AM IBOC
Ascertainment Project
Corporation for Public Broadcasting

The dTR/H&D Joint Venture

A Joint Venture of duTreil, Lundin & Rackley and Hatfield & Dawson

Project Objectives

- Determine if AM IBOC can be successfully added to AM Public Radio Stations
- Provide Information that will optimize the performance of the AM Station for improvements to both Analogue and IBOC
- Identify Problem Installations
- Provide Suggestive Remedies for Conversion to IBOC

Project Components

- Site Visits to 53 CPB Qualified AM Stations from the Bering Sea to Puerto Rico
- Station Physical Inspection
- Antenna System Measurements
  - System Bandwidth
  - Directional System Performance


WA
KWSU
KOAC
KBPS
KTBR
KRVM
OR
KAGI
KSYC
KSJK
KMJC
KSNA
KPMO
CA
NV
ID
KBSU
MT
WY
UT
KCFR
KGNU
KCFC
CO
KKPC
AZ
KUAZ
KAWC
KABR
NM
ND
SD
NE
KS
OK
TX
MN
KUOM
KRNI
IA
WOI
WSUI
MO
AR
LA
WLBL
WI
WHA
WILL
IL
MI
WGVU
WKAR
WBAA
IN
WOSU
OH
WOUB
KY
TN
MS
AL
GA
FL
SC
WWVT
NC
WV
VA
WVMR
MD
DE
PA
NJ
WSHU
WNED
WPSE
WXXI
WAMC
NY
VT
NH
ME
MA
CT
WFPB
WBUR
WIPR
CBP Stations
0 200 400 600
Kilometers


KBRW
Barrow
KOTZ
Kotzebue
KZPA
Fort Yukon
KIYU
Galena
ALASKA
KNSA
Unalakleet
KSKO
McGrath
ANCHORAGE
KCHU
Valdez
KYUK
Bethell
JUNEAU
KBBI
Homer
KDLG
Dillingham
KSDP
Sand Point
AK CBP Stations
0 100 200 300
Kilometers

Project Analysis and Report

- Antenna System’s compliance with Ibiquity’s recommended “desired characteristics”
- Information for optimization for both IBOC and Analog system
- Report problems installations
- Recommendations for IBOC implementation

Non-DA Antennas

Poor Performance May Result from:

- Electrically Short Antennas
- Poor Skirt-Feed Design
- Odd Vertical Geometry or Other Antenna Mounting or Structural Geometry

Directional Antennas

Poor Performance May Result from:

- High RSS/RMS Ratio
- Non-Optimum Feed System
- Possible Parameter Inversion
- Unfortunate Choice of System Geometry

RMS = Pattern Size

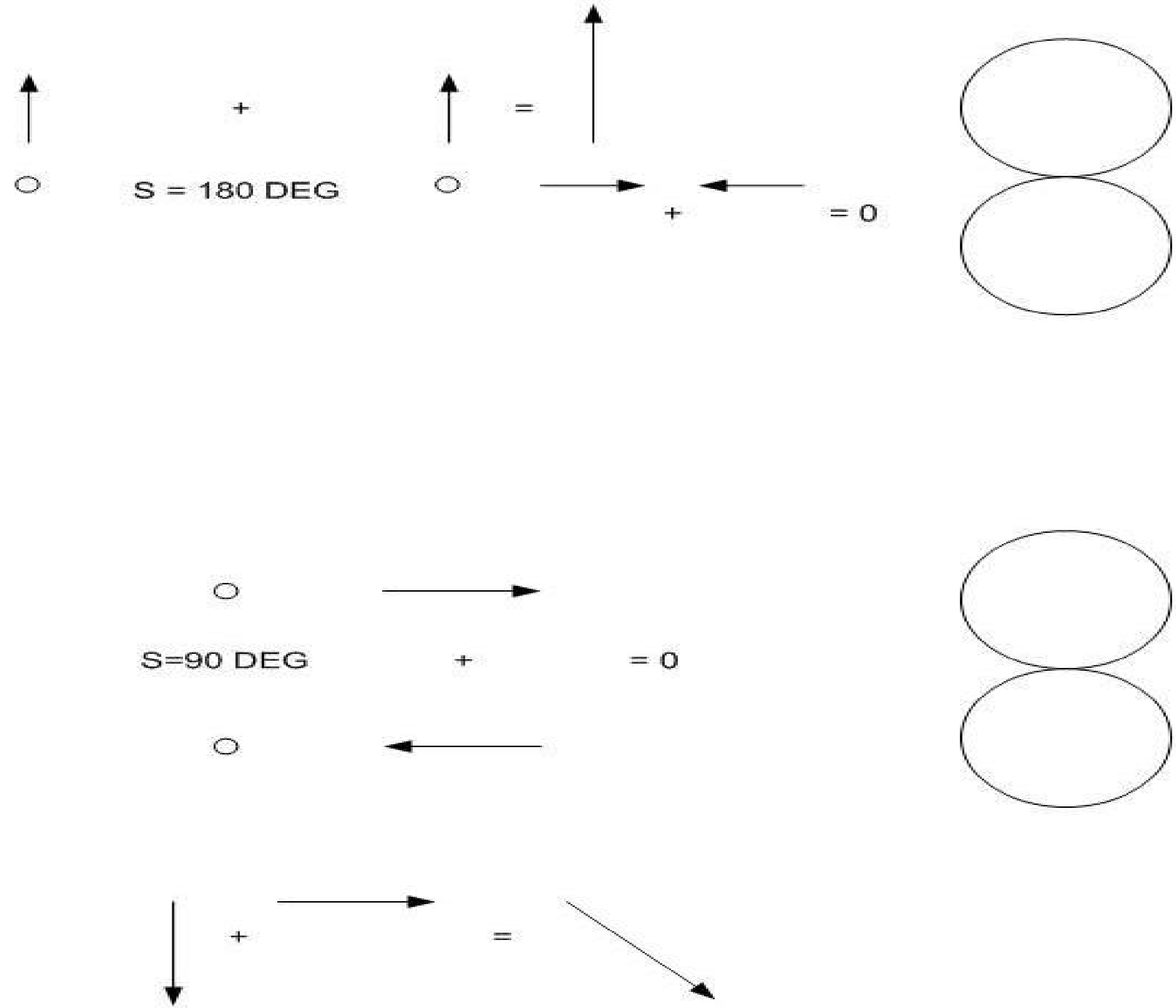
RSS = $(E_1^2+E_2^2+..+E_n^2)^{½}$

If E values are large

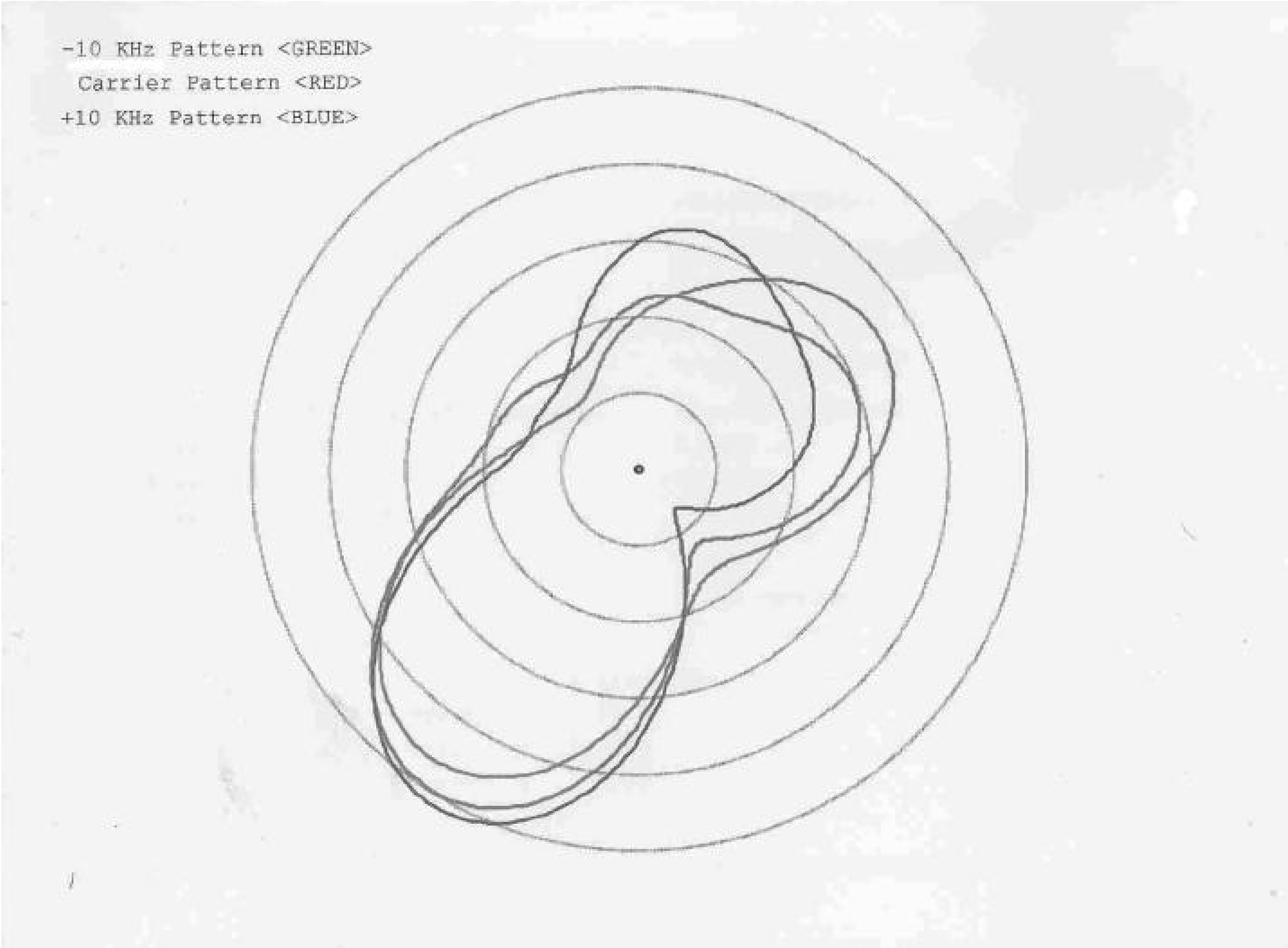
system is “sensitive” to small % changes

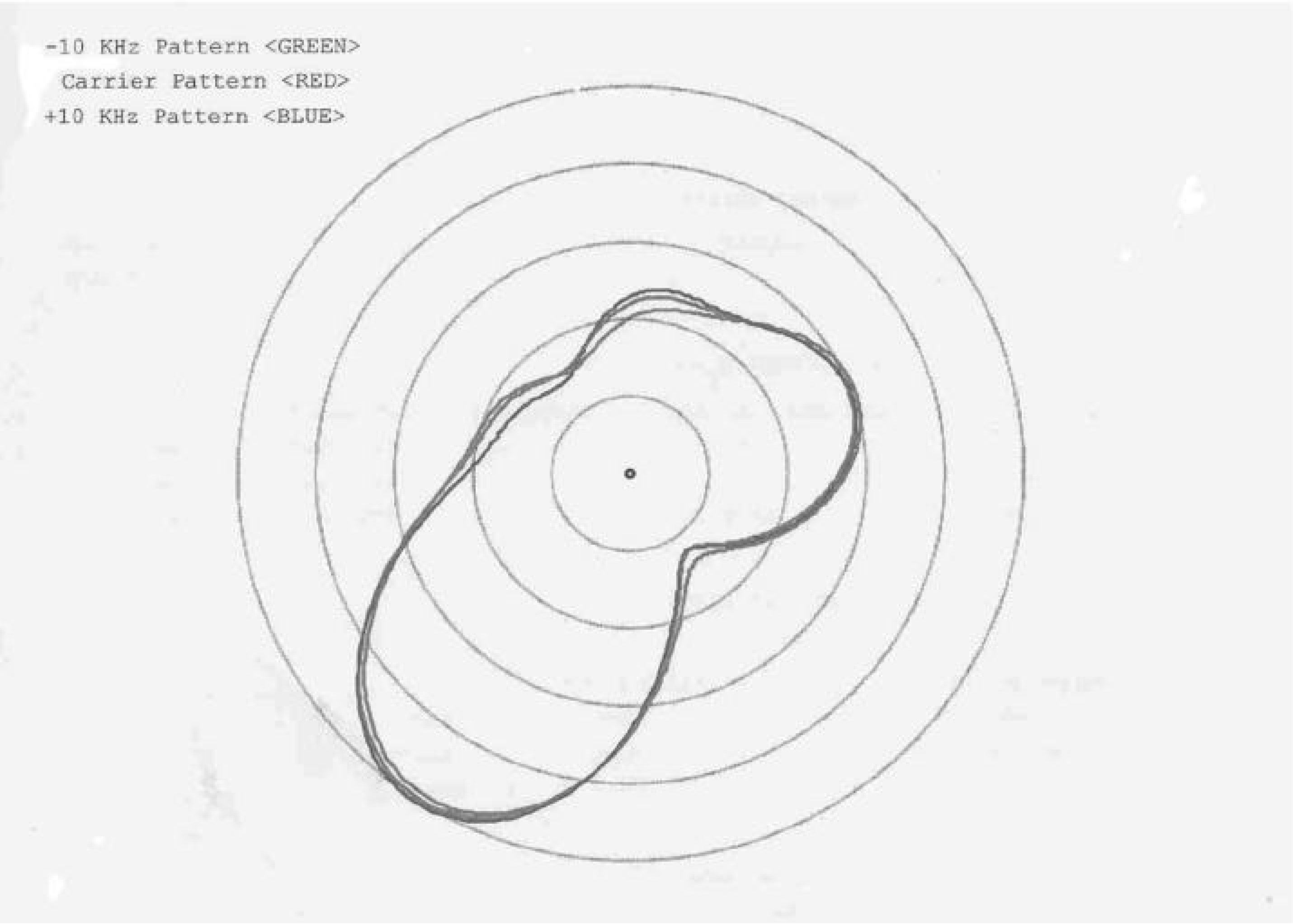
If E values are small

system is more stable and has less change with frequency (sidebands)



+
=
S = 180 DEG
+
= 0
S=90 DEG
+
= 0
+
=


-10 KHz Pattern <GREEN>
Carrier Pattern <RED>
+10 KHz Pattern <BLUE>


-10 KHz Pattern <GREEN>
Carrier Pattern <RED>
+10 KHz Pattern <BLUE>


-10 KHz Pattern <GREEN>
Carrier Pattern <RED>
+10 KHz Pattern <BLUE>

With simple straightforward feed system designs

	Lower VSWR	Upper VSWR
Example 1	1.11:1	2.17:1
Example 2	1.80:1	1.14:1
Example 3	2.17:1	1.18:1

The difference in feed system between Example 1 and Example 2 is only a 20 degree change in phase angle of the two ACU networks!

Best case for this simple feed system design

	Lower VSWR	Upper VSWR
Example 4	1.12:1	1.09:1
Input Z	45 +j2	48 –j4

Corrected with Phase Rotation Network to:

Input Z	46 +j3	47 –j3

IBOC Review

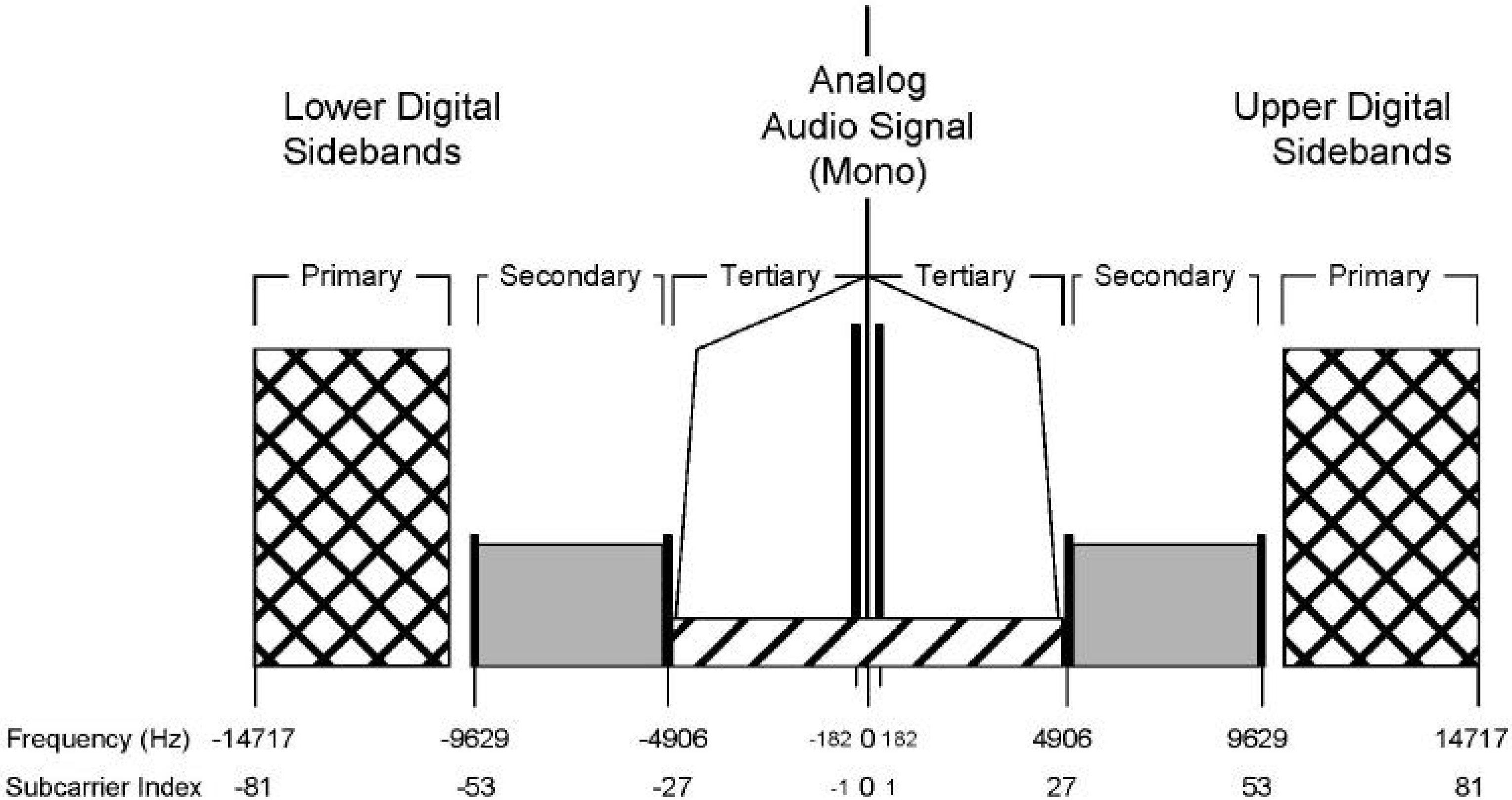


Figure 2 AM IBOC hybrid waveform spectrum.

Antenna Performance Concerns

- Unnecessarily High Digital-to-Analog Crosstalk (Hiss and “Bacon Frying” Sound)
- Decreased “Robustness” of Digital Signal
- Digital Coverage Area Limited by Pattern Bandwidth

Antenna Performance Concerns

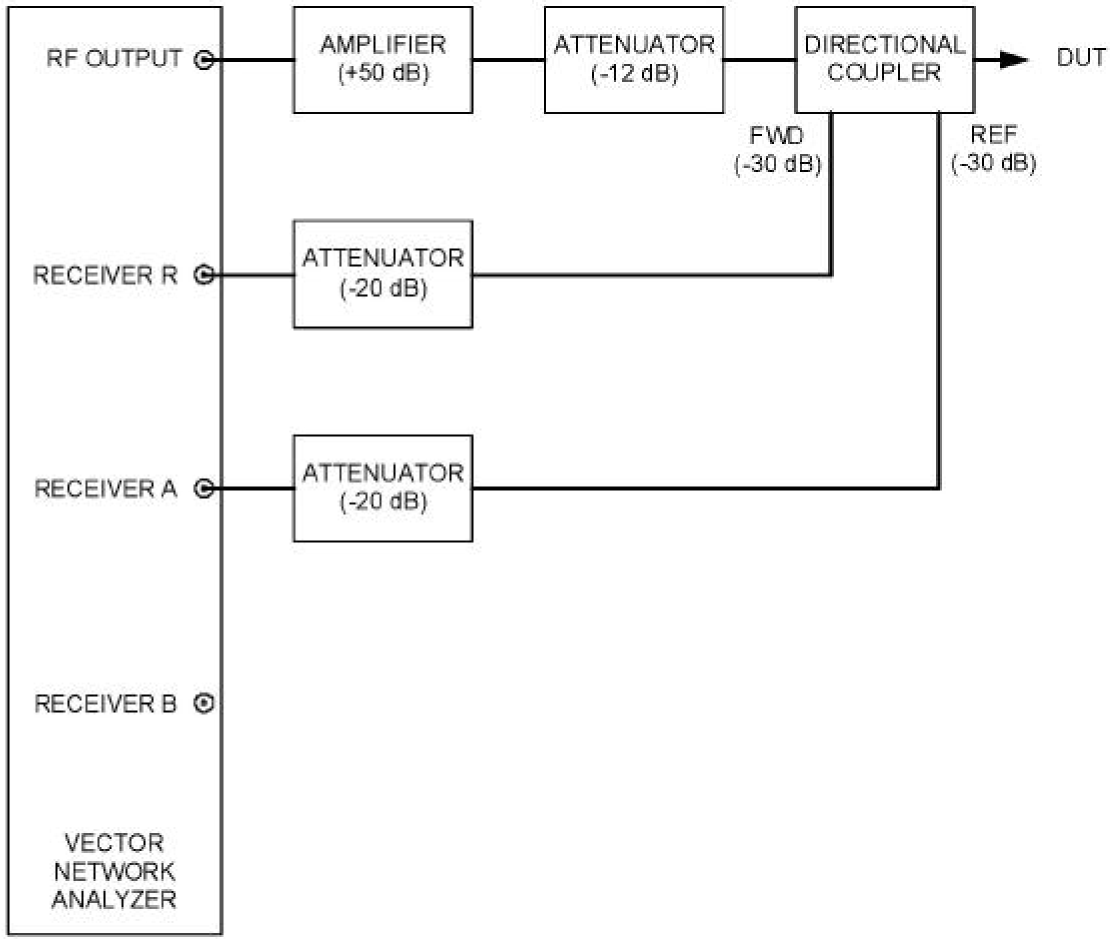
- Higher Adjacent Channel Interference Resulting from Poor Pattern Bandwidth
- Noisier Analog Reception in DA Null Region Due to Poor Pattern Bandwidth

IBOC Antenna System Requirements (as we know now)

- +/- 5 kHz – RF Final Amplifier Load Impedance Symmetry Such That VSWR of One Sideband Impedance Does Not Exceed 1.035:1 When Normalized to the Complex Conjugate of the Corresponding Sideband Impedance on the Other Side of Carrier Frequency (Hermitian Symmetry)

IBOC Antenna System Requirements (as we know now)

- +/- 10 kHz – RF Final Amplifier Load Impedance VSWR Not Exceeding 1.20:1
- +/- 15 kHz – RF Final Amplifier Load Impedance VSWR Not Exceeding 1.40:1



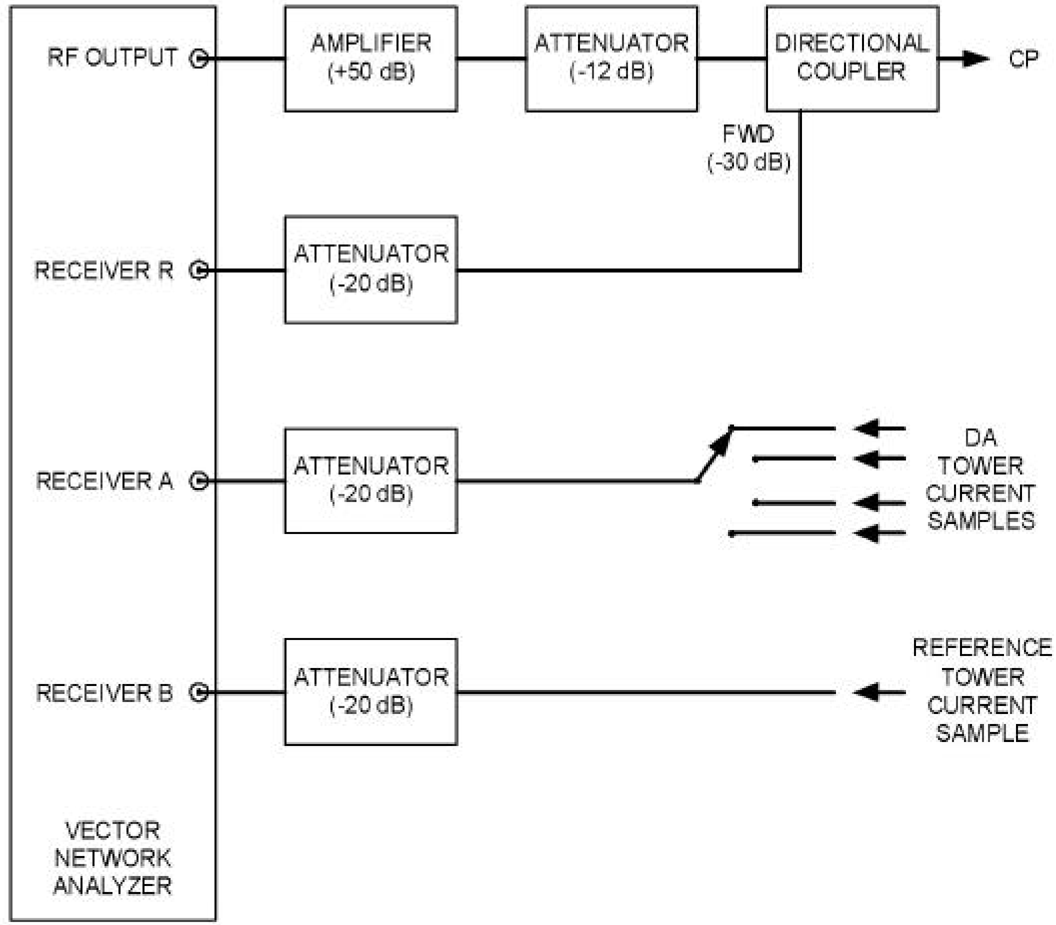
Input Impedance Measurement System

IBOC Antenna System Requirements (as we know now) Cont.

- For Directional Antennas
  - Amplitude Response of +/- 2 dB across the 30 kHz Bandwidth
  - Phase Response of less than 27º across the 30 kHz of Bandwidth

Directional Antenna Analysis

- System Measurements +/- 30 kHz Measured on Sample System
- Measurements used in MiniNEC model to determine Far-Field Performance



Antenna Array Parameter Measurement System

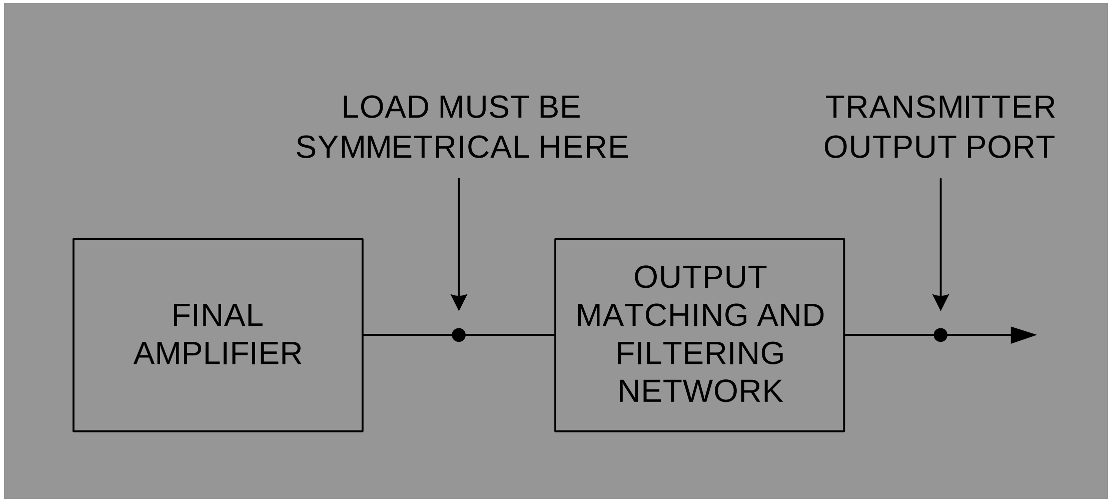
DRM Antenna System Requirements

- +/- 10 kHz –VSWR Not Exceeding 1.20:1
- +/- 15 kHz –VSWR Not Exceeding 1.40:1
- Hermitian Symmetry
- Re-injection of suppressed carrier may also be used in cases where bandwidth is limited

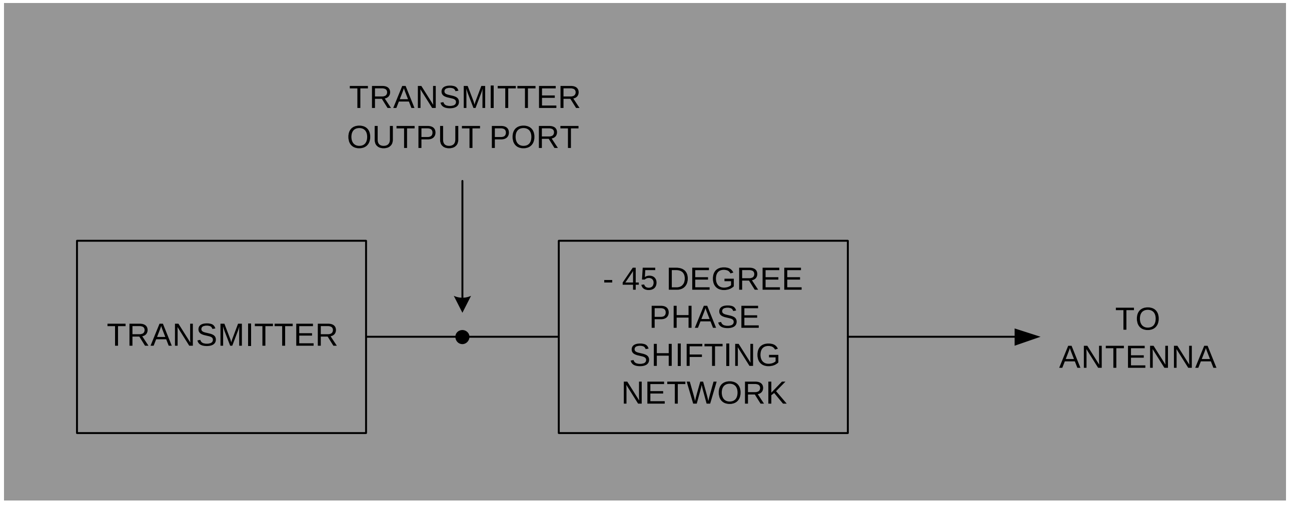
Optimizing Load Impedance

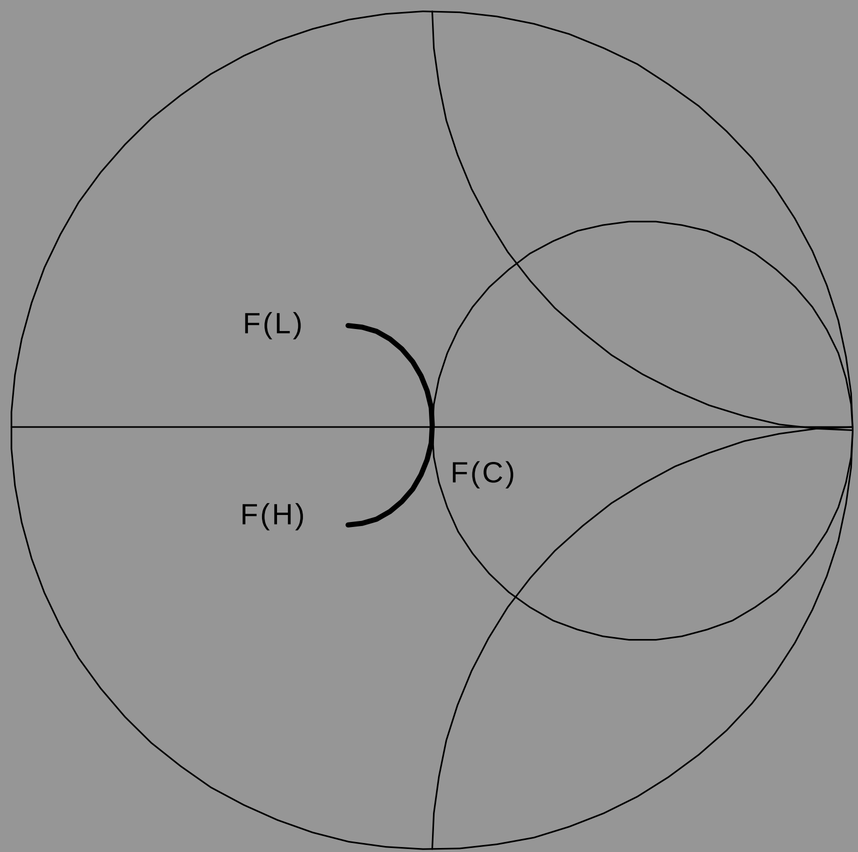
- Reduces Noise from Digital-To-Analog Crosstalk
- Improves Spectral Purity of Digital Signal
- Improves Headroom for Receiver Error Correction

Final Amplifier Load Optimization

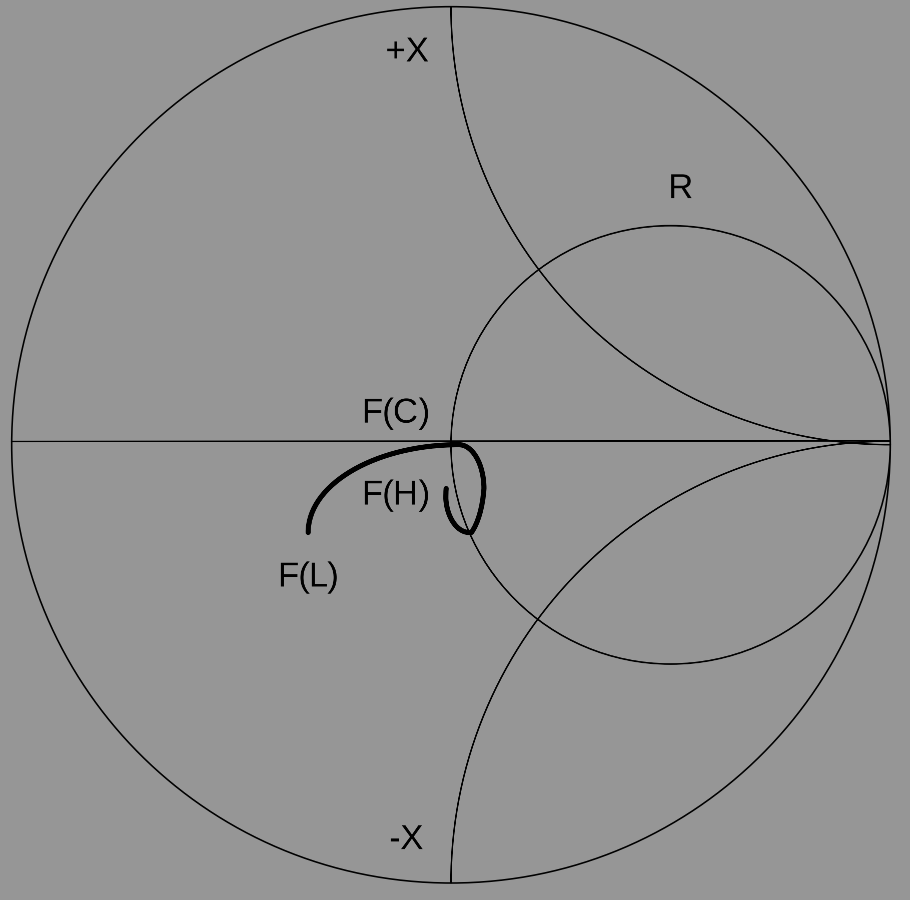


Phase Rotation Network



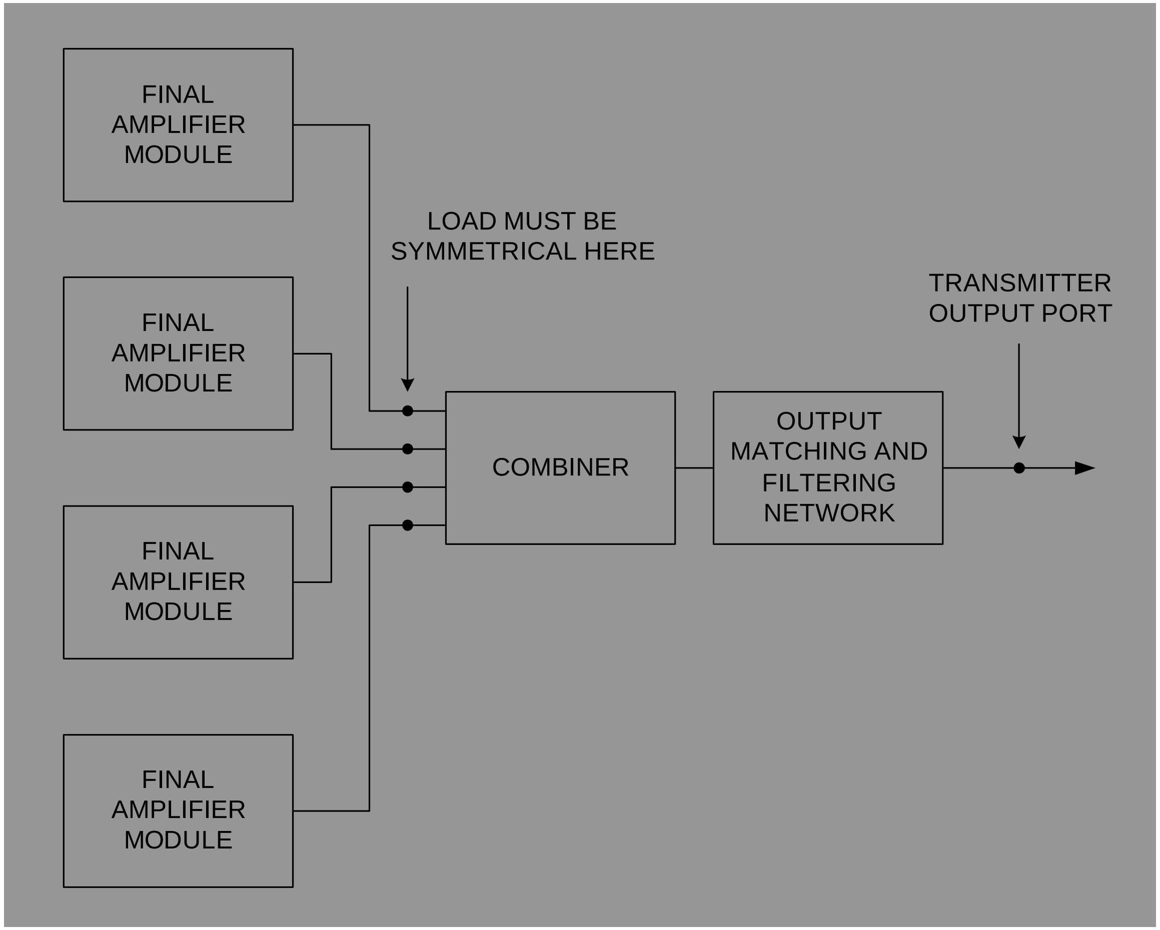


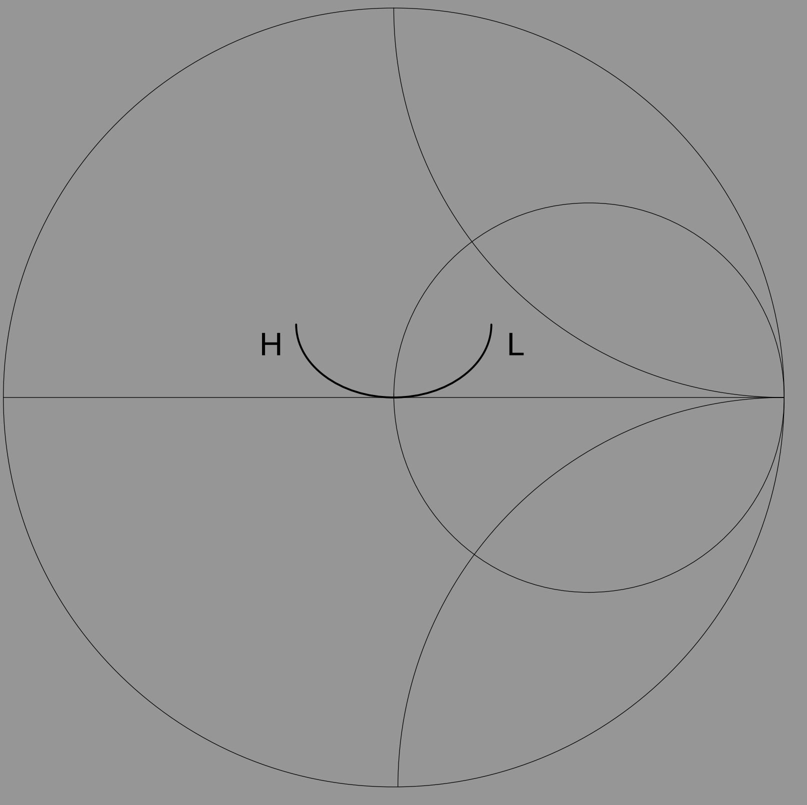
FINAL AMPLIFIER LOAD IMPEDANCE SYMMETRY



UNCORRECTABLE IMPEDANCE ASYMMETRY

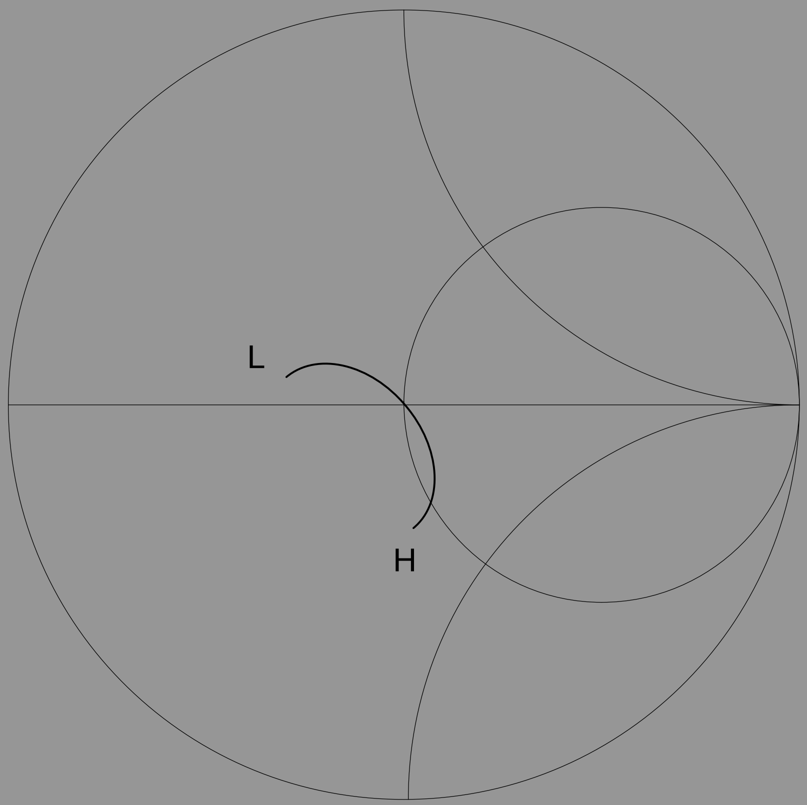
Transmitters With Transformer Combiners





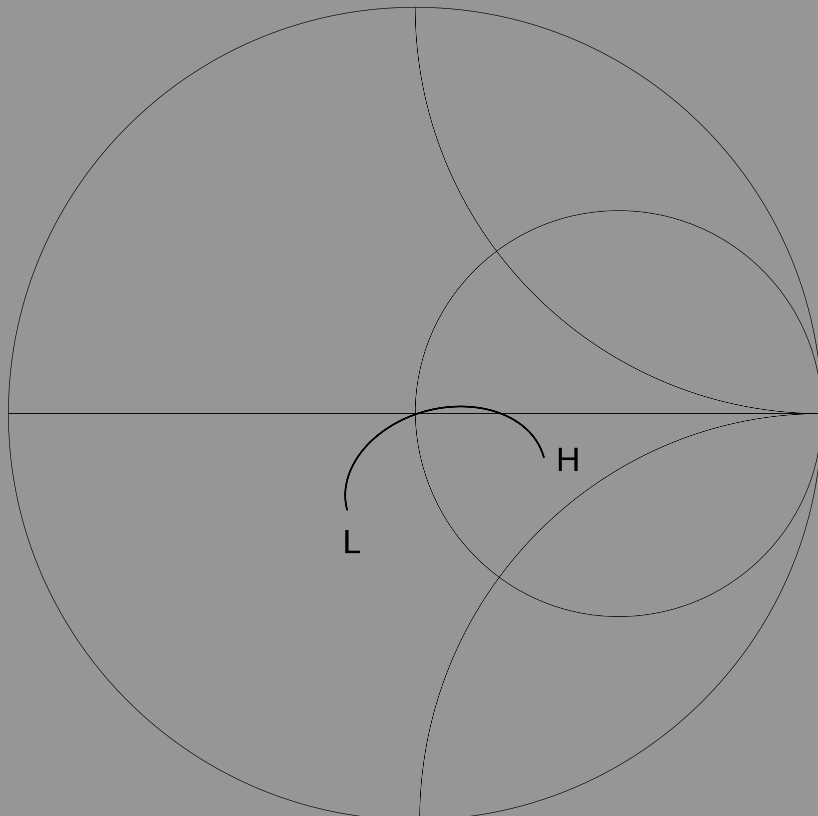
SYMMETRICAL SIDEBAND LOAD
FOR TRANSMITTER WITH
-135 DEGREE OUTPUT NETWORK

(MOST HARRIS MODELS)



SYMMETRICAL SIDEBAND LOAD
FOR TRANSMITTER WITH
-200 DEGREE OUTPUT NETWORK

(MOST BE MODELS)

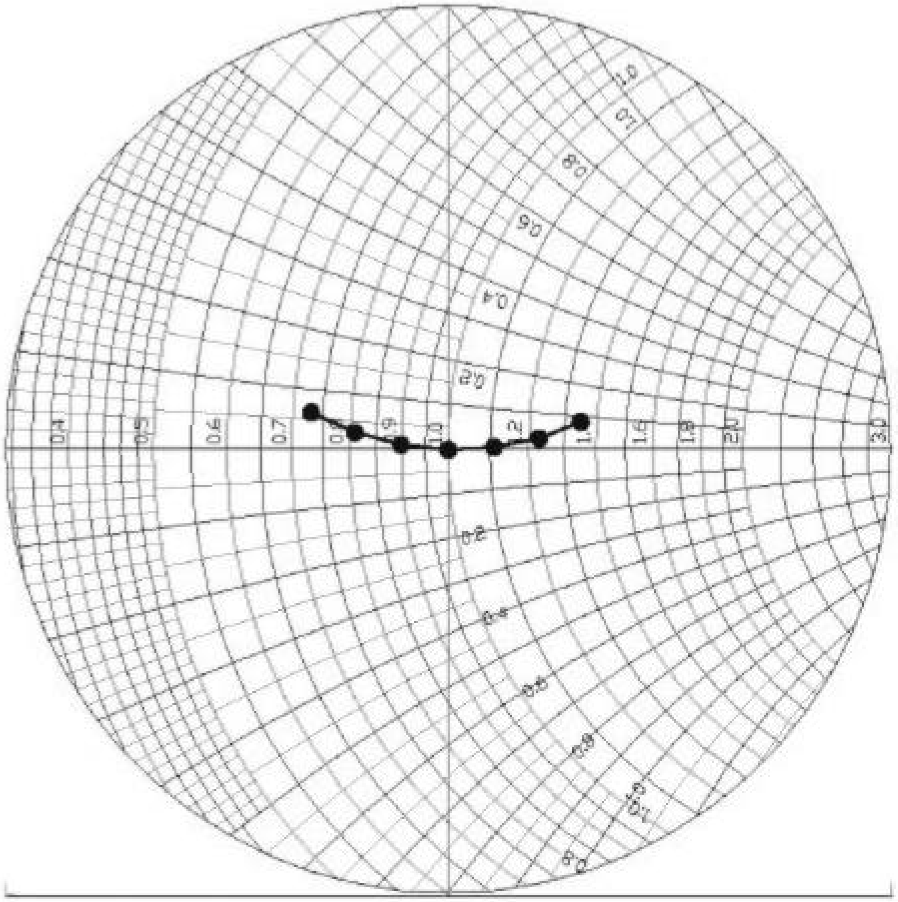


SYMMETRICAL SIDEBAND LOAD
FOR TRANSMITTER WITH
-60 DEGREE OUTPUT NETWORK

(NAUTEL MODELS?)

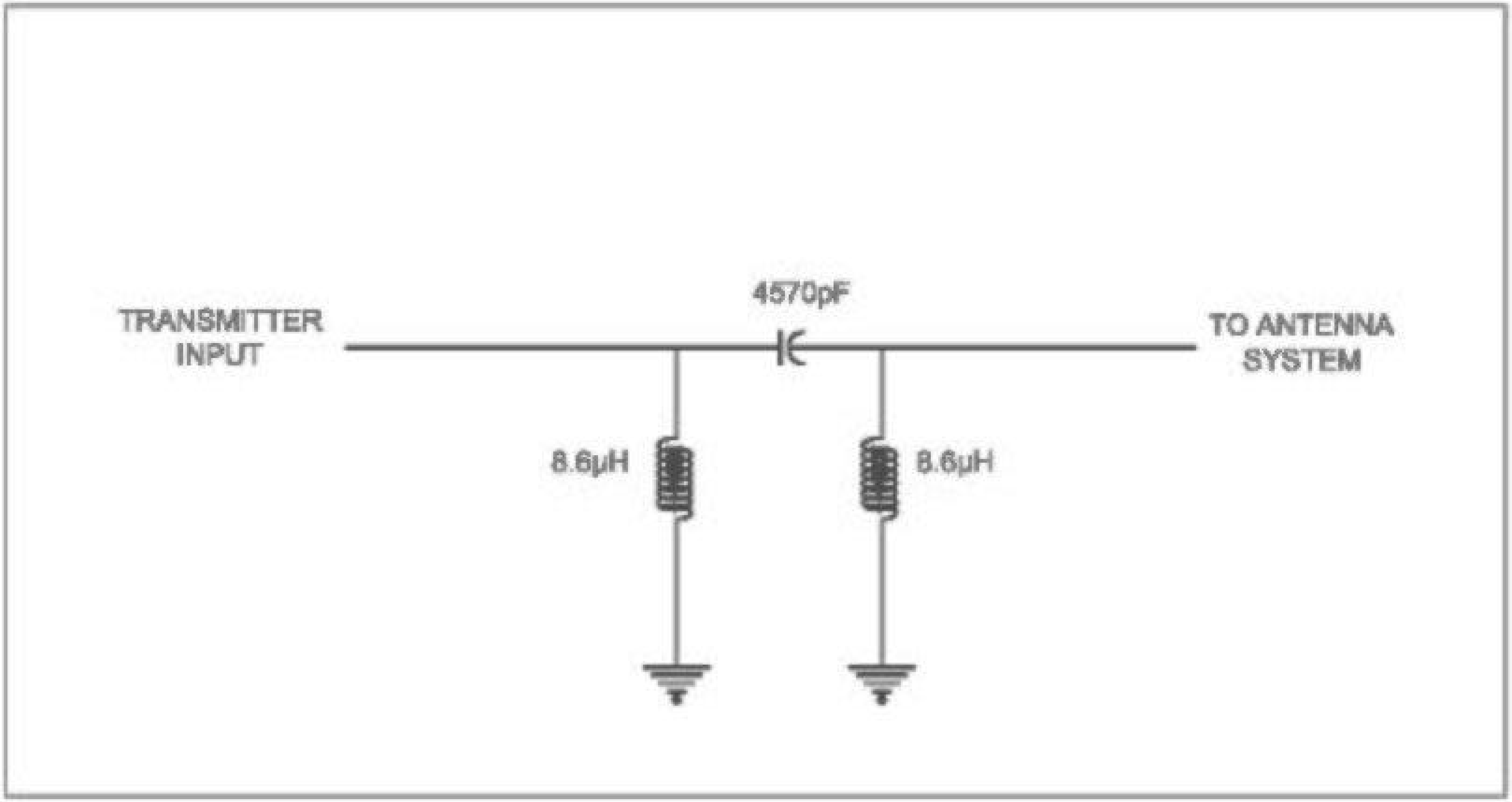
KOTZ

Frequency (kHz)	Impedance Resistance	Reactance	VSWR	IBOC VSWR	IBOC Symmetry	VSWR
705	67.5	4.4	1.363	Yes		
710	61.4	1.6	1.231	No		
715	55.5	0.4	1.110	Yes		
720	50.0	0.0	1.000		No	1.235
725	45.0	0.6	1.112	Yes		
730	40.4	1.7	1.241	No		
735	36.5	3.2	1.381	Yes		

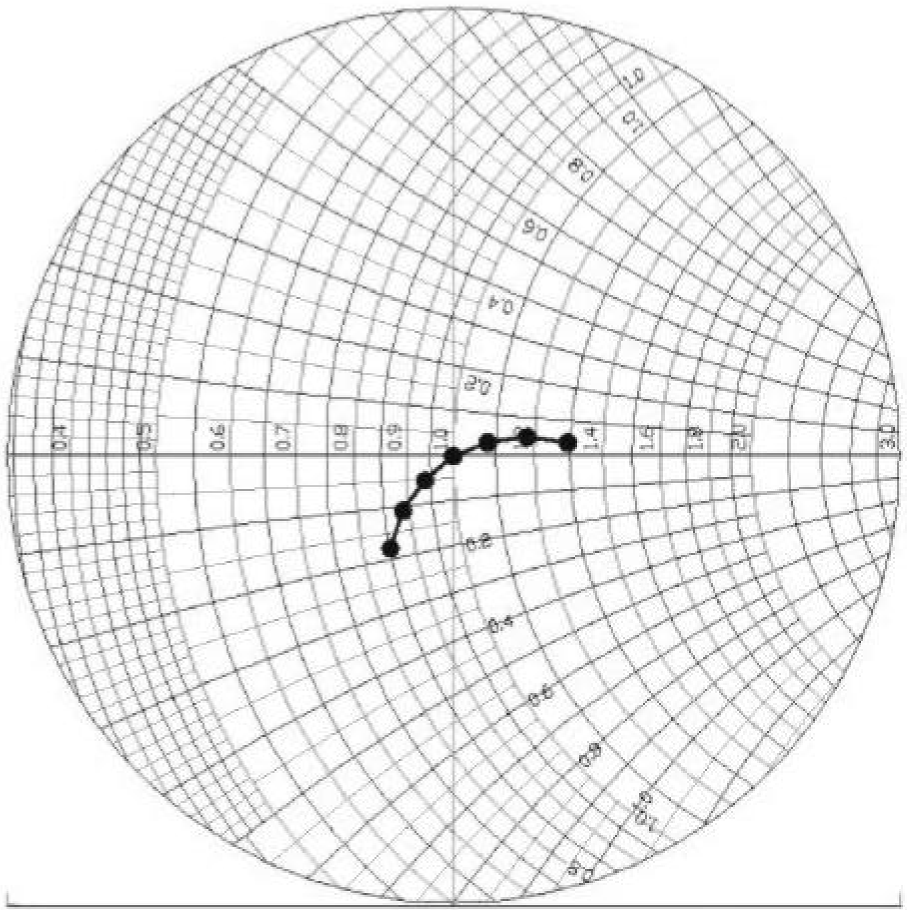


Load At Antenna Feed Line

104.5º Rotation

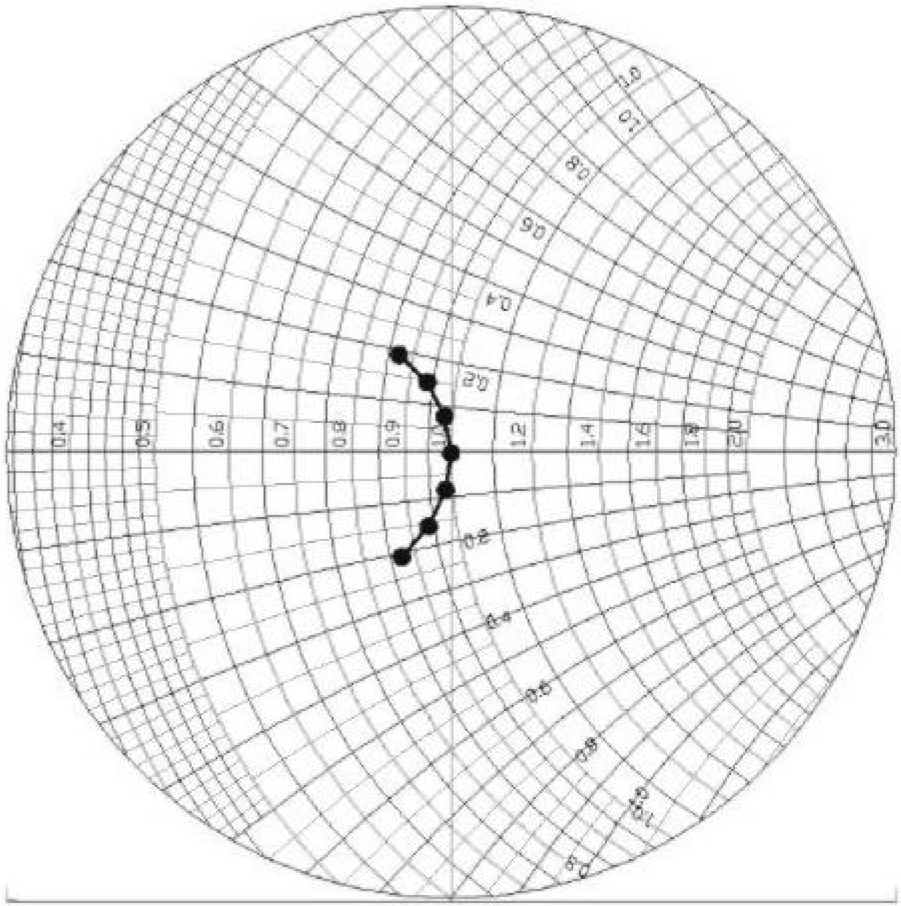


Frequency (kHz)	Impedance Resistance	Reactance	VSWR	IBOC VSWR	IBOC Symmetry	VSWR
705	42.6	-8.9	1.285	Yes		
710	44.3	-5.4	1.181	Yes		
715	46.8	-2.5	1.087	Yes		
720	50.0	0.0	1.000		No	1.155
725	54.0	1.7	1.088	Yes		
730	59.0	2.6	1.188	Yes		
735	64.6	2.0	1.296	Yes		

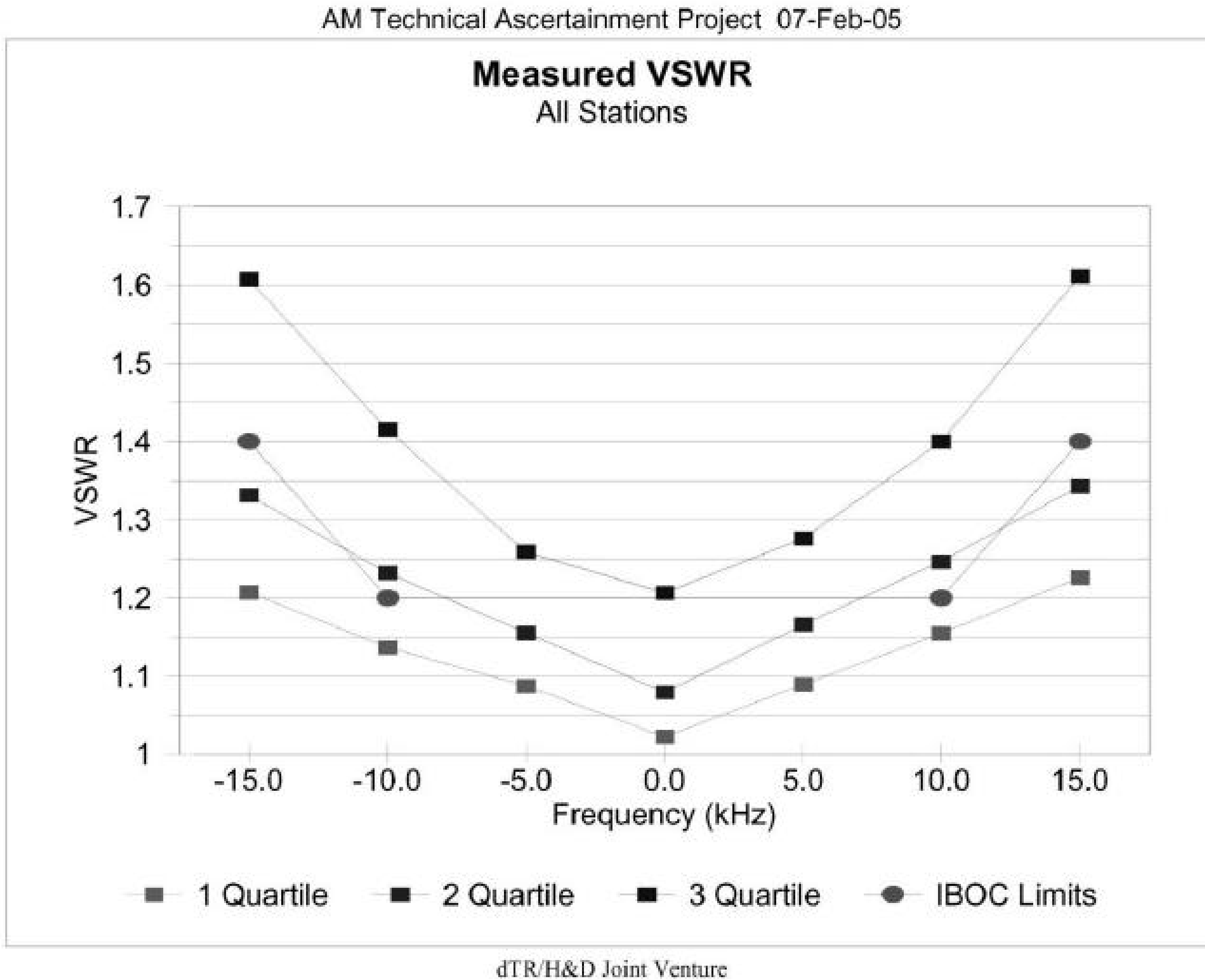


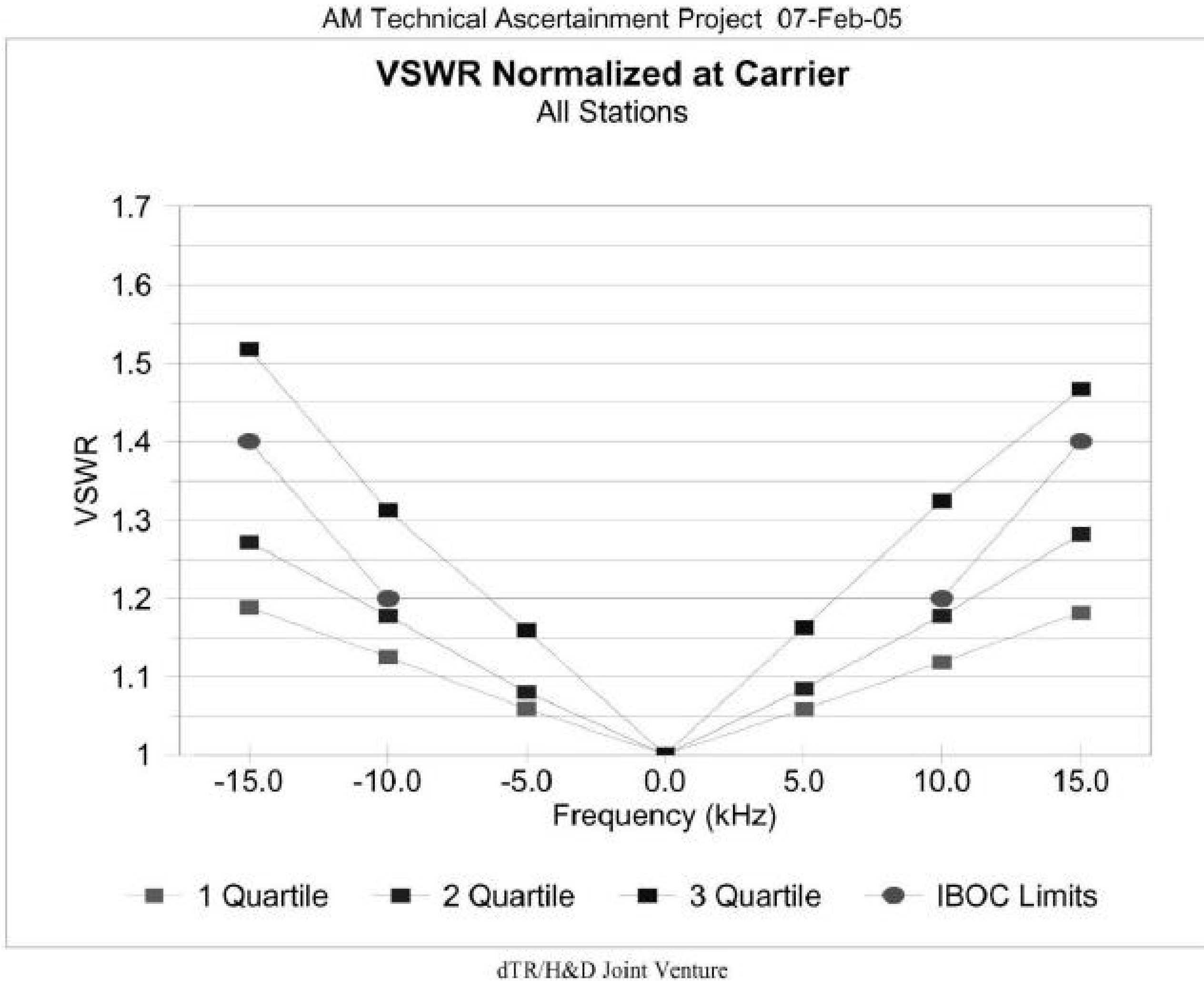
Load Rotated Through Phase Rotation Network

Frequency (kHz)	Impedance Resistance	Reactance	VSWR	IBOC VSWR	IBOC Symmetry	VSWR
705	43.5	9.7	1.285	Yes		
710	46.8	7.4	1.181	Yes		
715	49.1	4.0	1.087	Yes		
720	50.0	-0.0	1.000		Yes	1.003
725	49.2	-4.1	1.088	Yes		
730	46.9	-7.8	1.188	Yes		
735	43.6	-10.3	1.296	Yes		

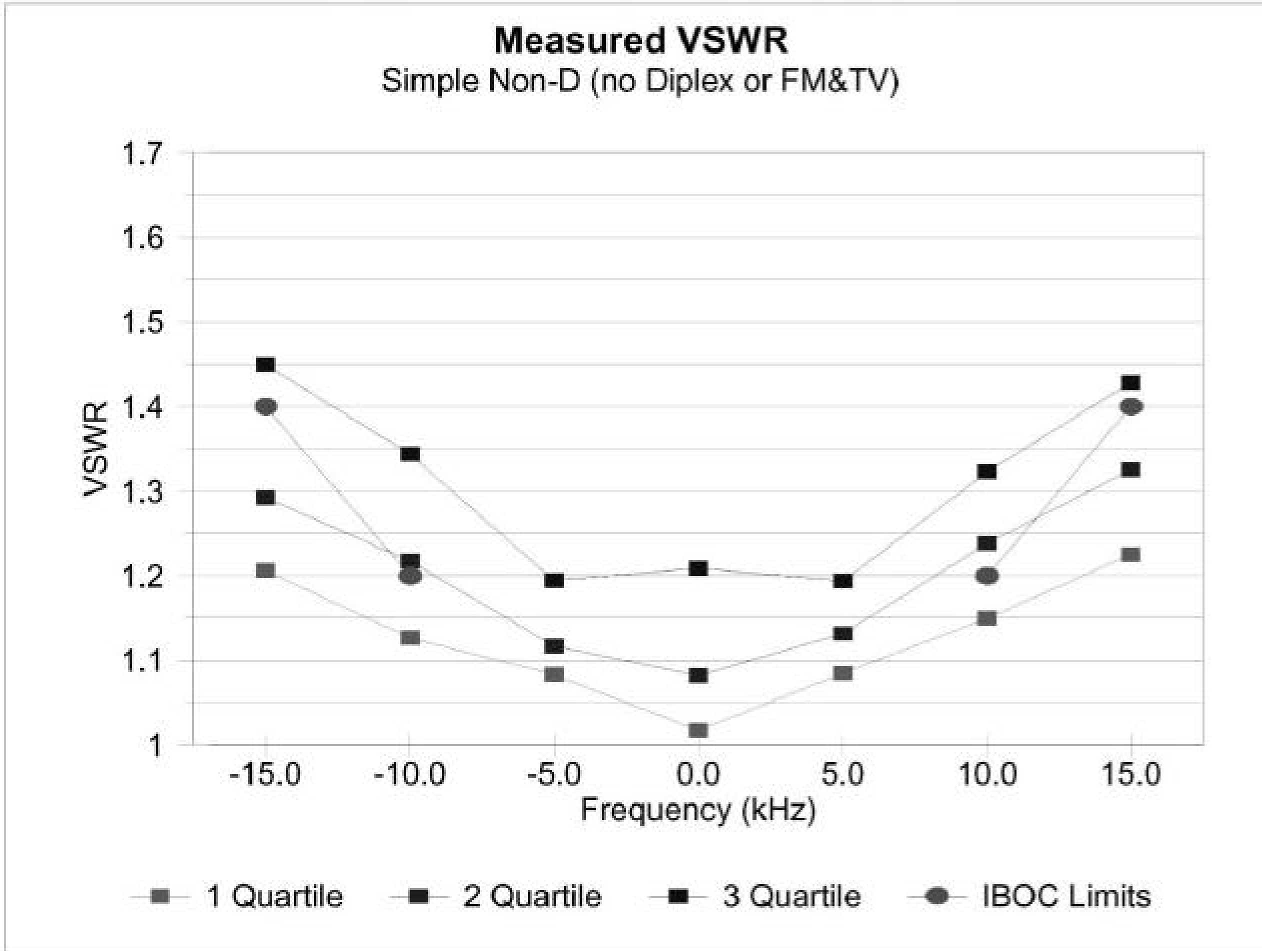


Load Rotated in Transmitter Ouput Network

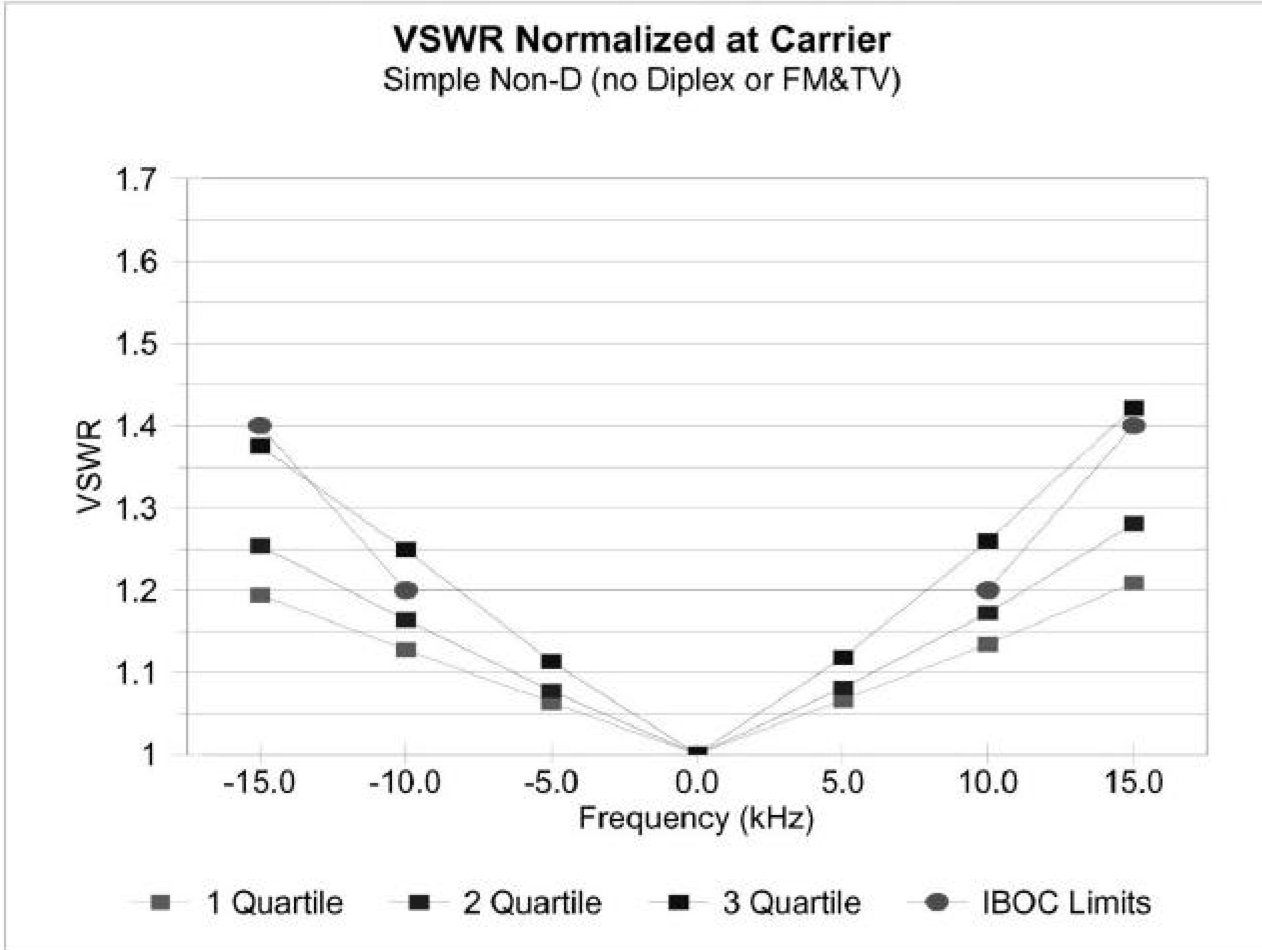

AM Technical Ascertainment Project 07-Feb-05
Measured VSWR
All Stations
VSWR
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
Frequency (kHz)
1 Quartile
2 Quartile
3 Quartile
IBOC Limits
dTR/H&D Joint Venture


AM Technical Ascertainment Project 07-Feb-05
VSWR Normalized at Carrier
All Stations
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
VSWR
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
Frequency (kHz)
1 Quartile
2 Quartile
3 Quartile
IBOC Limits
dTR/H&D Joint Venture

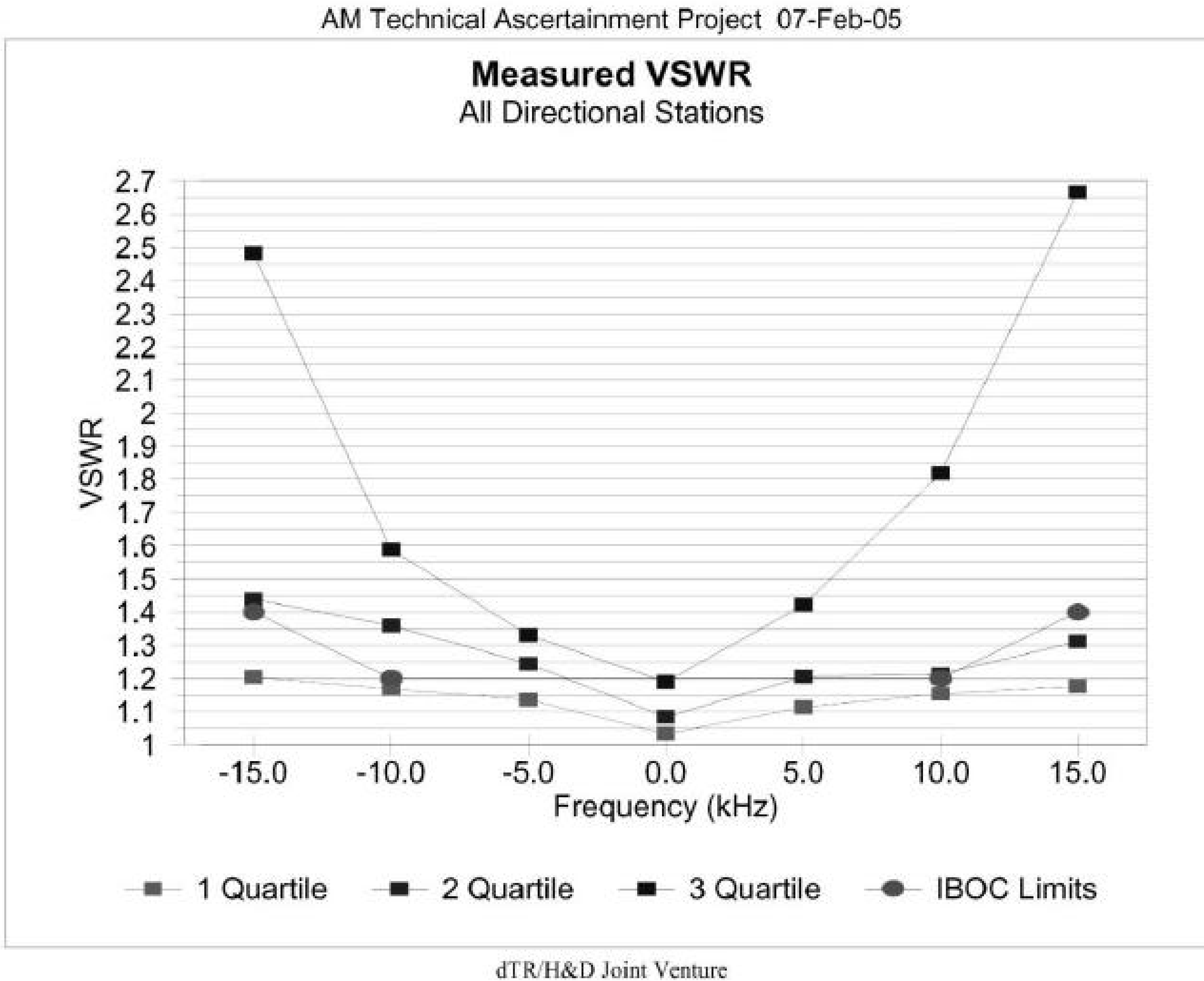
AM Technical Ascertainment Project 07-Feb-05

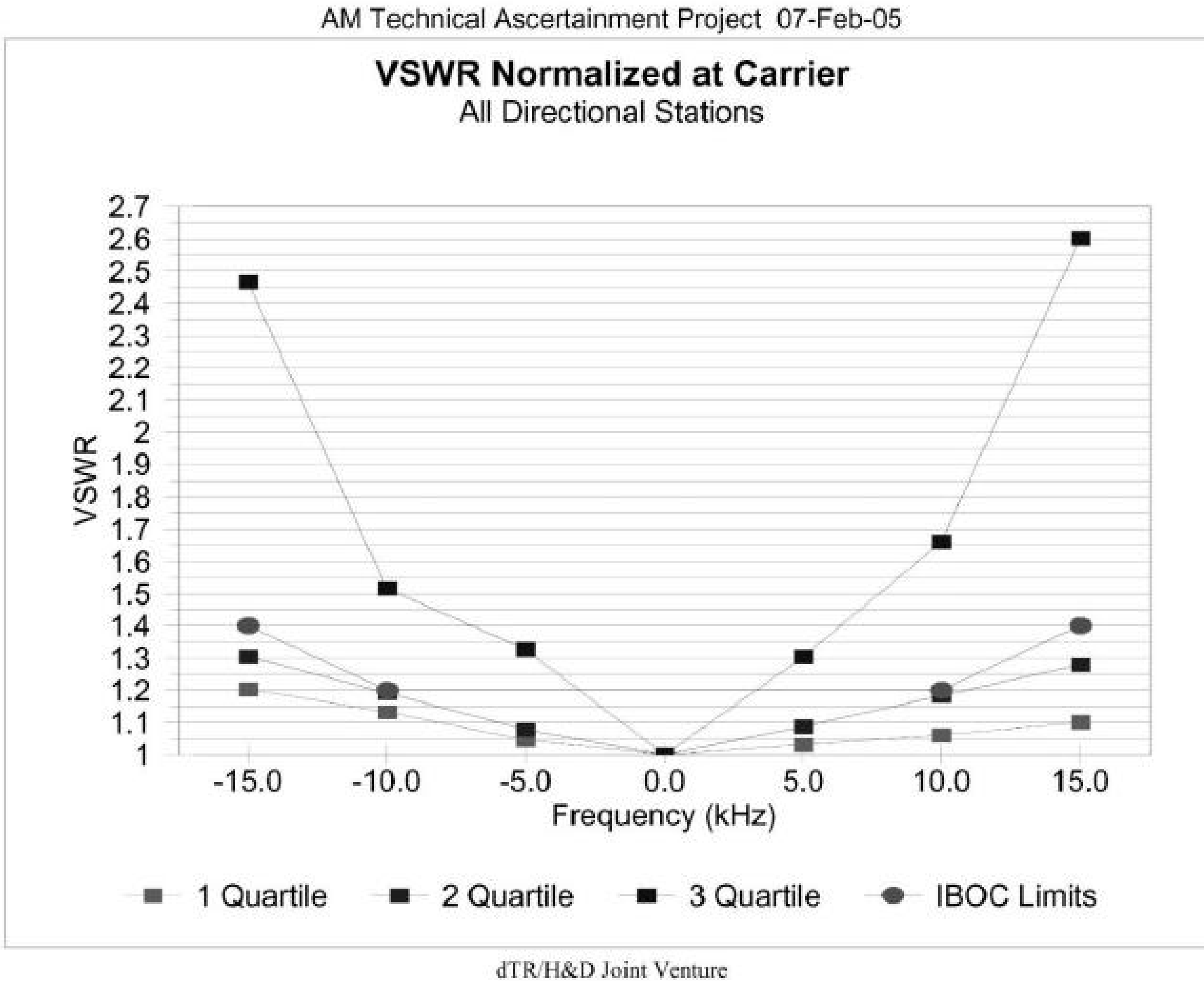


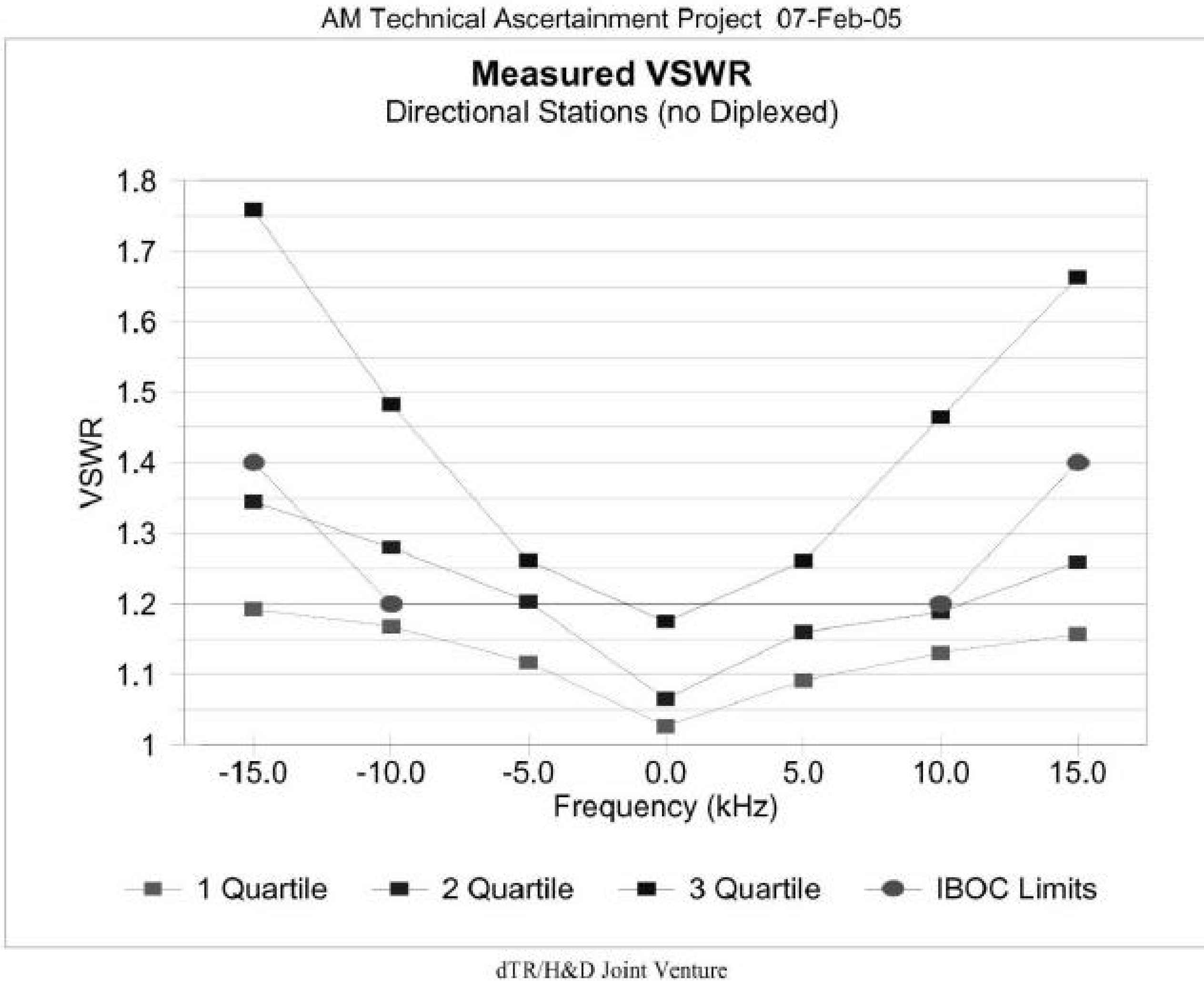
dTR/H&D Joint Venture

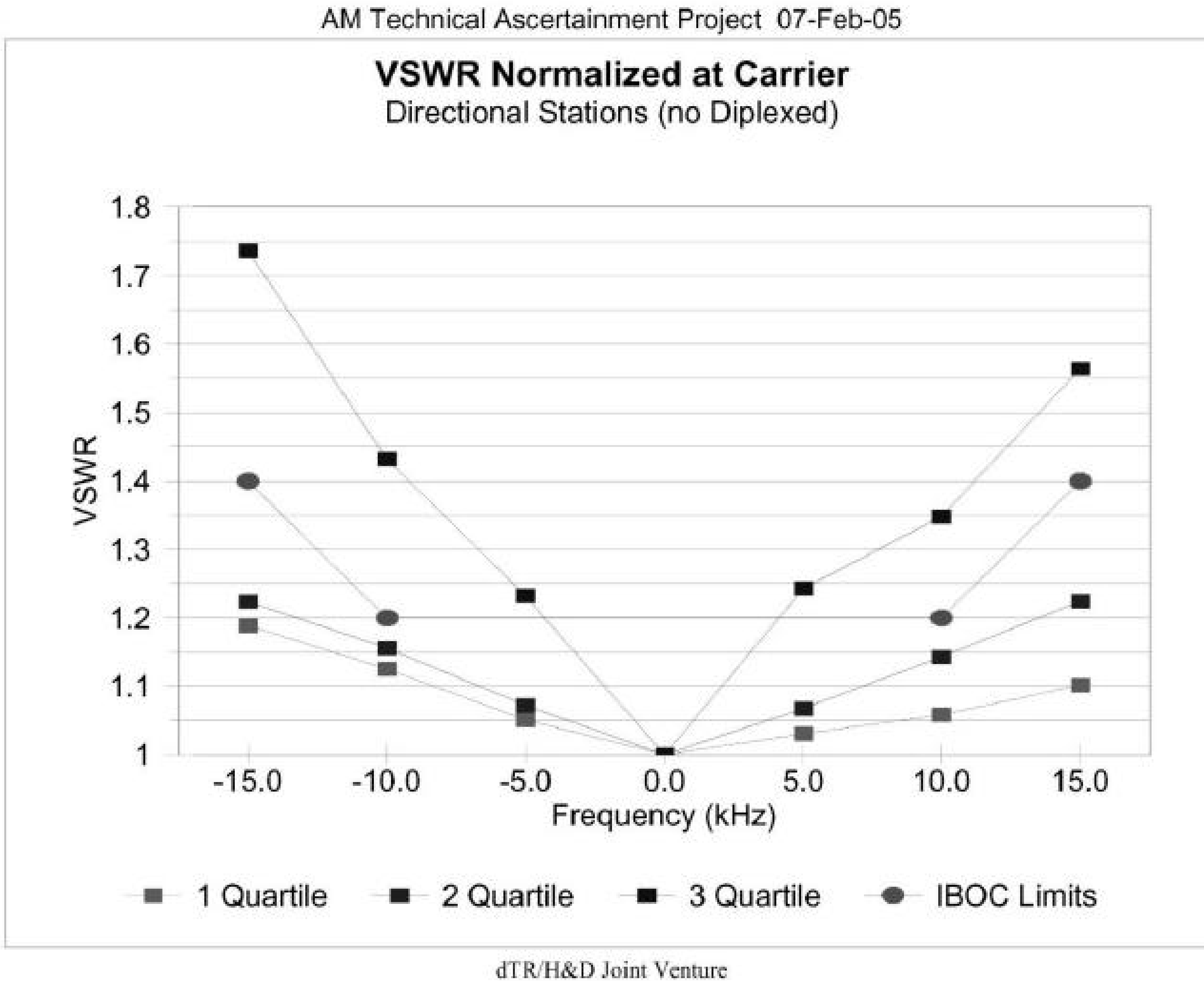


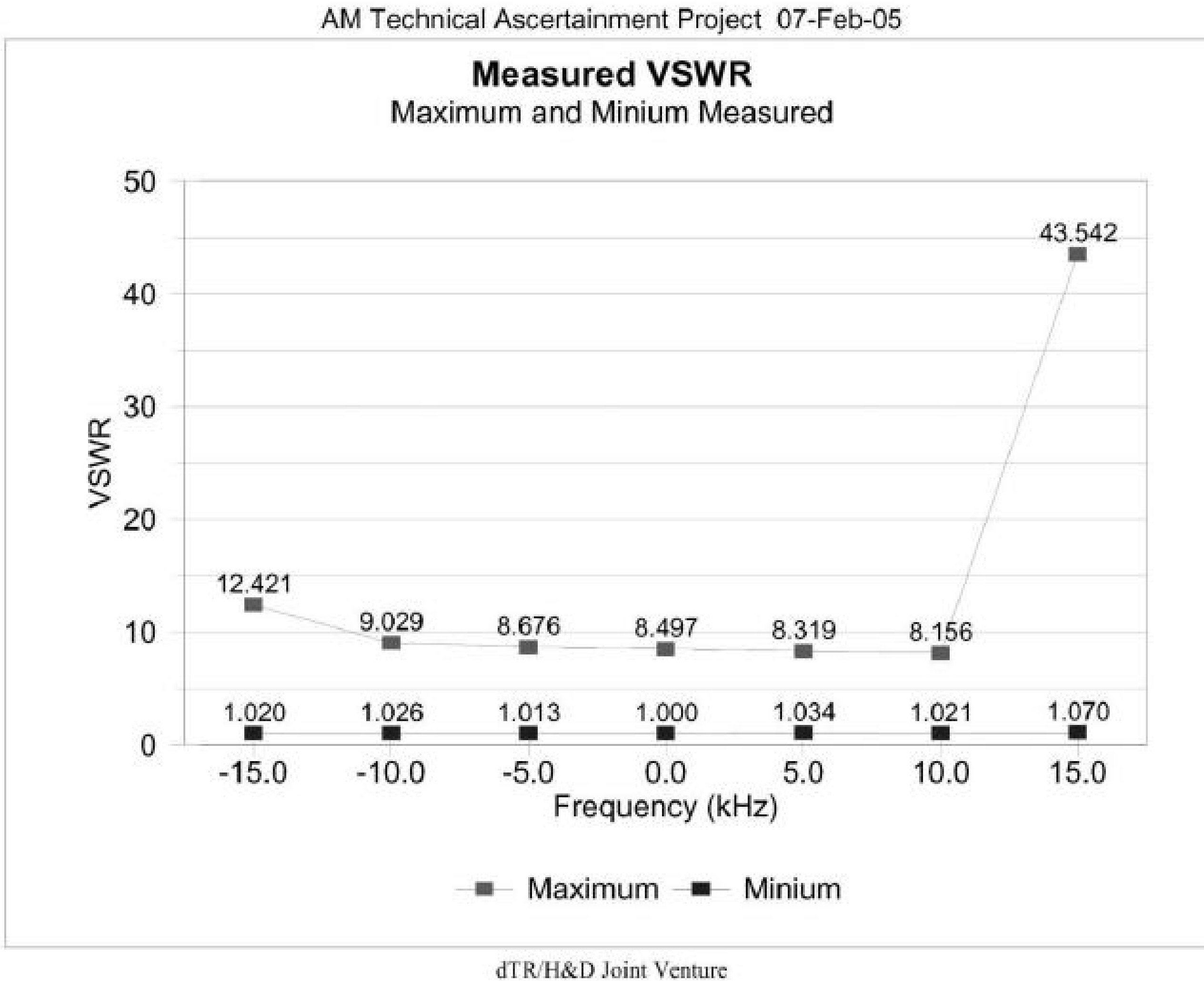
dTR/H&D Joint Venture


AM Technical Ascertainment Project 07-Feb-05
Measured VSWR
All Directional Stations
VSWR
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
Frequency (kHz)
1 Quartile
2 Quartile
3 Quartile
IBOC Limits
dTR/H&D Joint Venture


AM Technical Ascertainment Project 07-Feb-05
VSWR Normalized at Carrier
All Directional Stations
VSWR
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
Frequency (kHz)
1 Quartile
2 Quartile
3 Quartile
IBOC Limits
dTR/H&D Joint Venture


AM Technical Ascertainment Project 07-Feb-05
Measured VSWR
Directional Stations (no Diplexed)
VSWR
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
Frequency (kHz)
1 Quartile
2 Quartile
3 Quartile
IBOC Limits
dTR/H&D Joint Venture


AM Technical Ascertainment Project 07-Feb-05
VSWR Normalized at Carrier
Directional Stations (no Diplexed)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
VSWR
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
Frequency (kHz)
1 Quartile
2 Quartile
3 Quartile
IBOC Limits
dTR/H&D Joint Venture


AM Technical Ascertainment Project 07-Feb-05
Measured VSWR
Maximum and Minium Measured
50
40
30
20
10
0
VSWR
43.542
12.421
9.029
8.676
8.497
8.319
8.156
1.020
1.026
1.013
1.000
1.034
1.021
1.070
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
Frequency (kHz)
Maximum
Minium
dTR/H&D Joint Venture

Pattern Bandwidth

18 Directional Stations – 648 Azimuths
(10 Degree Intervals)

- 41% Meet IBOC Requirements
- 59% Do not

- Some Patterns Fail over Complete Range
- Most Patterns Fail in Minima or Backside

Overall Statistics

- <2% Essentially “Digital Ready”
- ~55% Only Modest Modifications Needed
- ~27% Significant Modification/Invesment
- ~15% Total Redesign/Rebuild Needed

Important Findings

- Poor Maintenance (or complete lack of any maintenance)
- Low power due to wrong operating impedance at carrier
- Poor modulation due to wrong operating impedance at carrier
- Patterns out of adjustment

Maintenance

- IBOC readiness allows attention to other critical infrastructure issues
- Do you buy a new transmitter to put it in a garden shed with a leaky roof?
- Is it time to improve?
  - Electrical service
  - Fencing
  - Security
  - Grounding
  - Etc.

Where to Go From Here

- Transmitter Manufactures are Thinking About This Problem – Adaptive Equalization
- Not Pass-Fail Test – IBOC Signal Has Redundancy
- See What Happens

Thanks!