

Core Sequences. Core sequences provide an additional basis for evaluating the performance of the *digital* HDTV Grand Alliance System. They allow for direct comparison of results from the current round of testing with results from the first round of ATV testing.

Mean difference scores (Test minus Reference) for interlaced and progressive modes are shown graphically in Figures 8 and 9, respectively. Numerical values used to create these figures are shown in Tables 10 and 11, respectively. In general, the *digital* HDTV Grand Alliance System was rated as good or better than the corresponding digital proponents from the first round of testing.

Comprehensive ANOVAs on differences scores (Test minus Reference) were performed to compare the results from the *digital* HDTV Grand Alliance System with the corresponding interlaced (AD-HDTV and HD-DigiCipher) and progressive (CC-DigiCipher and DSC-HDTV) systems from the first round of ATV testing. These ANOVAs are shown in detail in Appendices J and K for the interlaced and progressive systems, respectively. The ANOVAs showed a main effect of System, indicating that the systems differed in terms of rated quality. The interaction between System and Picture indicated that differences between Reference and Test varied with System. For example, the interlaced systems produced comparable levels of performance for certain sequences [e.g., Window (M1)] and different levels of performance for other sequences [e.g., Metal Table & Chairs (S1)]. For progressive systems, there was a wide range of differences between Reference and Test. Other interactions were examined and deemed to have no important implications for the evaluation of the *digital* HDTV Grand Alliance System.

Post hoc analyses were performed using the Newman-Keuls test. The analyses are summarized in Tables 12 and 13, for the interlaced and progressive systems, respectively. The post hoc analyses confirmed, on a sequence by sequence basis, that the *digital* HDTV Grand Alliance System performed as good ($p > .05$) or better ($p < .05$) than the corresponding interlaced or progressive systems from the first round of ATV testing. Comparison of these latter systems (AD-HDTV vs. HD-DigiCipher and CC-DigiCipher vs. DSC-HDTV) is shown for the reader's convenience.

The large differences between the *digital* HDTV Grand Alliance System in 720P mode and the progressive first round systems, can be attributed to two factors: 1) good performance of the *digital* HDTV Grand Alliance System in 720P mode, and 2) the use of less noisy source material for the six core camera originated motion sequences. As indicated in Section 2.2, Table 2, all camera originated source sequences used in the 720P tests were obtained by conversion from 1035I.

TABLE 10
BASIC RECEIVED QUALITY
CORE SEQUENCES - INTERLACED

ID	PICTURE	ROUND 2			ROUND 1					
		GRAND ALLIANCE			AD-HDTV			HD-DigiCipher		
		Mean	Std. Dev.	Conf. Int.	Mean	Std. Dev.	Conf. Int.	Mean	Std. Dev.	Conf. Int.
S1	Metal Table & Chairs	1.00	5.70	±1.56	-9.79	13.65	±3.88	-5.25	6.92	±2.21
S5	Tulips	-0.04	6.73	±1.84	-12.52	14.09	±4.01	-6.69	6.20	±1.98
S8	Toys	-0.22	6.83	±1.86	-6.47	11.56	±3.29	-4.01	5.95	±1.90
S9	Girls w Toys	-0.12	5.79	±1.58	-3.60	8.11	±2.30	-9.73	9.40	±3.01
M1	Window	-1.61	7.28	±1.99	-2.29	6.04	±1.72	-3.13	5.61	±1.80
M2	Fax Machine	-4.18	7.36	±2.01	-4.91	9.20	±2.61	-8.43	5.62	±1.80
M4	Mannequins	-5.90	9.69	±2.65	-8.84	10.57	±3.01	-9.13	7.57	±2.42
M5	Living Room	-7.5	10.57	±2.89	-14.10	16.99	±4.83	-11.09	9.85	±3.15
M6	Den	-1.25	7.55	±2.06	-4.78	8.93	±2.54	-9.36	7.32	±2.34
M10	Woman & Room	-3.45	7.21	±1.97	-3.82	9.31	±2.65	-7.15	8.27	±2.64

BASIC RECEIVED QUALITY
CORE SEQUENCES - INTERLACED

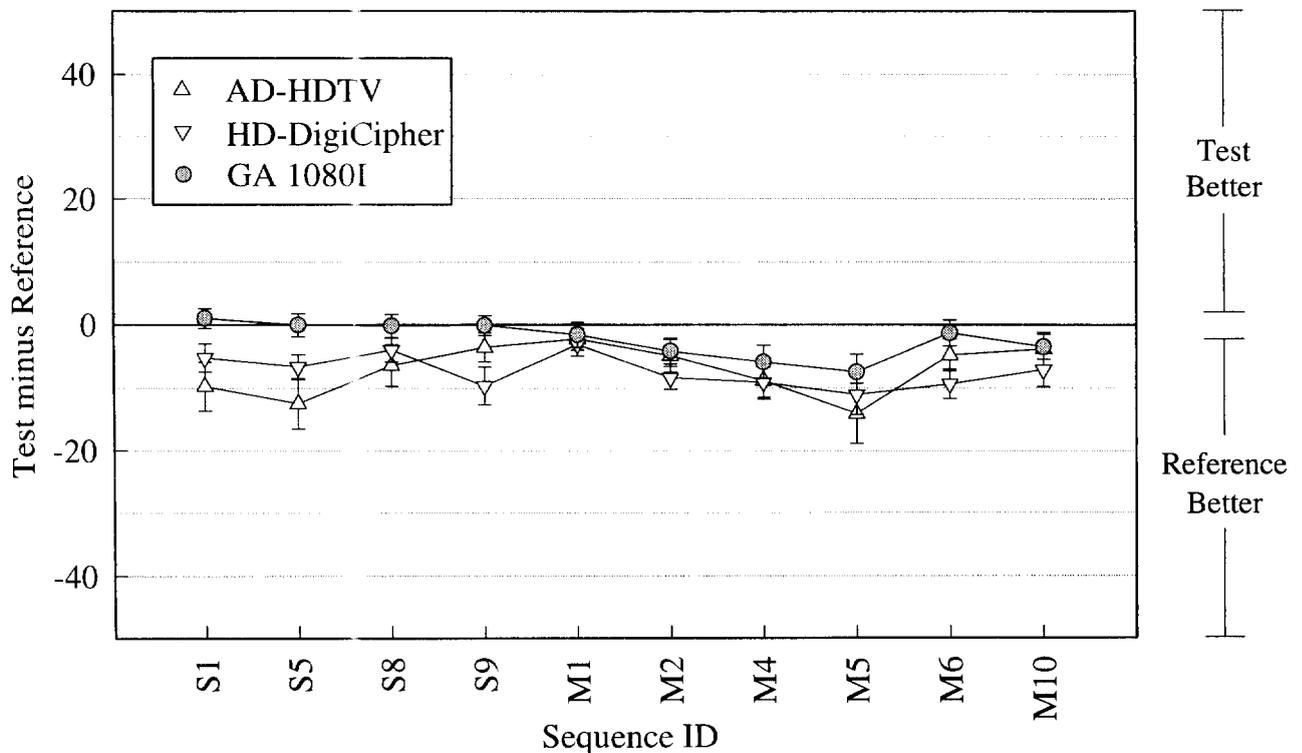


FIGURE 8. Differences in quality ratings (Test minus Reference) for the digital Grand Alliance, AD-HDTV, and HD-DigiCipher for the basic received quality tests.

TABLE 11
BASIC RECEIVED QUALITY
CORE SEQUENCES - PROGRESSIVE

ID	PICTURE	ROUND 2			ROUND 1					
		GRAND ALLIANCE			CC-DigiCipher			DSC-HDTV		
		Mean	Std. Dev.	Conf. Int.	Mean	Std. Dev.	Conf. Int.	Mean	Std. Dev.	Conf. Int.
S1	Metal Table & Chairs	-1.99	9.33	2.55	-7.16	14.51	±4.13	-23.38	20.56	±6.10
S5	Tulips	-3.07	8.26	2.25	-24.68	17.12	±4.87	-10.12	11.92	±3.54
S8	Toys	0.53	8.27	2.26	-13.78	18.90	±5.37	-10.62	15.17	±4.51
S9	Girls w Toys	-1.33	8.50	2.32	-21.83	18.42	±5.23	-10.73	14.11	±4.19
M1	Window	-0.50	7.19	1.96	-28.85	15.18	±4.32	-27.26	17.66	±5.25
M2	Fax Machine	-0.89	7.70	2.10	-19.35	15.11	±4.30	-16.10	21.34	±6.34
M4	Mannequins	-2.42	10.46	2.85	-33.80	18.39	±5.23	-18.15	19.95	±5.93
M5	Living Room	-1.75	9.52	2.60	-34.51	19.74	±5.73	-26.58	17.64	±5.24
M6	Den	-0.30	11.04	3.01	-34.65	17.20	±4.89	-24.96	15.02	±4.46
M10	Woman & Room	-1.78	6.65	1.81	-21.32	13.74	±3.90	-20.68	12.68	±3.77

BASIC RECEIVED QUALITY
CORE SEQUENCES - PROGRESSIVE

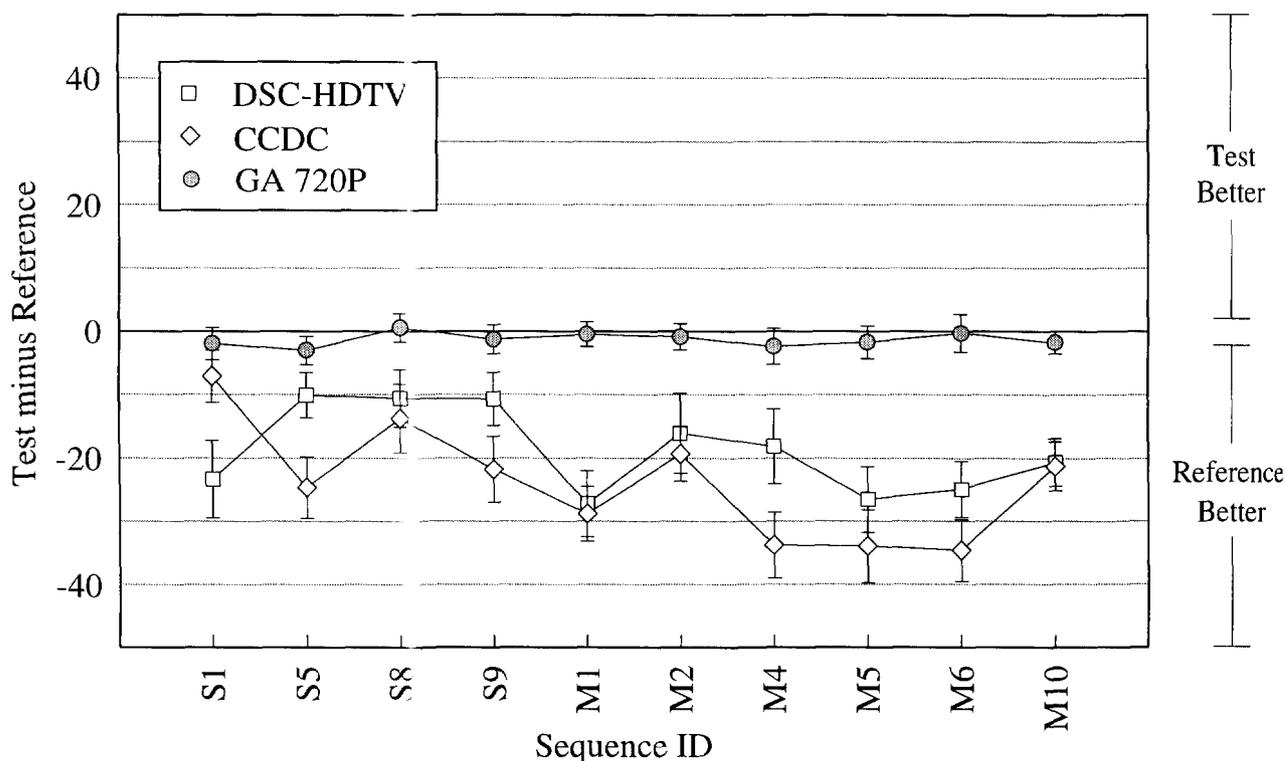


FIGURE 9. Differences in quality ratings (Test minus Reference) for the digital Grand Alliance HDTV System, CC-DigiCipher and DSC-HDTV, progressive systems.

TABLE 12
SUMMARY OF POST HOC TESTS
CORE SEQUENCES - INTERLACED

NEWMAN-KEULS				
ID	PICTURE	GRAND ALLIANCE (1080I) vs. AD-HDTV	GRAND ALLIANCE (1080I) vs. HD-DigiCipher	AD-HDTV vs. HD-DigiCipher
S1	Metal Table & Chairs	.00	.03	.28
S5	Tulips	.00	.02	.03
S8	Toys	.02	.42	.75
S9	Girls With Toys	.48	.00	.04
M1	Window	.73	.67	.61
M2	Fax Machine	.90	.32	.50
M4	Mannequins	.58	.58	.92
M5	Living Room	.01	.45	.20
M6	Den	.56	.00	.30
M10	Woman And Room	.97	.65	.71

TABLE 13
SUMMARY OF POST HOC TESTS
CORE SEQUENCES - PROGRESSIVE

NEWMAN-KEULS				
ID	PICTURE	GRAND ALLIANCE (720P) vs. CC-DigiCipher	GRAND ALLIANCE (720P) vs. DSC-HDTV	CC-DigiCipher vs. DSC-HDTV
S1	Metal Table & Chairs	.11	.00	.00
S5	Tulips	.00	.02	.00
S8	Toys	.00	.00	.16
S9	Girls With Toys	.00	.02	.00
M1	Window	.00	.00	.62
M2	Fax Machine	.00	.00	.41
M4	Mannequins	.00	.00	.00
M5	Living Room	.00	.00	.02
M6	Den	.00	.00	.00
M10	Woman And Room	.00	.00	.87

Significance levels $p < .05$ are shaded.

3.0 SUBJECTIVE TESTS OF IMPAIRMENT / INTERFERENCE

3.1 Objectives

The Impairment/Interference tests were conducted to assess the degradation in perceived quality of a NTSC picture when a *digital* HDTV Grand Alliance signal was present on an adjacent channel (Upper or Lower) or on the same channel (Co-Channel).

At the direction of the Chairman of SSWP2, the results of the Upper-Adjacent Channel Interference test are not included in this report. The impaired sequences were recorded at the ATTC using a nonrepresentative NTSC receiver, thus invalidating the results of the Upper-Adjacent Channel test. See Appendix D, document SSWP2-1462 for further details.

3.2 Methodology

Viewers. Viewers were recruited through a local university and were screened for visual acuity (normal or corrected-to-normal), contrast sensitivity (normal), color vision (normal), and English comprehension. Those who met the screening criteria were permitted to participate in the tests. All viewers, but for two in the Lower-Adjacent Channel and two in the Co-Channel Interference tests, were non-experts, defined as individuals with no previous exposure to video subjective evaluation experiments at the ATEL, or professional experience in television technology. Post hoc analyses indicated that the impairment/interference ratings for these viewers were consonant with the mean ratings for the other viewers.

Separate groups of viewers were used in the Lower-Adjacent Channel and Co-Channel Interference tests. Details of the composition of the two groups are presented in Table 14. A maximum of five viewers participated in any given session.

**TABLE 14
VIEWER CHARACTERISTICS**

IMPAIRMENT / INTERFERENCE TEST	TAPE ORDER 1			TAPE ORDER 2			COMBINED		
	N	MALE / FEMALE	MEAN AGE	N	MALE / FEMALE	MEAN AGE	N	MALE / FEMALE	MEAN AGE
LOWER-ADJACENT CHANNEL INTERFERENCE	15	5/10	24.7	15	12/3	23.6	30	17/13	24.2
CO-CHANNEL INTERFERENCE	13	8/5	29.3	13	8/5	22.2	26	16/10	25.7

Test Material. Three NTSC sequences were used in the Impairment/Interference tests: Girls with Toys, Co-Channel¹⁵ and Woman with Roses. Reference sequences consisted of these three sequences received at a given signal level in NTSC, but with no interference. Test sequences consisted of these three sequences received at the same given signal level in NTSC, but with the *digital* HDTV Grand Alliance signal present in either the Lower-Adjacent Channel or Co-Channel. For a detailed description of the material see Appendix B.

Design and Procedures. There were two types of Interference/Impairment tests: Lower-Adjacent Channel Interference and Co-Channel Interference. The design of each test had five factors: Picture, Replicate, Signal Level,¹⁶ Impairment Level, and Tape Order. All factors were varied within subjects except for Tape Order which was varied between subjects. Picture refers to the three NTSC sequences used in the Impairment/Interference tests. Replicate refers to the number of times a condition occurred during a session; each condition occurred twice per session. Signal Level refers to the level of the desired NTSC signal. The Signal Level was varied at -35 dBm (moderate)¹⁷ and -55 dBm (weak) for the Lower-Adjacent Channel Interference test, and was fixed at -55 dBm (weak) for the Co-Channel Interference test. Impairment Level refers to the level of the undesired (interfering) ATV signal. The Impairment Level was varied at the six levels shown in Tables 16 and 18. These levels were selected by a panel of "expert" observers at ATTC to ensure that the severity of perceived impairments ranged from "imperceptible" to "very annoying." To enhance the visibility of noise in the NTSC sequences, the content of the undesired ATV signal was switched between black and the sequence Rotating Pyramids (M16 uncorrected). This new sequence is referred to as Gated Rotating Pyramids (M16G). Tape Order refers to the random presentation of the experimental trials; two random presentation orders were used.

For the Lower-Adjacent Channel Interference test, viewers completed 72 experimental trials (2 Signal Levels x 3 Pictures x 6 Impairment Levels x 2 Replicates) plus 8 practice trials. Five practice trials were completed at the start of testing and 3 were completed after a 30 minute rest-break midway through the session. In the Co-Channel test, viewers completed 36 experimental trials (3 Pictures x 6 Impairment Levels x 2 Replicates) plus 5 practice trials at the start of testing. There was no rest-break in the Co-Channel test.

The five-grade impairment scale method described in ITU-R Recommendation 500¹⁸ was used to assess perceived impairment of the Test sequences. The layout of a trial is shown schematically in Figure 10. Each trial consisted of a Reference sequence followed by a Test sequence.

¹⁵ For historical reasons this sequence is named "Co-Channel", however this sequence was used in all Impairment/Interference tests reported here.

¹⁶ In the Co-Channel test only one desired signal level was used and, hence, this factor does not apply.

¹⁷ In the test plan (SSWP2-1306, version 24 March 1995) the specified power level for this test was -25 dBm (strong). However, -35 dBm (moderate) was substituted at the ATTC in order to establish a Point of Unusability (POU).

¹⁸ ITU-R International Telecommunications Union Radiocommunications Sector is an organization of the International Telecommunications Union, a United Nations agency. Formerly it was called the International Radio Consultative Committee (CCIR).

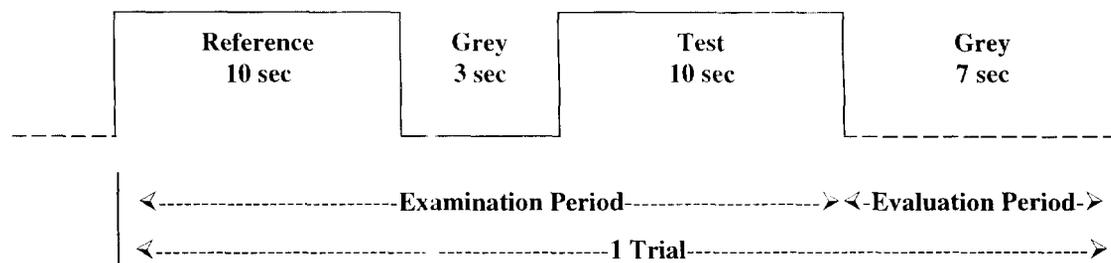


FIGURE 10. Layout of an Impairment / Interference assessment trial.

The five-grade impairment scale is shown in Figure 11. For each trial, viewers were instructed to rate the impairment of the Test sequence relative to the Reference sequence. For example, if the Test and Reference sequences contained impairments of equal magnitude, subjects were instructed to rate the impairment as imperceptible. If the Test sequence contained impairments of greater magnitude than the Reference sequence, subjects were instructed to rate the incremental impairment accordingly. Note, that the Reference sequences could contain visible impairments, especially at the weak signal level.

- IMPERCEPTIBLE
- PERCEPTIBLE, BUT NOT ANNOYING
- SLIGHTLY ANNOYING
- ANNOYING
- VERY ANNOYING

FIGURE 11. The five-grade impairment scale.

All viewers participated in a post session questionnaire. The results are summarized and presented in Appendix F.

Test Setup. The display was a Mitsubishi CS-3520R direct-view NTSC monitor. Playback was from a SONY DVR-10 D2 Digital VTR.

Viewing Conditions. The conditions in the ATEL viewing room matched the specifications shown in Table 15. The layout of the viewing room is shown in Section 2.2, Figure 3. The lightwall provided uniform illumination of the background surrounding the video display screen and is shown schematically in Section 2.2, Figure 4.

TABLE 15
VIEWING CONDITIONS FOR NTSC SUBJECTIVE ASSESSMENTS

CONDITION	SPECIFICATION ¹⁹	MAINTAINED VALUE
Peak monitor luminance (PML)	60 - 80 cd/m ²	68 - 72 cd/m ²
Monitor luminance (maximum, at beam cut-off under ambient lighting conditions)	2 % of PML	1.5 - 2 % PML
Monitor luminance (maximum, at black-level in dark room)	1 % of PML	.5 - 1 % of PML
Monitor white color temperature	6500° K	6400 - 6600° K
Luminance of controlled monitor surround	15 % of PML	14 - 16 % of PML
Color temperature of controlled monitor surround	6500° K	6400 - 6600° K
Size of controlled monitor surround	not specified	48° H x 73° W
Room illumination	low	9.5 - 10.5 lux
Color temperature of room lighting	6500° K	6400 - 6600° K
Wall colors	minimum color	white/grey
Ratio of viewing distance to picture height	5 - 6 H	5 H
Monitor size	not specified	35 in
Maximum off-center angle of view for individual viewer	30°	22 - 24°

¹⁹ Source for specification is Document SSWP2-1306.

3.3 Results - Impairment/Interference Assessments

Overview. The analyses examined the impairment ratings of Test sequences for Lower-Adjacent Channel and Co-Channel tests. Impairment ratings, ranging from 1 (“very annoying”) to 5 (“imperceptible”), were digitized for computer analysis from the five-grade impairment scales completed by the viewers.

The results are organized in graphical and tabular form. The mean impairment ratings for Lower-Adjacent Channel and Co-Channel tests are shown graphically in Figures 12 and 13, respectively. The error bars in each figure represent the 95% confidence interval around the mean. Numerical values used to create these figures are shown in corresponding tables on the facing pages (Tables 16 and 18, respectively). The tables beneath each figure (Tables 17 and 19) show parameters derived from the graphs. The mean 3.0 and 4.0 ratings correspond to dBm values of the interfering signal at which impairments became “slightly annoying” and “perceptible, but not annoying”, respectively. The mean level values of 3.0 are commonly used for spectrum planning purposes.

TABLE 16
LOWER-ADJACENT CHANNEL INTERFERENCE (ATV-to-NTSC)

DESIRED LEVEL	PICTURE	UNDESIRE D LEVEL (dBm)	MEAN RATING	STANDARD DEVIATION	CONFIDENCE INTERVAL	
SIGNAL 1 -35 dBm (MODERATE)	G. w. TOYS (S09)	SUB TOV	-36.23	4.87	0.34	0.09
		TOV	-34.23	4.82	0.60	0.15
		TOV+ 1	-24.39	3.78	0.69	0.18
		TOV + 2	-22.39	3.43	0.74	0.19
		TOV + 3	-20.64	2.33	0.73	0.19
		TOV + 4	-18.77	1.67	0.63	0.16
	CO-CHANNEL (M14)	SUB TOV	-36.23	4.93	0.25	0.06
		TOV	-34.23	4.92	0.28	0.07
		TOV+ 1	-24.39	4.00	0.66	0.17
		TOV + 2	-22.39	3.55	0.79	0.20
		TOV + 3	-20.64	2.63	0.88	0.23
		TOV + 4	-18.77	1.73	0.69	0.18
	W. w. ROSES (S11)	SUB TOV	-36.23	4.92	0.28	0.07
		TOV	-34.23	4.87	0.39	0.10
		TOV+ 1	-24.39	4.03	0.52	0.13
		TOV + 2	-22.39	3.55	0.65	0.17
		TOV + 3	-20.64	2.95	0.85	0.22
		TOV + 4	-18.77	1.62	0.61	0.16
SIGNAL 2 -55 dBm (WEAK)	G. w. TOYS (S09)	SUB TOV	-51.08	4.63	0.55	0.14
		TOV	-49.08	4.68	0.57	0.15
		TOV+ 1	-43.14	3.88	0.56	0.14
		TOV + 2	-38.89	3.25	0.70	0.18
		TOV + 3	-34.89	1.95	0.67	0.17
		TOV + 4	-31.89	1.28	0.80	0.21
	CO-CHANNEL (M14)	SUB TOV	-51.08	4.75	0.47	0.12
		TOV	-49.08	4.80	0.44	0.11
		TOV+ 1	-43.14	4.32	0.60	0.15
		TOV + 2	-38.89	3.50	0.62	0.16
		TOV + 3	-34.89	2.02	0.68	0.18
		TOV + 4	-31.89	1.13	0.39	0.10
	W. w. ROSES (S11)	SUB TOV	-51.08	4.77	0.53	0.14
		TOV	-49.08	4.68	0.54	0.14
		TOV+ 1	-43.14	4.25	0.60	0.15
		TOV + 2	-38.89	3.55	0.65	0.17
		TOV + 3	-34.89	2.35	0.78	0.20
		TOV + 4	-31.89	1.20	0.63	0.16

TOV refers to Threshold of Visibility.
SUB TOV refers to TOV minus 2dB.

LOWER-ADJACENT CHANNEL INTERFERENCE (ATV-to-NTSC)

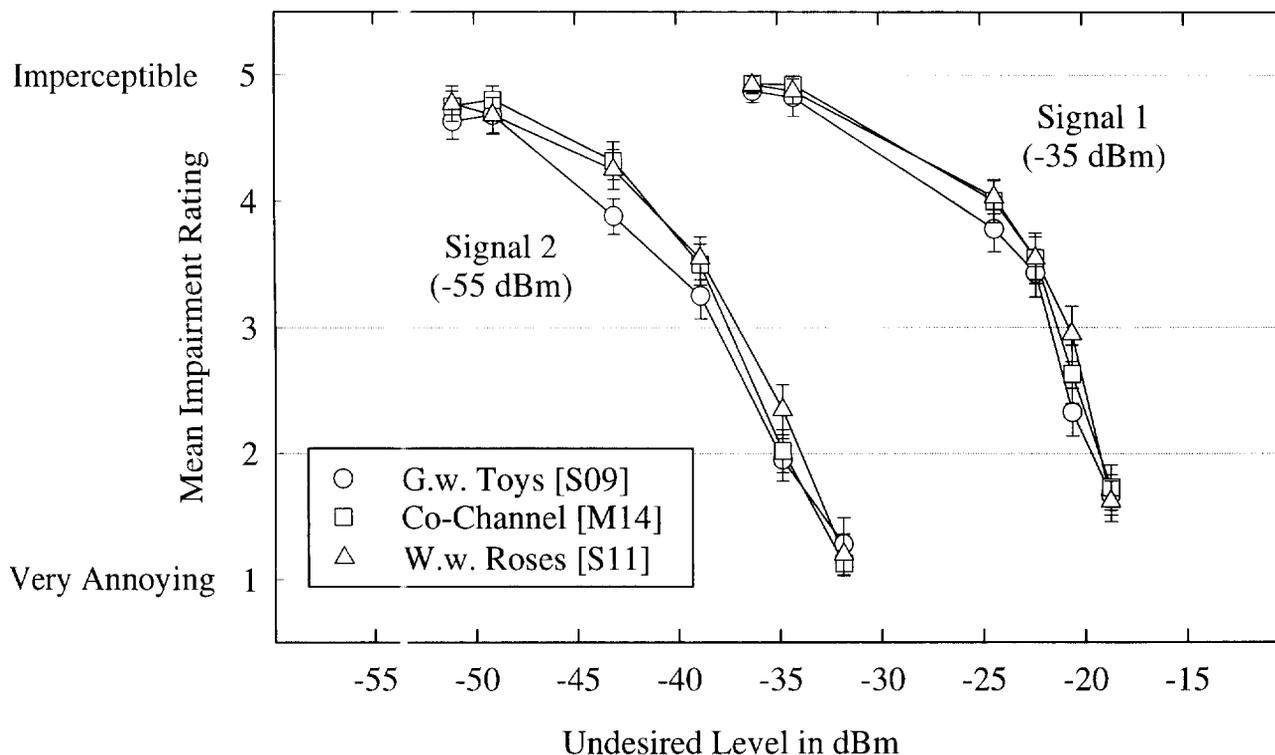


FIGURE 12. Mean impairment ratings for Lower-Adjacent Channel Interference tests for the *digital* Grand Alliance HDTV System.

TABLE 17
LOWER-ADJACENT CHANNEL INTERFERENCE (ATV-to-NTSC)
PARAMETERS

DESIRED LEVEL	PICTURE	4.0 LEVEL		3.0 LEVEL FOR SPECTRUM PLANNING	
		MEAN RATING	CONFIDENCE INTERVAL	MEAN RATING	CONFIDENCE INTERVAL
SIGNAL 1 -35 dBm (MODERATE)	G. w. TOYS (S09)	-26.47	±1.37	-21.71	±1.08
	CO-CHANNEL (M14)	-24.39	±1.11	-21.34	±0.71
	W.w. ROSES (S11)	-24.27	±1.29	-20.79	±0.52
	OVERALL	-25.04	±1.25	-21.28	±0.77
SIGNAL 2 -55 dBm (WEAK)	G. w. TOYS (S09)	-44.03	±1.25	-38.12	±0.96
	CO-CHANNEL (M14)	-41.48	±0.96	-37.54	±0.72
	W. w. ROSES (S11)	-41.62	±1.36	-37.06	±0.80
	OVERALL	-42.38	±1.16	-37.57	±0.83

TABLE 18
CO-CHANNEL INTERFERENCE (ATV-to-NTSC)

DESIRED LEVEL	PICTURE	UNDESIREO LEVEL (dBm)		MEAN RATING	STANDARD DEVIATION	CONFIDENCE INTERVAL
SIGNAL -55 dBm (WEAK)	G. w. TOYS (S09)	SUB TOV	-104.74	4.58	0.54	0.15
		TOV	-102.74	4.46	0.58	0.16
		TOV+ 1	-97.01	4.06	0.54	0.15
		TOV + 2	-90.26	3.04	0.66	0.18
		TOV + 3	-85.51	2.31	0.67	0.19
		TOV + 4	-79.80	1.15	0.36	0.10
	CO-CHANNEL (M14)	SUB TOV	-104.74	4.63	0.60	0.17
		TOV	-102.74	4.60	0.60	0.17
		TOV+ 1	-97.01	4.06	0.50	0.14
		TOV + 2	-90.26	3.10	0.69	0.19
		TOV + 3	-85.51	2.46	0.70	0.19
		TOV + 4	-79.80	1.21	0.64	0.18
	W. w. ROSES (S11)	SUB TOV	-104.74	4.65	0.48	0.13
		TOV	-102.74	4.63	0.53	0.15
		TOV+ 1	-97.01	4.37	0.49	0.14
		TOV + 2	-90.26	3.33	0.62	0.17
		TOV + 3	-85.51	2.25	0.71	0.20
		TOV + 4	-79.80	1.54	0.54	0.15

TOV refers to Threshold of Visibility.
SUB TOV refers to TOV minus 2dB.

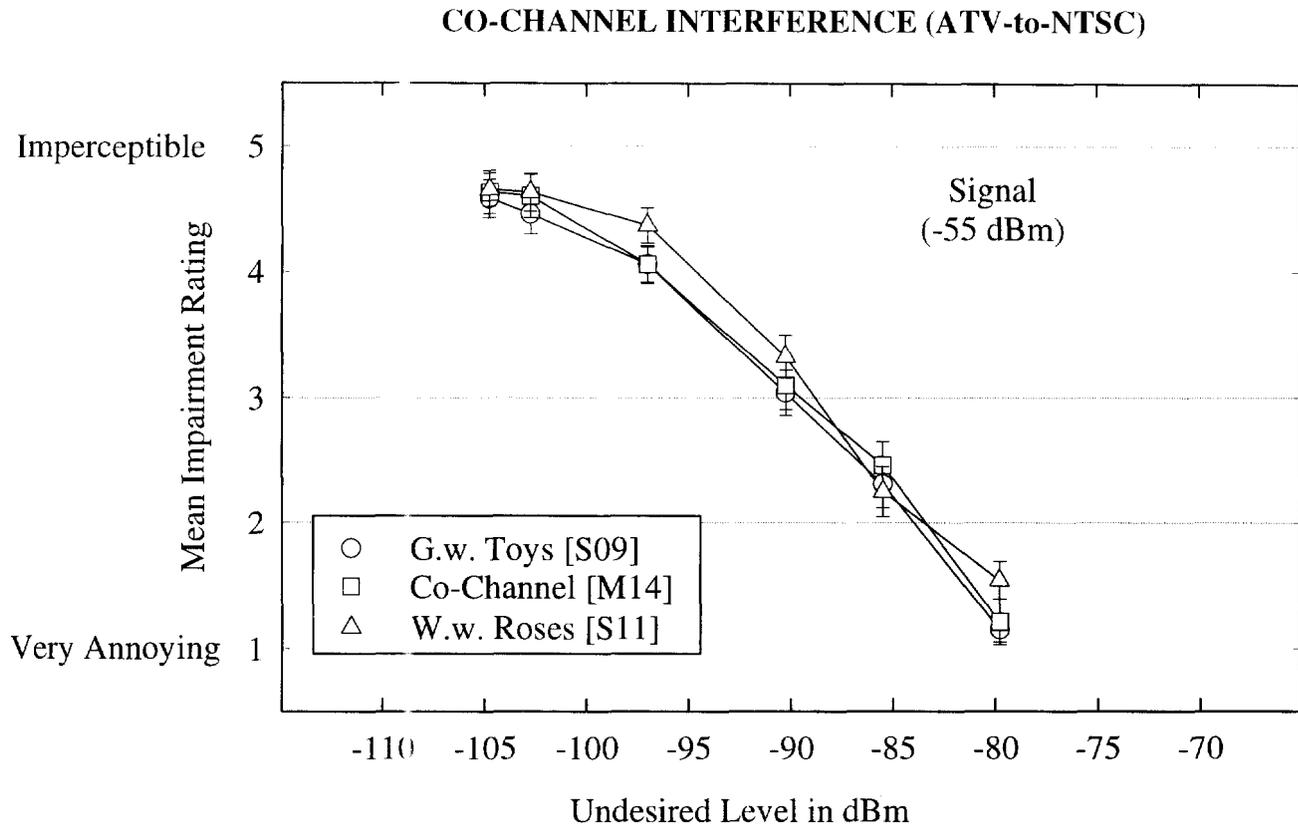


FIGURE 13. Mean impairment ratings for Co-Channel Interference tests for the *digital* Grand Alliance HDTV System.

**TABLE 19
CO-CHANNEL INTERFERENCE (ATV-to-NTSC)
PARAMETERS**

DESIRED LEVEL	PICTURE	4.0 LEVEL		3.0 LEVEL FOR SPECTRUM PLANNING	
		MEAN RATING	CONFIDENCE INTERVAL	MEAN RATING	CONFIDENCE INTERVAL
SIGNAL -55 dBm (WEAK)	G. w. TOYS (S09)	-96.61	±1.61	-90.00	±1.20
	CO-CHANNEL (M14)	-96.59	±1.54	-89.52	±1.43
	W. w. ROSES (S11)	-94.61	±1.40	-88.81	±0.91
	OVERALL	-95.94	±1.50	-89.44	±1.18

Statistical Analyses. The primary purpose of the statistical analyses was to determine whether the observed judgements were statistically reliable; that is, whether they could be attributed to chance variation or to actual rated differences. ANOVAs assessed overall effects of Tape Order, Signal Level, Impairment Level, Replicate and Picture.

ANOVAs were performed for the Lower-Adjacent Channel and Co-Channel tests, separately for each Signal Level. The results of the ANOVAs are shown in detail in Appendices L and M, respectively. In these ANOVAs, Tape Order was the between-subjects factor. The repeated measures factors were Picture, Replicate and Impairment Level. All ANOVAs showed robust main effects of Impairment Level and Picture and an interaction between Impairment Level and Picture. The main effect of Impairment Level indicated that increasing the power level of the interfering signal in the Lower-Adjacent Channel and Co-Channel resulted in a decrement in perceived image quality of the NTSC picture. The main effect of Picture indicated that the 3 pictures received different overall ratings of perceived impairment. For both tests, Woman with Roses was rated the most positively, followed by Co-Channel and then Girls with Toys. The interaction of Impairment Level and Picture indicated that the patterns of decrement in perceived quality varied with Picture. Other interactions were examined and deemed to have no important implications for the evaluation of the *digital* HDTV Grand Alliance System.

3.4 Comparative - Impairment / Interference

To facilitate evaluation of the *digital* HDTV Grand Alliance System, the mean impairment ratings of the System were graphed alongside those of the digital proponents from the first round of ATV testing.²⁰ Note, that mean impairment ratings have been averaged across all three pictures. Separate graphs are shown for Lower-Adjacent Channel and Co-Channel Interference in Figures 14 and 15, respectively.

Target Specifications. The target specification for each test, as indicated in the "Grand Alliance HDTV System Specification" manual (Chapter 9, version Dec. 7, 1994), is shown with a bull's-eye symbol in each figure and is also listed in Table 20. The *digital* HDTV Grand Alliance System exceeded the target specification for both Lower-Adjacent Channel and Co-Channel Interference. Detailed numerical values are shown in Table 20.

TABLE 20
IMPAIRMENT / INTERFERENCE (ATV-to-NTSC)
TARGET SPECIFICATIONS

TEST	TARGET RATING	OBSERVED RATING	TARGET D/U	OBSERVED D/U
LOWER-ADJACENT	≥ grade 3.0 @ -55 dBm	3.76	< -14.5	-17.43
CO-CHANNEL	≥ grade 3.0 @ -55 dBm	3.37	< 36.5	34.44

²⁰ There were 4 digital proponents (AD-HDTV, CC-DigiCipher, HD-DigiCipher and DSC-HDTV) in the first round of ATV testing.

LOWER-ADJACENT CHANNEL INTERFERENCE (ATV-to-NTSC)

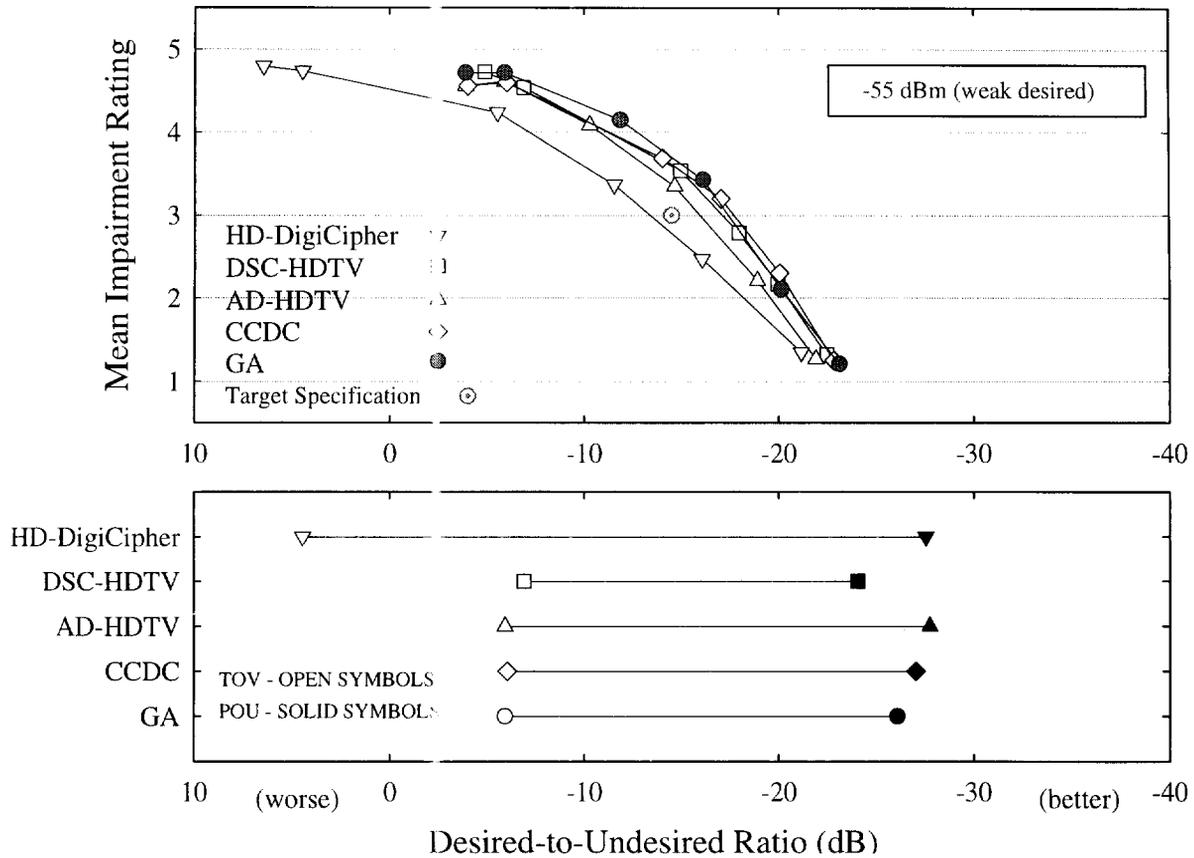


FIGURE 14. A comparison of the mean impairment ratings for Lower-Adjacent Channel Interference for the *digital* Grand Alliance HDTV System and the 4 digital proponent systems from the first round of testing. The corresponding Thresholds of Visibility (TOV) and Points of Unusability (POU) obtained from expert assessments at ATTC are shown on the bottom panel of the figure.

CO-CHANNEL INTERFERENCE (ATV-to-NTSC)

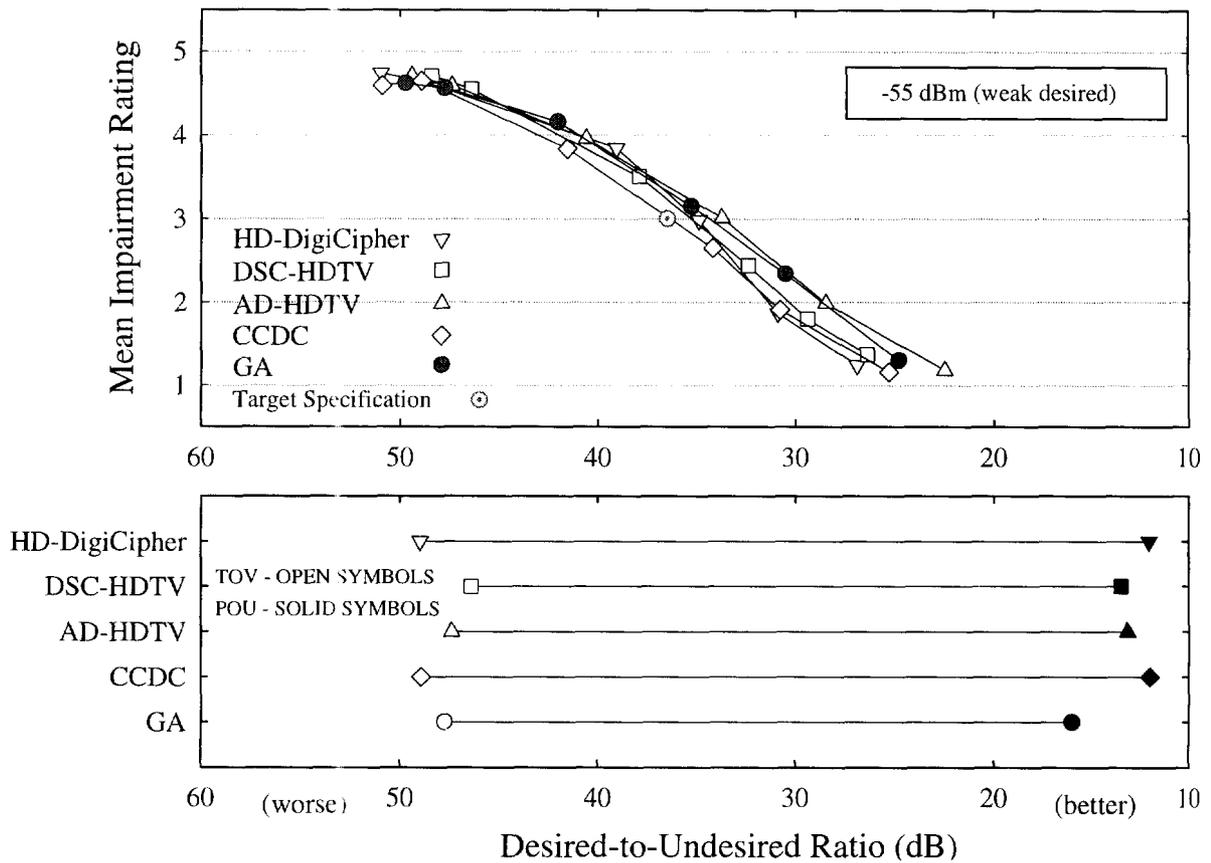


FIGURE 15 . A comparison of the mean impairment ratings for Co-Channel Interference for the *digital* Grand Alliance HDTV System and the 4 digital proponent systems from the first round of testing. The corresponding Thresholds of Visibility (TOV) and Points of Unusability (POU) obtained from expert assessments at ATTC are shown on the bottom panel of the figure.

4.0 SUBJECTIVE TESTS OF RECEIVER SCAN CONVERSION

Receiver Scan Conversion was an optional test performed at the recommendation of the Task Force on Digital Specific Tests (SSWP2). For this test, the Task Force selected only critical sequences in which conversion artifacts were observed by experts. Five sequences were selected for both 1080I to 720P, and 720P to 1080I conversion. One additional sequence was selected for 1080I to 720P and two for 720P to 1080I conversion. To further increase criticality for two sequences, different 10 second portions of the 15 second clips were selected as compared to the Basic Received Quality tests. Tape capacity restrictions precluded doing a full factorial design where all sequences were converted from 1080I to 720P and from 720P to 1080I.

4.1 Objectives

The Receiver Scan Conversion tests were conducted to assess the impact on quality of converting, at the receiver, between the two modes of operation (1080I and 720P) of the *digital* HDTV Grand Alliance System. Subjective image quality of unconverted (1080I and 720P) and converted (1080I to 720P, and 720P to 1080I) sequences was assessed.

4.2 Methodology

Viewers. Viewers were recruited through a local university and were screened for visual acuity (normal or corrected-to-normal), contrast sensitivity (normal), color vision (normal), and English comprehension. Those who met the screening criteria were permitted to participate in the tests. All viewers, but for two, were non-experts, defined as individuals with no previous exposure to subjective evaluation experiments at the ATEL, or professional experience in television technology. Post hoc analyses indicated that the image quality ratings for these viewers were consonant with the mean ratings for the other viewers.

As in all other tests, separate groups of viewers were used in each of the two Tape Orders. Details of the composition of the groups are presented in Table 21. A maximum of five viewers participated in any given session.

TABLE 21
VIEWER CHARACTERISTICS

TEST	TAPE ORDER 1			TAPE ORDER 2			COMBINED		
	N	MALE/ FEMALE	MEAN AGE	N	MALE/ FEMALE	MEAN AGE	N	MALE/ FEMALE	MEAN AGE
RECEIVER SCAN CONVERSION	14	4/10	24.5	12	7/5	26.4	26	11/15	25.4

Test Material. Eight sequences were used in the Receiver Scan Conversion tests: Metal Table and Chairs (S1), Rotating Pyramids (M16A), Dream Team (M40), Ducks (M43), Picnic with Ants (M49), Den (M6), Woman and Room (M10) and Cheshire Cat (S14A). The attributes of these sequences are listed in Section 2.2, Table 2, with the exception of Ducks (M43)²¹. As in the Basic Received Quality tests, each sequence was a central 10 second portion of a 15 second video clip. However, for Rotating Pyramids (M16A) and Picnic with Ants (M49), the 10 second portion was selected from the end of the clip instead of from the center (M16A comprised the period 4-14 seconds and M49 comprised the period 5-15 seconds). This was done to make these sequences more challenging for compression and conversion.

As in all quality tests described in this report, Reference sequences were displayed in the 1035I format.

Four types of Test sequences were defined in terms of the input - output combinations: 1080I - 1080I unconverted, 720P - 720P unconverted, 1080I - 720P converted, and 720P - 1080I converted. All four input - output combinations were generated for S1, M16A, M40, M43 and M49. For M6 and M10, Test sequences were generated for 720P - 720P unconverted and 720P - 1080I converted. For S14A, Test sequences were generated for 1080I - 1080I unconverted and 1080I - 720P converted. See Table 22 for a summary.

Geometric differences existed between images within a given trial, and where possible, it was undertaken to conceal these differences. For 1080I - 1080I unconverted Test sequences, an excellent Reference to Test picture content match was inherent, and no display compensation was required. For 720P - 720P unconverted Test sequences, a single compromise 720P projector display setup was used to minimize the slight geometric differences between Reference images and some 720P Test images (See Section 2.2, Test Material, for a discussion of 720P source sequences). An alternate 720P projector setup was used for displaying 1080I - 720P converted Test sequences. This setup centered and stretched valid video to remove from view 27 duplicate lines, a result of the 1080I to 720P conversion. For 720P to 1080I converted Test sequences, it was not possible to compensate for the elimination of 40 lines of active video, a result of the recording process, or for the slight geometric distortions inherent to some 720P source material. For details of the video sequences and the corrections applied see Appendix C.

Design and Procedures. There were four factors in the design: Picture, InOut, Replicate and Tape Order. Picture refers to the sequence name. InOut refers to the input - output combination (1080I - 1080I, 720P - 720P, 1080I - 720P, and 720P - 1080I). Replicate refers to the number of times a condition occurred during a session; each condition occurred twice per session. Tape Order refers to the random order of the experimental trials; two Tape Orders were used. Picture, InOut, and Replicate were varied within subjects, and Tape Order was varied between subjects.

²¹ This sequence was chosen to demonstrate complex motion. The 1035I video camera source was converted to 720P.

Viewers completed 52 experimental trials plus 8 practice trials. Five practice trials were completed at the start of testing, and 3 were completed after a 30 minute rest-break midway through the session. The 52 experimental trials were defined by the factorial combination of Replicate, Picture and InOut; Five Pictures (S1, M16A, M40, M43, M49) were varied at all four levels of InOut, and three Pictures (M6, M10, S14A) were varied at two levels of InOut (see Table 22).

Viewing conditions, rating scales and instructions to viewers were the same as those used in the Basic Received Quality tests (see Section 2.2), with the exception that the display parameters were adjusted to compensate for vertical distortion in the manner described in Appendix C.

All viewers participated in a post session questionnaire. The results are summarized and presented in Appendix G.

4.3 Results - Receiver Scan Conversion Assessments

Overview. The analyses examined the quality ratings of Reference and Test sequences for the Receiver Scan Conversion tests.

The quality ratings, ranging from 0 to 100, were digitized for computer analysis from the continuous quality scales completed by the viewers. Judgements of "BAD" corresponded to values between 0 and 20; "POOR" corresponded to values between 20 and 40; "FAIR" corresponded to values between 40 and 60; "GOOD" corresponded to values between 60 and 80; and "EXCELLENT" corresponded to values between 80 and 100.

The results are organized in graphical and tabular form. The mean quality ratings are shown in Figure 16 for Reference and Test sequences. Difference scores (Test minus Reference) are shown in Figures 17 and 18, for common input and common output, respectively. The error bars in the figures represent the 95% confidence interval around the mean. Numerical values used to create the figures are shown in Tables 22 and 23. In Figures 17 and 18, a score of 0 indicates that the mean rating of the Reference and Test sequence was equivalent. A rating greater than 0 indicates that the Test sequence was rated higher than the Reference sequence. A rating less than 0 indicates that the Test sequence was rated lower than the Reference sequence. Figures 16, 17 and 18 show that, for some sequences, receiver scan conversion resulted in no reduction in rated quality. For other sequences some reduction was observed; the maximum observed reduction was approximately 0.5 grade (10 units), although in most cases it was substantially less. The statistical analyses confirmed these observations.

TABLE 22
RECEIVER SCAN CONVERSION

ID	PICTURE	IN - OUT	REFERENCE			TEST		
			MEAN	STND. DEV.	CONF. INT.	MEAN	STND. DEV.	CONF. INT.
S1	Metal Table & Chairs	1080 - 1080	77.04	9.70	±2.70	75.29	8.91	±2.48
S1	Metal Table & Chairs	1080 - 720	74.89	10.54	±2.93	74.51	9.61	±2.68
S1	Metal Table & Chairs	720 - 720	76.33	10.92	±3.04	74.97	8.14	±2.27
S1	Metal Table & Chairs	720 - 1080	74.83	9.03	±2.51	74.19	10.04	±2.80
M16A	Rotating Pyramids	1080 - 1080	73.03	12.95	±3.61	66.34	14.79	±4.12
M16A	Rotating Pyramids	1080 - 720	78.16	9.72	±2.71	66.70	15.54	±4.33
M16A	Rotating Pyramids	720 - 720	74.97	14.80	±4.12	74.67	12.47	±3.47
M16A	Rotating Pyramids	720 - 1080	73.91	14.17	±3.95	67.09	13.31	±3.71
M40	Dream Team	1080 - 1080	72.59	12.62	±3.51	59.43	17.57	±4.89
M40	Dream Team	1080 - 720	75.18	12.85	±3.58	56.63	18.30	±5.10
M40	Dream Team	720 - 720	74.83	11.37	±3.17	63.41	15.42	±4.29
M40	Dream Team	720 - 1080	74.26	12.64	±3.52	60.06	16.54	±4.61
M43	Ducks	1080 - 1080	77.16	9.22	±2.57	67.68	10.41	±2.90
M43	Ducks	1080 - 720	77.99	10.01	±2.79	68.42	10.15	±2.83
M43	Ducks	720 - 720	77.21	10.92	±3.04	69.71	10.72	±2.99
M43	Ducks	720 - 1080	76.14	11.34	±3.16	66.25	14.40	±4.01
M49	Picnic With Ants	1080 - 1080	76.46	10.37	±2.89	45.11	18.44	±5.13
M49	Picnic With Ants	1080 - 720	77.31	10.67	±2.97	49.43	20.42	±5.69
M49	Picnic With Ants	720 - 720	79.14	8.49	±2.36	36.07	20.04	±5.58
M49	Picnic With Ants	720 - 1080	73.76	13.93	±3.88	29.12	18.51	±5.15
M6	Den	720 - 720	73.74	10.49	±2.92	71.36	13.69	±3.81
M6	Den	720 - 1080	75.89	9.74	±2.71	63.30	16.19	±4.51
M10	Woman And Room	720 - 720	78.64	10.03	±2.79	73.54	11.58	±3.22
M10	Woman And Room	720 - 1080	76.57	11.95	±3.33	69.14	13.64	±3.80
S14A	Cheshire Cat	1080 - 1080	77.91	8.77	±2.44	75.55	8.84	±2.46
S14A	Cheshire Cat	1080 - 720	78.60	8.71	±2.43	76.94	9.42	±2.62

RECEIVER SCAN CONVERSION

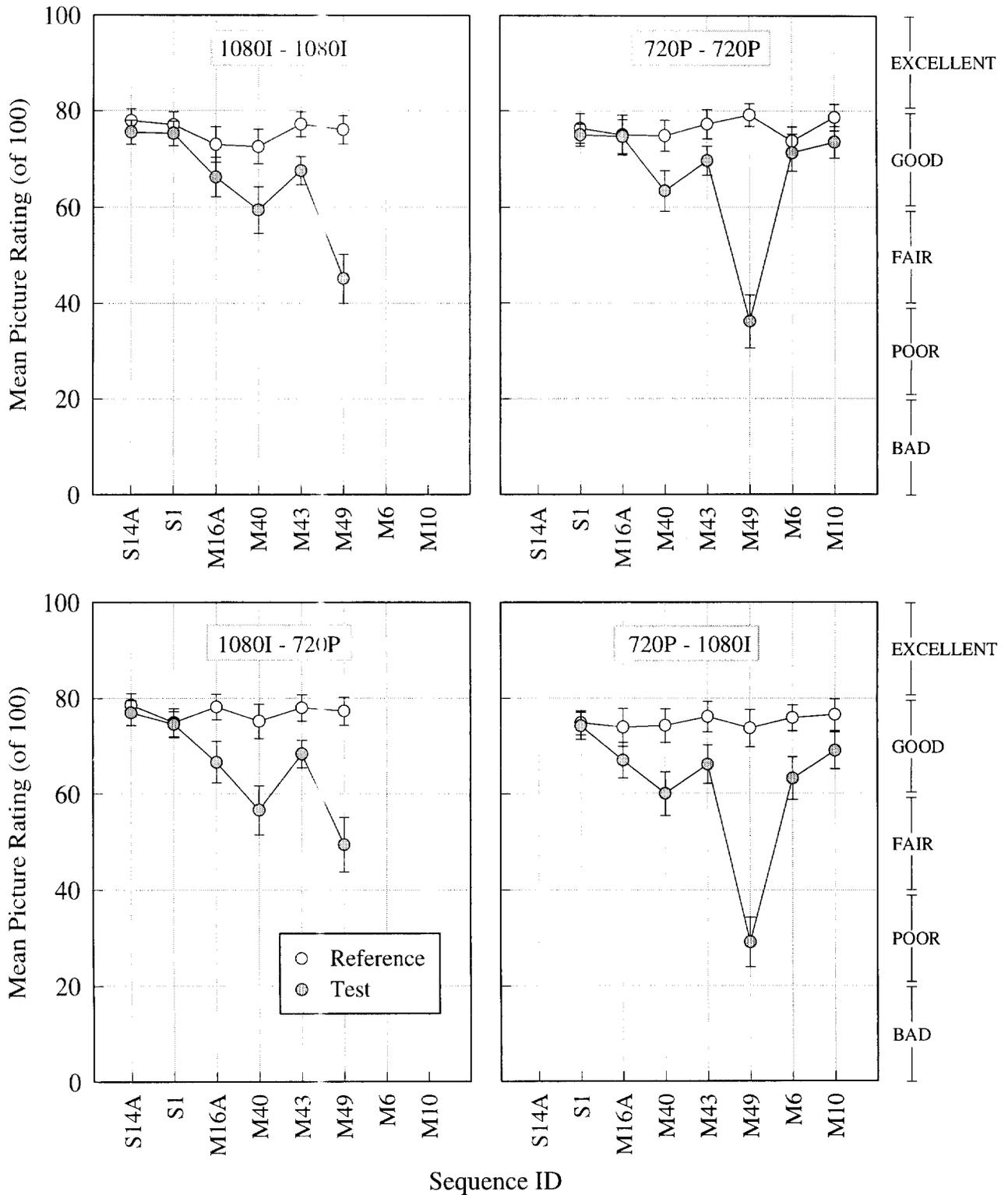


FIGURE 16. Mean quality ratings of Reference and Test sequences for the Receiver Scan Conversion tests for the digital Grand Alliance HDTV System.

TABLE 23
RECEIVER SCAN CONVERSION
DIFFERENCE SCORES (TEST minus REFERENCE)

ID	PICTURE	IN - OUT	TEST minus REFERENCE		
			MEAN	STANDARD DEVIATION	CONFIDENCE INTERVAL
S1	Metal Table & Chairs	1080 - 1080	-1.75	7.61	±2.12
S1	Metal Table & Chairs	1080 - 720	-0.38	9.47	±2.64
S1	Metal Table & Chairs	720 - 720	-1.36	9.92	±2.76
S1	Metal Table & Chairs	720 - 1080	-0.64	8.80	±2.45
M16A	Rotating Pyramids	1080 - 1080	-6.69	12.77	±3.55
M16A	Rotating Pyramids	1080 - 720	-11.46	15.92	±4.43
M16A	Rotating Pyramids	720 - 720	-0.30	17.75	±4.94
M16A	Rotating Pyramids	720 - 1080	-6.82	14.82	±4.13
M40	Dream Team	1080 - 1080	-13.16	15.91	±4.43
M40	Dream Team	1080 - 720	-18.54	17.14	±4.77
M40	Dream Team	720 - 720	-11.42	15.25	±4.25
M40	Dream Team	720 - 1080	-14.19	14.74	±4.10
M43	Ducks	1080 - 1080	-9.48	12.00	±3.34
M43	Ducks	1080 - 720	-9.57	10.54	±2.94
M43	Ducks	720 - 720	-7.51	11.39	±3.17
M43	Ducks	720 - 1080	-9.90	12.94	±3.60
M49	Picnic With Ants	1080 - 1080	-31.35	22.85	±6.36
M49	Picnic With Ants	1080 - 720	-27.88	23.92	±6.66
M49	Picnic With Ants	720 - 720	-43.07	22.44	±6.25
M49	Picnic With Ants	720 - 1080	-44.63	22.69	±6.32
M6	Den	720 - 720	-2.38	11.28	±3.14
M6	Den	720 - 1080	-12.59	15.76	±4.39
M10	Woman And Room	720 - 720	-5.10	9.14	±2.55
M10	Woman And Room	720 - 1080	-7.44	11.17	±3.11
S14A	Cheshire Cat	1080 - 1080	-2.35	8.00	±2.23
S14A	Cheshire Cat	1080 - 720	-1.66	10.34	±2.88

**RECEIVER SCAN CONVERSION
DIFFERENCE SCORES
COMMON INPUT FORMAT**

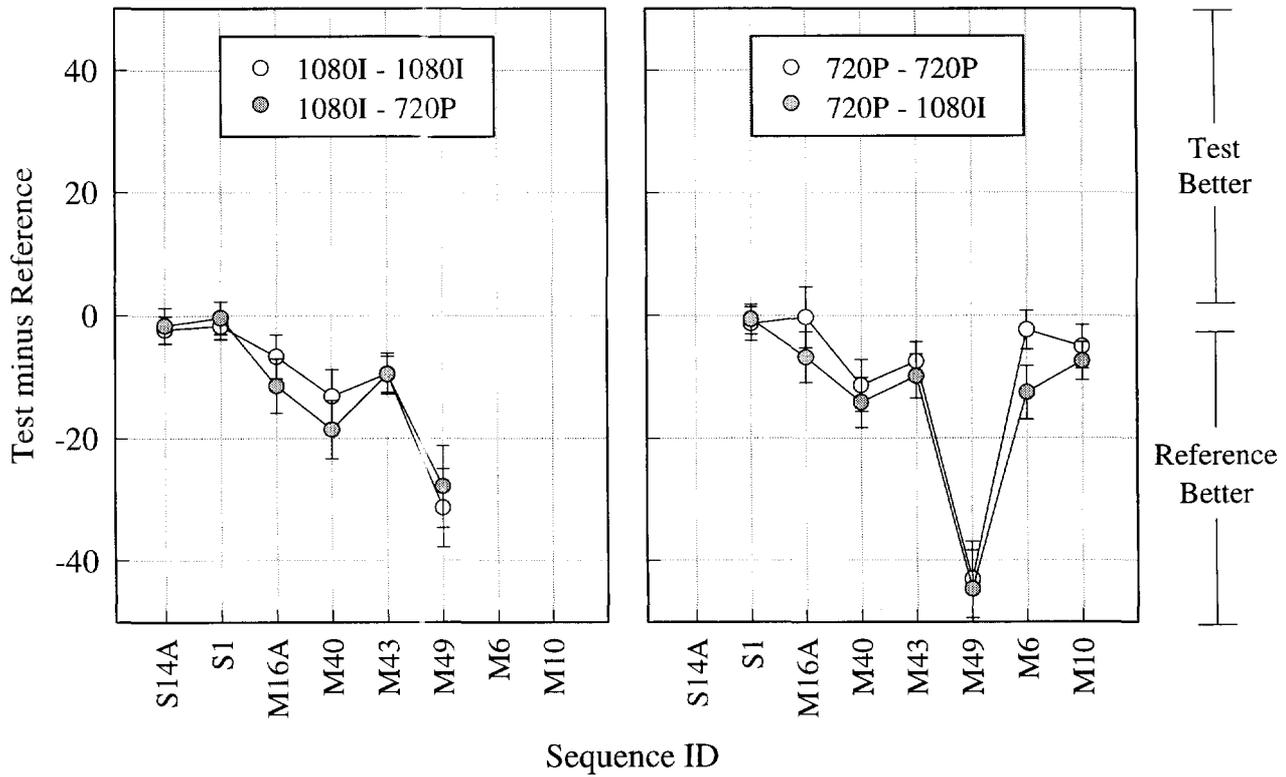


FIGURE 17. Differences in quality ratings (Test minus Reference) for the Receiver Scan Conversion tests, shown for a common input format (1080I or 720P) for the *digital* Grand Alliance HDTV System.

RECEIVER SCAN CONVERSION
DIFFERENCE SCORES
COMMON OUTPUT FORMAT

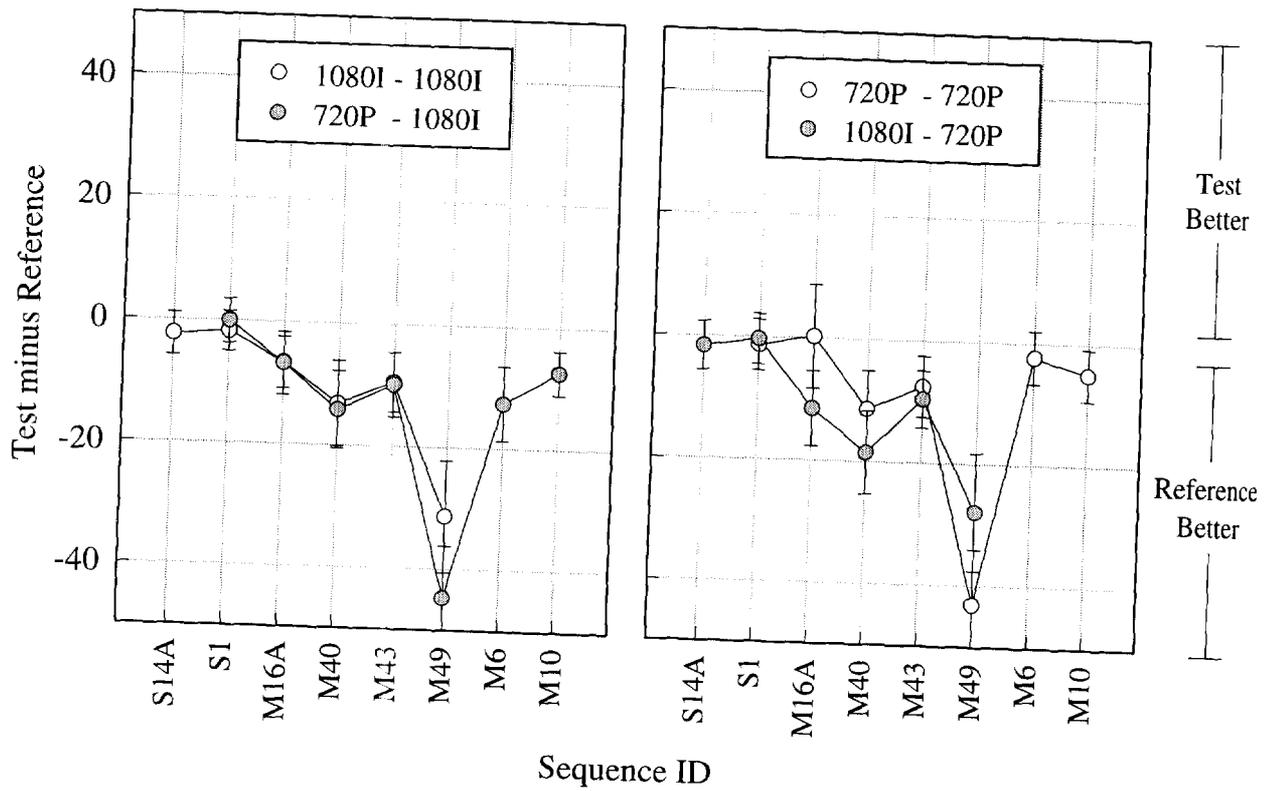


FIGURE 18. Differences in quality ratings (Test minus Reference) for the Receiver Scan Conversion tests, shown for a common output format (720P or 1080I) for the *digital* Grand Alliance HDTV System.