

5. Digital Performance Results Summary

The performance of the iBiquity Digital IBOC system was quantified under varied RF channel conditions. The Block Error Rate (BLER) of an IBOC receiver was objectively measured to determine digital performance under various interference scenarios over a range of impairment signal strengths. The test results are presented in a series of tables and figures in this section. In addition to objective tests, digital recordings were made for subjective testing. The test conditions for subjective testing are also tabulated in this section.

Each row in the table represents one test designated by an ATTC test number. In the *Desired* column, the mode of the desired signal is indicated as *Analog* or *Hybrid*. The power of the desired analog signal is indicated by *Strong* (-47 dBm) or *Moderate* (-62 dBm). In the interferer columns, the mode of the interferer is indicated: *Analog* or *Hybrid*. Adjacent channel interferers may have a fixed D/U number (e.g. +6) next to it indicating that the strength of this interferer is fixed at that particular D/U ratio. The *AWGN* column, where appropriate, indicates the presence (and level) or absence of a broadband noise floor. The designation of *Variable* indicates that a range of signal strengths were utilized.

For multipath interference, the *Multipath* column indicates the type of multipath scenario where *US* refers to Urban Slow, *UF* refers to Urban Fast, *TO* refers to Terrain Obstructed, and *RF* refers to Rural Fast.

The *RX* column indicates the receiver or receivers-under-test for each subjective test scenario. *IBOC* indicates the iBiquity Digital IBOC system. "*2 Auto*" refers to the Delphi 09394139 and Pioneer KEH-1900 automotive receivers. "*1 Hi-Fi*" refers to the Technics SA-EX110P-K hi-fi receiver and "*1 Portable*" refers to the Sony CFD-S22 portable receiver. The output of the receiver-under-test was digitally recorded for various interference scenarios over a range of impairment signal strengths. The scenarios are described in a similar series of tables in the following sections. The *Audio Cut* column indicates the audio material that was played on the desired channel, and ultimately recorded from the output of the digital receiver or analog reference receiver-under-test.

Cd/No ratios were measured where Cd is the average power (dBm) over all IBOC carriers and No is the average power density (dBm/Hz) of the AWGN.

The digital recordings for subjective evaluation were edited by ATTC to remove extraneous material such as silence between the test samples. The test samples were also edited to obtain constant perceptual loudness. The edited recordings were made available to Dynastat, Inc. for subsequent subjective evaluation.

5.1. IBOC Digital-Only Peak-to-Average Power Ratio (NRSC A.1)

The peak-to-average ratio of the digital-only IBOC signal was measured as shown in Table 12.

Table 12 – IBOC Peak-to-Average Power Ratio

Peak-to Average Power Ratio (dB) 99.99% Cumulative Distribution
6.9dB
Peak-to-Average Power Ratio (dB) 95.00% Cumulative Distribution
4.5dB

5.2. IBOC Performance in the Presence of Noise (NRSC B.1)

Table 13 summarizes the interference scenario for the objective performance test of the digital IBOC system in the presence of AWGN (NRSC B.1). The BLER was measured as a function of the Cd/No ratio in order to establish the point at which the block error rate reached 10 percent (*10% BLER*). Figure 1 illustrates the measurements above and below *10% BLER*. The 10% BLER point minus 2 dB was used to establish the AWGN level for the subsequent subjective recordings. Table 14 tabulates the subjective test scenarios.

**Table 13 – IBOC Performance Scenario
– AWGN Interference (NRSC B.1)**

#	Desired	AWGN
5001	Hybrid: Moderate	Variable

**Table 14 – Subjective Test Scenarios
– AWGN Interference (NRSC B.1)**

#	Desired	AWGN	RX	Audio Cut
5101	Hybrid: Moderate	10%BLER – 2dB	IBOC	Bach
5102	Hybrid: Moderate	10%BLER – 2dB	IBOC	Prince
5103	Hybrid: Moderate	10%BLER – 2dB	IBOC	Brokaw

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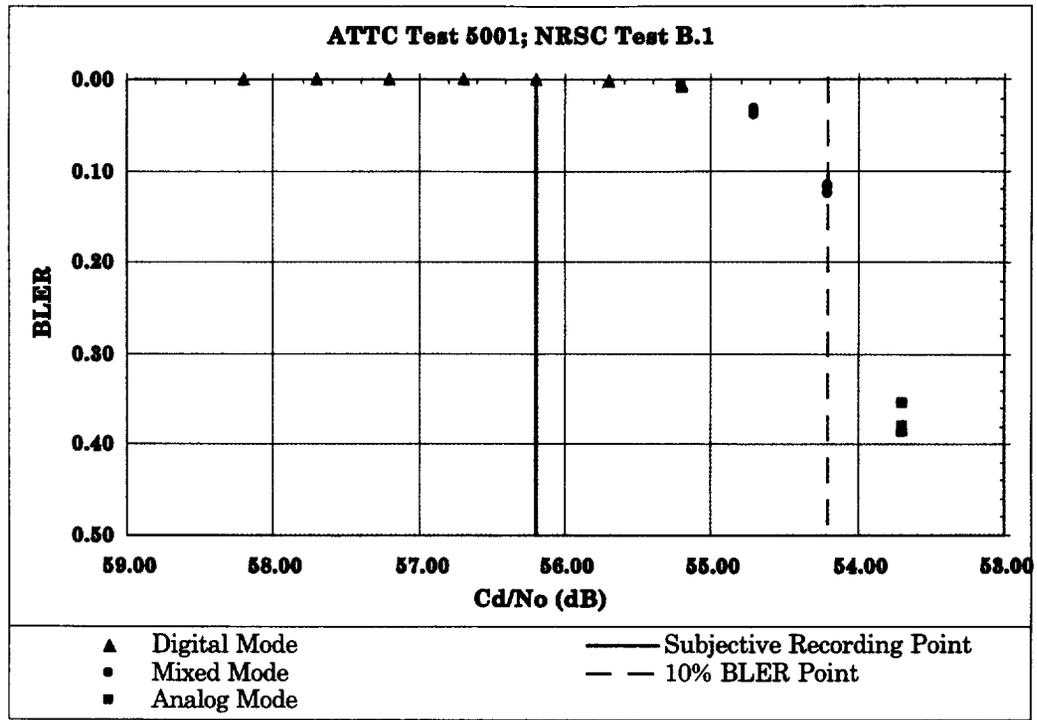


Figure 1 - Objective Test Results - Digital IBOC System Performance in the Presence of AWGN (NRSC B.1)

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5.3. IBOC Performance in the Presence of Multipath and Noise (NRSC B.2)

Table 15 summarizes the interference scenarios of the objective performance tests of the digital IBOC system in the presence of multipath and AWGN (NRSC B.2). The BLER was measured as a function of the Cd/No ratio in order to establish the point at which the block error rate reached 10 percent (*10% BLER*). Figure 2 through Figure 5 illustrate the measurements above and below *10% BLER*. The 10% BLER point minus 8 dB was used to establish the AWGN level for the subsequent subjective recordings. Table 16 tabulates the subjective test scenarios.

**Table 15 – IBOC Performance Scenarios
– AWGN and Multipath Interference (NRSC B.2)**

#	Desired	AWGN	Multi path
5201	Hybrid: Moderate	Variable	US
5209	Hybrid: Moderate	Variable	UF
5217	Hybrid: Moderate	Variable	TO
5225	Hybrid: Moderate	Variable	RF

**Table 16 – Subjective Test Scenarios
– Multipath and AWGN Interference (NRSC B.2)**

#	Desired	AWGN	Multi path	RX	Audio Cut
5251	Hybrid: Moderate	10%BLER – 8dB	US	IBOC	Saito
5252	Analog: Moderate	10%BLER – 8dB	US	2 Auto	Saito
5253	Hybrid: Moderate	10%BLER – 8dB	US	IBOC	Clapton
5254	Analog: Moderate	10%BLER – 8dB	US	2 Auto	Clapton
5255	Hybrid: Moderate	10%BLER – 8dB	US	IBOC	Woman
5256	Analog: Moderate	10%BLER – 8dB	US	2 Auto	Woman
5257	Hybrid: Moderate	10%BLER – 8dB	UF	IBOC	1812
5258	Analog: Moderate	10%BLER – 8dB	UF	2 Auto	1812
5259	Hybrid: Moderate	10%BLER – 8dB	UF	IBOC	Cole
5260	Analog: Moderate	10%BLER – 8dB	UF	2 Auto	Cole
5261	Hybrid: Moderate	10%BLER – 8dB	UF	IBOC	Man
5262	Analog: Moderate	10%BLER – 8dB	UF	2 Auto	Man
5263	Hybrid: Moderate	10%BLER – 8dB	TO	IBOC	Persian
5264	Analog: Moderate	10%BLER – 8dB	TO	2 Auto	Persian
5265	Hybrid: Moderate	10%BLER – 8dB	TO	IBOC	Crowded
5266	Analog: Moderate	10%BLER – 8dB	TO	2 Auto	Crowded
5267	Hybrid: Moderate	10%BLER – 8dB	TO	IBOC	Brokaw
5268	Analog: Moderate	10%BLER – 8dB	TO	2 Auto	Brokaw
5269	Hybrid: Moderate	10%BLER – 8dB	RF	IBOC	Messiah
5270	Analog: Moderate	10%BLER – 8dB	RF	2 Auto	Messiah
5271	Hybrid: Moderate	10%BLER – 8dB	RF	IBOC	Fagen
5272	Analog: Moderate	10%BLER – 8dB	RF	2 Auto	Fagen
5273	Hybrid: Moderate	10%BLER – 8dB	RF	IBOC	Woman
5274	Analog: Moderate	10%BLER – 8dB	RF	2 Auto	Woman

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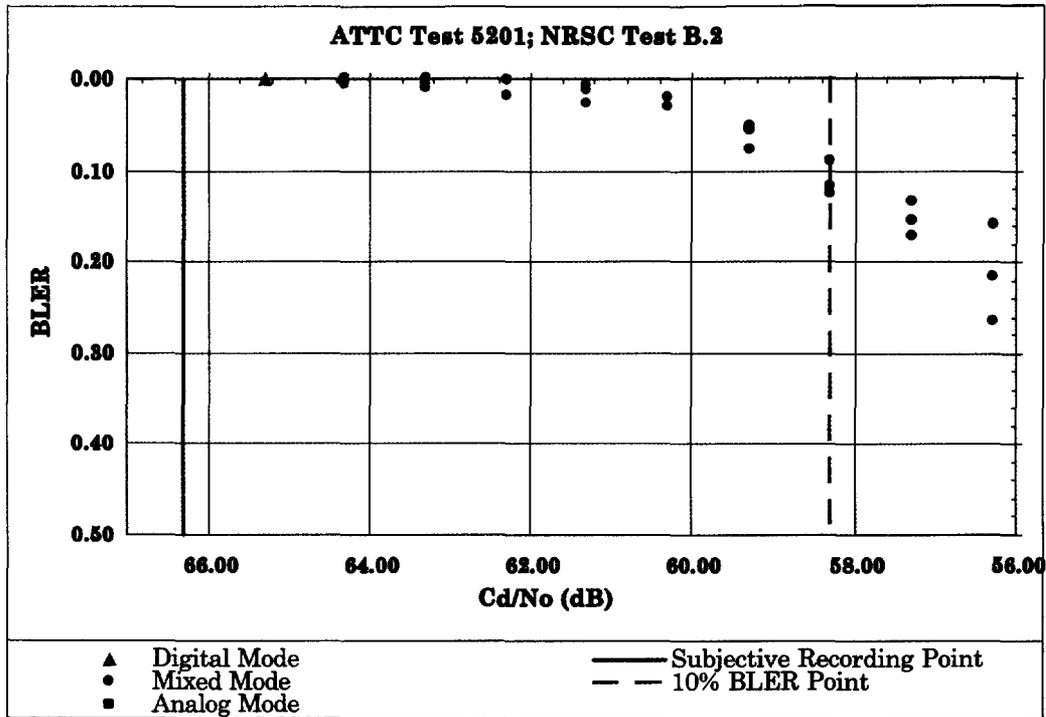


Figure 2 - Objective Test Result - Digital IBOC System Performance in the Presence of Urban Slow Multipath and AWGN (NRSC B.2)

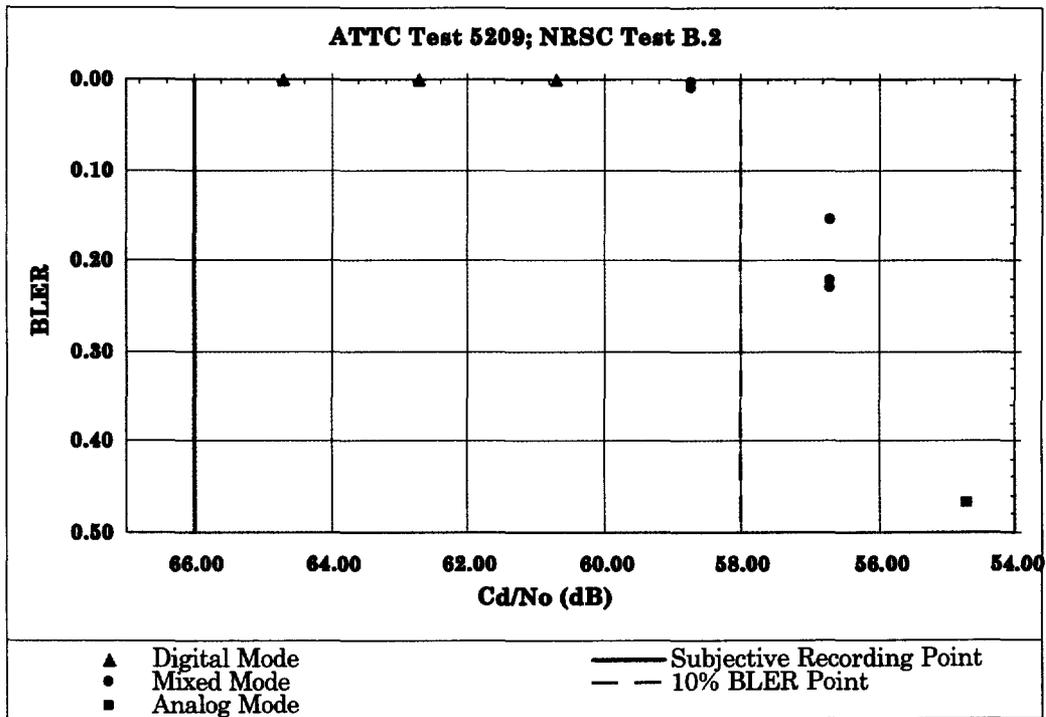


Figure 3 - Objective Test Results - Digital IBOC System Performance in the Presence of Urban Fast Multipath and AWGN (NRSC B.2)

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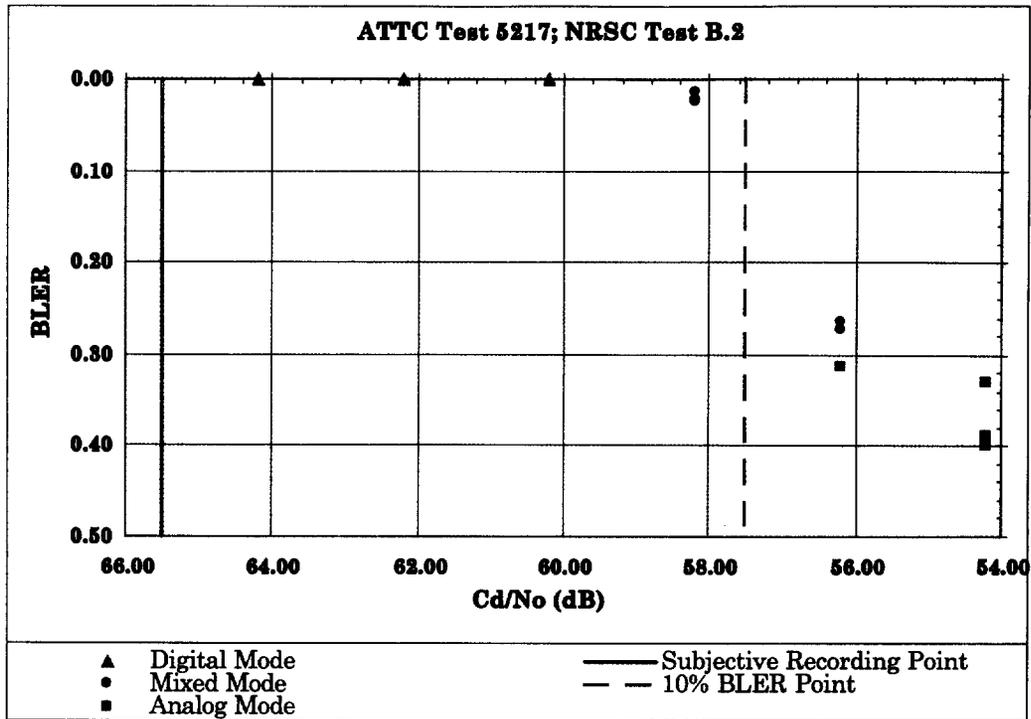


Figure 4 - Objective Test Results - Digital IBOC System Performance in the Presence of Terrain Obstructed Multipath and AWGN (NRSC B.2)

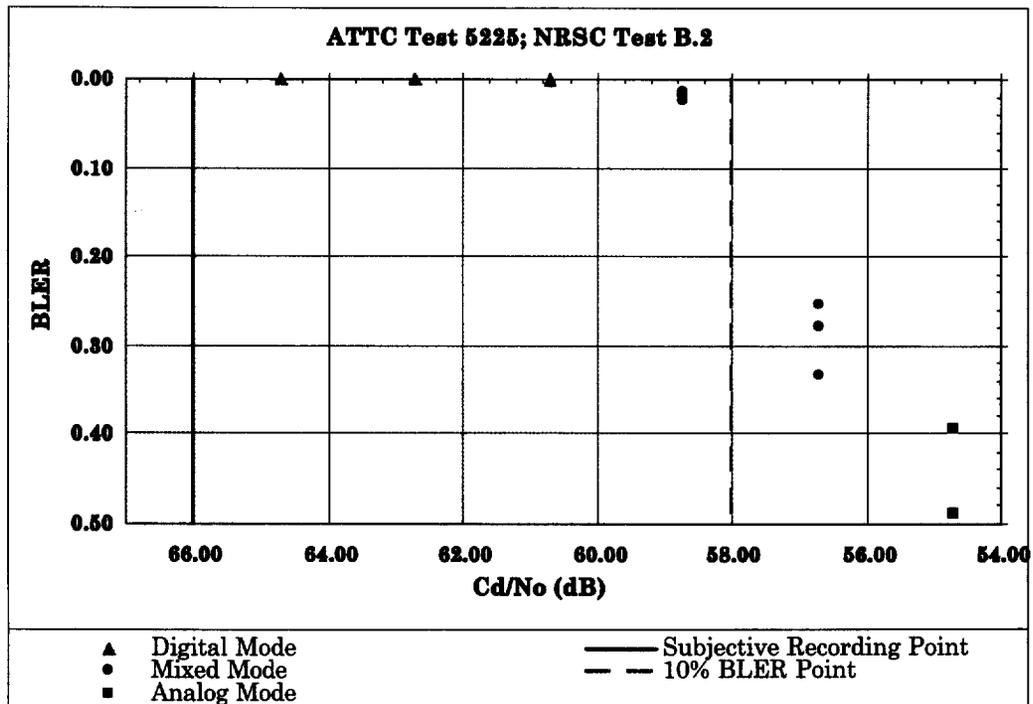


Figure 5 - Objective Test Results - Digital IBOC System Performance in the Presence of Rural Fast Multipath and AWGN (NRSC B.2)

5.4. IBOC Performance in the Presence of Impulse Noise (NRSC C.1)

Table 17 summarizes the interference scenarios of the objective performance tests of the digital IBOC system in the presence of impulse noise at various repetition rates (NRSC C.1). In addition, a single upper first adjacent interferer was also introduced at a +6 dB D/U in some cases. The BLER was measured as a function of impulse noise peak power in order to establish the point at which the block error rate reached 10 percent (*10% BLER*). Figure 6 through Figure 19 illustrate the measurements above and below *10% BLER*. The 10% BLER point minus 2 dB was used to establish the impulse noise level for the subsequent subjective recordings. Table 18 tabulates the subjective test scenarios.

**Table 17 – IBOC Performance Scenarios
– Impulse Noise Interference (NRSC C.1)**

#	Desired	Upper 1st adj.	Impulse Noise Peak Power (dBm)	Impulse Rep Rate (Hz)
5501	Hybrid: Moderate		Variable	120
5502	Hybrid: Moderate	Hybrid: +6dB	Variable	120
5503	Hybrid: Moderate		Variable	330
5504	Hybrid: Moderate	Hybrid: +6dB	Variable	330
5505	Hybrid: Moderate		Variable	510
5506	Hybrid: Moderate	Hybrid: +6dB	Variable	510
5507	Hybrid: Moderate		Variable	1200
5508	Hybrid: Moderate	Hybrid: +6dB	Variable	1200
5509	Hybrid: Moderate		Variable	1800
5510	Hybrid: Moderate	Hybrid: +6dB	Variable	1800
5511	Hybrid: Moderate		Variable	2000
5512	Hybrid: Moderate	Hybrid: +6dB	Variable	2000
5513	Hybrid: Moderate		Variable	Pseudo-Random
5514	Hybrid: Moderate	Hybrid: +6dB	Variable	Pseudo-Random

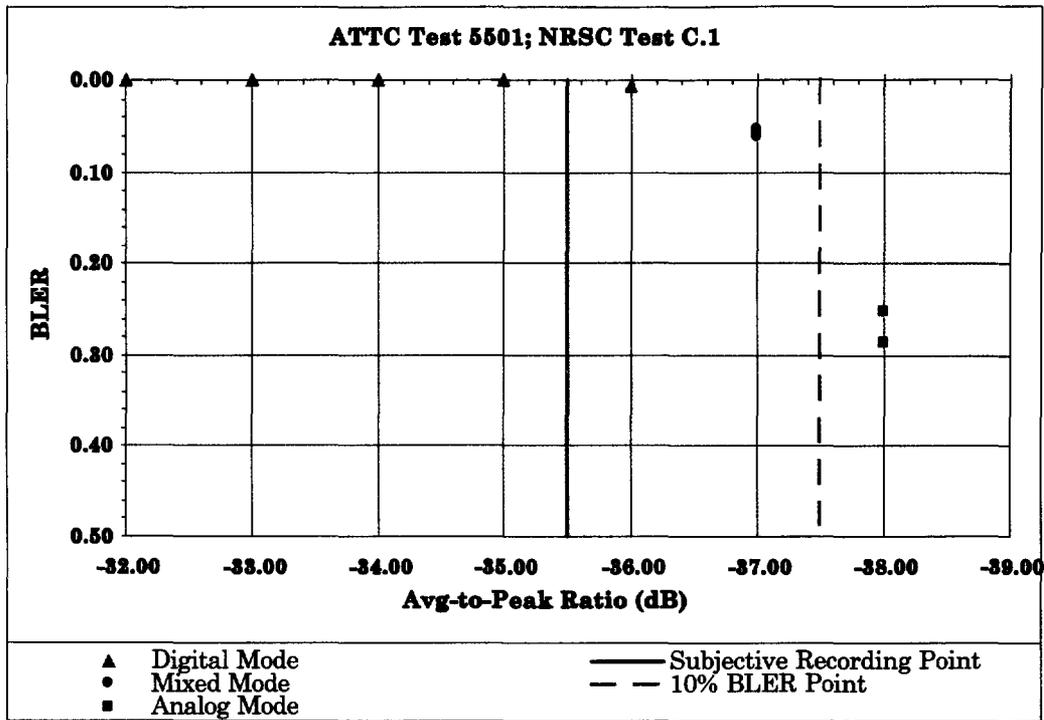


Figure 6 - Objective Test Results - Digital IBOC System Performance in the Presence of Impulse Noise at 120 Hz (NRSC C.1)

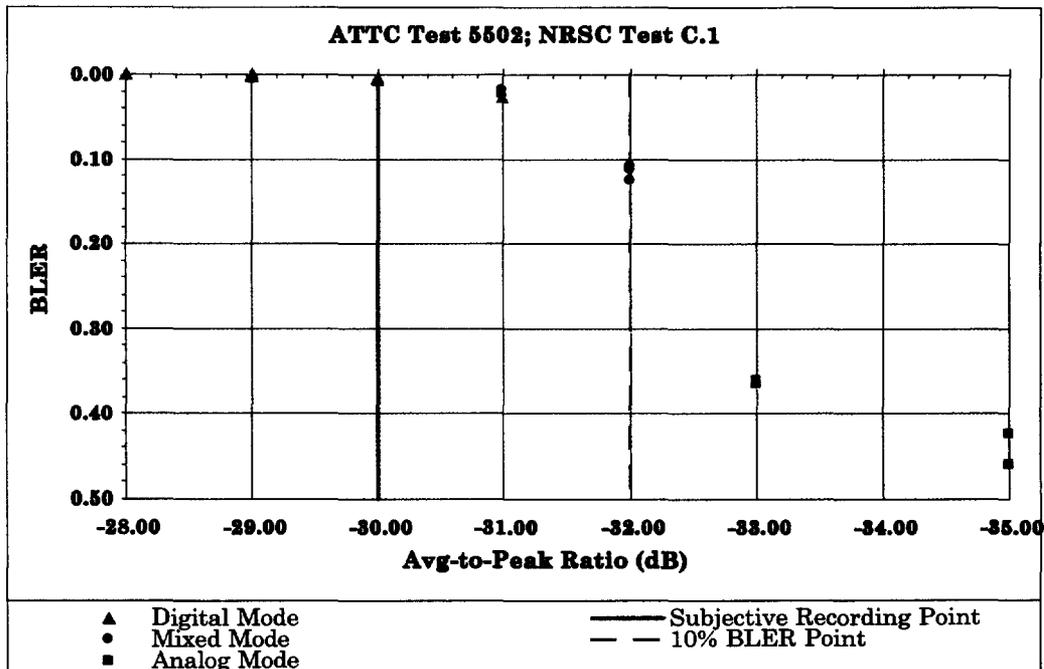


Figure 7 - Objective Test Results - Digital IBOC System Performance in the Presence of Impulse Noise at 120 Hz and Upper Adjacent Channel Interference (NRSC C.1)

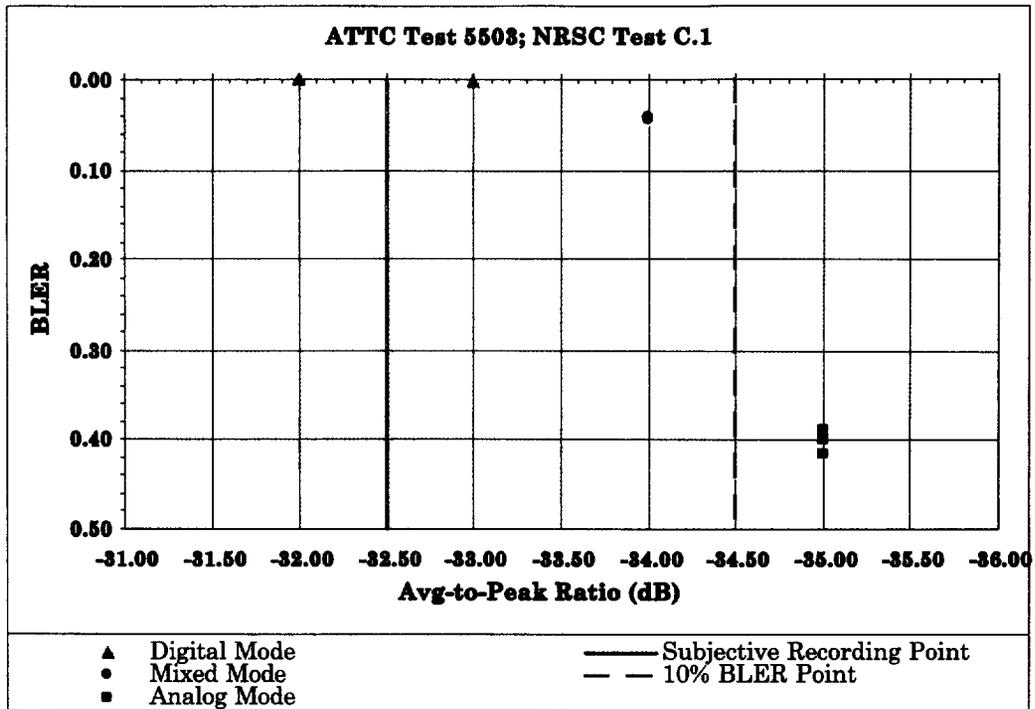


Figure8 - Objective Test Results - Digital IBOC System Performance in the Presence of Impulse Noise at 330 Hz (NRSC C.1)

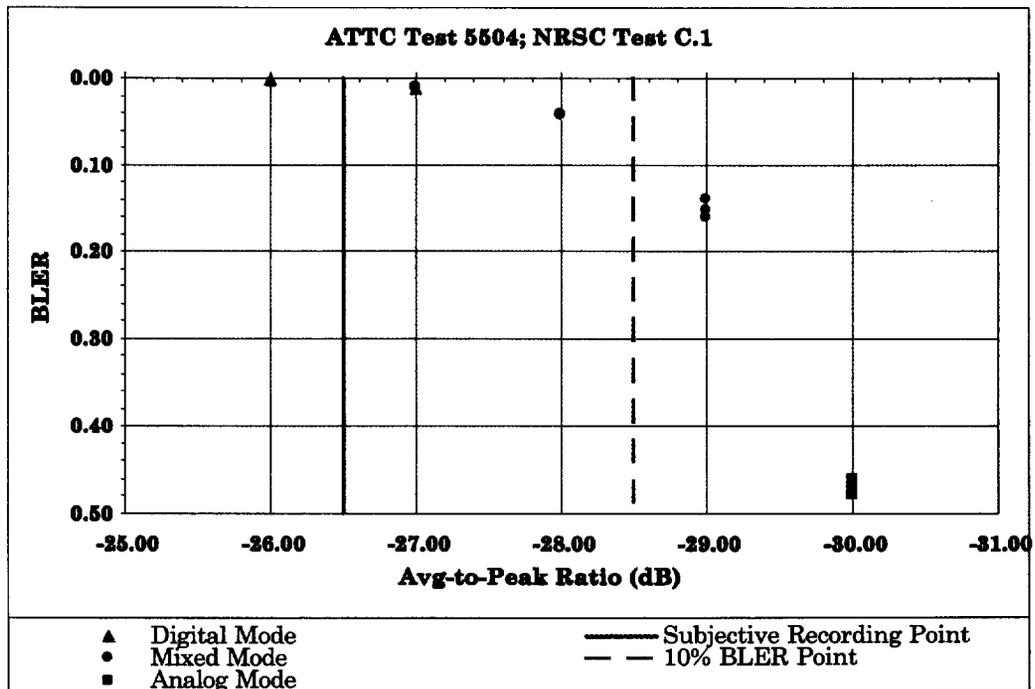


Figure9 - Objective Test Results - Digital IBOC System Performance in the Presence of Impulse Noise at 330 Hz and Upper Adjacent Channel Interference (NRSC C.1)

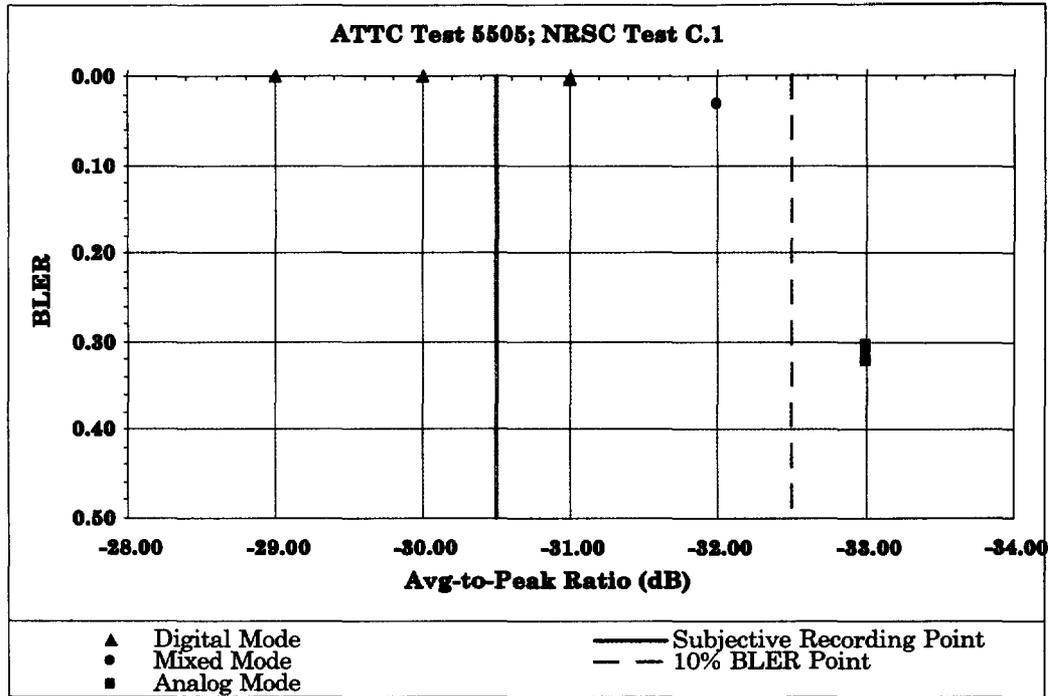


Figure 10 - Objective Test Results - Digital IBOC System Performance in the Presence of Impulse Noise at 510 Hz (NRSC C.1)

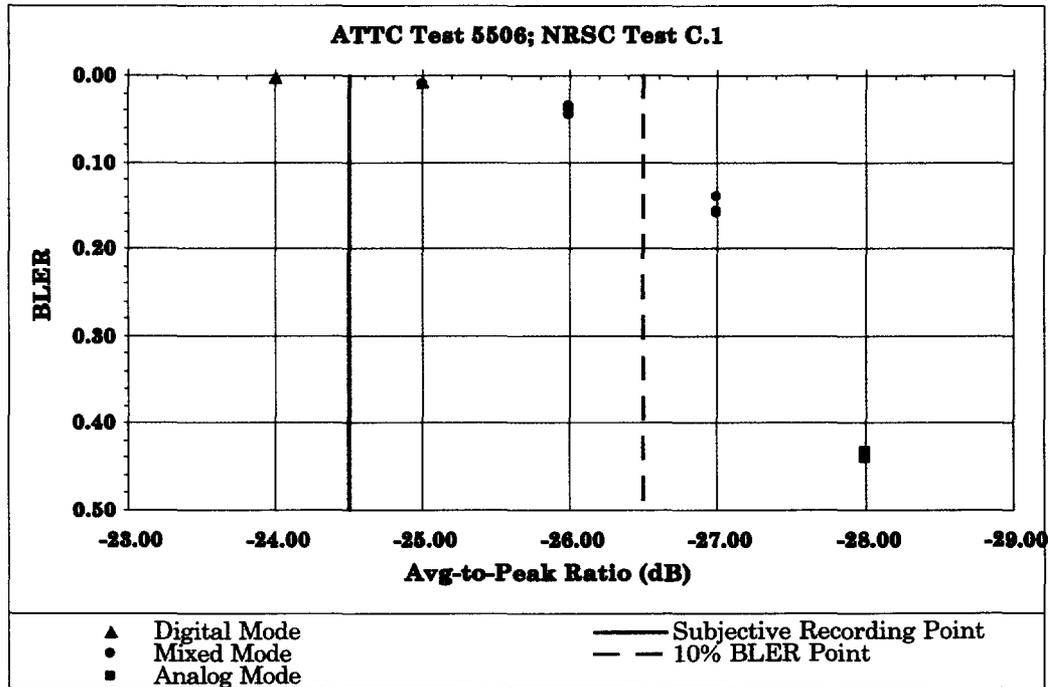


Figure 11 - Objective Test Results - Digital IBOC System Performance in the Presence of Impulse Noise at 510 Hz and Upper Adjacent Channel Interference (NRSC C.1)

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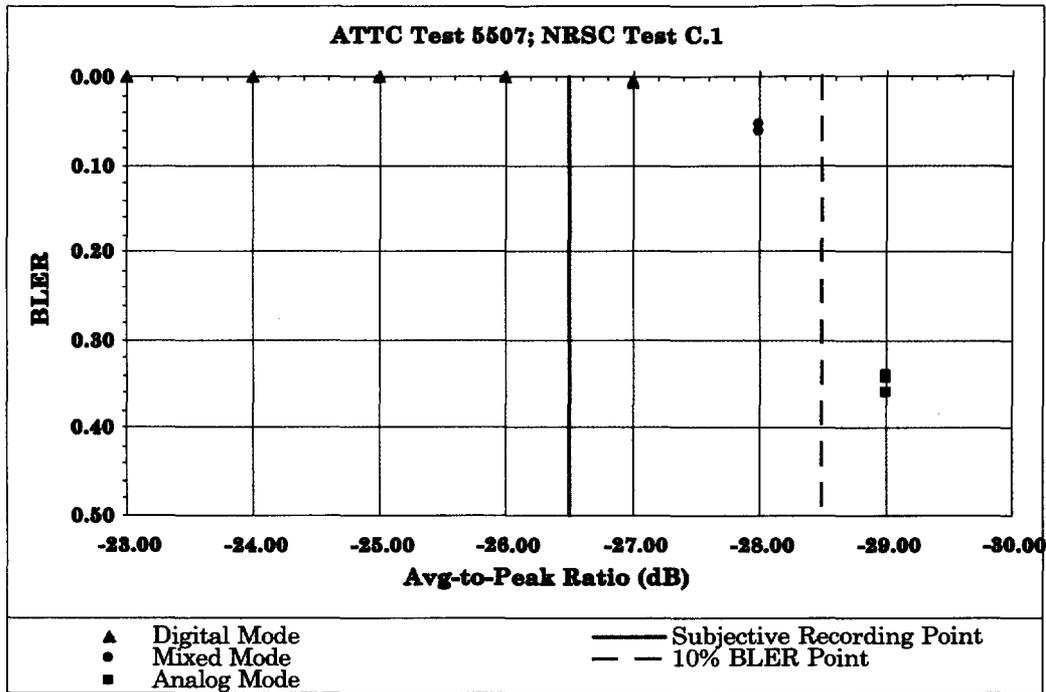


Figure 12 - Objective Test Results - Digital IBOC System Performance in the Presence of Impulse Noise at 1200 Hz (NRSC C.1)

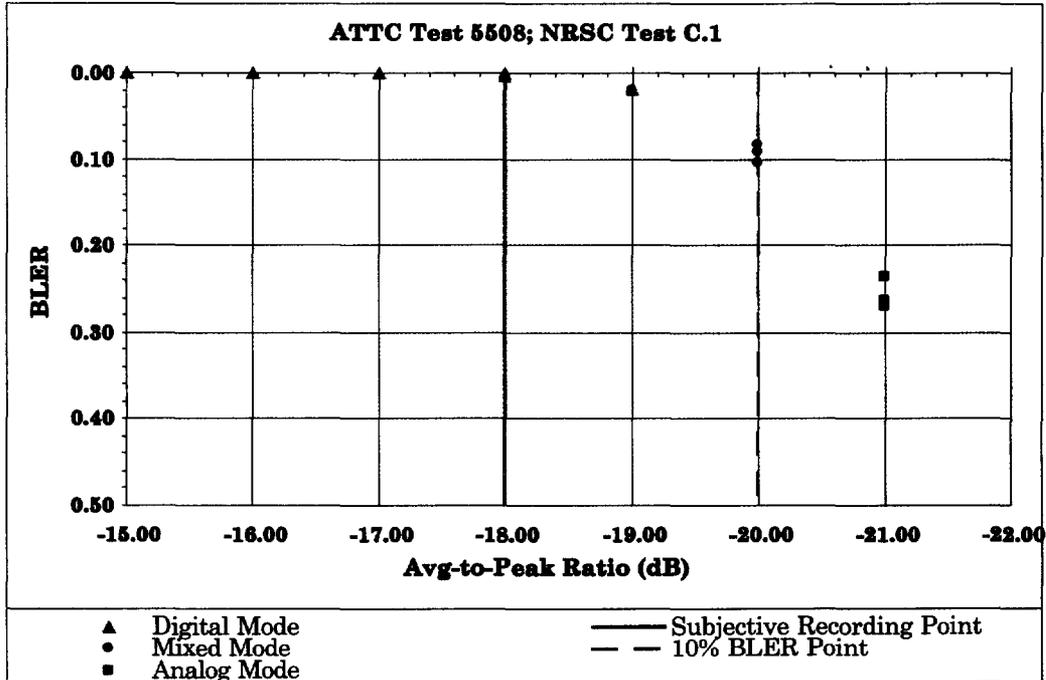


Figure 13 - Objective Test Results - Digital IBOC System Performance in the Presence of Impulse Noise at 1200 Hz and Upper Adjacent Channel Interference (NRSC C.1)

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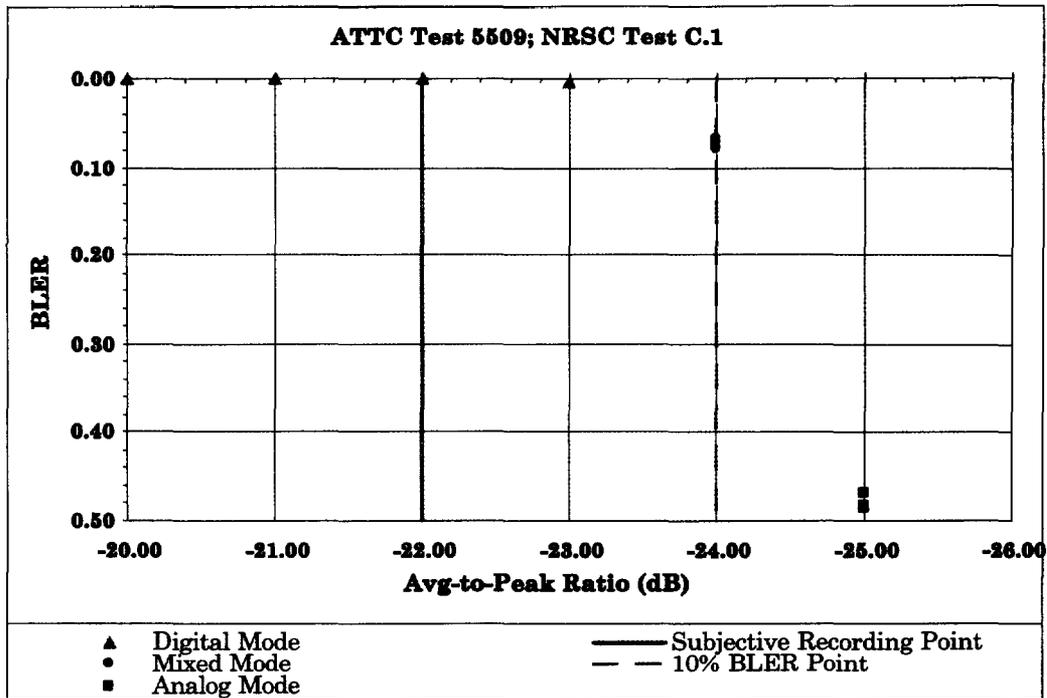


Figure 14 - Objective Test Results - Digital IBOC System Performance in the Presence of Impulse Noise at 1800 Hz (NRSC C.1)

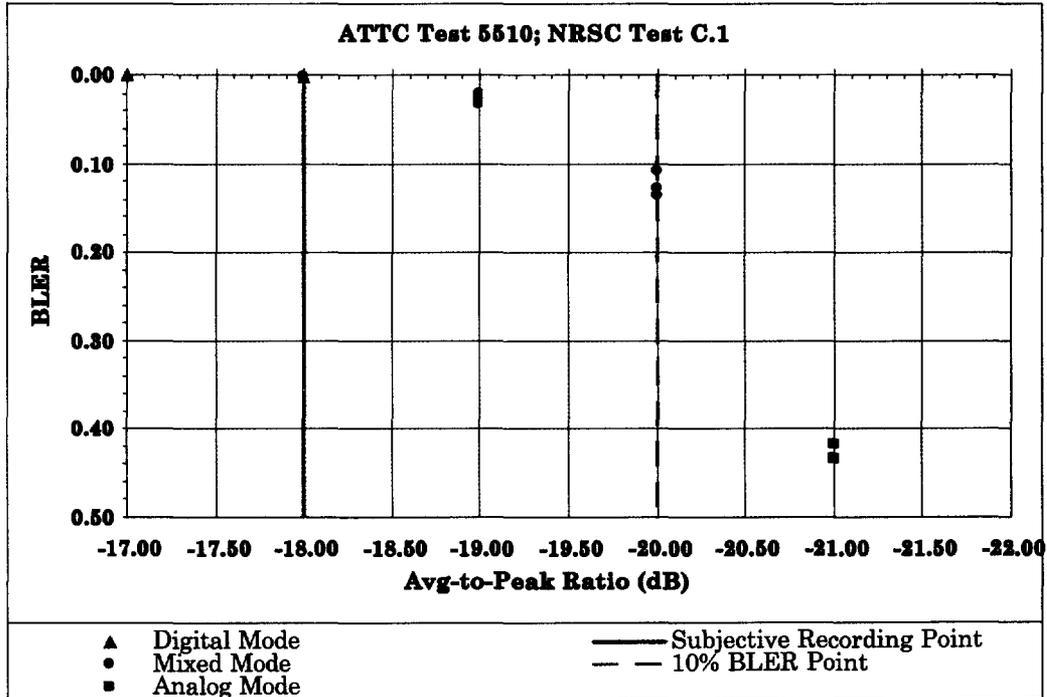


Figure 15 - Objective Test Results - Digital IBOC System Performance in the Presence of Impulse Noise at 1800 Hz and Upper Adjacent Channel Interference (NRSC C.1)

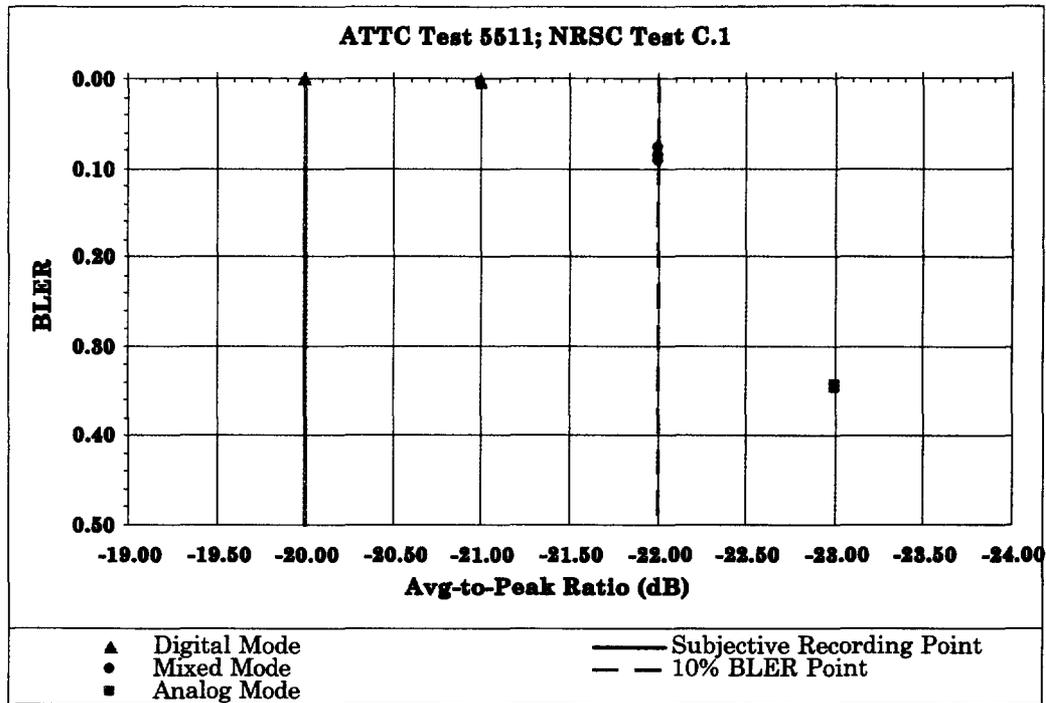


Figure 16 - Objective Test Results – Digital IBOC System Performance in the Presence of Impulse Noise at 2000 Hz (NRSC C.1)

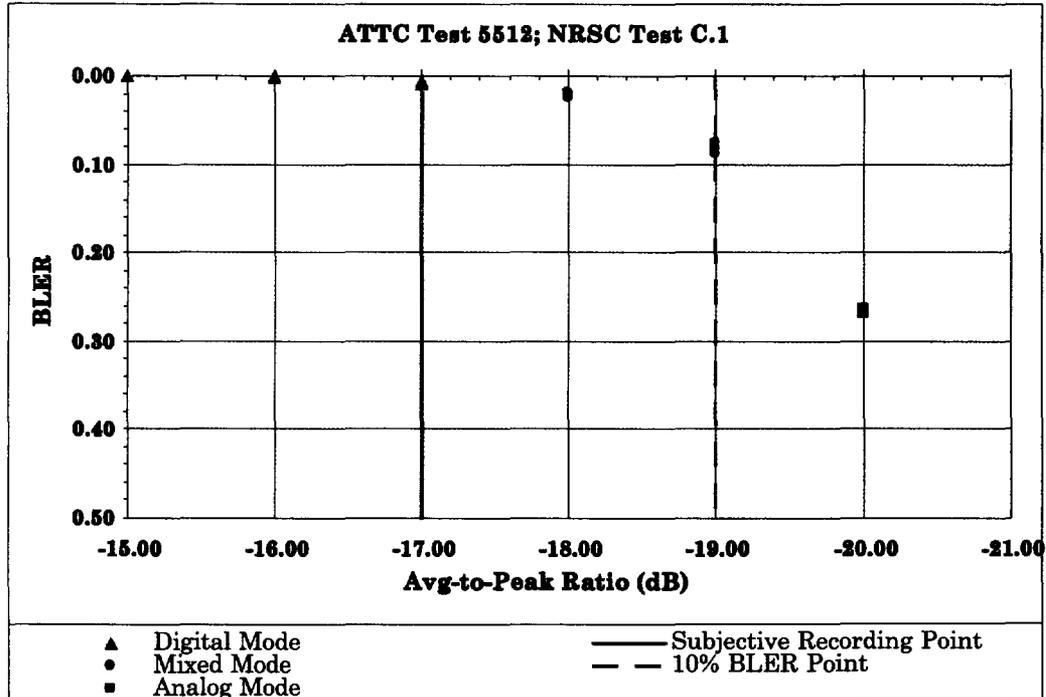


Figure 17 - Objective Test Results – Digital IBOC System Performance in the Presence of Impulse Noise at 2000 Hz and Upper Adjacent Channel Interference (NRSC C.1)

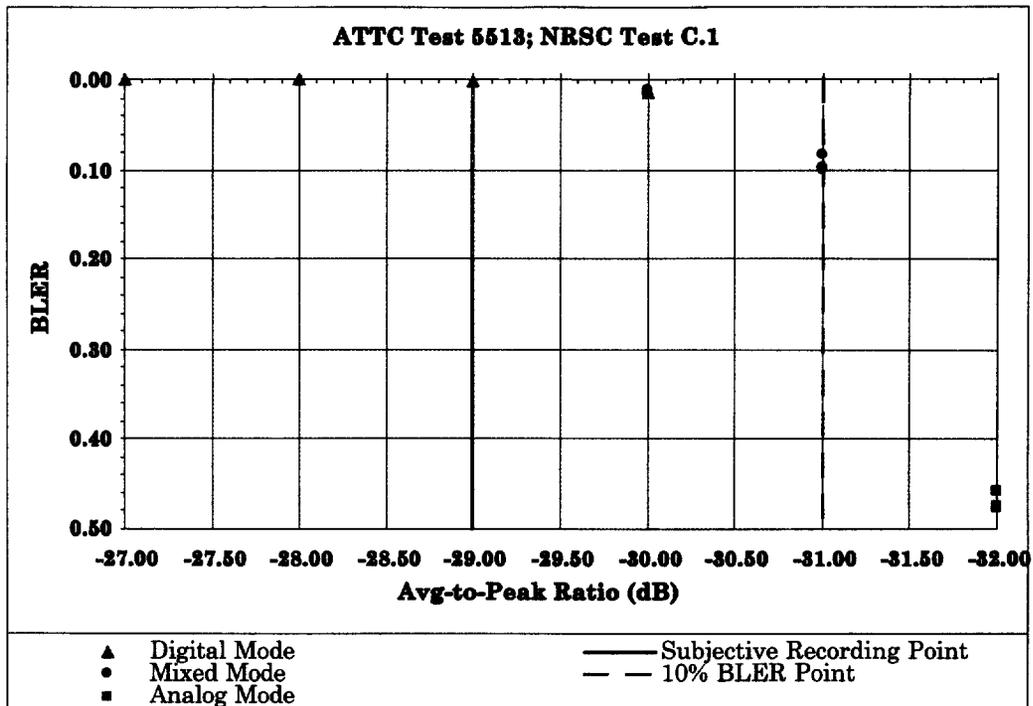


Figure 18 - Objective Test Results - Digital IBOC System Performance in the Presence of Pseudo-Random Impulse Noise (NRSC C.1)

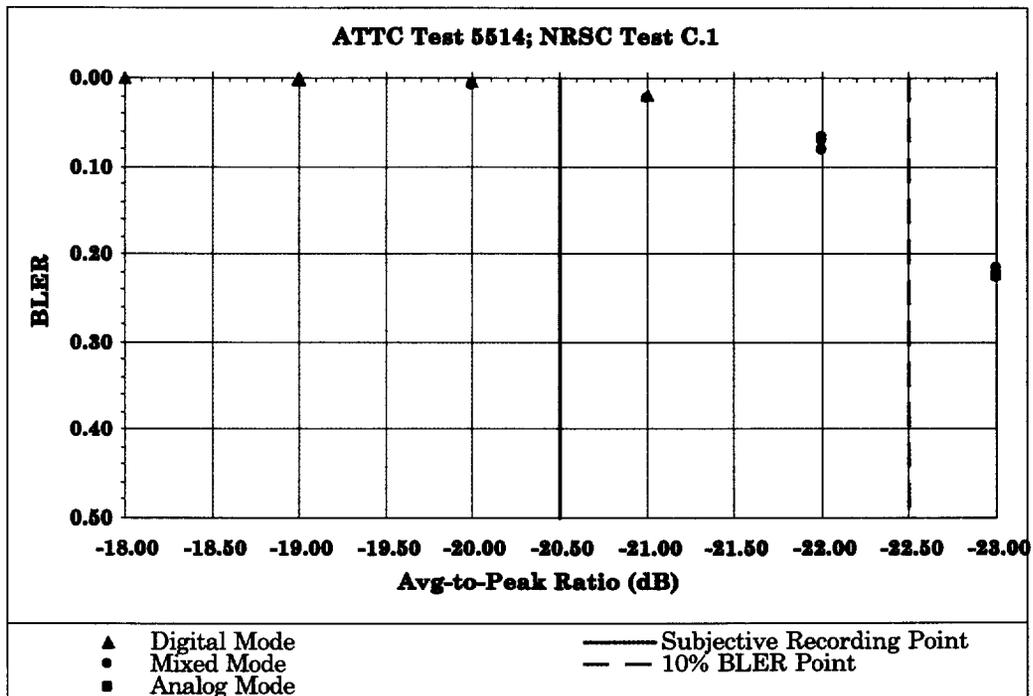


Figure 19 - Objective Test Results - Digital IBOC System Performance in the Presence of Pseudo-Random Impulse Noise and Upper Adjacent Channel Interference (NRSC C.1)

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Table 18 – Subjective Test Scenarios – Impulse Noise Interference (NRSC C.1)

#	Desired	Upper F st adj.	Impulse Noise Peak Power (dBm)	Rep Rate (Hz)	RX	Audio Cut
5601	Hybrid: Moderate		10% BLER – 2dB	120	IBOC	Stravinsky
5602	Analog: Moderate		10% BLER – 2dB	120	2 Auto	Stravinsky
5603	Hybrid: Moderate	Hybrid: +6dB	10% BLER – 2dB	120	IBOC	Ibert
5604	Analog: Moderate	Analog: +6dB	10% BLER – 2dB	120	2 Auto	Ibert
5605	Hybrid: Moderate		10% BLER – 2dB	330	IBOC	Debussy
5606	Analog: Moderate		10% BLER – 2dB	330	2 Auto	Debussy
5607	Hybrid: Moderate	Hybrid: +6dB	10% BLER – 2dB	330	IBOC	Carmen
5608	Analog: Moderate	Analog: +6dB	10% BLER – 2dB	330	2 Auto	Carmen
5609	Hybrid: Moderate		10% BLER – 2dB	510	IBOC	Messiah
5610	Analog: Moderate		10% BLER – 2dB	510	2 Auto	Messiah
5611	Hybrid: Moderate	Hybrid: +6dB	10% BLER – 2dB	510	IBOC	1812
5612	Analog: Moderate	Analog: +6dB	10% BLER – 2dB	510	2 Auto	1812
5613	Hybrid: Moderate		10% BLER – 2dB	1200	IBOC	Ibert
5614	Analog: Moderate		10% BLER – 2dB	1200	2 Auto	Ibert
5615	Hybrid: Moderate	Hybrid: +6dB	10% BLER – 2dB	1200	IBOC	Bach
5616	Analog: Moderate	Analog: +6dB	10% BLER – 2dB	1200	2 Auto	Bach
5617	Hybrid: Moderate		10% BLER – 2dB	1800	IBOC	Stravinsky
5618	Analog: Moderate		10% BLER – 2dB	1800	2 Auto	Stravinsky
5619	Hybrid: Moderate	Hybrid: +6dB	10% BLER – 2dB	1800	IBOC	Ibert
5620	Analog: Moderate	Analog: +6dB	10% BLER – 2dB	1800	2 Auto	Ibert
5621	Hybrid: Moderate		10% BLER – 2dB	2000	IBOC	Debussy
5622	Analog: Moderate		10% BLER – 2dB	2000	2 Auto	Debussy
5623	Hybrid: Moderate	Hybrid: +6dB	10% BLER – 2dB	2000	IBOC	Carmen
5624	Analog: Moderate	Analog: +6dB	10% BLER – 2dB	2000	2 Auto	Carmen
5625	Hybrid: Moderate		10% BLER – 2dB	Pseudo-Random	IBOC	Messiah
5626	Analog: Moderate		10% BLER – 2dB	Pseudo-Random	2 Auto	Messiah
5627	Hybrid: Moderate	Hybrid: +6dB	10% BLER – 2dB	Pseudo-Random	IBOC	Bach
5628	Analog: Moderate	Analog: +6dB	10% BLER – 2dB	Pseudo-Random	2 Auto	Bach