POSTAL AND TELECOMMUNICATIONS DEPARTMENT

BROADCASTING ENGINEERING DIVISION
FORWARD PLANNING BRANCH

LABORATORY REPORT NO. 68

"An Investigation of Intermediate Frequency Beat Interference in VHF-FM Broadcast Receivers"

Prepared By: K. Malcolm and R. Lesley
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1. INTRODUCTION

The initial operation of station 2CBA-FM on a frequency of 103.5 MHz revealed the existence of a significant reception difficulty arising from receiver IF beat frequency interference. The usual VHF-FM broadcast receiver has its intermediate frequency (IF) amplifier stages operating at a frequency of 10.7 MHz. The IF pass-band width of practical stereo receivers will be at least 250 kHz or greater so as to pass all the components of a pilot-tone coded stereo signal. The initial frequency of 2CBA-FM (103.5 MHz) was separated by 10.6 MHz from that of 2ABC-FM which operates on 92.9 MHz. The most common interference was manifest as a spurious signal appearing across the receiver dial independent of the receiver tuning.

A simplified theoretical analysis of bipolar transistor amplifiers suggested that IF beat interference would be a significant problem in receivers with inadequate RF selectivity even at relatively low signal levels (5mV or less).

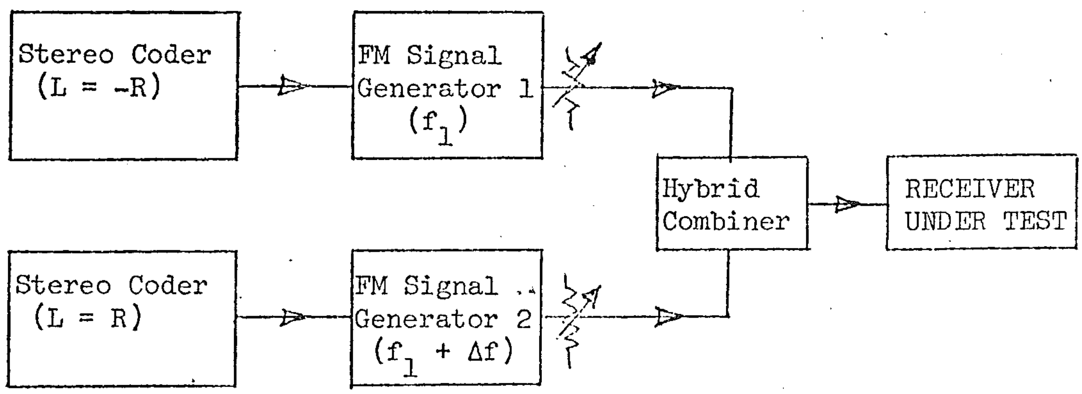
In response to the observed interference the frequency of 2CBA-FM was changed to 103.2 MHz pending investigation of the problem.

A series of laboratory measurements was performed to evaluate the extent of the problem at least under controlled conditions of input signal levels. A description of the tests and the results obtained is given in this report.

2. TEST PROCEDURES

2.1 The test procedures adopted required two frequency modulated signals, one of which was set at a fixed frequency, the other adjustable in frequency. The signals were combined and fed to the receiver under test as in the following block diagram.

Both signal generators were modulated with stereo coded signals: one with L = -R, the other with L = R.



The loss inserted by the hybrid combiner was measured and recorded so that the signal generator output levels could be set to give the required signals at the receiver input terminals.

The portable receivers tested were modified to provide a direct connection to the input in place of the internal whip antenna.

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Four series of measurements were performed. In each series, the frequency difference between signals (Δf) was varied, in 100 kHz steps, from 10.0 MHz to 11.4 MHz so as to cover the possible spread of IF's.

Ten receivers were tested: these included 5 portables, 2 car radios and 3 'hi-fi' tuners. Not all tests were performed on all receivers.

2.2 TEST 1: SPURIOUS SIGNALS BETWEEN WANTED SIGNALS

The initial interference reports from Sydney claimed that ABC-FM was audible all along the receiver dial independent of the receiver tuning. This aspect was investigated by setting the two signals at each of the defined separations in turn. The receiver was then tuned between the signals and the levels of the signals increased together until the onset of spurious signal generation was noted.

2.3 TEST 2: INTERFERENCE TO WANTED SIGNAL - EQUAL LEVELS OF WANTED AND INTERFERING SIGNALS

For this test, the receiver is tuned to one signal (the wanted signal) and the second signal (the interfering signal) is set, in turn, to a frequency separated from the wanted signal by the defined spacings.

The levels of wanted and unwanted signals are held at equal levels and increased together until the onset of interference, to the wanted signal, is noted.

2.4 TEST 3: INTERFERENCE TO A WANTED SIGNAL OF FIXED LEVEL

In this test the wanted signal level is set initially to 1mV at the input to the receiver under test. This level is chosen as typical of that required to achieve best performance from the receiver in the absence of interfering signals (as determined from previous measurements). The unwanted (interfering) signal is then set, in turn, to a frequency corresponding to each of the defined separations, and its level adjusted until the onset of interference, to the wanted signal, is noted. The test is repeated for wanted signals of 3mV and 10mV.

2.5 TEST 4: INTERFERENCE TO WANTED SIGNAL - WANTED SIGNAL 6 dB GREATER THAN AND 6 dB LESS THAN INTERFERING SIGNAL

The receiver is tuned to a signal (the wanted signal) and a second signal (the interfering signal) is set, in turn, to a frequency corresponding to each of the defined frequency separations. The levels of both signals are then adjusted together until the onset of interference to the wanted signal is observed. A constant difference in level between wanted and interfering signals is maintained throughout the test: in one case the wanted signal is 6 dB greater than the interfering signal while in the second case, the wanted signal is 6 dB lower than the interfering signal. The figure of 6 dB was selected as that variation in signal levels expected to be obtained at typical receiving sites when equal power, co-masted transmissions are employed.

One receiver was selected for testing under these conditions.

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3. MEASUREMENT RESULTS

3.1 The results of each of the tests are recorded as graphs of signal level vs separation for perceptible interference and are attached as figures 1, 2, 3, 4, 5 and 6.

Based on previous measurements, it is assumed that for satisfactory reception of a number of signals, the levels of the signals may vary between approximately 1mV and 10mV. This arises from the observation that listeners generally install an antenna such that the weakest wanted signal gives just satisfactory performance. For typical receivers this corresponds to an input of between 100μV and 1mV. With transmissions of comparable powers radiated from sites in reasonable geographic proximity, it is assumed that signal level variations between strongest and weakest signals are unlikely to exceed 20 dB.

On these grounds, receivers may be considered to give satisfactory performance if interference free reception is obtained with signal levels of up to 10mV at the terminals. It follows that, to avoid IF beat interference, frequency differences which result in interference at signal levels of 10mV or less cannot be used.

The form of spurious signals observed varied with signal level and frequency separation. At low signal levels and spacings close to IF, the spurious signals appeared as "across-the-band" rubbish, independent of receiver tuning. At separations further away from IF, and at higher levels, the spurious signals resolved themselves into discrete signals, which could be tuned separately as the receiver was tuned between the 'real' wanted signals.

The observed interference to the 'tuned-in' signal (in tests 2, 3 and 4) also varied with signal level and separation. It included effects such as interference to the program and the occurrence of pilot signal beats.

3.2 TEST 1: SPURIOUS SIGNALS BETWEEN WANTED SIGNALS (Fig 1)

This test provides the most sensitive indication of receiver intermodulation interference performance. All receivers exhibited the characteristic of producing spurious signals when tuned between wanted signals. This is a significant factor, the presence of the spurious signals would tend to make it difficult for listeners to tune to genuine signals - particularly with receivers that do not have a signal strength meter which would assist in discrimination between spurious and 'real' signals on the basis of level.

The most obvious impact of the tests, is the spread of the results, two receivers gave satisafactory performance at all separations investigated while one receiver gave barely acceptable results at any of the separations investigated.

All receivers tested had performances approximately symmetrical about the nominal IF centre frequency of 10.7 MHz. It is concluded therefore, that the reception problems did not arise from random variations in IF frequency.

In this test all but one receiver gave satisfactory performance except for separations between 10.3 and 11.1 MHz; fifty percent of receivers gave satisfactory results except for separations of between 10.4 and 11.0 MHz. Since FM channels are allocated at 200 kHz increments it is concluded that, from the point of view of this test, carrier frequency separations greater than 10.2 MHz but less than 11.2 MHz should not be used.

3.3 TEST 2: INTERFERENCE TO WANTED SIGNAL: EQUAL LEVEL WANTED AND UNWANTED SIGNALS (Fig 2)

For separations in the range investigated forty percent of the receivers tested did not generate interference to the wanted (tuned) signal, up to the maximum available signal level (1V RMS).
All but one of the receivers tested gave satisfactory performance except for frequency separations of between 10.5 and 10.9 MHz.

Although this is a somewhat idealistic situation, it is expected to provide a guide to the performance obtainable under carefully controlled conditions.

It appears from the measurements that the IF beat interference could be eliminated in a practical situation, simply by controlling the input signal level. Most receivers tested gave satisfactory performance on this test for input signal levels up to 2mV.

3.4 TEST 3: INTERFERENCE TO WANTED SIGNAL: WANTED SIGNAL OF FIXED LEVEL (Figs 3, 4, 5)

In this test, the wanted signal level was initially fixed at 1mV. Tests were repeated at 3mV and 10mV. Two of the receivers could not be driven into interference with the maximum available interfering signal. A further two receivers are considered to perform satisfactorily at any separation. All receivers gave satisfactory performance except for separations of between 10.4 and 11.1 MHz.

Receiver performance changed only slightly with wanted signal level. In general, best performance appears to be obtained for wanted signals of between 1 and 3mV.

3.5 TEST 4: INTERFERENCE TO WANTED SIGNAL: 6 dB DIFFERENCE BETWEEN WANTED AND INTERFERING SIGNALS (Fig 6)

The results for this test are comparable to the results obtained for a fixed level of input signal. The situation where the wanted signal is 6 dB lower than the interfering signal appears to be slightly more sensitive to interference although with only one receiver tested the results cannot be considered conclusive.

4. GENERAL COMMENTS

If the problem of spurious signals falling between wanted signals is considered to be of planning significance (experience with the Department's test transmissions indicates that many listeners have difficulty identifying spurious and real signals) then this is the limiting factor of receiver performance (for IF beat interference).

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The test results indicate that any given receiver will generate spurious signals "between stations" at signal levels much lower than those required to cause interference to a signal to which the receiver is tuned.

5. CONCLUSIONS.

5.1 The significance of IF beat interference, from a frequency allocation point of view, is dependent on the minimum quality of receiver, that is to be taken into account. The occurrence of IF beat interference is very dependent on receiver RF performance.

Design deficiencies; which are prevalent among portable receivers; cause portable receivers to be generally more susceptible to IF beat interference than other types of receiver.

If all but the poorest of receivers are to be protected from IF beat interference, then frequency separations of between 10.4 and 11.0 MHz inclusive must be avoided. To retain the concept of 200 kHz non-offset channelling, previously adopted for FM, permissible separations are therefore:

(i) up to and including 10.2 MHz;
(ii) 11.2 MHz and greater.

It should be noted that this conflicts with the planning policies adopted in the preparation of ABCB Report 43.

5.2 Provided that the signal level variations between stations are kept to a minimum (e.g. with co-masted transmissions) most receivers are capable of providing 'interference free' reception for separations other than 10.6 to 10.8 MHz inclusive. The remaining (lower quality) receivers require that separations of 10.4 to 11.0 MHz inclusive must not be used.

5.3 With separations in the range 10.2 to 11.2 MHz, many receivers will generate spurious signals which appear on the receiver dial between 'real' wanted signals. (This may not necessarily mean that there is audible interference to a correctly tuned wanted signal.) The existence of these spurious signals will cause some listeners considerable difficulty in tuning to a desired station. To avoid this problem separations between 10.2 and 11.2 MHz should not be used, even for co-masted services.

5.4 In situations where wanted and unwanted signals are maintained at approximately equal levels (e.g. by adopting co-masted, equal power transmissions) and the input levels at the receiver can be adjusted to an appropriate level (that level being determined by individual receiver characteristics and bounded on the lower side by receiver noise performance and on the upper side by receiver overload) the measurements indicate that IF beat interference would not be a problem, irrespective of signal separation.

6. IMPACT OF FM RECEIVER IF BEAT INTERFERENCE ON ABCB REPORT 43 FREQUENCY ALLOCATIONS

6.1 The impact of this potential interference made on the ABCB Report 43 allocations is dependent on two main factors:

(i) the density of allocations in an area;
(ii) the extent of protection required (frequency range to be avoided).

In Report 43, capital city FM channels are nominally allocated at 1MHz intervals over the available spectrum. Any prohibited frequency band must occupy considerably less than 1MHz if channel allocations are to be maintained by locating the prohibited band between nominal channels.

A prohibited band of 1MHz or more will mean that some channels are mutually exclusive; the prohibited range overlapping at least one nominal channel.

6.2 At the present time, the spectrum available for FM services is 92-94 MHz and 101-108 MHz. The segment 92-94 MHz is approximately receiver IF (10.7 MHz) separated from the 101-108 MHz segment.

If the minimum protection proposed in Section 5.2 (i.e. avoidance of 10.6-10.8 MHz separations) is adopted, then the only impact on Report 43 allocations is a minor revision of some allocations in Brisbane, Sydney (2CBA-FM) and Bathurst.

On the other hand, laboratory measurements have indicated that satisfactory protection of receivers against IF beat interference requires the avoidance of separations between 10.4 and 11.0 MHz inclusive: the first usable channel pairs, with separations approximating receiver IF, are thus separated by 10.2 and 11.2 MHz. If this restriction is adopted, the use of 92-94 MHz is mutually exclusive with maximum occupancy of 101-108 MHz (every channel used in the 92-94 MHz segment prevents the use of, at least, one channel in the 101-108 MHz segment). This poses a serious limitation on spectrum availability, it will be most keenly felt in capital cities where Report 43 proposed use of channels in both segments 92-94 MHz and 101-108 MHz. (It represents a loss of up to 3 potential channel allocations.).

6.3 Experience with 2CBA-FM indicates that offset channels with 10.3 MHz (and 11.1 MHz) separations are usable under certain conditions. Such an arrangement would permit qualified use of both segments 92-94 MHz and 101-108 MHz but restricts the flexibility of allocations and still results in the loss of one potential channel from the segment 92-94 MHz.

6.4 The requirement to provide protection against IF beat interference imposes a further restriction on frequency allocation planning. The adjacent channel spacing must be greater than the potential IF range if further restrictions on the use of "available" band space are to be avoided. (The protected band must occuply less spectrum than the adjacent channel spacing otherwise the protected band will overlap at least one nominal channel).

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6.5 It is obvious that from a frequency planning (spectrum occupancy) point of view, it is preferable that no cognizance be given to the requirement for IF beat interference protection: this is unlikely to be acceptable as it imposes a penalty on receiver cost. The minimum protection that realistically can be considered (avoidance of 10.6 to 10.8 MHz separations) appears to permit satisfactory reception on a reasonable range of receivers and has minimum impact on current channel allocations. Acceptance of this level of protection will require that the Department takes steps to have the minimum receiver performance upgraded (preferred action), or (at least) to advise the public of the likely penalties of purchasing inferior quality receivers.

FIG. 1. SEPARATION vs INPUT LEVEL for across-the-dial Spurious Signal Generation
(Two Equal Signals) (Each of 10 Receivers Tested)

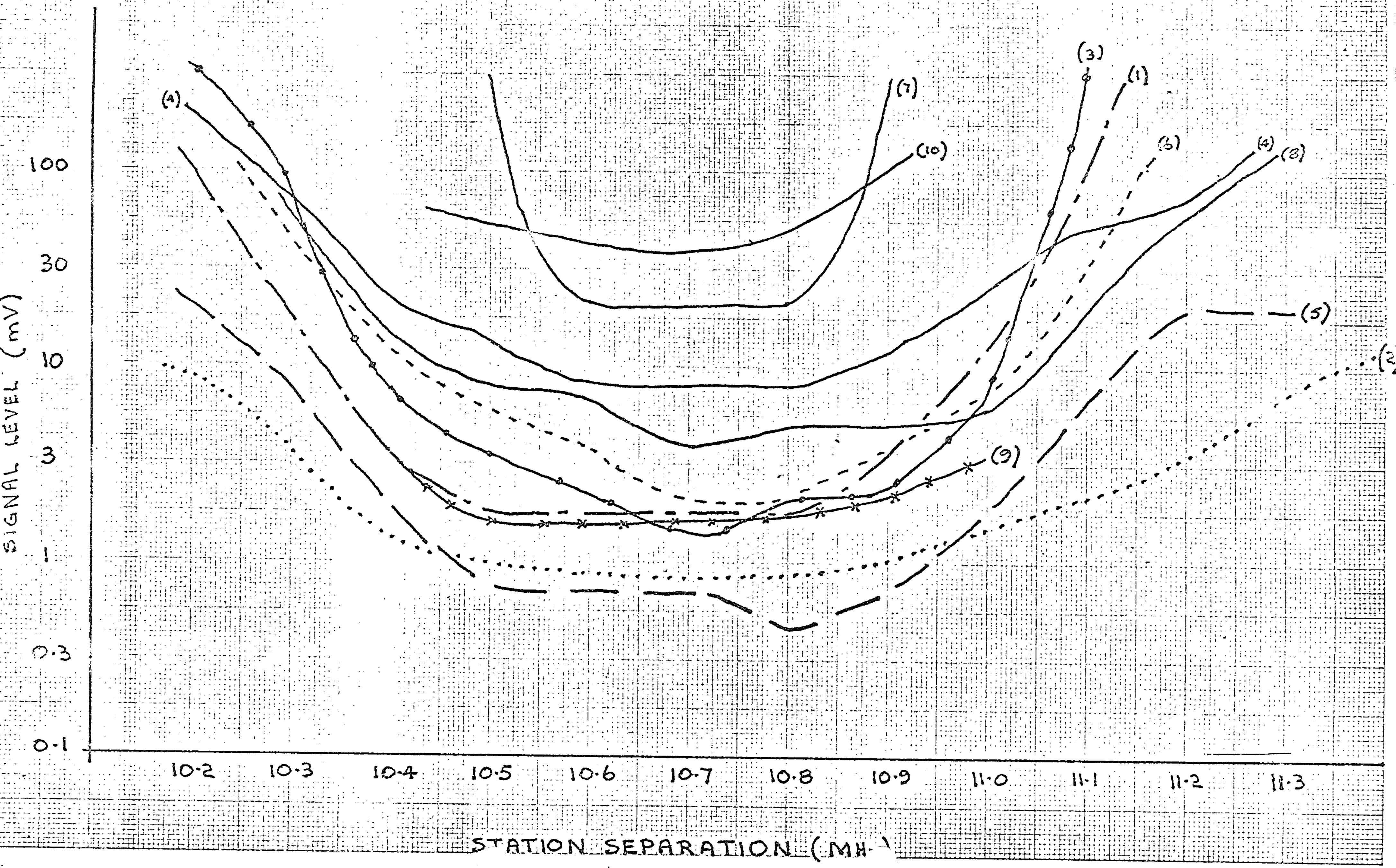


FIG. 2. SEPARATION vs INPUT LEVEL to cause Interference to Wanted Signal
(Two equal level signals) (8 Receivers tested)

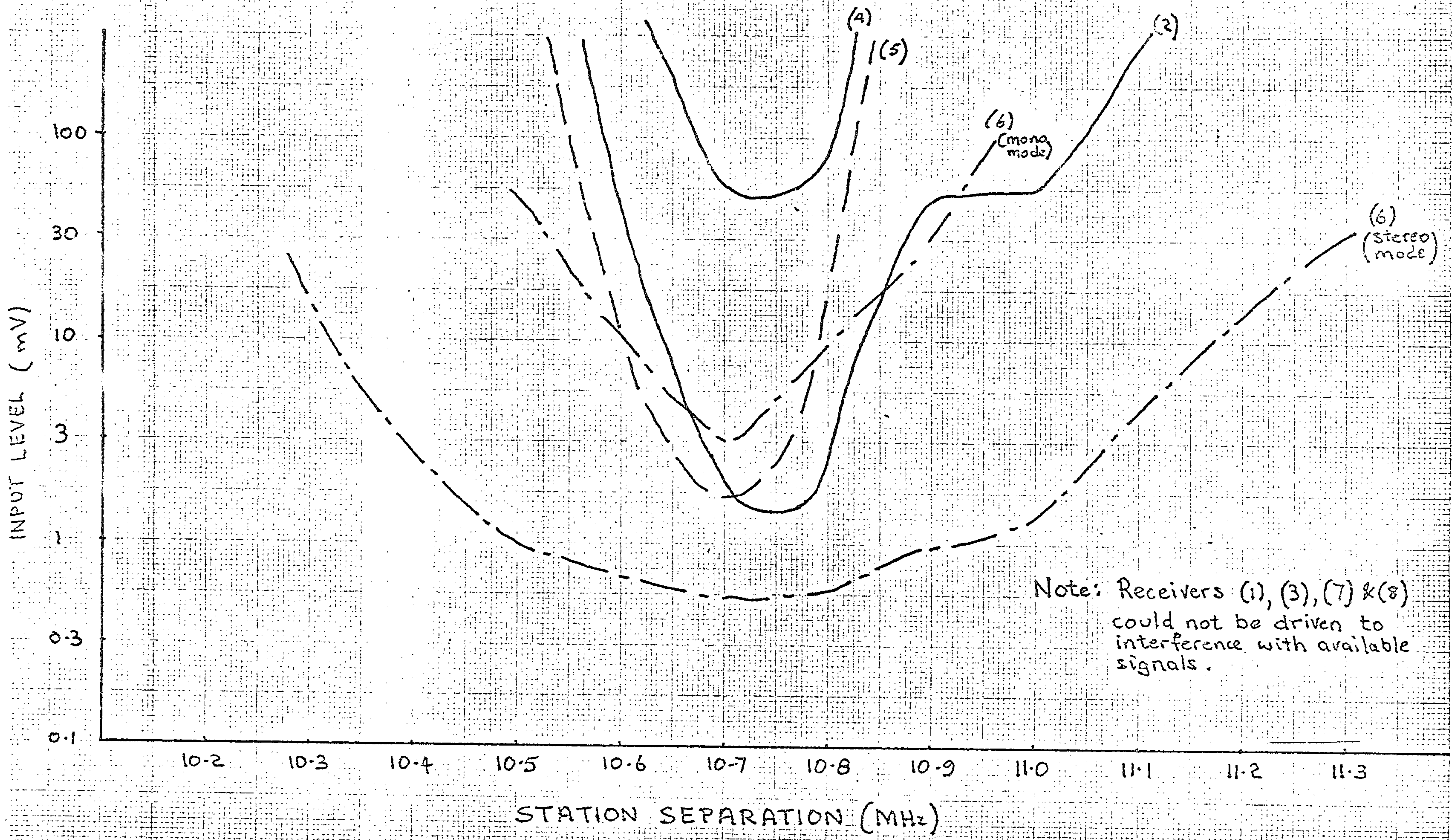


FIG. 3. SEPARATION vs INPUT LEVEL to cause interference to Wanted Signal of 1 mV.
(8 receivers tested)

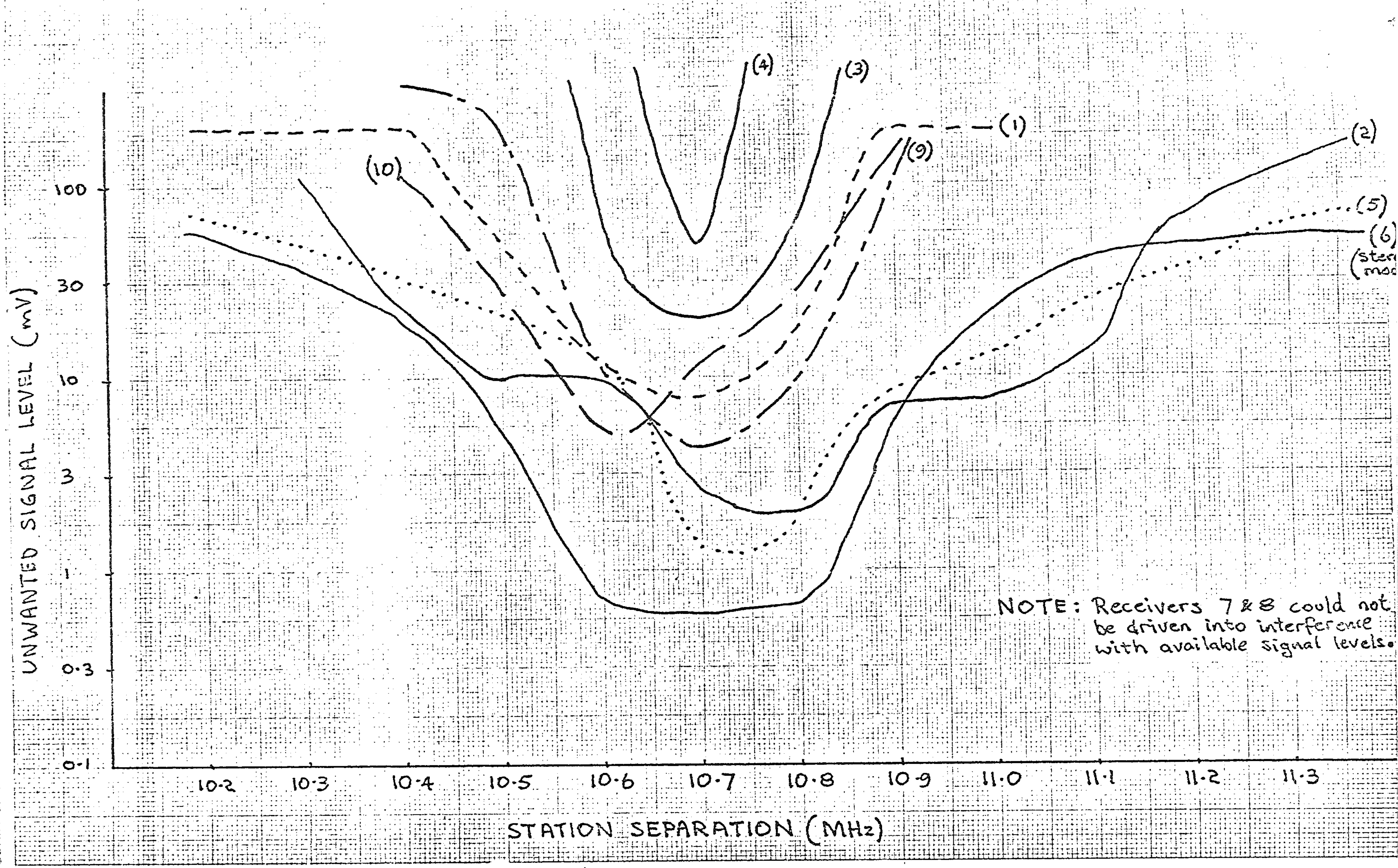
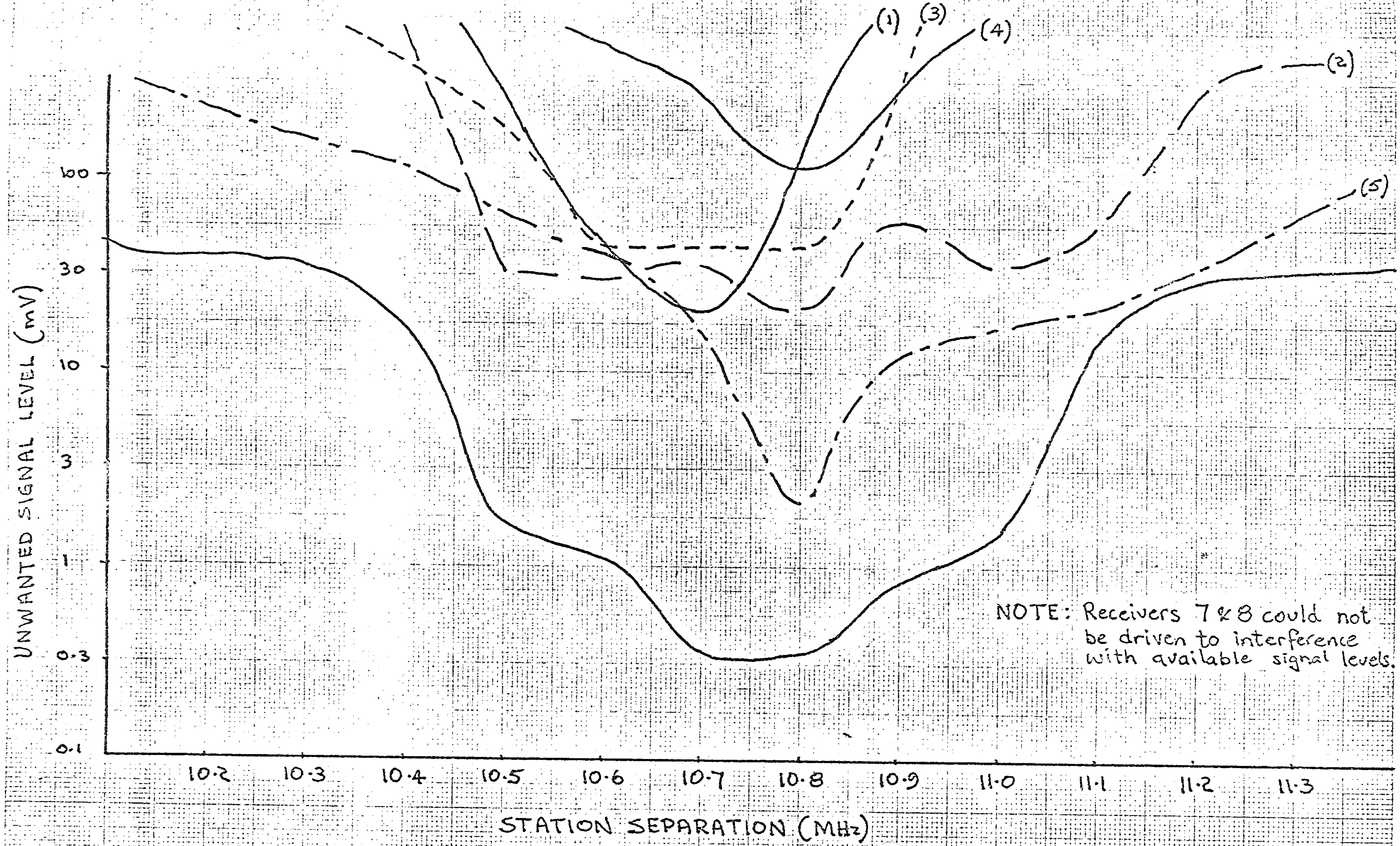


FIG. 4. SEPARATION vs INPUT LEVEL for Interference to Wanted Signal of 3 mV. (8 receivers tested)



NOTE: Receivers 7 & 8 could not be driven to interference with available signal levels.

FIG. 5. SEPARATION vs INPUT LEVEL for Interference to Wanted Signal of 10 mV.
(8 receivers tested)

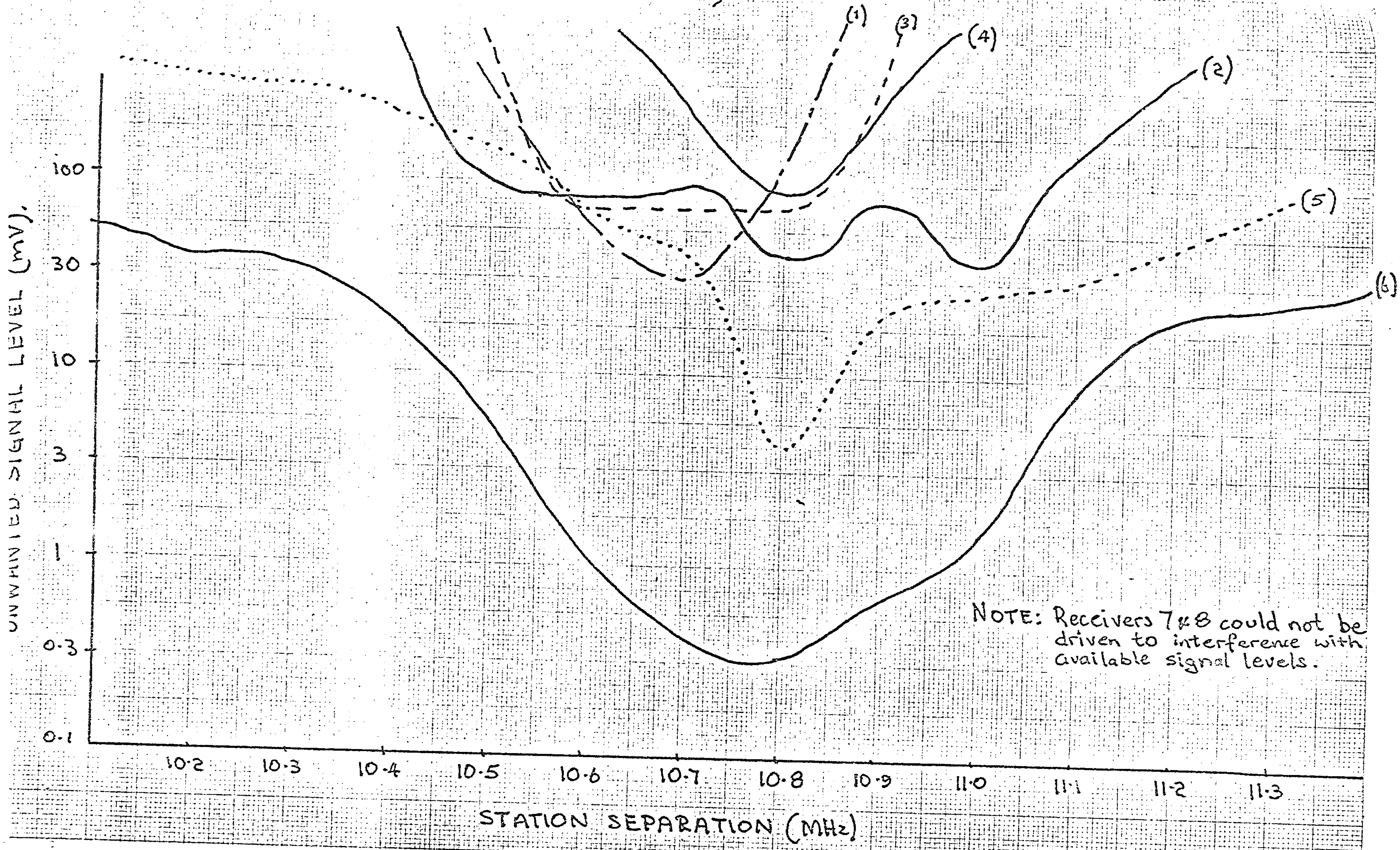


FIG. 6. SEPARATION vs INPUT LEVEL for Interference to Wanted Signal. (Wanted Signal 6dB greater and less than unwanted) (Receiver No 5)