NRSC REPORT

NATIONAL RADIO SYSTEMS COMMITTEE

Summary Report: Consumer Testing of AM Broadcast Transmission Bandwidth and Audio Performance Measurements of Broadcast AM Receivers

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Co-sponsored by the Consumer Electronics Association and the National Association of Broadcasters
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Summary Report:
Consumer Testing of AM Broadcast Transmission Bandwidth and Audio Performance Measurements of Broadcast AM Receivers

Prepared by the AMB Subcommittee
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The AM Broadcasting (AMB) Subcommittee of the National Radio Systems Committee (NRSC) was formed in 2004 to maintain NRSC standards relating to analog AM broadcasting. Currently, the Subcommittee has three standards under review: NRSC-1, NRSC-2 and NRSC-3, dealing with (respectively) AM broadcast preemphasis/deemphasis and audio transmission bandwidth, emission limitation for AM transmission, and audio bandwidth and distortion recommendations for AM receivers.[1] As part of the standards maintenance process, the Subcommittee can reaffirm, modify or retire these standards.

During the initial discussions within the Subcommittee regarding these Standards, it was noted that some broadcasters have already reduced the bandwidth of their analog AM signals from the 10 kHz specified by the NRSC standards to 5-6 kHz, in an effort to reduce the interference in the band, and with the understanding that most consumer receivers are band-limited to 5 kHz or less. A proposal was put forth that the NRSC consider reducing the bandwidth specification in NRSC-1, -2, and -3 to something less than 10 kHz, but the Subcommittee agreed that before such an action could be considered, a rigorous study of both analog AM receivers (characterizing, among other things, receiver bandwidth) and consumer reaction to reduced bandwidth would need to be conducted.

Consequently, in late 2004 the Subcommittee formed the AM Study Task Group (AMSTG) to determine whether consumers would reliably perceive the audio quality differences of AM transmissions at various bandwidths, recorded through commercially available receivers, and whether these perceptions would affect consumers' continued listening behavior. The AMSTG subsequently conducted a consumer subjective evaluation study of audio obtained from three prototypical receivers, as well as an objective evaluation of audio performance of a large number of current consumer analog AM receivers, including OEM and after-market car radios, shelf mini-systems, boom boxes, table radios and portables.

Before considering potential changes to the NRSC-1, -2, and -3 standards, the AMB is sharing the results of the AMSTG study and is seeking input from all interested parties. The following summarizes the methodology used and findings obtained from the AMSTG study.

Objective measurements of AM receivers

Objective measurements of 30 consumer analog AM receivers were completed in late 2005 with support from the Consumer Electronics Association (CEA) and the National

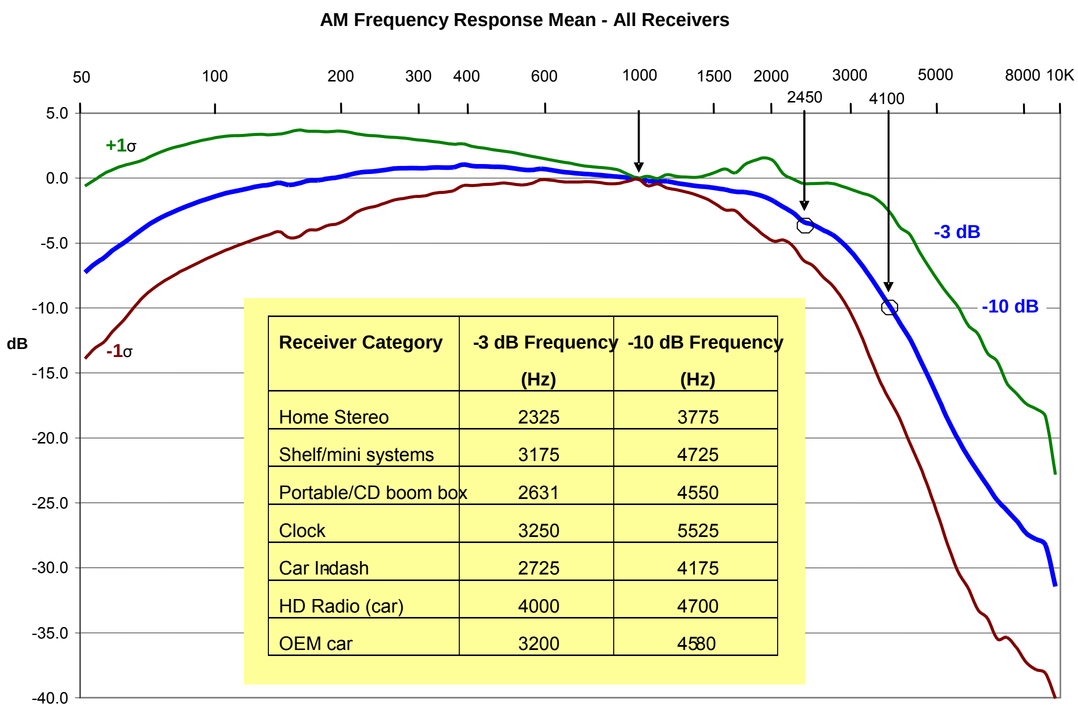
[1] NRSC-1, -2, and -3 are available at http://www.nrscstandards.org/Standards.asp.

Association of Broadcasters (NAB; CEA and NAB are the co-sponsors of the NRSC). These laboratory measurements, conducted by NPR Labs, collected data in two areas:

- Baseline audio performance of the receivers, including frequency response, harmonic distortion, intermodulation distortion and signal to noise ratio;

- Objective noise level differences with signal interference at several audio transmission bandwidths (i.e., 5, 6, and 7kHz), relative to the current transmission bandwidth standard of 10 kHz. Weighted quasi-peak noise measurements were taken to approximate the response of human hearing to audible noise. A first-adjacent channel (±10 kHz) interfering signal was modulated with a pulsed frequency-shaped noise to simulate the characteristics of program audio.

These objective measurements established that the majority of current analog AM receivers have audio bandwidths of less than 5 kHz.[2] In fact, with only a few exceptions, the frequency response of individual receivers falls off above 1 or 2 kHz. As shown in Figure 1, the combined frequency response of all receivers through the test bed (the middle curve, in blue) was -3 dB at 2450 Hz and -10 dB at 4100 Hz.[3]



Receiver Category	-3 dB Frequency (Hz)	-10 dB Frequency (Hz)
Home Stereo	2325	3775
Shelf/mini systems	3175	4725
Portable/CD boom box	2631	4550
Clock	3250	5525
Car Indash	2725	4175
HD Radio (car)	4000	4700
OEM car	3200	4580

Figure 1. AM frequency response mean for all measured receivers

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[2] Full receiver test data is available in the AMSTG report.

[3] The AM receiver audio frequency response graph was made with the NRSC-1 pre-emphasis curve in the transmission chain, representing the proper "end to end" performance of the receivers.

The overall variation in audio bandwidths was wide, as shown by the standard deviation for the entire test population (+1σ in green and -1σ in brown): at 4100 Hz, the first-order standard deviation was approximately -2.6 dB and -17.2 dB, a range of 14.6 dB. The table inset in Figure 1 lists the -3 dB and -10 dB bandwidths for the receivers by category.

Further, each receiver was evaluated for change in noise (at the audio output) with 1st-adjacent channel interference using audio transmission bandwidths of 5, 6, 7 and 10 kHz at desired-to-undesired RF signal ratios of 30, 15, 6 and 0 dB.[4] The effect of transmission bandwidth on weighted quasi-peak SNR for the combined receivers is summarized in the Figure 2, showing that reduced transmission bandwidth offers SNR improvements of up to 12 dB, relative to 10 kHz bandwidth, with 1st-adjacent channel interference.

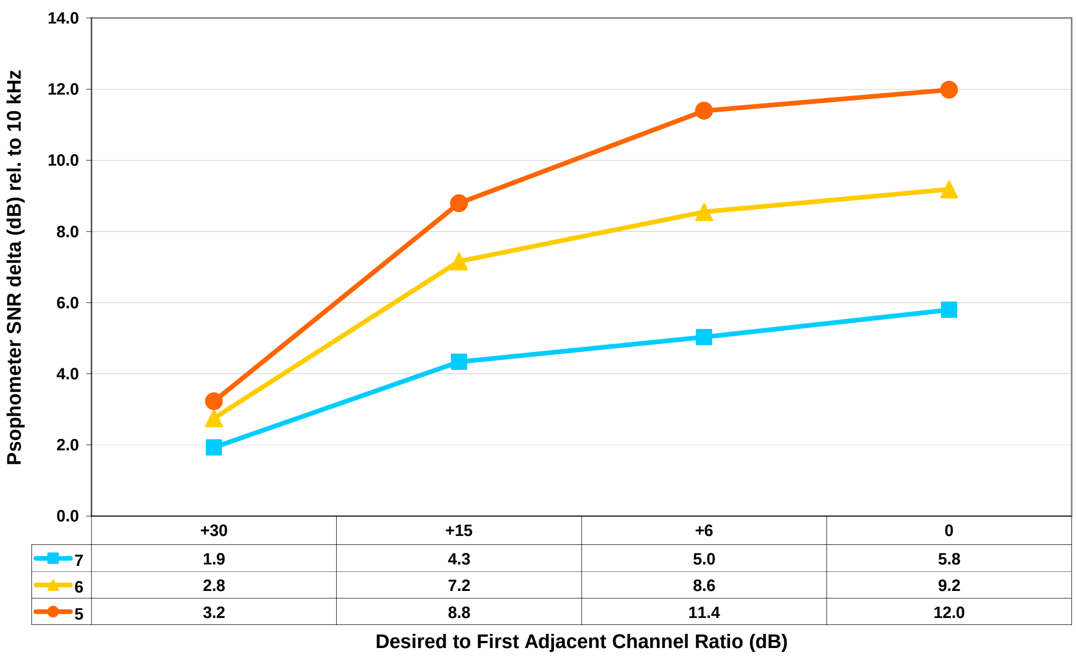


Figure 2. Effect Of transmission bandwidth on received SNR

Subjective broadcast industry and consumer testing

Based on the findings of the receiver measurements, subjective testing was conducted, by Sheffield Audio Consulting and NPR Labs, in two phases between February and May, 2006, using audio recorded from three of the tested receivers.[5] Because it was necessary, as a practical matter, to limit the number of bandwidths tested in the consumer study, the AMSTG decided to use three bandwidths: 10 kHz (current NRSC standard bandwidth and maximum bandwidth allowed under current FCC rules), 5 kHz (represents the maximum bandwidth where adjacent

[4] The audio processor for the interfering channel was operated with standard broadcast settings to process the audio for the undesired channel modulation for the receiver measurements.

[5] Receivers were selected to represent the 20th percentile, median, and 80th percentile of all receivers tested, with respect to receiver bandwidth.

channels do not overlap) and an intermediate bandwidth. To establish this intermediate bandwidth, a "phase 1" listening test was conducted in which 18 broadcast industry representatives participated and subsequently determined that 7 kHz was the best intermediate bandwidth, between 5 kHz and 10 kHz, to be included in the consumer test.

In the "phase 2" listening test, consumers judged (a) which transmission bandwidth, 5 kHz, 7 kHz or 10 kHz, had the best quality, (b) the magnitude of the difference between the quality experienced using these bandwidths, and (c) whether they would continue to listen to the audio, given the quality of each of the samples. Audio samples used in this phase 2 test included those impaired by 1st-adjacent channel interference in addition to unimpaired reception.[6] Audio source material was taken from NRSC music test samples, NPR speech samples, a sportscast and commercials supplied by Greater Media, Inc. Forty-four listeners participated in the consumer test, distributed between 19 and 71 years of age. Data from 40 qualified listeners—20 female and 20 male—was collected.

As previously noted, audio samples were recorded from three receivers selected from the pool of those that were objectively tested. The three receivers selected were the JVC KS-FX490 car in-dash cassette (median-bandwidth), the Panasonic CQ-CB9900U in-dash CD/HD Radio (80^{th} percentile bandwidth) and the Aiwa JAX-S77 portable boom box (20^{th} percentile bandwidth).

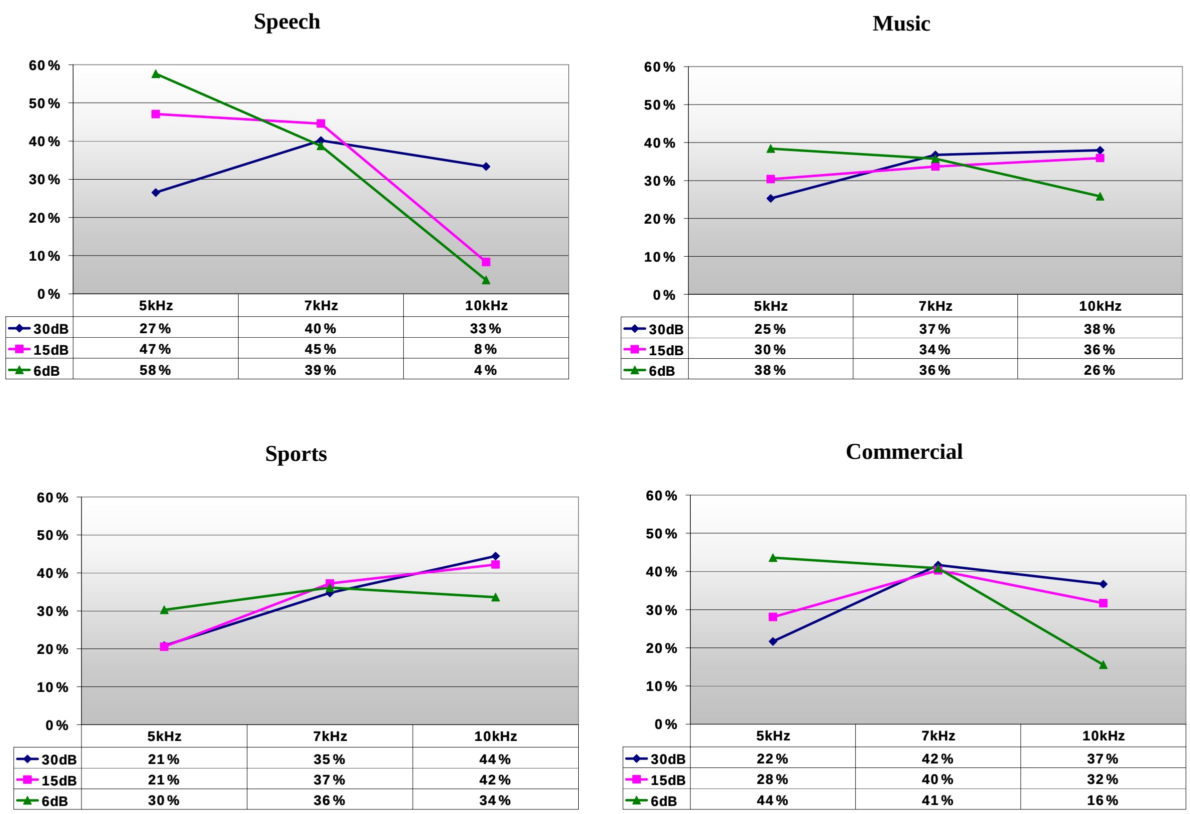
Because differences in audio quality among bandwidths were often small, an A/B pair-wise comparison was the appropriate method to use for obtaining listener's judgments. Test participants listened to seven different samples (recorded under a variety of conditions), including female and male speech, voice-over (commercial), a sportscast, and rock, country and classical music. Over the course of the entire test, participants listened to a total of 189 sample pairs. After listening to each sample pair, consumers were asked to judge which sample they thought had better quality, how big the quality difference between samples was, and whether they would continue to listen to the audio for either or both of the samples.

The graphs in Figure 3 show the percentage of participants who picked one bandwidth over another (*e.g.*, 5 kHz over 10 kHz) at various D/U signal conditions, separated by genre (*i.e.*, speech, music, commercial and sportscast) and aggregated for the three receiver bandwidths tested (20^{th} percentile, median and 80^{th} percentile bandwidth). Because participants were asked to choose which sample ("A" or "B") had better quality and there were three combinations of forced-choice pairs (i.e., 5 kHz vs. 7 kHz; 7 kHz vs. 10 kHz; 5 kHz vs. 10 kHz), 33% represents the level of responses that would be considered "at chance." Any positive or negative difference from 33% of 12 percentage points or more (*i.e.*, percentages greater than 45% or less than 21%) can be considered significantly different from chance. Thus, finding that less than 21% or more than 45% of respondents preferred a particular bandwidth in an individual condition should be considered significant.

Notice (in Figure 3) that the findings for "speech" follow a significantly different pattern than findings for all other genres. Participants clearly favored 5 kHz and 7 kHz in speech, while in music and commercials preferences were not as clearly articulated. For sportscasts,

[6] The Orban Optimod 9200 Digital AM Processor and Telos-Omnia 5EX-HD Processors, which are used commonly by the broadcast industry, were operated with standard broadcast settings to prepare the audio used in the listening tests.

participants demonstrated a slight preference for higher bandwidths under less impaired conditions.



Speech

	5kHz	7kHz	10kHz
30dB	27%	40%	33%
15dB	47%	45%	8%
6dB	58%	39%	4%

Music

	5kHz	7kHz	10kHz
30dB	25%	37%	38%
15dB	30%	34%	36%
6dB	38%	36%	26%

Sports

	5kHz	7kHz	10kHz
30dB	21%	35%	44%
15dB	21%	37%	42%
6dB	30%	36%	34%

Commercial

	5kHz	7kHz	10kHz
30dB	22%	42%	37%
15dB	28%	40%	32%
6dB	44%	41%	16%

Figure 3. Percentages of listeners who picked one bandwidth over another, by genre, with no 1st-adjacent channel interference (30 dB), moderate 1st-adjacent channel interference (15 dB), and heavy 1st-adjacent channel interference (6 dB).

Consumer subjective test results suggest the following:

- For music, commercials and sportscasts, little difference was heard between 7 and 10 kHz bandwidths, regardless of 1st-adjacent channel interference conditions. For speech, which does not mask noise and interference, larger differences were perceived, based on impairment conditions;

- In unimpaired or moderately impaired conditions (as determined by the desired-to-undesired signal ratio, D/U), people tended to prefer higher bandwidths to lower bandwidths. However, 7 kHz and 10 kHz bandwidths had equal preference;

- With speech in moderate to heavy impairment conditions, participants preferred lower bandwidths (5 kHz and 7 kHz) to higher bandwidths, despite a mutual reduction in transmission bandwidth on the desired channel.

Overall, although there was some variation in preference between genres and D/U ratios, these data suggest that in general consumers preferred lower bandwidths (between 5 kHz and 7 kHz) to higher bandwidths. In the majority of listening conditions, consumers preferred either 5 kHz or 7 kHz, and often reported that 7 kHz was equivalent to 10 kHz in unimpaired or moderately impaired conditions. These preferences were articulated most strongly in speech conditions, where noise from interference affected listeners the most.

In extrapolating this consumer data to general public listening, it is important to note that discerning background noise is easiest in speech conditions, and thus the speech testing represent the most critical results. This is important for two reasons: (a) the majority of AM programming includes speech, and (b) consumers will hear more noise in any music, sports, and commercials that are qualitatively less "dense" than the programmatic material included in this test. Since consumers seem to be most critical of "noise" and seem to tolerate more constrained bandwidth when they receive a clean signal, it is likely that lower bandwidths will satisfy consumers in most conditions.

The AMB Subcommittee welcomes additional participation and comments from interested parties (please see www.NRSCstandards.org for additional information on the NRSC). The full report of the AMSTG is available on the NRSC web page at www.nrscstandards.org/AMB/default.asp.

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