Tower Deflection
Impact on Station Service

2025 WBA Broadcasters Clinic

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Tower Deflection Basics

- Winds deflect towers
- Tower deflection causes antenna tilt
- Antenna tilt causes service losses & some gains
- Towers not plumb have greater deflection

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Presentation Overview

- Causes of Tower Deflection
- Deflection With Expected Wind
- Deflection Service Population Impact Study
  - 14 upper Midwest markets from Detroit to Des Moines
  - Service populations calculated for 39 scenarios per market
  - Data distilled into average service losses per market and deflection magnitude
- Theoretical Basis of Deflection Losses

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Tower Deflection Causes

- Wind Loading
  - All wind forces cause some deflection of the tower
  - Towers are designed to withstand specified wind conditions
  - Gusts can cause dynamic variation of deflection
- Ice Formation
  - Asymmetrical icing can cause static deflection
  - Icing increases wind loading and therefore deflection
  - Towers designed to withstand specified icing conditions
- Improper Guy Wire Tension
  - Causes constant deflection of tower
  - Can contribute to structural damage and/or failure

How Much Deflection is Normal?

- Some deflection is unavoidable.
- Deflection is a function of tower structural design.
- Theoretical deflection for assumed worst-case conditions (including icing) is frequently found in tower structural analysis reports.
- Graph of deflection (tilt) versus elevation is provided.

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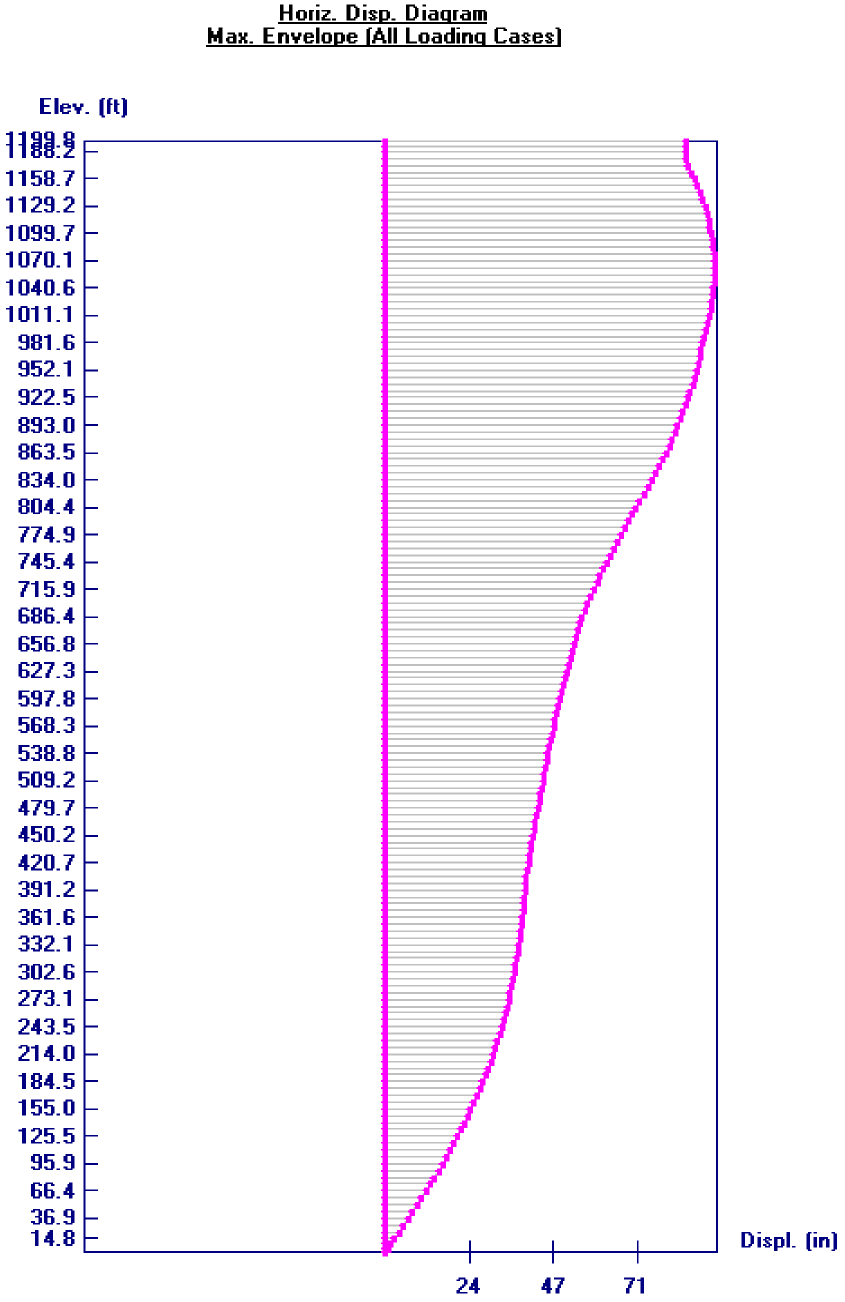
1200' Tower Deflection

Straight tower

Displacement in Inches Shown

Angle = $\tan^{-1}$ (defl/height)

= 0.42°



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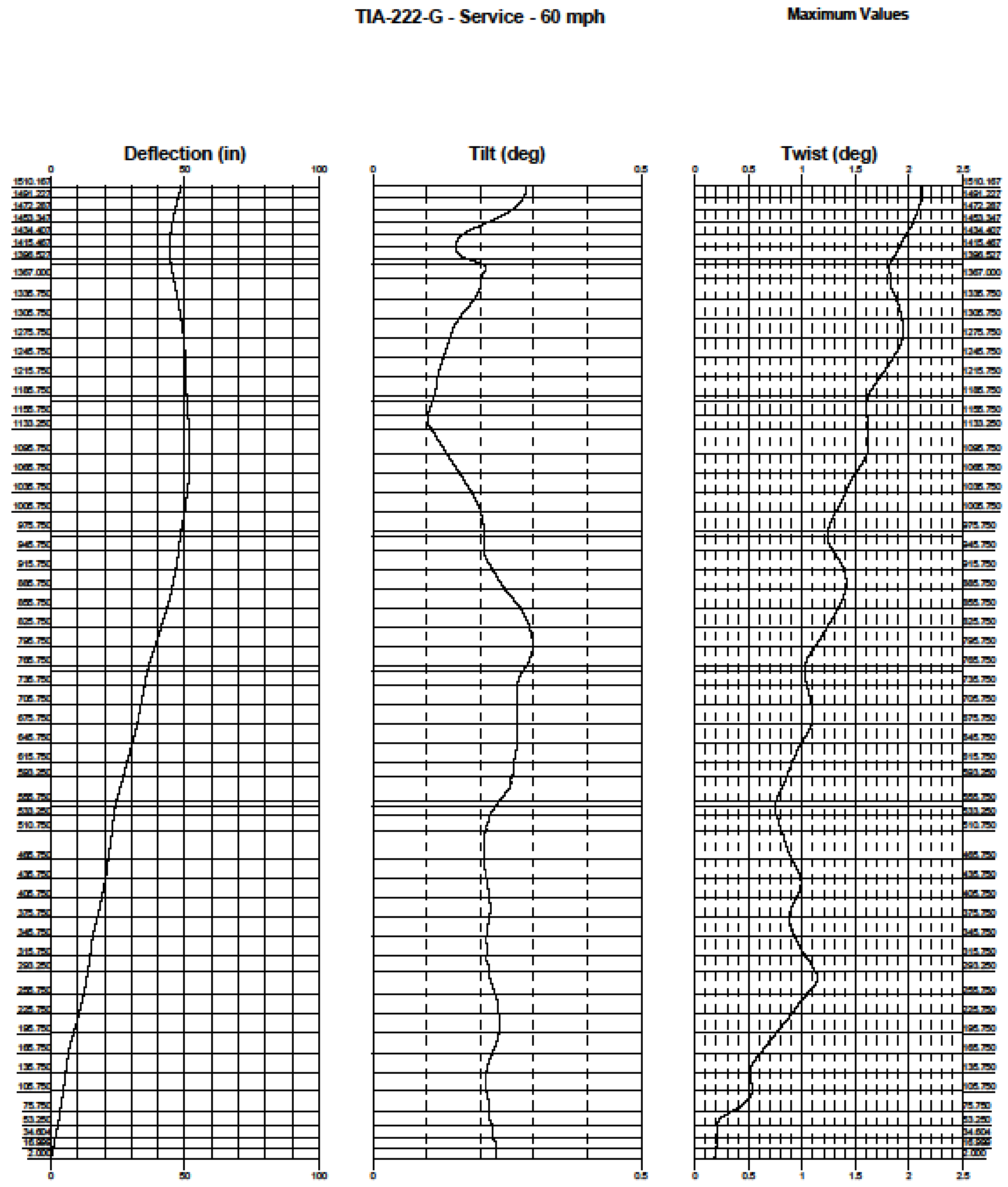
1510' Tower Deflection

tnxTower analysis details

Straight tower, multiple antennas

Tilt can be read directly from center plot

Maximum deflection 0.3°



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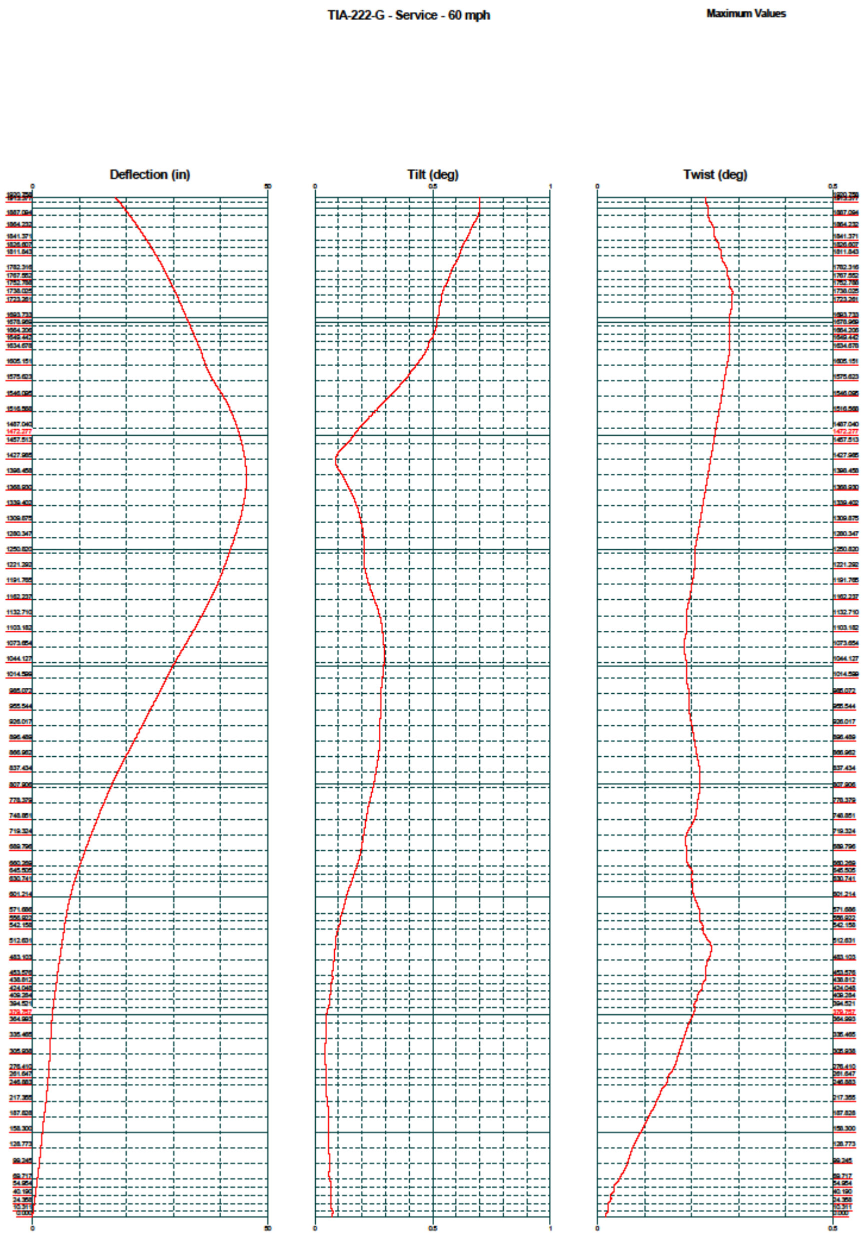
2000' Tower Deflection

tnxTower analysis details

Candelabra tower

Tilt can be read directly from center plot.

Maximum deflection 0.7°



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Physical Deflection Takeaways

- Towers are designed to minimize deflection
- Structural standards used in design & analysis include significant wind and ice loading assumptions
- Theoretical deflections of ½° are typical

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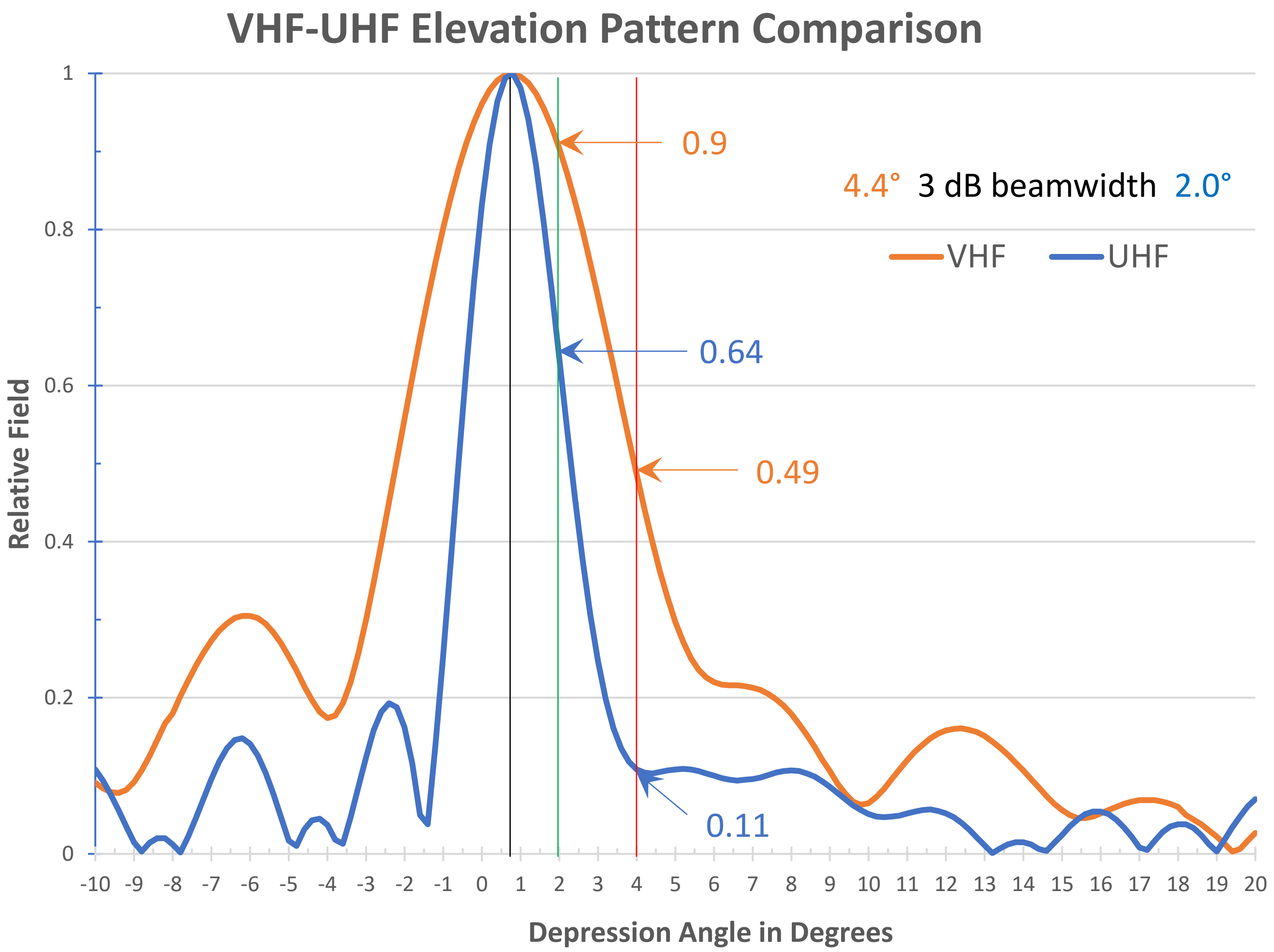
Impact of Tower Deflection

- Wind, Icing, or Mis-Tensioning Deflects Tower
- Antenna is Physically (Mechanically) Tilted
- Elevation Radiation Pattern is Tilted
- Signal Strength Varies from Normal Near Surface
  - Increased in some locations, decreased in others

Typical Elevation Radiation Patterns



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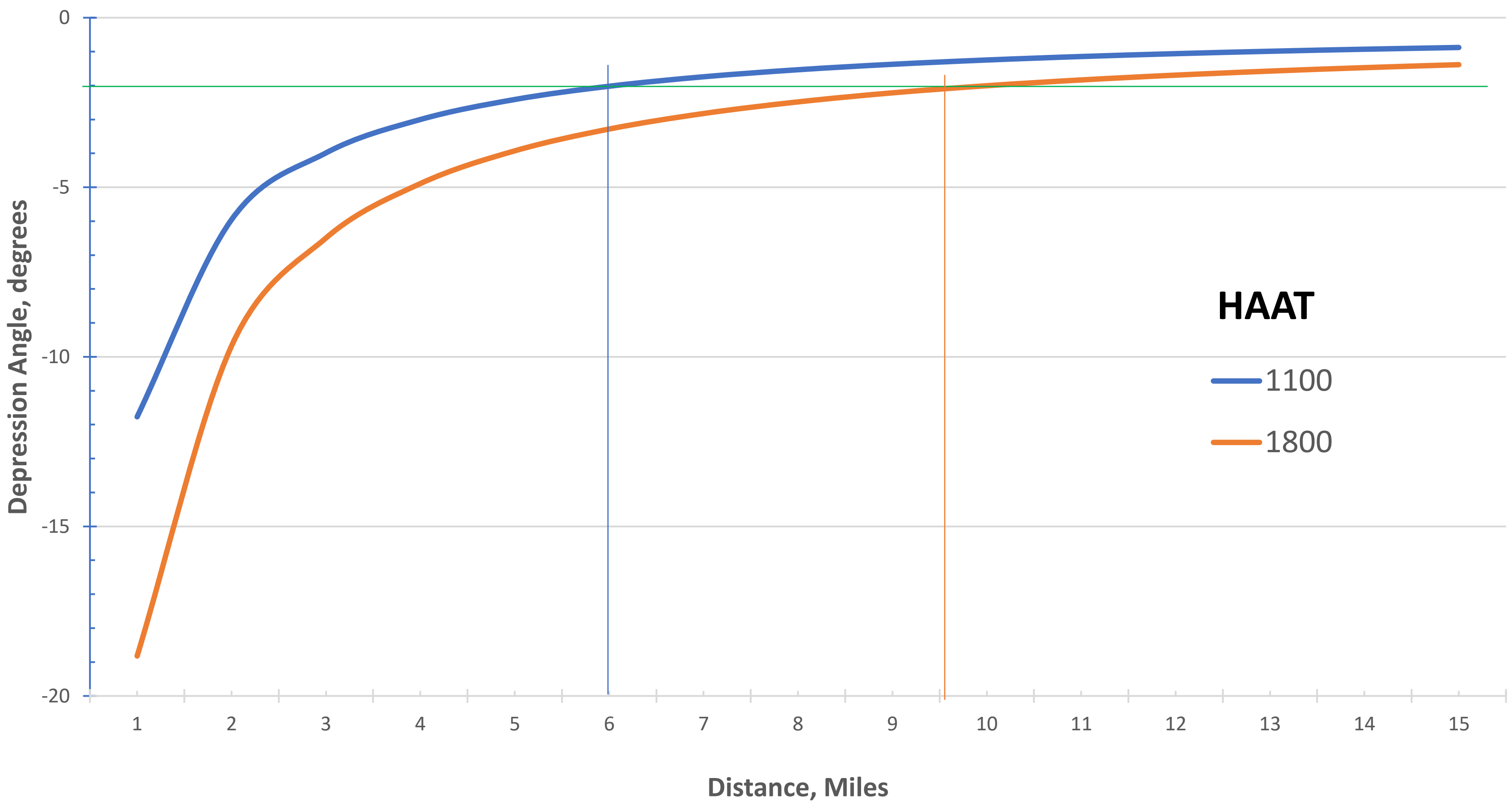
Depression Angle Distances



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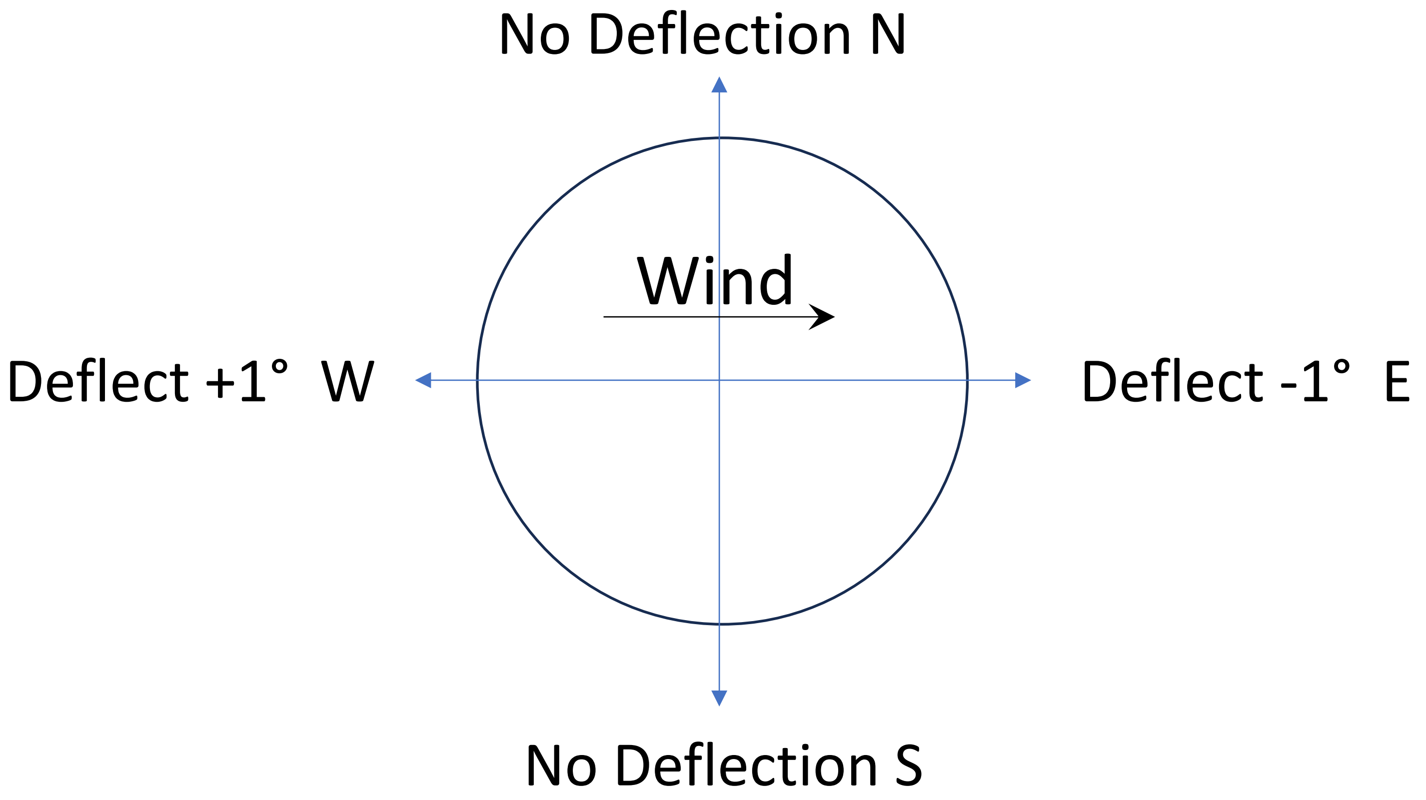
Deflection Impact Overview



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Pattern & Elevation Observations

- Narrower elevation beams are more sensitive to deflection: UHF more susceptible than HVHF
- Greater antenna elevation causes more sensitivity to deflection
- No impact in directions orthogonal to the direction of deflection, symmetrical opposite tilt inline

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Service Population Impact Study

- 14 Upper Midwestern Markets
- "Typical" Station Defined for Each Market
- 3 Deflection Scenarios in 4 Directions per Market
- 3 Receiving Scenarios
- 39 Total Scenarios per Market
- FCC's TVStudy Software Used

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Service Population Study Markets

- 14 Upper Midwest Markets
  - Detroit to Des Moines, Peoria to Duluth
- Some markets intentionally omitted
  - Buildings, not towers, used at Chicago
  - Substantial site diversity precludes "average" station derivation:
    - Grand Rapids, Lansing
    - Traverse City-Cadillac, Marquette
    - Eau Claire, Wausau etc.
  - Insufficient stations for averaging
    - Rockford

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"Typical" Station for Each Market

- Averaged UHF and VHF Channel
  - Used regardless of whether it is occupied in the market
- Hypothetical Transmitter Site
  - Located at centroid of actual station sites
  - "Outlier" sites not included in average
- Averaged radiation center elevation
  - Average based on both UHF and VHF stations (except Duluth)
- Averaged Effective Radiated Power
  - Separate averages for UHF and VHF
- Averaged Antenna Slot/Bay Count & Electrical Tilt
  - Antenna manufacturer & elevation pattern based on "market consensus"
- Omnidirectional Operation Assumed

VHF and UHF Stations Studied

- "Typical" UHF Station in All Markets
  - Most markets have no more than one VHF station
  - VHF ignored in these markets – deflection not critical in VHF
- "Typical" VHF Stations in Des Moines and Duluth
  - 3 VHF stations in Des Moines market
  - 2 VHF stations in Duluth market

"Typical" Station Data

Market	Channel	Latitude			Longitude			ERP	RCAMSL	Slots	Tilt	HAAT
		(°)	(')	(")	(°)	(')	(")	(kW)	(m)		(°)	(ft)
Cedar Rapids	28	42	17	21	91	53	56	663	821.8	31	1	1788
Des Moines (UHF)	26	41	49	2	93	36	60	671	891.5	28	1	1965
Detroit	27	42	27	46	83	13	1	483	522.3	22	0.75	1016
Duluth (UHF)	24	46	47	22	92	7	8	451	588.4	12	0.75	971
Flint-Saginaw-BayCity	25	43	13	20	83	55	35	546	530.4	22	0.75	1093
Green Bay	23	44	22	39	88	6	50	714	594.5	26	0.75	1170
La Crosse	25	43	48	19	91	22	9	550	599.1	22	0.75	1081
Madison	21	43	3	18	89	31	37	354	749.0	26	1	1475
Milwaukee	30	43	5	54	87	54	33	967	525.7	27	1	1063
Minneapolis-St.Paul	30	45	3	38	93	7	57	847	709.4	30	1	1416
Quad Cities	27	41	23	26	90	24	43	933	567.7	28	1	1144
Peoria	28	40	37	50	89	33	4	479	396.9	30	0.75	652
Rochester	26	43	38	34	92	31	36	349	699.9	21	1	1076
South Bend	31	41	36	34	86	11	45	329	565.5	30	0.62	0
Des Moines (VHF)	11	41	49	2	93	36	60	34.5	891.5	17	0.5	1965
Duluth (VHF)	9	46	47	22	92	7	8	39.5	608.4	12	1	990

What is TVSTUDY

- FCC’s multipurpose TV service analysis software
- Based on FCC/OET Bulletin 69 DTV analysis procedures
- Uses NTIA Integrated Terrain propagation model (a/k/a Longley-Rice)
- Nearly all analysis parameters can be configured, facilitating many tasks other than TV interference

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13 Hypothetical Deflection Scenarios

- No Deflection, Minimal Wind
- ½° Deflection – Normal Variations
  - North, East, South, West
- 1° Deflection – Wind/Ice Near Design Limit
  - North, East, South, West
- 1½° Deflection – Tower Not Plumb, Windy
  - North, East, South, West

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3 Receiving Scenarios per Market

TVStudy Parameter	Rural	Suburban	Urban
Receiving Height	33 ft (10 m)	13 ft (4 m)	6½ ft (2 m)
Minimum Signal Strength	48(UHF), 46(VHF) dBμ	60(UHF), 56(VHF) dBμ	80(UHF), 68(VHF) dBμ
Location Variability	50%	90%	90%
Time Variability	90%	90%	90%
Situational Variability	50%	90%	90%

Minimum Signal Strength Based On:

Receiver antenna gain, antenna/coax mismatch, coax loss, building penetration loss
Noise components & multipath effects

Deficiencies in FCC's 41 dBμ (UHF) and 36 dBμ (VHF) Thresholds:

Multipath effects, building penetration loss, antenna/coax mismatch not included
Antenna gain overly optimistic, coax loss based on 33' elevation

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TVStudy Analysis Assumptions

- Interference Not Considered
- Terrain Blockage/Attenuation Considered
- Land Use & Land Cover Losses Not Considered
- 2010 Census Population Data
- 0.2 km Terrain Sampling Interval
- ½ km Study Cell Size

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Impact Data Consolidation

- Output Data:
  - Service loss percentage calculated for 36 deflection scenarios
    - 3 deflections for each direction and receiving scenario
    - 3 receiving scenarios
    - 4 directions per receiving scenario
  - 39 data points per market (78 if VHF included)
- Data Processing:
  - Average of 4 directions calculated for each receiving scenario and deflection
  - 9 average loss percentages per UHF market, 18 for HVHF+UHF

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Normal Deflection Analysis

- Based on ½° to 1° antenna deflection
- Correlates with worst-case structural analysis results
- Assumes tower plumb throughout aperture absent wind

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Summary Data – ½° & 1° Deflection

				½° Population Impact			1° Population Impact		
Market	ERP	HAAT	Slots/Bays	Urban	Suburban	Rural	Urban	Suburban	Rural
Peoria	479	652	30	-0.2%	-0.6%	0.0%	-1.3%	-2.1%	-0.1%
Duluth UHF	451	990	21	-1.3%	-0.1%	-0.1%	-4.6%	-0.3%	-0.4%
Detroit	483	1016	22	-0.6%	-0.2%	-0.1%	-2.1%	-0.5%	-0.1%
South Bend	329	1058	30	-2.0%	-0.4%	-0.1%	-12.7%	-1.9%	-0.5%
Milwaukee	967	1063	27	-1.5%	-2.6%	-0.2%	-3.3%	-2.7%	-0.7%
Rochester	349	1076	21	-0.7%	-1.1%	-0.1%	-5.5%	-0.8%	-0.3%
La Crosse	550	1081	22	-0.2%	-0.1%	-0.2%	-0.5%	-0.5%	-0.6%
Flint-Saginaw Bay	546	1093	22	-0.7%	-0.2%	-0.2%	-3.6%	-0.8%	-0.6%
Quad Cities	933	1144	28	-0.3%	-1.0%	-0.3%	-2.0%	-4.4%	-1.7%
Green Bay	714	1170	26	0.7%	-0.3%	0.0%	-2.3%	-1.3%	-0.2%
Twin Cities	847	1416	30	-1.4%	-0.2%	-0.1%	-3.8%	-1.5%	-0.5%
Madison	354	1475	26	-0.2%	-0.4%	-0.2%	-2.9%	-1.3%	-0.8%
Cedar Rapids	663	1788	31	-2.7%	-0.2%	-0.2%	-12.6%	-1.3%	-1.2%
Des Moines UHF	671	1965	28	-1.1%	-0.2%	0.1%	-4.7%	-0.7%	-1.3%
Overall Average UHF Population Impact				**-0.9%**	**-0.5%**	**-0.1%**	**-4.4%**	**-1.4%**	**-0.6%**
Duluth VHF	39.5	971	12	-0.3%	-0.1%	-0.1%	-0.8%	-0.2%	-0.4%
Des Moines VHF	34.5	1965	18	-0.1%	0.0%	0.0%	-0.9%	-0.1%	-0.1%
Overall Average HVHF Population Impact				**-0.2%**	**-0.1%**	**-0.1%**	**-0.8%**	**-0.1%**	**-0.2%**

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HAAT Correlation, UHF Rural

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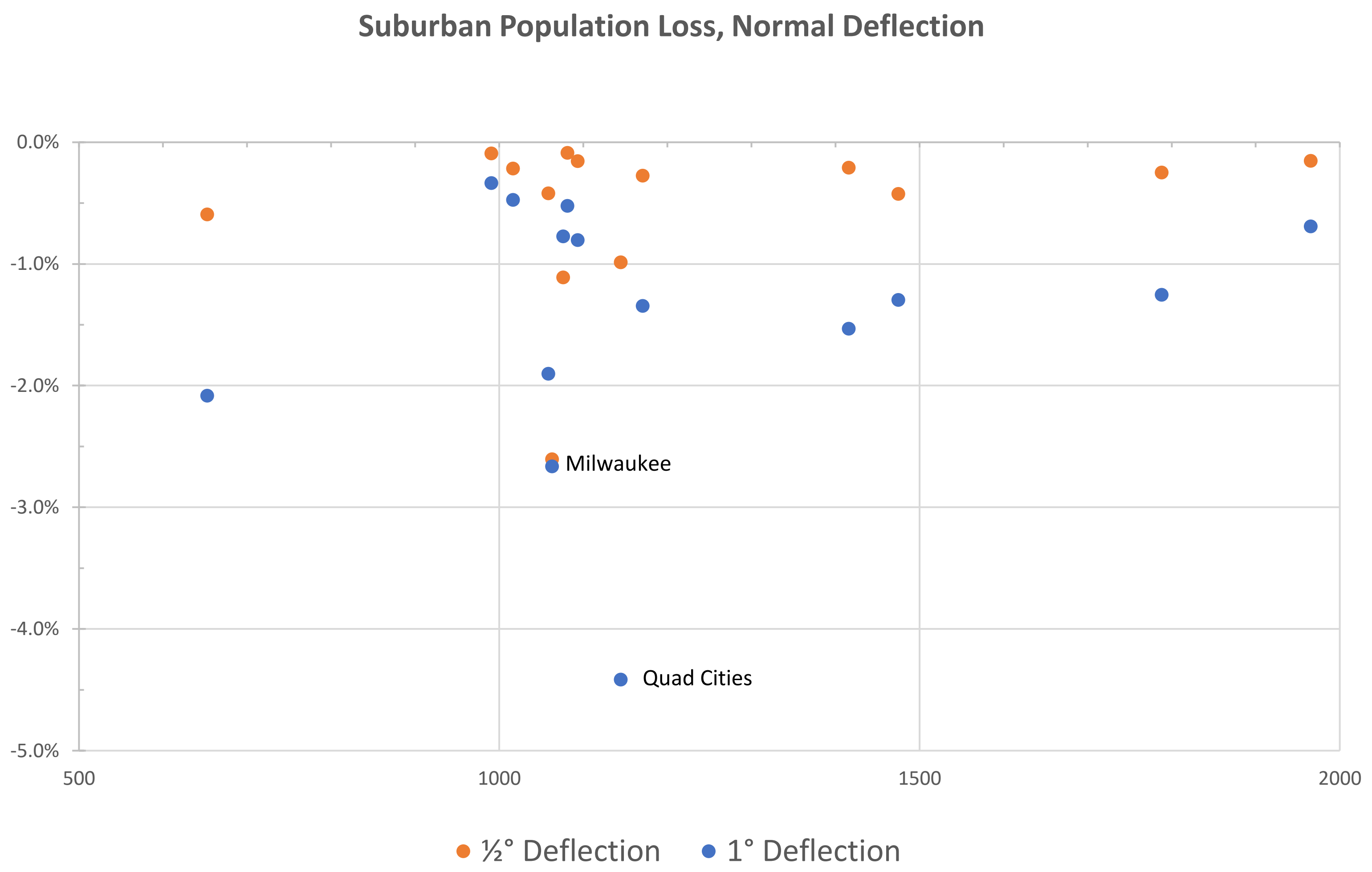
HAAT Correlation, UHF Suburban



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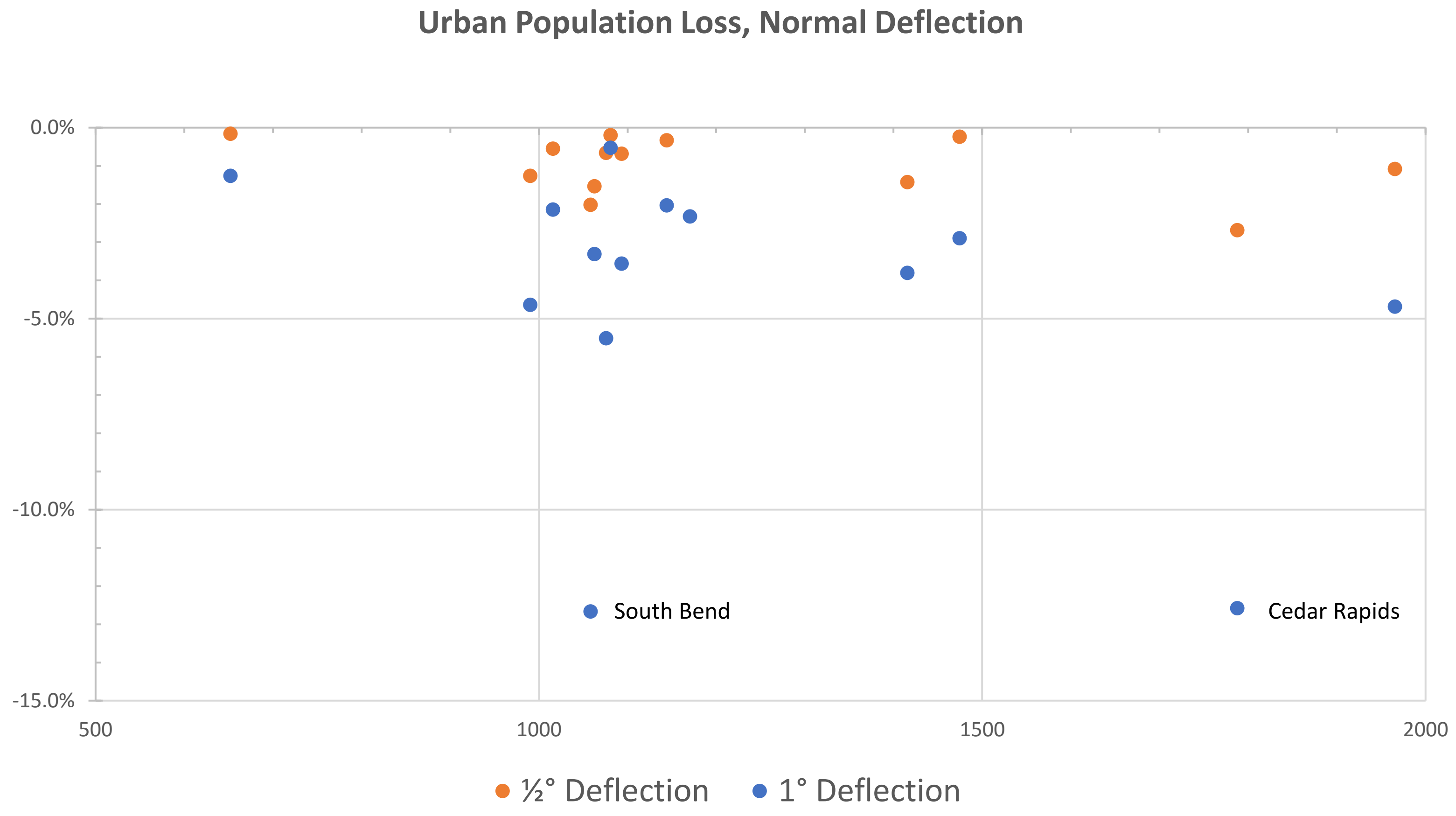
HAAT Correlation, UHF Urban



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Static Tilted Tower Scenario

- Tower out-of-plumb
- ½° to 1° static structural deflection
- ½° to 1° wind deflection
- 1½° total deflection

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Summary Data – 1½° Deflection

Market	ERP	HAAT	Slots/Bays	Urban	Suburban	Rural
Peoria	483	1016	22	-5.6%	-1.1%	-0.2%
Duluth UHF	546	1093	22	-7.4%	-1.9%	-1.5%
Detroit	329	1058	30	-22.1%	-4.5%	-1.8%
South Bend	967	1063	27	-4.3%	-4.1%	-3.6%
Milwaukee	714	1170	26	-6.7%	-3.0%	-0.8%
Rochester	479	652	30	-6.0%	-5.1%	-0.6%
La Crosse	933	1144	28	-8.9%	-7.9%	-4.5%
Flint-Saginaw Bay	354	1475	26	-11.5%	-3.1%	-2.2%
La Crosse	550	1081	22	7.2%	-1.1%	-1.3%
Duluth UHF	451	990	21	-10.0%	-0.7%	-1.0%
Cedar Rapids	663	1788	31	-24.1%	-3.8%	-3.0%
Des Moines U	671	1965	28	-20.9%	-1.7%	-0.6%
Rochester	663	1788	31	-1.5%	-2.7%	-0.3%
Twin Cities	847	1416	30	-16.4%	-2.0%	-1.2%
Overall UHF Average Population Impact				**-9.9%**	**-3.1%**	**-1.6%**
Des Moines VHF	34.5	1965	18	-1.8%	-0.1%	-0.2%
Duluth VHF	39.5	971	12	-1.6%	-0.4%	-1.0%
Overall HVHF Average Population Impact				**-1.7%**	**-0.3%**	**-0.6%**

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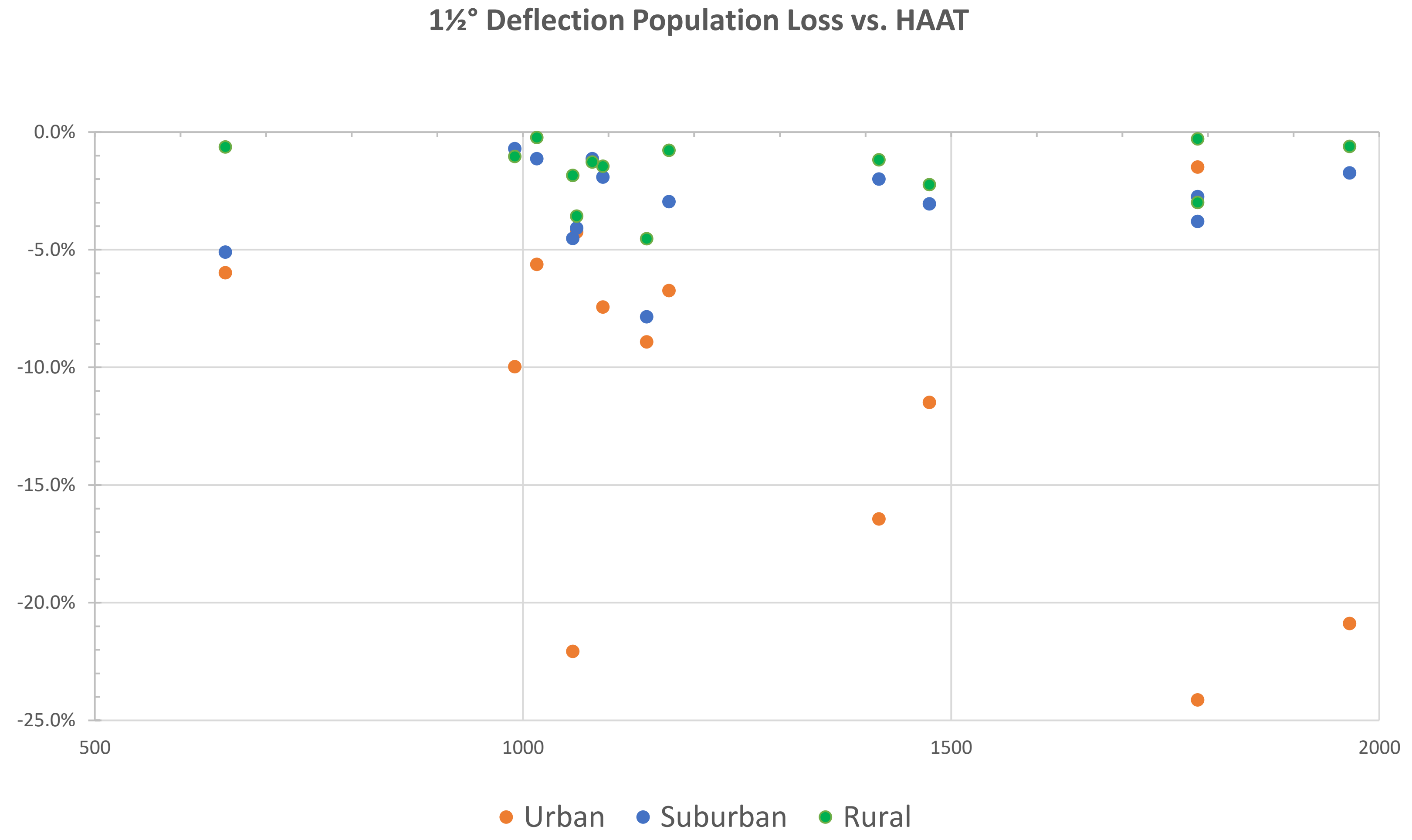
HAAT Correlation, UHF 1½° Deflection



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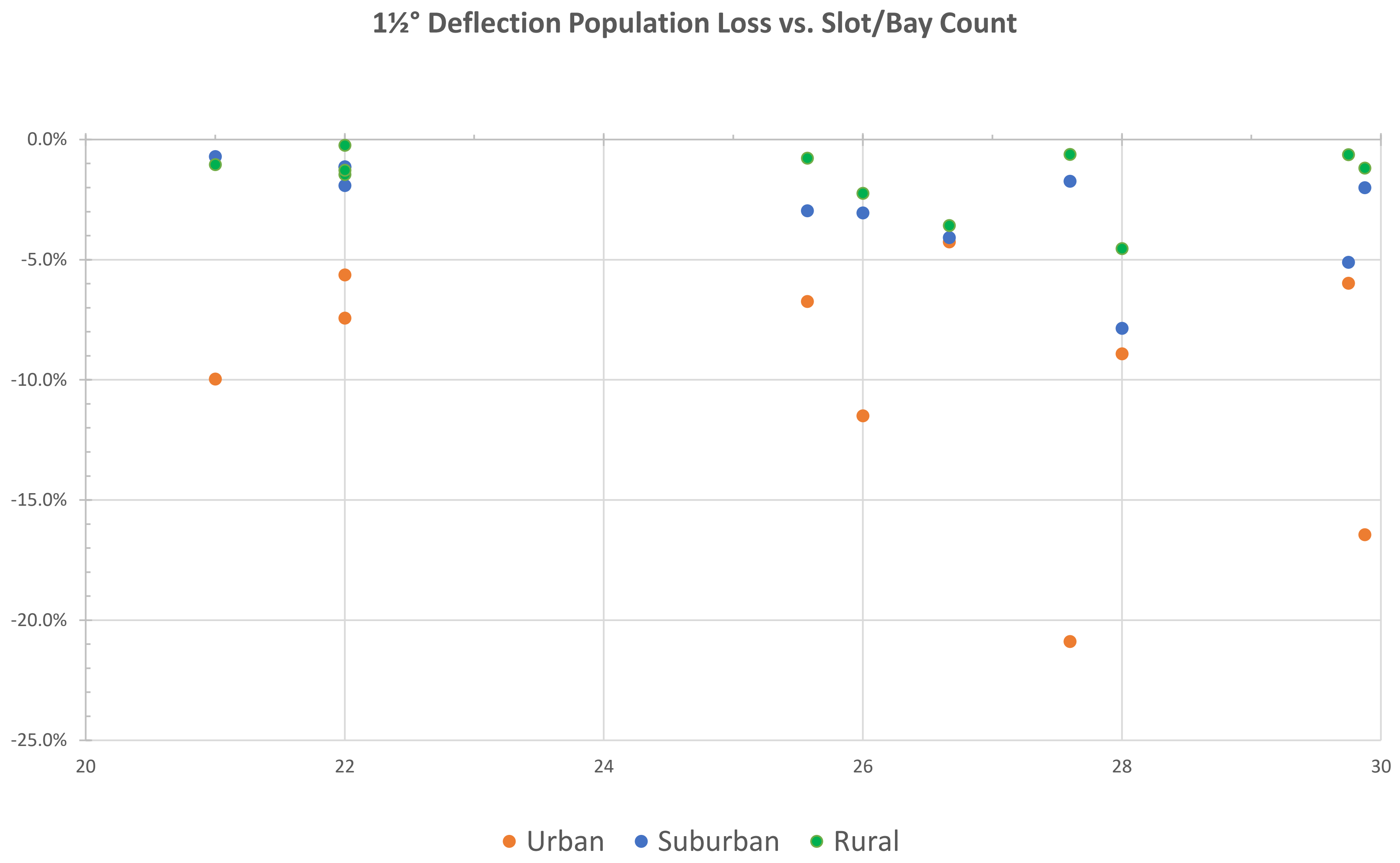
Slots/Bays Correlation, UHF 1½° Deflection



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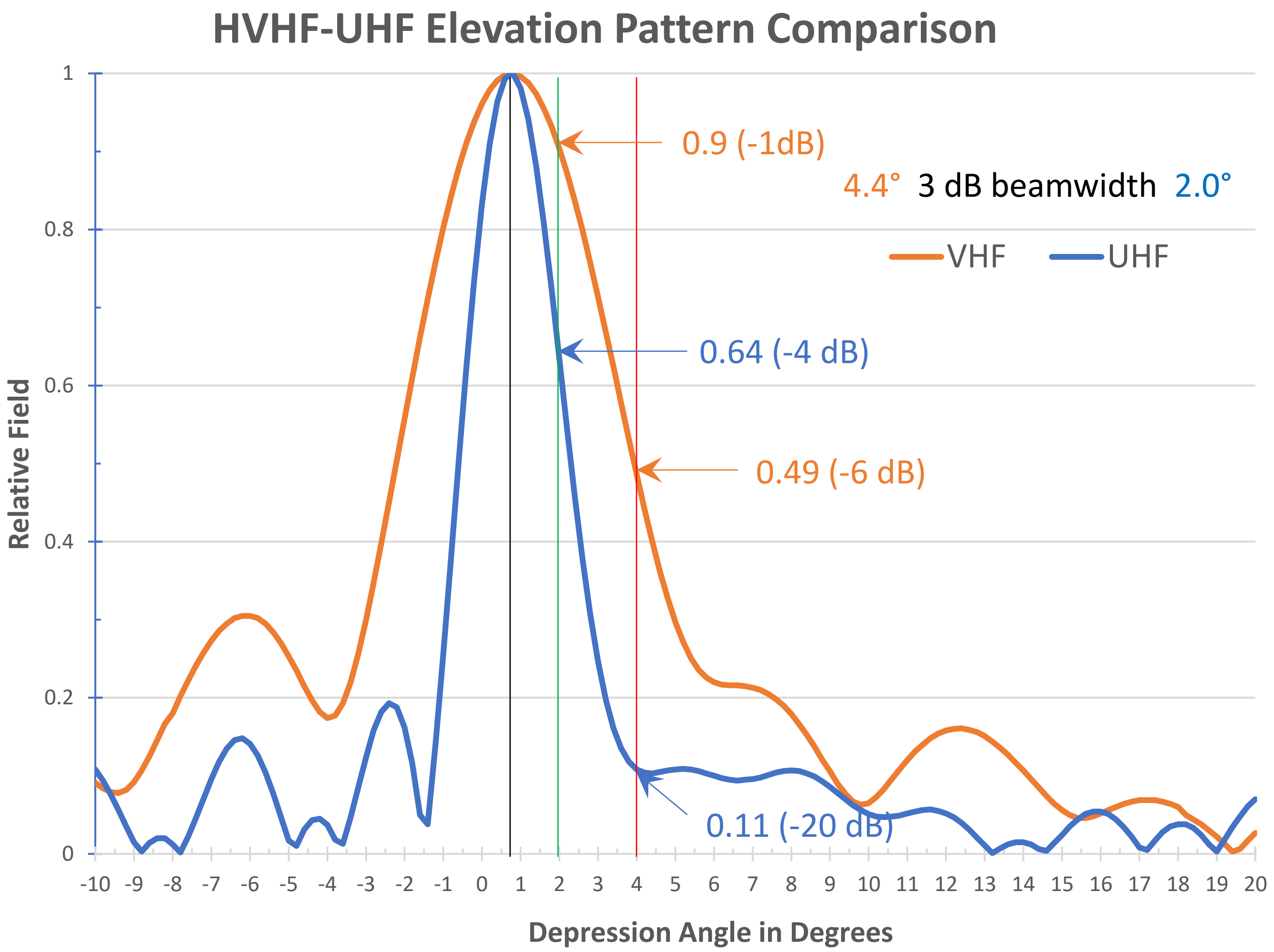
How Does This Happen?

- Antenna is mechanically tilted by tower deflection
- Elevation pattern is shifted by tilt
- Signal strength along ground changes

Why is Urban Indoor Service Impacted Most?

Typical Elevation Radiation Patterns



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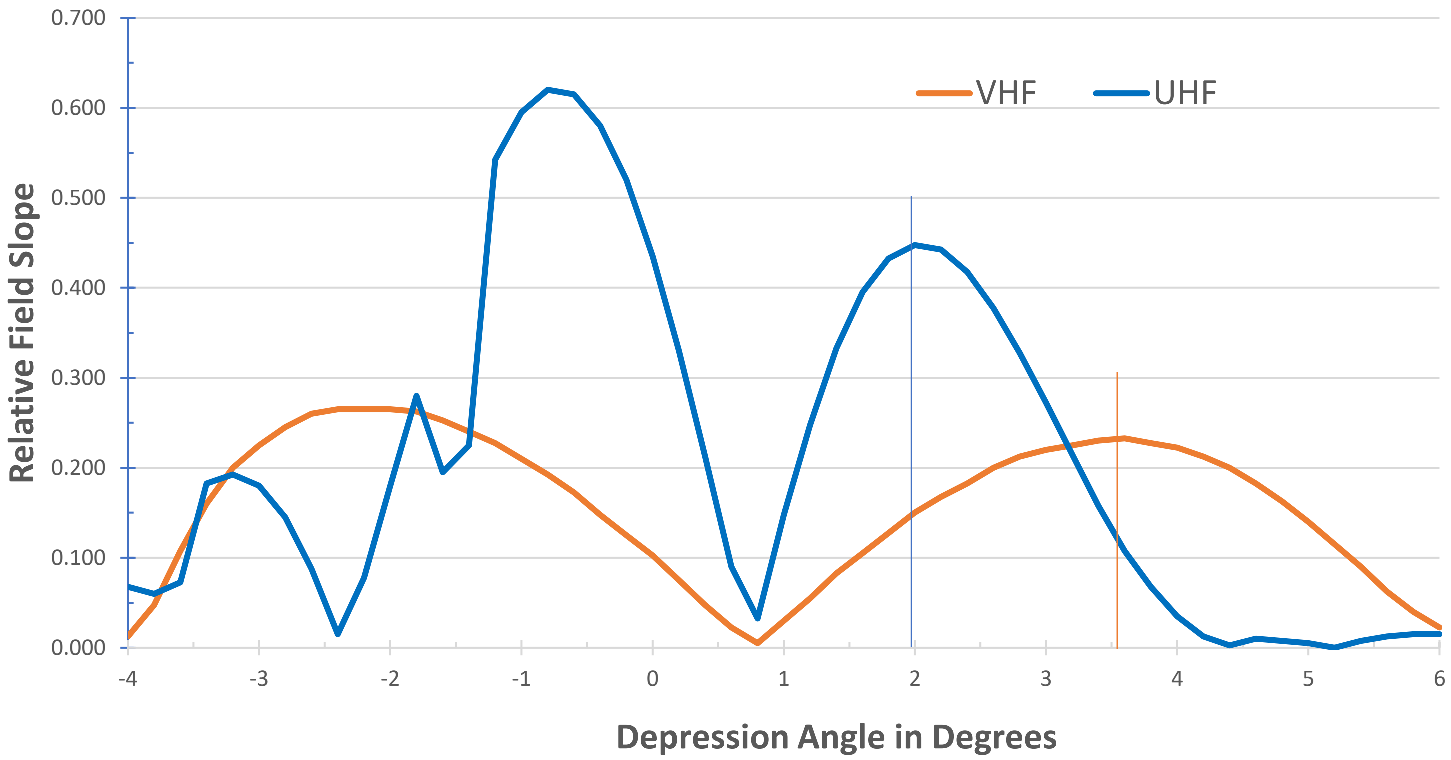
Elevation Pattern Slope



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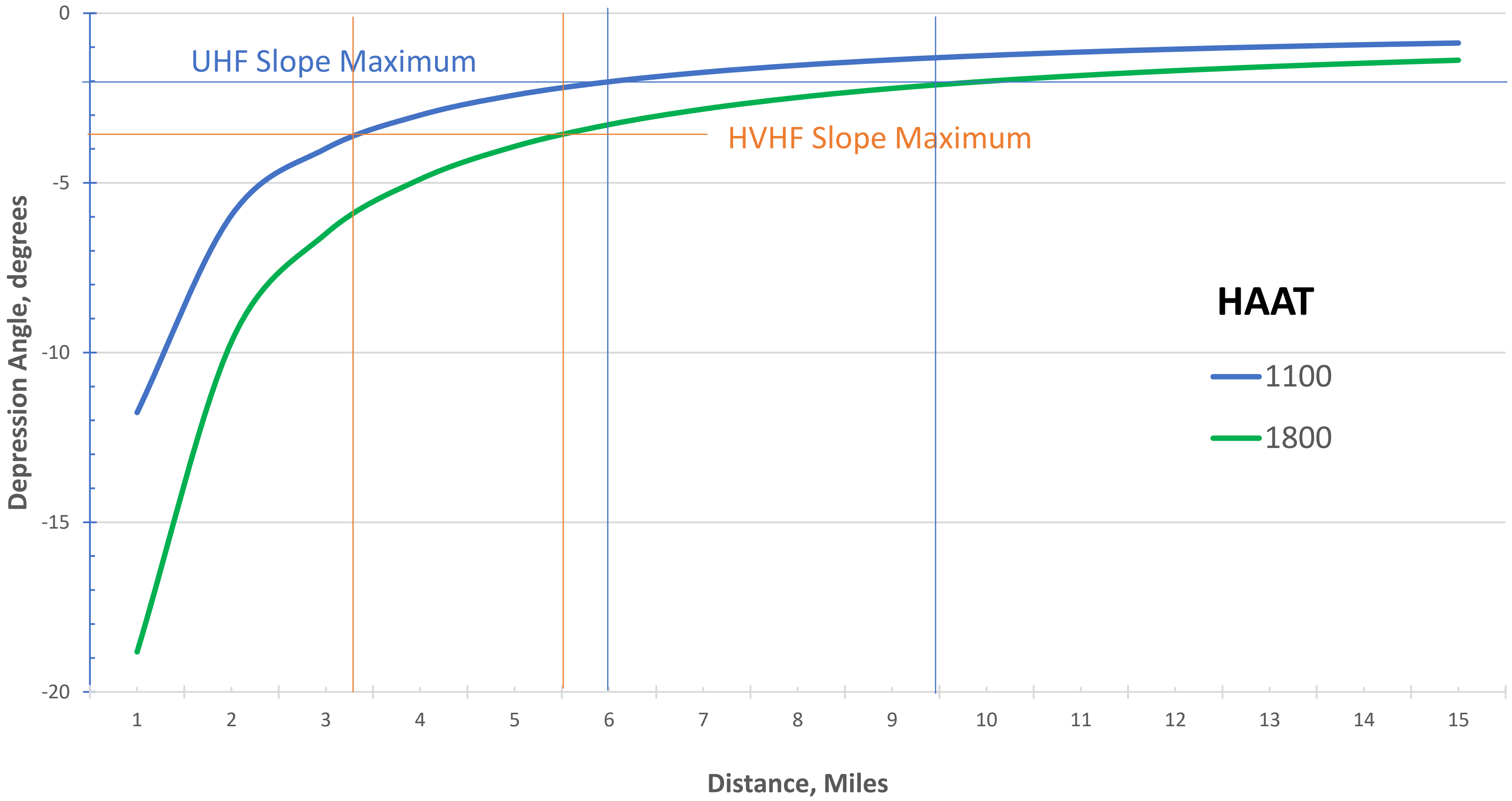
Depression Angle Distances



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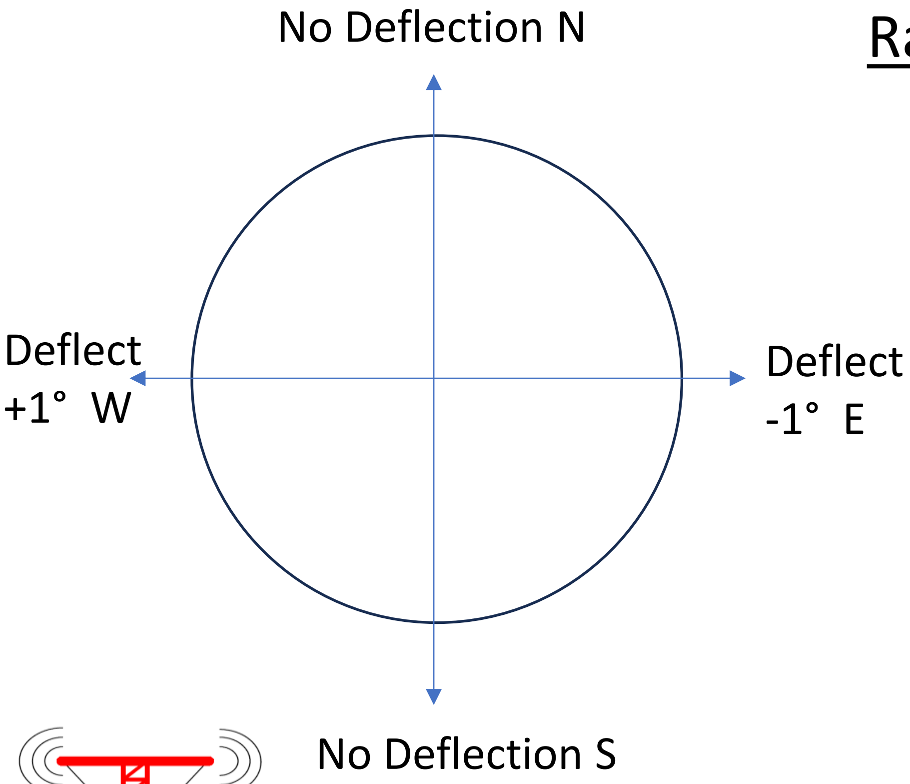
Deflection Impact on HVHF Elevation Pattern

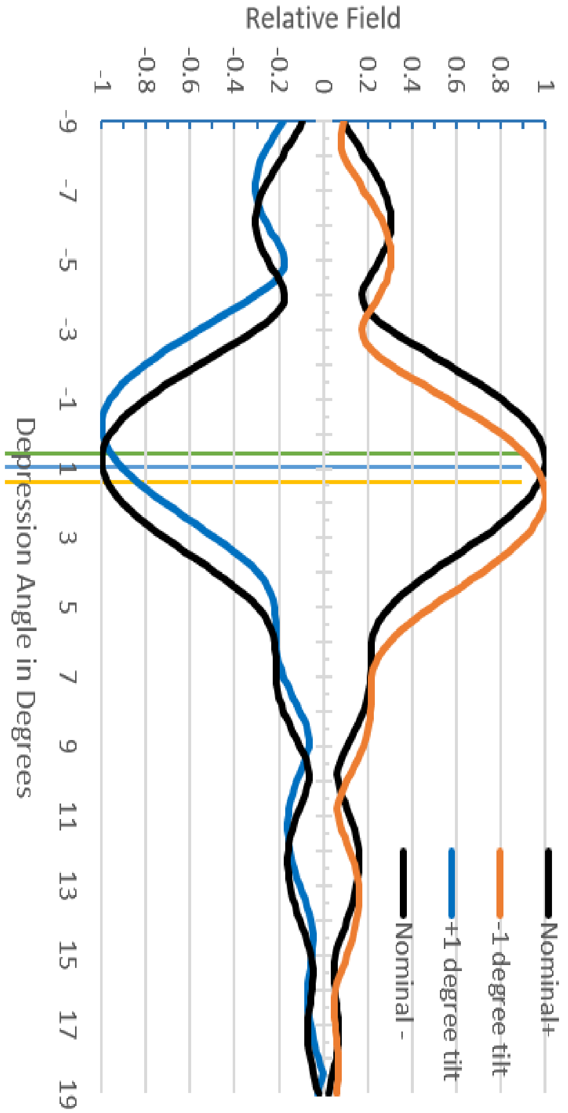
Deflection/Tilt Overview

1° downward eastward



Radiation Deviation (dB)

Horizon = -0.9 east, -0.3 west
13 mi = -0.3 east, -0.8 west
9 mi = +0.2 east, -1.3 west



12 slots
¾° beam tilt
HAAT 1100’

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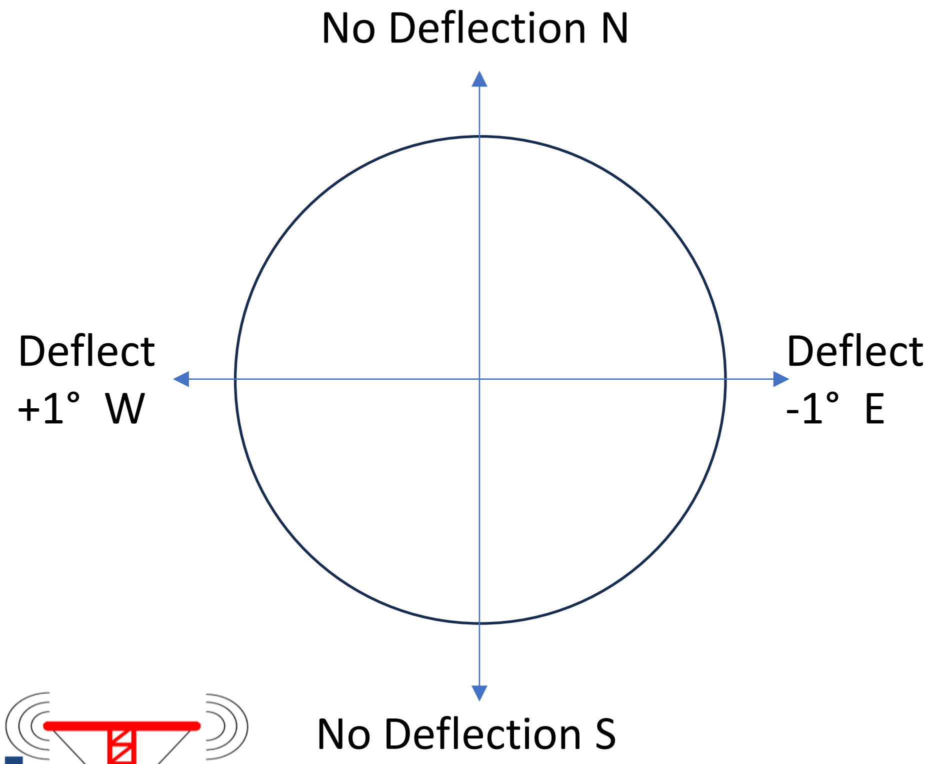
Deflection Impact on UHF Elevation Pattern

Deflection/Tilt Overview

1° downward eastward

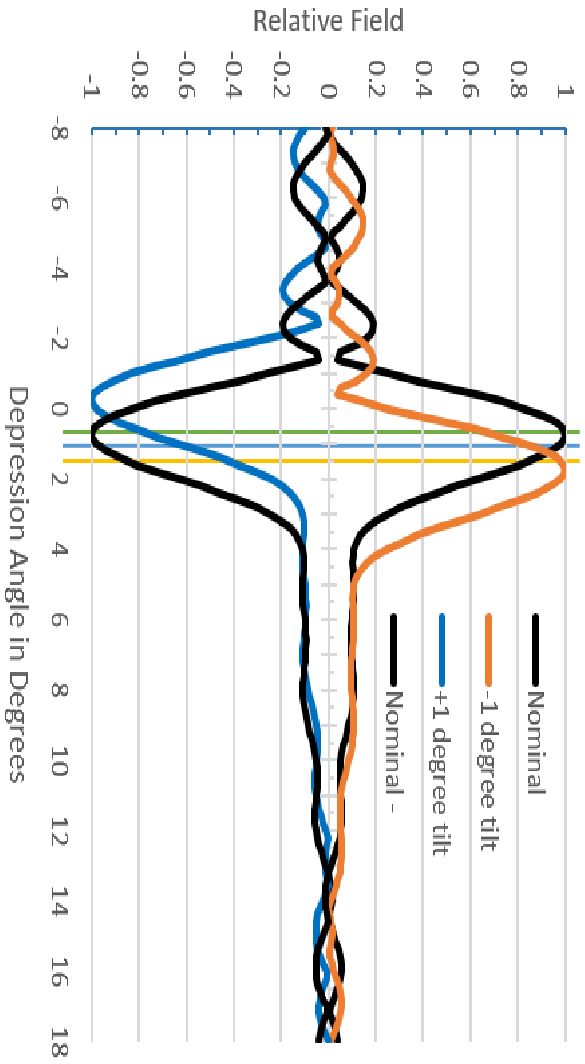


Radiation Deviation (dB)

Horizon = -4.8 east, -1.3 west

13 mi = -1.4 east, -3.8 west

9 mi = +0.8 east, -5.7 west



30 slots
¾° beam tilt
HAAT 1100’

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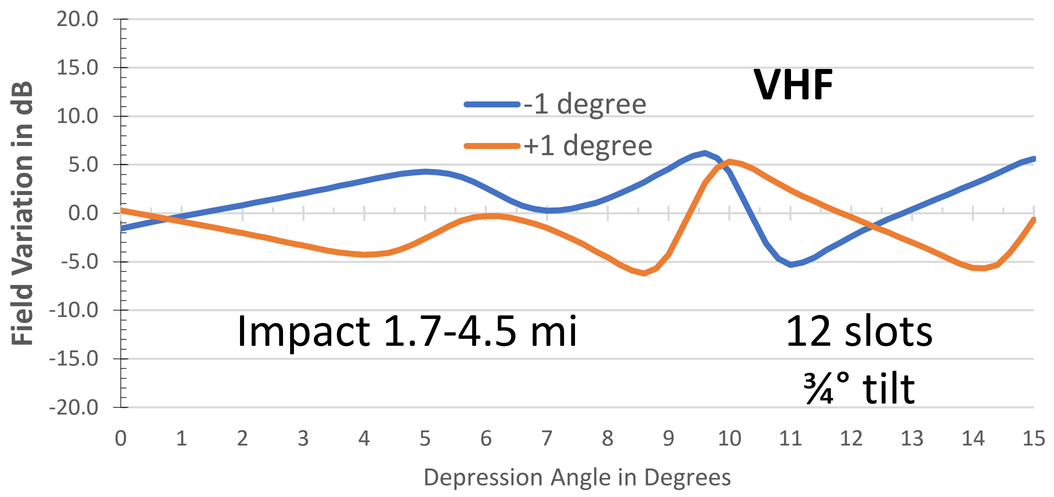
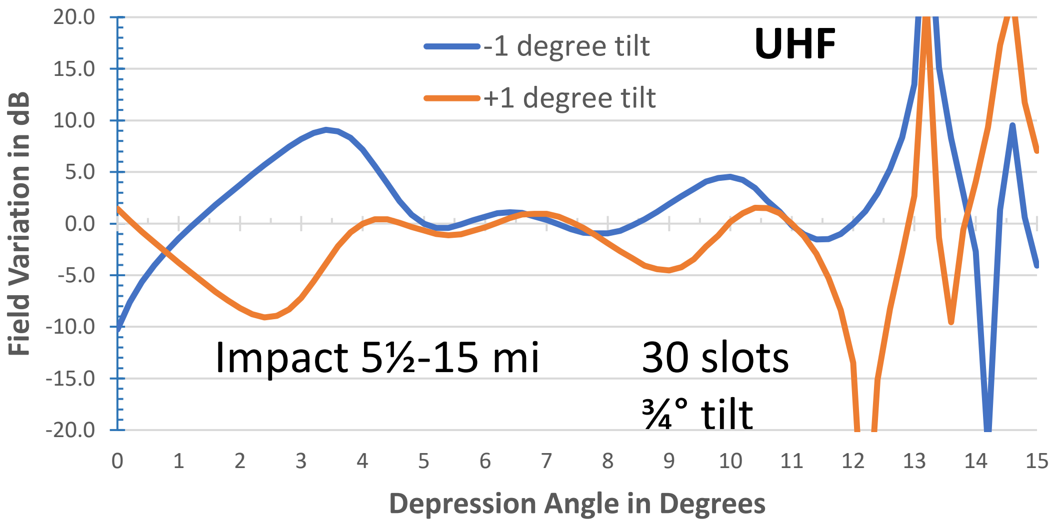
VHF-UHF Deflection Impact Comparison





	-1° (east) Deflection		+1° (west) Deflection	
Location	VHF	UHF	VHF	UHF
Horizon	-0.9	-4.8	-0.3	-1.3
13 miles	-0.3	-1.4	-0.8	-3.8
9 miles	0.2	0.8	-1.3	-5.7

HVHF much less impacted by antenna deflection than UHF.

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Electronic Impact Takeaways

- UHF much more sensitive to deflection than VHF

- Greatest VHF impact 8 to 11 degrees depression, 1-2 miles from tower (@1100’)

- Greatest UHF impact 1 to 4 degrees depression, 3 to 11 miles from tower (@1100’)

bts
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Conclusions

- Tower deflection mainly impacts urban service where indoor antennas are in use
  - Largest antenna radiation variations are closest to the transmitter site
- Service from tallest towers and highest-gain antennas is more vulnerable to deflection impact
- Population distribution has significant impact on results

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Recommendations

- Look at your tower from a distance regularly. Deflections of ~1° are visible to the human eye.
- Know your tower's sensitivity to wind-caused deflection – refer to structural analysis report
- Have qualified tower rigging crew check tower plumb and guy wire tensions at least annually

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Questions?