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Interference Immunities of Aviation Receivers Due to FM Broadcast Transmissions. Project EEB-89-2

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BACKGROUND

The FM broadcast band extends from 88 to 108 MHz and is adjacent to an aeronautical navigation and communications band at 108 to 137 MHz. There is concern that if additional FM stations are added without careful consideration of their impact on the aeronautical services, a dangerous situation could be created. For example, interference to airport instrument landing systems (ILS) caused by multiple FM broadcast stations (intermodulation) could compromise the safe use of affected runways.

The level of an ILS signal varies throughout its service volume but previous work examining interference immunities of aviation receivers primarily considered the case where the received ILS signal is assumed to be constant at the minimum desired level (-89 dBm at the ILS receiver's antenna terminal).[1] This paper considers cases where the ILS signal is stronger than the minimum desired level and shows the effect on the potential for intermodulation interference.

PROCEDURE

Ten aeronautical localizer receivers were tested to determine their susceptibility to intermodulation interference caused by combinations of two and three FM broadcast transmissions. The tests were conducted in a manner to show how the intermodulation responses of the receivers varied with respect to changes in the desired ILS signal level. The particular receiver models were selected based in part on their popularity in private and commercial aircraft and in part on their availability.

The equipment setup shown in Figure 1 was used in making the two and three signal intermodulation tests. The undesired signals were set to equal levels with their amplitudes controlled by a calibrated attenuator. In each group the highest frequency signal was modulated with FM stereo and the remaining signal, or signals, remained unmodulated. The FM stereo signal had a peak carrier deviation of 45 kHz and used shaped noise for the audio source.[2] The audio used to drive the FM signal generator was separated into a right and left channel with the amplitude of the right channel 6 dB lower than that of the left. The amplitude difference is necessary to insure that an L-R component is present in the FM signal.

The desired signal was a standard localizer signal. The localizer is used by the pilot, when landing, to determine the location of his airplane relative to the centerline of the runway. The actual localizer signal is equivalent to a carrier amplitude modulated by two audio tones, 150 Hz and 90 Hz. The depth of modulation of each tone is 20% when the aircraft is on the centerline of the runway. As the aircraft's location deviates to the left or the right of the centerline, the depth of modulation of the audio tones changes but the sum of the depths of modulation of the two audio frequencies is always equivalent to 40%. The difference in the depth of modulation (DDM) between the two tones indicates the position of the aircraft relative to the centerline of the runway.

For the data presented in this report, the desired signal was a standard localizer signal having a difference in depth of modulation of 9.3%. The amplitude of the 90 Hz tone was greater than the amplitude of the 150 Hz tone. This signal is a calibration and test point used by the aeronautical industry and represents a standard deflection of 90 uA in an aircraft receiver course indicator.

The level of the desired signal was initially set to -89 dBm.[3] It is based on an assumed localizer field strength of 32 dBuV/m and a lossless isotropic antenna/feeder system.

With the desired signal set to -89 dBm, measured at the antenna port of the receiver under test, the undesired signal levels were increased in equal increments until an average deflection of 7.5 uA from the standard deflection of 90 uA was noted in the course deviation indicator. A 7.5 uA deviation is the reference criterion for interference established by the CCIR.[4] The level of the undesired signals necessary to produce the 7.5 uA deviation was recorded.

The current through the course deviation indicator was measured by using an averaging digital voltmeter to monitor the voltage drop across the indicator. A digital computer was used to read the voltmeter and convert the readings to current deviation in uA from the standard of 90 uA. These readings were displayed on the computer terminal for observation and recording by the test operator.

This procedure was repeated for ILS signal levels of -79, -69, -59 and -49 dBm.

A total of 150 data points were obtained for each receiver. Fifty data points were collected for each of three localizer frequencies, 108.1, 109.1 and 110.1 MHz. At each of the localizer frequencies 25 of the data points were for two-signal, third order intermodulation and 25 were for three-signal, third order intermodulation. In all cases the levels of the individual undesired signals were equal to each other. The data are presented in Tables 1 through 10.

The data is also presented in Figures 2 through 6 as graphs of undesired signal levels in dBm versus the frequency product in MHz^3. This method of displaying intermodulation interference data is consistent with methods used by others to report similar data to the CCIR. It is a convenient way of grouping receivers for a quick visual comparison of their intermodulation interference responses.

The frequency product is calculated as follows:

For the two signal intermodulation cases:

DF1 = LOC-F1
DF2 = LOC-F2
FP = DF1 * DF1 * DF2

where:

LOC = The frequency of the localizer transmitter (MHz)
F1 = The highest undesired frequency (MHz)
F2 = The remaining undesired frequency (MHz)
FP = The frequency product (MHz^3)

For the three signal intermodulation cases:

DF1 = LOC-F1
DF2 = LOC-F2
DF3 = LOC-F3
FP = DF1 * DF2 * DF3

where:

LOC = The frequency of the localizer transmitter (MHz)
F1 = The highest undesired frequency (MHz)
F2 = The next highest undesired frequency (MHz)
F3 = The remaining undesired frequency (MHz)
FP = The frequency product (MHz^3)

Each point shown in the set of graphs may represent more than one receiver. For example in Figure 6, two points are shown for the three signal intermodulation frequency product of 2660 MHz^3. A check of Table 10 shows that nine of the receivers had values greater than zero and one had a value of -1.

The solid and dashed lines in each graph represent protection criteria values calculated in accordance with a mathematical model developed for the FAA by Ohio University.[5] The solid line is for two signal and the dashed line is for three signal intermodulation. Receivers with an intermodulation interference response on or above the lines meet or exceed the criteria for protection from two and three signal intermodulation.

The formulae for the lines are:

For two signal intermodulation (F1 > F2):

$$Th2 = 8.787 * LOG[DF1 * DF1 * DF2] - 44.59$$

For three signal intermodulation (F1 > F2 > F3):

$$Th3 = 9.019 * LOG[DF1 * DF2 * DF3] - 47.08$$

where:

Th2 = Threshold for two signal intermodulation
Th3 = Threshold for three signal intermodulation.

To better understand the intermodulation interference immunities of ILS receivers for cases of small frequency products (less than 3.5 MHz^3), additional two signal intermodulation tests were performed. Three receivers made by different manufacturers were selected and tested in the manner described above. The results of these tests are reported in Tables 11 through 13.

To understand the effects of differing interfering signal levels, the subset of three receivers was also tested for the condition where the two interfering signals were not at equal levels. The measurement procedure was carried out for two sets of conditions: first the level of the higher frequency was set 10 dB above that of the lower frequency; second the level of the higher frequency was set 10 dB below that of the lower frequency. The results are reported in Tables 14 through 16. In places where a signal level is shown, that value is the level of the undesired signal with greater magnitude.

DISCUSSION AND CONCLUSIONS

In general, when two or three signals mix in a receiver a third order intermodulation product can be produced. If the signals are at equal levels and are kept equal as they are increased, the intermodulation product will increase three dB for every one dB increase in the signals causing the product.

If the frequency of a desired signal coincides with the frequency of an intermodulation product interference occurs. A desired to undesired ratio (D/U) can be established for a predetermined criterion for interference. In the case of ILS localizer receivers, that interference criterion is a 7.5 uA deviation from a standard deflection of 90 uA. If the desired signal is increased by 10 dB then the product causing the interference must increase by 10 dB to achieve the same interference effect. Since there is a three to one relationship between the intermodulation product and the signals causing it, each of the intermodulating signals must be increased 3.3 dB. This is confirmed by examining the data tables, which show that for every 10 dB increase in desired signal the undesired signals had to be increased only three to four dB to achieve the interference criterion. In other words, a 10 dB increase in desired signal results in only a three to four dB increase in intermodulation interference protection.

The Tables show that exceptions to this conclusion do occur. They appear to be confined to cases where the interfering frequencies are close to the high end of the FM broadcast band and the localizer frequency is 108.1 MHz.

For individual receivers, the level of the undesired frequencies necessary to produce the interference criterion appears to be a function of the frequency product and not to be dependent upon the exact frequencies of the desired and undesired signals. This becomes more apparent when the data presented in Tables 11 through 13 are studied.

From the data plotted in Figures 2 through 6, it can be inferred that there is a close relationship between two and three signal intermodulation interference cases when they have close frequency products. This implies that a single model could be developed and used for all cases of third order intermodulation interference analysis.

From Tables 14 through 16 it can be seen that whenever the levels of the interfering signals differ, the level of the stronger signal must exceed the level of equal level interferers to produce the interference criteria. Thus, providing intermodulation protection based on equal level interferers will automatically provide protection in cases where they are of unequal level.

REFERENCES

1. The interference criterion of a 7.5 uA average deflection from the standard deflection of 90 uA and a desired signal level of -89 dBm are taken from a Canadian action paper presented to the ICAO Communications/Operations Divisional Meeting in September 1985. "Compatibility Between the FM Sound Broadcasting and the Aeronautical Radionavigation Services: Intermodulation Interference Tests on Aircraft Localizer Receivers" (CAN-10-2B).

2. The noise was shaped in accordance with recommendation 559 Curve B of the CCIR XIV Plenary Assembly, Kyoto, 1978, Volume X, Broadcasting Service (Sound).

3. "Compatibility Between the FM Sound Broadcasting and the Aeronautical Radionavigation Services: Intermodulation Interference Tests on Aircraft Localizer Receivers" (CAN-10-2B).

4. "Compatibility Between the FM Sound Broadcasting and the Aeronautical Radionavigation Services: Intermodulation Interference Tests on Aircraft Localizer Receivers" (CAN-10-2B).

5. This model is described in a paper presented to the CCIR Joint Interim Working Party JIWP 8-10/1 in March 1987.

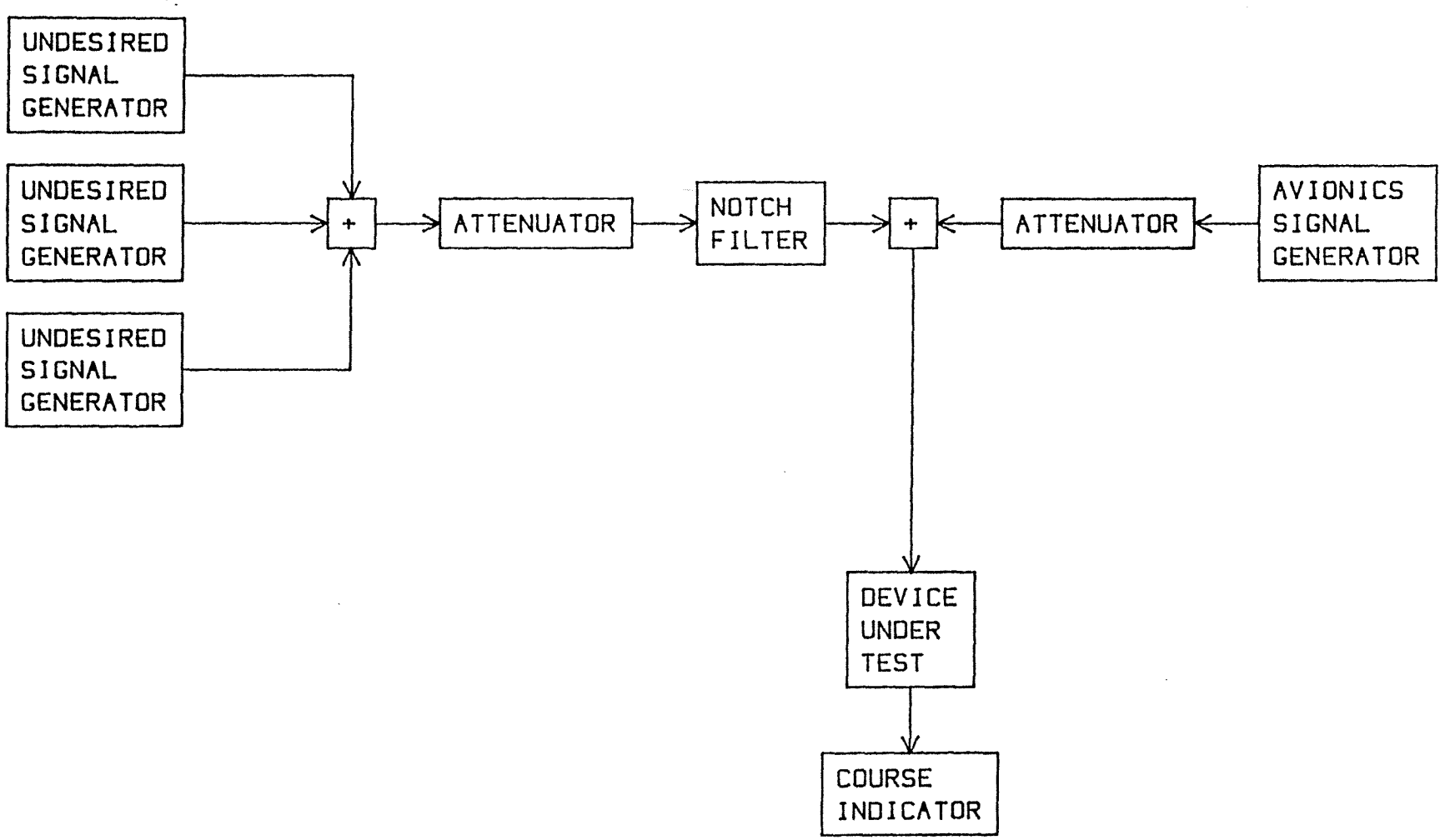

Figure 1. Block diagram of the equipment setup used in making the two and three signal intermodulation measurements.

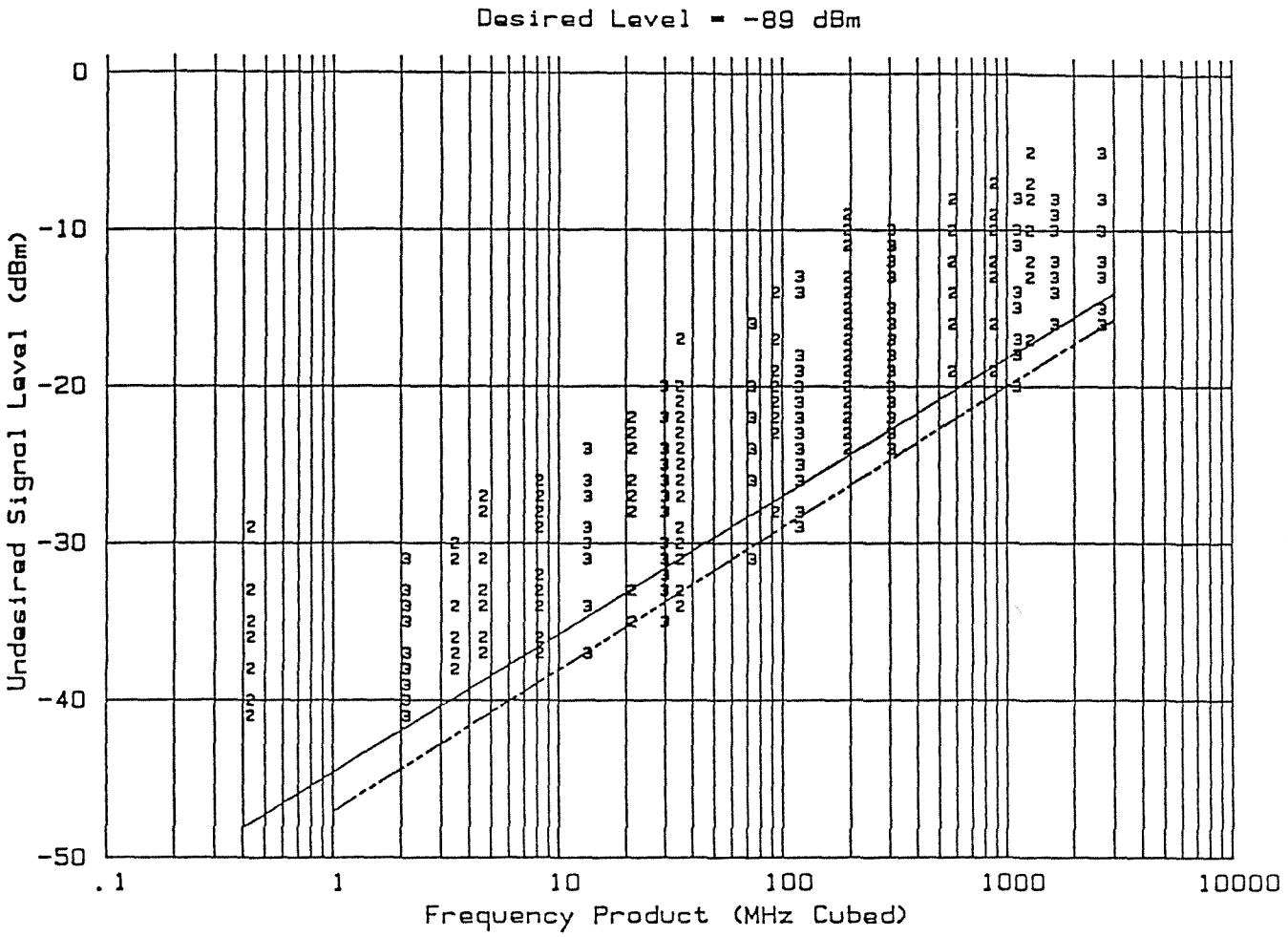

Figure 2. This is a plot of undesired signal level (dBm) vs frequency product (MHz cubed) for two and three signal intermodulation interference to aeronautical localizer receivers. The undesired signal levels shown are those necessary to produce a 7.5 uA deviation from a standard deflection of 90 uA in a course deviation indicator. The points plotted as "2" are for two signal and those plotted as "3" are for three signal intermodulation interference. The straight lines drawn represent interference criteria used in a model proposed for use in the USA. The solid line is for the two signal model and the dashed line is for the three signal model.

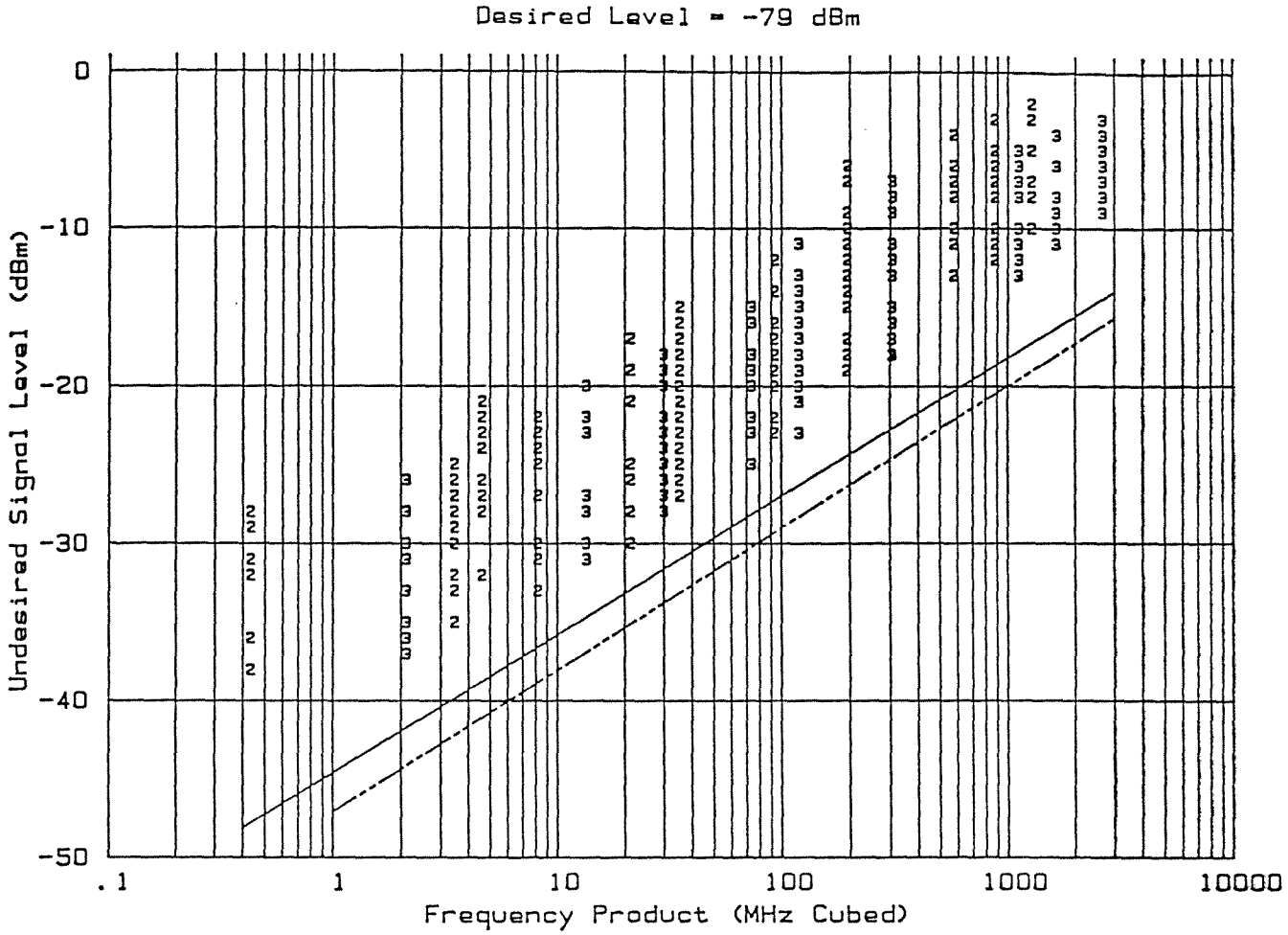

Figure 3. This is a plot of undesired signal level (dBm) vs frequency product (MHz cubed) for two and three signal intermodulation interference to aeronautical localizer receivers. The undesired signal levels shown are those necessary to produce a 7.5 uA deviation from a standard deflection of 90 uA in a course deviation indicator. The points plotted as "2" are for two signal and those plotted as "3" are for three signal intermodulation interference. The straight lines drawn represent interference criteria used in a model proposed for use in the USA. The solid line is for the two signal model and the dashed line is for the three signal model.

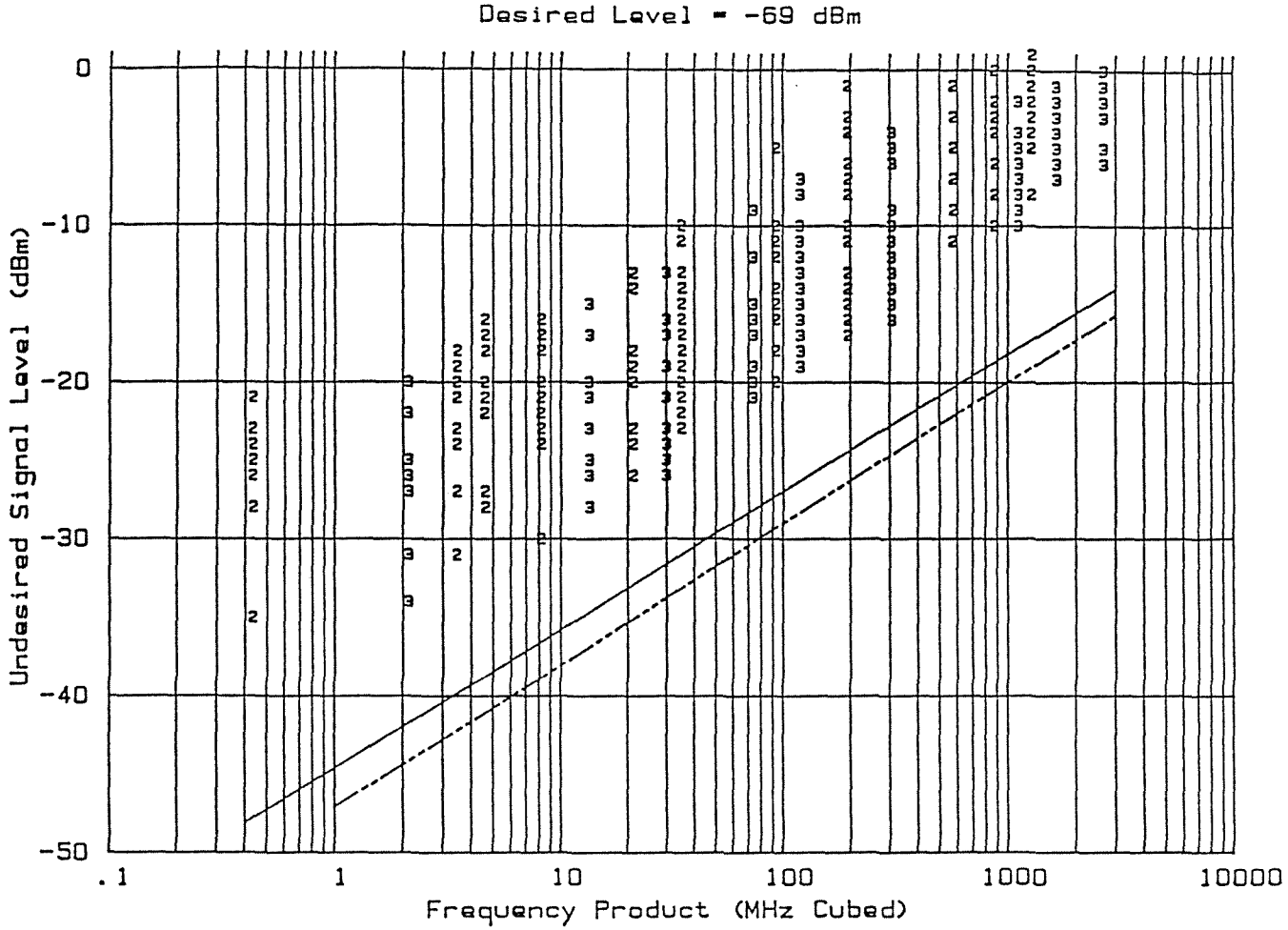

Figure 4. This is a plot of undesired signal level (dBm) vs frequency product (MHz cubed) for two and three signal intermodulation interference to aeronautical localizer receivers. The undesired signal levels shown are those necessary to produce a 7.5 uA deviation from a standard deflection of 90 uA in a course deviation indicator. The points plotted as "2" are for two signal and those plotted as "3" are for three signal intermodulation interference. The straight lines drawn represent interference criteria used in a model proposed for use in the USA. The solid line is for the two signal model and the dashed line is for the three signal model.

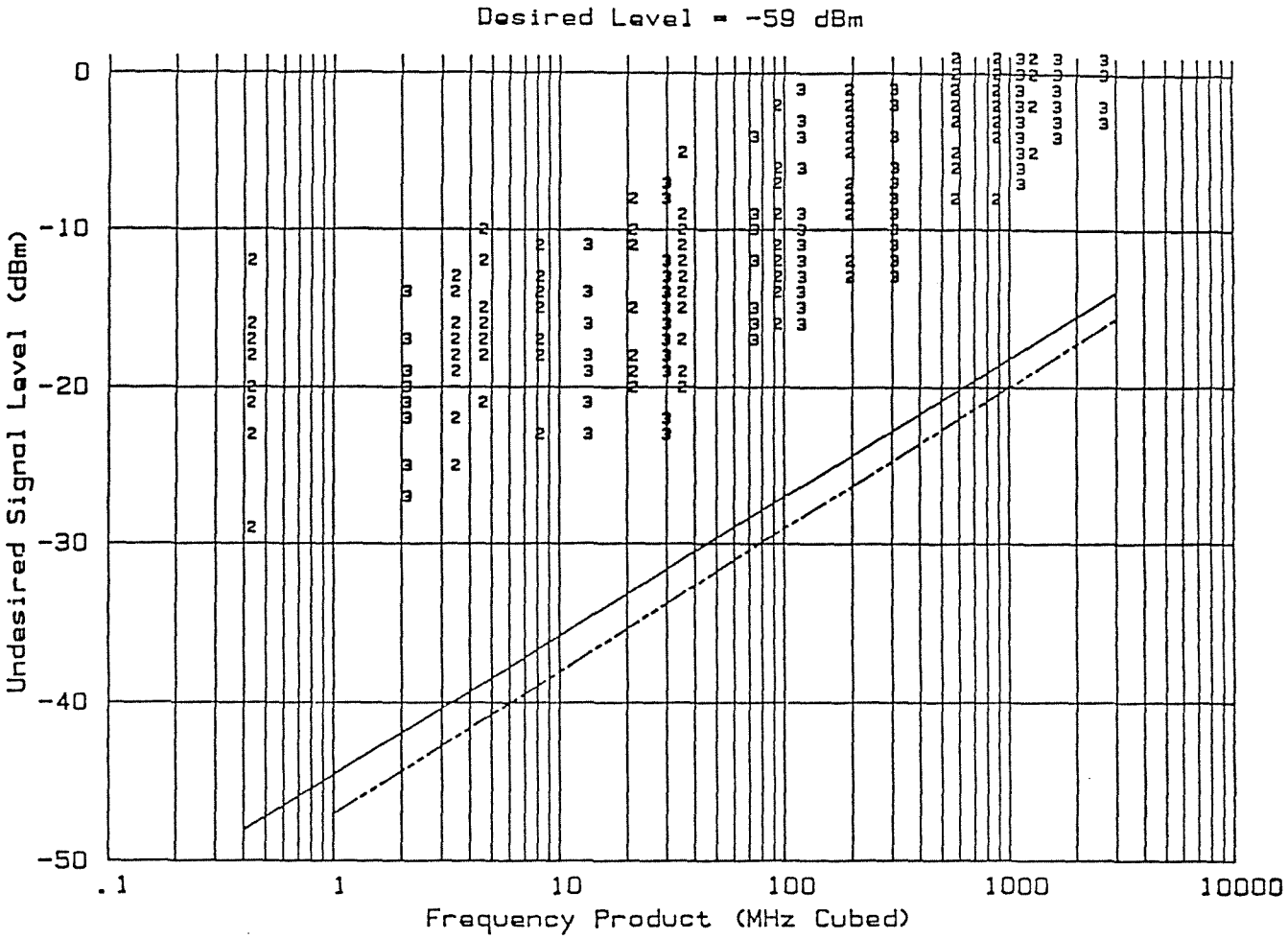

Figure 5. This is a plot of undesired signal level (dBm) vs frequency product (MHz cubed) for two and three signal intermodulation interference to aeronautical localizer receivers. The undesired signal levels shown are those necessary to produce a 7.5 uA deviation from a standard deflection of 90 uA in a course deviation indicator. The points plotted as "2" are for two signal and those plotted as "3" are for three signal intermodulation interference. The straight lines drawn represent interference criteria used in a model proposed for use in the USA. The solid line is for the two signal model and the dashed line is for the three signal model.

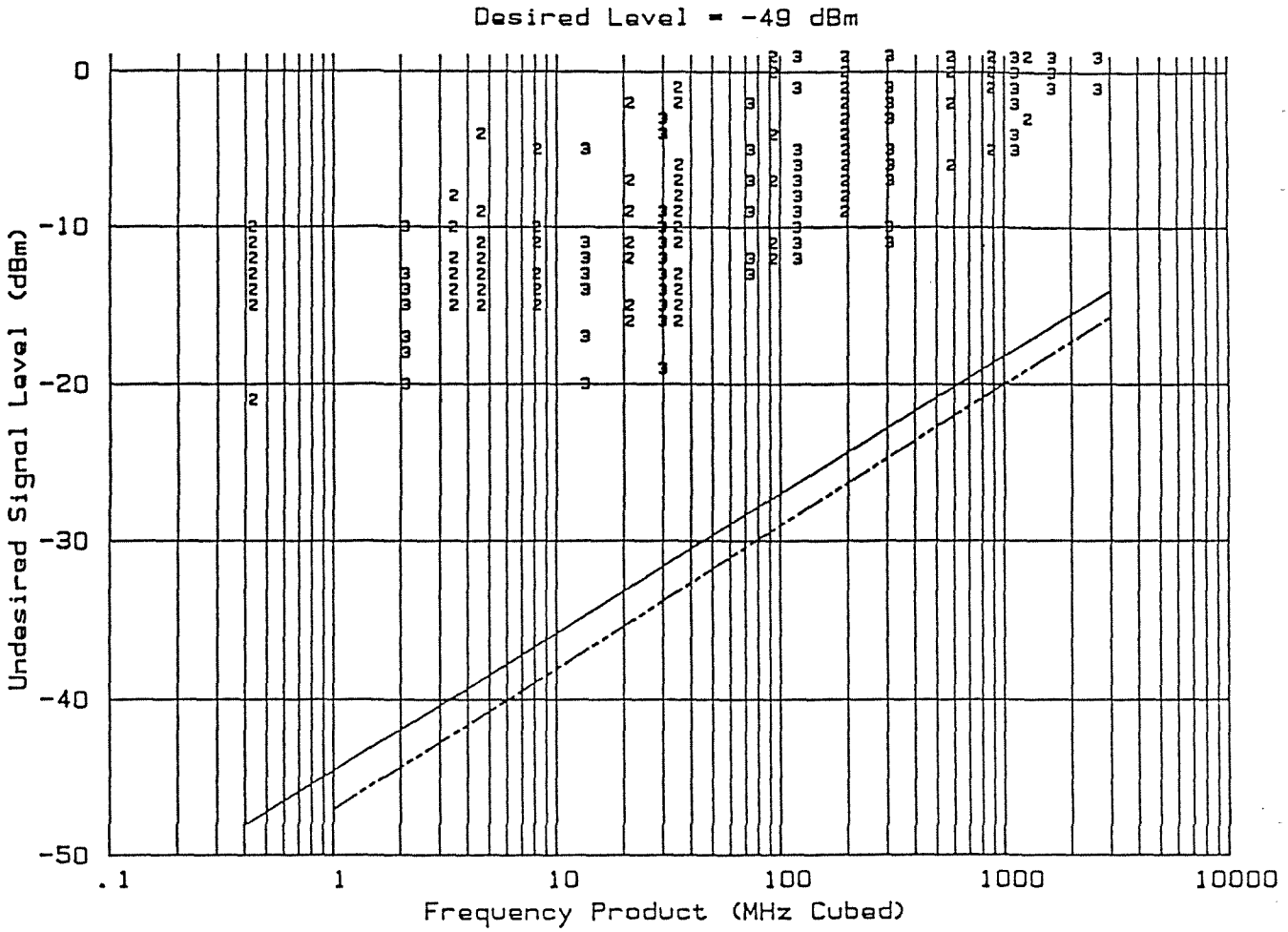

Figure 6. This is a plot of undesired signal level (dBm) vs frequency product (MHz cubed) for two and three signal intermodulation interference to aeronautical localizer receivers. The undesired signal levels shown are those necessary to produce a 7.5 uA deviation from a standard deflection of 90 uA in a course deviation indicator. The points plotted as "2" are for two signal and those plotted as "3" are for three signal intermodulation interference. The straight lines drawn represent interference criteria used in a model proposed for use in the USA. The solid line is for the two signal model and the dashed line is for the three signal model.

Frequencies (MHz)			Receiver, Equal Undesired Signal Levels (dBm)									
Undesired		Desired	A	B	C	D	E	F	G	H	J	L
107.5	106.9	108.1	-38	-36	-29	-33	-36	-40	-40	-41	-40	-35
106.9	104.9	108.1	-31	-37	-28	-27	-34	-33	-27	-36	-34	-27
105.5	102.9	108.1	-23	-30	-23	-21	-31	-24	-17	-27	-26	-22
103.5	98.9	108.1	-13	-22	-11	-16	-23	-18	-10	-16	-21	-18
101.5	94.9	108.1	-10	-16	-10	-12	-16	-14	-8	-12	-19	-14
107.9	106.7	109.1	-36	-37	-30	-30	-37	-36	-34	-38	-36	-31
107.5	105.9	109.1	-33	-36	-28	-27	-37	-34	-29	-37	-32	-26
106.5	103.9	109.1	-24	-26	-25	-22	-33	-24	-20	-29	-23	-22
104.5	99.9	109.1	-14	-22	-11	-15	-23	-18	-9	-16	-20	-17
101.5	93.9	109.1	-9	-13	-9	-10	-16	-12	-7	-10	-19	-13
107.9	105.7	110.1	-26	-28	-27	-24	-35	-28	-23	-33	-28	-22
107.5	104.9	110.1	-24	-21	-25	-22	-34	-25	-20	-30	-24	-21
106.5	102.9	110.1	-21	-23	-19	-17	-28	-20	-14	-22	-22	-19
105.5	100.9	110.1	-15	-20	-14	-15	-24	-18	-9	-16	-19	-17
101.5	92.9	110.1	-8	-10	-7	-8	-13	-10	-5	-8	-17	-12

Table 1. Undesired equal signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for two signal intermodulation interference, equal undesired signal levels and a desired signal level of 89 dBm.

Frequencies (MHz)				Receiver, Equal Undesired Signal Levels (dBm)									
Undesired			Desired	A	B	C	D	E	F	G	H	J	L
107.5	106.5	105.9	108.1	-39	-41	-31	-33	-37	-38	-35	-41	-40	-34
106.5	104.5	102.9	108.1	-27	-32	-25	-24	-33	-26	-20	-30	-28	-24
105.5	102.5	99.9	108.1	-20	-25	-14	-20	-28	-22	-14	-20	-26	-21
104.5	100.5	96.9	108.1	-16	-21	-15	-16	-23	-19	-12	-16	-24	-17
101.5	95.3	88.7	108.1	-9	-14	-10	-12	-12	-12	-8	-9	-16	-13
107.9	106.3	105.1	109.1	-30	-34	-29	-27	-37	-31	-26	-34	-31	-24
107.5	105.5	103.9	109.1	-27	-31	-26	-24	-35	-26	-22	-30	-26	-24
106.5	103.5	100.9	109.1	-21	-24	-18	-19	-29	-22	-13	-21	-24	-22
105.5	101.5	97.9	109.1	-17	-20	-13	-15	-23	-19	-11	-16	-22	-18
103.5	97.5	91.9	109.1	-11	-15	-11	-11	-17	-14	-8	-10	-18	-14
107.9	105.3	103.1	110.1	-22	-24	-22	-20	-31	-22	-16	-26	-26	-22
107.5	104.5	101.9	110.1	-20	-23	-19	-19	-29	-21	-14	-21	-24	-21
106.5	102.5	98.9	110.1	-17	-20	-11	-15	-24	-18	-10	-16	-22	-19
104.5	98.5	92.9	110.1	-11	-15	-10	-11	-17	-14	-8	-10	-20	-14
99.5	98.7	88.1	110.1	-8	-10	-8	-8	-13	-10	-5	-15	-16	-12

Table 2. Undesired equal signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for three signal intermodulation interference, equal undesired signal levels and a desired level of 89 dBm.

Frequencies (MHz) Undesired		Desired	Receiver, Equal Undesired Signal Levels (dBm) A	B	C	D	E	F	G	H	J	L
107.5	106.9	108.1	-28	-32	-28	-28	-29	-36	-31	-38	-32	-32
106.9	104.9	108.1	-22	-32	-26	-23	-27	-28	-21	-32	-26	-24
105.5	102.9	108.1	-19	-25	-21	-18	-23	-21	-15	-24	-21	-19
103.5	98.9	108.1	-10	-18	-7	-12	-17	-14	-7	-13	-17	-14
101.5	94.9	108.1	-7	-13	-6	-8	-11	-10	-4	-8	-13	-11
107.9	106.7	109.1	-26	-33	-28	-25	-30	-32	-25	-35	-29	-27
107.5	105.9	109.1	-24	-31	-27	-23	-30	-30	-22	-33	-25	-23
106.5	103.9	109.1	-19	-25	-22	-18	-27	-21	-16	-25	-21	-18
104.5	99.9	109.1	-10	-19	-9	-11	-18	-15	-6	-13	-18	-14
101.5	93.9	109.1	-6	-11	-5	-7	-11	-8	-3	-7	-12	-10
107.9	105.7	110.1	-21	-26	-25	-19	-28	-25	-19	-30	-21	-17
107.5	104.9	110.1	-20	-25	-22	-17	-27	-21	-17	-26	-21	-18
106.5	102.9	110.1	-18	-22	-17	-14	-23	-17	-12	-19	-20	-16
105.5	100.9	110.1	-12	-18	-10	-11	-19	-15	-7	-14	-17	-14
101.5	92.9	110.1	-5	-7	-3	-5	-8	-7	-2	-5	-10	-8

Table 3. Undesired equal signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for two signal intermodulation interference, equal undesired signal levels and a desired signal level of 79 dBm.

Frequencies (MHz) Undesired			Desired	Receiver, Equal Undesired Signal Levels (dBm) A	B	C	D	E	F	G	H	J	L
107.5	106.5	105.9	108.1	-30	-36	-30	-28	-31	-35	-26	-37	-33	-31
106.5	104.5	102.9	108.1	-22	-26	-23	-20	-25	-22	-18	-26	-23	-20
105.5	102.5	99.9	108.1	-17	-19	-14	-17	-21	-18	-11	-16	-21	-18
104.5	100.5	96.9	108.1	-13	-17	-11	-13	-17	-16	-8	-13	-17	-15
101.5	95.3	88.7	108.1	-6	-11	-6	-8	-8	-9	-4	-6	-9	-10
107.9	106.3	105.1	109.1	-23	-28	-27	-23	-30	-28	-22	-31	-22	-20
107.5	105.5	103.9	109.1	-22	-28	-24	-20	-28	-23	-19	-27	-23	-20
106.5	103.5	100.9	109.1	-17	-21	-16	-15	-23	-19	-11	-18	-20	-18
105.5	101.5	97.9	109.1	-13	-17	-9	-12	-18	-16	-7	-13	-18	-15
103.5	97.5	91.9	109.1	-7	-12	-7	-8	-11	-10	-5	-7	-11	-11
107.9	105.3	103.1	110.1	-18	-23	-20	-16	-25	-19	-15	-22	-22	-18
107.5	104.5	101.9	110.1	-17	-21	-17	-15	-23	-18	-13	-19	-21	-17
106.5	102.5	98.9	110.1	-13	-16	-7	-12	-18	-15	-7	-13	-18	-16
104.5	98.5	92.9	110.1	-8	-11	-6	-8	-11	-11	-5	-7	-13	-11
99.5	98.7	88.1	110.1	-5	-7	-4	-5	-7	-6	-3	-6	-8	-9

Table 4. Undesired equal signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for three signal intermodulation interference, equal undesired signal levels and a desired level of 79 dBm.

Frequencies (MHz) Undesired		Desired	Receiver, Equal Undesired Signal Levels (dBm) A	B	C	D	E	F	G	H	J	L
107.5	106.9	108.1	-21	-26	-24	-21	-24	-25	-23	-35	-24	-28
106.9	104.9	108.1	-20	-27	-22	-17	-22	-22	-16	-28	-18	-21
105.5	102.9	108.1	-16	-23	-17	-14	-19	-15	-10	-20	-17	-14
103.5	98.9	108.1	-6	-16	-4	-8	-13	-11	-4	-10	-14	-11
101.5	94.9	108.1	-3	-9	-3	-5	-7	-7	-1	-5	-11	-7
107.9	106.7	109.1	-20	-27	-24	-19	-23	-24	-18	-31	-21	-24
107.5	105.9	109.1	-21	-24	-23	-17	-24	-22	-16	-30	-18	-20
106.5	103.9	109.1	-16	-23	-18	-13	-21	-15	-11	-22	-14	-14
104.5	99.9	109.1	-7	-17	-1	-8	-13	-11	-3	-11	-14	-11
101.5	93.9	109.1	-3	-8	-2	-3	-6	-4	0	-4	-10	-6
107.9	105.7	110.1	-18	-24	-20	-14	-23	-19	-14	-26	-13	-13
107.5	104.9	110.1	-17	-22	-18	-13	-23	-17	-11	-23	-15	-14
106.5	102.9	110.1	-14	-20	-12	-10	-18	-11	-5	-16	-15	-12
105.5	100.9	110.1	-8	-15	-3	-8	-14	-10	-4	-11	-14	-10
101.5	92.9	110.1	-1	-4	0	-1	-3	-3	>0	-2	-8	-5

Table 5. Undesired equal signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for two signal intermodulation interference, equal undesired signal levels and a desired signal level of 69 dBm.

Frequencies (MHz) Undesired			Desired	Receiver, Equal Undesired Signal Levels (dBm) A	B	C	D	E	F	G	H	J	L
107.5	106.5	105.9	108.1	-22	-31	-26	-22	-26	-25	-20	-34	-25	-27
106.5	104.5	102.9	108.1	-19	-25	-19	-16	-21	-17	-13	-23	-17	-16
105.5	102.5	99.9	108.1	-13	-18	-8	-13	-16	-15	-7	-14	-17	-14
104.5	100.5	96.9	108.1	-10	-14	-9	-10	-12	-12	-5	-11	-15	-12
101.5	95.3	88.7	108.1	-2	-7	-2	-5	-4	-6	-1	-3	-6	-6
107.9	106.3	105.1	109.1	-20	-26	-23	-17	-25	-21	-17	-28	-15	-17
107.5	105.5	103.9	109.1	-19	-26	-19	-16	-23	-17	-13	-24	-17	-16
106.5	103.5	100.9	109.1	-14	-19	-10	-12	-18	-14	-7	-16	-17	-14
105.5	101.5	97.9	109.1	-10	-14	-6	-9	-13	-12	-4	-10	-15	-12
103.5	97.5	91.9	109.1	-4	-8	-4	-5	-6	-7	-2	-5	-9	-8
107.9	105.3	103.1	110.1	-15	-21	-15	-12	-20	-16	-9	-19	-17	-15
107.5	104.5	101.9	110.1	-13	-18	-12	-11	-17	-13	-7	-16	-17	-14
106.5	102.5	98.9	110.1	-10	-13	-6	-9	-13	-11	-4	-10	-16	-12
104.5	98.5	92.9	110.1	-5	-8	-4	-5	-6	-6	-2	-4	-10	-8
99.5	98.7	88.1	110.1	-2	-3	-1	-2	-2	-3	0	-1	-6	-5

Table 6. Undesired equal signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for three signal intermodulation interference, equal undesired signal levels and a desired level of 69 dBm.

Frequencies (MHz)			Receiver, Equal Undesired Signal Levels (dBm)									
Undesired		Desired	A	B	C	D	E	F	G	H	J	L
107.5	106.9	108.1	-18	-21	-20	-16	-18	-17	-12	-29	-18	-23
106.9	104.9	108.1	-17	-21	-18	-12	-16	-15	-10	-21	-15	-15
105.5	102.9	108.1	-13	-20	-12	-10	-15	-12	-5	-14	-15	-12
103.5	98.9	108.1	-3	-12	-2	-5	-8	-8	-1	-8	-12	-8
101.5	94.9	108.1	0	-6	>0	-1	-2	-3	>0	-3	-8	-5
107.9	106.7	109.1	-17	-22	-19	-14	-18	-16	-13	-25	-16	-19
107.5	105.9	109.1	-17	-18	-18	-13	-18	-14	-11	-23	-15	-15
106.5	103.9	109.1	-13	-19	-13	-9	-17	-12	-5	-15	-14	-11
104.5	99.9	109.1	-4	-13	-2	-5	-8	-8	-1	-9	-12	-8
101.5	93.9	109.1	>0	-4	>0	0	0	-1	>0	-2	-8	-3
107.9	105.7	110.1	-15	-20	-15	-10	-18	-11	-8	-19	-15	-11
107.5	104.9	110.1	-13	-19	-13	-9	-17	-11	-5	-15	-14	-11
106.5	102.9	110.1	-11	-16	-6	-7	-13	-9	-2	-12	-14	-9
105.5	100.9	110.1	-5	-12	-1	-5	-9	-8	-1	-9	-12	-7
101.5	92.9	110.1	>0	0	>0	>0	>0	>0	>0	0	-5	-2

Table 7. Undesired equal signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for two signal intermodulation interference, equal undesired signal levels and a desired signal level of 59 dBm.

Frequencies (MHz)				Receiver, Equal Undesired Signal Levels (dBm)									
Undesired			Desired	A	B	C	D	E	F	G	H	J	L
107.5	106.5	105.9	108.1	-20	-25	-21	-17	-20	-19	-14	-27	-20	-22
106.5	104.5	102.9	108.1	-16	-22	-15	-12	-16	-14	-7	-18	-17	-14
105.5	102.5	99.9	108.1	-10	-16	-1	-10	-11	-12	-4	-12	-15	-12
104.5	100.5	96.9	108.1	-6	-11	-6	-7	-7	-8	-2	-8	-13	-9
101.5	95.3	88.7	108.1	>0	-4	>0	-1	0	-2	>0	-1	-3	-3
107.9	106.3	105.1	109.1	-16	-23	-18	-14	-19	-14	-11	-21	-18	-14
107.5	105.5	103.9	109.1	-15	-23	-16	-12	-18	-13	-8	-19	-16	-14
106.5	103.5	100.9	109.1	-11	-16	-4	-9	-13	-11	-4	-13	-15	-12
105.5	101.5	97.9	109.1	-6	-10	-4	-6	-8	-8	-2	-9	-12	-8
103.5	97.5	91.9	109.1	0	-5	-1	-1	-2	-3	>0	-3	-6	-5
107.9	105.3	103.1	110.1	-12	-17	-10	-9	-15	-12	-4	-16	-16	-12
107.5	104.5	101.9	110.1	-10	-15	-6	-9	-12	-11	-3	-14	-15	-11
106.5	102.5	98.9	110.1	-7	-10	-4	-6	-8	-7	-1	-9	-13	-9
104.5	98.5	92.9	110.1	-1	-5	-1	-2	-1	-3	0	-2	-7	-4
99.5	98.7	88.1	110.1	>0	>0	>0	>0	>0	0	>0	>0	-3	-2

Table 8. Undesired equal signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for three signal intermodulation interference, equal undesired signal levels and a desired level of 59 dBm.

Frequencies (MHz)			Receiver, Equal Undesired Signal Levels (dBm)									
Undesired		Desired	A	B	C	D	E	F	G	H	J	L
107.5	106.9	108.1	-14	-15	-15	-13	-13	-11	-10	-21	-12	-14
106.9	104.9	108.1	-14	-14	-13	-9	-12	-11	-4	-15	-11	-14
105.5	102.9	108.1	-10	-16	-6	-7	-8	-10	-2	-13	-13	-11
103.5	98.9	108.1	0	-9	0	-1	-3	-4	>0	-6	-9	-5
101.5	94.9	108.1	>0	-2	>0	>0	>0	>0	>0	0	-6	-2
107.9	106.7	109.1	-14	-15	-15	-12	-13	-10	-8	-15	-12	-15
107.5	105.9	109.1	-14	-14	-13	-10	-13	-10	-5	-15	-11	-14
106.5	103.9	109.1	-11	-16	-7	-7	-9	-10	-1	-14	-10	-10
104.5	99.9	109.1	-1	-9	0	-1	-1	-4	>0	-7	-9	-5
101.5	93.9	109.1	>0	0	>0	>0	>0	>0	>0	>0	-5	-1
107.9	105.7	110.1	-12	-16	-11	-7	-11	-9	-2	-15	-11	-11
107.5	104.9	110.1	-11	-15	-8	-7	-10	-9	-1	-14	-11	-9
106.5	102.9	110.1	-7	-12	>0	-4	-4	-7	0	-11	-11	-7
105.5	100.9	110.1	-2	-8	>0	-2	-1	-5	>0	-8	-8	-4
101.5	92.9	110.1	>0	>0	>0	>0	>0	>0	>0	>0	-3	>0

Table 9. Undesired equal signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for two signal intermodulation interference, equal undesired signal levels and a desired signal level of 49 dBm.

Frequencies (MHz)				Receiver, Equal Undesired Signal Levels (dBm)									
Undesired			Desired	A	B	C	D	E	F	G	H	J	L
107.5	106.5	105.9	108.1	-17	-20	-17	-14	-15	-13	-10	-18	-15	-17
106.5	104.5	102.9	108.1	-12	-19	-9	-10	-9	-11	-4	-15	-14	-12
105.5	102.5	99.9	108.1	-7	-11	>0	-7	-5	-9	-1	-10	-12	-8
104.5	100.5	96.9	108.1	-3	-7	-3	-3	-3	-5	>0	-5	-10	-6
101.5	95.3	88.7	108.1	>0	0	>0	>0	>0	>0	>0	>0	-1	-1
107.9	106.3	105.1	109.1	-14	-20	-13	-11	-14	-12	-5	-17	-14	-14
107.5	105.5	103.9	109.1	-12	-19	-10	-9	-11	-11	-3	-16	-13	-12
106.5	103.5	100.9	109.1	-8	-12	>0	-6	-6	-8	-1	-11	-12	-8
105.5	101.5	97.9	109.1	-3	-7	-2	-2	-3	-5	>0	-5	-10	-5
103.5	97.5	91.9	109.1	>0	-2	>0	>0	>0	>0	>0	>0	-4	-1
107.9	105.3	103.1	110.1	-9	-13	-5	-7	-7	-9	-2	-13	-12	-9
107.5	104.5	101.9	110.1	-8	-11	>0	-5	-5	-8	-1	-12	-12	-8
106.5	102.5	98.9	110.1	-5	-6	-1	-2	-2	-5	>0	-6	-11	-6
104.5	98.5	92.9	110.1	>0	-1	>0	>0	>0	0	>0	>0	-5	-1
99.5	98.7	88.1	110.1	>0	>0	>0	>0	>0	>0	>0	>0	-1	>0

Table 10. Undesired equal signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for three signal intermodulation interference, equal undesired signal levels and a desired level of 49 dBm.

f 1 (MHz)	f 2 (MHz)	f(loc) (MHz)	Desired Signal Levels, Receiver L -89 (dBm)	-79 (dBm)	-69 (dBm)	-59 (dBm)	-49 (dBm)	F.P. (MHz 3)
107.7	107.3	108.1	-37	-33	-28	-23	-14	0.128
107.3	106.5	108.1	-34	-30	-27	-21	-14	1.024
107.9	107.5	108.3	-36	-32	-28	-22	-14	0.128
107.7	107.1	108.3	-35	-32	-28	-22	-14	0.432
107.5	106.7	108.3	-34	-31	-27	-21	-15	1.024
107.9	107.3	108.5	-35	-31	-28	-22	-13	0.432
107.7	106.9	108.5	-35	-31	-27	-22	-14	1.024
107.5	106.6	108.5	-33	-30	-26	-21	-15	2.000
107.9	107.1	108.7	-34	-30	-27	-22	-15	1.024
107.7	106.7	108.7	-32	-29	-25	-21	-15	2.000
107.9	106.9	108.9	-33	-30	-26	-21	-15	2.000
107.7	106.5	108.9	-32	-28	-24	-19	-15	3.457

Table 11. Undesired signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for two signal intermodulation interference, equal undesired signal levels, desired signal levels as indicated, and receiver L.

f 1 (MHz)	f 2 (MHz)	f(loc) (MHz)	Desired Signal Levels, Receiver G -89 (dBm)	-79 (dBm)	-69 (dBm)	-59 (dBm)	-49 (dBm)	F.P. (MHz 3)
107.7	107.3	108.1	-42	-34	-26	-17	>-14	0.128
107.3	106.5	108.1	-38	-29	-20	-14	-10	1.024
107.9	107.5	108.3	-42	-34	-25	-16	>-14	0.128
107.7	107.1	108.3	-40	-32	-23	-13	- 9	0.432
107.5	106.7	108.3	-37	-28	-20	-13	- 9	1.024
107.9	107.3	108.5	-40	-32	-23	-12	- 8	0.432
107.7	106.9	108.5	-37	-29	-21	-15	-10	1.024
107.5	106.5	108.5	-35	-27	-19	-14	- 8	2.000
107.9	107.1	108.7	-37	-28	-20	-13	- 9	1.024
107.7	106.7	108.7	-35	-26	-18	-13	- 7	2.000
107.9	106.9	108.9	-35	-26	-19	-13	- 8	2.000
107.7	106.5	108.9	-33	-25	-18	-12	- 7	3.457

Table 12. Undesired signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for two signal intermodulation interference, equal undesired signal levels, desired signal levels as indicated, and receiver G.

f 1 (MHz)	f 2 (MHz)	f(loc) (MHz)	Desired Signal Levels, Receiver H -89 (dBm)	-79 (dBm)	-69 (dBm)	-59 (dBm)	-49 (dBm)	F.P. (MHz 3)
107.7	107.3	108.1	-41	-38	-35	-28	-19	0.128
107.3	106.5	108.1	-40	-36	-32	-25	-16	1.024
107.9	107.5	108.3	-42	-39	-35	-28	-20	0.128
107.7	107.1	108.3	-42	-39	-35	-28	-19	0.432
107.5	106.7	108.3	-40	-37	-33	-25	-16	1.024
107.9	107.3	108.5	-41	-38	-35	-27	-18	0.432
107.7	106.9	108.5	-40	-37	-33	-25	-16	1.024
107.5	106.5	108.5	-39	-36	-32	-23	-15	2.000
107.9	107.1	108.7	-40	-37	-33	-26	-17	1.024
107.7	106.7	108.7	-39	-36	-31	-23	-15	2.000
107.9	106.9	108.9	-39	-35	-31	-24	-15	2.000
107.7	106.5	108.9	-38	-35	-31	-22	-15	3.457

Table 13. Undesired signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for two signal intermodulation interference, equal undesired signal levels, desired signal levels as indicated, and receiver H.

f 1 (MHz)	f 2 (MHz)	f(loc) (MHz)	Desired Signal Levels, Receiver G -89 (dBm)	-79 (dBm)	-69 (dBm)	-59 (dBm)	-49 (dBm)	Relative Levels
105.5	102.9	108.1	-17	-15	-10	- 5	- 2	f1=f2
105.5	102.9	108.1	-14	-12	- 6	- 2	> 0	f1>f2
105.5	102.9	108.1	-12	- 9	- 3	> 0	> 0	f1<f2
106.5	103.9	109.1	th	th	th	th	th	f1=f2
106.5	103.9	109.1	>th	>th	>th	>th	>th	f1>th>f2
106.5	103.9	109.1	<th	<th	<th	<th	<th	f1<th<f2

Table 14. The effect of unequal undesired signal levels on the intermodulation performance of receiver G.

Notes:

1. The column "Relative Levels" shows the amplitude relationship between f1 and f2.
2. In all cases where the amplitudes of f1 and f2 differed, that difference was always 10 dB.
3. In the lower half of each table, th represents the threshold interference effect, i.e., a 7.5 uA deviation from a standard 90 uA deflection. When the amplitudes of f1 and f2 were unequal one was 5 dB above the threshold and the other was 5 dB below the threshold.
4. The symbol ">th" means that the threshold interference was exceeded. The symbol "<th" means that the threshold interference was not exceeded.

f 1 (MHz)	f 2 (MHz)	f(loc) (MHz)	Desired Signal Levels, Receiver H -89 (dBm)	-79 (dBm)	-69 (dBm)	-59 (dBm)	-49 (dBm)	Relative Levels
106.5	103.9	109.1	-29	-26	-22	-16	-14	f1=f2
106.5	103.9	109.1	-27	-23	-18	-12	-11	f1>f2
106.5	103.9	109.1	-23	-19	-15	- 8	- 8	f1<f2
106.5	103.9	109.1	th	th	th	th	th	f1=f2
106.5	103.9	109.1	>th	>th	>th	>th	>th	f1>th>f2
106.5	103.9	109.1	<th	<th	<th	<th	<th	f1<th<f2

Table 15. The effect of unequal undesired signal levels on the intermodulation performance of receiver H.

Notes:

1. The column "Relative Levels" shows the amplitude relationship between f1 and f2.
2. In all cases where the amplitudes of f1 and f2 differed, that difference was always 10 dB.
3. In the lower half of each table, th represents the threshold interference effect, i.e., a 7.5 uA deviation from a standard 90 uA deflection. When the amplitudes of f1 and f2 were unequal one was 5 dB above the threshold and the other was 5 dB below the threshold.
4. The symbol ">th" means that the threshold interference was exceeded. The symbol "<th" means that the threshold interference was not exceeded.

f 1 (MHz)	f 2 (MHz)	f(loc) (MHz)	Desired Signal Levels, Receiver L -89 (dBm)	-79 (dBm)	-69 (dBm)	-59 (dBm)	-49 (dBm)	Relative Levels
106.5	103.9	109.1	-21	-19	-15	-12	-11	f1=f2
106.5	103.9	109.1	-19	-15	-11	- 9	- 7	f1>f2
106.5	103.9	109.1	-16	-12	- 7	- 5	- 4	f1<f2
106.5	103.9	109.1	th	th	th	th	th	f1=f2
106.5	103.9	109.1	>th	>th	>th	>th	>th	f1>th>f2
106.5	103.9	109.1	<th	<th	<th	<th	<th	f1<th<f2

Table 16. The effect of unequal undesired signal levels on the intermodulation performance of receiver L.

Notes:

1. The column "Relative Levels" shows the amplitude relationship between f1 and f2.
2. In all cases where the amplitudes of f1 and f2 differed, that difference was always 10 dB.
3. In the lower half of each table, th represents the threshold interference effect, i.e., a 7.5 uA deviation from a standard 90 uA deflection. When the amplitudes of f1 and f2 were unequal one was 5 dB above the threshold and the other was 5 dB below the threshold.
4. The symbol ">th" means that the threshold interference was exceeded. The symbol "<th" means that the threshold interference was not exceeded.