No. 1

	Sydney	Melbourne	Brisbane	Adelaide	Perth
Day	1,683,000	1,446,000	483,000	470,000	292,000
Night	466,000	677,000	114,000	341,000	278,000

Table No. 1

Under shared channel operation no secondary service is possible for any of the above cases.

3. Synchronized Operation of Transmitters.

As no standards covering acceptable conditions of service by transmitters operating with synchronized carriers have yet been considered by the Board, it is advisable to briefly state the theory underlying successful reception from synchronized transmitters, before proceeding to consider its application to the present proposal.

3.1 Primary Service Area.

The art of maintaining synchronous operation of carriers is so highly developed today that it is possible to restrict the frequency difference to a mere variation of phase. The following analysis refers to this condition.

The distortions encountered in the detected signal received from two identical synchronized transmitters are due to either a time delay difference in the modulating signal at the transmitters, a phase difference between carriers at the transmitters if modulation delay is present or to a difference in the length of path from the transmitters to the receiver.

With such delay present in the received modulated carriers, and assuming vector representation, it can be seen in figure 5 that the vectors which add to make the side band components of the wave are neither equal in magnitude nor symetrical with the resultant carrier vector. This is the source of the distortion when such a combination of waves is detected. It is also clear from figure 6 that the resultant carrier is overmodulated whereas the combining carriers are modulated to 75%. The extent of distortion depends upon the carrier ratio, the phase angle between carriers, the degree of modulation, the relative degree of modulation and the amount of delay in modulation. Figures 1, 2 and 3 indicate the influence of some of these variables on the required carrier ratio for the distortion to be just perceptible on programme listening tests.

An analysis of the form of distortion encountered, for a carrier ratio of 1:1 and equal degrees of modulation, shows that -

(a) With zero modulation delay at the receiver location the detected output varies from zero to a maximum as the phase between carriers is changed from 180° to 0°. In this case there is no distortion but a change in output level with a change in phase between carriers. See figure 5.

(b) With modulation delay present and zero phase difference between carriers at the receiver location, the detected output varies, according to the modulation frequency, from a maximum to a minimum depending on the modulation delay. Thus under these conditions frequency distortion occurs.

(c) In carriers set 180° out of phase at the receiver location, the detected second harmonic of the modulating frequency varies in amplitude, according to the modulating frequency, from a maximum to a minimum depending on the modulation delay.

(d) For any given carrier phase difference and delay in modulation at the receiver location, the detected amplitude of the fundamental and second harmonic of the modulating frequency vary in opposite directions with change in frequency, while an increase in carrier phase difference will increase the second harmonic amplitude and decreases the fundamental amplitude.

Briefly it can be said that with modulation delay present and little difference in phase between carriers the distortion in the detected output is almost wholly frequency distortion. When the phase difference between carriers approaches 180° then the distortion in the detected output is mostly amplitude distortion. Since the latter form of distortion is much more objectionable than the former it follows that the worst case for reception occurs when the carriers are 180° out of phase. This also coincides with the worse case for the signal to noise ratio.

A difference in path length of 97 metres will cause a phase change of 180° between carriers at 1550 kC/sec., while a path difference of 9.3 miles is required to produce a modulation delay of 50 μ sec.- the acceptable limit for a carrier ratio of 2 : 1.

In a practical case therefore, it must be assumed that the phase angle between carriers at the receiver location can have any value. Hence the information contained in figure 3 should be used to determine service areas.

At locations where the carriers cancel, the signal to noise ratio may be small. Such trouble can be remedied by using a directional aerial.

The F.C.C. of America specify a ratio of 2 : 1 desired to undesired carrier for satisfactory synchronized reception, but from the information given in figures 1, 2, 3, it would appear that the F.C.C. specification should be qualified with a programme delay figure. It is also clear that a carrier ratio of 4:1 will overcome all noticeable distortion no matter what the delay in modulation or phase angle between carriers in the limited extent of each variable considered here.

This explains why little distortion has been noticed between one high power station and one low power station separated by distances of approximately 200 miles.

It is difficult to predict the effect that different degrees of relative modulation between carriers will have except in the case where large programme time delays occur, in which case slight variations in the relative degree of modulation will have little serious effect.

3.2 <u>Transmitters separated by Short Distances.</u>

Provided the separation between transmitters is kept to within 25 miles, the path differences in most areas in the vicinity will not be great and it can be expected that no serious distortion will occur when there is zero modulation delay between carriers at the transmitters. Large path differences will occur at points near the transmitters but the ratio of field strengths will be large, reducing the distortion. This case however does not appear to suit the present proposed application of synchronized reception.

3.3 Secondary Service Area.

Where two synchronised transmitters are separated by 400 to 500 miles a considerable proportion of the area between them (the normal sky-wave secondary service area in clear channel operation) receives approximately equal skywave field strengths at night for equal powers radiated.

From the above theory it has been demonstrated that the successful reception of synchronised signals depends on the existence of one predominantly strong signal, and this would lead to the conclusion that in the area between the stations, dependent on skywave service, distortion would be present and the service unacceptable. Hence there would be no satisfactory service outside the limited primary service area surrounding each station.

However, it is suggested, notably by American writers, that in fact a satisfactory skywave service is provided, because a more steady signal is provided than by one station alone, owing to the fact that the chances of both stations fading together is small, and that when one station fades out the other will still provide an adequate signal. It is further commented that competent observers have failed to detect serious distortion under these conditions.

However, the F.C.C. do not lay down any rules at all regarding skywave service, except to state that as skywave service is in any case inferior to that of groundwave, a rather lower ratio of desired to undesired carrier could be tolerated.

It is therefore apparent that there is at least some uncertainty regarding the skywave service provided in the area between two synchronised transmitters, and in this regard some valuable practical experience should be obtained from the proposed synchronisation tests on 4QS-4QN, Queensland.

P.M.G. Drawing CR-543 Sheet 1 attached, illustrates the secondary service area that would exist between two stations, 500 miles apart, assuming that such a secondary service does in fact exist. This separation of stations generally represents the Adelaide-Melbourne-Sydney-Brisbane cases.

In addition to the effects already considered, if the path lengths from two transmitters, at a receiving location, differ by more than 370 miles, equivalent to an audio delay of 2 milliseconds, serious distortion will occur due to "echo" effects, or the one signal arriving later than the other.

This "echo" effect is responsible for the fact that the areas remote from the distant station, in the above drawing, are shown as not receiving a secondary service.

In the case under consideration it is therefore apparent that due to this distortion caused by "echo", there will be no satisfactory service in the eastern states from the four synchronized transmitters, outside the limited primary service area of each station.

Briefly, the cases of "echo" distortion in the various locations may be summarized as follows:-

Location	"Echo" distortion due to transmitters at
North of Brisbane	Sydney, Melbourne, Adelaide.
Between Brisbane and Sydney.	Melbourne, Adelaide.
Between Sydney and Melbourne.	Brisbane, Adelaide.
Between Melbourne and Adelaide.	Sydney, Brisbane.
West and north of Adelaide.	Melbourne, Sydney, Brisbane.

4. <u>Population in Primary Service Area.</u>

From the consideration of the shared channel case it is apparent that during daylight hours no advantage can be gained by synchronising transmitters as the service area boundary is then the 0.5 mV/m. contour.

The populations in the primary service areas for nighttime operation have been assessed on the basis of the F.C.C. standard of the 2:1 ratio of desired ground wave to undesired 10% quasimaximum skywave and are shown in Table 2.

Having regard to the earlier theoretical considerations this is by no means a conservative limit under the conditions being considered here.

Table 2.

	Sydney	Melbourne	Brisbane	Adelaide	Perth
Day	1,695,000	1,[illegible],100	405,000	470,000	292,000
Night	1,590,000	1,401,000	418,000	467,000	292,000

7. Conclusion

Service areas according to the standards laid down by the F.C.C. are shown in figure 4. In synchronized night operation these boundaries are set at 2:1 field strength ratios.

From the data presented it is considered that a ratio of field strengths of 4:1 is more desirable for the present proposed case of synchronised operation, but the service areas indicated are the most favourable circumstances possible.

In the case of Perth, synchronization with the eastern state stations would be difficult, if not impracticable, and in any case is not necessary.

The proportions of the total population of Australia included in the primary service areas are -

Day = 57.7%
Night (synchronised operation) 54.3%
Night (shared channel operation) 24.8%

The case presented for synchronised operation is in the frequency range 1500-1600 kc/sec. This represents the worst condition for such a scheme. The undesired signal at night is the same as that which would be received at lower frequencies in the broadcast band while the ground wave attenuation is at a maximum. Larger primary service areas could be served if a lower carrier frequency were chosen.

There seems to be a limit to the accuracy of synchronization required due to a Doppler effect when one or more of the received signals is by way of sky wave propagation, as the constantly changing path length is equivalent to a changing phase.

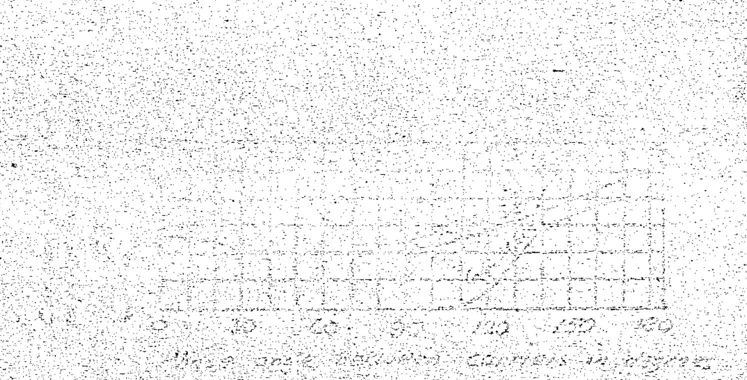


Fig. 1.

Effect of carrier phase angle on the field strength ratio at which distortion is just perceptible in the output of a linear detector. The relative time delay of modulation is constant for each curve as indicated. Both stations are modulated 30% at peaks of speech programme.

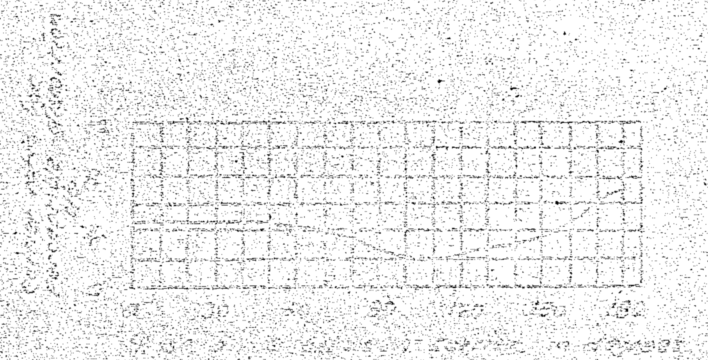


Fig. 2

Same as upper curve of Fig. 1 except that both stations are modulated about 27% on peaks.

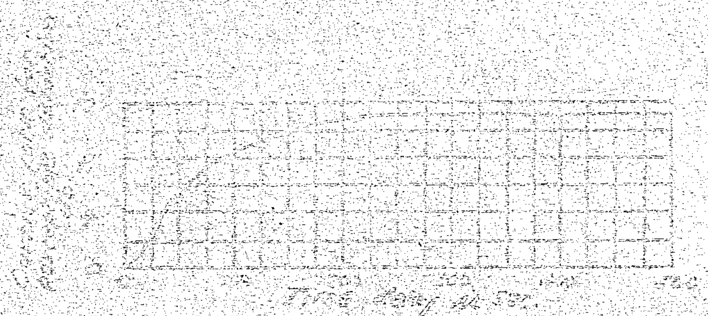
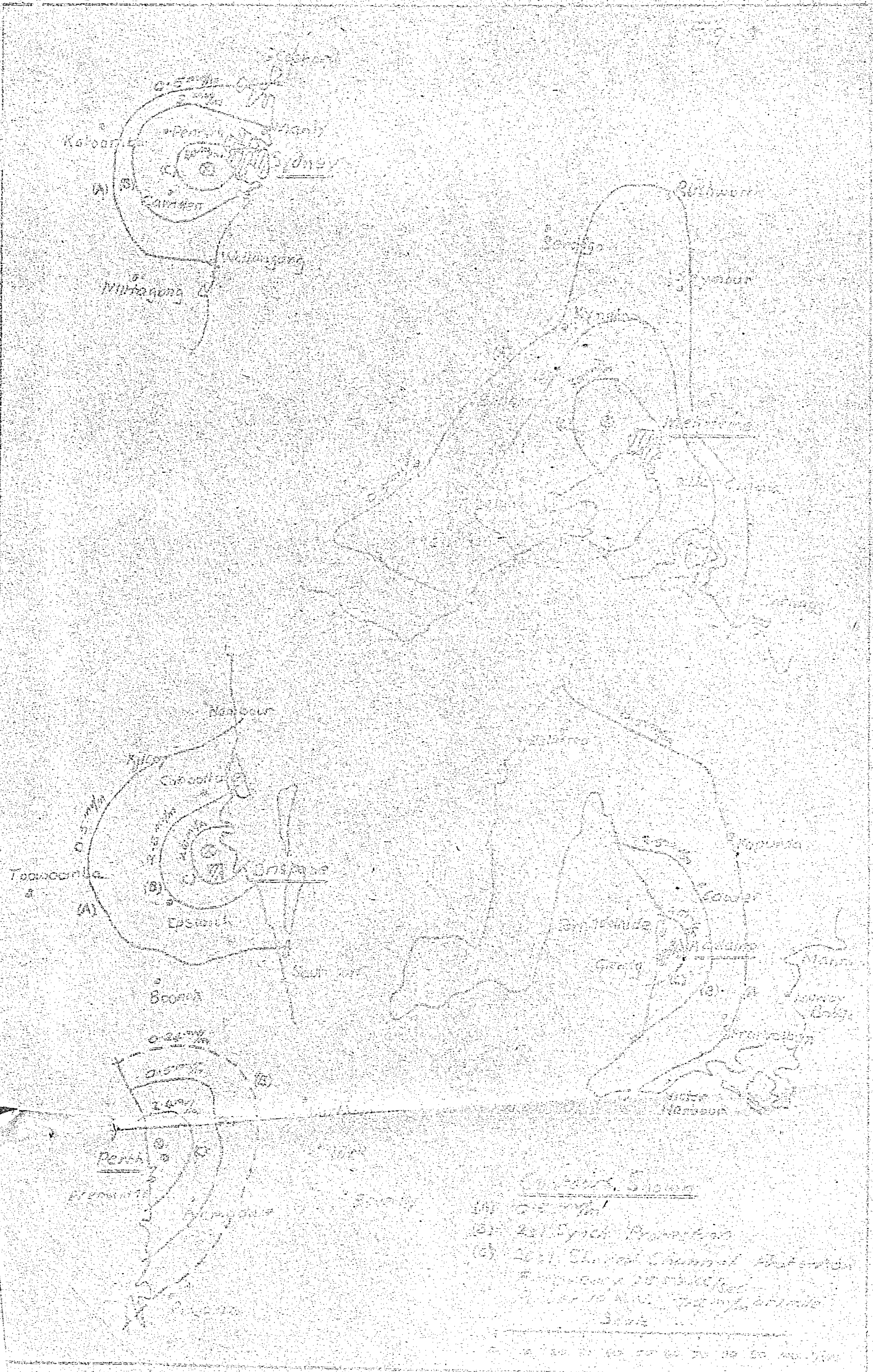


Fig. 3

Effect of relative time delay of modulation on field strength ratio at which distortion becomes just perceptible in output of linear detector. Carrier phase angle = 180° ± 1°. Both stations are modulated 28% on peaks.



Sydney
Katoomba
Penrith
Manly
Camden
Wollongong
Mittagong
Rushworth
Bendigo
Kyneton
Melbourne
Nambour
Kilcoy
Caboolture
Toowoomba
Brisbane
Ipswich
Southport
Beenleigh
Kapunda
Gawler
Adelaide
Strathalbyn
Victor Harbour
Perth
Fremantle
(A)
(B)
(C)

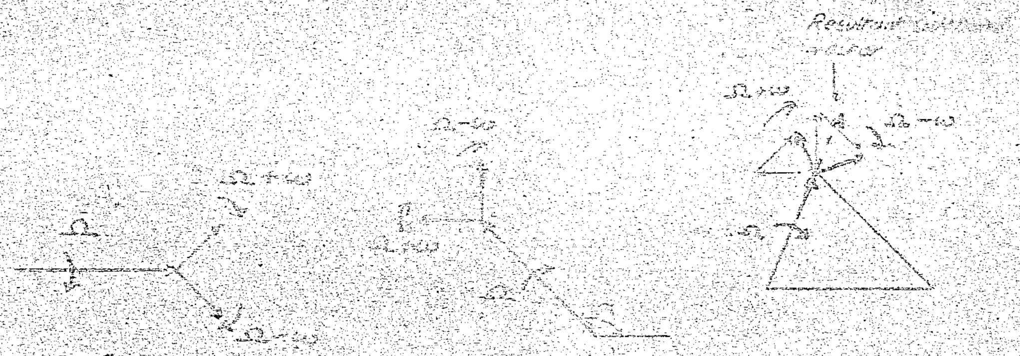


Fig. 5 Phase angle between carriers α
No modulation delay

Fig. 6 Phase angle between carriers α
Modulation delay β

Reference.

Reception from Synchronised Broadcast Stations - Charles B. Aiken. Proc. I.R.E. September, 1933.

Present Practice in the Synchronous Operation of Broadcast Stations as Exemplified by [illegible] and [illegible] - L. McC. Young. Proc. I.R.E. March, 1936.

Note on the Synchronisation of Broadcast Stations WJZ and WEAL - K.A. Norton. Proc. I.R.E. September, 1934.

F.C.C. Standards of Good Engineering Practice 1939 and revised to 1949.

Some Developments in [illegible] Broadcasting - [illegible] Gillett. Proc. I.R.E. [illegible]