

# **Report Of Intermodulation Product Findings**

***BOSTON, MASSACHUSETTS***

**WBZ-FM – 98.5 MHz.**

**WZLX – 100.7 MHz.**

**WODS – 103.3 MHz.**

**WBMX – 104.1 MHz.**

**Project# 27400**

*June 22, 2012*

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# TABLE OF CONTENTS

## Report of Findings for Intermodulation Product Measurements

Page 3-4.....	Introduction
Page 5 .....	Carrier Reference Levels
Page 5 .....	Table of Third order Products Expected
Page 6 .....	Intermodulation Product Measurements
Page 7 .....	Conclusion
Page 8 .....	Affidavit

## Exhibits Accompanying This Report

<b>EXHIBIT A</b> .....	Antenna and Combiner Specification Sheet and Drawing
A-1.....	Drawing Depicting Antenna
A-2.....	ERI Antenna Specification Sheet
A-3.....	Drawing Depicting Combiner Module
A-4.....	ERI Combiner Specification Sheet
A-5.....	Theoretical Vertical Plane Relative Field Antenna Plots
<b>EXHIBIT B-1</b> .....	Intermodulation Product Measurement Equipment Layout
B-2.....	Broadcasting Scheme of the Multiplexed System

## REPORT OF FINDINGS

### BOSOTON, MASSACHUSETTS BROADCAST FACILITY NEEDHAM, MASSACHUSETTS

**Introduction:** This report of findings is based on data collected at the FM broadcast facility located in Needham, MA. The report includes measurements offered as proof that the combined operations of WBZ-FM (98.5 MHz.), WZLX (100.7 MHz.), WODS (103.3 MHz.), and WBMX (104.1 MHz.) transmitters are in compliance with the FCC Rules and Regulations as required by the Code of Federal Regulations (CFR) Title 47 section 73.317 paragraph (b) through (d). In brief, the collection of measurements presented in this report shows that all possible third order inter-modulation (IM) products generated by this multiplexed system are less than the maximum allowable level as required by section 73.317 (b) through (d). Jeff Taylor of Electronics Research, Inc. located in Chandler, Indiana performed the measurements summarized herein on June 22, 2012.

**The following exhibits are provided:**

Exhibit A:

- A-1 Drawing Depicting Antenna.
- A-2 SHPXA-8AC-HW-SP Antenna Specification Sheet.
- A-3 Drawing Depicting Multiplexed Scheme.
- A-4 Multiplexer Specification Sheet.
- A-5 Theoretical Vertical Plane Relative Field Antenna Plots

Exhibit B:

- B-1 Equipment Employed In Intermodulation Product Measurement.
  - B-2 Broadcasting Scheme of the Multiplexed Systems.
- Table 1. Carrier Reference Levels.  
Table 2. Calculated Third Order Products.  
Table 3. Intermodulation Analysis Measurements.

**Exhibits Accompanying Report:** Exhibit A provides comprehensive information on both antenna and filters used by these radio stations. Exhibit B illustrates the broadcasting scheme of each station, the layout of the equipment used to isolate and measure potential intermodulation products and forward carrier reference levels. Found within Table 1 are the narrow band carrier frequency measurements that provide relative output signal levels for the IM analysis. Table 2 lists the calculated third order products that can be generated from FM transmitters broadcasting from the multiplexed system. The IM Analysis Measurements, in Table 3, provides detailed information obtained from the product frequency investigation.

**The Nature of Intermodulation Products (IM):** Intermodulation products result from inadequate transmitter-to-transmitter isolation. Intermodulation products are commonly generated from radio stations operating into multiplexed facilities and congested antenna broadcast sites. The mechanics associated with the phenomenon have been well documented. When two or more transmitters are coupled to each other, new spectral components are produced by the mixing of the station frequencies in the active circuits of each transmitter. The common term used to describe this phenomenon is third order product denoted by the mathematical expression  $[2(F_1)-(F_2)]$ , where  $F_1$  signifies the frequency of the transmitter that is generating the intermodulation product, and  $F_2$  signifies the frequency causing the interference.

**The Multiplexed System:** These measurements were taken with all FM stations operating from the combined antenna system. The WBZ-FM, WZLX, WODS, and WBMX multiplexed system is fundamentally comprised of antenna, feed line and multiplexer unit. The SHPXA-8AC-HW-SP (antenna), 970-8 Constant Impedance combiner units, and feedline, are products of Electronics Research, Inc. Refer to Exhibit B-1, for an illustration of the Broadcasting Scheme of these stations.

To accomplish the aggregation of four transmitter signals into a common antenna feed and provide transmitter-to-transmitter isolation, a multiplexing scheme consisting of 970-8 Constant Impedance Combiner, filter system was installed. Specifically, the combiner utilizes four ERI Model 970-8 modules for each frequency (98.5 MHz., 100.7 MHz., 103.3 MHz., and 104.7 MHz.). An interconnecting “u-link” is required to complete the combiner which is illustrated in the attached Exhibit A-3. The multiplexer, fully assembled, exhibited transmitter port-to-port isolation in excess of -66 dB. Other performance measurements, such as match, loss, group-delay, etc, revealed that the multiplexer unit was in proper working condition. Refer to Exhibit A-4 for the Combiner Specification Sheet.

**The IM Investigation:** Directional Couplers were placed at key locations throughout the combiner to monitor and maintain the multiplexer’s performance. All couplers furnished with the system are factory calibrated and capable of delivering accurate and repeatable RF measurements. To facilitate the taking of the measurements, the coupler located at the antenna output of the multiplexed system was used. Care was taken in the selection of the measurement location to insure that the measurements would be made far removed from transmitters and any filtering used to reduce broadcast emissions. The coupler selected would normally be used for antenna reflection measurements and thus would provide greater than -54 dB directivity and a forward signal sample of -40 dB.

The forward port of the coupler was used for sampling the outgoing carrier levels and IM products. The IM sampled signal was fed by shielded cable into a Band Pass Filter where all extraneous energy was steeply attenuated. Various attenuation pads were used, when needed, on the band pass filter and/or the Spectrum Analyzer to ensure an adequate signal level for measurements without overloading the measurement equipment. A Rohde & Schwarz ZVL Vector Network Analyzer with Spectrum Analyzer serial# 100396 was employed to record the level of all signals investigated. The Rohde & Schwarz was also used for selective tuning of the Band Pass Filter. The Spectrum Analyzer portion of the Rohde & Schwarz was used to measure the close in spectral attenuation of each carrier and wide band search for any anomalies that may need further investigation. See attached Exhibit B-1 for an illustration of the measurement equipment.

Prior to recording measurements, all pertinent broadcasting equipment including Transmitters, Multiplexer, Feed Line and Antenna were adjusted to optimal performance. Also, it was confirmed before taking any measurements that all transmitters were operating at full licensed power. From the equipment setup described above, the relative output signal level of each stations forward carrier was made. The resulting signal levels of these measurements are listed in Table 1, column labeled "Adjusted Level". This level will be used as the reference level for possible IM products of each carrier and was necessary to confirm that no significant levels of spurious energy, referenced to each carrier, were present from any transmitter operating from the multiplexed system.

**Table 1 - Carrier Reference Levels.**

<b>Carrier Frequency (MHz)</b>	<b>Pad One (dB)</b>	<b>Bandpass Filter Loss (dB)</b>	<b>Measured Level (dBm)</b>	<b>Adjusted Level (dBμ)</b>	<b>Notes</b>
<b>98.5</b>	<b>6</b>	<b>-</b>	<b>16.04</b>	<b>22.04</b>	
<b>100.7</b>	<b>6</b>	<b>-</b>	<b>11.04</b>	<b>17.04</b>	
<b>103.3</b>	<b>6</b>	<b>-</b>	<b>16.27</b>	<b>22.27</b>	
<b>104.1</b>	<b>6</b>	<b>-</b>	<b>11.59</b>	<b>17.59</b>	

Predictable third-order products due to system harmonics mixed with all on-site interfering frequencies that could be generated from the multiplexed system are calculated and listed in Table 2.

**Table 2 - Third order Products.**

<b>Interfering Frequencies</b>	<b>Carrier Frequencies</b>			
	<b>98.5</b>	<b>100.7</b>	<b>103.3</b>	<b>104.1</b>
WBZ-FM 98.5 MHz.	----	102.9	108.1	109.7
WZLX 100.7 MHz.	96.3	----	105.9	107.5
WODS 103.3 MHz.	93.7	98.1	----	104.9
WBMX 104.1 MHz.	92.9	97.3	102.5	----

Using the equipment previously described the IM product measurements were recorded and are listed in Table 3. The signal levels referenced to the carriers are calculated and listed in the column labeled "Level Referenced to Carrier". Refer to Exhibit B-2 for a layout of the measurement equipment.

**Table 3 – Intermodulation Measurements**

IM Measurements Taken in										
Product Frequency (MHz)	Transmitter Frequency (MHz)	Interfering Frequency (MHz)	Pad (dB)	Bandpass Filter Loss (dB)	Total Loss	Measured Level (dBm)	Adjusted Level (dBm)	Carrier Reference Level (dBm)	Level Referenced to Carrier (dBm)	Notes*
<b>Transmitter Mixes</b>										
	<b>98.5</b>		6		6	16.04	22.04	<b>22.04</b>		
	<b>100.7</b>		6		6	11.04	17.04	<b>17.04</b>		
	<b>103.3</b>		6		6	16.27	22.27	<b>22.27</b>		
	<b>104.1</b>		6		6	11.59	17.59	<b>17.59</b>		
92.9	98.5	104.1	6	7.86	13.86	-87.84	-73.98	22.04	<b>-96.02</b>	
93.7	98.5	103.3	6	7.86	13.86	-82.82	-68.96	22.04	<b>-91.00</b>	
96.3	98.5	100.7	6	7.87	13.87	-82.34	-68.47	22.04	<b>-90.51</b>	
97.3	100.7	104.1	6	7.78	13.78	-84.07	-70.29	17.04	<b>-87.33</b>	
98.1	100.7	103.3	6	8.21	14.21	-84.78	-70.57	17.04	<b>-87.61</b>	
102.5	103.3	104.1	6	8.04	14.04	-83.55	-69.51	22.27	<b>-91.78</b>	
102.9	100.7	98.5	6	8.16	14.16	-86.03	-71.87	17.04	<b>-88.91</b>	
104.9	104.1	103.3	6	8.04	14.04	-84.82	-70.78	17.59	<b>-88.37</b>	
105.9	103.3	100.7	6	7.67	13.67	-85.67	-72	22.27	<b>-94.27</b>	
107.5	104.1	100.7	6	8.09	14.09	-84.41	-70.32	17.59	<b>-87.91</b>	
108.1	103.3	98.5	6	8.23	14.23	-86.13	-71.9	22.27	<b>-94.17</b>	
109.7	104.1	98.5	6	7.77	13.77	-84.95	-71.18	17.59	<b>-88.77</b>	

The Spectrum Analyzer was used to check the close in spectral attenuation of the carrier to confirm the operation of the transmitter is in compliance with Sections (b) and (c) of the FCC Rules and Regulations.

As a final proof of the systems IM Product performance, a wide band search was undertaken using the Spectrum Analyzer. The purpose for this measurement was to look for suspicious anomalies that may warrant further investigation. My search ranged the complete frequency span of the receiver and resulted in no additional investigations.

**Conclusion:** Based upon my observations and measurements taken on June 22, 2012 as summarized in this document, I, Jeff Taylor, find the subject system, specifically the transmitter and filter system for the operation of WBZ-FM, WZLX, WODS, and WBMX into the antenna to be in proper working order. Furthermore, based on the measured data, it is my opinion that there are no inter-modulation products in excess of 80 dB below carrier levels generated from or within the station operating on the installed system. Based on this recorded data, I conclude that WBZ-FM, WZLX, WODS, and WBMX are in compliance with the requirements of Section 73.317 paragraph (b) through (d) of the FCC Rules and Regulations.

Respectfully submitted,  
Electronics Research, Inc.

Jeff Taylor, Field Technician





**A-2 ERI Antenna Specification Sheet**

**AUXILIARY TRANSMISSION SITE  
NEEDHAM, MASSACHUSETTS**

**General Specifications**

Antenna Type ..... High Power FM-Broadcast, Suitable For Multiplexing  
 Model Number ..... SHPXA-8AC-HW-SP  
 Number of Bay Levels ..... Eight  
 Polarization ..... Right Hand Circular

**Electrical Specifications**

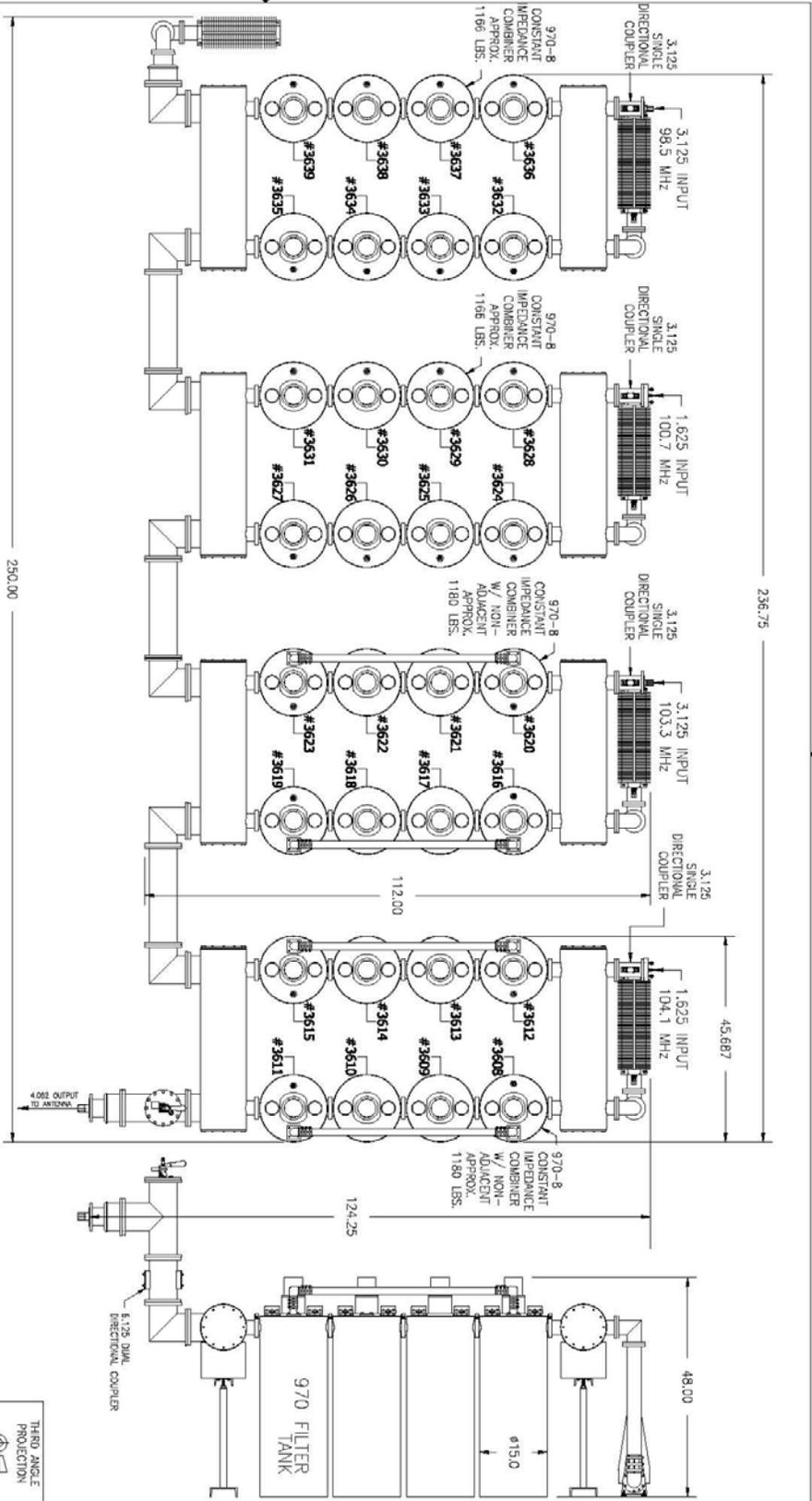
Antenna Input Power Capability ..... 20 kW Max <sup>(1)</sup>  
 Operating Frequency Band ..... 88 ~ 108 Megahertz.  
 VSWR ..... <1.11:1 @ Operating Frequencies<sup>(2)</sup>  
 Azimuthal Pattern Circularity ..... Better Than +/- 2dB From RMS ( Free Space )  
 Power Split ..... 50/50 ( Horizontal & Vertical )  
 Frequency Specific Information:

<u>Frequency</u>	<u>Station ERP</u>	<u>Beam Tilt</u>	<u>First Null Fill</u>	<u>Second Null Fill</u>	<u>Power Gain</u>	<u>Line Loss</u> <sup>(3)</sup>	<u>Filter Loss</u> <sup>(4)</sup>	<u>Computed TPO</u>
98.5	16.0 KW	0°	0.5 %	0 %	2.531	-0.6926 dB	-0.471 dB	8.264 kW
100.7	3.80 KW	0°	2.7 %	0 %	2.580	-0.6926 dB	-0.488 dB	1.933 kW
103.3	15.0 KW	0°	5.3 %	0 %	2.632	-0.7020 dB	-0.529 dB	7.567 kW
104.1	3.70 KW	0°	6.1 %	0 %	2.646	-0.7114 dB	-0.400 dB	1.806 kW

**Mechanical Specifications**

Antenna Feed System ..... Single Input  
 Input Connector ..... 6 1/8"-50 Ohm EIA Flanged  
 Element Deicing..... None  
 Interbay Spacing ..... 60" Center to Center  
 Array Length..... 40 Feet  
 Construction Material ( Antenna ) ..... Galvanized Plated Steel and Stainless Steel  
 Construction Material ( Mounting )..... Leg

1) Power Capability Has Been Rated Assuming an Operating Transmission VSWR of 1.5:1  
 2) VSWR Specification Achieved After On Site Tuning For User Specific Frequencies.  
 3) Line Loss Assumes A Feed Run of 936 Feet of MACXLine-450 4 1/16" Rigid.  
 4) Losses Taken From Actual Combiner.



FINISH	MATERIAL	UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES. TOLERANCES		DRAWN BY	03/08/2011	<b>ERI</b> ELECTRONICS RESEARCH, INC. Established 1943 © COPYRIGHT 2010 ERI, ELECTRONICS RESEARCH, INC. 7777 GARDNER RD. CHANDLER, IN. 47810-9637 PHONES: (812) 925-8000 FAX: (812) 925-4288
ALL SURFACES		UNLESS OTHERWISE SPECIFIED		S.D.EOM		
		1 PLACE DECIMALS ± .030 2 PLACE DECIMALS ± .010 3 PLACE DECIMALS ± .003 ANGLE ± .5°		DESIGN MGR.	04/12/2011	INSTALLATION MULTIPLEXER-FM COMBINER REPORT-BOSTON, MA (27400/2) 98.5 MHz, 100.7 MHz, 103.3 MHz & 104.1 MHz
				G.H.		
				ENG.		SIZE
				MANUF.		A
				SUPERSEDES PART NO.		CAGE CODE
						0ZNS1
						DWG NO.
						IM27400-R
						SCALE .030=1.00
						FILE NO.
						IM27400-R
						SHEET 1 OF 1

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**A-4 ERI Combiner Specification Sheet**

**AUXILIARY TRANSMISSION SITE  
NEEDHAM, MASSACHUSETTS**

**General Specifications:**

**Multiplexer Type ..... Band Pass Constant Impedance  
Number of Combining Units ..... Four  
Injected Port to Injected Port Isolation ..... < - 66 dB  
Output Connector ..... 6 1/8 "50 Ohm EIA (Flanged)  
Output Power (Designed) ..... 20 kW<sup>(1)</sup>**

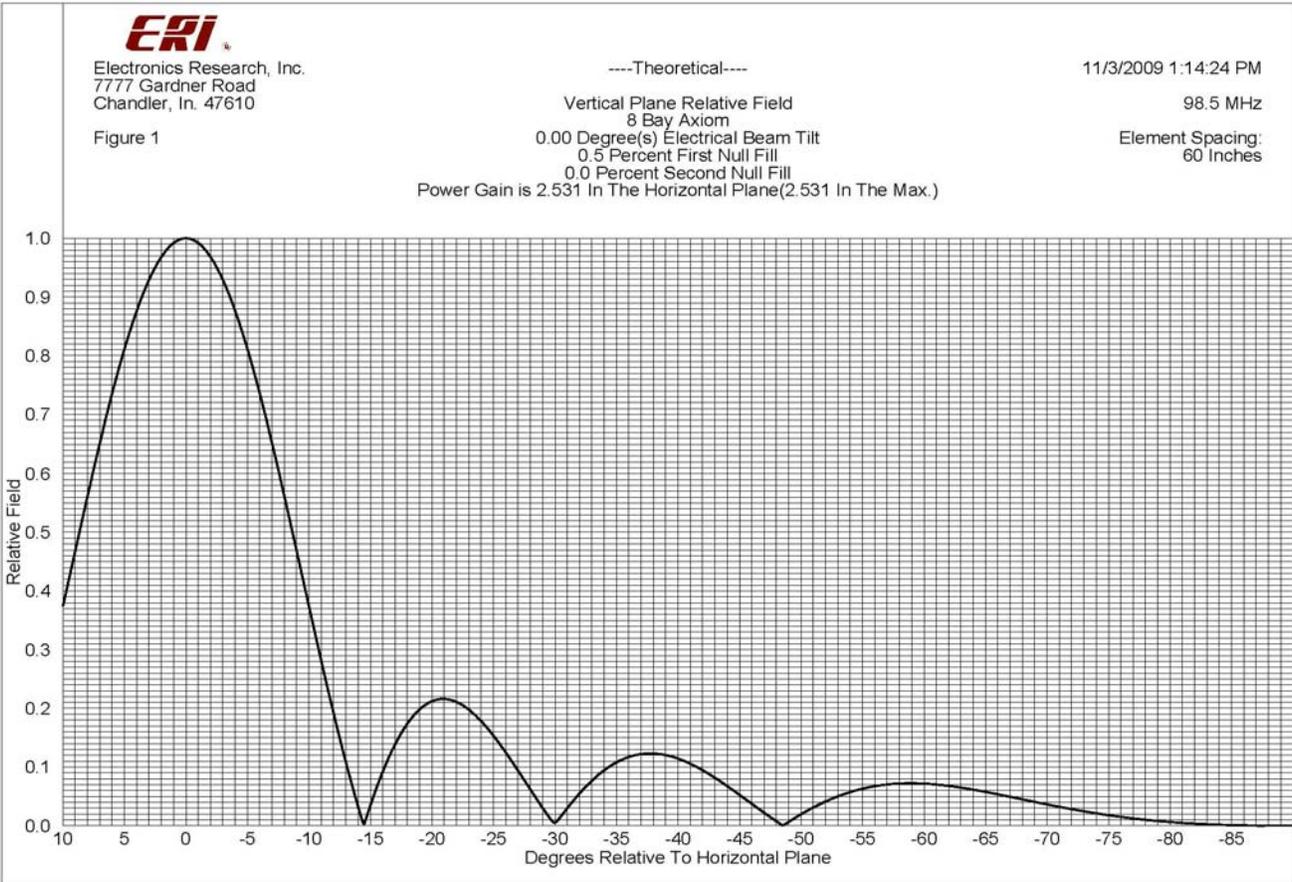
**Heat Removal ..... Natural Convection  
Physical Arrangement ..... All Components Floor Standing**

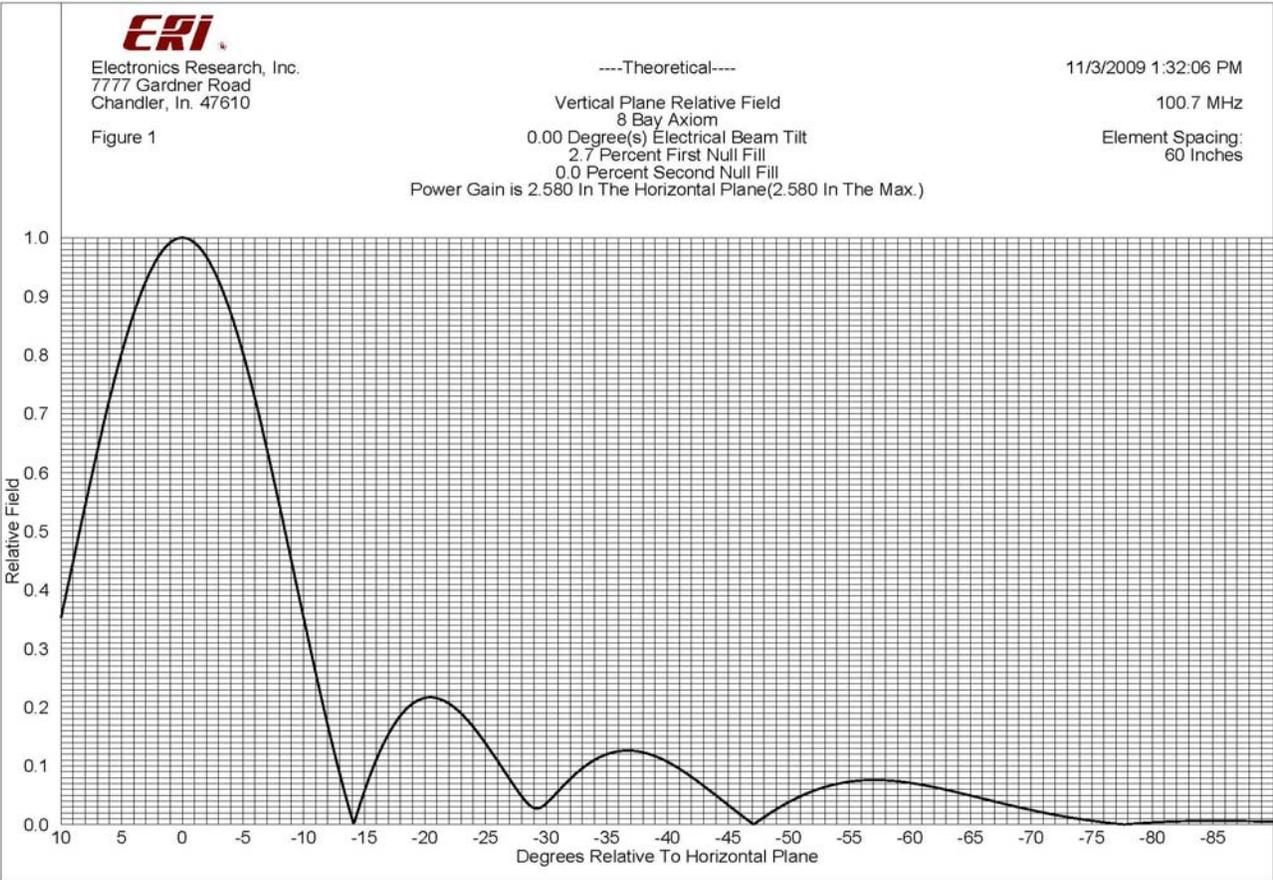
**Injected Port Specifications:**

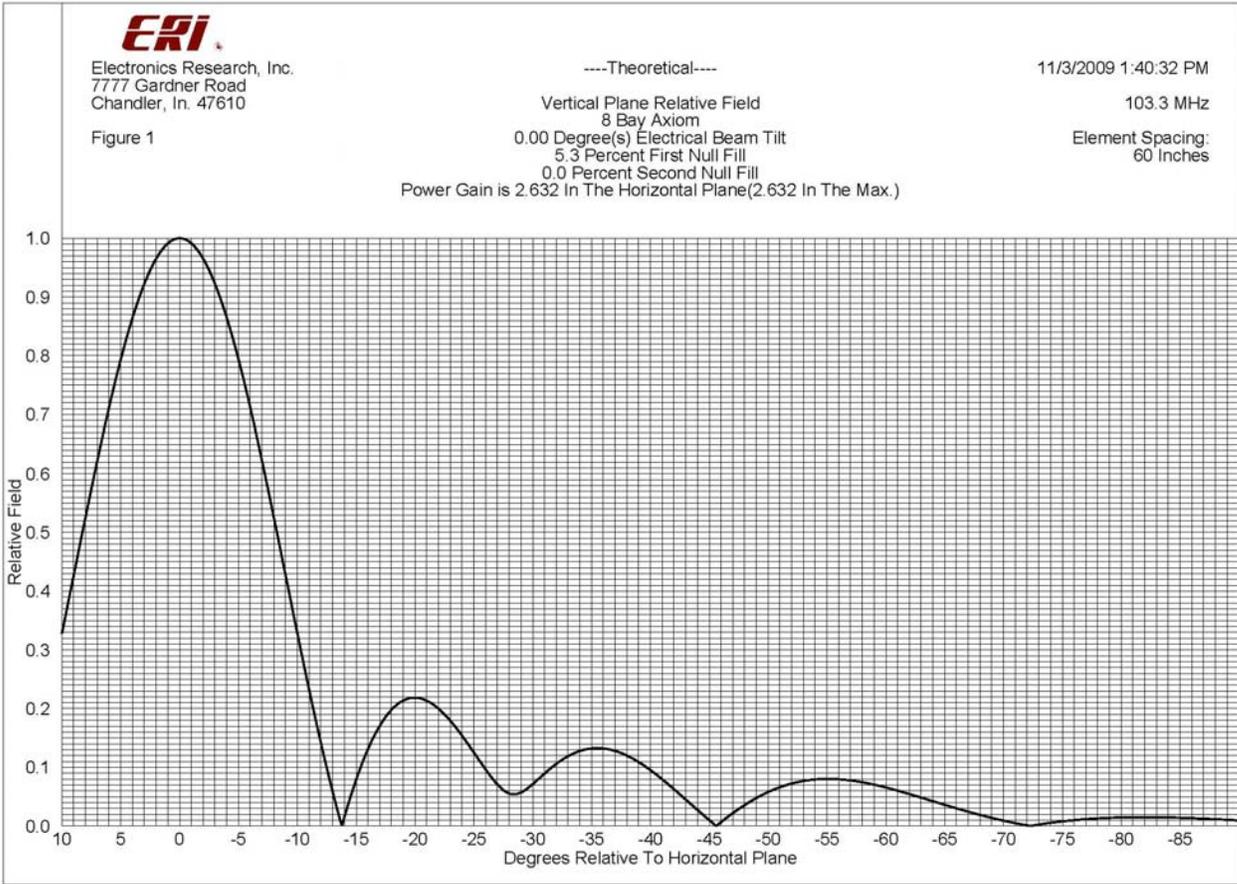
**Frequency Assignment ..... 98.5 ~ 100.7 ~ 103.3, and 104.1 MHz.  
Power Rating, Each Injected Port (Designed) ..... 10 kW  
Input Connector ..... 3-1/8" 50 Ohm EIA (Flanged).  
VSWR.....< 1.06:1 @ +/-200 KHz.<sup>(2)</sup>  
Group Delay .....Less than 175 ns Overall Variation, Carrier @ +/- 150 KHz.  
Insertion Loss (Measured):**

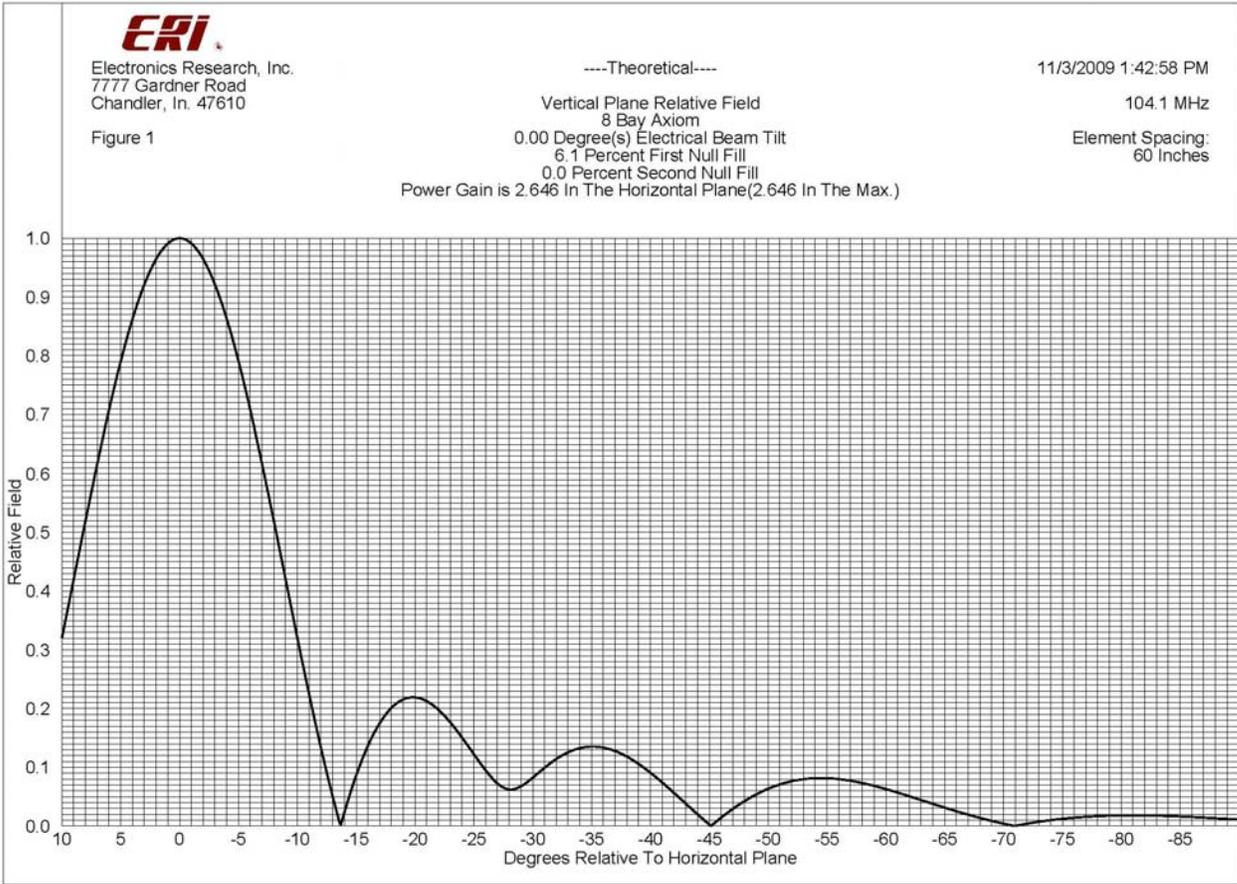
**98.5 MHz. .... - 0.471 dB  
100.7 MHz. .... - 0.488 dB  
103.3 MHz. .... - 0.529 dB  
104.1 MHz. .... - 0.400 dB**

1) Power Rating Listed is as Designed Only. Actual Power Capabilities May Vary.  
2) When Terminated in 50 Ohm Resistive Load.









## Broadcasting Scheme and Equipment Employed in Intermodulation Measurements

