Appendix J –
FM IBOC Compatibility with Reception of Subcarrier Services

NATIONAL
RADIO
SYSTEMS
COMMITTEE

DAB Subcommittee
Evaluation of the iBiquity Digital Corporation IBOC System

Part 1 – FM IBOC

Introduction

As part of a thorough evaluation of FM IBOC, the TPWG prepared a test procedure with which the Subcommittee could attempt to determine the impact of FM IBOC on FM subcarrier services. After completing tests under this test plan, iBiquity submitted a report entitled "SCA Compatibility of the iBiquity Digital IBOC System in the FM Band." The report contains data on lab tests conducted by ATTC and the field tests conducted by iBiquity, for which all subjective testing was performed by Dynastat. Both the laboratory and field tests of subcarrier compatibility were monitored by NRSC representatives.

Summary of Findings

Host Compatibility with Analog Subcarrier Receivers

While objectively measured analog subcarrier reception can get noisier with FM IBOC signals present, and while the increased noise is often perceptible, the perceptual scores indicate that overall utility of the subcarrier is not particularly diminished with the addition of FM IBOC signals. As distance to the desired station is increased, the relative impact of the FM IBOC signal on subcarrier reception should decrease.

First Adjacent Channel Compatibility

The effect of first adjacent interference without FM IBOC signals present appears to be the controlling factor in subcarrier reception. The addition of FM IBOC signals to the first adjacent signal did not affect subcarrier reception at the desired-to-undesired ratios tested.

Second Adjacent Channel Compatibility

In general, subcarrier receivers are susceptible to all second adjacent FM signals at moderate interferer levels. As subcarrier receivers progress toward failure with increasing second adjacent analog-only signal levels, their failure is accelerated by the addition of FM IBOC on second adjacencies.

RBDS Subcarrier Reception Compatibility

There is no indication of any incompatibility between FM IBOC signals and the reception of RBDS. Reception of the RBDS data subcarrier at moderate signal levels is unaffected by the addition of FM IBOC signals to the host or to first or second adjacent signals.

DARC Subcarrier Reception Compatibility

FM IBOC signals are compatible with reception of DARC subcarrier data. Reception of the DARC data subcarrier at moderate signal levels is unaffected by the addition of FM IBOC signals to the host or to first or second adjacent signals.

Background on Subcarriers

FM subcarriers are signals that contain information and are "piggy-backed" onto FM signals. This "piggy-backing" is called "multiplexing," and involves combining the station's main channel audio, any additional stereo information signals, and one or more subcarriers prior to transmitting the radio signal. A typical analog receiver is able to recover the audio of the main channel program without appreciable degradation caused by the presence of any subcarriers. Special receivers are utilized to recover the information on a station's subcarrier. Popular uses of analog subcarriers include subscription (background) music services and free specialty audio programming targeting ethnic constituencies or providing reading services intended for persons who are print impaired. Digital subcarriers are utilized to deliver proprietary data for data subscription services, electrical load management, internal station communication and control, and the like.

With the advent of Radio Broadcast Data System (RBDS) in the USA (after 1993), some stations began sending station-related data to consumers listening to the stations' broadcasts. RBDS consists of a specialized slow-speed data subcarrier that delivers text based information and control symbols. Only those consumers who own an RBDS-enabled receiver can benefit from the additional features. This data can include a variety of information, but is largely utilized for presentation of station identifiers and music title and artist information.

Subcarrier Reception Testing

The NRSC test plan incorporated both laboratory and field testing to evaluate potential impact on subcarrier reception. Common subcarrier types were employed in the testing-- two analog audio services and two digital services. The analog subcarriers were operated on the traditional 67 and 92 kHz baseband frequencies. The digital services tested were an RBDS subcarrier (at two injection levels) and a DARC data subcarrier, employed by commercial data service providers.

Analog Subcarrier Receiver Testing

Receivers employed in the analog test were chosen to represent a range of common receivers and manufacturers. The manufacturers represented were McMartin, ComPol, CozmoCom, and Norver. Each of these companies manufacture(d) a variety of receiver models. Two of these manufacturers no longer exist but represent a large installed base of subcarrier receivers. With the assistance of the International Association of Audio Information Services, four representative receivers were selected and provided for testing. Two were operated on the 67 kHz subcarrier and two on the 92.

The analog subcarrier receiver test was determined to be an efficient way to obtain basic information on whether subcarrier users may receive perceptible interference under conditions that may be expected to challenge subcarrier receivers. Due to the nature of analog audio subcarrier reception, this sampling of receivers is not intended to provide a definitive scientific and statistically rigorous analysis of analog subcarrier reception and compatibility. The test, then, can be employed by people familiar with subcarrier performance to make reasonable inferences about the potential effects of adding FM IBOC signals to the FM spectrum.

Host FM IBOC Compatibility with Analog Subcarrier Reception

Objective Test Data

The subcarrier receivers demonstrated a wide variability in their behavior under the lab test conditions. Not only was there varying response to the presence of FM IBOC signals on the host station, but also there was varying response to changes in signal level from strong to moderate, without the presence of the FM IBOC signals (Table 1).

These measurements demonstrate that there is considerable variation in subcarrier receiver performance within the expected protected contour of a radio station. When subcarriers are transmitted on analog-only FM signals and are received under realistic noise conditions with injected AWGN, the quality of analog subcarrier reception is dependent on the received signal strength and the receiver. When signal strength is reduced from strong to moderate levels there are measurable increases in the noise reception of the tested FM subcarrier receivers.

The addition of FM IBOC signals on the host station presents challenges to subcarrier receivers similar in magnitude to the challenges presented by typical environmental radio frequency noise, as seen by comparing the summary data in Table 1 and Table 2 below.1 For reference, Table 3 contains a summary of the subcarrier same receiver tests as in Table 2, but conducted without injected radio frequency background noise.

The lab test data, as noted in the tables below, make it clear that the addition of FM IBOC signals to a station that operates an analog subcarrier will reduce the signal-to-noise performance of the received subcarrier when signal levels are strong to moderate. Hence, the greatest relative impact of FM IBOC on host subcarrier reception will be where the signal is strongest and cleanest. This information also reinforces the finding that with declining signal strength, noise increases, and the relative effects of the FM IBOC on analog subcarrier reception diminish. Because of the masking effect of reception noise outside the station's protected contour, the addition of FM IBOC signals to the desired host will have the least relative impact on subcarrier reception when the receiver is outside a station's protected contour.

[1] The data in these tables is obtained from Tables 11-14 in the laboratory test report, SCA Appendix A of iBiquity's SCA Compatibility report, pages 40 and 41.

Table 1

Lab test: Host: Without hybrid FM IBOC—
Change In Subcarrier Audio Signal-To-Noise
With Change From Strong To Moderate Received Signal Level

	Without Injected AWGN		**With Injected AWGN[2]**	
Subcarrier Receiver	**Audio Signal-to-Noise (S/N) with Strong Signal**	**Change in Audio S/N With Change to Moderate Signal Level**	**Audio Signal-to-Noise (dB WQP) with Strong Signal**	**Change in Audio S/N With Change to Moderate Signal Level**
McMartin 67 kHz	36.5 dB WQP	+1 dB*	36.2 dB WQP	-5 dB
Norver 67 kHz	31.7	0	31.2	-6
CozmoCom 92 kHz	28.9	0	28.8	-1
ComPol 92 kHz	27.9	0	27.0	-9

*A positive figure in the highlighted "Change" columns represents improvement in noise performance at the moderate signal strength with respect to the strong signal strength. A negative figure represents deterioration in noise performance at the moderate signal strength.

Table 2

Lab Test: Host: Injected RF background noise (AWGN)--
Change In Subcarrier Audio Signal-To-Noise Level
With The Addition of FM IBOC Signals

With Injected AWGN	Desired At Strong Signal Level		Desired At Moderate Signal Level	
Subcarrier Receiver	**Audio S/N without IBOC**	**Change in Audio S/N with FM IBOC Added**	**Audio S/N without FM IBOC**	**Change in Audio S/N with FM IBOC Added**
McMartin 67 kHz	36.2 dB WQP	-6 dB	31.2 dB WQP	-3 dB
Norver 67 kHz	31.2	-12	24.8	-6
CozmoCom 92 kHz	28.8	-7	27.4	-6
ComPol 92 kHz	27.0	-19	18.5	-10

[2] The injection of 30,000 K noise into the test bed has been determined by the Committee to be a realistic simulation of actual reception conditions. In contrast, the use of a test bed with no injected noise presents the test receivers with unrealistically pristine RF conditions. Such conditions fail to adequately represent typical background energy to which receivers are subjected in the field. However, tests without injected background noise are valuable tools for qualifying results of injected noise tests and for isolating other variables in tests to view their particular effects for diagnostic purposes. This subcarrier report refers to tests with AWGN injected unless otherwise indicated.

Table 3

Lab Test: Host: No Injected RF background noise (AWGN)--
Change In Subcarrier Audio Signal-To-Noise Level
With The Addition of FM IBOC Signals

Without Injected AWGN	Desired At Strong Signal Level		Desired At Moderate Signal Level	
Subcarrier Receiver	**Audio S/N without IBOC**	**Change in Audio S/N with FM IBOC Added**	**Audio S/N without FM IBOC**	**Change in Audio S/N with FM IBOC Added**
McMartin 67 kHz	36.5 dB WQP	-7 dB	37.6 dB WQP	-8 dB
Norver 67 kHz	31.7	-12	31.3	-12
CozmoCom 92 kHz	28.9	-7	29.3	-7
ComPol 92 kHz	27.9	-19	27.9	-17

Because field conditions on the whole have been determined to be best reflected in the lab by the presence of AWGN on the test bed3, the results with AWGN in the subcarrier testing deserve the closer scrutiny. Throughout this subcarrier report, the lab tests with injected AWGN are utilized unless otherwise indicated.

Subjective Test Data

While the lab test data illustrate the numerical change in signal to noise performance of a received analog subcarrier on a small sample of receivers, the data cannot indicate the perceived significance of a change in noise performance. To evaluate the perceived impact of host FM IBOC signal effects on reception of the host station's analog subcarriers, subjective testing was conducted with recordings from both lab and field tests.

Male and female voice selections were recorded on both the lab and field subcarrier tests. Musical selections were recorded on the lab tests, but not employed in the subjective analysis. The vocal selections are most representative of the content broadcast on reading services. Vocal content is also likely to be the most challenging under interference conditions because a single voice is not aurally dense enough to continuously mask noise, whereas processed music often is.

iBiquity submitted a table, "Lab Compatibility, SCA Host," (page 1 of its SCA Appendix C) that presents the average subjective MOS scores4 for each subcarrier receiver, with and without the FM IBOC signal

[3] See the NRSC FM IBOC Evaluation Report, section 4.2 for further discussion on the Committee's findings regarding the use of injected AWGN in laboratory tests. It has been the experience of the EWG in main channel tests that the use of injected AWGN in the lab best corresponds with field results.

[4] The Absolute Category Rating Mean Opinion Scores (ACR-MOS) are averages of integer scores given by test listeners using a scale in which 5, 4, 3, 2, and 1 represent Excellent, Good, Fair, Poor, and Bad, respectively. The subcarrier tests utilized the same "anchor" points of reference for quality as the main channel audio tests. Since subcarrier audio is inherently lower in quality than good main channel audio, subcarrier scores are less likely to score high, giving them less resolution on the remainder of the ACR scale.

activated. The table separates male and female audio cuts (and averages them with little change in result). It also separates tests with and without AWGN inserted under the test signal.

AWGN in Subjective Tests

On first blush, the inclusion of AWGN does not affect the MOS score of the CozmoCom receiver. Its male/female total remains at 2.1 with or without AWGN (and no FM IBOC). However, the EWG observed that the CozmoCom host compatibility recordings in this lab test were compromised by the presence of main channel crosstalk. Hence, the addition of AWGN does not appear to affect the perception of the receiver performance possibly because the quality is already poor. In field tests, there was no apparent crosstalk in the CozmoCom, which was tested on WD2XAB with classical music on the main channel. It is therefore not clear whether the receiver or the lab test configuration may have been the cause of the crosstalk.

In contrast, the other three receivers, without FM IBOC signals present, were diminished in performance with the addition of AWGN. Their starting values were higher than the CozmoCom's 2.1 MOS, showing 3.6, 3.3, and 4.0 for the ComPol, McMartin, and Norver. After AWGN was added, their performance slipped to 2.6, 3.0 and 3.0 respectively—still better than the CozmoCom at its best. These average scores starting between Good and better-than-Fair, shifted to being between Fair and better-than-Poor.

This response to AWGN (at moderate and strong signal levels) demonstrates the susceptibility of subcarrier receivers to outside influences within the host station's protected contours, even without the addition of FM IBOC signals.

Subjective Tests of Host Compatibility Lab Recordings

Under AWGN conditions, the addition of FM IBOC signals in the lab yielded FM IBOC Mean Opinion Scores of 2.6/1.4, 3.0/2.9, and 3.0/2.4 (without FM IBOC/with FM IBOC) among the latter three receivers. The CozmoCom, already compromised by crosstalk, changed from 2.1 to 1.7. Among the other three receivers, the McMartin showed on the average essentially no perceptible change. The Norver showed a change that just exceeds the confidence interval, suggesting the change was perceptible in some cases. The ComPol, which audibly seemed to pass higher frequencies (including noise) more readily than the others, produced the most dramatic change in MOS score with the addition of FM IBOC signals.

Subjective Tests of Host Compatibility Field Recordings

The field tests for Host Compatibility of subcarrier reception included two radio stations, each with two subcarriers and one receiver per subcarrier, received at three locations each.

The test signals on WPOC were corrupted by main channel crosstalk that did not appear to be related to multipath reception or individual receiver performance. The Norver receiver at 67 kHz and the ComPol at 92 kHz rated 1.9 MOS or less in each location, whether or not the FM IBOC signal was activated. Data from these two tests is not considered here. However, an experienced listener may glean some understanding of FM IBOC related noise mechanisms by listening to these sound cuts with the rest. For instance, even in the presence of distracting crosstalk, the variations in background hiss that occur with variations in signal level, AWGN, and analog/FM IBOC modes, appear to be consistent with other field and lab test recordings.

The data in iBiquity's "Field Host Compatibility" table shows the McMartin and CozmoCom receivers scoring quite well, both with and without the FM IBOC signals present. At three locations the

CozmoCom receiver, on 92 kHz, scored from 3.1 to 4.4 without FM IBOC. With FM IBOC added, the scores changed to between 2.9 and 3.5. Performance that was good-to-fair diminished to fair-and-better-than-fair.

The McMartin receiver on 67 kHz ranged from 3.8 MOS to 4.5 without FM IBOC. With FM IBOC, the scores stayed within overlapping confidence intervals of the original values, ranging from 3.6 to 4.4. The McMartin showed that it received no material change in performance with the addition of FM IBOC signals to the host.

Lab and Field Test Differences

The lab and field recordings for host subcarrier compatibility differ somewhat. The lab test recordings reveal more noise on the recordings with the FM IBOC present than the field recordings do. Mean Opinion Scores reflect this disparity as well. Mean Opinion Scores remain fairly high in both cases with the addition of FM IBOC signals.

The signal strengths used in the lab represent strong reception well within a station's protected contour and moderate reception comparable to strength at the contour. The field tests of the McMartin and CozmoCom on experimental station WD2XAB ranged from 53 to 75 dBu, which are comparable to the range of strong to moderate as approximated in the lab tests. There is no clear explanation for the clear, minor differences in the lab and field recordings. It has been the experience of the committee and in particular of several of its members involved in this type of testing that field conditions, with respect to RF noise and non-interfering out of band signals, can affect the way a receiver responds to the desired signal. The use of the 30,000 K AWGN in the lab is an important factor in simulating the impact of the radio frequency energy environment in the field, but may not duplicate it entirely.

Effect of Signal Strength

Signal strengths below the moderate level utilized in the tests represent subcarrier reception typically outside a station's protected signal coverage area. The impact of host FM IBOC signals can be inferred based on the observations available. The ATTC laboratory test summary contains spectrum analyzer plots of the demodulated baseband of various signals under test.5 Assuming that the commercial demodulator used to generate the analyzer plots behaves similarly to a typical receiver, the baseband plots reveal the relationship between signal strength, injected RF noise, host FM IBOC presence, and resulting composite baseband noise. In general, as the RF noise is increased, or the signal level is decreased, the noise in the subcarrier portion of the FM baseband increases. Lower signal levels and higher RF noise levels produce a masking effect that diminishes the impact of FM IBOC signals on the demodulated baseband. Consequently, it is reasonable to infer that as a subcarrier receiver is moved further from the host station, the received baseband noise will increase, and the noise of receiving the station will meet and exceed the noise generated in the receiver with the presence of FM IBOC signals.

Host Compatibility with Analog Subcarrier Receivers Conclusion

While objectively measured analog subcarrier reception may get noisier with FM IBOC signals present, and while the increased noise is often perceptible, the perceptual scores indicate that overall utility of the subcarrier is not particularly diminished with the addition of FM IBOC signals, because the field test subjective scores remain well above the listener "tune-out" threshold of approximately 2 MOS that was

[5] SCA Compatibility Report, Appendix A, ATTC Document #01-16B, *SCA Compatibility of the iBiquity Digital IBOC System in the FM Band*, Oct 17, 2001, pp. 23-38

identified in Appendix J of the iBiquity main report. As distance to the desired station is increased, the relative impact of the FM IBOC signal on subcarrier reception should decrease.

First Adjacent Channel Compatibility with Subcarrier Reception

Laboratory tests were conducted on each of four subcarrier receivers, two on 67 kHz and two on 92 kHz subcarriers. Interferers on lower and upper adjacencies were tested separately. To obtain objective test data, test signals were utilized that permitted consistent measurement conditions. For recording subjective test audio samples, the test signals were replaced with program audio that permitted the main channels of the signals under test to have a "beat" component that is commonly found on radio stations and commonly heard when adjacent channel interference occurs.

First Adjacent Channel Compatibility Objective Tests

The objective tests for first adjacent channel interference to subcarrier reception were performed with the desired signal 6 dB and 16 dB above the undesired signal (+6 and +16 dB D/U). The 6 dB D/U ratio is the threshold utilized in protecting stations from interference at their protected contours. The 16 dB D/U value is less challenging to receivers.

The summary of results contained in the text below is derived from the iBiquity SCA Compatibility Report, Appendix A, Tables 3-6.

The McMartin receiver did not reveal any variation in Weighted Quasi Peak (WQP) noise between tests with and without FM IBOC signals on the first adjacent channel. Pairs of measured values were within 1 dB of each other.

The Norver receiver revealed no change at +16 dB D/U, with and without FM IBOC signals on first adjacent channel. However, its overall noise figures, around 15 dB WQP, were 9 to 12 dB worse than the McMartin. At 6 dB D/U, the Norver developed noise that measured in single digits, which may qualify as unlistenable. At 6 dB D/U, the Norver registered a 2 dB variation with the addition of FM IBOC on first adjacent channel. The Norver is clearly already compromised by first adjacent analog-only signals at these D/U ratios.

The CozmoCom receiver subjective lab recordings had what may have been the same main channel crosstalk that appeared in the lab tests for host compatibility, but the noise and interference components mostly masked the crosstalk. It is not clear whether the crosstalk also might have occurred during the objective tests with the different test audio signals employed. The CozmoCom receiver varied 0.3 dB or less with the addition of FM IBOC signals on first adjacent channel, with one exception. Without AWGN injected, the +16 D/U ratio revealed a 3.9 dB degradation on lower 1st adjacent channel and a1.6 dB change on upper. Like the Norver, 16 dB D/U measurements were in the teens of dB WQP, and in single digits at +6 dB D/U. The CozmoCom is clearly already compromised by first adjacent analog-only signals at these D/U ratios.

The signal to noise ratios for first adjacent interference in the ComPol receiver were all in the single digits and addition of FM IBOC signals on first adjacent channel did not vary the results more than 0.4 dB.

Overall, first adjacent channel interference exhibited by the tested subcarrier receivers in objective testing was challenging to the receivers whether or not the first adjacency had FM IBOC activated. The test results suggest that analog subcarrier reception is susceptible to first adjacent interference within the protected contour of a desired station.

First Adjacent Channel Compatibility Subjective Tests

Subjective testing of first adjacent channel compatibility of subcarrier reception with FM IBOC signals supports the results of the objective tests. With low figures of 1.1 MOS and a single high of 2.7, the subjective tests placed first adjacent performance without FM IBOC had a median of 1.8 MOS, slightly less than Poor. With FM IBOC the range was 1.1 to 2.6 MOS, with a median also of 1.8.

First Adjacent Channel Compatibility Conclusions

The effect of first adjacent interference without FM IBOC signals present appears to be the controlling factor in subcarrier reception. When the desired signal was sufficiently stronger than the undesired signal to meet FCC interference criteria, the subcarrier receivers delivered poor performance. The addition of FM IBOC signals to the first adjacent signal did not affect subcarrier reception at the desired-to-undesired ratios tested.

<u>Second Adjacent Channel Compatibility with Subcarrier Reception</u>

The subcarrier receiver tests utilized desired-to-undesired signal ratios that placed the undesired second adjacent analog signal equal to and greater than the desired signal in ten dB steps (from 0 to -30 dB D/U). The -30 dB desired-to-undesired signal ratio is not as severe as the endpoint of –40 dB D/U anticipated by FCC allocation methods. However, subcarrier receivers are generally not expected to perform at –40 dB D/U, as evidenced by their measured performance at –30. The -30 dB D/U ratio was a suitably challenging ratio for the purposes of this testing.

McMartin Receiver

Below is a graph (Figure 1) of the various tests performed on the McMartin receiver with a second adjacent signal. The X-axis contains the D/U ratio in dB. The Z-axis contains the variations in test conditions, grouped in two halves, with and without AWGN noise injected into the test bed. Each group contains two pairs-- one pair without FM IBOC signals on the adjacency and one pair with. Each pair consists of the test performed on the lower adjacency and the upper adjacency. The results are presented on the Y-axis as strips of weighted quasi peak signal to noise values. The lower the value, the poorer the signal quality.

The graph readily shows that the injection of AWGN into the test signal brings down the signal to noise ratio in comparison to those without 30,000 K AWGN. The Committee has determined that the injected noise more closely approximates the actual noise environment under field conditions.

In a noiseless environment, on the test bed, the introduction of FM IBOC signals to the second adjacent signal appear to have an impact on the McMartin reception quality at D/U ratios as low as –10 dB. With the noise masking that comes from the injected AWGN, the impact of the FM IBOC signals is less apparent, until the D/U ratio becomes more severe. At the –30 dB D/U ratio, the McMartin fails to produce discernable audio with FM IBOC signals on the second adjacency.

The McMartin retains respectable noise performance better than 29 dB WQP, in all conditions, from the zero through –20 dB D/U ratios. While there is better noise performance in the absence of AWGN, reception in the field is likely to contain energy more closely approximated by the 30,000 K AWGN.

Therefore, up through –20 dB D/U ratios, the impact of the second adjacent FM IBOC signals on the McMartin is likely to be negligible.

The subjective test data on the McMartin supports the lab data by showing that at –10 dB D/U the score is always 2.5 MOS or greater with AWGN and 3.6 or greater without AWGN. All MOS scores for analog only 2nd adjacent signals were matched within one-tenth dB by their corresponding FM IBOC test samples. Subjectively, second adjacent interference to the McMartin subcarrier receiver on 67 kHz is not discernable at this D/U ratio.

At the –20 D/U ratio the McMartin objective performance remains fairly stable without FM IBOC signals present. The addition of FM IBOC signals at –20 dB D/U shows a slight degradation that may or may not be perceptible.

Extended to –30 dB D/U, the analog-only adjacent signals appear to cause a slide in performance, but not steeply. The measured test signals with FM IBOC signals drive the receiver into very noisy performance at this ratio.

The subjective data at –30 dB D/U with FM IBOC present on second adjacent show the McMartin performing badly, which is consistent with the objective data. The 3.7 dB WQP signal to noise figures of the lower 2nd adjacent test correspond to Poor-to-Bad subjective results. On the upper adjacency the 0.3 dB signal to noise figures, essentially total failure, conform to the subjective audio which was not distinguishable enough to subjectively test.

Without FM IBOC, however, the upper second adjacent subjective audio was also not distinguishable or nearly so. Contrary to this subjective condition, the objective lab data show that upper second adjacency at –30 dB D/U should make a respectable showing of little noise degradation. This inconsistency could be caused by an error in the objective data collection or by a difference between the way the objective test signals were modulated versus the subjective test signals. The subjective test recordings were conducted under actual program audio modulation conditions rather than with test signals, and therefore are more likely to be reliable indicators of the McMartin performance.

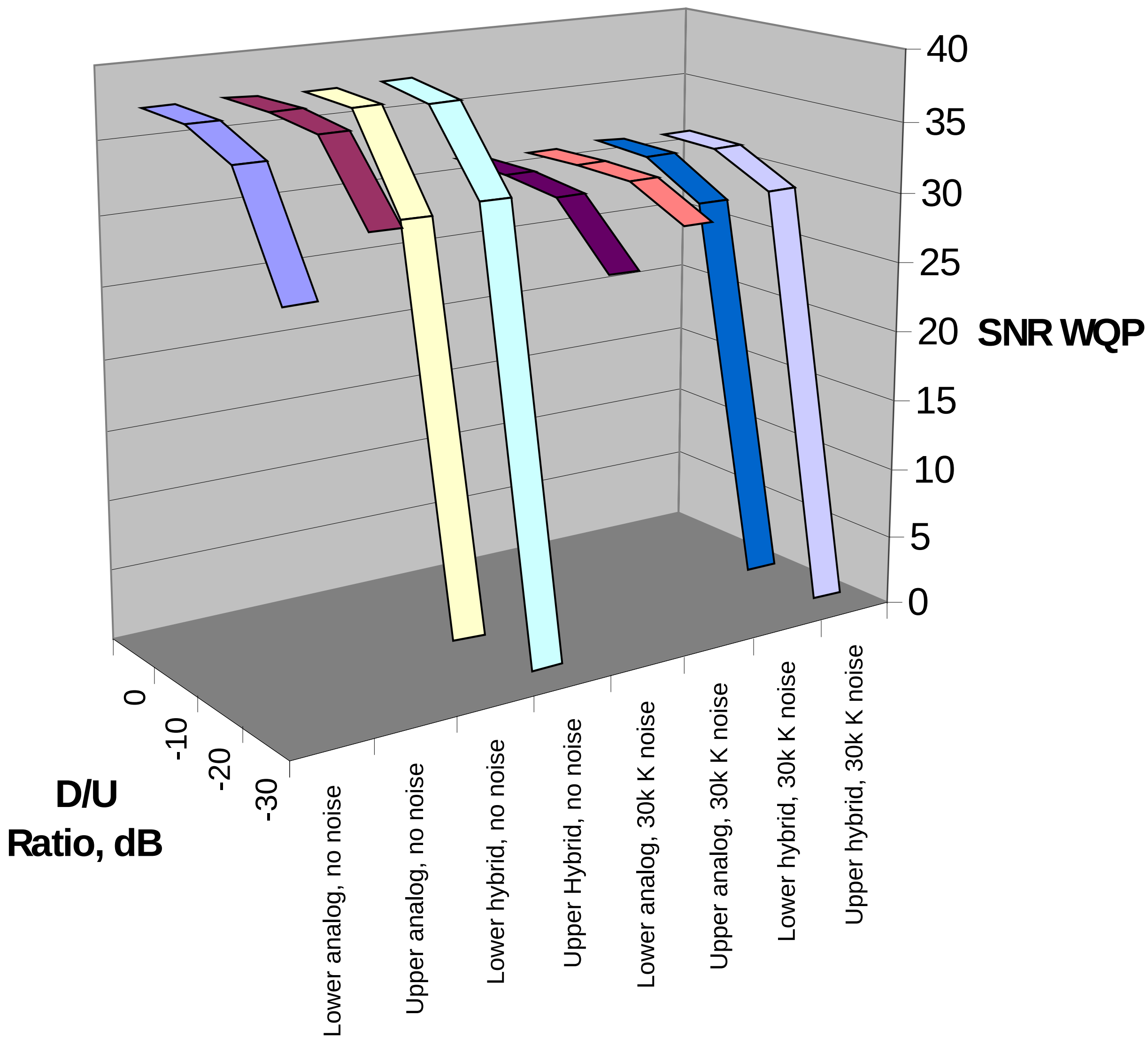
Norver Receiver

The Norver subcarrier receiver obtained poorer marks in objective testing than the McMartin. Its objective performance showed poor resistance to 2nd adjacent channel interference, regardless of the presence or absence of the FM IBOC signal. At –20 dB D/U, the Norver was already well on its way to failure without FM IBOC present. The addition of FM IBOC signals to the 2nd adjacencies accelerated the failure of the receiver, but not until it was well on its way already.

The subjective data for the Norver reinforce the objective results. At –10 dB D/U on 2nd adjacencies, the subjective scores hovered around 2.3 MOS (slightly above Poor) whether or not FM IBOC signals were present on a second adjacency. At –30 dB D/U the Norver was in failure, independent of the status of the FM IBOC signal. As with the McMartin, this, too, illustrates how the objective testing may understate the impact of the analog-only adjacency on the performance of the receiver. The Norver is simply susceptible to severe degradation in the presence of moderate to strong second adjacent analog interferers.

McMartin 2nd Adjacent Noise, 67 kHz

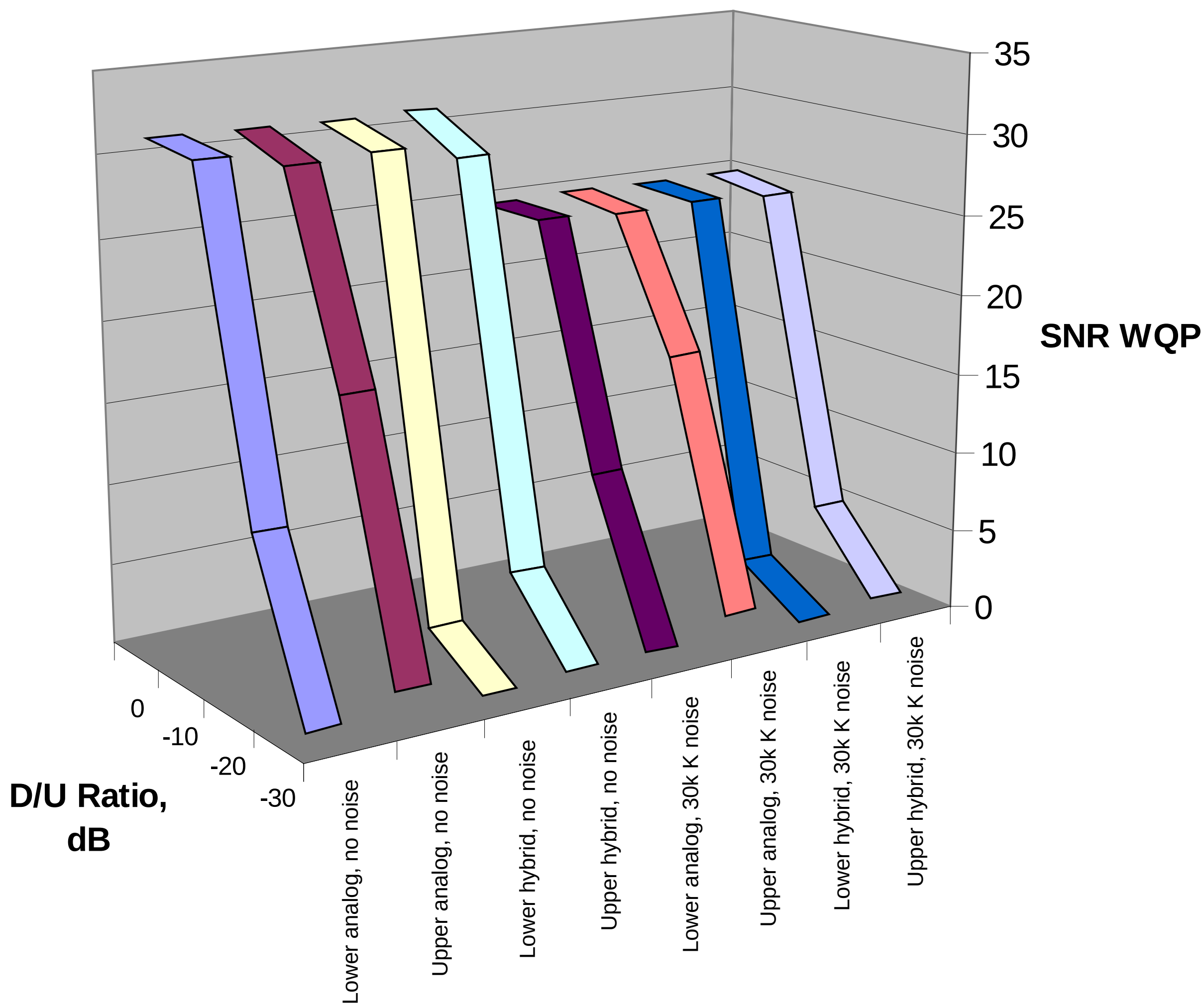
Figure 4
Data obtained from SCA Compatibility Report Appendix A, Table 3, pp. 10-11



	0	-10	-20	-30
Lower analog, no noise	37.5	37.3	35.7	28
Upper analog, no noise	37.5	37.5	37	31.8
Lower hybrid, no noise	37.4	37.2	30.7	3.7
Upper Hybrid, no noise	37.5	36.8	31.2	0.3
Lower analog, 30k K noise	31.3	31.2	30.7	26.6
Upper analog, 30k K noise	31.2	31.3	31.1	29.1
Lower hybrid, 30k K noise	31.3	31.2	28.8	3.7
Upper hybrid, 30k K noise	31.2	31.1	29	0.3

Norver 2nd Adjacent Noise, 67 kHz

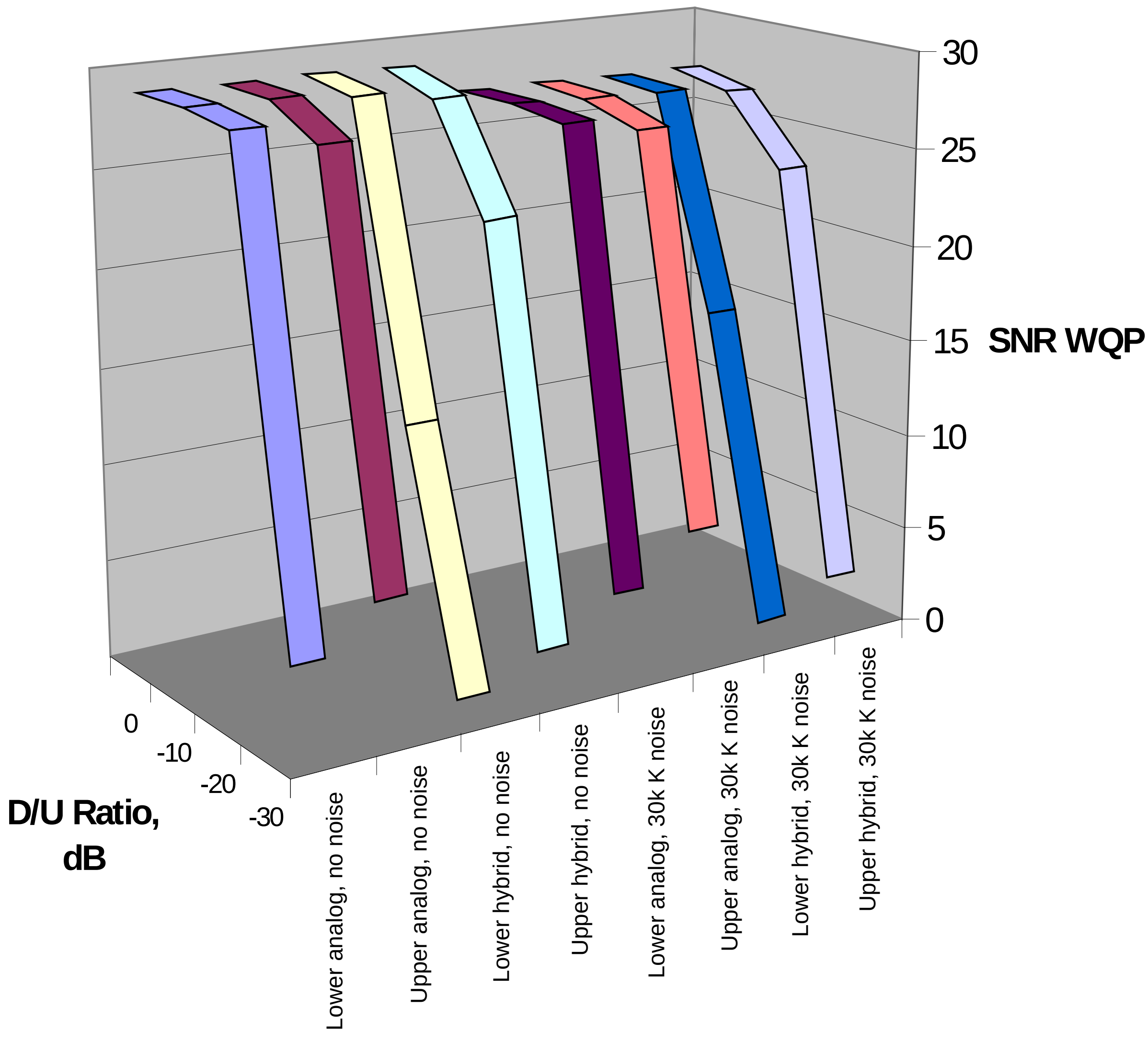
Figure 5
Data obtained from SCA Compatibility Report Appendix A, Table 4, pp. 12-13



	0	-10	-20	-30
Lower analog, no noise	31.2	30.8	10.5	0.4
Upper analog, no noise	31.2	29.9	17.6	1.6
Lower hybrid, no noise	31.1	30.1	2.6	0.1
Upper hybrid, no noise	31.2	29.2	4.9	0.4
Lower analog, 30k K noise	24.8	24.8	10	0.4
Upper analog, 30k K noise	24.9	24.5	16.6	1.6
Lower hybrid, 30k K noise	24.8	24.6	2.5	0.1
Upper hybrid, 30k K noise	24.9	24.3	5	0.5

CozmoCom 2nd Adjacent Noise, 92 kHz

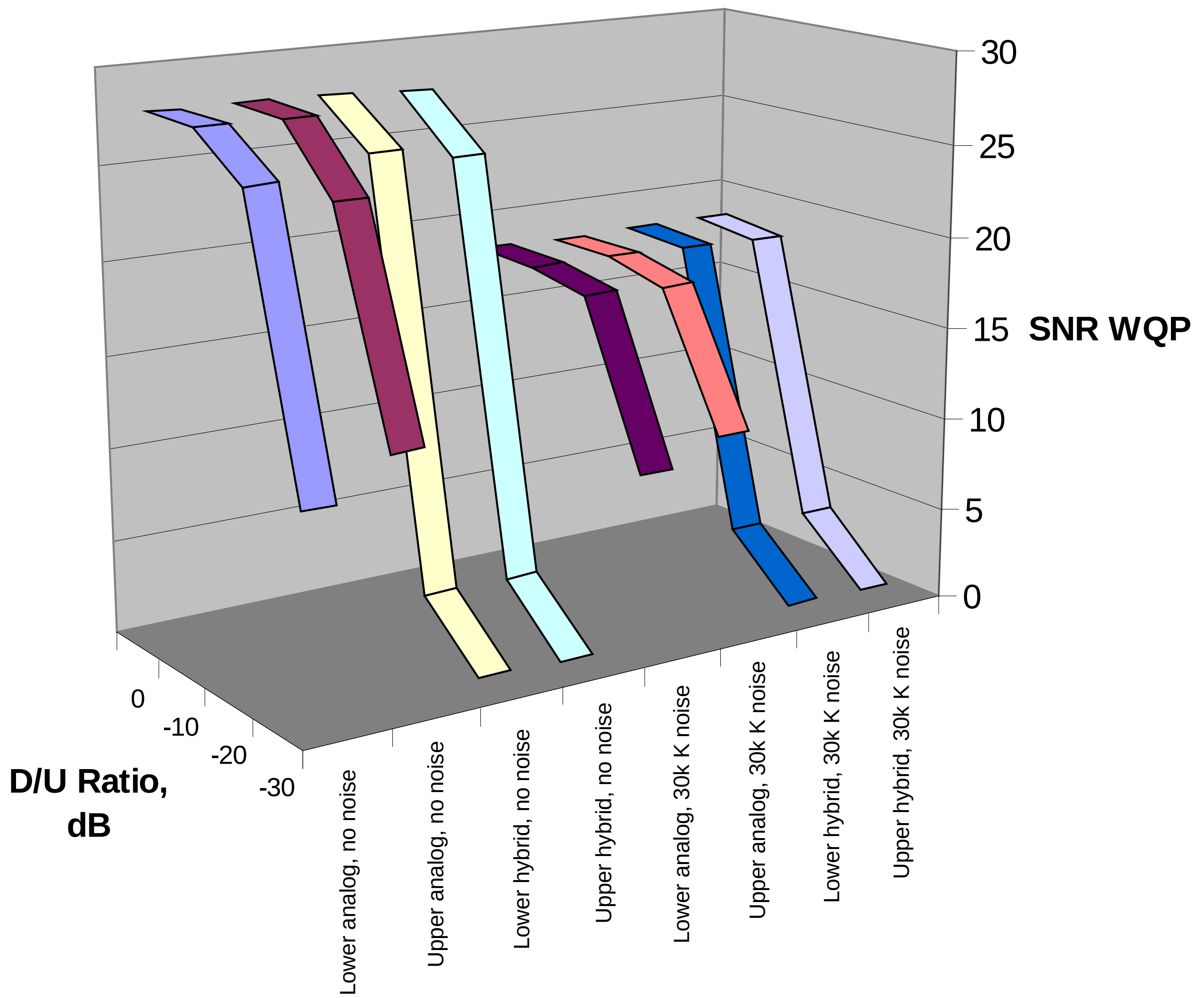
Figure 6
Data obtained from SCA Compatibility Report Appendix A, Table 5, pp. 14-15



	0	-10	-20	-30
Lower analog, no noise	29	29	28.6	4.3
Upper analog, no noise	29	28.9	27.4	6.5
Lower hybrid, no noise	29	28.6	13.2	0.6
Upper hybrid, no noise	28.9	28	22.7	2.1
Lower analog, 30k K noise	27.3	27.3	27	4.1
Upper analog, 30k K noise	27.3	27.1	26.2	6.5
Lower hybrid, 30k K noise	27.2	27	16.1	0.7
Upper hybrid, 30k K noise	27.2	26.6	23.2	2.2

ComPol 2nd Adjacent Noise, 92 kHz

Figure 7
Data obtained from SCA Compatibility Report Appendix A, Table 6, pp. 16-17



	0	-10	-20	-30
Low er analog, no noise	27.9	27.8	25.7	10.9
Upper analog, no noise	27.9	27.8	24.4	12.9
Low er hybrid, no noise	27.8	25.5	3.4	0.4
Upper hybrid, no noise	27.6	24.8	3.3	0.3
Low er analog, 30k K noise	18.5	18.4	17.8	9.3
Upper analog, 30k K noise	18.4	18.4	17.6	10.6
Low er hybrid, 30k K noise	18.5	18.2	3.3	0.4
Upper hybrid, 30k K noise	18.5	18.1	3.4	0.3

CozmoCom Receiver

The first of the two 92 kHz subcarrier receivers, the CozmoCom, was affected by second adjacent FM IBOC signals in objective tests but proved unaffected in the subjective tests.

At –20 dB D/U, upper second adjacent FM IBOC signals increased the measured noise by 3 dB, while on the lower adjacent it increased noise by 11 dB. At –30 dB D/U the measurements indicate the CozmoCom did not fail but performed poorly with noise measurements of 4 to 6.5 dB WQP.

The subjective testing was unaffected by the addition of an FM IBOC signal to the second adjacent channels with a –10 dB D/U ratio, showing only a couple of tenths of a dB difference in noise levels. At –30 dB D/U, the CozmoCom was in total failure with an analog-only second adjacent subjective test signal.

ComPol Receiver

The other 92 kHz subcarrier receiver, the ComPol, showed the most severe reduction in performance with second adjacent FM IBOC signals. The objective and subjective test results tracked fairly closely.

At –10 dB D/U there was no meaningful change in performance with both the objective and subjective tests in the presence of second adjacent FM IBOC. At –30 dB D/U, the objective tests begin with substantial noise (9-13 dB WQP) and go into failure when the FM IBOC signals are added to second adjacencies. Similarly, the subjective tests at –30 dB D/U go from nearly bad (1.1 to 1.6 MOS) to failure with FM IBOC on second adjacencies.

The –20 dB D/U point was only tested in the objective tests. The objective tests at –20 dB D/U show a significant increase in received noise with the addition of FM IBOC on second adjacencies, 14 dB. Because it falls between the unaffected –10 and the at-failure –30 dB D/U levels, the –20 test is in the midst of the ComPol receiver's transition to interference failure.

The ComPol receiver showed a measurable and significant reduction in performance only at the –20 dB D/U level when FM IBOC signals were added on second adjacencies. The performance with and without FM IBOC signals was essentially equalized at –30 dB D/U. The data suggest that the addition of FM IBOC on second adjacencies does accelerate the failure of the ComPol in the presence of second adjacent FM signals.

General Observations on Second Adjacent IBOC Compatibility with Subcarriers

In general, subcarrier receivers are susceptible to all second adjacent FM signals at moderate interferer levels (considering that –40 dB D/U is the FCC limit and that the subcarrier receivers typically failed between –10 and –30 dB D/U). Receiver failure is accelerated by the addition of FM IBOC on second adjacencies.

The resolution of the objective tests is at 10 dB D/U steps. The data suggest that FM IBOC induced degradation of subcarrier reception is likely to occur when the undesired signal is within 10 dB or less of the level at which an analog-only signal would cause the same conditions.

Limitations of Tests

The tests are extremely valuable and meaningful to the evaluation of FM IBOC compatibility with subcarrier reception. More detailed study in the future may help characterize the obvious variabilities in subcarrier receiver performance due to signal levels, in-band noise, upper-versus-lower adjacencies, and D/U ratios, as well as their responses to the addition of FM IBOC signals.

Simplifications and assumptions were made to streamline the testing process and obtain a battery of data that was readily processed. They include:

- Use of a limited sample of subcarrier receivers, two on 67 kHz and two on 92kHz;
- Laboratory objective tests utilizing standard, and modified standard, test signals rather than typical program audio;
- Injection of AWGN to approximate field reception conditions;
- Use of customary field practices for setting up main and subcarrier modulation and compression, limiting the precision and repeatability of the setups;
- Use of limited range and resolution of Desired-to-Undesired signal ratios;
- Limited characterization of receivers under test;
- Field tests with a simple vertical antenna was positioned in the judgment of the testers by ear without more rigorous characterization of the multipath environment;
- Field tests on WPOC and lab tests on the CozmoCom receiver in which there is apparent crosstalk on the recorded samples for which there was insufficient time and resources to verify causes and regenerate the tests;
- Subjective testing was conducted, for consistency, with headphones rather than speakers like those utilized in the subcarrier receivers;
- Subjective testing was conducted without limiting audio frequencies to the effective passbands of speakers utilized in subcarrier reception.

Data Subcarrier Compatibility

It stands to reason that just as an increase in composite baseband noise affects analog subcarrier reception, an increase in composite baseband noise may affect reception of digital subcarriers. Baseband noise is increased by the presence of insufficiently filtered adjacent channel signals, strong co-channel signals, and the general level of background noise.

The iBiquity subcarrier test report, Appendix A pp. 23-38, shows the spectral baseband components demodulated by a Belar monitor under a variety of noise and interference conditions. This series of graphs illustrates how variables such as signal level, injected noise, main channel modulation, and the presence of FM IBOC signals affect the noise level in the subcarrier portion of the demodulated FM baseband. Individual receivers, with the myriad tradeoffs in cost, filtering methods, demodulators, mixing and amplification, and other factors, will present varying results given the same reception conditions.

RBDS Compatibility

For the RBDS subcarrier test, a commercial analyzer, the Audemat, was utilized to measure Block Error Rates on the received RDS subcarrier in the presence of various test conditions. Consumer receivers may perform differently. However, the Audemat permitted accurate tabulation of data reception errors, and its results should prove to be a useful benchmark in the analysis of FM IBOC compatibility with RBDS reception.

Under strong and moderate signal levels in the laboratory, with 3% and 10% RBDS injection, with and without injected AWGN, with and without main channel modulation, RBDS reception exhibited no block errors (to a precision of 0.00%). Similarly, in first and second adjacent channel tests, with moderate signal levels, over a range of desired-to-undesired signal levels, with and without AWGN, there were no data errors.

Limited field tests were conducted on host RBDS reception to see whether they confirm the laboratory tests. Three locations were selected based on their approximate analog-only block error rates—0%, 1% and 10%. The injection of the RBDS subcarrier was 1 to 2%.

With the introduction of FM IBOC, the 0% location continued to deliver 0% errors over a 30-minute period.

At the 1% error location, the three three-minute analog-only samples ranged from 1.2 to 2.6% block errors. With FM IBOC on, three three-minute samples, which were alternated in time with the analog-only samples, yielded errors from 1.3% to 2.7 %. Clearly, at this level of resolution, the only variable in the error rate was a variation over time that resulted in the highest error rates being about double the lowest error rates. Perhaps with a much longer sample time, one could accumulate sufficient data to characterize the changes in error rates over time and determine if there are any subtle effects caused by the addition of FM IBOC signals to the host.

At the location yielding 10% errors, the analog-only rates ranged from 9.4 to 12.4% over three three-minute samples. With FM IBOC on, the rates ranged from 6.1 to 13.4%. As with the 1% test data, this data illustrates there is no obvious deterioration in error rates due to the addition of FM IBOC to the host station.

There is no indication of any incompatibility between FM IBOC signals and the reception of RBDS.

DARC Compatibility

Tests of the 76 kHz DARC digital subcarrier reception were performed with a commercially available DARC receiver. The received data stream was tested for errors both before and after the receiver's error correction stage.

Host Compatibility

Testing FM IBOC on the host signal, with moderate and strong signal levels, and with and without AWGN and main channel modulation, no block errors were detected prior to error correction.

In field tests, four locations with impaired reception were tested. One location was tested for a total of 30 minutes with host FM IBOC on, and 30 minutes with host analog only. The FM IBOC was turned on and off for ten-minute intervals over the period until each mode had accumulated thirty minutes of data. This represents nearly 100,000 blocks of data for each mode.

The raw received data in the thirty-minute tests, prior to error correction, indicated 0.00% error rate in analog-only mode, and 0.074% with FM IBOC. After error correction, the rates were zero.

At two locations the uncorrected error rates without FM IBOC were between 0.13 and 0.38% (plus an unusual value of 0.9%). With FM IBOC present, the uncorrected errors ranged from 0.15 to 0.37%. After error correction, all values were zero (except the unusually high analog-only measurement which resulted in a 0.232% post correction error rate). These tests included three three-minute samples of each mode at each location, for a total of 12 samples.

In the field tests with uncorrected error rates below 0.4% there is no apparent increase in errors due to the addition of FM IBOC to the host signal.

The remaining field test was run at a location with 6.2 to 9.9% uncorrected errors without FM IBOC. With FM IBOC, the uncorrected errors ranged from 7.7 to 10.8%. After error correction, the errors without FM IBOC ranged from 0.00% to 0.08%. With FM IBOC, the errors ranged from 0.02% to 0.1%. While these data may appear to hint at a slight increase in error rates with FM IBOC on, the apparent change is not statistically significant due to the limited number of samples (three three-minute samples each—FM IBOC on and off) and the large variations in errors over time.

The tests at approximately 10% uncorrected error rates do not indicate a significant change in error rates with the addition of FM IBOC to the host.

First Adjacent Compatibility

The first adjacent channel tests yielded significant block errors without FM IBOC present under certain conditions. At +16 dB D/U and in the absence of FM IBOC, block errors ranged about 1 to 2% prior to correction. These errors were fully corrected by the error correction scheme. At +6 dB D/U the pre-corrected block errors rose to 70-80%. Clearly, first adjacent signals at this ratio present a significant challenge to the DARC receiver. It is a testament to the robustness for the error corrector that these errors were reduced to a post-correction range of 1½ to 5%.

With the addition of FM IBOC on the first adjacent signal, no new errors were found in modes where errors had not previously occurred. The +16 dB D/U errors remained close to the analog-only errors, with the confidence intervals overlapping. These errors were fully corrected as were the analog-only errors in the same conditions.

At +6 dB D/U, the massive pre-correction errors increased by 1-2% with the addition of FM IBOC, still within overlapping confidence intervals of the analog-only results. Similarly, the corrected data at +6 dB D/U was very close to that of the analog-only tests, within the confidence intervals of the results.

There is a clear trend that shows a slight increase in errors with the presence of FM IBOC on first adjacent channels at +6 and +16 dB D/U, where there are already similar magnitude errors on the analog-only results. However, this trend is not statistically significant due to the overlapping confidence intervals of the results. More importantly, if this trend is indeed representative of the behavior of the DARC receiver in the presence of FM IBOC, it remains an extremely positive indication of compatibility. Small errors on both the analog-only and the FM IBOC signals are readily corrected under the same reception circumstances. Huge errors observed with analog-only first adjacent signals are incompletely corrected to the same magnitude of error as the huge errors that occur in the presence of analog with FM IBOC on first adjacent signals.

Second Adjacent Compatibility

Overall, the second adjacent compatibility data shows no impact of second adjacencies on the reception of DARC data. Error rates before correction were almost entirely zero with and without FM IBOC present. The –30 dB D/U ratio with the lower second adjacency produced fully correctable errors of less than 0.1% both with and without FM IBOC present.

Limitations of Testing

The most obvious variable observed in the field tests was that of reception quality over time. The data error rates obtained in the host field tests showed in some cases a 2 to 1 variation over only three three-minute samples. (One sample indicated a possible 4 to 1 variation). These tests do not provide the degree of resolution necessary to determine whether the addition of FM IBOC to the host signal causes any subtle but consistent variation in DARC reception.

First and second adjacent channel FM IBOC signals are not readily isolated as variables in field tests such that field-testing adjacent interference was not a part of this test plan. The laboratory tests show some consistently higher error rates for first adjacent channel reception with FM IBOC present. These differences in rates are statistically insignificant.

DARC Subcarrier Reception Compatibility Conclusion

FM IBOC signals are compatible with reception of DARC subcarrier data. Reception of the DARC data subcarrier at moderate signal levels is unaffected by the addition of FM IBOC signals to the host or to first or second adjacent signals.

Attachment 1 - Analog Subcarrier Receiver Characterization Tests

These tests were designed to insure that each receiver was meeting basic performance parameters prior to IBOC compatibility testing. The first column of the table below lists the characterization tests. The test procedure for these tests is on page 13 of the of the SC receiver characterization report which follows.

All tests were conducted with 10% subcarrier injection and 5 kHz deviation for both subcarrier frequencies (67 kHz and 92 kHz).

The RMS S/N was measured at five levels -85, -75, -65, -55, and -45 dBm. Only the -62 dBm S/N is listed in the Table. The S/N at the five levels is listed in the complete data report.

For the 1st adjacent tests the undesired transmitter was modulated with a 1kHz tone and deviated 75kHz. The tests were conducted on the upper and lower first adjacent channels at 16dB and 6dB D/U ratios. The results are WQP S/N.

Changes in 67 kHz subcarrier WQP S/N with and without 57kHz 3% RDS were measured at a signal level of -45 dBm.

Page 7 of the complete test data report lists the SC generator calibration data. Pages 8 through 12 show subcarrier calibration plots.

Summary of Analog Subcarrier Receiver Characterization Measurements

Make	CozmoCom	CozmoCom	Compol	McMartin	McMartin
Model	---	---	SCA-BL	TR-E5/55M	---
Serial Number	0073696	0073696	Sample 1001	286834	A0012461
SC Frequency	67 kHz	92 kHz	92 kHz	67 kHz	67 KHz
THD _45dBm 1kHz tone	1.0 V RMS 1.5% THD	1.0 V RMS 1.8% THD	0.5 V RMS 1.9% THD	0.175 V RMS 0.57% THD	1.0 V RMS 2.6% THD
S/N RMS at -65dBm (dB)	59	57	54	63	56
U 1st 16dB D/U WQP S/N (dB)	24	35	27	30	26
L 1st 16dB D/U WQP S/N (dB)	26	32	24	32	29
U 1st 6dB D/U WQP S/N (dB)	19	22	18	4	17
L 1st 6dB D/U WQP S/N (dB)	19	22	15	22	20
WQP S/N without and with 3% RDS (dB)	50/47	49/49	36/34	49/43	42/33

FM Receiver Test Laboratory

Date: 3/31/2001
Engineers: RMc
Project: SCA RX Characterization

Scope:

Basic SCA receiver tests to ensure that test radios are in good working condition for compatibility testing and to baseline receiver performance at a basic level. Further testing to be defined at a later date.

SCA receiver tests include:

1. Standard test audio output level (volume control calibration) and distortion
   SCA at 10% injection, 5kHz deviation, -45dBm RF level
   Audio measured RMS

2. Signal, noise curve at RF levels from -45dBm to -85dBm, 10dB resolution
   Audio measured RMS

3. First Adjacent selectivity using FM adjacent signal modulated 1kHz tone, 75kHz deviation at 16 and 6dB D/U
   Audio measured Weighted Quasi Peak (WQPK)

4. SCA receiver performance with and without 57kHz RBDS subcarrier
   Audio measured Weighted Quasi Peak (WQPK)

Receivers

1. CozmoCom FM portable radio with SCA audio for both 67kHz and 92kHz

2. Compol dedicated SCA receiver for 92kHz

3. McMartin dedicated SCA receiver for 67kHz

4. McMartin dedicated SCA receiver for 92kHz

FM Receiver Test Laboratory

Date: ######
Engineers: RMc
Project: SCA RX Characterization

Receiver Test No.:
Class: Portable
Radio Mfg.: CozmoCom
Model: FM Radio Receiver
Serial: 0073696

Antenna Network: None FM

RF Channel Frequency
RF: 97.90 MHz

Subcarrier Frequency

SCA: 67 kHz
Injection: 10 %

1 Standard Audio Output
RF Lev.: -45 dBm

Level: 1.00 Vrms

THD: 1.50 %

2 Curve test

RF Level (dBm)	Signal (dBr)	Noise (dBr)
-85.00	-0.50	-39.00
-75.00	0.00	-49.00
-65.00	0.00	-58.50
-55.00	0.00	-66.00
-45.00	0.00	-70.00

3 Selectivity 1st Adj
Desired: -45 dBm
Undesired: +/- 200kHz, 1kHz, 75kHz Dev
Measurement: WQPK Signal-to-Noise ratio

		S/N	
No Interference		50.00	dB
D/U (dB)	Upper	23.90	dB
16	Lower	25.80	dB
D/U (dB)	Upper	19.20	dB
6	Lower	18.50	dB

4 SC WQPK S/N With and Without 57kHz RBDS (3% / 2.25kHz)
Desired: -45 dBm
Undesired: None
Measurement: WQPK Signal-to-Noise ratio

	S/N	
Without 57kHz	50.00	dB
With 57kHz	48.50	dB

FM Receiver Test Laboratory

Date: ######
Engineers: RMc
Project: SCA RX Characterization

Receiver Test No.:
Class: Portable
Radio Mfg.: CozmoCom
Model: FM Radio Receiver
Serial: 0073696

Antenna Network: None FM

RF Channel Frequency
RF: 97.90 MHz

Subcarrier Frequency

SCA: 92 kHz
Injection 10 %

1 Standard Audio Output
RF Lev.: -45 dBm

Level: 1.00 Vrms

THD: 1.80 %

2 Curve test

RF Level (dBm)	Signal (dBr)	Noise (dBr)
-85.00	0.00	-37.25
-75.00	0.00	-47.00
-65.00	0.00	-57.00
-55.00	0.00	-65.00
-45.00	0.00	-69.00

3 electivity 1st Adj
Desired: -45 dBm
Undesired: +/- 200kHz, 1kHz, 75kHz Dev
Measurement: WQPK Signal-to-Noise ratio

		S/N	
No Interference		49.00	dB
D/U (dB) 16	Upper	34.50	dB
	Lower	32.20	dB
D/U (dB) 6	Upper	22.00	dB
	Lower	21.50	dB

4 SC WQPK S/N With and Without 57kHz RBDS (3% / 2.25kHz)
Desired: -45 dBm
Undesired: None
Measurement: WQPK Signal-to-Noise ratio

	S/N	
Without 57kHz	49.00	dB
With 57kHz	49.00	dB

FM Receiver Test Laboratory

Date: ######
Engineers: RMc
Project: SCA RX Characterization

Receiver Test No.:
Class: Table
Radio Mfg.: ComPol
Model: SCA-BL
Serial: Sample 1001

Comments:
This receiver has a problem when tur
past a certain point the audio goes int
Therefore the audio output level was

Antenna Network: None FM

RF Channel Frequency
RF: 97.90 MHz

Subcarrier Frequency

SCA: 92 kHz
Injection 10 %

1 Standard Audio Output
RF Lev.: -45 dBm

Level: 0.50 Vrms

THD: 1.90 %

2 Curve test

RF Level (dBm)	Signal (dBr)	Noise (dBr)
-85.00	0.00	-37.50
-75.00	0.00	-47.00
-65.00	0.00	-54.25
-55.00	0.00	-57.25
-45.00	0.00	-57.50

3 electivity 1st Adj
Desired: -45 dBm
Undesired: +/- 200kHz, 1kHz, 75kHz Dev
Measurement: WQPK Signal-to-Noise ratio

		S/N	
No Interference		35.60	dB
D/U (dB)	Upper	27.00	dB
16	Lower	24.30	dB
D/U (dB)	Upper	17.80	dB
6	Lower	15.00	dB

4 SC WQPK S/N With and Without 57kHz RBDS (3% / 2.25kHz)
Desired: -45 dBm
Undesired: None
Measurement: WQPK Signal-to-Noise ratio

	S/N	
Without 57kHz	35.60	dB
With 57kHz	34.20	dB

FM Receiver Test Laboratory

Date: ######
Engineers: RMc
Project: SCA RX Characterization

Receiver Test No.:
Class: Table
Radio Mfg.: McMartin
Model: TR-E5/55M
Serial: 286834

Comments:
Output at line level at jack on rear pa
Volume control does not affect audic
audio output jack on rear panel

Antenna Network: None FM

RF Channel Frequency
RF: 97.90 MHz

Subcarrier Frequency

SCA: 67 kHz
Injection 10 %

1 Standard Audio Output
RF Lev.: -45 dBm

Level: 0.175 Vrms

THD: 0.57 %

2 Curve test

RF Level (dBm)	Signal (dBr)	Noise (dBr)
-85.00	0.00	-42.00
-75.00	0.00	-52.25
-65.00	0.00	-62.00
-55.00	0.00	-63.00
-45.00	0.00	-64.00

3 electivity 1st Adj
Desired: -45 dBm
Undesired: +/- 200kHz, 1kHz, 75kHz Dev
Measurement: WQPK Signal-to-Noise ratic

		S/N	
No Interference		49.00	dB
D/U (dB)	Upper	30.30	dB
16	Lower	32.20	dB
D/U (dB)	Upper	4.16	dB
6	Lower	21.70	dB

4 SC WQPK S/N With and Without 57kHz RBDS (3% / 2.25kHz)
Desired: -45 dBm
Undesired: None
Measurement: WQPK Signal-to-Noise ratic

	S/N	
Without 57kHz	49.00	dB
With 57kHz	42.60	dB

FM Receiver Test Laboratory

Date: ######
Engineers: RMc
Project: SCA RX Characterization

Receiver Test No.:
Class: Table
Radio Mfg.: McMartin
Model: Unsure - Comm Center R9
Serial: A0012461

Comments:
Audio output is headphone output on
(varies with volume control)

Antenna Network: None FM

RF Channel Frequency
RF: 97.90 MHz

Subcarrier Frequency

SCA: 67 kHz
Injection 10 %

1 **Standard Audio Output**
RF Lev.: -45 dBm

Level: 1.000 Vrms

THD: 2.60 %

2 **Curve test**

RF Level (dBm)	Signal (dBr)	Noise (dBr)
-85.00	-0.25	-39.50
-75.00	-0.25	-48.50
-65.00	0.00	-55.75
-55.00	0.00	-59.00
-45.00	0.00	-60.00

3 **electivity** 1st Adj
Desired: -45 dBm
Undesired: +/- 200kHz, 1kHz, 75kHz Dev
Measurement: WQPK Signal-to-Noise ratio

		S/N	
No Interference		42.60	dB
D/U (dB)	Upper	26.40	dB
16	Lower	29.30	dB
D/U (dB)	Upper	17.20	dB
6	Lower	20.00	dB

4 **SC WQPK S/N With and Without 57kHz RBDS (3% / 2.25kHz)**
Desired: -45 dBm
Undesired: None
Measurement: WQPK Signal-to-Noise ratio

	S/N	
Without 57kHz	42.40	dB
With 57kHz	33.30	dB

FM Receiver Test Laboratory

3/31/2001
RMc
SCA Generator Calibration Data
For 5kHz deviation

SCA Gen	**Mod Sci Sidekick**	
SCA Freq	67	kHz
Mod Freq	400	Hz
Input	1,2	Unbal
Input Lev	1.08	Vrms

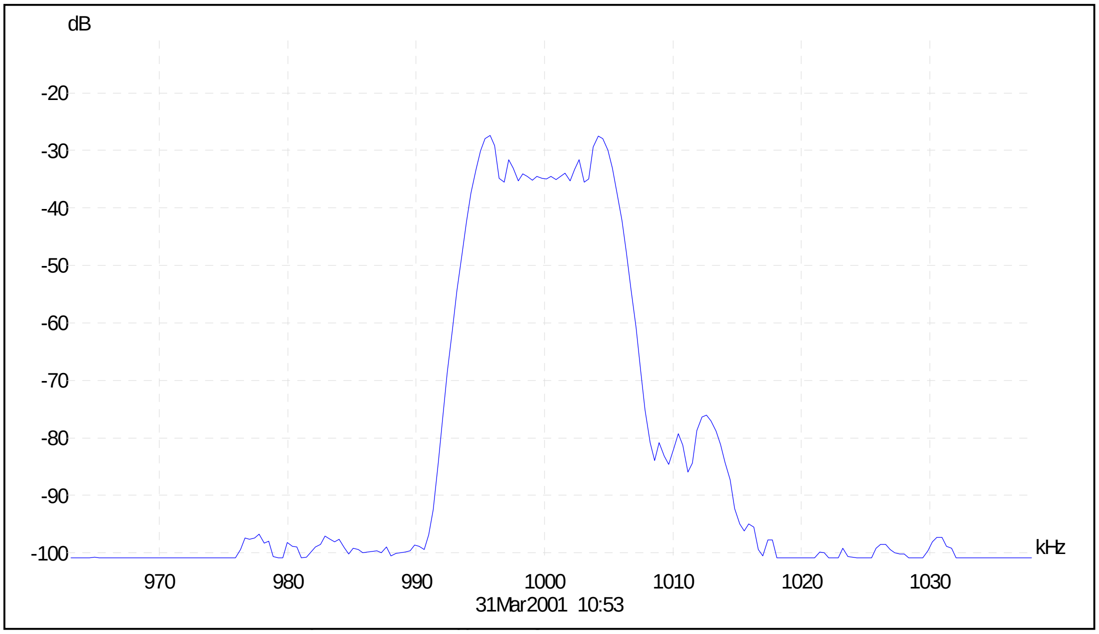
SCA Gen	**Mod Sci Sidekick**	
SCA Freq	92	kHz
Mod Freq	400	Hz
Input	1,2	Unbal
Input Lev	1.08	Vrms

RE533 RBDS Generator

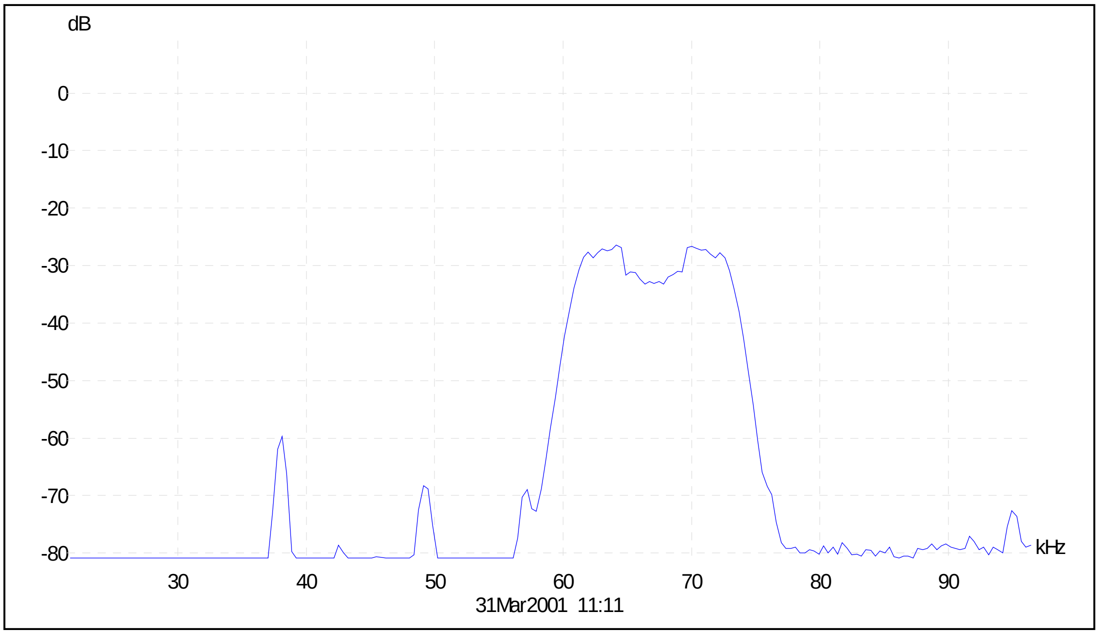
SCA Freq	57	kHz	
Phase Lock	19	kHz	(Pilot)

FM Receiver Test Laboratory

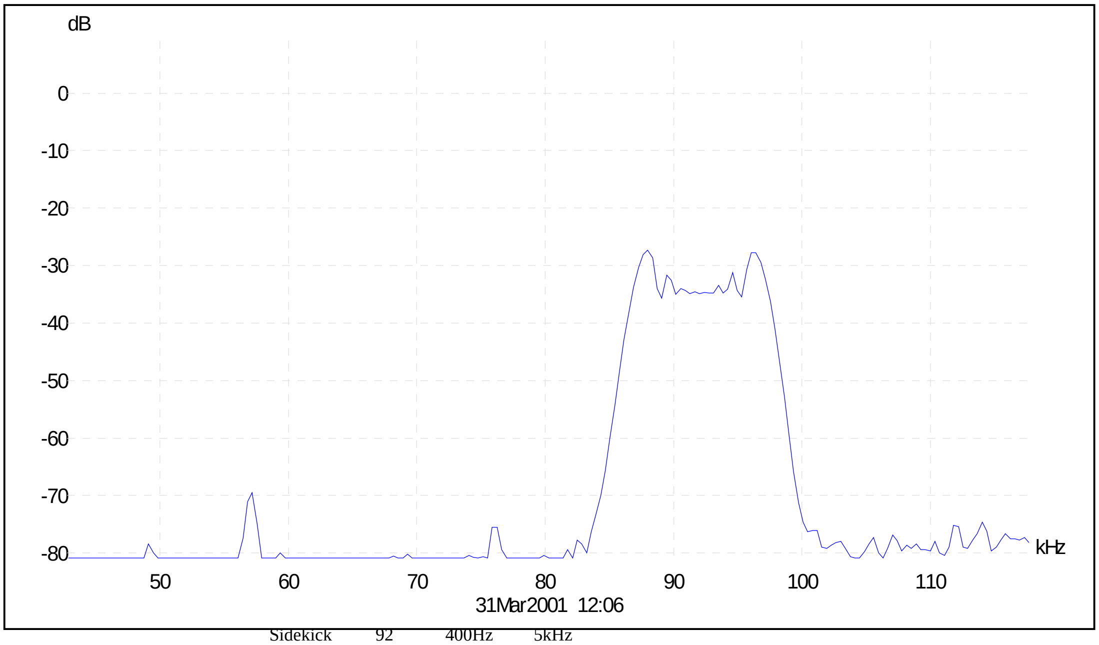
Initial plot of RE107 calibrated to Modulation analyzer establishes reference plot of spectrum analyzer.
Plot of Modulation Analyzer output



Plot of 67kHz SCA signal from Modulation Analyzer output

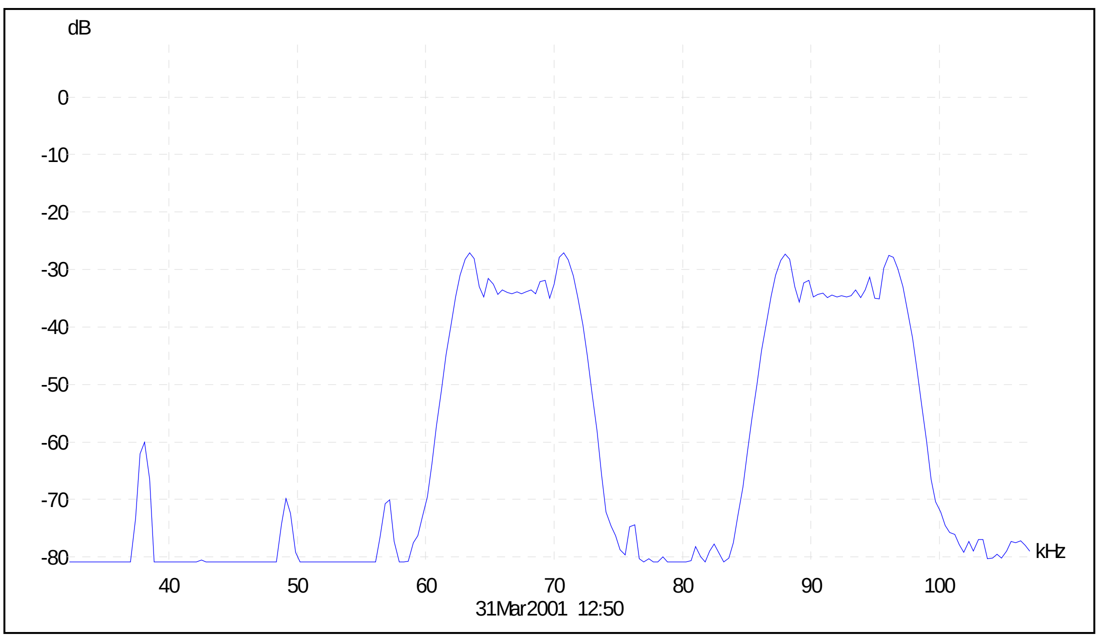


Plot of 92kHz SCA signal from Modulation Analyzer output

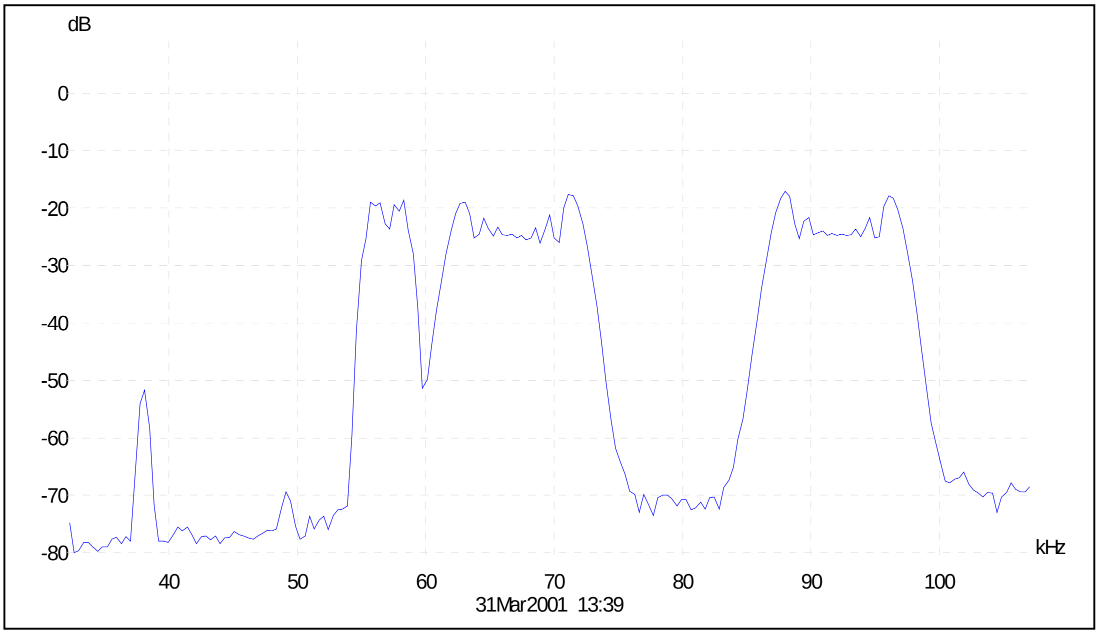


Sidekick 92 400Hz 5kHz

Plot of 67kHz and 92kHz SCA signals from Modulation Analyzer output



Plot of 57kHz, 67kHz and 92kHz SCA signals from Modulation Analyzer output



FM Receiver Test Laboratory

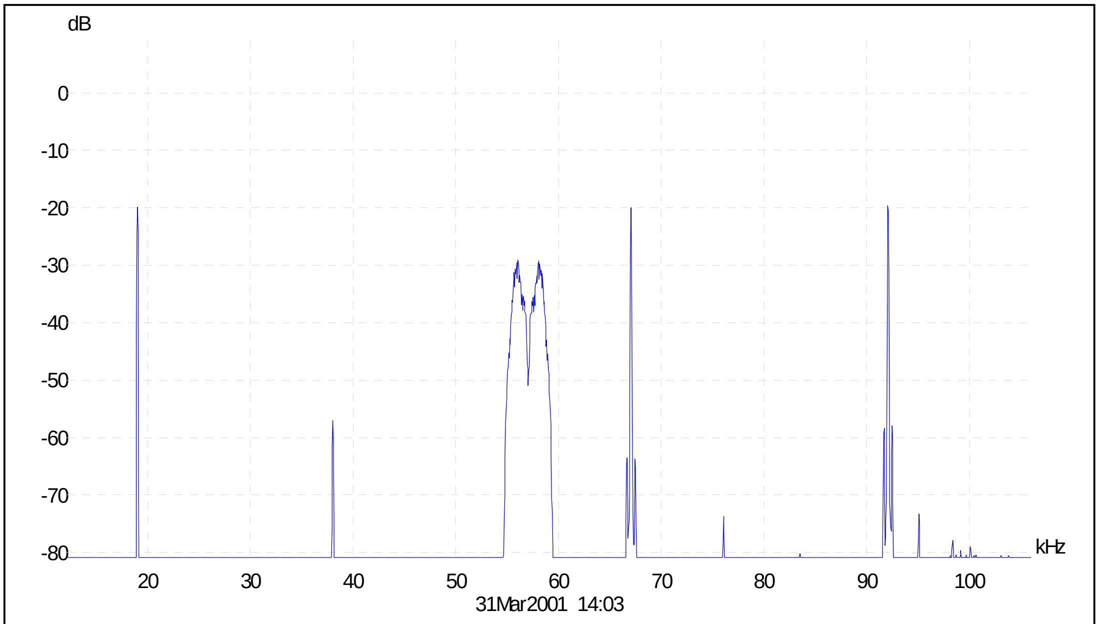
3/31/2001 RMc

Spectrum Analyzer

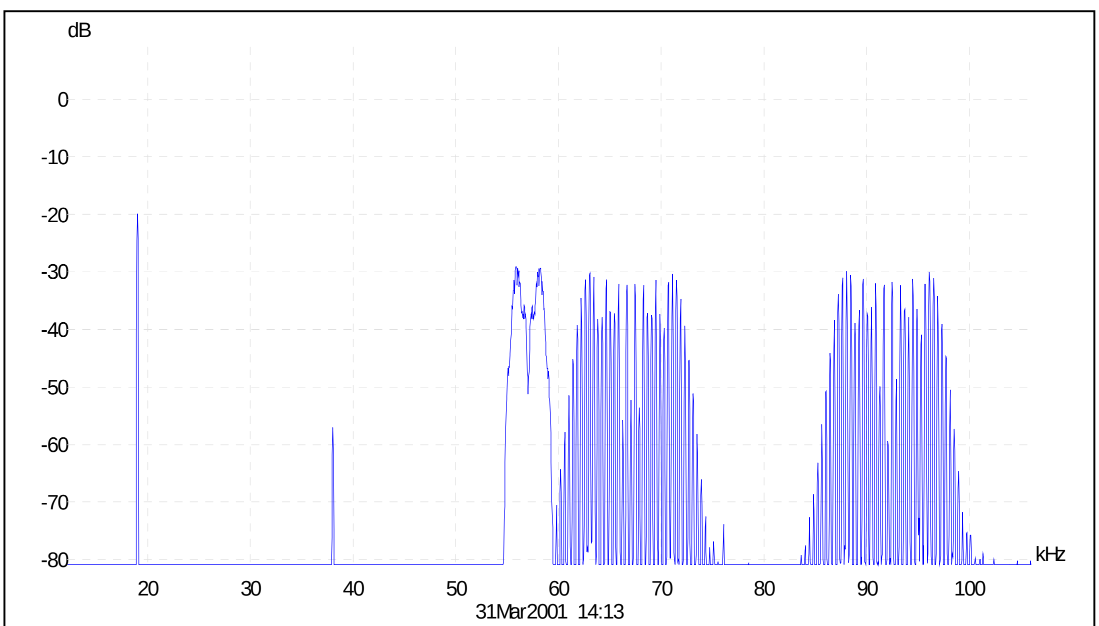
Type:	Pico ADC 212	
Input:	Fixed	
Level:	1	V
Timebase:	187	kHz
Mag:	2	X
Window:	Blackman	
No. of Bands:	4096	Bins
Disp. Mode:	Peak	

Source

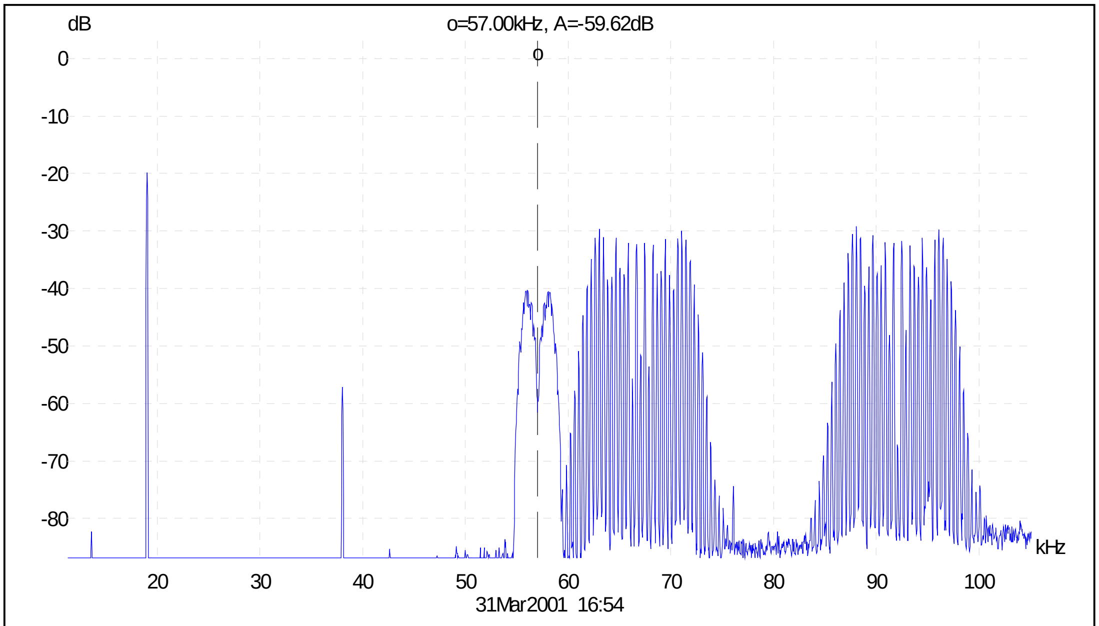
Type:	AFM 2	
Meter range:	30	kHz
Filter Set:	200	kHz (wide)



-20dB	10% injection
19 kHz	10%
57 kHz	10%
67 kHz	10%
92 kHz	10%



-20dB	10% injection	Deviation	
19 kHz	10%	NA	
57 kHz	10%	Std RDS	
67 kHz	10%	5	kHz
92 kHz	10%	5	kHz



-20dB	10% injection		Deviation	
19	kHz	10%	NA	
57	kHz	3%	Std RDS	
67	kHz	10%	5	kHz
92	kHz	10%	5	kHz