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In the Matter of	)	
	)	
Digital Audio Broadcasting Systems	)	
And Their Impact On the Terrestrial	)	MM Docket No. 99-325
Radio Broadcast Service	)	

ERRATUM

On January 24, 2000, Lucent Digital Radio, Inc. ("Lucent"), by its attorneys, timely filed Comments with the Commission in the above-captioned proceeding. Thereafter, Lucent discovered that pages in Appendix F of its Comments are either out-of-order or missing. This error occurred while duplicating the Comments for filing. With this Erratum, Lucent submits the corrected Appendix F and respectfully requests that the Commission replace the Appendix F in Lucent's Comments with the corrected version.

Respectfully submitted,
Lucent Digital Radio, Inc.

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APPENDIX F

LDR FM IBOC Hybrid Performance

Lucent Digital Radio, Inc.

20 Independence Blvd

Warren, NJ 07059, USA

APPENDIX F.1

SIGNAL QUALITY DISTRIBUTION

FM ANALOG VS LDR FM HYBRID

ACR VS DISTANCE

Lucent Digital Radio, Inc.

20 Independence Blvd

Warren, NJ 07059, USA

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Introduction

For the purpose of comparing disparate systems such as FM analog and digital IBOC it is necessary to design a testing methodology that (a) captures the key differences and (b) adequately reflects the listening experience of a population of listeners in the coverage area. Ideally, such methodology would result in a simple metric that could be used to directly compare the systems.

One such metric that can be used is signal quality distribution and aggregate quality which integrates (or weights) signal quality depending on the percentage of the coverage area for a given quality. This metric encompasses other measures of quality, such as fidelity and robustness, and is a good proxy of the aggregated listener experience. A fidelity measure is often used to quantify signal quality in perfect channel conditions, which occurs in a relatively small area of coverage in analog systems. In contrast, the quality distribution shows quality as a function of channel conditions occurring in the entire area of coverage and therefore includes the fidelity at some point. Similarly, robustness, which is a fairly vague term, may have different connotations in different circumstances and is not easily comparable. However robustness can be related to the quality distribution that is based on measured or theoretical signal conditions and impairments.

Impairment conditions affect FM analog and IBOC systems in fundamentally different way. Thus, in order to fairly and accurately compare analog and digital audio transmission systems subjected to various impairments, it is necessary to use subjective tests that quantify overall resulting audio quality.

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LDR has implemented a comprehensive test program designed specifically for this purpose.

Several tests have already been preformed and additional tests are in progress and will continue into the near future.

Summary

The tests performed by LDR included a statistically representative sample of the existing FM receivers, which include several mobile, home, and portable receivers. The FM receivers were subjected to multipath fading (mobile only), co-channel, and first and second adjacent channel interference. A perfect channel performance is also considered for the reference. The test results are shown in other parts of this appendix.

Findings are summarized and interpreted in this appendix.

Based on these test results an exemplary comparison is made between the FM analog system and LDR FM Hybrid system. This comparison is captured in the following figure, which shows signal quality versus distance from the transmitter. The distance is normalized relative to the protected contour distance.

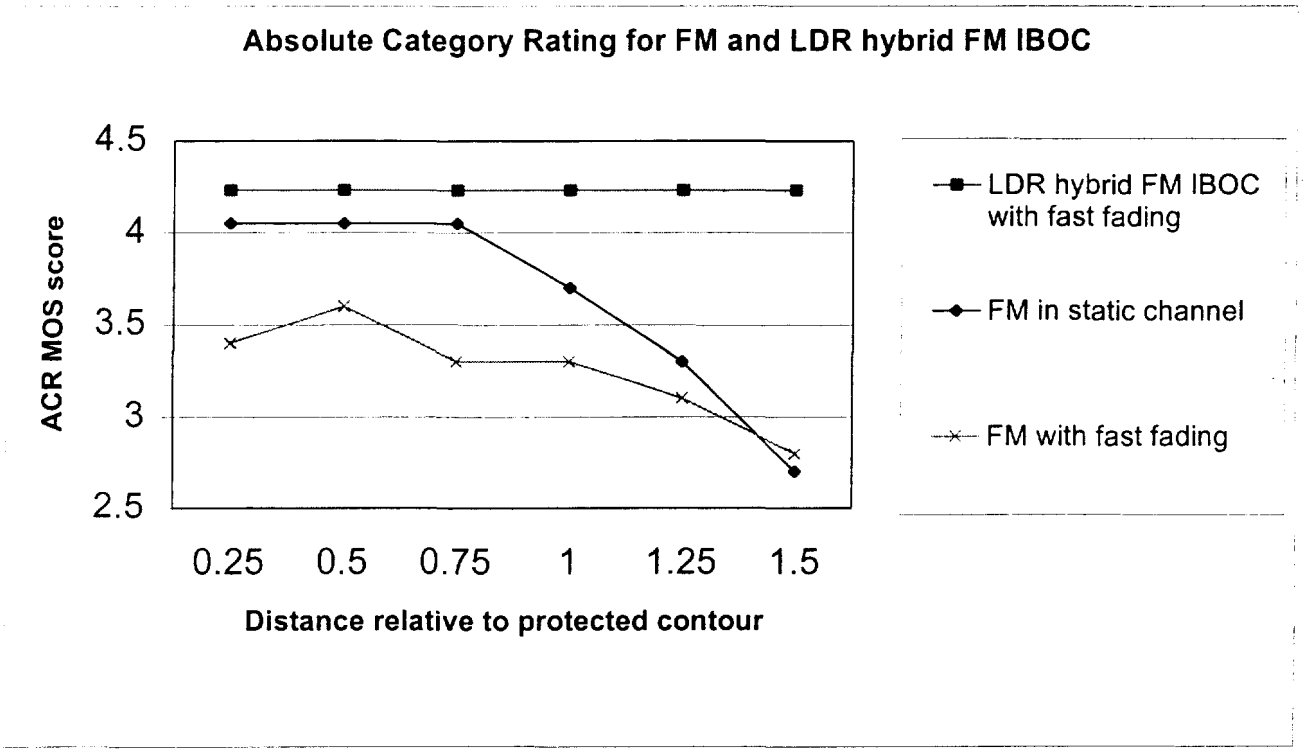

Figure F1-1: Signal quality as a function of the receiver distance from the transmitter in static channel and with fast fading

Figure F1-1 represents the average performance of a sample population of FM receivers and the performance of the LDR FM Hybrid system. Two conditions are shown: (a) clean channel impaired only by the diminishing signal level and (b) signal affected by multipath fading experienced by a receiver in motion. The first condition was used in testing non-automotive receivers and the second condition was used in testing automotive receivers. The fading was set to be rural fast Rayleigh fading with Doppler equivalent to 88km/h.

It can be observed that while FM stationary receivers produce quite good quality audio at a distance that is relatively close to the transmitter, the quality diminishes fairly quickly beyond the protected contour area. The automotive receivers have a considerably lower level of signal

quality even close to the transmitter. In addition, as the receiver moves away from the transmitter, the signal quality diminishes gradually beyond the protected contour area.

In contrast, *according to LDR laboratory tests of the FM Hybrid receiver in static and fading conditions, at the signal level commensurate with the distance of 1.5 times the protected contour, bit error rate is so low that the full quality audio can be reproduced.*

It is clear that the aggregate listening experience that can be provided by the LDR system for the population of listeners is vastly better than is currently provided by the FM system.

Assumptions and data processing

In plotting the chart in Figure F1-1, FCC charts were used for estimating received signal strength. The protected contour radius of 80km and antenna height of 200m were assumed. Accordingly, the approximate power of the desired signal is assumed +54dBu at the protected contour distance. The signal level decreases by 17dB at twice the protected contour, another 14dB at three times the protected contour, and another 12 dB at four times the protected contour. The signal level increases relative to the protected contour by 15dB at one half the protected contour and by another 12dB at one fourth of the protected contour distance.

The tests performed by LDR included a statistically representative selected sample of the existing receivers including several mobile, home, and portable receivers. Only mobile receivers were subjected to fading test. Several audio samples (clips) were used. The results were averaged. The detailed results for these tests are included in Appendix F.3.

Three separate tests were performed: (1) a subjective test that compares the LDR FM Hybrid compressed audio quality with CD source and best FM audio, (2) a subjective test that measures FM audio quality with different impairments (without CD or IBOC as a reference), and

(3) bit error rate for the IBOC receiver at the signal level commensurate with the distance equal to 1.5 times the protected contour.

The result of the first test indicates that audio compressed by the FM IBOC system has a quality rating of 4.23 which is better than best FM (4.05) by approximately 0.2 points on the MOS scale. The difference between the CD source (4.32) and the FM IBOC is less than 0.1 point.

It should be noted that the test 2 did not include either a CD source or IBOC audio sound samples.

It is well documented that listeners rate audio samples based on their entire experience of test. That is, in a particular test, the presence of high quality samples tends to push the scores of other samples down and, conversely, the presence of lower quality samples tends to push the scores of higher quality samples up.

In order to plot both FM analog and IBOC tests results on the same chart, we have adjusted the floating FM analog scores. However, it should be understood that MOS scale is highly nonlinear and such adjustments may not be accurate. Nevertheless, we are convinced that future tests will result in only minor adjustments without changing the overall picture.

In separate tests, FM receivers were subjected to the first adjacent channel interference. The mobile receivers were subjected to a combination of both first adjacent channel interference and multipath fading. In determining the test conditions we were changing the ratio of the desired to the undesired signal (d/u) depending on the distance from the transmitter according to the signal propagation loss. The signal propagation loss was determined based on the FCC charts.

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The following assumptions were made: at the protected contour the desired signal level is equal to 54dBu and the undesired signal level is equal to –6dB relative to the desired signal; the protected contour radius is 80km, both transmitters' height is 200m. As the receiver is moved towards the undesired transmitter and away from the desired transmitter, d/u is: 6dB at the protected contour, -1.5dB at 1.125 times the protected contour radius, and -9dB at 1.25 times the protected contour radius. Similarly when the receiver is moved in the opposite direction, d/u is 18.5dB at 0.875 times the protected contour radius, and 31dB at 0.75 times the protected contour radius.

In the same tests, the FM Hybrid audio samples were also tested. The audio samples were based on the error rates commensurate with the same signal conditions as the conditions used for the FM radios.

The results of the tests are shown in the appendix F.3. The IBOC quality was determined at three points corresponding to the distance 1, 1.125, and 1.25 times the protected contour distance. Only one measurement result is shown because the error rate at these points resulted in identical audio quality. Figure F1-2 illustrates the results.

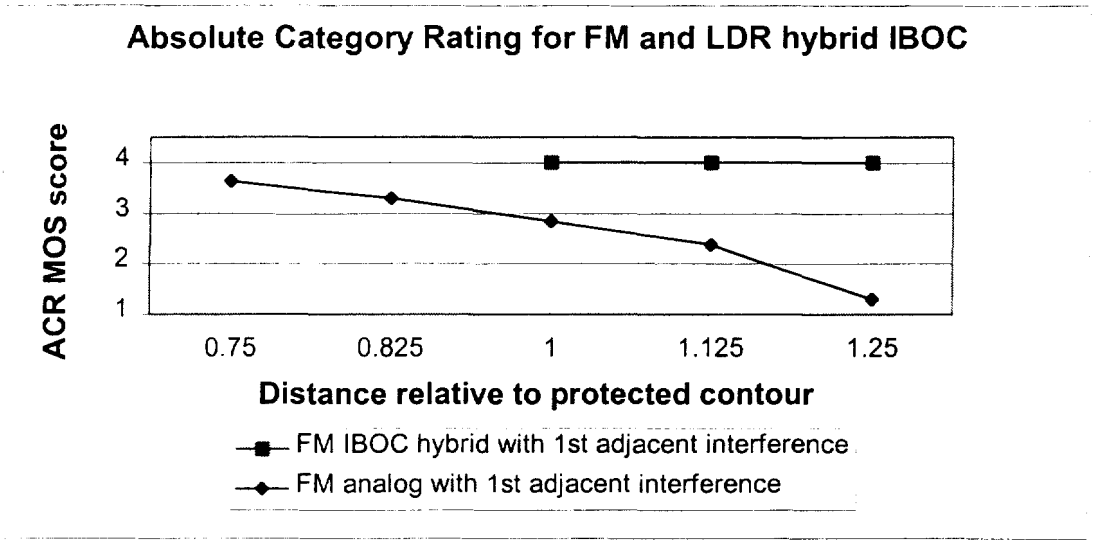

Figure F1-2: Signal quality as a function of the receiver distance from the transmitter with first adjacent interference and fading

Conclusions

Although analog broadcast systems signal propagation and quality have been analyzed and understood fairly thoroughly in the past, these measurements add new insights into this area. They show that *when quantitative quality measurements are used, the FM analog system performance is astonishingly low under even a modest level of common impairments*, and that reasonable quality can only be expected within a relatively small area around the transmitter that barely exceeds the protected contour.

Some FM receivers boast impressive sensitivity indicating that they are capable of receiving signals at fairly low levels. In fact, CEMA report [1] indicates that average receiver

[1] Consumer Electronics Manufacturing Association, 1999, *"FM Receiver Tests – Laboratory Test Report"*

produces 25dB SNR at the output when the input is approximately –102dBm and 40dB SNR at –96dBm. Although well accepted, this is an imperfect indicator. For example, the effect of stereo image loss that occurs at a much higher level must be shown as a separate quantity, *i.e.* stereo separation. Having more parameters does not make it easier to make a comparison, *e.g.* it is not clear what is better: 40dB SNR with 10dB channel separation or 36dB SNR with 14dB channel separation. In addition, many receivers effectively limit the output signal bandwidth at low signal conditions to improve SNR. As evidenced, subjective tests indicate that listeners give poor ratings to FM reception even at fairly high input signal levels that are far from the sensitivity limits as indicated by SNR alone. In contrast, Lucent's FM IBOC system can provide a much better quality over a wide area of coverage.

Although the presented results are based on limited tests performed by LDR thus far, they already indicate that LDR FM Hybrid system has potential to provide enormous benefits to broadcast industry and consumers. As more tests are performed we expect that IBOC system will show more advantages over the present FM analog system.

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APPENDIX F.2

SUBJECTIVE TESTING METHODOLOGY

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There are numerous ways to measure and characterize audio system performance, such as objective measures, subjective testing and expert listener assessment. It is widely held that subjective assessment plays a critical role in effectively characterize transmission devices, audio compression, codecs and other non-linear DSP techniques.[1,2] Subjective evaluation is considered "the gold standard of audio system evaluation"[3] in both the telecommunications and audio worlds. As is evident from the vast number of ITU-T and ITU-R standards[4,5,6,7] the audio and codec communities have embraced methodologies that rely on subjective input to assess the audio quality of new products. The specific test methodology that is chosen to subjectively assess the audio quality of any given system depends in part on the intent of the assessment. That is, when deciding *how* to evaluate a product, one may likely wish to choose a methodology that predicts the real world behavior of the general population. If an experimental task closely matches how people will react in a real world situation, the experiment will more likely produce an accurate prediction of customer acceptance of a product. Several methodologies have been designed to test various aspects of audio product performance. These methods include testing for transparency, small and large impairments, overall quality, etc. The Absolute Category Rating (ACR) Mean Opinion Score Test has been used in a variety of circumstances to test customer opinion of products entering the marketplace. In the ACR MOS methodology subjects judge sound samples on an individual basis, using an implicit reference to judge the quality of the sound sample. Within a particular ACR MOS test, subjects generally hear a variety of sound-samples that may differ on several dimensions. They are initially trained by listening to

several sound samples that parameterize the listening experience (e.g., they hear an "excellent" sample, a "bad" sample and a "fair sample"). Their mission is to give a statement of "overall quality", taking into consideration the variety of audio dimensions or impairments that may be present.

The "ACR Listening-Only" methodology has been used for all subjective tests conducted at Lucent Digital Radio, with the exception of Test G, "Host compatibility: Subjective testing and expert listening results (Test L)". There, the ITU-R recommended A/B comparative test was selected. In general, ACR methodology was chosen because it best tests customer preference and market acceptability, two concepts in which LDR was particularly interested. The ITU-R recommends that various five-point and seven-point category-judgement scales should be used for different purposes, as needed. In LDR-ACR testing, participants listened to sound samples, one-by-one, and assessed their quality. Judgments were made on a five-point category-judgment scale. Following ITU-R recommendations, the 5-point quality scale was employed (5 = Excellent, 4 = Good, 3 = Fair, 2 = Poor, 1 = Bad). In Test G, when a comparison scale was required, a 7-grade ITU-R recommended scale was used (see report on Host compatibility).

[1] *Thorpe, L.A. & Shelton, B. R. (1993) Subjective Test Methodology: MOS vs DMOS in Evaluation of Speech Coding Algorithms. Proccedings of the IEEE Speech Coding Workshop, St. Agathe, Quebec, Sept. 1993.*

[2] *Thorpe, L.A. (2000) Subjective Evaluation of Speech Compression Codecs and other Non-linear Voice-path Devices for Telephony Applications (ms. under review)*

[3] *Pickholtz, R. L., Jackson, C. L. (1999) A Review of four Studies of FM Receiver Adjacent-Channel Immunity (review submitted to the NAB).*

[4]*Methods for the Subjective Assessment of Small Impairments in Audio Systems Including Multichannel Sound Systems, ITU-R Recommendation BS.1116, Geneva*

[5]*Subjective Assessment of Sound Quality, ITU-R Recommendation 562-3, Geneva*

[6]*Methods for the Subjective Assessment of Sound Quality, ITU-R BS.1284, Geneva*

[7]*Methods for subjective determination of transmission quality, ITU-T P.800, Geneva*

APPENDIX F.3

Results from Subjective Testing of LDR's PAC™

Lucent Digital Radio, Inc.

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Moulton Laboratories

Lucent Technologies' Multimedia Perception Assessment Center

Results from Subjective testing of Lucent Digital Radio's Perceptual Audio Coder (PAC)

January 15, 2000

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1. Introduction

This report describes procedures and results from a subjective study conducted by Lucent's Multimedia Perception Assessment Center and Moulton Laboratoriess, Groton, MA. End-user testing was conducted between January 10th and January 16th, 2000. This study was designed to solicit public opinion of Lucent Digital Radio's Perceptual Audio Codec (LDR-PAC) under clean channel conditions. All methodological procedures were administered identically by both laboratories with two, minor exceptions: (a) participants at Moulton Labs listened over Sony MDR 7506 headphones, while participants at MPAC listened over Sennheiser 600 headphones, and (b) participants at Moulton Labs recorded their answers on paper, while participants at MPAC recorded their answers directly into a computer.

2. Overview

The primary goal of this study was to determine customer acceptance of LDR-PAC in today's audio marketplace. Participants were asked to rate sound samples using the ITU-R recommended 5-point Quality Mean Opinion Score (MOS) scale.

Forty-six participants listened to 32 samples during the test. Listening was conducted in sound rooms that were configured to acoustically simulate extremely quiet environments (28-35 dBA).

3. Methodology

3.1 Sound file processing, facilities and playback

All recordings were supplied by Lucent Digital Radio. CD source material was selected to be representative of typical broadcast material, including both female and male voices and complex instrumental samples. Female and male speech samples were also included. The ITU-R recommends selecting music where the "the artistic or intellectual content of a programme sequence should be neither so attractive nor so disagreeable or wearisome that the subject is distracted from focusing on the detection of impairments. The expected frequency of occurrence of each type of programme material in actual broadcasts should be taken into account" (ITU-R, BS.1116-1) Thus, every effort was made to select material that would represent a broad range of music, and at the same time would significantly stress both systems under test.

Table 1 describes the source material and processing.

Table 1: Lucent Digital Radio FM/PAC Test Cuts

Sound Sample					Source	Audio Processing	
Order	Code	Description	Format	Sample Rate		FM Host (Orban 8200)	DAB (PAC)
1	CF	Classical Female	16-bit PCM stereo	44.1 kHz	Moulton Labs, *Critical Listening Excerpts* CD, cut 3 *(Kyoko Saito)*	2 dB Pur Classical	None
2	RI	Rock Instrumental	16-bit PCM stereo	44.1 kHz	Jeff Beck, *Who Else* CD, cut 1 (*What Mama Said)*	Rock Dense	None
3	CI	Classical Instrumental	16-bit PCM stereo	44.1 kHz	Moulton Labs, *Critical Listening Excerpts* CD, from cut 11 *(Bang & Olufsen Test Sequence -- Introduction to Classical Music)*	Classical	None
4	CM	Blues/Jazz Male	16-bit PCM stereo	44.1 kHz	Moulton Labs, *Critical Listening Excerpts* CD, cut 11 (*Bang & Olufsen Test Sequence -- Robert Cray Band)*	Jazz	None
5	SF	Speech Female	16-bit PCM stereo	44.1 kHz	From EIA SQAM CD	News/Talk	None
6	RF	Rock Female	16-bit PCM stereo	44.1 kHz	Susan Vega, *Nine Objects of Desire* CD, cut 3 *(Caramel)*	Jazz	None
7	RM	Rock Male	16-bit PCM stereo	44.1 kHz	Crowded House, *Woodface* CD, cut 5 *(Weather with You)*	Rock Open	None
8	SM	Male Voiceover	16-bit PCM stereo	44.1 kHz	Gravity Music Library, cut 1 *(Introduction)*	Pop Medium	None

4.2 Participant selection

Twenty-five (25) females and 21 males participated in this study. Participants varied in age, but were all under the age of 50 (See Table 2 for a demographic breakdown). Participants were chosen from the general public. The decision to use the general public, rather than experienced and trained, subjects was made in accordance with basic principals of psychological research. The goal of this study was to predict customer

acceptability of digital radio to the general population. Thus we were interested to know how the average person with no special training or prior experience in professional audio would react to PAC. Additionally, a screening procedure was included to ensure that listeners were sensitive to differences in the quality of Source, PAC, and FM sound-cuts. In a separate test, participants listened to 18 sound-sample triads (*CD Source/FM/PAC*) in which two trials contained the same sound sample three times (e.g., *CD Source/CD Source/CD Source*). In order to pass the screening procedure and take part in the ACR testing, participants had to reliably and consistently rate the CD Source sound samples as the same or close to the same (4 or 5 out of a 5 point scale). Of 62 listeners who participated the study, eight were removed for failing to identify the sound sources as the same or "similar".

Table 2: Demographic Description

	Male	Female
18-30	3	5
30-40	11	11
40-50	8	9

4.3 Participant training

MPAC Laboratory participants were given some information about the nature of the study (e.g., that they would be listening to sound samples and rating them), but were not told specifically that they were listening to source material, PAC and FM transmissions. Participants were presented with an example of an ACR trial. Moulton Laboratories participants were told that they were listening to a range of such signals, but with no discussion of the sonic or technical nature or behavior of those signals. Samples were either played over HD-600 headphones (MPAC Laboratory) or Sony MDR 7506 headphones (Moulton Laboratory). MPAC subjects were shown how to register their answers via a PC. Moulton Laboratory subjects were shown how to register their answers on answer-sheets.

4.4 Testing Procedure

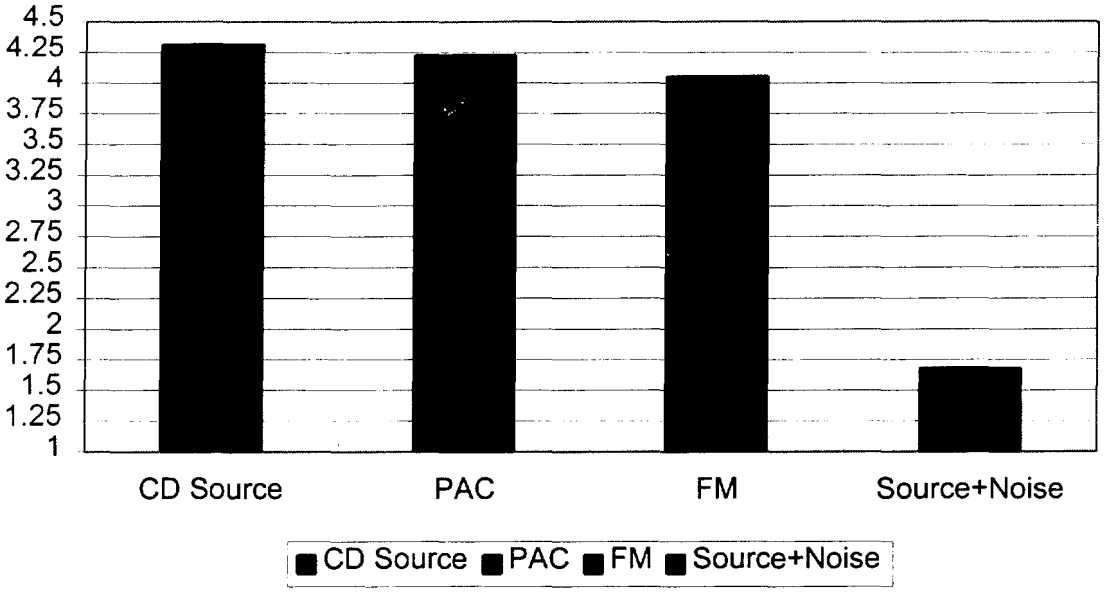
Following training, participants proceeded to take the test. Participants listened to 32 sound-samples: 8 FM, 8 PAC, 8 CD Source and 8 CD Source mixed with noise (referred to as "Source+Noise"). Again, the presentation of samples was randomly determined. For a single trial, participants heard a single sound sample and rated it on the ITU-R recommended 5-point "Quality" Mean Opinion Score (MOS) scale (5 =Excellent; 4 = Good; 3 = Fair; 2 = Poor; 1 = Bad).

4. Results

All data was analyzed using analysis of variance (ANOVA), with significance at p = .05. Interactions were analyzed using Neuman-Keuls post-hoc tests, p = .05. A preliminary analysis showed both an effect of gender and an effect of age. For gender differences, female subjects rated PAC significantly higher (4.27) than they rated FM (4.01). In contrast, males rated PAC (4.15) and FM (4.11) as the same. For age differences, younger participants rated all sound samples significantly lower than older participants, although there were no significant differences between PAC and FM.

Figure 1 shows participants' total ACR responses. Overall, PAC and the CD Source sound cuts were rated the same statistically, with MOS scores of 4.23 and 4.32 respectively. In contrast, FM (4.05) was rated significantly lower than both CD Source and PAC. Source+Noise was rated significantly lower than all other samples.

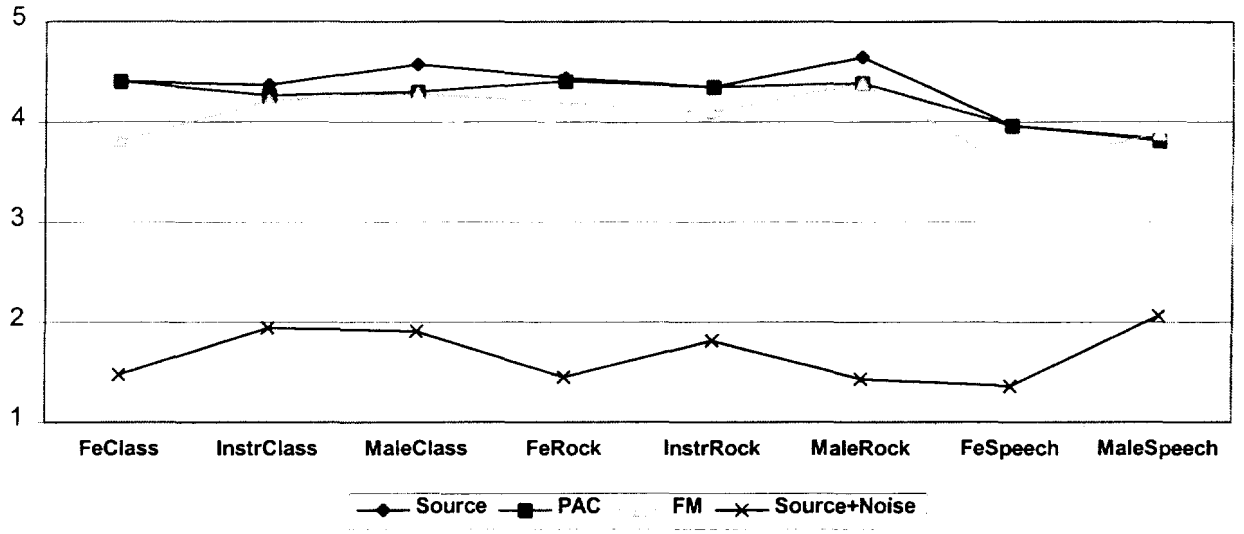
Figure 1: Participants' ACR Responses



5 = Excellent; 4 = Good; 3 = Fair; 2 = Poor; 1 = Bad

Figure 2 shows participants' responses by sound cuts. Notice that in the case of Classical Female, PAC was rated significantly higher than FM. In all other cases, although not statistically different, PAC was rated either equal to or slightly better than FM sound samples.

Figure 2: Participants' ACR Responses



5 = Excellent; 4 = Good; 3 = Fair; 2 = Poor; 1 = Bad

APPENDIX F.4

LDR FM Hybrid Performance

Lucent Digital Radio, Inc.

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Advanced Technologies

Multimedia Perception Assessment Center

LDR FM Hybrid Performance

January 21, 2000

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Introduction

This report describes procedures and results from a subjective study conducted by Lucent's Multimedia Perception Assessment Center for Lucent Digital Radio. End-user testing was conducted between January 19thth and January 21stth, 2000. This study was designed to solicit Mean Opinion Scores (MOS) from the general public concerning analog FM transmission under both static and dynamic multipath impaired conditions.

Six FM receivers were included in this study. Two were automobile radios: the Ford Visteon XWIF-18C870 and the Sony XR-2390 receivers. Three were home receivers: (a) Pioneer SX-205; (b) Sony CFD-S47; and (c) Denon TU-1500RD. All receivers were selected to represent a broad range of receivers currently available in the commercial market.

Ninety-six participated in this study. Participants were evenly divided by gender and varied in age, but were all under the age of 50. Participants were chosen from the general public. Listening was conducted in sound rooms that were configured to acoustically simulate extremely quiet environments (28-35 dBA).

All recordings were supplied by Lucent Digital Radio. CD source material was selected to be representative of typical broadcast material, including both female and male voices and complex instrumental samples (see Appendix B – Selection of Processing of Audio Samples for FM analog and FM-IBOC subjective testing). Female and male speech samples were also included. Table 1 lists the RF channel conditions used in this experiment.

Table 1: Summary of conditions for FM Impairment Test

Average Signal Strength (dBm)	Static Condition	Multipath Condition*
-72.0	ANO1	ARF1
-62.0	ANO2	ARF2
-54.5	ANO3	ARF3
-47.0	ANO4	ARF4
-42.0	ANO5	ARF5
-32.0	ANO6	ARF6
-9.0 D/U	CN01	CRF1
-1.5 D/U	CNO2	CRF2
6.0 D/U	CNO3	CRF3
18.5 D/U	CNO4	CRF4
31.0 D/U	CNO5	CRF5
Output SNR (AWQP)(dB)		
55dB	ENO1	ERF1
45 dB	ENO2	
35 dB	ENO3	ERF3
25 dB	ENO4	

*** Rural Fast Rayleigh, 13.1 Hz Doppler**

Methodology

Testing of receivers was conducted in round-robin fashion. Because listeners' scores are typically influenced by all of the sound samples presented in a listening session, it was important to pair each radio with at least 2 other radios to minimize the risk of obtaining inflated or deflated scores for a particular radio. Participants were divided into 6 groups, with each group listening to sound samples received by two radios. Each radio was presented to two groups. Therefore, 32 participants rated sound-cuts received by each radio. For example, Group 1 participants listened to sound samples received by the Visteon and the Denon and Group 2 participants listened to samples received by the Sony XR-2390 and the Denon. Thus, by combining Group 1 and Group 2's listening experience, a total of 32 participants listened to samples received by the Denon. Table 2 lists Receivers and Participant Groups.

Table 2: Test Plan

Participant Group	Visteon XWIF-18C870	Sony XR-2390	Pioneer SX-205	Denon TU-1500RD	Panasonic RF-FX430	Sony CFD-S47
Group 1 (n = 16)	x			x		
Group 2 (n = 16)		x		x		
Group 3 (n = 16)		x			x	
Group 4 (n = 16)	x				x	
Group 5 (n = 16)			x			x
Group 6 (n = 16)			x			x

Participant Training and Testing

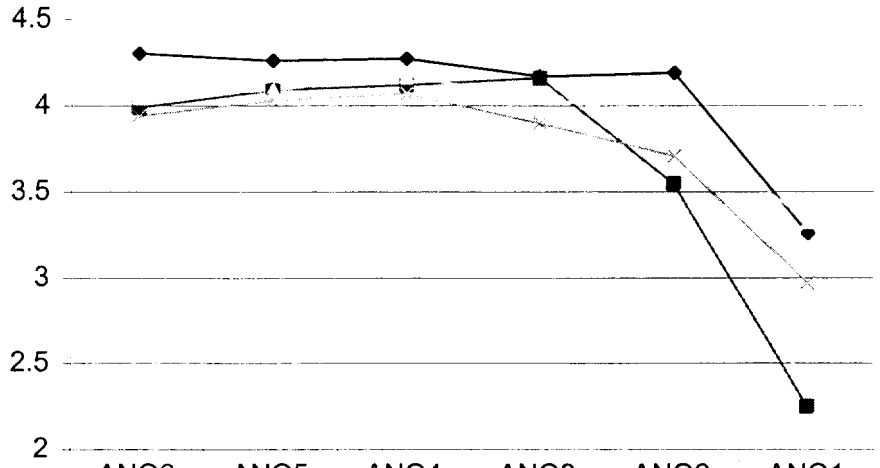
Participants were told that they would be listening to sound samples and rating them for overall quality. Samples were played over Sennheiser HD-600 headphones. Before testing, participants were given information about the kinds of impairments they would hear during the test. They listened to three practice samples (a clean audio recording, a moderately impaired audio recording and a highly impaired audio recording) and were shown how to use the data collection software to register their responses. Participants were encouraged to concentrate on the "quality of the transmission" when rating each sound sample, and were discouraged from rating samples based on whether they "liked" the particular genre of music.

Presentation of samples was randomly determined. For a single trial, participants heard a single sound sample and rated it on the ITU-R recommended 5-point "Quality" Mean Opinion Score (MOS) scale (5 =Excellent; 4 = Good; 3 = Fair; 2 = Poor; 1 = Bad).

Results

Figure 1 shows MOS as a function of signal levels in static conditions. For all receivers, MOS scores remain consistent between conditions ANO6 and ANO3. Participants' ratings begin to drop in the ANO2 condition, and are substantially degraded by the ANO1 condition. Table 3 shows Mean Opinion Scores of static conditions, divided by sound sample.

Figure 1: ACR Mean Opinion Scores vs. Average RF Signal Level in Static Conditions



	ANO6	ANO5	ANO4	ANO3	ANO2	ANO1
Denon	4.3	4.26	4.27	4.17	4.19	3.26
Panasonic	3.99	4.09	4.12	4.16	3.55	2.25
Pioneer	4.05	4.09	4.17	4.05	3.92	3.33
Sony Home	3.94	4.03	4.07	3.9	3.71	2.97

Table 3: ACR Mean Opinion Scores of static conditions by sound sample

Mean Opinion Scores (5=Excellent; 4=Good; 3=Fair; 2=Poor; 1=Bad)								
Receiver	Condition	Classical Instrumental	Classical Female	Classical Male	Rock Instrumental	Rock Female	Rock Male	Total MOS
Denon	ANO6	4.31	4.63	4.44	3.5	4.5	4.44	4.30
	ANO5	4.31	4.35	4.38	3.69	4.29	4.50	4.19
	ANO4	4.31	4.25	4.10	4.06	4.38	4.44	4.17
	ANO3	4.19	4.19	4.50	3.38	4.06	4.69	4.27
	ANO2	4.19	4.25	4.56	3.69	4.00	4.44	4.26
	ANO1	3.13	2.56	3.63	3.13	2.94	4.19	3.30
Panasonic	ANO6	4.06	4.18	4.25	3.12	4.44	3.94	3.99
	ANO5	3.94	4.63	3.94	3.31	4.29	4.44	4.09
	ANO4	3.94	4.24	4.63	3.59	4.56	3.82	4.12
	ANO3	4.06	4.63	3.94	3.69	4.35	4.31	4.16
	ANO2	3.69	3.76	3.94	2.94	3.44	3.53	3.55
	ANO1	2.47	1.81	2.24	2.25	2.12	2.63	2.25
Pioneer	ANO6	3.95	4.38	4.18	3.44	4.36	3.88	4.08
	ANO5	4.06	4.03	4.50	3.36	4.56	4.13	3.99
	ANO4	3.79	4.56	4.23	3.81	4.10	4.56	4.12
	ANO3	4.13	3.97	4.44	3.49	4.31	4.03	3.96
	ANO2	3.54	4.31	4.18	3.81	3.38	4.44	3.84
	ANO1	3.56	2.23	3.75	3.38	3.00	4.03	3.28
Sony CFD-S47	ANO6	4.00	3.58	4.69	3.16	4.31	4.11	3.94
	ANO5	3.63	4.44	4.16	3.56	4.11	4.31	4.03
	ANO4	4.00	4.16	4.25	3.47	4.50	4.11	4.07
	ANO3	3.58	4.38	3.84	3.38	4.00	4.25	3.90
	ANO2	3.81	3.58	3.88	3.16	3.94	4.00	3.71
	ANO1	3.26	2.25	3.00	3.38	2.37	3.63	2.97

Figure 2 shows MOS as a function of signal level in rural fast Rayleigh multipath. Receivers tested in these conditions were the Sony XR-3490 and the Visteon XWIF-18C870. Again, there is a marked drop in MOS scores between ARF6 and ARF1, especially for Sony. Table 3 shows Mean Opinion Scores of multipath conditions, divided by sound sample.

Figure 2: ACR Mean Opinion Scores vs. Average RF Signal Level in Rural Fast Rayleigh Multipath

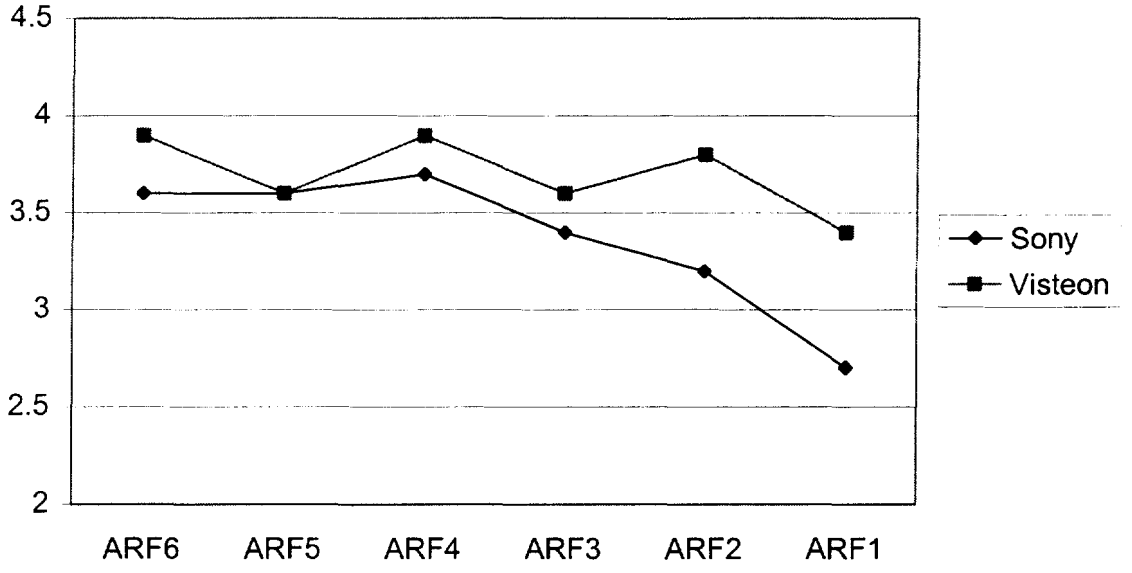


Table 3: ACR Mean Opinion Scores of Rural Fast Rayleigh Multipath conditions by sound sample

Mean Opinion Scores (5=Excellent; 4=Good; 3=Fair; 2=Poor; 1=Bad)								
Receiver	Condition	Classical Instrumental	Classical Female	Classical Male	Rock Instrumental	Rock Female	Rock Male	Total MOS
Sony XR-2390	ARF6	2.44	2.41	2.88	2.94	2.19	3.38	2.70
	ARF5	3.19	2.38	3.00	3.75	3.25	3.88	3.24
	ARF4	3.06	2.69	3.44	3.69	3.50	4.13	3.42
	ARF3	3.19	2.88	4.00	4.00	3.56	4.56	3.70
	ARF2	3.31	3.00	3.81	3.56	3.63	4.19	3.58
	ARF1	3.25	2.88	3.69	3.81	3.94	4.25	3.64
Visteon XWIF-18C870	ARF6	3.13	2.59	3.88	3.18	3.88	3.47	3.35
	ARF5	3.47	3.19	4.18	3.19	4.29	4.25	3.77
	ARF4	3.50	3.24	2.75	3.71	3.94	4.12	3.55
	ARF3	4.18	2.94	4.35	3.25	4.35	4.50	3.94
	ARF2	3.44	2.94	4.00	3.41	4.06	3.88	3.62
	ARF1	3.88	2.94	4.41	3.19	4.12	4.63	3.87

Tables 4 and 5 show participants' ratings of FM sound samples with 1st adjacent channel interference. Notice that Table 4 does not include multipath interference, whereas Table 5 does. In Table 4, the 4 home receivers are listed; in Table 5 the 2 auto receivers are listed. Total mean opinion scores are listed in the far-right column.

Table 4: ACR Mean Opinion Scores of conditions with 1st adjacent channel interference

Mean Opinion Scores (5=Excellent; 4=Good; 3=Fair; 2=Poor; 1=Bad)								
Receiver	Condition	Classical Instrumental	Classical Female	Classical Male	Rock Instrumental	Rock Female	Rock Male	Total MOS
Denon	CNO5	4.38	4.31	4.44	3.81	4.25	4.75	4.32
	CNO4	3.81	4.38	4.19	3.75	4.06	4.44	4.10
	CNO3	3.69	3.88	3.75	3.50	3.44	4.06	3.72
	CNO2	3.25	3.31	4.13	3.06	3.94	3.81	3.58
	CNO1	1.88	1.50	1.88	2.00	1.69	1.44	1.73
Panasonic	CNO5	4.06	4.69	4.06	3.44	4.12	4.19	4.09
	CNO4	4.19	4.29	4.63	3.24	4.56	4.00	4.14
	CNO3	3.76	4.38	4.06	3.44	4.18	4.25	4.01
	CNO2	3.69	3.53	4.00	3.12	3.19	3.76	3.55
	CNO1	3.41	2.13	3.18	2.94	2.47	3.44	2.93
Pioneer	CNO5	4.38	4.00	4.63	3.08	4.63	4.26	4.00
	CNO4	3.74	3.94	3.97	3.69	3.95	4.13	3.90
	CNO3	3.63	2.05	3.88	3.15	2.81	3.90	3.15
	CNO2	2.46	1.75	1.97	3.19	1.51	3.38	2.21
	CNO1	1.75	1.36	1.81	2.67	1.31	1.85	1.86
Sony CFD-S47	CNO5	3.68	4.38	4.26	3.69	4.26	4.13	4.07
	CNO4	3.75	2.68	4.31	3.05	3.75	3.84	3.53
	CNO3	2.42	2.06	2.21	3.31	1.95	3.75	2.58
	CNO2	2.56	1.63	2.13	2.74	1.81	2.32	2.20
	CNO1	1.11	1.06	1.05	1.44	1.11	1.13	1.14

Table 5: ACR Mean Opinion Scores of Rural Fast Rayleigh Multipath conditions with 1st adjacent channel interference

Mean Opinion Scores (5=Excellent; 4=Good; 3=Fair; 2=Poor; 1=Bad)								
Receiver	Condition	Classical Instrumental	Classical Female	Classical Male	Rock Instrumental	Rock Female	Rock Male	Total MOS
Sony XR-2390	CRF5	3.44	3.00	4.31	3.31	3.56	4.19	3.64
	CRF4	2.88	3.00	3.50	3.44	3.56	4.06	3.41
	CRF3	2.94	2.44	4.06	3.38	3.56	3.56	3.32
	CRF2	2.75	2.06	3.19	3.81	2.94	3.69	3.07
	CRF1	2.38	1.94	2.31	3.00	2.13	3.13	2.48
Visteon XWIF-18C870	CRF5	3.50	3.35	4.25	3.65	2.88	4.00	3.80
	CRF4	3.71	3.19	4.59	3.44	4.00	4.44	3.96
	CRF3	3.75	3.24	4.25	3.35	3.81	4.00	3.73
	CRF2	3.65	2.63	4.12	3.13	4.35	4.19	3.63
	CRF1	3.06	2.82	3.75	3.24	4.06	4.12	3.31

Table 6 shows MOS in signal to noise conditions, divided by individual sound-samples. Again, total mean opinion scores are listed in the far-right column.

Table 6: ACR Mean Opinion Scores vs. SNR

Mean Opinion Scores (5=Excellent; 4=Good; 3=Fair; 2=Poor; 1=Bad)								
Receiver	Condition	Classical Instrumental	Classical Female	Classical Male	Rock Instrumental	Rock Female	Rock Male	Total MOS
Denon	ENO1	4.25	4.38	4.38	3.63	4.25	4.50	4.23
	ENO2	3.50	3.00	3.25	3.38	3.38	3.94	3.41
	ENO3	2.50	2.19	2.19	2.75	2.13	2.81	2.43
	ENO4	2.19	1.44	2.44	2.50	2.56	2.38	2.25
Panasonic	ENO1	4.19	4.06	4.31	3.53	4.25	3.94	4.04
	ENO2	4.12	4.06	4.35	3.75	4.29	4.06	4.11
	ENO3	3.81	2.47	2.88	3.18	2.44	3.76	3.09
	ENO4	2.53	1.63	1.76	2.56	1.59	2.69	2.12
Pioneer	ENO1	3.72	4.19	4.28	3.88	4.33	4.38	4.12
	ENO2	3.94	3.13	4.00	3.36	3.81	3.90	3.59
	ENO3	3.10	2.69	2.72	3.56	2.18	3.69	2.85
	ENO4	2.44	1.74	2.75	2.38	2.38	2.85	2.38
Sony CFD-S47	ENO1	3.94	3.74	4.44	3.26	4.38	4.00	3.93
	ENO2	2.95	3.69	3.58	3.63	3.37	4.44	3.58
	ENO3	3.13	1.89	3.19	2.89	2.56	3.37	2.83
	ENO4	2.05	1.63	1.47	2.75	1.42	2.50	1.94
Visteon	ERF1	3.88	3.06	4.24	3.25	4.00	4.25	3.79
	ERF3	1.19	1.47	1.44	1.82	1.31	1.47	1.45
Sony Auto	ERF1	3.06	2.56	3.75	3.94	3.63	3.94	3.48
	ERF3	1.81	1.56	2.19	2.06	1.75	2.19	1.93

Table 7: Performance of LDR IBOC system subjected to the first adjacent channel interference and fast rural fading

Mean Opinion Scores (5=Excellent; 4=Good; 3=Fair; 2=Poor; 1=Bad)								
Receiver	Condition	Classical Instrumental	Classical Female	Classical Male	Rock Instrumental	Rock Female	Rock Male	Total MOS
IBOC	AAA	4.05	4.11	3.75	3.58	4.33	3.79	3.94