Postal and Telecommunications Department

BROADCASTING ENGINEERING DIVISION

ENGINEERING REPORT NO 55

Title Departmental FM Test Transmissions (October-December 1978)

- Investigations of various factors which could influence the planning of FM services in Australia.

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ABSTRACT

For the planning of FM stereo broadcasting station allocations, information was required regarding typical receiver installations and the extent of interference which would be produced in these receivers by:

(1) varying the adjacent channel separation, and
(2) introducing SMT into the composite FM baseband.

This information was obtained from a questionnaire survey, phone enquiries made to the Department by the public and several separate Departmental investigations.

Other work undertaken during the course of these tests included:

(1) A field strength survey of the test station and 3ABC-FM
(2) An investigation into field strength differences between horizontal and vertical field components of linearly polarised transmissions.

Although some worthwhile results were obtained (as outlined in this Report), the tests revealed other factors which could also play a significant part in the formulation of planning guidelines. A further set of test transmission should be undertaken to enable the Department to evaluate fully the extent of these factors and their likely effect upon future planning.

Section 1 INTRODUCTION

This summary report is a compilation of data and results obtained during the conduct of the Postal and Telecommunications Department's FM test transmissions held during the period 12/10/1978 to 20/12/1978. These results were obtained from investigations which were conducted to provide information required to assist in the planning of optimum station allocations within the 88-108MHz VHF-FM band.

A series of six tests was conducted by the Department in association with Telecom Australia, the Australian Broadcasting Commission and the Australasian Performing Right Association.

The two fundamental areas of investigation involved:

a) obtaining information on minimum usable frequency separation between co-sited station transmissions, and

b) examining the compatibility of S.C.A. (or Supplementary Monophonic Transmission) with pilot-tone stereo in view of reported crosstalk problems.

A test transmission was located adjacent in frequency to 3ABC-FM so that 3ABC-FM could be used as one station in the spacing trials.

The two transmitting antennae were co-sited on the ABV-2 tower at Mount Dandenong (See Figure A).

The actual broadcast levels of the 3ABC-FM and Test-FM transmissions were 50kw ERP and 10kw ERP respectively, both being horizontally polarised.

The test transmission schedule was as follows:

Test No	Period	Test Frequency	Nature of Test
A	12/10/1978 - 25/10/1978	104.7MHz	Separation from 3ABC-FM: 1MHz
B	26/10/1978 - 1/10/1978	104.7MHz	S.M.T. at 3.5kHz deviation
C	2/11/1978 - 8/11/1978	104.7MHz	S.M.T. at 7.5kHz deviation
D	9/11/1978 - 22/11/1978	104.9MHz	800kHz separation
E	23/11/1978 - 6/12/1978	105.1MHz	600kHz separation
F	7/12/1978 - 20/12/1978	105.3MHz	400kHz separation

(N.B.) All of the test transmissions outlined above were modulated in stereo only.

Implementation of the tests was achieved by the use of the 3ABC-FM standby equipment. Recorded programme material compiled by Telecom state office personnel was chosen to appeal to as wide a cross section of the listening community as possible by including a wide ranging selection of music.

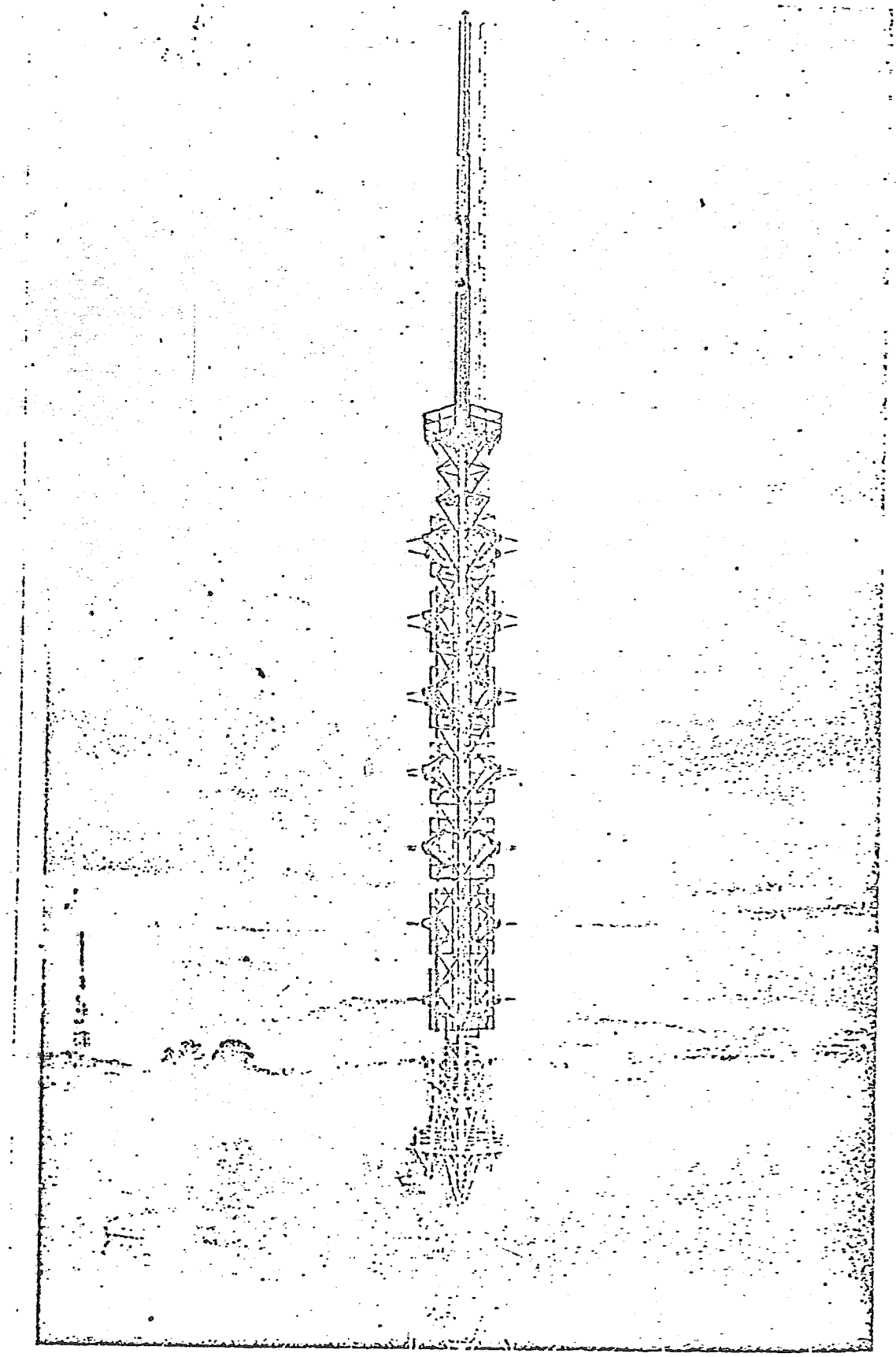

Fig. A. 3ABC-FM antenna system installed above ABV-2 antenna on top of tower at Mt Dandenong.

Antenna: Marconi Model BDT92 (12 Stack VHF quadrant)

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Section 2 SUMMARY OF RESULTS

The various restrictions which affect channel allocations for VHF-FM Services necessitate a careful choice of factors which include the minimum channel spacing to be employed, the polarisation sense of the transmitted signal, the transmitting antenna sites and the possibility of incorporating Supplementary Monophonic Transmission into the composite baseband stereo signal.

The FM transmissions were conducted by the Postal and Telecommunicat Department to obtain information which would assist in the planning of future FM station allocations in the 88-108MHz VHF-FM frequency band. The following test results were obtained:

For the 3ABC-FM and Test-FM broadcast powers used, (50kw ERP and 10kw ERP respectively - both omni-directional) the Melbourne metropolitan area was found to be adequately served.

The typical receiver installation comprised a medium to highly-price stereo Hi-Fi tuner or receiver housed in a quiet environment, possibly near main roads and employing a reasonably adequate antenna system. It should not be inferred here that the "typical receiver installation" is representative of the actual population of receivers which have been purchased with an FM reception facility. Sales figures show that within the community the proportion of "Hi-Fi" tuners or receivers is extremely small compared to the total number of FM receivers sold.

The receiver installation referred to herein was found to be typical of installations owned by people who responded to the questionnaire. It is typical of the type of receiver which is actually employed by listeners who have an interest <u>at the present time</u> in receiving FM broadcasts.

As the use of the FM band is expanded and a larger variety of services are introduced, a great deal more use may be made of a greater variety of receivers. When this occurs, the "typical receiver installation" <u>in regular use</u> may vary dramatically. With this prospect in mind, it may be necessary to qualify some

of the conclusions which have been drawn from the responses to the questionnaire.

Overall, reception of 3ABC-FM was very good. Reception of the test transmission, based on relatively strong signal strength readings and 'noisefree' reception (reported by approximately 60% of survey listeners), was also good.

Interference between the ABC and Test transmissions appears to become quite significant when the channel separation is reduced to 400kHz. A separation of 600kHz, on the basis of information extracted from the Questionnaire survey, may be a reasonable choice of channel separation. However further work must be undertaken to confirm this.

The introduction of an S.M.T. component appears to result in significant interference to stereo reception. The Questionnaire responses indicate that a low deviation (3.5kHz) S.M.T. signal may provide an acceptably low level of interference to stereo reception.

In view of laboratory investigations of stereo S.M.T. crosstalk problems, the introduction of an S.M.T. signal is not recommended at this time.

At typical receiving sites, the field provided by the horizontally polarised test and ABC-FM signals contains a vertical component that is typically 11 to 14db smaller than the horizontal component. This would possibly affect those listeners using vertical whip or telescopic antennas such as those used with car or portable radios.

Finally, there appears to be a need in the listening community for information to permit them to improve their antenna and receiver installations and thereby make best use of the available signals.

The test transmissions involved the implementation of two main investigatory trials; these being firstly a sequential decrease in channel separation between the Test and ABC-FM transmissions and secondly the inclusion of two Supplementary Monophonic Transmissions.

The 3ABC-FM antenna system (a 12 stack VHF quadrant, Marconi model BD792) has a gain of approximately five and is mounted on the top of the ABV-2 tower at Mount Dandenong. The Postal and Telecommunication Department test transmission (Test-FM) was radiated from a unity gain antenna array comprising four Hills translator antennae of the corner reflector type (Hills model 4CR-ITXP-274) mounted some 200 feet below the 3ABC-FM antenna.

Three additional Departmental investigations, without the participation of the listening public, were conducted to furnish further information which could be directly related to, and assist in, the interpretation of the listening test results. The results of these investigations have been compiled as individual internal laboratory reports, summaries of which are outlined later in this report (See Section 4).

The test program was organised as follows with each investigation being reported separately.

3.1 Questionnaire Response Report

The questionnaire sought information in two major categories. Firstly, details of the respondent's FM receiver installation were requested. The required information covered the listening environment, receiver type and cost, the antenna system used and additional facilities provided on the FM receiver.

Secondly, test signal reception reports were sought. The details requested in this section included the standard of 3ABC-FM reception, whether or not spurious signals and/or noise on the test signal were present and finally, whether or not any interference to the signal was evident and if so, the nature of the interference n

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Approximately 2000 questionnaires were despatched to the general public in the following proportions:

a) 700 (representating approximately 35%) were sent to a technically oriented section of the community and included persons from both private and public business sectors, eg. industry, educational institutions, various government departments etc.

b) Approximately 1300 (65%) were sent to members of the public who made telephone enquiries to the Department in response to invitations announced on the test transmissions.

From the end of the first week until completion of the tests, a telephone recorded message requested callers to inform the Department if any interference to 3ABC-FM and/or the test transmission was detected in their receivers as a consequence of a test transmission and if so, whether a follow-up investigation at the complainants' premises could be arranged.

As at 22 February 1979, 625 completed questionnaires had been received by the Postal and Telecommunications Department. This represented a 31.25% return on the originally despatched 2000 questionnaires. This was a good response and allowed a reasonable degree of confidence to be placed in the derived trends as being representative of typical VHF-FM receiver installations.

The raw data was extracted from the received questionnaires and displayed in the form of a statistical histogram from which various trends (eg. population spread of receiver installations) were quickly and easily identifiable.

3.2 Listener Complaint Investigation Report

Together with the questionnaire mentioned above, information circulars were despatched to listeners of the Test-FM transmissions. In these it was explained that some listeners' receivers might experience interference to the test transmission, the 3ABC-FM transmission, or both of these. Consequently, some listeners

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contacted the Department when some form of interference was being suffered.

If a follow-up visit to investigate the interference symptoms could be arranged, the investigating officer recorded details of the complainant's FM receiving installation and the signal levels obtained at TV and FM antenna terminals. Also, the horizontal component of the field intensity (in microvolts/meter) using an extendable 30 foot antenna attached to a Departmental vehicle was measured in the street outside the complainant's house.

Finally, the investigating officer undertook a subjective assessment as to the degree of crosstalk, spurious responses evident, and tuning difficulties, as well as possible causes of signal degradation which might emanate from the receiver installation itself.

115 complaints were investigated involving a total of 122 receivers covering 42 different brands.

3.3 Field Strength Survey

The first of the three Departmental investigations involved a field strength survey of the FM test transmission's coverage to supplement information provided by the questionnaires. Field strength measurements were made of the 3ABC-FM transmissions at the same time to allow comparisons to be made between the two services. Also, subjective listening tests were carried out using a Sony CF55 portable receiver (chosen to represent a typical portable unit in public use) to determine if any inference existed between the two stations (104.7MHz, test transmission and 105.7MHz, 3ABC-FM). Also an attempt was made to measure the aerial radiation pattern of the test transmitter at a radial distance of 15km.

(N.B.) The exact pattern could not be determined because of the variations in topography and evaluation throughout the area.

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3.4 Laboratory S.M.T. Investigation

The second of the Departmental investigations was conducted in the Postal and Telecommunications Department's laboratory. A 67kHz sub-carrier which was itself frequency modulated, was added to the composite baseband input to the FM transmitter to provide a separate third channel (S.M.T.). The two basic forms of crosstalk, linear and non-linear crosstalk, were investigated, firstly with respect to crosstalk of the S.M.T. signal into the main channel and secondly with respect to crosstalk of the main channel into the S.M.T. channel. The report on this investigation, a copy of which appears in full in Appendix A at the end of this report, discusses where these problems of crosstalk are most likely to arise and the means employed to minimise the occurrence of crosstalk problems.

3.5 Vertical Vs. Horizontal Polarisation Investigation*

The third of the Departmental investigations involved the determination of the typical difference between the horizontal field component and the vertical field component radiated by 3ABC-FM and the Departmental test transmissions (Test-FM), both of which were horizontally polarised. This investigation developed from phone comments made to the Department by listeners who suffered various interference difficulties with mobile reception. The reports indicated better mobile reception of the test transmission compared to reception of the ABC-FM transmission. The difference in field components is important as it indicates the additional transmission loss suffered by receivers using vertically polarised whip antennas (AM/FM car radios) to receive a basically horizontal polarised signal.

*Refer to Appendix B

Section 4 DISCUSSION OF RESULTS

The results of the various investigations conducted during the test transmission period have been compiled in separate Departmental laboratory reports. This section presents a summary based on data derived from these reports.

To provide a basis for the following dicussion, the results from the field strength survey should be outlined to give an insight into the relative size of the service areas provided by the 3ABC-FM and test FM transmissions. The outline, in section 4.1, is an extract of the report covering the Department's field strength survey.

4.1 Field Strength Survey

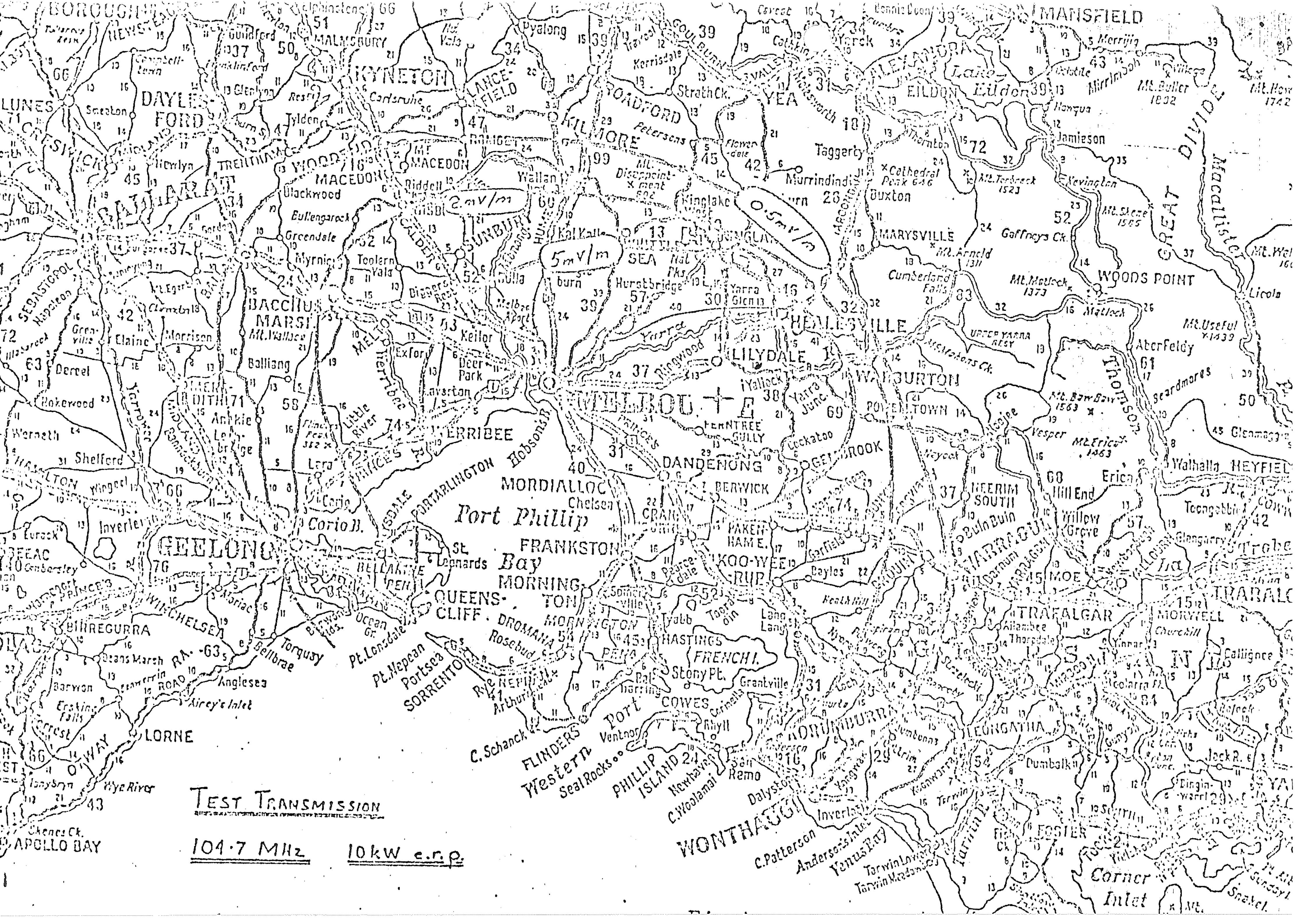
4.1.1 Service Area

The Melbourne metropolitan area is adequately served by the test transmission and the 3ABC-FM service and is within the 5mV/m. field strength contour as recommended by the C.C.I.R. Recommendation 412-1 for stereo reception in large city areas.

The 2mV/m. contour of 3ABC-FM passes through Geelong, the largest population centre beyond Melbourne. Consequently the signal level from this station may be marginal in certain areas for good stereo reception. Geelong was beyond this contour for the test transmission. However, some sites at higher elevations would receive a signal adequate for stereo reception.

The aerial radiation patterns for both transmissions were nominally omni-directional but mountain ranges to the North and North-East of the transmitter site modified significantly the shape of the service areas. The field strength was attenuated rapidly with increasing radial distance in these areas. Similarly, the rural service area (0.5mV/m contour) was contained by a mountain range running from Nerrim South to Wonthaggi in the South-East and by mountains to the North-West in the Mt. Macedon area.

Field strength contours for the test and ABC-FM transmissions are shown in figures 1 and 2 attached.



Test Transmission
104·7 MHz
10 kW e.r.p.
5 mV/m
2 mV/m
0.5 mV/m
Port Phillip
Bay
Western Port
Corner Inlet
GREAT DIVIDE
Macallister
Thomson
Yarra
MANSFIELD
WOODS POINT
Jamieson
Mt. Buller 1802
Mt. Useful 1439
Aberfeldy
Walhalla
HEYFIELD
Licola
YEA
Taggerty
Murrindindi
Buxton
MARYSVILLE
Mt. Arnold 1311
Cumberland Falls
WARBURTON
POWELLTOWN
HEALESVILLE
LILYDALE
Yarra Glen
Hurstbridge
KILMORE
Pyalong
Wallan
LANCEFIELD
KYNETON
MALMSBURY
DAYLESFORD
CLUNES
CRESWICK
BALLARAT
BACCHUS MARSH
Mt. Wallace
Balliang
Melton
Exford
Keilor
Deer Park
Laverton
WERRIBEE
Little River
Lara
Corio B.
GEELONG
Inverleigh
Shelford
WINCHELSEA
BIRREGURRA
Deans Marsh
Anglesea
Torquay
Bellbrae
Airey's Inlet
LORNE
Wye River
APOLLO BAY
Skenes Ck.
Barwon
Erskine Falls
QUEENSCLIFF
Pt. Lonsdale
Ocean Gr.
PORTARLINGTON
St. Leonards
Pt. Nepean
Portsea
SORRENTO
Rosebud
DROMANA
Arthurs Seat
C. Schanck
FLINDERS
MORNINGTON
FRANKSTON
MORDIALLOC
Chelsea
DANDENONG
BERWICK
PAKENHAM
KOO-WEE-RUP
Tyabb
HASTINGS
FRENCH I.
Stony Pt.
COWES
Rhyll
Ventnor
Seal Rocks
PHILLIP ISLAND
Newhaven
San Remo
C. Woolamai
WONTHAGGI
Dalyston
Inverloch
C. Paterson
Andersons Inlet
Venus Bay
Tarwin Lower
KORUMBURRA
LEONGATHA
Dumbalk
FOSTER
Toora
Yarram
Grantville
Lang Lang
Bayles
Garfield
GEMBROOK
Cockatoo
Ferntree Gully
Yarra Junc.
NEERIM SOUTH
Noojee
Vesper
Mt. Baw Baw 1563
Mt. Erica 1463
Erica
Hill End
Willow Grove
MOE
TRAFALGAR
YARRAGON
WARRAGUL
MORWELL
TRARALGON
Churchill
Callignee
Glengarry
Toongabbie
Jack R.
Hobsons B.
Princes
Tooradin
Mt. Macedon
MACEDON
Riddell
Gisborne
Sunbury
Kalkallo
Whittlesea
Kinglake West
Flowerdale
Strath Ck.
Alexandra
Eildon
Lake Eildon
Thornton
Cathedral Peak 646
Mt. Torbreck 1523
Gaffneys Ck.
Mt. Matlock 1373
Matlock
Mt. Disappointment 802
Woodend
Blackwood
Greendale
Myrniong
Trentham
Glenlyon
Guildford
Smeaton
Sebastopol
Meredith
Morrison
Elaine
Dereel
Rokewood
Lethbridge
Teesdale
Bannockburn
Hamilton
Tylden
Carlsruhe
Romsey
Broadford
Mitchell
Petersons
Seymour

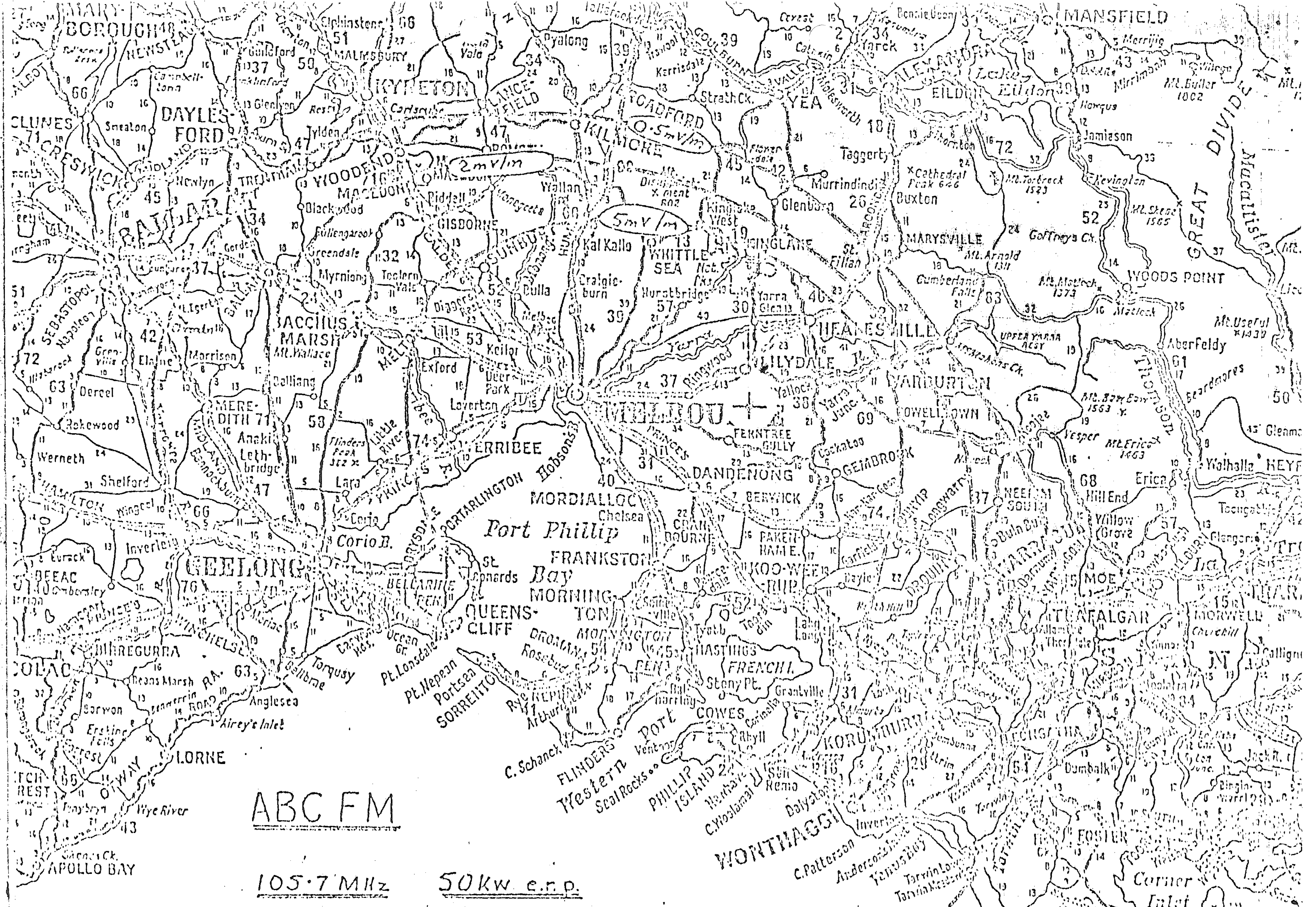

ABC FM
105·7 MHz
50kw e.r.p.
2mV/m
5mV/m
0.5mV/m
MELBOURNE
Port Phillip Bay
GEELONG
BALLARAT
DAYLESFORD
KYNETON
WOODEND
MACEDON
GISBORNE
SUNBURY
BACCHUS MARSH
MELTON
WERRIBEE
FRANKSTON
MORNINGTON
MORDIALLOC
DANDENONG
LILYDALE
HEALESVILLE
WARBURTON
KILMORE
LANCEFIELD
YEA
ALEXANDRA
EILDON
MANSFIELD
WOODS POINT
MARYSVILLE
MOE
TRAFALGAR
MORWELL
KORUMBURRA
LEONGATHA
WONTHAGGI
FOSTER
COLAC
LORNE
APOLLO BAY
QUEENSCLIFF
SORRENTO
FLINDERS
Western Port
PHILLIP ISLAND
Corner Inlet
GREAT DIVIDE
Macallister
Thomson
Lake Eildon
CLUNES
CRESWICK
MARYBOROUGH
SEBASTOPOL
WINCHELSEA
BIRREGURRA
DROUIN
WARRAGUL
PAKENHAM
KOO-WEE-RUP
BERWICK
CRANBOURNE
HASTINGS
COWES
PORTARLINGTON
DRYSDALE
Torquay
Anglesea
Airey's Inlet
Hobsons B.
Corio B.

Fig. 2

FOOTNOTE

Technical Operating Conditions for Melbourne FM Services

	Frequency	Power	Antenna Polarisation (Pattern)
3ABC-FM	105.7MHz	50kw ERP	Horizontal (Omni-direction
3MBS-FM	93.7MHz	4kw ERP	Horizontal (Omni-direction
3RRR-FM	102.7MHz	1kw ERP	Horizontal (Omni-direction

4.1.2 Subjective Tests

The subjective listening tests carried out at a number of locations failed to reveal any interference between 3ABC-FM and the test transmission when the transmissions were operating on frequencies of 105.7MHz and 104.7MHz respectively. The highest field strengths measured during the survey were 94dBuV/M and 91 dBuV/m for the ABC and test transmissions respectively.

The lowest field strength at which the receiver gave subjectively acceptable portable stereo performance was of the order of 50dBuV/m (approximately 300uV/m) in a relatively noise-free rural area.

4.1.3 Aerial Radiation Pattern

An attempt was made to measure the aerial radiation pattern of the test transmitter at a radial distance of 15km. Although measurements were taken at a total of 56 sites determined by this radial distance, large variations in field strength were encountered from point to point.

This could be due to (i) variations in local topography, and
(ii) various degrees of obstruction in the radio path.

To partially overcome this difficulty, it was assumed that the 3ABC-FM aerial radiation pattern was perfectly omni-directional an a polar plot of the difference between the 3ABC-FM and Test FM transmission field strengths was made. The results, shown in figure 3 attached, indicate that the test transmission aerial radiation pattern was approximately omni-directional.

4.1.4 Summary

(i) Both the Test-FM and the 3ABC-FM transmissions provided an adequate signal strength for Melbourne and the metropolitan areas.

(ii) Subjective listensing tests indicated no interference between the stations (Test-FM 104.7MHz and 3ABC-FM 105.7MHz), even at high field strengths (91dBuV/m and 94dBuV/m respectively).

(iii) The radiation pattern of the test transmitter aerial was approximately omni-directional.

4.2 Questionnaire and Listener Complaint Survey Reports

Important sources of information from the test transmissions were obtained from the questionnaire survey and the investigations made into listener complaints. The results of the two surveys are categorised into two sections, viz, "FM receiver installation details" and "Results of test signals reception". Where appropriat comparisons will be made of results derived from allied and relevant areas of both reports.

This section will discuss the results of Tests, A,D,E,F which relate to the frequency separation between the test signal and 3ABC-FM. Discussion of results of the remaining tests B and C which relate to S.M.T. tests follow in Section 4.3.

4.2.1 FM Receiver Installation Details

4.2.1.1 Questionnaire Survey Results

Refer to Table 1 for receiver installation details.

Difference In Field Strength Of ABCFM And Test Transmission At A Constant 15 km Radius

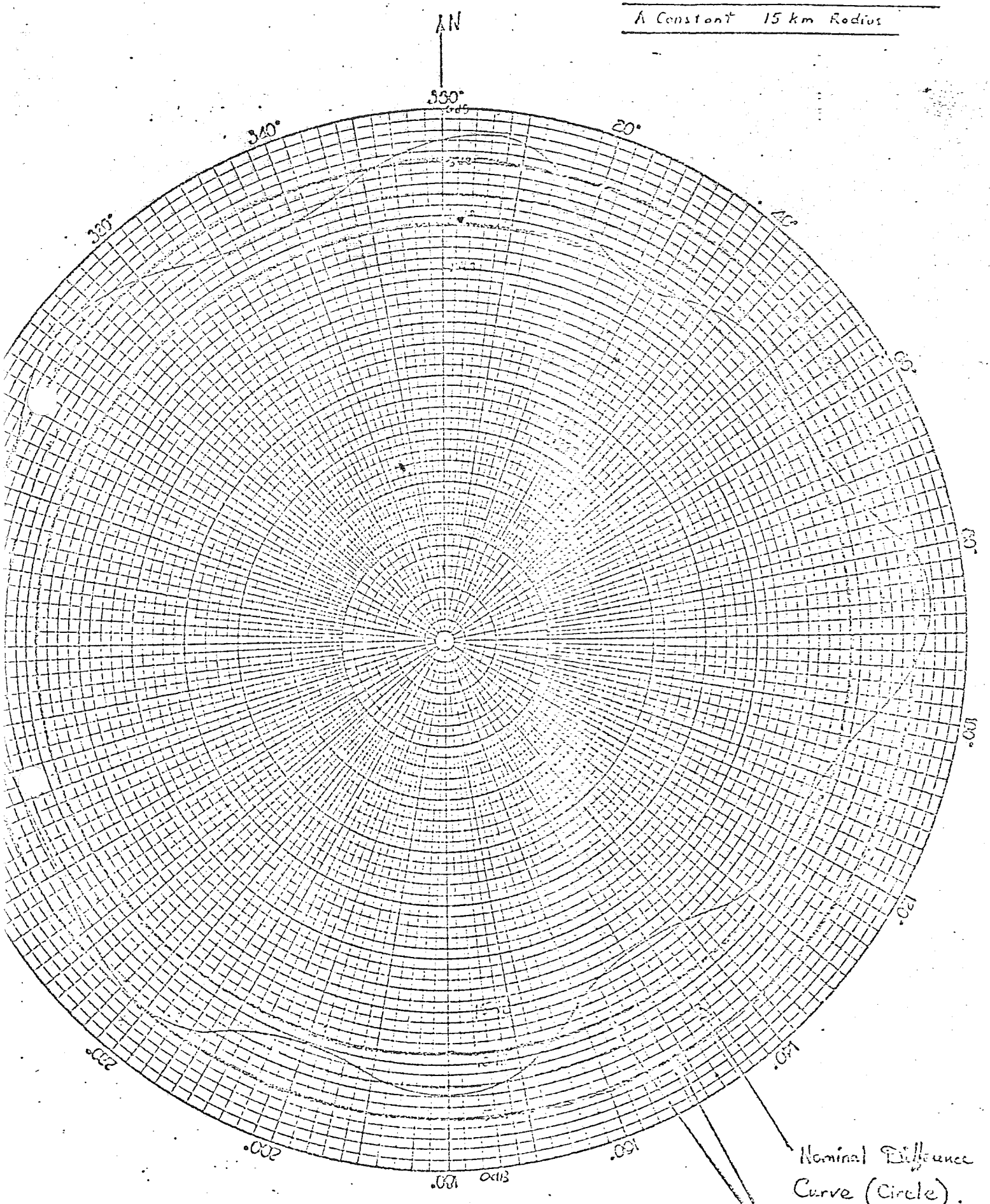


Figure 3

FM TESTS' QUESTIONNAIRE SUMMARY

COMPILATION DATE (1) 18th Jan (584 returned) (2) 22nd Feb (625 returned)

ENVIRONMENT	TOTAL	GROUP REP. PERCENTAGE %	TOTAL	GROUP REP. PERCENTAGE
Quiet	428	73.3	455	72.8
Near Main Roads	169	28.9	182	29.1
Near Power Lines	72	12.3	77	12.3
Near Factories	27	4.6	30	4.8
RECEIVER TYPE				
Stereo	493	84.4	521	83.4
Mono	71	12.2	78	12.5
Portable	83	14.2	89	14.2
Car Radio	33	5.7	39	6.2
Hi-Fi Tuner	231	39.6	247	39.5
Hi-Fi Receiver	174	29.8	184	29.4
3 in 1	40	6.8	42	6.7
Clock Radio	26	4.5	28	4.5
Mantel Radio	1	0.2	1	0.2
Other	6	1.0	6	1.0
RECEIVER COST				
$50	40	6.8	44	7.0
$50-150	156	26.7	168	26.9
$150-300	230	39.4	240	38.4
$300	172	29.5	184	29.4
ANTENNA				
Built-in	117	20.0	126	20.2
Indoor Ribbon	191	32.7	206	33.0
TV (Shared)	98	16.8	101	16.2
Outdoor FM	114	19.5	119	19.0
Other	79	13.5	85	13.6
S-METER				
Yes	378	64.7	398	63.7
No	215	36.8	234	37.4
READING				
Test Stronger	15	2.6	15	2.4
ABC-FM Stronger	182	31.2	189	30.2
Equal	175	30.0	187	29.9
AFC SWITCH				
Yes	168	28.8	180	28.8
No	418	71.6	446	71.4
STEREO/MONO SWITCH				
Yes	470	80.5	498	79.7
No	119	20.4	131	21.0

TABLE 1 - RECEIVER INSTALLATION SURVEY

Based on the data extracted from the questionnaire survey, a typical receiver installation was found to comprise a medium to highly-priced ($150 to greater than $300) stereo Hi-Fi tuner or receiver housed in a quiet environment and possibly near main roads. For example, it was found that the receiver housed in a "quiet" environment represented 72.7% of respondents (based on 625 returned questionnaires), which obviously represents the majority of the FM receiver installation environments in the sample.

The antenna systems, however, fall into two main categories with nearly equal representation. The first of these is the outdoor antenna group comprising the 'outdoor FM antenna' (19.0%), the 'antenna shared with the TV aerial' (16.2%) and part of the 'other' group (approximately 8%) which comprised roof dipole antennas etc. Altogether this category represented approximately 43% leaving the other category of antenna installation comprising built-in (20.2%) 'indoor ribbon' (33.0%) and 'car antenna' (approximately 4%) to represent the remaining 57% of the sample.

This latter category could have been made up of the transient listener section of the survey's respondents, although, with strong signals, a "built-in" or "ribbon" antenna might give satisfactory listening on a permanent basis.

The typical installation within the survey appears to include a reasonably adequate antenna system which lends itself to good FM stereo reception with comparatively strong 3ABC-FM and Test-FM signals. High signal strength readings were reported by respondents who could refer to an S-meter. A majority of listeners in the survey did not have an AFC switching facility (71.4%) and thus tuning of closely spaced stations could present a problem. For the majority of listeners in the sample who had stereo/mono switching facility (79.7%), man-made noise may not cause significant problems since the provision of a stereo/mono switch allows monophonic mode to be selected in a noisy environment thus obtaining an improvement to the output audio signal-to-noise ratio.

The poor performance exhibited by some receivers in the sample may influence the particular station allocation format which can be adopted in the VHF-FM band.

4.2.1.1. Listener Complaints Vs. Questionnaire Survey

In the period 19/10/1978 to 2/1/1979 inclusive, 4764 telephone calls relating to the test transmissions were received by the Department. Of these 498 recorded enquiries related to the tests themselves, the questionnaires or comments on the tests (e.g. interference, reception, program material), including 222 specific complaints of interference.

Approximately 290 complaints relating to interference were received by the Department of which 115 were investigated revealing a total of 122 receivers and 42 brand names. See Table 2 for breakdown of the 122 sample.

Of this 122 total, 47 units (or 38.5%) had no problem attributable to receiver performance. Included amongst this group were 6 European receivers whose tuning capabilities were limited to a frequency of less than 105MHz, thus making if difficult to tune to 3ABC-FM which operates at a frequency of 105.7MHz.

Also, it was found that 14 of those 47 investigated units were either incorrectly tuned or had the source of complaint related to comments on programme material. With respect to the remaining 27 units, it was found that either low field strength (determined by the 30 ft. field intensity reading) or inadequate antenna installations were responsible for insufficient signal level being available at the receiver input, thus resulting in an audible "hiss" superimposed on the signal. It was found on further investigation that 12 units were found to be in an area of below 5mV/m field intensity for the Test-FM signal and 5 were found to be in an area below 5mVm/m for the ABC-FM signal.

(N.B.) 5mV/m is the field strength limit as recommended by C.C.I.R. recommendation 412-1 for stereo reception in large city areas.

(TABLE 2) Breakdown of 122 sample into constituent categories of faults encountered upon investigation

(a) No real receiver problem on investigation	14 units
(b) Inadequate antenna installations/low field strength	27 units

(c)	Spurious products only	29 units
(d)	Spurious products and crosstalk	8 units
(e)	Desenitisation and detuning effects - odd whistles and noises	7 units
(f)	Crosstalk only	11 units
(g)	Tuning problems - unable to separate etc	20 units
(h)	88-104MHz FM tuning band only (European receivers)	6 units
	TOTAL FAULTS INVESTIGATED	122 units

(N.B.) Total number of valid receiver problems attributable to the tests = 75 units.

As noted above, only 75 units of the original 122 unit sample suffered degraded reception due to receiver performance in the presence of the test transmissions and it is these 75 units that are investigated in the following examination.

Table 3 provides a comparison between results obtained from the questionnaire survey and the listeners' complaints survey.

4.2.1.3. Comparison of Receiver Installation Results

(i)	Questionnaire Survey (Sample 625)		Listener Complaint Survey (Sample 12	
	Receiver Type	Percentage of Sample	% Valid Sample - 75 units	% Total Sample - 122 units
	Portable	14.2	8.0	14.8
	Car Radio	6.2	0	0.8
	Hifi Receiver	29.4	28.0	27.9
	Hifi Tuner	39.5	30.7	27.7
	3 in 1	6.7	25.3	23.8
	Mantel Radio	0.2	1.3	0.8
	Clock Radio	4.5	6.7	4.0
	Other	1.0	--	--

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(ii) Antenna Type

	(Sample 625) Percentage	(Sample 110) Percentage
Built-in	20.2	11
Indoor ribbon	33.0	34
TV (shared)	16.2	12
Outdoor FM	19.0	21
Other - car aerial etc	13.6	22

TABLE 3

Study of the results in Table 3 yields some interesting data. It should be noted that not all of the complainants visited during the listener complaint investigation and survey were necessarily participants in the questionnaire survey. No figures regarding the proportion of those complainants who also submitted questionnaires are available so it will be assumed that the spread of the receiver and antenna type populations given in the questionnaire survey listings fairly reflects that of the general community. The listener complaint figures will be compared under this premise.

This assumption is based on the random nature of the sample and of the relatively large sample size. Since requests for questionnaires and the subsequent return of results were open to all sections of the general community, there was no bias introduced into the survey sample. However, the Department did circulate questionnaires to a technically orientated section of the community (approximately 35% of the total despatched). Although this may influence the sample profile somewhat, the benefit of accurately observed results of the test would tend to reinforce the validity of the data. These two factors were assumed to balance out and not unduly effect the validity of the survey.

(i) In the receiver installation results shown in Table 3(i), the first item that comes to notice is the similarity of receiver type proportions. The questionnaire responses indicated that a typical FM receiver was either a Hi-Fi tuner or Hi-Fi receiver. This is supported by the observations during the complaints survey. However, one discrepancy between the results that is evident is the marked increase in complaints relating to 3-in-1 receivers (25.3%) compared to the

proportion of those receivers in the questionnaire survey (6.7%). Assuming a random nature of the complaint sample, it would appear that there exists a more widespread problem associated with 3 in 1 receiver performance than with other receivers. For example, the other main categories of receiver represented in the questionnaire and complaint surveys are of roughly the same order: Tuners 39.5% and 30.7% respectively, receivers 29.4% and 28% resp., portables 14.2% and 8% resp. (N.B.) The complaint survey figures are based on the valid receiver complaints reported. The remaining categories of receiver, viz. car radio, mantel radio, clock radio and others, were too small in quantity to validly make any comparisons and conclusions.

(ii) A similar comparison of the antenna types used in the two surveys listed in Table 3(ii) shows reasonable correlation between the occurrence of categories of antennas with the obvious exceptions of the "built-in" and "other" categories.

It was found that a significant proportion (22%) of the antenna types noted in the investigation survey consisted of a "piece of wire or no wire at all". Of the sample of 110 systems, this represents 24 installations. It could be reasonably assumed that this category of antenna type could be contributing to the 27 cases where poor reception was attributed to the listeners antenna installation.

In complement to the above, it is observed that, both in the questionnaire and complaint surveys, a large proportion of the listeners' installations employed suitable antennas. It was found from measurements made during interference investigations that FM receiving antenna efficiency (using the 30 ft. field intensity measurement as a reference) was rather low. The mean efficiency of FM antennas was 16% with a large variation from one installation to another. Most installations were below 10% efficient compared to the mean efficiency of TV antennas of 30%. The significance of this is that, while providing satisfactory reception, the average installation does not make best use of available signals.

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4.2.2. Results of Test Signal Reception Report

4.2.2.1. Questionnaire Survey Results (Refer Table 4 for details)

The results of the "Test Signal Reception Report" in the questionnaire survey reveal some interesting information. Firstly, the great majority (99.7%) of this survey indicated good to very good reception of 3ABC-FM. A smaller majority of the sample stated that their receivers were free of spurious signals, (57.4%) (i.e. 290 of the 505 who responded to this question on the questionnaire) and also free of noise (63.7%) (i.e. 362 of the 568 who responded to this part of the questionnaire).

However, an appreciable number of the respondents, 173 in total, stated that "noticeable hiss" was evident. Since a majority of listeners indicated that reception of the test signal was good, it would seem that these respondents were fairly tolerant to low level background interference.

Table 5 provides the extracted data on reported interference with the test transmission during the four test sequences which involved variation of the separation of 3ABC-FM and Test-FM (See Section 4.3, Table 6, for results of S.M.T. test sequences B and C).

RESULT	TEST A 1MHz	TEST D 800kHz	TEST E 600kHz	TEST F 400kHz
No interference	76.5%	75%	76.2%	72.5%
interference	5.6%	8.6%	12.6%	18.9%
No report	17.9%	16.4%	11.2%	8.6%

TABLE 5 - Reported Interference results from questionnaire survey.

Data from these four tests reveal that as the separation between the Test and 3ABC-FM transmissions was decreased, there was an increasing proportion of respondents who noted interference to the test signal. Also, it is observed that the overall percentage of the sample who reported no interference to the test transmission

CORRELATION DATE	(1) 10th January		(2) 22nd February	
ABC-FM RECEPTION	TOTAL	% REP.	TOTAL	% REP.
Very Good	475	81.3	503	80.5
Good	110	18.6	120	19.2
Fair	14	2.4	15	2.4
Poor	1	0.2	2	0.3
Very Poor	2	0.4	2	0.3
SPURIOUS SIGNALS				
ABC-FM	102	17.5	105	16.8
Test	109	18.7	116	18.6
None	272	46.6	290	46.4
NOISE ON TEST SIGNAL				
None	336	57.5	362	57.9
Noticeable	179	30.7	183	29.3
Annoying	21	3.6	23	3.7
Hiss	167	28.6	173	27.7
Pop-Pop	11	1.9	11	1.8
Clicks	46	7.9	47	7.5
TEST A - 1MHz				
OK	454	77.7	478	76.5
No	34	5.8	35	5.6
TEST B - SMT LOW				
OK	433	74.1	456	73
No	53	9.0	53	8.5
TEST C - SMT HIGH				
OK	408	69.9	433	69.3
No	73	12.5	74	11.8
TEST D - 800 kHz				
OK	443	75.9	469	75.0
No	52	8.9	54	8.6
TEST E - 600 kHz				
OK	448	76.7	476	76.2
No	74	12.7	79	12.6
TEST F - 400 kHz				
OK	430	73.7	453	72.5
No	111	19.0	118	18.9

*Seemingly unaccountable errors are due to some questionnaires being multiple replies which were then designated (e.g.) 368 (a), 368 (b), etc.

TABLE 4 - TEST SIGNAL RECEPTION REPORT DETAILS

It will be noted however, that for "test F", where the frequency separation was 400kHz, there is a noticable reduction in the numbers reporting no interference from the average 75.9% for the first three tests to 72.5%. This factor, coupled with the marked increase in reported interference which occured with this frequency separation, would suggest that a separation of 400kHz may be too small to provide generally satisfactory, interference-free reception.

Based on the finding that for 600kHz 76.2% of the respondents reported interference-free reception and that this figure compared favourably with those for 1MHz separation (76.5%) and 800kHz separation (75%), a choice of 600kHz separation might be adequate. However, consideration must also be given to the number of respondents who reported that interference did occur. It is impossible, upon inspection of these figures alone, to make a definitive statement as to which frequency separation would in fact be most suitable. Further investigative work will be required therefore, before a final determination regarding the most suitable frequency separation for FM services may be made.

4.2.2.2. Complaint Investigation Survey

The information for this sub-section has been extracted from an internal departmental report.

(i) Field Intensity Differential

The field intensity measurements (conducted at the listeners' homes) at a height of 30ft gave a mean difference of 6.6dB between the 3ABC-FM and test-FM signal. There were large variations in the difference, ranging from the test transmission 20dB above the ABC-FM to the ABC-FM signal 19dB above the test signal. The large differentials occurred generally in the hilly suburbs, close to the transmitter, such as Mt Evelyn and Kilsyth.

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Terminal voltage measurements at listeners' FM and TV antennas had mean differences and variations similar to those found during Field Intensity measurements. These results closely conform to those outlined in Section 4.1.3. in which large variations in F.I. were encountered from point to point.

(ii) Distribution of Complaints

The distribution of valid complaints (sample size 75) when compared to the total population distribution (for the Melbourne Statistical Division) reveals a significant number of extra complaints in the region to 20km radius from the transmitter. Also, for distances greater than 20km, the number of complaints is fewer than expected when compared to the total population.

(iii) Frequency Separation during Investigations

During the period of the complaints' investigation, the Test-FM station changed frequency twice, giving separations of 800, 600 and 400kHz. The respective numbers of complaints investigated during each interval were 5, 28 and 81 respectively. These findings also conform to those of the questionnaire in which a trend of higher reported interference coincides with decreasing channel separation.

Considering only crosstalk and tuning problems (i.e. frequency separation related), the respective proportions of these specific complaints for the 3 spacings were 20%, 29% and 44%. As the sample size for the 800kHz spacing was only 5, the 20% value should be treated with caution.

Again, these findings follow the above described trend of greater interference with decreasing frequency separation and thus offers evidence to support the responses reported in the questionnaire returns.

(N.B.) No findings were obtained for the test trials involving Supplementary Monophonic Transmission (S.M.T.) in this survey.

4.3 Supplementary Monophonic Transmission (S.M.T.) Test Results

Due to the different nature of Tests B and C (i.e. the inclusion of a separate third channel (S.M.T.) into the composite baseband stereo signals as against the other tests which only involved a progressive incremented decrease in channel separation between the two transmissions) the results of these tests are treated separately.

The Departmental report which discusses various limiting factors in the use of an S.M.T. signal is included as Appendix A at the end of this report.

It is important to note that no data is available from the Complaint Investigation Survey relating to reported interference during the two S.M.T. tests: thus the data used for these S.M.T. tests has been extracted from the Questionnaire Survey alone and is summarised in Table 6.

Test B	S.M.T. Low (3.5kHz deviation of the S.M.T. sub-carrier)	Respondents	
	No interference	456	73%
	Interference	53	8.5%
	No information given	116	18.5%
Test C	S.M.T. High (7.5kHz deviation of the S.M.T. sub-carrier)	Respondents	
	No interference	433	69.3%
	Interference	74	11.8%
	No information given	118	18.9%

TABLE 6 Questionnaire S.M.T. results

With reference to those respondents who gave no information in the two S.M.T. tests, i.e. 116 respondents for Test B & 118 respondents for Test C, it could be reasonably assumed that because these figures are nearly identical, the same group of listeners is represented. Having made this assumption, it thus leaves an approximate 81% of the sample which forms the base for a comparison of those reporting either interference or non-interference to the test transmission due to the presence of the S.M.T. signal.

The result observed is that for a higher frequency deviation of the S.M.T. sub-carrier (for the same deviation of the main carrier by the S.M.T. signal i.e. 10%) there was an accompanying increase in reported interference. Results from Table 6 indicate that a further 3.3% of respondents reported interference (8.5% to 11.8%) when the frequency deviation was increased from 3.5kHz to 7.5kHz respectively. Possible causes of the interference between S.M.T. and main channel are discussed in Appendix A.

The level of reported interference represents a significant minority of listeners and thus, if the S.M.T. signal was to be introduced as part of the FM service, it would bring with it problems of interference neither dependent upon nor associated with channel separation.

4.4 Polarisation Survey

(Refer to Appendix B for Vertical-Horizontal Polarisation Report)
The purpose of this investigation was to determine the typical difference between the horizontal and vertical field components of 3ABC-FM and the test transmission (Test-FM), both of which radiate nominally horizontally polarised signals.

The investigation arose from reports that mobile reception of the test signal was superior to 3ABC-FM suggesting a significant vertical component of signal from the test transmission.

The results of this investigation indicate that at typical receiving sites, the fields provided by the horizontally polarised VHF transmission contain vertical components that are typically 11 to 14dB smaller than the horizontal components. This difference was found to be largely independent of the receiving antenna height (for a maximum test height of 10 metres). It should be noted that there may be considerable variation from the average where results are examined on an individual basis.

These tests were conducted when the separation between 3ABC-FM and Test-FM was 1MHz and 800kHz respectively.

Listener comments on the relative quality of reception had suggested that the test transmission may have contained a larger vertical component than the 3ABC-FM signal. Although these tests were by no

means exhaustive (27 sites checked), it was found that the test transmission field intensity rarely exceeded the 3ABC-FM intensity regardless of the receiving antenna height or polarisation.

In addition to the Departmental Investigation, some information was obtained from listeners who monitored the test transmissions on car radios (using vertical whip antennas). This information revealed that of the 37 listeners in this category, 20 reported noise (of varying degree of annoyance) on the test transmission, 11 reported noise-free reception of the test transmission and 6 failed to supply any details.

It is seen that 65% of the sample who supplied information reported noisy reception. These findings indicate that the input signal level was inadequate due to a low field strength in the particular reception area, reduced input signal level into the receiver resulting from the use of a substantially vertically polarised antenna, or a combination of both of these. It is assumed that it is the combination of these two factors which would predominate in the majority of reception circumstances.

It is concluded, based on measurements and the questionnaire report, that the reported improved car radio reception of the test signal (relative to 3ABC-FM) was due not to the radiation of a significant vertical component of signal but to other factors.

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5. FURTHER INVESTIGATIONS REQUIRED

The existence of significant intermodulation product generation was reported in some telephone comments regarding the test transmissions. The occurrence of FM receiver intermodulation interference signals in high field strength areas was confirmed in the laboratory and in investigations conducted at listeners' homes.

With some receivers, the problem was so great that some listeners were tuned to spurious signals and not the 'real' test or ABC-FM signals.

Laboratory investigations indicate that the problem increases as the spacing between transmissions is reduced and that this factor may limit the minimum acceptable separations.

Because of the difficulty of accurately simulating practical situations in the laboratory, further test transmissions will be necessary to determine the impact of this problem.

The Department is currently investigating the optimum polarisation for the VHF-FM Sound Broadcasting Service. The reports of car radio reception of the test transmission and the polarisation measurements indicate that further work is required in this area.

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6. ACKNOWLEDGEMENT

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1. Telecom Australia.

   (a) Headquarters, - Supervision and co-ordination of the test transmissions.

   (b) Victorian Administration - Implementation, operation and maintenance of the service.

2. Listeners of the test transmission including:

   - those who participated in the questionnaire survey
   - those who allowed home visits to be carried out by Department technical personnel to undertake signal measurements
   - those who suffered interference to 3ABC-FM as a result of the test transmissions.

3. Australasian Performing Right Association - Copyright agreement

4 Australian Broadcasting Commission - Recorded announcements