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Interference Immunities of Aviation Receivers Due to FM Broadcast Transmissions.

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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.

A study of this problem has been conducted jointly by Canada and by the USA. Results were released at the International Civil Aviation Organization (ICAO) Communications/Operations Divisional Meeting in Montreal, Canada in September 1985. The work appears to accurately characterize the susceptibility of aeronautical receivers to intermodulation interference caused by FM broadcast stations. However, the studies did not address the possibility of improving aviation receiver performance by adding external components such as filters or RF attenuators. Therefore, a program of receiver measurements was conducted by the FCC to study the effects of such devices.

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 the effects of external components on the performance of the receivers. The particular models were selected based in part by their popularity in private and commercial aircraft and by 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 stereo signal was generated using shaped noise for the audio source with the amplitude of the right channel 6 dB lower than the left and with a peak FM carrier deviation of 75 kHz. The noise was shaped in accordance with recommendation 559 of the CCIR XIV Plenary Assembly, Kyoto, 1978, Volume X, Broadcasting Service (Sound).

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 an RF 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 aircarft 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 adjusted to -89 dBm. This value is taken from the Canadian report presented to the ICAO Communications/Operations Divisional Meeting held in Montreal in September 1985. It is based on an assumed localizer field strength of 32 dB(uV/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. The level of the undesired signals necessary to produce the 7.5 uA deviation was recorded. This was repeated for three different sets of receiver input configurations:

1. Direct connection to the receiver;

2. A 50 ohm, 6 dB, RF attenuator in front of the receiver (the input device shown in Figure 1);

3. A bandpass filter (108 to 132 MHz BP) in front of the receiver (the input device shown in Figure 1).

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.

A total of 90 data points were obtained for each receiver. Data were taken for each of the three receiver input conditions for each of three different localizer frequencies, 108.1, 109.1 and 110.1 MHz. For each localizer frequency ten data points were collected for each receiver. Five of the data points were for the two signal intermodulation cases and five data points were

for the three signal intermodulation cases. The data are presented in Tables 1 through 6. Tables 7 and 8 compare the average receiver susceptibility to two and three signal intermodulation interference for the different receiver input configurations.

The intermodulation data for the receivers with and without filters are also presented in Figures 4 through 15 as graphs of undesired signal levels in dBm versus the product of the frequency differences in MHz cubed. In all cases the levels of the individual undesired signals were equal to each other. This method of displaying intermodulation interference data is used to be consistent with similar data reported to the CCIR by other countries. It appears to be a convenient way of grouping receivers for a quick visual comparison of their intermodulation interference responses.

It should be noted that each point shown in this set of graphs may represent more than one receiver. For example, in Figure 5, single points are shown for levels greater than zero for frequency difference products of 195 and 575 MHz cubed. A check of Table 5 shows that all ten receivers had values greater than zero for these particular frequency differences.

The product of the frequency differences are calculated as follows:

For the two signal intermodulation cases:

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

where:

LOC = The frequency of the localizer transmitter (MHz)
F1 = The highest undesired frequency (MHz)
F2 = The remaining undesired frequency (MHz)
PDF = The product of the frequency differences (MHz cubed).

For the three signal intermodulation cases:

DF1 = LOC-F1
DF2 = LOC-F2
DF3 = LOC-F3
PDF = 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)
PDF = The product of the frequency differences (MHz cubed).

The dashed line in each graph represents the protection criteria values calculated in accordance with recommendation No. GTECH/1 of the Final Acts of the Regional Administrative Radio Conference for the Planning of VHF Sound

Broadcasting (CARR-1(2)) Geneva, 1984. Receivers with an intermodulation interference response on or above the line meet or exceed the criteria. The formulae are:

(where i =1,2,3 and corresponds to each interfering frequency)

Ni = The level of the FM sound broadcasting station at the input of the localizer receiver (dBm)
Fi = The frequency of the FM sound broadcasting station (MHz)
Ai = [Max (0.4 ; 108.1 - Fi)]/0.4
A(Fi) = 20 * LOG(Ai)

For two signal intermodulation (F1 > F2):

$$2 * N1 + N2 - 2 * A(F1) - A(F2) + 120 > 0$$

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

$$N1 + N2 + N3 - A(F1) - A(F2) - A(F3) + 126 > 0$$

The solid line in each graph represents the protection criteria values calculated in accordance with a mathematical model developed for the FAA by the Ohio University. This model is described in a paper, U.S. Document JIWP 8-10/1-5, presented to the CCIR Joint Interim Working Party JIWP 8-10/1 in Rio de Janeiro in March 1987. Receivers with an intermodulation interference response on or above the line meet or exceed the criteria. The formulae 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.

The intermodulation interference data for receiver Configuration 2, with the 6 dB attenuator in front of the receiver have not been graphed because they are very similar to the data collected for the receiver without an input filter or attenuator. In fact, the average differences between the receiver with and without an input attenuator were 2.6 dB and 2.5 dB for the two and three signal intermodulation cases respectively. See Tables 7 and 8.

To determine the effects of the external device on other receiver characteristics, the input impedance of each receiver for configurations 1 and 3 was measured using an HP 8507 automatic network analyzer system. With the receiver tuned to a selected frequency, 110.1 MHz, the input impedance of each receiver was measured at points on and around the tuned frequency. The measured impedances are reported in Tables 9 through 14.

CONCLUSIONS

Adding an RF bandpass filter to the input of an aeronautical navigation receiver can significantly improve its imtermodulation immunity characteristics. In Tables 7 and 8 it can be seen that by adding the bandpass filter to the receiver, an average minimum improvement of 4 dB was attained for the two signal case and 8 dB for the three signal case. As the frequencies of the undesired signals decreased, the performance of the receiver with the filter improved rapidly. In 10 of the 15 cases of two signal intermodulation interference, receiver performance improved at least 9 dB when the filter was used. In 13 of the 15 cases of three signal intermodulation interference, receiver performance improved at least 12 dB with the filter.

One argument against using a bandpass filter to improve the intermodulation characteristics of aeronautical navigation receivers is that the filter might create a mismatch between the antenna and the receiver and thus degrade receiver performance. The input impedance and the VSWR of 12 receivers were measured with and without the bandpass filter. Looking at the VSWR measurements reported in Tables 9 through 14, it can be seen that the addition of the bandpass filter did not significantly alter the input impedance of the receivers tested.

It has been suggested that by adding a simple RF attenuator in front of the receiver, its intermodulation performance could be significantly improved. The tests conducted suggest that in practical situations this is not the case. Theoretically, for a perfectly matched system, putting a 6 dB RF attenuator in front of the receiver will improve its intermodulation performance by 4 dB. However, Tables 7 and 8 show a measured average increase in performance of 2.6 dB for two signal intermodulation and 2.5 dB for three signal intermodulation. This could be because the receiver input is not exactly 50 ohms and a mismatch exists betwen the 50 ohm 6 dB attenuator and the receiver (see Tables 9 through 11).

Another disadvantage to using an RF attenuator is that the receiver's weak signal performance would be degraded. If the receiver has marginal weak signal performance to begin with, it could become unusable at the outer contours of the ILS pattern.

In summary, the data presented in this Technical Memorandum are for two different approaches for minimizing FM broadcast intermodulation interference to aeronautical navigation receivers. The graphs and tables show that adding an external input bandpass filter to a receiver can significantly improve its intermodulation interference immunities. However, adding an external attenuator to an aeronautical navigation receiver will not significantly improve its intermodulation performance over a receiver without an attenuator.

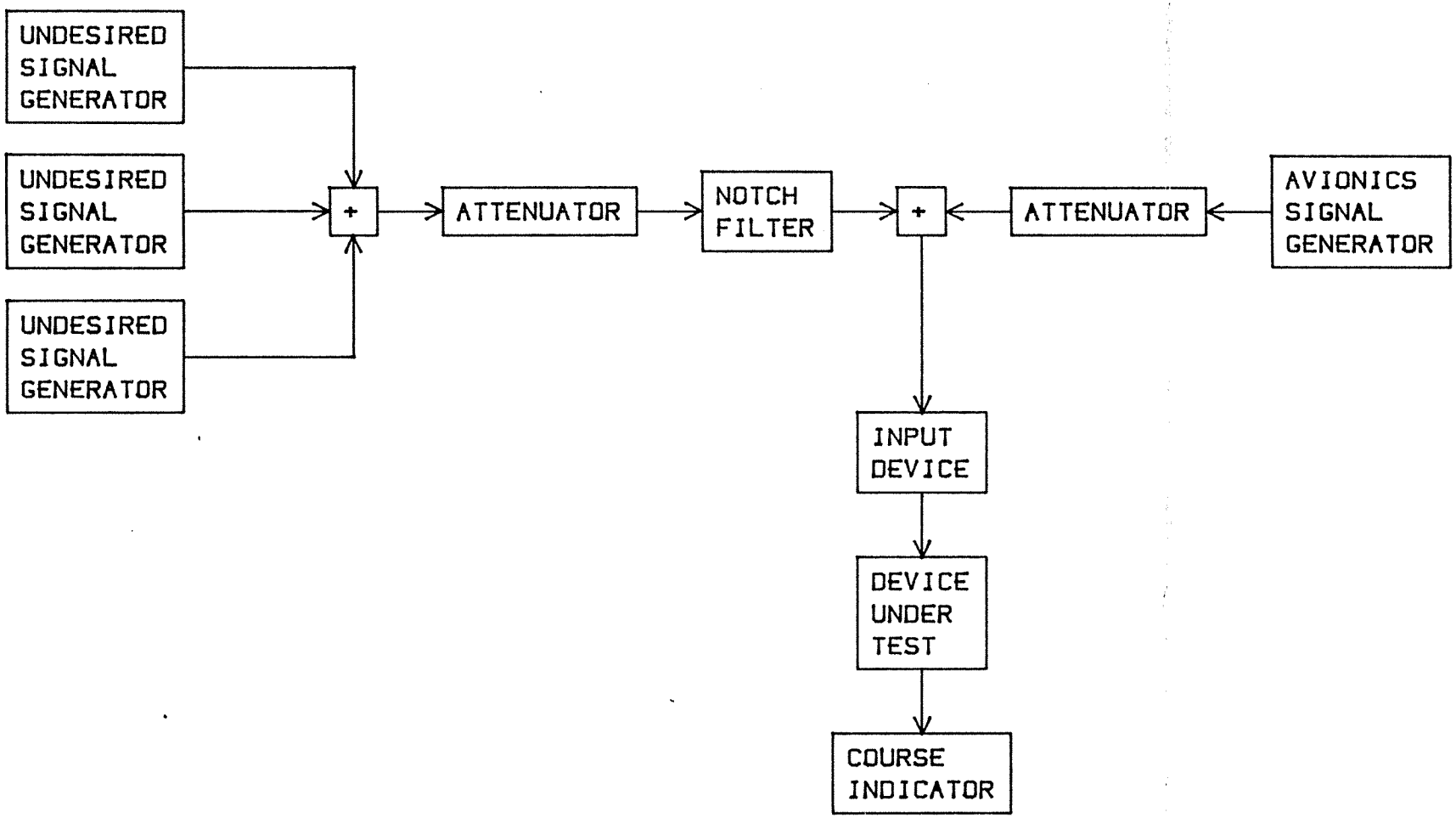


Figure 1. Block diagram of the equipment setup used in making the two and three signal intermodulation measurements.

Figure 2. The frequency response of the 50 ohm 6 dB attenuator.

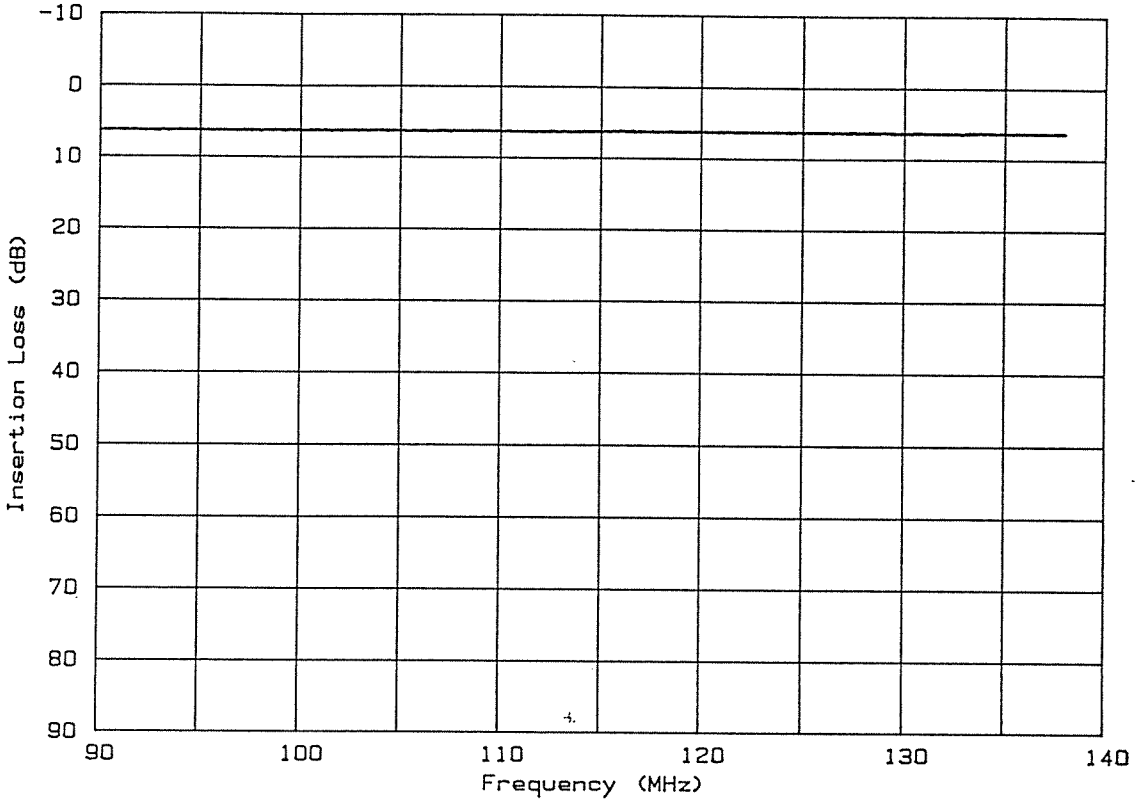


Figure 3. The frequency response of the bandpass filter (108 to 132 MHz BP).

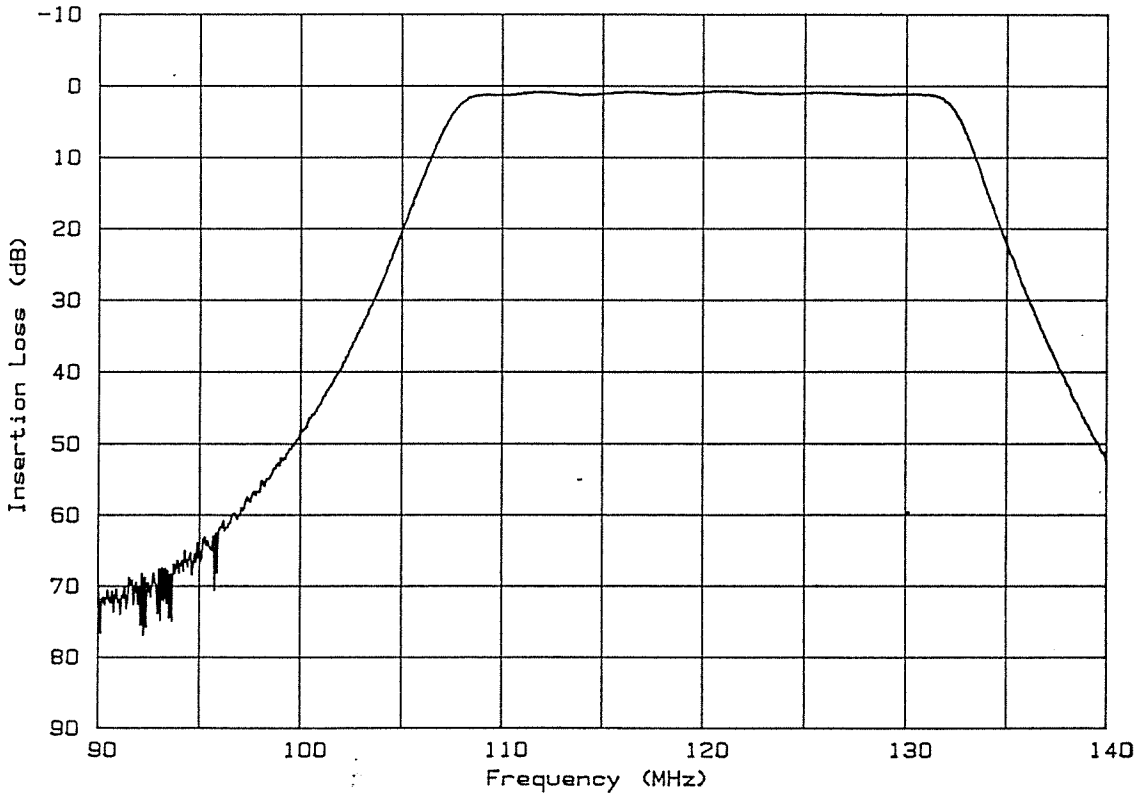


Figure 4. Two signal type B1 interference to 108.1 MHz, bare receiver.

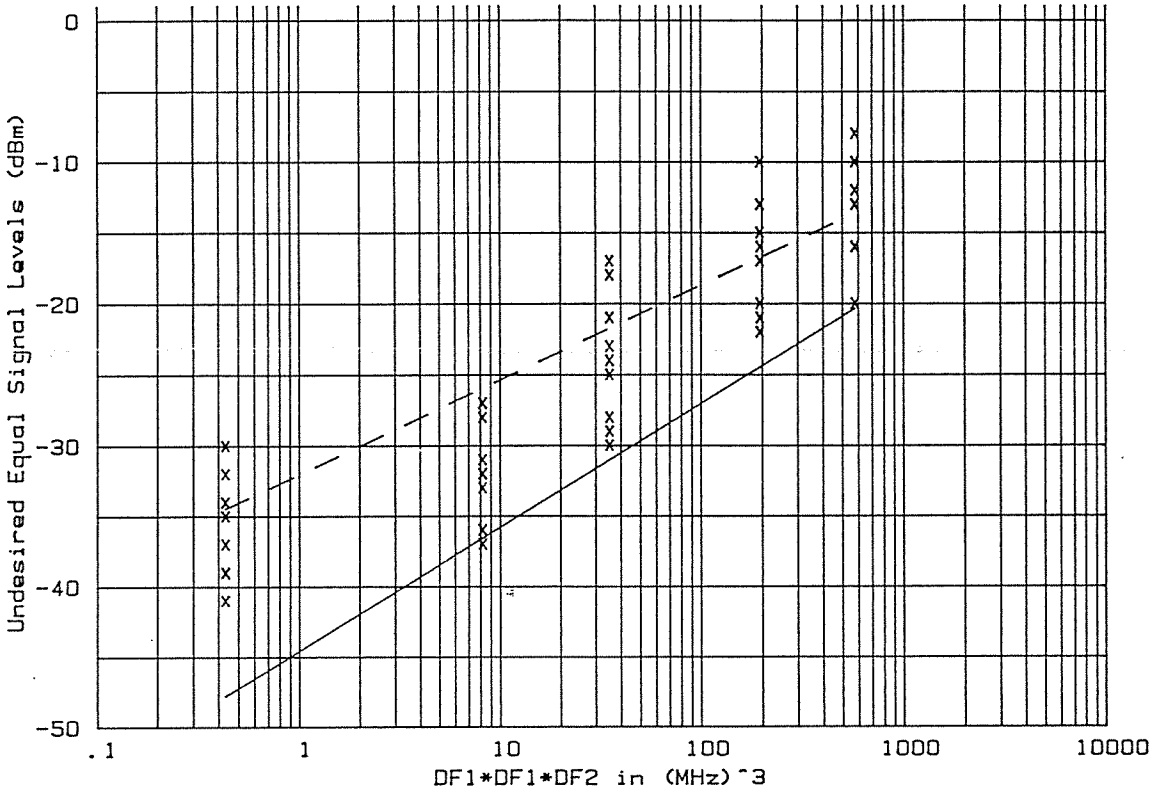


Figure 5. Two signal type B1 interference to 108.1 MHz, filtered receiver.

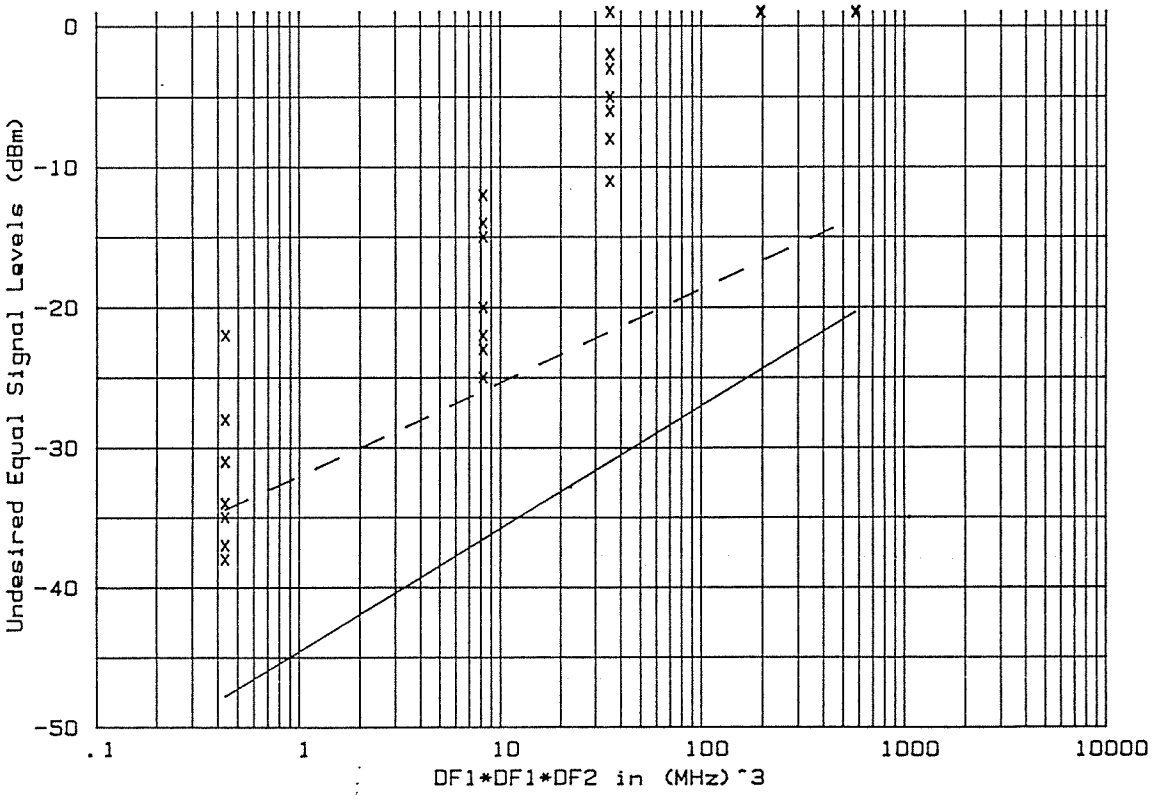


Figure 6. Two signal type B1 interference to 109.1 MHz, bare receiver.

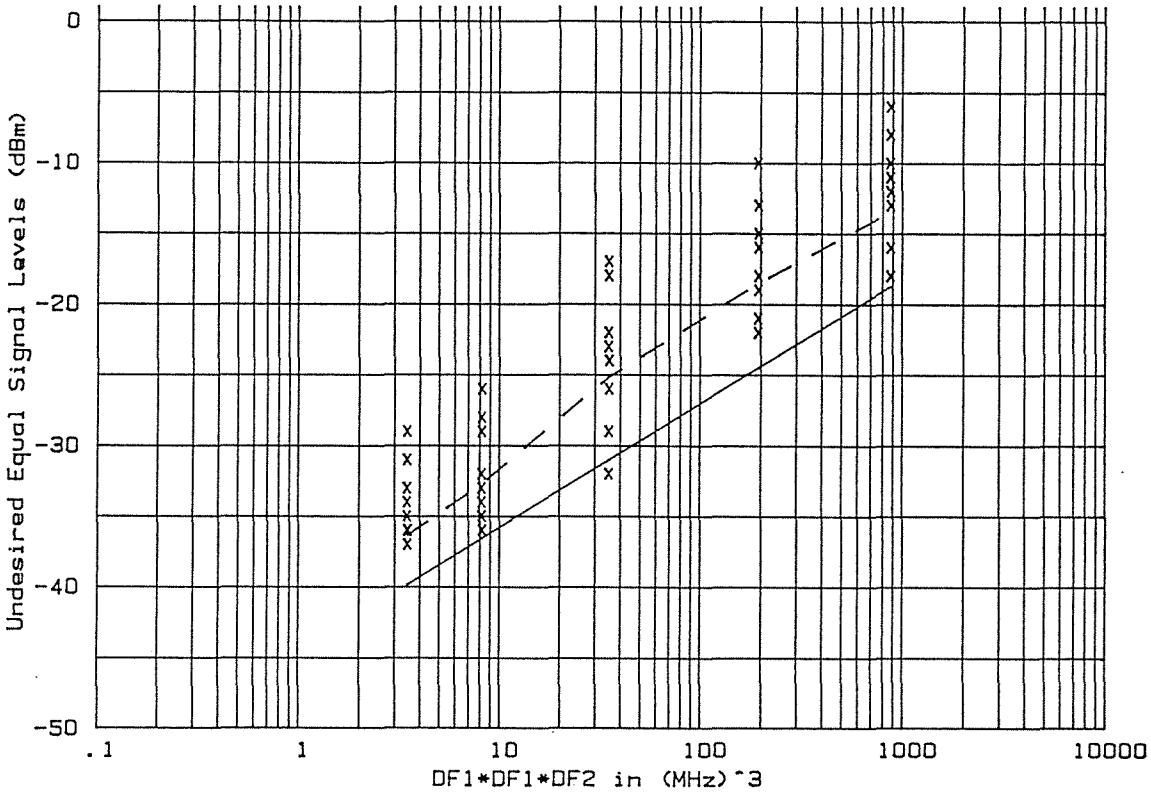


Figure 7. Two signal type B1 interference to 109.1 MHz, filtered receiver.

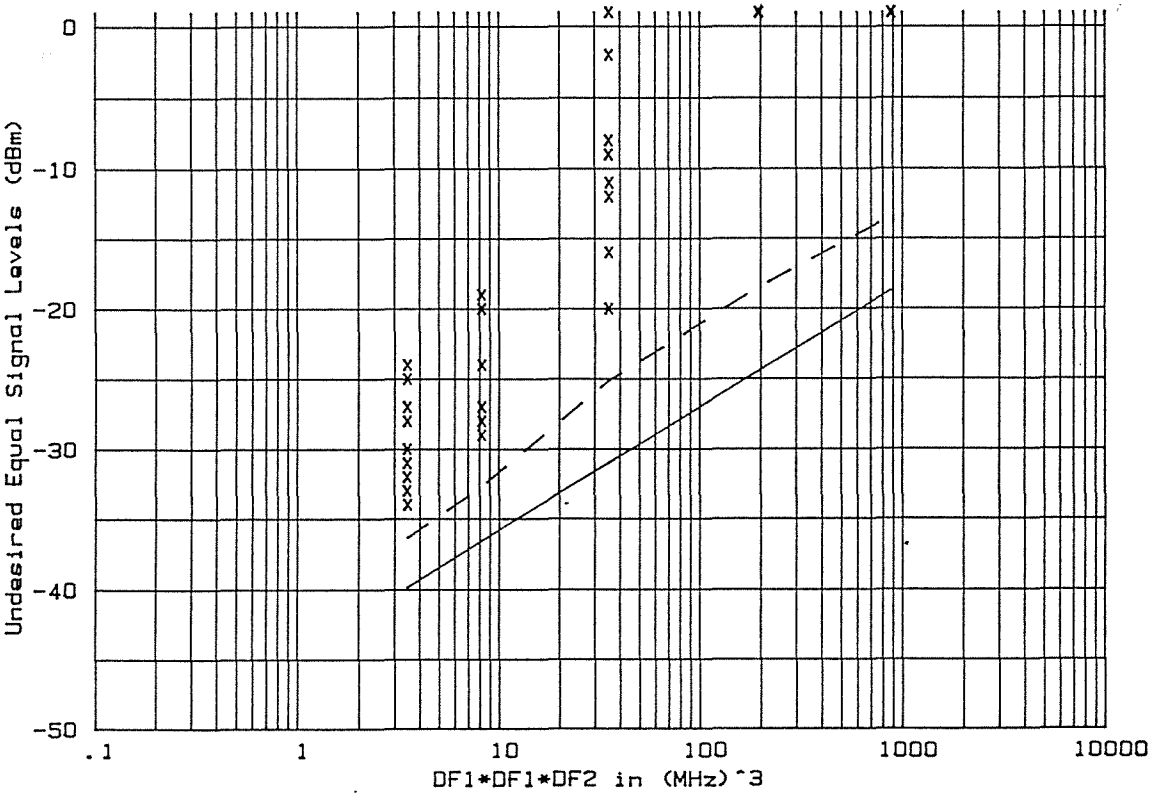


Figure 8. Two signal type B1 interference to 110.1 MHz, bare receiver.

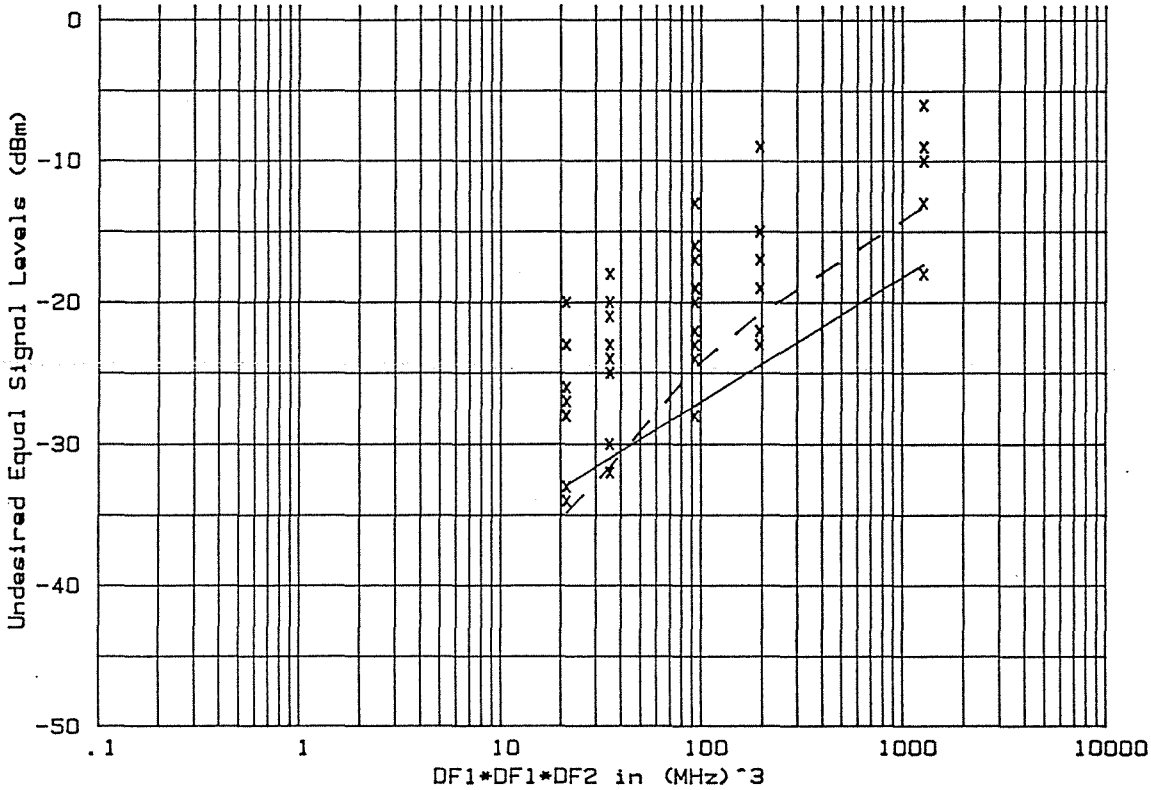


Figure 9. Two signal type B1 interference to 110.1 MHz, filtered receiver.

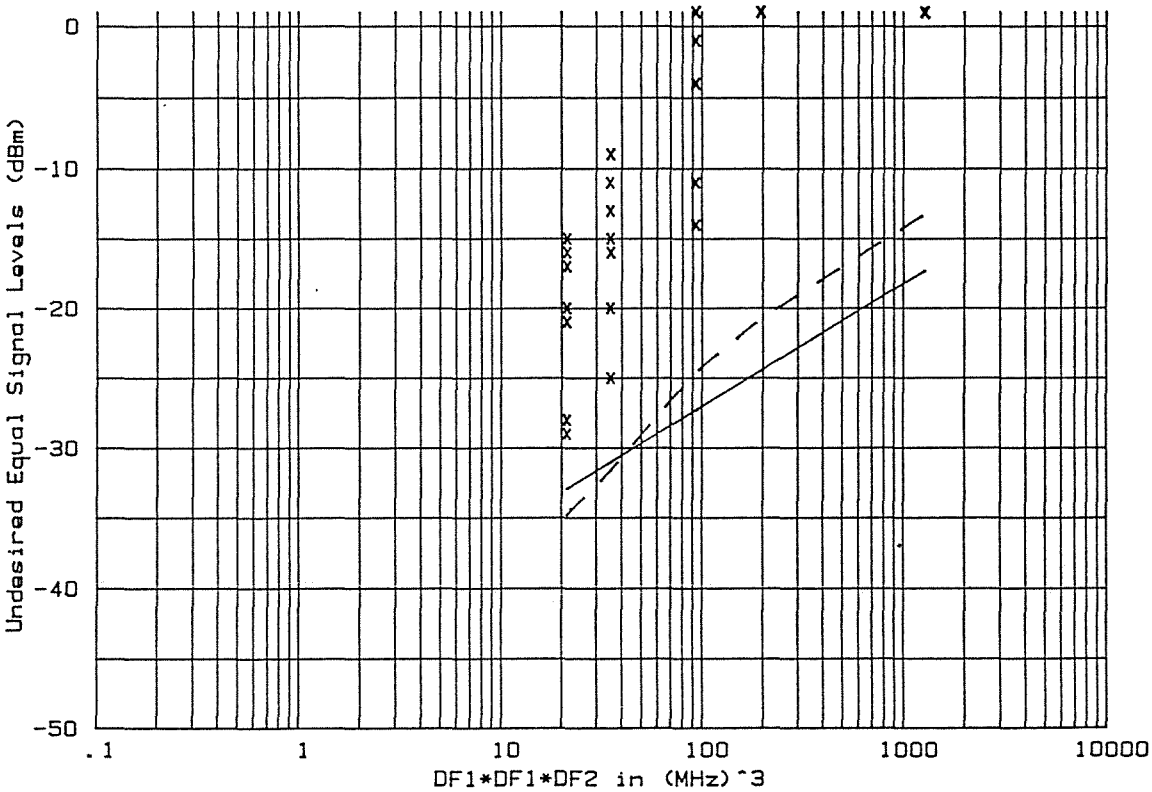


Figure 10. Three signal type B1 interference to 108.1 MHz, bare receiver.

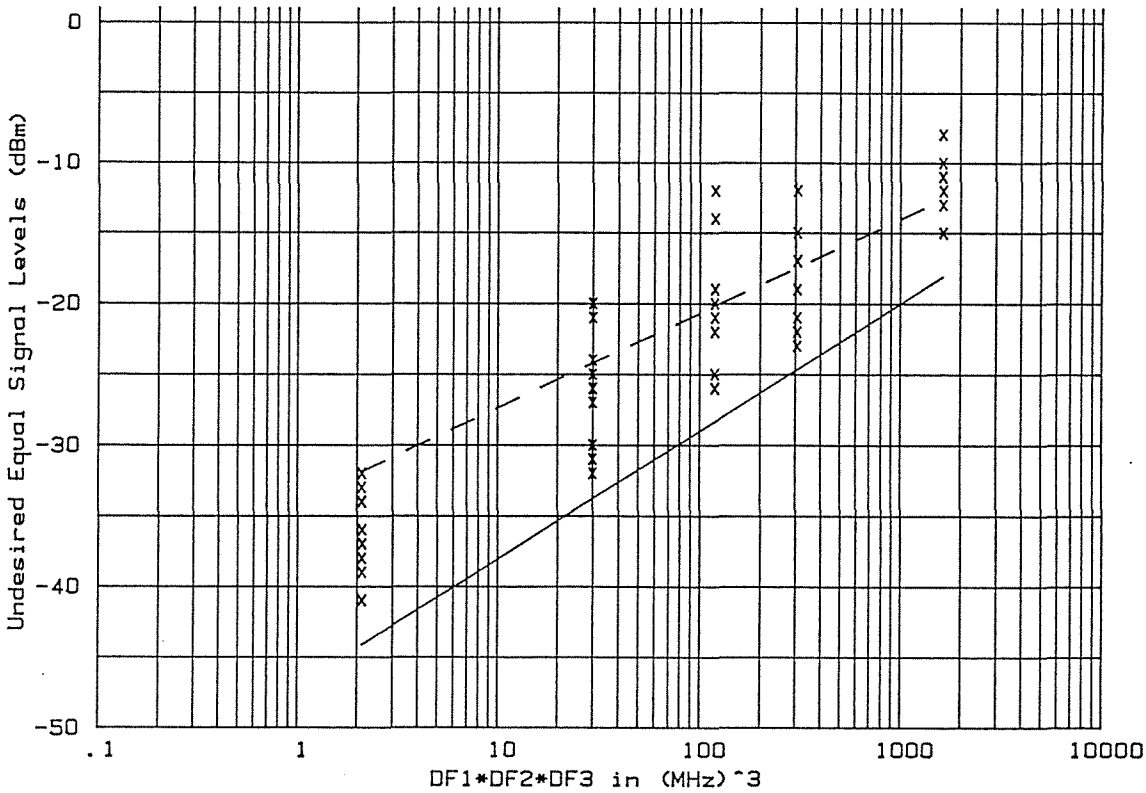


Figure 11. Three signal type B1 interference to 108.1 MHz, filtered receiver.

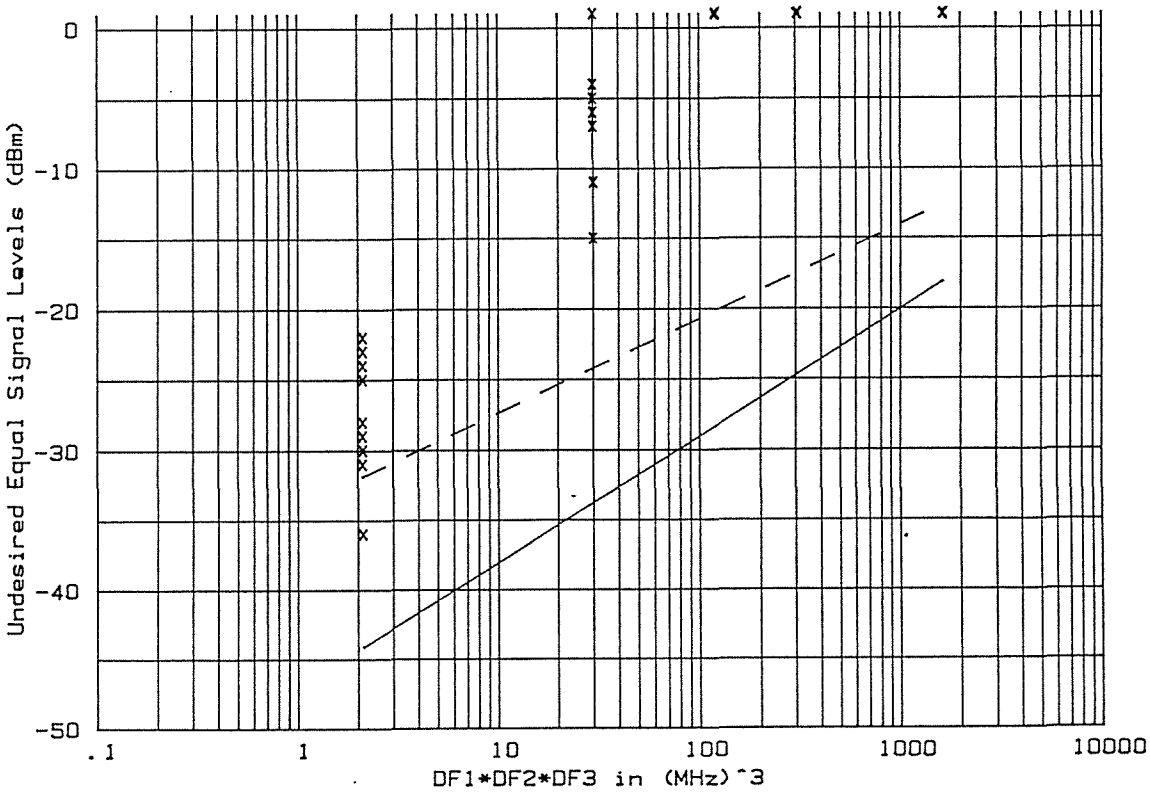


Figure 12. Three signal type B1 interference to 109.1 MHz, bare receiver.

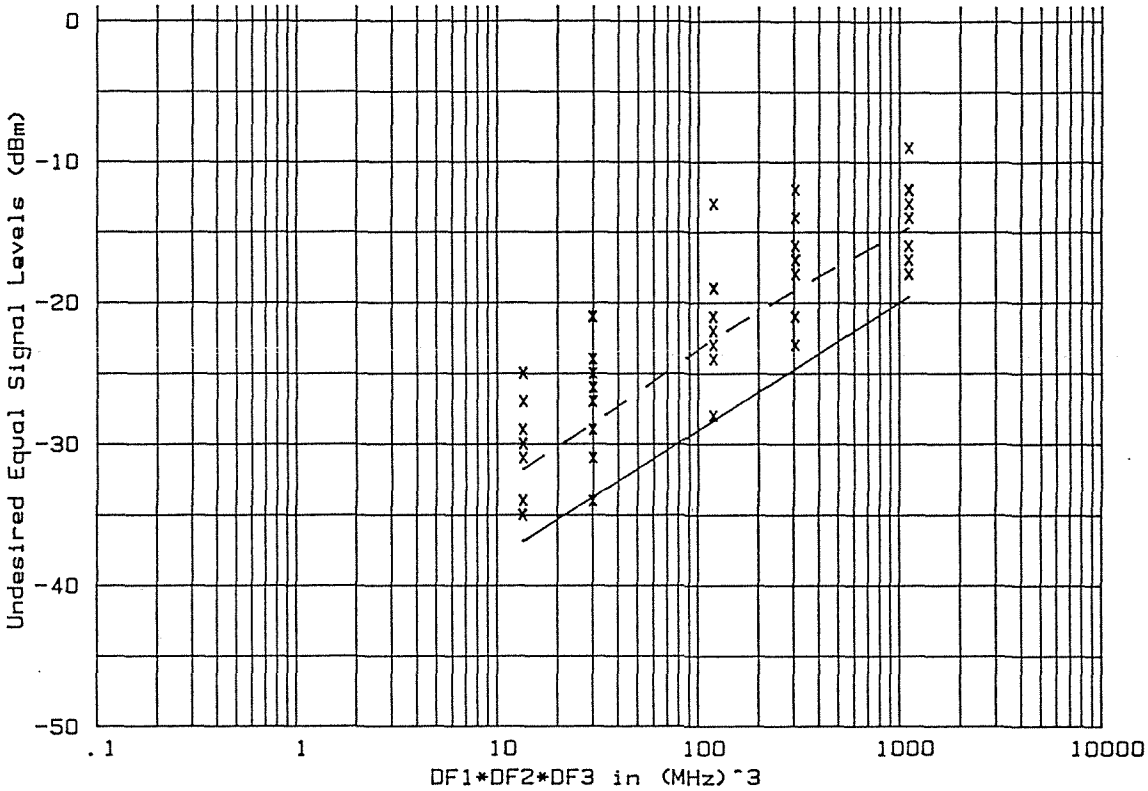


Figure 13. Three signal type B1 interference to 109.1 MHz, filtered receiver.

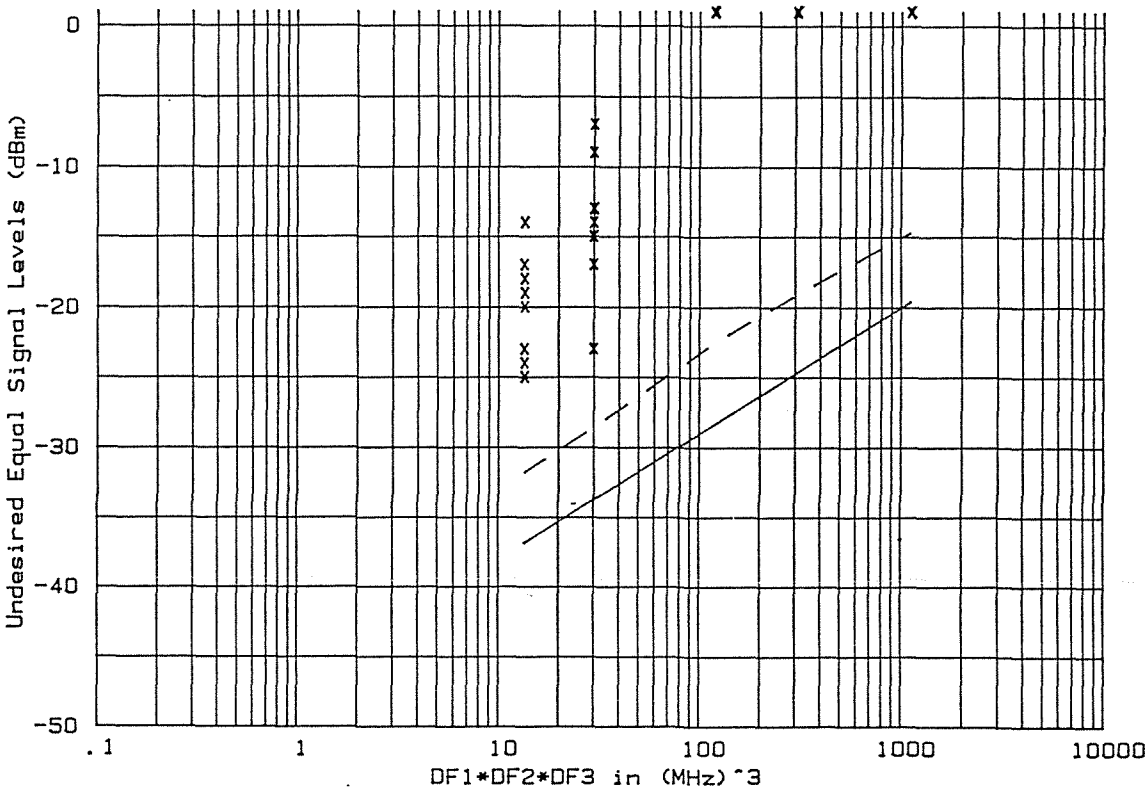


Figure 14. Three signal type B1 interference to 110.1 MHz, bare receiver.

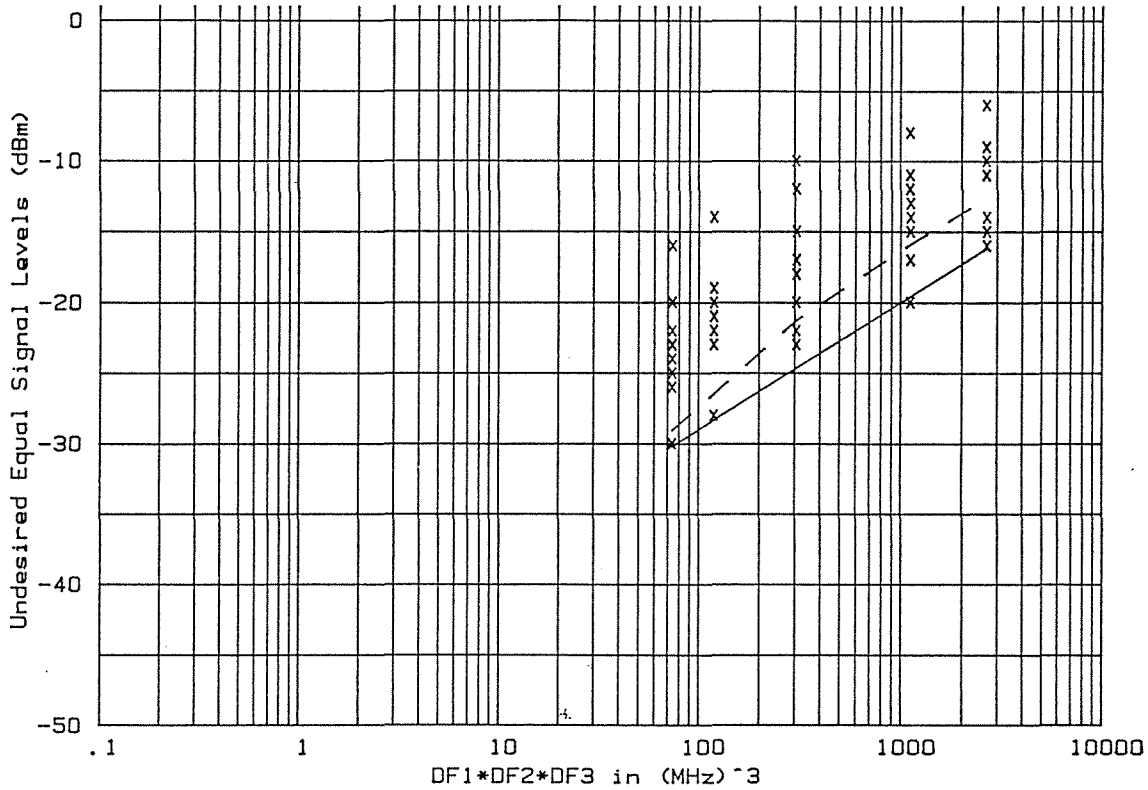
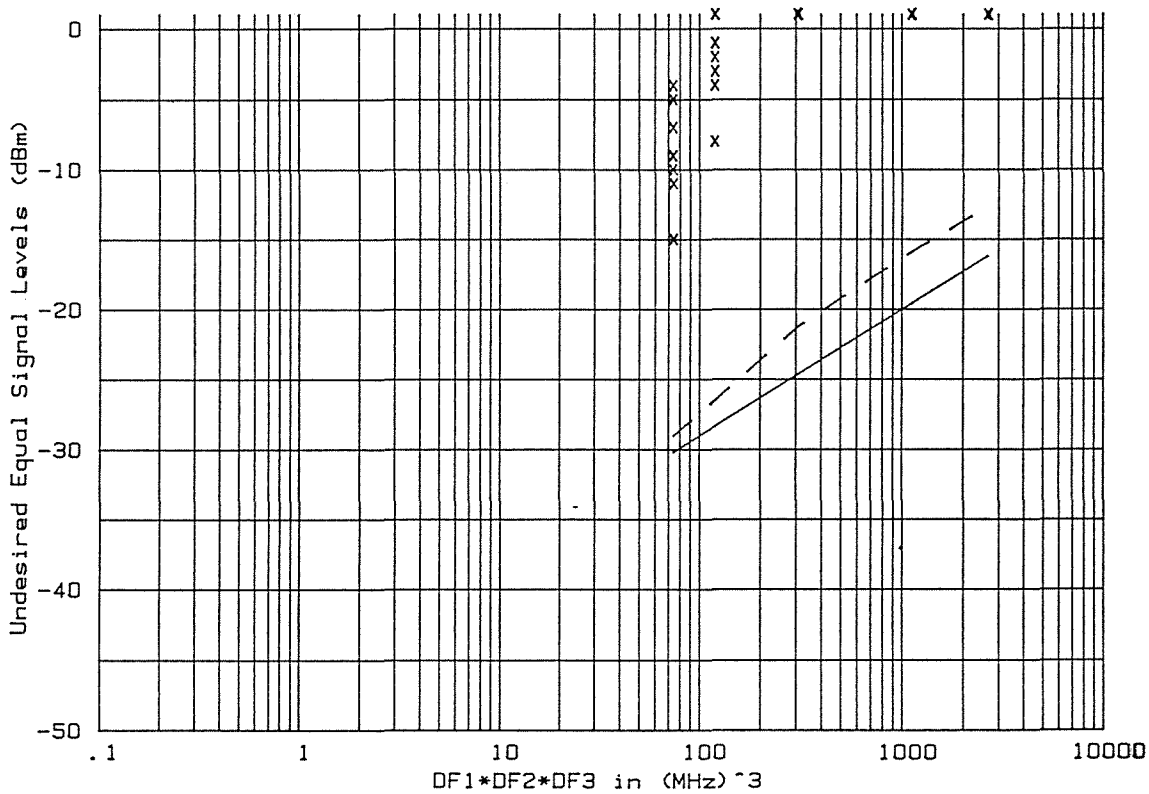


Figure 15. Three signal type B1 interference to 110.1 MHz, filtered receiver.



Frequencies (MHz) Undesired		Desired	Bare Receiver, Equal Undesired Signal Levels (dBm) A	B	C	D	E	F	G	H	J	K
107.5	106.9	108.1	-39	-37	-30	-32	-35	-39	-39	-41	-39	-34
106.5	104.9	108.1	-31	-37	-28	-27	-32	-32	-27	-36	-33	-27
105.5	102.9	108.1	-23	-30	-24	-21	-29	-24	-18	-28	-25	-17
103.5	98.9	108.1	-13	-22	-13	-15	-21	-17	-10	-16	-20	-15
101.5	94.9	108.1	-10	-16	-10	-12	-16	-13	-8	-13	-20	-12
107.9	106.7	109.1	-35	-37	-31	-29	-34	-36	-33	-36	-36	-31
107.5	105.9	109.1	-34	-35	-29	-26	-35	-32	-28	-36	-33	-26
106.5	103.9	109.1	-24	-26	-24	-22	-32	-24	-18	-29	-23	-17
104.5	99.9	109.1	-15	-21	-13	-15	-22	-18	-10	-16	-19	-15
101.5	93.9	109.1	-10	-13	-8	-10	-16	-12	-6	-11	-18	-11
107.9	105.7	110.1	-26	-28	-27	-23	-34	-28	-23	-33	-28	-20
107.5	104.9	110.1	-24	-24	-25	-21	-32	-25	-20	-30	-23	-18
106.5	102.9	110.1	-19	-23	-19	-17	-28	-20	-13	-24	-22	-16
105.5	100.9	110.1	-15	-22	-15	-15	-23	-17	-9	-17	-19	-15
101.5	92.9	110.1	-9	-10	-6	-9	-13	-10	-6	-10	-18	-10

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 the bare receiver and two signal intermodulation interference.

Frequencies (MHz) Undesired			Desired	Bare Receiver, Equal Undesired Signal Levels (dBm) A	B	C	D	E	F	G	H	J	K
107.5	106.5	105.9	108.1	-37	-41	-32	-33	-36	-38	-34	-41	-39	-34
106.5	104.5	102.9	108.1	-25	-32	-26	-24	-31	-27	-20	-30	-26	-21
105.5	102.5	99.9	108.1	-20	-25	-12	-19	-26	-22	-14	-21	-26	-19
104.5	100.5	96.9	108.1	-17	-21	-15	-17	-22	-19	-12	-17	-23	-17
101.5	95.3	88.7	108.1	-10	-15	-11	-11	-12	-13	-8	-10	-15	-12
107.9	106.3	105.1	109.1	-29	-34	-30	-27	-35	-31	-25	-35	-30	-25
107.5	105.5	103.9	109.1	-27	-29	-27	-24	-34	-26	-21	-31	-25	-21
106.5	103.5	100.9	109.1	-21	-23	-19	-19	-28	-22	-13	-21	-24	-19
105.5	101.5	97.9	109.1	-17	-21	-14	-16	-23	-18	-12	-17	-21	-17
103.5	97.5	91.9	109.1	-12	-16	-12	-12	-17	-14	-9	-12	-18	-13
107.9	105.3	103.1	110.1	-22	-24	-23	-20	-30	-23	-16	-26	-25	-20
107.5	104.5	101.9	110.1	-21	-23	-20	-19	-28	-21	-14	-22	-23	-19
106.5	102.5	98.9	110.1	-18	-20	-12	-15	-23	-18	-10	-17	-22	-17
104.5	98.5	92.9	110.1	-12	-15	-11	-12	-17	-14	-8	-11	-20	-13
99.5	98.7	88.1	110.1	-9	-11	-9	-10	-14	-11	-6	-15	-16	-11

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 the bare receiver and three signal intermodulation interference.

Frequencies (MHz) Undesired		Desired	Receiver with 6 dB Pad, Equal Undesired Signal Levels (dBm) A	B	C	D	E	F	G	H	J	K
107.5	106.9	108.1	-35	-34	-25	-30	-36	-35	-37	-37	-30	-31
106.5	104.9	108.1	-28	-33	-23	-25	-35	-28	-24	-32	-30	-24
105.5	102.9	108.1	-19	-27	-15	-19	-30	-20	-14	-24	-32	-15
103.5	98.9	108.1	-9	-19	-9	-11	-21	-14	-8	-12	-28	-13
101.5	94.9	108.1	-6	-12	-5	-8	-14	-9	-5	-9	-25	-9
107.9	106.7	109.1	-32	-34	-27	-27	-34	-32	-32	-33	-32	-27
107.5	105.9	109.1	-30	-32	-22	-24	-35	-28	-26	-32	-31	-22
106.5	103.9	109.1	-21	-24	-18	-19	-31	-20	-14	-25	-31	-15
104.5	99.9	109.1	-10	-18	-8	-11	-22	-14	-9	-12	-28	-12
101.5	93.9	109.1	-5	-8	-4	-6	-14	-7	-3	-7	-22	-8
107.9	105.7	110.1	-22	-25	-21	-21	-34	-24	-18	-29	-31	-17
107.5	104.9	110.1	-20	-21	-19	-19	-33	-21	-15	-26	-31	-15
106.5	102.9	110.1	-15	-20	-14	-14	-27	-17	-11	-18	-28	-12
105.5	100.9	110.1	-10	-18	-9	-12	-23	-13	-9	-12	-27	-11
101.5	92.9	110.1	-5	-6	-2	-5	-11	-6	-3	-6	-13	-6

Table 3. Equal undesired signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for the receiver with a six dB pad and two signal intermodulation interference.

Frequencies (MHz) Undesired			Desired	Receiver with 6 dB Pad, Equal Undesired Signal Levels (dBm) A	B	C	D	E	F	G	H	J	K
107.5	106.5	105.9	108.1	-34	-30	-29	-31	-37	-34	-33	-37	-37	-30
106.5	104.5	102.9	108.1	-21	-29	-18	-21	-31	-24	-17	-26	-35	-18
105.5	102.5	99.9	108.1	-15	-22	-12	-15	-25	-18	-12	-17	-33	-15
104.5	100.5	96.9	108.1	-13	-17	-11	-12	-21	-15	-9	-12	-29	-14
101.5	95.3	88.7	108.1	-6	-10	-7	-7	-10	-9	-4	-6	-19	-9
107.9	106.3	105.1	109.1	-26	-31	-22	-25	-35	-27	-22	-31	-34	-20
107.5	105.5	103.9	109.1	-23	-28	-21	-21	-33	-22	-18	-27	-34	-18
106.5	103.5	100.9	109.1	-17	-21	-11	-16	-27	-18	-12	-17	-32	-15
105.5	101.5	97.9	109.1	-13	-17	-10	-13	-22	-15	-10	-13	-27	-13
103.5	97.5	91.9	109.1	-8	-12	-8	-7	-14	-10	-5	-8	-22	-10
107.9	105.3	103.1	110.1	-18	-23	-17	-18	-30	-19	-15	-22	-32	-16
107.5	104.5	101.9	110.1	-17	-20	-13	-16	-28	-17	-14	-18	-30	-16
106.5	102.5	98.9	110.1	-13	-17	-9	-11	-22	-15	-9	-13	-27	-13
104.5	98.5	92.9	110.1	-8	-11	-7	-7	-15	-10	-5	-8	-23	-9
99.5	98.7	88.1	110.1	-5	-7	-4	-5	-11	-7	-2	-17	-17	-7

Table 4. Equal undesired signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for the receiver with a six dB pad and three signal intermodulation interference.

Frequencies (MHz) Undesired		Desired	Receiver with Filter, Equal Undesired Signal Levels (dBm) A	B	C	D	E	F	G	H	J	K
107.5	106.9	108.1	-35	-31	-22	-28	-31	-34	-34	-37	-38	-31
106.5	104.9	108.1	-20	-23	-14	-15	-22	-20	-12	-23	-25	-15
105.5	102.9	108.1	-3	-6	-2	-2	-11	-5	>0	-6	-8	>0
103.5	98.9	108.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
101.5	94.9	108.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
107.9	106.7	109.1	-31	-32	-25	-24	-30	-31	-28	-33	-34	-27
107.5	105.9	109.1	-27	-28	-20	-19	-27	-24	-20	-29	-28	-20
106.5	103.9	109.1	-9	-8	-12	-9	-20	-11	-2	-11	-16	0
104.5	99.9	109.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
101.5	93.9	109.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
107.9	105.7	110.1	-20	-20	-20	-17	-28	-21	-16	-29	-21	-15
107.5	104.9	110.1	-15	-11	-16	-13	-25	-16	-9	-20	-16	-9
106.5	102.9	110.1	-1	-4	-1	>0	-11	-4	>0	>0	-14	>0
105.5	100.9	110.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
101.5	92.9	110.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0

Table 5. Equal undesired signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for the receiver with a bandpass filter (108 to 132 MHz BP) and two signal intermodulation interference.

Frequencies (MHz) Undesired			Desired	Receiver with Filter, Equal Undesired Signal Levels (dBm) A	B	C	D	E	F	G	H	J	K
107.5	106.5	105.9	108.1	-29	-30	-22	-23	-28	-30	-24	-31	-36	-25
106.5	104.5	102.9	108.1	-6	-11	-5	-7	-15	-11	0	-6	-11	-4
105.5	102.5	99.9	108.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
104.5	100.5	96.9	108.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
101.5	95.3	88.7	108.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
107.9	106.3	105.1	109.1	-20	-23	-17	-18	-25	-24	-14	-25	-19	-14
107.5	105.5	103.9	109.1	-14	-17	-13	-13	-23	-13	-9	-15	-15	-7
106.5	103.5	100.9	109.1	>0	0	>0	>0	-1	>0	>0	>0	>0	>0
105.5	101.5	97.9	109.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
103.5	97.5	91.9	109.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
107.9	105.3	103.1	110.1	-7	-10	-5	-7	-15	-9	-9	-15	-11	-4
107.5	104.5	101.9	110.1	0	-4	0	-2	-8	-3	-1	>0	-3	-1
106.5	102.5	98.9	110.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
104.5	98.5	92.9	110.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0
99.5	90.7	88.1	110.1	>0	>0	>0	>0	>0	>0	>0	>0	>0	>0

Table 6. Equal undesired signal levels necessary to produce a 7.5 uA deviation from a standard ILS localizer deflection of 90 uA. This table is for the receiver with a bandpass filter (108 to 132 MHz BP) and three signal intermodulation interference.

Frequencies (MHz)			Receiver Input Conditions				
Undesired		Desired	Bare	Pad	Diff.	Filter	Diff.
107.5	106.9	108.1	-36.5	-33.8	2.7	-32.1	4.4
106.5	104.9	108.1	-31.0	-28.2	2.8	-18.9	12.1
105.5	102.9	108.1	-23.9	-21.5	2.4	-5.4	18.5
103.5	98.9	108.1	-16.2	-14.4	1.8	>0.0	>16.2
101.5	94.9	108.1	-13.0	-10.0	3.0	>0.0	>13
107.9	106.7	109.1	-33.8	-31.0	2.8	-29.5	4.3
107.5	105.9	109.1	-31.4	-28.2	3.2	-24.2	7.2
106.5	103.9	109.1	-23.9	-21.8	2.1	-10.9	13.0
104.5	99.9	109.1	-16.4	-14.4	2.0	>0.0	>16.4
101.5	93.9	109.1	-11.5	-8.4	3.1	>0.0	>11.5
107.9	105.7	110.1	-27.0	-24.2	2.8	-20.7	6.3
107.5	104.9	110.1	-24.2	-22.0	2.2	-15.0	9.2
106.5	102.9	110.1	-20.1	-17.6	2.5	-6.8	13.3
105.5	100.9	110.1	-16.7	-14.4	2.3	>0.0	>16.7
101.5	92.9	110.1	-10.1	-6.3	3.8	>0.0	>10.1

Table 7. Average level of the undesired equal signals necessary to produce a 7.5 uA deviation from a standard ILS localizer 90 uA deflection. This table is for the two signal intermodulation cases and shows the results for different receiver input conditions. Column four is for the bare receiver, column five is for a 50 Ohm 6 dB pad in series with the receiver, column six is the difference between the padded condition and the bare receiver, column seven is for a bandpass filter (108 to 132 MHz BP) in series with the receiver and column eight is the difference between the filtered receiver and the bare receiver.

Frequencies (MHz)				Receiver Input Conditions				
Undesired			Desired	Bare	Pad	Diff.	Filter	Diff.
107.5	106.5	105.9	108.1	-36.5	-34.0	2.5	-27.8	8.7
106.5	104.5	102.9	108.1	-26.2	-24.0	2.2	-8.4	17.8
105.5	102.5	99.9	108.1	-20.4	-18.4	2.0	>0.0	>20.4
104.5	100.5	96.9	108.1	-18.0	-15.3	2.7	>0.0	>18
101.5	95.3	88.7	108.1	-11.7	-8.7	3.0	>0.0	>11.7
107.9	106.3	105.1	109.1	-30.1	-27.3	2.8	-19.9	10.2
107.5	105.5	103.9	109.1	-26.5	-24.5	2.0	-13.9	12.6
106.5	103.5	100.9	109.1	-20.9	-18.6	2.3	>0.0	>20.9
105.5	101.5	97.9	109.1	-17.6	-15.3	2.3	>0.0	>17.6
103.5	97.5	91.9	109.1	-13.5	-10.4	3.1	>0.0	>13.5
107.9	105.3	103.1	110.1	-22.9	-21.0	1.9	-9.2	13.7
107.5	104.5	101.9	110.1	-21.0	-18.9	2.1	-3.1	17.9
106.5	102.5	98.9	110.1	-17.2	-14.9	2.3	>0.0	>17.2
104.5	98.5	92.9	110.1	-13.3	-10.3	3.0	>0.0	>13.3
99.5	98.7	88.1	110.1	-11.2	-8.2	3.0	>0.0	>11.2

Table 8. Average level of the undesired equal signals necessary to produce a 7.5 uA deviation from a standard ILS localizer 90 uA deflection. This table is for the three signal intermodulation cases and shows the results for different receiver input conditions. Column five is for the bare receiver, column six is for a 50 Ohm 6 dB pad in series with the receiver, column seven is the difference between the padded condition and the bare receiver, column eight is for a bandpass filter (108 to 132 MHz BP) in series with the receiver and column nine is the difference between the filtered receiver and the bare receiver.

Freq. (MHz)	Impedance (Ohms) and VSWR											
	Receiver A			Receiver B			Receiver C			Receiver D		
	R	X	VSWR	R	X	VSWR	R	X	VSWR	R	X	VSWR
96.1	132.6	13.4	2.7	1.8	-36.3	43.4	26.0	-205.1	34.8	218.7	-470.8	24.8
97.1	137.6	-5.8	2.8	3.3	-33.0	21.7	18.7	-172.5	34.8	96.2	-304.9	21.7
98.1	131.2	-18.5	2.7	2.7	-29.4	24.8	11.4	-148.7	43.4	55.1	-233.3	21.7
99.1	117.6	-42.7	2.7	4.3	-25.3	14.5	11.1	-129.4	34.8	33.5	-195.1	24.8
100.1	110.8	-53.8	2.8	3.1	-21.2	19.3	12.6	-113.8	24.8	21.9	-155.8	24.8
101.1	87.7	-49.8	2.5	3.2	-16.7	17.4	17.7	-95.5	13.4	17.7	-128.1	21.7
102.1	73.2	-56.7	2.6	3.6	-11.5	14.5	7.1	-87.9	29.0	18.9	-104.4	14.5
103.1	62.2	-56.9	2.7	5.0	-7.0	10.3	6.8	-76.6	24.8	16.6	-91.7	13.4
104.1	50.4	-52.4	2.7	7.7	0.9	6.5	7.3	-67.1	19.3	7.3	-73.6	21.7
105.1	43.0	-46.5	2.6	16.5	13.3	3.3	8.4	-55.8	13.4	12.0	-62.6	10.9
106.1	33.9	-38.5	2.6	54.9	6.7	1.2	10.8	-43.9	8.3	8.9	-51.0	11.6
107.1	27.4	-28.6	2.6	32.0	-31.3	2.4	15.9	-32.0	4.5	7.0	-39.3	11.6
108.1	25.8	-5.8	2.0	17.2	-19.1	3.4	33.6	-17.2	1.8	10.8	-22.9	5.7
108.3	31.1	2.1	1.6	16.7	-19.7	3.5	38.5	-20.6	1.7	13.1	-19.5	4.4
108.5	38.7	7.9	1.4	19.0	-17.7	3.0	45.0	-23.5	1.7	18.3	-13.4	3.0
108.7	49.8	16.8	1.4	20.3	-15.9	2.8	49.0	-23.6	1.6	21.7	-9.5	2.4
108.9	65.5	9.1	1.4	22.3	-17.6	2.6	50.5	-33.1	1.9	27.7	6.5	1.9
109.1	71.6	0.5	1.4	22.5	-17.5	2.5	51.0	-39.9	2.2	35.7	-8.1	1.5
109.3	81.4	-15.0	1.7	22.0	-19.5	2.7	46.1	-41.5	2.3	40.5	-12.0	1.4
109.5	69.0	-20.1	1.6	22.0	-22.9	2.8	40.2	-42.6	2.3	44.9	-15.5	1.4
109.7	68.2	-31.2	1.8	22.7	-22.1	2.7	41.0	-45.0	2.6	40.0	-18.0	1.4
109.9	61.4	-29.6	1.8	21.3	-22.7	2.9	40.7	-39.2	2.4	47.2	-22.7	1.6
110.1	58.2	-34.5	1.9	17.7	-24.5	3.6	38.6	-41.7	2.6	46.8	-16.0	1.4
110.3	56.6	-35.8	2.0	16.0	-27.2	4.1	38.1	-37.1	2.4	46.7	-22.8	1.6
110.5	55.7	-32.1	1.8	11.4	-24.4	5.5	42.2	-29.6	1.9	52.3	-21.7	1.5
110.7	51.9	-37.1	2.0	9.4	-27.5	7.0	41.8	-30.2	2.0	55.1	-20.0	1.5
110.9	53.2	-40.6	2.2	7.8	-24.4	7.9	46.4	-28.1	1.8	61.7	-24.5	1.6
111.1	50.1	-42.3	2.3	7.4	-20.8	7.9	55.5	-28.2	1.7	68.3	-29.0	1.8
111.3	52.6	-39.9	2.1	5.8	-21.5	10.3	58.5	-24.0	1.6	81.8	-30.9	2.0
111.5	43.9	-43.7	2.5	5.7	-20.0	10.3	74.8	-32.4	1.9	84.4	-44.7	2.3
111.7	42.2	-37.0	2.2	7.1	-17.9	7.9	75.5	-34.1	2.0	84.4	-49.7	2.5
111.9	37.2	-41.1	2.6	4.2	-17.6	13.4	81.3	-43.8	2.3	73.6	-68.5	3.1
112.1	34.6	-36.1	2.5	4.8	-17.6	11.6	87.1	-68.2	3.1	68.8	-78.9	3.6
113.1	31.9	-33.6	2.5	3.0	-11.5	17.4	45.4	-97.7	6.0	28.0	-77.6	6.5
114.1	27.8	-25.4	2.4	2.7	-8.3	19.3	22.7	-73.6	7.3	12.0	-66.2	11.6
115.1	23.7	-24.3	2.7	2.6	-5.2	19.3	7.6	-69.5	19.3	11.4	-57.2	10.3
116.1	21.0	-19.4	2.8	2.3	-3.1	21.7	12.8	-60.1	9.7	9.2	-46.6	10.3
117.1	21.6	-17.3	2.6	2.6	0.0	19.3	4.1	-50.7	24.8	5.8	-40.9	14.5
118.1	19.1	-13.6	2.8	2.9	2.2	17.4	3.6	-44.9	24.8	2.5	-33.7	29.0
119.1	19.1	-10.7	2.8	2.6	4.4	19.3	4.0	-42.5	21.7	2.7	-30.0	24.8
120.1	18.2	-6.5	2.8	2.3	6.6	21.7	2.2	-37.0	34.8	2.2	-24.9	29.0
121.1	18.3	-4.6	2.8	2.4	8.3	21.7	5.6	-34.7	13.4	1.7	-22.2	34.8
122.1	19.9	-0.4	2.5	2.7	11.5	19.3	1.2	-30.6	57.9	2.0	-18.7	29.0
123.1	18.4	0.8	2.7	3.4	13.3	15.8	4.5	-28.1	14.5	1.9	-15.3	29.0
124.1	50.0	0.0	1.0	3.5	15.2	15.8	0.7	-26.0	86.9	2.4	-12.4	21.7

Table 9. Impedance looking directly into the antenna port of each receiver. Each receiver was tuned to 110.1 MHz.

Freq. (MHz)	Impedance (Ohms) and VSWR											
	Receiver E			Receiver F			Receiver G			Receiver H		
	R	X	VSWR	R	X	VSWR	R	X	VSWR	R	X	VSWR
96.1	123.4	-401.5	29.0	33.6	-151.8	15.8	7.0	-70.9	21.7	2.9	17.2	19.3
97.1	67.3	-301.0	29.0	29.3	-127.9	13.4	3.0	-63.9	43.4	2.4	22.2	24.8
98.1	47.1	-215.8	21.7	22.8	-111.1	13.4	2.1	-59.5	57.9	2.6	27.1	24.8
99.1	29.4	-182.2	24.8	19.7	-101.7	13.4	2.3	-50.8	43.4	1.3	35.0	57.9
100.1	16.1	-143.6	29.0	18.4	-93.2	12.4	2.6	-45.0	34.8	5.5	38.8	14.5
101.1	18.9	-124.4	19.3	12.8	-81.7	14.5	1.5	-41.9	57.9	8.3	47.6	11.6
102.1	19.7	-101.7	13.4	12.4	-71.3	12.4	1.8	-38.3	43.4	11.4	60.4	10.9
103.1	9.4	-80.8	19.3	10.3	-61.8	12.4	2.5	-33.0	29.0	18.3	75.3	9.2
104.1	8.9	-72.0	17.4	10.2	-51.6	10.3	4.2	-28.7	15.8	42.6	116.9	8.3
105.1	9.4	-53.7	11.6	10.2	-38.8	7.9	3.2	-23.8	19.3	177.9	111.2	5.0
106.1	8.3	-41.3	10.3	14.4	-26.5	4.5	3.2	-15.7	17.4	109.6	-87.6	3.8
107.1	14.8	-22.6	4.1	19.9	-9.4	2.6	6.8	-9.1	7.6	31.6	-45.4	3.2
108.1	40.2	-13.7	1.5	58.3	-0.8	1.2	16.4	0.4	3.1	19.8	-15.2	2.8
108.3	43.4	-21.5	1.6	64.0	-4.0	1.3	19.8	4.1	2.5	17.1	-10.2	3.1
108.5	49.5	-23.4	1.6	65.4	-17.5	1.5	26.0	1.3	1.9	15.8	-8.4	3.3
108.7	46.3	-31.0	1.9	63.2	-23.7	1.6	31.7	-4.0	1.6	16.0	-5.1	3.2
108.9	43.2	-33.2	2.0	64.0	-26.2	1.7	35.9	-10.9	1.5	14.6	-2.4	3.4
109.1	46.2	-33.9	2.0	57.7	-26.4	1.7	31.0	-17.1	1.9	14.0	0.4	3.6
109.3	43.4	-35.2	2.1	59.6	-30.2	1.8	24.8	-18.9	2.4	14.1	4.0	3.6
109.5	39.3	-29.2	2.0	55.1	-26.4	1.7	23.4	-16.7	2.4	11.8	6.6	4.3
109.7	39.9	-26.8	1.9	57.7	-29.4	1.7	20.5	-16.8	2.8	11.7	9.2	4.4
109.9	44.0	-29.5	1.9	61.9	-28.3	1.7	20.9	-18.0	2.8	12.6	12.2	4.2
110.1	45.5	-20.7	1.6	64.9	-30.0	1.8	20.8	-20.4	2.9	13.6	14.7	4.0
110.3	44.4	-15.9	1.4	70.9	-24.3	1.7	18.5	-11.7	2.9	13.4	17.5	4.2
110.5	52.9	-18.8	1.4	71.3	-30.7	1.9	19.4	-10.7	2.7	13.5	22.9	4.5
110.7	52.7	-22.0	1.5	81.5	-27.0	1.9	19.3	-7.1	2.6	15.4	22.5	3.9
110.9	61.4	-21.4	1.5	81.9	-38.3	2.1	23.6	-4.8	2.1	19.2	24.5	3.3
111.1	75.9	-28.5	1.9	92.5	-44.5	2.4	27.3	-2.5	1.8	21.1	26.0	3.1
111.3	93.9	-37.7	2.3	93.7	-57.8	2.8	34.0	-2.8	1.5	21.5	28.7	3.2
111.5	88.6	-52.9	2.6	96.2	-70.4	3.2	39.2	-6.0	1.3	24.0	27.5	2.8
111.7	90.4	-61.2	2.8	86.6	-81.7	3.6	46.7	-15.5	1.4	23.4	26.1	2.8
111.9	77.6	-78.6	3.5	75.5	-78.1	3.5	45.5	-23.4	1.6	21.6	28.0	3.2
112.1	63.3	-90.6	4.4	73.8	-86.6	3.9	43.8	-32.2	2.0	23.7	26.0	2.8
113.1	20.4	-81.1	9.2	30.2	-85.9	7.0	17.1	-39.7	4.9	25.1	25.8	2.6
114.1	8.3	-63.3	15.8	18.7	-73.7	8.7	8.6	-30.0	7.9	18.8	25.7	3.4
115.1	6.3	-54.2	17.4	17.9	-59.6	7.0	6.0	-24.1	10.3	13.1	32.1	5.5
116.1	6.0	-43.1	14.5	9.9	-56.5	11.6	3.3	-18.6	17.4	10.3	44.0	8.7
117.1	5.0	-36.7	13.4	12.0	-46.8	7.9	1.6	-16.2	34.8	9.0	51.9	11.6
118.1	2.5	-34.3	29.0	7.0	-43.0	12.4	1.5	-12.9	34.8	11.7	61.5	10.9
119.1	2.3	-28.8	29.0	7.8	-41.4	10.9	1.8	-8.8	29.0	12.1	74.2	13.4
120.1	2.6	-26.0	24.8	7.4	-32.6	9.7	1.5	-6.6	34.8	15.6	88.1	13.4
121.1	2.4	-21.7	24.8	4.8	-31.6	14.5	1.4	-3.5	34.8	18.9	104.4	14.5
122.1	1.6	-18.7	34.8	4.3	-29.9	15.8	1.7	-1.7	29.0	18.2	123.0	34.8
123.1	1.6	-14.8	34.8	3.7	-26.5	17.4	1.7	0.9	29.0	38.4	154.9	14.5
124.1	2.7	-12.0	19.3	3.6	-24.3	17.4	1.4	3.5	34.8	58.5	191.5	14.5

Table 10. Impedance looking directly into the antenna port of each receiver. Each receiver was tuned to 110.1 MHz.

Freq. (MHz)	Impedance (Ohms) and VSWR											
	Receiver J			Receiver K			Receiver L			Receiver M		
	R	X	VSWR	R	X	VSWR	R	X	VSWR	R	X	VSWR
96.1	2.1	45.0	43.4	17.0	147.7	29.0	6.9	78.0	24.8	3.5	50.8	29.0
97.1	5.3	51.5	19.3	18.7	172.5	34.8	7.1	87.9	29.0	0.1	54.6	**
98.1	6.2	59.2	19.3	33.4	211.6	29.0	12.0	94.9	19.3	4.3	60.5	29.0
99.1	8.9	66.8	15.8	57.9	257.2	24.8	15.4	110.5	19.3	3.0	62.8	43.4
100.1	9.6	76.1	17.4	107.3	320.6	21.7	17.7	128.1	21.7	4.4	71.2	34.8
101.1	10.0	84.0	19.3	285.2	574.2	29.0	19.7	147.1	24.8	4.1	79.9	43.4
102.1	3.9	93.9	57.9	1048.9	198.5	21.7	25.3	183.3	29.0	6.9	86.2	29.0
103.1	12.1	111.2	24.8	404.6	-475.1	19.3	62.0	218.5	17.4	7.0	97.7	34.8
104.1	26.2	132.8	15.8	150.8	-332.9	17.4	135.8	294.7	15.8	16.7	115.8	19.3
105.1	26.3	159.6	21.7	72.6	-235.7	17.4	359.2	360.7	14.5	24.9	154.9	21.7
106.1	62.5	188.8	13.4	62.7	-150.6	9.2	435.1	-145.4	9.7	103.1	208.5	10.9
107.1	181.0	186.2	7.6	35.3	-102.3	7.9	153.1	-157.8	6.5	200.7	13.3	4.0
108.1	240.4	50.6	5.0	38.8	-60.9	3.7	86.0	-57.0	2.7	60.8	25.4	1.6
108.3	216.1	31.6	4.4	37.2	-59.3	3.7	74.7	-42.2	2.2	57.7	30.4	2.0
108.5	177.9	10.2	3.6	38.8	-53.1	3.2	68.4	-32.2	1.9	54.9	40.5	2.1
108.7	170.7	14.1	3.4	43.9	-40.8	2.3	60.4	-21.4	1.6	49.2	50.3	2.6
108.9	138.7	11.8	2.8	44.1	-39.2	2.3	76.2	-5.3	1.5	46.9	50.4	2.7
109.1	125.6	14.2	2.5	49.8	-35.0	2.0	82.4	2.3	1.7	44.9	63.1	3.5
109.3	120.2	27.0	2.5	53.0	-30.1	1.8	84.8	12.1	1.7	45.4	60.5	3.3
109.5	120.2	27.0	2.5	61.7	-27.1	1.7	96.8	17.9	2.0	45.2	69.1	3.9
109.7	100.3	48.2	2.6	63.7	-31.1	1.8	98.5	23.7	2.1	44.6	76.6	4.4
109.9	110.3	48.6	2.7	66.4	-27.7	1.7	114.3	25.9	2.4	47.9	78.0	4.3
110.1	104.1	62.0	3.0	68.8	-33.9	1.9	121.6	27.7	2.6	51.3	82.3	4.4
110.3	91.2	66.5	3.0	58.2	-34.1	1.9	112.4	3.5	2.2	70.1	117.0	5.8
110.5	103.9	70.7	3.2	59.2	-25.6	1.6	107.6	-11.3	2.2	82.6	108.3	4.9
110.7	108.1	77.3	3.4	54.6	-26.1	1.7	96.7	-4.8	1.9	103.8	94.5	4.0
110.9	97.1	82.2	3.6	52.5	-19.0	1.5	86.1	-2.6	1.7	82.6	99.3	4.4
111.1	105.5	79.7	3.5	55.8	-10.9	1.3	74.1	-2.1	1.5	87.9	90.7	3.9
111.3	102.9	96.8	4.1	54.0	1.6	1.1	65.8	11.9	1.4	80.4	87.2	3.9
111.5	99.8	92.2	3.9	65.8	12.7	1.4	59.9	26.6	1.7	89.4	73.9	3.3
111.7	105.7	106.9	4.5	64.4	25.7	1.7	60.8	40.4	2.1	83.1	64.4	2.9
111.9	104.9	112.2	4.8	73.7	38.1	2.1	58.0	54.0	2.6	75.9	64.2	2.9
112.1	110.1	102.0	4.3	95.3	50.7	2.6	55.0	64.5	3.2	54.6	59.4	3.0
113.1	139.4	137.0	5.7	50.5	-1.8	1.0	84.0	131.9	6.3	26.7	81.9	7.3
114.1	170.8	171.2	7.0	201.6	-164.4	7.6	140.4	234.3	10.9	22.0	108.6	13.4
115.1	277.7	207.6	8.7	96.6	-188.3	9.7	346.3	260.2	10.9	26.2	132.8	15.8
116.1	411.6	171.9	9.7	42.9	-164.1	14.5	594.0	-128.1	12.4	32.5	157.4	17.4
117.1	594.0	-128.1	12.4	28.5	-132.0	14.5	273.4	-373.9	15.8	22.5	214.3	43.4
118.1	312.1	-304.5	15.8	17.1	-110.1	17.4	117.7	-312.4	19.3	55.1	272.8	29.0
119.1	131.6	-328.1	19.3	11.3	-91.0	19.3	61.2	-230.2	19.3	120.4	337.7	21.7
120.1	63.5	-269.1	24.8	10.0	-84.0	19.3	54.7	-185.4	14.5	310.7	536.1	24.8
121.1	43.7	-207.9	21.7	9.4	-74.7	17.4	27.9	-164.5	21.7	569.6	1150.2	57.9
122.1	26.0	-170.7	24.8	5.5	-66.1	24.8	17.0	-135.5	24.8	1361.4	-343.7	29.0
123.1	17.0	-147.7	29.0	3.4	-58.4	34.8	13.1	-116.6	24.8	527.2	-797.7	34.8
124.1	20.7	-130.9	19.3	2.3	-50.8	43.4	8.9	-101.9	29.0	285.2	-574.2	29.0

** VSWR exceeded 99:1

Table 11. Impedance looking directly into the antenna port of each receiver. Each receiver was tuned to 110.1 MHz.

Freq. (MHz)	Impedance (Ohms) and VSWR											
	Receiver A			Receiver B			Receiver C			Receiver D		
	R	X	VSWR	R	X	VSWR	R	X	VSWR	R	X	VSWR
96.1	0.6	-0.4	86.9	0.3	-0.4	**	0.0	-0.9	**	0.0	-0.4	**
97.1	0.6	1.7	86.9	0.3	1.3	**	0.3	0.9	**	0.3	1.7	**
98.1	0.3	3.5	**	0.3	3.1	**	0.6	3.1	86.9	0.9	3.1	57.9
99.1	0.0	4.8	**	0.0	5.3	**	-0.3	4.0	**	0.0	5.3	**
100.1	0.3	7.9	**	0.3	7.5	**	0.6	7.5	86.9	0.3	7.9	**
101.1	-0.3	9.7	**	0.3	10.2	**	0.0	9.3	**	-0.3	10.2	**
102.1	0.3	12.9	**	0.6	14.3	86.9	0.6	13.4	86.9	-0.9	13.4	**
103.1	0.6	17.2	86.9	0.0	18.7	**	1.0	17.7	57.9	-0.3	18.2	**
104.1	0.7	22.8	86.9	1.0	22.3	57.9	1.4	22.2	43.4	1.7	21.7	34.8
105.1	2.0	30.6	34.8	-0.4	30.6	**	1.2	30.0	57.9	-0.8	31.2	**
106.1	3.0	43.4	29.0	5.6	43.9	15.8	3.0	42.6	29.0	1.5	44.2	57.9
107.1	17.4	78.8	10.3	22.7	83.0	8.7	13.5	79.9	13.4	17.3	89.5	12.4
108.1	71.5	-1.8	1.4	61.5	-30.5	1.8	103.4	-7.2	2.1	52.0	-44.2	2.3
108.3	66.5	14.3	1.5	38.0	-15.9	1.6	76.4	-20.9	1.7	33.6	-17.2	1.8
108.5	72.9	11.9	1.5	32.6	0.8	1.5	59.1	-21.7	1.5	32.4	4.9	1.6
108.7	76.0	1.1	1.5	29.5	9.3	1.8	43.7	-12.5	1.3	33.7	12.5	1.6
108.9	56.1	-16.7	1.4	30.1	15.5	1.9	32.9	-9.6	1.6	38.8	15.1	1.5
109.1	37.0	-8.3	1.4	27.9	20.2	2.2	26.6	-1.6	1.9	40.3	11.1	1.4
109.3	29.9	-1.1	1.7	27.5	26.2	2.5	22.2	6.4	2.3	37.3	12.2	1.5
109.5	24.1	7.9	2.1	30.3	34.1	2.6	20.4	16.4	2.8	35.2	15.2	1.7
109.7	24.5	15.1	2.3	31.6	45.4	3.2	22.6	22.7	2.8	34.5	18.8	1.8
109.9	24.4	21.4	2.5	36.3	54.3	3.4	22.8	29.9	3.1	31.1	23.3	2.1
110.1	29.1	28.1	2.4	52.7	60.3	3.1	29.8	37.6	2.9	39.2	26.3	1.9
110.3	34.5	35.4	2.5	71.8	89.5	4.1	43.0	45.1	2.6	44.9	33.8	2.0
110.5	38.3	42.1	2.6	122.4	80.4	3.6	51.0	49.0	2.5	49.3	36.2	2.0
110.7	50.9	46.9	2.5	205.9	7.0	4.1	62.6	38.8	2.0	49.2	36.7	2.1
110.9	73.3	52.1	2.5	134.6	-93.6	4.1	71.9	35.3	2.0	62.6	39.4	2.1
111.1	95.9	43.9	2.4	63.5	-81.0	3.9	80.3	32.5	2.0	71.9	39.2	2.1
111.3	119.7	21.7	2.5	32.7	-66.2	4.6	81.5	28.6	1.9	92.3	48.1	2.5
111.5	109.0	-29.3	2.4	20.6	-48.3	4.9	106.7	19.7	2.2	128.2	25.7	2.7
111.7	80.3	-37.4	2.1	17.6	-32.0	4.1	107.0	0.0	2.1	125.6	-14.2	2.5
111.9	55.9	-46.8	2.4	10.9	-24.0	5.7	102.6	-33.2	2.3	92.1	-59.5	2.8
112.1	38.5	-34.7	2.2	10.1	-16.6	5.5	77.7	-62.1	2.8	60.7	-66.0	3.2
113.1	18.8	-4.9	2.7	8.0	17.3	7.0	12.5	-21.1	4.8	8.8	-12.6	6.0
114.1	18.6	21.6	3.3	25.8	66.1	5.7	5.4	10.1	9.7	7.0	16.9	7.9
115.1	55.5	48.0	2.4	169.5	-140.6	5.8	13.2	49.1	7.6	17.4	72.7	9.2
116.1	89.0	-33.3	2.1	11.7	-41.3	7.3	191.3	213.2	8.7	297.7	-154.7	7.6
117.1	34.3	-28.7	2.2	7.2	-3.9	7.0	18.4	-78.5	9.7	14.9	-55.3	7.6
118.1	23.5	-2.7	2.1	12.1	29.9	5.7	6.3	-23.0	9.7	5.4	-11.4	9.7
119.1	36.8	18.3	1.7	78.2	125.2	6.0	5.8	6.1	8.7	9.0	20.1	6.5
120.1	84.5	5.7	1.7	44.3	-115.7	7.9	14.2	48.8	7.0	38.6	89.4	6.0
121.1	52.1	-39.2	2.1	9.7	-36.1	7.9	322.4	153.5	7.9	77.0	-150.4	7.9
122.1	28.7	-22.2	2.2	6.8	-8.2	7.6	14.1	-78.2	12.4	7.5	-46.1	12.4
123.1	25.8	-1.3	1.9	12.4	24.2	5.0	7.9	-27.8	8.3	5.4	-11.4	9.7
124.1	52.2	17.7	1.4	87.5	115.4	5.2	5.7	0.9	8.7	11.1	22.9	5.5

** VSWR Exceeded 99:1

Table 12. Impedance looking into a bandpass filter (108 to 132 MHz BP) connected to each receiver. Each receiver was tuned to 110.1 MHz.

Freq. (MHz)	Impedance (Ohms) and VSWR											
	Receiver E			Receiver F			Receiver G			Receiver H		
	R	X	VSWR	R	X	VSWR	R	X	VSWR	R	X	VSWR
96.1	0.3	-0.0	**	0.0	-0.4	**	0.3	-0.4	**	0.3	0.0	**
97.1	0.3	-1.7	**	0.9	1.3	57.9	0.6	1.3	86.9	0.0	1.3	**
98.1	0.0	3.5	**	0.3	3.1	**	0.3	3.5	**	0.3	3.9	**
99.1	0.6	5.7	86.9	0.3	5.3	**	0.3	5.7	**	0.3	4.0	**
100.1	0.3	7.5	**	0.0	7.5	**	0.6	7.5	86.9	0.6	7.5	86.9
101.1	0.3	11.1	**	0.3	10.6	**	0.6	10.2	86.9	0.6	10.2	86.9
102.1	0.0	14.8	**	0.6	13.4	86.9	0.3	13.9	**	0.0	13.4	**
103.1	0.6	17.7	86.9	0.3	16.7	**	0.3	18.2	**	0.6	17.2	86.9
104.1	0.7	24.9	86.9	1.4	22.0	43.4	0.0	23.8	**	-0.4	24.4	**
105.1	0.0	31.9	**	1.2	30.0	57.9	1.6	32.4	43.4	1.2	30.6	57.9
106.1	3.8	46.5	24.8	-0.5	44.2	**	2.6	45.0	34.8	4.5	42.5	19.3
107.1	31.6	99.1	8.3	19.9	79.6	9.2	26.6	99.1	9.7	15.5	79.4	11.6
108.1	89.3	-14.2	1.9	115.4	31.7	2.5	47.7	8.2	1.2	60.8	-20.9	1.5
108.3	65.6	-23.6	1.6	105.0	0.0	2.1	44.5	19.6	1.5	36.3	-2.3	1.4
108.5	48.0	-16.8	1.4	70.9	-25.9	1.7	51.4	16.0	1.4	31.1	10.7	1.7
108.7	34.0	-11.3	1.6	47.1	-20.8	1.5	49.7	8.8	1.2	32.2	24.2	2.1
108.9	26.9	-2.5	1.9	34.8	-9.7	1.5	41.7	11.1	1.4	35.0	36.5	2.5
109.1	26.6	6.4	1.9	28.6	-0.3	1.7	33.6	14.4	1.7	46.3	47.9	2.6
109.3	25.0	13.3	2.2	28.1	6.7	1.8	29.4	22.8	2.2	68.1	62.0	2.9
109.5	24.1	20.1	2.5	25.5	11.6	2.1	29.9	33.6	2.6	99.4	43.1	2.5
109.7	26.8	25.5	2.5	27.0	17.0	2.1	35.4	40.0	2.6	113.1	-7.2	2.3
109.9	32.1	29.8	2.3	29.2	22.4	2.2	55.1	52.2	2.6	79.4	-41.8	2.2
110.1	44.9	33.8	2.0	29.4	27.3	2.4	64.0	54.7	2.6	49.6	-39.3	2.2
110.3	46.3	31.0	1.9	30.4	35.6	2.7	90.6	33.2	2.1	32.2	-27.8	2.2
110.5	50.1	42.3	2.3	37.3	37.0	2.4	90.5	-3.8	2.0	27.6	-14.7	2.0
110.7	53.5	36.6	2.0	39.3	47.1	2.0	72.4	-18.5	1.6	21.0	-6.5	2.4
110.9	57.3	41.1	2.1	49.8	49.1	2.6	59.2	-18.7	1.5	21.8	1.1	2.3
111.1	74.4	40.8	2.1	68.1	62.0	2.9	50.0	-8.7	1.2	22.2	8.2	2.3
111.3	100.8	53.8	2.7	94.7	61.7	2.9	53.2	-4.6	1.1	24.3	16.0	2.3
111.5	122.4	22.9	2.5	130.1	42.4	3.1	59.2	-5.2	1.2	27.7	19.8	2.2
111.7	132.9	-28.1	2.8	152.7	-26.4	3.2	66.6	-16.7	1.5	29.2	23.0	2.2
111.9	89.4	-75.5	3.3	105.6	-66.7	3.1	56.1	-26.5	1.7	30.3	29.8	2.4
112.1	49.2	-68.6	3.6	62.8	-69.0	3.3	43.4	-32.9	2.0	30.5	29.4	2.0
113.1	6.9	-11.3	7.6	9.6	-17.1	5.8	10.3	-2.9	4.9	78.0	12.9	1.6
114.1	7.2	18.8	7.9	7.9	12.6	6.7	8.3	30.6	8.3	56.5	-36.3	2.0
115.1	23.0	71.9	7.0	9.2	52.8	11.6	55.9	122.9	7.3	14.3	-15.5	3.9
116.1	229.6	-163.6	7.0	258.9	128.2	6.5	35.4	-94.2	7.0	10.5	17.0	5.3
117.1	13.6	-46.4	7.0	27.1	-68.3	5.7	6.9	-25.6	9.2	29.1	71.8	5.7
118.1	5.7	-10.5	9.2	7.4	-20.3	7.9	7.0	7.3	7.3	159.1	-183.5	7.6
119.1	8.5	21.2	7.0	7.7	9.1	6.7	14.5	49.6	7.0	11.2	-53.3	9.7
120.1	48.2	98.4	5.8	15.9	50.1	6.5	378.2	-24.6	7.6	5.6	-15.1	9.7
121.1	66.1	-140.7	7.9	292.4	0.0	5.8	16.2	-63.8	8.3	7.4	14.0	7.3
122.1	8.3	-44.3	10.9	18.6	-70.8	8.3	4.9	-23.1	12.4	19.2	75.0	8.7
123.1	5.4	-10.1	9.7	7.2	-25.1	8.7	6.1	6.0	8.3	121.9	-198.1	9.2
124.1	12.6	25.3	5.0	8.0	-4.3	6.3	21.7	50.0	5.7	8.9	-54.7	12.4

** VSWR Exceeded 99:1

Table 13. Impedance looking into a bandpass filter (108 to 132 MHz BP) connected to each receiver. Each receiver was tuned to 110.1 MHz.

Freq. (MHz)	Impedance (Ohms) and VSWR											
	Receiver J			Receiver K			Receiver L			Receiver M		
	R	X	VSWR	R	X	VSWR	R	X	VSWR	R	X	VSWR
96.1	0.0	-0.4	**	0.3	0.4	**	0.3	-0.9	**	0.0	-0.4	**
97.1	0.0	1.7	**	0.3	1.3	**	0.3	0.9	**	0.3	-1.3	**
98.1	0.0	3.5	**	0.3	3.1	**	0.6	3.1	86.9	0.0	3.1	**
99.1	0.6	5.7	86.9	0.0	4.4	**	0.3	5.7	**	0.3	4.8	**
100.1	0.0	8.4	**	0.3	7.0	**	0.6	7.9	86.9	0.3	7.5	**
101.1	0.3	10.6	**	0.3	10.2	**	0.0	9.7	**	0.6	10.6	86.9
102.1	-0.9	14.3	**	0.0	13.4	**	-0.9	13.4	**	0.6	12.9	86.9
103.1	-0.3	18.7	**	0.0	16.7	**	1.0	17.7	57.9	-0.3	17.2	**
104.1	1.4	24.4	43.4	-1.0	22.3	**	1.4	22.8	43.4	1.4	22.8	43.4
105.1	-0.4	34.4	**	2.7	30.0	24.8	-1.2	31.2	**	1.2	31.8	57.9
106.1	5.1	38.8	15.8	0.5	42.7	**	2.3	37.6	34.8	8.8	47.5	10.9
107.1	12.7	72.6	12.4	10.0	73.2	15.8	7.1	72.3	21.7	10.2	65.3	13.4
108.1	250.8	43.6	5.2	201.6	-41.9	4.2	205.1	13.9	4.1	84.9	64.3	2.9
108.3	142.4	-87.7	4.0	87.1	-66.8	3.0	109.3	-40.3	2.5	100.4	58.5	2.8
108.5	63.6	-61.9	2.9	48.6	-41.6	2.3	66.0	-37.6	2.0	111.8	39.9	2.6
108.7	44.7	-42.4	2.4	35.7	-18.8	1.7	48.6	-23.4	1.6	126.6	25.0	2.6
108.9	30.2	-25.6	2.2	29.4	-9.7	1.8	44.9	-13.8	1.4	115.3	-24.2	2.4
109.1	25.0	-15.7	2.2	28.3	-1.8	1.8	40.1	-11.3	1.4	91.5	-42.7	2.3
109.3	23.2	-7.0	2.2	26.3	4.5	1.9	32.5	-9.5	1.6	51.1	-46.4	2.4
109.5	22.0	-1.8	2.3	25.8	11.9	2.1	27.4	-4.9	1.9	34.7	-36.8	2.5
109.7	18.9	5.3	2.7	25.7	13.8	2.1	22.5	0.7	2.2	26.0	-24.8	2.5
109.9	19.4	9.5	2.7	24.0	19.7	2.5	20.7	7.7	2.5	19.5	-15.3	2.8
110.1	18.6	16.4	3.0	26.2	25.2	2.5	19.6	15.7	2.8	15.0	-5.2	3.4
110.3	16.8	21.1	3.6	34.1	34.9	2.5	19.6	24.9	3.3	12.6	6.6	4.0
110.5	18.2	27.0	3.6	39.5	41.8	2.5	25.8	30.8	2.8	13.3	15.2	4.1
110.7	21.8	37.0	3.7	36.7	29.2	2.1	30.0	40.9	3.1	14.3	18.8	4.0
110.9	22.6	43.8	4.1	61.7	32.7	1.9	42.3	44.6	2.6	16.9	26.3	3.9
111.1	32.2	51.5	3.6	66.6	26.3	1.7	55.8	36.1	2.0	21.9	34.2	3.5
111.3	42.5	68.0	3.9	57.8	22.5	1.6	54.9	28.9	1.7	22.7	42.9	4.0
111.5	56.9	77.4	3.9	63.7	27.6	1.7	51.5	31.7	1.9	36.7	48.6	3.1
111.7	90.7	91.2	3.9	61.0	33.7	1.9	56.5	40.9	2.1	42.4	47.4	2.7
111.9	154.3	70.3	3.8	77.1	38.5	2.1	69.5	50.4	2.4	63.3	52.1	2.5
112.1	171.5	-24.1	3.5	119.7	21.7	2.5	95.7	51.8	2.6	63.9	47.8	2.3
113.1	18.5	-40.7	4.6	20.1	-40.8	4.3	26.5	-55.5	4.5	128.2	-86.6	3.9
114.1	7.5	-3.8	6.7	6.6	-2.6	7.6	7.9	-8.6	6.5	11.2	-31.3	6.3
115.1	9.2	26.4	7.0	6.7	26.8	9.7	6.2	18.9	9.2	5.5	3.5	9.2
116.1	25.3	79.0	7.3	36.6	101.5	7.6	21.1	69.8	7.3	7.4	35.8	10.3
117.1	157.7	-190.3	7.9	93.5	-167.9	8.3	373.7	-177.2	9.2	46.8	144.9	10.9
118.1	8.9	-51.0	11.6	8.4	-42.0	10.3	11.2	-59.4	10.9	32.8	-130.1	12.4
119.1	5.3	-14.2	10.3	5.0	-8.3	10.3	4.8	-17.1	11.6	5.5	-38.8	14.5
120.1	7.1	14.1	7.6	7.7	23.4	7.9	5.1	10.5	10.3	4.7	-7.9	10.9
121.1	23.4	68.8	6.5	35.0	108.3	8.7	18.4	57.2	6.5	6.0	23.6	10.3
122.1	221.9	-204.5	8.3	72.3	-155.7	8.2	397.1	-85.1	8.3	35.3	102.3	7.9
123.1	9.6	-62.0	13.4	7.6	-46.9	12.4	11.5	-67.5	12.4	70.0	-103.1	11.6
124.1	6.4	-20.9	9.2	4.6	-12.8	11.6	4.3	-24.2	14.5	6.3	-49.6	15.8

** VSWR Exceeded 99:1

Table 14. Impedance looking into a bandpass filter (108 to 132 MHz BP) connected to each receiver. Each receiver was tuned to 110.1 MHz.

The following receivers were used to gather the data reported herein. The receivers are listed in no particular order and do not correspond in sequence to the receiver labels "A" through "M". Intermodulation tests were performed on ten of the receivers and impedance measurements were performed on all 12 receivers:

1. ARC
   Model: RT-384A
2. Collins
   Model: VIR-30
3. King
   Model: KX 175B
4. Narco (Two tested)
   Model: NAV-121
5. Collins
   Model: VIR-351
6. King
   Model: KN 53
7. King
   Model: KX 170B
8. Narco
   Model: MK 12D
9. King
   Model: KX 155
10. Narco
    Model: NAV 824
11. Arizona Avionics
    MX 300