FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF CHIEF ENGINEER
LABORATORY DIVISION

A STUDY OF THE CHARACTERISTICS OF TYPICAL TELEVISION RECEIVERS RELATIVE TO THE UHF TABOOS

Project Number 2229-63

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SUMMARY

This report details the study and measurements made on forty-seven contemporary TV receivers with respect to their susceptibility to interference on UHF created by the signals from certain combinations of undesired UHF channels. Protection against this type interference is provided for by the FCC in the allocation of UHF channels, making use of mileage separation restraints that have become known as "UHF Taboos."

Included in this report are TASO picture gradings as a function of the input signal level when receiver noise (snow) was the only source of interference.

INTRODUCTION

Section 73.610 of the Federal Communications Commission's Rules and Regulations sets forth minimum mileage separations for TV stations assigned to the same channel and for those assigned to adjacent channels. Table IV, Section 73.698, lists the UHF TV channels and additional minimum mileage separations that must be maintained between UHF stations having certain specified channel relationships. All of these assignment limitations were adopted by the Commission in April 1952 and noted in its Sixth Report and Order in Dockets 8736, 8975, 8976, and 9175.

Those mileage separations formed the basis for the table of TV assignments by cities (Section 73.606) which was adopted in that order and have been used in subsequent modifications of that table. One of the main objectives of that table was to minimize the interference with a desired signal created in a TV receiver when more than one TV signal existed in the area of reception.

Minimum mileage separations, except those that are provided as protection against co-channel signals, are related to the interference susceptibility characteristics of receivers. Among the pertinent receiver characteristics that were considered in establishing the mileage separations for UHF TV channels are adjacent channel response, sound and picture image ratios, IF beat response, strength of local oscillator radiation, and intermodulation distortion. The mileage separations established as minima for specific UHF TV channel assignments have come to be known as the "UHF Taboos." Column headings (2)-(7) in the table of "taboos" (Table IV, Section 73.698, FCC Rules and Regulations) give the particular receiver characteristics for which the mileage protections are being provided.

Considerable criticism has been directed at these UHF mileage restraints since their adoption. It has been asserted that the subsequent improvements in receiver design make the "taboos" needlessly restrictive and therefore wasteful of spectrum space. This was countered, of course, by arguments that improvements were not made in those areas of design which affected the interference susceptibility of the receiver. However, some critics feel that the improvements in the desired areas were not made because the protections ("taboos") built into the assignment plan had eliminated the need!

In an effort to obtain quantitative information as to the validity of the existing "UHF Taboos," it was decided that the Commission's Laboratory should conduct a series of suitable tests on contemporary TV receivers. The data obtained should be that which could be used to re-examine the mileage constraints placed on channel assignments in UHF TV. As a side benefit, a file on TV receiver characteristics would be available for future use by the FCC staff. Such data have not been readily available in the past.

In March 1972, the Laboratory developed a work plan for such a project, after discussions and consultations with the Technical and the Research Divisions of the Office of Chief Engineer, the Rules and Standards Division of the Broadcast Bureau, and the Industrial and Public Safety Rules Division of the Safety and Special Radio Services Bureau. This plan proposed the purchase of approximately fifty contemporary TV receivers and necessary additional test equipment above that already owned by the Commission. Interference susceptibility tests pertinent to the "UHF Taboos" would be carried out on each receiver at desired signal levels ranging from those existing in fringe areas to those found in metropolitan areas.

RECEIVER SELECTION

Considerable thought was given to the selection of the receivers to be tested. It was highly desirable that they constitute a representative sample of TV receivers available for purchase in the United States. However, it was equally important that the sample should include those engineering design features affecting interference performance that might be expected to be common in the next few years.

The initial basis of the selection came from a survey by the Research Division, Office of Chief Engineer, of the receiver sales in the U.S., based upon data covering the past several years. The number of receivers to be purchased from each manufacturer was to approximate his share of the total sales. Choice of individual models from any one manufacturer was to be dictated by their relevant circuitry. Relevant circuit features were to include front end circuitry, varactor tuning, solid state components, number of IF stages, etc., in fact any design feature that might affect the interference susceptibility.

In following such guide lines, "top-of-the-line" models were selected only when the desired engineering design (circuit) features were not available on the lower priced models. However, care was exercised so that the models chosen were not special or limited production units that could bias our sample, although our choice of receivers did include eight with varactor tuning of the UHF channels. This number is larger than the true sales proportion of models containing that feature, but it was considered desirable to provide an adequate sample of this new, and probably important, tuning system.

Consideration of the economics of the study and the time involved for completion of contemplated tests led to a restriction on the sample size, forty-seven receivers. Ten sets would be monochrome and the rest would be color, roughly corresponding to the projected ratio of monochrome to color receivers in use in 1975 as indicated by the market survey mentioned previously. (Greater detail of the sample selection is given in Laboratory Project Report 2229-51, May 21, 1972.)

Although we acknowledged that the single sample of receivers selected was not random, we believe Report 2229-51 fully justified the selection method we chose. Furthermore, the use of the market survey permits a weighting of the sample that gives more assurance to results obtained by statistical analysis of the data. If market conditions change, new weighting factors can be used for data examination.

The receivers were purchased by the Commission in mid 1972 from distributors or dealers, except in the few cases where the manufacturers had no outlets in the area. When this occurred, the receivers were obtained directly from the manufacturers. All receivers were delivered in unopened factory cartons and no internal adjustments or alignments were attempted. In case abnormal operation or lack of function obviously affecting test results occurred, the receivers were taken to authorized factory repair centers for correction of defects. The exception to this procedure was for tube failures, in which case replacements were made at the Laboratory. These purchase and maintenance procedures were adopted to assure normal performance from the receivers tested, and to enhance the statistical validity of the test results obtained from the sample.

INTERFERENCE CRITERION

The information from this study is to be used in examining the present UHF TV allocation plan, considering the interference created to the desired signal by one or more undesired signals as a result of receiver characteristics. If the results warrant, a new plan (mileage separations) may be proposed. Because the interfering signals involved in such plans will exist nearly 100% of the time, it was considered that the significant criterion is perceptible interference during program reception. While there may be some interest in studying other levels of impairment, such levels are probably of only academic importance.

Perceptible interference to the picture and to the sound do not usually occur at the same levels of the undesired signal. For this study, only one level was recorded; the lowest level of the undesired causing interference of any nature. In almost all cases, interference to the picture occurred first.

CATEGORIES OF UNDESIRED CHANNELS

The purpose of this project was to determine the interference susceptibility characteristics of contemporary UHF TV receivers. Characteristics of the sample investigated include the interference produced by the following types of undesired channel TV signals:

- Adjacent channels.
- Image frequency channels.
- Channel combinations creating intermodulation (two undesireds).
- Channels creating cross-modulation.
- Channels differing in frequency by the IF of the receiver.

Some comment on these five categories, as they relate to the "taboo table," Table IV of Section 73.698, appears justified. (The actual channel numbers involved are detailed in a following section of this report.) First, it will be noticed that co-channel interference was not investigated in this study; it is a transmission problem, independent of receiver characteristics. Image frequency channels appear in Table IV as two separate columns, sound and picture image. Cross-modulation from a single undesired channel, a category that was not specifically protected against by the assignment plan, is included in our study to provide information that may be of possible use.

The final category covers interference from TV signals in two undesired channels differing in number by seven or eight, as well as that from one undesired channel seven or eight channels removed from the desired. In both cases, the interference is created by spurious receiver products whose frequencies fall in the IF channel of the receiver. It might be noted here that the mileage separation given in the "taboo table" for a spacing of seven channels was designed to protect against interference due to local oscillator signals radiated by receivers. The interference from this source was felt to be more significant than that from the seven-channel IF beat. Nevertheless, seven-channel IF beat interference was included to make this study more complete. (Field strength values of the local oscillator radiation from the forty-seven receivers used in this study are given in Project Number 83059.)

THE TEST SETUP

It was decided that the desired and undesired signals for this study should contain actual off-the-air video and aural program material. Each signal was to differ in content but only color video would be used. To accomplish this purpose, the UHF signals would be provided by VHF-UHF translators receiving programs from three local network-affiliated stations. The translator output frequencies would be readily switchable to the channels required by the test combinations. Since translators having desired characteristics are not standard items, specifications were drawn up and presented for competitive bidding. The contract was awarded to Rodelco, Deer Park, New York.

The three translators were required to have the following channel capabilities:

Translator A:	Input on Channel 7, output on Channel 34.
Translator B:	Input on Channel 9, output switchable to Channels 36, 39, 40, 41, or 42.
Translator C:	Input on Channel 11, output switchable to Channels 35, 37, 38, 48, 49, or 50.

The choice of VHF Channels 7, 9, and 11 as inputs was made to satisfy the requirement for different program material at the output of each translator; the three channels selected carry programs from the three nationwide TV networks.

Selection of the UHF output channels required careful consideration. No suitable shielded laboratory space was available, but interference from direct pickup of local UHF TV signals by the receivers under test had to be minimized. The complete criteria for channel selection were as follows:

- Channels of interest were those required by the five categories of interfering signals listed previously in this section.

- No channel could be co-channel with, or adjacent to, the channel assigned to an existing or planned UHF station in the Laboratory (Washington-Baltimore) area.

- No channel could be seven channels higher than an existing or planned UHF assignment in the Laboratory area. This avoids co-channel interference from the local oscillator radiation of a nearby receiver tuned to such assignment.

- No channel could be fourteen or fifteen channels below the channel of an existing or planned UHF assignment in the Laboratory area. This protects against image interference from the local area assignment.

- Channels should be in the central portion of the UHF TV band, where the results of the tests are expected to be typical of the whole band.

The allocation of channel capability to the three translators took into account the requirement for simultaneous availability of those combinations of channels called for in the test plan.

Technical specifications for the translators had been established by considering:

the power output needed for full range receiver testing,

the leakage and radiation acceptable from the transmitters and connecting cables,

the need for a low level of intermodulation and other spurious signals,

and the desire that the quality of the translated signals not be detectably different, to a viewer, from the VHF input signals.

The performance of the translators was typically:

- Power Output: One watt of rf at sync tips for an input signal level of 1 mV across 50 ohms. The sound carrier was within the minus 7 to 10 dB range specified by the Rules and Regulations and was primarily dictated by the off-air ratios of the VHF signals as received at the Laboratory.

- Intermodulation and Spurious Signals: In channel: the 920 kHz beat at least 46 dB below sync tip level--no other significant signals present. Out of channel: signals at 4.5 MHz below the visual carrier and 4.5 MHz above the aural carrier ranged from 70 to 50 dB below sync tip level--other signals within the test range used were at least 80 dB below sync tip level. (The out of channel performance included an additional band pass filter.)

- Signal/noise: This ratio was measured as 40 dB.

- Frequency response: For a CW input signal constant in level but varied in frequency from a few MHz below to a few MHz above the channel, total output amplitude variations were no greater than 2 dB in the channel, with slope attenuation to 30 dB when the signal was 3 MHz removed from the edges of the channel.

- Frequency Control: The frequency of the visual carrier in each channel was crystal-controlled and was maintained within $\pm$1 kHz of the nominal value; the aural carrier retained the 4.5 MHz frequency separation from the visual carrier that existed in the input VHF signal.

- Radiated signals (undesirable since there would be some receiver response to them and such signals could differ from the intended signals conducted by coaxial cables): The maximum values of radiated fields averaged less than 1.5 mV/m at 3 meters distance. This level was sufficiently low that no effects were observed which would limit the validity of the test results when the up-converter of the translator was separated from the receivers' test area as detailed in the following paragraph.

In Figure 1, a block diagram of the complete test setup is given. Each translator is composed of a down-converter (to standard U.S. TV receiver IF) and an up-converter (to the desired UHF channel). Physically, the down-converters were located in the test area to facilitate adjustments of level and frequency, while the up-converters were located in a room separated from that area by a heavy concrete floor. The latter location reduced the level of the output signals radiated into the test area by the up-converters.

The tunable bandpass filters on the output of each translator are Telonic Model 640-1-5EE1, having a 3 dB bandwidth of 1%.

Both the desired and undesired attenuators are made by Weinschel. These 50 ohm units, Models 940-14, are continuously variable from 6 to 120 dB. They were fitted with special dials providing direct indication of the signal level at the receiver under test in dBm (decibels referenced to one milliwatt).

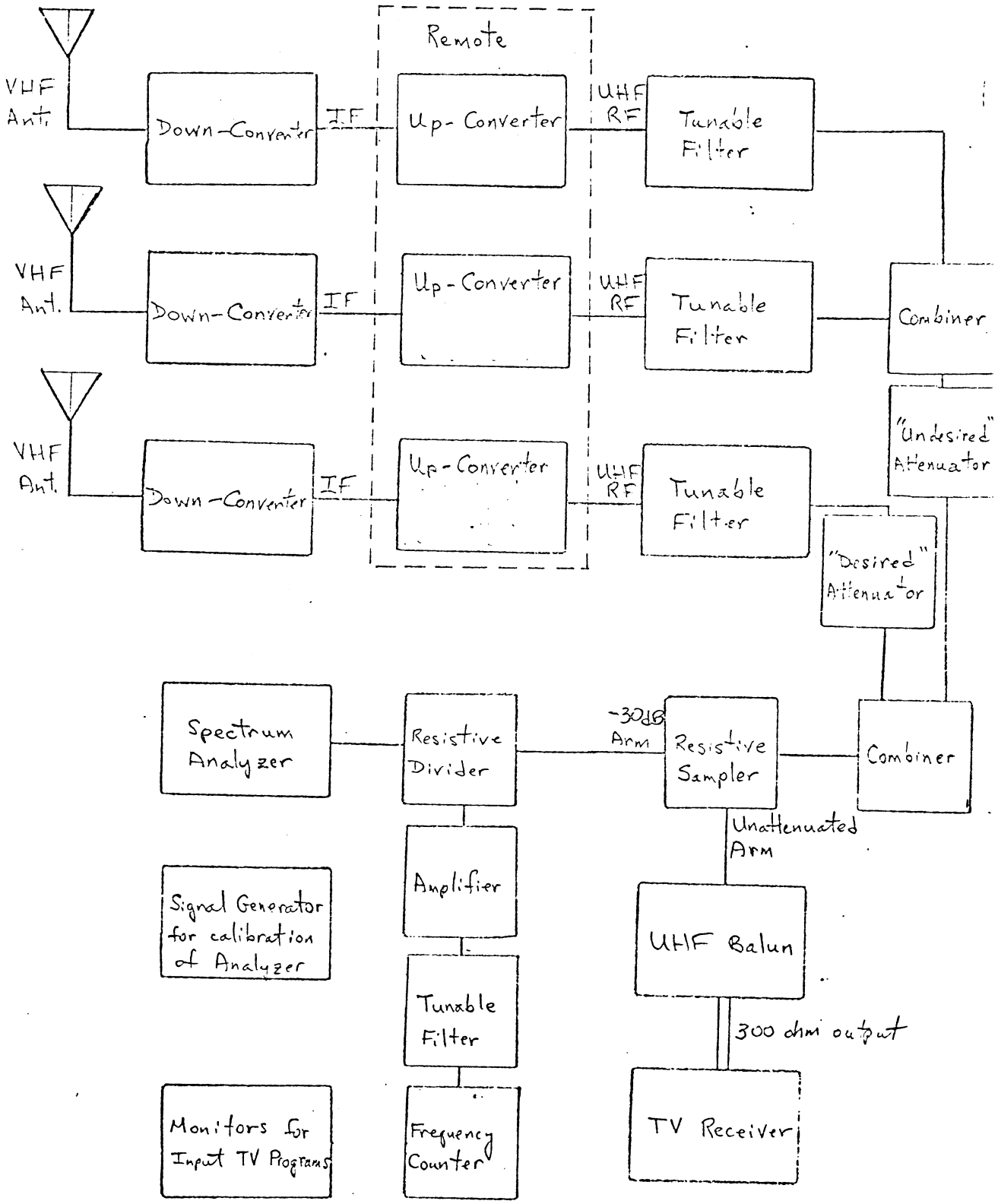

Remote
VHF Ant.
Down-Converter
IF
Up-Converter
UHF RF
Tunable Filter
VHF Ant.
Down-Converter
IF
Up-Converter
UHF RF
Tunable Filter
Combiner
"Undesired" Attenuator
VHF Ant.
Down-Converter
IF
Up-Converter
UHF RF
Tunable Filter
"Desired" Attenuator
Spectrum Analyzer
Resistive Divider
-30dB Arm
Resistive Sampler
Combiner
Unattenuated Arm
Amplifier
Signal Generator for calibration of Analyzer
UHF Balun
Tunable Filter
300 ohm output
Monitors for Input TV Programs
Frequency Counter
TV Receiver

FIG. 1

The combiners were constructed at the Laboratory, using design material given in the article, "A Wide-Band Hybrid Ring for UHF," page 81, Proceedings of the I.R.E., 1953. These units match two 50 ohm sources to a 50 ohm load. Although there is a 4 dB loss, the impedance matching provided is essential. In addition, 30 to 35 dB isolation is provided between input signals. The sum of this isolation and that provided by the tunable filters serves as adequate protection against the possibility of intermodulation due to coupling between the outputs of the translators.

A resistive sampler receives the combined desired and undesired signal(s) and feeds a Measurements UHF Balun, Model U2A, from its unattenuated output. Previous tests have shown this balun to provide an excellent impedance match to 300 ohms (the nominal input impedance of the TV receiver) and to have less than 0.5 dB loss at all frequencies used in these tests. Its output was fed to the receiver under test through a 3 inch length of 300 ohm twin lead and a "clothes-pin" connector. This connector was used for the convenience it provided during the actual test procedure, although it introduced an additional loss approaching one dB. Except for this balanced output, all connections in the test setup were by 50 ohm coaxial cables.

The attenuated output from the resistive sampler proceeds to a resistive divider which feeds a spectrum analyzer and a frequency counter for signal monitoring purposes. TV displays of the VHF input "pictures" were also provided to ascertain that color video material was present on the undesired signals. The desired signal, viewed on the receiver under test, was judged for interference only when it and the undesired signal(s) were in color.

It is to be emphasized that considerable effort was expended in optimizing the equipment's electrical performance and physical placement, so that the resulting TV pictures were as high in quality and as free from undesired interference as possible.

CHANNEL RELATIONSHIPS IN THE INTERFERENCE TESTS

In a previous section of this report, the broad categories of TV interference investigated in this study were listed. In the table below, the channel relationships of the interfering signals are detailed for each test:

Test No.	Predicted Type of Interference	Undesired Channel Number(s) (referenced to the Desired)
1	Intermodulation	+2, +4
2	Cross Modulation	+2
3	Intermodulation	-2, -4
4	Cross Modulation	-2
5	Intermodulation	+3, +6
6	Intermodulation	-3, -6
7	Image, sound	+14
8	Image, picture	+15
9	Intermodulation	+4, +8
10	Cross Modulation	+4
11	Intermodulation	-4, -8
12	Cross Modulation	-4
13	Intermodulation	+8, +16
14	IF Beat, single undesired	+8
15	Intermodulation	-8, -16
16	IF Beat, single undesired	-8
17	Adjacent Channel	+1
18	Adjacent Channel	-1
19	Cross Modulation	+16
20	Cross Modulation	-16
21	IF Beat, two undesireds	-4, +4
22	IF Beat, two undesireds	-4, +3
23	Intermodulation	+1, +2
24	Intermodulation	-1, -2
25	IF Beat, single undesired	+7
26	IF Beat, single undesired	-7

DESCRIPTION OF DATA POINTS

Each receiver was arbitrarily assigned an identification number from 1 to 47 and subjected to the twenty-six channel combinations detailed above. Judgments were made of the interference at each of seven levels of desired signal at the receiver, starting at -65 dBm and increasing in 10 dB increments to -5 dBm. (It had been estimated previously that this range included the receiver input level necessary to produce an acceptable (TASO Grade 3) picture, as well as the high levels which might be expected to exist in some areas near transmitters.) Since three observers made separate interference judgments at each test condition, there were 26 X 47 X 7 X 3 or 25,662 interference susceptibility data points.

INTERFERENCE OBSERVATIONS

In making his interference level judgment, the observer was seated at a distance of four to six times the picture height from the face of the picture tube. (The range permitted the testing of various screen sizes in convenient groups, usually five receivers in a group.) No light source was directed at the screen and the level of room illumination approximated that of ordinary home viewing.

With the channel combinations set up as required for the test in progress and with the calibration of the test setup accomplished, the engineer in charge of the test set the desired attenuator for one of the seven desired test levels. The observer then adjusted the receiver controls, including fine tuning (AFC off), to obtain, in his judgment, the best picture quality in the absence of any desired interference.

Next, the undesired signal(s) were set by the engineer in charge to a level producing a noticeable interference effect on the desired picture. The observer would then readjust the fine tuning of the receiver to minimize this effect, if possible without degrading the desired color picture and sound. If this minimization could not be accomplished without noticeable degradation, the final tuning was made with the undesired signal(s) below perceptibility level.

The observer now adjusted the level of the undesired signal(s) with the "undesired" variable attenuator to that level above which, in his opinion, the interference to the desired picture or sound was perceptible, but below which it was not. The magnitude of the perceptible level so determined was read from the "undesired" attenuator dial by the engineer in charge and recorded for the level of the desired signal that had been set. The observer was not made aware of the level of the undesired signal(s) he had established. (If the test involved two undesired signals, the levels of the two were maintained equal in the determination.)

After the observer had thus established the perceptible level, the AFC system of the receiver, if so equipped, was actuated, and the observer indicated any effects upon the interference observed.

Receiver Group _____ Test _____

UHF Television Taboo Study

Laboratory Project No. 8229-63

Taboo Type: _____

Date: _____

Desired Channel: _____

Undesired Channels: _____ _____

Rcvr. No.	Observer	Undesired Channel Levels (dBm) For Barely Perceptible Interferenc						
		Desired Channel Levels (dBm)						
		-65	-55	-45	-35	-25	-15	-5

Effect of AFC: L = Less IX, M = More IX, S = Same IX

FIG. 2

The entire procedure was repeated at each desired level for the interference tests.

Results of the tests were tabulated on the basis of the test numbers (combination of channels) and receiver number. A sample data sheet is shown in Figure 2.

SUBJECTIVE OBSERVATIONS OF TV RECEIVER NOISE

It was apparent that test data correlating picture quality (TASO picture grades) and receiver input signal level would be useful in various ways; for example, in evaluating the results of this study and in computation of service contours of TV stations. Accordingly, additional tests were run on all forty-seven receivers in which the three observers determined the desired signal levels required for the various TASO grades, with receiver noise (snow) being the interference criterion. These evaluations were made with only the single desired signal. The definitions of picture quality were modeled on the TASO grades, but with the wording expanded to make it clear that receiver noise ("snow") was the parameter being examined.

GRADE NUMBERS AND DESCRIPTION

1 - EXCELLENT

THIS PICTURE IS OF EXTREMELY HIGH QUALITY, AS GOOD AS YOU COULD DESIRE, IN THAT RECEIVER NOISE INTERFERENCE (SNOW) IS NOT PERCEPTIBLE.

2 - FINE

THE PICTURE IS OF HIGH QUALITY PROVIDING ENJOYABLE VIEWING. RECEIVER NOISE INTERFERENCE (SNOW) IS PERCEPTIBLE.

3 - PASSABLE

THE PICTURE IS OF ACCEPTABLE QUALITY. RECEIVER NOISE INTERFERENCE (SNOW) IS NOT OBJECTIONABLE.

4 - MARGINAL

THE PICTURE IS POOR IN QUALITY AND YOU WISH YOU COULD IMPROVE IT. RECEIVER NOISE INTERFERENCE (SNOW) IS SOMEWHAT OBJECTIONABLE.

5 - INFERIOR

THE PICTURE IS VERY POOR BUT YOU COULD WATCH IT. DEFINITELY OBJECTIONABLE RECEIVER NOISE INTERFERENCE (SNOW) IS PRESENT.

6 - UNUSABLE

THE PICTURE IS SO BAD THAT YOU COULD NOT WATCH IT.

There are various procedures that could have been followed in obtaining the data of signal level versus picture quality for each receiver. For example, the observer could have been asked to grade the quality of the desired signal at each of the seven desired levels used in the interference susceptibility tests, with the actual levels set in a random sequence. However, the statistical variance of the results from initial tests using that method indicated that a large number of observers would be required to obtain reasonable confidence in the statistics. After careful consideration of the factors involved, the test procedure described below was devised and used. It was felt that, although valid and unbiased, it should produce a smaller variance than other alternatives. This was borne out in a pilot test.

The observer, seated as for the interference susceptibility tests, was requested to vary the continuously-variable attenuator knob controlling the level of the desired signal and get a general idea of the range of the picture grades defined previously. After a reasonable amount of time for the observer to become familiar with the concept, he was asked to adjust the knob for the least receiver noise (snow), best picture quality, and to state the TASO grade of that picture. (The observer was cautioned to consider only the visible receiver noise and ignore the picture defects.)

The observer was then requested to adjust the desired signal level to obtain the next lower TASO grade. This was to be accomplished by varying the knob of the desired signal's attenuator around the setting where he felt that grade occurred. He was further informed that this "centering" was to assist him in finding the middle position of the picture level for that grade; TASO grades not being sharply defined with respect to signal level. The desired signal level established by the observer following this procedure was then recorded opposite the requested TASO grade.

Next, the same procedure of the preceding paragraph was followed at one grade lower, and that level and grade recorded. This procedure was continued until Grade 5 was obtained.

At this point, the method was altered--Grade 6 is the lowest defined grade and hence the observer could not adjust below it in his attempt to "center." Instead, the engineer decreased the desired level from the Grade 5 point by three dB increments until the observer indicated that he felt the picture quality had been degraded to TASO Grade 6.

The engineer next returned the desired level to that which produced the observer's first recorded grade. Now the observer was unable to "center" on the next better grade, since he had previously determined it to be the maximum obtainable. Therefore, the operator followed a method similar to that for Grade 6 by increasing the desired level in three dB increments until the observer indicated the best grade had been reached. Recording of this value completed the grading of picture quality on the receiver under test.

Precautions were taken so that the observer was not permitted to make judgments of the TASO grades when the picture portion of the composite video signal itself contained perceptible noise. Examples of this type noise are "snow" appearing in picture areas of low illumination and excessive grains of film material. Determination of such conditions was made by observation of the picture displayed on the monitoring TV receiver being fed by the actual off-the-air VHF signal.

In all cases, the attenuator dial indicating desired signal level was obscured from the view of the observer so that its indications would not influence his judgments.

OBSERVERS

Interference susceptibility tests were run with three observers for all forty-seven receivers. The three observers were male engineers, two of whom had no prior experience in picture quality judgments.

In order to estimate the confidence in the picture quality data available from only three observers, twenty-six additional observers graded three of the receivers--two color sets and one monochrome. These receivers had been chosen on the basis of previous tests as representative of a low, a moderate, and a high noise receiver. The additional data provides a means of statistically comparing the values from the three observers, so that their grading of all forty-seven receivers has a predictable limit of statistical confidence.

Of the additional twenty-six observers, twenty-one were male engineers, four were females (secretaries, clerk typists) and one was a male general maintenance worker. Twenty-four of the twenty-six had no appreciable experience in grading TV pictures.

DATA ANALYSIS AND PRESENTATION

Interference Susceptibility Data

Each of three observers determined the level of the undesired signal(s) which, in his opinion, created perceptible interference with the desired. Separate observations were made on each of forty-seven receivers at seven different desired levels and for the twenty-six different channel combinations chosen. This raw data is available in the Laboratory files on the completed data sheets. (See INTERFERENCE OBSERVATIONS for exact test procedures.)

However, it was felt that a more useful and yet concise presentation could be given in graphic form. For this purpose, the following analysis of the data was made:

1. The median values of the three separate determinations of the levels of the undesired signal(s) were selected. (This reduced the total data by one third.)

2. These selected values were then processed so that for each channel combination (test) and each desired level the following statistics of undesired levels were available:

   - The highest level.
   - The fifth highest level (approximately the upper decile of the forty-seven receiver values).
   - The mean level of the forty-seven receiver values.
   - The fifth lowest level (approximately the lower decile of the forty-seven receiver values).
   - The lowest level.

These statistics were then plotted on separate graph sheets, Figures 3 through 28, (one for each channel combination, test) as a function of the desired levels. When the undesired levels in each of the five groups of statistics are connected, they present a family of curves that not only provide the individual levels but also display the distribution and range of values for each test. The limit of the undesired to desired signal ratio in dB at any desired level before perceptible interference occurs can be obtained as the difference between the appropriate ordinate and abscissa values.

A few minor departures from the above stated processing were necessary for a small portion of the test data. Some of the medians of the undesired levels determined by the three observers were beyond +11 dBm, the maximum available from the test setup. Naturally, such indeterminate values could not be properly plotted or employed in obtaining a mean. For these few cases, a median of the forty-seven values was substituted for the mean. In some tests all upper level curves were precluded.

There was also one receiver that did not produce a usable picture at a desired signal level of -65 dBm. For this desired level, only forty-six values were considered in calculating the mean.

It is to be noted that weighting factors, as discussed in RECEIVER SELECTION, do not appear in the data processing. Actually, that technique was used in initial analyses of several channel combinations (tests). However, the results obtained differed so little from the results using unweighted values, that the weighting factors were not employed for the statistics plotted in this report.

Picture Quality Data

Each of three observers determined the level of the desired signal which, in his opinion, resulted in a stated TASO grade of picture as displayed by the TV receiver. For these tests, the interference was solely that due to receiver noise. Separate observations were made on each of the forty-seven receivers to determine the desired level required for each of the six TASO grades. (See SUBJECTIVE OBSERVATIONS OF TV RECEIVER NOISE for exact test procedure.)

The data obtained were analyzed as follows:

1. The median values of the three separate determinations of the levels of the desired signal were selected. (This reduced the total data by one third.)

2. These selected values were then processed so that for each TASO grade the following statistics of desired levels were available:

    - The highest level.

    - The fifth highest level (approximately the upper decile of the forty-seven receiver values).

    - The mean level of the forty-seven receiver values.

    - The fifth lowest level (approximately the lower decile of the forty-seven receiver values).

    - The lowest level.

These statistics were then plotted on a separate graph sheet, Figure 29, as a function of the TASO grade. When the desired levels in each of the five groups of statistics are connected, they present a family of curves that not only provide the individual levels but also display the distribution and range of values for the picture quality (TASO grades). (It should be remembered that for this plot, TASO grades, the highest level actually represents the worst result, while the lowest level corresponds to the best.)

In the picture quality tests, it was found that TASO Grade 1 could not be obtained on five of the receivers. Therefore, the highest-level and highest-five-level families terminate at TASO 2 on Figure 29, and the plotted mean for TASO 1 was calculated on the basis of forty-two receivers.

No weighting factors were used for the statistics graphed in Figure 29. As for the data on Interference Susceptibility, the results obtained with the use of such factors did not differ to any significant degree from those obtained without.

The picture grade data from the twenty-six additional observers are given in a tabulated comparative form, Figure 30. Mean and median values of desired levels versus TASO grades are given for the three chosen receivers from the judgment of the three observers who also made the interference judgments, from the twenty-six observers who judged picture quality (TASO grades) only, and from the sum of these two groups (twenty-nine observers).

DISCUSSION

Interference Susceptibility

The graphical displays of the data given in this report were designed to permit those interested to draw their own conclusions from the results of these UHF receiver interference tests. However, the reasons for the occurrence of certain results were fairly obvious during the actual time the tests were run and should be mentioned.

At the lower levels of the desired signals, many curve families may be seen to be "flattening out." These results are due to a masking of the perceptible interference created by the undesired signal(s) at these lower desired signal levels by receiver noise. A similar slope condition is also apparent at some of the highest levels of the desired signal, but here the receiver noise was essentially imperceptible. In these cases, it is considered that the levels of the signals were sufficiently high that they produced a saturation of the characteristic.

It was also apparent, while the tests were being conducted, that the channel category involving cross modulation was much more independent of desired signal level than other categories. The resulting slopes, nearly horizontal, bear out that observation.

For ease of comparison, the graphs of Interference Susceptibility, Figure 3-28, are placed in groups corresponding to their channel interference categories. However, it should be remembered, when making comparisons, that television signals are not symmetrically placed in their channels. Differences are to be expected between the results for interference from interfering channel signals that are below the desired and those for interference from above, even when the actual channel separation is the same.

The tests did provide substantial justification for the provision by the "UHF Taboos" of greater protection of a desired channel against the picture image channel than against the sound image channel. It can be seen from Figures 3 and 4, that perceptible interference to a desired signal is created by much lower undesired levels when the interference is eight channels above (picture image) than when it is

seven channels above (sound image). The actual magnitude differences are 14 dB or more, depending on desired signal level. (The "taboos" provide 75 miles protection for the picture image but only 60 miles for the sound image channel.)

It should always be borne in mind, when observing the graphs, that the actual interference mechanism involved might be more complicated than the single type indicated by the graph titles. Any conclusions drawn should include this consideration.

Picture Quality

It is felt that the statistics of the picture quality tests, TASO grades versus signal levels, can be accepted with considerable assurance, despite their being obtained from only three observers. Such assurance is based on a comparison of the grading of three selected receivers by the three observers with the grading by twenty-six additional observers. This comparison is tabulated in Figure 30, and the goodness of the correlation is apparent.

Probably the most significant result obtained from the picture quality tests is the mean value of the level of input signal that produced a "passable" (Grade 3) picture. The value of this mean was found to be -56.2 dBm.

It is to be noted that the factors involved in this level (inherent thermal noise at the receiver terminals, noise figure of the receiver, and the signal to noise ratio required for a satisfactory picture) have been used by the FCC in the derivation of the numerical values for Grade A and Grade B contours. The assumed value of those factors result in an input level of -63.4 dBm. However, the assumptions represented the best judgments at the time of the "Third Report and Order" in 1951. Thus, it is not unreasonable to find a different value from the measurements of contemporary receivers. For example, the 1951 assumptions may have been based on superior receivers rather than the average values from a random sample.

The significance of this calculated mean value of -56.2 dBm is that it represented the level of the input signal which produced a TASO Grade 3 picture or better on 50 percent of the receivers tested when receiver noise (snow) was the only interference. Our examination and analysis of the data indicates that it is probably valid as the value for 50 percent of the universe of contemporary receivers since the test distribution was normal. The test distribution had a standard deviation of 4.5 dBm.

From these considerations, it is a logical extension to use -56 dBm as the desired signal level for obtaining necessary protection ratios from

the Interference Susceptibility Curves relevant to service at Grade A and Grade B Contours. (A "passable," TASO Grade 3, picture is a criterion of the service at these Contours.)

The complete data from these tests have been given to the Research Division of the OCE who will analyze their impact on the present mileage restraints placed on UHF channel allocations.

Interference Created by Adjacent Channels

Figures 3, 4

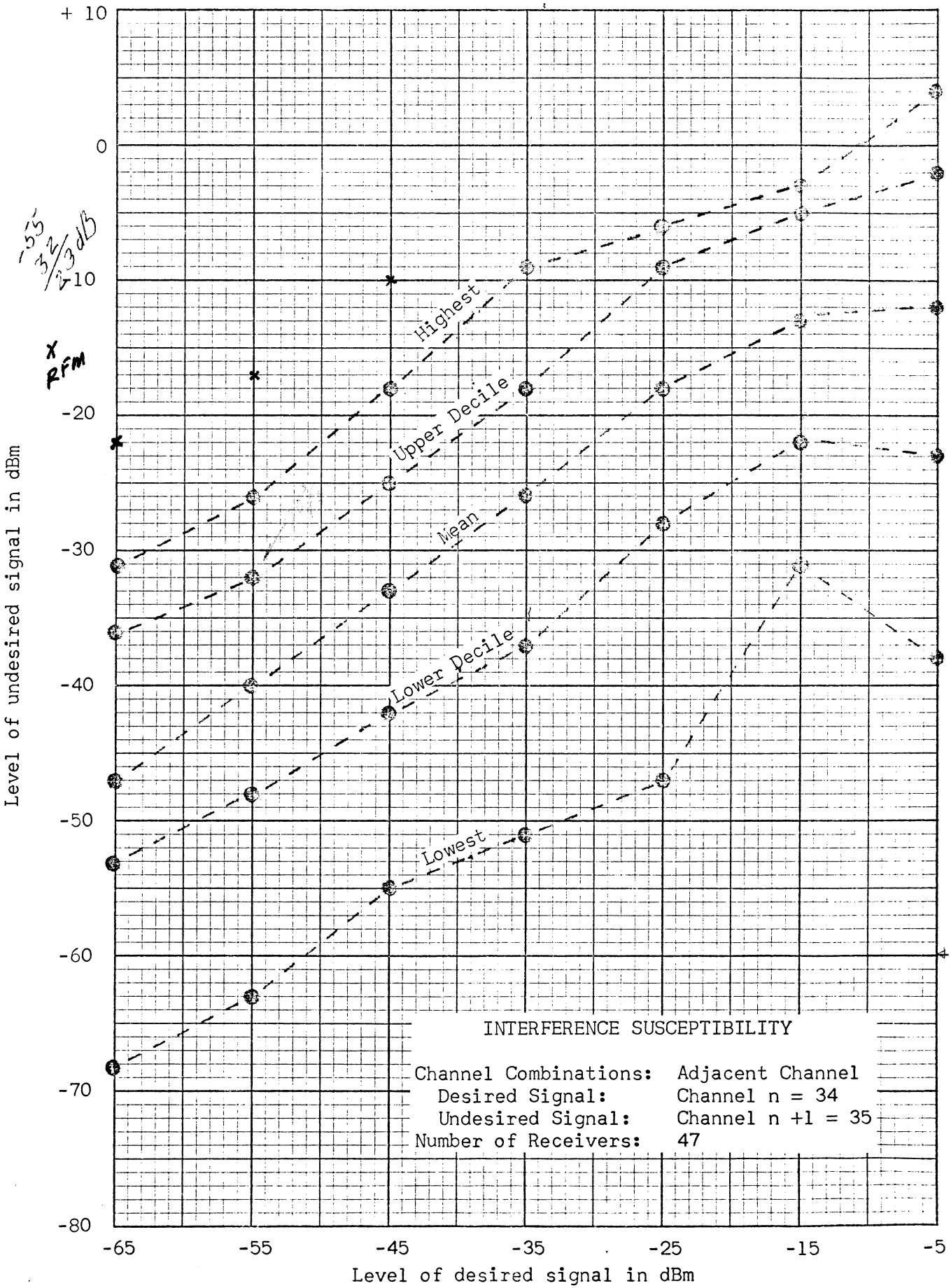

+ 10
0
-10
-20
-30
-40
-50
-60
-70
-80
-65
-55
-45
-35
-25
-15
-5
Level of undesired signal in dBm
Level of desired signal in dBm
Highest
Upper Decile
Mean
Lower Decile
Lowest
-55
32
33dB
X
RFM
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Adjacent Channel
Desired Signal: Channel n = 34
Undesired Signal: Channel n +1 = 35
Number of Receivers: 47

Figure #3

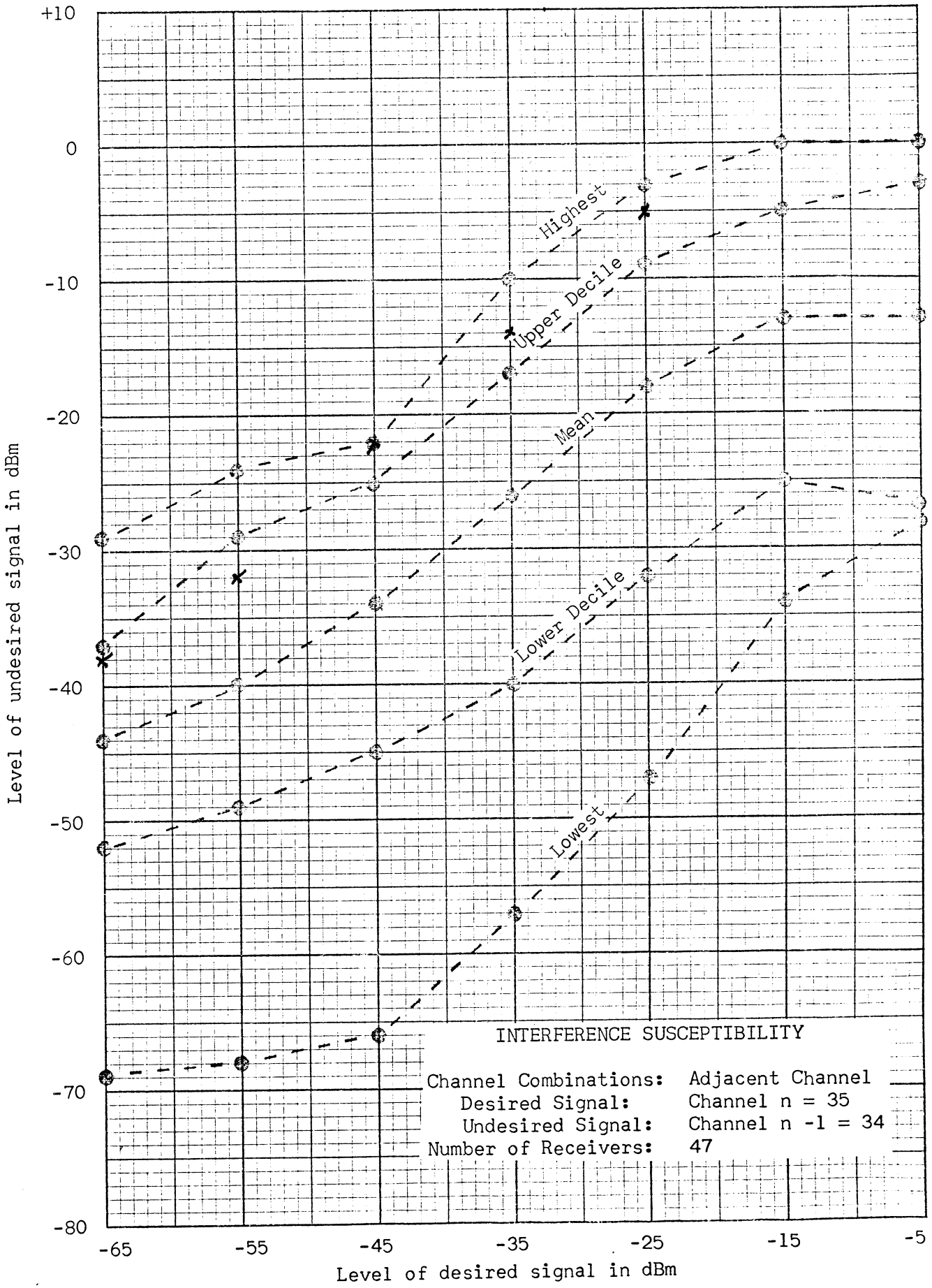

+10
0
-10
-20
-30
-40
-50
-60
-70
-80
Level of undesired signal in dBm
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Adjacent Channel
Desired Signal: Channel n = 35
Undesired Signal: Channel n -1 = 34
Number of Receivers: 47
-65
-55
-45
-35
-25
-15
-5
Level of desired signal in dBm

Figure #4

Interference Created by Image Channels

Figures 5, 6

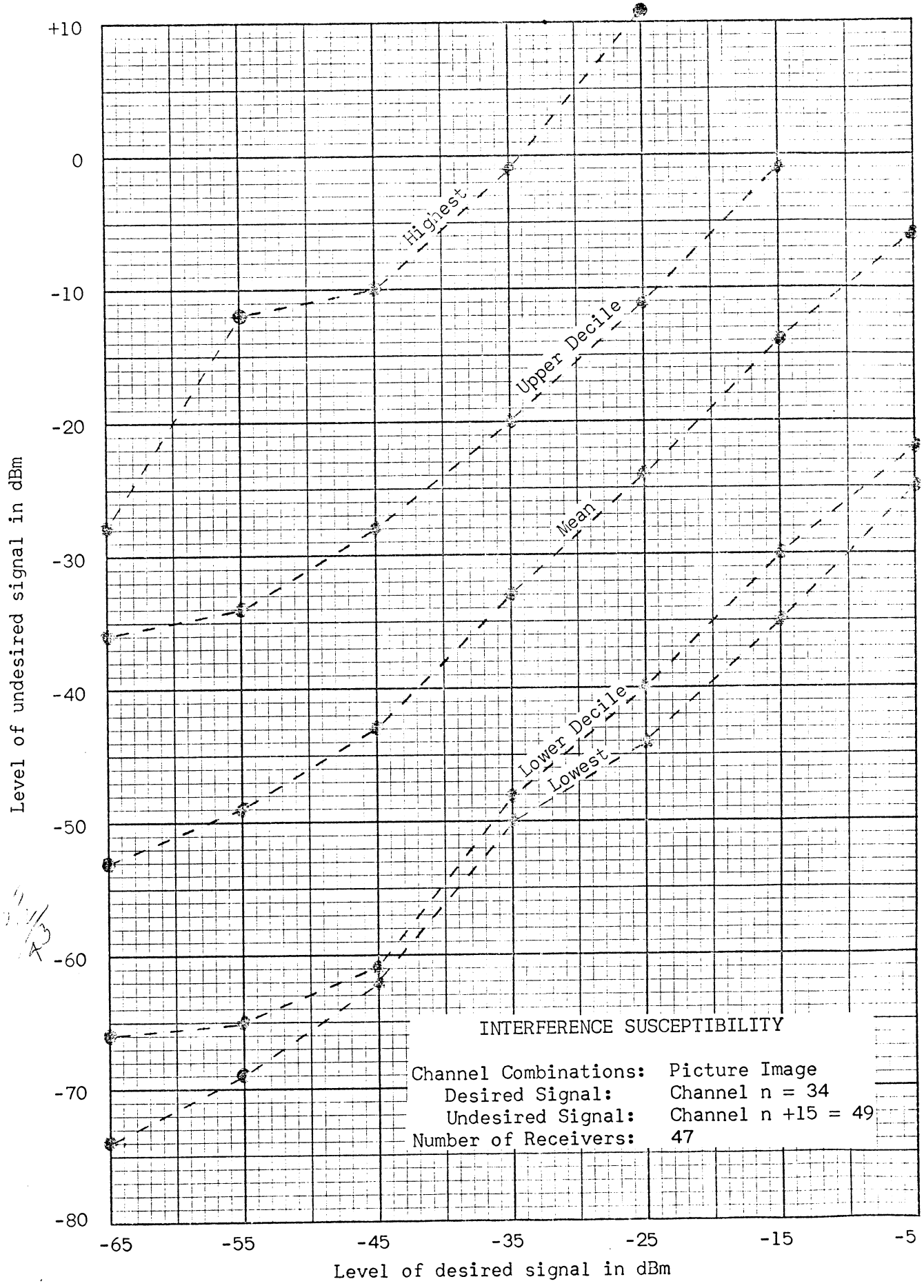

+10
0
-10
-20
-30
-40
-50
-60
-70
-80
Level of undesired signal in dBm
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Picture Image
Desired Signal: Channel n = 34
Undesired Signal: Channel n +15 = 49
Number of Receivers: 47
-65
-55
-45
-35
-25
-15
-5
Level of desired signal in dBm

Figure #5

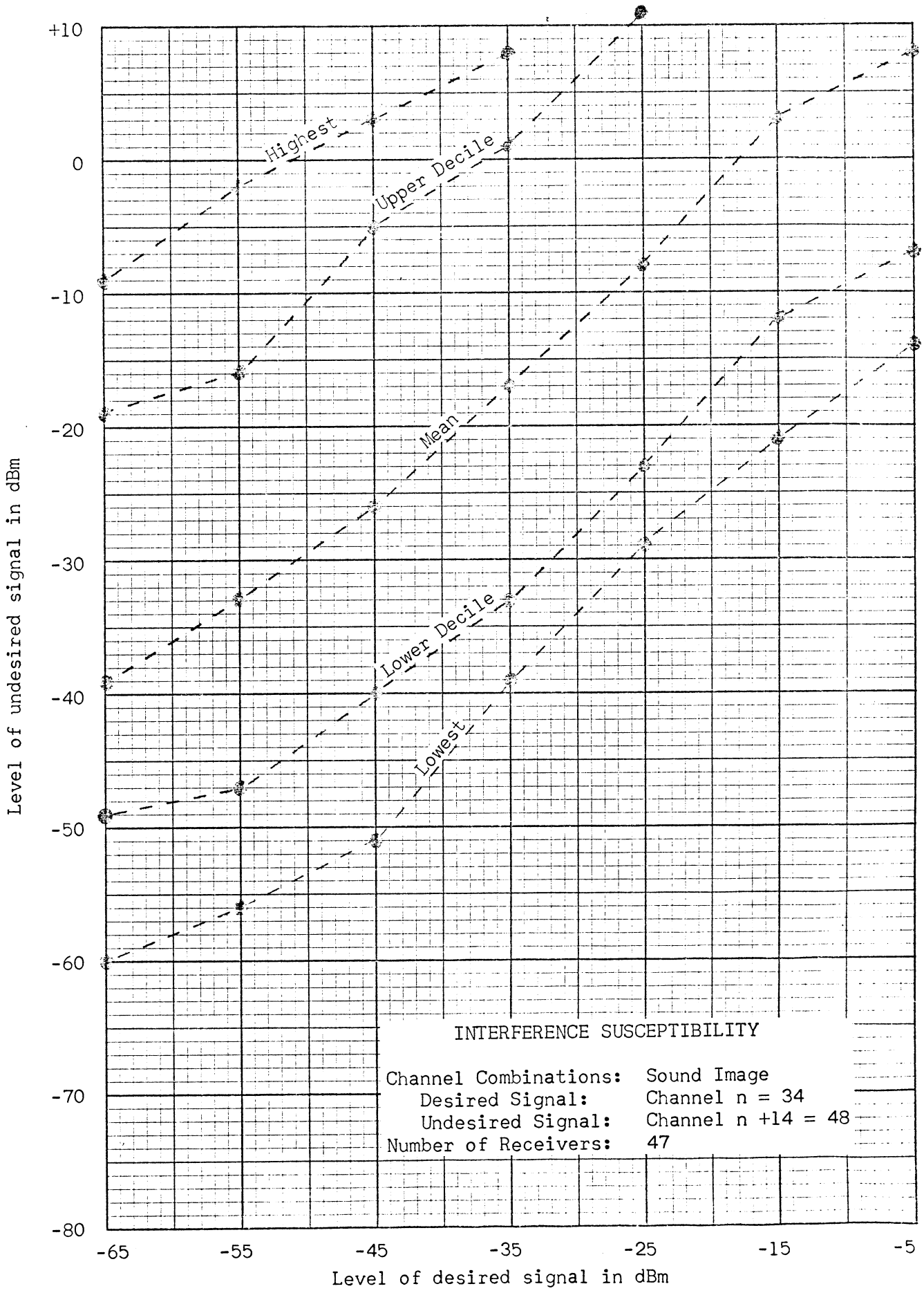

+10
0
-10
-20
-30
-40
-50
-60
-70
-80
Highest
Upper Decile
Mean
Lower Decile
Lowest
Level of undesired signal in dBm
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Sound Image
Desired Signal: Channel n = 34
Undesired Signal: Channel n +14 = 48
Number of Receivers: 47
-65
-55
-45
-35
-25
-15
-5
Level of desired signal in dBm

Figure #6

Interference Created by Intermodulation and Cross Modulation

Figures 7-22

(The absence of some points and even entire level curves on some of the Figures in this group result from those values being beyond maximum undesired level available from our test setup, +11 dBm.)

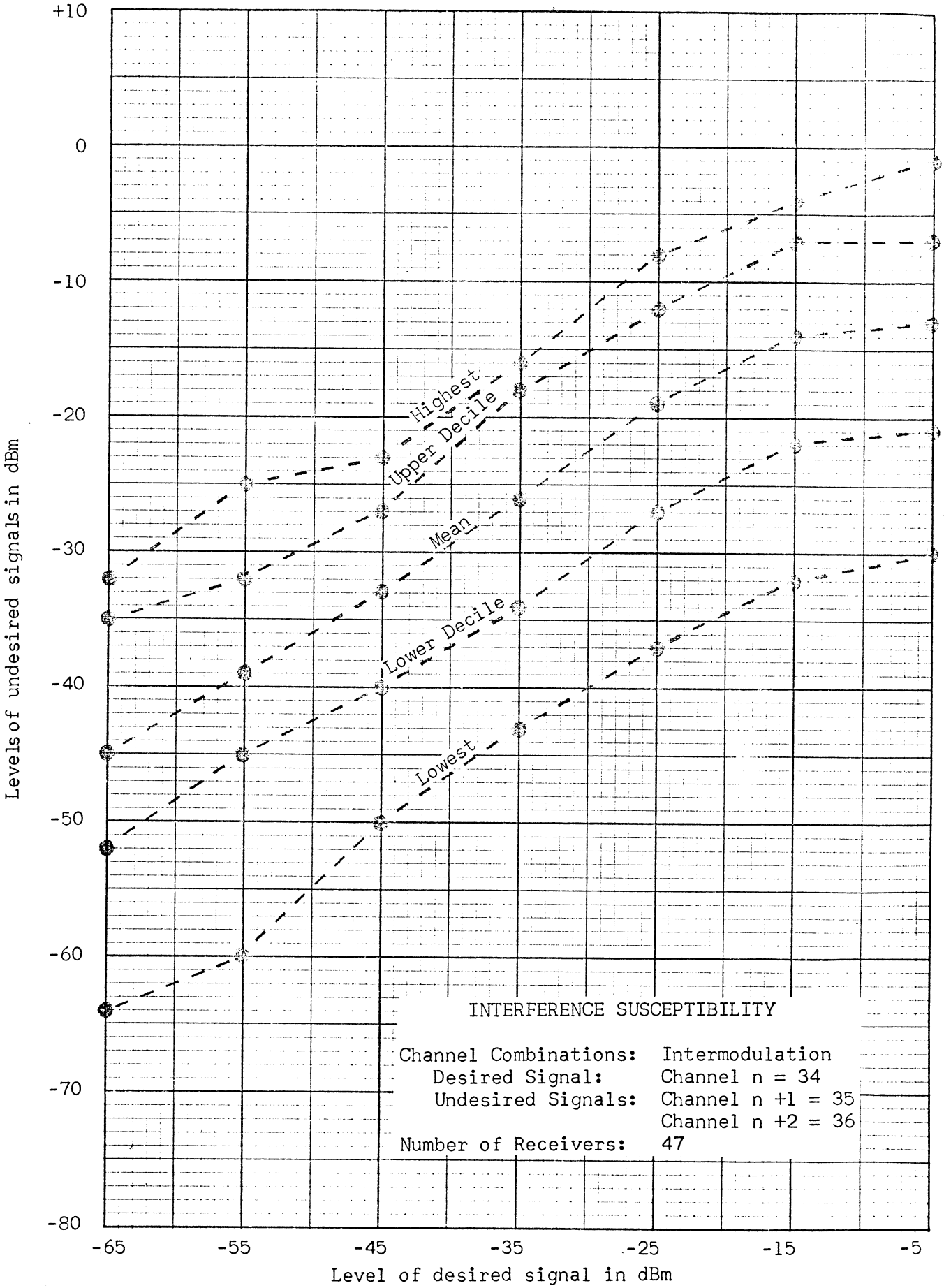

+10
0
-10
-20
-30
-40
-50
-60
-70
-80
Levels of undesired signals in dBm
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Intermodulation
Desired Signal: Channel n = 34
Undesired Signals: Channel n +1 = 35
Channel n +2 = 36
Number of Receivers: 47
-65
-55
-45
-35
-25
-15
-5
Level of desired signal in dBm

Figure #7

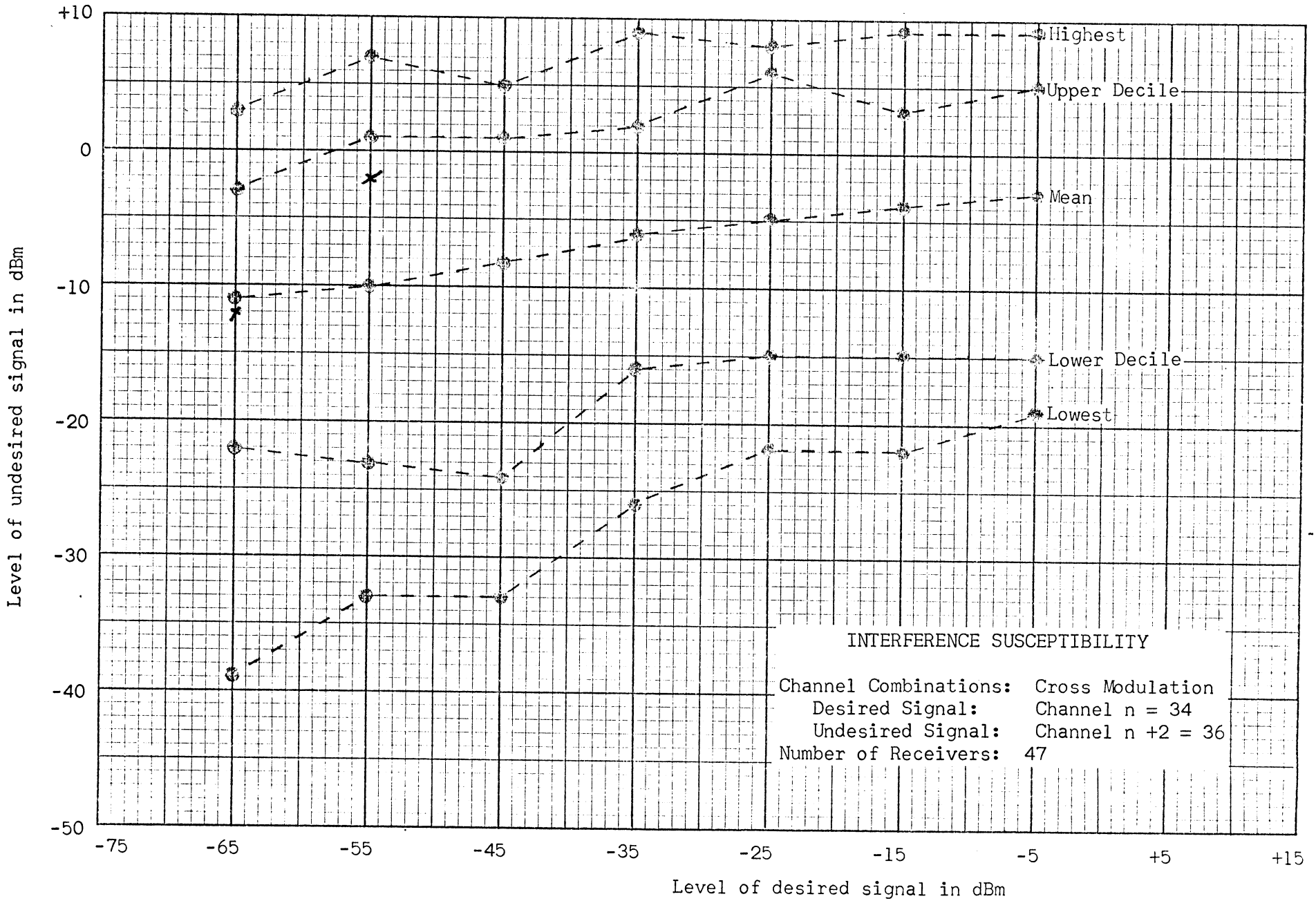

+10
0
-10
-20
-30
-40
-50
Level of undesired signal in dBm
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Level of desired signal in dBm
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Cross Modulation
Desired Signal: Channel n = 34
Undesired Signal: Channel n +2 = 36
Number of Receivers: 47

Figure #8

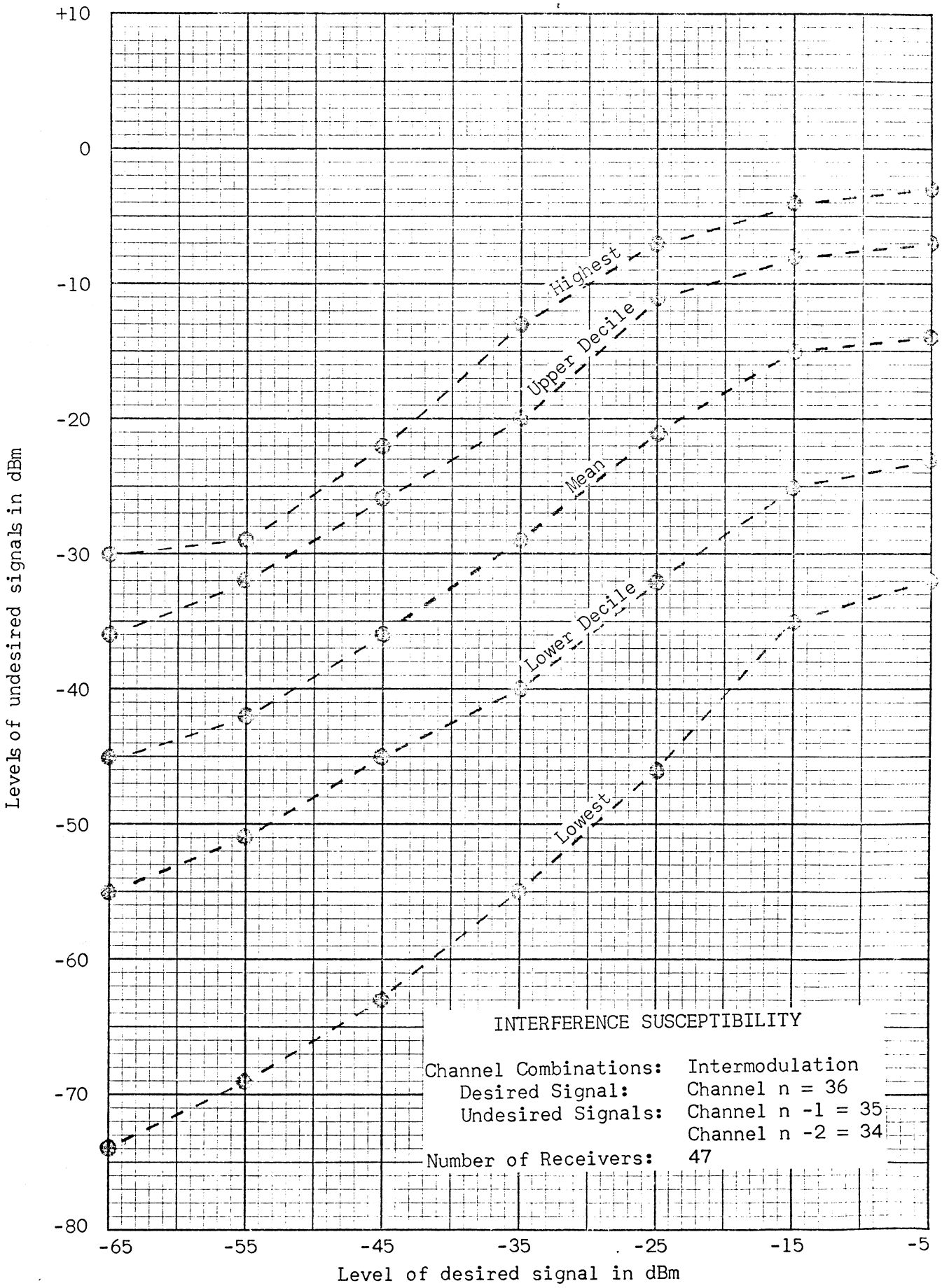
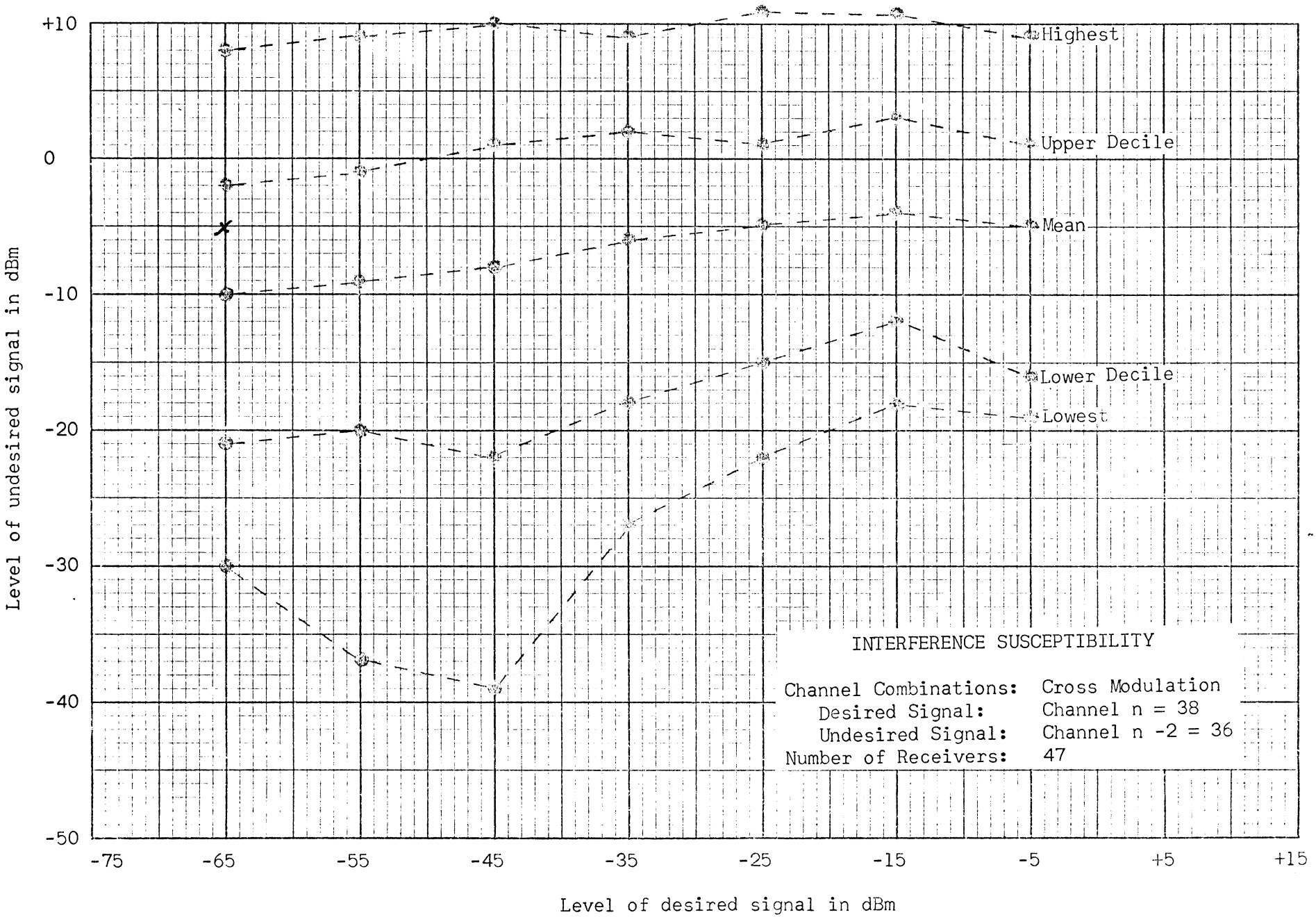

+10
0
-10
-20
-30
-40
-50
-60
-70
-80
Levels of undesired signals in dBm
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Intermodulation
Desired Signal: Channel n = 36
Undesired Signals: Channel n -1 = 35
Channel n -2 = 34
Number of Receivers: 47
-65
-55
-45
-35
-25
-15
-5
Level of desired signal in dBm

Figure #9


+10
0
-10
-20
-30
-40
-50
Level of undesired signal in dBm
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Level of desired signal in dBm
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Cross Modulation
Desired Signal: Channel n = 38
Undesired Signal: Channel n -2 = 36
Number of Receivers: 47

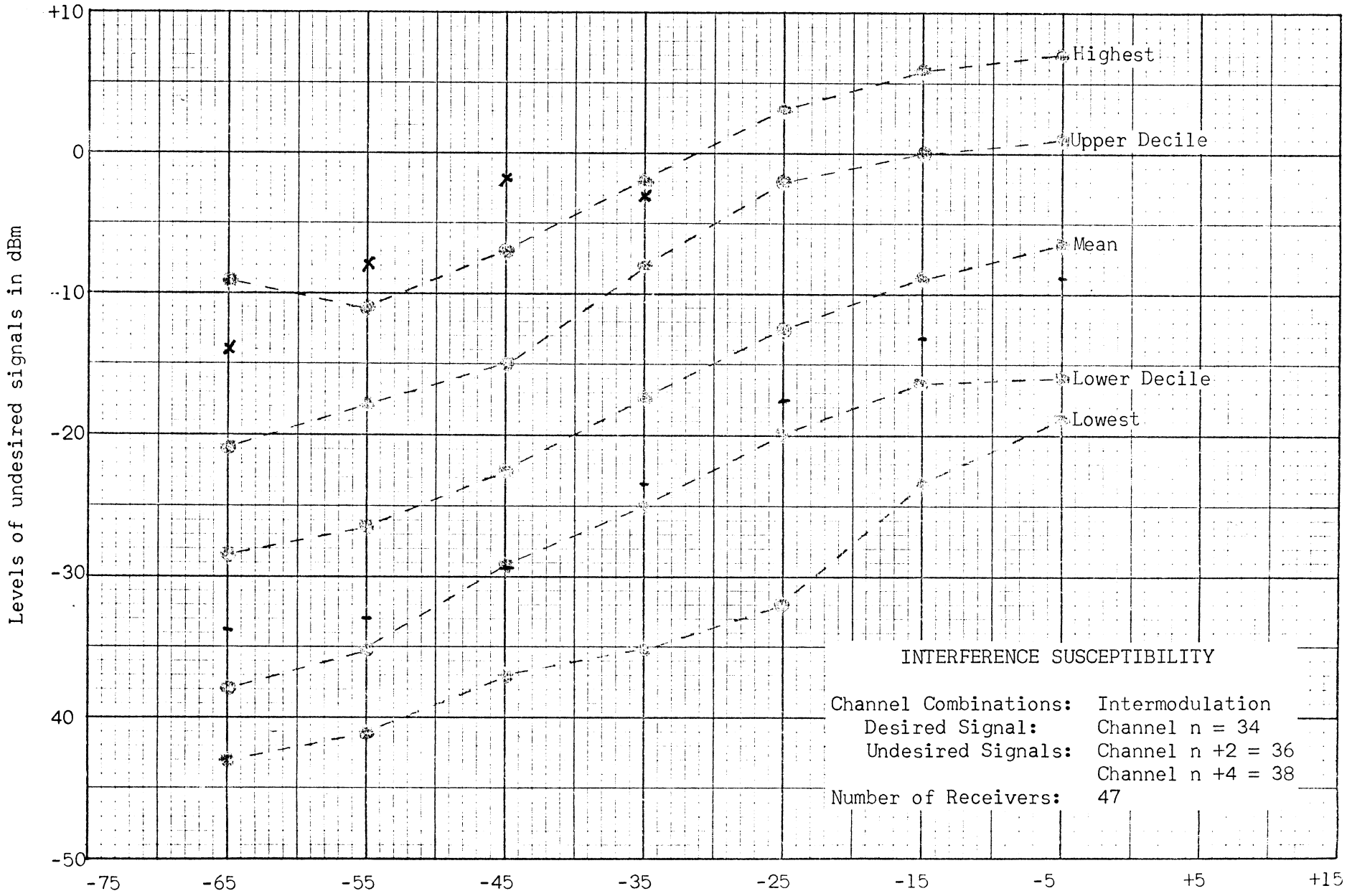

+10
0
-10
-20
-30
40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Highest
Upper Decile
Mean
Lower Decile
Lowest
Levels of undesired signals in dBm
Level of desired signal in dBm
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Intermodulation
Desired Signal: Channel n = 34
Undesired Signals: Channel n +2 = 36
Channel n +4 = 38
Number of Receivers: 47

Figure #11

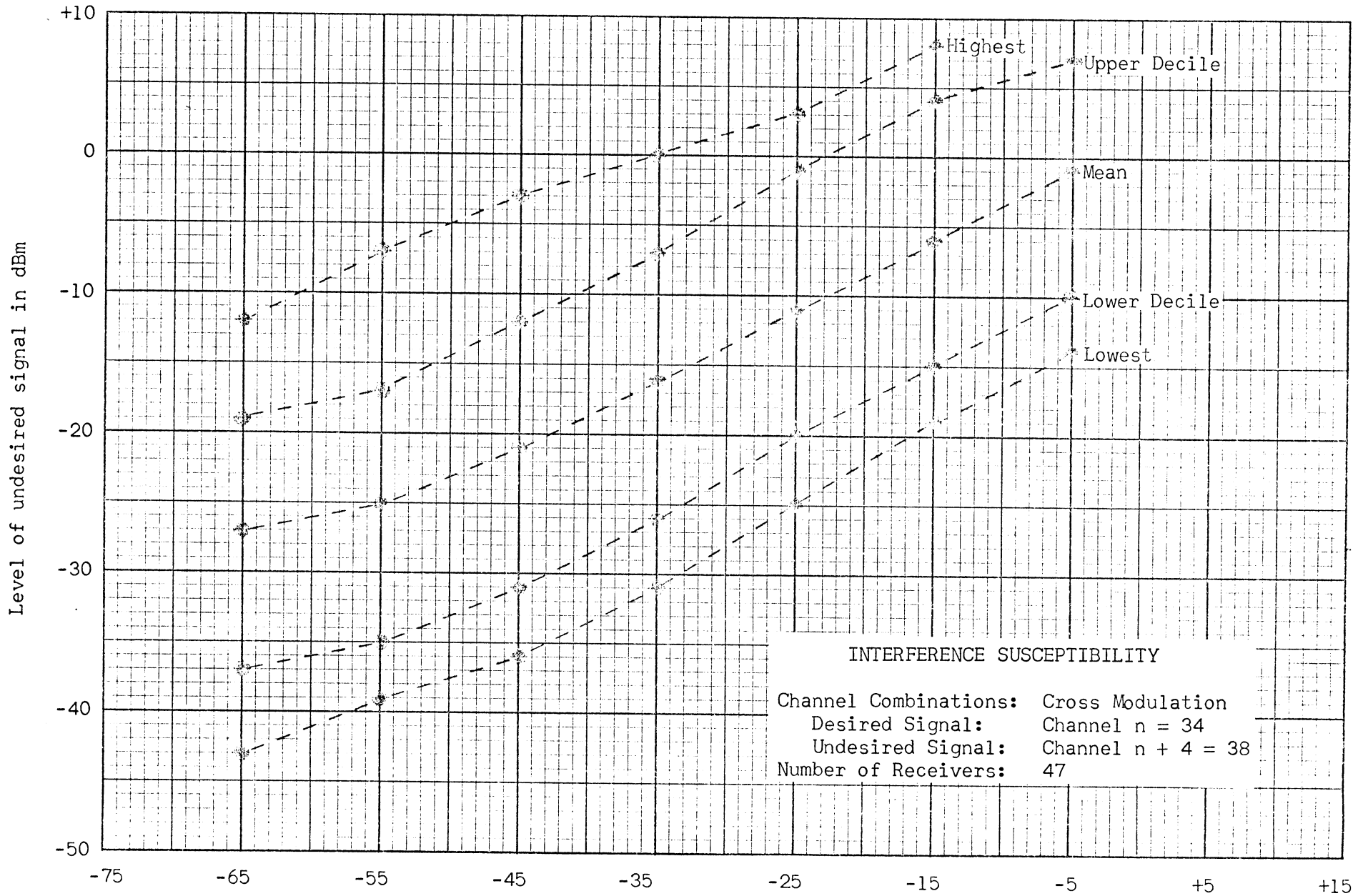

+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Highest
Upper Decile
Mean
Lower Decile
Lowest
Level of undesired signal in dBm
Level of desired signal in dBm
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Cross Modulation
Desired Signal: Channel n = 34
Undesired Signal: Channel n + 4 = 38
Number of Receivers: 47

Figure #12

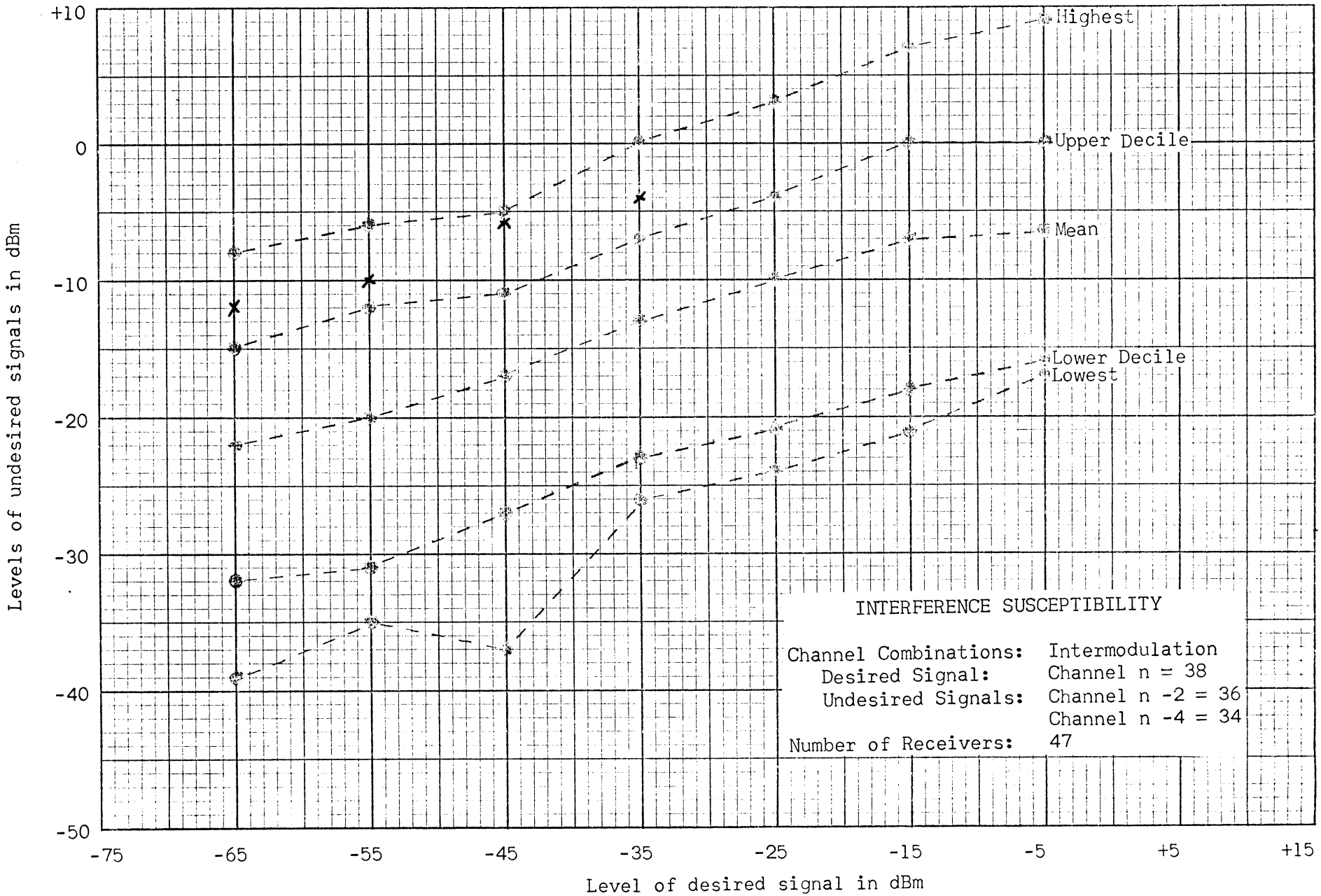

+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Levels of undesired signals in dBm
Level of desired signal in dBm
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Intermodulation
Desired Signal: Channel n = 38
Undesired Signals: Channel n -2 = 36
Channel n -4 = 34
Number of Receivers: 47

Figure #13

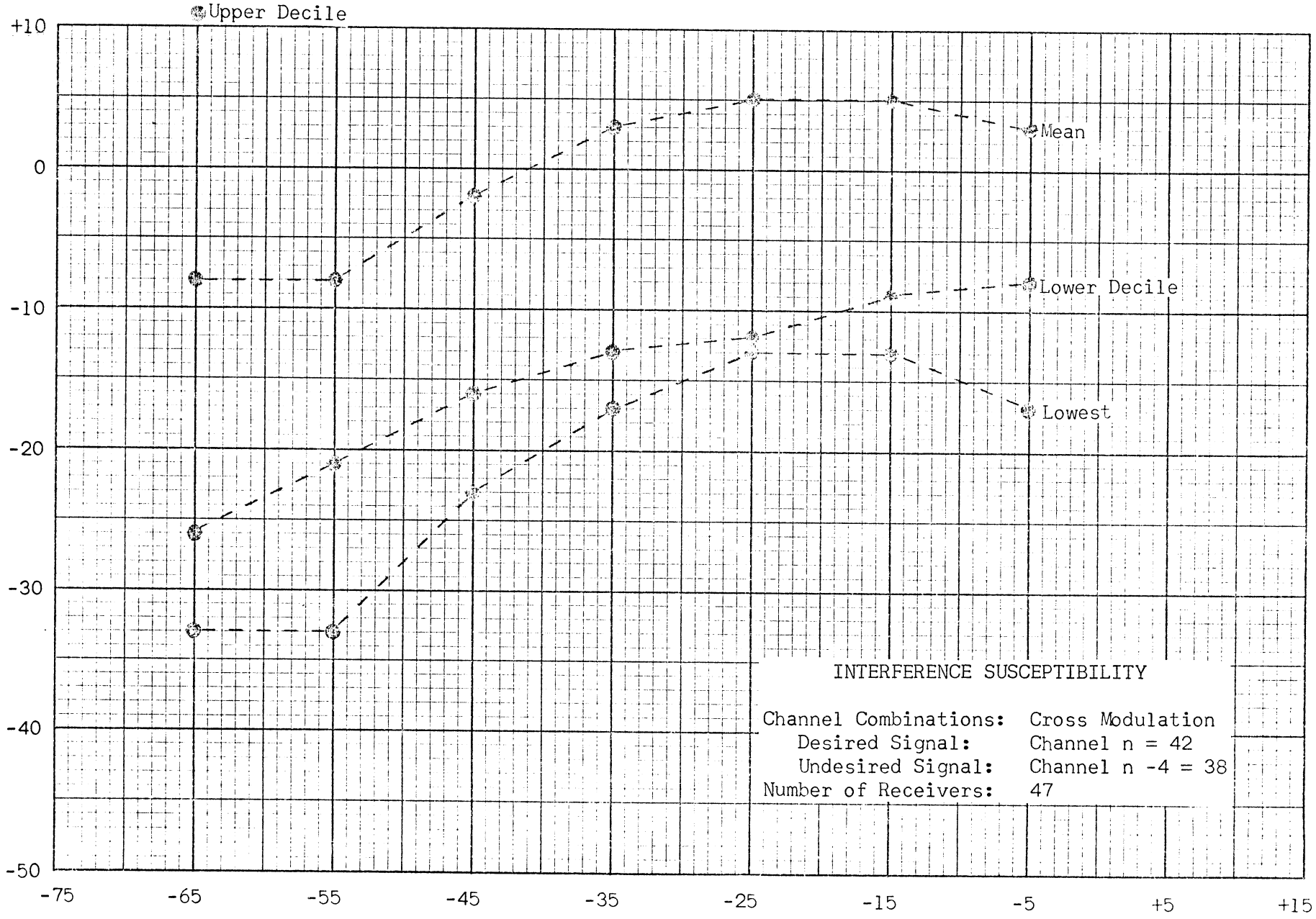

Upper Decile
Mean
Lower Decile
Lowest
+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Cross Modulation
Desired Signal: Channel n = 42
Undesired Signal: Channel n -4 = 38
Number of Receivers: 47
Level of desired signal in dBm

Figure #14

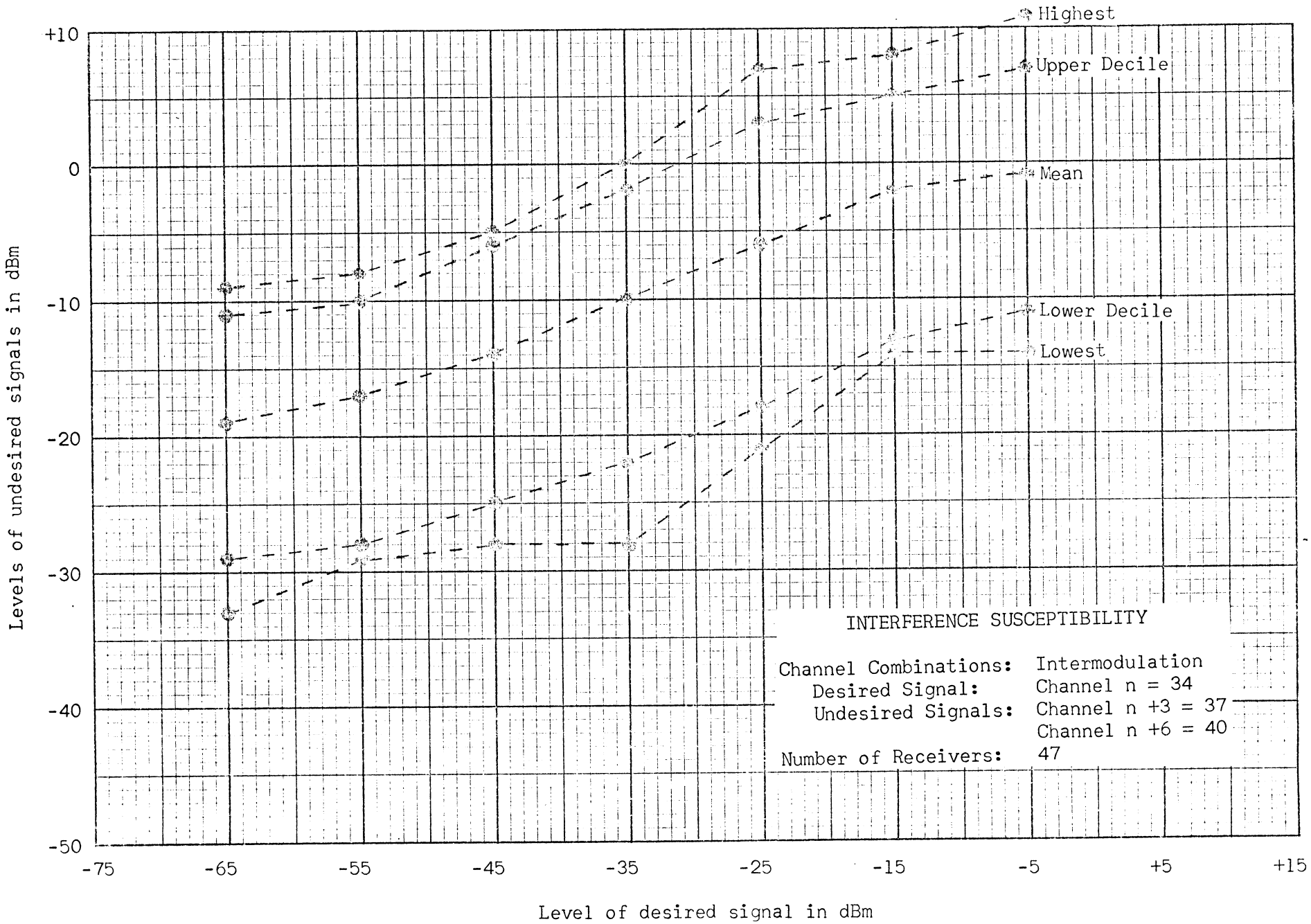

Highest
Upper Decile
Mean
Lower Decile
Lowest
+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Levels of undesired signals in dBm
Level of desired signal in dBm
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Intermodulation
Desired Signal: Channel n = 34
Undesired Signals: Channel n +3 = 37
Channel n +6 = 40
Number of Receivers: 47

Figure #15

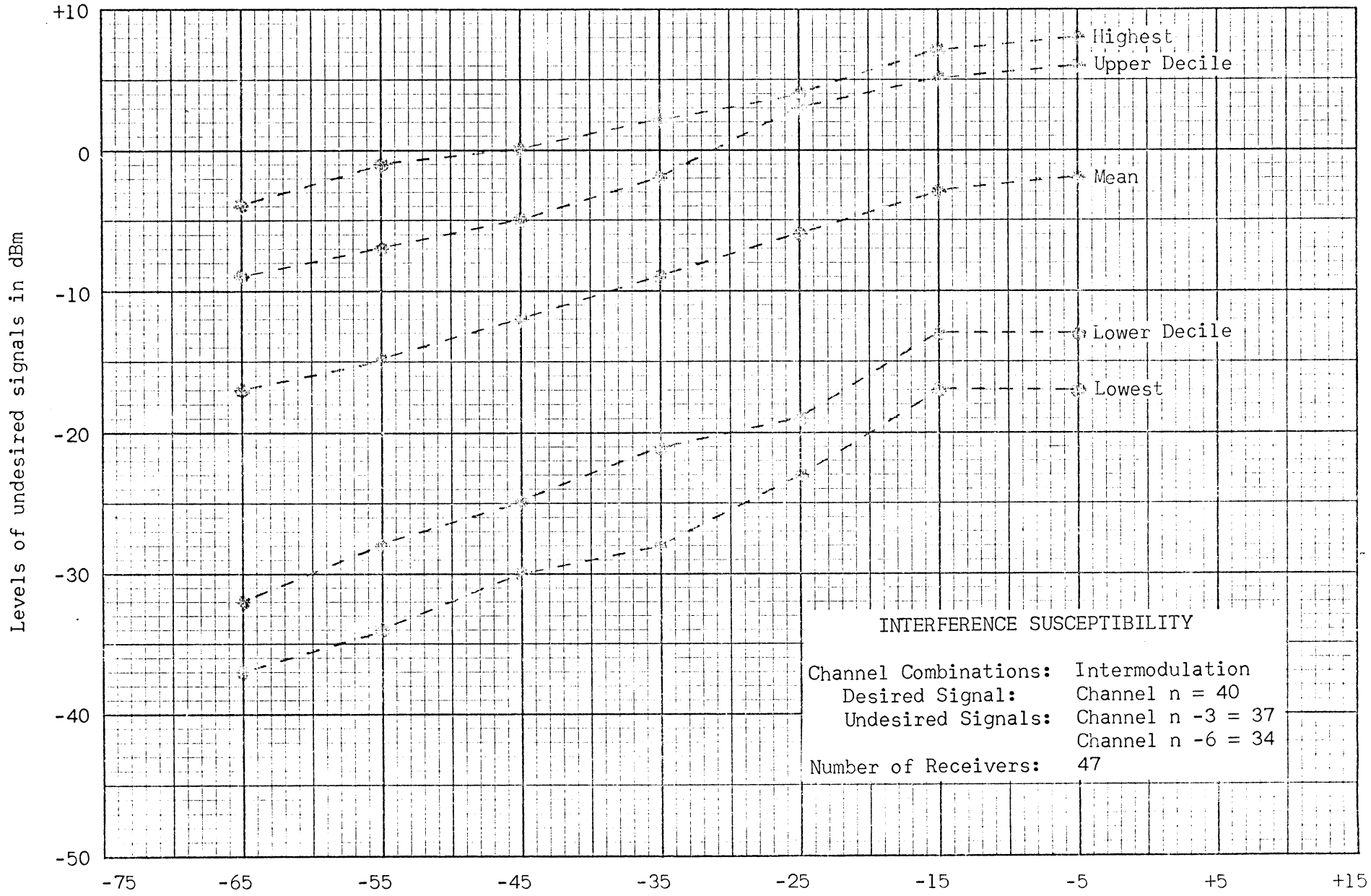

+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Levels of undesired signals in dBm
Level of desired signal in dBm
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Intermodulation
Desired Signal: Channel n = 40
Undesired Signals: Channel n -3 = 37
Channel n -6 = 34
Number of Receivers: 47

Figure #16

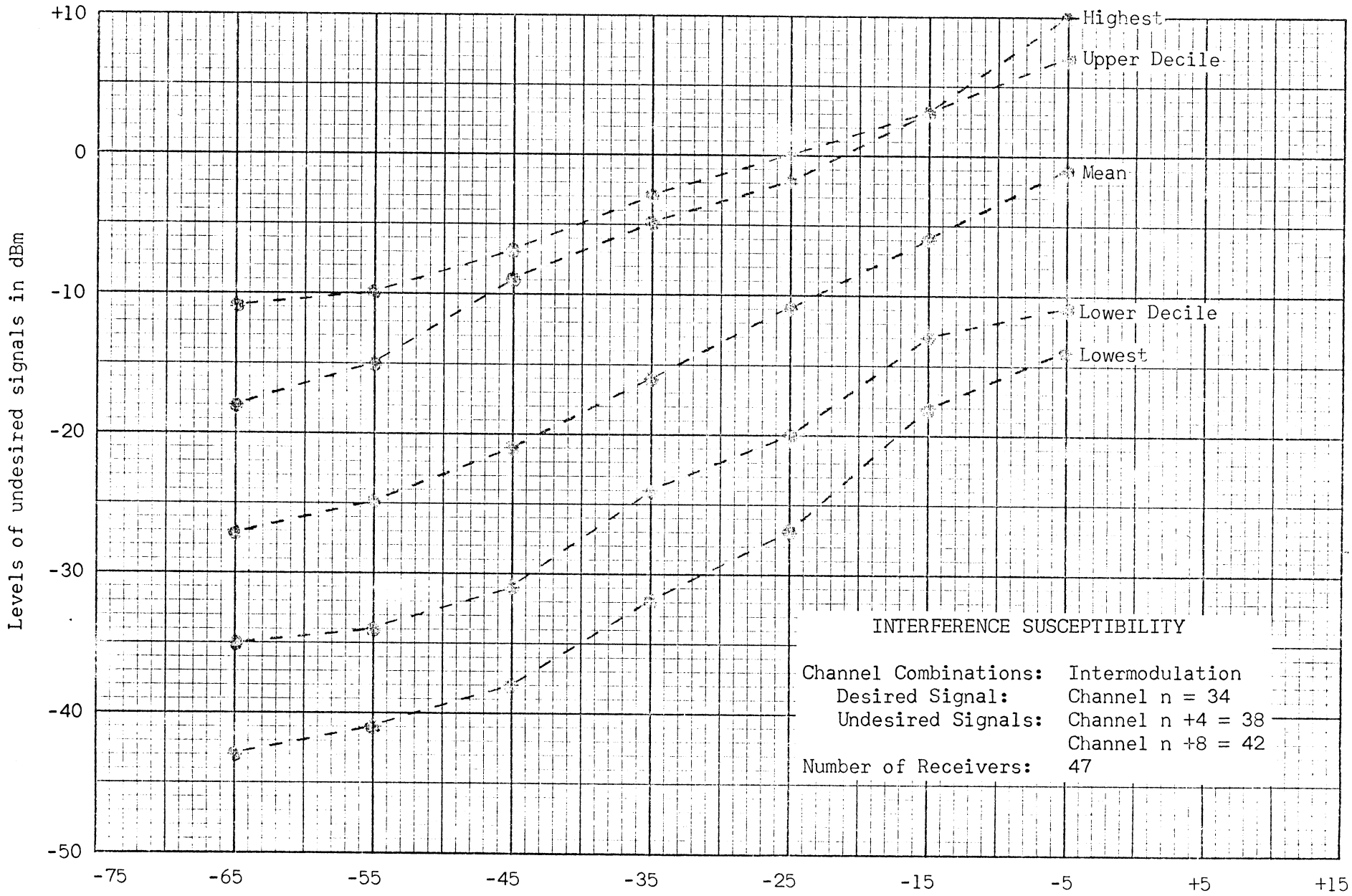

+10
0
-10
-20
-30
-40
-50
Levels of undesired signals in dBm
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Intermodulation
Desired Signal: Channel n = 34
Undesired Signals: Channel n +4 = 38
Channel n +8 = 42
Number of Receivers: 47
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Level of desired signal in dBm

Figure #17

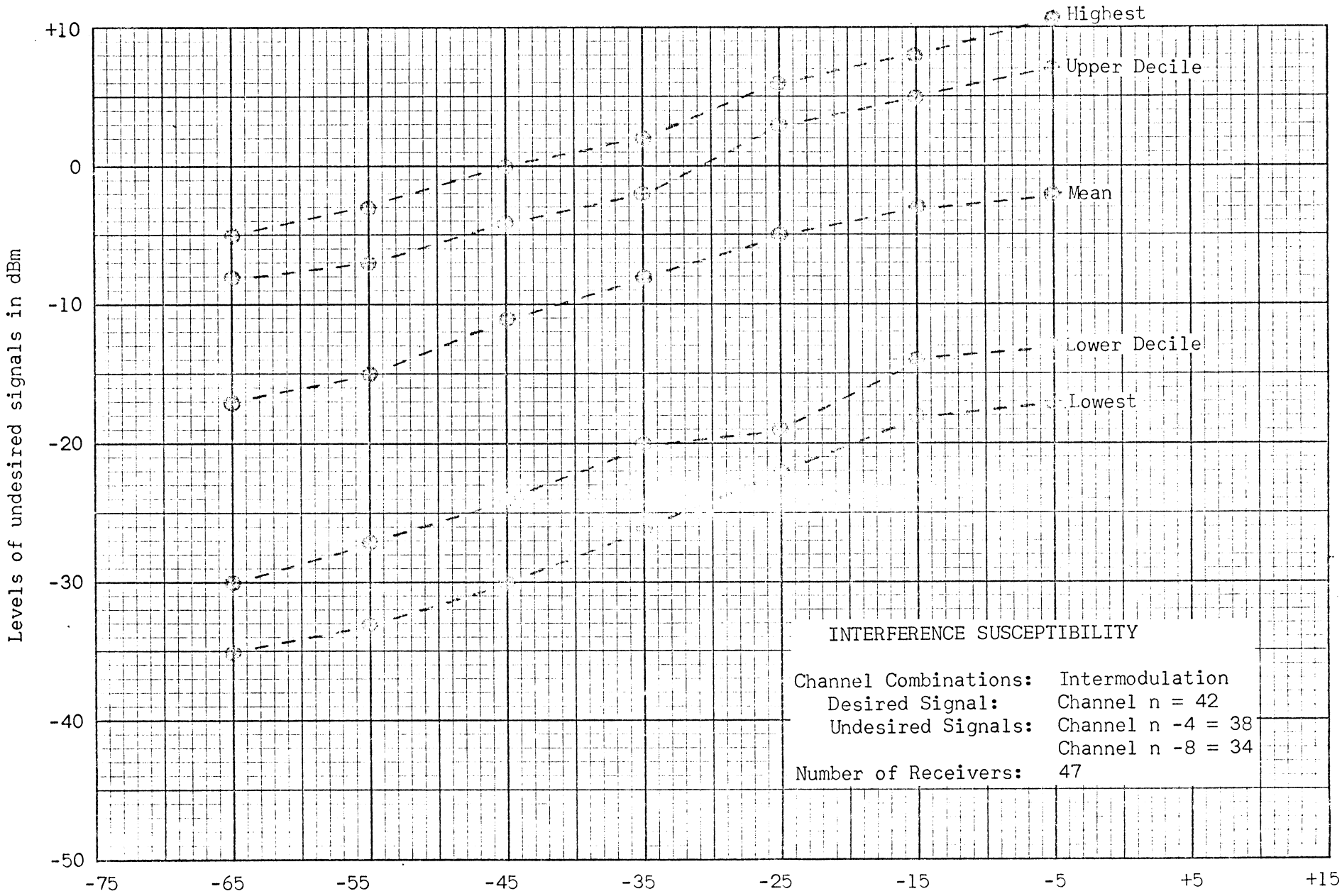

Highest
Upper Decile
Mean
Lower Decile
Lowest
+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Levels of undesired signals in dBm
Level of desired signal in dBm
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Intermodulation
Desired Signal: Channel n = 42
Undesired Signals: Channel n -4 = 38
Channel n -8 = 34
Number of Receivers: 47

Figure #18

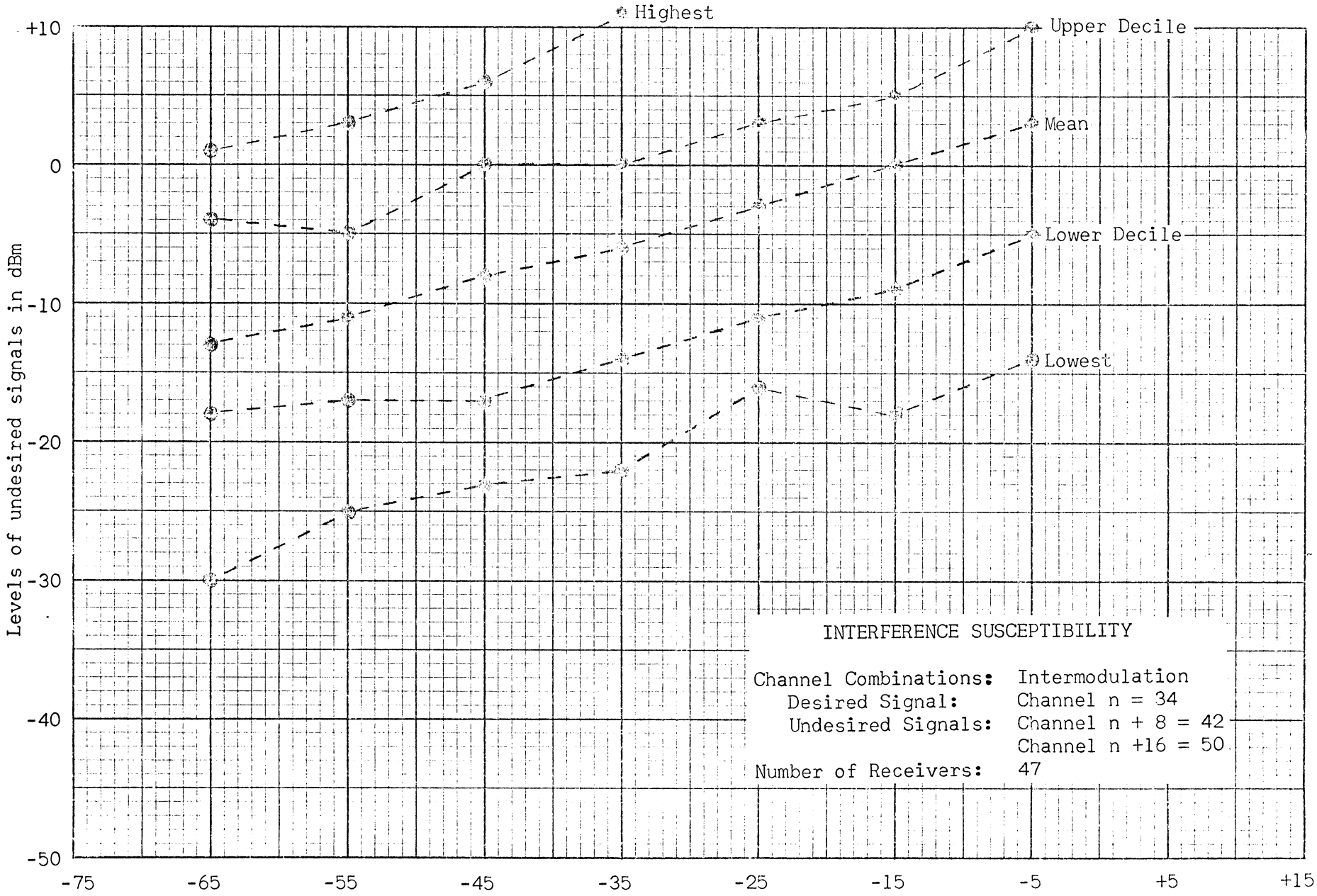

Highest
Upper Decile
Mean
Lower Decile
Lowest
+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Levels of undesired signals in dBm
Level of desired signal in dBm
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Intermodulation
Desired Signal: Channel n = 34
Undesired Signals: Channel n + 8 = 42
Channel n +16 = 50
Number of Receivers: 47

Figure #19

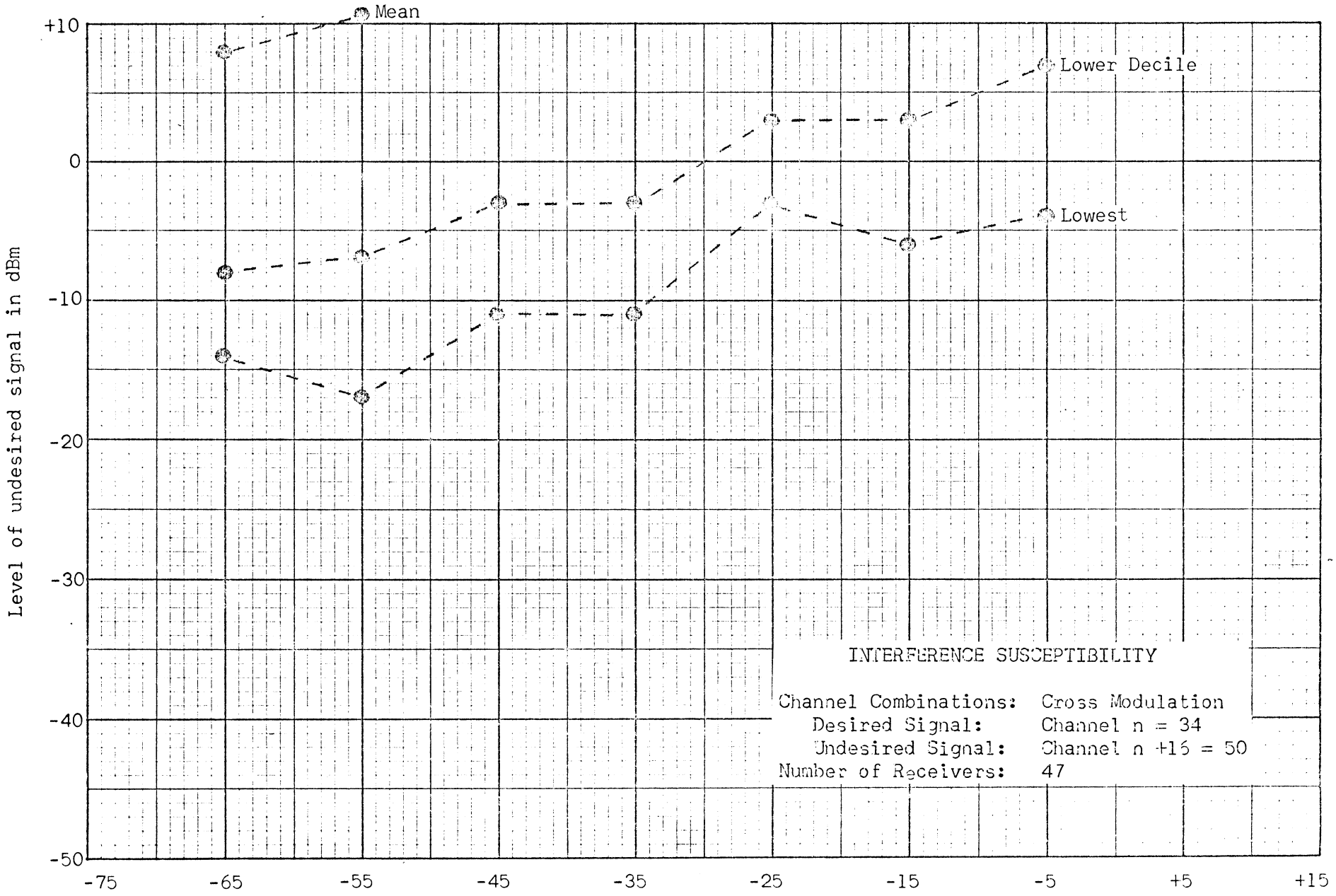

Mean
Lower Decile
Lowest
+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Level of undesired signal in dBm
Level of desired signal in dBm
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Cross Modulation
Desired Signal: Channel n = 34
Undesired Signal: Channel n +16 = 50
Number of Receivers: 47

Figure #20

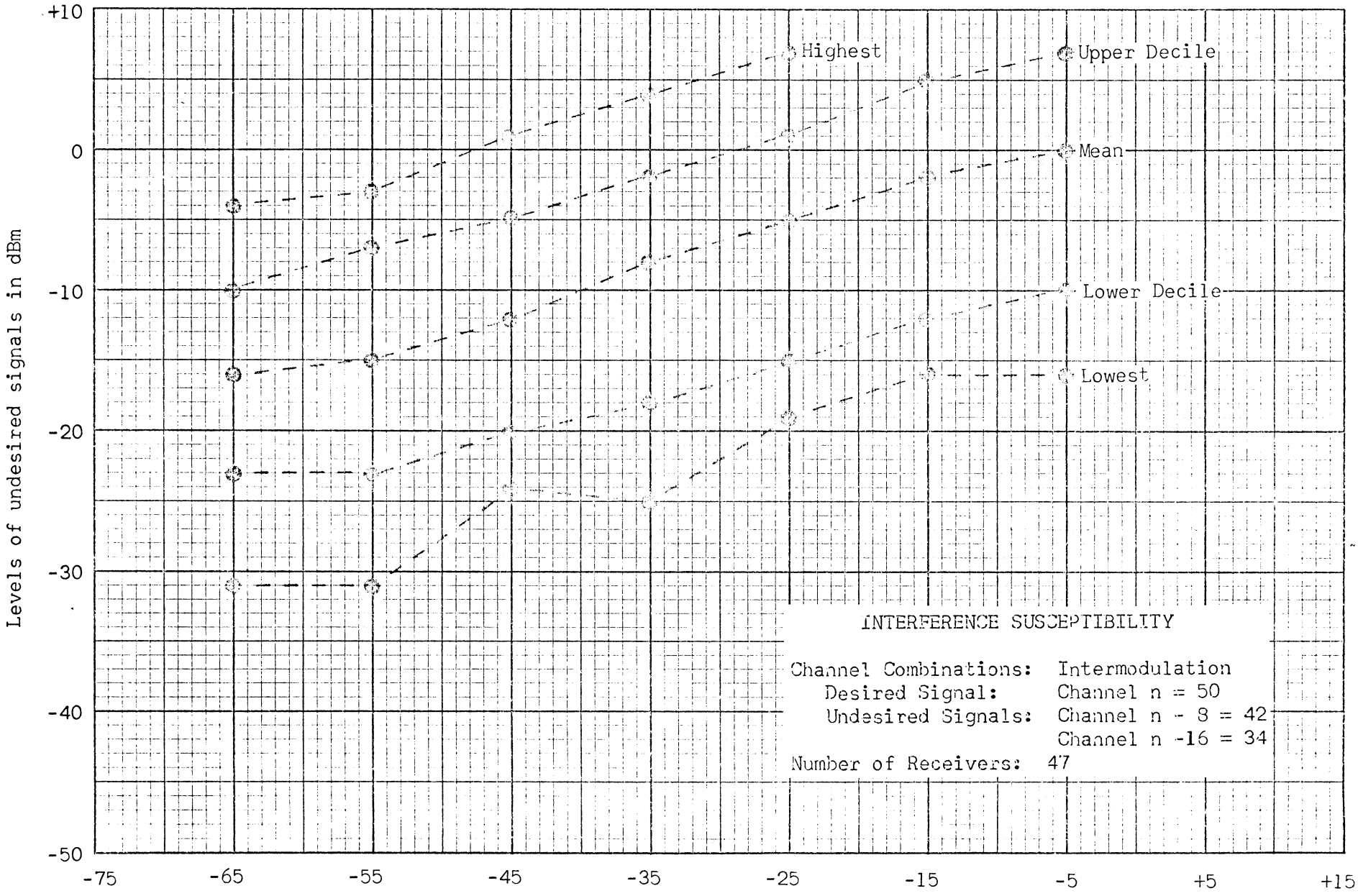

+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Intermodulation
Desired Signal: Channel n = 50
Undesired Signals: Channel n - 8 = 42
Channel n -16 = 34
Number of Receivers: 47
Levels of undesired signals in dBm
Level of desired signal in dBm

Figure #21

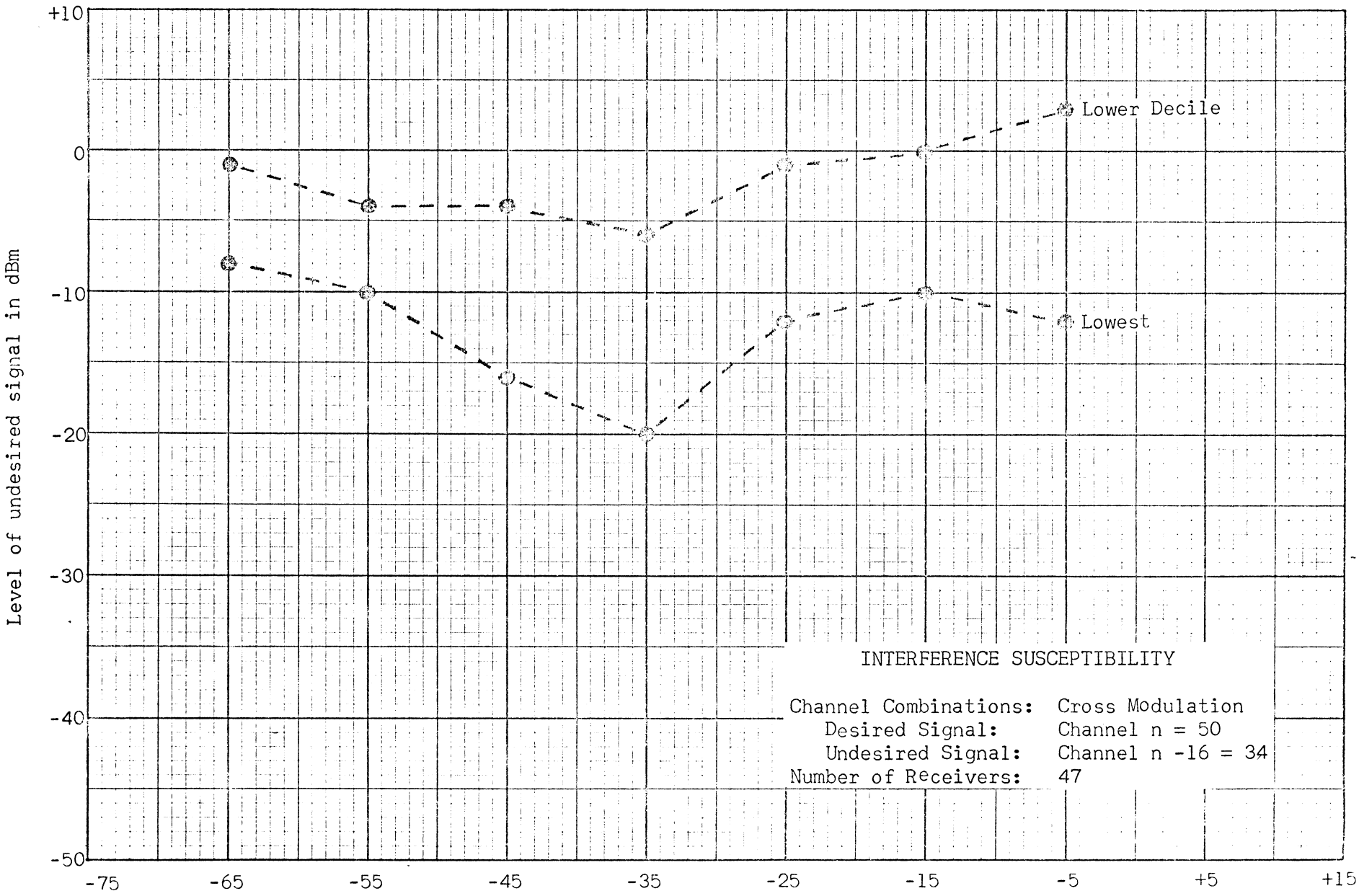

+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Level of undesired signal in dBm
Level of desired signal in dBm
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: Cross Modulation
Desired Signal: Channel n = 50
Undesired Signal: Channel n -16 = 34
Number of Receivers: 47

Figure #22

Interference Created by IF Beat

Figures 23-29

(The absence of some points and even entire level curves result from those values being beyond the maximum undesired level available from our test setup, +11 dBm.)

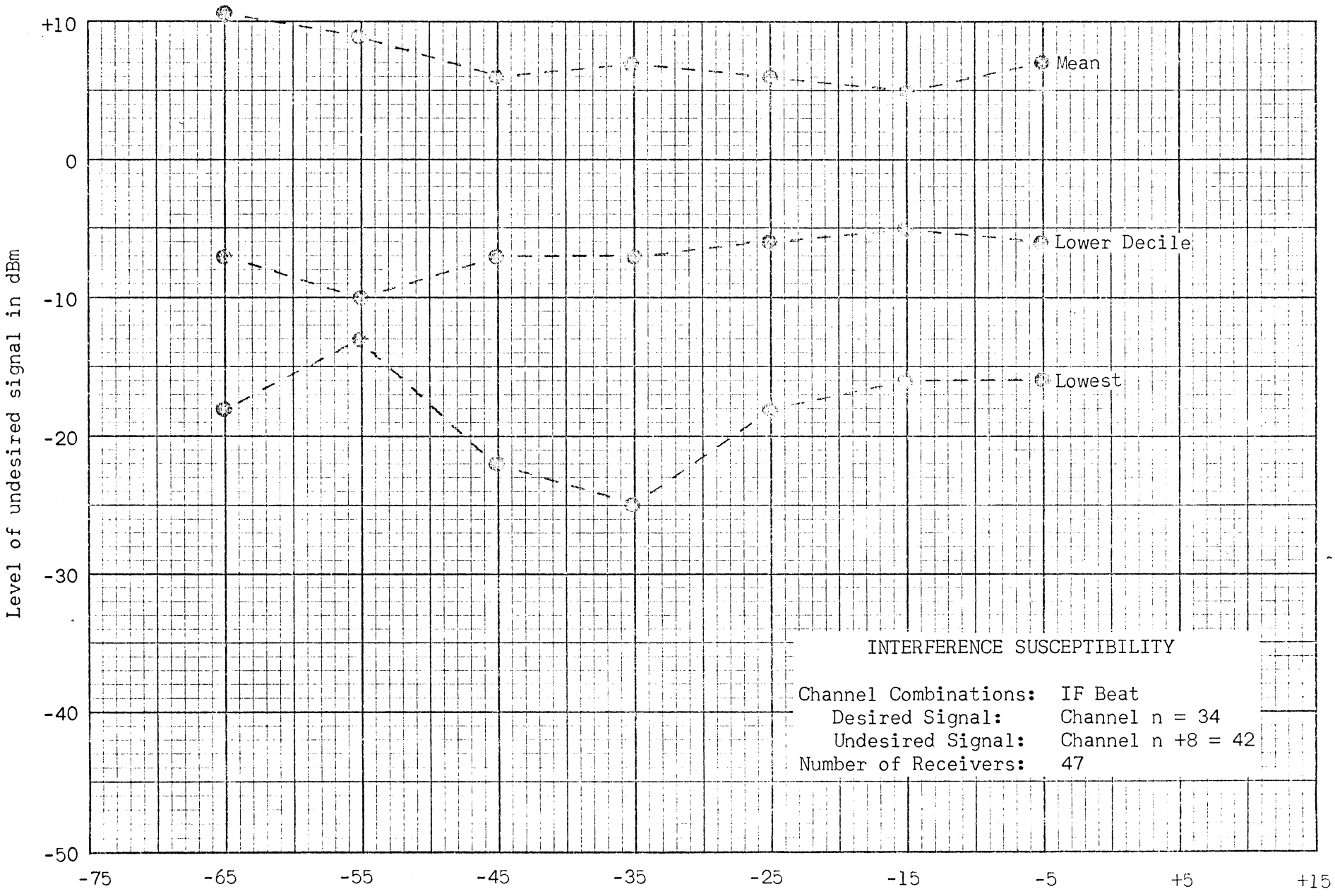

+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: IF Beat
Desired Signal: Channel n = 34
Undesired Signal: Channel n +8 = 42
Number of Receivers: 47
Level of undesired signal in dBm
Level of desired signal in dBm

Figure #23

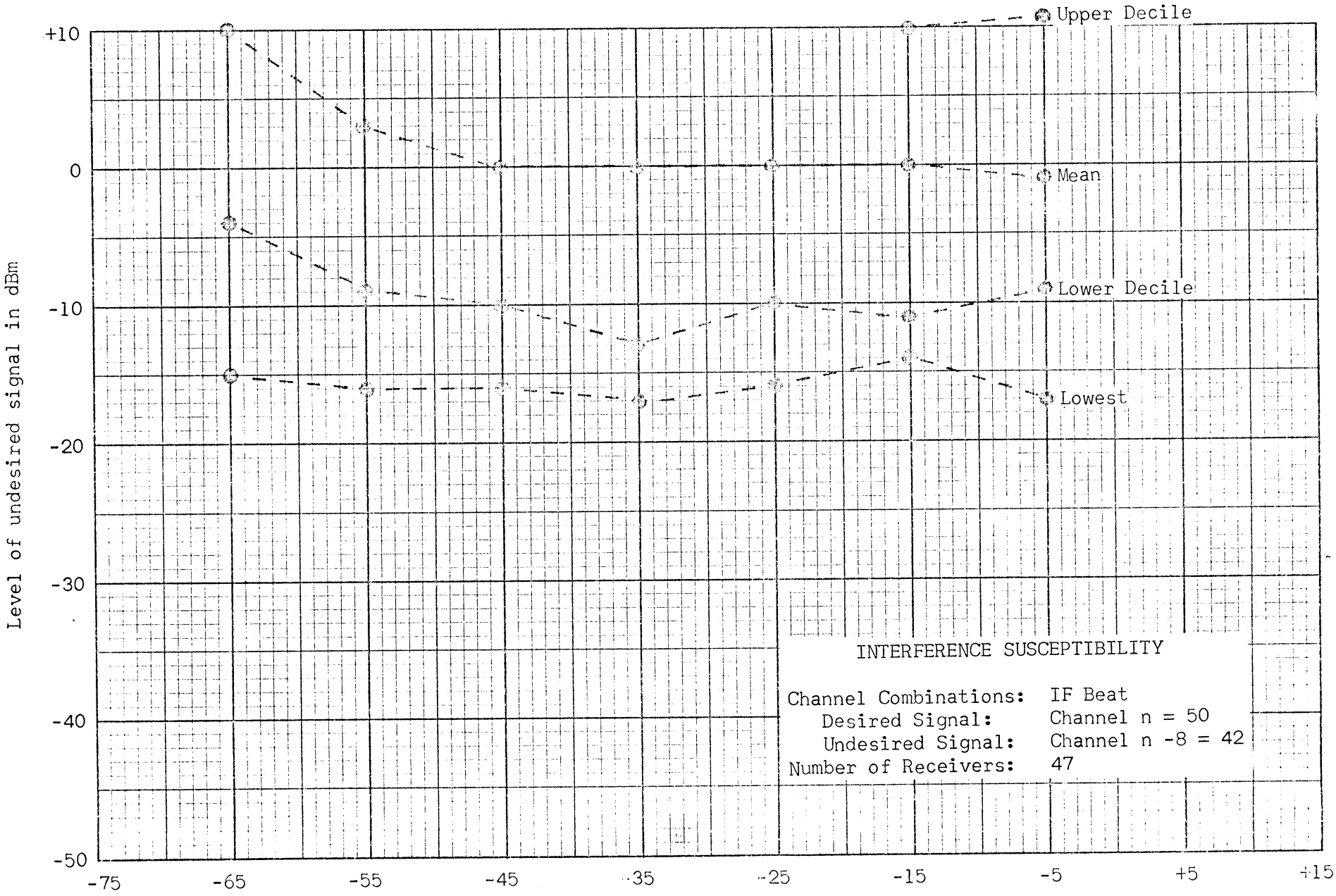

Upper Decile
Mean
Lower Decile
Lowest
+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Level of undesired signal in dBm
Level of desired signal in dBm
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: IF Beat
Desired Signal: Channel n = 50
Undesired Signal: Channel n -8 = 42
Number of Receivers: 47

Figure #24

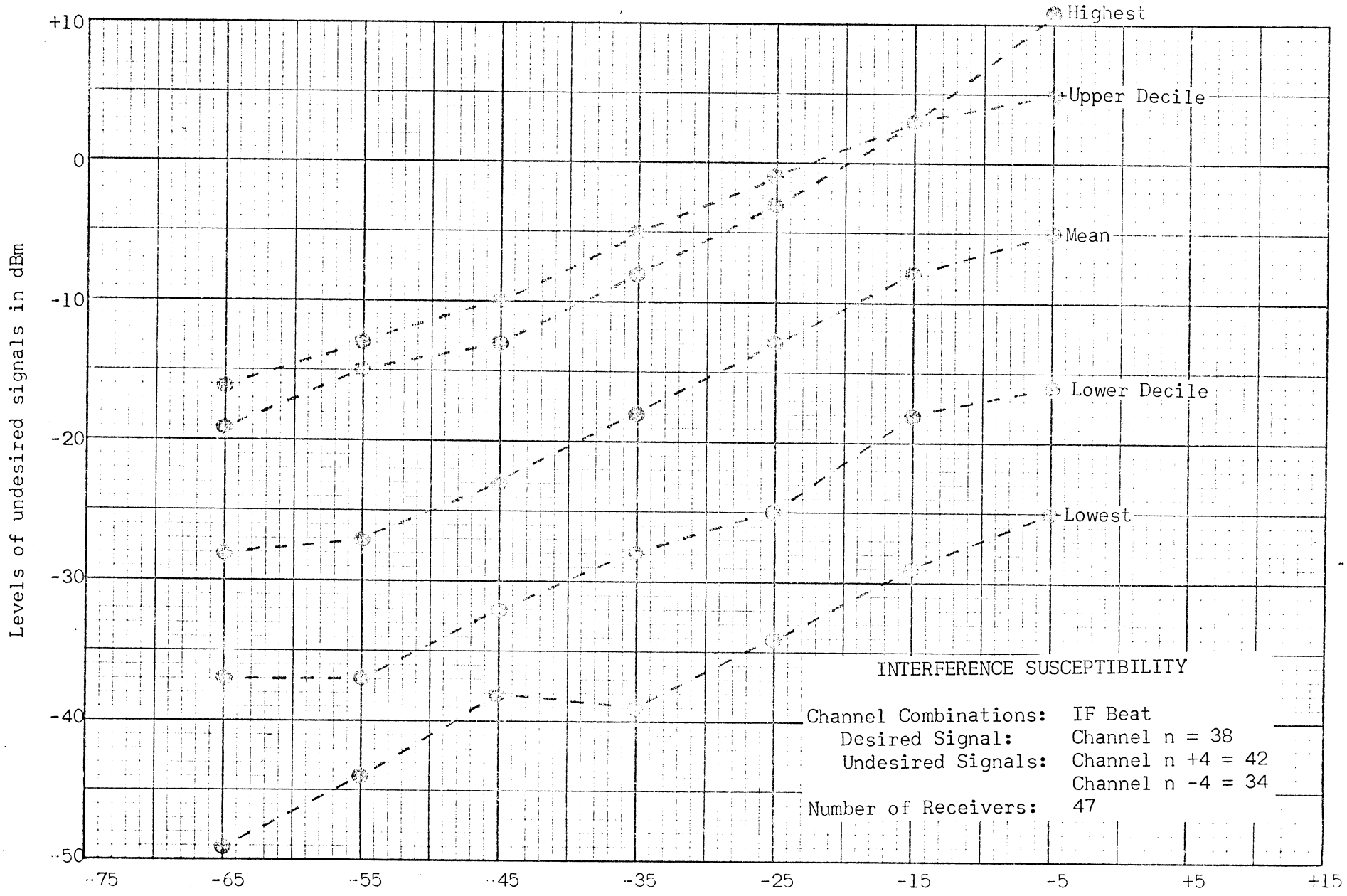

Highest
Upper Decile
Mean
Lower Decile
Lowest
+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Levels of undesired signals in dBm
Level of desired signal in dBm
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: IF Beat
Desired Signal: Channel n = 38
Undesired Signals: Channel n +4 = 42
Channel n -4 = 34
Number of Receivers: 47

Figure #25

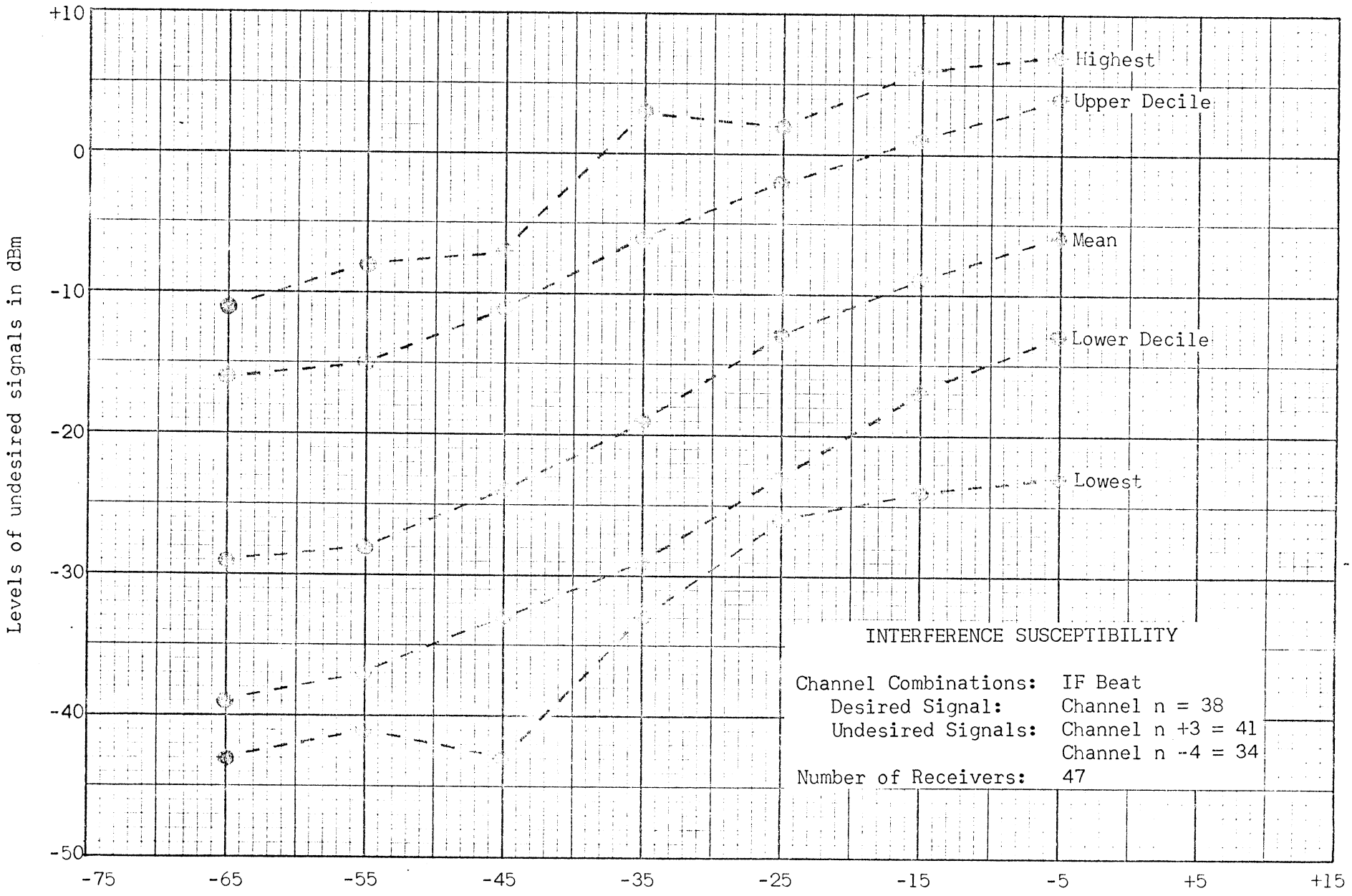

+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Highest
Upper Decile
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: IF Beat
Desired Signal: Channel n = 38
Undesired Signals: Channel n +3 = 41
Channel n -4 = 34
Number of Receivers: 47
Levels of undesired signals in dBm
Level of desired signal in dBm

Figure #26

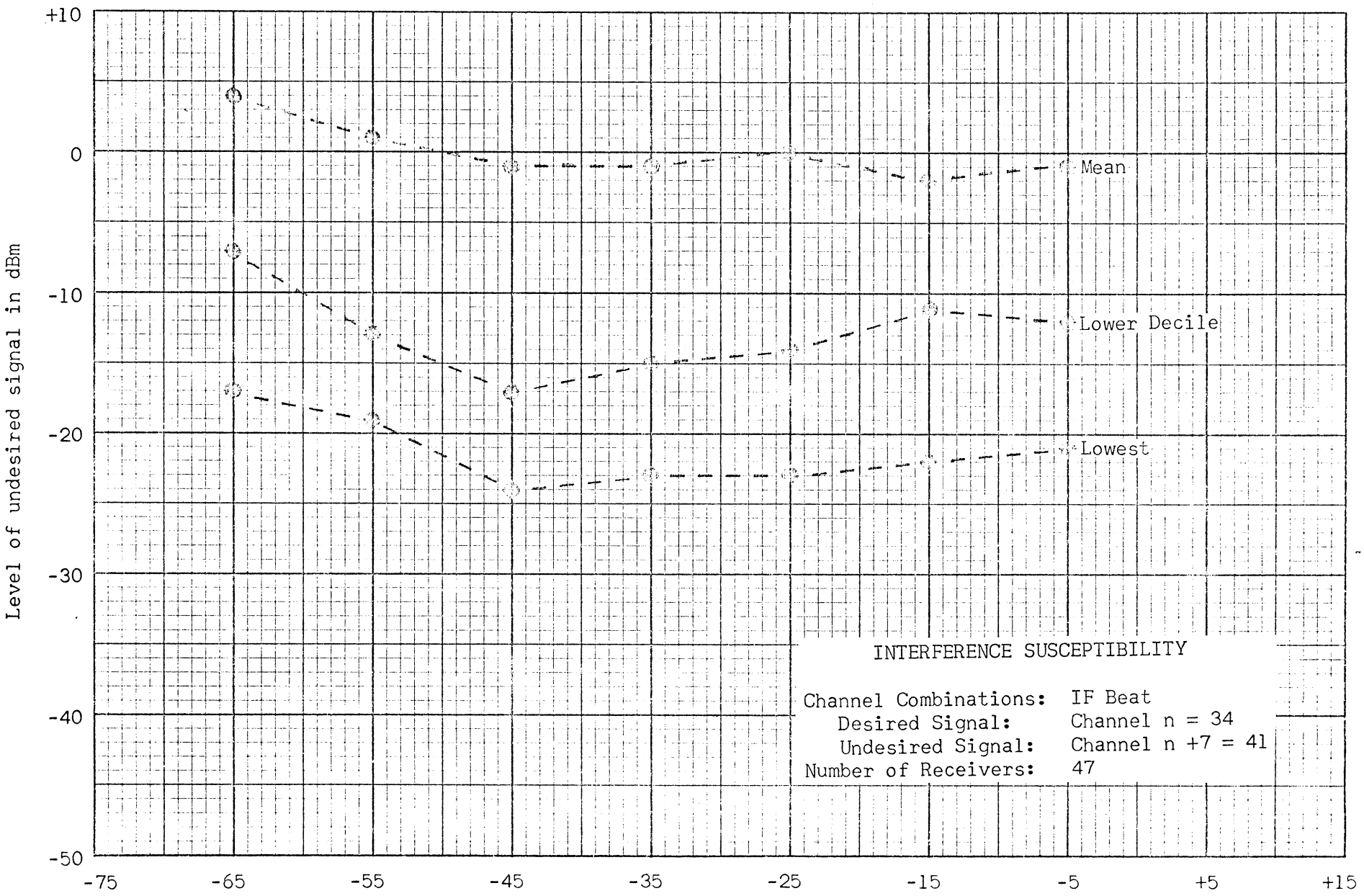

+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Level of undesired signal in dBm
Level of desired signal in dBm
Mean
Lower Decile
Lowest
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: IF Beat
Desired Signal: Channel n = 34
Undesired Signal: Channel n +7 = 41
Number of Receivers: 47

Figure #27

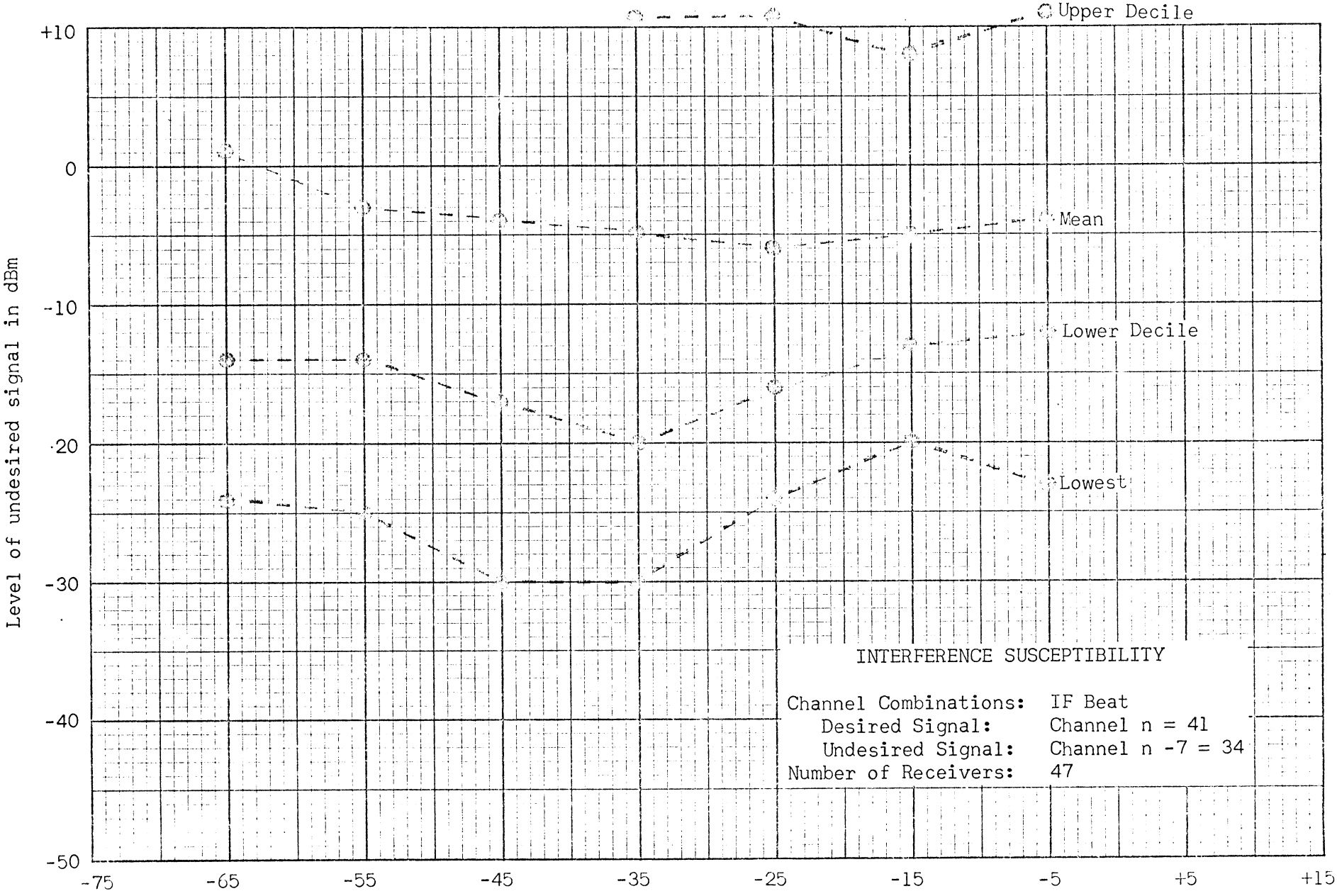

Upper Decile
Mean
Lower Decile
Lowest
+10
0
-10
-20
-30
-40
-50
-75
-65
-55
-45
-35
-25
-15
-5
+5
+15
Level of undesired signal in dBm
Level of desired signal in dBm
INTERFERENCE SUSCEPTIBILITY
Channel Combinations: IF Beat
Desired Signal: Channel n = 41
Undesired Signal: Channel n -7 = 34
Number of Receivers: 47

Figure #28

Picture Quality, TASO Grade (Receiver Noise as Only Interference)

vs. Signal Level

Figures 29-30

(TASO Grade 1 could not be obtained on some receivers.)

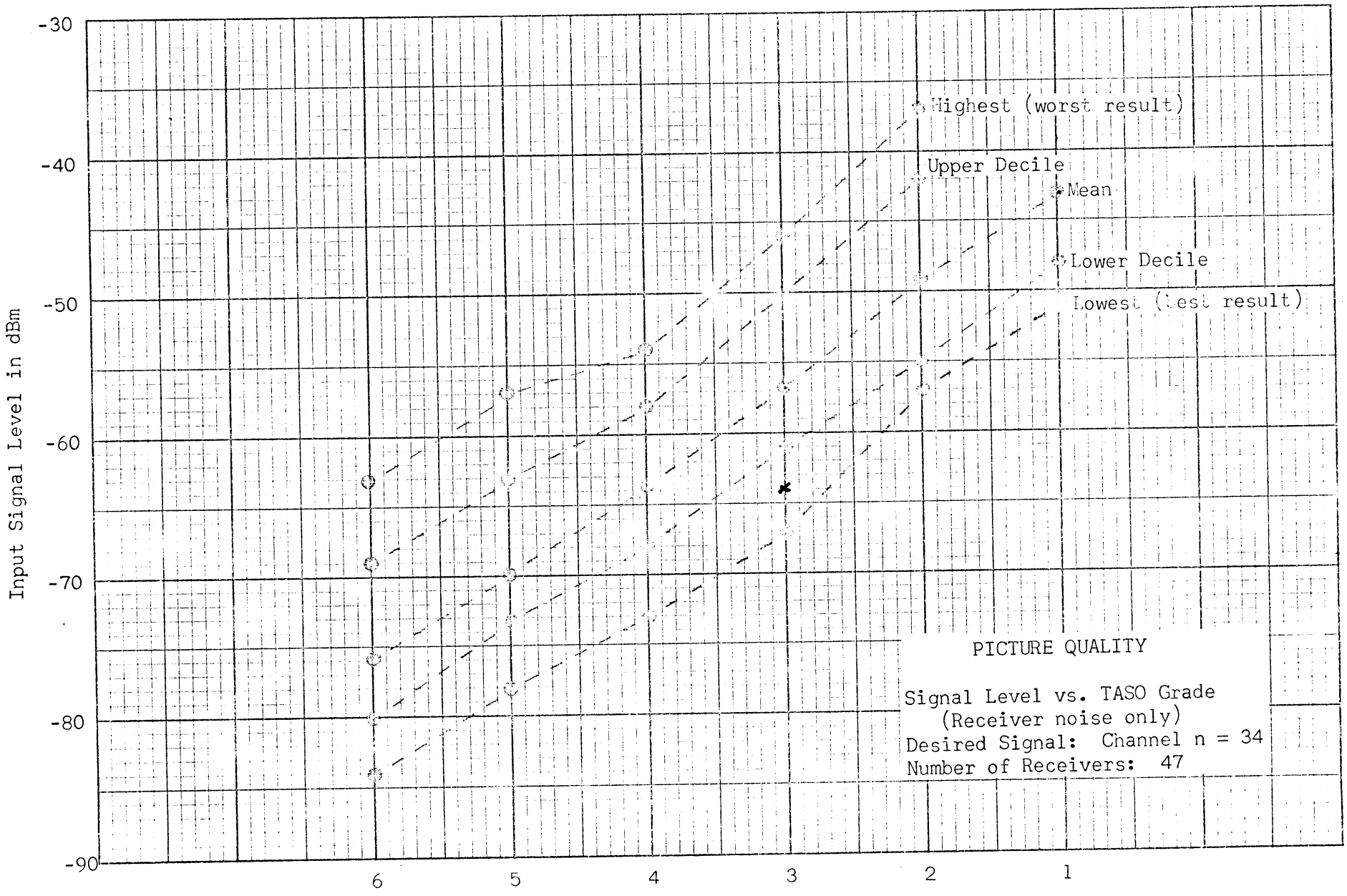

-30
-40
-50
-60
-70
-80
-90
Input Signal Level in dBm
Highest (worst result)
Upper Decile
Mean
Lower Decile
Lowest (best result)
PICTURE QUALITY
Signal Level vs. TASO Grade
(Receiver noise only)
Desired Signal: Channel n = 34
Number of Receivers: 47
6
5
4
3
2
1
TASO Picture Grade

Figure #29

Picture Quality Grades
vs
Desired Signal Level (dBm)

Color
Receiver No. 38

Observer Statistic	TASO Grades 1	2	3	4	5	6
Median of 29	-31	-39	-46	-55	-63	-68
Median of 26	-31	-37.5	-46	-55	-62.5	-67.5
Median of 3	-35	-41	-46	-58	-64	-70
Mean of 29	N.A.	-38.5	-46.1	-55.1	-61.1	-67.1
Mean of 26	N.A.	-38.3	-46.2	-55.1	-60.8	-66.9
Mean of 3	-34.3	-40.3	-45.7	-55.3	-63.3	-69.3

Color
Receiver No. 43

Observer Statistic	TASO Grades 1	2	3	4	5	6
Median of 29	-32.0	-38.0	-45.0	-52	-58	-65.0
Median of 26	-28.0	-38.0	-44.5	-52	-59	-65.5
Median of 3	-36.0	-40.0	-45	-55	-58	-64
Mean of 29	N.A.	-38.0	-43.7	-52.3	-58.7	-64.4
Mean of 26	N.A.	-38.3	-43.4	-52.2	-58.8	-64.4
Mean of 3	-30.3	-35.7	-45.7	-53.3	-57.3	-64.3

Monochrome
Receiver No. 47

Observer Statistic	TASO Grades 1	2	3	4	5	6
Median of 29	-44	-50	-57	-63	-71	-77
Median of 26	-44	-50	-56.5	-63	-71.5	-76.5
Median of 3	-43	-49	-57	-65	-71	-77
Mean of 29	N.A.	-49.5	-56.8	-64.4	-70.8	-77.9
Mean of 26	N.A.	-49.5	-56.8	-64.3	-71.0	-78.0
Mean of 3	-43.0	-49.0	-57.0	-65.0	-69.3	-76.3

FIG. 30

The work described herein was accomplished through the efforts of:

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