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The Subjective Effect of Multiple Co-Channel Frequency Modulated Television Interference

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THE SUBJECTIVE EFFECT OF MULTIPLE CO-CHANNEL FREQUENCY MODULATED TELEVISION INTERFERENCE

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SUMMARY

As the geostationary orbit/spectrum becomes saturated, there is a need for the ability to reuse frequency assignments. Protection ratios (the ratio of wanted signal power to interfering signal power at the receiver) play a key role in determining efficient frequency reuse plans.

A knowledge of the manner in which multiple sources of co-channel interference combine is vital in determining protection ratio requirements such that suitable margin may be allocated for multiple interfering signals. This paper presents results of tests examining the subjective assessment of multiple co-channel frequency modulated television signals interfering with another frequency modulated TV system.

INTRODUCTION

As communications via satellite becomes increasingly utilized, the need for spectrum management becomes vital to the efficient use of the orbit/spectrum resource. An important factor in the effective utilization of this resource is the ability to reuse frequency assignments. Frequency reuse is possible through the combined effect of orbital spacing, polarization isolation and earth terminal separation. A key technical parameter in determining what spacing or isolation is necessary is the television protection ratio (the ratio of wanted-to-unwanted signal power at the receiver input for a specified grade of service). The protection ratio for frequency modulated television is a function of several factors including the frequency deviation and hence bandwidth of the signals, the impairment grade, the number of interfering signals, the output signal-to-noise ratio chosen for system design, and other factors.

This report presents the results of television interference protection ratio tests involving multiple co-channel frequency modulated television sources interfering with a single FM TV system. In an earlier test (ref. 1) involving subjective assessment of multiple co-channel AM TV interference, it was determined that unrelated interferences added on a power basis. These tests (ref. 1) were conducted on a 625-line system using monochrome pictures. It is important to understand the interfering environment affecting the quality of service when planning and designing communications satellite systems. The way that multiple sources of interference subjectively combine is a critical factor in understanding this environment.

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Considerable information concerning protection ratios for frequency modulated television systems is available (ref. 2) for a single FM TV interferer. or planning purposes assumptions have been made concerning the subjective effect of multiple interference sources based only on data for a single interferer. This report presents results of tests specifically examining the relationship between the subjective effect of a single interferer and that of multiple sources of interference.

APPARATUS

The test setup used for investigating the subjective effect of multiple interferers is shown in figure 1. Measurement conditions and test procedures were generally in accordance with CCIR (International Radio Consultative Committee) Recommendation 600 (ref. 3) and Recommendation 500-1 (ref. 4). The experiment was conducted as a comparison between a single reference interferer and the interference caused by multiple sources.

The video baseband signal source modulating the wanted 6.4 GHz FM transmitter was a 35 mm telecine slide projector. The sources of the video baseband signal to modulate each of the interfering 12 GHz FM transmitters were video tape recorders. After modulation and summation of the interfering sources the signal was translated down to 6.4 GHz through use of a mixer and frequency stable local oscillator. The wanted and interfering signals were combined at 6.4 GHz, and after detection the resultant video signal was displayed on a high resolution studio monitor with 51 cm (20 in.) diagonal measure. Switching between the single reference interferer and the multiple interference path was handled by an RF switch prior to combination with the wanted signal.

All video sources provided System M/NTSC color TV signals. Each transmitter was operated with preemphasis according to CCIR Recommendation 405-3 (ref. 5). An unmodulated sound subcarrier at 7.5 MHz was present on the wanted signal. Unmodulated sound subcarriers at 6.2 and 6.8 MHz were present on each interfering signal. The ratio between the power in the video carrier to that in the first side band of the audio subcarrier was 30 decibels for all subcarriers. For all signals frequency deviation by video (white-to-sync peak level) was 12 MHz peak to peak with white producing the highest frequency. The intermediate frequency (IF) filter used in the 6.4 GHz, fixed-tuned FM receiver was a four-section, Chebyshev filter with a 1-decibel bandwidth of 21 MHz. All interfering signals were co-channel with respect to the wanted signal.

TEST PROCEDURES

The baseband video resulting from the demodulation of the signal composed of the wanted and interfering signals was displayed on a 51 cm (20 in.) monitor. Seventeen trained viewers were used in the tests (training involved recognition of interference impairment). Six out of the seventeen were expert viewers. Room light was controlled and the viewer was positioned at a distance of approximately five times the screen height. One viewer at a time participated in the testing.

The test was conducted as a comparison between the impairment caused by a single reference interferer and the impairment caused by multiple sources of interference. Strictly co-channel interference was investigated. Each viewer participated in three separate presentations each lasting approximately 30 minutes. The three presentations involved comparison of the reference interference with the interference caused by four, two and one interfering sources respectively. Initially all interfering carrier powers were set equal to the wanted carrier power. The aggregate interfering signal was then attenuated such that for C/I ref. = 0 dB the following condition was satisfied:

(C/I) reference = (C/I) summation multiple = 0 dB

(i.e., for four interferers in the multiple path the aggregate interfering signal was attenuated by 6 dB).

The viewer controlled an RF switch to alternate between the reference interference path and the multiple interference path. In addition the viewer controlled a continuously variable attenuator (attenuator B in fig. 1) which varied the aggregate interference in the multiple path. Both controls were positioned such that the viewer could continually view the screen while making adjustments. The experimenter set a particular carrier-to-interference (C/I) ratio in the reference path by varying (with step attenuator A) the power of the interfering signal. The viewer was instructed to vary the interference level in the multiple path by adjusting attenuator B until an equivalent level of impairment to the overall picture was obtained when compared to the impairment caused by the single reference interferer at the given C/I level. Attenuator C was adjusted, by the experimenter, corresponding to the change in attenuator A such that the range of interest on attenuator B would remain approximately constant. The setting for attenuator B was recorded after the viewer determined equivalence.

Four baseband video signals were used to modulate the wanted signal. The four test slides selected were chosen as being representative of critical scenes (ref. 3): Two are from the Society of Motion Picture and Television Engineers' (SMPTE) color reference series (No. 1 - beach scene and No. 14 - girl against a plain background), and two are from the Philips test slide series for color television (No. 8 - bowl of fruit and No. 14 - makeup scene). A random ordering of the four test slides at five nominal C/I levels (10, 15, 20, 25, and 30 dB) for the reference interference path was used.

The signal to unweighted noise ratio of the baseband video modulating the wanted signal was 48 decibels. The signal to unweighted noise ratio of the link, comprising the modulator, demodulator, and the hardware between the two was 49 to 51 decibels. A noise voltage was added to the link so that the primary noise affecting the overall signal to noise ratio was due to the link rather than the source. The final signal to unweighted noise ratio was chosen to be approximately 42 decibels (or 52 dB weighted for both noise and pre-emphasis - deemphasis effects).

Line synchronization was established between the wanted and interfering baseband signals so that the sync bars of the interfering signals were transmitted during the picture portion of the wanted signal. The sync bars for each of the multiple interfering sources were offset independently such that they were positioned in different portions of the wanted picture.

MEASUREMENT ACCURACY

The power-ratio measurements presented are subject to small errors. Common to all setups are the errors in equalizing the powers of the wanted and interfering signals using the spectrum analyzer (±0.4 dB) and errors due to the attenuators accuracy. The attenuators were calibrated and the errors were adjusted out in the data analysis.

A spectrum analyzer was used to align the wanted and interfering signals for co-channel operation. The uncertainty in measurements using this method is ±0.1 MHz. Frequency adjustments were made prior to each presentation of the 20 scenes. Throughout the duration of the presentation a frequency drift occurred in the transmitters of ±0.25 MHz. The FM signals were centered in the pass band of the receiver. The accuracy of this adjustment is ±1 MHz.

RESULTS AND DISCUSSION

The procedures and test setup outlined in the previous sections were used to determine the method by which multiple co-channel sources of interference combine. The data presented in figures 2 to 5 show the difference between the C/I for the multiple path and the C/I for the reference path versus the C/I for the reference path (i.e., ΔC/I (C/I_c - C/I ref.) versus C/I ref.). A ΔC/I = 0 dB would indicate addition on a power basis for multiple interfering sources. Figure 2(a) to (c) presents data averaged over all scenes for one, two and four interferers respectively. Table I contains the sample mean and standard deviation values for each wanted test slide while table II details the 95 percent confidence limits on the mean (μ) for all slides collectively.

For C/I levels from 10 dB through 25 dB the results shown in figures 2(a) to (c) indicate that multiple interferers add on a power basis. Over this range, deviation from the ΔC/I = 0 dB level was <0.5 dB (except for four interferers at C/I = 25 dB where the deviation from ΔC/I = 0 was 0.72 dB). At C/I = 30 dB the degree of impairment caused by the single reference interferer was virtually imperceptible, and a fair comparison was impossible to make. The viewer was asked to vary the level of interference in the multiple path until equivalence was determined, and since the interference became virtually imperceptible between C/I levels of 25 and 30 dB it would be expected that the viewer would obtain equivalence for a C/I somewhat less than 30 dB. The results in all cases at C/I = 30 dB are therefore inconclusive and should not be taken as a representative comparison for the objective of these tests.

Table III presents 95 percent confidence limits on the mean (μ) for each wanted signal test slide. Figures 3(a) to (d), 4(a) to (d), and 5(a) to (d) show ΔC/I versus C/I of the reference interferer for each slide with one, two and four interferers respectively.

SUMMARY OF RESULTS

The television protection ratio tests performed according to the reference condition guidelines suggested by the International Radio Consultative Committee (CCIR) have produced the following result for multiple co-channel frequency modulated television sources interfering with a single FM TV system.

Multiple co-channel FM TV sources of interference were found to add on a power basis when directly compared with the interference due to a single FM television system. Seventeen viewers participated in tests in which one, two and four interfering sources were compared to a reference interfering source. Four test slides were used for the wanted picture and video tape recorded commercial television programming was used for the interfering sources.

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TABLE I

No. Int.	Scene	C/I_{Nom}				
		10	15	20	25	30
1	Beach	0.319 .677	0.31 .866	-0.10 1.521	-0.37 1.318	-3.91 2.131
	Make-Up	-0.06 .568	0.36 .721	0.23 1.270	0.02 2.266	-2.49 3.1[illegible]5
	Girl	-0.062 .676	0.38 .572	-0.41 .858	0.58 1.767	-2.11 2.198
	Basket	0.025 .416	0.21 .695	0.04 .755	0.46 1.512	-1.28 2.081
	Total	0.055 .6005	0.315 .7074	-0.06 1.1408	0.713 1.752	-2.448 2.549
2	Beach	0.24 .742	0.49 1.122	0.23 1.503	-0.2 2.386	-4.54 2.820
	Make-Up	-0.03 .794	0.36 .943	-0.35 1.063	0.59 1.636	-2.05 3.142
	Girl	0.22 .878	-0.05 .535	-0.77 .816	-0.36 1.457	-3.50 2.623
	Basket	0.06 .734	0.44 .789	-0.47 1.502	-0.66 1.121	-2.59 3.003
	Total	0.123 .779	0.31 .881	-0.34 1.281	-0.453 1.685	-3.17 2.994
4	Beach	0.15 .888	0.26 1.098	0.08 1.507	-1.23 2.926	-4.47 2.062
	Make-Up	0.25 1.068	-0.14 1.072	0.31 2.164	-0.40 1.872	-3.50 3.933
	Girl	-0.01 1.208	-0.48 .865	-0.78 1.018	-0.45 2.468	-2.60 3.332
	Basket	0.19 1.005	-0.33 1.325	-0.75 1.522	-0.80 2.602	-4.29 2.307
	Total	0.145 1.030	-0.173 1.113	-0.285 1.643	-0.72 2.463	-3.715 3.032

Upper entries are means.
Lower entries are standard deviations.

TABLE II. - 95 PERCENT CONFIDENCE

LIMITS ON μ (ALL SLIDES)

C/I Nom.	1 Intf.	2 Intf.	4 Intf.
10	0.055±0.150	0.123±0.188	0.145±0.249
15	0.315±0.177	0.310±0.213	-0.173±0.269
20	-0.060±0.285	-0.340±0.310	-0.285±0.398
25	0.173±0.438	-0.453±0.408	-0.720±0.596
30	-2.448±0.637	-3.170±0.724	-3.715±0.734

TABLE III. - 95 PERCENT CONFIDENCE LIMITS ON μ (EACH SLIDE)

#Int.	C/I Nom.	Beach	Make-up	Girl	Basket
1	10	0.319±0.361	-0.060±0.303	-0.062±0.360	0.025±0.222
	15	0.310±0.461	0.360±0.384	0.380±0.305	0.210±0.370
	20	-0.100±0.810	0.230±0.677	-0.410±0.457	0.040±0.402
	25	-0.370±0.702	0.020±1.207	0.560±0.941	0.460±0.806
	30	-3.910±1.135	-2.490±1.665	-2.110±1.171	-1.280±1.109
2	10	0.240±0.382	-0.030±0.408	-0.220±0.451	0.060±0.377
	15	0.490±0.577	0.360±0.485	-0.050±0.275	0.440±0.406
	20	0.230±0.773	-0.350±0.547	-0.770±0.420	-0.470±0.772
	25	-0.200±1.227	-0.590±0.841	-0.360±0.749	-0.660±0.576
	30	-4.540±1.450	-2.050±1.616	-3.500±1.349	-2.590±1.544
3	10	0.150±0.457	0.250±0.549	-0.010±0.621	0.190±0.517
	15	0.260±0.565	-0.140±0.551	-0.480±0.445	-0.330±0.681
	20	0.080±0.775	0.310±1.113	-0.780±0.523	-0.750±0.783
	25	-1.230±1.504	-0.400±0.963	-0.450±1.269	-0.800±1.338
	30	-4.470±1.060	-3.500±2.022	-2.600±1.713	-4.290±1.186

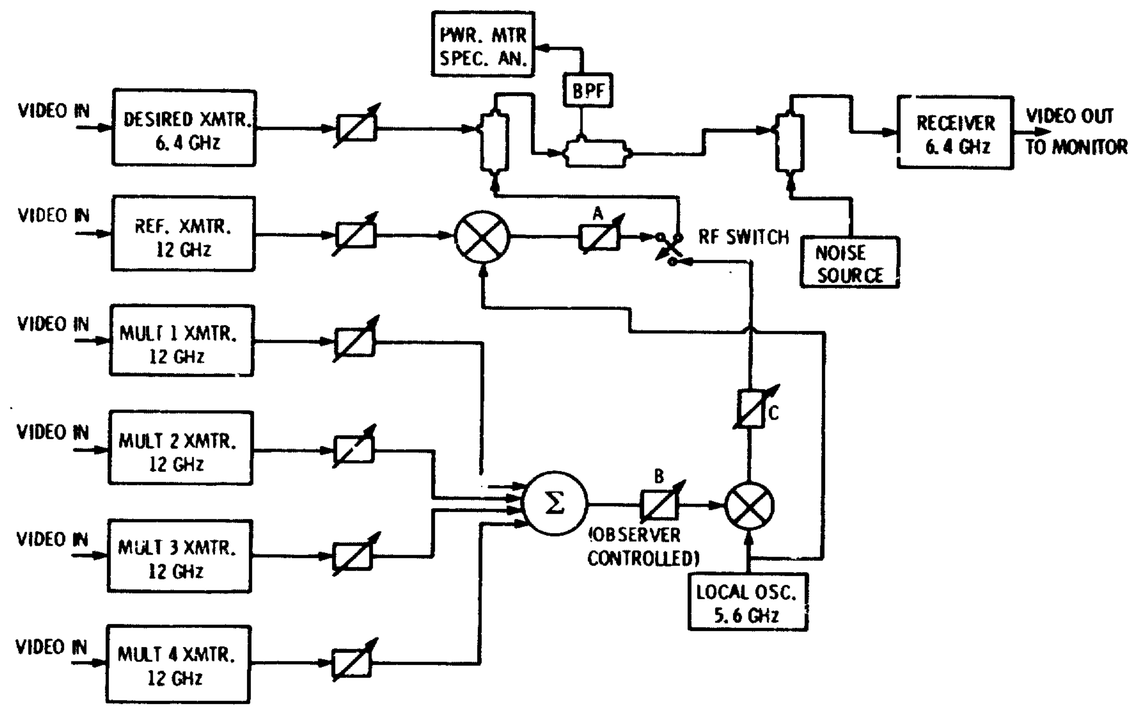

Figure 1. - Multiple interference block diagram.

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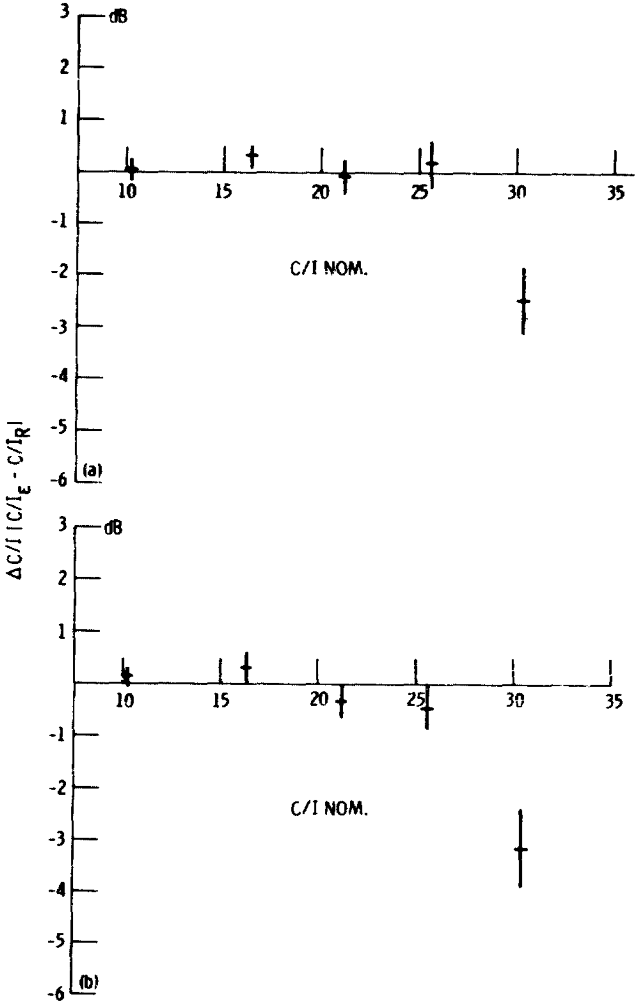
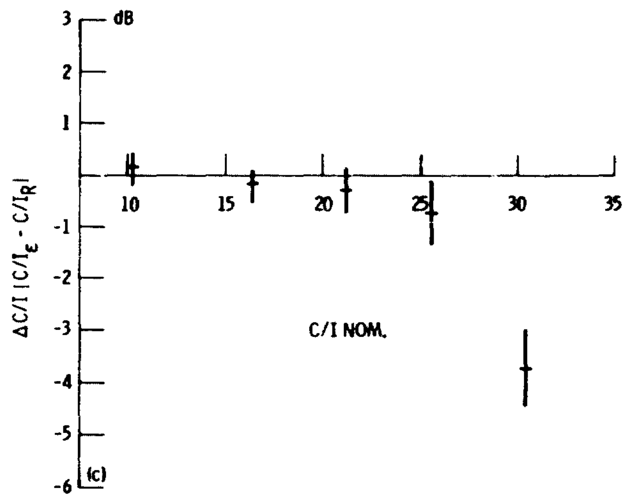


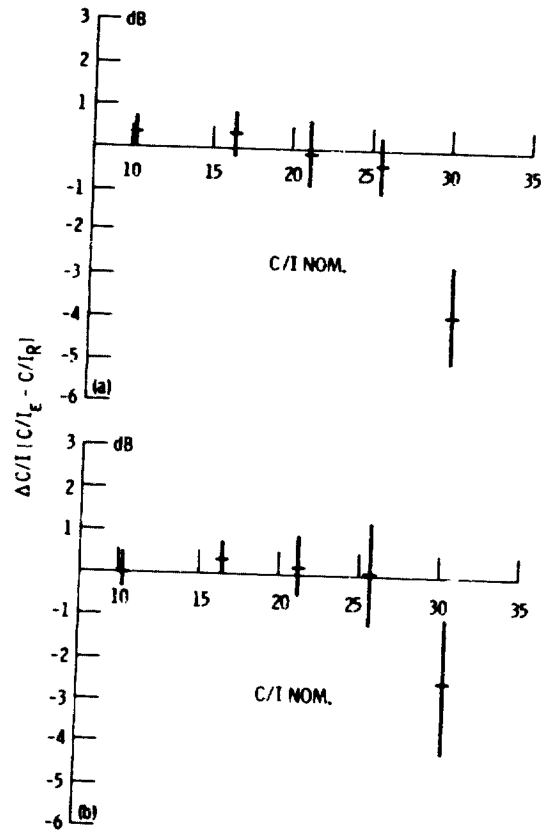
(a) All scenes one interferer.
(b) All scenes two interferers.

Figure 2. - $\Delta C/I$ versus C/I for single interfer for all scenes with one, two and four interferers.



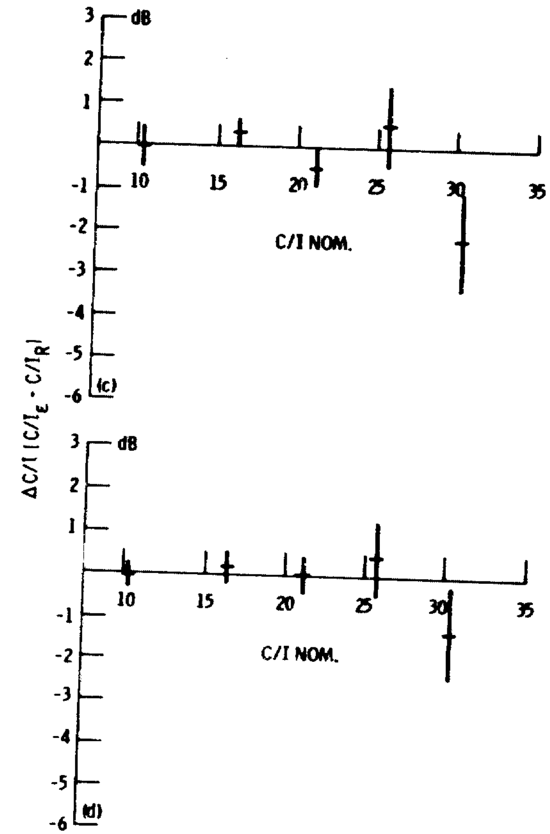
(c) All scenes four interferers.

Figure 2. - Concluded.



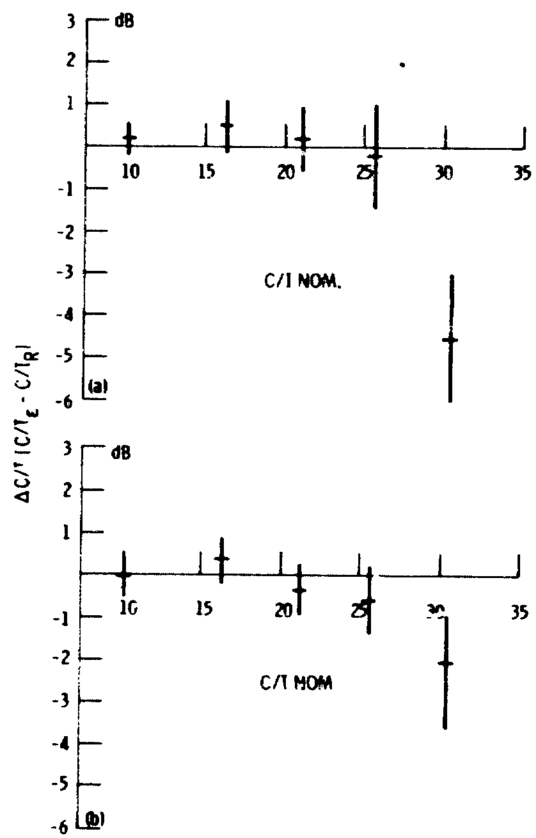
(a) Beach scene one interferer.
(b) Make-up scene one interferer.

Figure 3. - $\Delta C/I$ versus C/I for single interferer for each scene with one interferer.



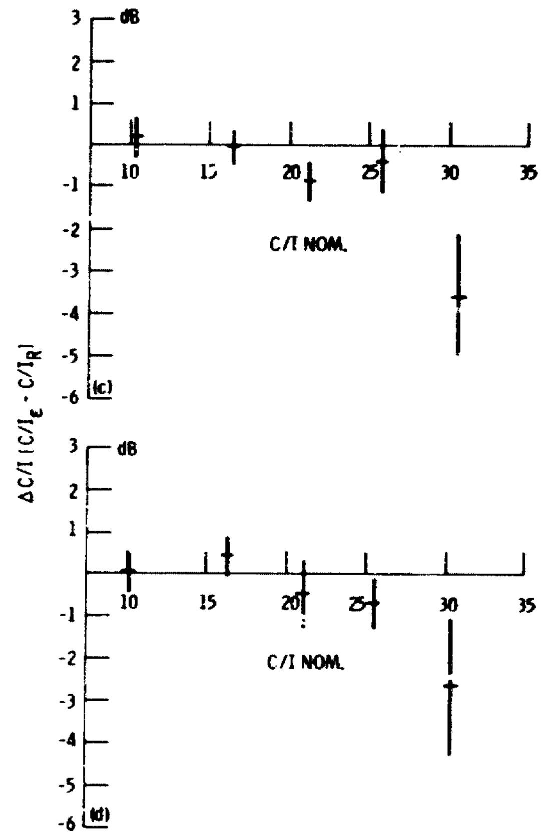
(c) Girl scene one interferer.
(d) Basket scene one interferer.

Figure 3. - Concluded.



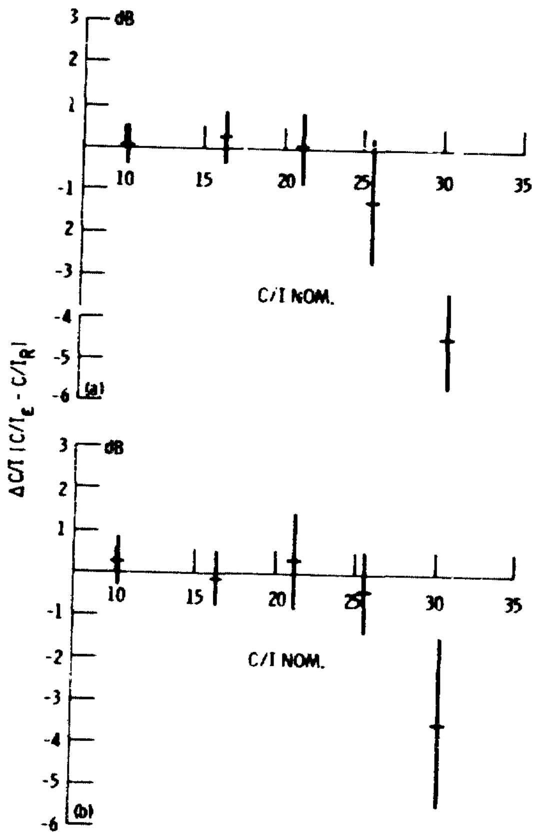
(a) Beach scene two interferers.
(b) Make-up scene two interferers.

Figure 4. - $\Delta C/I$ versus C/I for single interferer for each scene with two interferers.



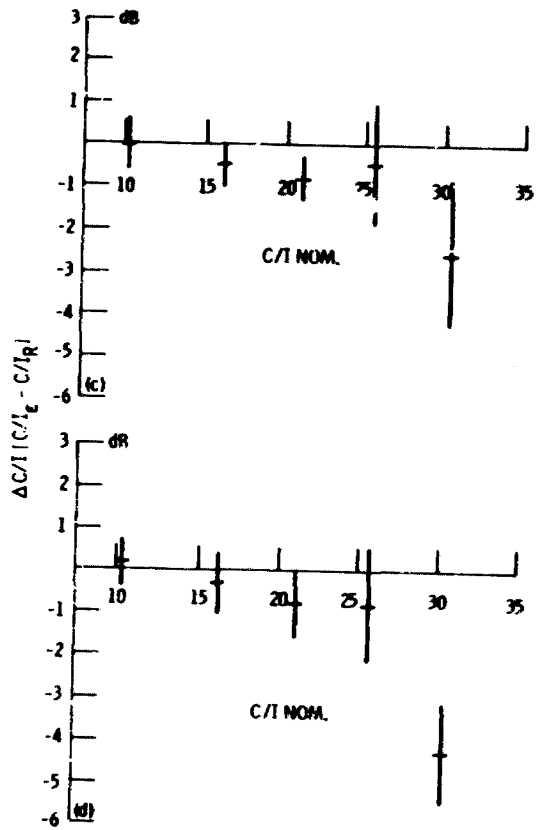
(c) Girl scene two interferers.
(d) Basket scene two interferers.

Figure 4. - Concluded.



(a) Beach scene four interferers.
(b) Make-up scene four interferers.

Figure 5. - ΔC/I versus C/I for single interferer for each scene with four interferers.



(c) Girl scene four interferers.
(d) Basket scene four interferers.

Figure 5. - Concluded.