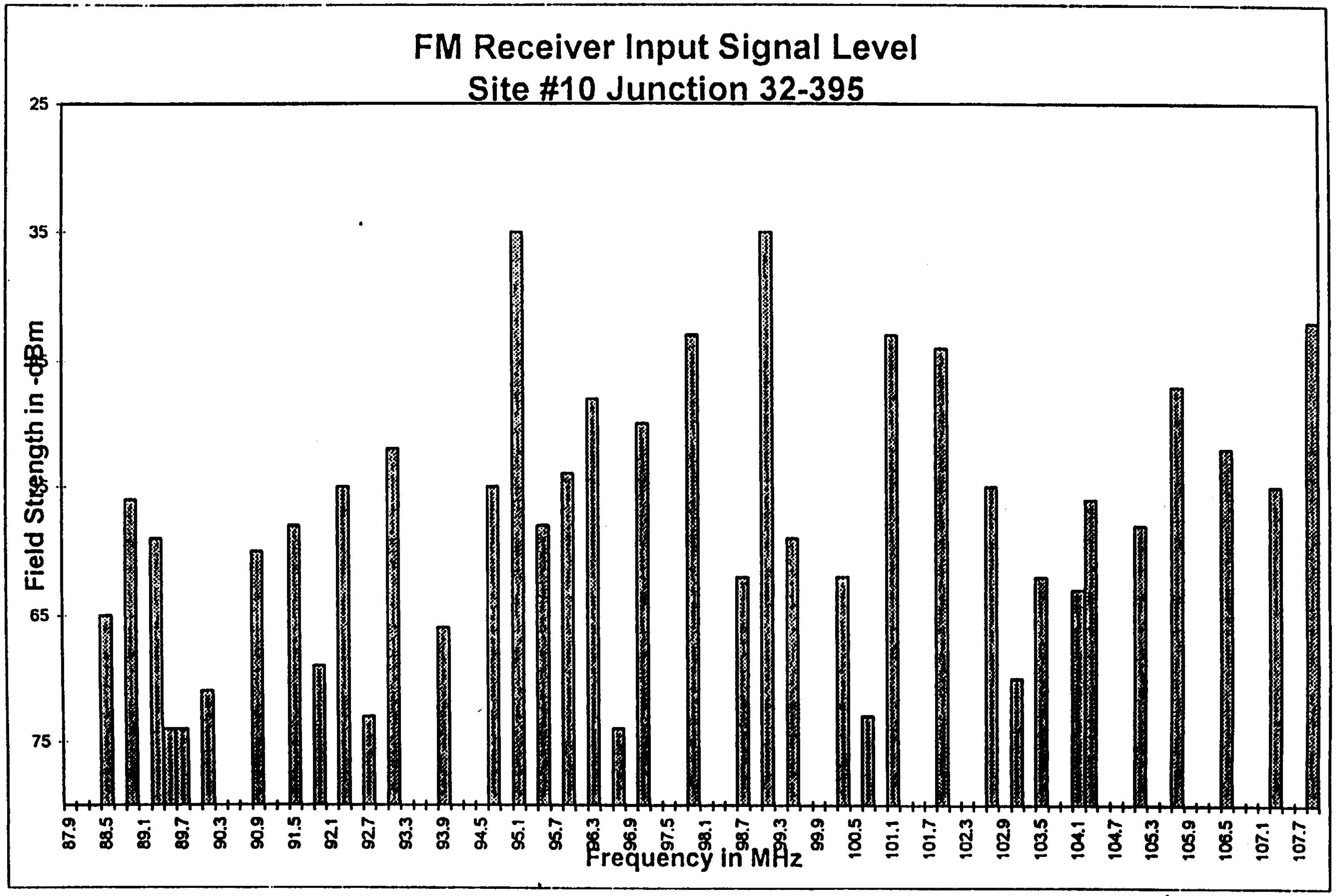


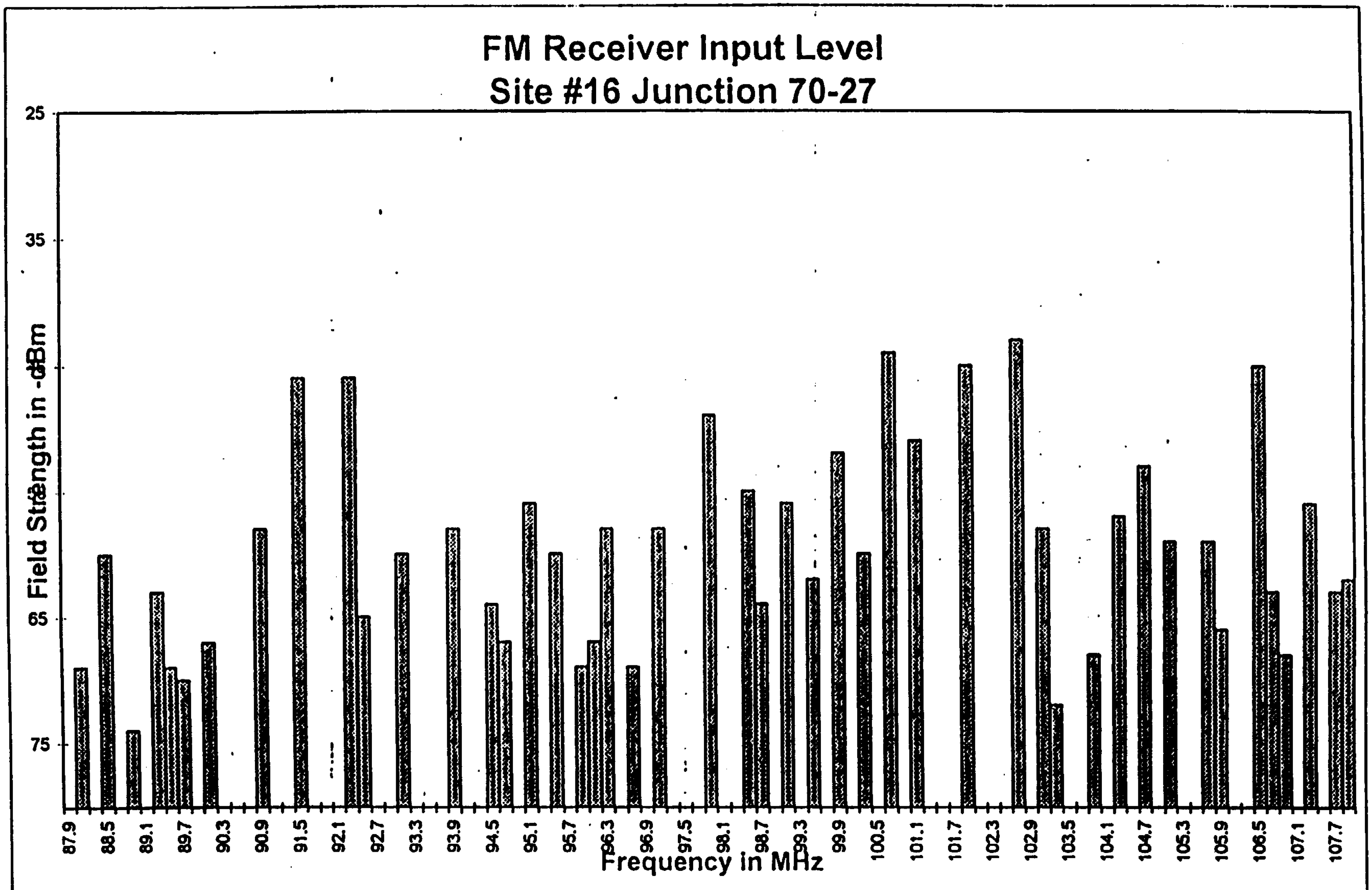
FM Receiver Input Signal Level
Site #10 Junction 32-395
25
35
65
75
Field Strength in -dBm
87.9
88.5
89.1
89.7
90.3
90.9
91.5
92.1
92.7
93.3
93.9
94.5
95.1
95.7
96.3
96.9
97.5
98.1
98.7
99.3
99.9
100.5
101.1
101.7
102.3
102.9
103.5
104.1
104.7
105.3
105.9
106.5
107.1
107.7
Frequency in MHz

Graph 2

FM Receiver Input Level
Site #16 Junction 70-27

FM Band	Field Strength in -dBm	FM Band	Field Strength in -dBm	FM Band	Field Strength in -dBm	FM Band	Field Strength in -dBm
87.9	80	93.5	80	99.1	56	104.7	53
88.1	69	93.7	80	99.3	80	104.9	80
88.3	80	93.9	58	99.5	62	105.1	59
88.5	60	94.1	80	99.7	80	105.3	80
88.7	80	94.3	80	99.9	52	105.5	80
88.9	74	94.5	64	100.1	80	105.7	59
89.1	80	94.7	67	100.3	60	105.9	66
89.3	63	94.9	80	100.5	80	106.1	80
89.5	69	95.1	56	100.7	44	106.3	80
89.7	70	95.3	80	100.9	80	106.5	45
89.9	80	95.5	60	101.1	51	106.7	63
90.1	67	95.7	80	101.3	80	106.9	68
90.3	80	95.9	69	101.5	80	107.1	80
90.5	80	96.1	67	101.7	80	107.3	56
90.7	80	96.3	58	101.9	45	107.5	80
90.9	58	96.5	80	102.1	80	107.7	63
91.1	80	96.7	69	102.3	80	107.9	62
91.3	80	96.9	80	102.5	80		
91.5	46	97.1	58	102.7	43		
91.7	80	97.3	80	102.9	80		
91.9	80	97.5	80	103.1	58		
92.1	80	97.7	80	103.3	72		
92.3	46	97.9	49	103.5	80		
92.5	65	98.1	80	103.7	80		
92.7	80	98.3	80	103.9	68		
92.9	80	98.5	55	104.1	80		
93.1	60	98.7	64	104.3	57		
93.3	80	98.9	80	104.5	80		

Table 3

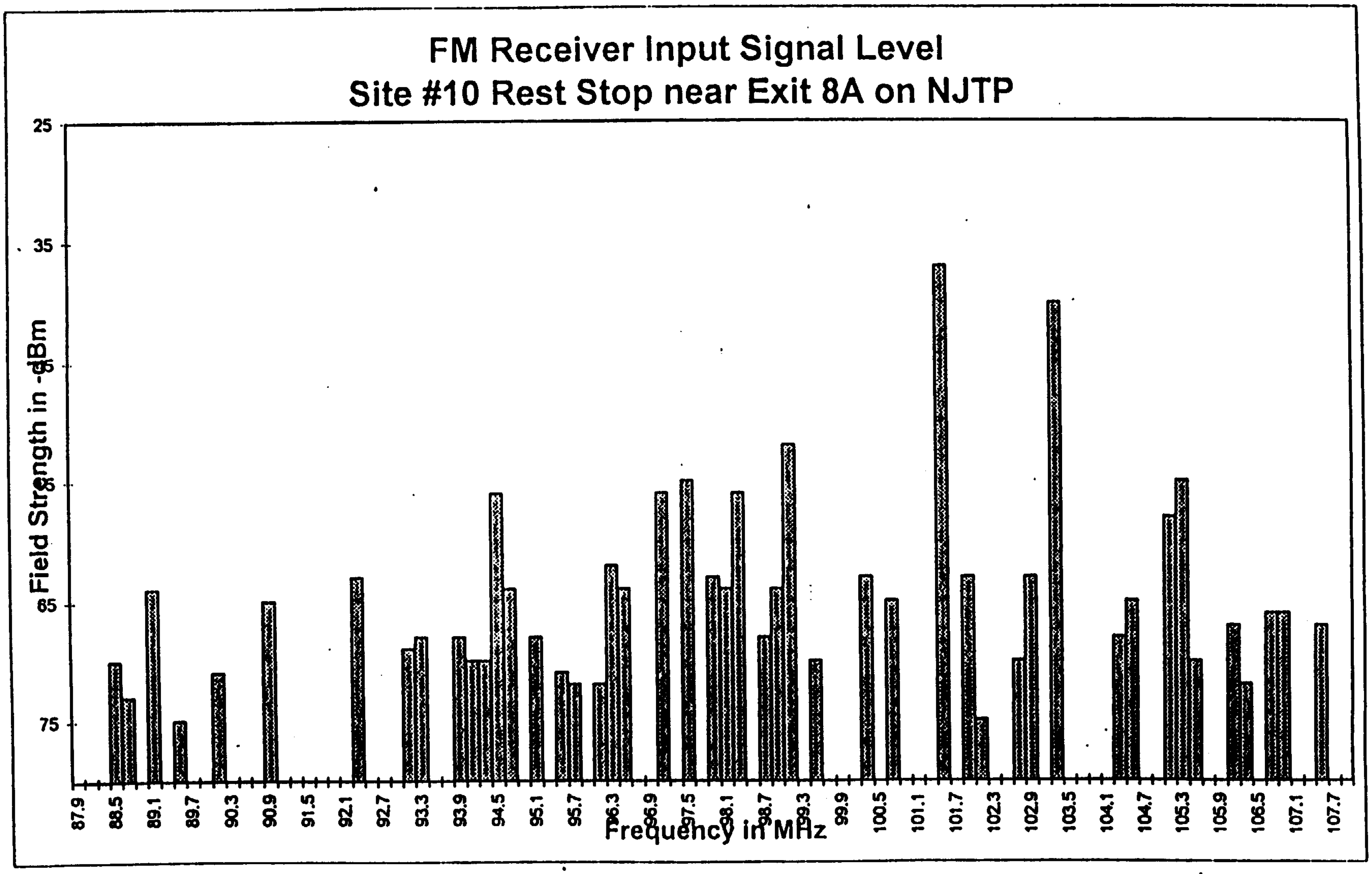

FM Receiver Input Level
Site #16 Junction 70-27
25
35
65
75
Field Strength in -dBm
87.9
88.5
89.1
89.7
90.3
90.9
91.5
92.1
92.7
93.3
93.9
94.5
95.1
95.7
96.3
96.9
97.5
98.1
98.7
99.3
99.9
100.5
101.1
101.7
102.3
102.9
103.5
104.1
104.7
105.3
105.9
106.5
107.1
107.7
Frequency in MHz

Graph 3

FM Receiver Input Level
Site #10 Rest Stop near Exit 8A on NJTP

FM Band	Field Strength in -dBm	FM Band	Field Strength in -dBm	FM Band	Field Strength in -dBm	FM Band	Field Strength in -dBm
87.9	80	93.5	80	99.1	52	104.7	80
88.1	80	93.7	80	99.3	80	104.9	80
88.3	80	93.9	68	99.5	70	105.1	58
88.5	70	94.1	70	99.7	80	105.3	55
88.7	73	94.3	70	99.9	80	105.5	70
88.9	80	94.5	56	100.1	80	105.7	80
89.1	64	94.7	64	100.3	63	105.9	80
89.3	80	94.9	80	100.5	80	106.1	67
89.5	75	95.1	68	100.7	65	106.3	72
89.7	80	95.3	80	100.9	80	106.5	80
89.9	80	95.5	71	101.1	80	106.7	66
90.1	71	95.7	72	101.3	80	106.9	66
90.3	80	95.9	80	101.5	37	107.1	80
90.5	80	96.1	72	101.7	80	107.3	80
90.7	80	96.3	62	101.9	63	107.5	67
90.9	65	96.5	64	102.1	75	107.7	80
91.1	80	96.7	80	102.3	80	107.9	80
91.3	80	96.9	80	102.5	80		
91.5	80	97.1	56	102.7	70		
91.7	80	97.3	80	102.9	63		
91.9	80	97.5	55	103.1	80		
92.1	80	97.7	80	103.3	40		
92.3	63	97.9	63	103.5	80		
92.5	80	98.1	64	103.7	80		
92.7	80	98.3	56	103.9	80		
92.9	80	98.5	80	104.1	80		
93.1	69	98.7	68	104.3	68		
93.3	68	98.9	64	104.5	65		

Table 4


FM Receiver Input Signal Level
Site #10 Rest Stop near Exit 8A on NJTP
Field Strength in -dBm
25
35
65
75
87.9
88.5
89.1
89.7
90.3
90.9
91.5
92.1
92.7
93.3
93.9
94.5
95.1
95.7
96.3
96.9
97.5
98.1
98.7
99.3
99.9
100.5
101.1
101.7
102.3
102.9
103.5
104.1
104.7
105.3
105.9
106.5
107.1
107.7
Frequency in MHz

Graph 4

Appendix 6

FM Modulation Increasing Baseband Noise In The Presence of An IBOC Digital Signal

I. Introduction

Certain types of VHF In-Band/On-Channel (IBOC) digital audio broadcasting (DAB)systems transport digital audio information on independent adjacent RF signals on either side of the host FM signal. In conventional FM stereo broadcasting, normal deviation of the carrier (modulation) does not significantly contribute to the recovered composite baseband noise floor in a receiver. During laboratory testing of IBOC DAR systems of the type utilizing the adjacent RF signals, modulation of the main analog channel caused an increase in the recovered composite baseband noise floor when the adjacent DAR signals were present.

II. Background

Testing by the Electronic Industries Association's Consumer Electronics Manufacturers Association (EIA/CEMA) DAR Laboratory revealed an unexpected increase in recovered baseband noise when FM modulation occurred in the presence of IBOC DAR system signals of the proposed types using adjacent RF signals. These IBOC systems transmit digital audio at a reduced power level in the first adjacent channels and combine the digital and analog signals at the RF output of the transmitter (see Figure 1).

The noise floor increase was initially detected during the set up and measurement of subcarrier (SCA) performance with and without the DAR signal. During the set up and calibration of analog modulation with the IBOC digital signal, it was observed that *without* analog modulation the baseband noise increase ranged from 15 to 20 dB; *with* analog modulation, the increase was, significantly, 40 dB.

III. Testing

Follow-up testing to explore causes of the 40 dB increase in noise relied upon using a professional SCA receiver, a wideband modulation receiver/analyzer, a spectrum analyzer and synthesized signals. SCA receivers recover information (audio or data) transmitted on subcarrier frequencies typically from 57 kHz to 92 kHz inserted into the composite baseband by the broadcaster. Tests using the SCA receiver revealed that the SCA signal-to-noise ratio is not only impacted by the presence of the digital signal, but also by the addition of main channel modulation (with DAR). Under these conditions, SCA signal-to-noise performance would be reduced by as much as 33 dB. This is significant because main channel modulation would not normally affect SCA performance except under dynamic signal conditions like multipath, which even then would not cause much degradation. Tests with the modulation analyzer showed that the composite baseband noise floor is noticeably increased by the addition of main channel modulation, especially in the regions above 40 kHz.

Testing showed that the RF and IF spectrums were free of distortion and spurious signals with no encroachment of one signal on another. Further testing with other modulation analyzers showed that the baseband noise increase was not limited to, or an anomaly of, one particular type of receiver.

Additional tests substituted the DAR signal with synthesized CW and modulated signals to study the interaction of multiple RF signals at the composite level. The complex DAR signals were replaced with a CW signal (RF1) positioned 200 kHz away from the center of the main channel (RF1). Viewed on a spectrum analyzer the recovered baseband spectrum showed the resultant component at 200 kHz (see Figure 2). Modulation of RF2 resulted in the deviation appearing on the component at 200 kHz (see Figure 3). The same modulation of RF1, while RF2 was not modulated, resulted in precisely the same baseband signature with the component at 200 kHz *appearing* to be modulated even though it was not. More testing showed that modulation of the main channel (RF1) mathematically *added* itself to any existing modulation of RF2 resulting in the component at 200 kHz to appear to have more deviation than it really had, if any. What was demonstrated was that the component at 200 kHz represents the difference between the two RF signals and that frequency modulation -- an instantaneous difference in frequency -- is mirrored in the recovered adjacent component.

As a final investigative step, mathematical modeling of the limiter and FM detector resulted in similar findings under the same signal conditions.

IV. Conclusion

The test results revealed that the characteristics of the limiter and FM detector may be the mechanisms responsible for increasing noise with modulation in the presence of a non-coherent adjacent RF signal. The design of a detector for FM broadcast receivers is normally wideband in nature, typically from 600 kHz up to 1 MHz in bandwidth. This bandwidth is required in order to keep the phase delay of the composite stereo signal, especially the L-R sidebands, very low in order to recover a high quality stereo signal. With the non-linear process of limiting in the limiter section and detector containing non-linear devices, mixing of the two signals occurs. The detector is essentially a mixer with one input being a variable phase-shifted version of the other. If two input signals fall into the linear range of the detector, the output will be proportional to the frequency difference between them.

For example, when signals at 94.1` MHz and 94.2 MHz are applied to an FM receiver, a the detector output will be 100 kHz and harmonics of 100 kHz. Modulation of either carrier will show as modulation (or additional modulation) of the 100 kHz beat, as well as the modulation of the specific carrier. When the undesired adjacent RF signals are modulated, the main channel modulation will effectively be added to any adjacent component recovered by the detector. If the proximity or spacing of the signals is too close, the *added* modulation of the recovered adjacent component caused by the mixing action will "spill" into the composite baseband region and increase baseband noise.

This has implications for implementing IBOC DAR systems.

Figure 1

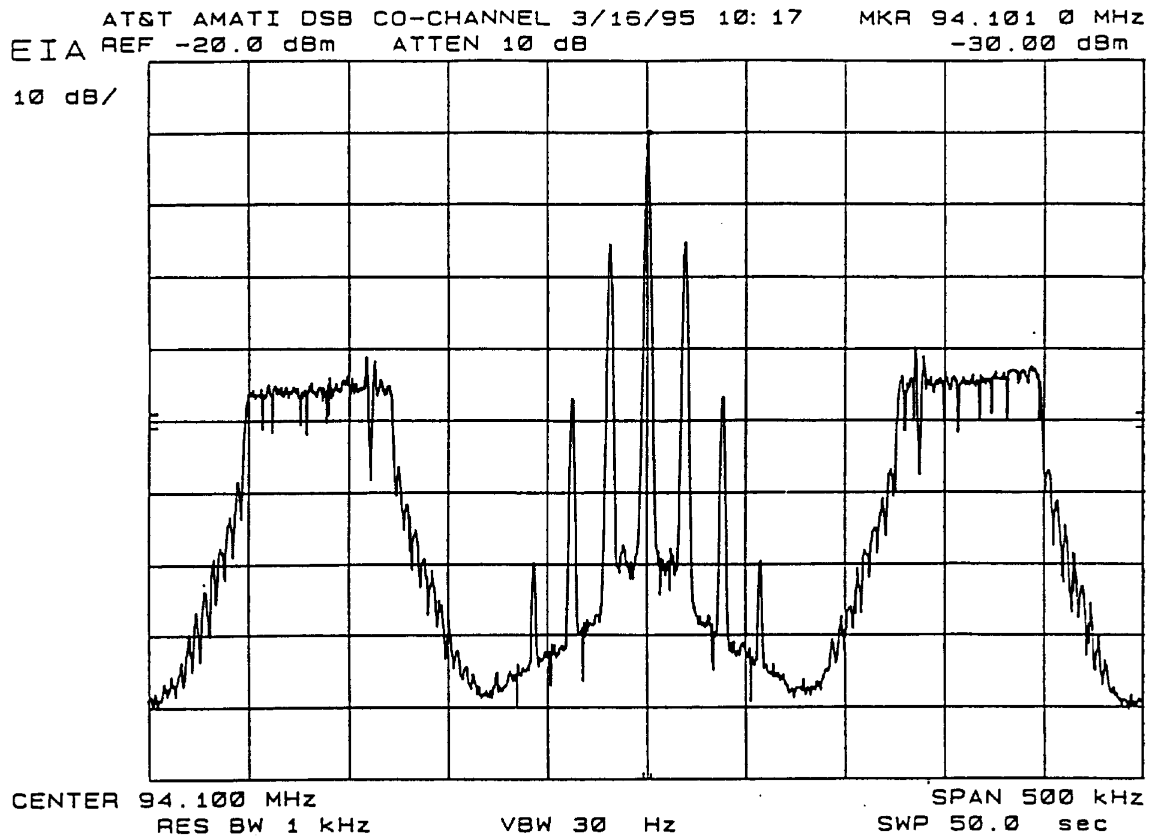
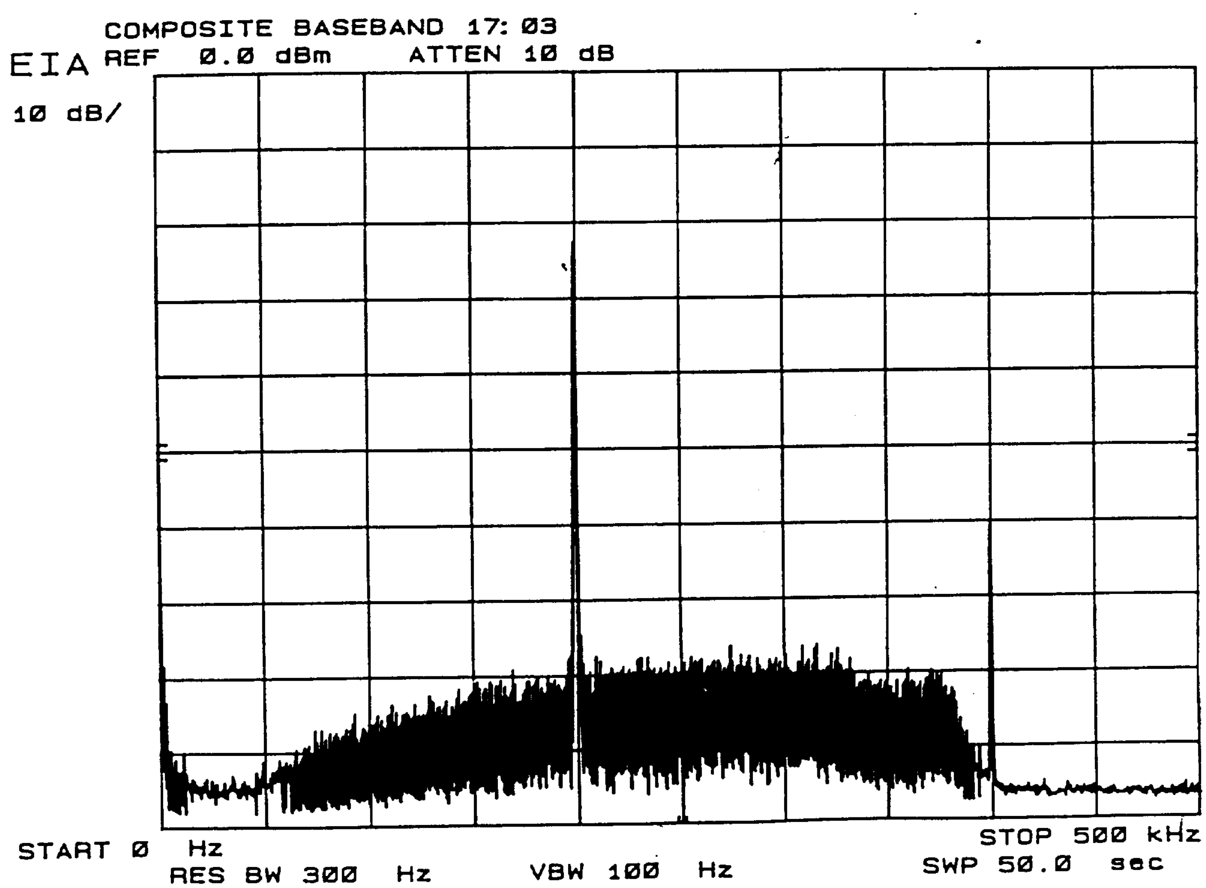


Figure 2



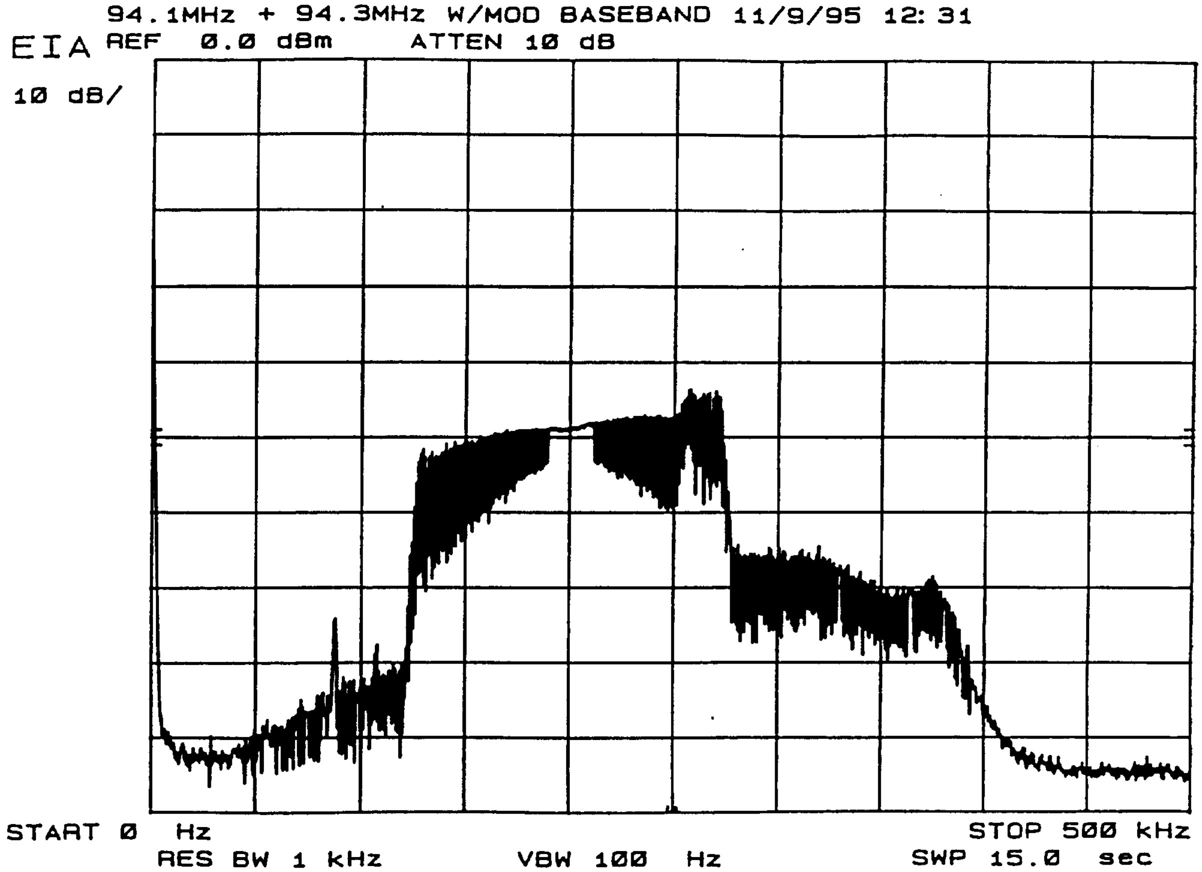

94.1MHz + 94.3MHz W/MOD BASEBAND 11/9/95 12: 31
EIA REF 0.0 dBm ATTEN 10 dB
10 dB/
START 0 Hz
STOP 500 kHz
RES BW 1 kHz
VBW 100 Hz
SWP 15.0 sec

Figure 3

Appendix 7

In-Band Digital Sound Broadcasting Subcarrier Tests

I. Introduction

Two of the FM In-Band/On-Channel (IBOC) Digital Audio Radio (DAR) systems transmit the digital audio on independent upper and lower first adjacent RF signals. During laboratory testing of the adjacent channel IBOC DAR systems, a significant increase in the 92 kHz analog subcarrier noise floor was observed. This noise existed only when the main channel was modulated and with the digital signal present. Controlled conventional main channel modulation does not significantly contribute noise to FM subcarriers. For more information on the theory of this problem, refer to Appendix 6.

II. General Description of Tests

These tests compared the conventional FM station analog and digital subcarrier performance with that of a station transmitting the IBOC digital signal. Strong (-47 dBm) and weak (-77 dBm) signal levels were used for the tests. The tests were also conducted with simulated multipath. The results multipath are not included in the document. RMS noise measurements were used for the analog subcarriers. The main program channel was modulated with clipped pink noise. Total modulation for the analog channel was set for 110%.

The IBOC to FM subcarrier tests were conducted for the IBOC systems using three different subcarrier groups:

Group A: 57 kHz RBDS 3% injection, 66.5 kHz HS digital (Seiko) 8.5% injection, and 92 kHz FM 8.5% injection.

Group B: 57 kHz RBDS 10% injection and 67 kHz analog 10% injection.

Group C: Not used in this test series.

Group D: 92 kHz digital (Mainstream Data) 10% injection

III. Test Results

The test results without multipath are shown in Table 1. The subcarrier data on the FM line is the reference without the digital signal. For the -47 dBm signal level tests, the two systems transmitting the digital signal in the first adjacent channels showed a 26 dB increase in the noise floor for the 92 kHz analog subcarrier. The 57 kHz RBDS and 66.5 kHz digital subcarriers were not effected by the addition of the digital signal. The 67 kHz FM subcarrier noise floor was increased by 4 dB.

The weak signal level (-77 dBm) was too low for the 66.5 and 92 kHz subcarriers to operate. The 92 kHz subcarrier showed a 6 dB increase in noise floor with the IBOC systems that transmit the digital in the upper and lower first adjacent channels.

IV. Receivers Used for the Tests

SERVICE	RECEIVER
57 kHz RBDS:	Denon TU-380D
66.5 kHz Digital:	Seiko RPA
67 kHz Analog:	Compol SCA receiver
92 kHz Analog:	Compol SCA receiver
92 kHz Digital:	Mainstream Data

V. Ancillary Data

Each of the DAR systems incorporates an ancillary data channel within the digital audio channel. The BER for this channel was measured with the interference set at the level that produced TOA for each of the noise and co-channel impairments.

EIA Digital Audio Radio Test Laboratory

Test L-2 & L-3 Subcarriers DAR -> Host SC		Composite Subcarrier Group A			Composite Subcarrier Group B		Group D		
		57 KHz RBDS 3% ERRORS MAX (%)	66.5 KHz HS Data 8.5% ERRORS log BER	92KHz Analog 8.5% S/N (dB)	57KHz RBDS 10% ERRORS MAX:(%)	67KHz Analog 10% S/N (dB)	92KHz Digital 10% SS # FEC1	#FEC2	SQ #UNC
FM	Strong Signal Level (-47 dBm)	0	-6	46	0	45.3	210 0	0	170 0
AT&T / Amati DSB	Strong Signal Level (-47 dBm)	0	-5.95	20	0	41	209 1290	4558	92-130 455
AT&T / Amati LSB	Strong Signal Level (-47 dBm)	0	-6	27	0	43	209 1310	4272	76-130 475
USADR FM1	Strong Signal Level (-47 dBm)	0	-5	20	0	41	209 1350	6199	58-109 288
USADR FM2	Strong Signal Level (-47 dBm)	0	-5.3	32.5	0	43.2	210 0	0	167 0
FM	Weak Signal Level (-77 dBm)	0	NA	22.4	0	35.4	113 NA	NA	0 NA
AT&T / Amati DSB	Weak Signal Level (-77 dBm)	0	NA	16	0	34		NA	
AT&T / Amati LSB	Weak Signal Level (-77 dBm)	0	NA	18	0	34.5		NA	
USADR FM1	Weak Signal Level (-77 dBm)	0	NA	16	0	33.5		NA	
USADR FM2	Weak Signal Level (-77 dBm)	0	NA	19.9	0	34.6		NA	

NOTES:
- Digital SCA's graded as the number of observed errors within a five minute period.
- 57KHz RDS: Error = Percentage of maximum block errors indicated by MAX:(%) in the RDS CHECKUP utility
- 66.5KHZ Seiko: Error = Average log BER observed on the Seiko RPA utility with a print-out of a typical 20 sec. segment
- 92KHz Mainstream: Error = # FEC1, # FEC2, # Blocks Uncorrected(#UNC) figures, as indicated on the Mainstream receiver. Failure considered as > 5 first layer errors (# FEC1) in a five minute period.
- Main channel modulation: Abba
- NA = RF level too low for proper operation

EIA Digital Audio Radio Test Laboratory

Test L-4 Subcarriers DAR -> Host SC Moderate Signal Level		Composite Subcarrier Group A			Composite Subcarrier Group B		Group D		
		57 KHz RBDS 3% ERRORS	66.5 KHz HS Data 8.5% (log BER)	92KHz Analog 8.5% EO&C	57KHz RBDS 10% ERRORS	67KHz Analog 10% EO&C	92KHz Digital 10% ERRORS # FEC1	# FEC2	# UNC
FM	Urban Slow Rayleigh	2	-5.5	Good audio. medium noise and some main chan. audio noise detected during fades	0	Good audio with mild noise during fades. Weak main ch. audio noise heard during fades	110	142	3
AT&T / Amati DSB	Urban Slow Rayleigh	4	-5.2	Poor audio (raspy) with main chan. audio noise heard at all times - worse during fades Unusable audio	2	Good audio with mild main channel audio noise heard during the fades Usable audio	1274	4608	524
AT&T / Amati LSB	Urban Slow Rayleigh	4	-4.8	Fair audio quality with main channel audio noise heard in background most of the time Usability: Marginal	3	Good audio with mild main channel audio heard during the fades Usable audio	1334	1325	219
USADR FM1	Urban Slow Rayleigh	3	-4.5	Poor audio (raspy) with main chan. audio noise heard at all times - worse during fades Unusable audio	3	Fair audio with mild main channel audio at all times - more during fades Usable audio	1333	5494	626
USADR FM2	Urban Slow Rayleigh	2	-3.8	Fair audio - noisy (hiss) most of the time - worse during fades usable audio	1	Good audio with mild noise during fades Usable audio	965	1023	106
FM	Urban Fast Rayleigh	11	-2.6	Good audio with medium multipath type spits Usable audio	8	Good audio with mild multipath type spits Usable audio	271	527	245
AT&T / Amati DSB	Urban Fast Rayleigh	12	-2.3	Poor raspy audio with severe tearing sounds. Main chan. audio noise heard at all times Unusable audio	9	Fair audio with medium multipath type spits Usable audio	318	684	300
AT&T / Amati LSB	Urban Fast Rayleigh	12	-2.4	Fair audio quality - noisy with some main channel audio noise Usabilty: Marginal	11	Fair audio with medium multipath type spits Usable audio	273	644	249
USADR FM1	Urban Fast Rayleigh	13	-2.1	Poor raspy audio with severe tearing sounds. Main chan. audio noise heard at all times Unusable audio	9	Fair audio with medium to heavy spitting or tearing noise Usability: Marginal	294	716	257
USADR FM2	Urban Fast Rayleigh	1	-1.9	Fair audio quality -noisy with faint whine in background Usable audio	0	Good audio with medium multipath type spits Usable audio	254	405	238

NOTES:
* Digital SCA's graded as the number of observed errors within a five minute period.
* 57KHz RDS: Error = Percentage of maximum block errors indicated by MAX:(%) in the RDS CHECKUP utility
* 66.5KHZ Seiko: Error = Average log BER observed on the Seiko RPA utility with a print-out of a typical 20 sec. segment
* 92KHz Mainstream: Error = # FEC1, # FEC2, # Blocks Uncorrected(#UNC) figures, as indicated on the Mainstream receiver. Failure considered as > 5first layer errors (# FEC1) in afive minute period
* Analog SCA quality: EO&C of 1KHz audio quality
* Main channel modulation : Abba
* Mainstream data not valid - Rx not in lock during multipath

File Name: LSC.XLS L-4 SC

APPENDIX 8

International Telecommunication Union
Radio Communication Study Groups
Working Party 10B

Document 10B/USA-L
September 4, 1996
Original: English

UNITED STATES OF AMERICA

Update on In-Band On-Channel Digital Sound Broadcasting Development

I. Introduction

The development of IBOC-DSB continues to proceed. Testing has revealed several criteria critical to the practical acceptance of IBOC-DSB. This paper describes those criteria as well as various design strategies being used to address these acceptance criteria.

II. Progress to Date

IBOC-DSB has been under development since 1990. IBOC-DSB systems have either claimed or demonstrated various audio codec rates, digital audio fidelity, signal-to-noise performance, digital signal coverage, non-interference with existing analog broadcast signals and performance in interference environments [1-8].

III. Critical Acceptance Criteria

Recent studies have scrutinized several DSB systems, including IBOC-DSB, in light of various criteria critical to the practical acceptance of IBOC-DSB [9]. These issues include digital signal audio quality, non-interference with host analog, digital coverage limited by first-adjacent interference, analog coverage impaired by first-adjacent IBOC-DSB interference and digital coverage limited by second-adjacent interference.

IV. Solutions Under Development

Modifications to existing IBOC-DSB systems are being developed which address these critical acceptance criteria.

Digital audio quality is being addressed through advances in audio codec technology [10-12]. Progressive development in audio codec quality versus codec rate has resulted in improved audio quality with respect to codec rate, as well as in reduced codec rates with respect to transcoded audio quality. Each successive reduction in codec rate enables performance improvements in coverage, interference performance or impaired channel performance as a consequence of the reduced data rate throughput required.

Interference of IBOC-DSB to the host analog has been shown to be most significantly a function of unintentional stereo matrix conversion of odd harmonics of the stereo separation carrier [9,13]. The FM stereo separation carrier at 38 kHz has a third harmonic at 114 kHz. Receivers prone to noise injection due to unintentional third-harmonic conversion are susceptible to FM composite noise within ± 15 kHz of 114 kHz (the third harmonic of 38 kHz), or 99 kHz to 129 kHz [14]. RF signals appearing 99 to 129 kHz removed from the carrier are the most likely to appear between 99 and 129 kHz in the FM composite. Because receivers susceptible to this interference currently exist, avoidance of the ± 99 kHz to ± 129 kHz region of the RF spectrum by IBOC-DSB modulation is effective in reducing or eliminating perceived L-R (stereo separation) noise when listening in stereo on the most vulnerable FM receivers [15].

Coverage limitations resulting from first adjacent analog interference pose significant challenges which are being addressed through the use of diversity IBOC-DSB sidebands. While some IBOC-DSB systems propose signals using spectrum on both adjacent channels to transmit the digital information, improved codec performance should enable a single digital sideband to accommodate the entire required transmission capacity. The use of diversity DSB sidebands refers to duplicate information transmission on each (upper and lower) sideband of the host FM signal.

In the case where first adjacent interference limits IBOC-DSB coverage, application of diversity sidebands enables the receiver to extend coverage by choosing the more reliable of the two IBOC-DSB sidebands. In the case where IBOC-DSB is expected to interfere with existing first-adjacent analog signals, the presence of redundant IBOC-DSB sidebands allows for each sideband's power levels to be established (or modified), as a regulatory matter, to balance IBOC-DSB coverage against potential interference to existing analog first-adjacent channels.

Finally, second-adjacent interference is largely controlled by limiting the spectral occupancy of IBOC-DSB modulation to no more than ± 200 kHz removed from the carrier.

V. Conclusion

Issues of digital signal quality, non-interference with host analog, digital coverage limited by first-adjacent interference, analog coverage impaired by first-adjacent IBOC-DSB interference and digital coverage limited by second-adjacent interference have been identified as critical to the practical acceptance of IBOC-DSB. These issues are being addressed in the United States through advances in audio codec technology as well as modulation spectrum planning and the development of diversity-sideband IBOC-DSB modulation.

VI. Notes

[1] Thomas B. Keller, "Summary of FM Band IBOC Laboratory Tests Results" *Proceedings, Annual Broadcast Engineering Conference*, April 13-18, 1996, pp 5-13.

[2] David H. Layer and David Wilson, "IBOC DAB: Its Potential for Broadcasters," *Proceedings, Annual Broadcast Engineering Conference*, April 13-18, 1996, pp 14-20.

[3] David P. Maxson and David K. Murotake, "On-Carrier Digital FM Technology: A New Approach for Digital Audio Broadcasting and Extra High Speed Data Transmission," *Proceedings, Annual Broadcast Engineering Conference*, April 13-18, 1996, pp 21-26.

[4] Kenneth D. Springer, "Multipath Propagation and Fading Statistics for Digital Audio Broadcasting in the VHF and UHF Bands," *Proceedings, Annual Broadcast Engineering Conference*, April 18-22, 1993, pp 229-233.

[5] Skip Pizzi, "Projected Conversion Costs for Digital Audio Broadcasting," *Proceedings, Annual Broadcast Engineering Conference*, April 18-22, 1993, pp 234-239.

[6] John M. Cioffi and John A.C. Bingham, "Digital Sound Broadcast with Auxiliary Overhead Control," *Proceedings, Annual Broadcast Engineering Conference*, April 18-22, 1993, pp 243-248.

[7] Daniel A. Fleisch, A.J. Vigil and Bill J. Hunsinger, "An In-Band On-Channel FM Digital Audio Broadcast System," *Proceedings, Annual Broadcast Engineering Conference*, April 18-22, 1993, pp 249-258.

[8] Skip Pizzi and Robert Culver, "The Current Context for Digital Radio: Climate, Opinion and Activities in the Industry," *Proceedings, Annual Broadcast Engineering Conference*, April 12-16, 1992, pp 139-148.

[9] Thomas B. Keller, David M. Londa, Robert W. McCutcheon and Stanley S. Toncich, "Digital Audio Radio Laboratory Tests: Transmission Quality, Failure Characterization and Analog Compatibility," Electronic Industries Association, Consumer Electronics Group, Volumes I and II, August 11, 1995.

[10]Nikil Jayant, "Status Report on PAC and MPAC: Perceptual Audio Coders from AT&T," *International Academy of Broadcasting*, October 1994

[11]N. Jayant, J. Johnston and R. Safranek, "Signal Compression Based on Models of Human Perception," *Proceedings of the IEEE*, vol. 81, no. 10, October 1993.

[12]Nikil Jayant, "Signal Compression: Technology Targets and Research Directions," *IEEE Journal on Selected Areas in Communications*, vol. 10, no. 5, June 1992.

[13]Shigeki Inoue, Yoshimi Iso and Masanori Ienaka, "High Quality FM Stereo Decoding IC with Birdie Noise Cancelling Circuit," *IEEE Transactions on Consumer Electronics*, vol. CE-27, no. 3, August 1991, pp. 243-253.

[14]Consumer radio receivers used in analog compatibility testing [9] represent a wide range of susceptibility to spurious noise and interference as described in [13]. Receivers susceptible to spurious noise and interference are also vulnerable to noise induced by existing adjacent channel interference. Receiver manufacturers today employ remedies which, applied to the design of receivers to mitigate existing adjacent channel interference, are effective as well in mitigating potential interference of IBOC-DSB with FM stereo [15].

[15]Unintentional stereo matrix conversion of odd harmonics of the stereo separation carrier presently introduces noise due to existing first adjacent channel interference. Receiver manufacturers presently mitigate this interference by including combinations of effective FMIF filtering, FM composite filtering (lowpass below 99kHz) and harmonic conversion cancellation in the design of currently manufactured FM receivers. Today's FM stereo receiver designs often employ at least one of these three interference mitigation techniques, sometimes more, depending on market and cost considerations.

Appendix 9

"*IMPROVED IBOC DAB TECHNOLOGY FOR AM AND FM BROADCASTING*" Brian W. Kroeger, Westinghouse Wireless Solutions Co., A.J. Vigil, USA Digital Radio, presented and distributed at the September, 1996 Society of Broadcast Engineers convention.

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Evaluations of IBOC systems proposed by USADR revealed deficiencies in measured performance. Compromises in coverage area may be necessary as theoretical limits are approached. Discussed are those weaknesses and certain design modifications and techniques including:

* spread spectrum biorthogonal waveforms with spectral shaping, reduced digital signal injection levels and reduced source coding rate

* waveform analysis and characteristics of autocorrelation and crosscorrelation and equalizer performance, use of Gold codes, OFDM modulation and blend with time diversity