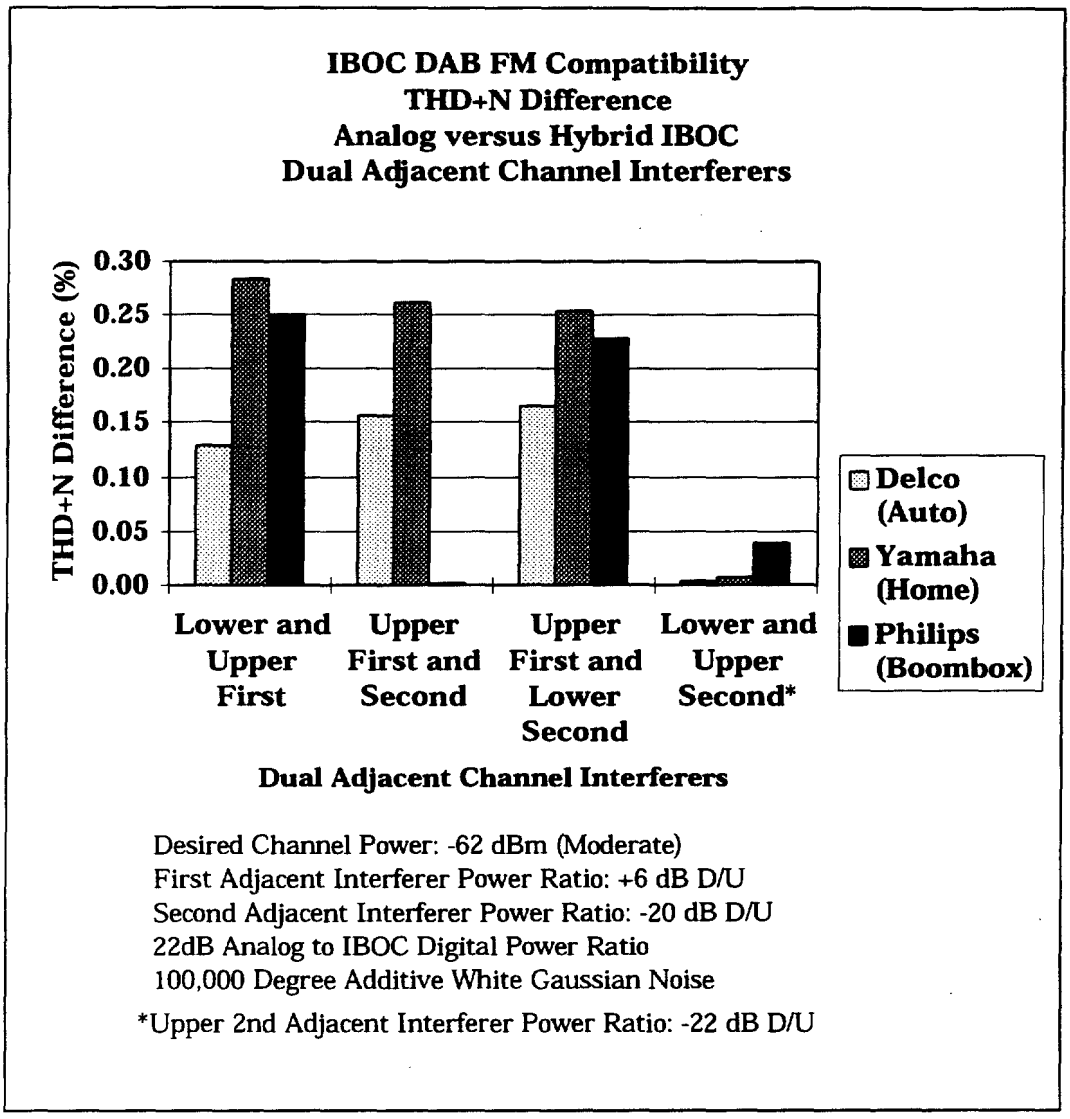

Figure 4 - Summary results showing the difference in THD+N between Analog and Hybrid IBOC in the presence of Dual Adjacent Channel Interferers for a linear channel

Table 10 - Summary results showing the difference between Analog and Hybrid IBOC in the presence of Dual Adjacent Channel Interferers for a linear channel

IBOC DAB FM Compatibility
Analog versus Hybrid IBOC
Dual Adjacent Channel Interferers

Tests 28, 34, 38, 41, 44, 47, 50, and 53

Radio	**Delco (Auto)**	**Yamaha (Home)**	**Philips (Boombox)**
Interferer:	**S/N Difference (dB)**		
Lower and Upper First	6.4	3.0	4.8
Upper First and Second	6.9	6.0	0.1
Upper First and Lower Second	4.8	5.1	6.8
Lower and Upper Second*	0.1	0.1	0.0

Radio	**Delco (Auto)**	**Yamaha (Home)**	**Philips (Boombox)**
Interferer:	**THD+N Difference (%)**		
Lower and Upper First	0.13	0.28	0.25
Upper First and Second	0.16	0.26	0.00
Upper First and Lower Second	0.17	0.25	0.23
Lower and Upper Second*	0.00	0.01	0.04

Desired Power Level:	Moderate	-62 dBm

22dB Analog to IBOC Digital Power Ratio

Criteria	
First Adjacent:	+6 dB D/U
Second Adjacent:	-20 dB D/U
* except noted Upper Second: -22 dB D/U	

Radio Model No:	**Serial No:**
Delco 16195161	89BKRMM38293G378
Yamaha HTR5130	Y025169QS
Philips AZ1020/17	KT009917021837

5.3. Analog Compatibility in the Presence of Hybrid IBOC Co-Channel Interferers, Linear Channel (NRSC F)

Figure 5 and Figure 6 illustrate analog compatibility in the presence of co-channel hybrid IBOC interferers showing the difference in signal-to-noise and THD+N, respectively, for each radio. Table 11 tabulates the results.

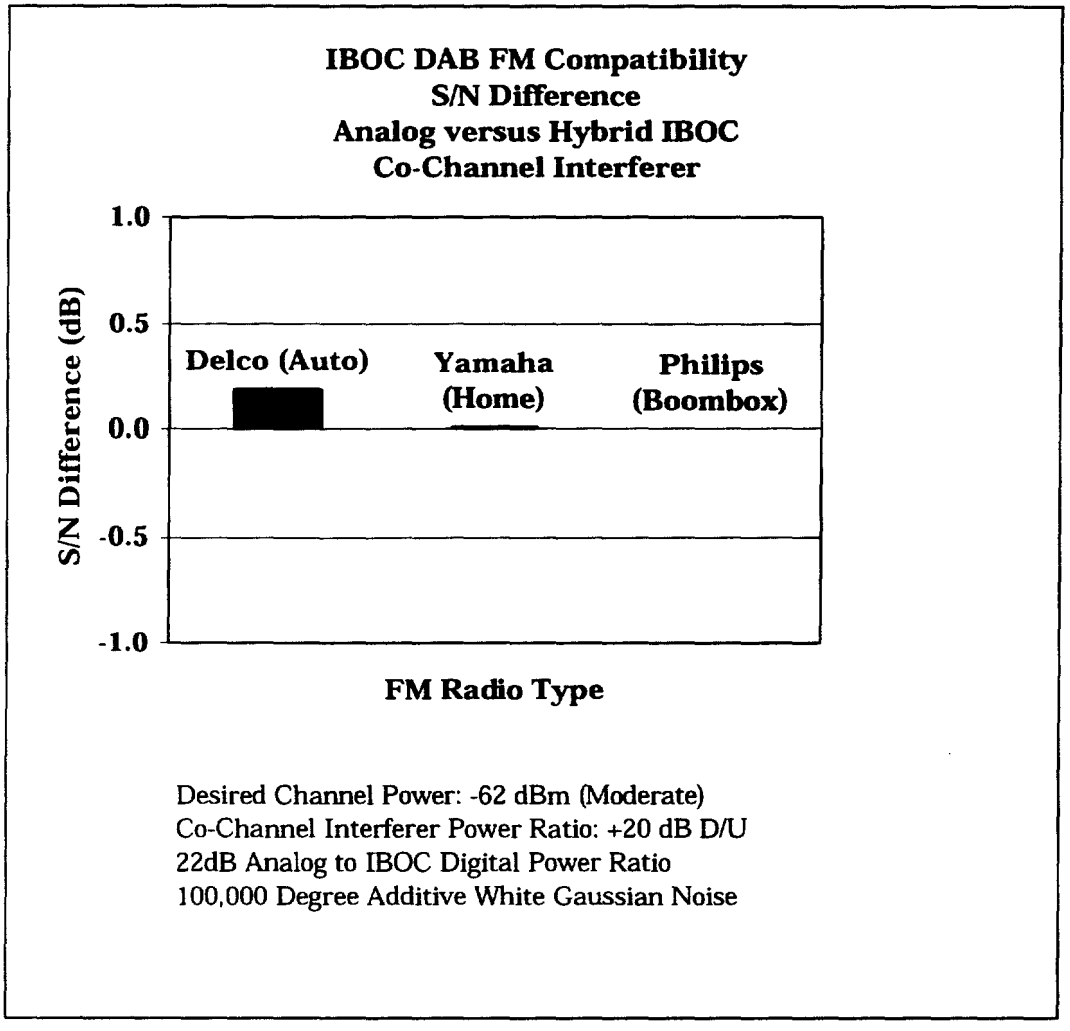

Figure 5 - Summary results showing the difference in signal to noise ratio between Analog and Hybrid IBOC in the presence of a Co-Channel Interferer for a linear channel

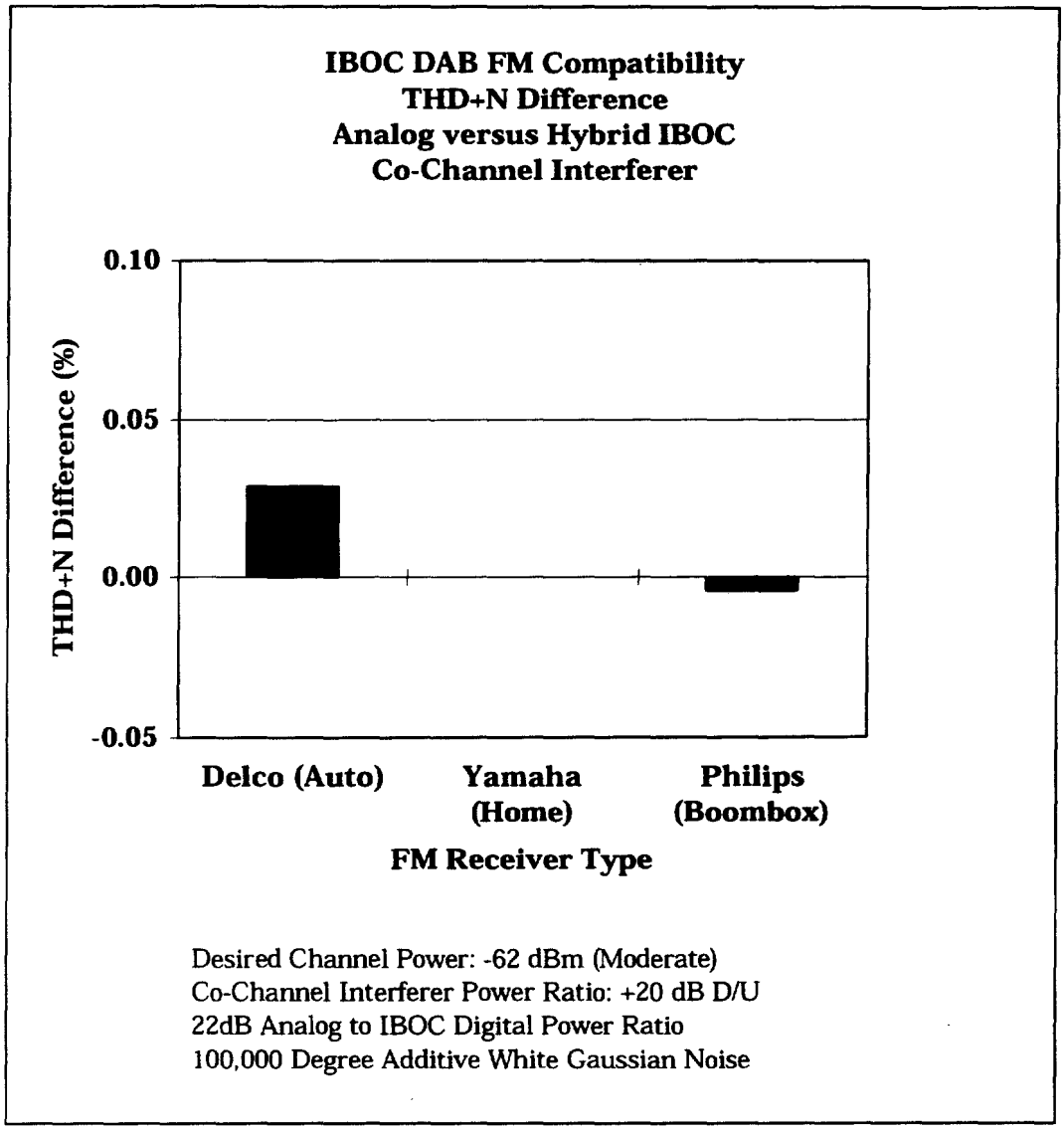

Figure 6 - Summary results showing the difference in THD+N between Analog and Hybrid IBOC in the presence of a Co-Channel Interferer for a linear channel

Table 11 - Summary results showing the difference between Analog and Hybrid IBOC in the presence of a Co-Channel Interferer for a linear channel

IBOC DAB FM Compatibility
Analog versus Hybrid IBOC
Co-Channel Interferer

Tests 55 and 56

Radio	Delco (Auto)	Yamaha (Home)	Philips (Boombox)
S/N Difference (dB)	0.2	0.0	0.0
THD+N Difference (%)	0.03	0.00	0.00

Desired Power Level:	Moderate	-62 dBm

22dB	Analog to IBOC Digital Power Ratio

Edge of Coverage Criteria	
Co-Channel:	+20 dB D/U

Radio Model No:	**Serial No:**
Delco 16195161	89BKRMM38293G378
Yamaha HTR5130	Y025169QS
Philips AZ1020/17	KT009917021837

5.4. Host Analog Compatibility in the Presence of IBOC, Linear Channel (NRSC L)

Figure 7 and Figure 8 illustrate host analog compatibility in the presence of hybrid IBOC interferers showing the difference in signal-to-noise and THD+N, respectively, for each radio. Table 12 tabulates the results.

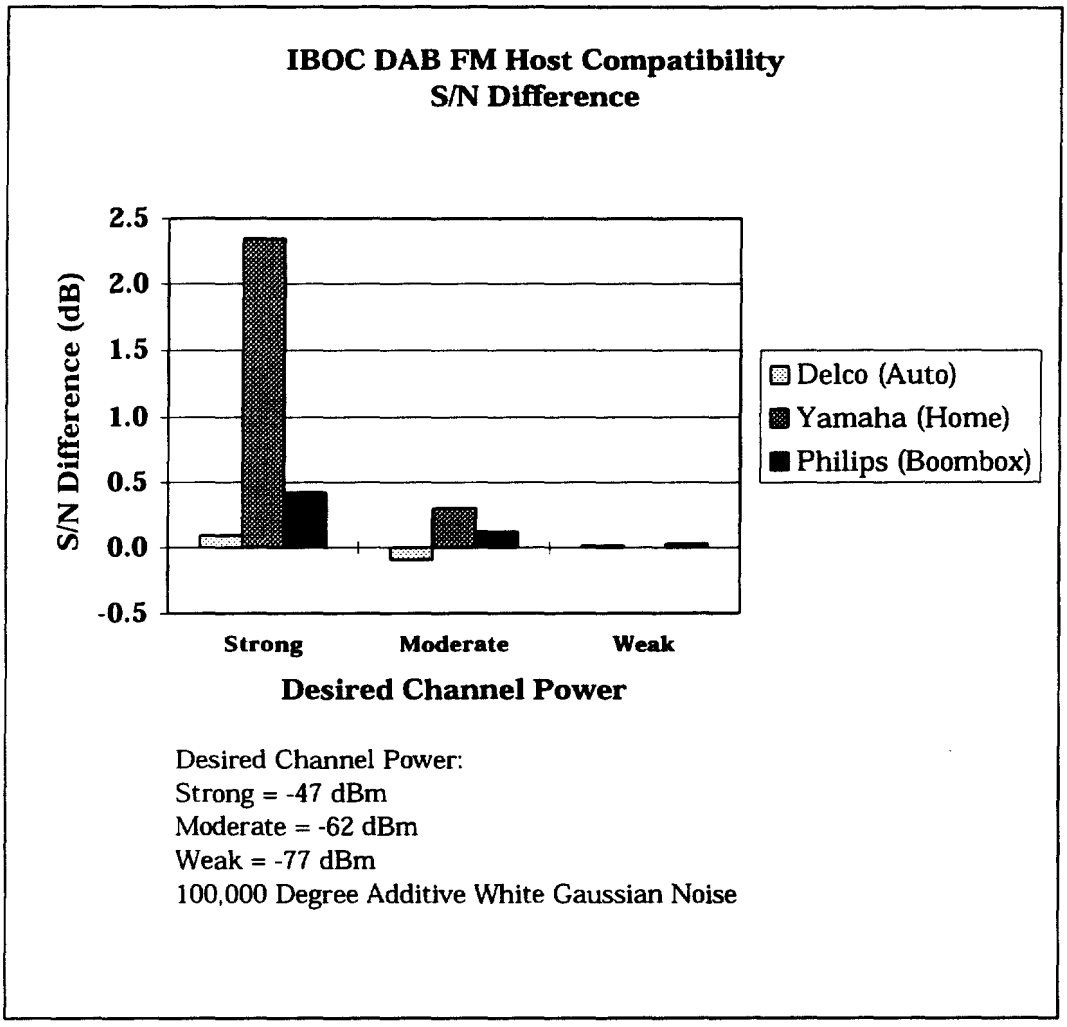

Figure 7 - Summary results showing the differences in signal to noise ratio caused by Digital IBOC to the Analog Host for a linear channel

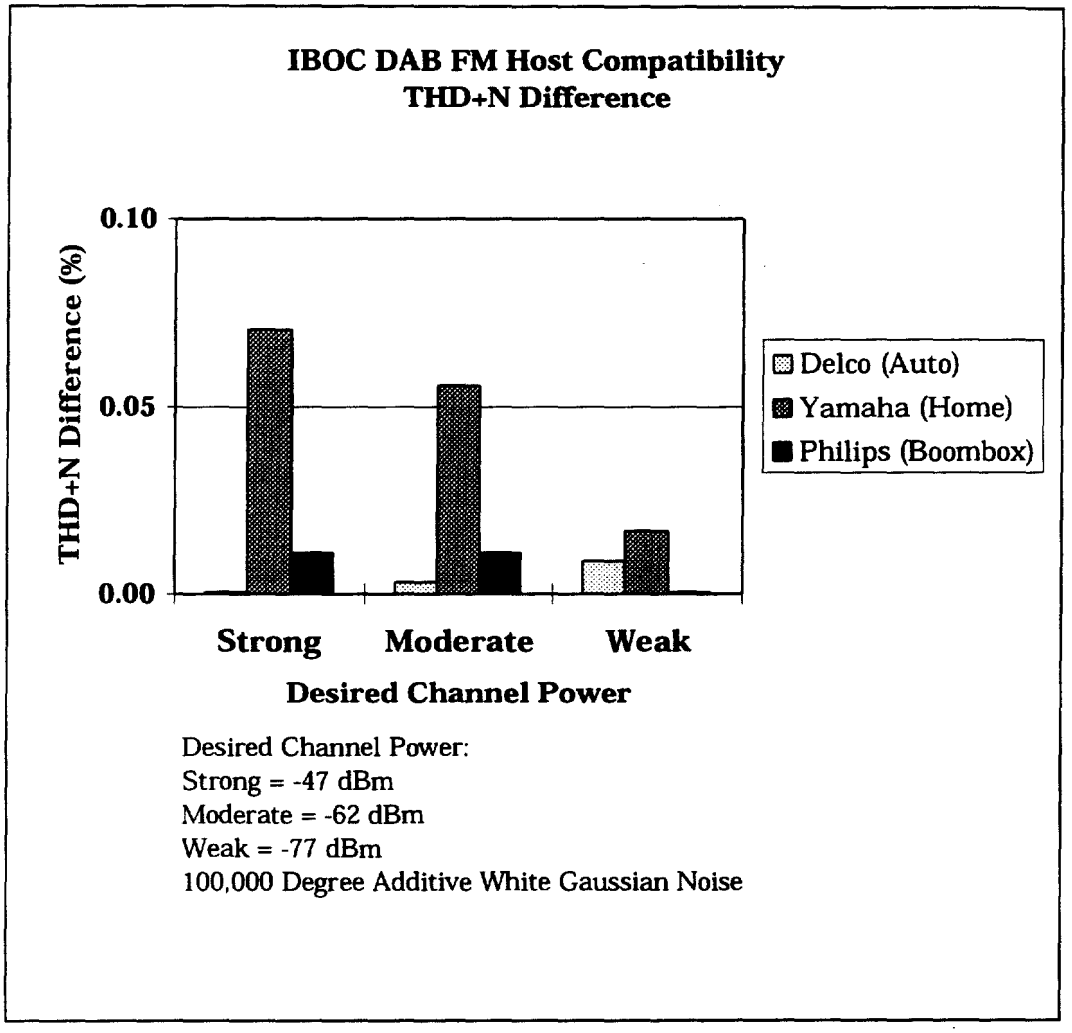

Figure 8 - Summary results showing the differences in THD+N caused by Digital IBOC to the Analog Host for a linear channel

Table 12 - Summary results showing the differences caused by Digital IBOC to the Analog Host for a linear channel

IBOC DAB FM Host Compatibility
Digital into Host Analog

Tests 57, 58, 59, 60, 61, and 62

	S/N Difference (dB)		
	Radio		
Desired Power	**Delco (Auto)**	**Yamaha (Home)**	**Philips (Boombox)**
Strong	0.1	2.4	0.4
Moderate	-0.1	0.3	0.1
Weak	0.0	0.0	0.0

	THD+N Difference (%)		
	Radio		
Desired Power	**Delco (Auto)**	**Yamaha (Home)**	**Philips (Boombox)**
Strong	0.00	0.07	0.01
Moderate	0.00	0.06	0.01
Weak	0.01	0.02	0.00

Desired Power Levels	
Strong	-47 dBm
Moderate	-62 dBm
Weak	-77 dBm

22dB Analog to IBOC Digital Power Ratio

Radio Model No:	Serial No:
Delco 16195161	89BKRMM38293G378
Yamaha HTR5130	Y025169QS
Philips AZ1020/17	KT009917021837

5.5. Analog Compatibility in a Multipath Impaired Channel (NRSC G)

Table 13 lists the DAT recordings made for each subjective test of the Delco radio in the presence of multipath interference. The DAT recordings have an embedded time code plus test date contained in the User Bit.

Table 13 - Date/Time - Sorted Subjective Test List of Recordings

Test No.	Start Day	Start Time	Stop Day	Stop Time
1001	12/5/99	18:15:49	12/5/99	18:17:45
1002	12/5/99	18:18:08	12/5/99	18:20:04
1003	12/5/99	18:20:51	12/5/99	18:22:50
1004	12/5/99	18:23:20	12/5/99	18:25:14
1005	12/5/99	18:25:45	12/5/99	18:27:40
1006	12/5/99	18:28:10	12/5/99	18:30:05
1007	12/5/99	18:30:54	12/5/99	18:32:48
1008	12/5/99	18:33:11	12/5/99	18:35:05
1009	12/5/99	18:35:32	12/5/99	18:37:28
1010	12/5/99	18:37:53	12/5/99	18:39:51
1011	12/5/99	18:40:18	12/5/99	18:42:12
1012	12/5/99	18:42:37	12/5/99	18:44:32
1025	12/5/99	18:45:39	12/5/99	18:47:34
1026	12/5/99	18:48:00	12/5/99	18:49:54
1027	12/5/99	18:56:22	12/5/99	18:58:20
1028	12/5/99	18:58:45	12/5/99	19:00:43
1029	12/5/99	19:01:27	12/5/99	19:03:28
1030	12/5/99	19:03:55	12/5/99	19:06:02
1031	12/5/99	19:06:40	12/5/99	19:08:48
1032	12/5/99	19:09:16	12/5/99	19:11:14
1033	12/5/99	19:11:59	12/5/99	19:14:11
1034	12/5/99	19:14:41	12/5/99	19:16:39
1035	12/5/99	19:17:06	12/5/99	19:19:08
1036	12/5/99	19:19:38	12/5/99	19:21:33
1049	12/5/99	21:09:05	12/5/99	21:11:07
1050	12/5/99	21:17:13	12/5/99	21:19:11
1051	12/5/99	21:19:51	12/5/99	21:21:47
1052	12/5/99	21:22:20	12/5/99	21:24:16
1053	12/5/99	21:24:57	12/5/99	21:26:54
1054	12/5/99	21:30:44	12/5/99	21:32:37
1055	12/5/99	21:33:17	12/5/99	21:35:13
1056	12/5/99	21:35:43	12/5/99	21:37:37
1057	12/5/99	21:38:09	12/5/99	21:40:05
1058	12/5/99	21:40:28	12/5/99	21:42:22
1059	12/5/99	21:42:57	12/5/99	21:44:52
1060	12/5/99	21:45:23	12/5/99	21:47:17
1105	12/5/99	21:51:29	12/5/99	21:53:24

Test No.	Start Day	Start Time	Stop Day	Stop Time
1006	12/5/99	18:28:10	12/5/99	18:30:05
1107	12/5/99	21:56:09	12/5/99	21:58:19
1108	12/5/99	21:59:11	12/5/99	22:01:06
1109	12/5/99	22:45:18	12/5/99	22:47:11
1110	12/5/99	22:48:46	12/5/99	22:50:41
1111	12/5/99	22:51:08	12/5/99	22:53:01
1112	12/5/99	22:53:20	12/5/99	22:55:13
1113	12/5/99	22:55:34	12/5/99	22:57:27
1114	12/5/99	22:57:45	12/5/99	22:59:41
1115	12/5/99	23:00:25	12/5/99	23:02:18
1116	12/5/99	23:02:38	12/5/99	23:04:34
1117	12/5/99	23:04:59	12/5/99	23:06:52
1118	12/5/99	23:07:08	12/5/99	23:09:02
1119	12/5/99	23:09:19	12/5/99	23:11:12
1120	12/5/99	23:11:30	12/5/99	23:13:24

6. Acknowledgements

The Advanced Television Technology Center (ATTC) and its staff are grateful to the representatives of USADR for their support during this testing. ATTC wishes to thank Thomas Keller, Charles Rhodes, and Robert McCutcheon for their expertise and guidance.

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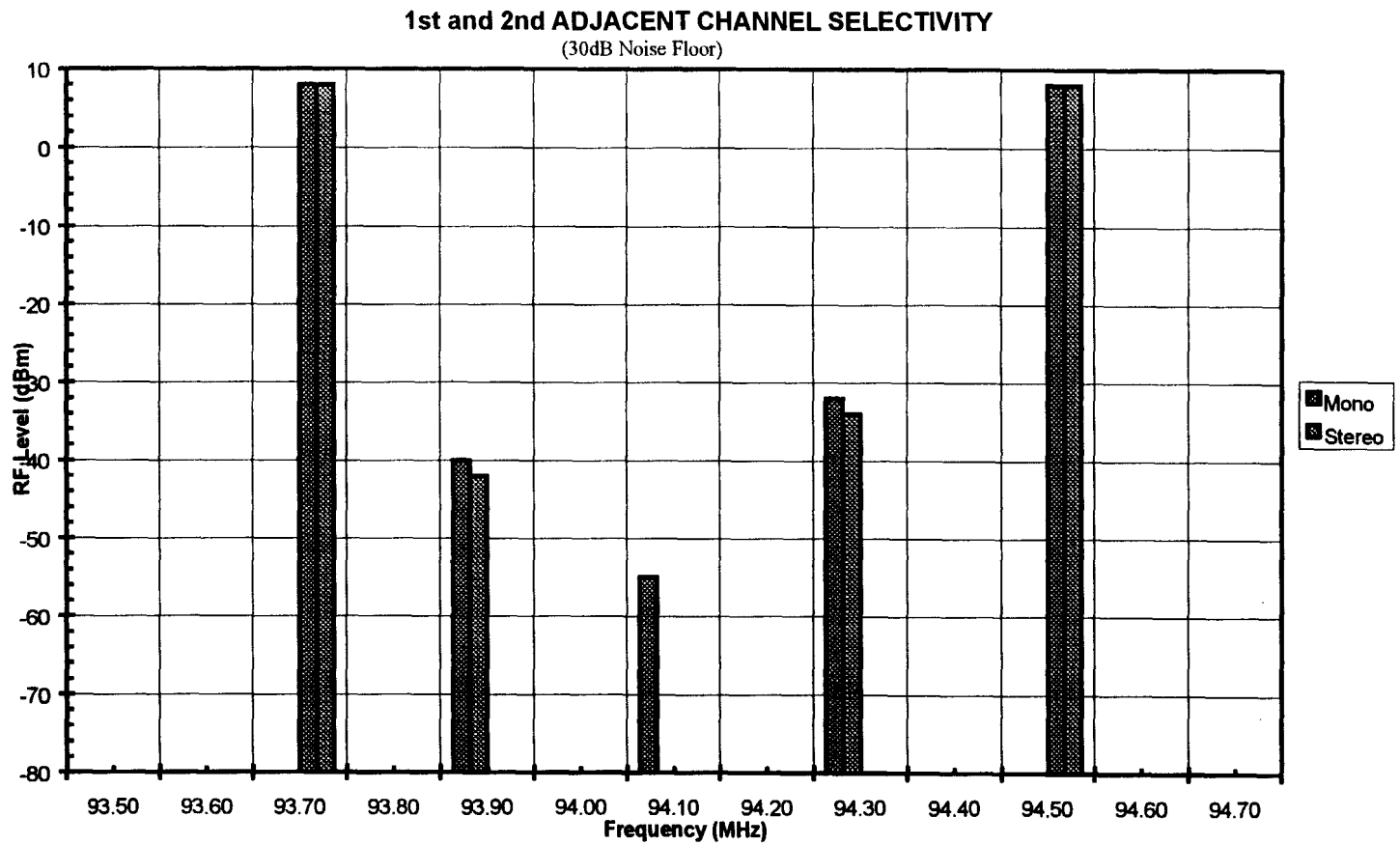
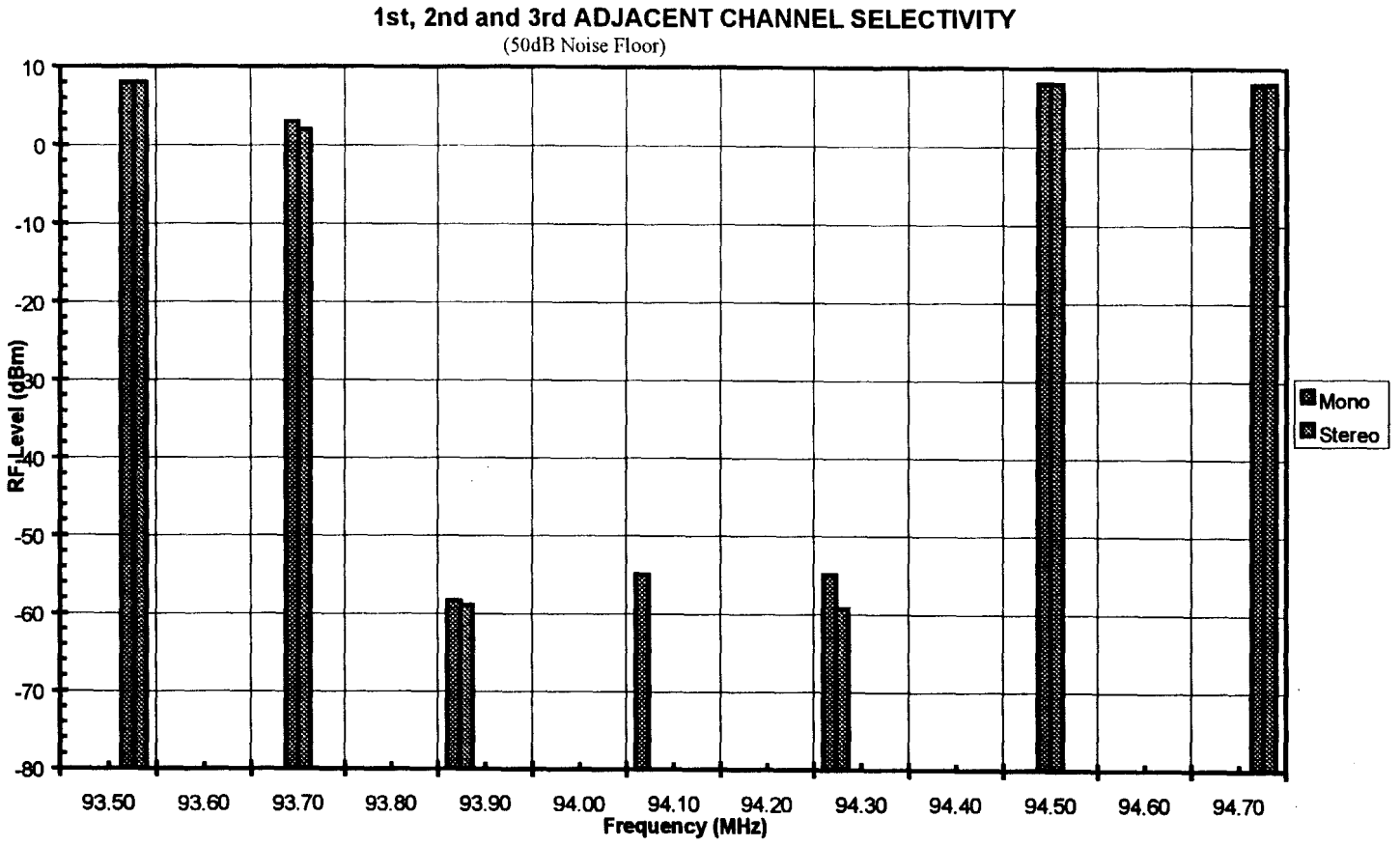
Appendix A – Delco Receiver Selectivity Characterizations

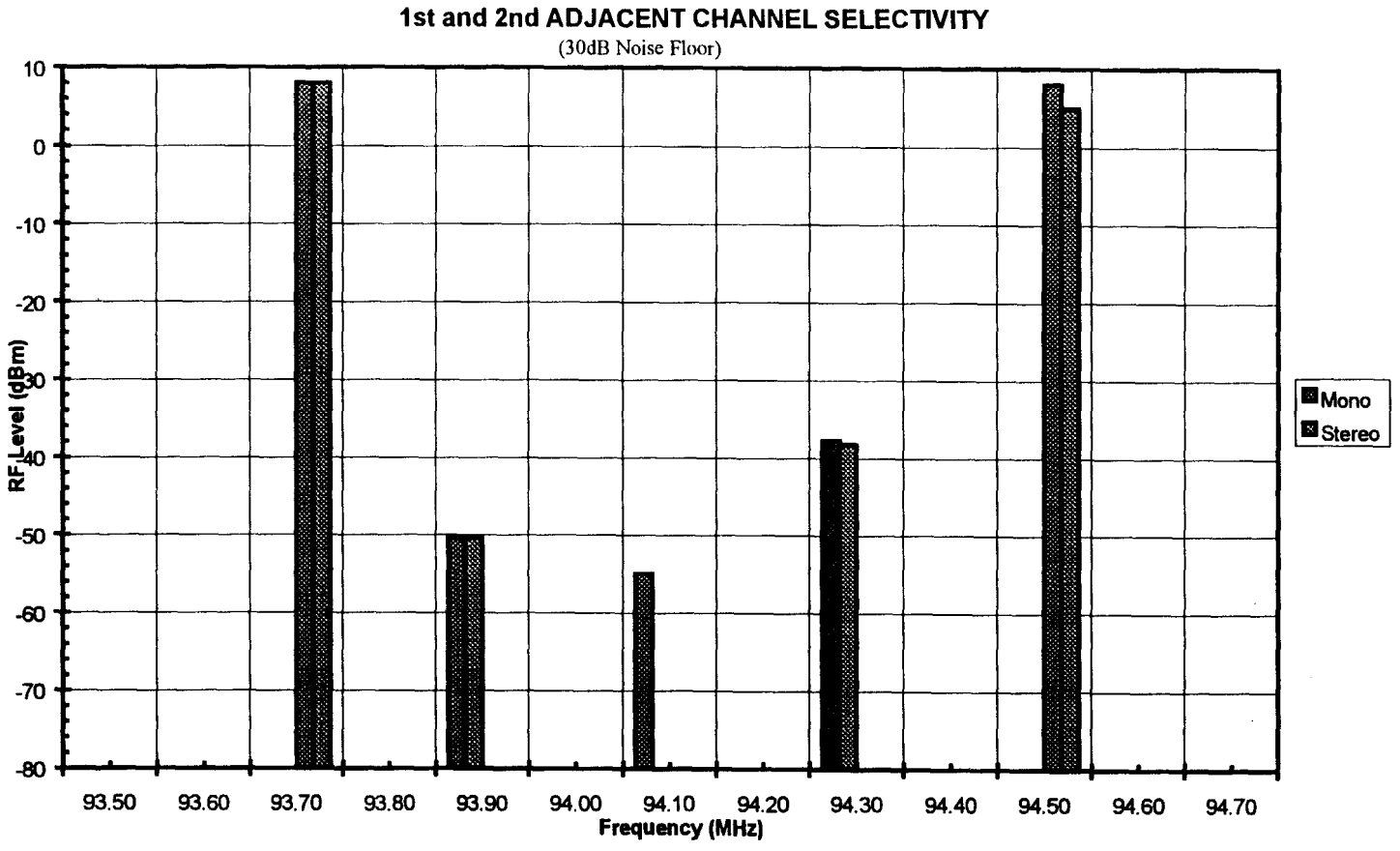


Delco 16195161

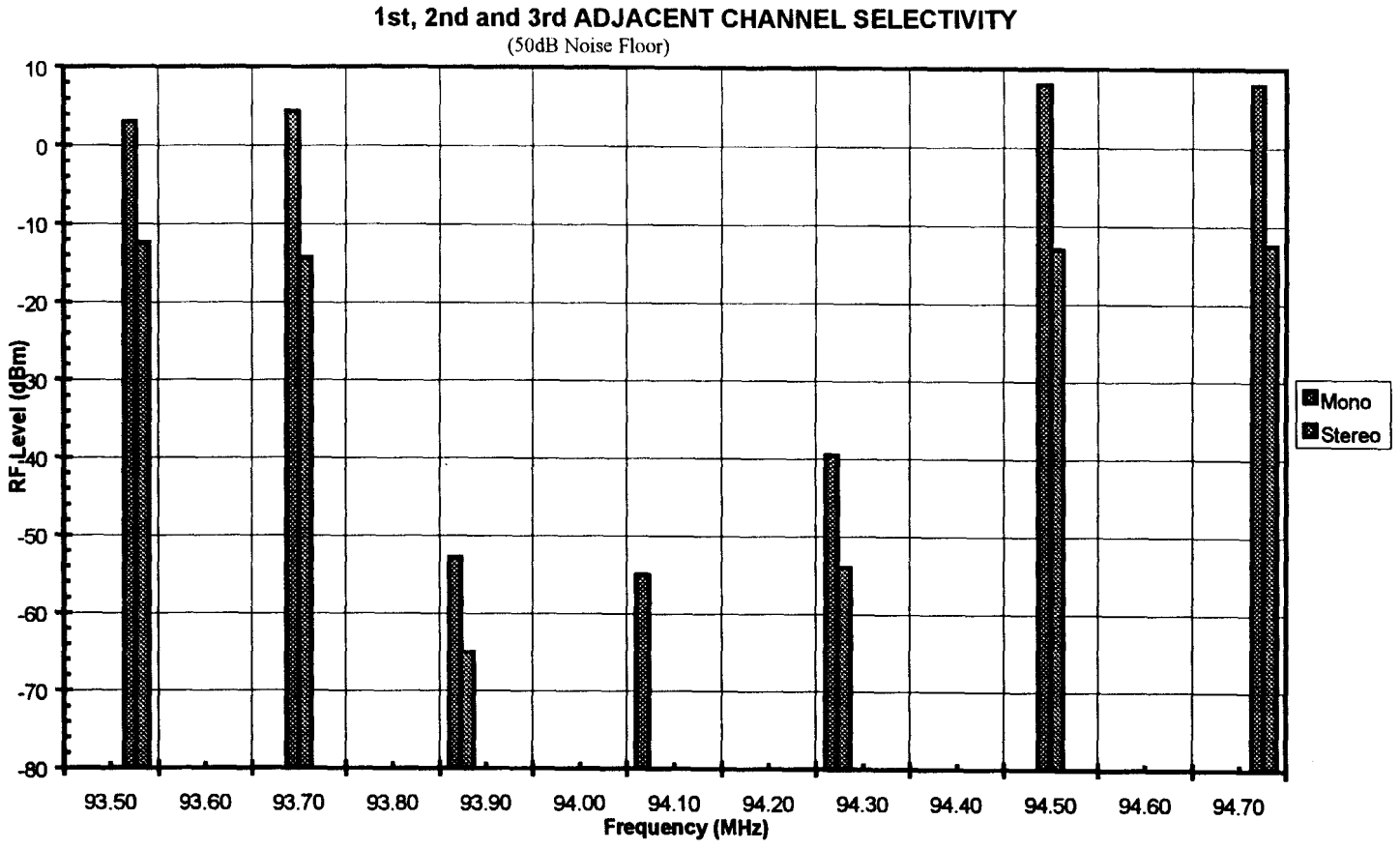


Delco 16195161

Appendix B – Yamaha Receiver Selectivity Characterization

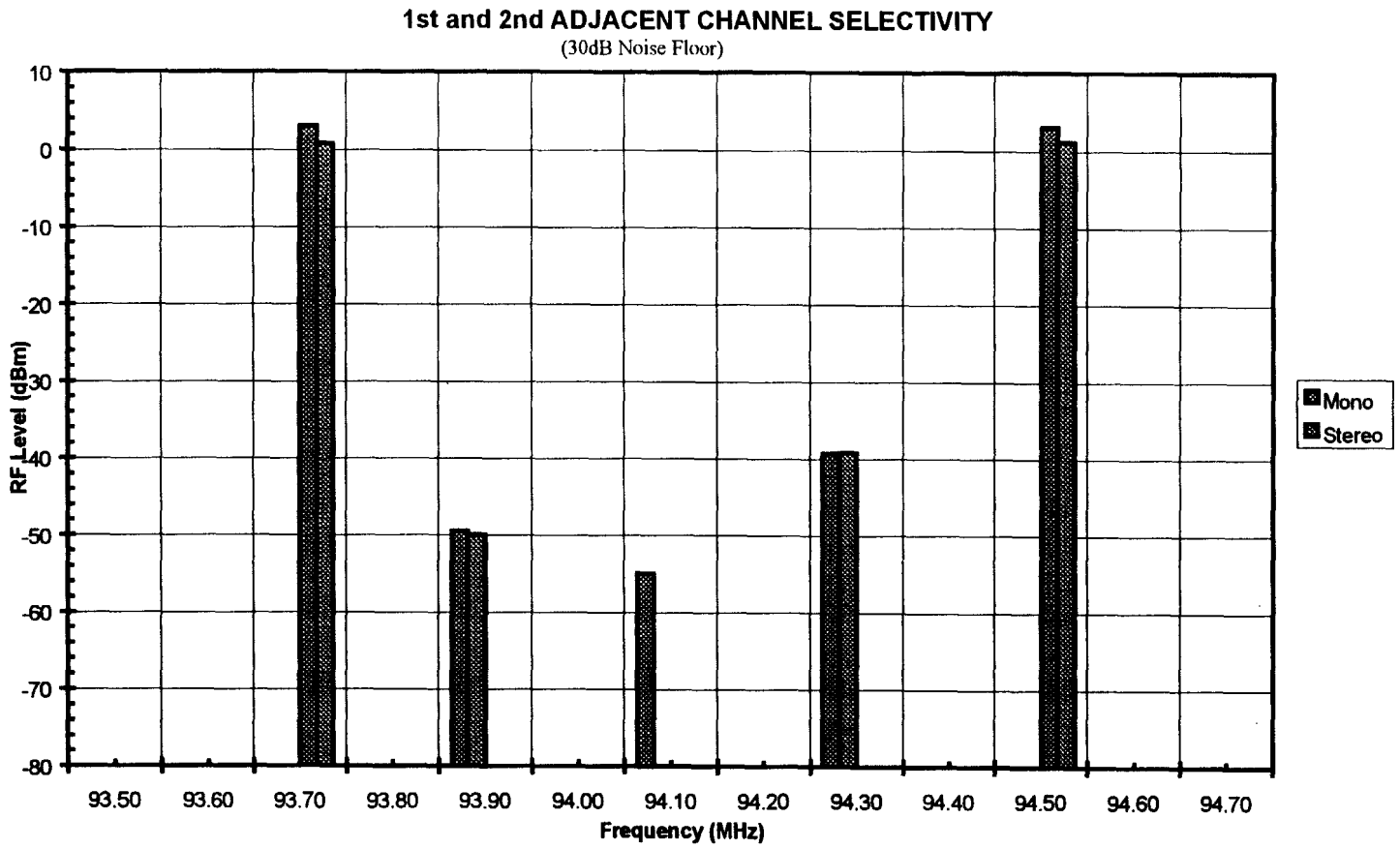


Yamaha HTR-5130

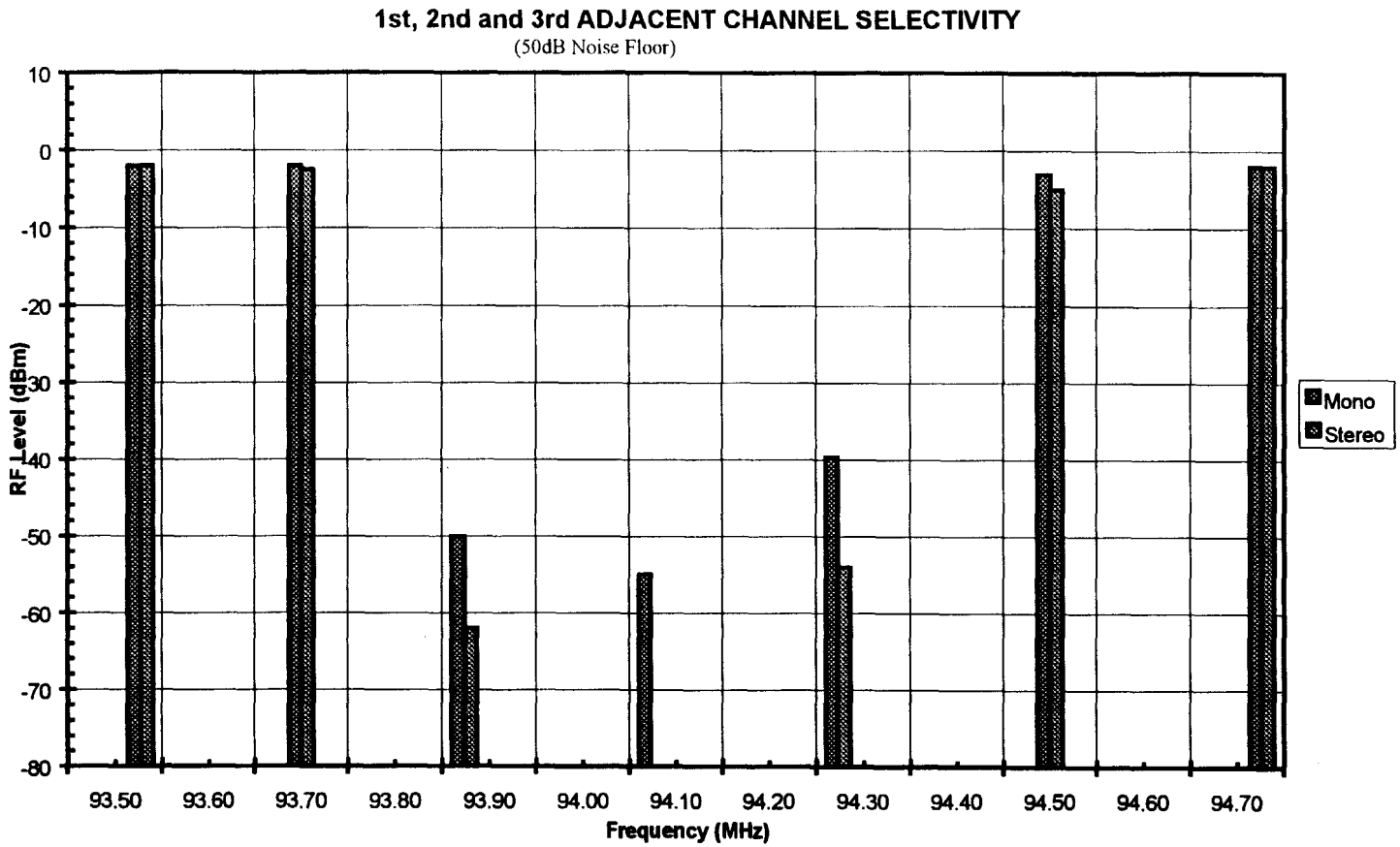


Yamaha HTR-5130

Appendix C – Philips Boombox Selectivity Characterization



Philips/Magnavox AZ1020/17



Philips/Magnavox AZ1020/17

Digital Audio Broadcasting

Analog Compatibility of the USADR IBOC System in the FM Band

Test Procedure

Document No. 99-07

December 14, 1999

Revision 3.0

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Table of Contents

1 INTRODUCTION 1

1.1 GENERAL OVERVIEW 1
1.1.1 Objectives 1
1.2 METHODOLOGY OVERVIEW 1
1.2.1 Evaluation Methods 1
1.2.2 Simulated Channel Conditions and Desired Results 1
1.2.3 Background 2
1.3 STANDARD PRACTICES 4
1.3.1 Test Bed Calibration 4
1.3.2 Daily Calibration 4
1.3.3 Automated Tests 4

2 SIGNAL DESCRIPTIONS 5

2.1 FM BAND SIGNALS 5
2.1.1 Desired Analog 5
2.1.2 Undesired Analog Interferer 5
2.1.3 Undesired Hybrid Interferer 6
2.1.4 Additive White Gaussian Noise 6
2.2 BASEBAND AUDIO 7
2.2.1 Standard Interferer - Clipped Pink Noise 7
2.2.2 Standard Interferer – Processed Rock 9

3 MEASUREMENT METHODS 13

3.1 FM BAND RF MEASUREMENTS 13
3.1.1 FM Analog Power 13
3.1.2 FM IBOC Hybrid Mode Power 14
3.1.3 FM IBOC Hybrid Mode - Ratio of Analog to Digital Power 16
3.1.4 FM Power in the Presence of Multipath 18
3.1.5 Additive White Gaussian Noise Power and Temperature 18
3.1.6 FM Deviation 19
3.2 BASEBAND AUDIO MEASUREMENTS 20
3.2.1 Signal-to-Noise (S/N) 20
3.2.2 Harmonic Distortion (THD+N) 22

4 FM BAND TEST PROCEDURES 23

4.1 ANALOG PERFORMANCE IN THE PRESENCE OF IBOC INTERFERERS, LINEAR CHANNEL (NRSC F-SERIES) .. 23
4.2 ANALOG PERFORMANCE IN THE PRESENCE OF IBOC INTERFERERS, MULTIPATH FADING CHANNEL (NRSC G-SERIES) 26
4.3 HOST ANALOG PERFORMANCE IN THE PRESENCE OF IBOC (NRSC L-SERIES) 29

A. APPENDIX A – LIST OF RECEIVERS UNDER TEST 32

B. APPENDIX B – AUDIO PROCESSOR SETTINGS 34

C. APPENDIX C – MULTIPATH SCENARIOS 36

D. APPENDIX D – CALIBRATION FORMS 39

E. APPENDIX E – DEFINITION OF UNITS 43

F. APPENDIX F – SPECTRUM CHARACTERIZATION 44

G. APPENDIX G – TEST BED DIAGRAMS 45

1 Introduction

1.1 General Overview

1.1.1 Objectives

The test procedures outlined in this document are collectively referred to as A*nalog Compatibility Testing.* The objective of analog compatibility testing is to evaluate and characterize the impact that an In-Band-On-Channel (IBOC) Digital Audio Broadcasting (DAB) system would have on the existing analog radio services within the FM broadcast band. These tests are to be performed under controlled laboratory conditions that simulate interference due to digital sidebands on both adjacent channels and the analog host channel.

These tests are *not* an attempt to measure the *absolute* performance of the radio broadcast bands. Rather, the objective is to evaluate the *difference* between analog radio performance without IBOC present and analog radio performance with IBOC present. This is an extremely important distinction to make, and the resulting test data should be presented in a format where the data is presented *relative* to baseline measurements (where the baseline measurements are analog performance without IBOC modulation present).

1.2 Methodology Overview

1.2.1 Evaluation Methods

The evaluation and characterization of IBOC's impact on analog services occurs in two stages: 1) Objective evaluation; 2) Subjective evaluation.

Objective evaluation is comprised of test methods whose results can be numerically quantified in an accurate and repeatable manner. For example, Signal-to-Noise (S/N) and Total Harmonic Distortion plus Noise (THD+N) are two of the primary benchmarks used to objectively quantify audio quality in these tests.

The second stage, subjective evaluation, is comprised of test methods that take into account the human auditory system. These methods may incorporate listening tests, computer algorithms that utilize perceptual evaluation of audio quality (e.g. ITU-R BS.1387), or some other procedure in order to evaluate the 'overall quality' as perceived by a human listener. For this test plan, digital audio recordings shall be made, which can undergo 'scoring' and subjective evaluation in an 'offline' environment.

1.2.2 Simulated Channel Conditions and Desired Results

The addition of IBOC DAB to the existing analog radio spectrum may potentially impact 1st and 2nd adjacent channels. In addition, it is possible that the performance of the analog *host* may also be impacted by the addition of IBOC on the host channel.

In order to evaluate any such impact, a sampling of three (3) FM receivers will be used. These receivers are representative of 'typical' consumer devices, including auto, home, and

portable units. The entire series of tests will be performed on each receiver individually, and the resulting test data for each receiver will be presented. A list of the receivers to be used can be found in Appendix A.

Therefore, the channel conditions, which are simulated in these tests, include various combinations of 1st and 2nd adjacent channel interference as well as multipath conditions for subjective tests. In addition, the strength of the desired signal will be varied in order to simulate various distances from the transmitting antenna. In summary, the independent variables for these tests are:

1) 1st and 2nd adjacent channel scenarios with varying Desired to Undesired ratios (D/U)[1]
2) Signal strength of desired signal
3) Presence or absence of IBOC on the host channel
4) Multipath Scenarios

For objective testing, the test results will be S/N and THD+N measurements on the main analog service. For subjective testing, the results will be digital audio recordings for further analysis in an offline environment. Note that it is not possible to gather S/N and THD+N data for a signal undergoing dynamic multipath conditions. Therefore, tests which include dynamic multipath (e.g. 4.3) are limited to subjective evaluation.

1.2.3 Background

This test plan was developed with the intention of providing results that are consistent with those required by the NRSC System Test Guidelines.[2] The NRSC Guidelines primarily focus on tests that examine interference from co-channels, 1st and 2nd adjacent, and host digital into host analog. It should be recognized, however, that there might be other relevant tests beyond those recommended by the NRSC. These other tests may include an examination of non-linear effects such as intermodulation.

NRSC test series F, G, and L outline the tests that should be included in analog compatibility testing with objective and subjective evaluation. The focus of this plan is on providing results as specified by these NRSC sections. However, it was found that additions and changes to the NRSC tests were necessary for the sake of completeness and practicality.

The following measurement changes have been made to the NRSC Guidelines:

- Total Harmonic Distortion plus Noise (THD+N)
- S/N as a function of D/U

---

[1] Throughout the remainder of this document, the following conventions are used: D refers to a desired analog signal; U refers to a single undesired interferer (which could be analog or hybrid). If a D/U ratio is positive, then the desired signal has *more* power than the undesired signal.

[2] National Radio Systems Committee, DAB Subcommittee, "IBOC DAB System Test Guidelines, Part I – Laboratory Tests", Rev 1.0, 12/03/98

- Three desired signal strengths instead of one
- Constant 100,000°K Noise Floor

The first change involves the addition of THD+N measurements. There is some concern that S/N measurements alone may not adequately characterize an impaired signal. This is particularly true in the FM case where a strong interferer is present. These additional THD+N measurements impose little extra overhead on the testing process and their inclusion provides a better overall picture of an interference scenario.

The second change involves the NRSC's recommendation that a D/U be determined for each of two specific audio S/N ratios. There are several difficulties with this approach. The first difficulty is that in practice it is very difficult to find a D/U ratio given an exact S/N ratio. If the target S/N ratio is 35dB for example, it may only be possible to find a D/U for a S/N of 33dB and 37dB. Even with ¼ dB steps in D/U ratio, the S/N ratio may only be accurate to within a couple dB. This is particularly true in the FM case, where S/N is a strongly non-linear function of D/U. Furthermore, the 1995 EIA tests illustrated that there are some interference scenarios where the specified audio S/N was not attainable under *any* D/U ratio. This leads to the unfortunate situation where no data is collected on that particular interference scenario. In addition to this difficulty, it was also determined that two data points (two D/U ratios) were not enough to characterize the performance of the system under all realistic conditions.

Given these considerations, it was determined that the D/U ratio would be stepped within a range and at each step the audio S/N and THD+N would be found. This will provide a sufficient number of data points to adequately characterize the interference scenario and also allow for the development of curves illustrating S/N vs. D/U and THD+N vs. D/U.

Since this change represents an increase in the number of data points, the NRSC requirements are still met. For example, even if an exact audio S/N of 35dB is not found, the recorded curves will still at some point cross through a 35dB S/N. Consequently the D/U ratio could be linearly interpolated from the curve at this point.

The third change involves signal strength of the desired signal. In NRSC test series F, it is specified that the interference tests should be conducted with the desired signal at a strength of 'moderate' (which corresponds to –62dBm). This does not appear to adequately characterize the interference scenario, particularly in the FM case. The ability of a receiver to reject undesired signals is expected to vary non-linearly with desired signal strength. Consequently, lab tests performed with a desired signal strength of moderate would not reveal any information about fringe area or near field performance. It was therefore determined that tests would be conducted under weak, moderate and strong desired signal strengths.

The fourth change is the insertion of additive white gaussian noise across the RF channels of interest. USADR has requested the addition of this noise at a level of 100,000°K, which shall remain constant throughout the duration of all analog compatibility tests. This noise floor represents both the cosmic and man-made noise that is present in the United States FM Band today.

These changes retain the spirit of the NRSC guidelines, but they also add important additional dimensions to the characterization of the interference scenarios. It is expected that these changes will provide a more accurate overall picture, and also allow for a much smoother testing process.

1.3 Standard Practices

The procedures for each individual test are specified in detail in later sections. However, there are some methodologies and standard practice common to all tests, which shall be described here and are applicable to all test groups.

1.3.1 Test Bed Calibration

Calibration of instruments within the DAB test bed is performed on a yearly basis, or in accordance to the manufacturers recommendation if less than one year. The ATTC DAB test bed is also environmentally controlled in order to minimize variations in calibration.

Upon construction of the test bed, an inclusive list of all equipment shall be generated. In addition, a detailed table of all jumper, switch, menu, and other settings shall be maintained. During final integration of the test bed, sufficient proof-of-performance measurements shall be made, and the results of such measurements shall exhibit appropriate performance characteristics.

1.3.2 Daily Calibration

The performance of the DAB test bed shall be verified on a daily basis. The verification shall be consistent with the NRSC Guidelines and will include a checklist to be completed by the test engineer. Appendix D shows a sample of the daily calibration form and an example plot. The test engineer will complete this form before the beginning of the test day. Supplementary calibrations should also be taken throughout the day if equipment within the test bed is reconfigured.

1.3.3 Automated Tests

In order to perform the required tests in a reasonable amount of time, it may be necessary to automate some of the measurement and test bed setup procedures. The details of any automation system shall be documented separately from this test plan. This test plan shall outline the necessary steps to perform a measurement, and these steps shall be performed regardless of whether the routine is ultimately performed manually or by the automation system.