

HD Radio in a Low Power Application

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Los Angeles is a unique radio market and ranked number 2 by Arbitron in the nation. The FM broadcast band is very crowded in Southern California, and KPCC broadcasts 600 watts ERP analog signal to cover 4,000 square miles of Metropolitan Los Angeles from high on top of Mt. Wilson. The prospect of a low power IBOC digital signal covering the same area generated doubts. This test of low power digital coverage was conducted to find out what 6 watts of IBOC would do.

We were all impressed with the coverage of the 6-watt IBOC digital test signal. Our measurement team drove the freeways of Southern California for several days making signal strength and reception quality measurements. Where the digital signal was weak and the receiver reverted to the analog signal, the analog signal was noisy, also. (See the appendix for the coverage map.)

Yet, new observations as IBOC is introduced to the FM Band were noticed and lead to even more concerns and questions. For example: Spurious emissions and "Spectral Regrowth" of the IBOC signal were noticed. Low power IBOC spurious emissions caused interference to FM band receivers on an adjacent channel 30 miles from the transmitter. At this writing it's not clear under what circumstances these emissions occur. However, it is clear that these emissions do cause interference to weak analog signals on adjacent channels. There are remedies available, but who will be responsible to suppress spurious emissions if these emissions are within the FCC's "FM Mask" for IBOC?

This test of HD Radio, in a low power application, took place in February 2004 with the help of fellow radio engineers. The weather was cold, rainy, and overcast. Mt. Wilson was covered with 6 inches on snow.

Mt. Wilson is an antenna farm with a changing population of several television and radio stations and business band repeaters. The mountain is 5780 feet above sea level and the tower KPCC's antenna is on is another 100 feet above that. At 5880 feet above sea level it's easy to understand why KPCC's signal covers the area so well.

Before our technical report begins, there are some people and companies that need to be recognized for their personal effort in making this test possible. First, two men encouraged and financed this report: Mr. Don Creighton, Senior VP Technology Minnesota Public Radio and Mr. Mike Starling, VP Engineering and Technology National Public Radio. Broadcast Electronics and Shively Labs provided the HD Radio equipment.

KPCC's analog and IBOC signals are weak from the get-go. Yet, both the FM and IBOC modulation methods covered Los Angeles and parts of Riverside, San Bernardino, Ventura, and Orange counties amazingly well. Building penetration of KPCC's analog signal is poor and has always been a problem.

Mr. Ethan Torrey, Chief of Research and Development for Minnesota Public Radio, and Mr. Jan Andrews, Senior Engineer National Public Radio, drove the freeways of Southern California. In their Chrysler Mini Van they assembled Kenwood HD Radio receivers with specialized test and measurement gear borrowed from the ‘Tomorrow Radio Project’ to map and plot the low power, IBOC coverage.

Two 1.5A BE analog transmitters provide redundant service. A photo of the pre-installation transmitter configuration is shown in the appendix. The transmitter on the left was used in this test.

The plant is plumbed in 1 5/8 " rigid transmission line to a motorized coaxial switch. From this point gassed Heliac completes the run to the 1/2 wave spaced Jampro 2 bay antenna. A Broadcast Electronics FMi 31 was used to provide the digital IBOC signal. A Shively Labs 5526 HD Radio Digital Injector was used to combine the signals.

The installation process itself was quite simple. The injector was placed on top of the center equipment rack. The injector's analog input and combined output were plumbed in 1 5/8" rigid copper. LDF4-50 1/2" Heliac was used to plumb the IBOC input and reject output. The reject port fed a 5Kw load placed on the floor behind the transmitters.

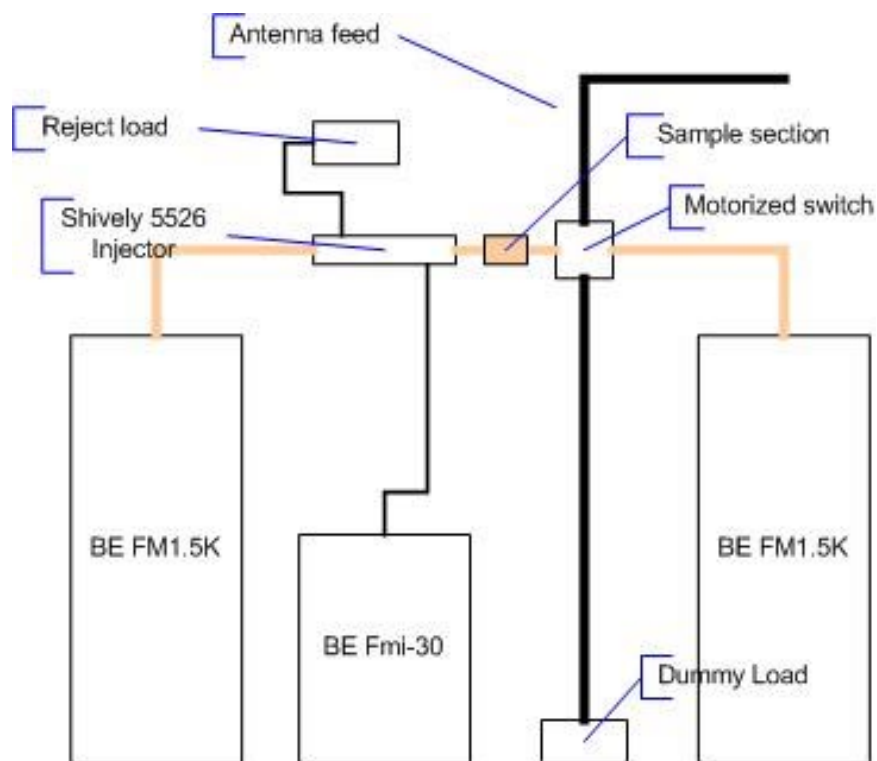


Figure 1 IBOC installation diagram.

The measured injector performance results were as follows: Analog to digital isolation, -30.8 dB; analog in to combined out, -.5 dB; digital in to combined out, -9.6 dB. The normal TPO for the analog transmitter was 1060 watts. The desired digital ERP of 6 watts

(-20dBc) required a 10.6 watts digital signal after the injector. 97.3 watts at the injector's digital input compensates for the 9.6 dB coupling loss. Similarly, increasing the analog transmitter TPO to 1191 watts compensated for the .5 dB analog insertion loss. Minimal line loss in the LDF-50 was compensated for resulting in a digital TPO of 100 watts from the FMi 31. Similarly, the injector analog insertion loss was compensated for and yielded an analog TPO of 1191 watts.

After the hardware installation was completed, the IBOC injection level was measured and adjusted. A method recommended by Broadcast Electronics was used to set the IBOC injection level. The measurement setup was straightforward. A -53 dB slug was used in the sample section shown in figure 1. The sample fed an HP 8591E spectrum analyzer. The analyzer was set to a span of 2 MHz per division, resolution bandwidth of 1 KHz, video bandwidth of 3 KHz, and video averaging was turned on. This method is problematical on several counts, but the desired result of -20 dBc IBOC can be confirmed by other methods. However, the issue of peak power IBOC measurement remains unanswered at this time.

The first step in the process was to get a reference measurement of the unmodulated analog carrier. This measurement shown below, yielded a value of 8.8 dBm.

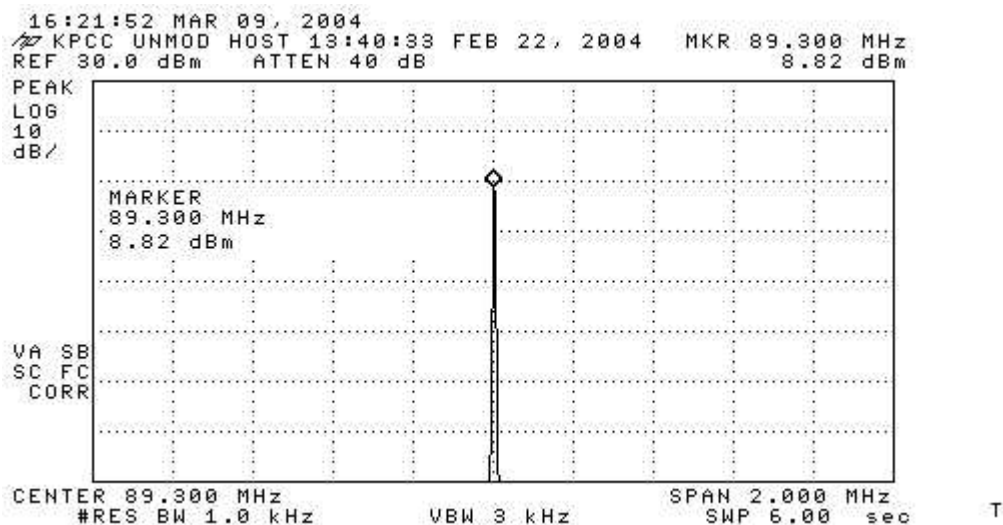


Figure 2 Spectrum analyzer display of analog-only signal.

Next, the analog carrier was turned off. Leaving the analyzer settings as is, the digital transmitter is turned on. Markers were placed on each of the two OFDM carrier families. The marker values should show -43 dBc relative to the unmodulated analog carrier. In KPCC's case, the desired value was -34.2 dBm (8.8 - 43). The actual values are shown below. The upper and lower groups are within a fraction of a dB of each other.

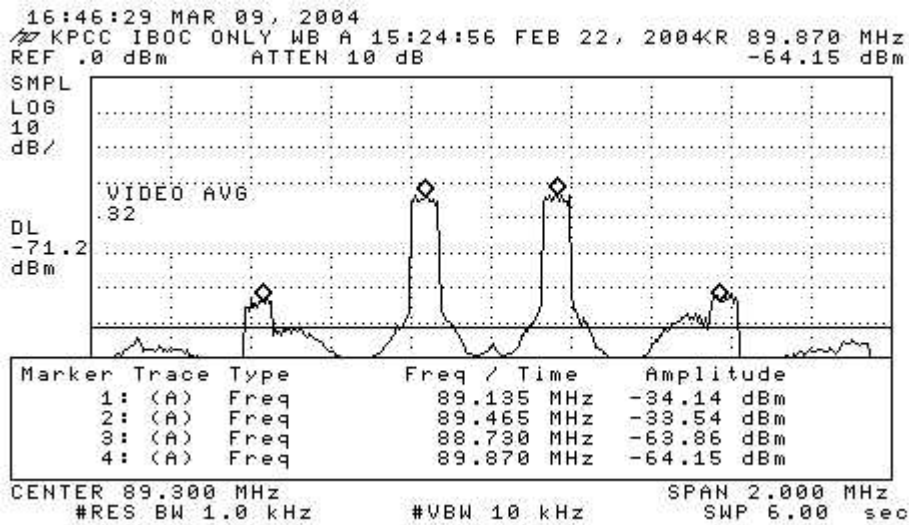


Figure 3 Spectrum analyzer display of IBOC-only signal.

The desired end result was to inject a digital signal at -20 dBc. This means that with half of that power in each of the two IBOC groups, each group should have a total channel power of -23 dBc. Figures four and five show channel power measurements for the lower and upper carrier groups.

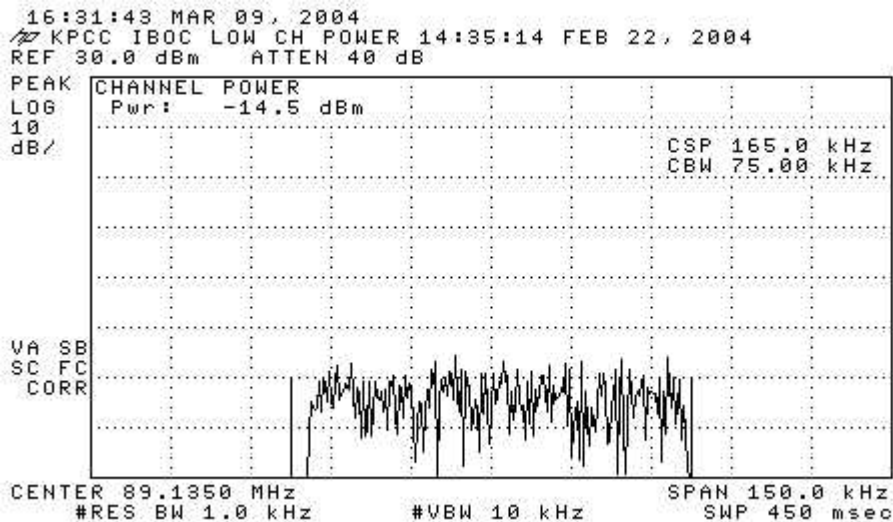


Figure 4 Spectrum analyzer display of lower carrier group.

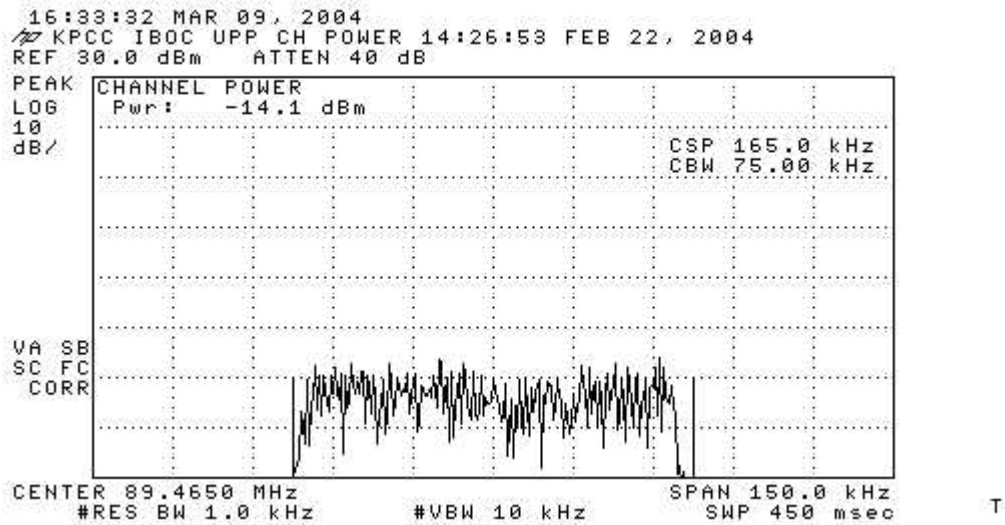


Figure 5 Spectrum analyzer display of upper carrier group.

An adjacent channel power measurement would produce a display as shown in figure six. Unfortunately, this figure doesn't show the actual trace, due to an error made while attempting to save the trace data. Nonetheless, it shows a quick and accurate way of getting the full picture of IBOC injection with a single measurement. Notice that the main channel power is shown in dBm, and the adjacent channels are shown in dB relative to the main channel.

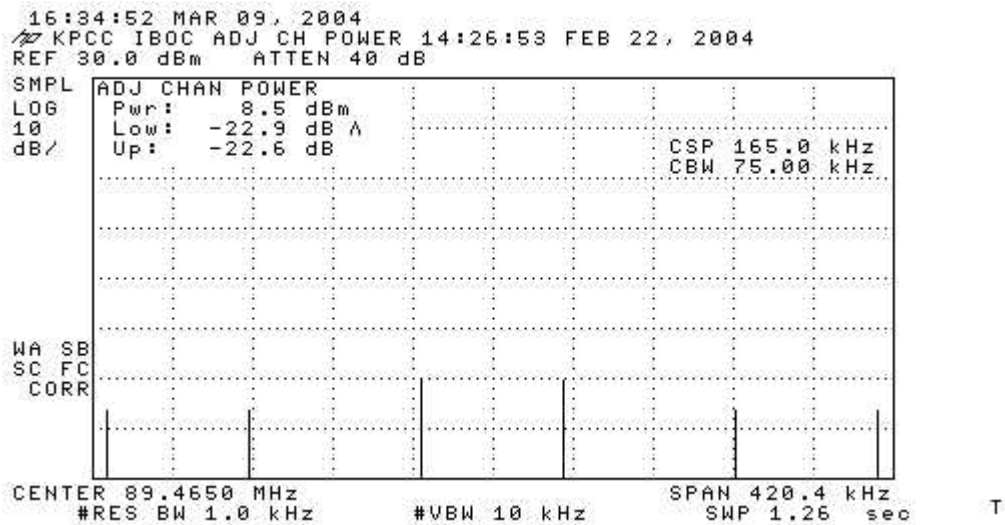


Figure 6 Spectrum analyzer display of IBOC injection in a single, fast measurement.

Mr. Lyle Henry, CPBE, performed SCA noise measurement tests from the IBOC signal in SCA channels. Noise measurements were made to both 67 and 92 KHz SCAs with a Belair SCA monitor. At 10% SCA injection both 67 and 92 KHz SCAs noise increased

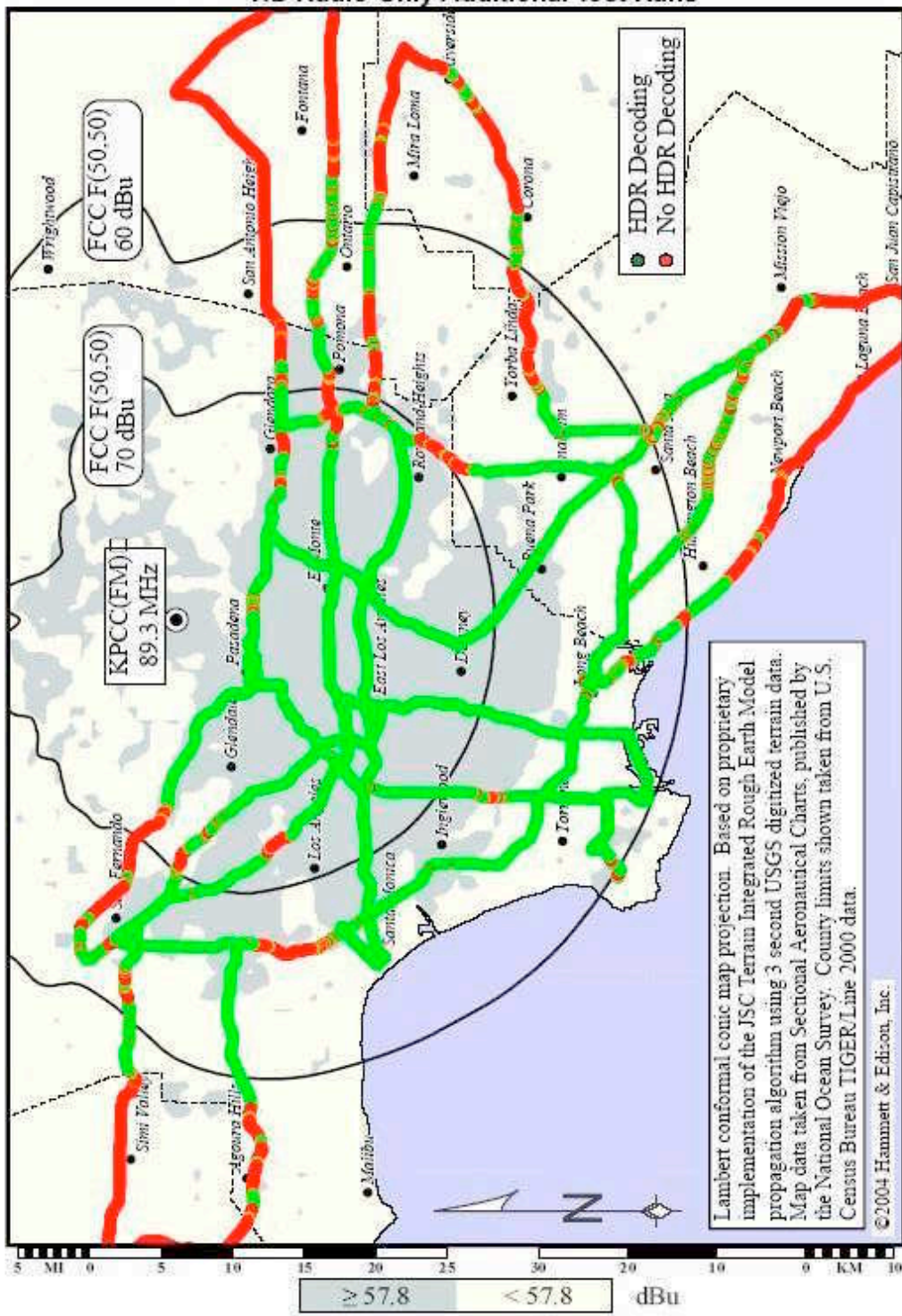
2.5 dB with the application of the IBOC signal. At 5% injection 67KHz noise measured 4.1 dB while the 92 KHz SCA noise measured 1.5dB.

Mr. Henry performed an SCA radio listening test, also. He used to two different SCA receivers: one of good quality and one of average quality. He reports, "Neither of these radios showed any increase in noise on the SCA channels at either 10 or 5% injection when IBOC was on."

The coverage map produced by Mr. Andrews and Hammett & Edison, Consulting Engineers, demonstrates how amazingly well 6 watts ERP of IBOC signal covered the greater Los Angeles area. As the Kenwood HD Radio receiver's digital signal faded to analog in fringe areas, the analog signal was just about ready to fade out as well. Building penetration by the 6-watt digital signal was not possible. KPCC's analog signal at 600 watts ERP often fails to penetrate buildings within it's general coverage area.

More information is needed regarding the IBOC signal and possible interference to neighboring FM stations. A presentation scheduled to be presented at the NAB's Broadcast Engineering Conference, Las Vegas, Tuesday April 2004 LVCC N110, "Radio RF and Transmission Developments," may address some points in this interference issue.

Los Angeles/Long Beach Area Field Test Results HD Radio-Only Additional Test Runs



Lambert conformal conic map projection. Based on proprietary implementation of the JSC Terrain Integrated Rough Earth Model propagation algorithm using 3 second USGS digitized terrain data. Map data taken from Sectional Aeronautical Charts, published by the National Ocean Survey. County limits shown taken from U.S. Census Bureau TIGER/Line 2000 data.

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HD Radio Digital-Only Coverage for KPCC



KPCC Transmitter Room