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

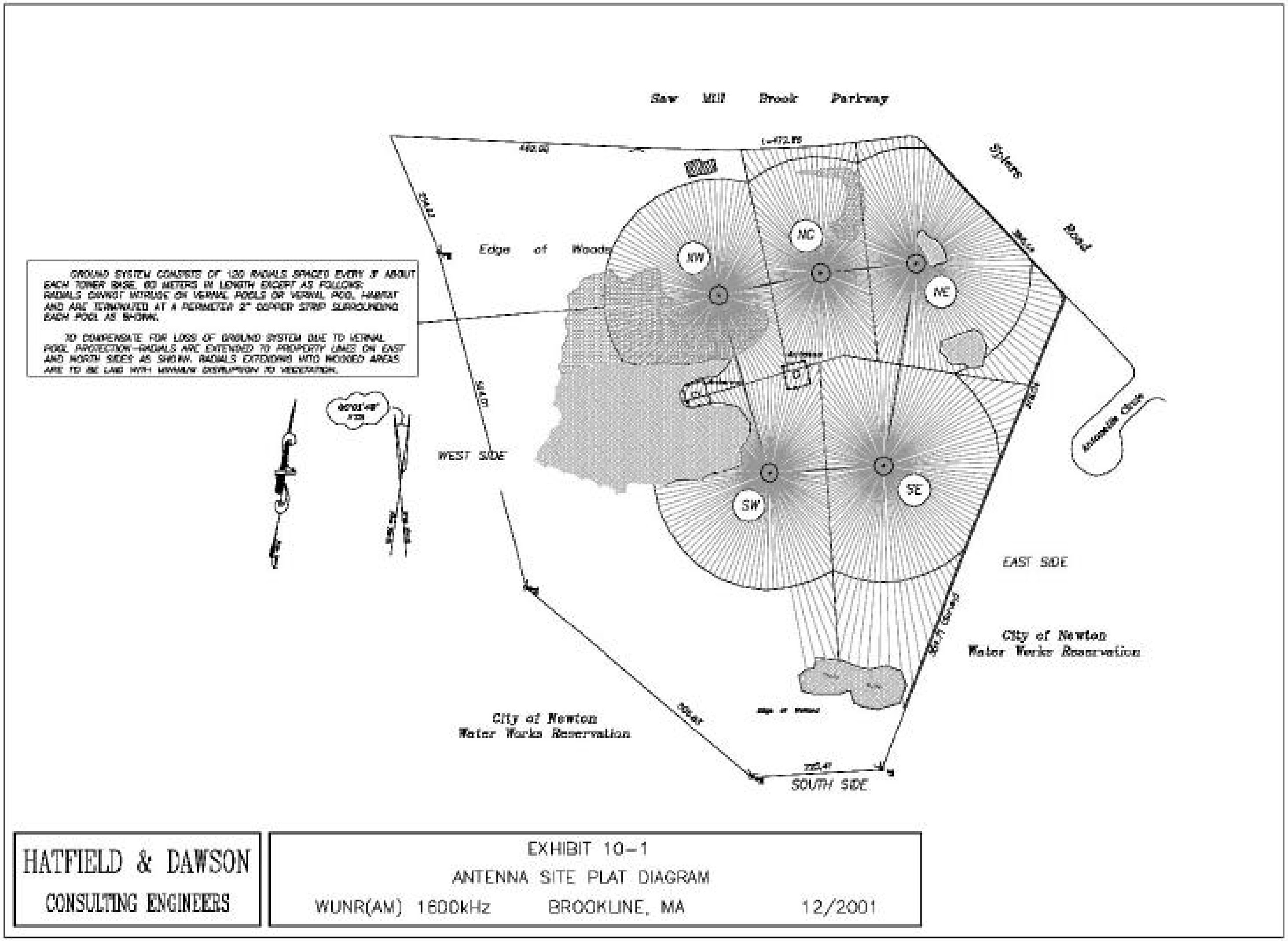

WA
KWSU
KOAC
KBPS
KTBR
KRVM
OR
KAGI
KSYC
KSJK
KMJC
KSNA
KPMO
ID
KBSU
MT
ND
SD
WY
NV
CA
UT
KCFR
KGNU
KCFC
CO
KKPC
NE
KS
AZ
KUAZ
KAWC
KABR
NM
TX
OK
MN
KUOM
KRNI
WOI
IA
WSUI
MO
AR
LA
WLBL
WI
WHA
WILL
IL
MS
MI
WGVU
WKAR
WBAA
IN
AL
WOSU
OH
WOUB
KY
TN
GA
FL
WV
WVMR
VA
WWVT
NC
SC
WNED
WPSE
WXXI
NY
WAMC
PA
MD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

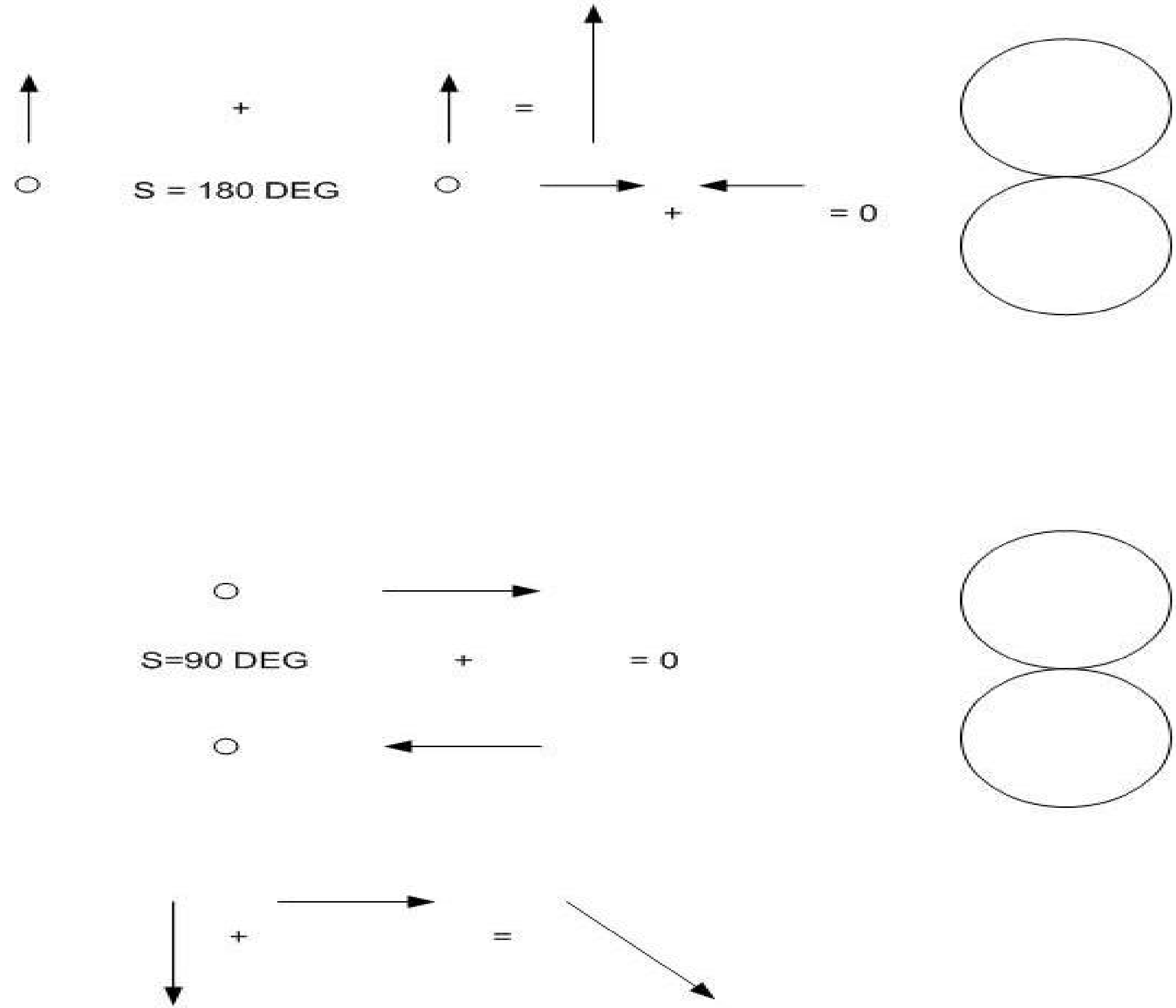
Project Analysis and Report

- 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

Directional Antenna Review



Saw Mill Brook Parkway
Spiers Road
Edge of Woods
GROUND SYSTEM CONSISTS OF 120 RADIALS SPACED EVERY 3° ABOUT EACH TOWER BASE, 60 METERS IN LENGTH EXCEPT AS FOLLOWS: RADIALS CANNOT INTRUDE ON VERNAL POOLS OR VERNAL POOL HABITAT AND ARE TERMINATED AT A PERIMETER 2" COPPER STRIP SURROUNDING EACH POOL AS SHOWN.
TO COMPENSATE FOR LOSS OF GROUND SYSTEM DUE TO VERNAL POOL PROTECTION—RADIALS ARE EXTENDED TO PROPERTY LINES ON EAST AND NORTH SIDES AS SHOWN. RADIALS EXTENDING INTO WOODED AREAS ARE TO BE LAID WITH MINIMUM DISRUPTION TO VEGETATION.
NW
NC
NE
SW
SE
WEST SIDE
EAST SIDE
SOUTH SIDE
City of Newton
Water Works Reservation
City of Newton
Water Works Reservation
HATFIELD & DAWSON
CONSULTING ENGINEERS
EXHIBIT 10-1
ANTENNA SITE PLAT DIAGRAM
WUNR(AM) 1600kHz
BROOKLINE, MA
12/2001


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

RMS = Pattern Size

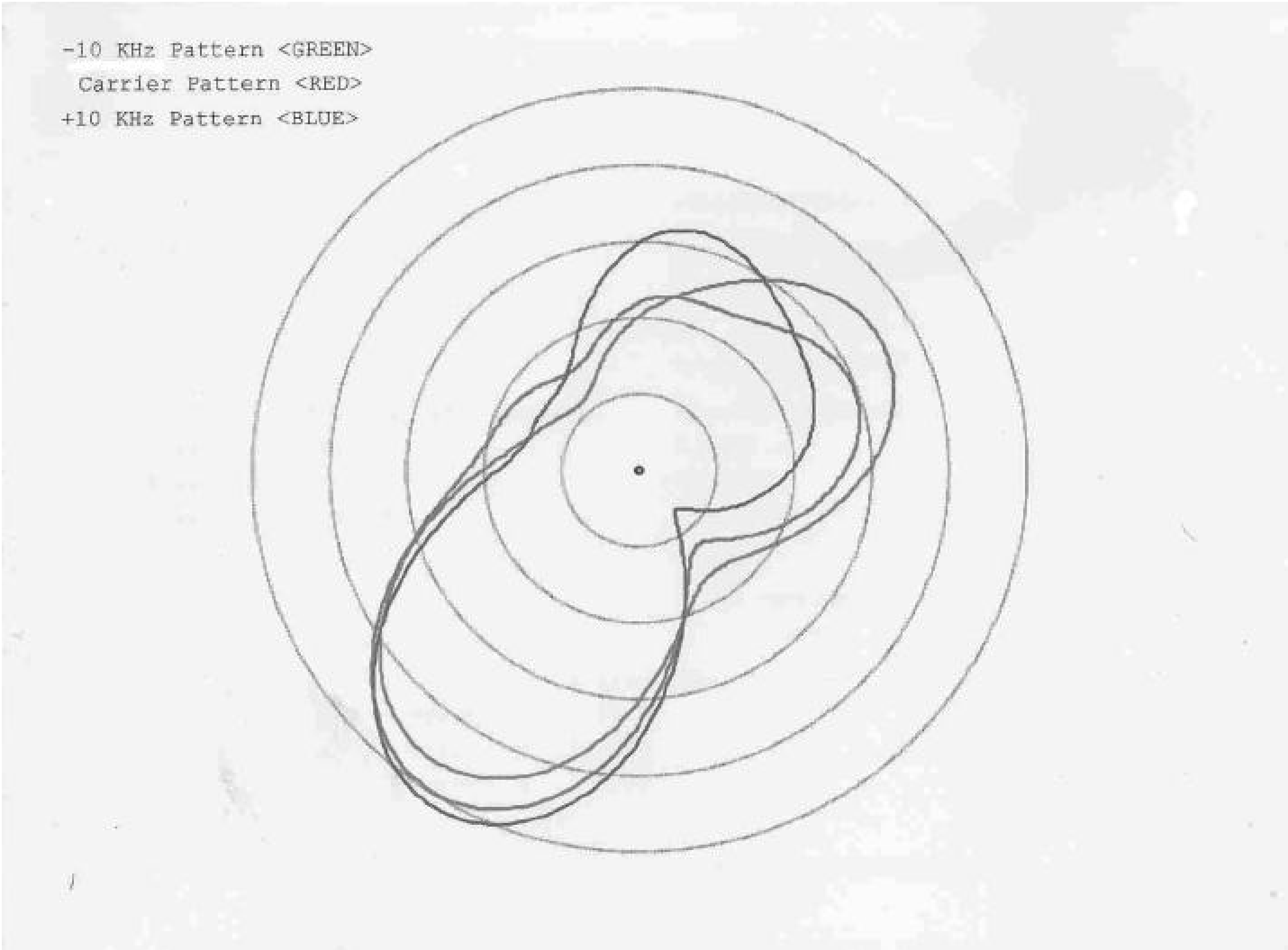
$RSS = (E_1^2+E_2^2+..+E_n^2)^{½}$

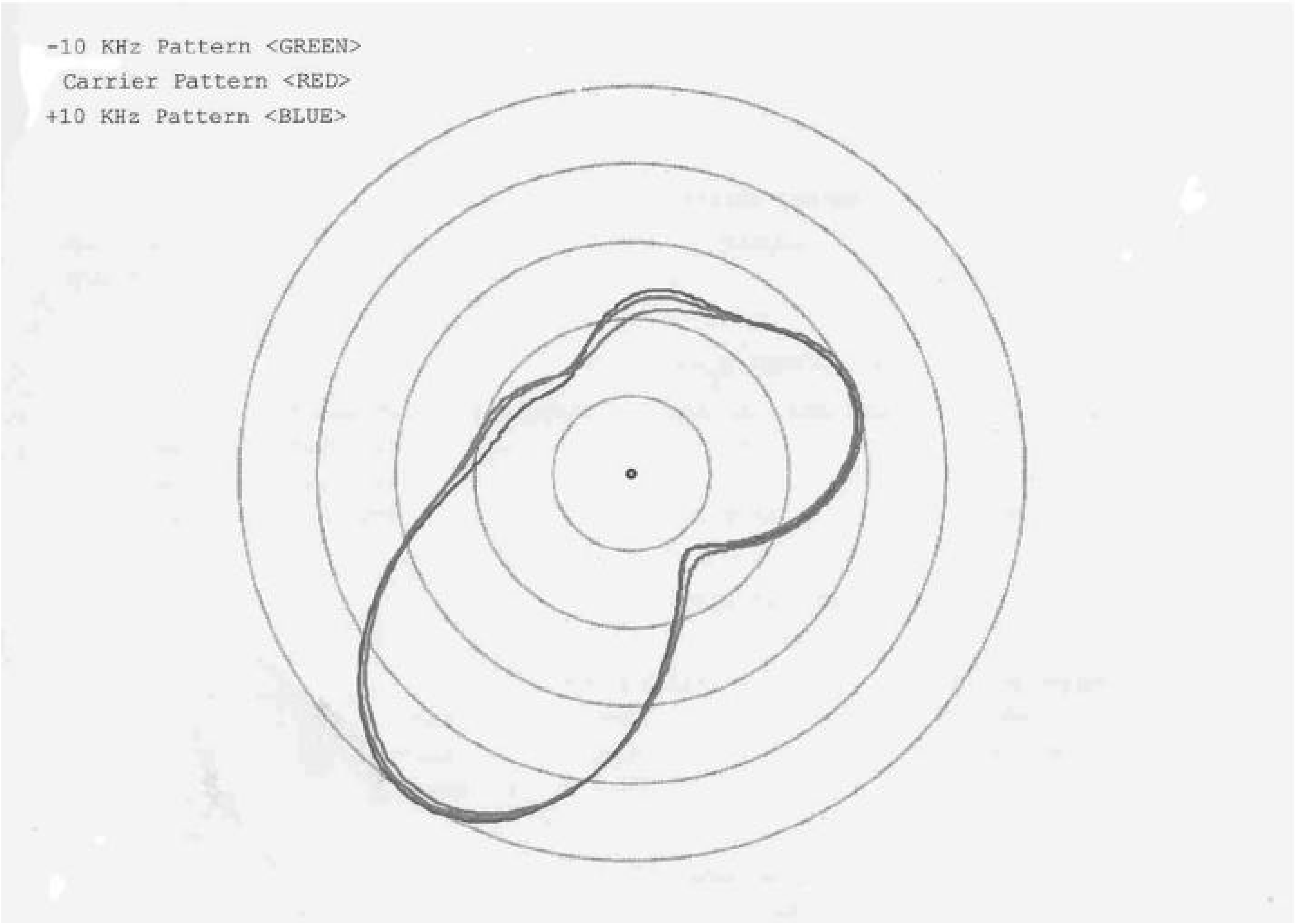
If E values are large

system is "sensitive" to small % changes

If E values are small

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


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


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

INPUT IMPEDANCE RANGE FOR A SIMPLE PATTERN


-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

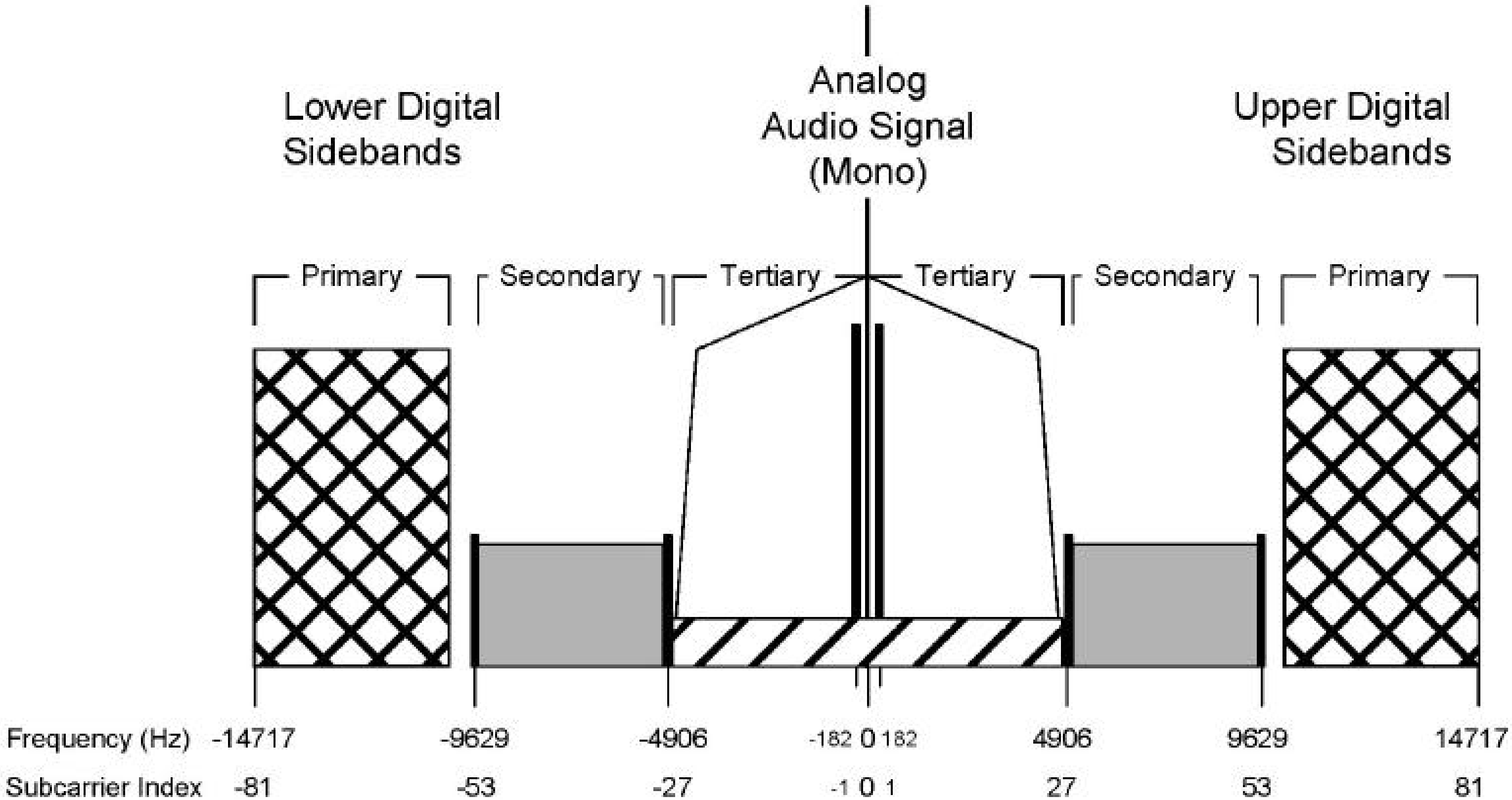


Figure 2 AM IBOC hybrid waveform spectrum.

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

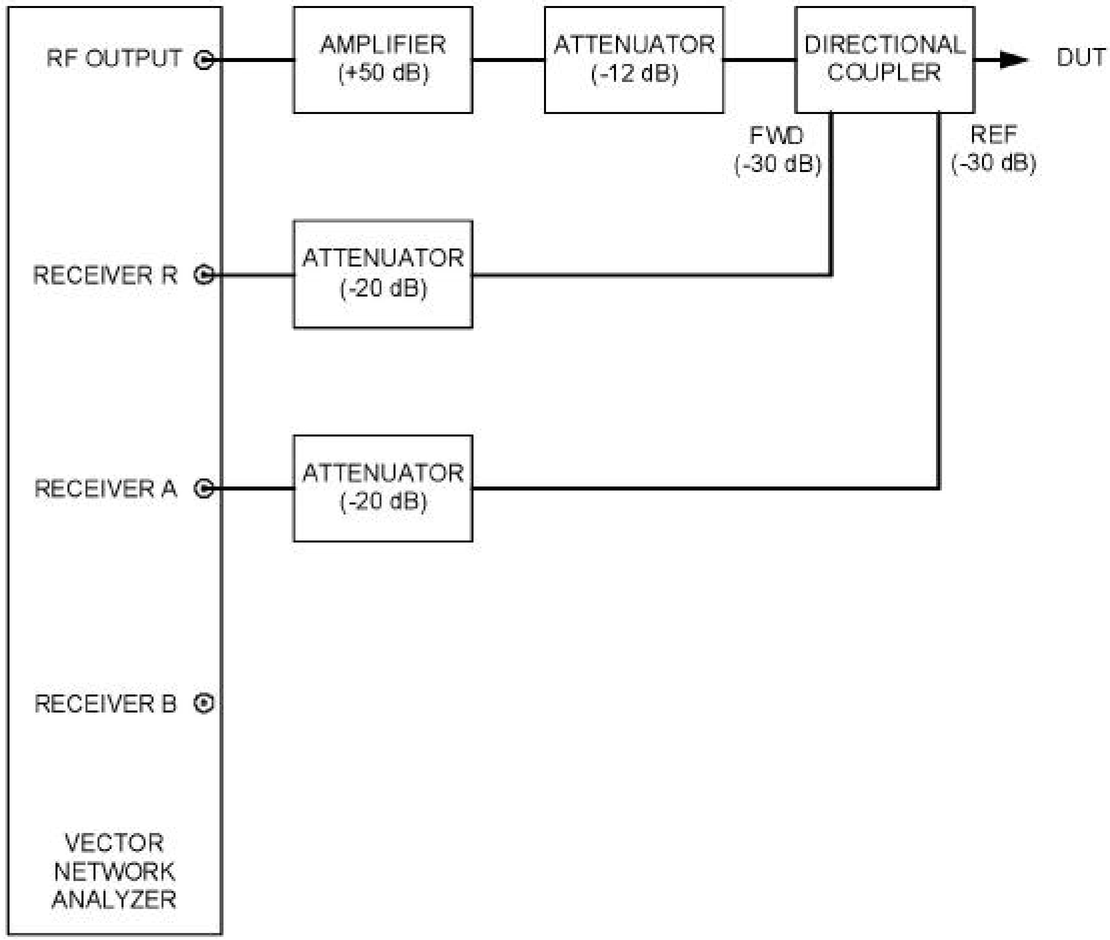
- Higher Adjacent Channel Interference Resulting from Poor Pattern Bandwidth
- Noisier Analog Reception in DA Null Region Due to Poor Pattern Bandwidth

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)

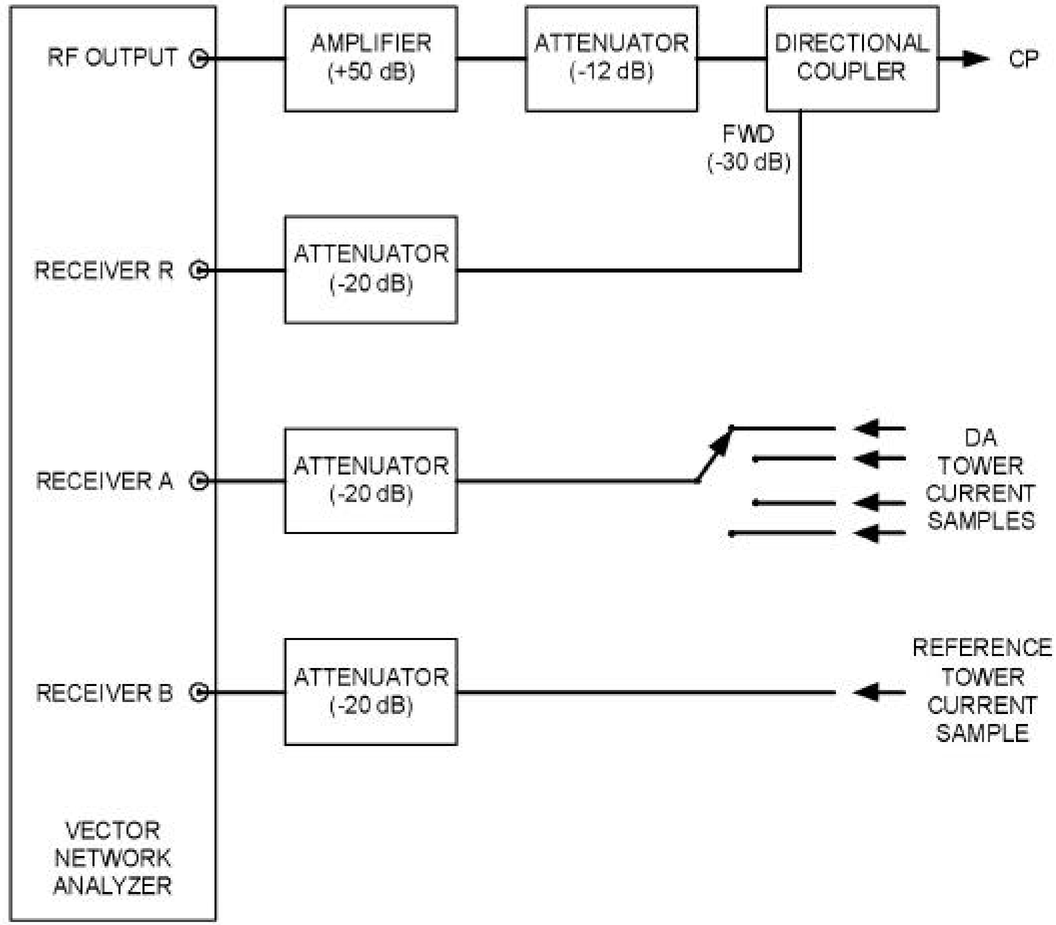
- +/- 10 kHz – RF Final Amplifier Load Impedance VSWR Not Exceeding 1.20:1
- +/- 15 kHz – RF Final Amplifier Load Impedance VSWR Not Exceeding 1.40:1



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



Antenna Array Parameter Measurement System

Directional Antenna Analysis

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

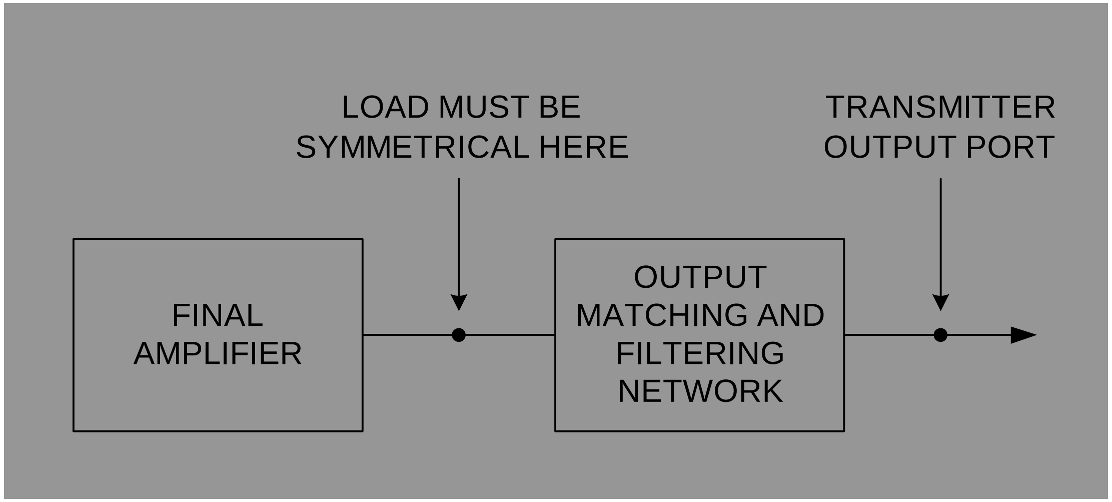
DRM Antenna System Requirements

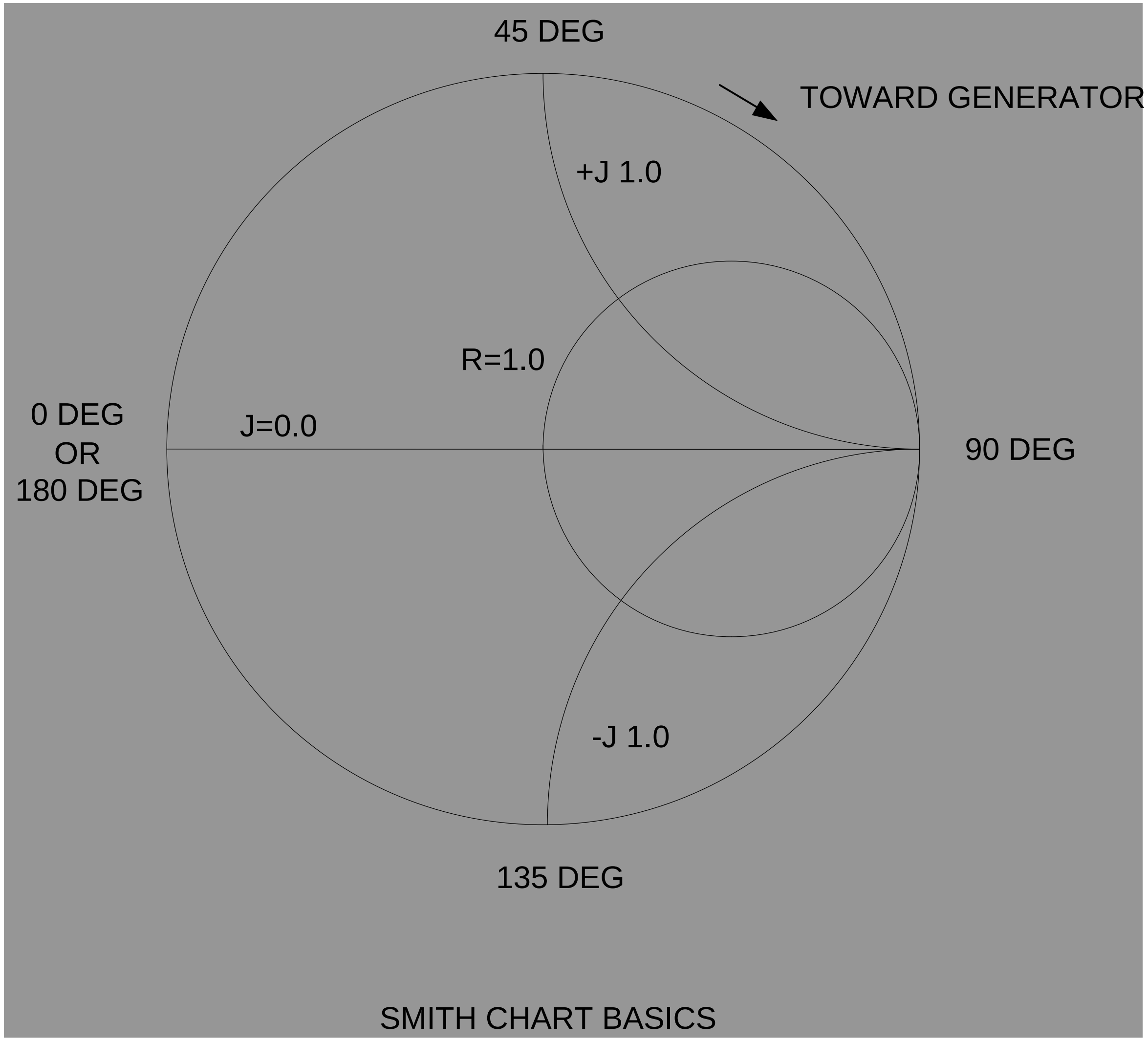
- +/- 10 kHz –VSWR Not Exceeding 1.20:1
- +/- 15 kHz –VSWR Not Exceeding 1.40:1
- Hermitian Symmetry
- Re-injection of suppressed carrier may also be used in cases where bandwidth is limited

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



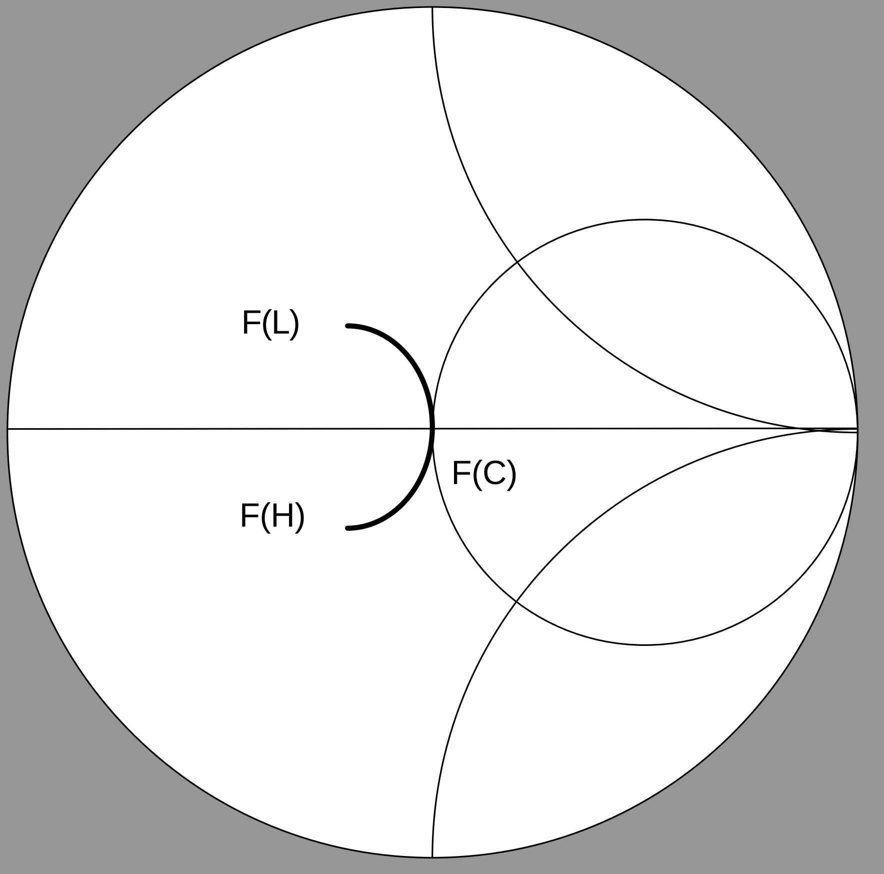

45 DEG
TOWARD GENERATOR
+J 1.0
R=1.0
0 DEG
OR
180 DEG
J=0.0
90 DEG
-J 1.0
135 DEG
SMITH CHART BASICS

Normalizing Per-Unit Values of Impedance

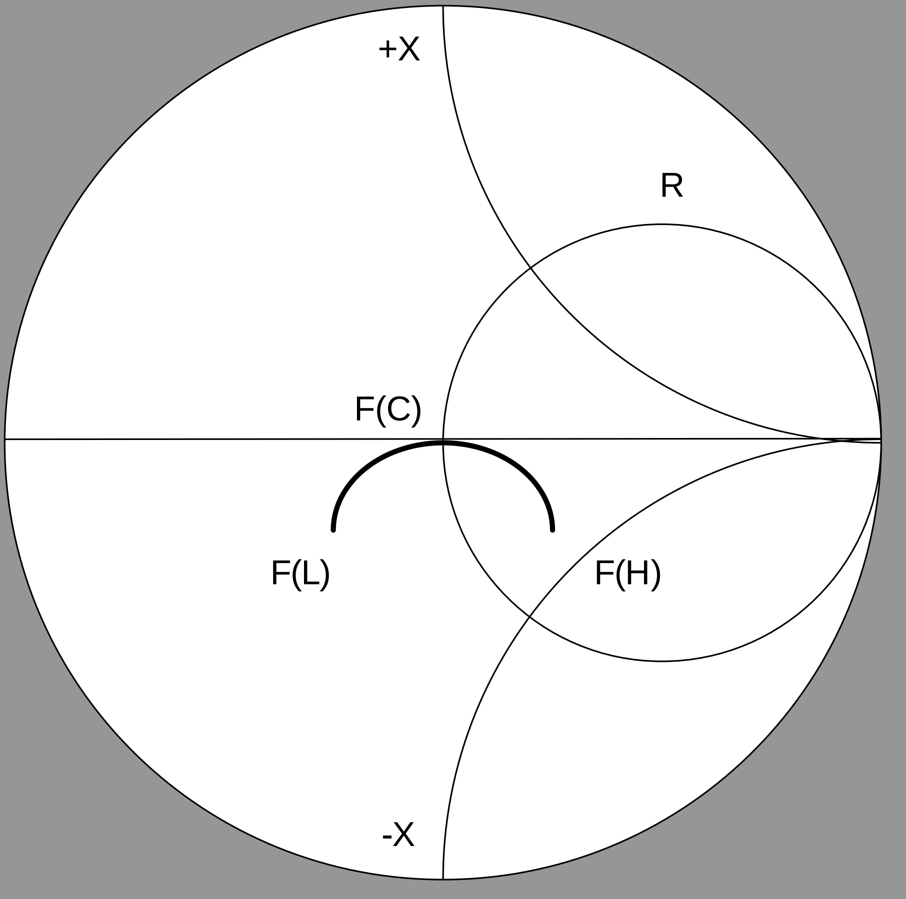
- Divide Each Sideband Resistance by the Carrier Resistance
- Divide the Difference Between Each Sideband Reactance and the Carrier Reactance by the Carrier Resistance

Normalizing Examples

Frequency	Resistance	Reactance	Per-Unit Resistance	Per-Unit Reactance
-15 kHz	45.0	-j 8.0	0.90	-j 0.16
Carrier	50.0	j 0.0	1.00	j 0.00
+15 kHz	57.0	+j 10.0	1.14	+j 0.20
-15 kHz	45.0	-j 8.0	0.86	-j 0.09
Carrier	52.5	-j 3.5	1.00	j 0.00
+15 kHz	57.0	+j 10.0	1.09	+j 0.12

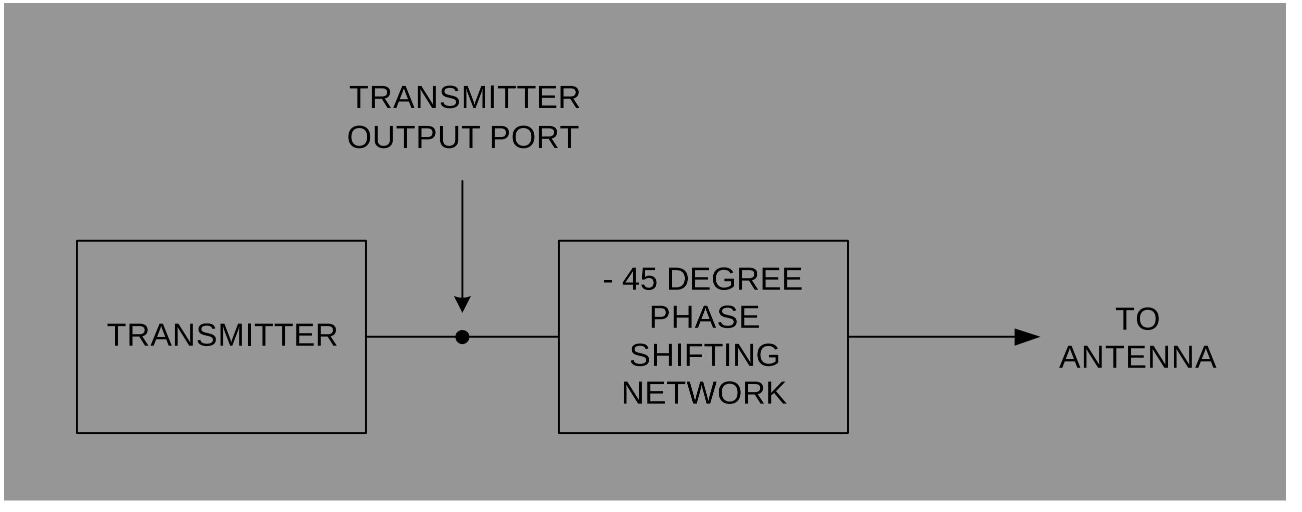


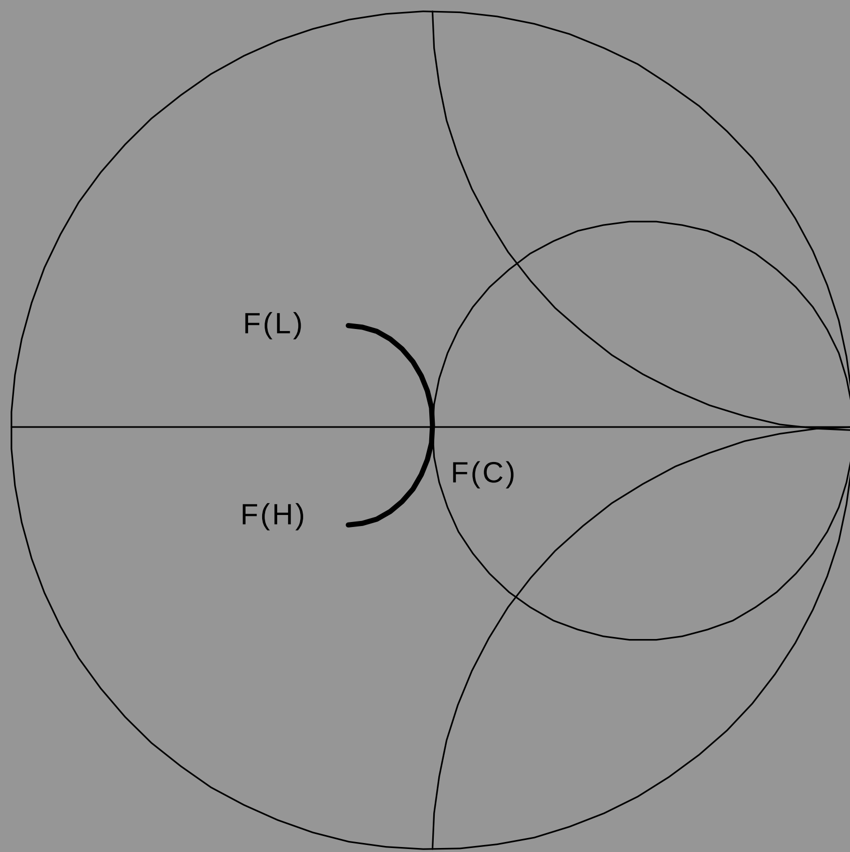
FINAL AMPLIFIER LOAD IMPEDANCE SYMMETRY



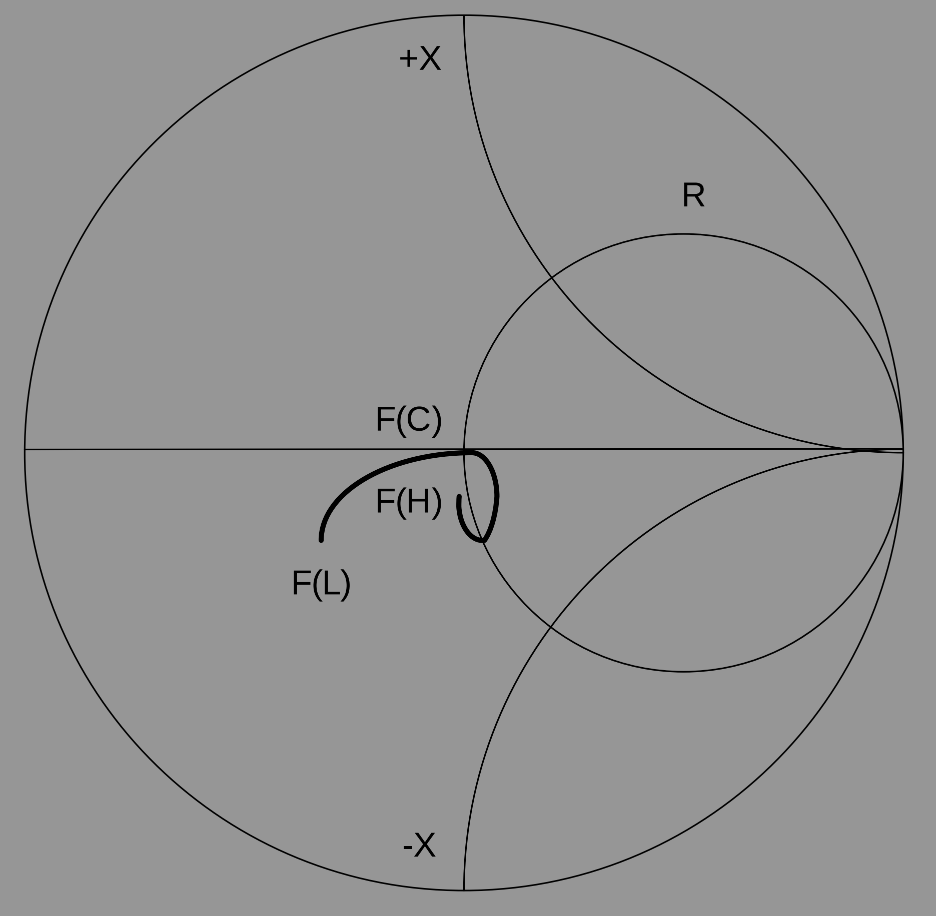
FINAL AMPLIFIER
LOAD IMPEDANCE ASSYMMETRY

Phase Rotation Network



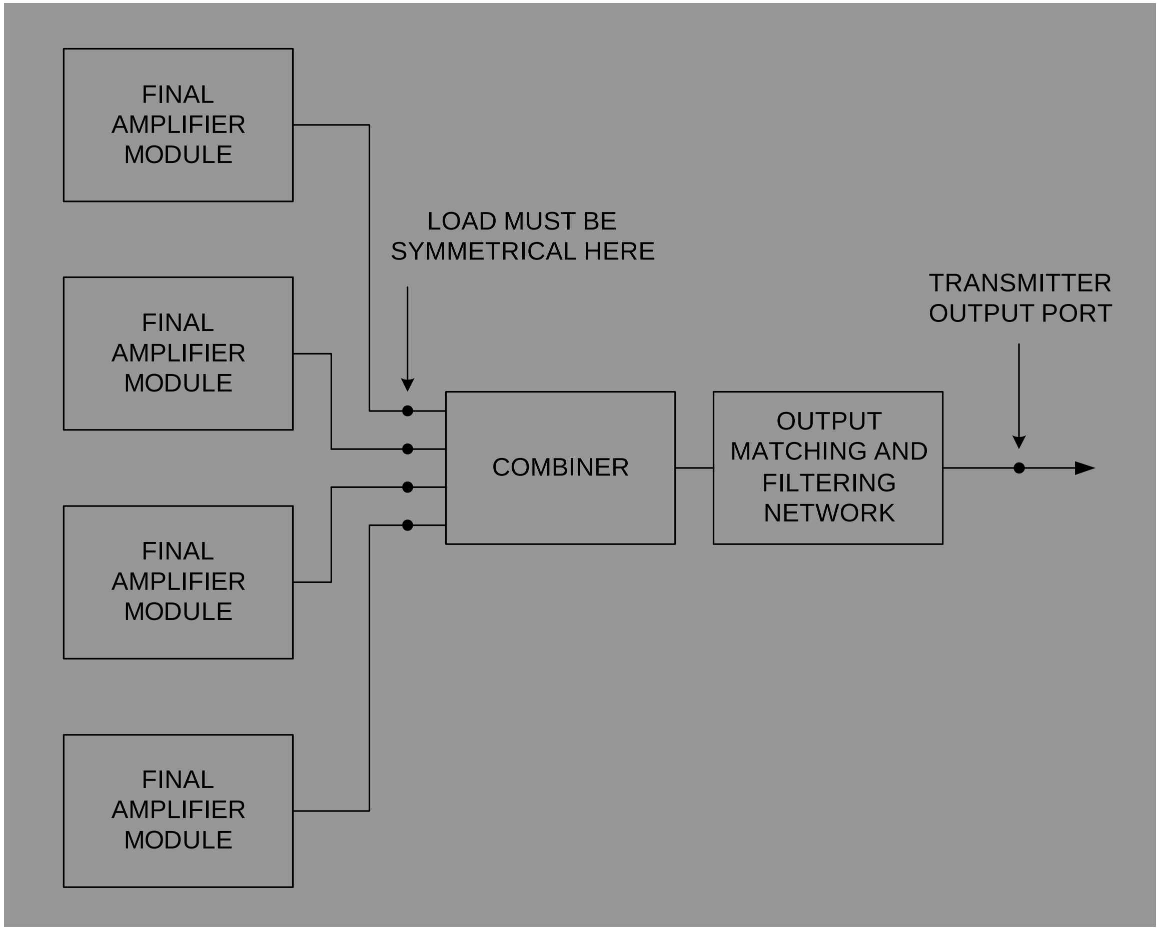


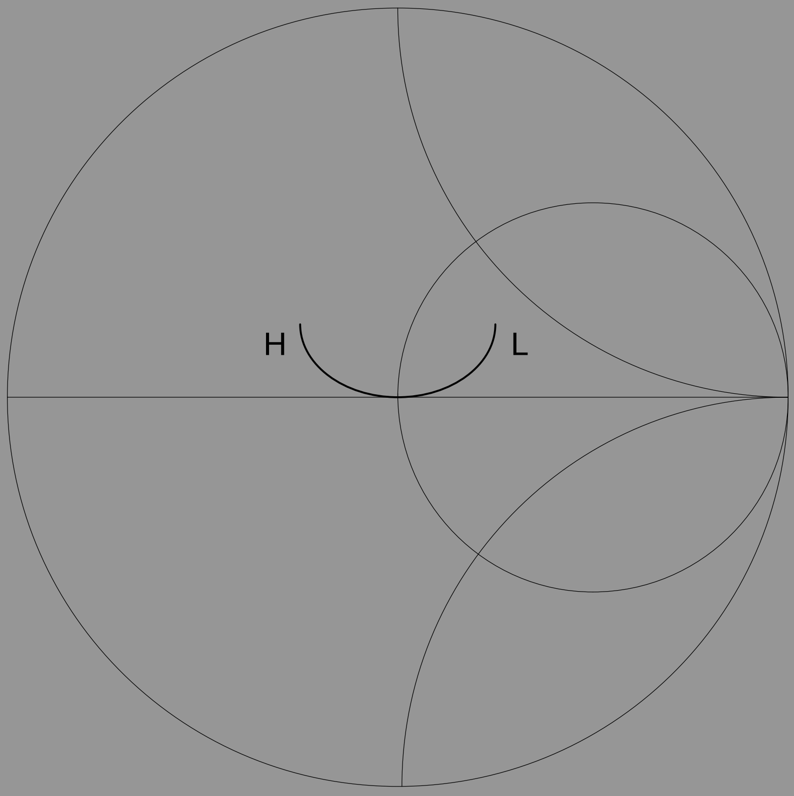
FINAL AMPLIFIER LOAD IMPEDANCE SYMMETRY



UNCORRECTABLE IMPEDANCE ASYMMETRY

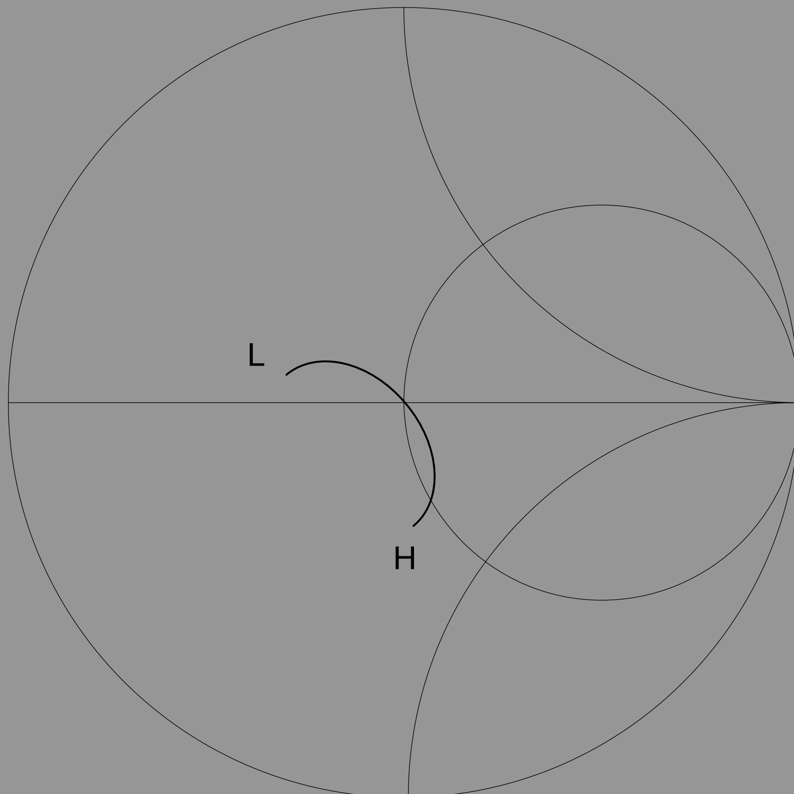
Transmitters With Transformer Combiners





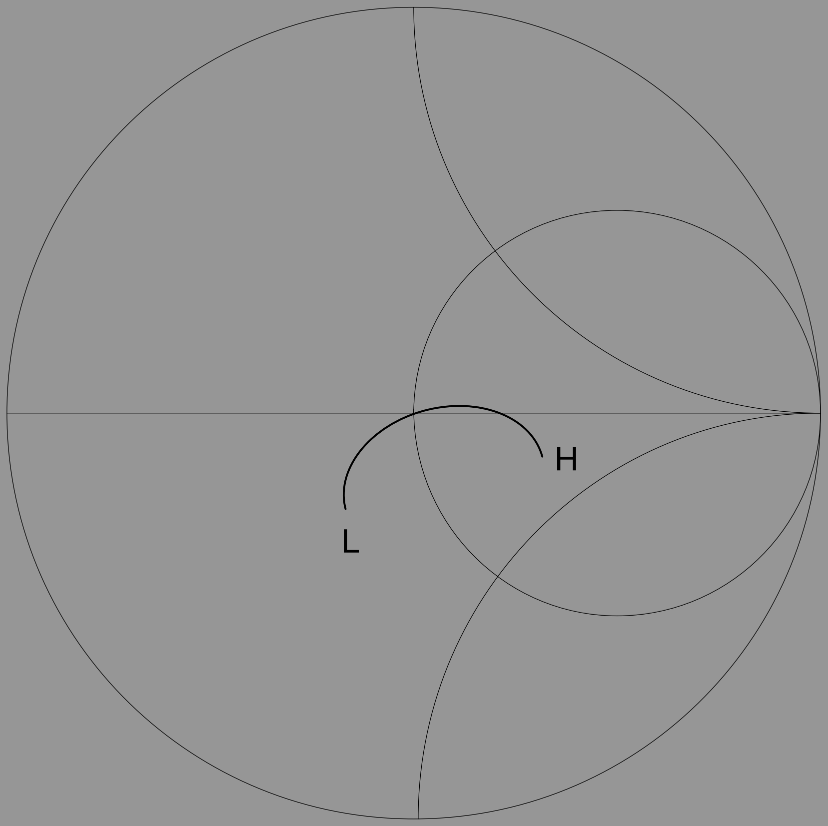
SYMMETRICAL SIDEBAND LOAD
FOR TRANSMITTER WITH
-135 DEGREE OUTPUT NETWORK

(MOST HARRIS MODELS)



SYMMETRICAL SIDEBAND LOAD
FOR TRANSMITTER WITH
-200 DEGREE OUTPUT NETWORK

(MOST BE MODELS)

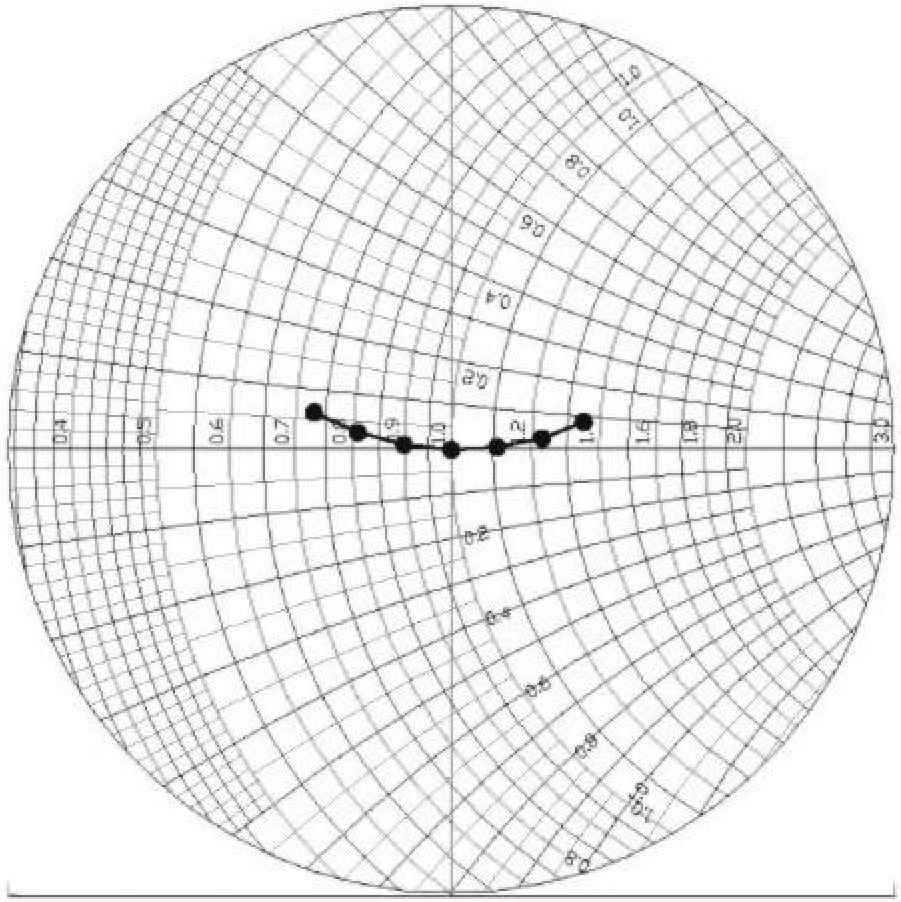


SYMMETRICAL SIDEBAND LOAD
FOR TRANSMITTER WITH
-60 DEGREE OUTPUT NETWORK

(NAUTEL MODELS?)

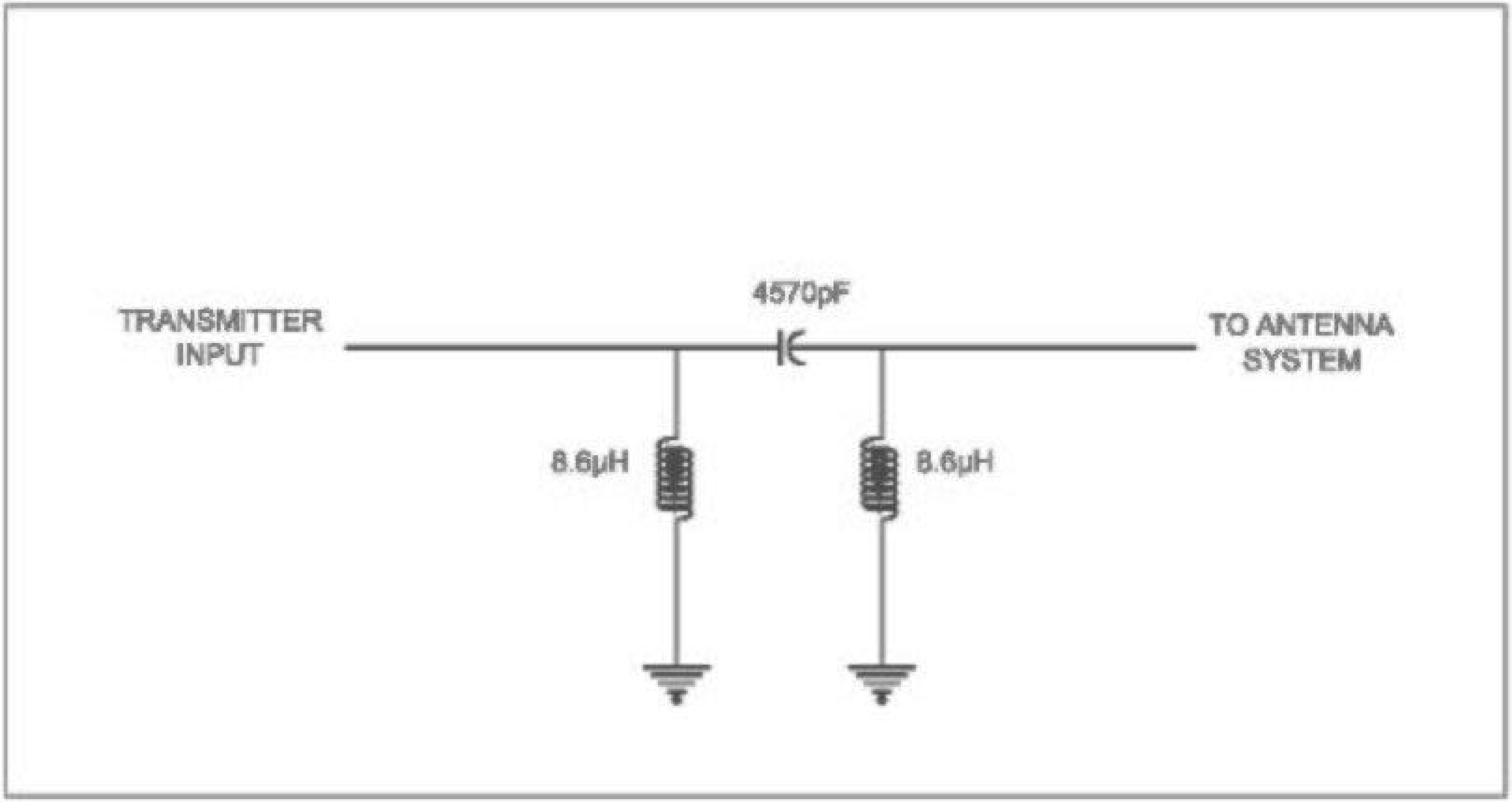
KOTZ

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		

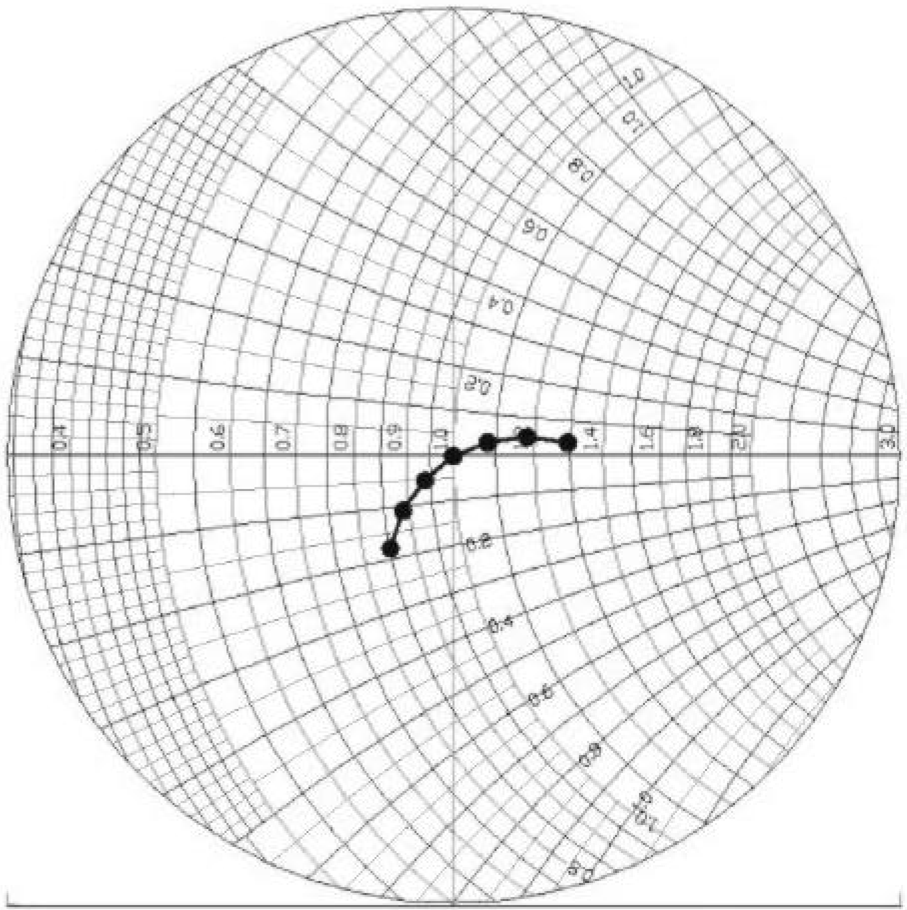


Load At Antenna Feed Line

104.5º Rotation

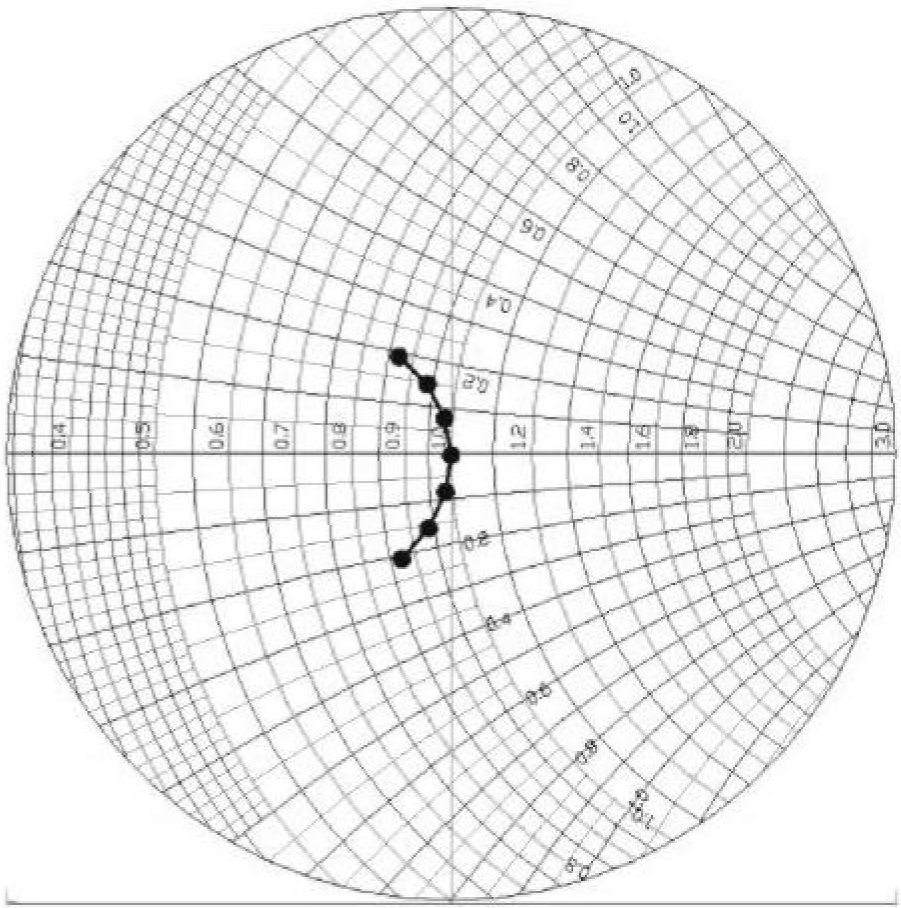


Frequency (kHz)	Impedance Resistance	Reactance	VSWR	IBOC VSWR	IBOC Symmetry	VSWR
705	42.6	-8.9	1.285	Yes		
710	44.3	-5.4	1.181	Yes		
715	46.8	-2.5	1.087	Yes		
720	50.0	0.0	1.000		No	1.155
725	54.0	1.7	1.088	Yes		
730	59.0	2.6	1.188	Yes		
735	64.6	2.0	1.296	Yes		

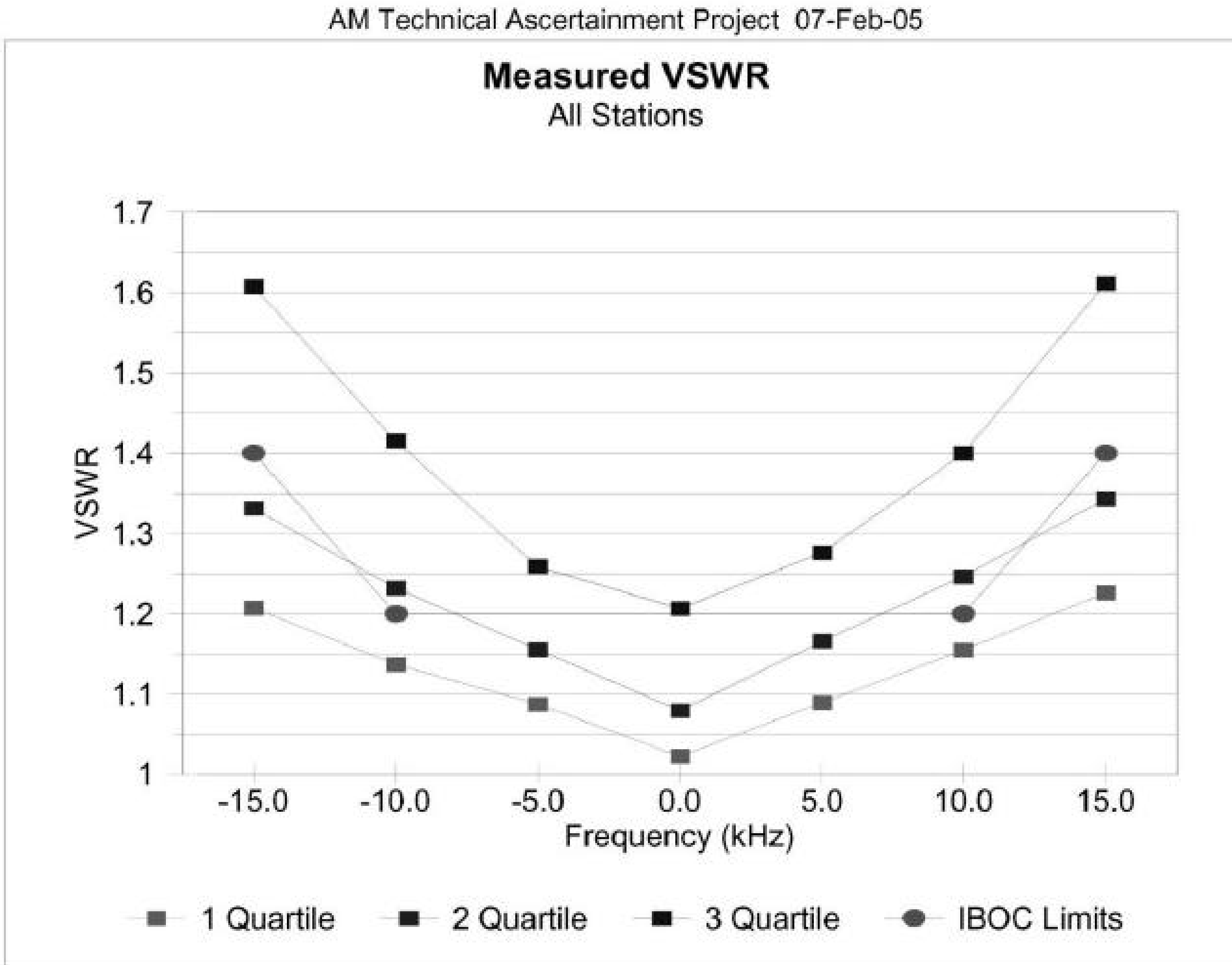


Load Rotated Through Phase Rotation Network

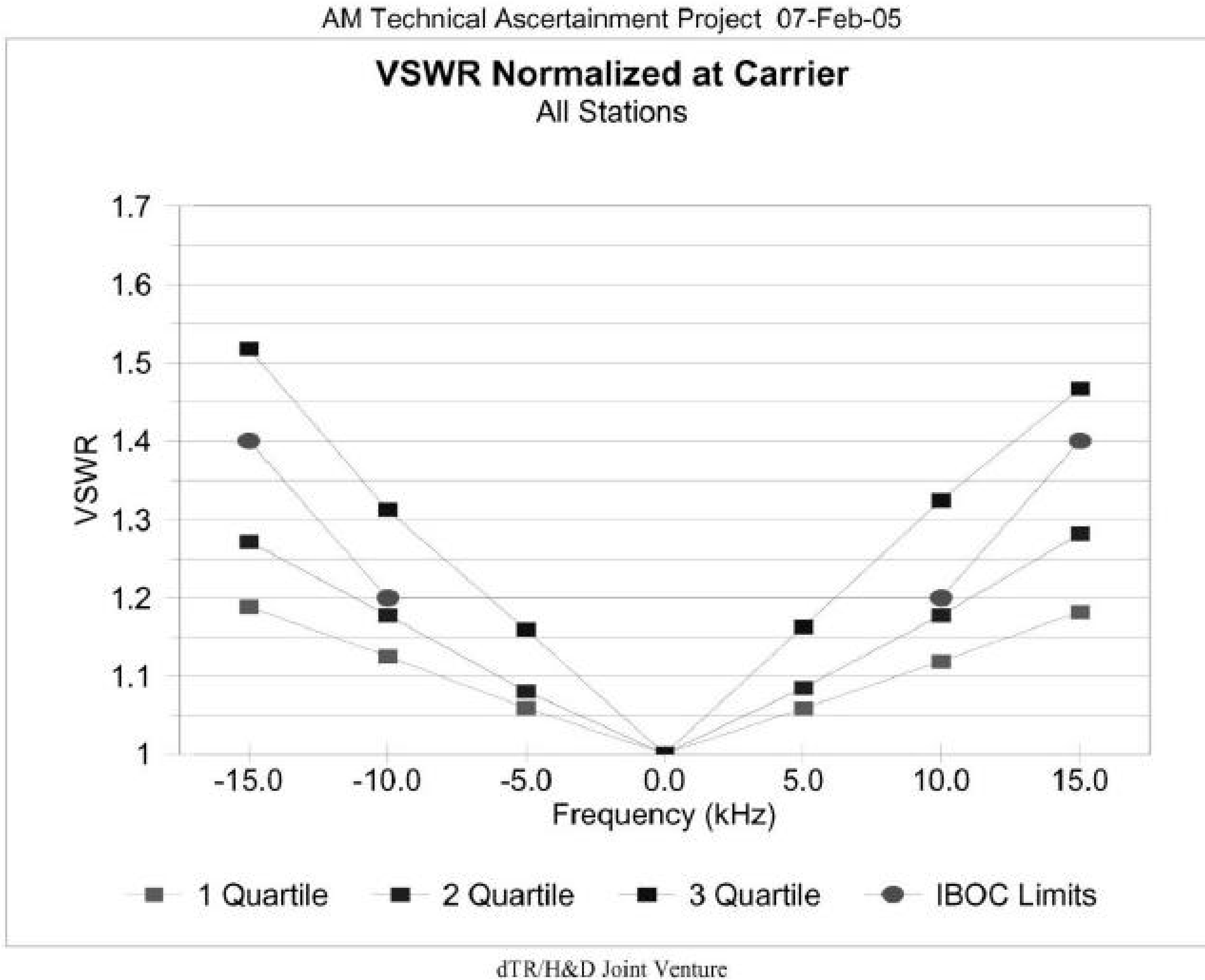
Frequency (kHz)	Impedance Resistance	Reactance	VSWR	IBOC VSWR	IBOC Symmetry	VSWR
705	43.5	9.7	1.285	Yes		
710	46.8	7.4	1.181	Yes		
715	49.1	4.0	1.087	Yes		
720	50.0	-0.0	1.000		Yes	1.003
725	49.2	-4.1	1.088	Yes		
730	46.9	-7.8	1.188	Yes		
735	43.6	-10.3	1.296	Yes		

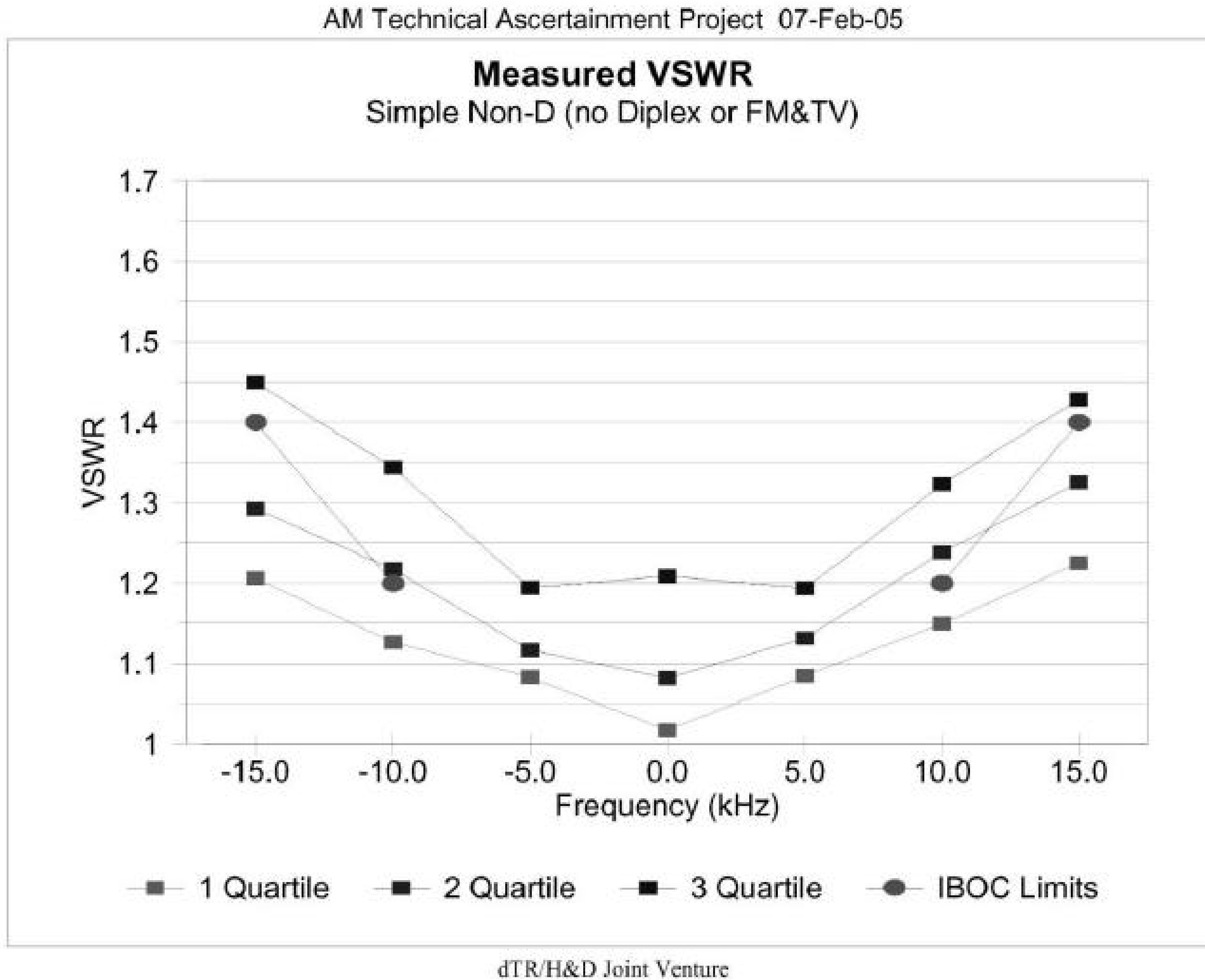


Load Rotated in Transmitter Ouput Network

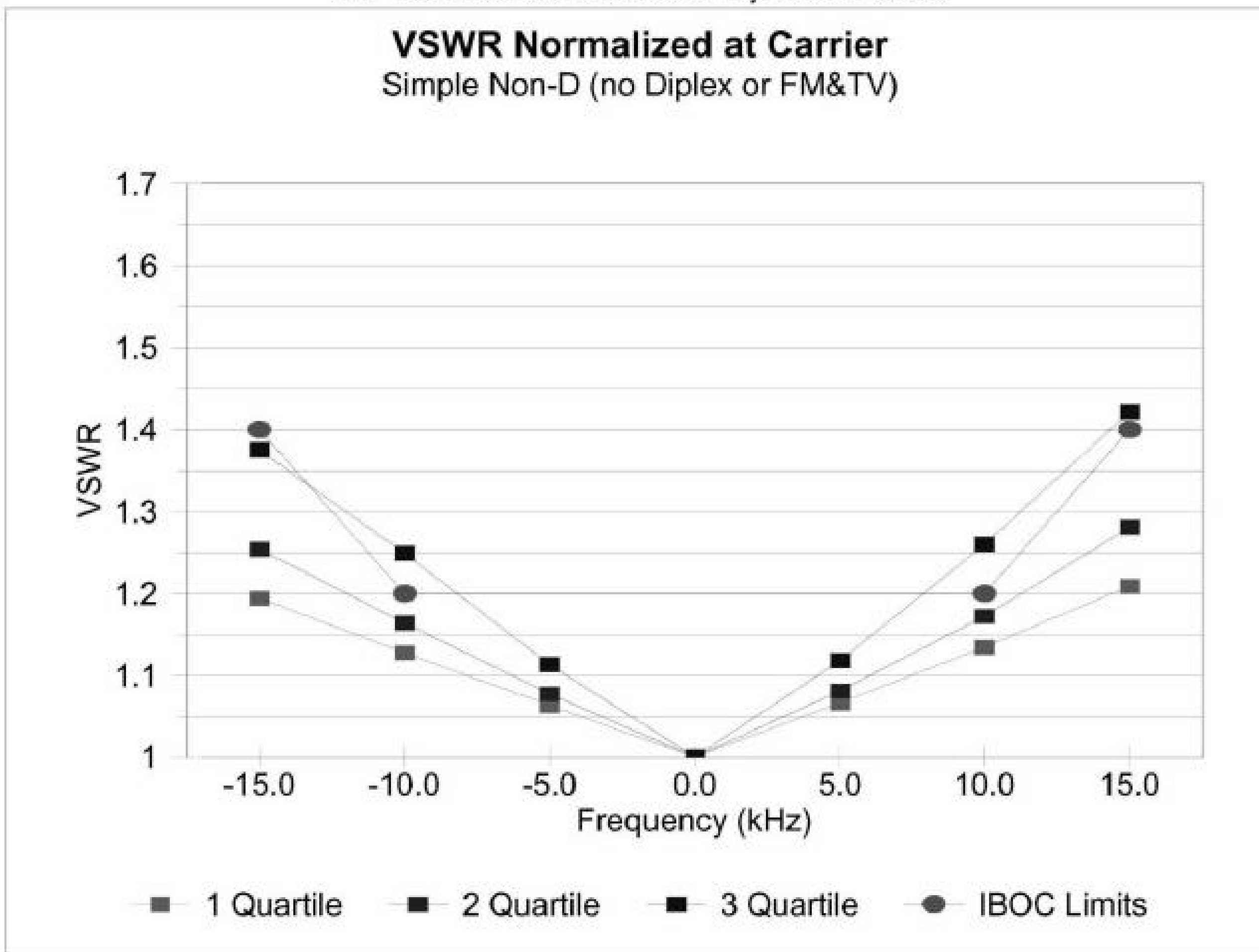


dTR/H&D Joint Venture

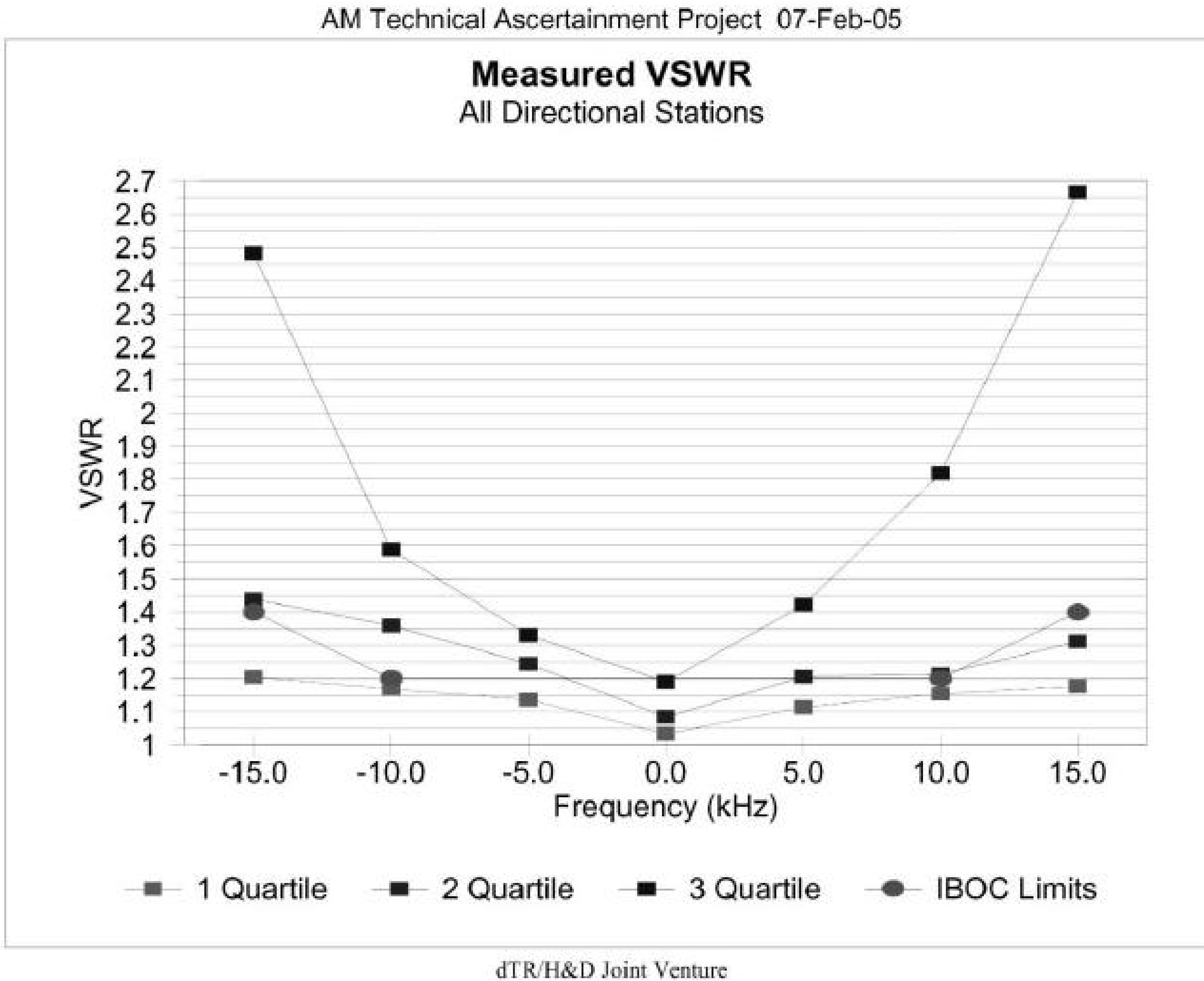

AM Technical Ascertainment Project 07-Feb-05
VSWR Normalized at Carrier
All Stations
VSWR
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
Frequency (kHz)
1 Quartile
2 Quartile
3 Quartile
IBOC Limits
dTR/H&D Joint Venture


AM Technical Ascertainment Project 07-Feb-05
Measured VSWR
Simple Non-D (no Diplex or FM&TV)
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

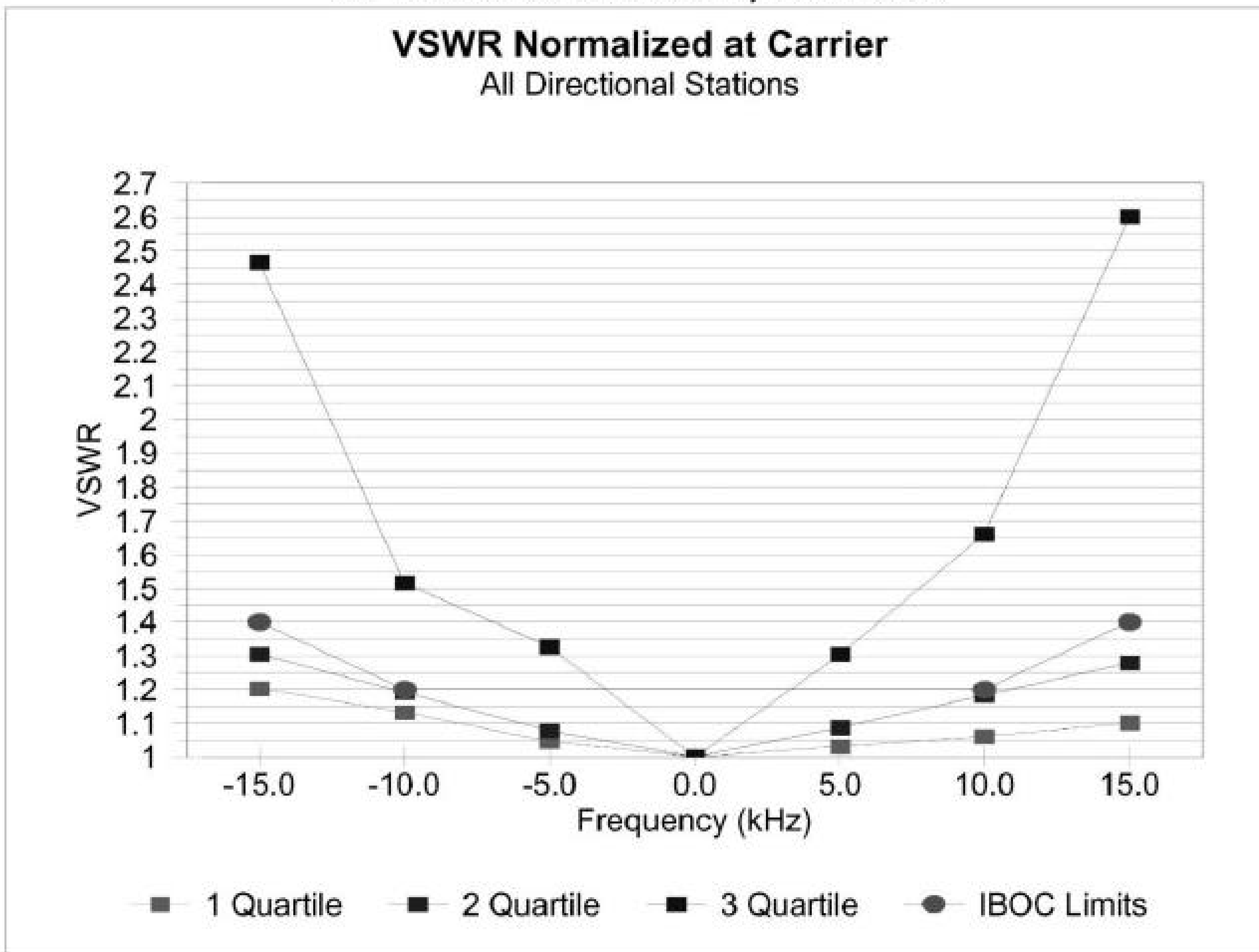
AM Technical Ascertainment Project 07-Feb-05



dTR/H&D Joint Venture

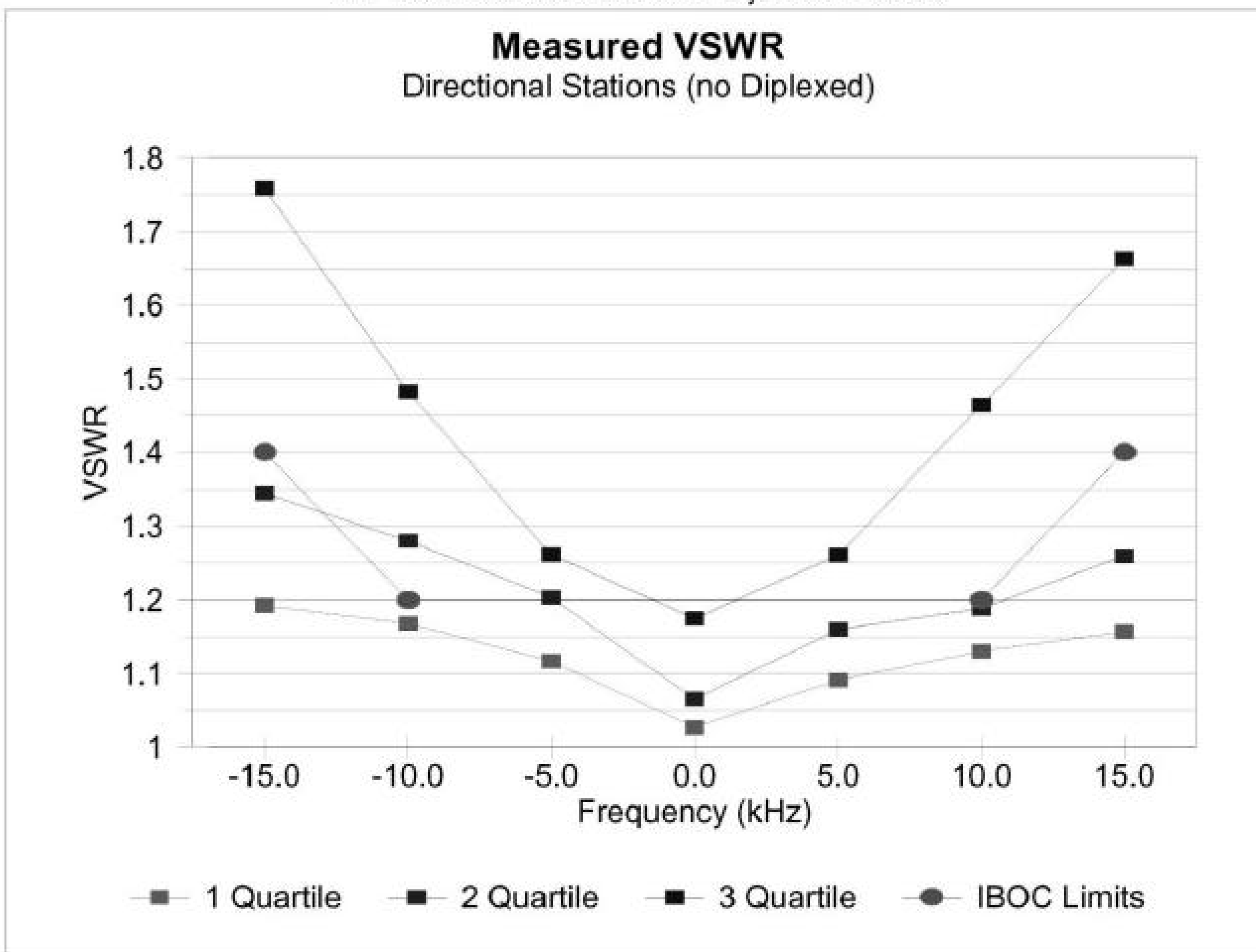

AM Technical Ascertainment Project 07-Feb-05
Measured VSWR
All Directional Stations
VSWR
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
Frequency (kHz)
1 Quartile
2 Quartile
3 Quartile
IBOC Limits
dTR/H&D Joint Venture

AM Technical Ascertainment Project 07-Feb-05

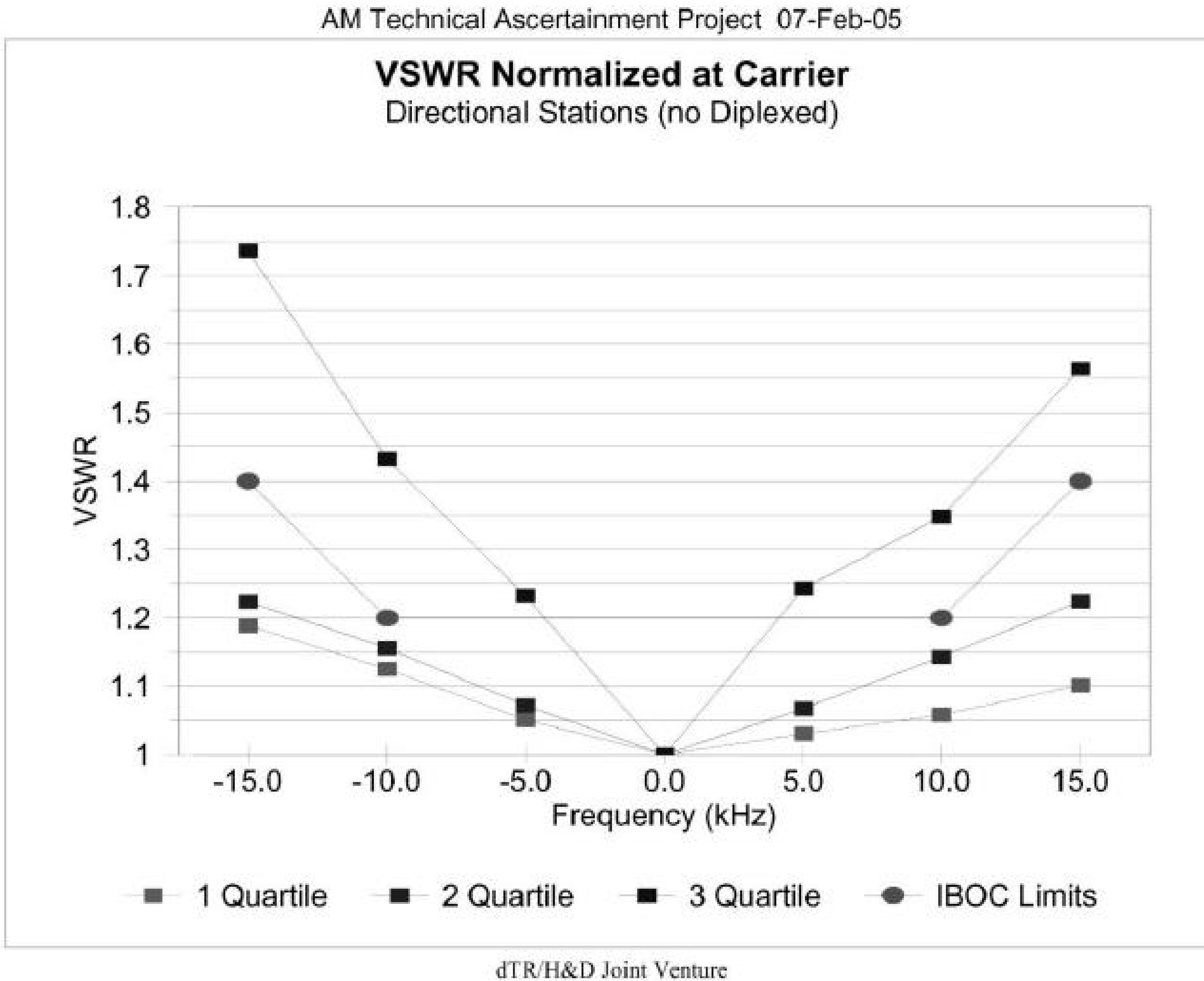


dTR/H&D Joint Venture

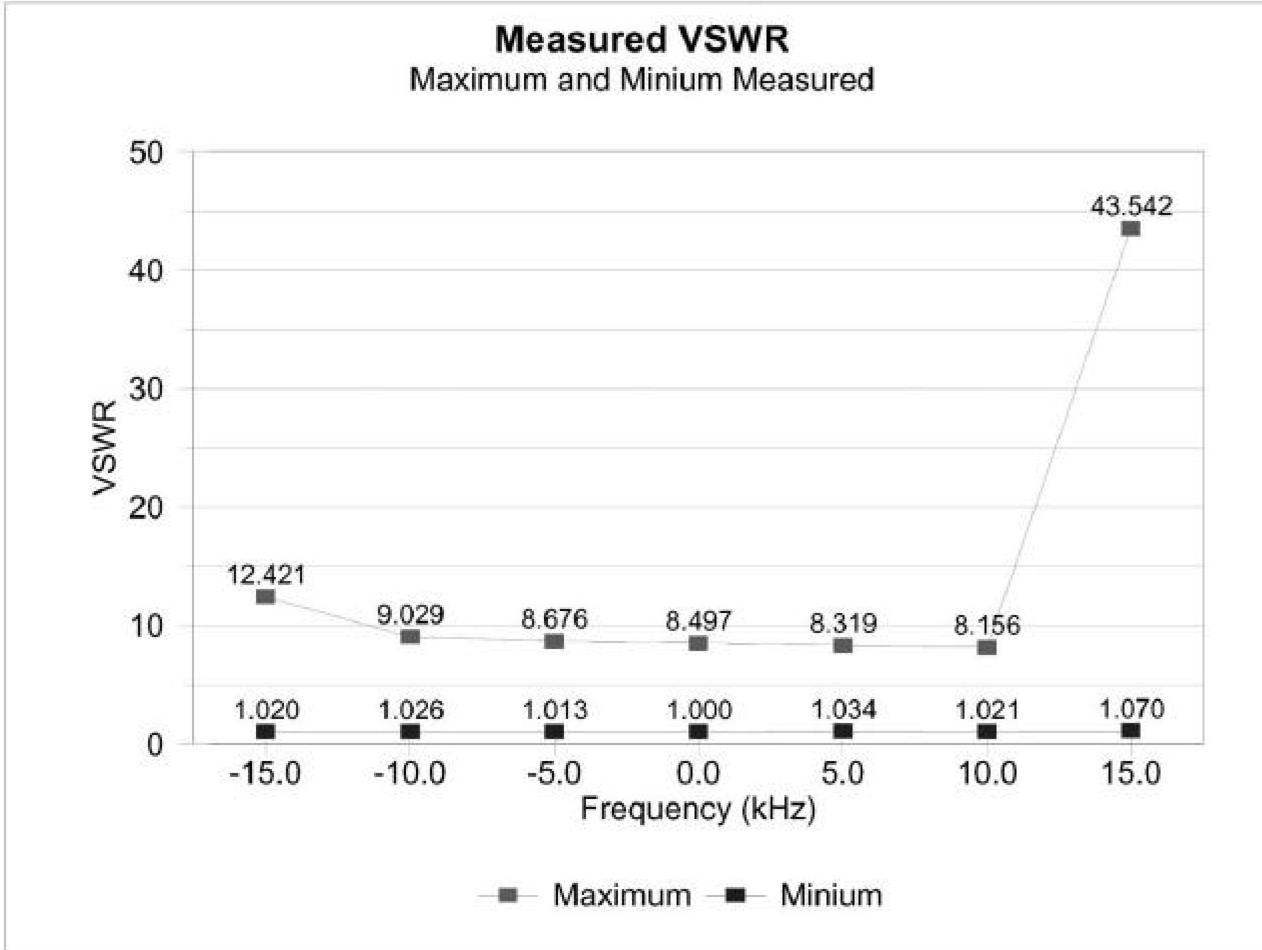
AM Technical Ascertainment Project 07-Feb-05



dTR/H&D Joint Venture


AM Technical Ascertainment Project 07-Feb-05
VSWR Normalized at Carrier
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



dTR/H&D Joint Venture

Important Findings

- Poor Maintenance (or complete lack of any maintenance)
- Low power due to wrong operating impedance
- Bad modulation due to wrong operating impedance
- 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

Where to Go From Here

- Use the Report to design optimal feed system for the selected IBOC transmitter
- Alaska (Public Stations along with Alaska Broadcasters Association) Could Propose a State Wide STA or Waiver to Use IBOC For Daytime and Nighttime to Test Nighttime Operation

Questions?

E-Mail or Call Us

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