FINAL REPORT ON THE SUBJECTIVE EVALUATION OF IMPAIRED TELEVISION PICTURES AND STATISTICAL ANALYSIS OF THE RESULTS

Philip A. Lapp Limited

FINAL REPORT ON THE
SUBJECTIVE EVALUATION OF
IMPAIRED TELEVISION PICTURES
AND STATISTICAL ANALYSIS
OF THE RESULTS

Philip A. Lapp Limited

CONSULTANTS TO INDUSTRY AND GOVERNMENTS

HEAD OFFICE: SUITE 302, 14A HAZELTON AVENUE, TORONTO, ONTARIO, CANADA M5R 2E2
Phone (416) 920-1994

OTTAWA OFFICE: SUITE 904, 280 ALBERT STREET, OTTAWA, ONTARIO, CANADA K1P 5G8
Phone (613) 238-2452, Telex 053-3314

Government of Canada Gouvernement du Canada

Department of Communications

DOC CONTRACTOR REPORT DOC-CR-SP - 83 - 043

DEPARTMENT OF COMMUNICATIONS - OTTAWA - CANADA

SPACE PROGRAM

TITLE: FINAL REPORT ON THE SUBJECTIVE EVALUATION OF IMPAIRED TELEVISION PICTURES AND STATISTICAL ANALYSIS OF THE RESULTS

AUTHOR(S): PHILIP A. LAPP LIMITED

ISSUED BY CONTRACTOR AS REPORT NO: 21 - 83

PREPARED BY: Dr. John N. Barry
Mr. Kenneth E. Hancock
Ms Charlene Balko

DEPARTMENT OF SUPPLY AND SERVICES CONTRACT NO: OST - 83 - 00009

DOC SCIENTIFIC AUTHORITY: G. Chouinard

CLASSIFICATION: Unclassified

DATE: August 31, 1983

CONTENTS LIST

CONTENTS LIST (Cont'd)

LIST OF FIGURES

LIST OF TABLES

THE SUBJECTIVE EVALUATION OF IMPAIRED TELEVISION PICTURES AND STATISTICAL ANALYSIS OF THE RESULTS

1. INTRODUCTION

The imminence of Direct-to-Home television via broadcast satellite in North America has, over the past 3 to 5 years, brought the matter of Direct Broadcast Satellite Direct Broadcast Satellite (DBS) system coordination planning on an international scale into sharp focus. The study reported here is part of a series initiated by the Department of Communications to develop Canadian positions in this planning process. The background of this study was the 983 CCIR Regional Administrative Radio Conference, officially known as RARC-SAT-R2 1983, held in June and July, 1983. Two of the issues to be resolved at this conference were that of interference protection ratios, and the ranges of Effective Isotropic Radiated Power (EIRP) for satellite television channels operating in the Broadcast Satellite Service (BSS) in Region 2. The limits of subjective perceptibility of impairments, and the rate of change of subjective tolerance levels as the level of impairment in a channel increases, are key measurements for establishing system design margins against single and multiple co-channel interference, adjacent channel interference, and signal-to-noise. The limits of perceptibility of these impairments clearly affect, in turn, channel spacing, carrier deviation within a channel, satellite spacing, and (EIRP) from satellites operating in the BSS. The urgency of the work is highlighted by the fact that there are already a number of applications before the Federal Communications Commission (FCC) of the United States for direct broadcast satellite in the continental United States. Some of these applications envisaged the use of very high power satellites with an EIRP approaching 60 dbW while others propose EIRP's in the range of 48 dbW. Since Canadian planning for BSS is coordinated with that of the United States and other administrations in Region 2 the exact Canadian position is an urgent issue.

The basic objective of the present study was to collect data on the subjective assessment of perceptibility of, and annoyance levels by impairments in simulated DBS reception from 100 non-expert TV viewers. A cross-section of viewers in the greater Ottawa area was recruited to make up a sample of 100 viewers. The sample included viewers from the public and private sector, homes and schools and covered a wide range of ages.

In the following chapters the test procedures, the methods of analysing data statistically and the conclusions are presented. The results are compared to data previously obtained through similar experiments at the Communications Research Centre using either expert viewers, or concerned viewers, that is, viewers with above-average awareness of the importance of impairments.

As a general conclusion it is observed that subjective assessment of impairments by viewers at large is less critical than that of expert or concerned viewers.

Reflecting results from the earlier experiments, wide variation is found in the limits of perceptibility, and the change of annoyance level with impairment, between television scenes containing saturated colours and scenes containing moderate colour levels. The evidence suggests that the spread of results due to picture content is compares to the differences between the viewing public at large and groups of experts and concerned viewers. It is concluded therefore, that a critical element in tests of this kind is a full range of scenes having both heavily saturated colours and scenes having large amounts of detail with moderate colour levels.

Confirming the earlier work at CRC, it is found that interference from an adjacent channel displays a sharp perceptibility threshold and a steep rise in annoyance level after the perceptibility threshold has been crossed. The rise in annoyance level is some three to five times as steep as the equivalent rise in annoyance due to noise or co-channel interference. Such a sharp threshold, when combined with the usual variations due to different scenes as noted above, essentially rules out any expectation for acceptable gradual degradation of the picture seen by a viewer as the impairment due to an interfering adjacent channel increases. The phenomenon is better treated as a "trigger point" beyond which picture quality will in many cases be unacceptable. Although these remarks apply especially to interference by adjacent channel separated by 13MHz from the desired channel, both channels having specific (equal) modulating parameters, the trigger effect at 15MHz with the modulating parameters unchanged is still very pronounced.

The statistical analysis of the raw data from the viewing tests confirms that the data base obtained in the study is satisfactory from the point of view of stability and consistency of results when compared to other work, and may be used with confidence in the BSS planning process. Specifically, non-expert viewer limits of perceptibility and annoyance levels for interference due to noise, single or multiple co-channel interference, or co-channel-plus-noise interference are consistent and follow the same trend as reported by other workers. Not unexpectedly, changes in absolute value of mid-points and slopes are reported. Interference by adjacent channel has been clearly and amply demonstrated to show a sharp threshold with rapid deterioration of the picture from 'imperceptibly' impaired to 'very annoying'. This rapid collapse of picture quality can occur in a change of carrier to interferor ratio as small as 4 dB. This phenomenon will require special attention in the BSS planning.

2. SUBJECTIVE ASSESSMENT TECHNIQUE

2.1 General Remarks

The experimental techniques followed in this study were modelled after the techniques that have been used in Europe and in North America for the past two decades. These techniques have been widely reported in the literature and are referenced in the CCIR documents References 1 through 6.

A number of viewers are presented with a sequence of scenes containing the desired impairments at various impairing levels. Each viewer forms and records an opinion of the subjective effect of the impaired scene. The impairments in the scenes range from zero, that is to say the picture presented on the television screen is as perfect as is possible with the equipment used, to heavily impaired, which is tantamount to saying that the majority of viewers would consider the picture very objectionable as far as impairment is concerned.

2.2 Viewers

The aim of the study was to collect data from 100 non expert viewers. A non expert, in accordance with the CCIR definition, is a viewer who does not "work in television engineering or in the photographic or allied fields involving visual arts", Ref. 3, Annex IV.

Volunteers who were prepared to act as viewers were recruited from the business community, from government offices, from the Ottawa Fire Department, from the local universities and high schools, from a local computer training college and from the home. An effort was made to have a range of age groups. When the invitation to become a viewer was issued, it was requested that people have normal vision, corrective lenses were allowed, and that they not be colour blind. No experience was necessary otherwise, except that they be at least occasional viewers of television in the home. The distribution of viewers among the various groups is given in Table 1.

TABLE 1: DISTRIBUTION OF VIEWERS IN OCCUPATIONAL CATEGORIES, AGE GROUPS AND SEX

Student	- 25	Age 18 to 25	- 30
Office and Clerical Workers	- 60	Age 26 to 39	- 40
Engineers	- 5	Age 40 or over	- 30
Firemen	- 5		
Housewives	- 20		
Other	- 25		
Male Viewers	- 49		
Female Viewers	- 51		

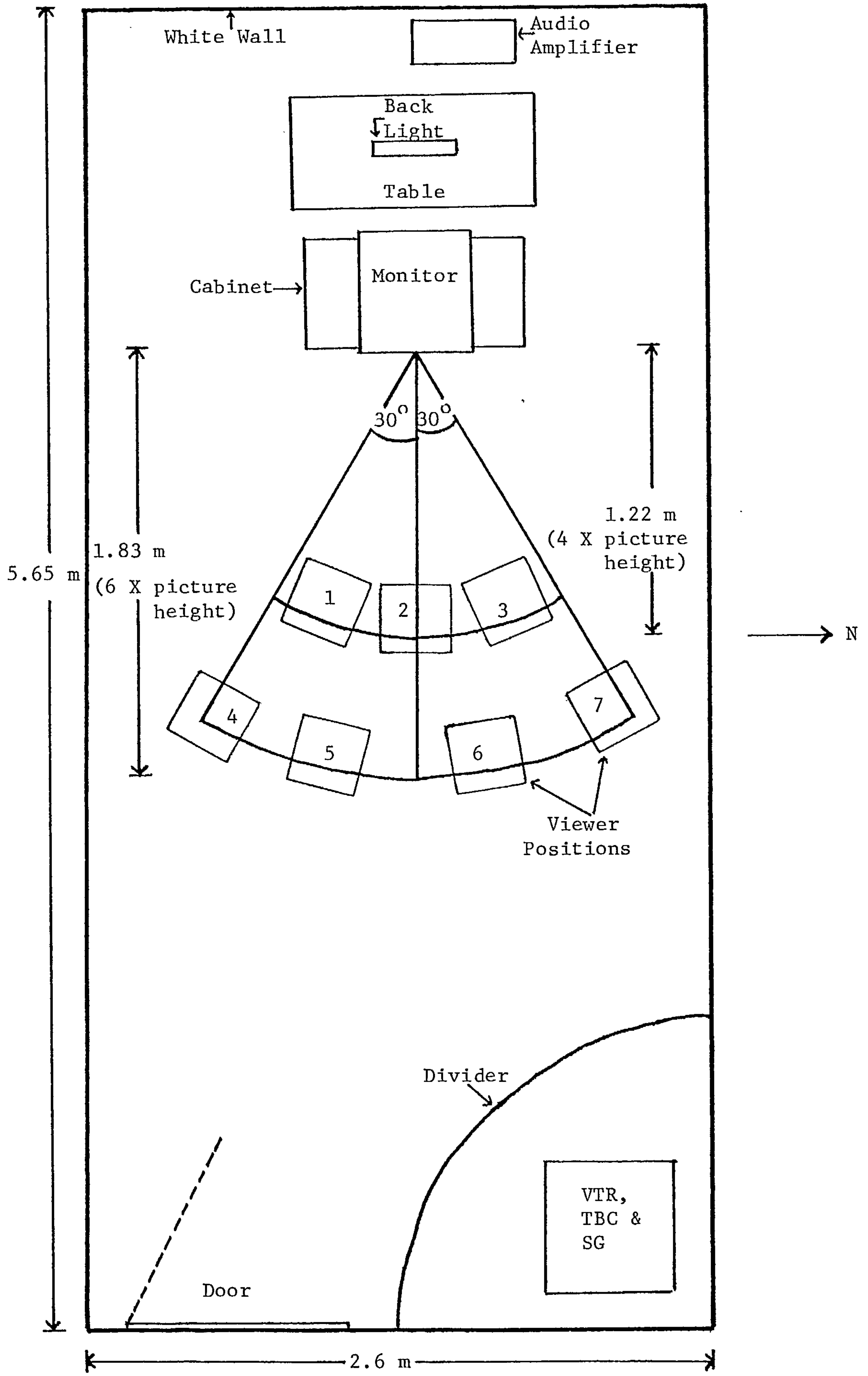
All viewers were given a visual acuity test on each eye, using a standard Snellen chart, and a simple red-green colour blindness test. For the latter tests a Dvorine Pseudo-Isochromatic Plate with a red '32' on a green background and an Ishihara plate with a green '3' on a red background were used. Viewers were asked to identify the numerals and name the colours. No viewer was given the results of a poor test so all volunteers were permitted to remain in their group for the picture assessment phase.

2.3 Viewing Laboratory

To provide a systematic mechanism for viewing, a viewing laboratory was established at PHILIP A. LAPP LIMITED. A sketch of the viewing laboratory is given in Figure 1. The equipment in the Viewing Laboratory consisted of the following:

Colour Television Monitor: CONRAC Model 5322RS19,
Manufactured October, 1982

FIGURE 1: VIEWING LABORATORY



Backlight: Desk Model 15 watt fluorescent fixture with daylight fluorescent tube (D6500 colour temperature)

Audio: Integral Preamplifier/Amplifier/Speaker Unit

Video Tape Recorder: (VTR) Sony BVH-1000A, 1 inch C-Format, complete with Digital Time Base Corrector, (DTBC) Sony BVT1000

Test Signal Generator: (TSG) Tektronix Model R146 NTSC Test Signal Generator

Set Up Instruments: Philips Split Field Colour Comparator, Reference D6500K Colour Comparator, Commercial Light Meter

The layout of the laboratory and the calibration of the lighting and the colour television monitor was in accordance with CCIR Recommendations 500-2. The wall behind the colour television monitor was covered with white cotton cloth and illuminated by the desk lamp. Peak luminance on the television monitor was set at 20 foot lamberts and D6500 colour for all tests. The illumination on the wall behind the monitor was set at 15 percent of the peak luminance of the picture.

Viewers were seated at 4 to 6 times picture height in groups of 5, 6 or 7 depending on the number available for a particular session. All viewers were seated within 30^{o} of the centre line of the monitor. Viewing positions were numbered so that the records taken from different positions might be screened subsequently to see if there was any consistent variation in the opinion rating with viewer position. Analysis along these lines may be reported later.

All presentations to viewers, including a 5 minute audio introduction, were made on video tape to obtain maximum assurance of duplications of test conditions for each viewer group.

The Sony BVH 1000A tape recorder used for the experiments is the property of the Department of Commmunications and has been in use for several years. Specified signal-to-noise performance of this instrument is 48dB unweighted. Experience has shown that the instrument will consistently deliver signals at 50 to 53 dB signal to noise ratio, weighted. The most recent calibration of 51 dB S/N, weighted, was assumed for this study.

2.4 Test Material

Four test slides were chosen for the study, selected as recommended in CCIR Rec. 600.

Slide 1 - Girl in Green Dress (GGD), SMPTE Slide No. 14

Slide 2 - Basket Of Fruit (BOF), Philips Slide No. 8

Slide 3 - Beach Scene (BS), SMPTE Slide No. 1

Slide 4 - Make-Up Scene (MUS), Philips Slide No. 14

All test scenes were shown without sound. In the pre-recorded introduction to the test viewers were advised that the scenes would be shown without sound in order to allow them to concentrate on the pictures.

The impairments chosen for the study were:

(i) impairment by triangular noise, characteristic of an fm transmission system,

(ii) co-channel interference typical of the interference to be expected in a direct broadcast environment,

(iii) lower adjacent channel interference typical of the interference to be expected from adjacent channels on a direct broadcast environment, with channel spacing: 13 MHz,

(iv) adjacent channel interference typical of the interference to be expected from adjacent channels on a direct broadcast environment, with channel spacings: 15 MHz.

(v) multiple co-channel with 3 interfering carriers, all at the same level, and

(vi) aggregated noise and co-channel: slides with a constant noise background were further impaired by variable levels of simulated single co-channel interference.

The six impairment series were broken down into the 27 test conditions in TABLE II.

TABLE II

	IMPAIRMENT SERIES	IMPAIRMENT LEVEL (test condition)					
1.	Noise	S/N	47dB	43	37	33	27
2.	Single Co-Channel	C/I	28dB	22	14	08	03
3.	Three Co-Channel	C/I (each)	32dB	26	18	12	
4.	Single lower Channel, 15 MHz spacing	C/I	05dB	03	01	-1	
5.	Single lower adjacent channel 13 MHz spacing	C/I	09dB	07	05	03	
6.	Single Co-Channel with constant Noise: S/N 46 dB	C/I	28dB	22	14	08	
7.	UNIMPAIRED	S/N	51dB (Note 1).				

Note 1 - This scene served as a "top" anchor for all six impairment series.

The total number of scenes shown including top anchor (no impairment) and bottom anchor (significant impairment) was 112.

Each impairment series was given a distinctive 'key' according to the sample in Figure 2.

The format of presentations on the tape was as follows:

(i) introduction 5-minute pre-recorded, spoken,

(ii) demonstration of 4 slides and impairments; each slide is shown with each of the three basic types of impairment, the impairment being added to the wanted signal smoothly from zero to full value and back to zero in approximately ten seconds, 2 - 020 - 00 - 42 - 27

- 27 → C/I (dB)
- 42 → S/N (dB)
- 00 → △F Intercarrier spacing (MHz)
- 020 → Interfering channels arrangement (2 co-channel)
- 2 → Slide number

FIGURE 2: KEYING SYSTEM FOR INDIVIDUAL SCENES

(iii) presentation of the 112 scenes to be rated, 15 seconds for the scene followed by 10 seconds of 50 "IRE" grey level.

Scenes, impairment type and impairment level were randomized during recording. The same slide or the same impairment were never shown in consecutive scenes. Three different randomizations of all scenes were made on three separate tapes. One third of the viewers were shown each tape. The purpose of having more than one randomization was to average out any bias in the opinion rating for slides when they appear with large changes in impairment level. This is the so-called 'carry-over' effect. There is some evidence to suggest that viewers' opinion rating on a scene is conditioned by recollection of how badly, or mildly, previous scenes were impaired.

Direct and indirect anchoring was used in the test. Direct anchoring was provided during presentation of the sample scenes (slides) in the introduction to the test. Each slide shown in the introduction started and ended unimpaired. After a few seconds of unimpaired presentation an impairment was introduced rising smoothly to the maximum test level, and then fading to zero. This procedure was done for each slide and each of the six impairments. Indirect anchoring was accomplished by introducing the best and worst picture at random during the test sequence without advising the viewers.

The test tapes were prepared at the Communications Research Centre, Ottawa in a well-calibrated permanent installation that is in regular use for simulating satellite television transmission and reception. The facility is fully described in Reference 10. The relevant sections of Ref. 10 have been reproduced in this report, with permission, in Appendix 1. All impairments were introduced at RF.

All tapes used in the test were first generation masters.

2.5 Test Procedures

Visual acuity and colour blindness pre-tests were conducted as the members of a viewing group arrived. At the same time viewers were given a score sheet and pencil in a hard-cover folder and asked to fill in their personal data. The information in the "OFFICE USE" block was obtained at the completion of the test. Viewers were not told whether or not their records would be used, based on these visual pre-tests. When all pre-tests were completed viewers were taken to the viewing laboratory and given seats within the prescribed 4H-to-6H viewing distance and $\pm$ 30° viewing angle. Tape on the floor served as a guide to the distance/angle limits. A standard colour bar test signal was present on the monitor screen during seating.

Picture impairment assessment scale followed CCIR Recommendation 500-2 using the five grade impairment scale. Although numerals were assigned to the five grade scale for the purposes of analysing the data no numerals that might assist the viewer in establishing grades were assigned in the score sheets. The viewers were given the five impairment statements and asked to assess their reaction to the picture according to the five cues. A copy of a viewer's record sheet is given in Appendix 2.

A copy of the text prerecorded as an introduction is reproduced in Appendix 3. This text was given over a period of five minutes during which the words SUBJECTIVE ASSESSMENT OF IMPAIRED TELEVISION SCENES was shown in printed form on the television screen. During periods in which the tape recorder was turned off a colour bar reference signal appeared on the screen automatically. Viewers were given a 5 to 10 minute break after the first twenty-five minutes of this test, that is after sixty scenes had been shown. In all, forty-six minutes was actually spent rating scenes. Another forty minutes was spent in eye tests, pre-recorded introduction, showing of sample scenes and the 5 to 10 minute break mentioned above.

3. DATA ANALYSIS

3.1 Introduction

Analysis of the data was carried out in 4 steps:

1. screen raw data and identify inconsistent viewers;

   collect and aggregate data for each slide in each test condition in each of the six impairment series;

Note: a test condition is the particular impairment level at one of the steps in an impairment series.

   tabulate data for each slide in each test condition to form a histogram of opinion-rating versus impairment level;

2. calculate means, medians, standard deviations and 95% confidence levels of the means for all histograms;

   aggregate data for all four slides in each test condition into a final histogram. Calculate mean, medians, standard deviations and 95% confidence levels of the means;

3. mathematical analysis and curve fitting;

4. final curve plotting.

3.2 Screening of Results

After all records were in, the 5 rating categories were re-labelled 1 to 5 for processing purposes, 5 indicating "imperceptible", and so on, 1 indicating "very annoying". The data was entered using a software program in the CRC computer. This software had been developed at CRC and used in previous tests. One software program tabulated all ratings in a viewer-versus-scene matrix for the three tapes. A portion of the record for one of the matrices is shown in Figure 3. Another program tested each viewer's ratings for the top and bottom anchor scenes. A third program collected the notes the various scenes and impairment series into histograms.

Any viewer rating a topic anchor below '3' was eliminated from the data set*. Instances of isolated high and low ratings for all other scenes were marked for further study. Where an isolated high or low rating was found to have more than one grade difference between it and the rest of the ratings for a scene it was deleted unless the histogram was very 'flat'. See for example, Viewer #110, Scene 8 in Figure 3.

Complete records for 3 viewers were discarded:

(i) one viewer had no rating below 3 for the 112 scenes;,

---

* With one exception-see the penultimate paragraph of this section (3.2).

Detail on Viewer

e.g., Viewer #130, Male,
Viewing Position #7,
Tape #2, Age Group 3,
Occupation Group 1,
Self-assessed as a Discriminating
(versus Tolerant) Viewer,
20/20 Vision both eyes,
No (N) Colour Blindness,
Tested June 20, 1983

Figure 3: Tape 2

Partial Printout of Viewer/Scene Rating Results

```
30. #130M7231D  20/20 20/20 N  83/06/20
31. #131F3213T  20/20 20/20 N  83/06/21
32. #132M7215T  20/20 20/20 N  83/06/21
33. #133M6213T  20/20 20/20 N  83/06/21
34. #134M4213T  20/20 20/20 N  83/06/21
35. #135M5223T  20/20 20/20 N  83/06/21
```

Viewer #

Scene # K]	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135
1]	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	4	5	4	5	5	5	4	5	5	5	5	5	5	5	5	5	5
2]	1	1	1	2	1	1	2	1	1	2	1	1	1	2	1	1	1	1	1	2	1	1	3	1	1	1	1	1	1	1	2	2	2	2	3
3]	2	3	2	3	3	3	2	2	2	2	3	1	2	3	2	2	2	2	1	3	2	1	2	3	2	3	3	1	1	1	3	2	3	2	2
4]	1	3	1	3	2	1	3	1	2	4	1	1	2	3	2	2	1	2	2	2	1	1	4	2	1	2	2	1	2	1	4	3	3	3	2
5]	3	4	5	4	4	5	5	4	4	3	4	4	5	4	3	4	4	4	3	4	3	3	4	4	3	5	4	4	4	4	5	3	4	4	5
6]	4	4	4	3	4	4	4	3	4	(5)	3	3	4	4	3	3	3	3	2	2	4	(1)	3	3	2	4	4	2	3	2	4	3	3	3	3
7]	(3)	4	5	4	5	5	4	5	4	5	4	5	5	5	4	5	4	5	4	4	4	4	4	4	5	5	5	5	4	5	4	4	5	4	5
8]	5	5	4	5	5	5	4	4	5	(1)	5	4	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	3	5	4	5	5	5
9]	1	2	3	3	2	1	2	1	2	1	2	2	2	2	1	2	1	1	2	2	3	1	3	2	1	1	2	1	2	1	5	3	2	4	1
10]	4	4	3	4	4	5	3	3	4	5	3	3	4	4	4	3	3	3	3	4	4	(1)	4	4	3	4	5	5	4	3	5	4	4	3	4
11]	4	5	5	5	5	4	5	5	4	5	5	4	5	5	5	4	4	4	5	4	4	(1)	5	3	5	4	4	5	5	4	5	4	4	4	5
12]	4	5	4	5	4	5	4	5	5	5	5	4	4	5	5	4	4	4	5	5	3	(1)	4	4	3	4	5	4	4	4	4	4	5	4	5
13]	2	2	2	3	2	2	2	1	1	2	2	2	1	3	1	1	2	1	1	2	1	1	3	1	1	2	2	2	2	1	2	2	2	3	2
14]	5	5	5	5	5	5	5	5	5	5	4	5	5	5	(3)	5	5	5	5	4	4	5	5	5	5	5	5	5	5	5	5	4	5	4	4
15]	5	5	4	5	5	5	5	5	5	5	5	4	5	5	4	5	5	5	4	5	5	(3)	4	5	5	5	5	5	5	4	5	4	5	5	5
16]	4	5	4	5	4	4	4	5	4	5	4	4	5	4	5	4	4	4	5	4	3	3	5	5	4	4	5	5	4	4	4	4	5	5	5
17]	2	3	3	3	3	3	2	2	2	2	3	2	3	3	2	2	2	2	2	3	2	1	(4)	2	1	3	3	3	3	1	2	2	3	3	3
18]	3	3	4	4	3	2	3	2	3	3	3	3	3	4	2	2	3	2	2	3	2	(1)	4	2	2	3	3	2	2	2	4	2	4	3	4
19]	2	4	2	4	3	1	2	3	2	2	2	3	4	3	1	2	1	2	2	1	1	1	3	2	2	2	2	3	2	1	2	3	4	4	4
20]	1	1	2	2	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	2	1	1	2	1	1	2	1	1	1	1	2	2	2	(3)	1
21]	5	5	5	5	5	5	5	5	5	5	5	4	5	5	4	5	5	5	5	4	5	(3)	5	5	4	5	5	5	5	4	5	4	5	4	5
22]	2	3	4	4	4	1	2	2	2	4	3	2	3	3	1	2	1	3	2	1	1	1	3	2	2	2	1	2	3	2	4	3	4	3	3
23]	1	3	3	3	3	1	2	2	2	3	1	2	2	3	1	2	1	1	2	1	1	1	3	1	1	1	1	2	2	1	2	3	3	3	3
24]	2	2	2	2	2	1	1	1	1	3	3	1	1	3	2	1	1	1	1	2	2	1	2	2	1	2	1	1	1	1	2	2	3	2	3
25]	5	5	5	5	5	5	5	5	5	5	4	5	5	5	4	5	5	4	4	4	5	5	5	5	5	5	5	4	5	4	5	4	5	5	5
26]	5	5	5	5	5	5	4	5	4	4	5	4	5	5	5	4	5	5	5	5	5	3	5	5	5	5	5	5	4	3	5	4	5	5	5
27]	4	5	4	5	5	5	4	5	5	5	4	4	5	5	4	5	4	4	4	4	5	(3)	5	4	4	5	5	5	5	4	5	4	4	5	5
28]	4	4	4	4	4	4	4	3	4	3	4	3	3	4	2	2	4	2	3	3	4	(1)	3	3	3	4	4	4	3	3	4	3	4	3	(5)
29]	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2	2	1	1	1
30]	4	3	4	3	3	2	2	2	4	(5)	4	3	2	3	3	2	2	3	3	3	4	1	4	2	1	3	2	2	3	1	4	2	4	3	4
31]	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	3	5	4	4	5	4	5	5	3	5	4	5	5	5
32]	2	3	3	3	2	2	2	2	4	3	3	2	2	3	2	1	2	3	2	3	3	1	4	1	1	2	1	1	2	1	2	2	4	3	3
33]	5	5	5	5	5	5	5	5	5	5	5	3	5	4	4	5	4	4	5	4	4	5	4	5	4	5	4	4	5	3	5	4	5	5	5

(ii) one viewer had erratic high and low ratings;

(iii) one viewer had 18 invalid responses: 2 with double votes and 16 with no vote. The viewer was judged to be indecisive and was dropped.

No viewer was rejected for colourblindness. This result was expectd, as the invitation to be a volunteer contained as a prerequisite that viewers not be colour blind.

The complete record for one viewer with poor eyesight was eliminated because of the high number of spoiled ratings. (See (iv) above.)

The rating pattern for one top anchor scene on each of two of the tapes indicated a flaw of some kind in the presentation. In tape #1 the scoring histogram for the unimpaired "Make-Up Scene" slide at scene 84 was 8-6-12-6-0. The first number is the number of votes in grade 5 and so on. The same unimpaired slide scored 26-6-0-0-0 at scene 98. With 47 dB S/N it scored 21-10-1-00 at scene 111. Clearly scene 84 was unintentionally impaired. This top anchor was therefore removed from the data for Tape #1. By similar re-examination of data one of the top anchor Beach Scene slides was removed from the results in Tape #2.

The top anchor presentations of the Girl-in Green Dress Slide in Tape 2 were weak, scoring, individually, 22-8-5-0-0 and 15-15-4-1-0 at scenes 94 and 11 respectively. However, with medians well above 4.0 it was decided to let them remain.

The final effect of dropping 3 viewers, 2 scenes, and occasional invalid responses was the elimination of 460 data points in a set of 11,200.

3.3 Tabulation of Final Data

The histograms with means (MOS) medians, standard deviations (SIGMOS) and 95% confidence levels of the means (R95) for each slide and the aggregate of all slides in each test condition are reproduced in Appendix 4.

3.4 Mathematical Analysis

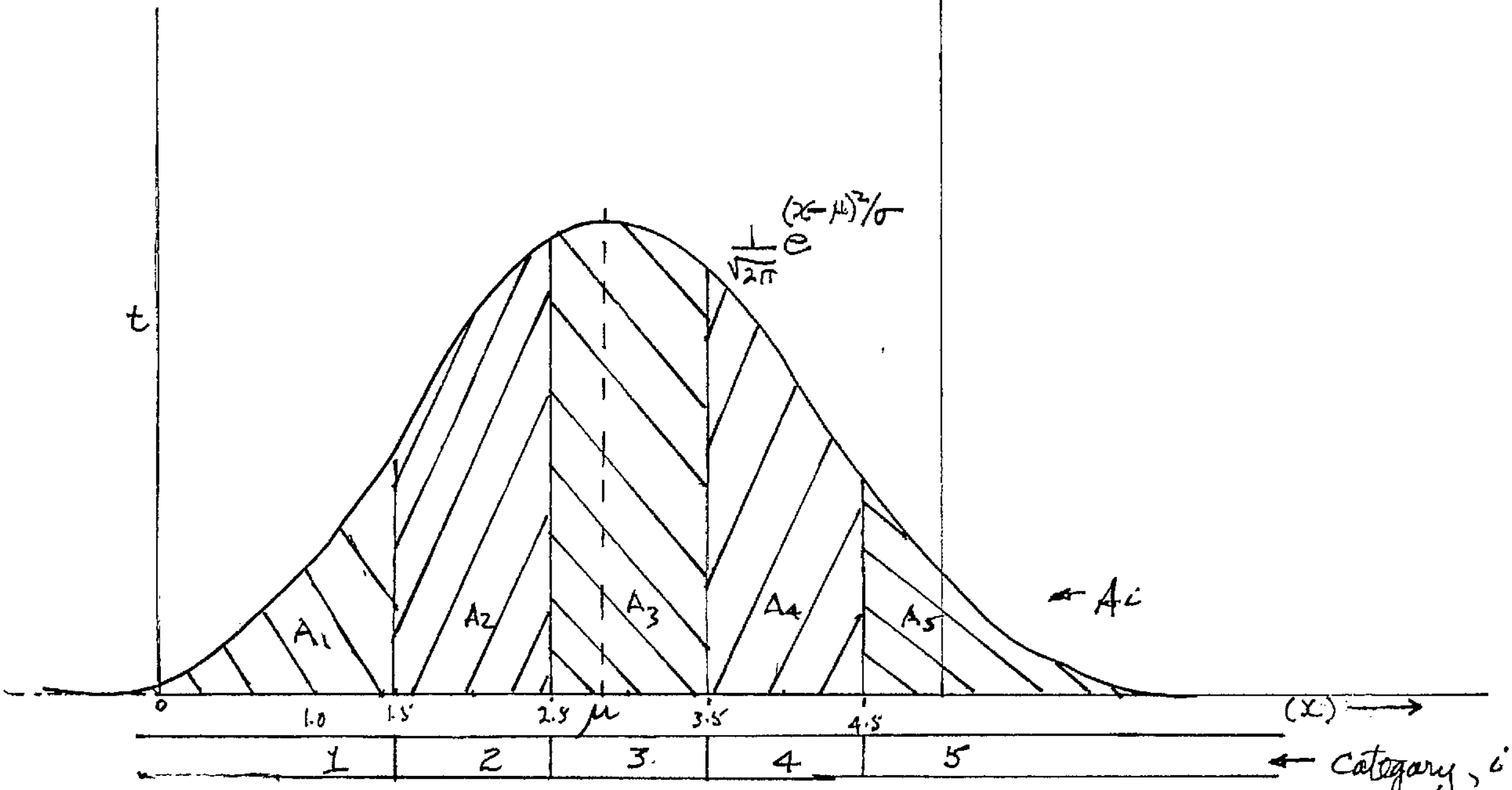
The histograms for each impairment series are of necessity taken at isolated points on the level-of-impairment axes. Further mathematical analysis of the data is required to link the histogram points and establish a smooth relationship between opinion ratings and impairment level for each impairment series. A considerable body of work exists in the literature on the subject of fitting appropriate analytical curves to individual histograms and linking sets of histograms by other curves. These latter curves can be used to interpolate on the impairment - level axis with more confidence than is possible with a simple curve fitted to the original, raw results. Equally important, an analytic curve fitted to the histograms in a series contains width parameters that are, hopefully, valid at the interpolation points. The work of Allnatt and his colleagues as reported in References 11, 12, 14, 15 and 16, the work of Lessman, with others, as reported in References 7, 8 and 9 and the work of Siocos, as reported in References 17 and 18 are to be noted in particular. For this analysis, the method of Lessman and Cavanaugh has been used.

There is a body of opinion - see for example Annex 111, Note 3 of Ref. 3 - to the effect that for the same type or class of impairment, the 'width' parameter of the mathematical model fitted to the histograms is relatively constant where the objective impairment level is varied. This width parameter is related to the variance or standard deviation of the histogram. There is a further body of opinion to the effect that saturation of the histograms at the upper and lower limit (5 and 1 for the work reported here) is, in effect, an artificial barrier in this type of psychometric test and that opinion rating is most probably normally distributed everywhere and, for a specific sample of raters or in this case viewers, has a fixed variance which is independent of the objective impairment or the associated subjective rating histogram. The method of Lessman and Cavanaugh derives from this concept. Lessman and Cavanaugh have implemented the concept of Gaussion distributions and fixed variance through a quantization process (Ref. 8).

Refer to Figure 4 in which is sketched (not to scale) a normal distribution curve $(2\pi)^{-1/2} \exp (x-\mu)^2/\sigma$ of mean μ and standard deviation σ. μ is not bounded by any upper or lower limits. Colinear with the x-axis are drawn five opinion-rating intervals used in the tests.

FIGURE 4

QUANTIZATION TRANSFORMATION



Quantized mean, $MOSQ_J = \sum_{i=1}^{5} i A_i \approx MOS$

$\sum_{i=1}^{5} A_i = 1$

The particular normal distribution curve has the following properties:

(i) the area A_1 from $-\infty \leq x \leq 1.5$ represents the proportion of opinions in rating Category 1, Area A_2 the proportion of votes in Category 2, and so on. These areas are the basic elements in the quantization transformation.

(ii) $\sum_{i=1}^{5} iA_i$ defines a quantized mean, MOSQ, which equals the original sample mean, MOS.

(iii) σ is constant for all values of μ for the particular impairment in question. A quantized standard deviation SIGMOSQ is defined initially for each histogram through the transformation

$$\text{SIGMOSQ} = \left[\sum_{i=1}^{5} i^2 A_i - (\text{MOSQ})^2\right]^{1/2}$$

where, as for MOSQ, SIGMOSQ equals SIGMOS, the standard deviation of the sample. All SIGMOSQ's for the impairment series in question are averaged to a constant σ. This is followed by a final adjustment to μ to maintain the equality between MOSQ and MOS for each histogram.

Briefly stated, μ's and a fixed σ for all histograms are developed through a 2-dimensional convergence process in which differences between MOSQ and MOS and SIGMOSQ and SIGMOS are minimized simultaneously through a numerical convergence process involving the interation of the quantization transformation. Details on the algorithm used by Lessman and Cavanaugh will be found in Ref. 8.

When μ's and the single value of σ have been calculated for each test condition i.e. from the histogram for each level of impairment, a smooth logistic curve for μ is fitted through the experimental values of μ. This curve, is of the form

$$\mu = 1 + 4/[1/U + \exp(D_m - D)/K]$$

The parameters U, Dm and K are related to, in order, the asymptotic value of μ for unimpaired scenes, the mid-point or point of inflection of the logistic (approximately), and the slope of the curve at the mid-point. D is the independent variable. In the tests described here D is the carrier-to-interference or carrier-to-noise ratio in dB.

All subsequent analysis was based on data derived from the logistic curve for μ and the fixed value of σ .

Details on the software developed for the analysis will be found in Appendix 5.

To relate the results more closely to CCIR usage, opinion ratings must be normalized, converted to 'IMP' units, and plotted against the level of impairment as in Figure 5. (Figure 5 has been reproduced from Ref. 3).

Normalization is accomplished through the transformation $u = \frac{Um-1}{4}$, where Um is the mean of interest; in the present case Um = MOSQ.

CCIR practice suggests a logistic fit of the form $u = 1/[1/u_0 + \exp(D-Dm)G]$ to u at this point. In the present case a logistic has already been fitted to the μ's, hence the values for the normalizaiton of MOSQ's are already smoothed.

Transformation to 'Imp' units, I, is accomplished by setting $I = (1/u)-1$, u being calculated from a smooth curve. u_o is of course the asymptotic value of the subjective assessment of a scene when the objective impairment of interest has reached zero.

Denoting $I_o = (1/u_o)-1$ and subtracting it from the experiment values I_{exp} leads to a new parameter $I_u = I_{exp} - I_o$.

I_u is then in the convenient form $I_u = \exp(D-Dm)G$ and plots of ln I_u are linear with D. (See Figure 5).

The mid-point Dm on Figure 5 is the point at which the Impairment level $I_u = 1$. On a 1 to 5 rating scale $I_u = 1$ corresponds to a mean opinion score of 3.00. Other noteworthy levels are $I_u = 0.25$ or ¼ Imp and $I_u = 0.125$ or 1/8 Imp. IN Ref. 3, $I_u = 1/8$ Imp is equated with the lowest impairment obtainable in a laboratory set-up.

The slope G of the I_u versus D curve is the reciprical of ΔD, the increment from Dm at which I_u falls to 1/e of its mid-point value. Both G and Dm are related to the K and Dm parameters in the logistic curve for μ but the relationship is not a simple one because of the non-linear quantization step in calculating MOSQ.

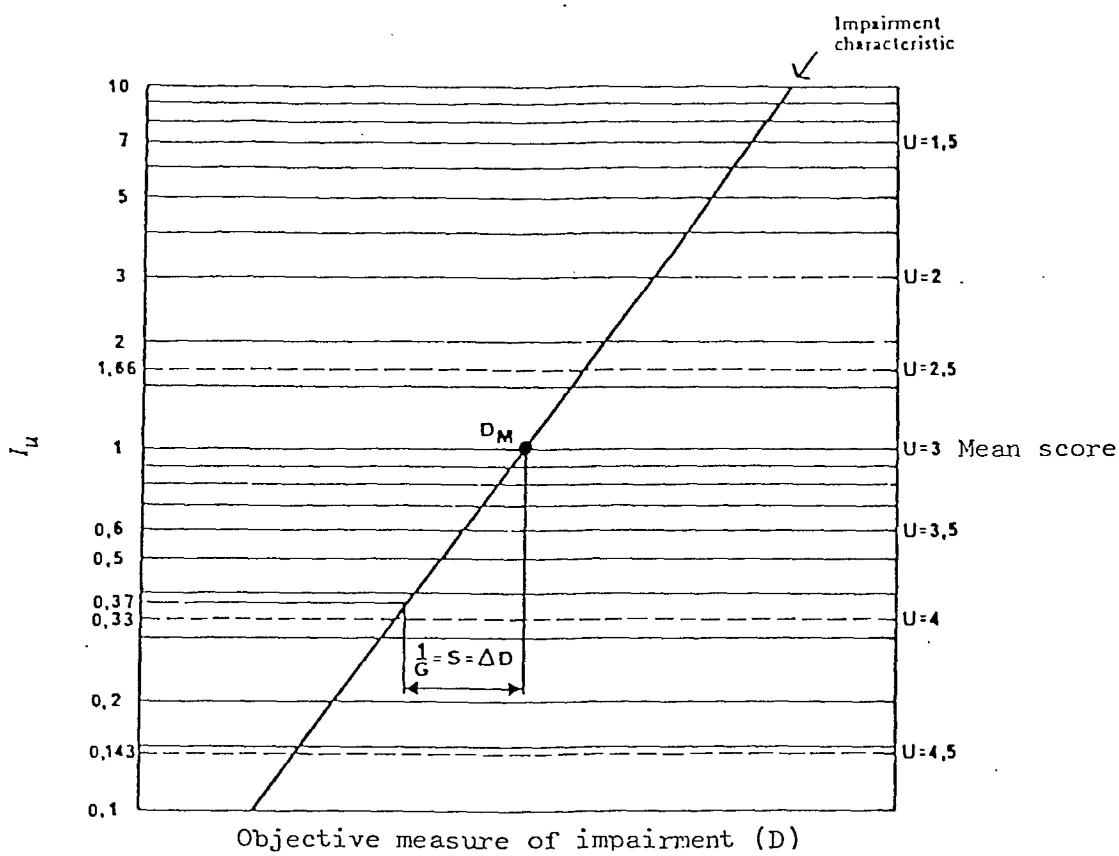


FIGURE 5: Representation of the impairment characteristic U - Mean score, 5-grade scale

Curves for I_u were derived in 7 steps as follows:

(i) the range of interest of impairments for a particular impairment series was selected and specific values, D, of objective impairment chosen;

(ii) 'smoothed' μ's corresponding to these levels objective D-values were calculated from the logistic curve for μ;

(iii) the values of μ from step (ii) and the fixed value of σ were used to produce quantized means, MOSQ's at these objective impairment points;

(iv) MOSQ's were normalized and converted to Imp units through the transformation

$$I_{exp} = 4/(MOSQ-1) - 1$$

(v) I_o was noted and subtracted from all values of I_{exp} to yield I_u.

(Note: In keeping with a cautionary note in CCIR to the effect that the reliability of Imp values greater than 2 is still to be determined, values of $I_{exp} \geq 3$ were not used to calculate I_u.

(vi) I_u was plotted against D on semi-log paper;

(vii) Dm and G were not measured from the graphs. A linear regression through the data points was used to derive the equation $\ln I_u = \beta + \alpha D$.

The $\ln I_u = 0$ and $\ln I_u = -1$ intercepts were used to establish Dm and D. Slope parameter G is obtained from Δ D immediately. This value of G is in fact G', or G/8.868, because CCIR practice reserves G for the slope of the Imp versus impairment curve when the impairment axis is in arithmetic units, d, rather than logarithmic units, D. Accordingly the values of G' as derived from ΔD (dB) have been multiplied by 8.868 and are thus consistent with published CCIR G values.

Two supplementary mathematical routines were carried out for all test conditions.

New, 'smooth' MOSQ's corresponding to the impairment levels at the original test points were calculated from the smooth curves for μ and σ. The new MOSQ's were compared to the original experimental values of MOS for interest. The deviation of the MOSQ's from the MOS's was consistently less than 0.2 σ where σ refers to the computed constant standard deviation for the theoretical normal distribution curves.

For interest, a logistic curve of the same form as that for μ was fitted to these points as was done for μ, and new values of U, Dm and K recorded. The two logistics and hence the 2 sets of U, Dm, K parameters are linked through the quantization process but the linkage is not self-evident intuitively. It is certainly not linear.

These results are included for interest, but no MOSQ vaues based on a logistic for MOSQ were used in the analysis. All MOSQ values were calculated by quantization from a fixed σ and the logistic for μ.

4. RESULTS

Detailed analysis sheets for the CRC concerned-viewer data and the non-expert viewer data obtained in this study are appended as Appendix 6. A sample is reproduced in TABLE 3.

All sheets contain a software file name for one of three series of data. INDATA files refer to CRC concerned viewer results. NNDATA files refer to unscreened non-expert results and FIDATA files refer to the final screened non-expert results. Each sheet represents a specific impairment series.

Each sheet contains the coefficients U, Dm, K for the logistic fit to the μ's and derived constant value of σ. The second set of logistic coefficients for MOSQ are also given, as explained in the previous sections.

I_{exp} is tabulated for a range of carrier to interference ratios and the asymptotic value of I_{exp} ($\simeq I_o$) is given. ('Interference' is taken to include interference by noise and/or other signals.)

I_o was calculated by extending the range of C/I at least 20 dB beyond the point where, by inspection, I_{exp} becomes asymptotic.

Finally, each sheet contains the first-order polynomial for $\ln I_u$ as derived by the linear regression through the C/I versus I_u table of values. As noted in the previous chapter, Dm and G are calculated from the $\ln I_u \simeq o$ and $\ln I_u \simeq -1$ intercepts.

TABLE 3: STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA6

IMPAIRMENT: A11-100-13-00-XX

PROGRAM: PROA5' PROA6' PROB5' PROB6

U(mu) = 1.13 U(MOSQ) = 1.00

Dm(mu) = 4.44 D(MOSQ) = 4.22

K(mu) = 1.13 K(MOSQ) = 5.00

σ = 1.2532

C/I	$I_{exp} = \frac{4}{MOSQ-1} - 1$	$I_u = I_0 - I_{exp}$
2	4.51	4.42
3	2.76	2.69
4	1.31	1.24
5	.538	.47
6	.234	.163
7	.130	.06
8	.093	.02
9	.080	---
10	.075	---

LINEAR REGRESSION FIT

$\ln I_u = B + \alpha D = 4.10 - .990D$

Dm = 4.14

G = -8.78

Graphs of I_u versus C/I are shown in Figures 6 through 17. For convenience the calculated values of Dm and G are repeated in the legend block on each graph. Figures 6 through 11 apply to the final screened data for the 97 non-expert viewers and contain co-plots of the results for each slide and the aggregated results for all slides. Figures 14, 15, and 16 are co-plots of non-expert, and concerned-viewer results for noise impairment, single co-channel impairment, and triple co-channel impairment, respectively.

The straight lines drawn through the plotted points on all of the graphs have been established visually. In cases where the straight line does not coincide exactly with the tabulated value of Dm, the tabulated values is to be taken as more correct.

The results for each of the impairment series, aggregated for all pictures are given in Table 4 below.

TABLE 4: SUMMARY OF RESULTS

IMPAIRMENT SERIES	VIEWER GROUP	DM (db)	G	I_o (Imps)	
A11-000-00-xx-00	Non-Exp.	35	-3.0	.114	(Note 1)
ditto	Concerned GRPA	39	-2.5	.041	
ditto	Concerned GRPB	40	-2.8	.075	
A11-010-00-00-xx	Non-Exp.	14	-2.4	.101	(Note 1)
ditto	Concerned GRPA	14	-2.0	.029	
ditto	Concerned GRPB	18	-2.7	.034	
A11-030-00-00-xx	Non-Exp.	17	-2.5	.089	(Note 1)
ditto	Concerned GRPA	18	-2.5	.048	
ditto	Concerned GRPB	21	-2.4	.031	
A11-010-00-46-xx	Non-Exp.	14	-1.9	.094	(Note 1)
A11-100-15-00-xx	Non-Exp.	1.4	-6.9	.096	(Note 1)
A11-100-13-00-xx	Non-Exp.	4.1	-8.8	.071	(Note 1)

Note 1: Relatively high level of I_o illustrates the effect of residual VTR noise, as compared to I_o for the CRC groups.

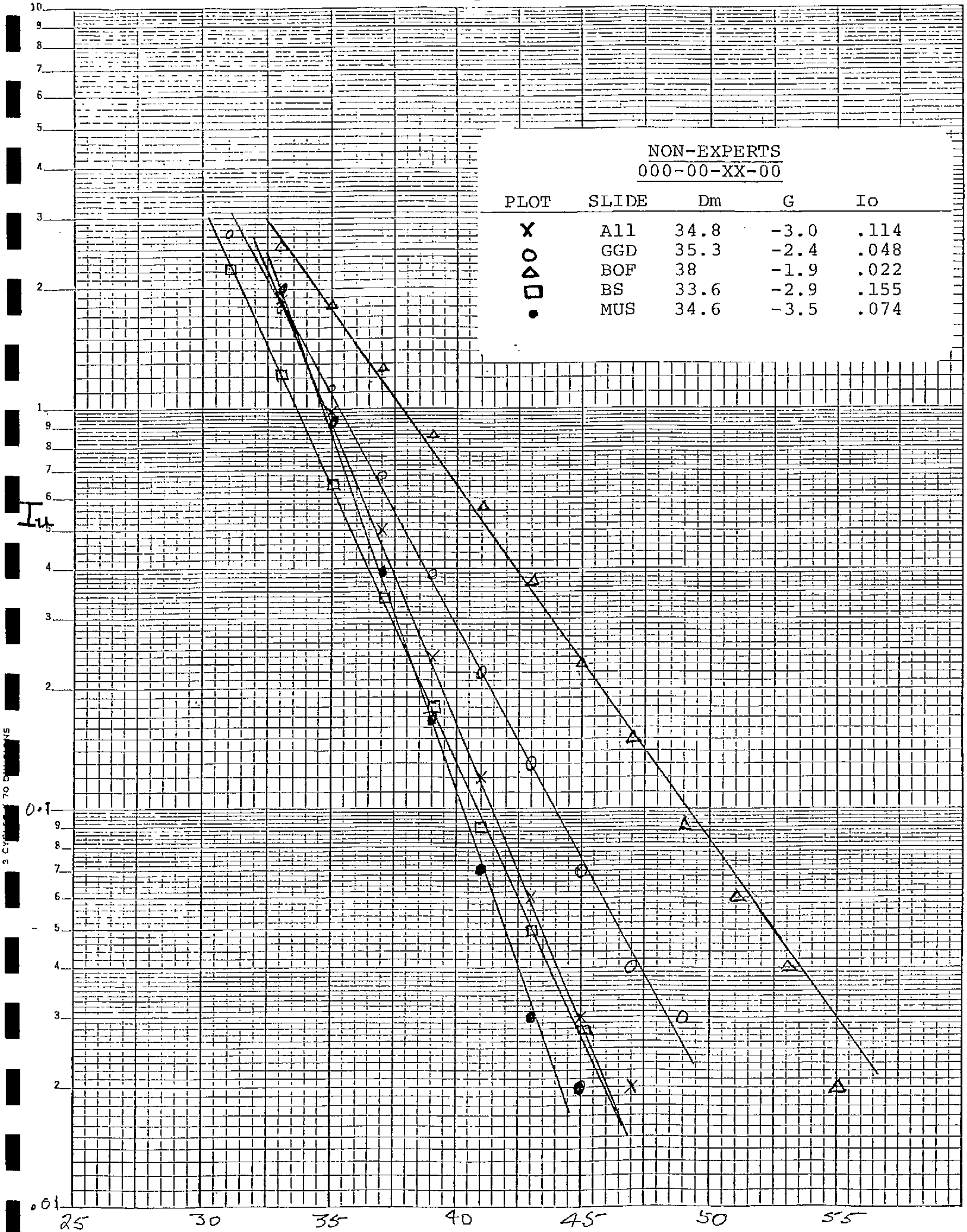
The last figure, Figure 17, is a co-plot of four values of I_u derived from the noise impaired series as follows:

(i) from the 'raw' MOS values for unscreened data;

(ii) from the 'raw' MOS values for screened data;

(iii) from the 'smooth' MOSQ values for unscreened data, see Appendix 6, NNDATA.1;

(iv) from the 'smooth' MOSQ values for final screened data, see Appendix 6, FIDATA.1.



PLOT	SLIDE	Dm	G	Io
X	All	34.8	-3.0	.114
O	GGD	35.3	-2.4	.048
Δ	BOF	38	-1.9	.022
□	BS	33.6	-2.9	.155
•	MUS	34.6	-3.5	.074

FIGURE 6: C/I, Weighted Noise, dB

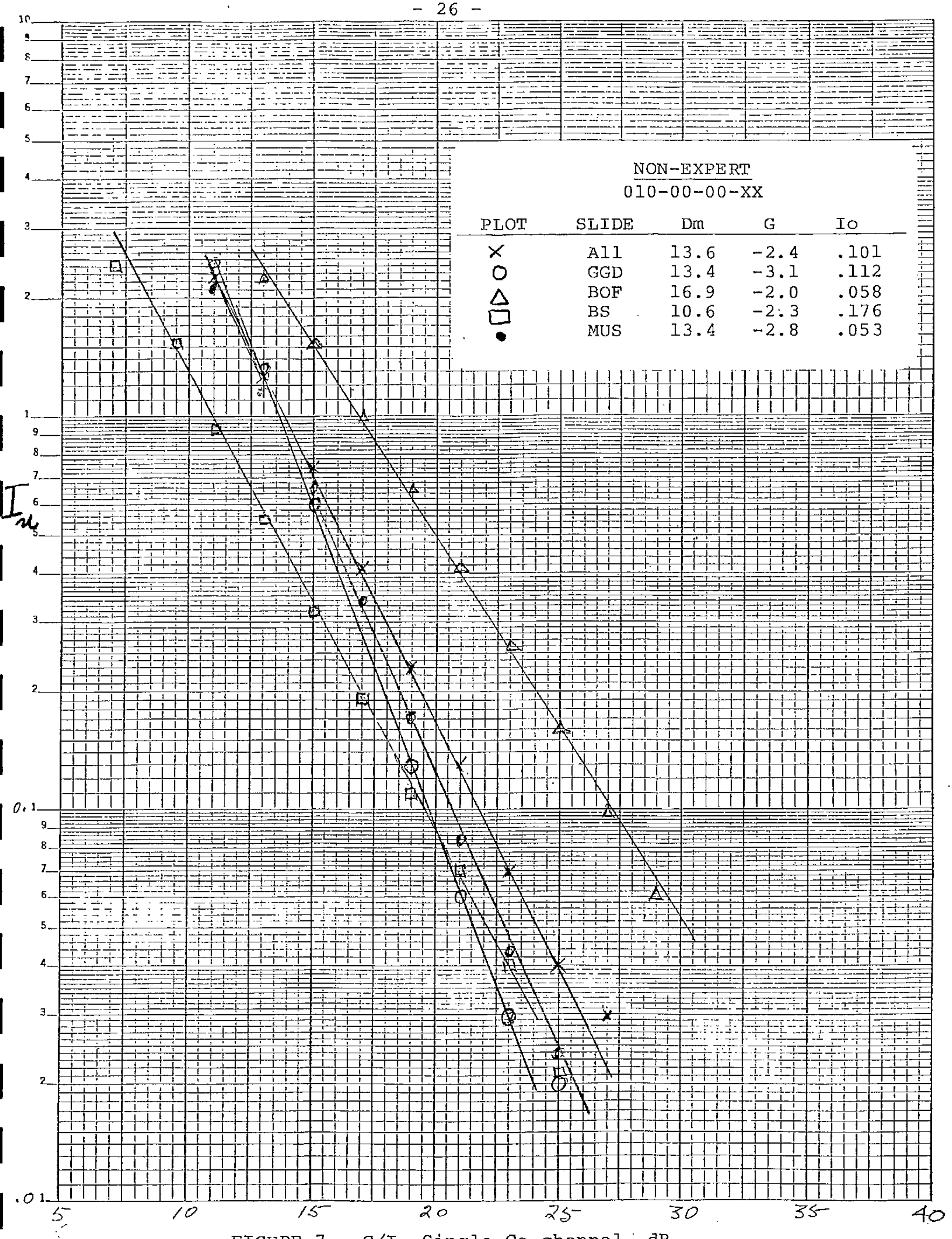


FIGURE 7: C/I, Single Co-channel, dB

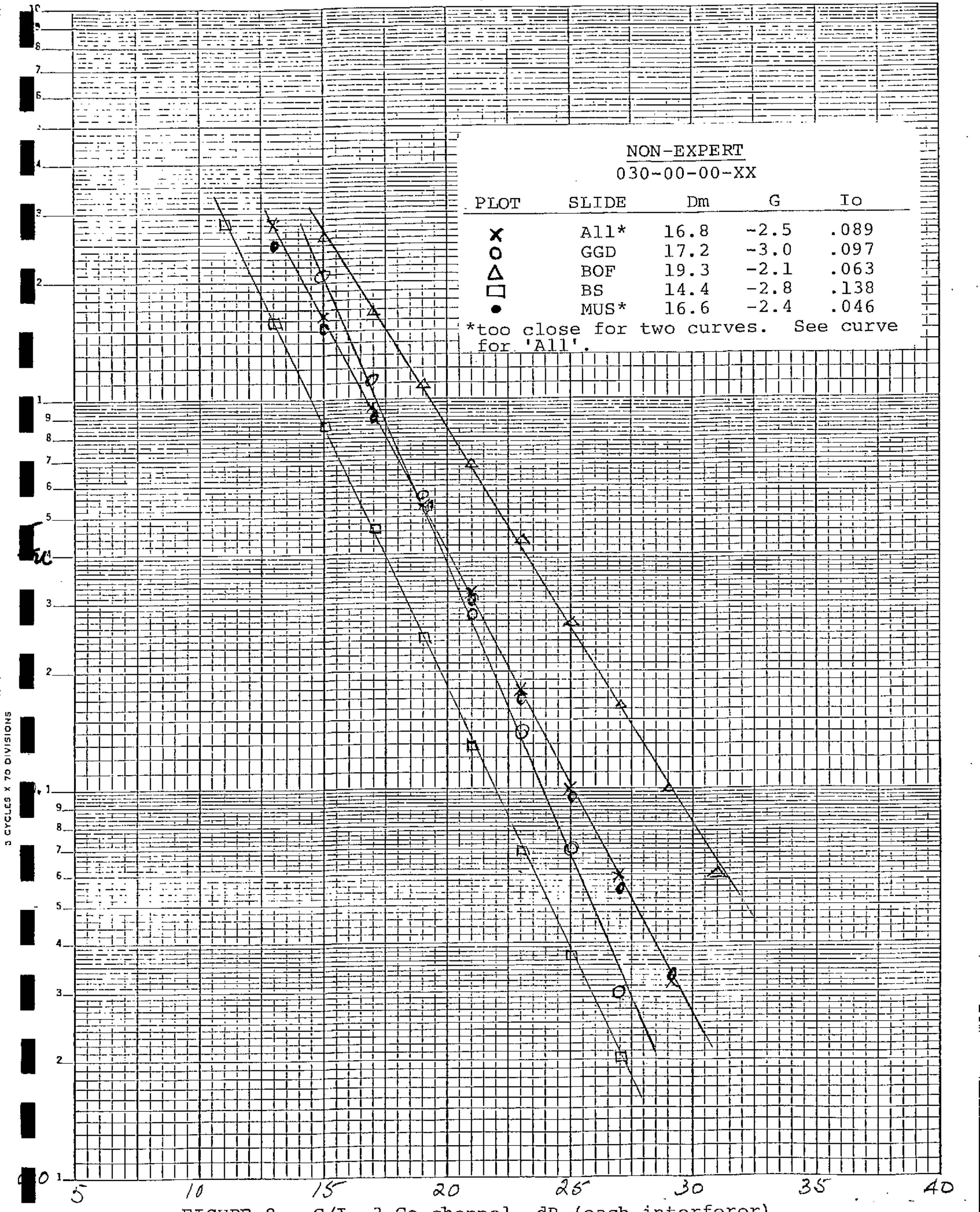


FIGURE 8: C/I, 3 Co-channel, dB (each interferor)

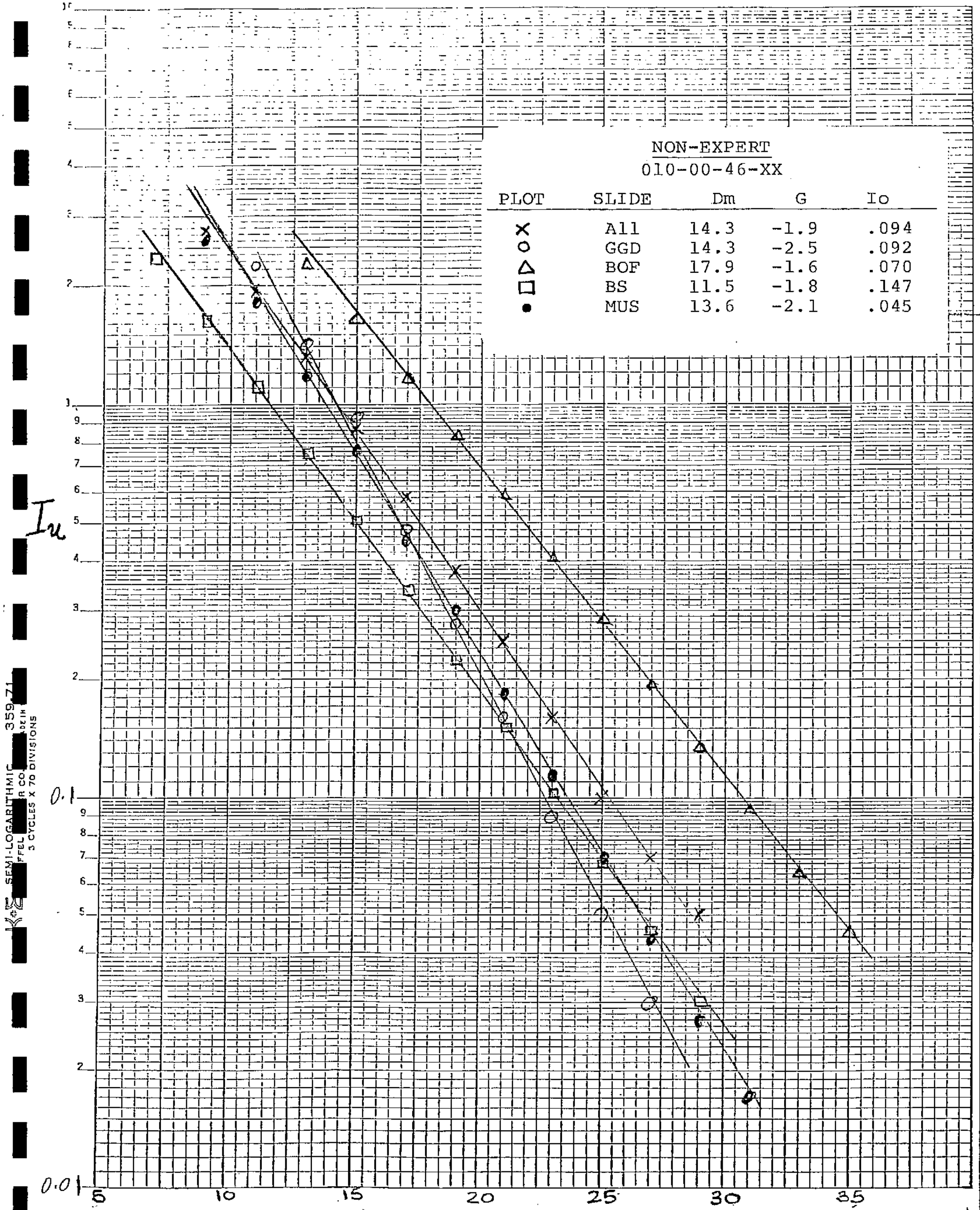


FIGURE 9: C/I, Single Co-Channel with Constant (-46dB) Noise, dB

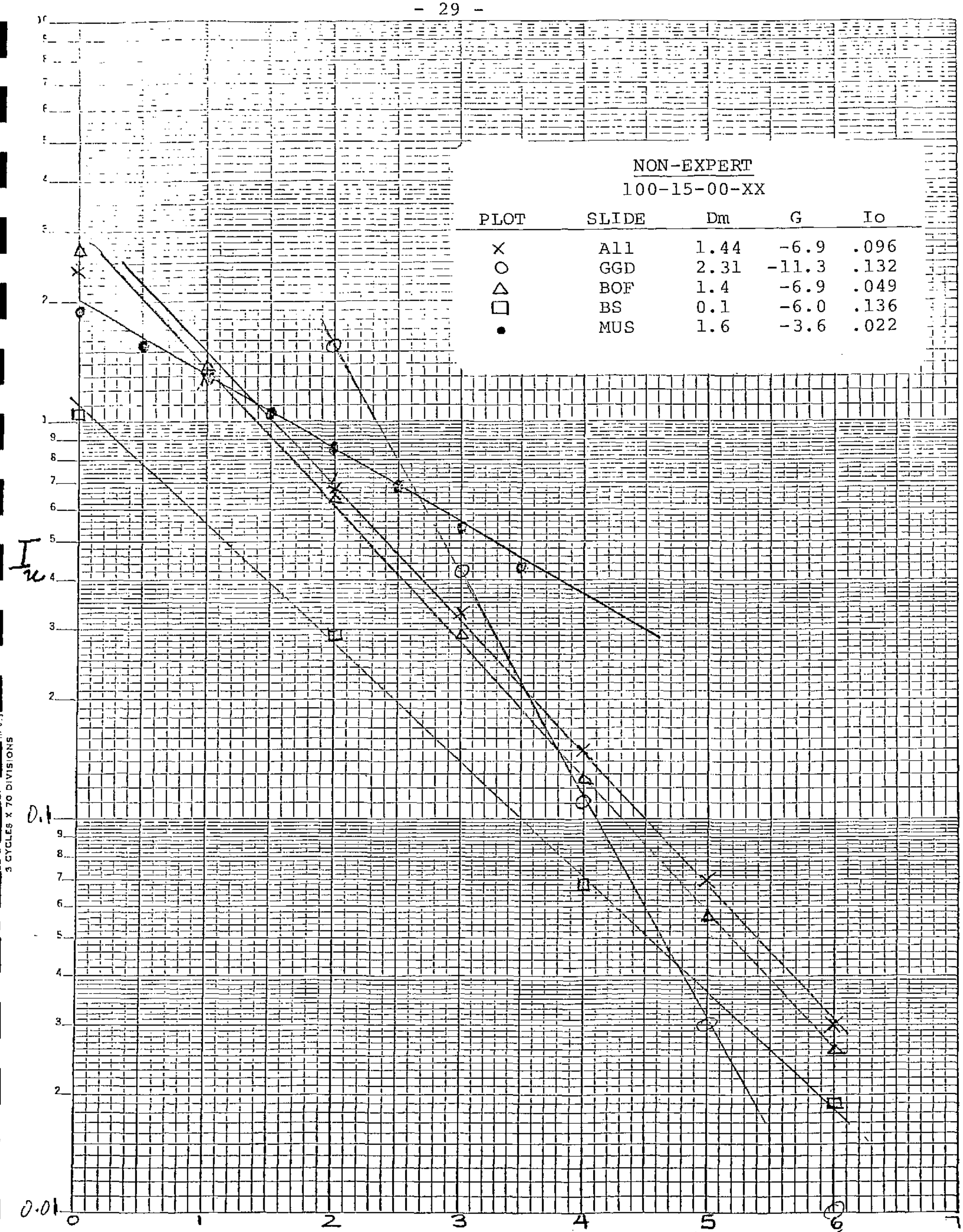


FIGURE 10: C/I, Single Adjacent Channel, 15MHz Separation, dB

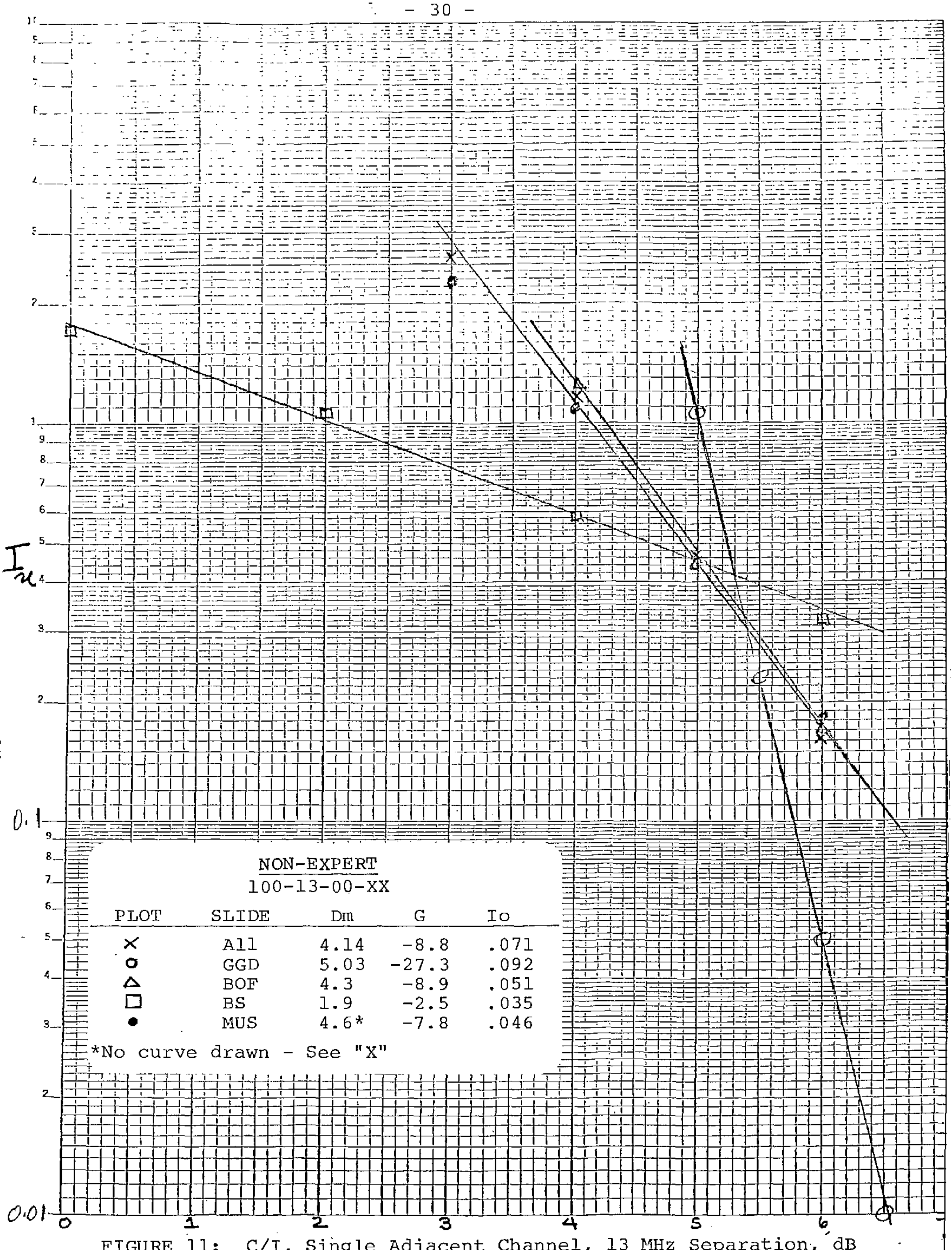


FIGURE 11: C/I, Single Adjacent Channel, 13 MHz Separation, dB

KEUFFEL & ESSER CO. MADE IN U.S.A.

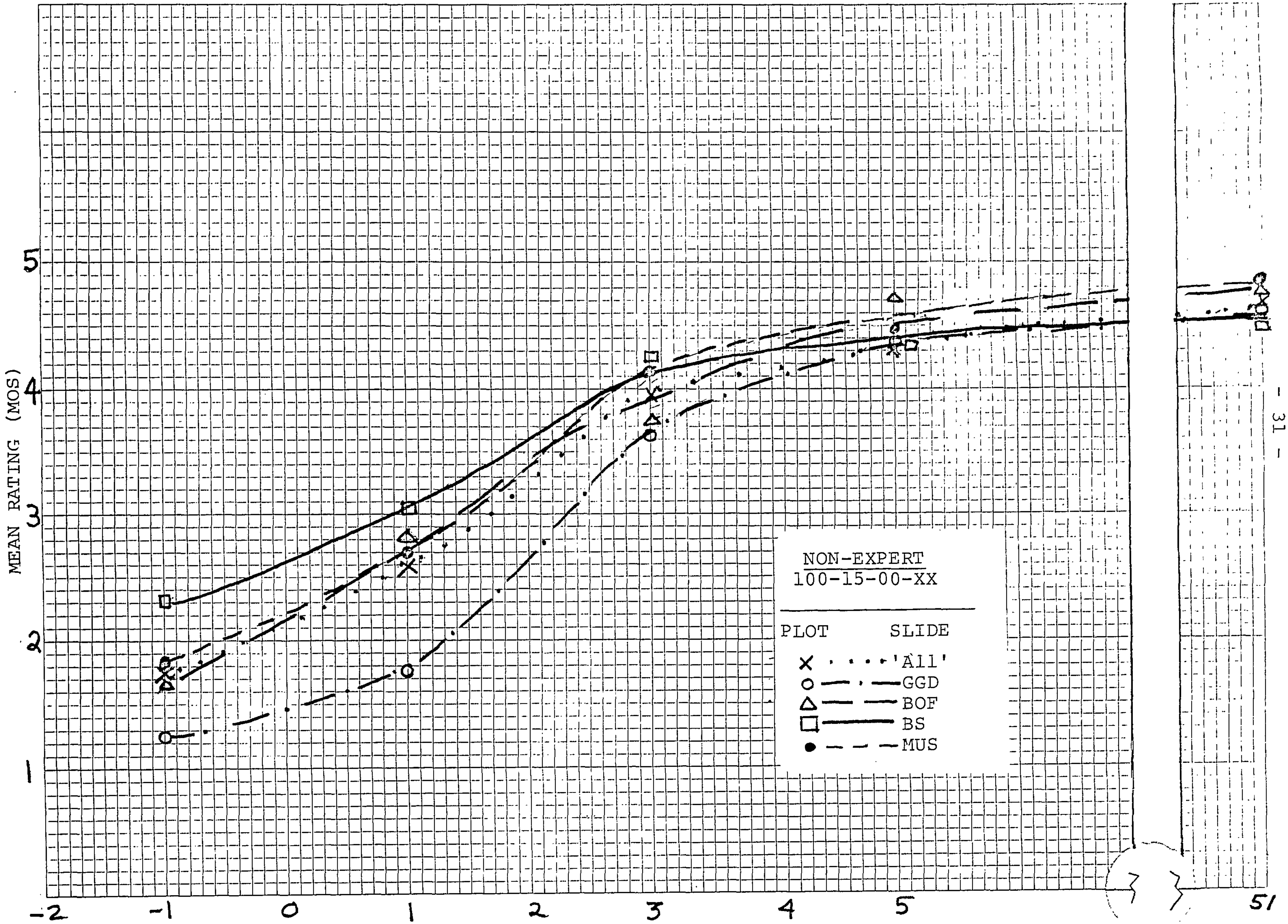


FIGURE 12: C/I, Single Adjacent Channel, 15MHz Separation, dB

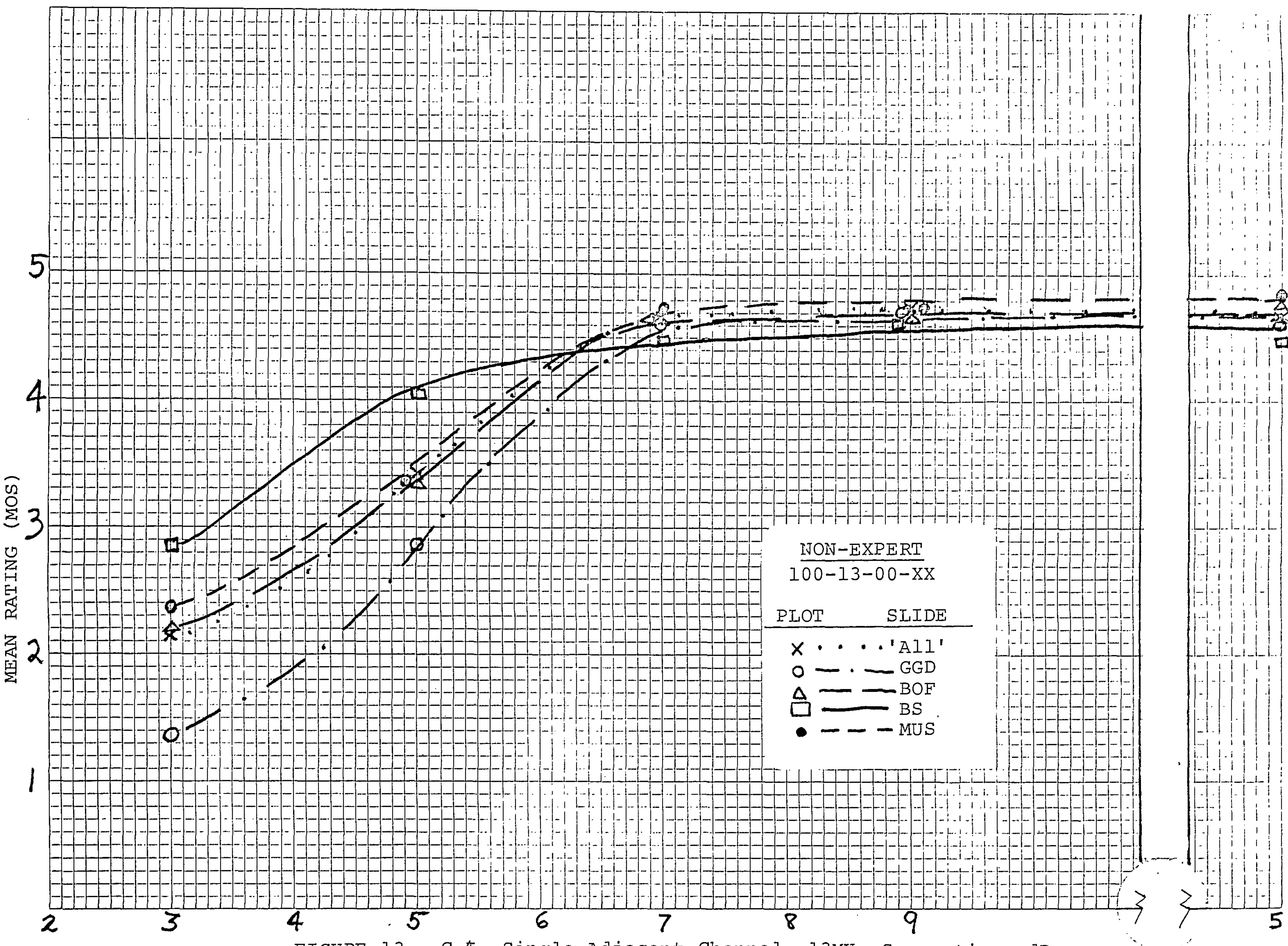


FIGURE 13: C/I, Single Adjacent Channel, 13MHz Separation, dB

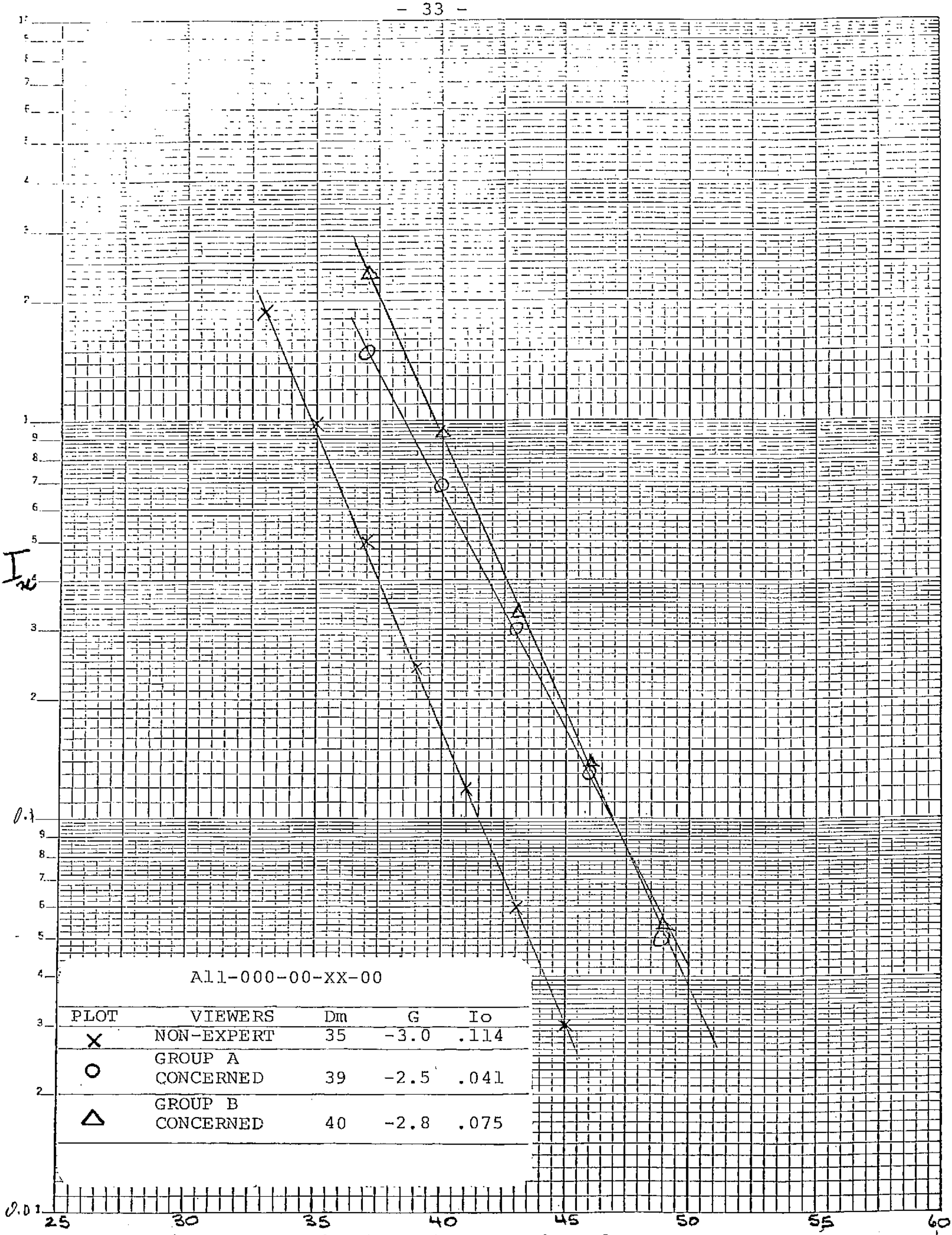


FIGURE 14: C/I, Weighted Noise, dB

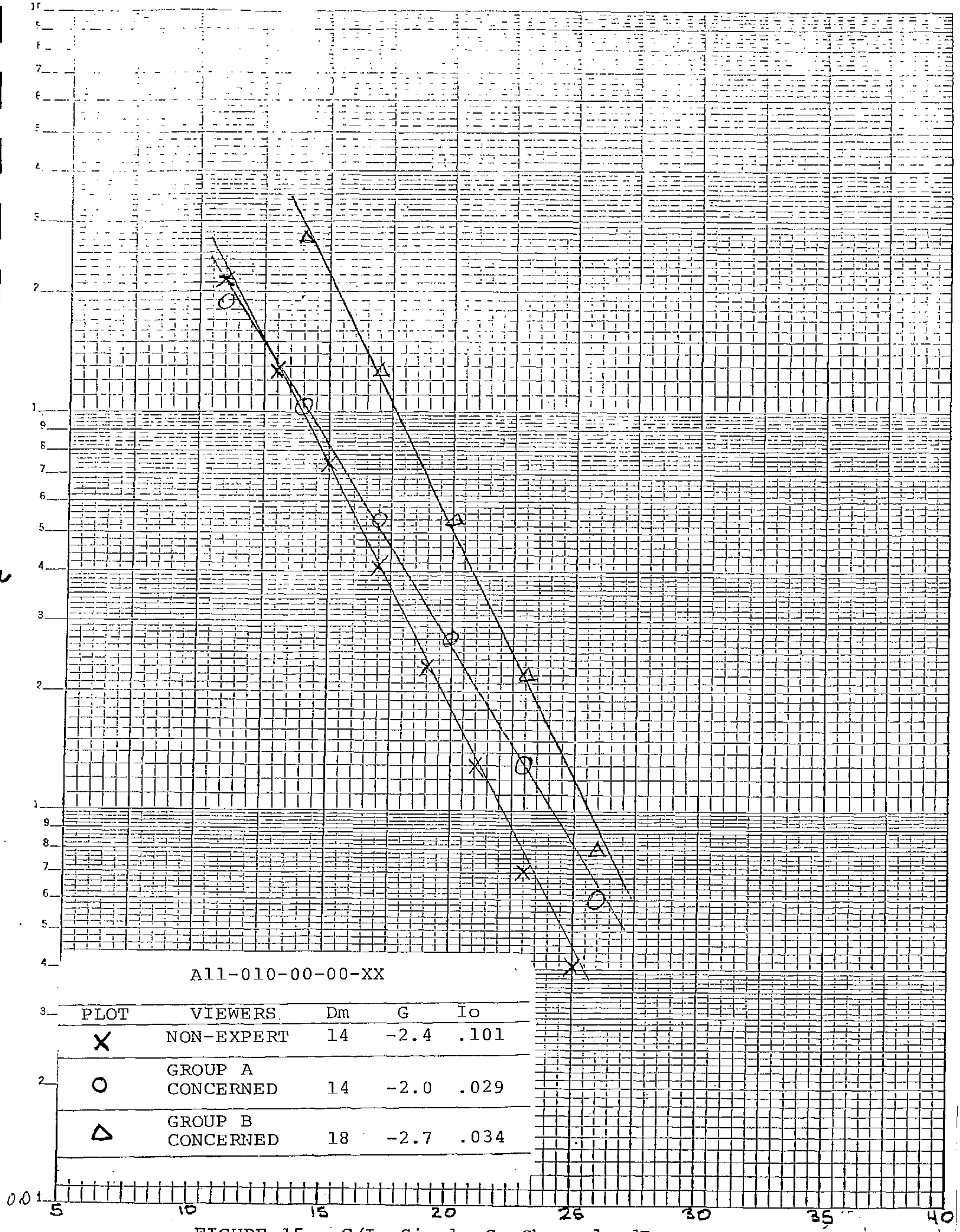


FIGURE 15: C/I, Single Co-Channel, dB

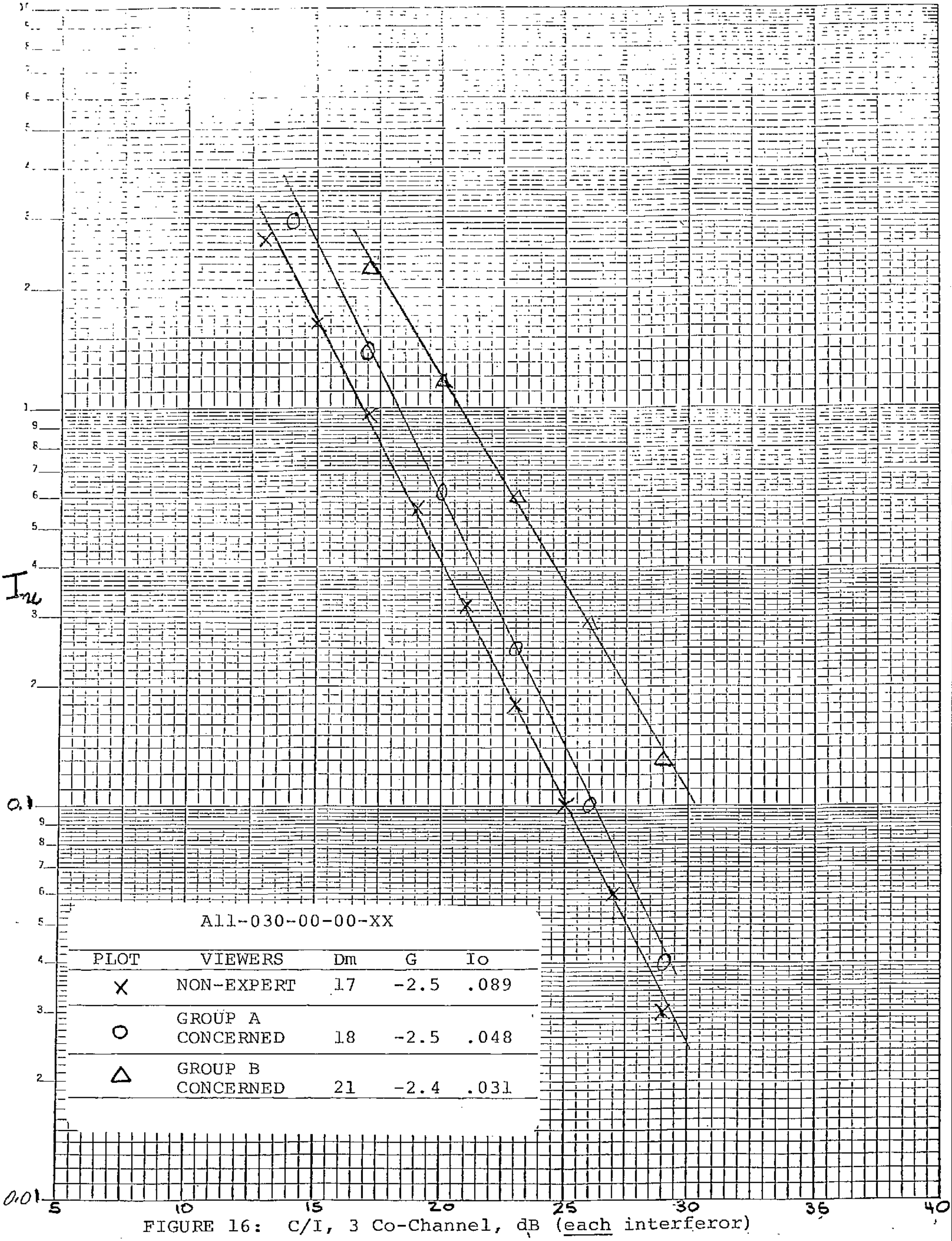


FIGURE 16: C/I, 3 Co-Channel, dB (each interferor)

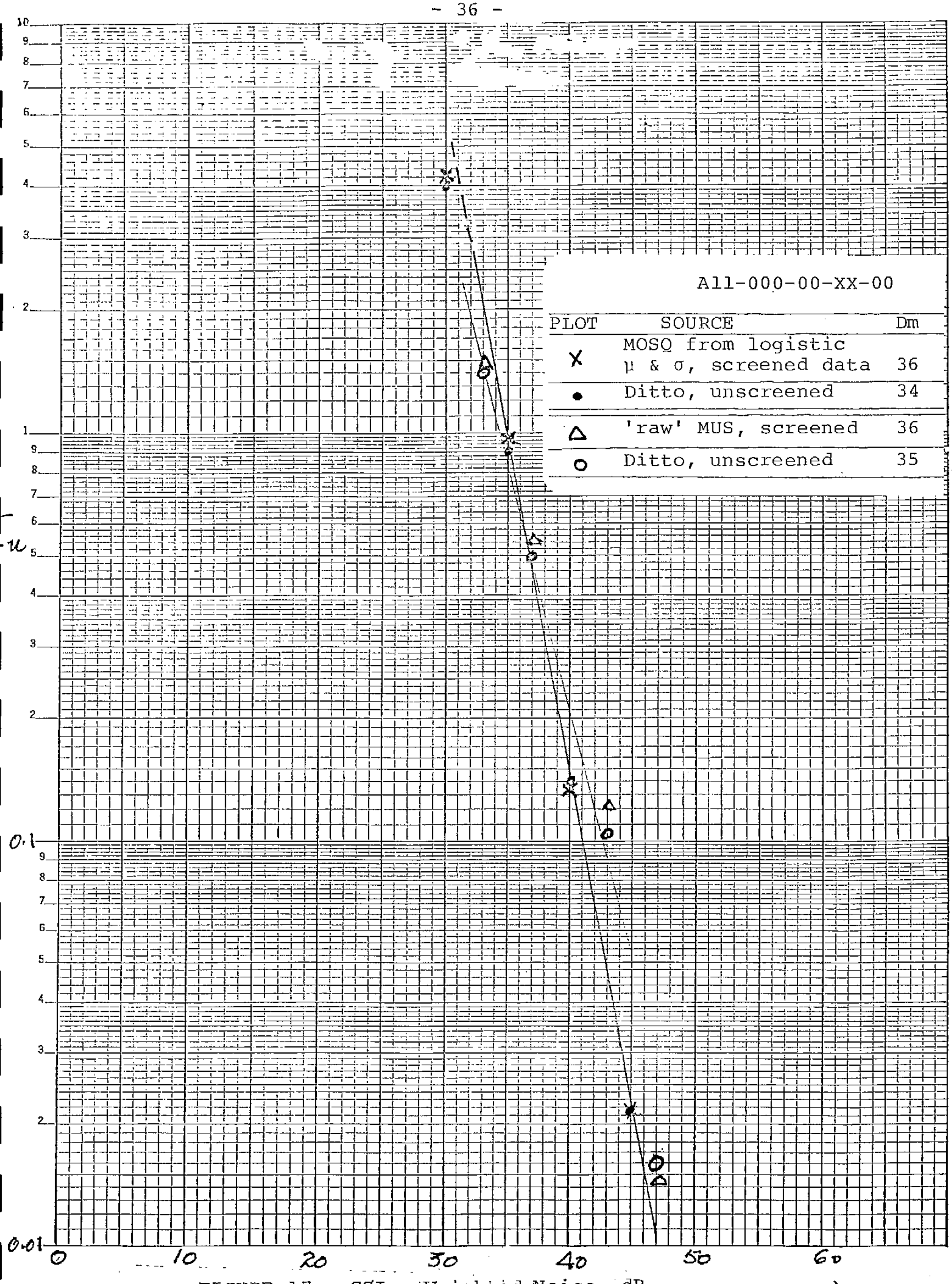


FIGURE 17: C/I, Weighted Noise, dB

5. DISCUSSION OF RESULTS

5.1 General Observations

The final line of histogram data in Appendix 4 is the histogram for all slides, all impairments, and all impairment levels. The sample mean for this histogram is 3.4 indicating that the choice of impairment levels and slide material accorded well with the requirements of CCIR Recommendation 500-2 which states that the average of all the presentations should be in the neighbourhood of the mid-point. The mid-point on a five grade rating scale is 3.

At the conclusion of some of the sessions viewers remarked that one particular impairment cause them considerable discomfort. When the tape was replayed to discover which impairment it was, it was invariably the impairment due to co-channel interference. About a half a dozen viewers remarked that their discomfort when viewing this impairment gave them a feeling of nausea or vertigo.

The general shape of the subjective ratings for the various impairments show clearly that the impairments divide into two groups, the first group being impairments due to noise and co-channel interference and the second group being impairments due to adjacent channel interference.

The difference in mid-point, Dm, between noise interference and other channel interference is some 20 to 25 dB, but the difference is somewhat immaterial in that the effect of other-channel interference varies with modulation parameters. The general shape of the curves as given by the slopes does not vary widely except for the cases of the subjective ratings for impairments due to adjacent channel interference. Here the slopes vary widely, from a high of 27 to a low of 2.4. With five exceptions the slopes of the other 20 curves all lie between 2 and 3.

The basket of fruit scene contains saturated or near saturated red colours. Scenes with saturated colours are know to be very sensitive to noise impairment and this is borne out in all of the plots of ratings for both noise impairment and co-channel impairment. It is not surprising that impairment by co-channel interference is increased as much as for noise in a scene with saturated colours because the interference pattern is composed of non-random but scattered points of distortion in the picture. Interference from adjacent channel on the other hand simply appears as a background picture. (In this respect it is interesting to note that some viewers had difficulty rating the subjective effect of the adjacent channel interference because they found themselves being interested in the interfering scene.)

5.2 Impairment by Triangular Weighted Noise, Figure 6

The curves for the individual slides and the aggregate of all slides appear to be well defined and consistent. The points for slide No. 2, the basket of fruit, have a slight downward curvature which might be taken to indicate so that the measured I_o was slightly high. A lower value for I_o would cause a smaller amount to be subtracted from I_{exp} thus raising the I_u values in the range of low I_u where they are very sensitive to small changes. It is interesting to note that, because of the variation in slope, all scenes tend to a common impairment rating as the Imp level rises above 2, even though they differ widely in their sensitivity to just-perceptible impairments.

5.3 Interference Due to a Single Co-Channel, Figure 7

The curve for subjective assessment for interference due to a single co-channel in a basket of fruit scene indicates that interference that does not cause the carrier-to-interference ratio to fall below 26 dB will produce subjective rating equivalent to that obtained in a laboratory set-up i.e. the mark point at $I_u \simeq 1/8$ Imp will be obtained. (Note 1) The scenes other than the basket of fruit scene are assessed close to but somewhat to the left of the average curve as would be expected, since the basket of fruit scene pulls the average to the right. The average of all 4 scenes predicts 1/8 Imp at $C/I \simeq 21$ dB.

Note 1: Although 1/8 Imp may be what is achievable, practically, in a laboratory set-up, impairments may be perceptible to the 1/10 or 1/20 Imp level.

5.4 Interference Due to Three Co-Channels of Equal Power, Figure 8

The curves for this impairment have the most equal slopes of any of the impairment series. Note that the beach scene is consistently rated higher, that is it is rated as having a lower impairment at all impairment levels. In the scene for interference by a single co-channel the beach scene appears to be more lightly impaired at severe impairment levels and more heavily impaired relative to the other scenes as the level of impairment dropped. That is, it has a low slope (G).

This general trend towards having a low slope is also observed in other test conditions with the beach scene slide.

It is concluded that at slight impairment the beach scene is found to be critical but as the impairment becomes more severe, the annoyance factor does not rise proportionately and the scene becomes more 'robust', probably because the scene itself is so busy with detail.

5.5 Summability of 3 Co-Channel Impairments

It is generally believed that multiple co-channel impairments sum on a power basis, that is, the objective level of a single co-channel producing the same subjective impairment as equal multiple co-channels would be the power sum of the multiple channels. Intuitively this might be expected, and there is some evidence to support the thesis that summing on a power basis is valid.

To test the validity of this thesis the subjective ratings for impairment by one co-channel interferor and three co-channel interferors were examined. If power addition holds in the 3-interferor case, the same subjective rating would be observed when the three interfering carriers were each 4.8dB lower then in the case of the single interfering carrier. In Table 5 the difference in objective impairment magnitude D has been calculated at three subjective impairment levels: mid-point ($I = 1$), $I = \frac{1}{4}$, and $I = 1/8$. The results from the concerned viewer tests have been included for comparison.

TABLE 5: DIFFERENCES IN OBJECTIVE IMPAIRMENT, D, (dB), TO PRODUCE IDENTICAL SUBJECTIVE RATING FOR 1 VERSUS 3 CO-CHANNEL INTERFERORS

VIEWER	SLIDE	ΔDm (I = 1)	ΔD (I = 1/4)	ΔD (I = 1/8)
Non Expert	All	3.3	3.5	3.5
	GGD	3.8	3.5	4
	BOF	2.4	2.0	2.0
	BS	3.8	3.0	3.0
	MUS	3.2	5.0	4.5
Concerned GRPA	All	4.3	2.8	2.3
Concerned GRPB	All	3.0	4.0	4.7

The non-expert viewer results range from a low of ΔD=2 dB to a high of ΔD=5 dB. The preponderance of the measurements are in the region of 3.5 dB.

The concerned viewer results are higher on average with a preponderance of measurements in the neighbourhood of 4.

Both sets of data seem to indicate that the post-demodulation effect has a statistical maximum, power addition, but the complex phenomena occurring in an FM demodulator/limiter circuit tend to reduce the effect. Given the complexity of an FM limiter/demodulator circuit operating on one strong and three weak carriers, all of them at the same nominal frequency, it is doubtful if a rigorous analysis could be carried out with sufficient precision to establish the objective post-detection signal-to-impairment level.

5.6 Interference Due to Aggregated (Constant) Noise and a Single Co-Channel Interferor Figure 9

This graph is quite similar to that for single co-channel interference alone (Figure 7). The mid-points are moved slightly to the right as expected in all cases with the make-up scene moving the least at 0.2dB. In all cases slope is less steep as would be expected in a situation with a fixed residual impairment.

The consistent drop in I_o is unexpected. The most that can be said is that I_o values are small in both situations and a change up or down in order of 10 to 15% is within the limits of statistical expectation.

The particular level of noise interference selected - S/N 46dB - would of itself produce a very mild subjective impairment for all scenes except the basket of fruit. From Figure 6, the basket of fruit would be rated at approximately ¼-Imp at 46 dB S/N; all other are below 1/10 Imp. Accordingly, the effect of the noise would be expected to be large only at low levels of co-channel interference. Slopes on a logarithmic plot are highly sensitive to the residual impairment rating at the higher C/I's; the lower slopes in the doubly impaired scenes bear this out, asdoes the fact that the change in mid-point is not very large, being in the order of 1 dB.

5.7 Summability of Imp Units

Summability of Imp units is known to be valid for different impairments as long as the impairments give rise to different subjective effects. In the case of noise and co-channel interference the difference in subjective effect is probably viewer-dependent to some degree, except to expert viewers who recognize the difference.

In Tables 6 and 7 are tabulated several values of I_u and the unadjusted value I_{exp} for the single co-channel and the single co-channel plus noise impairments. Table 6 is for all slides, Table 7 is for the basket of fruit. The difference in the two ratings should equal the impairment level for 46 dB S/N alone.

Both cases show the summability effect over part of the range. For 'all' scenes, summability is evident at very low impairment levels, the difference increasing as the mid-point is approached. The basket of fruit scene shows less overall variation and, except for the highest and lowest I values, it indicates summability over a wide range of C/I. On the basis of the present results it would be difficult to confirm or deny the general validity of the summability thesis since in the examples cited summability does not occur in the same Imp range.

TABLE 6

ADDITIVE PROPERTIES OF
TWO DIFFERENT IMPAIRMENTS
(ALL SLIDES)

C/I	A11-010-00-46-XX		A11-010-00-00-XX		ΔI_u	ΔI_{exp}
	I_u	I_{exp}	I_u	I_{exp}		
11	1.93	2.02	2.12	2.22	.19	.2
13	1.31	1.40	1.27	1.37	.04	.03
15	.87	.968	.73	.83	.14	.14
17	.58	.671	.41	.51	.17	.16
19	.38	.471	.23	.33	.15	.14
21	.25	.339	.13	.23	.12	.11
23	.16	.25	.07	.17	.09	.08
25	.10	.20	.04	.14	.06	.06
27	.07	.16	.03	.13	.04	.04
29	.05	.14	.02	.12	.03	.03
31	.03	.12	.01	.11	.02	

C/I (Noise only) = 46 db, I_u = .025

TABLE 7

ADDITIVE PROPERTIES OF
TWO DIFFERENT IMPAIRMENTS
(BASKET OF FRUIT)

C/I	2-010-00-46-XX		2-010-00-00-XX		ΔI_u	ΔI_{exp}
	I_u	I_{exp}	I_u	I_{exp}		
13	2.27	2.34	2.28	2.34	-.01	0.0
15	1.65	1.72	1.52	1.57	.13	.15
17	1.18	1.25	.99	1.05	.19	.20
19	.84	.91	.64	.70	.20	.21
21	.59	.66	.41	.47	.18	.19
23	.41	.48	.26	.32	.15	.16
25	.29	.36	.16	.22	.13	.13
27	.20	.27	.10	.16	.1	.11
29	.13	.20	.06	.12	.07	.08

C/I (Noise) = 46 db, I_u = 0.19

5.8 Single, Lower Adjacent Channel Interference, 15 MHz Carrier Spacing, Figure 10

The plots for this impairment have been done on a 5-fold expanded horizontal axis to separate the curves. Accordingly visual differences among the slopes are accentuated.

The make-up scene slide, with a (low) slope that compares to that for noise and co-channel interference is the most noticeable departure from the remainder of the cluster. Note that the basket of fruit slide does not stand out in this series.

5.9 Single, Lower, Adjacent Channel Interference, 13 MHz Carrier Spacing Figure 11

The curves in Figure 11 indicate that the change from 15 MHz to 13 MHz spacing implies approximately 2 to 3 dB more isolation in terms of C/I ratio to keep the impairment below the perceptible limit.

The beach scene and the make-up scene have changed slope significantly from that for the 15 MHz carrier separation series. Furthermore they have changed in opposite directions.

Because of the steepness of the slopes generally in both this series and the 15 MHz series, some thought must be given to the accuracy, even the suitability of the logistic fit to the μ's. Any errors in the parameters or even the form of the logistic will be propagated in the methodology used for this analysis.

For this reason the original experimental means (MOS) have been plotted against C/I in Figures 12 and 13. Note again the five-fold increase in the calibration of the C/I axes. The results suggest that the onset of impairment is, relative to other situations, sudden and dramatic, with picture quality collapsing in a range of a few dB change in C/I. Accordingly, the only real and useful significance of the plots is identification of the 'trigger' point at which subjective impairment begins.

It is interesting to note in Figures 12 and 13 that the curves for Girl-in-Green-Dress and Beach Scene slides lie to either side of the other two slides and, of course, the mean. Evidence of this is found also in the mid-points on the logarithmic plots in Figures 10 and 11.

5.10 Comparison of Non-Expert and Concerned Viewer Results, Noise Impairment, Figures 14, 15 and 16

Figures 14, 15, and 16 illustrate the variation in subjective ratings by non experts and the two CRC groups of concerned viewers, for noise, single co-channel and triple co-channel impairment respectively. The slopes for all three groups do not differ greatly, with the slope for concerned viewer group A showing the greatest relative change from one graph to the next. Slopes for non-experts and concerned group B are very similar.

The mid-point for the non-expert is markedly lower, by some 4 dB, than that of the two concerned groups in the case of impairment by noise. The distinction is much less evident in the curves for single co-channel interference, with triple co-channel somewhere in between.

In general, the non-expert viewers appear to be consistently less critical, in the order of 1 to 2 dB at mid-point, than concerned viewers. A factor that might tend to close this gap is the fact that concerned viewers were shown the basket of fruit and two other less critical slides, girl in green dress and beach scene, whereas the non-experts were shown the basket of fruit and three other less critical slides. In the results for concerned viewers the basket of fruit has more effect on the aggregated scores for all pictures, tending to pull the average towards harsher rating.

5.11 Comparison of Imp Values As Derived From Raw Data and Smoothed Data, and Screened and Unscreened Data, Figure 17

The curves in Figure 17 were constructed to give an indication of the effects of screening and the mathematical smoothing and quantizing transformations on the original data. The four sources of points are noted on the graph. The noise impairment series was used.

It can be seen at once that the effect of screening was very modest since the screened and unscreened points lie almost together.

The effect of the mathematical smoothing has served to increase the slope slightly. In the case of the screened data the mid-point has remained stable at 36 dB.

The good coincidence between the raw data and the smoothed data speaks well for the integrity of the original data set and the subsequent mathematical transformations. The smoothed data, in closed analytical form, can be used with confidence in other transformations to produce, for example, percentiles.

6. CONCLUSIONS AND RECOMMENDATIONS

From the discussion of results it is concluded that

(i) the data obtained for 97 non-expert viewers is a stable, reliable data set;

(ii) the range of impairments shown is sufficient to avoid any build-up of bias towards either harsh or benign subjective assessments;

(iii) the choice of slides to include at least one slide with saturated colours is an absolute necessity in order to cover the range of typical pictures broadcast in normal programming, including highly saturated colour pictures.

(iv) the four slides chosen have characteristic individual slopes and mid-points for various impairments, and the range covered is satisfactory.

It is concluded further that the results can be used with confidence as input to the Broadcast Satellite Service planning function.

It is recommended that the analysis of the data be taken in other directions to answer the following questions:

(i) What, if any, are the variations between viewers seated at 4 times picture height and viewers at 6 times picture height. Does Dm or G or both change?

(ii) What do the curves for percentiles of viewers rating scenes with various impairments and levels of impairments looks like?

(iii) Are there any statistically significant differences between viewers due to sex, age, or occuption?

(iv) How much, if any, do the statistical results vary between each of the 3 individual tapes?

(v) How do the results change in going from 100 viewers down to 50, or 30, or 20?

(vii) Is there any significant difference in final results when working from quantized means and logistic fits to μ, as has been done here, as opposed to working with logistic fits to 'raw' means or medians, or means or medians derived by other mathematical analysis: for example Allnatt's concept of a Sliding Logistic on a Logistic Transform (Slolt), as in Ref. 11?

7. REFERENCES AND SELECTED BIBLIOGRAPHY

1. STANDARDIZED SET OF TEST CONDITIONS AND MEASUREMENT PROCEDURES FOR THE SUBJECTIVE AND OBJECTIVE DETERMINATION OF PROTECTION RATIOS FOR TELEVISION IN THE TERRESTRIAL BROADCASTING AND THE BROADCASTING-SATELLITE SERVICES. CCIR Recommendation 600.

2. METHOD FOR THE SUBJECTIVE ASSESSMENT OF THE QUALITY OF TELEVISION PICTURES. CCIR Recommendation 500-2.

3. SUBJECTIVE ASSESSMENT OF THE QUALITY OF TELEVISION PICTURES. CCIR Report 405-3 (MOD F). November 11, 1981.

4. EXPERIMENTAL RESULTS RELATING PICTURE QUALITY TO OBJECTIVE MAGNITUDE OF IMPAIRMENT. CCIR Report 959.

5. ASSESSMENT OF THE QUALITY OF TELEVISION PICTURES. CCIR Report 313-5.

6. SUBJECTIVE QUALITY OF TELEVISION PICTURES IN RELATION TO THE MAIN IMPAIRMENTS OF THE ANALOGUE COMPOSITE TELEVISION SIGNAL. CCIR Report 960.

7. Cavanaugh, John R. and Lessman, Anthony M. SUBJECTIVE EFFECTS OF DIFFERENTIAL GAIN AND DIFFERENTIAL PHASE DISTORTIONS IN NTSC COLOUR TELEVISION PICTURES. Journal of the SMPTE Vol. 80. August, 1971.

8. Lessman, A.M. THE SUBJECTIVE EFFECTS OF ECHOES IN 525-LINE MONOCHROME AND NTSC COLOR TELEVISION AND THE RESULTING ECHO TIME WEIGHTING. Journal of the SMPTE Vol. 81. December, 1972.

9. Cavanaugh, John R. A SINGLE WEIGHTING CHARACTERISTIC FOR RANDOM NOISE IN MONOCHROME AND NTSC COLOR TELEVISION. Journal of the SMPTE Vol. 79 February, 1970.

10. Bouchard, M. and Chouinard. SUBJECTIVE EVALUATION OF THE INTERFERENCE PROTECTION RATIO FOR FREQUENCY MODULATED NTSC TELELVISION SIGNALS. CRC Report. April, 1983.

11. Allnatt, J.W. OPINION-RATING MODEL APPLIED TO TELEVISON-TRANSMISSION-SYSTEM STUDIES. PROC. IEF. Vol. 122. No. 8. August, 1975.

REFERENCES AND SELECTED BIBLIOGRAPHY (Cont'd)

12. Allnatt, John W. SUBJECTIVE ASSESSMENT OF IMPAIRMENTS IN TELEVISION PICTURES. Applied Ergonomics. December, 1971.

13. Bednarek, Robert A. ON EVALUATING IMPAIRED TELEVISON PICTURES BY SUBJECTIVE MEASUREMENTS. IEEE Transactions on Broadcasting, Vol. BC-25, No. 2. June, 1979.

14. Allnatt, J.W. QUALITY GRADING OF IMPAIRED TELEVISION PICTURES. PROC. IEE, Vol. 111, No. 3. March, 1964.

15. Prosser, R.D. and Allnatt, J.W. SUBJECTIVE QUALITY OF TELEVISION PICTURES IMPAIRED BY RANDOM NOISE. PROC. IEE, Vol. 112, No. 6. June, 1965.

16. Allnatt, John. OPINION-DISTRIBUTION MODEL FOR SUBJECTIVE RATING STUDIES. INT.J. Man-Machine Studies 5,1-15. May, 1972.

17. Siocos, C.A. SUBJECTIVE IMPAIRMENT OF TELEVISION PICTURES - CONDSIDERATIONS REGARDING THE SUMMABILITY OF IMPAIRMENT UNITS. Journal of the SMPTE, Vol. 81. December, 1972.

18. Siocos, C.A. NUMERICAL VALUES FOR SUBJECTIVE PICTURE QUALITY IN TELEVISION. Journal of the SMPTE, Vol. 80. December, 1971.

19. EUROPEAN BROADCASTING UNION - E.B.U. REVIEW. Technical 192. April, 1982.

20. Fletcher, R. and Powell, M.J.D. CONVERGENT DESCENT METHOD FOR MINIMIZATION. The Computer Journal, 6: No.2. July, 1963.

21. Allnatt, J.W. and Bragg, E.J.W. SUBJECTIVE QUALITY OF TELEVISION PICTURES IMPAIRED BY SINEWAVE NOISE AND LOW-FREQUENCY RANDOM NOISE. Proc. IEE, Vol. 115, No.3. March, 1968.

22. Cavanaugh, John R., Lessman, Anthony M. THE SUBJECTIVE EFFECT OF RANDOM NOISE SPECTRA ON 525-LINE NTSC COLOUR TELEVISION. Journal of the SMPTE, 83, 829-835. October, 1974.

REFERENCES AND SELECTED BIBLIOGRAPHY (Cont'd)

23. Limb, John O. DISTORTION CRITERIA OF THE HUMAN VIEWER. IEEE Transactions on Systems, Man, and Cybernetics, Vol. SMC-9, No. 12. December, 1979.

24. Bennett, David. SMPTE COMPONENT-CODED DIGITAL VIDEO-PICTURE QUALITY ASSESSMENTS. SMPTE Journal. October, 1981.

25. Tooms, M.S. SYSTEMS ENGINEERING CONSIDERATIONS IN THE ALL DIGITAL TELEVISION PRODUCTION AND TRANSMISSION CENTRE. Digital Coding Standards, IBA Tech. Rev. 16. March, 1982.

ACKNOWLEDGEMENT

It is a pleasure to acknowledge the continual support of Dr. G. Chouinard, the Scientific Authority for the contract. The statistical analysis of the data has been significantly improved through Dr. Chouinard's flexible input to the project implementation plan.

We also wish to thank Mr. Mike Zanichkowski of CRC for his patience and ready assistance in setting up and using the various software programs in the CRC computer.

* * *

APPENDIX 1

CRC DBS SIMULATION AND
VIDEO TAPE RECORDING LABORATORY

CRC DBS SIMULATION AND VIDEO TAPE RECORDING LABORATORY

The equipment set-up is outlined in Figure A1. It is basically constructed around a wanted signal path to which thermal noise and up to 4 interfering signals can be added. The frequency of each interfering signal can be adjusted to correspond to co-channel or adjacent channel interference. The frequency conversion from the first Intermediate Frequency (70 MHz) to a second IF around 500 MHz allowed this frequency change.

The frequency change was performed by connecting different local oscillators to the first frequency converters (mixers) on the interfering paths. This was done using a patch panel. The levels of insertion of noise and interference were adjusted with calibrated attenuators.

The NTSC video signal of the wanted path was obtained from a telecine chain ($S/N_W = 51$ dB) for the test slides. The video signals of the interfering paths were off-air signals obtained from 4 professional AM-VSB demodulators and had no synchronization relationship with the wanted signal or with each other.

The receiver pre-detection filter was a non-equalized 4 pole Chebychev type filter at 70 MHz having and equivalent noise bandwidth of 22.7 MHz. The amplitude response and group-delay characteristic of this filter are shown in Figure A2. A peak-to-peak carrier deviation of 9.52 MHz for a IV video signal was used to obtain a 30 dB FM improvement including weighting (CCIR unified) and pre-emphasis such that a $S/N_W = 42$ dB was available for a carrier-to-noise ratio of 12 dB. The standard pre-emphasis, as specified in CCIR Recommendation 405* for System M/NTSC, was used.

Two unmodulated sound sub-carriers at 5.41 MHz and 5.79 MHz were added to the video signal in the wanted and interfering paths. The deviation of the main carrier by each sound sub-carrier was adjusted at 2 MHz peak-to-peak. Considering 5.79 MHz as the top baseband frequency, the Carson bandwidth is 21.1 MHz resulting in a 7.6% extra bandwidth in the receive filter for sound sub-carriers. An equalized video filter was inserted after demodulation to reject these two sound sub-carriers. No artificial energy dispersal was used.

---

* CCIR Recommendation 405, Volume XI, XVth Plenary Assembly, GENEVA, 1982.

The video synchronisation was re-inserted before being sent to the video tape recorder. This synchronization re-insertion was found to have no effect on picture quality.

All pieces of equipment used in this set-up were aligned for best performance giving the following nominal overall performance for the wanted video path of the set-up alone:

S/N_W	$\simeq$	60 dB
Differential Gain	$<$	3%
Differential Phase	$<$	3°
2T K-factor	$<$	2%

A calibration routine was performed before the start of the tape production.

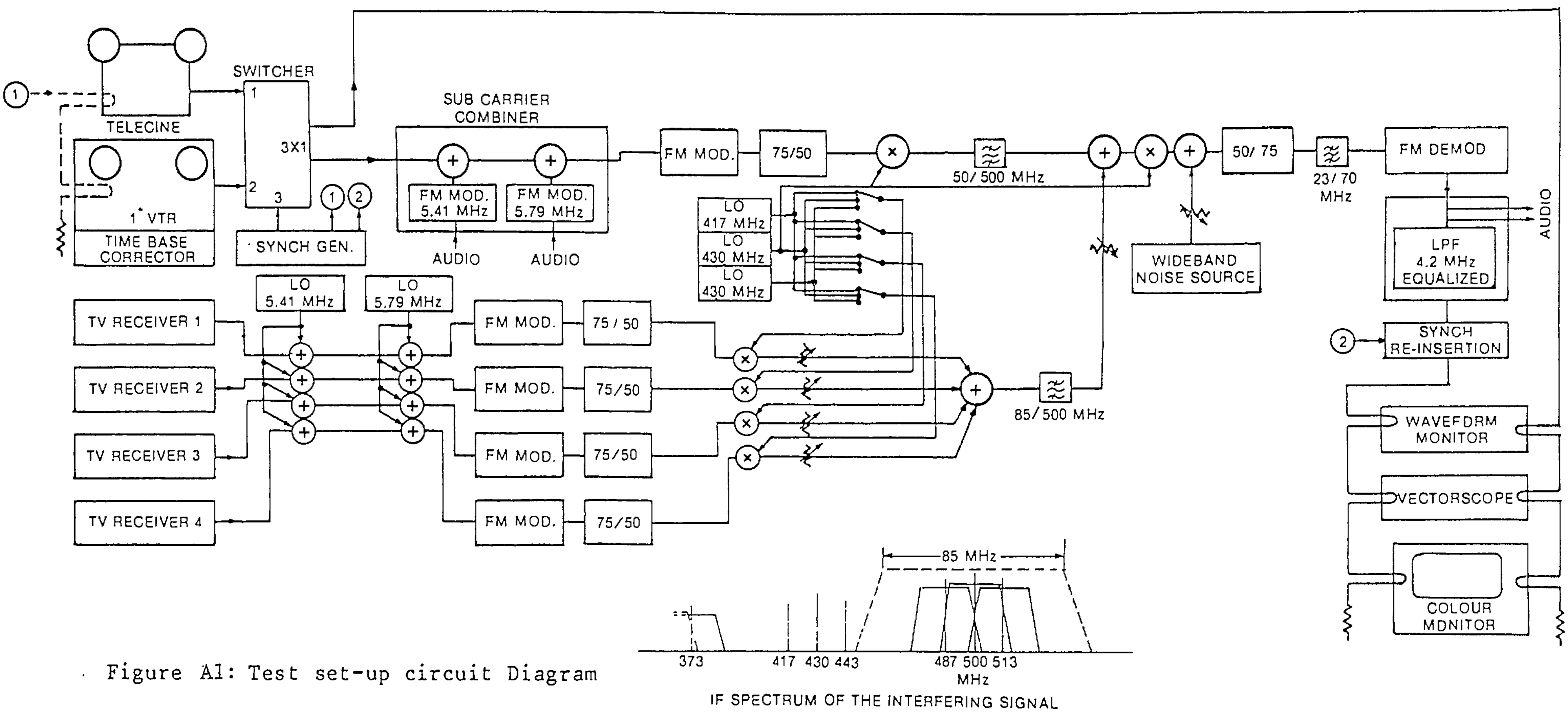


Figure A1: Test set-up circuit Diagram

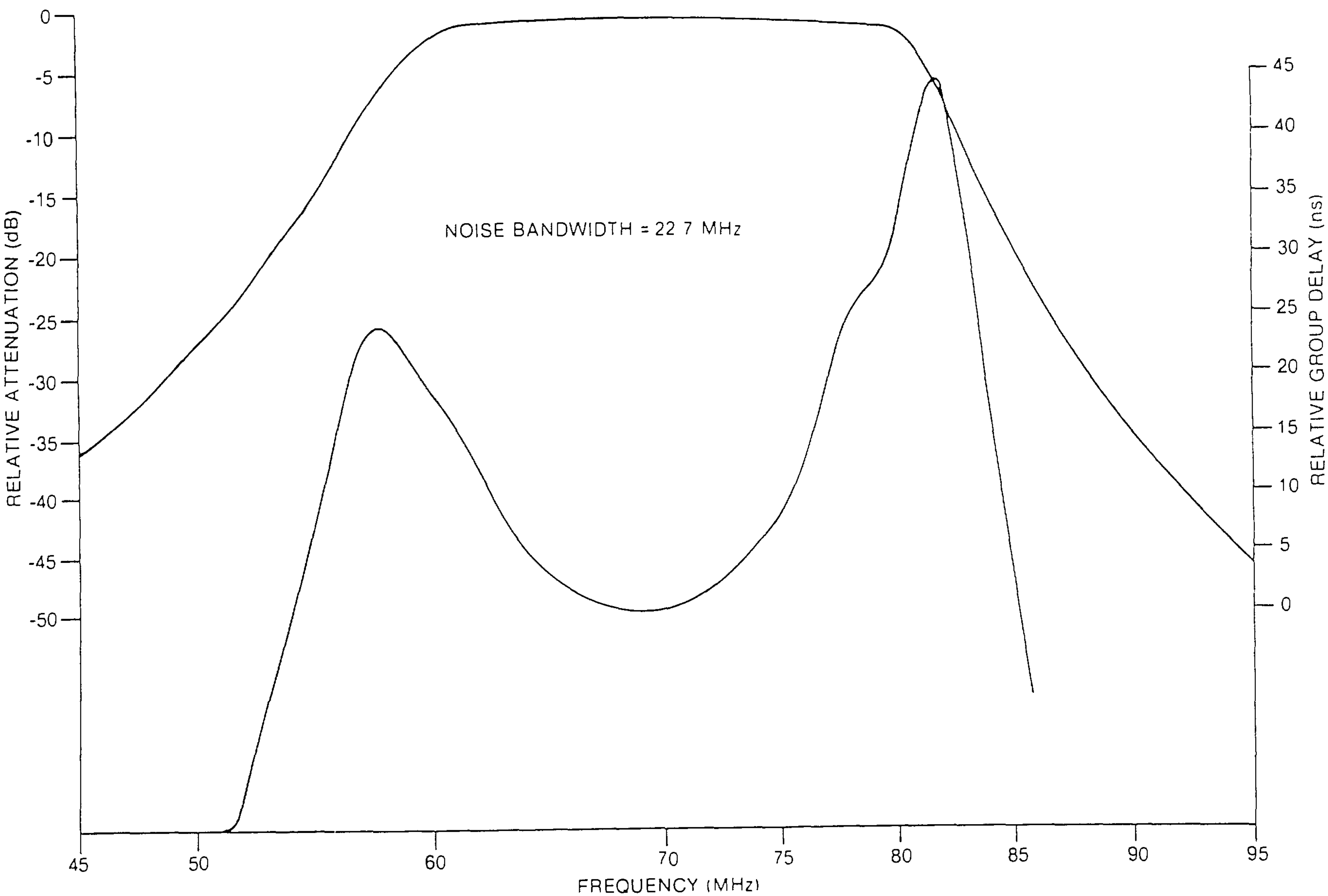


Figure A2: Frequency response of the 4-pole IF pre-detection filter

APPENDIX 2

SAMPLE VIEWER'S RECORD

V

OBSERVER # 157

1983 SUBJECTIVE ASSESSMENT OF IMPAIRED TELEVISION PICTURES

NAME OF OBSERVER KAREN DETERLING

PHONE NUMBER 995-9095

SESSION NOON

DATE JUNE 24, 1983

VIEWER POSITION 2

TAPE 3

157 F 23 21T 20/20 20/20 N 83/06/24

SCORE SHEET

PICTURE NUMBER	IMPAIRMENT GRADE					
	IMPERCEPTIBLE	PERCEPTIBLE BUT NOT ANNOYING	SLIGHTLY ANNOYING	ANNOYING	VERY ANNOYING	
1			✓			3
2		✓				4
3		✓				4
4		✓				4
5		✓				4
6	✓					5
7	✓					5
8			✓			3
9	✓					5
10			✓			3

PHILIP A. LAPP LIMITED
PROJECT 83-181

OBSERVER #

PICTURE NUMBER	IMPAIRMENT GRADE					
	IMPERCEPTIBLE	PERCEPTIBLE BUT NOT ANNOYING	SLIGHTLY ANNOYING	ANNOYING	VERY ANNOYING	
11				✓		2
12		✓				4
13	✓					5
14				✓		2
15			✓			3
16		✓				4
17	✓					5
18			✓			3
19		✓				4
20				✓		2
21			✓			3
22	✓					5
23			✓			3
24		✓				4
25				✓		2
26	✓					5
27		✓				4
28		✓				4
29			✓			3
30	✓					5

PICTURE NUMBER	IMPAIRMENT GRADE					
	IMPERCEPTIBLE	PERCEPTIBLE BUT NOT ANNOYING	SLIGHTLY ANNOYING	ANNOYING	VERY ANNOYING	
31			✓			3
32	✓					5
33	✓					5
34	✓					5
35				✓		2
36			✓			3
37		✓				4
38	✓					5
39				✓		2
40	✓					5
41				✓		2
42	✓					5
43	✓					5
44	✓					5
45	✓					5
46	✓					5
47		✓				4
48		✓				4
49		✓				4
50		✓				4

OBSERVER # ______

PICTURE NUMBER	IMPAIRMENT GRADE					
	IMPERCEPTIBLE	PERCEPTIBLE BUT NOT ANNOYING	SLIGHTLY ANNOYING	ANNOYING	VERY ANNOYING	
51		✓				4
52			✓			3
53	✓					5
54					✓	1
55	✓					5
56			✓			3
57					✓	1
58					✓	1
59	✓					5
60				✓		2
61		✓				4
62			✓			3
63		✓				4
64			✓			3
65	✓					5
66		✓				4
67	✓					5
68			✓			3
69			✓			3
70		✓				4

PICTURE NUMBER	IMPAIRMENT GRADE					
	IMPERCEPTIBLE	PERCEPTIBLE BUT NOT ANNOYING	SLIGHTLY ANNOYING	ANNOYING	VERY ANNOYING	
71			✓			3
72	✓					5
73		✓				4
74			✓			3
75	✓					5
76	✓					5
77		✓				4
78			✓			3
79				✓		2
80		✓				4

81			✓			3
82		✓				4
83		✓				4
84					✓	1
85		✓				4
86				✓		2
87		✓				4
88	✓					5
89				✓		2
90				✓		2

OBSERVER # ______

PICTURE NUMBER	IMPAIRMENT GRADE					
	IMPERCEPTIBLE	PERCEPTIBLE BUT NOT ANNOYING	SLIGHTLY ANNOYING	ANNOYING	VERY ANNOYING	
91	✓					5
92	✓					5
93		✓				4
94			✓			3
95		✓				4
96		✓				4
97	✓					5
98	✓					5
99	✓					5
100		✓				4
101			✓			3
102		✓				4
103				✓		2
104		✓				4
105	✓					5
106		✓				4
107					✓	1
108		✓				4
109				✓		2
110	✓					5

OBSERVER # ______

PICTURE NUMBER	IMPAIRMENT GRADE					
	IMPERCEPTIBLE	PERCEPTIBLE BUT NOT ANNOYING	SLIGHTLY ANNOYING	ANNOYING	VERY ANNOYING	
111			✓			3
112		✓				4

OBSERVER STATISTICS

(CHECK ONE ☑ IN EACH SECTION)

1. MALE ☐
   FEMALE ☑

2. AGE: 18-25 ☐
   26-39 ☑
   40+ ☐

3. TYPE OF EMPLOYMENT: OFFICE ☑
   MANUAL ☐
   MIXED ☐
   STUDENT ☐

OFFICE USE
Tolerant Number of categories fine.

My participation in this test, the content and purpose of which have been explained to me, is voluntary and I forego any claim on Philip A. Lapp Limited as a result of my participation in this test.

Signature Karen L. Dettrit

I acknowledge receipt of ten dollars ($10) to cover out-of-pocket expenses related to this test.

Signature Karen L. Dettrit

APPENDIX 3

INTRODUCTION REMARKS
(PRE-RECORDED TEXT)

INTRODUCTION REMARKS

SUBJECTIVE RATING OF IMPAIRED TELEVISION SCENES

THANK YOU FOR COMING TODAY LADIES AND GENTLEMEN.

WE HOPE YOU ENJOY TAKING THESE TESTS WITH US, WE THINK YOU WILL FIND THEM INTERESTING.

TESTS OF THIS KIND ARE DONE REGULARLY THROUGHOUT THE WORLD TO MEASURE WHAT THE VIEWING PUBLIC DEMANDS OF THEIR TELEVISION SERVICE. THESE PARTICULAR TESTS ARE PART OF A MUCH LARGER PROGRAM INVOLVING CANADA, THE UNITED STATES AND OTHER COUNTRIES IN THIS HEMISPHERE - TESTS THAT ARE NECESSARY TO ESTABLISH STANDARDS FOR THE QUALITY OF DIRECT-TO-HOME TELEVISION BY SATELLITE.

THE TITLE OF OUR TEST IS SUBJECTIVE RATING OF IMPAIRED TELEVISION PICTURES. LET ME EXPLAIN WHAT THE WORDS MEAN.

IMPAIRED TELEVISION PICTURES ARE TELEVISION PICTURES THAT ARE DEGRADED IN QUALITY BY THE SYSTEM USED TO BRING THEM TO THE VIEWER.

FOR EXAMPLE, A BADLY TUNED TV SET WILL IMPAIR A PICTURE - AS EVERYONE KNOWS - WHETHER ITS BECAUSE THE STATION IS NOT TUNED IN OR BECAUSE SOMEONE HAS ADJUSTED THE COLOUR KNOBS AND MADE ALL THE PEOPLE LOOK GREEN! ANOTHER COMMON CAUSE OF IMPAIRMENT IS A WEAK SIGNAL THAT CAN ONLY PRODUCE A PICTURE WITH SNOW IN IT. THERE ARE MANY OTHER KINDS OF IMPAIRMENT - SOME PRODUCE A VENETIAN BLIND EFFECT, SOME CAUSE ANOTHER PICTURE TO APPEAR IN THE BACKGROUND. MOST OF US HAVE SEEN ONE KIND OR ANOTHER - AND BEEN ANNOYED BY THEM.

NOTICE THAT IN WHAT WE HAVE SAID ABOUT IMPAIRMENTS WE HAVE NOT REFERRED TO THE SCENE ITSELF. THE REASON FOR THIS IS SIMPLE - THE SYSTEM THAT BRINGS YOU THE PICTURES CAN'T DO ANYTHING ABOUT THE ORIGINAL PRODUCT. IT CAN'T MAKE AN UGLY PERSON HANDSOME, OR WELL-DRESSED, AND IT CAN'T CORRECT A STAGE SETTING THAT HAS THE WRONG BLEND OF COLOURS. THESE FAULTS OCCUR DURING PRODUCTION, AND WE IGNORE THEM IN THESE TESTS. WE WILL CONCENTRATE ON THE IMPAIRMENTS CAUSED BY THE SYSTEM THAT DELIVERS THE PICTURES TO THE SCREEN.

SO FAR I HAVE TALKED ABOUT IMPAIRMENTS, NOW A WORD ABOUT SUBJECTIVE RATING.

SUBJECTIVE RATING MEANS JUST WHAT THE WORDS SAY - HOW DO THE IMPAIRMENTS IN A SCENE AFFECT YOU, PERSONNALLY, AS A VIEWER. YOU ARE NOT BEING ASKED YOUR OPINION ON HOW AN IMPAIRMENT MIGHT AFFECT ANOTHER INDIVIDUAL OR A GROUP OF INDIVIDUALS. EACH PERSON IS BEING ASKED TO ASSESS HOW THE PICTURE AFFECTS THEM. BECAUSE ITS HOW THE SCENE AFFECTS YOU THAT COUNTS, THERE IS NO RIGHT OR WRONG LIKE THERE MIGHT BE IN AN EXAMINATION - EVERYONE IS RIGHT AS LONG AS THEY TELL IT LIKE IT IS.

NOW A WORD ABOUT THE TESTS. YOU WILL BE SHOWN SCENES FROM FOUR SLIDES DURING THE TESTS. MOST OF THE TIME THESE SCENES WILL BE IMPAIRED IN VARIOUS DEGREES BY DIFFERENT KINDS OF IMPAIRMENTS.

EACH SLIDE WILL BE SHOWN ABOUT 25 TIMES. MIXED IN WITH THESE IMPAIRED SCENES OCCASIONALLY WILL BE UNIMPAIRED VERSIONS.

THE TYPE OF IMPAIRMENT NEED NOT CONCERN YOU BECAUSE, AS WE SAID BEFORE, WE ARE LOOKING FOR ITS EFFECT ON YOU, REGARDLESS OF WHAT IT IS.

THERE IS NO RELATION BETWEEN ONE SCENE AND THE NEXT BECAUSE THE SCENES, THE IMPAIRMENTS, AND THE VARIOUS LEVELS OF IMPAIRMENT WILL BE MIXED UP IN RANDOM ORDER.

NONE OF THE SCENES HAS ANY SOUND BECAUSE WE WANT YOU TO CONCENTRATE ON THE PICTURE.

SO FAR WE HAVE SPOKEN ABOUT WHY WE ARE DOING THE TESTS, WHAT IMPAIRMENTS AND SUBJECTIVE RATING ARE AND WHAT YOU WILL BE SEEING DURING THE TESTS. THE FINAL PART OF THIS INTRODUCTION IS AN EXPLANATION OF HOW THE TEST IS RUN.

EACH SCENE WILL BE SHOWN FOR TEN SECONDS DURING WHICH YOU LOOK AT IT. THERE IS THEN 15 SECONDS WITH NO PICTURE. YOU MARK YOUR OPINION DURING THIS 15 SECONDS. TO REPEAT: 10 SECONDS FOR VIEWING, 15 SECONDS FOR DECIDING AND MARKING.

MARK YOUR ASSESSMENT OF THE SCENE ON YOUR RATING SHEET. YOU WILL SEE ON YOUR RATING SHEET THAT YOU ARE ALLOWED ONE OF 5 OPINIONS:

- "IMPERCEPTIBLE" - THAT MEANS YOU DON'T SEE ANY IMPAIRMENT,
- "PERCEPTIBLE, BUT NOT ANNOYING",
- "SLIGHTLY ANNOYING",
- "ANNOYING",
- "VERY ANNOYING".

YOU MAY FEEL UNCERTAIN SOMETIMES AS TO WHICH COLUMN IS BEST FOR A SCENE, BUT WE EXPECT VARIATIONS FROM ONE PERSON TO ANOTHER ANYWAY SO MARK IT AS HONESTLY AS YOU CAN AND DON'T WORRY ABOUT IT. THE NUMBER OF EACH SCENE WILL BE ANNOUNCED BEFORE IT IS SHOWN SO IF YOU MARK YOUR SCORE FOR THE WRONG SCENE YOU CAN CORRECT YOURSELF ON THE NEXT ONE. AFTER APPROXIMATELY 50 TEST SCENES HAVE BEEN SHOWN - THAT IS, AFTER ABOUT 20 MINUTES OF TEST, WE WILL STOP THE VIDEO TAPE RECORDER AGAIN AND TAKE A SHORT BREAK.

IMMEDIATELY FOLLOWING THIS INTRODUCTION, AND BEFORE WE BEGIN THE FORMAT TEST, WE WILL SHOW YOU THE FOUR SLIDES WITH AND WITHOUT IMPAIRMENT. THE IMPAIRMENT WILL BE FAMILIAR TO YOU WHEN YOU SEE IT.

THIS SEQUENCE ONLY TAKES A COUPLE OF MINUTES. WHEN IT IS OVER WE WILL STOP THE VIDEO TAPE RECORDER FOR A MINUTE OR TWO TO MAKE SURE EVERYONE UNDERSTANDS WHAT WE'RE DOING.

WHEN ANY QUESTIONS HAVE BEEN ANSWERED WE WILL START THE TEST.

TO REVIEW THE IMPORTANT POINTS - STAY RELAXED, DON'T WORRY ABOUT A PARTICULAR RATING. KEEP YOUR ASSESSMENT PERSONAL, THAT IS, KEEP IT SUBJECTIVE. FINALLY ENJOY YOURSELF, AND THANK YOU FOR VOLUNTEERING.

THE SAMPLE SCENES WILL APPEAR IN APPROXIMATELY 30 SECONDS.

APPENDIX 4

HISTOGRAM DATA FROM 97 VIEWERS

HISTOGRAM DATA FROM 97 VIEWERS

SLIDE	KEY	5	4	3	2	1	POP	MOS	SIGMOS	R95	MEDIAN
1	-000-00-00-00	130	52	11	1	0	194	4.603	.619	.088	4.754
2	-000-00-00-00	156	35	3	0	0	194	4.789	.445	.063	4.878
3	-000-00-00-00	91	57	12	0	0	160	4.494	.632	.099	4.621
4	-000-00-00-00	132	27	1	0	0	160	4.819	.401	.063	4.894
1	-000-00-47-00	76	16	3	2	0	97	4.711	.625	.126	4.862
2	-000-00-47-00	34	55	6	1	0	96	4.271	.620	.125	4.245
3	-000-00-47-00	54	35	7	1	0	97	4.464	.674	.136	4.602
4	-000-00-47-00	70	23	4	0	0	97	4.680	.548	.110	4.807
1	-000-00-43-00	52	39	4	2	0	97	4.454	.674	.135	4.567
2	-000-00-43-00	9	60	21	4	2	96	3.729	.770	.156	3.850
3	-000-00-43-00	41	47	7	1	1	97	4.299	.734	.148	4.340
4	-000-00-43-00	52	41	4	0	0	97	4.495	.577	.116	4.567
1	-000-00-37-00	3	56	30	7	1	97	3.546	.718	.144	3.688
2	-000-00-37-00	13	26	33	21	4	97	3.237	1.063	.214	3.212
3	-000-00-37-00	3	39	43	10	2	97	3.320	.781	.157	3.349
4	-000-00-37-00	10	49	33	4	0	96	3.677	.714	.144	3.724
1	-000-00-33-00	0	18	36	33	10	97	2.639	.899	.181	2.653
2	-000-00-33-00	0	2	15	47	33	97	1.856	.746	.150	1.830
3	-000-00-33-00	12	26	32	22	5	97	3.186	1.078	.217	3.172
4	-000-00-33-00	0	8	44	35	9	96	2.531	.777	.157	2.591
1	-000-00-27-00	0	0	0	14	82	96	1.146	.353	.071	1.085
2	-000-00-27-00	0	0	13	23	61	97	1.505	.720	.145	1.295
3	-000-00-27-00	0	0	1	25	71	97	1.278	.471	.095	1.183
4	-000-00-27-00	0	0	0	13	81	94	1.138	.345	.070	1.080
1	-010-00-00-28	68	24	5	0	0	97	4.649	.575	.116	4.787
2	-010-00-00-28	51	43	3	0	0	97	4.495	.558	.112	4.549
3	-010-00-00-28	50	37	9	1	0	97	4.402	.698	.140	4.530
4	-010-00-00-28	77	18	2	0	0	97	4.773	.465	.094	4.870
1	-010-00-00-22	36	53	6	0	0	95	4.316	.585	.119	4.283
2	-010-00-00-22	20	53	20	3	1	97	3.907	.788	.158	3.962
3	-010-00-00-22	37	37	18	4	1	97	4.082	.904	.182	4.189
4	-010-00-00-22	56	35	5	0	0	96	4.531	.594	.120	4.643
1	-010-00-00-14	0	34	39	21	3	97	3.072	.828	.166	3.128
2	-010-00-00-14	0	4	39	44	10	97	2.381	.724	.146	2.375
3	-010-00-00-14	3	55	31	7	1	97	3.536	.719	.145	3.673
4	-010-00-00-14	1	33	40	19	4	97	3.082	.858	.172	3.137

HISTOGRAM DATA FROM 97 VIEWERS (cont'd)

SLIDE	KEY	5	4	3	2	1	POP	MOS	SIGMOS	R95	MEDIAN
1	-010-00-00-08	0	1	12	37	47	97	1.660	.731	.147	1.541
2	-010-00-00-08	0	0	8	42	47	97	1.598	.637	.128	1.536
3	-010-00-00-08	0	4	41	39	12	96	2.385	.755	.153	2.423
4	-010-00-00-08	0	3	14	46	34	97	1.856	.773	.155	1.815
1	-010-00-00-03	0	0	2	12	83	97	1.165	.423	.085	1.084
2	-010-00-00-03	0	0	0	5	91	96	1.052	.222	.045	1.027
3	-010-00-00-03	0	2	8	31	56	97	1.546	.732	.147	1.366
4	-010-00-00-03	0	1	3	9	84	97	1.186	.524	.105	1.077
1	-030-00-00-32	69	25	3	0	0	97	4.680	.528	.106	4.797
2	-030-00-00-32	60	33	4	0	0	97	4.577	.571	.115	4.692
3	-030-00-00-32	58	32	7	0	0	97	4.526	.627	.126	4.664
4	-030-00-00-32	75	20	2	0	0	97	4.753	.477	.096	4.853
1	-030-00-00-26	50	40	6	0	0	96	4.458	.611	.123	4.540
2	-030-00-00-26	23	61	11	2	0	97	4.082	.653	.131	4.082
3	-030-00-00-26	49	39	8	0	0	96	4.427	.641	.130	4.520
4	-030-00-00-26	62	34	1	0	0	97	4.629	.504	.101	4.718
1	-030-00-00-18	1	37	38	14	7	97	3.113	.918	.185	3.224
2	-030-00-00-18	1	19	47	26	4	97	2.866	.808	.162	2.894
3	-030-00-00-18	10	61	18	4	4	97	3.711	.861	.173	3.869
4	-030-00-00-18	1	37	44	12	3	97	3.216	.789	.159	3.261
1	-030-00-00-12	0	0	6	33	27	66	1.682	.631	.154	1.682
2	-030-00-00-12	0	0	6	37	54	97	1.505	.611	.123	1.398
3	-030-00-00-12	0	0	38	43	16	97	2.227	.711	.143	2.256
4	-030-00-00-12	0	3	27	64	34	128	1.992	.755	.132	1.969
1	-010-00-46-28	69	26	2	0	0	97	4.691	.505	.101	4.797
2	-010-00-46-28	19	59	14	3	2	97	3.928.	.803	.161	4.000
3	-010-00-46-28	42	50	4	0	0	96	4.396	.568	.115	4.380
4	-010-00-46-28	72	24	1	0	0	97	4.732	.466	.094	4.826
1	-010-00-46-22	31	56	10	0	0	97	4.216	.613	.123	4.188
2	-010-00-46-22	6	65	20	2	4	97	3.691	.791	.159	3.846
3	-010-00-46-22	30	51	12	3	1	97	4.093	.801	.161	4.137
4	-010-00-46-22	40	52	4	1	0	97	4.351	.610	.123	4.337
1	-010-00-46-14	0	21	48	24	4	97	2.887	.785	.158	2.927
2	-010-00-46-14	0	6	43	39	9	97	2.474	.747	.150	2.512
3	-010-00-46-14	4	39	39	11	3	96	3.312	.845	.171	3.372
4	-010-00-46-14	1	26	45	22	3	97	3.000	.812	.163	3.022

HISTOGRAM DATA FROM 97 VIEWERS (cont'd)

SLIDE	KEY	5	4	3	2	1	POP	MOS	SIGMOS	R95	MEDIAN
1	-010-00-46-08	0	1	6	33	26	66	1.727	.686	.167	1.712
2	-010-00-46-08	0	0	7	33	57	97	1.485	.628	.126	1.351
3	-010-00-46-08	0	7	30	41	19	97	2.258	.853	.171	2.220
4	-010-00-46-08	0	1	21	45	30	97	1.928	.750	.151	1.911
1	-100-15-00-05	52	33	7	4	1	97	4.351	.862	.173	4.567
2	-100-15-00-05	71	25	1	0	0	97	4.722	.471	.095	4.817
3	-100-15-00-05	58	29	8	1	1	97	4.464	.774	.156	4.664
4	-100-15-00-05	32	25	20	13	6	96	3.667	1.239	.250	3.860
1	-100-15-00-03	30	29	17	14	7	97	3.629	1.254	.252	3.862
2	-100-15-00-03	35	24	20	15	3	97	3.753	1.184	.238	3.938
3	-100-15-00-03	38	49	8	1	1	97	4.258	.736	.148	4.286
4	-100-15-00-03	37	41	15	4	0	97	4.144	.825	.166	4.220
1	-100-15-00-01	0	2	14	42	38	96	1.792	.763	.154	1.738
2	-100-15-00-01	7	24	20	36	10	97	2.814	1.134	.228	2.625
3	-100-15-00-01	13	20	27	30	6	96	3.042	1.145	.231	2.944
4	-100-15-00-01	15	15	19	22	26	97	2.701	1.408	.283	2.526
1	-100-15-00--1	0	0	5	13	78	96	1.240	.535	.108	1.115
2	-100-15-00--1	0	5	11	29	50	95	1.695	.871	.177	1.450
3	-100-15-00--1	1	15	24	31	26	97	2.320	1.061	.213	2.226
4	-100-15-00--1	0	1	22	20	54	97	1.691	.854	.172	1.398
1	-100-13-00-09	75	19	2	1	0	97	4.732	.547	.110	4.853
2	-100-13-00-09	71	23	3	0	0	97	4.701	.521	.105	4.817
3	-100-13-00-09	68	25	3	0	0	96	4.677	.530	.107	4.794
4	-100-13-00-09	71	24	2	0	0	97	4.711	.497	.100	4.817
1	-100-13-00-07	68	23	6	0	0	97	4.639	.595	.120	4.787
2	-100-13-00-07	75	21	1	0	0	97	4.763	.449	.090	4.853
3	-100-13-00-07	55	36	4	2	0	97	4.485	.675	.136	4.618
4	-100-13-00-07	76	18	3	0	0	97	4.753	.498	.100	4.862
1	-100-13-00-05	20	17	11	28	21	97	2.866	1.462	.294	2.482
2	-100-13-00-05	21	30	16	23	7	97	3.361	1.253	.252	3.583
3	-100-13-00-05	40	33	14	9	1	97	4.052	1.009	.203	4.242
4	-100-13-00-05	29	16	24	15	13	97	3.340	1.391	.280	3.354
1	-100-13-00-03	0	0	6	24	67	97	1.371	.598	.120	1.224
2	-100-13-00-03	3	16	19	17	42	97	2.186	1.238	.249	1.882
3	-100-13-00-03	18	18	19	15	27	97	2.845	1.474	.296	2.842
4	-100-13-00-03	6	23	11	17	39	96	2.375	1.379	.279	2.029

HISTOGRAM DATA FROM 97 VIEWERS (cont'd)

SLIDE	KEY	5	4	3	2	1	POP	MOS	SIGMOS	R95	MEDIAN
ALL	-000-00-00-00	509	171	27	1	0	708	4.678	.551	.041	4.616
ALL	-000-00-47-00	234	129	20	4	0	387	4.532	.644	.065	4.673
ALL	-000-00-43-00	154	187	36	7	3	387	4.245	.757	.076	4.289
ALL	-000-00-37-00	29	170	139	42	7	387	3.444	.850	.086	3.532
ALL	-000-00-33-00	12	54	127	137	57	387	2.553	1.003	.101	2.496
ALL	-000-00-27-00	0	0	14	75	295	384	1.268	.519	.052	1.151
ALL	-010-00-00-28	246	122	19	1	0	388	4.580	.598	.060	4.711
ALL	-010-00-00-22	149	178	49	7	2	385	4.208	.768	.078	4.256
ALL	-010-00-00-14	4	126	149	91	18	388	3.018	.886	.089	3.070
ALL	-010-00-00-08	0	8	75	164	140	387	1.873	.789	.079	1.826
ALL	-010-00-00-03	0	3	13	57	314	387	1.238	.543	.055	1.116
ALL	-030-00-00-32	262	110	16	0	0	388	4.634	.561	.056	4.760
ALL	-030-00-00-26	184	174	26	2	0	386	4.399	.637	.064	4.448
ALL	-030-00-00-18	13	154	147	56	18	388	3.227	.900	.090	3.316
ALL	-030-00-00-12	0	3	77	177	131	388	1.876	.743	.075	1.856
ALL	-010-00-46-28	202	159	21	3	2	387	4.437	.680	.068	4.542
ALL	-010-00-46-22	107	224	46	6	5	388	4.088	.751	.076	4.112
ALL	-010-00-46-14	5	92	175	96	19	387	2.917	.853	.086	2.949
ALL	-010-00-46-08	0	9	64	152	132	357	1.860	.794	.083	1.806
ALL	-100-15-00-05	213	112	36	18	8	387	4.302	.961	.097	4.592
ALL	-100-15-00-03	140	143	60	34	11	388	3.946	1.057	.106	4.122
ALL	-100-15-00-01	35	61	80	130	80	386	2.588	1.232	.124	2.369
ALL	-100-15-00--1	1	21	62	93	208	385	1.738	.935	.094	1.425
ALL	-100-13-00-09	285	91	10	1	0	387	4.705	.524	.053	4.821
ALL	-100-13-00-07	274	98	14	2	0	388	4.660	.572	.058	4.792
ALL	-100-13-00-05	110	96	65	75	42	388	3.405	1.358	.136	3.625
ALL	-100-13-00-03	27	57	55	73	175	387	2.194	1.332	.134	1.753

SLIDE	KEY	5	4	3	2	1	POP	MOS	SIGMOS	R95	MEDIAN
ALL	ALL	3195	2752	1622	1504	1667	10740	3.401	1.431	.027	3.677

APPENDIX 5

SOFTWARE PROGRAMS FOR STATISTICAL ANALYSIS OF HISTOGRAM DATA

The software developed to analyse the histogram data comprises 5 basic programs elements with certain options.

1. Histogram data, as derived using the original CRC software was prepared for analysis by rebuilding it into four series of files labelled INDATA, NNDATA, FIDATA and FID. INDATA files contain a limited set of results of earlier viewer tests at CRC with two groups of concerned viewers. NNDATA files contain raw, unscreened data from a limited number of histograms from the non-experts tested in the present project. FIDATA files contain final data from all 30 histograms of non-expert viewer results. There are six FIDATA files for aggregated results of all slides for each of the six impairment series and 24 FIDATA additional files for each of the six series for each of the four slides. The six FID files are a supplementary set of files of reduced data for the Girl-in-Green-Dress slide. In the FID files the weak histogram for the top anchor presentation of this Girl-in-Green-Dress slide at scene #11 in Tape #2 has been deleted as a consequence of which there is only one top anchor in Tape #2.

   Figure 1 is a reproduction of two of the FIDATA files. FIDATA1 is the histogram data for the aggregate of all slides impaired by noise only. Each row of the first six rows is a histogram of votes corresponding to a particular impairment level. The columns in these first six rows represent the number of viewers rating the scene in each of the 5 rating categories permitted. For example, at C/N = 47 dB, there are 237 'imperceptible' ratings, 129 'perceptible but not annoying' ratings, and so on.

   Row seven is the levels of carrier-to-noise interference for each of the histograms.

   Row 8 is a weighting factor used in one of the options (PROB) for deriving the μ's and σ for the series.

   Row 9 is the lowest, highest, and increment size of S/N assigned for calculating MOSQ by quantization from a fixed σ and the logistic curve for μ. These MOSQ values were then used in the preparation of the final curves.

```
12:23 AUG 16 '83 FIDATA1.STA0130X

   1 -      1.000 509 171 27 1 0
   2 -      2.000 234 129 20 4 0
   3 -      3.000 154 187 36 7 3
   4 -      4.000 29 170 139 42 7
   5 -      5.000 12 54 127 137 57
   6 -      6.000 0 0 14 75 295
   7 -      7.000 51 47 43 37 33 27
   8 -      8.000 1
   9 -      9.000 29 75 2
```

```
12:23 AUG 16 '83 FIDATA5.STA0130X

   1 -      1.000 509 171 27 1 0
   2 -      2.000 213 112 36 18 8
   3 -      3.000 140 143 60 34 11
   4 -      4.000 35 61 80 130 80
   5 -      5.000 1 21 62 93 208
   6 -      6.000 51 5 3 1 -1
   7 -      7.000 1
   8 -      8.000 -2 30 1
```

Figure 1: Typical File of Histogram Data

FIDATA5 is for an impairment series with five data points and hence 5 histograms.

The various files of histogram data were used one at a time as input to a program labelled PROA6 or PROA5, 6 or 5 depending on the number of histograms used to create the data file.

2. The PROA program is described in the printed "INFO", "INSTRUCTIONS", and program listing at the end of this appendix. Its basic purpose is to compute the μ's and an average value of σ in accordance with the Lessman-Cavanaugh algorithm of Reference 8 at each of the five or six objective impairment test points.

3. Following calculation of the μ's and a fixed σ a smooth logistic curve of the form

$$\mu = 1 + 4/[1/U + \exp(D_m - D)/K]$$

was fitted through the experimental μ values.

4. Quantized means were evaluated from σ and the 'smoothed' μ's for subsequent plotting.

   Note: This software element has been duplicated as a separate program called MOSQ. The program calls for U, Dm and K, σ, and the lowest, highest, and incremental value of objective impairment desired. The program calculates from the logistic curve at each impairment level. It then combines μ and σ in the Gaussian distribution to calculate the quantized means.

5. An additional short table of MOSQ's were calculated from smoothed μ's at each of the original objective impairment points and a logistic fit of the same form as that for μ was attempted (with some success). Note: this logistic <u>was not used</u> as a source of MOSQ data because of <u>uncertainty</u> as to its relationship, mathematically speaking, to the logistic for μ. Further analysis is needed to establish this relationship.

A variation of PROA, labelled PROB was developed to accommodate files with a histogram with votes in only two categories. In earlier test data such a histogram was found to produce an invalid result for σ and μ in Lessman-Cavanaugh's first minimization step. In the revised algorithm, σ is not calculated for each histogram and then averaged, it is set as a variable having the same value for all histograms in the file. The weighting factor noted earlier emphasizes the importance of minimizing $(MOSQ-MOS)^2$ relative to minimizing σ in the PROB version. PROB was not needed in the analysis reported here.

Program listings for all of the above software are included in this appendix.

To run the software, the data file is SET to 105 and the appropriate program, PROA6, PROA5, PROB6 or PROB5 selected for execution.

When used separately, program MOSQ prompts for U, Dm, K, σ, and the lowest and highest objective impairment levels and the incremental values.

* * *

PROA_LM AND PROB_LM ARE THE TWO COMPILED VERSIONS OF THE PROGRAM. PROA_LM CALCULATES THE MEANS ACCORDING TO J.R. CAVANAUGH'S METHOD (IN LESSMAN'S PAPER), AND PROB_LM DOES A SIMULTANEOUS ESTIMATION OF THE SIX MU'S AND UNIQUE SIGMA BY MINIMIZING THE SQUARES OF THE DIFFERENCES BETWEEN THE EXPERIMENTAL VALUES OF THE MEAN AND THE MEANS OF THE QUATITIZED DISTIRIBUTIONS (WHERE THESE DISTRIBUTIONS HAVE THE PARAMETERS OF THE SIX MU'S AND THE SAME SIGMA). GIVEN AN ASSUMPTION OF THE SAME STANDARD DEVIATION FOR EACH OF THE (SIX) CASES, THIS SECOND METHOD MIGHT SEEM MORE LOGICAL. FURTHERMORE SOME DATA WILL NOT BE USABLE BY CAVANAUGH'S METHOD (I.E. WHEN A GIVEN C/I YEILDS RATINGS IN ONLY TWO CATEGORIES). HOWEVER THERE REMAINS THE QUESTION OF THE RELATIVE WEIGHTING OF THE SIGMAS AND THE MUS SO PROB_LM READS AN ADDITIONAL PARAMETER THAT IT MULTIPLIES THE SIGMAS BY (I.E. 1 GIVES EQUAL WEIGHT,.5 GIVES HALF WEIGHTING TO THE SIGMAS, ETC.).

IN GENERAL THE COMPILED VERSION OF A PROGRAM WILL HAVE THE SAME NAME AS ITS EDITABLE VERSION, FOLLOWED BY _BI. THE TWO LINK PROGRAMS WILL LINK THE APROPRIATE COMPILED VERSIONS OF VARIOUS PROGRAMS INTO PROA_LM OR PROB_LM. PROA AND PROB ARE THE (RESPECTIVE) MAIN PROGRAMS OF PROA_LM AND PROB_LM; PRO1, PRO2, PRO3 AND PRO4 SUBROUTINES OF THESE, AND THE SIX SUB PROGRAMS CONTAIN THE FUNCTIONS THAT ZXMIN (AN IMSL ROUTINE USED IN ITS DOUBLEPRECISION VERSION) CALLS.

SIZ AND PARA ARE TWO (INCLUDE) FILES THAT ARE INCLUDED IN MOST OF THE PROGRAMS: SIZ CONTAINS PARAMETERS STATEMENTS FOR SIZ2 AND SIZ1 WHICH REPRESENT RESPECTIVELY THE NUMBER OF RATINGS POSSIBLE (5 IN THIS CASE) AND THE NUMBER OF DIFFERENT C/I RATIOS FOR WHICH RATINGS WERE TAKEN FOR EACH TEST CONDITION. (IN MATRIX FORM, SIZ2 IS THE NUMBER OF COLUMNS AND SIZ1 IS THE NUMBER OF ROWS.) FOR INPUT DATA OF DIFFERENT SHAPE, SIMPLY CHANGE THESE VALUES, RECOMPILE EACH SEGMENT (ANYTHING THAT DOESN'T HAVE A '_' IN ITS NAME, BUT NOT THE TWO INCLUDE FILES), AND XEQ THE LINK FILES. THE RESULTING PROGRAMS WILL WORK, HOWEVER THE OUTPUT FORMAT WILL NOT LOOK VERY GOOD IF YOU CHANGE SIZ2.

PARA CONTAINS TWO ADDITIONAL PARAMETERS: NSIG (INTEGER) WHICH IS THE NUMBER OF SIGNIFICANT DIGITS THAT ZXMIN WILL WILL RETURN (THIS SEEMS TO BE A GUARANTEE: ACTUAL ESTIMATED ACCURACY WILL BE ABOUT 15 DIGITS), AND LDCR WHICH IS A CRITERION THAT REJECTS PAIRS OF MOS AND SIGMOS IF THEY

WILL NOT CONVERGE (WHEN ONLY TWO DIFFERENT RATINGS HAVE BEEN CHOSEN). THIS OF COURSE IS ONLY USED IN PROA_LM.

FINALLY, THE END OF BOTH PROGRAMS CALCULATES THE PARAMETERS OF A LEAST SQUARES FITTED LOGISTIC EQAUTION OF FORM MU=1+4/((1/U)+EXP((D-C/R)/K).

ALSO FINALLY, ZXMIN REQUIRES INITIAL ESTIMATES OF ITS PARAMETERS: FOR THE ESTIMATIONS OF MUS AND SIGMAS, THE MOS AND SIGMOS VALUES ARE USED, FOR THE ESTIMATION OF U, D, AND K, U IS ESTIMATED TO BE ONE, D IS ESTIMATED WITH A SORT OF LINEAR GUESS BASED ON THE DATA (D IS THE C/I AT WHICH MU IS 3), AND K IS ESTIMATED TO BE 5 (BECAUSE IT WORKS MOST OF THE TIME).

EVEN MORE FINALLY THE SHREWD OBSERVER WILL NOTICE LITTLE NUMBERS IN CURLY BRACKETS APPEARING IN THE OUTPUT. THIS IS INFORMATION ON THE PERFORMANCE OF ZXMIN AND HAS THE FOLLOWING FORMAT:

{no. of function calls, estd. no. of sig. digits, value of function}

(possibly followed by the values of the parameters}

IN THE CASE THAT ZXMIN REALLY HAS PROBLEMS IT WILL PRINT A MESSAGE SAYING IER ERROR NO. WHATEVER, MOST OF WHICH MEAN THAT IT DIDN'T CONVERGE. THIS IS NOT EXPECTED TO HAPPEN BUT MAY BE POSSIBLE WITH CERTAIN DATA SETS.

FINAL FINAL NOTE: IF YOU WISH TO CHANGE THE PROGRAM TO WRITE INTO A FILE, MOST OF THE WRITES ARE PRINTS IN THE MAIN PROGRAMS, BUT THEY ARE ALSO IN PRO3 (THE VALUES OF U,D,K ARE PRINTED OUT HERE), ALTHOUGH THEY ARE ALSO SENT BACK TO THE MAIN PROGRAM, SO YOU CAN INSERT ANY WRITES OF THE IMPORTANT ANSWERS IN PROA AND PROB.

UPDATE(JULY 6,1983): DUE TO THE FREQUENCY OF FAILURE OF THE PARAMETER ESTIMATES TO CONVERGE THE PROGRAM HAS BEEN MODIFIED. THE CHIEF CULPRIT SEEMS TO BE A POOR ESTIMATE OF K INITIALLY, SO NOW IF ZXMIN DOES NOT ESTIMATE MORE THAN 4 SIGNIFICANT DIGITS IN ITS FINAL ANSWERS, THE PROGRAM WILL CHOSE A NEW INITIAL VALUE OF K AND TRY AGAIN. THIS WILL BE DONE FOR K=5,4,3,2,1,10,9,8,7,6 AND THEN IT WILL TRY TO READ A VALUE FOR ITS INITAL ESTIMATE IF ALL THE PREVIOUS ONES FAIL. IN THIS FINAL CASE,IT WILL PROBABLY CRASH BY RUNNING OUT OF DATA IN THE FILE IT IS READING FROM, SO JUST ADD AN ESTIMATE ONTO THE END OF YOUR DATA AND TRY RUNNING AGAIN IF YOU WANT. THE LIKELIHOOD OF THIS OCCURANCE SEEMS QUITE SMALL WITH ANY REASONABLE DATA (SO FAR THE FARTHEST IT HAD TO GO WAS TO K=4) SO DON'T WORRY TO MUCH ABOUT THIS IF YOU DON'T HAVE TO.

Instructions for running PROA_LM AND PROB_LM:

To run a program type its name followed by a period. First however, the program requires input which may be given to it in two ways: directly and indirectly.

1. THE DIRECT METHOD

   Normally if the program is just run, it will prompt the user to enter all the data from the keyboard with a ?. It will continue to give a prompt until it has enough information to run, i.e 36 integers (and a real if you are running PROB_LM), or until program execution is interrupted (hit the break key a few times if this is what you want). The order of the input is as follows: Each line of scores for the given C/I ratios (or whatever), i.e 6 lines of 5 integers each (although the lines do not matter, only the order), followed by the six ratios (in the order of the scores to which they pertain); these may be integers or reals if you like (stored as double precision). In the case of PROB of course it asks for another number which is the weight given to the sigmas when doing the simultaneous estimation.

2. THE INDIRECT METHOD

   This is the same as the direct method as far as the computer cares; instead of typing in the data, you store it in a FILE and tell the computer to get its data form there. Thus the input order is the same. To build a file, type: B INDATAFILE where INDATAFILE is any name you wish to give the set of data (thus you can have many of these with different names). This will prompt with a line number and you can start typing in the data. A carriage return on an empty line will put you back to the ! To edit a datafile, type: E INDATAFILE which will put you in edit mode. When prompted by the *, you can do one of:

   - RR linenumber - types out that line and permits you to delete and add characters to that line
   - IN linenumber - prompts with linenumber. Entering any characters will erase previous information on that line and store new line. Useful for inserting lines between exixting lines. May prompt with the next line (if empty).
   - and other stuff if you know how...

   To get out of edit mode simply type E (or END).

Once your data file is successfully built and edited, and you are back in !, type SET 105 INDATAFILE, which sets the indatafile to be read instead of the computer asking for input. Thus if you haven't given it enough data it will give you an error. Now you can run the program (which will echo the input for you to double check).

UPDATE: JULY 28,1983

There are now two other programs for different sized(5 by 5) input. Unfortunately your account ran out of disc space so I could not save them. You can still use them but you will have to link them over a * file (any file name prefixed by a * does not use up your disc space but unfortunately also doesn't stay, i.e. it disappears when you log off). Therefore you have two choices:

1. get more disc space, or wipe out some existing files that you dont need. Then type (when you have a !):

   XEQ LINK_PROA

   which will create a file called PROA5_LM, and then

   XEQ LINK_PROB

   which will create a file called PROB5_LM. (you will get some stuff on the screen that says it is linking)

2. if you can't get more disc space or just want a short term copy of the programs then just do the same thing, only do XEQ LINK_PROA_STAR instead (same idea for PROB), which will create star files of the same names as previous (only prefixed by a star), which can be run like normal files. (just type the name , including the *).

ALSO

for example input see INDATA2_5.

UPDATE JULY 29,1983

There are now 4 main programs: PROA5_LM, PROA6_LM,PROB5_LM, and PROB6_LM, one for method and size of input. They will calculate the MOSQ values again and some other things you wanted. The old stand alone program also is still running if you want that. The new programs also try to fit a logistic curve to the new mosq's (with some success). I also calculated the new mosq values for the c/i values that I have original mos values so you can compare the two. For the format of the input see INDATA2_5 and INDATA2_6 These orograms were not very thoroughly checked so if you find something odd going on please contact me.

12:23 AUG 16 '83 LINK-PROA.STA0130X

```
1.000 !LINK ;
2.000 PROA_BI,;
3.000 PRO1_BI,;
4.000 PRO2_BI,;
5.000 PRO3_BI,;
5.500 MOSQ_BI,;
6.000 SUB1_BI,;
7.000 SUB2_BI,;
8.000 SUB3_BI,;
9.000 SUB4_BI,;
10.000 SUB5_BI OVER PROA6_LM (UNSAT=IMSLD.:LIBRARY)
```

12:23 AUG 16 '83 LINK-PROB.STA0130X

```
1.000 !LINK ;
2.000 PROB_BI,;
3.000 PRO1_BI,;
4.000 PRO4_BI,;
5.000 PRO3_BI,;
6.000 SUB1_BI,;
6.500 MOSQ_BI,;
7.000 SUB2_BI,;
8.000 SUB6_BI,;
10.000 SUB5_BI OVER PROB6_LM (UNSAT=IMSLD.:LIBRARY)
```

```
      PROGRAM MOSQER
      REAL U1,D1,K1,INIT,FINAL,INCREM,AVSIG1
      INTEGER SIZ2,I
      PARAMETER (SIZ2=5)
      DOUBLE PRECISION U2,D2,K2,X(2),AVSIG2,M,MOSQ(50),CIRVAL,DMOSQ
      PRINT*,"INPUT U,D,K VALUES:"
      READ*,U1,D1,K1
      U2=DBLE(U1)
      D2=DBLE(D1)
      K2=DBLE(K1)
      PRINT*,"INPUT SIGMA VALUE:"
      READ*,AVSIG1
      AVSIG2=DBLE(AVSIG1)
      PRINT*,"INPUT INITIAL,FINAL,AND INCREMENT VALUES FOR C/I:"
      READ*,INIT,FINAL,INCREM
      I=0
      PRINT'(T9,A,T19,A)','C/I','MOSq'
      DO 10 CIRVAL=DBLE(INIT),DBLE(FINAL),DBLE(INCREM)
        I=I+1
        M=1D0+4D0/(1D0/U2+EXP((D2-CIRVAL)/K2))
        X(1)=M
        X(2)=AVSIG2
        CALL MOSCAL(X,DMOSQ,SIZ2)
        MOSQ(I)=DMOSQ
        PRINT'(T5,F10.5,T15,F10.5)',CIRVAL,MOSQ(I)
10    CONTINUE
      END
```

12:23 AUG 16 '83 MOSQ-AGAIN.STA0130X

```
      SUBROUTINE  MOSQER(U,D,K)
      INCLUDE SIZE
      REAL INIT,FINAL,INCREM
      INTEGER I
      DOUBLE PRECISION U,D,K,X(2),SIGMA,M,MOSQ(50),CIRVAL,DMOSQ,
     :                 MU(SIZ1),CIR(SIZ1),MOS(SIZ1),SIGMOS(SIZ1),
     :                 IMPE(50),MUTEMP(SIZ1),UT,DT,KT
      COMMON /BLOCK1/MOS,SIGMOS
      COMMON /BLOCK2/MU,CIR
      COMMON /BLOCK3/SIGMA
      READ*,INIT,FINAL,INCREM
      I=0
      PRINT'(T9,A,T19,A,T29,A)','C/I','MOSq','IMPE'
      DO 10 CIRVAL=DBLE(INIT),DBLE(FINAL),DBLE(INCREM)
        I=I+1
        M=1D0+4D0/(1D0/U+EXP((D-CIRVAL)/K))
        X(1)=M
        X(2)=SIGMA
        CALL MOSCAL(X,DMOSQ,SIZ2)
        MOSQ(I)=DMOSQ
        IMPE(I)=4D0/(DMOSQ-1D0)-1D0
        PRINT'(T5,F10.5,T15,F10.5,T25,F10.5)',CIRVAL,MOSQ(I),IMPE(I)
10    CONTINUE
      PRINT*
      PRINT '(T9,A,T19,A,T29,A)','C/I','MOSq','MOS'
      DO 20 I=1,SIZ1
        M=1D0+4D0/(1D0/U+EXP((D-CIR(I))/K))
        X(1)=M
        X(2)=SIGMA
        CALL MOSCAL(X,DMOSQ,SIZ2)
        MUTEMP(I)=MU(I)
        MU(I)=DMOSQ
        PRINT '(T5,F10.5,T15,F10.5,T25,F10.5)',CIR(I),DMOSQ,MOS(I)
20    CONTINUE
      CALL PARCAL(UT,DT,KT)
      END
```

```
12:23 AUG 16 '83 NNDATA1.STA0130X

      1 -      1.000 535 192 50 17 4
      2 -      2.000 238 132 24 4 2
      3 -      3.000 161 190 36 8 3
      4 -      4.000 33 172 144 43 8
      5 -      5.000 17 57 125 142 59
      6 -      6.000 2 1 19 78 296
      7 -      7.000 51 47 43 37 33 27
      8 -      8.000 1
      9 -      9.000 28 75 3
```

12:23 AUG 16 '83 NNDATA2.STA0130X

1 -	1.000	535	192	50	17	4	
2 -	2.000	252	123	21	2	1	
3 -	3.000	157	179	49	8	4	
4 -	4.000	10	129	153	90	18	
5 -	5.000	0	12	77	167	143	
6 -	6.000	4	5	14	61	316	
7 -	7.000	51	28	22	14	8	3
8 -	8.000	1					
9 -	9.000	5	60	3			

12:23 AUG 16 '83 NNDATA3.STAU130X

```
1 -      1.000 535 192 50 17 4
2 -      2.000 267 112 17 1 2
3 -      3.000 189 174 29 4 3
4 -      4.000 16 159 148 58 19
5 -      5.000 2 6 80 179 133
6 -      6.000 51 32 26 18 12
7 -      7.000 1
8 -      8.000 5 60 3
```

12:23 AUG 16 '83 NNDATA4.STA0130X

1 -	1.000	535 192 50 17 4
2 -	2.000	207 161 24 5 3
3 -	3.000	110 229 46 6 8
4 -	4.000	6 98 181 94 19
5 -	5.000	1 11 66 153 137
6 -	6.000	51 28 22 14 8
7 -	7.000	1
8 -	8.000	5 60 3

12:23 AUG 16 '83 NNDATA5.STA0130X

```
1 -      1.000 535 192 50 17 4
2 -      2.000 217 141 39 19 9
3 -      3.000 142 148 61 36 11
4 -      4.000 38 64 86 131 78
5 -      5.000 3 24 66 98 207
6 -      6.000 51 5 3 1 -1
7 -      7.000 1
8 -      8.000 -5 50 3
```

12:23 AUG 16 '83 NNDATA6.STA0130X

```
1 -     1.000 535 192 50 17 4
2 -     2.000 288 92 13 3 2
3 -     3.000 281 96 15 5 2
4 -     4.000 111 98 74 74 42
5 -     5.000 30 62 57 77 173
6 -     6.000 51 9 7 5 3
7 -     7.000 1
8 -     8.000 -5 60 3
```

12:23 AUG 16 '83 PARA.STA0130X

```
INTEGER NSIG
DOUBLEPRECISION LDCR
DATA NSIG,LDCR/8,0.0001/
```

```
      SUBROUTINE RATE (RATING)
      INCLUDE SIZE
      INTEGER RATING(SIZ1,SIZ2),I,J
      DOUBLEPRECISION MOS(SIZ1),SIGMOS(SIZ1),SUM1,SUM2,SUM3
      COMMON /BLOCK1/MOS,SIGMOS
      DO 100 I=1,SIZ1
        SUM1=SUM2=SUM3=0.0
        DO 50 J=1,SIZ2
          SUM1=SUM1+RATING(I,J)
          SUM2=SUM2+J*RATING(I,J)
          SUM3=SUM3+J*J*RATING(I,J)
50      CONTINUE
        MOS(I)=SUM2/SUM1
        SIGMOS(I)=SQRT((SUM3/SUM1)-(MOS(I)**2))
100   CONTINUE
      END
```

```
          SUBROUTINE MUCAL(MU)
          EXTERNAL FUNCT1,FUNCT2
          INCLUDE SIZE
          INCLUDE PARA
          INTEGER I,J,K
          DOUBLEPRECISION MOS(SIZ1),SIGMOS(SIZ1),SUM,X1(2),X2(1),F,
     :                    H1(3),H2(1),G1(2),G2(1),W1(6),W2(3),
     :                    AVSIG,MU(SIZ1)
          COMMON /BLOCK1/MOS,SIGMOS
          COMMON /BLOCK3/AVSIG
          COMMON /COUNT/I
          SUM=0
          J=0
          DO 100 I=1,SIZ1
            DO 50 K=1,SIZ2-1
              IF(ABS(SIGMOS(I)**2-(K+1-MOS(I))*(MOS(I)-K)).LT.
     :          (LDCR)) GOTO 100
    50      CONTINUE
            X1(1)=MOS(I)
            X1(2)=SIGMOS(I)
            CALL ZXMIN (FUNCT1,2,NSIG,500,0,X1,H1,G1,F,W1,IER)
            PRINT*,'{',NINT(W1(2)),NINT(W1(3)),F,X1(1),X1(2),'}'
            J=J+1
            SUM=SUM+X1(2)
   100    CONTINUE
          AVSIG=SUM/J
          PRINT '(A,F6.4)',' AVERAGE OF SIGMAS IS ',AVSIG
          PRINT*
          DO 200 I=1,SIZ1
            X2(1)=MOS(I)
            CALL ZXMIN(FUNCT2,1,NSIG,500,0,X2,H2,G2,F,W2,IER)
            PRINT*,'{',NINT(W2(2)),NINT(W2(3)),F,'}'
            MU(I)=X2(1)
   200    CONTINUE
          END
```

```
         SUBROUTINE PARCAL(U,D,K)
         EXTERNAL FUNCT3
         INCLUDE SIZE
         INCLUDE PARA
         INTEGER I,IER
         DOUBLEPRECISION CIR(SIZ1),MU(SIZ1),X(3),H(6),G(3),F,W(9),
     :                   U,D,K
         COMMON /BLOCK2/MU,CIR
         X(1)=1
         I=2
 100     IF ((MU(I).GT.3).AND.(I.LT.SIZ1)) THEN
           I=I+1
           GOTO 100
         ENDIF
         X(2)=CIR(I-1)*((3-MU(I))/(MU(I-1)-MU(I)))+
     :        CIR(I)*((MU(I-1)-3)/(MU(I-1)-MU(I)))
         X(3)=5
 200     PRINT*
         K=X(3)
         PRINT*,'INITIAL ESTIMATES OF U,D,K:'
         PRINT '(F10.6,3X,F9.6,3X,F9.6)',X
         PRINT*
         CALL ZXMIN(FUNCT3,3,NSIG,500,0,X,H,G,F,W,IER)
         PRINT*,'  FINAL ESTIMATES OF U,D,K:'
         PRINT '(F10.6,3X,F9.6,3X,F9.6)',X
         PRINT*,'{',NINT(W(2)),NINT(W(3)),F,'}'
         IF (W(3) .LT. 8) THEN
           PRINT*
           IF (ABS(K-6) .LT. .2) GOTO 300
           PRINT*, 'TRYING AGAIN WITH A NEW ESTIMATE FOR K:'
           IF (K .GT. 1) THEN
             X(3)=K-1
           ELSE
             X(3)=10
           ENDIF
           GOTO 200
 300       PRINT*,'NO CONVERGENCE WAS ACHIEVED ON ESTIMATES'
           PRINT*,'OF K.  IF YOU HAVE A BETTER ESTIMATE,'
           PRINT*,'ENTER IT NOW:'
           PRINT*,'(IF YOU DON''T, TYPE IN A 5)'
           READ*,X(3)
           IF (ABS(X(3)-5) .GT. .005) GOTO 200
         ENDIF
```

```
44 -     21.000     U=X(1)
45 -     22.000     D=X(2)
46 -     23.000     K=X(3)
47 -     24.000     END
```

```
      SUBROUTINE MUCUL(MU)
      EXTERNAL FUNCT4
      INCLUDE SIZE
      INCLUDE PARA
      INTEGER I,IER
      DOUBLEPRECISION MOS(SIZ1),SIGMOS(SIZ1),SUM,X(SIZ1+1),
     :                H((SIZ1+1)*(SIZ1+2)/2),G(SIZ1+1),F,
     :                W(3*(SIZ1+1)),MU(SIZ1),SIGMA
      COMMON /BLOCK1/MOS,SIGMOS
      COMMON /BLOCK3/SIGMA
      SUM=0
      DO 100 I=1,SIZ1
        X(I)=MOS(I)
        SUM=SUM+SIGMOS(I)
100   CONTINUE
      X(SIZ1+1)=SUM/SIZ1
      CALL ZXMIN(FUNCT4,SIZ1+1,NSIG,500,0,X,H,G,F,W,IER)
      PRINT*,'{',NINT(W(2)),NINT(W(3)),F,'}'
      PRINT*,'VALUE OBTAINED FOR SIGMA: ',X(SIZ1+1)
      PRINT*
      DO 200 I=1,SIZ1
        MU(I)=X(I)
200   CONTINUE
      SIGMA=X(SIZ1+1)
      END
```

12:23 AUG 16 '83 PROA.STA0130X

```
 1.000          PROGRAM MAIN
 2.000          INCLUDE SIZE
 4.000          INTEGER RATING(SIZ1,SIZ2),I,J
 5.000          DOUBLEPRECISION MOS(SIZ1),SIGMOS(SIZ1),MU(SIZ1),CIR(SIZ1),U,D,K
 6.000          COMMON /BLOCK1/MOS,SIGMOS
 6.500          COMMON /BLOCK2/MU,CIR
 7.000          DO 100 I=1,SIZ1
 8.000            READ*, (RATING(I,J),J=SIZ2,1,-1)
 9.000    100   CONTINUE
 9.500          READ*,(CIR(I),I=1,SIZ1)
 9.700          READ*,DUMMY
10.000          PRINT*
10.500          PRINT*,'CIR/RATING   5   4   3   2   1'
11.000          DO 200 I=1,SIZ1
12.000            PRINT '(I4,I11,I4,I4,I4,I4)',CIR(I),(RATING(I,J),J=SIZ2,1,-1)
13.000    200   CONTINUE
14.000          PRINT*
15.000          CALL RATE(RATING)
16.000          CALL MUCAL(MU)
17.000          PRINT*
18.000          PRINT*,'       MOS   SIGMOS        MU'
19.000          DO 300 I=1,SIZ1
20.000            PRINT '(F10.5,F9.5,F9.5)',MOS(I),SIGMOS(I),MU(I)
21.000    300   CONTINUE
23.000          CALL PARCAL(U,D,K)
24.000          CALL MOSQER(U,D,K)
25.000          END
```

```
      PROGRAM MAIN
      INCLUDE SIZE
      INTEGER RATING(SIZ1,SIZ2),I,J
      DOUBLEPRECISION MOS(SIZ1),SIGMOS(SIZ1),MU(SIZ1),CIR(SIZ1),U,D,K
      COMMON /BLOCK1/MOS,SIGMOS
      COMMON /BLOCK2/MU,CIR
      COMMON RATIO
      DO 100 I=1,SIZ1
        READ*, (RATING(I,J),J=SIZ2,1,-1)
100   CONTINUE
      READ*,(CIR(I),I=1,SIZ1)
      READ*,RATIO
      PRINT*
      PRINT*,'CIR/RATING   5   4   3   2   1'
      DO 200 I=1,SIZ1
        PRINT '(I4,I11,I4,I4,I4,I4)',CIR(I),(RATING(I,J),J=SIZ2,1,-1)
200   CONTINUE
      PRINT*
      CALL RATE(RATING)
      CALL MUCUL(MU)
      PRINT*
      PRINT*,'       MOS   SIGMOS        MU'
      DO 300 I=1,SIZ1
        PRINT '(F10.5,F9.5,F9.5)',MOS(I),SIGMOS(I),MU(I)
300   CONTINUE
      CALL PARCAL(U,D,K)
      CALL MOSQER(U,D,K)
      END
```

12:23 AUG 16 '83 REVDAT1.STA0130X

```
1 -      1.000 0 0 0 35 290
2 -      2.000 0 0 1 10 64
3 -      3.000 0 0 0 23 52
4 -      4.000 0 0 6 35 34
5 -      5.000 0 2 27 42 4
6 -      6.000 12 40 22 1 0
7 -      7.000 40 30 27 23 17 10
8 -      8.000 1
```

12:23 AUG 16 '83 SIZE.STA0130X

```
INTEGER SIZ1,SIZ2
PARAMETER (SIZ1=6,SIZ2=5)
```

12:23 AUG 16 '83 SUB1.STA0130X

```
      SUBROUTINE MOSCAL(X,MOSQ,SIZ2)
      DOUBLEPRECISION X(2),MOSQ,DERF,SUM,K
      INTEGER SIZ2,J
      SUM=0
      DO 100 J=1,SIZ2-1
        K=DERF((J+.5-X(1))/X(2)/SQRT(2.))
        SUM=SUM+.5+.5*K
100   CONTINUE
      MOSQ=SIZ2-SUM
      END
```

```
      SUBROUTINE SIGCAL(X,MOSQ,SGMOSQ,SIZ2)
      DOUBLEPRECISION X(2),MOSQ,SGMOSQ,DERF,SUM,K
      INTEGER J,SIZ2
      SUM=0
      DO 100 J=1,SIZ2-1
        K=DERF((J+.5-X(1))/X(2)/SQRT(2.))
        SUM=SUM+(2*J+1)*(.5+.5*K)
100   CONTINUE
      SGMOSQ=SQRT(SIZ2**2-SUM-MOSQ**2)
      END
```

12:23 AUG 16 '83 SUB3.STA0130X

```
      SUBROUTINE FUNCT1(N,X,F)
      INCLUDE SIZE
      DOUBLEPRECISION X(2),F,MOS(SIZ1),SIGMOS(SIZ1),MOSQ,SGMOSQ
      INTEGER I,N
      COMMON /COUNT/I
      COMMON /BLOCK1/MOS,SIGMOS
      CALL MOSCAL(X,MOSQ,SIZ2)
      CALL SIGCAL(X,MOSQ,SGMOSQ,SIZ2)
      F=(MOS(I)-MOSQ)**2+(SIGMOS(I)-SGMOSQ)**2
      END
```

```
SUBROUTINE FUNCT2 (N,X,F)
INCLUDE SIZE
INTEGER I,N
DOUBLEPRECISION X(1),F,MOS(SIZ1),SIGMOS(SIZ2),MOSQ,XP(2),AVSIG
COMMON /COUNT/I
COMMON /BLOCK1/MOS,SIGMOS
COMMON /BLOCK3/AVSIG
XP(1)=X(1)
XP(2)=AVSIG
CALL MOSCAL(XP,MOSQ,SIZ2)
F=(MOS(I)-MOSQ)**2
END
```

```
      SUBROUTINE FUNCT3(N,X,F)
      INCLUDE SIZE
      DOUBLEPRECISION MU(SIZ1),CIR(SIZ1),X(3),M,SUM
      INTEGER I,N
      COMMON /BLOCK2/MU,CIR
      SUM=0
      DO 100 I=1,SIZ1
        M=1+4/(1/X(1)+EXP((X(2)-CIR(I))/X(3)))
        SUM=SUM+(MU(I)-M)**2
100   CONTINUE
      F=SUM
      END
```

```
      SUBROUTINE FUNCT4(N,X,F)
      INCLUDE SIZE
      INTEGER I,N
      DOUBLEPRECISION MOS(SIZ1),SIGMOS(SIZ1),X(SIZ1+1),A(2),SUM,
     :                MOSQ,SGMOSQ,F,RATIO
      COMMON /BLOCK1/MOS,SIGMOS
      COMMON RATIO
      SUM=0
      DO 100 I=1,SIZ1
        A(1)=X(I)
        A(2)=X(SIZ1+1)
        CALL MOSCAL(A,MOSQ,SIZ2)
        CALL SIGCAL(A,MOSQ,SGMOSQ,SIZ2)
        SUM=SUM+(MOS(I)-MOSQ)**2+RATIO*(SIGMOS(I)-SGMOSQ)**2
100   CONTINUE
      F=SUM
      END
```

APPENDIX 6

DETAILED ANALYSIS SHEETS

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA1

IMPAIRMENT: A11-000-00-XY-0D

PROGRAM: PROA5; (PROA6); PROB5; PROB6

U(mu) = .964 U(MOSQ) = .912

D_m(mu) = 35.2 D_m(MOSQ) = 34.85

K(mu) = 3.16 K(MOSQ) = 3.47

σ = .8809 I_0 = .114

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = [I_0 - I_{exp}]$	ln I_u	
33	2.00	1.89		
35	1.10	.99		
37	.61	.50		
39	.358	.24		
41	.234	.12		
43	.174	.06		
45	.144	.03		
47	.129	.02		
49	.122	-		
51	.118	-		
53	.116	-		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 11.69 - .336 D$

Dm = 34.8

G = -2.98

STATISTICAL ANALYSIS SHEET

DATA FILE: TIDATA 2

IMPAIRMENT: 711 - 016 - 00 - 00 - XX

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .99 — U(MOSQ) = .92

D_m(mu) = 14.21 — D_m(MOSQ) = 13.69

K(mu) = 3.89 — K(MOSQ) = 4.298

σ = .8995

I_0 = .101

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~7~~	~~4.91~~	~~4.81~~		
~~9~~	~~3.43~~	~~3.33~~		
11	2.22	2.12		
13	1.37	1.27		
15	.832	.73		
17	.513	.41		
19	.331	.23		
21	.229	.13		
23	.174	.07		
25	.143	.04		
27	.125	.02		
29	.116	.02		
31	.110	.01		
33	.106	.01		
35	.104			

LINEAR REGRESSION FIT

ln I_u = [illegible] - 3.64 - .27 C

Dm = 13.6

G = - 2.37

OK

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA3

IMPAIRMENT: A11-030-00-00-XX

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .98 U(MOSQ) = .92

D_m(mu) = 17.14 D_m(MOSQ) = 16.75

K(mu) = 3.97 K(MOSQ) = 3.85

J = .7844

I_o = .089

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
11	4.23	4.13		
13	2.196	2.107		
15	1.72	1.63		
17	1.05	.96		
19	.646	.56		
21	.405	.32		
23	.267	.18		
25	.189	.10		
27	.147	.06		
29	.122	.03		
31	.109	.02		
33	.106	.01		
35	.096	–		

LINEAR REGRESSION FIT

ln I_u = β – D = 4.70 – .280D

Dm = 16.78

G = – 2.48

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDA-A4

IMPAIRMENT: A11-010-00-46-VV

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .98 U(MOSQ) = .97

D(mu) = 14.72 D(MOSQ) = 14.17

K(mu) = 5.26 K(MOSQ) = 5.03

σ = .8228

$I_0 = .094$

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	$\ln I_u$	
~~7~~	~~3.91~~	~~3.80~~		
9	2.85	2.76		
11	2.02	1.93		
13	1.40	1.31		
15	.968	.87		
17	.671	.58		
19	.471	.38		
21	.339	.25		
23	.253	.16		
25	.198	.10		
27	.162	.07		
29	.139	.05		
31	.124	.03		
33	.114	.02		
35	.108	.01		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 3.01 - .211D$

Dm = 14.3

G = -1.87

STATISTICAL ANALYSIS SHEET

DATA FILE: FIOA7A5

IMPAIRMENT: A11-100-15 00-...

PROGRAM: (PROA5); PROA6; PROB5; PROB6

U(mu) = 1.08 U(MOSQ) = .92

D(mu) = 1.78 D(MOSQ) = 1.4

K(mu) = 1.5 K(MOSQ) = 1.6

T = 1.2664 I_0 = .096

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} -1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~-2~~	~~5.11~~	~~5.01~~		
~~-1~~	~~3.93~~	~~3.85~~		
0	2.62	2.52		
1	1.52	1.42		
2	.809	.71		
3	.430	.33		
4	.250	.15		
5	.169	.07		
6	.131	.03		
7	.113	.01		
8	.104			
9	.100			
10	.098			

LINEAR REGRESSION FIT

ln I_u = β + γ D = 1.13 − .78D

Dm = 1.44

G = −6.9 OK

STATISTICAL ANALYSIS SHEET

DATA FILE: F'CL'A'S

IMPAIRMENT: A 11 - 100 - 13 ·00 - XY

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = 1.13 U(MOSQ) = 1.00

D_m(mu) = 4.44 D_m(MOSQ) = 4.27

K(mu) = 1.13 K(MOSQ) = 5.00

= 1.253

I_0 = .071

C/I	$I_{exp}=\left[\frac{4}{MOSQ-1}-1\right]$	$I_u=\left[I_0-I_{exp}\right]$	ln I_u	
~~2~~	~~4.51~~	~~4.42~~		
3	2.76	2.69		
4	1.31	1.24		
5	.538	.47		
6	.234	.163		
7	.130	.06		
8	.093	.02		
9	.080	–		
10	.075	–		

LINEAR REGRESSION FIT

ln I_u = K ∝ D = 4.10 − .9900

Dm = 4.14

G = −8.78

STATISTICAL ANALYSIS SHEET

DATA FILE: F10A71:7

IMPAIRMENT: 1-000-00-XY-00

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = 1.11 U(MOSQ) = .98

D_m(mu) = 36.08 D_m(MOSQ) = 35.39

K(mu) = 4.42 K(MOSQ) = 4.49

σ = .9336 √K = .723 I_0 = .048

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~29~~	~~4.04~~	~~3.73~~		
31	2.83	2.18		
33	1.87	1.82		
35	1.18	1.13		
37	.724	.68		
39	.441	.39		
41	.272	.22		
43	.175	.13		
45	.121	.07		
47	.091	.04		
49	.074	.03		
51	.064	.02		
53	.058	.01		
55	.054	—		

LINEAR REGRESSION FIT

ln I_u = β + αD = 9.46 − .268 D

Dm = 35.3

G = −2.38

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATAX

IMPAIRMENT: 2-000-00-XY-00

PROGRAM: PROA5; ~~PROA6;~~ PROB5; PROB6

U(mu) = 1.17

D_m(mu) = 39.15

K(mu) = 5.89

σ = .8311

U(MOSQ) = 1.06 – MOSQ asymptotic to 4.91774 at C/I = 110dB

D_m(MOSQ) = 38.46

K(MOSQ) = 5.89

MKS = .170

I_0 = .022

C/I	$I_{exp}=\left[\frac{4}{MOSQ-1}-1\right]$	$I_u=\left[I_0-I_{exp}\right]$	ln I_u	
~~29~~	~~4.60~~	~~4.53~~		
~~31~~	~~3.53~~	~~3.46~~		
33	2.60	2.58		
35	1.86	1.84		
37	1.29	1.27		
39	.884	.86		
41	.593	.57		
43	.391	.37		
[illegible]	.255	.23		
[illegible]	.167	.15		
49	.112	.09		
51	.079	.06		
53	.058	.04		
55	.046	.02		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha\,\theta = 8.32 - .219\,\theta$

Dm = 38.0

G = −1.94

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA9

IMPAIRMENT: 3 - 000 - 00 - XX - 00

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .90 U(MOSQ) = .87

D_m(mu) = 33.79 D_m(MOSQ) = 33.50

K(mu) = 3.31 K(MOSQ) = 3.5

σ = .8107 1/K = .286

I_0 = .155

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~29~~	~~3.93~~	~~3.77~~		
31	2.37	2.22		
33	1.37	1.22		
35	.804	.65		
37	.494	.34		
39	.332	.18		
41	.248	.09		
43	.204	.05		
45	.181	.03		
47	.169	.01		
49	.163	—		
51	.159	—		
53	.157	—		
55	.156	—		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 11.0 - .327 D$

Dm = 33.6

G = 2.90

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA 10

IMPAIRMENT: 4-000-00-XX-00

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .99 U(MOSQ) = .94

D_m(mu) = 34.84 D_m(MOSQ) = 34.59

K(mu) = 2.71 K(MOSQ) = 2.81

σ = .6948 1/K = .356 I_0 = .074

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~29~~	~~6.83~~	~~6.74~~		
~~31~~	~~3.94~~	~~3.85~~		
33	1.98	1.91		
35	.956	.88		
37	.466	.39		
39	.242	.17		
41	.146	.07		
43	.106	.03		
45	.089	.02		
47	.081	-		
49	.077	-		
51	.075	-		
53	.075	-		
55	.074	-		

LINEAR REGRESSION FIT

ln I_u = $\beta + \alpha D$ = 13.7 - .40 D

Dm = 34.6

G = -3.51

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDA [illegible]

IMPAIRMENT: 1-010-00-00-[illegible]

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .95 U(MOSQ) = .91

D_m(mu) = 13.81 D_m(MOSQ) = 13.51

K(mu) = 5.06 K(MOSQ) = 3.41 I_0 = .114

σ = .8237

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
	4.56	4.45		
	[illegible]	2.49		
[illegible]	1.37	1.26		
	.713	.60		
	.392	.28		
	.242	.13		
	.174	.06		
	.143	.03		
[illegible]	.128	.02		
[illegible]	.121	.01		
[illegible]	.118	.01		
[illegible]	.116	.01		
[illegible]	.115			
35	.115			

LINEAR REGRESSION FIT

ln I_u = $\beta + \alpha D$ = 4.11 − .35 D

Dm = 13.4

G = −3.1

(OK)

STATISTICAL ANALYSIS SHEET

DATA FILE: F12A7/12

IMPAIRMENT: 2-010-00-00-XX

PROGRAM: PROA5; (PROA6;) PROB5; PROB6

U(mu) = 1017 U(MOSQ) = 1957

D_m(mu) = 17.33 D_m(MOSQ) = 16.73

K(mu) = 5.015 K(MOSQ) = 5.03

σ = 1.6902 I_0 = .058

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	$\ln I_u$	
~~11~~	~~3.408~~	~~3.35~~		
13	2.338	2.28		
15	1.574	1.52		
17	1.053	.995		
19	.702	.644		
21	.468	.41		
23	.315	.257		
25	.217	.159		
27	.157	.099		
29	.120	.062		
31	.097	.039		
33	.083	.025		
35	.074	.016		
37	.069	.011		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 3.86 - .228D$

Dm = 16.9

G = -2.0

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA 13

IMPAIRMENT: 3-010-00-00-xx

PROGRAM: PROA5; (PROA6); PROB5; PROB6

U(mu) = .884 U(MOSQ) = .855

D_m(mu) = 10.87 D_m(MOSQ) = 10.55

K(mu) = 4.03 K(MOSQ) = 4.27

σ = .83385

$I_0 = .176$

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	$\ln I_u$	
~~5~~	~~3.93~~	~~3.75~~		
7	2.64	2.46		
9	1.71	1.53		
11	1.10	.924		
13	.724	.548		
15	.499	.323		
17	.366	.19		
19	.288	.112		
21	.242	.066		
23	.216	.04		
25	.200	.024		
27	.190	.014		
29	.185	.009		
31	.181	.005		
33	.179	.003		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 2.76 - .260D$

Dm = 10.61

G = -2.30

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA 14
IMPAIRMENT: 4-010-00-00-XX
PROGRAM: PROA5; (PROA6;) PROB5; PROB6

U(mu) = 1.08	U(MOSQ) = .965
D_m(mu) = 14.10	D_m(MOSQ) = 13.48
K(mu) = 3.56	K(MOSQ) = 3.90
σ = .8911	

$I_0 \cong .053$

C/I	$I_{exp}=\left[\frac{4}{MOSQ-1}-1\right]$	$I_u=\left[I_0-I_{exp}\right]$	ln I_u	
~~9~~	~~3.64~~	~~3.59~~		
11	2.24	2.19		
13	1.28	1.23		
15	.709	.656		
17	.389	.336		
19	.221	.168		
21	.138	.085		
23	.097	.044		
25	.077	.024		
27	.066	.013		

LINEAR REGRESSION FIT

ln $I_u = \beta + \alpha D = 4.44 - .330 D$

Dm = 13.57

G = -2.9

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDA A13

IMPAIRMENT: I-030-00-00-XX

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .97 U(MOSQ) = .92

D_m(mu) = 17.53 D_m(MOSQ) = 17.23

K(mu) = 3.22 K(MOSQ) = 3.28 I_0 = .097

σ = .7702

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
13	3.82	3.72		
[illegible]	2.2	2.1		
[illegible]	1.21	1.11		
[illegible]	.669	.57		
[illegible]	.382	.28		
[illegible]	.239	.14		
[illegible]	.169	.07		
[illegible]	.134	.03		
[illegible]	.116	.02		
[illegible]	.107	.01		
[illegible]	.103 I_0			
35	.100			

LINEAR REGRESSION FIT

ln I_u = β + γ D = 5.84 − .34D

Dm = 17.2

G = −3.00

OK

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA16

IMPAIRMENT: 2-030-00-00-xx

PROGRAM: (PROA5) PROA6; PROB5; PROB6

U(mu) = 1.01 U(MOSQ) = .947

D_m(mu) = 19.70 D_m(MOSQ) = 19.19

K(mu) = 4.82 K(MOSQ) = 4.57

σ = .7042 I_0 = .063

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~13~~	~~3.81~~	~~3.75~~		
15	2.60	2.54		
17	1.74	1.68		
19	1.15	1.09		
21	.754	.691		
23	.497	.434		
25	.331	.268		
27	.227	.164		
29	.163	.1		
31	.125	.062		
33	.102	.039		
35	.088	.025		

LINEAR REGRESSION FIT

ln I_u = $\beta + \alpha D$ = 4.51 − .234 D

Dm = 19.26

G = −2.08

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA17

IMPAIRMENT: 3-030-00-00-xx

PROGRAM: (PROA5;) PROA6; PROB5; PROB6

U(mu) = .913	U(MOSQ) = .879
D_m(mu) = 14.67	D_m(MOSQ) = 14.46
K(mu) = 3.39	K(MOSQ) = 3.26
σ = .7574	I_0 = .138

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~9~~	~~4.76~~	~~4.622~~		
11	2.95	2.81		
13	1.72	1.58		
15	1.00	.862		
17	.601	.463		
19	.383	.245		
21	.267	.129		
23	.207	.069		
25	.175	.037		
27	.158	.02		
29	.149	.011		
31	.144	.006		
33	.142	.004		

LINEAR REGRESSION FIT

ln I_u = $\beta + \alpha D$ = 4.49 − .31 D

Dm = 14.44

G = −2.76

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA 18

IMPAIRMENT: 4-030-00-00-xx

PROGRAM: (PROA5;) PROA6; PROB5; PROB6

U(mu) = 1.04 U(MOSQ) = .961

D_m(mu) = 17.04 D_m(MOSQ) = 16.60

K(mu) = 4.19 K(MOSQ) = 3.90

σ = .6806 I_0 = .046

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	$\ln I_u$	
~~11~~	~~3.99~~	~~3.94~~		
13	2.56	2.51		
15	1.59	1.54		
17	.972	.926		
19	.590	.544		
21	.357	.311		
23	.220	.174		
25	.143	.097		
27	.101	.055		
29	.078	.032		
31	.065	.019		
33	.057	.011		
35	.053	.007		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 4.57 - .276D$

Dm = 16.60

G = - 2.44

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA7

IMPAIRMENT: 1-010-00

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .97 U(MOSQ) = .92

D_m(mu) = 14.04 D_m(MOSQ) = 14.11

K(mu) = 4.09 K(MOSQ) = 4.01 I_0 = .092

.7220

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	$\ln I_u$	
~~9~~	~~3.64~~	~~3.54~~		
11	2.33	2.24		
13	1.46	1.37		
15	.907	.82		
17	.572	.48		
[illegible]	.370	.28		
[illegible]	.251	.16		
[illegible]	.184	.09		
[illegible]	.146	.05		
[illegible]	.124	.03		
[illegible]	.111	.01		
31	.103	.01		
33	.099	–		
35	.096	–		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 4.04 - .283D$

Dm = 14.25

G = −2.51

△

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA20

IMPAIRMENT: 2-010-00-46-xx

PROGRAM: (PROA5) PROA6; PROB5; PROB6

U(mu) = 1.00 U(MOSQ) = .940

D(mu) = 18.40 D(MOSQ) = 17.74

K(mu) = 6.26 K(MOSQ) = 6.01

σ = .7231 I_0 = .070

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	$\ln I_u$	
~~11~~	~~3.15~~	~~3.08~~		
13	2.34	2.27		
15	1.72	1.65		
17	1.25	1.18		
19	.908	.838		
21	.660	.59		
23	.481	.411		
25	.355	.285		
27	.266	.196		
29	.204	.134		
31	.163	.093		
33	.134	.064		
35	.115	.045		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \gamma D = 3.21 - .180D$

Dm = 17.88

G = -1.60

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA21

IMPAIRMENT: 3-010-00-46-xx

PROGRAM: (PROA5); PROA6; PROB5; PROB6

U(mu) = .904 U(MOSQ) = .873

D(mu) = 11.79 D(MOSQ) = 11.51

K(mu) = 5.33 K(MOSQ) = 5.13

σ = .7596 I_0 = .147

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~5~~	~~3.48~~	~~3.33~~		
7	2.51	2.36		
9	1.78	1.63		
11	1.26	1.11		
13	.902	.755		
15	.655	.508		
17	.487	.34		
19	.373	.226		
21	.298	.151		
23	.248	.101		
25	.215	.068		
27	.193	.046		
29	.178	.031		
31	.168	.021		

LINEAR REGRESSION FIT

ln I_u = $\beta + \alpha D$ = 2.28 − .198 D

Dm = 11.49

G = −1.76

STATISTICAL ANALYSIS SHEET

DATA FILE: F.IDATA22

IMPAIRMENT: 4-010-00-46-xx

PROGRAM: (PROA5); PROA6; PROB5; PROB6

U(mu) = 1.04 U(MOSQ) = .963

D_m(mu) = 14.17 D_m(MOSQ) = 13.64

K(mu) = 4.96 K(MOSQ) = 4.55

σ = .6718 I_0 = .045

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~7~~	~~4.02~~	~~3.98~~		
9	2.76	2.72		
11	1.85	1.81		
13	1.23	1.19		
15	.809	.764		
17	.523	.478		
19	.345	.3		
21	.228	.183		
23	.156	.111		
25	.113	.068		
27	.087	.042		
29	.072	.027		
31	.062	.017		

LINEAR REGRESSION FIT

ln I_u = $\beta + \alpha D$ = 3.19 − .234 D

Dm = 13.64

G = −2.08

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA23

IMPAIRMENT: 1 - 100 - 15 - 00 · x·

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .97 U(MOSQ) = .9

D_m(mu) = 2.46 D_m(MOSQ) = 2.27

K(mu) = .81 K(MOSQ) = 1.00 I_0 = .132

σ = 1.1417

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~1~~	~~4.14~~	~~4.01~~	—	
2	1.69	1.56		
3	.554	.42		
4	.238	.11		
5	.160	.03		
6	.140	.01		
7	.134	–		
8	.132	–		

LINEAR REGRESSION FIT

ln I_u = $\beta + \alpha D$ = 2.94 - 1.27 D

Dm = 2.31

G = -11.29

OK

Δ

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA24

IMPAIRMENT: 2-100-15-00-xx

PROGRAM: (PROA5) PROA6; PROB5; PROB6

U(mu) = 1.13 U(MOSQ) = .965

D(mu) = 1.69 D(MOSQ) = 1.35

K(mu) = 1.50 K(MOSQ) = 1.46

σ = 1.0379 I_0 = .049

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~-1~~	~~4.30~~	~~4.25~~		
0	2.67	2.62		
1	1.44	1.39		
2	.707	.658		
3	.341	.292		
4	.176	.127		
5	.106	.057		
6	.075	.026		
7	.062	.013		
~~8~~	~~.055~~	~~.006~~		
9	~~.052~~	~~.003~~		
~~10~~	~~.050~~	~~.001~~		
11	~~.050~~	~~.001~~		
12	.049	—		

LINEAR REGRESSION FIT

ln I_u = β+αD = 1.06 −.776 D

Dm = 1.36

G = − 6.88

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA25

IMPAIRMENT: 3-100-15-00-xx

PROGRAM: (PROA5) PROA6; PROB5; PROB6

U(mu) = .959 U(MOSQ) = .882

D(mu) = .225 D(MOSQ) = .030

K(mu) = 1.60 K(MOSQ) = 1.53

σ = 1.0192 I_0 = .136

C/I	$I_{exp}=\left[\frac{4}{MOSQ-1}-1\right]$	$I_u=\left[I_0-I_{exp}\right]$	$\ln I_u$	
~~-2~~	~~3.41~~	~~3.27~~		
0	1.19	1.05		
2	.405	.269		
4	.205	.069		
6	.155	.019		
~~8~~	~~.141~~	~~.005~~		
~~10~~	~~.137~~	~~.001~~		
12	.136			
14	.136			
16	.136			
18				
20				

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = -.034 - .670 D$

Dm = -.051

G = -5.94

STATISTICAL ANALYSIS SHEET

DATA FILE: F10A7A26

IMPAIRMENT: 4-100-15-00-xx

PROGRAM: (PROA5) PROA6; PROB5; PROB6

U(mu) = 1.26 U(MOSQ) = .984

D(mu) = 2.21 D(MOSQ) = 1.51

K(mu) = 2.74 K(MOSQ) = 2.38

σ = 1.0812 I_0 = .022

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = [I_0 - I_{exp}]$	$\ln I_u$	
~~-3.5~~	~~4.87~~	~~4.85~~		
~~-3~~	~~4.43~~	~~4.41~~		
-2.5	3.98	~~3.96~~		
-2	3.53	~~3.51~~		
~~-1.5~~	~~3.09~~	~~3.07~~		
-1	2.67	2.65		
-.5	2.28	2.26		
0	1.92	1.90		
.5	1.60	1.58		
1	1.32	1.30		
1.5	1.08	1.06		
2	.878	.856		
2.5	.707	.685		
3	.566	.544		
3.5	.451	.429		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = .630 - .406\ D$

Dm = 1.55

G = -3.60

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA 27

IMPAIRMENT: 1-100-13-00-xx

PROGRAM: (PROA5); PROA6; PROB5; PROB6

U(mu) = 1.06 U(MOSQ) = .94

D_m(mu) = 5.07 D_m(MOSQ) = 4.98

K(mu) = 3.67 K(MOSQ) = 0.8

σ = 1.1557 I_0 = .092

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	$\ln I_u$	
~~4~~	~~6.20~~			
~~4.5~~	~~3.54~~			
5	1.15	1.06		
5.5	.317	.23		
6	.140	.05		
6.5	.103	.01		
7	.095	–		
7.5	.093	–		
8	.092	–		

LINEAR REGRESSION FIT

$\ln I_u$ = 15.6 - 3.100

Dm = 5.03

G = -27.5

Δ

STATISTICAL ANALYSIS SHEET

DATA FILE: F10A7A28

IMPAIRMENT: 2-100-13-00-xx

PROGRAM: (PROA5); PROA6; PROB5; PROB6

U(mu) = 1.13 U(MOSQ) = 1.08

D(mu) = 4.46 D(MOSQ) = 4.45

K(mu) = 1.17 K(MOSQ) = 2.91

σ = 1.0576 I_0 = .051

C/I	$I_{exp}=\left[\frac{4}{MOSQ-1}-1\right]$	$I_u=\left[I_0-I_{exp}\right]$	$\ln I_u$	
2	~~5.01~~	~~4.96~~		
4	1.34	1.29		
6	.221	.17		
8	.074	.023		
~~10~~	~~.055~~	~~.004~~		
12	~~.052~~	~~.001~~		
14	.051			
16	.051			
18	.051			
20				
22				
24				
26				

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 4.28 - 1.01\ D$

Dm = 4.25

G = -8.93

☐

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA29

IMPAIRMENT: 3-100-13-00-xx

PROGRAM: (PROA5); PROA6; PROB5; PROB6

U(mu) = 1.22 U(MOSQ) = .967

D(mu) = 2.95 D(MOSQ) = 2.23

K(mu) = 4.20 K(MOSQ) = 3.33

σ = 1.1374 I_0 = .035

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	$\ln I_u$	
~~-6~~	~~4.81~~	~~4.78~~		
~~-4~~	~~3.73~~	~~3.70~~		
-2	2.66	2.63		
0	1.74	1.71		
2	1.07	1.04		
4	.626	.591		
6	.359	.324		
8	.209	.174		
10	.129	.094		
12	.087	.052		
14	.064	.029		
16	.052	.017		
~~18~~	~~.045~~	~~.01~~		
~~20~~	~~.041~~	~~.006~~		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = .536 - .288 D$

Dm = 1.86

G = −2.55

STATISTICAL ANALYSIS SHEET

DATA FILE: FIDATA30

IMPAIRMENT: 4-100-13-00-xx

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = 1.20 U(MOSQ) = 1.01

D_m(mu) = 4.38 D_m(MOSQ) = 2.22

K(mu) = 1.34 K(MOSQ) = 3.46

σ = 1.1969 I_0 = .046

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	$\ln I_u$	
~~2~~	~~3.90~~	~~3.85~~		
3	2.33	2.28		
4	1.15	1.10		
5	.509	.463		
6	.227	.181		
7	.118	.072		
8	.076	.03		
9	.059	.013		
~~10~~	~~.052~~	~~.006~~		
~~11~~	~~.049~~	~~.003~~		
~~12~~	~~.047~~	~~.001~~		
13	.046			
14				
15				

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 3.54 - .878 D$

Dm = 4.04

G = − 7.78

STATISTICAL ANALYSIS SHEET

DATA FILE: NW DATA I

IMPAIRMENT: AU-000-00-XX-00

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .95 U(MOSQ) = .89

D_m(mu) = 35.02 D_m(MOSQ) = 34.58

K(mu) = 2.95 K(MOSQ) = 3.48

$\sigma = 1.0395$ $I_0 = .142$

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
31	3.32	3.18		
34	1.43	1.29		
37	.579	.44		
40	.285	.14		
43	.190	.05		
46	.159	.02		
49	.148			
52	.144			
55	.143			
	$I_0 = .142$			

LINEAR REGRESSION FIT

ln I_u = 11.9 - .135D

Dm = 34.5

G = -3.1

STATISTICAL ANALYSIS SHEET

DATA FILE: [illegible]

IMPAIRMENT: A11-010-00-00-XY

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .98 U(MOSQ) = .90

D_m(mu) = 13.98 D_m(MOSQ) = 13.31

K(mu) = 3.59 K(MOSQ) = 0.35

σ = 1.0957

I_0 = .128

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~8~~	~~3.92~~	~~3.79~~		
11	2.14	2.01		
14	1.01	.88		
17	.481	.35		
20	.267	.14		
23	.184	.05		
26	.152	.02		
29	.138	.01		
32	.133			
35	.130			

LINEAR REGRESSION FIT

ln I_u = $\beta + \alpha D$ = 4.06 - .30 D

Dm = 13.4

G = -2.7

OK

STATISTICAL ANALYSIS SHEET

DATA FILE: [illegible] 3

IMPAIRMENT: A11 - 030 - 00 - 00 - xy

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .98	U(MOSQ) = 0.90
D_m(mu) = 17.02	D_m(MOSQ) = 16.51
K(mu) = 3.73	K(MOSQ) = 3.76

σ = .9700

I_0 = .116

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~11~~	~~4.06~~	~~3.94~~		
14	2.17	2.05		
17	1.03	.91		
20	.491	.38		
23	.268	.15		
[illegible]	.179	.06		
[illegible]	.143	.02		
[illegible]	.127	.01		
[illegible]	.121			

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 5.03 - .303 D$

Dm = 16.60

G = -2.69

STATISTICAL ANALYSIS SHEET

DATA FILE: NUD[illegible]

IMPAIRMENT: A11-010-00-46 [illegible]

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = .95 U(MOSQ) = .89

D_m(mu) = 14.34 D_m(MOSQ) = 13.77

K(mu) = 4.76 K(MOSQ) = 4.74

σ = .9529

I_o = .131

C/I	$I_{exp}=\left[\frac{4}{MOSQ-1}-1\right]$	$I_u=\left[I_0-I_{exp}\right]$	ln I_u	
~~8~~	~~3.36~~	~~3.22~~		
11	2.	1.87		
14	1.12	.99		
17	.632	.50		
20	.380	.25		
[illegible]	.255	.13		
[illegible]	.194	.06		
[illegible]	.164	.03		
[illegible]	.148	.02		
[illegible]	.148	—		

LINEAR REGRESSION FIT

ln I_u = [illegible] = 3.08 − .223D

Dm = 13.8

G = −1.98

STATISTICAL ANALYSIS SHEET

DATA FILE: NNDATA5

IMPAIRMENT: FM - 100 - 15 - 00 - XX

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = 1.17 U(MOSQ) = .94

D_m(mu) = 1.60 D_m(MOSQ) = .6

K(mu) = 4.67 K(MOSQ) = 4.24

J = 1.3394 I_0 = .066

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
-5	2.94	2.87		
-2	1.81	1.74		
1	.992	0.92		
4	.512	.45		
7	.272	.21		
10	.162	.10		
13	.112	.05		
16	.089	.12		
19	.077	.01		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = .049 - .211 D$

Dm = .231

G = −1.87

STATISTICAL ANALYSIS SHEET

DATA FILE: NNDATA6

IMPAIRMENT: A1 - 100 - 13 - 00 - XX

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = 1.16 U(MOSQ) = .92

D_m(mu) = 2.37 D_m(MOSQ) = 1.82

K(mu) = 3.04 K(MOSQ) = 2.65

I = 1.4564 Io = .084

C/I	$I_{exp}=\left[\frac{4}{MOSQ-1}-1\right]$	$I_u=\left[I_0-I_{exp}\right]$	ln I_u	
~~-5~~	~~4.35~~	~~4.23~~		
-2	2.83	2.75		
1	1.35	1.27		
4	.53	.45		
7	.224	.14		
10	.130	.05		
13	.100	.02		
16	.090	-		
19	.086	-		

LINEAR REGRESSION FIT

ln I_u = β + α D = .455 - .338D

Dm = 1.35

G = -3.00

STATISTICAL ANALYSIS SHEET

DATA FILE: INDATA1

IMPAIRMENT: ALL - 010 - 00 - 00 - XX GRPA, CFC

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = 1.08 U(MOSQ) = .98

D_m(mu) = 14.2 D_m(MOSQ) = 14.08

K(mu) = 5.32 K(MOSQ) = 4.68

σ = .6693

I_0 = .029

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	$\ln I_u$	
~~8~~	~~3.35~~	~~3.26~~		
11	1.92	1.89		
14	1.06	1.03		
17	.572	.54		
20	.299	.27		
23	.157	.13		
26	.090	.06		
29	.059	.03		
32	.044	.02		
35	.036	–		
38	.033	–		
41	.031	–		
44	.029	–		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 3.16 - .226\, D$

Dm = 14.00

G = – 2.00

STATISTICAL ANALYSIS SHEET

DATA FILE: INDATA 2

IMPAIRMENT: A11-010-00-00-XY GPPB, CKC

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = 1.07	U(MOSQ) = .97
D_m(mu) = 18.22	D_m(MOSQ) = 18.08
K(mu) = 3.95	K(MOSQ) = 3.14

$\sigma = .6700$ $\quad I_0 = .034$

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~2~~				
14	2.81	2.78		
17	1.30	1.27		
20	.577	.54		
23	.249	.22		
26	.115	.08		
29	.066	.03		
32	.048	.01		
35	.040	-		
38	.037	-		
41	.035	-		
44	.035	-		
47	.034	-		

LINEAR REGRESSION FIT

$\ln I_u = \beta + \alpha D = 5.55 - .31 D$

Dm = 17.7

G = ~ 2.7

STATISTICAL ANALYSIS SHEET

DATA FILE: INDATA3

IMPAIRMENT: All-101-13-00-xx GRPB, CEC

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = 1.09 U(MOSQ) = 1.04

D_m(mu) = 7.71 D_m(MOSQ) = 6.81

K(mu) = 1.74 K(MOSQ) = 4.97

σ = .7544

I_0 = .035

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~4~~	~~6.36~~	~~6.28~~		
~~5~~	~~4.23~~	~~4.15~~		
6	2.53	2.50		
7	1.41	1.38		
8	.763	.73		
9	.401	.37		
10	.211	.18		
11	.119	.08		
12	.076	.04		
13	.056	.02		
14	.046	.01		
15	.041	–		
16	.038	–		
17	.037	–		

LINEAR REGRESSION FIT

ln I_u = β + α D = 5.24 − .702 D

Dm = 7.46

G = −6.23

no graph

STATISTICAL ANALYSIS SHEET

DATA FILE: \N DATA 4

IMPAIRMENT: All - 030 - 00 00 - xx GBIA, CRC

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = 1.04 U(MOSQ) = .97

D(mu) = 18.56 D(MOSQ) = 18.02

K(mu) = 4.00 K(MOSQ) = 3.85

σ = .7111

I_0 = .048

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
14	3.00	2.95		
17	1.43	1.38		
20	.657	.61		
23	.299	.25		
[illegible]	.148	.10		
[illegible]	.089	.04		
[illegible]	.066	.02		
[illegible]	.056	–		
38	.051	–		
41	.049	–		

LINEAR REGRESSION FIT

ln I_u = ~~β + α~~ D = 5.12 - .284 D

Dm = 18.02

G = - 2.52

STATISTICAL ANALYSIS SHEET

DATA FILE: INDATA6

IMPAIRMENT: AU-000-00-XY 00 GRPB, CRC

PROGRAM: PROA5; (PROA6) PROB5; PROB6

U(mu) = .98 U(MOSQ) = .93

D_m(mu) = 39.98 D_m(MOSQ) = 39.77

K(mu) = 3.34 K(MOSQ) = 3.10

σ = .1699

I_0 = .075

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
37	2.44	2.37		
40	1.01	.94		
43	.426	.35		
46	.200	.13		
49	.121	.05		
52	.092	.02		
55	.082	-		
58	.078	-		
61	.076	-		
64	.075	-		

LINEAR REGRESSION FIT

ln I_u = ~~14.3 - .36D~~ 12.74 - .32D

Dm = ~~31.8~~ 39.72

G = ~~-3.2~~ -2.84

STATISTICAL ANALYSIS SHEET

DATA FILE: INDATA7

IMPAIRMENT: ALL-000 -00-XX-00 GRPH, CEC

PROGRAM: PROA5; (PROA6) PROB5; PROB6

U(mu) = 1.009 U(MOSQ) = .97

D_m(mu) = 38.75 D_m(MOSQ) = 38.58

K(mu) = 4.08 K(MOSQ) = 3.75

σ = .5295 I_0 = .041

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~34~~	~~3.18~~	~~3.13~~		
37	1.53	1.49		
40	.728	.69		
43	.345	.30		
46	.168	.13		
49	.094	.05		
52	.064	.02		
55	.051	.01		
58	.046	–		
61	.043	–		

LINEAR REGRESSION FIT

ln I_u = ~~12.7 – .33 D~~ 10.98 – .284 D

Dm = ~~38.8~~ 38.6

G = ~~-2.9~~ -2.52

STATISTICAL ANALYSIS SHEET

DATA FILE: INDMAY

IMPAIRMENT: All-030-00-00-KY GRP B, CRC

PROGRAM: PROA5; PROA6; PROB5; PROB6

U(mu) = 1.12 U(MOSQ) = .97

D_m(mu) = 21.43 D_m(MOSQ) = 20.71

K(mu) = 5.08 K(MOSQ) = 4.15

J = .8109 I_0 = .031

C/I	$I_{exp} = \left[\frac{4}{MOSQ-1} - 1\right]$	$I_u = \left[I_0 - I_{exp}\right]$	ln I_u	
~~14~~	~~3.82~~	~~3.73~~		
17	2.24	2.21		
20	1.21	1.18		
23	.630	.60		
26	.317	.29		
29	.162	.13		
32	.061	.03		
35	.046	.02		
38	.039	—		

LINEAR REGRESSION FIT

ln I_u = $\beta + \alpha D$ = 5.65 − .2740 D

Dm = 20.65

G = −2.43