COMMONWEALTH OF AUSTRALIA

AUSTRALIAN BROADCASTING CONTROL BOARD
TECHNICAL SERVICES DIVISION

REPORT No. 6

TITLE: SELECTION OF STANDARD TELEVISION RECEIVER INTERMEDIATE FREQUENCIES FOR USE IN AUSTRALIA.

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Title: SELECTION OF STANDARD TELEVISION RECEIVER INTERMEDIATE FREQUENCIES FOR USE IN AUSTRALIA.

Report on theoretical investigation carried out by W. R. Baker for the Director, Technical Services, to determine suitable television frequencies as a standard for recommendation for use by Australian receiver manufacturers.

R. B. Mair
Director, Technical Services.

Date of issue:

AUSTRALIAN BROADCASTING CONTROL BOARD

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SELECTION OF STANDARD TELEVISION RECEIVER INTERMEDIATE FREQUENCIES FOR USE IN AUSTRALIA.

Introduction.

A circular was directed to Australian radio receiver manufacturers inviting them to indicate what were their preferences for standard TV receiver intermediate frequencies. From a consideration of the replies to this circular, and discussions which have taken place with various receiver manufacturer's representatives, it has been possible to choose tentative values for the intermediate frequencies. In an endeavour to place quantitative figures on some of the important interferences which are possible in T.V. receivers using the Australian standards, a theoretical investigation has been conducted, the results of which are set out below in the report and in the Appendices. No attempt was made to determine quantitative figures for the feed-back types of interference, which depend to a large extent on individual designs. Their importance, however, has been given due recognition in seeking the optimum intermediate frequency values.

The proposed channels are enumerated as follows, although it is uncertain whether all the channels will be used, particularly those in the 90-108 Mc/sec. band where it is probable that not more than one would be necessary.

Channel No.	1	44 - 51.5 MC/sec.
	2	62.5 - 70 MC/sec.
	3, 4	Between 90 and 108 MC/sec.
	5	174 - 181.5 MC/sec.

Channel No.	6	181.5 - 189 MC/sec.
	7	189 - 196.5 MC/sec.
	8	196.5 - 204 MC/sec.
	9	208.5 - 216 MC/sec.

Important Criteria in Selection of Intermediate Frequencies.

It is considered that desirable criteria for a selection of intermediate frequencies are as follows:-

(1) External Signal Break-Through at Intermediate Frequency.

The I.F. channel (7.5 m.c. wide) should be chosen clear of the frequencies of strong external signals, which are likely to break through the signal frequency tuned circuits into the I.F. amplifier.

(2) I.F. Harmonic Feed-back.

Harmonics of the I.F. picture and sound carrier frequencies should not fall within any of the 9 chosen T.V. channels (7.5 m.c. wide).

(3) Oscillator Radiation.

Receiver local oscillators should not have frequencies which cause serious interference with any of the other T.V. channels or with non T.V. services.

(4) Guard Band between the I.F. Channel and Carrier Channels.

The chosen I.F. channel should be sufficiently spaced in frequency from any carrier channel to prevent troublesome I.F. feed-back with reasonable receiver practices.

(5) Image Interference.

It should not be possible for T.V. channel carriers or strong external signals to beat with the local oscillators of lower frequency channels to form interfering side bands, which fall within the I.F. channel.

(6) Local Oscillator Break Through to Second Detector.

Harmonics of the I.F. picture carrier frequency should not fall within 5.5 m.c. of any of the 9 receiver local oscillator frequencies.

(7) Stability of I.F. Amplifier.

The chosen I.F. channel frequency should be sufficiently low that feed-back and A.G.C. stability is attainable with reasonable design, and the required circuit tuning arrangements and Q values (having adequate production stability) should be attainable with reasonably priced and available tubes.

(8) Carrier Second Harmonic beating Local Oscillator of same Channel.

The second harmonic of a picture or sound channel carrier should not beat with the local oscillator of the same channel, to produce an I.F. side band falling within the chosen I.F. channel. This criterion is really covered by the second I.F. harmonic requirements of (2) above, but it is listed separately since it is not the result of I.F. harmonic feed-back.

(9) I.F. Beats.

THE difference in frequency of any two channel carriers of the 9 channels should not fall within the chosen I.F. band.

(10) Oscillator Second Harmonic Interference.

The second harmonic of the local oscillator of any channel, should not beat with another channel carrier or strong external signal to form an interfering side band, which falls within the chosen I.F. band.

(11) Miscellaneous Third Order Interferences.

The second harmonic of a channel carrier should not beat with the fundamental of another channel carrier or with a local oscillator to form I.F. side bands falling within the chosen I.F. band. These are only serious when one or both of the carriers is very strong.

Broad Selection of Intermediate Frequencies.

It is obvious that the fulfilment of all of the above requirements is a very formidable task, and in practice no values can be found which satisfy all of the more important of these criteria. Generally speaking criteria (4) and (7) limit the choice to frequencies below 40 m.c., and criterion (1) makes it desirable to choose frequencies above 30 m.c. It then becomes necessary to choose values between 30 and 40 m.c. which cause the least trouble under criteria (1), (2), (3), (4), (5) and (6), since the analysis has shown that the overall effects of criteria (9), (10) and (11) do not change appreciably with small changes of intermediate frequency. The analysis will also show that criterion (6) can be eliminated for the I.F. values being considered (30-40 m.c.).

If a picture I.F. value of 37.25 M.C. is chosen, criteria (5) is eliminated and (1), (2) and (3) have a minimum disturbing effect as indicated below in a more detailed discussion of interferences.

Detailed Consideration of various possible I.F. Values.

(a) Sound carrier 30 and picture carrier 36 m.c.

The only significant interference product arising within the T.V. receiver is the 6th harmonic of the sound I.F. carrier (180 m.c.) beating with channel 5 picture carrier to give a 4.75 MC/sec. video interfering frequency which is not serious because such high order harmonics are readily filtered out of the video circuits, and also because such a high value video signal is much less disturbing than a low value near zero. The most serious objection to these intermediate frequencies is that 30 M.C. has been internationally allocated for a 10 K.W. standard frequency transmission and the discrimination of the radio frequency circuits of the T.V. receiver may not be good enough to prevent the standard frequency transmission from passing through the I.F. amplifier to heterdyne the sound I.F. carrier.

(b) Sound carrier 31.25 m.c. and picture carrier 37.25 mc.

In this case the 30 m.c. standard frequency interfering transmission falls almost on the normal adjacent channel "vision trap" in the I.F. amplifier and is thereby attenuated to a point at which it is less likely to interfere with the 31.25 m.c. frequency modulated sound carrier.

The second harmonic of the I.F. sound carrier falls at a point which is almost on the frequency where the sound carrier of the adjacent lower frequency channel adjacent to channel 2 (62.5-70 MC/sec.) would be located if used. This channel is not used for television, but the undesired I.F. 2nd harmonic carrier which is fed back from the video circuits to the R.F. circuits will be attenuated by the "trap" in the I.F. amplifier, which normally attenuates the adjacent channel sound carrier. The third harmonic of the sound I.F. carrier falls within channel 3 (assumed 93 to 100.5) to give a - 0.5 MC/sec. beat with the picture carrier. If channels 3 and 4 were located at 90 to 97.5 and 97.5 to 105 MC/sec. this beat with the picture carrier of channel 3 would be 2.5 MC/sec., a much less objectionable beat. Since odd harmonics of the I.F. sound and picture carriers generated at the video detector have smaller amplitudes than the even harmonics, it should be possible to eliminate this interfering harmonic with the normal low pass filter in the video circuits. If this filter is not sufficient a 93.75 m.c. "trap" circuit could be used in the output at the video circuits. Image interference between channels 4 and 5 is only present when using the band 93-108 m.c., andnot present when the 90-105 band is used. Interference to channel 1can also be caused by the second harmonic of channel 1 local oscillator beating with one or two of the higher frequency channel carriers, but the ratio of unwanted to wanted carriers in the aerial must be about 40 db before this becomes troublesome. The police in Victoria use a frequency of 31 MC/sec. and in New South Wales they use 32.6 m.c. The former is at the edge of the sound I.F. channel and the latter is about 4½ m.c. off the I.F. picture carrier. Any interference from these sources would have to be treated with a "trap" in the aerial, but no serious trouble is anticipated. A variety of other types of interference which have been listed in Appendix I and in Tables 1 - 4 can be in evidence when either the wanted or unwanted signal or both exceed about 0.1 volts, which is high enough to give an excellent service.

(c) Picture I.F. Carriers higher than 37.25 m.c.

It is considered that intermediate carrier frequencies higher than 31.25 m.c. (sound) and 37.25 m.c. (picture) are impracticable for the dual reasons that inter-channel "images" occur and also because the gap between the upper edge of the I.F. channel and the lower edge of channel 1 (44 m.c.) would become so small that it would be difficult to prevent overall oscillation at intermediate frequency or if oscillation were prevented, the feed-back at intermediate frequency may be great enough to seriously distort the response curve of channel 1. This would also be at least one serious objection to placing the intermediate frequency in the gap between channels 1 and 2 or in the gap between channels 2 and 3.

(d) Sound Carrier 21.5 and picture carrier 27.5 m.c.

On the lower side of the above optimum values, sound and picture carriers of 21.5 and 27.5 respectively would comfortably clear the amateur band (28-29.7 m.c.) but two zero beat image responses between carriers are possible. One of these would not be objectionable until the intensity of the unwanted carrier in the aerial exceeded the wanted carrier intensity, and the other requires an unwanted carrier about 10 times the wanted carrier to cause trouble. Second and third I.F. harmonic interference is likely to be a little more troublesome than in the cases outlined above and the same applies to interferences caused by high level input signals. The use of 21.5 and 27.5 MC/sec. intermediate frequencies may involve interference from high power transmitters, located in this band at geographical locations near capital cities, whereas the frequency allocations on the 30 to 40 MC/sec. band are of much lower power. On the credit side, the frequency spacing between this I.F. channel and the first television channel should ensure more margin of safety in the reception of this channel, and the I.F. amplifier design should be simpler in regard to feed-back and automatic gain control instability.

Quantitative Analysis.

Brief outline designs of a typical signal frequency and a typical picture I.F. amplifier were made, and the design data used to compute the various interfering responses. Quantitative figures have been obtained for the following interference categories, both with the recommended intermediate frequencies and other intermediate frequencies.

(a) Image Interference (Criteria(5) above)

This, when present, is in the order of 40-50 db. for equal intensity wanted and unwanted signals. Its effect could be eliminated, at some cost of system flexibility by geographical positioning of the transmitters, which give rise to the interference.

(b) Local Oscillator Break-Through to Second Detector (Criteria (6) above)

For the I.F. carriers considered this interference is present only with the high frequency channels and is sufficiently small to be completely negligible. Its effect could be more serious if a picture I.F. were chosen, the harmonics of which interfered with a local oscillator frequency below about 100 m.c.

(c) Carrier Second Harmonic beating Local Oscillator of same Channel (Criterion (8) above)

This is potentially serious on the second channel for input signals greater than about 0.1 volts. It is the result of non linear action in the mixer between channel 2 sound carrier and the local oscillator of this channel. With an I.F. sound carrier of 21.5 m.c. the interference occurs on channel 1.

(d) I.F. Beats (Criterion (9) above)

There are about a dozen different interference possibilities among the 9 channels, but fortunately they are negligible, if the input intensity of the unwanted carrier is less than about 0.1 volts.

(e) Oscillator Second Harmonic Interference (Criterion (10) above)

This type of interference occurs only on channel 1 with the 30-40 m.c. I.F. values. With the chosen I.F. values it is not expected to be noticable until the unwanted carrier input exceeds the wanted carrier input by about 40 db.

(f) I.F. Beats between Carrier fundamental and Carrier second harmonic (CRiterion (11) above)

Numerous cases of interference of this category can occur with 9 channels, but in all cases it is negligible with input signals as high as $\frac{1}{4}$ volt.

Conclusion.

If channels 3 and 4 can be made to occupy the frequency space 90-105 m.c. the use of 31.25 and 37.25 sound and picture I.F. carriers give rise to a minimum of potential sources of interference; the worst of these is the third harmonic of the sound I.F. carrier interfering with channel 3 picture carrier to form a 2.5 m.c. video signal, but this should be rendered innocuous by suitable design of video detector and amplifier. If channels 3 and 4 occupy the space 93-108 m.c. the above harmonic interference assumes more serious proportions and in addition image interference between channels 4 and 5 is a possibility.

The use of the lower frequency I.F. carriers, 21.5 and 27.5 m.c. results in image interference between channels 1 and 3, second and third I.F. harmonic interferences which are more severe than in either of the above cases, and direct I.F. interference from powerful short wave stations is possible in some localities.

Higher I.F. picture carriers than 37.25 m.c. are not feasible because of the possibility of undesired feed-back or oscillation when tuned to channel 1.

In all of the above cases it is assumed that the input signal to the receiver from transmitters on any channel can be limited to 0.1 volts by such means as directional receiving aerials, geographical positioning of transmitters, etc. With greater input signals one or more of the interferences outlined in the attached tables will tend to assume importance. Quantitative figures for the intensity of these interferences are given so that treatment required for each particular case will be evident.

It is recommended that intermediate frequency values of 31.25 M.C. for the picture and 37.25 M.C. for the sound be standardised in Australia.

TABLE I - CASES OF INTERFERENCE

Intermediate Frequencies - Picture Carrier 36 M.C.
Sound " 30 M.C.
Channels 3 and 4 - 90-105 M.C.

Input Signals 0.1 Volts

Type of Interference	Channel Interfered with	Beating Signal of this Channel	Second Beating Signal: Channel	Second Beating Signal: Type	Frequency of Video interfering Signal, M.C.	Ratio of Wanted Picture Carrier to interfering I.F. side band (db) for 0.1 volt input signals	Video interference (db) below 100% modulation of the picture carrier for 0.1 volt input signals
Carrier 2nd harmonic beating L.O. of same channel	2	Sound Harmonic	2	Oscillator	- 3.75	29	50
Difference of frequency of two carriers within or near the I.F. Channel	2	Picture	3	Sound	2.5	48	42
	3	Sound C	2	Picture C	"	47	41
	2	Picture A	4	" A	1.0	48	42
	4	" R	2	" R	"	51	45
	2	Sound R	4	Sound R	"	48	42
	4	" I	2	" I	"	48	42
	6	Picture E	9	" E	3.5	47	41
	9	Sound R	6	Picture R	3.5	47	41
	5	"	9	Sound	2.0	51	45
	9	"	5	"	2.0	47	41
	5	Picture	9	Picture	"	48	42
	9	"	5	"	"	51	45
2nd harmonic of wanted carrier beating with unwanted carrier	2	Picture C H	3	Picture C	- 0.25	76	78
	2	" A A	3	Sound A	5.75	80	86
	2	Sound R R	5	Picture R	0.25	101	102.5
	4	" R M	5	" R	1.75	86	80
	2	" I O	4	Sound I	1.25	83	77
	3	Picture E N	9	" E	3.25	102	96
	1	Sound R I C	2	" R	3.25	74	68

2nd harmonic of unwanted carrier beating with wanted carrier	3 3 5 5 4 9 2	Picture Sound Picture " Sound " " } CARRIER	2 2 2 4 2 3 1	Picture " Sound " " Picture Sound } CARRIER HARMONIC	- 0.25 5.75 0.25 1.75 1.25 3.25 "	113 113 157 147 105 > 100 91	115 > 113 158.5 141 99 > 100 85
2nd harmonic of unwanted carrier beating with wanted L.O.	6 7 9 8 4 3	Oscillator " " " " "	3 3 4 4 1 1	Picture Sound } Carrier " Picture Sound Picture } Harmonic	- 0.25 4.25 0.25 - 0.25 3.75 - 0.75	130 130 135 >100 109 108	133 124 129.5 >100 103 102
2nd harmonic of L.O. beating unwanted carrier	1 1	Oscillator " } Harmonic	7 8	Sound Picture } Carrier	2.25 0.75	72.5 72.5	66.5 66.5
I.F. harmonics	2 3	Picture " } Carrier	Sound I.F. second harmonic Sound I.F. third harmonic		-3.75 -1.25		
Oscillator radiation	4 9	Picture " } Carrier	2 5	Oscillator "	1 2		

TABLE 2 - CASES OF INTERFERENCE

Intermediate Frequencies - Picture Carrier 37.25 M.C.
Sound " 31.25 M.C.

Channels 3 and 4 - 90 - 105
Input Signals 0.1 volts

Type of Interference	Channel Inter-fered with	Beating Signal of this Channel	Second beating signal: Channel	Second beating signal: Type	Frequency of Video inter-fering Signal, M.C.	Ration of Wan-ted Picture Carrier to interfering I.F. side band for 0.1 volt input signals	Video inter-ference (db) below 100% modulation of the picture carrier for 0.1 volt in-put signals
Carrier 2nd harmonic beating L.O. of same channel	2	Sound Carrier Harmonic	2	Oscillator	- 1.25	9 db	28 db
Difference frequency of two carriers within or near the I.F. channel	2	Picture)	3	Sound)	3.75	48 db	42 "
	3	Sound)	2	Picture)	"	47 "	41 "
	2	Picture)C	4	")C	2.25	48 "	42 "
	4	")A	2	")A	"	51 "	45 "
	2	Sound)R	4	Sound)R	"	48 "	42 "
	4	")R	2	")R	"	48 "	42 "
	6	Picture)I	9	")I	4.75	47 "	41 "
	9	Sound)E	6	Picture)E	"	47 "	41 "
	5	")R	9	Sound)R	3.25	51 "	45 "
	9	")	5	")	"	47,"	41 "
	5	Picture)	9	Picture)	"	48 "	42 "
	9	")	5	")	"	51 "	45 "
2nd harmonic of wanted carrier beating with unwanted carrier	2	Picture)Car-	3	Picture)C	1.0	76	70
	2	Sound)rier	5	")A	1.5	101	95
	4	")	5	")R	3.0	86	80
	2	")Har-	4	Sound)R	2.5	83	77
	3	Picture)mon-	9	")I	4.5	102	96
	1	Sound)ic	2	")E	4.5	74	68
				R			

Table 2 (contd.)

2nd harmonic of unwanted carrier beating with wanted carrier	3	Picture	C	2	Picture	C	1.0	113	107
	5	"	A	2	Sound	A Har-	1.5	157	151
	5	"	R	4	"	R mon-	3.0	147	141
	4	Sound	R	2	"	R ic	2.5	105	99
	9	"	I	3	Picture	I	4.5	> 100	> 100
	2	"	E	1	Sound	E	4.0	91	85
			R			R			
2nd harmonic of unwanted carrier beating with wanted L.O.	6	Oscillator		3	Picture	Car-	- 0.25	130	133
	7	"		3	Sound	rier	4.25	130	124
	9	"		4	"		0.25	135	129
	8	"		4	Picture	Har-	- 0.25	> 100	> 100
	4	"		1	Sound	mon-	3.75	109	103
	3	"		1	Picture	ic	- 0.75	108	102
2nd harmonic of L.O. beating with unwanted carrier	1	Oscillator harmonic		7	Sound	Car-	6(S=0)	72.5	-
	1			8	Picture	rier	4.5	72.5	66.5
I.F. Harmonics	2	Picture	Car-		sound I.F. second harmonic		- 1.25		
	3	Picture	rier		sound I.F. third harmonic		2.5		
Oscillator radiation	4	Picture	Car-	2	Oscillator		2.25		
	9	Picture	rier	5	Oscillator		3.25		

TABLE 3 - CASES OF INTERFERENCE

Intermediate Frequencies - Picture Carrier 37.25 M.C.
Sound " 31.25 M.C.

Channels 3 and 4 - 93 - 108
Input Signals - 0.1 volts

Type of Interference	Channel Interfered with	Beating Signal of this Channel	Second Beating signal		Frequency of Video interfering Signal, M.C.	Ratio of Wanted Picture Carrier to interfering I.F. side band for 0.1 volt input signals	Video interference (db) below 100% modulation of the picture carrier for 0.1 volt input signals
			Channel	Type			
Carrier 2nd harmonic beating with L.O. of same channel	2	Sound Carrier 2 harmonic	2	Oscillator	-1.25	29 db	48
Difference frequency of two carriers within or near the I.F. channel	2	Picture	3	Sound	0.75	50 db	44
	3	Sound	2	Picture	"	49	43
	2	Picture C	4	" C	-0.75	50	57
	4	" A	2	" A	"	52	59
	2	Sound R	4	Sound R	"	50	57
	4	" R	2	" R	"	49	56
	2	" I	4	Picture I	5.25	49	43
	4	Picture E	2	Sound E	"	49	43
	6	" R	9	" R	4.75	47	41
	9	Sound	6	Picture	"	47	41
	5	"	9	Sound	3.25	51	45
	9	"	5	"	"	47	41
	5	Picture	9	Picture	"	48	42
	9	"	5	"	"	51	45
2nd harmonic of wanted carrier beating with unwanted carrier	2	Picture Carrier	3	Picture Carrier	4	78	72
	2	Sound	5	"	1.5	101	95
	1	"	2	Sound	4.5	74	68
	2	" Harmonic	4	Picture	-0.5	82	87
	2	"	4	Sound	5.5	85	79

Table 3 (contd.)

2nd harmonic of unwanted carrier beating with wanted carrier	3 5 2 4 4	Picture) Car- " Sound rier Picture Sound	2 2 1 2 2	Picture) Car- Sound) rier " ") Har- ") monic	4 1.5 4.5 -0.5 5.5	113 147 91 115 115	107 141 85 120 109
2nd harmonic of unwanted carrier beating with L.O. of wanted channel	4 6 8	Oscillator " "	1 3 4	Sound) Car- rier Picture) Harm- ") onic	0.75 5.75 5.75	109 >100 >100	103 >100 >100
2nd harmonic of L.O. beating with unwanted carrier	1 1	Oscillator) Har- mon- Oscillator) ic	7 8	Sound) Car- Picture) rier	6(β=0) 4.5	72.5 72.5	- -
I.F. harmonics	2 3	Picture) Car- ") rier	Sound I.F. 2nd harmonic - 1.25 " " 3rd " - 0.5				
Oscillator radiation	4 9	Picture) Car- ") rier	2 5	Oscillator "	- 0.75 3.25		
Image Interference	4	Oscillator	5	Picture carrier	11	46	40

TABLE 4 - CASES OF INTERFERENCE

Intermediate Frequencies - Picture Carrier 27.50 M.C.
Sound " 21.50 M.C.

Channels 3 and 4 - 93-108 M.C.
Input Signals 0.1 Volts

Type of Interference	Channel interfered with	Beating Signal of this Channel	Second Beating Signal		Frequency of Video interfering Signal, M.C.	Ratio of Wanted Picture Carrier to interfering I.F. side band for 0.1 volt input signals	Video interference (db) below 100% modulation of the picture carrier for 0.1 volt input signals
			Channel	Type			
Carrier 2nd harmonic beating with L.O. of same channel.	1	Sound carrier harmonic	1	Oscillator	-2.25	29 db	37
Difference frequency of 2 carriers within or near I.F. frequency.	1	Picture } C	2	Sound } C	3	41.5 db	35.5
	2	Sound } A	1	Picture } A	"	40.5	34.5
	3	Picture } R	2	Sound } R	"	45.5	39.5
	2	Sound } R	3	Picture } R	"	46	40
	5	Picture } I	8	" } I	5	39.5	33.5
	8	" } E	5	" } E	"	44	38
	6	" } R	9	" } R	1	43.5	37.5
	9	"	6	"	"	46.5	40.5
	7	"	9	Sound	2.5	42.5	36.5
	9	Sound	7	Picture	"	41.5	35.5
	5	"	8	Sound	5	44.5	38.5
	8	"	5	"	"	39	33
	6	"	9	"	1	47	41
	9	"	6	"	"	42	36
2nd harmonic of wanted carrier beating with unwanted carrier.	1	Picture } Car-	2	Picture } C	0.75	65	59
	2	" } rier	4	" } A	1.75	79	73
	2	"	3	Sound } R	0.25	78	80
	3	" } har-	9	" } R	0.75	100	94
	4	" } mon-	5	" } I	5.25	92	86
	3	Sound } ic	5	Picture } E	2.25	92	86
	4	"	7	" } R		94	88
	4	"	6	Sound	0.75	93	87

Table 4 (contd.)

2nd harmonic unwanted carrier beating with wanted carrier	2 4 3 9 5 5 7 6	Picture) C ")A Sound)R ")R ")I Picture)E ")R Sound)	1 2 2 3 4 3 4 4	Picture)Car- ")rier ") ")har- ")mon- Sound)ic ") ")	0.75 1.75 0.25 0.75 5.25 2.25 2.25 0.75	94.5 117.5 110.5 >100 138.5 >120 " "	88.5 111.5 104.5 >100 132.5 >120 " "
2nd harmonic of unwanted carrier beating with L.O.	6 8 4 8	Oscillator " " "	3 4 1 3	Picture)Car- ")rier Sound)Har- ")monic	5.75 5.75 0.75 2.75	>120 >120 >110 >120	>120 >120 >100 >120
2nd harmonic of L.O. beats with unwanted carrier.	2	Oscillator harmonic	9	Picture carrier	0.75	72	66
Image interference	1 1	oscillator "	3 3	Picture)car- Sound)rier	6 (sound 0) 0	39 41	sound negligibl[e] 41
I.F. harmonics	1 2	picture carrier " "	Sound "	I.F. 2nd harmonic " 3rd "	- 2.25 0.75		
Oscillator radiation	8 9	" " " "	5 6	Oscillator "	5 1		

COMPUTATION OF INTERFERENCE ORIGINATING AT THE FREQUENCY CHANGER.

1. Carrier Second Harmonic Beating with Local Oscillator of same Channel giving Beat Frequency within or close to the I.F. Channel

Let local oscillator angular frequency be Wo and corresponding voltage . Eo sin Wo t.

Let carrier angular frequency be Wc and corresponding voltage Ec sin Wct.

Then the equivalent constant current generator in a pentode mixer plate circuit at (Terman's Handbook P. 464) angular frequency (Wo-Wc) is

$$\frac{1}{2} E_o E_c \frac{\partial g_m}{\partial E_g} \quad \text{--------} \quad (1)$$

The equivalent constant current generator in the mixer plate circuit at angular frequency (2Wc - Wo) is

$$\frac{1}{8} E_o E_c^2 \frac{\partial^2 g_m}{\partial E_g^2} \quad \text{--------} \quad (2)$$

The ratio of (1) to (2) is the ratio of wanted to unwanted signals appearing in the mixer plate circuit without regard to the I.F. amplifier response.

i.e. Ratio of wanted to unwanted mixer plate currents

$$= \frac{4}{E_c} \; \frac{\partial g_m}{\partial e_g} \bigg/ \frac{\partial^2 g_m}{\partial E_g^2} \quad \text{----------} \quad (3)$$

For a typical television pentode mixer circuit the ratio $\frac{\partial g_m}{\partial E_g} \Big/ \frac{\partial^2 g_m}{\partial E_g^2}$ has been approximately computed as 5 and hence (3) becomes- ratio of wanted to unwanted mixer plate currents

$$\doteqdot \frac{20}{E_c} \quad \text{-------------} \quad (3a).$$

Example.

Sound I.F. = 31.25 M.C., picture I.F. = 37.25 M.C. Channel 2 sound carrier frequency is 69.75 M.C. and its second harmonic beats with the local oscillator of this cahnnel to give a beat frequency of 38.5 M.C., which is right at the edge of the T.V. I.F. channel. If 0.1 volts exists at the aerial, and the R.F. stage gain is 5, $E_c = 0.5\sqrt{2}$ volts peak.

$$\therefore \frac{\text{Wanted}}{\text{Unwanted}} \text{ mixer plate currents} = \frac{20}{0.5\sqrt{2}} = 29 \text{ db.}$$

Actually the sound "trap" in the I.F. channel will attenuate this unwanted side band by a further 19 db. giving a 1.25 M.C. video interference output which is 48 db. down on 100% modulation of the I.F. picture carrier.

The response of a typical I.F. amplifier taking account of sound and vision "traps", was taken from a curve published by Radio Corporation of America.

2. Second Harmonic of the local Oscillator of a wanted channel beating with an unwanted carrier to form and interfering I.F. sideband.

The ratio of wanted to unwanted mixer plate currents is -

$$\frac{1}{2} E_o E_c \frac{\partial g_m}{\partial E_g} \Big/ \frac{1}{8} E_o^2 E_i \frac{\partial^2 g_m}{\partial E_g^2}$$

$$= 20 \frac{E_c}{E_o E_i}$$ With a typical mixer

where Eo, Ec and Ei are respectively the peak amplitudes at the mixer input of the local oscillator fund amental, the wanted television carrier and the interfering carrier.

Example.

Channel 1 (47.5 - 55 M.C.) oscillator harmonic 172 M.C. beats with channel 9 picture carrier, 209.25 M.C., to form a $37\frac{1}{4}$ M.C. intermediate frequency side band, which zero beats the I.F. picture carrier at the second detector.

Assume the wanted picture carrier (Ec., 48.75 M.C.) has an intensity of 0.1 volts R.M.S. at the aerial or 0.5 volts R.M.S. at the frequency changer input.

Assume that the unwanted picture carrier (Ei, $209\frac{1}{4}$ M.C.) has an intensity of 0.1 volts R.M.S. at the aerial and in passing through the radio frequency amplifier (one R.F. stage) this unwanted carrier is attenuated by two single tuned circuits each tuned to channel 1 (mid frequency 51.25 M.C.), and each having a bandwidth of 10 M.C., 3db. down. The attenuation of the channel 9 picture carrier ($209\frac{1}{4}$ M.C.) relative to the resonant response of each tuned circuit is

$$\frac{10}{209} - \left(\frac{51.25}{209}\right)^2 = \frac{10}{196}$$

Consequently Ei at the mixer input is 0.5 $\left(\frac{10}{196}\right)^2$ volts R.M.S.

Assume that the oscillator voltage at the mixer input is 3 volts R.M.S. Then the ratio of wanted to unwanted currents in the mixer plate circuit is -

$$\frac{20 \times 0.5 \cdot \sqrt{2}}{3 \cdot \sqrt{2} \times 0.5 \cdot 2 \times \left(\frac{10}{196}\right)^2} = 1820.$$

Consequently the interfering I.F. signal at the video detector is 65 db down on 100% modulation of the picture carrier.

3. <u>Carriers with difference frequency falling within the I.F. Band</u>

Using the same terms as above, suffixes O.,C. and i representing local oscillator, wanted carrier and unwanted carrier respectively, it is easily shown that the ratio of currents at wanted and unwanted angular frequencies (Wo - Wc and Wc - W1) is -

$$\frac{1}{2}\frac{\partial gm}{\partial Eg} EcEo \Big/ \frac{1}{2}\frac{gm}{Eg} EcEi = \frac{Eo}{Ei}$$

, the ratio being independent of the intensity of the wanted carrier.

Example.

The picture carrier frequencies of channels 2 and 3 are respectively 63.75 and 98.75 M.C., and these two signals beat in the frequency changer to give an I.F. side band of 35 M.C., which beats the I.F. picture carrier (37.25 M.C.) at the second detector to give an undesired 2.25 M.C. video signal.

If channel 2 is the wanted signal, channel 2 radio frequency tuned circuits attenuate channel 3 picture carrier by a factor $\left(\frac{10}{58}\right)^2$ relative to the resonant response of the tuned circuits.

Then with a 0.1 volt unwanted aerial signal, the unwanted mixer input voltage $\mathcal{E}i = 0.5 \times \left(\frac{10}{58.}\right)^2$ R.M.S.

With a local oscillator voltage of 3 as before the ratio of wanted to unwanted mixer plate currents is $\frac{3 . \sqrt{2}}{0.5 . \sqrt{2} \times \left(\frac{10}{58.}\right)^2} = 200 = 46$ db.

In passing through the I.F. amplifier, the wanted picture carrier is attenuated 6 db. with respect to this unwanted side band, which is consequently only 40 db down on the former at the video detector. The unwanted video signal is 2.25 M.C.

When channel 3 is the wanted signal and 63.75 M.C. is the unwanted carrier, the ratio of wanted to unwanted mixer plate currents is $\frac{3 . \sqrt{2}}{0.5 . \sqrt{2} \times \left(\frac{10}{89.}\right)^2} = 475 = 53.5$ db.

For the same reason as above this ratio is reduced by 6 db at the video end giving a $2\frac{1}{4}$ M.C. video signal which is down 47.5 db on 100% modulation of the picture carrier.

4. <u>Second harmonic of wanted carrier beating with another carrier to form an I.F. side band</u>

Ratio of wanted to unwanted mixer plate currents

$$= \frac{1}{2} \; E_cE_o \frac{\partial g_m}{\partial E_g} \qquad \frac{1}{8}E_c^2 \; E_l \; \frac{\partial^2 g_m}{\partial E_g^2}$$

$$= 20 \frac{E_o}{E_cE_i} \qquad \text{for a typical frequency changer.}$$

<u>Example</u>.

An unwanted channel 2 picture carrier (63.75 M.C.) beats with the second harmonic (97.5 M.C.) of the wanted channel 1 picture carrier to form a 33 $\frac{3}{4}$ M.C. I.F. side band, which beats with the I.F. picture carrier in the second detector to give a $3\frac{1}{2}$ M.C. unwanted video signal.

Channel 2 picture carrier is spaced 12.5 M.C. from channel 1 mid frequency and consequently the intensity of the unwanted carrier ε_i at the mixer input for 0.1 volts in the aerial is -

$$0.5 \times \left(\frac{5}{12.5}\right)^2 \quad \text{volts R.M.S.}$$

Ratio of wanted to unwanted mixer plate currents is

$$\frac{20 \times 3 \cdot \sqrt{2}}{0.5 \cdot \sqrt{2} \times 0.5 \cdot \sqrt{2} \times \left(\frac{5}{125}\right)^2} = 1060 = 60.5 \text{ db.}$$

The interfering I.F. side band at the second detector is 54.5 db down on 100% modulation of the picture carrier.

5. Wanted carrier beating with second harmonic of an unwanted carrier to form an I.F. side band

Ratio of wanted to unwanted mixer plate currents

$$= \tfrac{1}{2}\, E_c E_o \frac{\partial g_m}{\partial E_g} \Big/ \tfrac{1}{8} E_i^2\, E_c \frac{\partial^2 g_m}{\partial E_g^2}$$

$$= 20 \frac{E_o}{E_i^2} \quad \text{in a typical case.}$$

Example.

As in 4 above with the channels reversed, channel 2 being wanted channel.

Ratio of wanted to unwanted mixer plate currents is

$$20 \times 3 \cdot \sqrt{2} \Big/ \left[0.5 \cdot \sqrt{2} \times \left(\frac{5}{17.5}\right)^2\right]^2 = 25{,}400 = 88 \text{ db.}$$

The interfering I.F. sideband at the second detector is 82 db down on 100% modulation of the picture carrier.

6. Local oscillator of a wanted channel beating with the second harmonic of an unwanted carrier

Ratio of wanted to unwanted mixer plate currents

$$= \tfrac{1}{2}\, E_c E_o \frac{g_m}{E_g} \Big/ \tfrac{1}{8}\, E_o E_i^2 \frac{\partial^2 g_m}{\partial E_g^2}$$

$$= 20 \frac{E_c}{E_i^2} \quad \text{in a typical case.}$$

Example.

The second harmonic, 182.5 M.C., of channel 3 picture carrier beats with channel 6 local oscillator, 219¼ M.C., to form an I.F. side band.

The intensity of the 91.25 M.C. interfering carrier at the mixer grid when receiving chanel 6, for 0.1 volts at the aerial, is -

$$6.5 \cdot \sqrt{2} \times \left(\frac{5}{94}\right)^2$$

Ratio of wanted to unwanted mixer plate currents

$$= 20.0.5 \cdot \sqrt{2} \Big/ \left[0.5 \cdot \sqrt{2}\left(\frac{5}{94}\right)^2\right]^2 = 3.5 \times 10^6 = 131 \text{ db.}$$

Interfering I.F. side band at the second detector is 126 db down on 100% modulation of the picture carrier.

APPENDIX II

COMPUTATION OF I.F. HARMONIC INTERFERENCE DUE TO OSCILLATOR BREAK THROUGH

If the local oscillator voltage gets through to the second (video) detector, and has a value which is within 5.5 M.C. of a picture I.F. carrier harmonic, then a video interference at this beat frequency can be formed by third order detection in the second detector. To get an idea of the order of magnitude of this interference a specific case, which occurs with the Australian standards was investigated. With the proposed Australian picture I.F. of 37.25 M.C. the local oscillator frequencies for various channels are:

Channel	Oscillator Frequency	Channel	Oscillator Frequency	Channel	Oscillator Frequency
1	82.5 M.C.	4	136 M.C.	7	227.5 M.C
2	101 "	5	212.5 "	8	235 "
3	128.5 "	6	220 "	9	246.5 "

The picture carrier I.F. harmonics are in order 74.5, 111.75, 149, 186.25 and 223.5 M.C. It is seen that the sixth harmonic (223.5 M.C.) will form a 3.5 M.C. beat with channel 6 local oscillator and a 4 M.C. beat with channel 7 local oscillator.

Ratio of I.F. picture carrier to local oscillator (220 M.C.) signals at the second detector for channel 6

To arrive at this ratio the basic constants for a staggered quintuple I.F. amplifier will be made. Assume the centre frequency of the I.F. amplifier to be 35 M.C. with a bandwidth of 5.5 M.C., 3 db down.

Then from Wallman's design data (Ref. Electronics, May, 1948) the constants for the various stages are -

Flat Top Response and picture carrier I.F. response.

The response of each tuned circuit to a frequency of 35 M.C. is next determined relative to the resonant response of each circuit, which occurs at the centre frequency tabulated above.. Universal selectivity curves for a simple tuned circuit can be used for this purpose. If the response ratios for each tuned circuit are multiplied together, a figure is obtained which represents the 35 M.C. response of the I.F. amplifier, relative to a hypothetical response figure obtained by multiplying together the maximum responses of each stage, and this latter will be used as a datum figure for amplifier response.

35 M.C. response or gain (relative to datum level)

$= 0.84 \times 0.79 \times 0.31 \times 0.29 \times 1.0 = 0.0605.$

The 35 M.C. response is, of course, the flat top response of the staggered quintuple.

Since the picture I.F. carrier frequency (37.25 M.C.) response of the I.F. amplifier is 6 db down relative to the flat top response, the picture I.F. carrier frequency response is $\frac{0.0605}{2} = 0.03$ relative to the datum response.

Response to local oscillator frequency (220 M.C.)

At frequencies having skirt responses which are about 6 db or more below the resonant response of a tuned circuit the actual response is given by the expression $\frac{B}{f} - \frac{f_o^2}{f}$ relative to the resonant response.

Where B is the bandwidth 3 db down (tabulated above)
f_o is the centre or resonant frequency (tabulated above)
and f " " frequency at which the response is required.

This formula assumes that tuned circuit damping is provided by a fixed shunt resistor. This will generally be the case, and likely departures from this condition, due to valve input loading, will not appreciably alter the result, because of the small value of the tuned circuit impedance at 220 M.C.

The response of the first tuned circuit at 220 M.C. relative to the resonant response is:

$$\frac{4.65}{220 - \frac{(36.6)^2}{220}} = \frac{4.65}{214}$$

Tabulating similar responses for all 5 circuits

Stage	1	2	3	4	5
220 M.C. Response relative to resonant response	$\frac{4.65}{214}$	$\frac{4.25}{215}$	$\frac{1.83}{213.5}$	$\frac{1.58}{215.3}$	$\frac{5.5}{214.5}$

Multiplying these responses together, the overall response of the 5 tuned circuits relative to the above defined response is 6.95×10^{-10}.

Ratio of Picture carrier and local oscillator responses in the I.F. tuned circuits.

The ratio of responses of the I.F. amplifier tuned circuits to the picture I.F. carrier (37.25 M.C.) and oscillator (220 M.C.) Voltages is $\frac{0.03}{6.95} \times 10^{-10} = 4.3 \times 10^{7}$.

Ratio of I.F. picture carrier to local oscillator voltage at the input to the first I.F. tuned circuit

Assume that 50 m.v. at the receiver input is the smallest picture channel carrier voltage to be received, and assume a gain of

5 to 1 from receiver input to mixer grid. Assume also that the 220 M.C. local oscillator voltage applied to the mixer grid is 3 volts. Then the ratio of channel picture carrier to local oscillator voltage at the mixer grid is $250 / 3 \times 10^6$.

The 220 M.C. local oscillator voltage will be amplified with virtually the full amplifier conductance of the mixer, whereas the picture carrier will change frequency, and consequently is amplified only by the conversion transconductance of the tube which is about ¼ the amplifying conductance. Hence the ratio of picture I.F. mixer plate current to 220 M.C. oscillator mixer plate current is

$$\frac{1}{4}\ \frac{250}{3 \times 10^6} = 250 / 12 \times 10^6$$

Then the ratio of I.F. picture carrier to 220 M.C. local oscillator voltage at the second detector input is -

$$4.3 \times 10^7 \times \frac{250}{12 \times 10^6} = 895$$

Since it is the sixth harmonic of the picture carrier which is involved in the interfering beat, the demodulating efficiency of the interfering signal will be down by a ratio of at least 6 to 1 relative to the wanted de-modulated signals. Hence the ratio of wanted video output (100% modulated) to the unwanted video output will be at least 6 x 895 = 5370 = 74.6 db.

The effects of this interference will be entirely negligible, but if an intermediate frequency is chosen which causes interference with local oscillator frequencies below about 100 M.C., the effect assumes more serious proportions.