Australian Broadcasting Control Board
TECHNICAL SERVICES DIVISION

REPORT No. 15

TITLE: Tests on Reflections from Television Masts

Issued by —

The Chairman,
Australian Broadcasting Control Board,
Rialto Building,
497 Collins Street,
MELBOURNE C.1.

Technical Report No. 15

Title: Tests on Reflections from Television Masts

Prepared by: W. R. Baker, S. F. Brownless

J. M. Dixon and P.J. Credlin

Associated file No. TS/1/1

D McDonald

(D. McDonald)

Director

Technical Services Division

6/3/59

Issue ~~re~~-typed 18/8/61

TESTS ON REFLECTIONS FROM TELEVISION MASTS

CONTENTS

TESTS ON REFLECTIONS FROM TELEVISION MASTS

Abstract

Magnitudes of reflections have been measured in Melbourne from a 400 foot self supporting mast illuminated by a small transmitter located approximately 3400 feet away and operating on channel 10 (209 - 216 Mc/s) with horizontal polarisation. Subsequent measurements have been made using the small transmitter feeding the GTV transmitting aerial at approximately the same distance from the reflecting mast. Measurements have also been made feeding the HSV7 transmitting aerial approximately 280 feet from the ABV2 mast acting as a reflector and feeding a Yagi aerial at a much lower level on the HSV7 mast. Some measurements have been made with vertically polarized signals and some subjective tests on the tolerable level of ghost reflections.

The conclusion is reached that although for spacing of masts of the order of 350 feet ghosts due to such reflections should be above the threshold of perceptibility they are unlikely to be serious for any mast spacing.

Section 1 - Introduction

General

1. In connection with the siting of Australian television stations reports had been received from the United Kingdom and Canada (1), that aerials spaced by relatively short distances may cause "ghosts" in the home television receivers due to unwanted reflections from transmitting aerials. These reports suggested the desirability of locating all transmitting aerials serving the one area on the one mast. On the other hand, in the case of a number of United States cities, transmitting aerials have been located at relatively short distances of several hundred feet and enquiries made have indicated no troubles due to reflections.

When these tests were commenced, the sites and masts for the Melbourne and Sydney television stations had been decided on and the practice had been followed of locating transmitting aerials on separate masts at a relatively short distance apart of the order of 100 yds. to 1 mile. While the enquiries made regarding operating conditions in the United States indicated that ghosts due to such reflections would not cause serious trouble, it was considered desirable to obtain some objective figures on the magnitude of such reflections. A programme of tests was therefore carried out to determine magnitudes of reflections from the mast erected by the Herald Sun TV station (HSV7) at Barnes' Lookout near Mt. Dandenong.

These tests carried out on reflections from the HSV7 mast some 3400 feet from the temporary transmitter were made prior to the introduction of the Melbourne television service and while the aerial for the HSV7 transmitter was in course of installation and before the erection of the ABV2 and GTV9 masts. While it was not expected that serious reflections would be encountered, it was desired to check this experimentally before work had proceeded too far. After all the stations were in operation tests were carried out using a low power transmitter feeding signals on channel 9 into the GTV9 aerial system to assess reflections from the HSV7 and ABV2 masts some 2900 feet away and on channel 7 from the HSV7 aerial system to assess reflections from the ABV2 mast some 280 feet away. Some subjective tests were also made using both a video system and a television receiver to assess the magnitude of reflections which could be observed on a television picture.

Location of the masts

3. The relative location of the GTV9, HSV7 and ABV2 masts are shown in Figure 1 attached to the end of this report.

The HSV7 mast is a self supporting one 396 feet in height with a square cross section of 60 feet side at the base falling to approximately 6ft. side at the summit. The aerial was of the super gain type employing 16 tiers extending 72 feet from the summit. About half the aerial was erected before the tests, erection of the remainder proceeding during the tests.

The HSV7 mast is oriented so that one diagonal is approximately 6° west of the direction of the test transmitter.

The ABV2 mast also self supporting is located on ground some 20 feet lower than that of the HSV7 mast. It is 400 feet high, the top 66 feet being occupied by a steel pole supporting a Marconi quadrant 100 mc/s aerial and approximately the next 100 feet from the top occupied by an 8 bay Marconi supergain aerial. The base of the mast is some 70 feet and the cross section of the mast at the super-gain aerial is approximately 6 feet. The HSV7 aerial is thus approximately at the same level as the Marconi quadrant aerial at the top of the ABV mast. The GTV9 mast is a 200 ft. overall self supporting type on ground of level approximately 30 feet above that of HSV7.

Section 2 - Initial Tests transmitting from a Temporary Aerial

General

4. This section describes the test made on channel 10 (209 - 216 Mc/s) from a low power transmitter located approximately at the side of GTV9. The site of the small transmitter was approximately 3400 feet from the HSV7 mast. Measurements were made at about 14 receiving sites ranging from 3.5 to 13 miles distant from the test transmitter and at various angles in a 200 degree arc.

Equipment Used

5. The equipment employed was as follows:-

(a) Transmitting Equipment.

An R.C.A. type T.T.X.-1H television transmitter was used with a 6 element Yagi antenna at a height of 43 feet above ground. The nominal output of the transmitter was 18 watts peak. The transmitter was modulated by a Pye type 3673 bar pattern generator, which was modified to give 8 microsecond spacing of the vertical bars in lieu of the normal spacing of 3.2 microseconds. The vertical bar output pulses of the pattern generator were approximately 0.3 micro-seconds in width, this arrangement being satisfactory for viewing echos having the expected delay times. The "excitation" and "bias" controls of the transmitter were adjusted to ensure that the transmitted carrier was reduced to zero during white periods of the picture pattern. This could be observed on a monitoring cathode ray oscillograph which was fed from a demodulating diode loosely coupled to the transmitter output pick-up coil. A direct current amplifier was available on the C.R. oscillograph. These precautions were necessary to ensure that the "ghosts" of the vertical bars could not combine, in or out of phase, with any part of the picture signal transmitted in a direct line to the receiver. The equivalent radiated power of the transmission in the forward direction of the Yagi, was approximately 40 watts.

In operation the Yagi antenna was first pointed directly at the HSV7 mast, and measurements were made at the receiving point of the direct field intensity (D) and of the "ghost" field intensity (G). The transmitting antenna was then pointed directly at the receiver and the direct field intensity (Do) was again measured. At some receiving sites the direct ray path from the transmitting aerial had "first Fresnel clearance" above obstructions at the transmitting end, and the ghost to signal ratio was then simply the ratio of the received "ghost" signal intensity G to the direct signal intensity (Do).

The ray paths of other receiving sites did not have "first Fresnel clearance" at the transmitting end due to obstructing trees, etc., and in these cases the ghost to signal ratio was taken as the ratio of the "ghost" signal intensity "G" to the calculated free space field intensity of the transmission Eo when beamed in the receiving direction. In all cases the "ghost" to signal ratio was corrected to allow for the shorter distance travelled by the direct signal, giving figures which are more representative of the expected ghost to signal ratio at a considerable distance from the transmitter, and in the same directions from the transmitter.

(b) Receiving Equipment

At the receiving end a 6 element Yagi similar to that at the transmitter was used to pick-up the television signals. The antenna output was fed either to a television receiver via a calibrated R.F. attenuator, or direct to a television field intensity meter, an R.C.A. type BW7A. The latter instrument was specially calibrated for use with the Yagi antenna in lieu of the dipole it normally uses, and was used for taking the field intensity measurements designated as D and Do in section (a) above, D being the direct field intensity with the transmitting Yagi pointed as HSV7. The Y axis of an E.M.I. waveform monitor, was connected to the receiver output, through a small coupling condenser to preserve the high frequency response. When the Yagi antenna was connected via the R.F. attenuator to the receiver input, the direct and reflected synchronising and vertical bar pulses were displayed on the cathode ray oscillograph of the waveform monitor. The relative amplitudes of the direct bar pulse and the bar pulse reflected from HSV7 mast were measured by means of the R.F. attenuator, the criterion being the input ratio measured on the attenuator for equal amplitudes of direct and reflected pulses as measured on the C.R.O. screen with the automatic gain control disconnected on the receiver. This ratio (R) was measured with the transmitting antenna pointed directly at the HSV7 mast, and the "ghost" field intensity G is given by the expression D/R. It can be seen that the ghost field intensity was found from an absolute measurement of the direct synchronising pulse field intensity, together with relative measurements of the direct and reflected bar pulses. Both of these measurements were made with high grade attenuators.

The procedure adopted in regard to receiving antenna height and the determination of the correction for the transmitting path was as follows -

The transmitting antenna was at first beamed on the receiving site and the direct field intensity measured with the BW7A field intensity set for various antenna heights. In this way consecutive maximum and minimum field intensities were measured and from these measurements the ground reflection co-efficient and the local free space field E_1 can be simply computed. The local free space field intensity is the component of the space wave which strikes the receiving aerial directly without reflection from the ground. The amount by which the calculated free space field intensity, Eo exceeded the local free space field intensity was assumed to be the path loss (P decibels) introduced by the obstacles at the transmitting end. As the path between the transmitting Yagi and HSV7 mast was clear with "first Fresnel zone" clearance, and a normal service transmitting aerial would have similar clearance in the receiver direction as well, it was considered legitimate to allow for the factor P in computing the true expected "ghost" - signal ratio in a normal service.

Having established the receiving aerial height for maximum received field intensity, the transmitting Yagi was beamed on HSV7 and a normal "ghost" to signal ratio measurement was made for this height. The delay of the "ghost" relative to the direct signal was also measured on the waveform monitor and recorded. The receiving antenna height was then changed to another value (not for minimum signal, because of the difficulty introduced when measuring very low signals) and another "ghost" - signal ratio measurement was made. This procedure was repeated at 12 other sites with horizontally polarised aerials.

Results of measurements

6. Some of the sites at which measurements were taken, showed very small transmitter site loss, P. This was particularly the case in Easterly directions from the transmitter because of the position of the transmitting antenna. In table 1, the transmitting path loss, P decibels, is computed from the known equivalent radiated power of the transmission and the measured maximum and minimum field intensities at the receiving site. In Appendix 1 examples of this calculation are given. Table 1 is for reflection from the HSV7 mast. (See page 6)

Table 1

Results of measurements - Reflections from HSV7 mast using temporary aerial and transmitter

Receiving Site	Distance from transmitter Miles	Bearing from transmitter (clock-wise from HSV7 mast direction) degrees.	Measured time delay micro-seconds	Transmitter end path loss "P" decibels	True signal - ghost ratio of HSV7 mast at considerable distances, d.b. Optimum receiving antenna height	Non optimum receiving antenna height.
Bayswater	5.0	43.5	1.1 calc.		delay too small to get echo clear of direct pulse.	
Vermont	7.9	52°	1.48 "	5.7	44.2	46.4
Heathmont	5.5	58°	1.87 "	5.6	53.1	47.1
Mont Albert	13	58°		echo not discernable		
Mitcham	8.25	65°	2.15	-0.7	48.4	Not discernable
Croydon Monastery	4.8	83°	3.31	0.6	41.6	39.6
Croydon Sports Ground	4.4	86°	3.5	3.4	47.8	
Lilydale (West) Black Springs	4.8	124°	5.68	8.3	45.4	
Lilydale (Plants)	4.75	129°	5.47	10	41	37
Lilydale (Greys)	4.28	131°	6.0 calc.	9.9	35.5	
Lilydale (East)	4.4	157.5	6.74	8.4	46.1	44
Silvan North	3.9	225°	6.0	6.4	42.3 (could be higher)	42.3
Silvan (Hamilton)	4.75	235.5	5.8	1.4	47.1	indiscernable

In all cases the equivalent radiated power of the transmitter was 37.5 watts in the maximum direction of the Yagi antenna.

From the table the following applies -

Median of maximum readings 45.4 db.
Median of all readings 44.2 db.
Value for which 90% of readings are exceeded 39.6 db.

Table 2 (see Page) gives the results of reflections from undetermined reflectors, usually with a smaller time delay than that from HSV7 mast. The equivalent radiated power of the transmitter was 37.5 watts in the maximum direction. This table contains only reflections which have a greater amplitude than that from HSV7 mast. These reflections are probably from the slopes of the mountain between the HSV mast and the transmitter and could be the limiting factor rather than reflections from the mast.

Measurements with vertical polarisation.

7. Measurements were made at three sites with vertically polarised transmitting and receiving Yagi antennae. The equivalent radiated power was the same as for the tests withhorizontal polarisation. Table 3 (See page 8) is a summary of the results.

Table 2

Results of measurements - Reflections from mountain slopes

Receiving Site	Distance from transmitter (Miles)	Bearing from transmitter clockwise from side of HSV7 mast direction degrees	Measured time delay micro-seconds	Transmitter end path loss "P" decibels	True signal - ghost ratio of HSV7 mast at considerable distances, d.b. Optimum receiving antenna height	Non Optimum receiving antenna height
Mont Albert	13	58°	1.15	- 2 db	28	31
"	"	"	2.5	"	35	-
"	"	"	3.5	"	35	-
"	"	"	2.0	"	-	35
Mitcham	8.25	65°	-	- 0.7	45.4	-
Lilydale (Plants)	4.75	129°	4.75	10	39	-
Lilydale (Greys)	4.28	131°	3.6 & 4.4	9.9	Approx.30	-
Lilydale (East)	4.4	157.5	-	8.4	45	
Silvan (Hamiltons)	4.4	235.5	5.4	1.4	47.1	38.1

Table 3

Results of Measurements - Reflections from HSV7 mast - Vertical Polarisation

Mitcham	8.25	65	2.26	1.8	39.2	43.2
Lilydale (East)	4.4	157.5	4.95 (not HSV7 mast)	7.6	43.1	44.1
Silvan (Hamiltons)	4.75	235.5	5.7	1.1	43.5	35.5
Silvan (Hamiltons)	4.75	235.5	3.6 (not HSV7 mast)	1.1	31.5	-

These signal-echo ratios are compared with those measured for horizontal polarisation in Table 4 as follows -

Table 4

Comparison of measurements with Vertical and Horizontal Polarisation

Receiving site	Delay (approx) microseconds.	Signal-ghost ratio, decibels Horizontal polarisation	Vertical polarisation	Remarks
Mitcham	2.2	48.4	39.2	HSV7 mast, aerial height optimum.
Lilydale (East)	not recorded	45	-	not HSV7, aerial height optimum.
	5.0	-	43.1	not HSV7, aerial height optimum.
Silvan (Hamiltons)	5.7	47.1	43.5	HSV7 mast, aerial optimum.
	5.4	38.1	-	not HSV7, non optimum aerial height
	3.6	-	31.5	not HSV7, optimum aerial height.

From table 4 it is seen that a direct comparison between horizontal and vertical polarisation can only be made at two sites, Mitcham and Silvan (Hamiltons). In both cases horizontal polarisation gave the higher signal-ghost ratio, 9.2 db. higher at Mitcham and 3.6 db. higher at Silvan.

Variation of reflected signal with bearing from the mast.

8. There are not sufficient measurements of reflected signal to indicate very definitely any variation with variation of bearing from the mast. Two sides of the mast are illuminated, the bearing of the transmitter being approximately 6° east of the mast diagonal as already indicated. There is slight evidence that reflections are of greater magnitude in the direction of the transmitter but the difference does not appear to exceed a magnitude of 3 or 4 db.

Accuracy of Measurements

9. The following comments are made on accuracy -

(a) Accuracy of Instruments

The transmitter power and the received field intensity were each measured with the same basic voltmeter contained in the R.C.A. field intensity measuring set type BW7A. To the extent of the accuracy of the attenuator in this instrument, any errors of absolute voltage measurement would cancel out in measuring the "ghost" ratio. The accuracy of measurement would then depend chiefly on the original calibration of the field intensity set in regard to the passive networks which transfer field intensity units to voltage units. The accuracy of this calibration by the makers of the instrument is believed to be of a high order, and the same applies to the signal generator attenuator in the instrument. The relative measurements of direct to "ghost" signal ratio R, depended also on the accuracy of an R.F. attenuator in the receiving aerial input, as described above. This was a good quality instrument, the calibration of which was checked when set up in the field. This ratio was also checked with a synchronised V.H.F. pulse signal generator, the output of which was fed into the receiver input and the corresponding receiver output pulses were displayed on the cathode ray oscillograph side by side with the transmitter and "ghost" pulses, and amplitude comparisons made with fixed R.F. attenuator settings. Of the two methods the R.F. attenuator method was generally the more conservative, and was used for computing the "signal ghost" ratio in preference to the signal generator method. The television receiver picture tube was also used as an indicator of equal brightness for "ghost" and direct signal when the R.F. attenuator was operated. It also gave results which were generally less conservative than the R.F. attenuator - C.R.O. comgination, and the latter method was always used for computing results.

(b) Terrain, Obstacles, etc.

At some of the receiving sites, there was evidence that a reflecting object quite close to the transmitter was producing a reflected pulse, smaller in amplitude, but not negligible in comparison with the ground pulse, in cases where the ground pulse was severely attenuated by the transmitting Yagi antenna. As it was not possible to spearate the direct and reflected synchronising pulses in these cases, a small error could possibly have been introduced in the BW7 received field intensities, with an equal probability of positive or negative errors. At the sites in question this effect could have been virtually eliminated by the use of a higher transmitting aerial. The transmitting antenna was only 43 feet high, whereas a television broadcasting antenna would normally be at least 200 feet high, with the possibility of a different pattern of illumination of the reflecting mast. This could posibly cause some difference of signal-"ghost" ratio in the two cases, but it was not expected to be great.

Discussion of results

10. Measurements were made of reflections from the HSV7 mast at 11 sites, distributed over an arc of about 180 degrees. The transmitting site was at the observatory, Mount Dandenong, a distance of about 3400 feet, the transmitting antenna being 43 feet above ground. The median of 17 (11 of them at optimum height) actual signal-ghost ratio measurements was 44 db., and the lowest ratio was 35.5 db at a South Lilydale site. The value exceeded for 90% of the readings is 39.6 db. At some sites (see table 2) other unidentified echoes were greater in amplitude than that from the HSV7 mast. The poorest ratios measured were 28 db. at Mont Albert and 30 db. at South Lilydale. The Mont Albert measurements should be regarded with some suspicion because the echo was very close to the direct pulse and no discernable echo from the HSV7 mast was found. Comparisons were made between vertical and horizontal polarisation of the transmitted signal at three of the receiving sites. Direct comparisons of the reflection from HSV7 mast was made at two of the sites, and it was lower for horizontal polarisation in both cases. At the third site, the highest measured reflection was for vertical polarisation, from a reflector other than HSV7 mast. Subjective tests have been made on the ghost ratio for acceptable pictures and are recorded in Section 5 below. These indicate that for the worst path difference possible, for the mast separation employed in this case, namely 6800 feet, a ratio of about 36 db could be tolerated for like fixed ghosts.

The following inferences were made for other spacings proposed. The spacings for other cases in Melbourne and Sydney are -

Melbourne

ABV	- HSV	280 feet
GTV	- HSV	3400 feet

Sydney

ABN	- ATN	300 feet
TCN	- ATN	4600 feet

It was inferred that there would be no difficulty in the case of the higher path difference of 6800 feet (HSV - GTV), or the higher path difference of 9200 feet (ATN - TCN) in Sydney, although masts of height of the order of 500 feet are used in Sydney. For the lower spacings the worst path difference would be approximately 600 feet for which Section 5 indicates an acceptable ghost ratio of 31.5 db for the worst case of like fixed images and 28.5 db for a fixed unlike image. Allowing 3 db change in magnitude of reflected signal for each reduction of half in path difference between transmitter and reflecting object the median ratio for the 17 receiving points for

600 ft. path difference would be 34 db and the ratio exceeded in 90% of the locations 29.5 db. The figure of 3 db change in magnitude of reflected signal for each reduction of half in path difference is based on a theoretical analysis, making certain simplifying assumptions. The figure may be departed from in actual practice and this could be particularly so for the short path difference considered. Assuming that the 3 db figure is correct, the results would mean that in 10% of the locations a reflected signal would exist of magnitude slightly in excess of the value necessary for an acceptable ghost for the path difference of 600 feet. However, in most of these locations the path difference is less than 600 feet depending on the bearing from the masts. Accordingly, on this basis a slight perceptible ghost would be observed in less than 10% of the locations. The situation for the close spacing of HSV and ABV and of ATN and ABN, is further alleviated by the fact that the 200 Mc/s aerials are higher than the reflecting masts, and the reflected signals for the 60 Mc/s transmissions should be lower in magnitude. In any case the reports of American transmissions suggest that the situation is acceptable for conditions not unlike the spacings considered here. Reflections have been noted, probably from the mountain slopes, of greater magnitude than those from the HSV mast. There is some evidence of a somewhat greater reflection of signals in the direction back towards the transmitter from the illuminated side of the mast. However, enough data has not been obtained to draw very definite conclusions. The conclusion was reached that in the case of the Melbourne and Sydney configuration of television transmitting masts the existence of ghosts due to reflections from the masts is unlikely to be a serious matter generally in the service areas of the stations.

Section 3 - Reflection Tests with Transmission from GTV's Aerial

General

11. Further confirmatory tests were conducted in November, 1957, using GTV9's transmitting aerial and an R.C.A. 18 watt transmitter to determine the level of reflections from the Barnes Lookout area, particularly the HSV7 and ABV2 antenna towers. Although tests had been previously carried out by means of transmissions from a location close to GTV9, it was desired to verify the conclusions under conditions closer to actual television transmissions. The previous test transmissions differ from the actual transmissions by GTV9 in that the aerial was considerably closer to the ground and reasonable clearances did not always exist necessitating corrections to the reflection ratios measured. Further, the polar curve of the transmitting Yagi aerial differed from that of the GTV9 transmitting aerial. Test using the GTV transmitter involved staffing difficulties and power costs, and would have been in no way preferable to the use of a test transmitter, the latter having the advantage of being

double sideband with less likelihood of masking of reflections due to overshoot and ringing. No ghosts attributable to mast reflections had been observed on the transmissions from the Melbourne stations but they may have been masked by overshoot or ringing on the transmission.

Transmitting Equipment

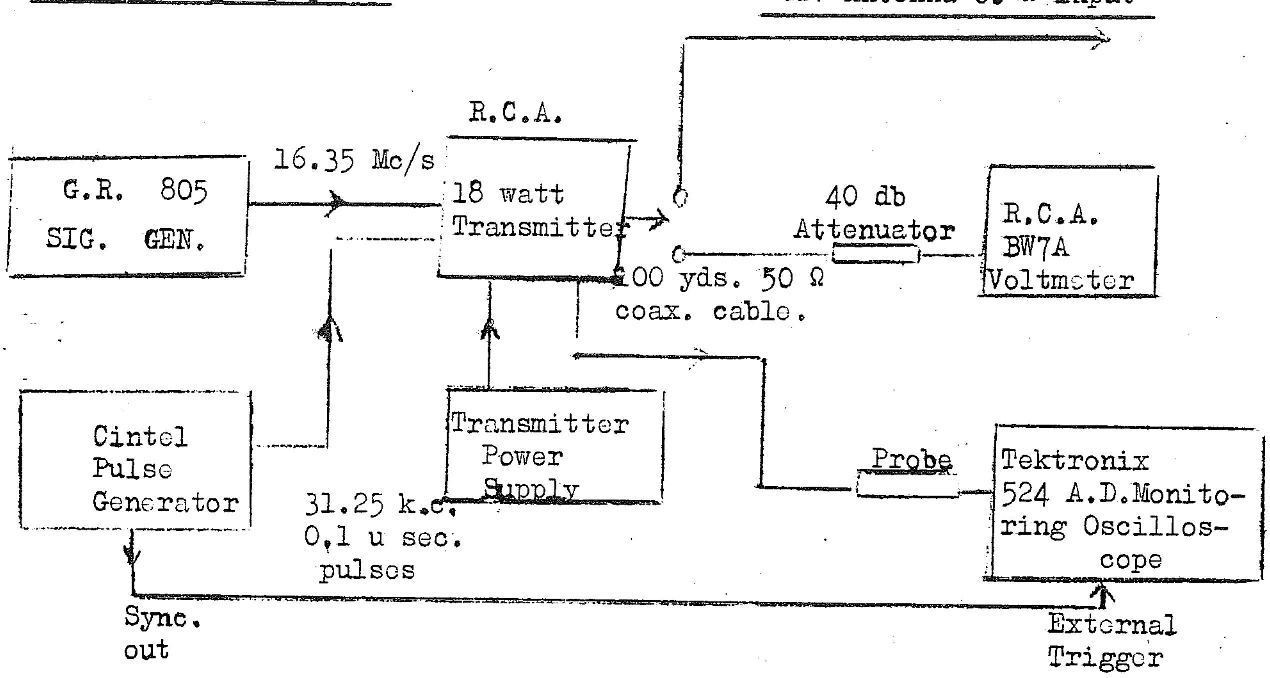


Figure 2

12. Figure 2 shows the test transmitter set up. The R.C.A. transmitter, was excited by about 3.5 volts at 16.35 Mc/s from the G.R. 805 signal generator. The Cintel pulse generator delivers positive and negative 0.1 microsecond pulses ofabout 3 volt amplitude to the video input of the transmitter. The positive pulse was suppressed in the modulator by increasing the "bias" (black level) and the "excitation". The C.W. power was monitored on the BW7A with the video input removed, by attenuating with 100 yards of coaxial cable and the 40 db attenuator. The pulse power and width was monitored on a Tektronix 524AD oscillograph by using a pickup loop and crystal demodulator to recover the video modulation. Approximately 20 watts peak power at 196 Mc/s was delivered, and approximately 200 watts e.r.p. was radiated from GTV's antenna.

A state of zero carrier is required between pulses. This condition is checked by temporarily making a direct connection between the crystal demodulator output and the input to the D.C. amplifier in the Tektronix oscilloscope.

Later the exciter frequency was changed to 15.17 Mc/s and HSV's frequency of 182.25 Mc/s was radiated in lieu of GTV's picture carrier.

Receiving Equipment

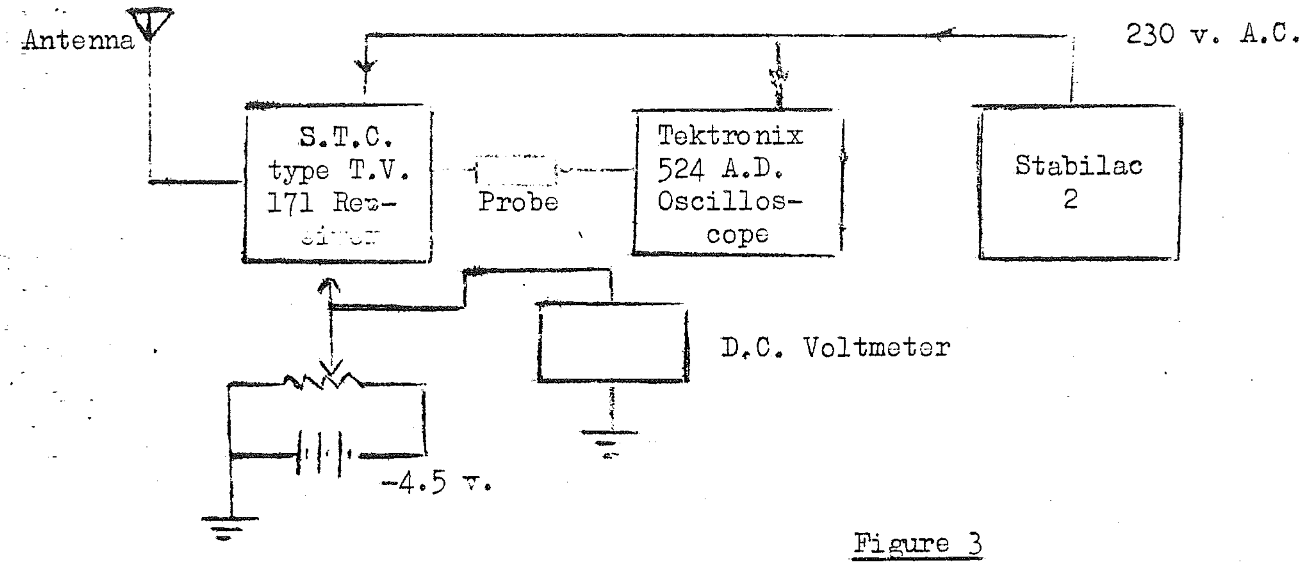


Figure 3

13. The receiving equipment shown in Figure 3 was carried in a van and taken to various sites in the metropolitan area. A channel-master 5 element travelling-wave aerial was used to pickup the transmission, which was fed into an S.T.C. type T.V.171 television receiver, from which the A.V.C. had been disconnected and replaced by a metered D.C. potential from a battery. The video output at the picture tube was taken via the probe to a Te[illegible] type 524 AD oscilloscope on which the peak to peak voltages of direct and reflected pulses were measured, as well as the time delay between echo and direct pulse. The bias was adjusted so that the receiver was in its most sensitive position without over-loading, and this bias voltage was recorded for use when calibrating the receiver in terms of output versus input voltages.

Calibration of receivers

14. As the receiver was decidedly non linear over the range of direct and reflected voltages received, it was necessary to determine in the laboratory the input voltages necessary to give the output voltages measured in the field.

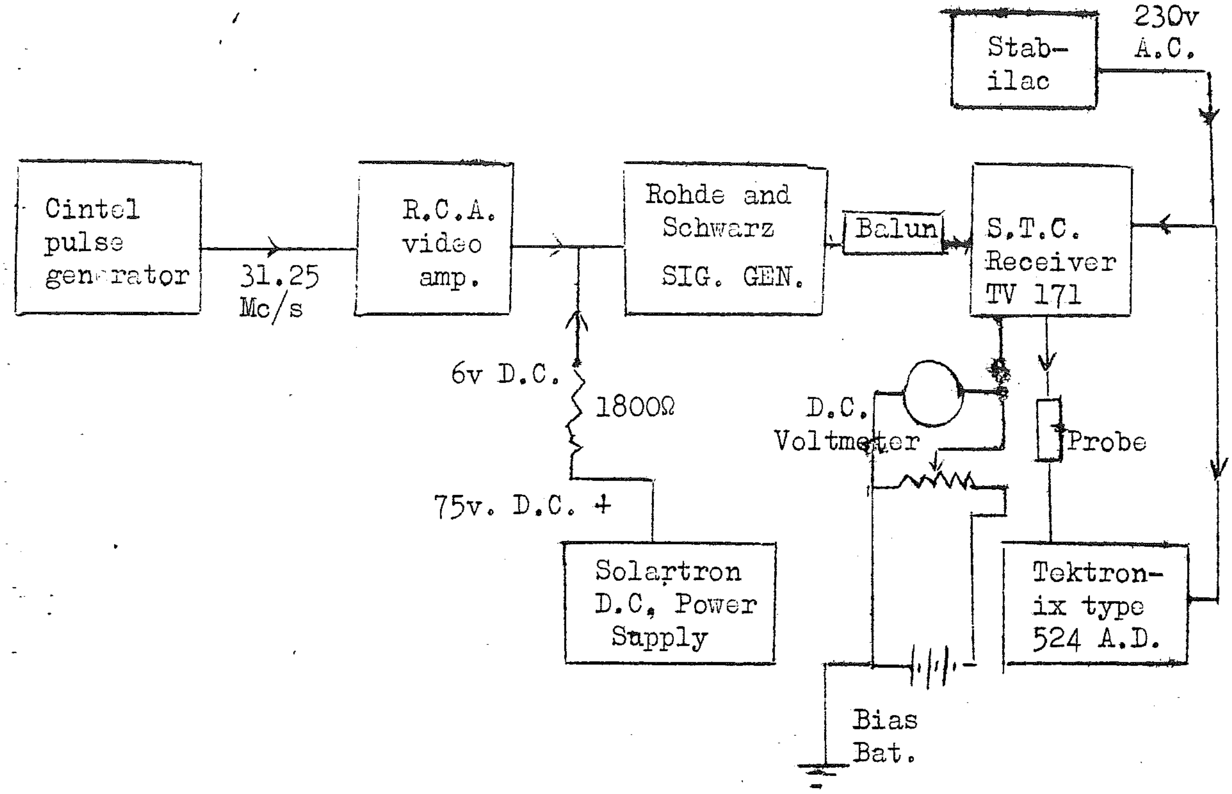


Figure 4

For this purpose a Cintel pulse generator of the same type as that used at the transmitter was used with the R.C.A. video amplifier (type 120A) to modulate a Rohde + Schwarz-type BN41404 signal generator with 0.1 microsecond pulses as shown in Figure 4. The unwanted positive pulses produced by the Cintel unit were suppressed to a level of about 40 db below the wanted pulse amplitude by applying a direct positive potential of 6 volts from a Solartron power supply to the modulation input terminal. The quiescent carrier level between pulses was also minus 40 db., this suppression being sufficient for calibration purposes. The output from the Rohde and Schwarz signal generator was applied via a balun to the input of the S.T.C. receiver with battery bias applied as in the field tests. The Tektronix type 524 AD oscilloscope and the stabilac were also connected in the same way as for the field tests.

The output attenuator of the Rohde and Schwarz signal generator was then adjusted for sufficient R.F. pulse output to give the same reading on the oscilloscope voltage measuring device as that given by the direct pulse received in the field test, the receiver gain control bias having been set to the same value as that used in the field test. The signal generator output voltage VD was recorded and then reduced to give the same pulse voltage reading on the oscilloscope as that produced by the reflected pulse from the transmitter. If the new output reading of the signal generator is V_R volts, then the true ratio of direct to reflected field intensity is $\frac{V_D}{V_R}$.

Results of Measurements

15. The results of measurements are tabulated in Table 5. The angles shown are those subtended at the transmitter by the receiving site and HSV7 mast. With angles up to 79° it was not possible with the pulse used to discriminate between the different echoes that appeared to be originated at the Barne's Lookout area. With angles of 83 degrees and greater it was possible to obtain separate echoes which appeared to be originating in the Barne's Lookout area. The Croydon echo is of particular interest in that the calculated delay between echoes from ABV and HSV masts was 0.24 microseconds whereas the measurement delay between the two echoes received was 0.35 microseconds suggesting that at least one of these echoes was not due to television masts. The median ratio of direct to reflected signal for measurements at 7 sites was 39.4 db with a 9 ft. receiving antenna. At two sites only, measurements were made with a 15 ft. receiving aerial giving direct to reflected echo signal ratios 1.3 and 2.2 db higher than the corresponding 9 ft. antenna measurements. The ratios used to determine the median are underlined. These results are slightly worse than the value of 44 db obtained for the median value for 17 locations in Section 1.

The results have been plotted on polar coordinates in figure 5 attached to the end of this report. The number of points at which measurements have been taken are not sufficient to draw any conclusions as regards any directional effect of the radiated signal.

Table 5

Results of Measurements - Reflections from HSV7 and ABV2 Masts - Transmission from GTV9 aerial

Receiving Site	Transmitter Distance (Miles)	Angle with GTV to HSV direction (degrees clockwise)	Calculated delay. microseconds		Measured delay microseconds	Direct to echo signal ratio		Remarks
			ABV mast	HSV mast		Video output db	R.F. input db.	
Mont Albert	13	59.5	1.435	1.56	not visible		>40	9ft. aerial
Mitcham	8¼	66.2	1.92	1.78	1.85	53.7	39	9ft. aerial
Doncaster	12.3	71.0	2.125	1.975	1.85 - 1.9	55.6	40	9ft. aerial
Templestowe	11.5	79.1	2.56	2.36	2.7 2.7	57 56.9	38.6 39.9	9ft. aerial 15ft. aerial
Croydon	4.9	83.1	2.64	2.88	2.65 3.0 3.0	45.4 51.4 45.8	29.2 32.1 34.3	9ft. aerial 9ft. aerial 15ft. aerial
Lilydale (Plants)	4.8	130	5.13	4.68	3.4 4.7 5.2	54.9 64.5 64.5	37.7 43.2 43.2	9ft. aerial 9ft. aerial 9ft. aerial
Yarra Glen	11.6	158.2	5.93	5.38	5.8	57.3	39.4	9ft. aerial
MEASUREMENTS USING CHANNEL 7 PICTURE CARRIER IN LIEU OF CHANNEL 9 PICTURE CARRIER								
Templestowe	11.5	79.1	2.56	2.36	2.6 2.3 2.4	58.2 50.7 50.4	38.3 32.5 32.5	15ft. aerial 9ft. aerial 9ft. aerial

Section 4 - Reflection Measurements on Channel 7 with Transmission from HSV7 Mast and Reflection from ABV2 Mast

General

16. Following the reflection tests using GTV's transmitting aerial, it was decided to carry out similar tests using HSV's transmitting aerial. The main reflections of interest in this particular case were those from ABV's transmitting aerial and tower, which is spaced a distance of 280 feet from HSV's tower. Three types of measurements were made corresponding to typical cases, which might be encountered in the planning of future television stations in other cities. They were as follows:-

(1) Transmitting from HSV7's lower antenna, which is at about the same height as the F.M. antenna on ABV's tower reserved for a possible future F.M. service. This is the highest antenna on the ABV mast.

(2) Transmitting from HSV7's upper antenna which is higher than any of the ABV antennas.

(3) Transmitting from a level of about 120 feet above ground on HSV7's mast with a Yagi type antenna. This simulates a channel 7 antenna that is appreciably lower than the corresponding channel 2 antennas.

It was not possible to make suitable transmissions using HSV7's two antennas simultaneously without considerable equipment complications, and accordingly this was not done.

Equipment

17. Because of the small spacing between the transmitting antenna and the reflecting structures it was necessary to use a pulse transmission with very narrow pulses, and with the R.C.A. transmitter, the narrowest pulses obtainable were about 0.2 microseconds wide. An ordinary television receiver could not be used [illegible] small delay time of the reflected signals and its limited bandwidth. In its place a special I.F. strip, turret tuner and video amplifier was used, the overall bandwidth being about 10 Mc/s.

A block diagram of the transmitting equipment is shown in Figure 6, indicating little change from the set up for the GTV tests. At the receiving end a similar technique to that used for the GTV tests was at first used exclusively. This comprised measuring the amplitude of direct and reflected output pulses on a Te[illegible] C.R.O. with a

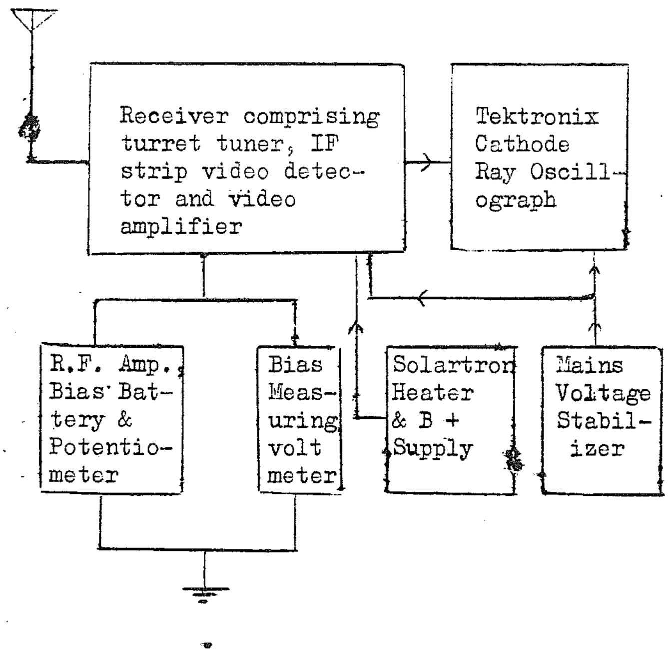


Figure 6

known bias voltage and subsequently measuring the input voltages to give output pulses on the C.R.O. of equal amplitude to those measured in the field. The ratio of these input voltages was the required direct to reflected signal ratio. The input voltage pulses were obtained from the transmitter operating through a calibrated variable attenuator, from which the desired input ratio was obtained. It was suspected that, because of the closeness of the reflected pulse to the ground pulse, the paralysing effect of the ground pulse was altering the amplification of the reflected pulse, and that this method was not giving the true signal-interference ratio.

Transmission Line Calibrating Method

18. Accordingly, a different technique was later used, which eliminates errors which could arise from the overloading effect cited above. A 50 ohm transmission line, having variable length and variable attenuation was shunted across the feed line from the receiving antenna. The transmission line was either open circuited or short circuited, and its length could be varied in large and small amounts so that the delay of the pulse reflected from the end was equal to the delay of the "ghost" pulse from ABV's aerial and out of phase with it. Then by varying the attenuation of this line, the "ghost" can be completely cancelled, and the criteria for cancellation are independent of "paralysis" effects in the receiver since the "ghost" and the line reflected pulse are unlike pulses which cancel each other before entering the receiver. Errors, resulting from residual transmitter carrier between ground pulses, are also eliminated with this method. When the impedance Z_D of the aerial paralleled with the receiver is 50 ohms non reactive as seen by looking back from the input of the 50 ohm measuring line, the signal to ghost ratio in decibels is just double the attenuation of the measuring line in decibels. A value of 50 ohms, non reactive, is the optimum value

for this impedance and efforts were made, where practicable, to maintain this value. A formula for computing the reflection ratio when the aerial and receiver does not match the measuring line is derived in the appendix. This technique can also be used to advantage for displaying an artificial "ghost" of any given strength relative to the signal, when viewing a standard station transmission, or a test signal from a signal generator. The components of the measuring line are shown in Figure 7 below.

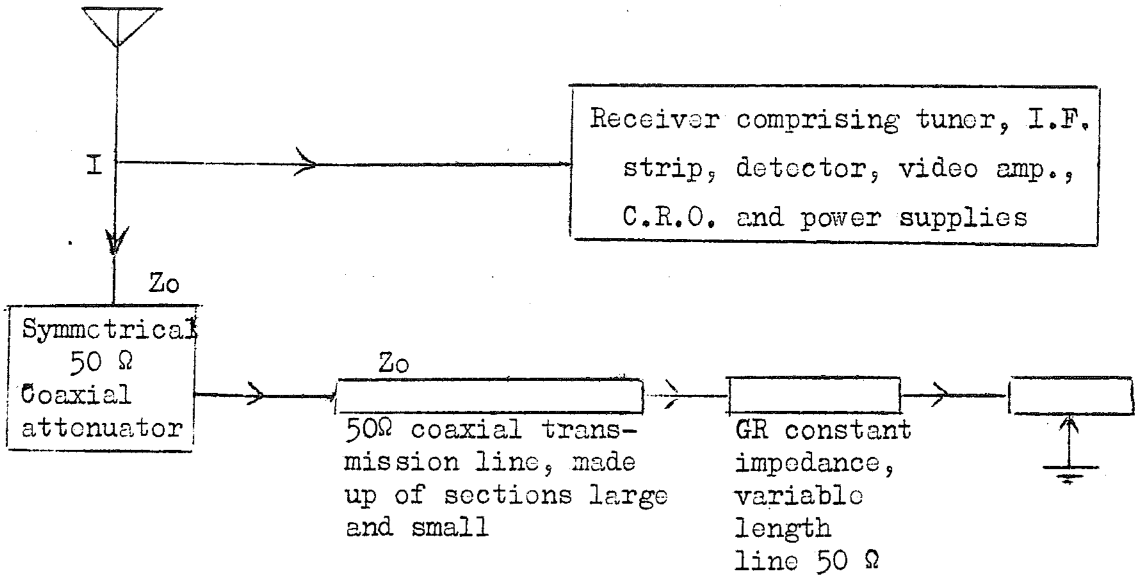


Figure 7

The coaxial attenuator was variable in 1 db. steps up to 80 db, and in order to properly simulate a 50 ohm transmission line it is necessary that its impedance characteristic be constant at 50 ohms in both directions, a condition attainable with symmetrical T or π section attenuators. The coaxial cable had a length corresponding to half the delay of the "ghost" pulse relative to the direct pulse, and was made up of several lengths of 50 ohm polythene cable (a large length and trimming lengths) plus a G.R. 50 ohm air spaced variable length line and finally a variable short circuited stub. The variation required to get a null is just over one half wave length when the overall length is approximately right.

The results are shown in table 6 below.

Table 6 - Results of Measurements - Reflections from ABV Mast

Transmission Line Calibrating Method

A. HSV's Lower Antenna

Receiving Site	Distance (Miles)	Angle relative ABV-HSV direction degrees	Delay of echo micro-seconds	Combined Antenna and receiver admittance, millimhos	Correction for mismatch "A" db	Total attenuation of measuring line "B" db.	Direct to echo signal ratio A + 2B db.
Dunn's Hill	3.1 "	32.3° anti-clockwise "	- 0.60	14.6 - j3.6 25.2 - j7.6	- 1.2 + 1.4	15.4 12.8	29.6 27.0
"Pine Hills" (1 mile nth. of Lysterfield Hills)	7.6 " "	7° anti -clockwise " "	0.6 0.6	25.2 - j7.6 14.6 - j3.6 "	+1.4 - 1.2 "	12.05 13.4 14.9	25.5 25.6 low receiving ant. 28.6 high receiving ant.
Scoresby (S[illegible]), Taylor's Lane	7.[illegible] "	2.3° anti-clockwise "	0.62	25.2 - j7.6 14.6 - j3.6	+ 1.4 - 1.2	11.5 14.2	24.4 27.2
Scoresby	7.[illegible]	5.4° clockwise	0.6	25.2 - j7.6	+ 1.4	14.9	31.2
Mulgrave (Jackson's Rd.)	10.[illegible]	7.5° clockwise	0.6	25.2 - j7.6	+ 1.4	15.8	33.0
1 mile east of Wheelers Hill	8.7	8.5° clockwise	-	25.2 - j7.6	+ 1.4	14.0	29.4
Mulgrave (Wellington Rd.)	10.2	[illegible].8° clockwise	[illegible]6	14 6 - j3.6	- 1.2	15 55	29.9
Glen Waverley (East)	9.9	19.5° clockwise	-	25.2 -j7.6	+ 1.4	16.4	34.2
Glen Waverley (Monastery)	10	22° clockwise	0.62	25.2 -j7.6	+ 1.4	21.5	44.4

Receiving Site	D'stance (Miles)	Angle relative ABV-HSV direction degrees	Delay of echo micro-seconds	Combined Antenna and receiver admittance, millimhos	Correction for mismatch "A" db	Total attenuation of measuring line "B" db.	Direct to echo signal ratio A + 2B db
Syndal	10.6	30.2° clockwise	0.6				40db approx.
Surrey Dive	12.4	40.1° clockwise	0.56	25.2 - j7.6	+1.4	14.9	31.2

Averaging for sites at which more than 1 measurement was made the median direct to echo signal ratio was 31.2 db.

B. HSV's Upper Antenna

Dunn's Hill	3.1	32.3° anti-clockwise	0.6	14.6 - j3.6 millimhos	-1.2		37 db
Wellington Rd. 1 mile East of Wheeler's Hill	8.7	8.5° clockwise	0.6	14.6 - j3.6 millimhos	-1.2	20.6	40 db
Scoresby (South), (Taylor's Lane)	7.9	2.3° anti-clockwise	0.62	14.6 - j3.6 millimhos	-1.2	17.4	33.6 db

The median value of the reflection ratio for the lower section of the HSV7 aerial is 31 db and the value exceeded in 90% of the locations is 26 db. The higher section of the HSV aerial gives a significantly higher median reflection ratio of 37 db as would be expected.

Amplitude Calibrating method

19. As a check on the accuracy of the previous measurements amplitude measurements were performed by the indirect method of measuring the direct and echo pulse amplitudes on the output C.R.O. and subsequently translating them into relative input voltages by varying the attenuator of a pulse signal generator in a closed circuit or by the transmitter feeding the receiver in a closed circuit through a calibrated attenuator. At other times the amplitude measurement was completely performed at the receiving site by inserting a calibrated attenuator in the aerial lead and varying the attenuation in such a way that the amplitude of the echo pulse on the C.R.O. with zero attenuation inserted was the same as the amplitude of the direct pulse with attenuation inserted. Because of direct pick up effects at the receiver terminals this method is only effective when measuring fairly small direct to echo signal ratios. To remove this limitation a known attenuation was inserted in the feed line to the transmitting antenna when the amplitude of the direct pulse was being measured. Using these methods the following results were obtained with HSV's lower antenna.

Table 7

Results of measurements using HSV7 lower aerial - Amplitude Calibrating Method

Receiving Site	Distance (Miles)	Angle relative to ABV-HSV direction degrees	Direct to echo signal ratio db.
Dunn's Hill	3.1	32.3° anti-clock	33.6
Mulgrave South	10.5	4° clockwise	30.3
Mulgrave (Wellington Rd.)	10.2	8.5° clockwise	3[illegible].4 db low antenna 30.5 db high antenna
Glen Waverly Monastery	10.0	22° clockwise	35.7 db low antenna 31.6 db high antenna

There is no consistent tendency for this method to produce a higher or lower reflection ratio than in the case of the previous method.

Yagi type Antenna Mounted on HSV7's Tower

20. As already pointed out the HSV aerial is at approximately the same level as the Marconi Quadrant aerial at the top of the ABV2 mast. It was felt that in the event of a high band aerial being located close and opposite the actual structure of a mast a worse reflection might be experienced. Accordingly, it was considered desirable to carry out tests with a transmitting aerial located on the HSV7 mast at a level below the ABV2 aerial and opposite the actual structure of the mast. In these tests an Antiference type 215 receiving antenna was used, at a distance of 120 feet above ground and spaced at a distance of about 8 feet from the west side of HSV's tower (25 feet from the centre of the tower). The antenna was beamed at ABV's tower at a point about 130 feet above ground (below ABV's antenna), and the signal to echo ratio was measured at a number of points. The polar diagram of the Antiference 215 antenna was measured later with the antenna mounted about 16 feet above ground in a flat field. The measured signal to echo ratios were then corrected to allow for the directivity of the antenna. The results are shown in Table 8 on page 25.

21. As the Yagi type transmitting antenna was mounted relatively close to the side of HSV7's tower (about 8feet), the possibility existed that the directivity of the antenna when mounted on the side of the tower was different from that measured on the ground thereby introducing errors in the signal-ghost ratio measurement. To check this possibility it was decided to do at least one measurement by a method which did not depend on the Yagi directivity. The site giving the poorest signal to ghost ratio was chosen for the measurement (Taylor's Lane, Scoresby South). The forward direction of the Yagi was at first pointed directly at ABV's tower giving maximum "illumination" of the tower, and the direct and ghost signal pulse amplitudes Vd and Vr were measured at the receiving sites by the methods described above in section 4-19 (Amplitude Calibrating Method). The two voltages were measured relatively on the C.R.O., and their ratio was measured with an attenuator in the receiving aerial feeder as a check. The forward direction of the transmitting Yagi was then pointed directly at the receiving site without changing the transmitter power or the receiver gain giving a direct path voltage V_D at the receiver. This voltage was measured on the C.R.O. and in addition attenuation was added until the pulse output voltage was reduced to the same amplitude as V_d of the first part of the measurement. In this way the ratio $\frac{V_D}{V_d}$ was obtained in two ways, by direct relative voltage measurements and by the calibrated attenuator. The true signal-ghost ratio is $\frac{V_D}{V_r} = \frac{V_D}{V_d} \times \frac{V_d}{V_r}$ and consequently $\frac{V_D}{V_r}$ is simply computed from the separate measurements of $\frac{V_D}{V_d}$ and $\frac{V_d}{V_r}$.

Table 8

Results of measurements of reflections from ABV mast with Yagi aerial transmitting from HSV mast.

Receiving Site	Distance (Miles)	Angle relative to ABV-HSV direction, degrees	Delay of echo microseconds	Measured signal to echo ratio. db	Correction for antenna directivity. db.	True direct to echo signal ratio. db.
Scoresby South (Taylor's Lane)	7.9	2.3 anti-clockwise	0.61	9	12.	21.
Scoresby	7.7	5.4 clockwise		17	12.5	29.5
1 mile East of Wheeler's Hill	8.7	8.5 clockwise	0.6	18	13.3	31.3
Glen Waverly (East)	9.9	19.5 clockwise	0.59	17	22.3	39.3
Glen Waverly (Monastery)	10.0	22 clockwise	0.59	9	25.0	34.
Syndal	10.6	31° clockwise	0.6	16	20.	36.
Surrey Dive	12.4	50° clockwise	0.56	11	15.9	26.9

As, the results of this measurement at the Scoresby South site agreed very closely with the previous measurement, which depended on the Yagi directivity, it was decided that the former measurements were sufficiently accurate for the purpose and no further measurements were made using the Yagi rotation method.

Discussion of results

22. The reflection coefficients for this series of measurements have been plotted on polar coordinates in figure 8, attached to the end of this report.

There is some evidence of an aggravation of reflection ratio at angles near the direction of reflected signals back to the transmitting mast. In figure 9 the ratios are averaged over 4° increments, and a fairly directive polar curve is obtained using both the HSV and Yagi aerials - more directive in the case of the Yagi.

R.C.A. data has been published for the calculated distortion of the polar curve produced by a longer cylinder of 1.3 wavelength (7 ft. at 182 Mc/s) 15 wavelength (80 ft. at 182 Mc/s) from a transmitting aerial. From this curve reflection ratios in azimuth may be deduced. This has been done and a figure of 5.5 db added to transfer from 80 ft. spacing to 280 ft. spacing. The polar curve so obtained is plotted in figure 9 attached to the end of this report. It is a much less directional curve giving the same order of magnitude of reflection ratio.

The difference in directivity between the calculated curve and the measured one is possibly due to local effects at the receiving sites or differences associated with various transmission paths. The diagonal of the ABV2 mast is oriented in the direction of the HSV7 mast. Figure 6 indicates a maximum reflection at approximately 0° and another near 45°. There appears to be no evident corelation between the direction of maximum reflection, and the orientation of the mast.

23. There is no very significant tendency for the results using the Yagi aerial to be higher or lower than those attained using the lower section of the HSV7 aerial, although comparison of the figures at the seven individual sites where measurements were made under both conditions suggest a tendency for lower reflection ratios using the Yagi. The median value of the reflection ratios obtained with the Yagi is 31 db the same as that obtained with the lower section of HSV aerial and the 90% value 27 db, 1 db higher. The reflections are about 8db worse than those measured from the GTV9 [illegible] and 13 db worse than those measured from a temporary aerial sited near GTV9. The theoretical figure of 3 db per octave of distance suggests a figure of 11 db difference between the two sites.

Ghosts due to transmitting Antenna effects

24. A "ghost" pulse with a delay of about 1.2 microseconds was present at all receiving sites. Its ratio to the direct pulse was approximately constant at all receiving sites, and the delay time corresponded fairly closely to an excursion up the feed line from transmitter to antenna and back. Tests indicated that this "ghost" was probably being formed in two ways as follows:-

(1) Because of a slight mis-match of the antenna to the feed line, a signal was being reflected down from the antenna and reflected up again at the mismatch between the feed line and the transmitter.

(2) When HSV7's lower antenna was being used, the upper one was open-circuited at the transmitter end, and consequently the residual coupling between the two antennas caused a signal to be picked up by the upper antenna, propagated down the feed line to the open circuited end of the feeder, reflected back up the feed line and radiated as a "ghost" by the upper aerial. This effect could be eliminated by terminating the lower end of the upper aerial feeder in 50 ohms. Such a termination did reduce the "ghost" appreciably but did not eliminate it, suggesting that the "ghost" remaining was the result of (1) above.

The combined effect of these "ghosts" was measured at a number of sites with the following results:-

Table 9
Measurements of Reflections existing in HSV7 transmissions

Transmissions from HSV's antenna, upper or lower	Receiving Site	Signal to ghost ratio db.
lower	Scoresby South (Taylor's Lane)	34.8
lower	Scoresby	38.7
lower	Mulgrave (Jackson's Rd.)	27.4
lower	1 mile East of Wheeler's Hill	37.5
lower	Glen Waverly Monastery	32.0
lower	Syndal	35.2
upper	Taylor's Lane	33.8
upper	Mulgrave, Wellington Rd.	33.3

The median value of the signal to ghost ratio when transmitting with HSV's lower antenna was 33.7 db with a scatter from 27.4 to 38.7 which is probably due to the different phase additions of the two components of the ghost. The median when transmitting from the upper antenna was about the same. Part (1) of this "ghost" could also be measured at the transmitter end of the antenna feed line. It had about the same relative amplitude at this point as at the receiving points.

Section 5 - Subjective Examination of the Magnitude of Ghost Reflection on a 625 Line Picture

General

25. An examination was made in the laboratory to ascertain what levels of reflection were tolerable on typical pictures. The examination was carried out using both video signals, and 200 Mc/s video modulated signals.

Previous Results

26. Information exists in the technical literature on the tolerable magnitude of ghost reflections. In particular the B.P.O. (2) give the figures shown in Table 10 -

Table 10

B.P.O. Observation of Tolerable Ghost Signals.

Level of ghost relative to direct signal	Still test pattern	Moving picture
- 20 b.	very apparent	Noticeable
- 30	Noticeable	Just noticeable
- 40	Just Noticeable	No sign
- 44	No sign	No sign

No difference was noticeable in these tests in the results obtained for like and unlike ghosts. The delay employed was 0.9 microseconds.

The ghost ratio tolerable for a given time delay depends on the television system employed, the results quoted here being strictly applicable only to the British 405 line system. Thus the horizontal sweep of the 625 line 50 field or 525 line 60 field system lasts 53 microseconds, whereas that of the 405 line 50 field system lasts 88 microseconds. It is to be expected that the same picture displacement and tolerable ghost ratio will occur for a delay in the 405 line system of 0.9 microsecond as for a delay in the 525 and 625 line systems of 0.5 microsecond. For the same time delay the object and ghost are closer together in the 405 line system, and should be less noticeable.

Video tests

27. Accordingly some subjective tests were made on video signals in which reflections were generated by means of a line of adjustable length terminated in an impedance differing from its characteristic impedance. At the input to the delay line were connected a 12 inch video monitor and a cathode ray oscilloscope. The width of the pulse was 0.2 microsecond. The ghosts were observed by replacing the pulse generator with a monoscope or camera.

Results of the tests are shown in Table 11.

Table 11

Observation of tolerable ghost reflection magnitude in a 625 line picture

Delay microseconds	Path difference (free space)	Spacing of ghost in 21 inch diagonal picture.	Type of ghost	Ratio signal/ghost for an acceptable picture. Still picture	Moving picture
0.9	900 ft.	0.3 inch	Like	33 db	28.5 db
			Unlike	30	26.5
0.45	450	0.15	Like	30	25.5
			Unlike	26.5	22.5
0.3	300	0.1	Like	26	20.5
			Unlike	22	17

Although the figure of 33 db was considered suitable for an acceptable picture with a delay of 0.9 microsecond, ghosts were just perceptable for ratios of 40 db at this delay. The figures are in qualitative agreement with the B.P.O. figure but indicate a different tolerable magnitude of like and unlike ghosts.

200 Mc/s test

28. Further tests were made at 200 Mc/s on pictures on a television receiver. The same measuring line as that used in the field tests was shunted across the feed line from the Kay Megapix to the input terminals of an ordinary household television receiver. The signal to "ghost" ratio could be varied by varying the attenuator in the measuring line and the "ghost could be changed from a like "ghost" to an opposite "ghost" simply by varying the length of the transmission line. If

initially adjusted for a like "ghost" a change of $\frac{1}{4}$ wave length would produce an opposite "ghost" and a change of $\frac{1}{8}$ wavelength would practically eliminate the "ghost". A type G test pattern produced by a monoscope was at first used, and it was found that a 21 db "ghost" with a delay of about 0.9 microseconds produced a visible but not objectionable interference. Increasing the signal to "ghost" ratio from 21 to 30 db practically eliminated the visibility of the "ghost", and the sensations of visibility changed slowly when the ratio was varied from 21 to 30 db. A grid pattern generator was then used as a modulator in lieu of the monoscope. It produced on the screen about 15 vertical black bars of about $\frac{1}{4}$ microsecond duration. Each of the bars was made to modulate the picture completely from standard white level to standard black level. The "ghost" of each bar was noticeable with a 21 db signal to "ghost" ratio, and was just perceptible with a ratio of 30 db. The "ghost" could be black, white, or virtually eliminated by varying the phase of the "ghost" signal. Due to over-shoot in the receivers it was not easy to distinguish "ghosts" of 0.6 microseconds delay corresponding to those caused by ABV's antenna reflection as in the video experiments which indicated that the signal to "ghost" ratio for threshold visibility of the "ghost" is from 1 to 2 db less for 0.6 microseconds delay than for 0.9 microseconds. This would make the signal to "ghost" ratio for just perceptible "ghost" pictures between 28 and 29 db in the HSV-ABV case, for which the measurements were made. In the video experiment, a smaller signal to "ghost" ratio could be tolerated with a moving picture; a reduction of about 4db in the signal to "ghost" ratio being obtained.

Discussion of results

29. Figure 10 attached to the end of this report, plots these subjective figures against delay expressed as a path difference for free space propagation. The acceptable reflection ratio is higher in the case of the video observations possibly because of a more fastidious observer. On the graph has been plotted an arbitrary straight line of slope 3 db per octave. The implication from the slope of this line and that of the subjective curves is that the worst spacing is about 350 feet. A closer spacing reducing the delay allows a stronger ghost to be accepted as it merges into the main image. A wider spacing reduces the magnitude of the reflection. The compensating effect also implies that the best spacing is not critical.

Section 6 - Summary of Results

30. The following table 12 shows the median figures obtained for reflection ratio as well as the figures exceeded for 90% of the locations and the lowest reflection ratio obtained for all the series measurements made.

Table 12

Summary of reflection ratios

	Reflection Median	Ratio 90%	db 100 %
Initial tests with temporary aerial near GTV9 (3400 ft. spacing)	44	40	35.5
Tests using GTV9 aerial (2900ft. spacing)	39	39	32
Tests using HSV lower section aerial.	31	26	24
Tests using Yagi on HSV mast	31	27	21

The median and 90% figures have been taken without regard to any possible directional effect of the radiation of reflected signals in azimuth. The magnitudes of the reflection ratios are approximately consistent with the theoretical change of 11 db for a change of spacing of mast and transmitter aerial from 280 ft. to 3400 ft. and 1 db for 3400 to 2900 ft. corresponding to 3 db per octave of distance.

31. For a spacing of 280 feet corresponding to a ghost displacement of 0.56 microseconds the acceptable figure is of the order of 28-31 db whereas the reflections measured from the ABV tower with the transmitting aerial both opposite the Marconi quadrant aerial and opposite the lower part of the tower exceed 26-27 db for 90% of the locations. The calculated figures for two turnstiles spaced 75 feet exceed 20 db for 90% of locations corresponding to 26 db at 280 ft. spacing.

32. It is inferred that a reflected signal 2-4 db worse than acceptable, in the case of the maximum delay occurring when the receiving point is in a line through the two masts away from the reflecting one, occurs in 10% of the locations. In other directions because of the reduced delay a lower reflected ratio would be acceptable. From an annoyance point of view a spacing of 280 feet is almost as bad as can occur. Closer spacings by reducing the delay make lower reflection ratios tolerable and greater spacings increase the reflection ratio. The conclusion is reached that reflection from masts and aerials is not a serious or even annoying source of ghosts at any spacing even with spacings as low as can be tolerated from the point of view of polar diagram distortion (60-75ft.) or with the transmitting aerial opposite any part of the mast. It has been suggested that the reflection from a mast is reduced if the diagonal of the mast faces the transmitting aerial but it has not been possible to check this point, the results exhibiting no evidence of the effect.

No ghosts definitely attributable to mast reflections have been reported in the Melbourne area, and the existence of such ghosts would be masked by ringing or overshoot in the transmitter or receiver.

ACKNOWLEDGMENTS

It is desired to acknowledge the co-operation of the staff of the P.M.G. Research Laboratories in carrying out the initial tests using a temporary aerial described in Section 1.

REFERENCES

1. Spacing of Television Transmitting Towers to avoid Multiple Increases - Report of the Canadian Broadcasting Corporation Engineering Division Montreal. Aug. 30, 1954.

2. The Cancellation of Echoes on Television Signals - British Post Office Engineering Department Radio Report No. 1715. Oct. 17, 1947.

3. Predicting Performance of Candelabra Antennas by Mathematical Analysis - Matti Siukola - Broadcast News. October, 1957.

APPENDIX 1

COMPUTATION OF RESULTS OBTAINED IN SECTION 1 USING A TRANSMITTING YAGI.

The method of computation of the signal - "Ghost" ratio and the transmitting site loss is illustrated by a specific example at the Lilydale East site using horizontal polarisation. With the transmitting Yagi beamed on the receiving site, a maximum field intensity of 4.34 mV/m metre was observed at a receiving aerial height of 10 feet, and a minimum field of 0.144 mV/m was measured with aerial height 19¼ft. Consequently the reflection co-efficient of the ground is -

$$\frac{\frac{4.34}{0.144} - 1}{\frac{4.34}{0.144} + 1}$$

which is 0.935.

It follows that the measured maximum signal of 4.34 mV/m was 1.935 times the "local" free space signal E_I, which is defined as the intensity of the signal which strikes the antenna direct without touching the ground.

$$\text{Hence } E_I = \frac{4.34}{1.935} = 2.24 \text{ millivolts/meter.}$$

The free space field intensity which would be expected at this site from a good transmitting antenna of 37.5 watts E.R.P. and at the distance 4 3/8 miles is 6.1 mV/m. Hence the actual transmitter site used was incurring a loss of $20 \log. \frac{6.1}{2.24} = 8.4$ db. relative to a good site in this particular direction.

When the Yagi transmitting antenna was beamed at HSV7 mast, the received field intensity at this height of 10 feet was 0.89 mV/m, and the signal reflected from HSV7 mast (as measured by the receiver R.F. attenuator) was 26 db below 0.89 mV/m. i.e. 0.0445 mV/m. A good transmitting aerial of the same E.R.P. would give a field intensity of 6.1 x 1.935 = 11.8 mV/m at this optimum receiving antenna height. Hence the signal - "ghost" ratio is -

$$\frac{11.8}{0.0445} = 265 = 48.4 \text{ db.}$$

In this particular case the "ghost" signal travels 5.7 miles from the transmitter to the receiver and the direct signal 4.4 miles, so that at a great distance the signal - ghost ratio could be expected to reduce by this distance ratio. i.e. signal - "ghost" ratio

$$= 48.4 - 20 \log \frac{5.7}{4.4} \text{ db.} = 48.4 - 2.2 = 46.2 \text{ db.}$$

A ratio was also taken at a receiving antenna height of 23½ feet and in this case the ratio of direct and reflected bar pulses entering the receiver was 24 db., as measured with the R.F. attenuator in the receiver. In this case the expected field intensity from a good transmitting antenna, and the actual directly received signal are both reduced by the same amount relative to the 10 ft. receiving aerial position, so that the signal - ghost ratio is 46.2 - 26 + 24 db. = 44.2db.

APPENDIX 2

COMPUTATION OF REFLECTION RATIO USING AN INPUT TRANSMISSION LINE

Measuring transmission line has Attenuation a and

Characteristic impedance Z_o

The input impedance of the transmission line to a pulse which is not wide enough to produce standing waves is Z_o, the characteristic impedance of the line, and the impedance of the effective driving source is Z_D, which comprises all the impedances at terminals I paralleled, except the measuring line impedance Z_o. Refer Figure 7.

The input power to the line is $\frac{V_I^2}{Z_o}$, V_I being the voltage at the input terminals.

The power reaching the short circuited far end of the line is $\frac{V_I^2}{a^2 Z_o}$, where a is the attenuation of the line expressed as a voltage ratio. Since the reflection coefficient is unity, this same amount of power is reflected toward the input end and if $Z_D = Z_o$ all the power at I is delivered to load Z_D.

Its magnitude is $\frac{V_I^2}{a^2 Z_o} \times \frac{1}{a^2} = \frac{V_I^2}{Z_o a^4}$

Consequently the ratio of reflected to input power across terminals I is

$$\frac{V_I^2}{Z_o a^4} \Big/ \frac{V_I^2}{Z_o} = \frac{1}{a^4}$$

The corresponding ratio of reflected to input voltage is $\frac{1}{a^2}$

If Z_D is not equal to Z_o some of the power is reflected at terminals I back toward the short circuited end. From the theory of transmission lines, the ratio V of the voltage across the load Z_D to the travelling wavé voltage incident at this point is given by –

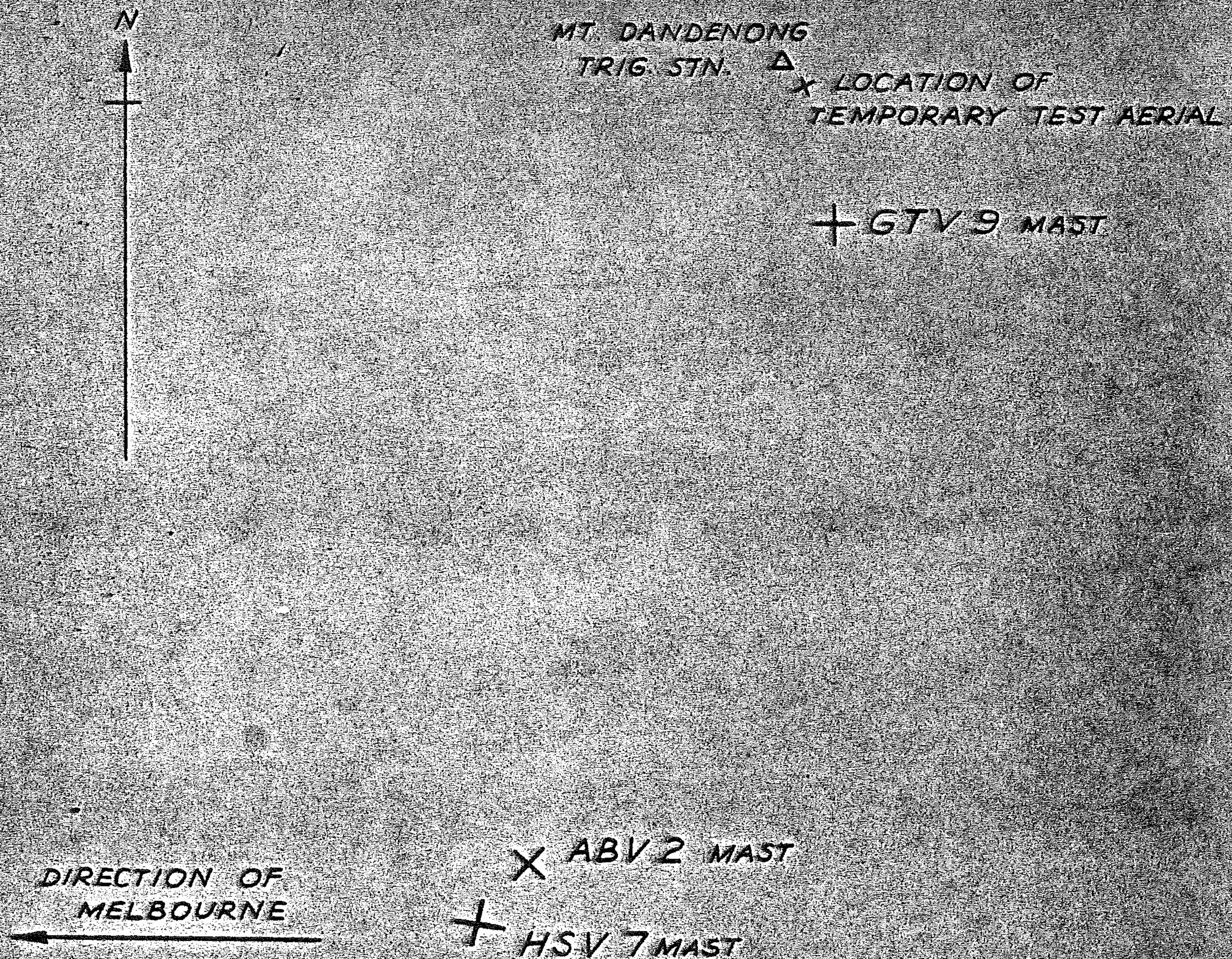
$$V = \frac{2\ Z_D}{Z_D + Z_o} = \frac{2\ Y_o}{Y_o + Y_D}$$

where Y_o is the characteristic admittance of the measuring line and Y_D is the admittance corresponding to the impedance Z_D. It is seen that this ratio is low when Z_D is low and high when Z_D is high.

The complete expression for the ratio of reflected to input voltage across terminals I is -

$$\frac{1}{a^2} \times \frac{2\ Z_D}{Z_D + Z_o} = \frac{1}{a^2} \times \frac{2\ Y_o}{Y_o + Y_D}$$

AUSTRALIAN BROADCASTING CONTROL BOARD

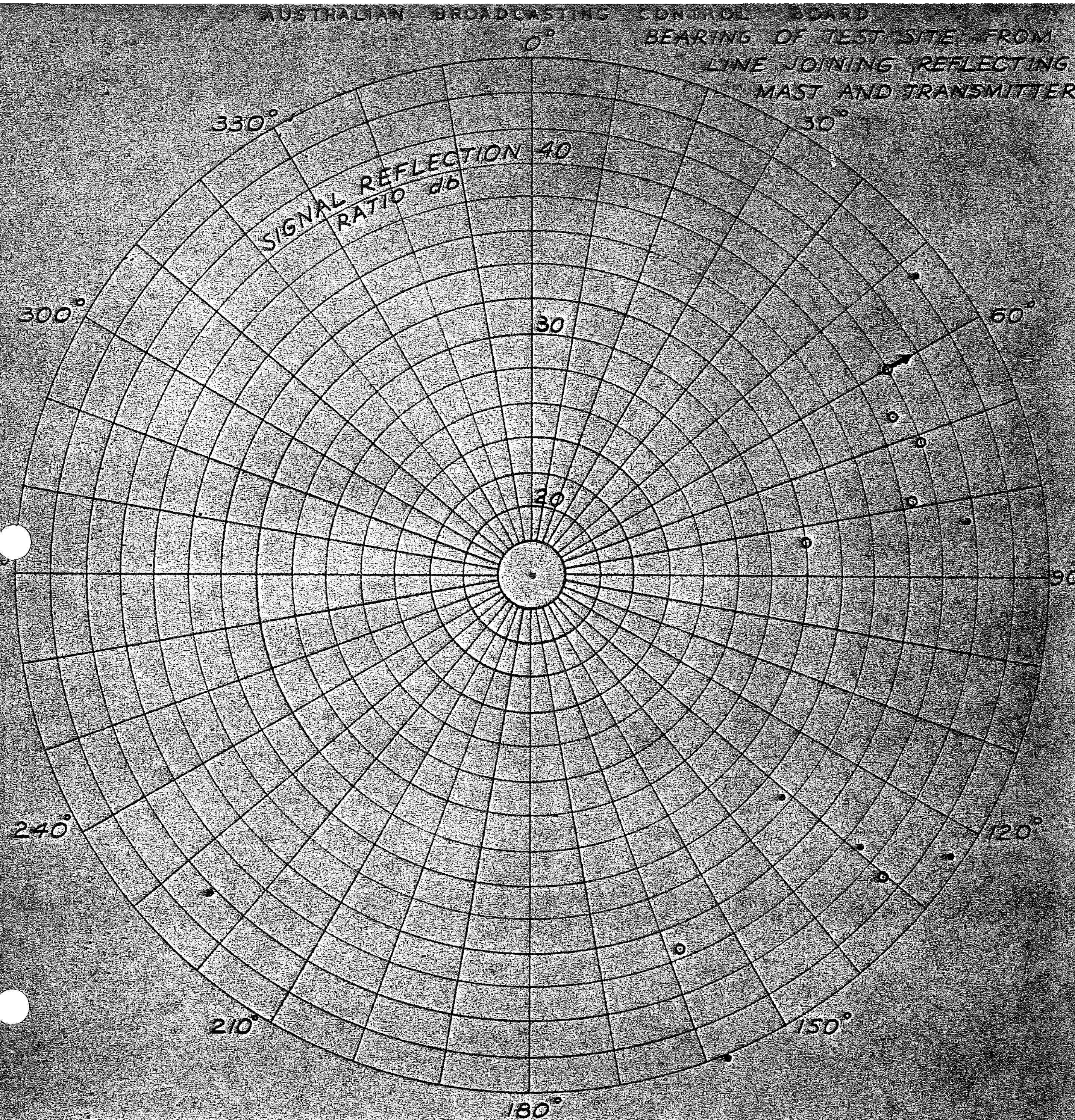


NOTE:-
THE LINES OF THE CROSSES SHOWING MAST POSITIONS PASS THROUGH THE MAST DIAGONAL.

SCALE 500 0 500 1000 1500 FEET

FIGURE I. LOCATION OF TV TRANSMITTING MASTS.

TESTS ON REFLECTIONS FROM T.V. MASTS PART OF TECHNICAL REPORT No 15	DRAWN:- M.O. APPRD.:- A.J.M. DATE:- 19-11-58 ZC-19 SHEET 1 OF 5 SHEETS



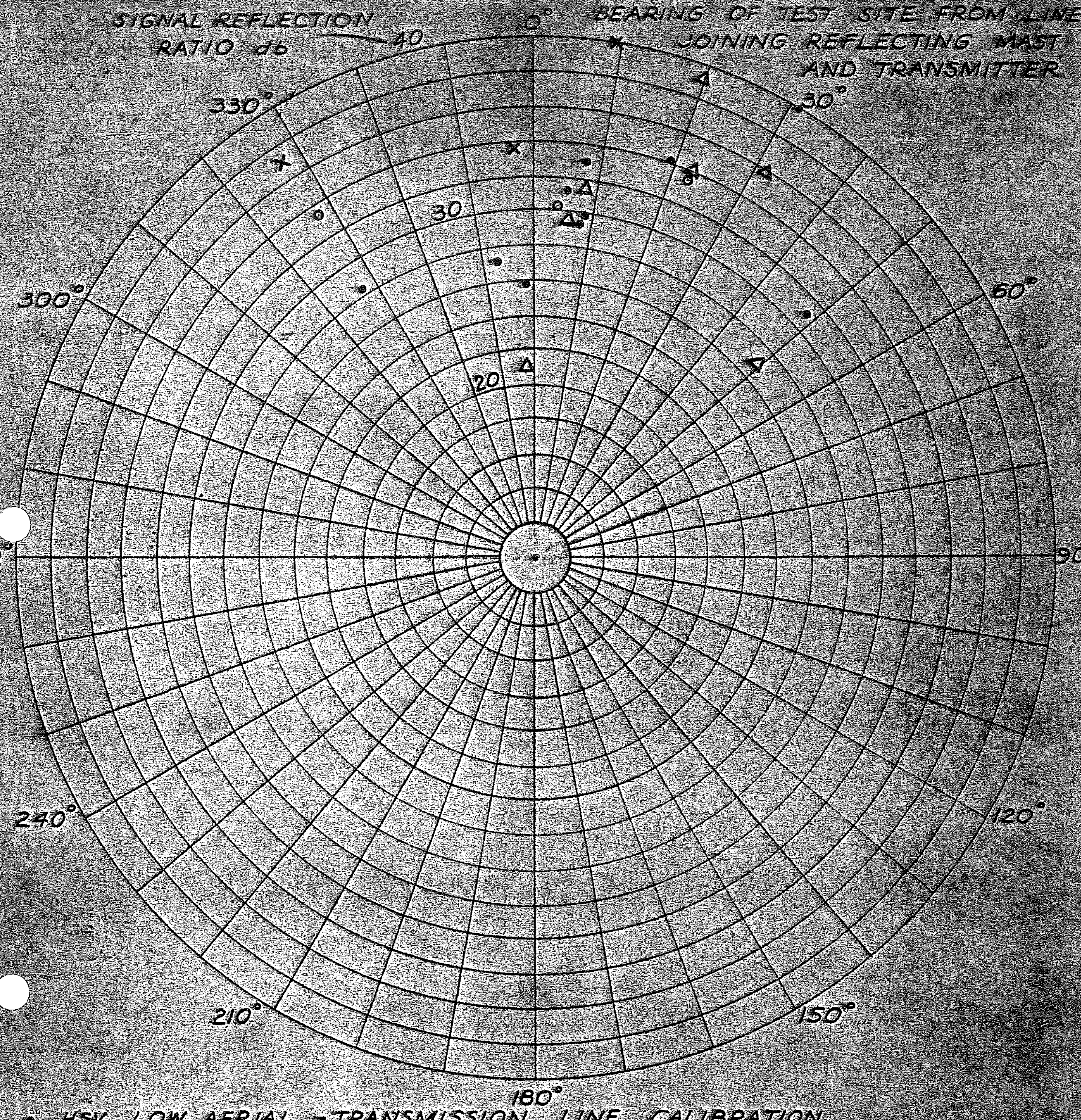
• TESTS WITH TEMPORARY AERIAL NEAR GTV 9 SITE REFLECTIONS FROM HSV MAST.

⊙ TESTS WITH GTV 9 AERIAL REFLECTIONS FROM HSV & ABV MASTS.

FIGURE 5. REFLECTION RATIOS TRANSMITTING FROM GTV 9 SITE.

TESTS ON REFLECTIONS FROM T.V. MASTS PART OF TECHNICAL REPORT No 15	DRAWN:- M.O. APPRD.:- A.J.M. DATE:- 19-11-58 ZC-19 SHEET 2 OF 5 SHEETS

AUSTRALIAN BROADCASTING CONTROL BOARD



• HSV LOW AERIAL - TRANSMISSION LINE CALIBRATION.

⊙ HSV LOW AERIAL - AMPLITUDE CALIBRATION

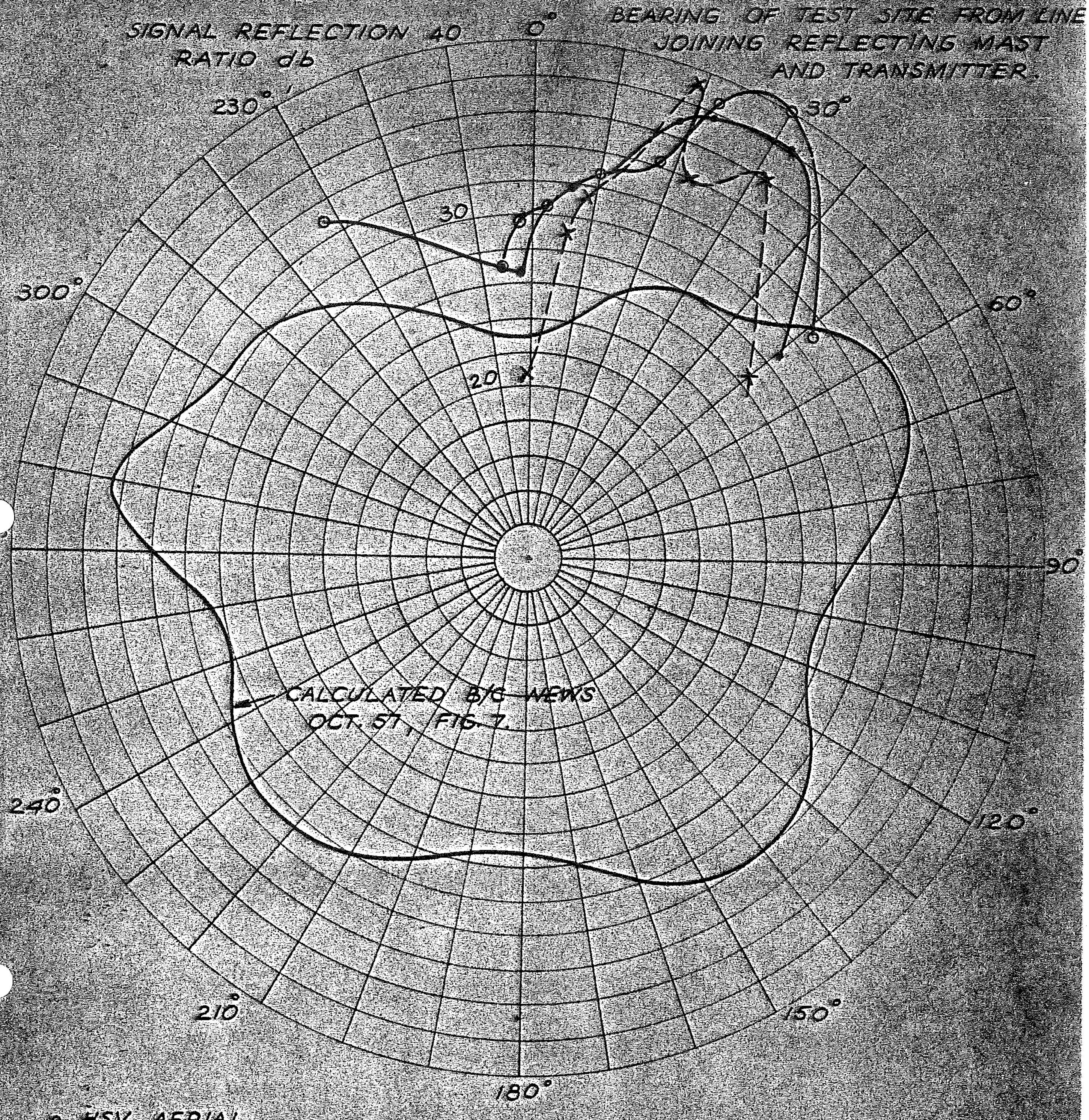
× HSV HIGH AERIAL - TRANSMISSION LINE CALIBRATION

Δ YAGI AERIAL

FIGURE 8. REFLECTION RATIOS TRANSMITTING FROM HSV MAST

TESTS ON REFLECTIONS FROM T.V. MASTS PART OF TECHNICAL REPORT No 15	DRAWN - M.O APPRD - A.J.M. DATE - 19.11.58 ZC-19 SHEET 3 OF 5 SHEETS

AUSTRALIAN BROADCASTING CONTROL BOARD



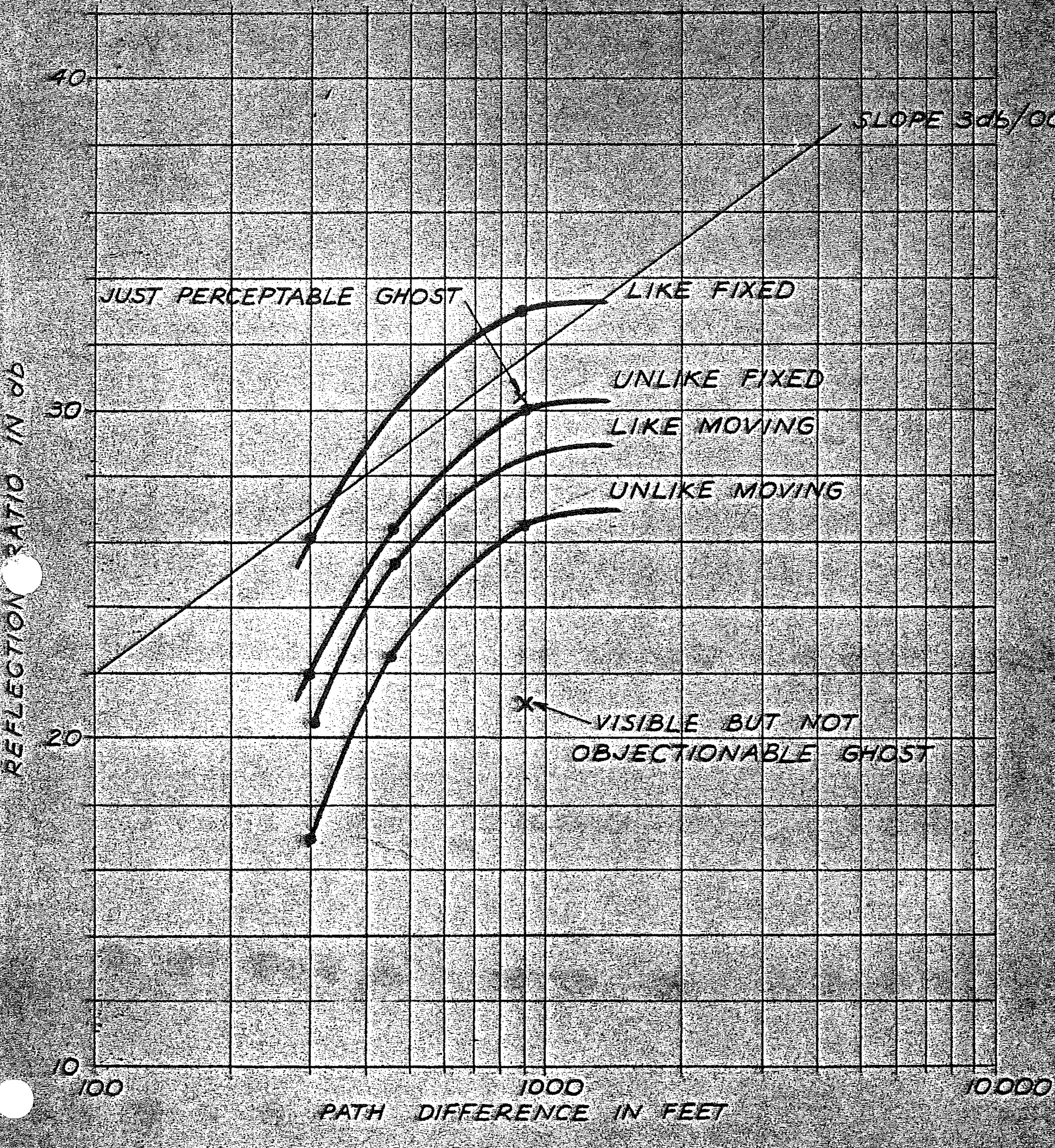
o HSV AERIAL

x YAGI AERIAL

• AVERAGE ALL MEASUREMENTS

FIGURE 9. REFLECTION RATIOS TRANSMITTING FROM HSV MAST. AVERAGED OVER 4° INCREMENTS.

TESTS ON REFLECTIONS FROM T.V. MASTS PART OF TECHNICAL REPORT No 15.	DRAWN:- M.O. APPRD:- A.J.M. DATE :- 19.11.58. ZC-19 SHEET 4 OF 5 SHEETS



• ACCEPTABLE PICTURE USING VIDEO EQUIPMENT.

X RATIOS MEASURED USING TYPICAL RECEIVER.

FIGURE 10. SUBJECTIVE TESTS ON TOLERABLE GHOST LEVELS.

TESTS ON REFLECTIONS FROM T.V. MASTS PART OF TECHNICAL REPORT No. 15	DRAWN:- M.O. APPRD:- A.J.M. DATE:- 19.11.58 **ZC-19** SHEET 5 OF 5 SHEETS