Receiver Susceptibility Measurements Relating to Interference Between UHF Television and Land Mobile Radio Services. Project No. EEB-84-4

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EXECUTIVE SUMMARY

This report describes certain susceptibilities of a sample of 27 modern television receivers to interference caused by land mobile transmissions. This study does not address certain other factors, such as antenna discrimination and adjustment for picture quality, that may be taken into account in determining appropriate interference protection between the land mobile and television broadcast services.

In general, as the frequency of a land mobile transmitter approaches the frequency of a television station to which a receiver is tuned, interference to television reception becomes more pronounced. In the group of television receivers tested, "just perceptible" interference or worse could be noted in at least half of the receivers when an interfering signal equal in amplitude to the television picture carrier was operated at adjacent channel frequencies from 3 MHz below the television channel to 1 MHz above the television channel or in the image channel of the television receiver.

The reverse situation to the one described above also exists. A television transmitter operated in close proximity in frequency to a land mobile receiver can cause interference to land mobile operations. In the land mobile receivers tested, the amplitude of the undesired television signal necessary to produce a degradation in the land mobile signal had to be much larger, on the order of 70 to 90 dB greater than the desired land mobile signal.

The amplitude values of desired and undesired signals used to test the receivers are the actual values impressed on the antenna terminals of the receivers under test. These values may not be directly related to the ambient field strengths due to such factors as signal polarization and antenna directivity. The sample of television receivers was selected as a rough representation of models produced in 1984 and 1985.

It can be concluded from the levels of the signals necessary to cause interference that television receivers are much more sensitive to interfering land mobile operations than land mobile receivers are to television operations.

INTRODUCTION

The demand for radio frequencies used for land mobile communications is great. Solutions which have been implemented to some extent to help relieve the problem are sharing frequencies allocated for television broadcast with other services and reassigning television channels for other use. For example,

television channels 14 through 20 are now shared with the Private Land Mobile (Part 90) and the Public Mobile (Part 22) Radio Services and former television channels 70 through 83 have been reassigned for other uses including the Land Mobile Radio Services.

This project was started in order to develop data that would characterize the responses of this sample of modern television receivers to land mobile type interfering signals. This data base could then be used in making decisions when questions arise concerning the sharing of frequencies between the Television Broadcast and the Land Mobile Radio Services.

Based on past experience in testing television receivers, it was known that television receivers are generally most susceptible to interference caused by transmitters operating cochannel to the television station and by transmitters operating on upper and lower adjacent channel frequencies. Another television receiver susceptibility of some concern occurs on the frequencies which are images to the desired television channel.

This report concentrates on these four basic types of interference to television reception that can potentially be caused by land mobile radio operations.

SAMPLE SELECTION

First, a sample of television receivers to be tested had to be selected. It was desired that the test sample be roughly representative of a cross section of new television receivers (circa 1984 and 1985) currently being bought and used by consumers. The test sample was composed of the following types of receivers:

11 Color, Mechanical Tuners
12 Color, Electronic Tuners
4 Black and White, Mechanical Tuners

The land mobile test sample was composed of the following UHF transceiver types:

2 Mobile (450 to 470 MHz)
1 Hand-held portable (450 to 470 MHz)

TEST PROCEDURE, LAND MOBILE TO TELEVISION INTERFERENCE

The procedure used in testing the television receiver sample was identical for all four interference types. In general, an interfering signal simulating a land mobile transmission was added to a desired television signal. The level of the desired signal and the level of the undesired signal necessary to

produce "just perceptible" interference in a victim receiver were recorded. The specific desired and undesired frequencies used for each interference type are given in Table 1.

First, a desired television signal was generated locally using television test signal generation equipment as shown in Figure 1. The video modulation consisted of a 50 IRE flat field with color burst and the aural carrier was unmodulated. This will be referred to as the "normal" desired television test signal.

As can be seen in Figure 1, some flexibility in generating the desired television test signal was allowed with regard to the type of video and audio modulating signals. This flexibility allowed the observers to explore the effects of different television modulation on the observed interference patterns. The "normal" television test signal was used for nearly all reported data, however, on the few occasions when color effects were noted, full field color bars were used for the desired video modulation.

It was only necessary to use full field color bars as the desired modulation when doing the testing for the lower adjacent type interference. When the interfering frequency ranged between 580 and 578 MHz four receivers had to be tested using color bars as the desired modulation. When the interfering frequency was 581.67 MHz three receivers had to be tested using color bars as the desired modulation. The desired modulation was a 50 IRE flat field for all other instances.

Ideally, program modulation would have been used for the desired video in all test situations, but due to the constantly changing nature of program material it takes an observer much longer to determine "just perceptible" interference than if a constant test pattern is observed. In the past we have compared "just perceptible" interference to a 50 IRE flat field with "just perceptible" interference program material. The results of these observations were usually within plus or minus 4 dB with a tendency for the interference to be more observable in the flat field.

The level of the desired signal was controlled with a variable attenuator. For the purpose of these tests the levels of the desired picture carrier were -15, -35 and -55 dBm with the ratio of the picture carrier to aural carrier maintained at 10 dB. These are levels which could occur at the antenna terminals of a UHF television receiver being operated near a television transmitter (-15 dBm), within the principal community (-35 dBm) and near the grade B contour (-55 dBm).

The undesired signal, which was intended to simulate a land mobile station, was generated using a signal generator and could be modulated with an audio tone. By selecting modulated or unmodulated undesired signals the observers could see how the desired signal was affected. In general, an unmodulated undesired signal produces a regular beat pattern in the desired picture, which

is easy to observe. When modulation is applied to the undesired signal the regular beat pattern or herringbone is broken up and the visual effect is less noticeable. For all the data reported here an unmodulated undesired signal was used. This choice can be rationalized by considering the natural pauses in speech during which the interference will be most noticeable.

The level of the undesired signal could be varied continuously to a maximum of 0 dBm (1 milliwatt) using a variable attenuator calibrated to indicate the undesired signal level at the antenna terminals of the television receiver under test. This signal level is representative of the maximum land mobile signal levels likely to occur at a television receiver.

Both the desired and undesired signals were filtered to insure their purity. They were then combined in a summing network and connected to the UHF antenna terminals of the television receiver under test. A block diagram of the test setup is shown in Figure 1.

The frequency of the undesired signal was then stepped across the undesired channel in 14 steps, roughly spaced every 0.5 MHz. The exact frequencies, being dependent upon the interference type, can be found in Table 1. At each step the frequency of the undesired signal was adjusted a few kHz in order to enhance the visibility of the interference pattern. It can be seen on a spectrum analyzer that the television video produces spectral lines approximately every 15 kHz, the horizontal sweep frequency. If the interfering component is aligned with one of these spectral lines the visual effect of the interference is significantly increased. At each step the undesired signal level was adjusted until "just perceptible" interference, as determined by two expert observers (1), was noted on the television receiver under test. This value was recorded. This procedure was repeated for the three desired television signal levels of -15, -35 and -55 dBm and for each of 14 different undesired frequencies for each of four different interference types. This gives a total of 168 data points for each receiver tested.

TEST PROCEDURE, TV TO LAND MOBILE

Three UHF land mobile receivers were tested in a manner similar to that specified in EIA Standard RS-204-C (2) for adjacent channel selectivity and desensitization. The exception to this standard was that an off-the-air television signal was translated to obtain the desired frequency separation and used as the undesired signal.

Two cases were tested. In one case the frequency of the television station was above the desired land mobile channel and in the other the frequency of the television station was lower.

In the first case the frequency of the television station was chosen such that the lower edge of the television channel was first equal to the frequency of

the land mobile channel. The frequency of the television signal was increased in steps and the RS-204-C procedure was followed. The undesired signal rejection ratios are reported in Table 2.

In the second case the frequency of the television signal was chosen such that the upper edge of the television channel was first equal to the frequency of the land mobile channel. The frequency of the television signal was decreased in steps and the RS-204-C procedure was followed. The undesired signal rejection ratios are reported in Table 2.

RESULTS

The data collected for this report are presented as plots of undesired signal level versus frequency. The undesired signal levels are those necessary to produce "just perceptible" interference for each of three desired signal levels of -15, -35 and -55 dBm. The data plotted in Figures 2 through 5 represent the median values for all the television receivers tested and not a single "median" receiver. In Figure 6, lower adjacent channel data for five randomly selected receivers (labeled "A" through "E") are plotted along with the median line. This shows how typical individual receivers behaved in relation to the median value.

For the purposes of this report, we have assumed that the collected data apply in general to all the UHF television channels and not just the specific channels used. For this reason the frequencies shown on the plots have been normalized to show the lower edge of the desired channel as 0 MHz and other frequencies as offsets to this reference. In other words:

-6 to 0 MHz	Lower Adjacent Channel
0 to 6 MHz	Cochannel / Desired Channel
6 to 12 MHz	Upper Adjacent Channel
88 to 94 MHz	Image Channel

In most cases the level for "just perceptible" interference was for the conditions of a "normal" television test signal and a CW undesired signal. In a few cases color bars were substituted for the 50 IRE flat field used for the desired signal modulation. This was done only when the undesired signal produced color effects, i.e. loss of color, in the desired picture and resulted in greater desired signal to undesired signal (D/U) ratios than could be obtained using the "normal" television test signal. This occurred in five receivers when the lower adjacent frequency band was the undesired band and only for the tested frequencies between -6 and -4 MHz inclusive.

It was observed in making these tests that an unmodulated undesired signal was generally easier to observe than a modulated undesired signal. This is because the frequency modulation breaks up the more stable beat pattern which is normally observed for a CW signal. This makes the interference harder to

see and does not include effects from land mobile radios such as pauses in modulation and operations with on-off signals.

In the past it has been theorized that the image channel response is equal to the cochannel response plus the image rejection. For television receivers with accessible tuner outputs, the image channel rejection can be measured by injecting a signal at the image frequency and measuring its attenuation at the tuner output. This was done for 13 television receivers and the results are presented in Figure 7. Figure 7 is a graph of image rejection versus image channel frequency. Each plotted line represents data collected for a single receiver. From this graph it can be seen that the median value for image rejection is approximately 50 dB and is relatively flat across the image channel. Because of overlap, 13 separate lines are not seen. If 50 dB is added to each image median point in Figure 5, the curves thus produced will be very close to the observed cochannel median points of Figure 3. The agreement is generally within 5 dB across the channel for each desired level.

Impairment of the desired television picture rather than the sound was the dominant form of interference observed in conducting these tests. Audio interference was noted on some receivers, especially at undesired frequencies 4.5 MHz below the desired channel picture carrier. This frequency is an "image" of the desired aural carrier at 4.5 MHz above the desired picture carrier. For all cases of "just perceptible" interference reported here, picture impairment was used as the criterion. This was because the picture degradation was observed before audio impairment was apparent.

The following statements are made with reference to the median data plotted for each interference type:

1. Lower Adjacent Channel Interference, see Figure 2: A D/U ratio ranging from approximately 0 to 10 dB will produce "just perceptible" interference over the lower adjacent channel, from about -3 MHz to -.25 MHz. At approximately -3 MHz the D/U ratio quickly becomes negative. The changing interference immunity may be useful in some situations. For example, higher powered base stations could be placed at frequencies where the interference rejection is greater.

2. Cochannel Interference, see Figure 3: A D/U ratio of about 60 dB will produce "just perceptible" interference or worse from about 1 MHz above the lower channel edge to about 1 MHz below the upper channel edge. At the Grade B contour (desired level of -55 dBm), the D/U ratio is about 65 dB in the most susceptible frequencies within a desired channel. The most susceptible frequencies occur between about 1.5 and 2 MHz above the lower channel edge.

3. Upper Adjacent Channel Interference, see Figure 4: A D/U ratio for "just perceptible" interference is 0 dB or less past the first 2 MHz of this band. This again shows that the upper adjacent land mobile

operations could be planned that exploit the frequency dependence of television receiver immunities.

4. Image Interference, see Figure 5: This appears to be analogous to cochannel interference with the image channel rejection characteristics, due to the shape of the IF bandpass, of the television receivers added (Figure 7). D/U ratios to produce "just perceptible" interference range from about 0 to 15 dB between 89 and 93 MHz.

At frequencies adjacent to a desired television channel, from approximately 3 MHz below the desired channel to approximately 1 MHz above the desired channel, an interfering signal equal in amplitude to the television signal will produce "just perceptible" interference or worse in at least half of the television receivers tested.

In the land mobile receivers tested, the amplitude of the undesired signal necessary to produce a degradation in land mobile reception had to be much larger than the land mobile signal, on the order of 70 to 90 dB greater. In other words the land mobile receivers are much more tolerant of undesired signals in close frequency proximity to their operating frequency than television receivers.

The data in the curves presented here can be used with other data in planning for compatible use of land mobile service with UHF television services.

TABLE 1

Actual Undesired Frequencies (MHz) Used for Each Interference Type (1)

Image (2)	Cochannel (2)	Upper Adjacent (3)	Lower Adjacent (3)
858.00	764.00	590.00	578.00
857.50	764.50	590.50	578.50
857.00	765.00	591.00	579.00
856.75 (4)	765.25 (5)	591.25 (6)	579.50
856.50	765.50	591.50	580.00
856.00	766.00	592.00	580.75 (7)
855.50	766.50	592.50	581.00
855.00	767.00	593.00	581.67 (8)
854.50	767.50	593.50	582.00
854.00	768.00	594.00	582.50
853.50	768.50	594.50	583.00
853.00	769.00	595.00	583.50
852.50	769.50	595.50	583.75 (9)
852.00	770.00	596.00	584.00

NOTES:

(1) The frequencies shown were adjusted a few kHz to enhance the visibility of the interference pattern.

(2) Channel 63 was the desired television channel, 764 to 770 MHz.

(3) Channel 33 was the desired television channel, 584 to 590 MHz.

(4) Image frequency of the desired channel's picture carrier.

(5) Desired channel visual carrier.

(6) Visual carrier frequency in the upper adjacent channel.

(7) The desired visual carrier minus 4.5 MHz, (the desired aural carrier is at +4.5 MHz).

(8) The desired visual carrier minus 3.58 MHz, (the desired aural carrier is at +3.58 MHz).

(9) Aural carrier frequency of the lower adjacent channel.

TABLE 2

D/U Ratios in dB for Land Mobile Receivers
Measured in Accordance with EIA Standard RS-204-C (1)
for Adjacent Channel Selectivity.

(The undesired signal is a television signal adjacent in frequency to the desired land mobile channel. The reference level for the television signal is the level of the visual carrier.)

Land Mobile Receiver	Television Signal Frequency Offset (MHz)*						
	0	+.25	+.50	+.75	+1.0	+2.0	+3.0
A	-83	-85	-98	-105	-109	>-116	>-116
B	-80	-83	-84	- 91	- 92	- 95	- 90
C	-88	-92	-94	- 91	- 92	- 97	- 95

Land Mobile Receiver	Television Signal Frequency Offset (MHz)**						
	0	-.25	-.50	-.75	-1.0	-2.0	-3.0
A	-79	-84	-89	-91	-79	-103	-106
B	-69	-78	-81	-88	-88	- 90	- 92
C	-77	-82	-87	-93	-96	-103	-107

*: The undesired television signal is higher in frequency than the desired land mobile channel. The reference or "0" frequency is when the frequency of the lower edge of the television channel equals the land mobile frequency.

**: The undesired television signal is lower in frequency than the desired land mobile channel. The reference or "0" frequency is when the frequency of the upper edge of the television channel equals the land mobile frequency.

REFERENCES

1. Advanced Technology UHF Receiver Study Part I, Receiver Performance Measurements by H. Davis, FCC/OST R-83-1, February, 1983.

2. Minimum standards for Land Mobile Communications FM or PM Receivers, 25 to 947 MHz, EIA Standard RS-204-C, January, 1982.

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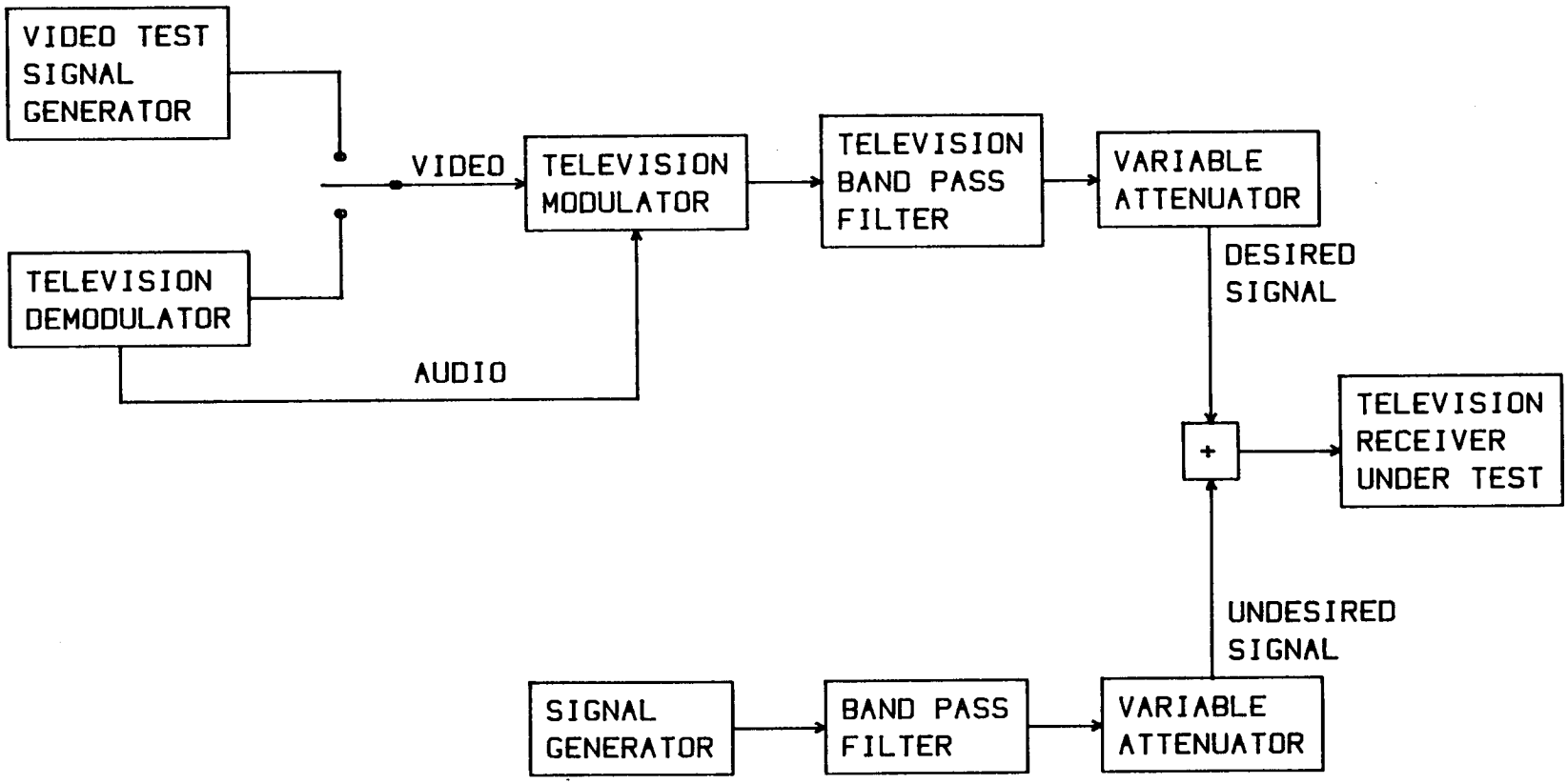

Figure 1. Block diagram of the equipment setup used in testing the television receivers.

Figure 2. Lower adjacent medians for indicated desired levels.

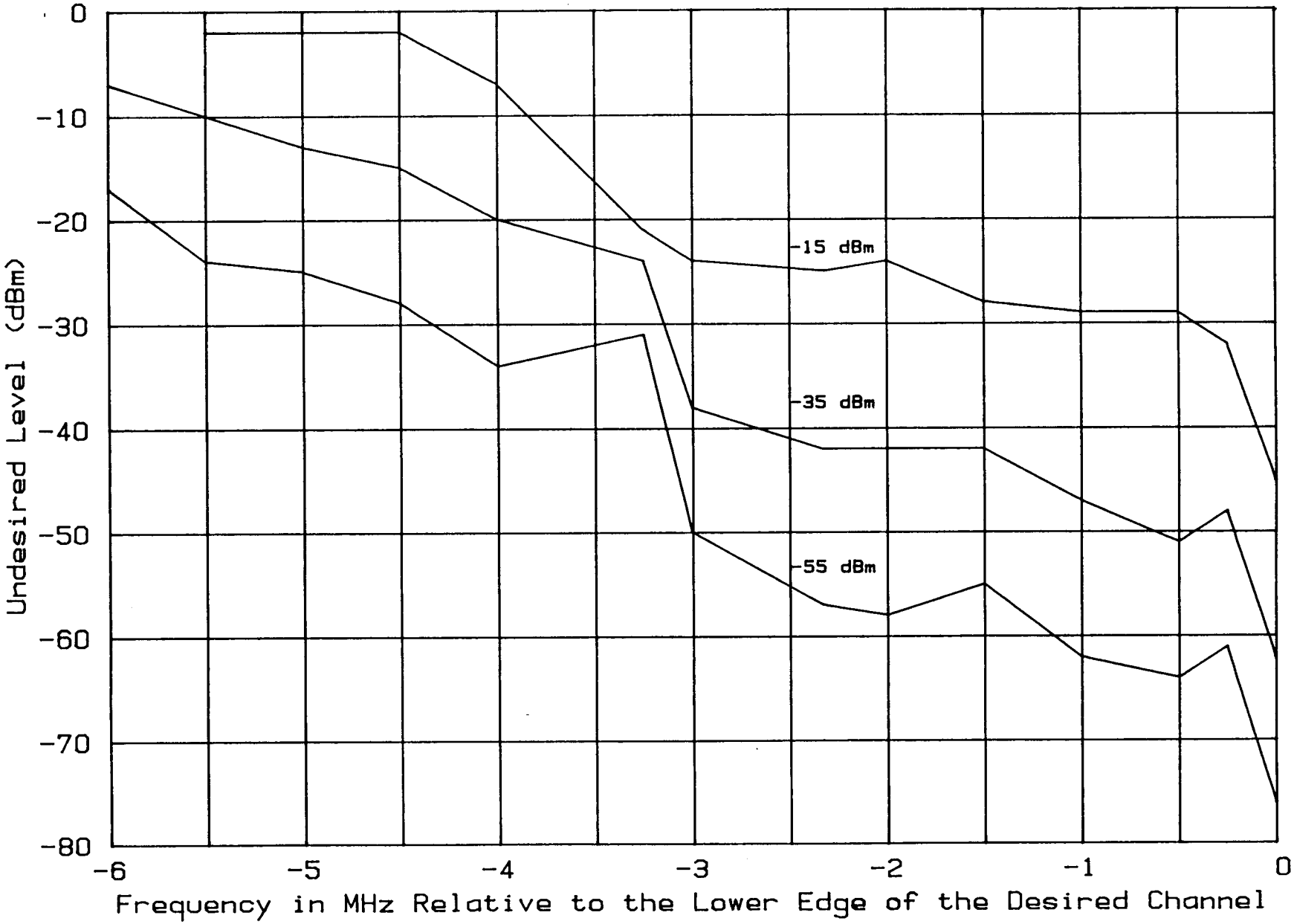

Figure 3. Cochannel medians for indicated desired levels.

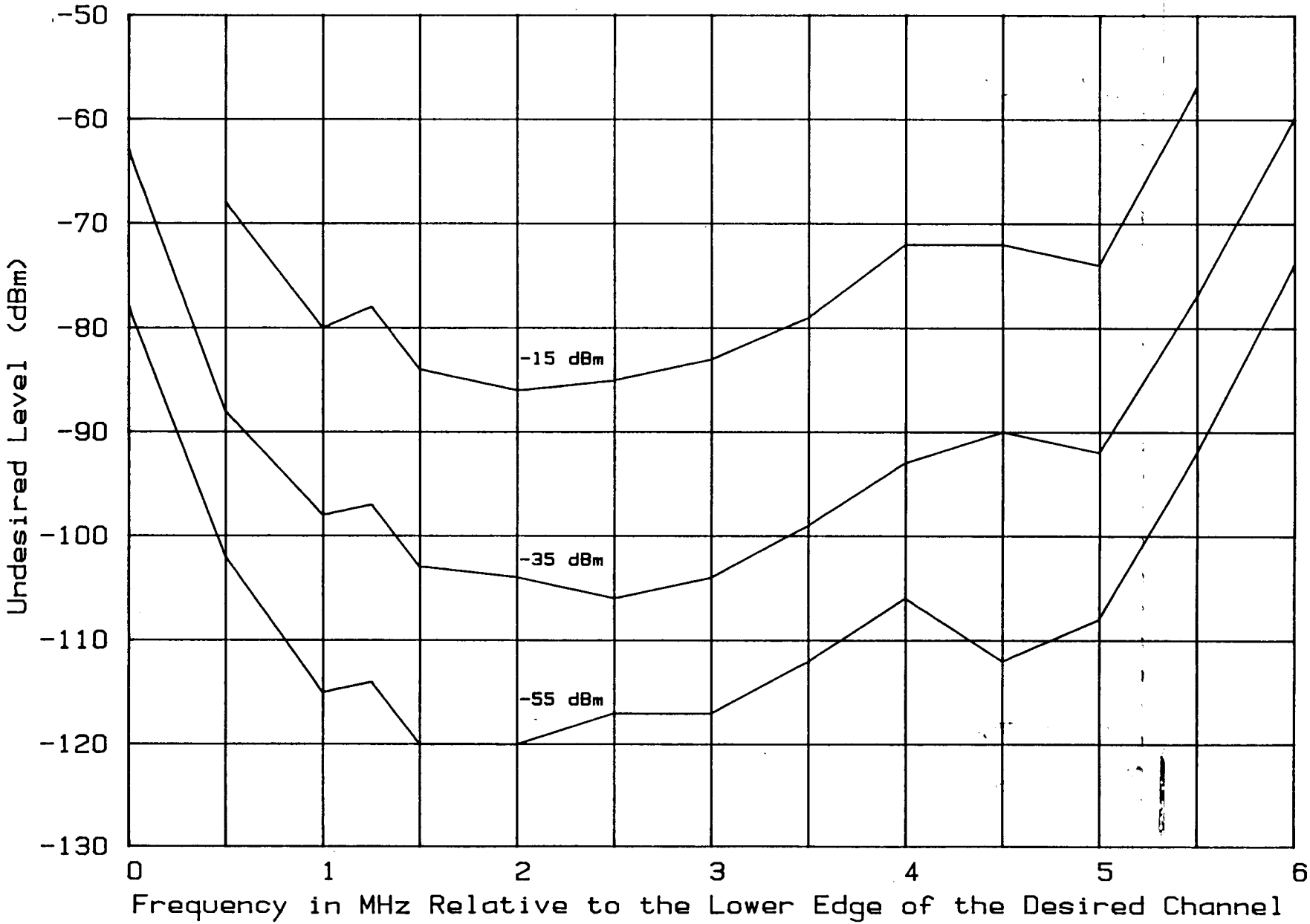

Figure 4. Upper adjacent medians for indicated desired levels.

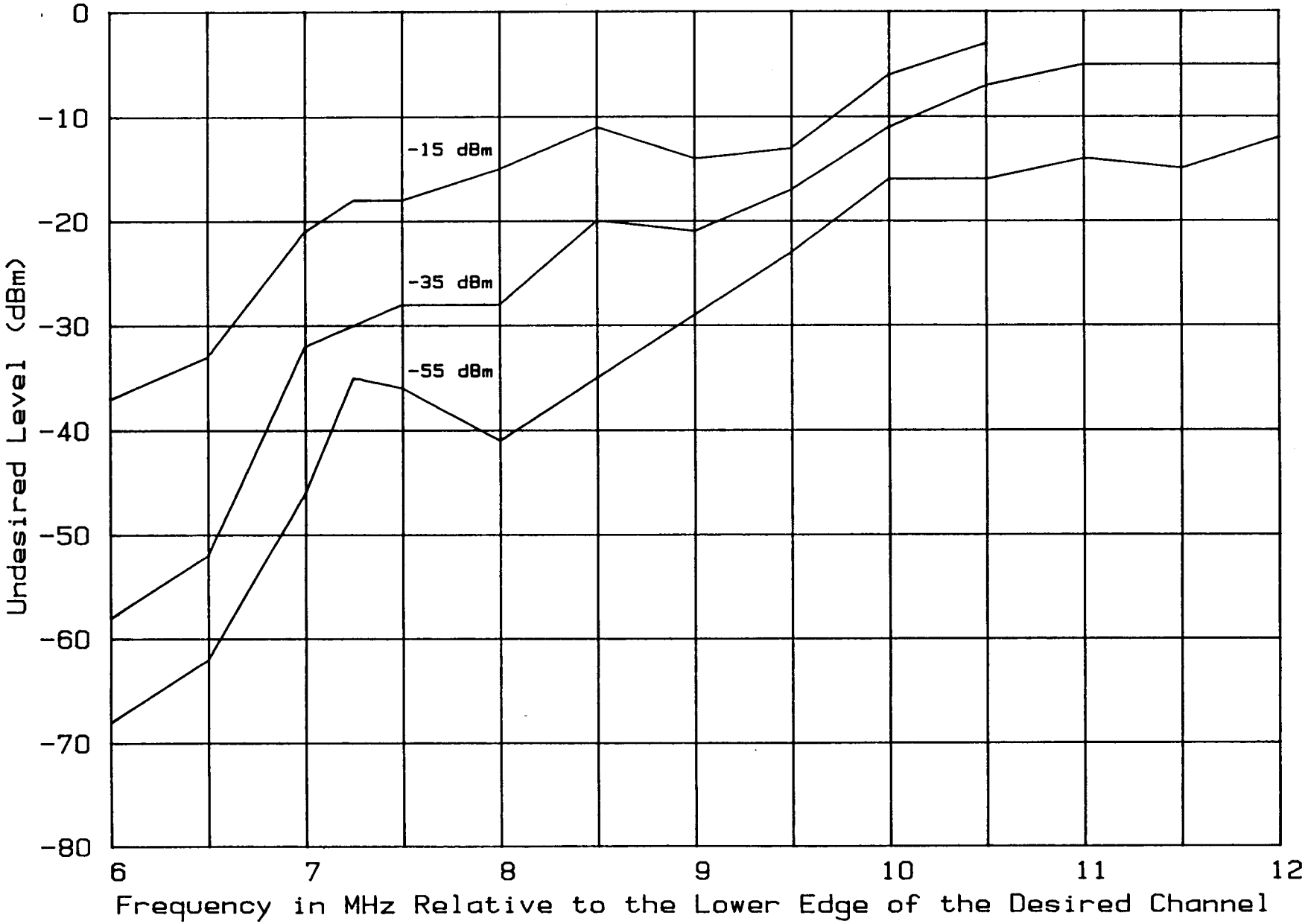

Figure 5. Image medians for indicated desired levels.

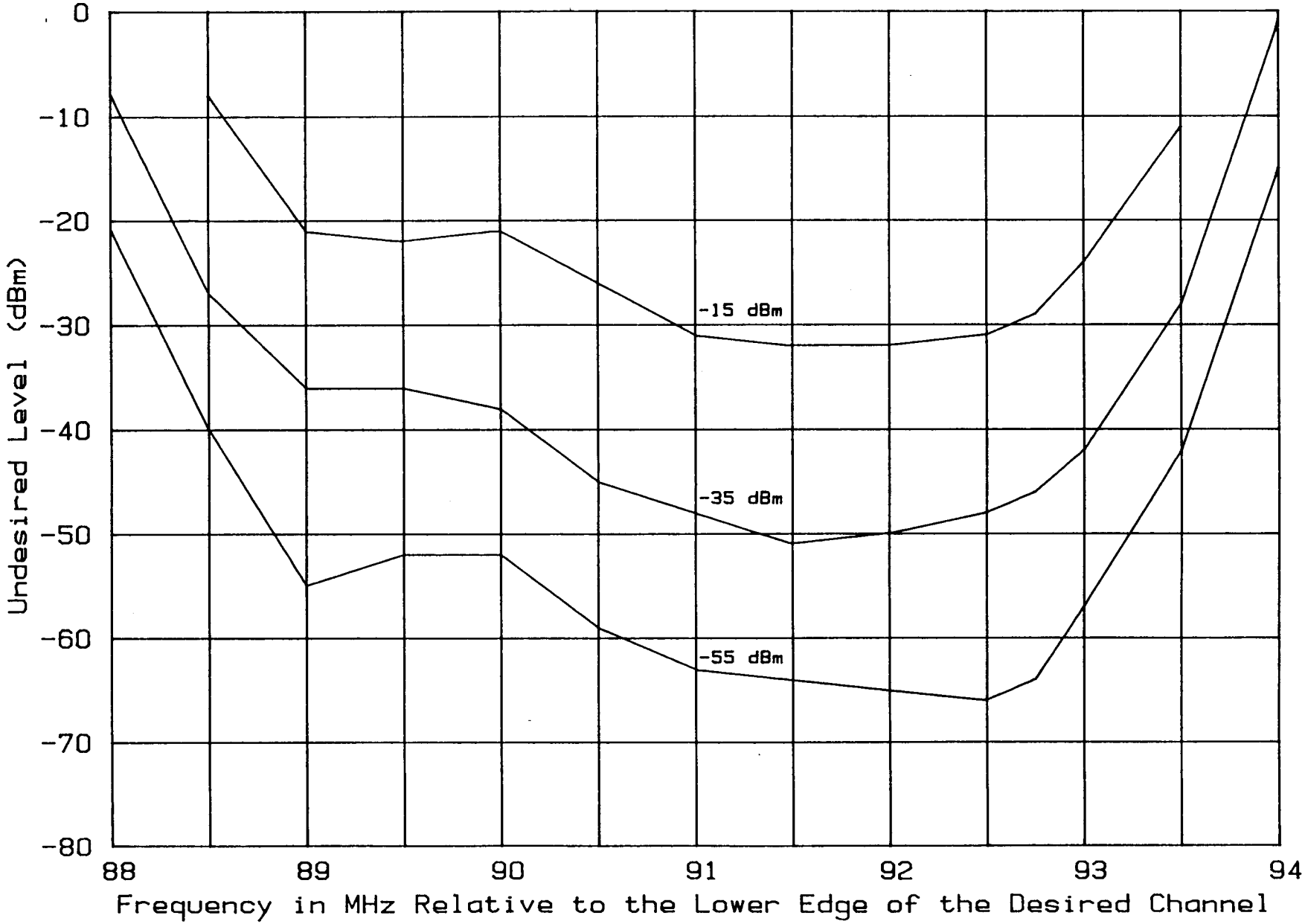

Figure 6. Lower adjacent median and 5 Individual Receivers.

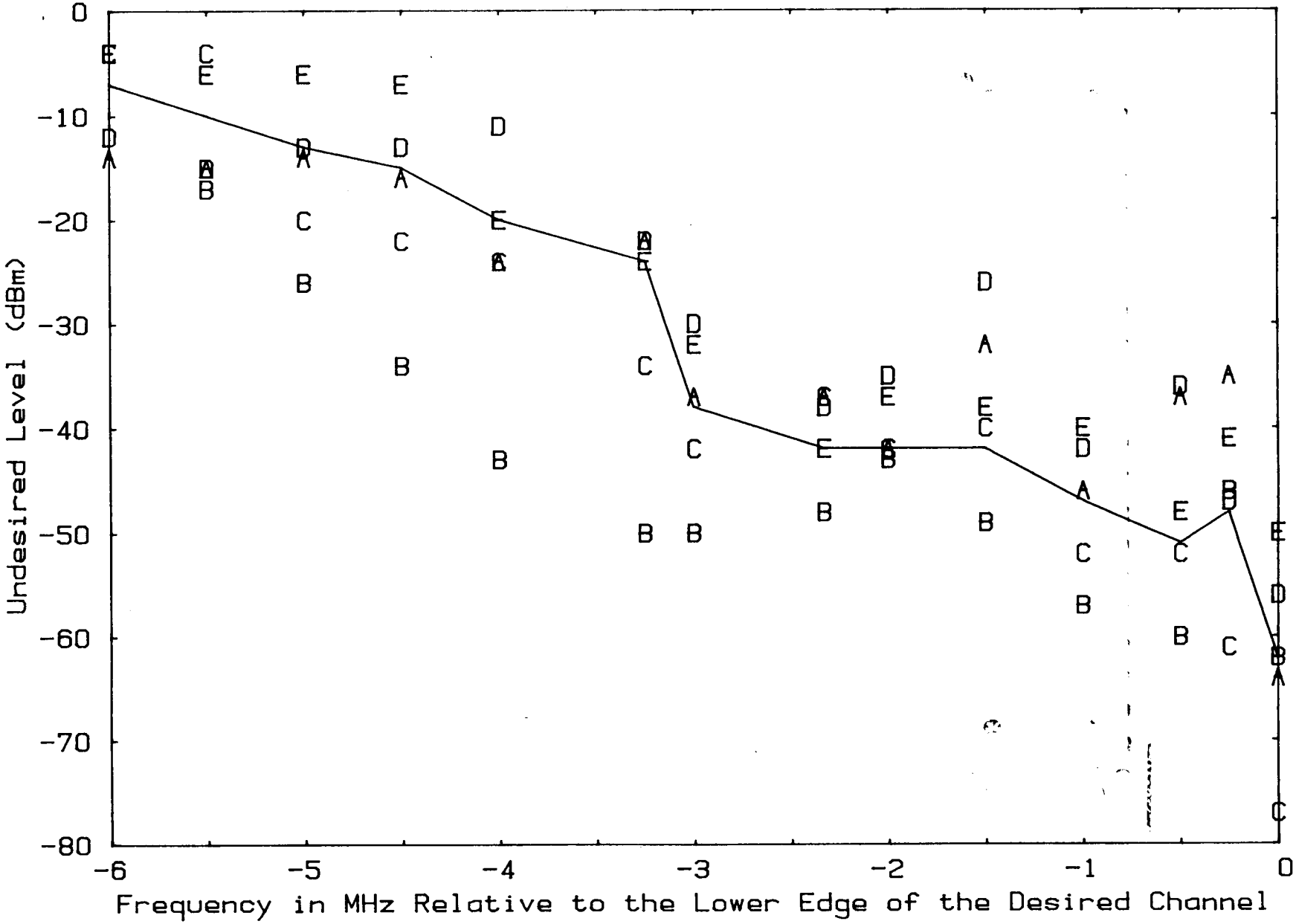

Figure 7. Objective image channel rejection for 13 receivers.