Contest Antennas

DX or Domestic, What's Your Pleasure?

A Presentation at the International DX Convention in Visalia, CA

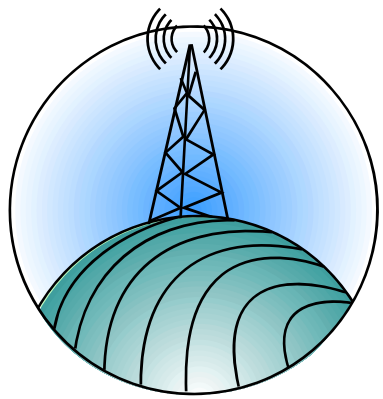
Saturday, April 18, 2009

by Dean Straw, N6BV
Senior Assistant Technical Editor, ARRL (Retired)

Scientifically Planning a Station

There are three elements needed to plan an HF station *scientifically*:

- The range of elevation angles needed.
- Antenna performance parameters (modeling).
- The effects of local terrain.



For Years People Have Said:

- For DX contests you need high antennas.
- For domestic contests (like Sweepstakes) you need low antennas.
- Is this really true? Are domestic and DX contests mutually exclusive?

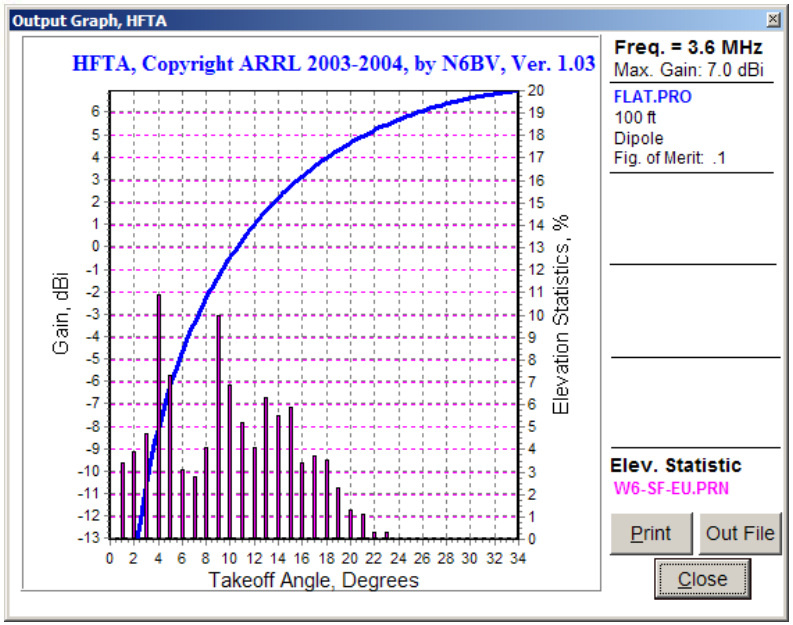
Range of Elevation Angles

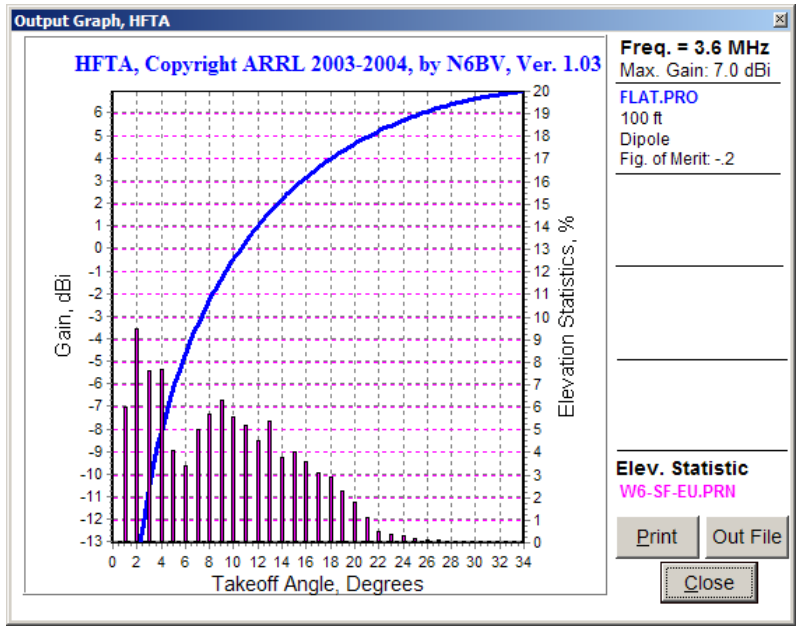
• More than sixteen years ago I started a detailed study at ARRL HQ on the range of elevation angles needed for communication between various locations around the world.

• I used the *IONCAP* program (now upgraded to *VOACAP*), along with some proprietary software I wrote.

• Recently, I upgraded the statistics using corrected *IONCAP* loss tables in the latest version of *VOACAP*, plus more receiver QTHs.

Old vs New from *VOACAP*





Old elevation-angle statistics (incorrect low-frequency loss tables in *VOACAP*).

New statistics — subtly showing more emphasis on low angles and less “blank” stats for exotic paths on 80.

Even Domestic Contests Get Down Low — to Low Angles, That Is

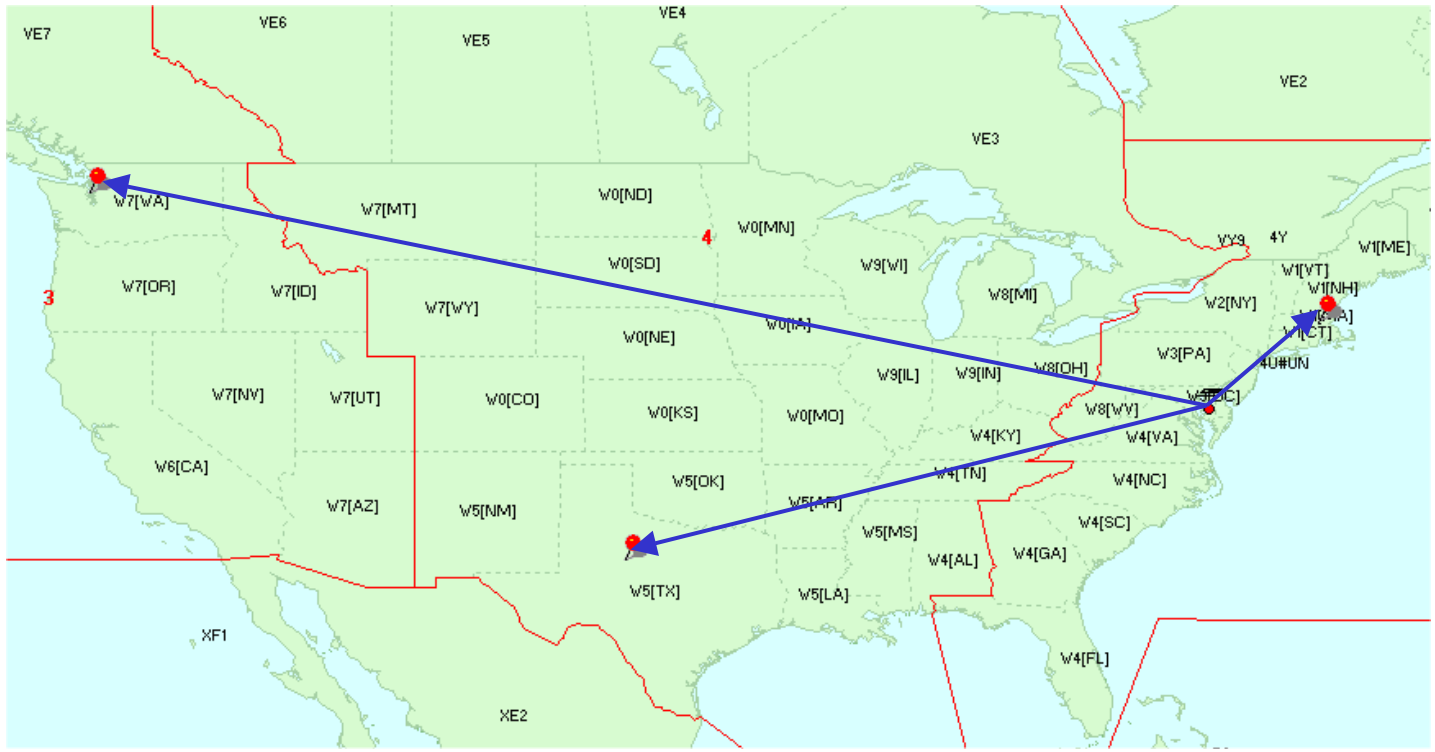
- You would think that domestic US contests involve relatively short distances.
- They do — and they don't. The continental US covers a *large* area: four time zones.
- Let's look at the paths from Washington, DC — to Boston, to Dallas and then to Seattle.

Distances from Washington, DC, Around the USA

To Boston:
294 miles

To Dallas:
1183 miles

To Seattle:
2322 miles



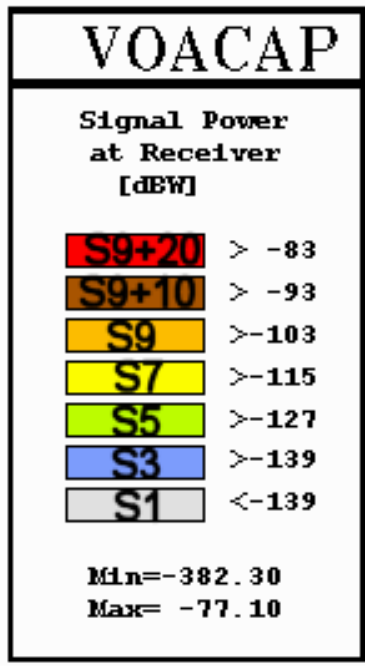
Distances from Washington, DC, Around the USA

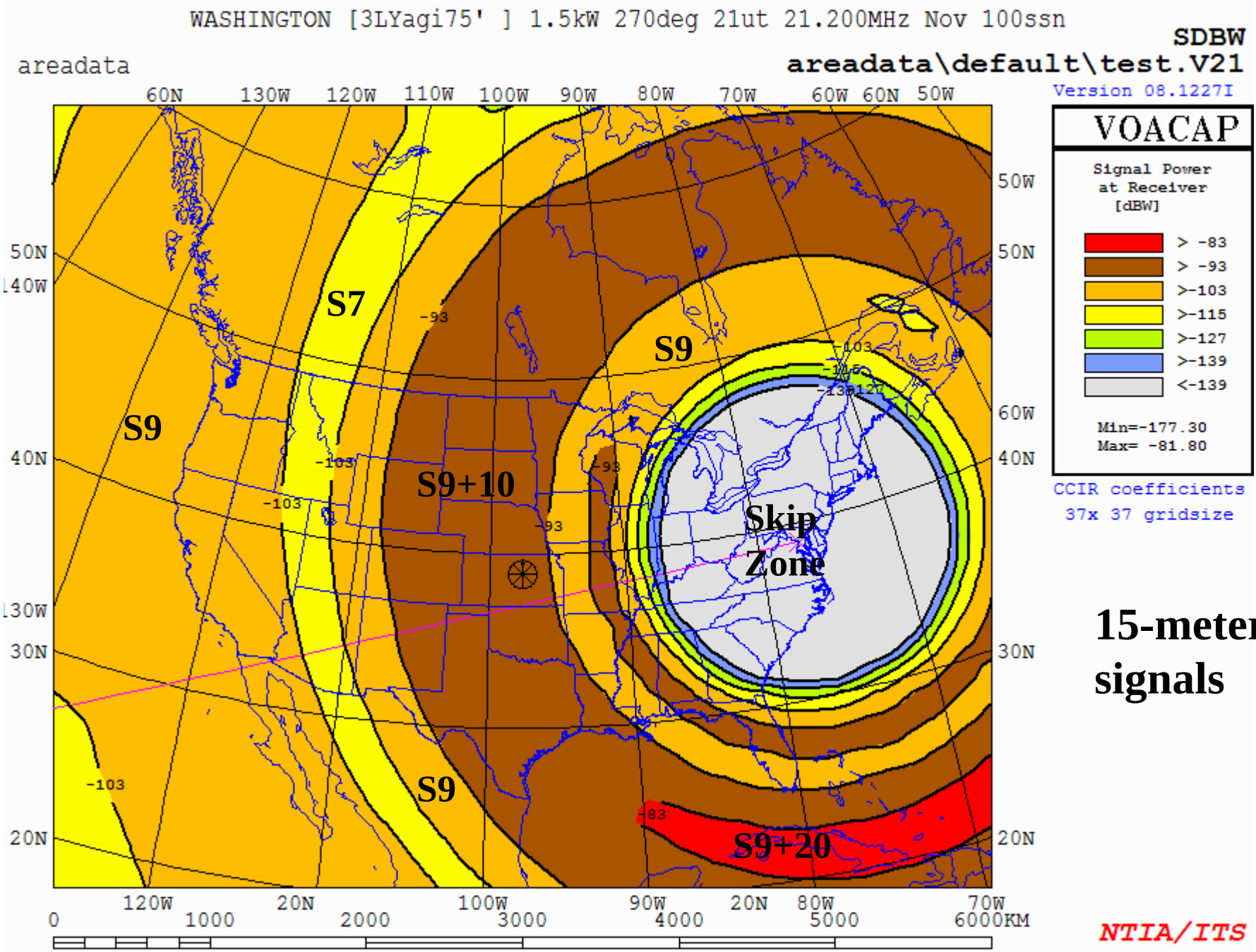
- To Boston: 294 miles — Must be a high-angle path, right? Yes, that's true.
- To Dallas: 1183 miles — Must be a medium-angle path, right?
- To Seattle: 2322 miles — Must be a low-angle path, right?

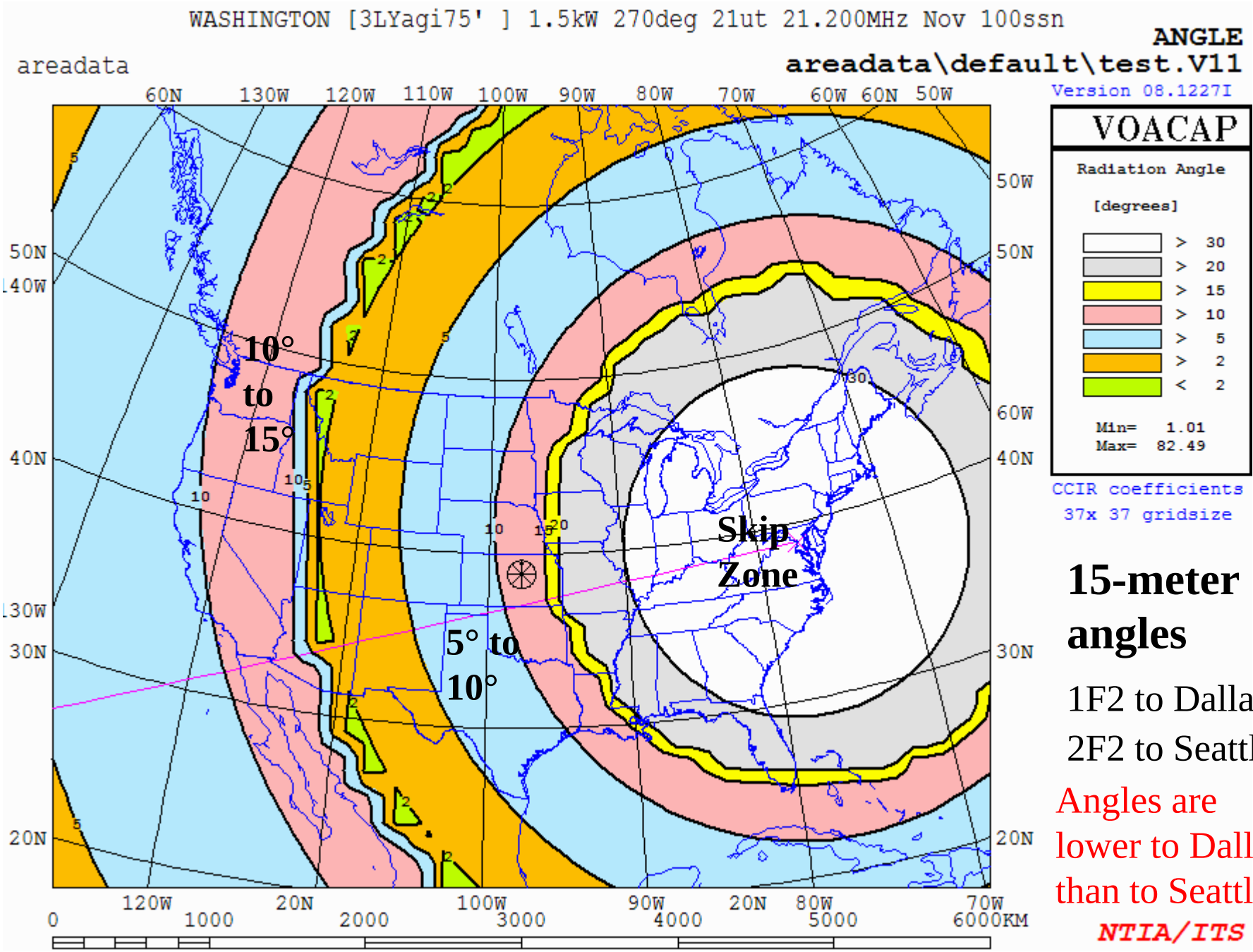
S-Meter Calibration for Area Coverage

In the following *VOAAREA* figures, the signal-strength calibration is in dB below 1W (dBW). Here's how that translates to S-units.

Let's start on 15 meters from Washington, DC.



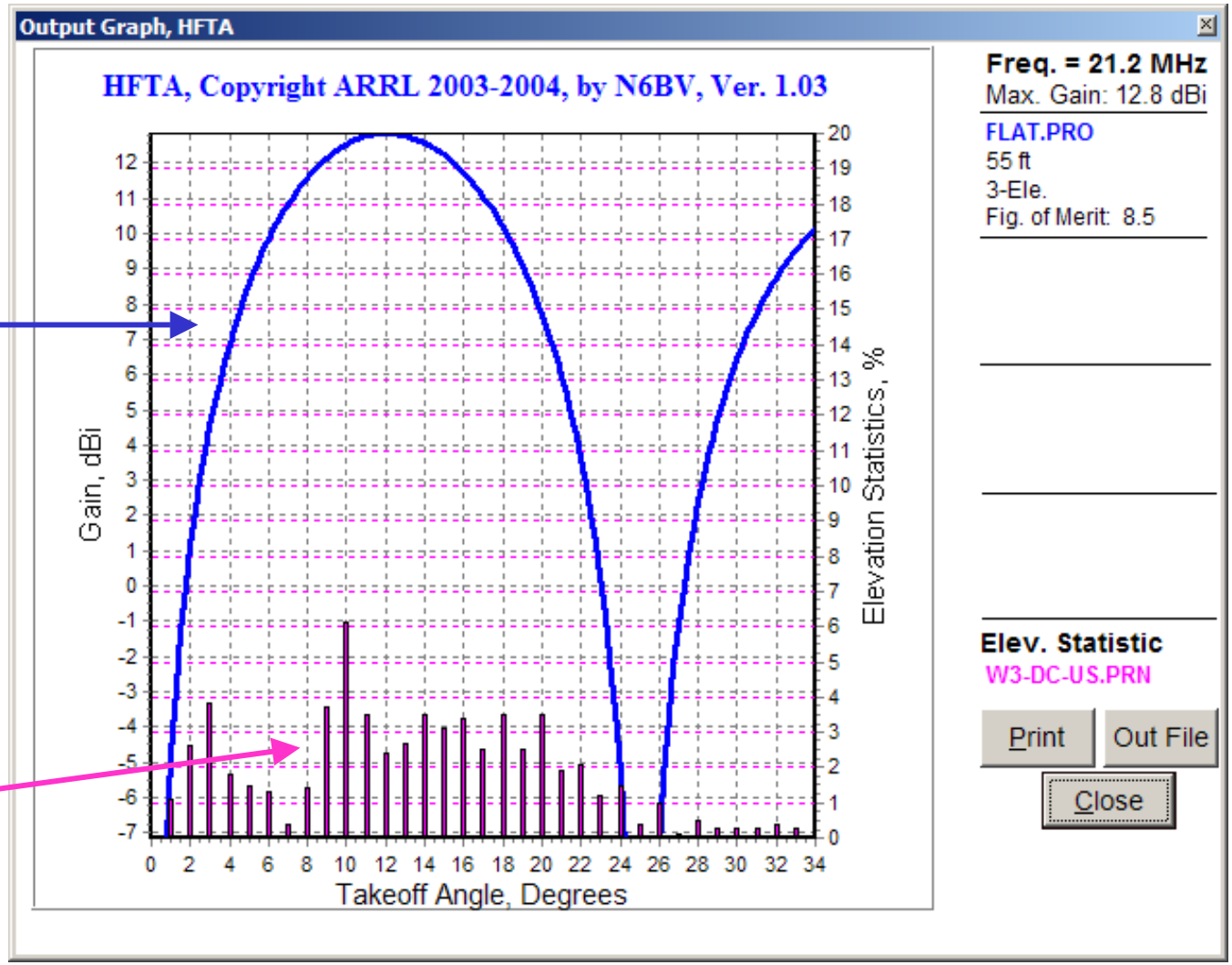

WASHINGTON [3LYagi75'] 1.5kW 270deg 21ut 21.200MHz Nov 100ssn
SDBW
areadata
areadata\default\test.V21
Version 08.1227I
VOACAP
Signal Power at Receiver [dBW]
> -83
> -93
>-103
>-115
>-127
>-139
<-139
Min=-177.30
Max= -81.80
CCIR coefficients
37x 37 gridsize
S7
S9
S9+10
S9
S9
S9+20
Skip Zone
15-meter signals
NTIA/ITS


WASHINGTON [3LYagi75'] 1.5kW 270deg 21ut 21.200MHz Nov 100ssn
areadata
ANGLE
areadata\default\test.V11
Version 08.1227I
VOACAP
Radiation Angle
[degrees]
> 30
> 20
> 15
> 10
> 5
> 2
< 2
Min= 1.01
Max= 82.49
CCIR coefficients
37x 37 gridsize
10° to 15°
5° to 10°
Skip Zone
15-meter angles
1F2 to Dallas
2F2 to Seattle
Angles are lower to Dallas than to Seattle!
NTIA/ITS

Needed Angles vs Antenna Response

Elevation response of 3-element Yagi at 55’ over flat ground

Elevation-angle stats for entire 11-year solar cycle



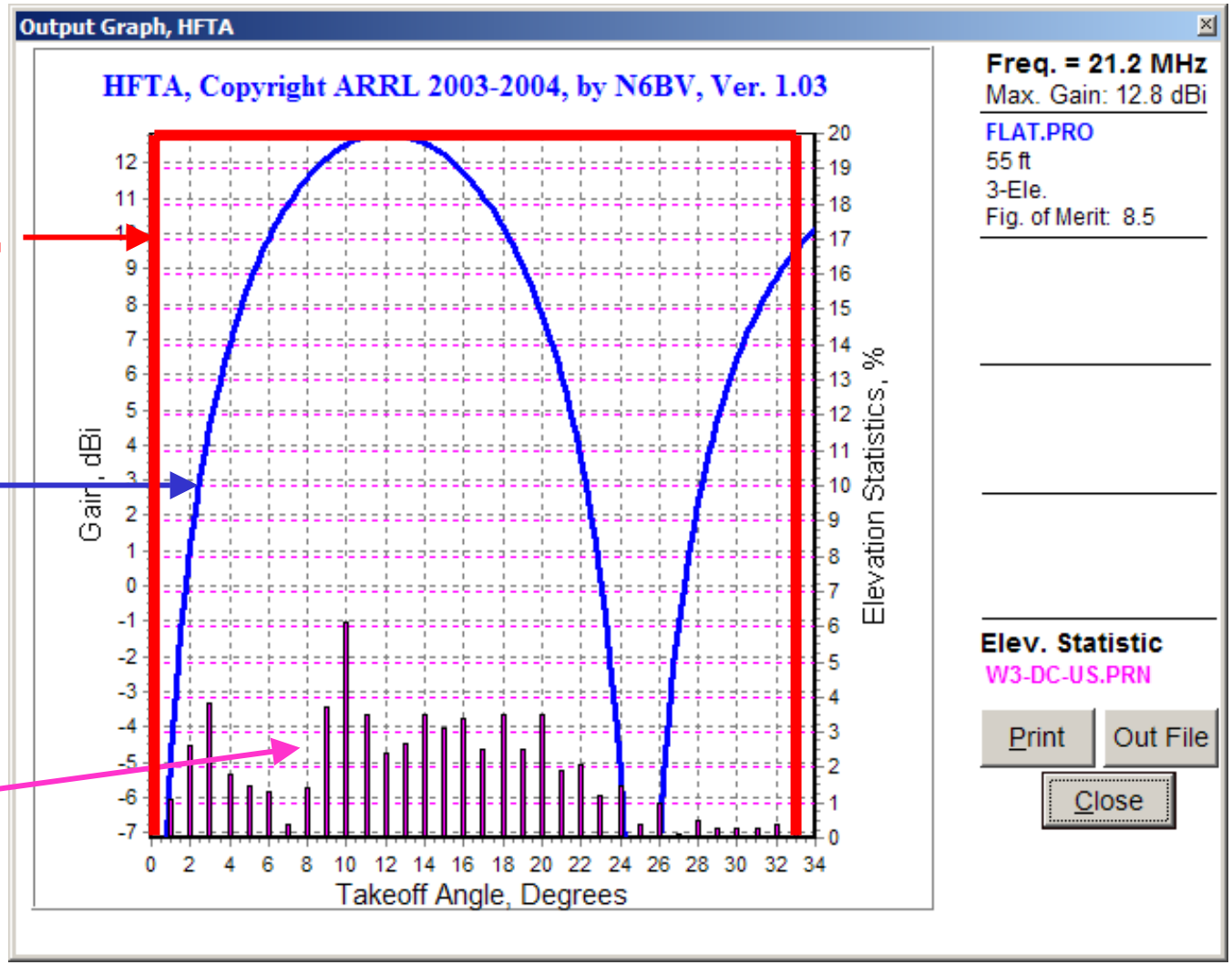
From Washington, DC: W3

Needed Angles vs Antenna Response

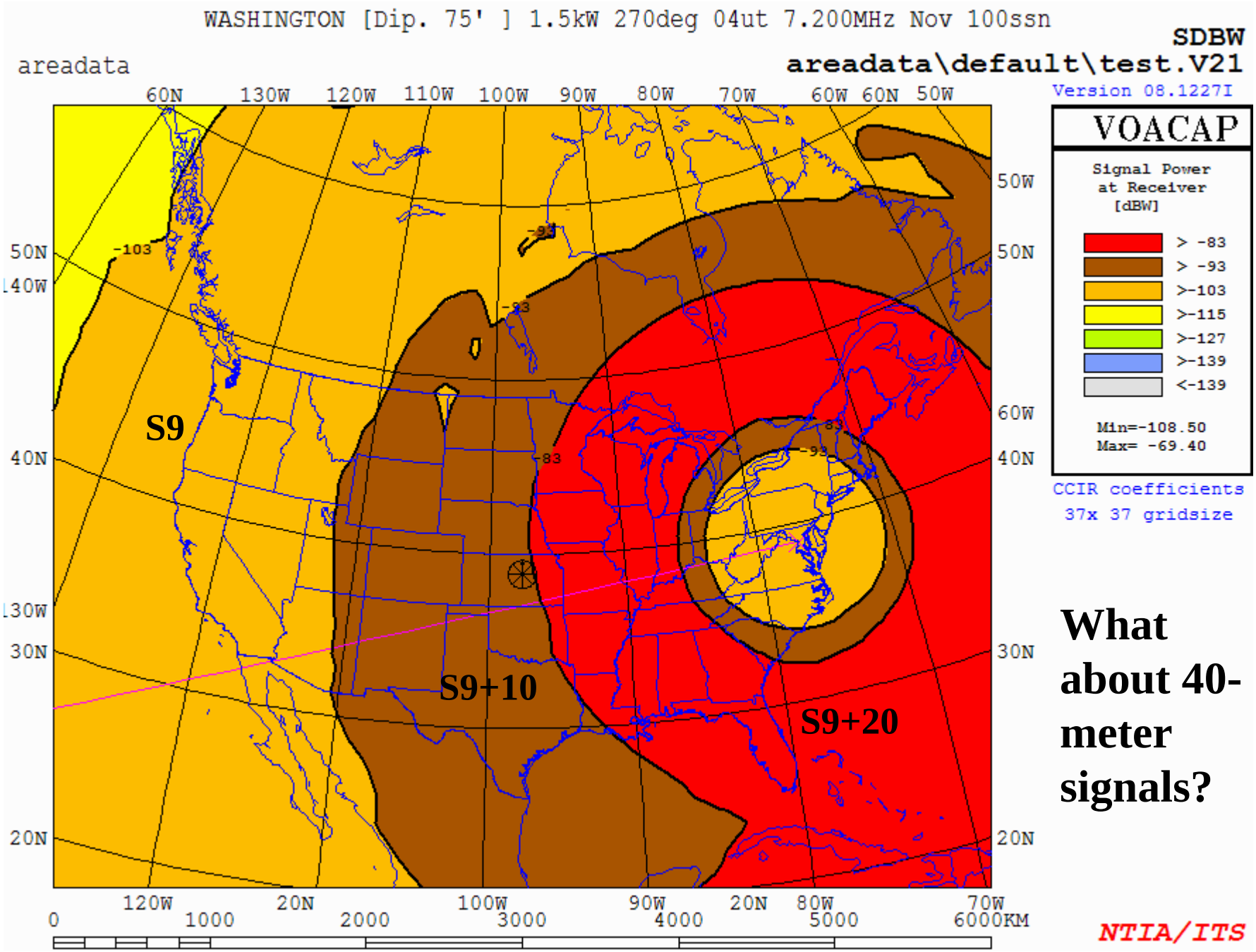
Perfect antenna pattern to cover entire range of angles

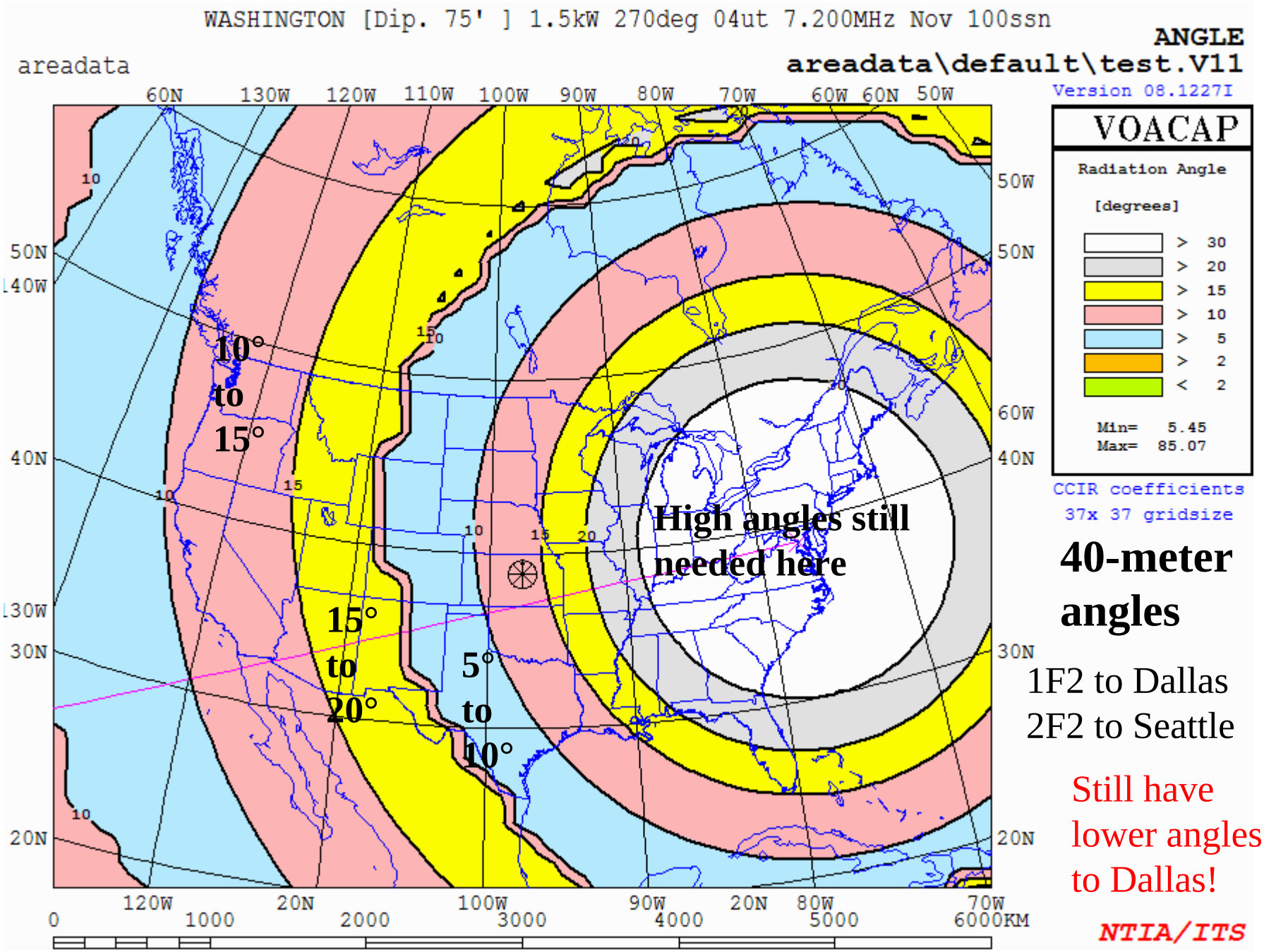
3L20 at 55’

Elevation-angle stats for entire 11-year solar cycle

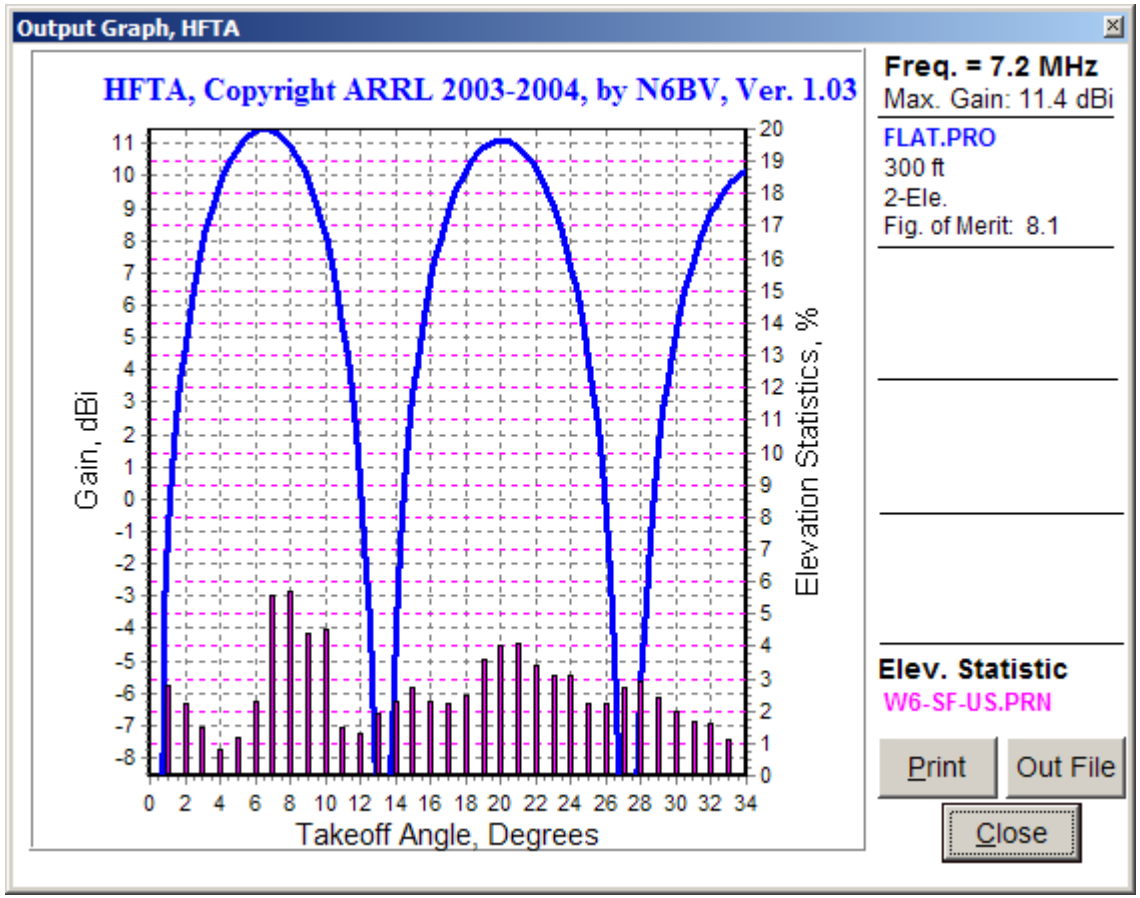


More about *HFTA* later.


WASHINGTON [Dip. 75'] 1.5kW 270deg 04ut 7.200MHz Nov 100ssn
areadata
SDBW
areadata\default\test.V21
Version 08.1227I
VOACAP
Signal Power at Receiver [dBW]
> -83
> -93
>-103
>-115
>-127
>-139
<-139
Min=-108.50
Max= -69.40
CCIR coefficients
37x 37 gridsize
S9
S9+10
S9+20
What about 40-meter signals?
NTIA/ITS


WASHINGTON [Dip. 75'] 1.5kW 270deg 04ut 7.200MHz Nov 100ssn
areadata
ANGLE
areadata\default\test.V11
Version 08.1227I
VOACAP
Radiation Angle
[degrees]
> 30
> 20
> 15
> 10
> 5
> 2
< 2
Min= 5.45
Max= 85.07
CCIR coefficients
37x 37 gridsize
10° to 15°
15° to 20°
5° to 10°
High angles still needed here
40-meter angles
1F2 to Dallas
2F2 to Seattle
Still have lower angles to Dallas!
NTIA/ITS

How High Must an Antenna Be to Cover 5° to 10° on 40 Meters?

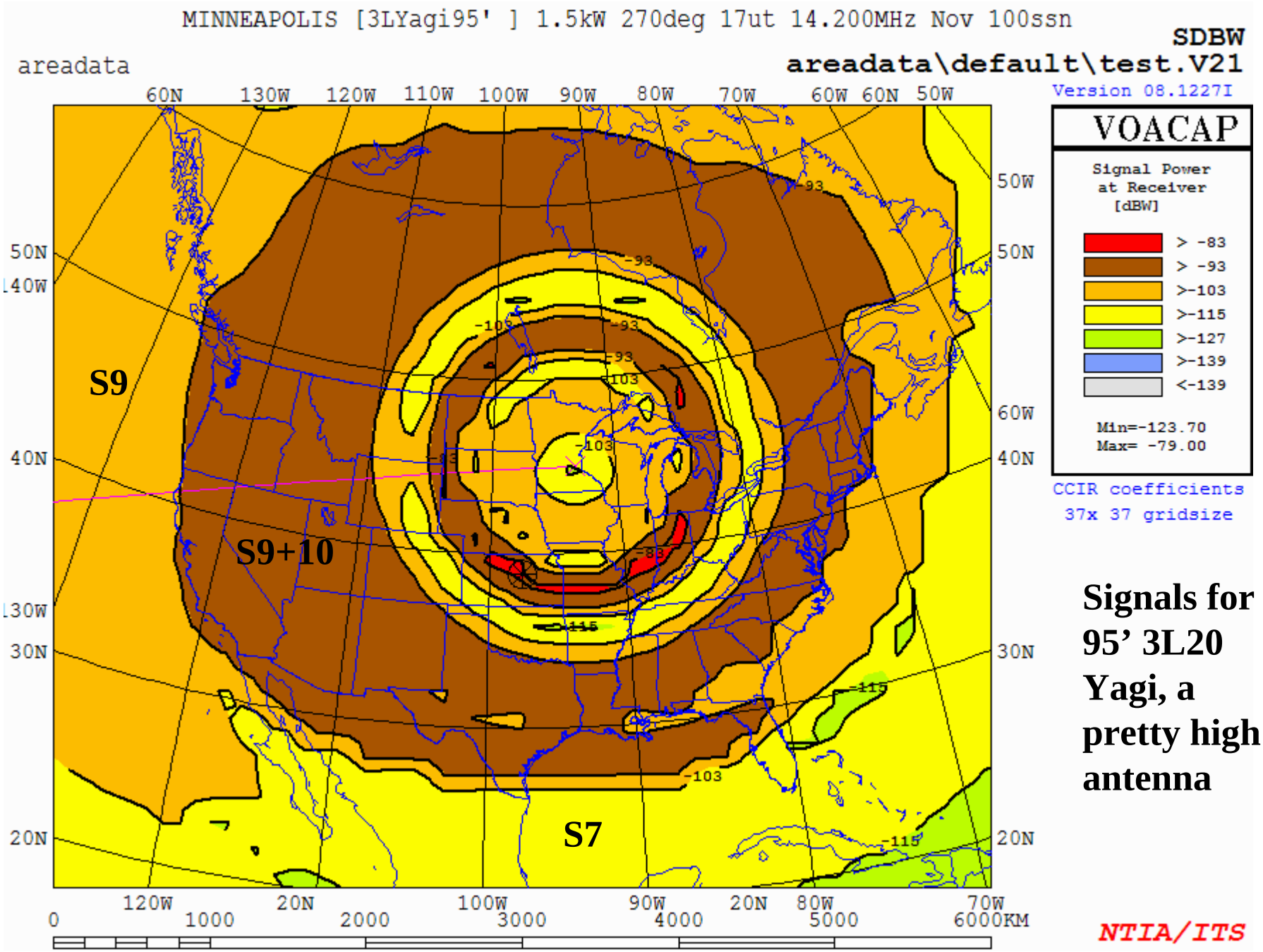


From San Francisco

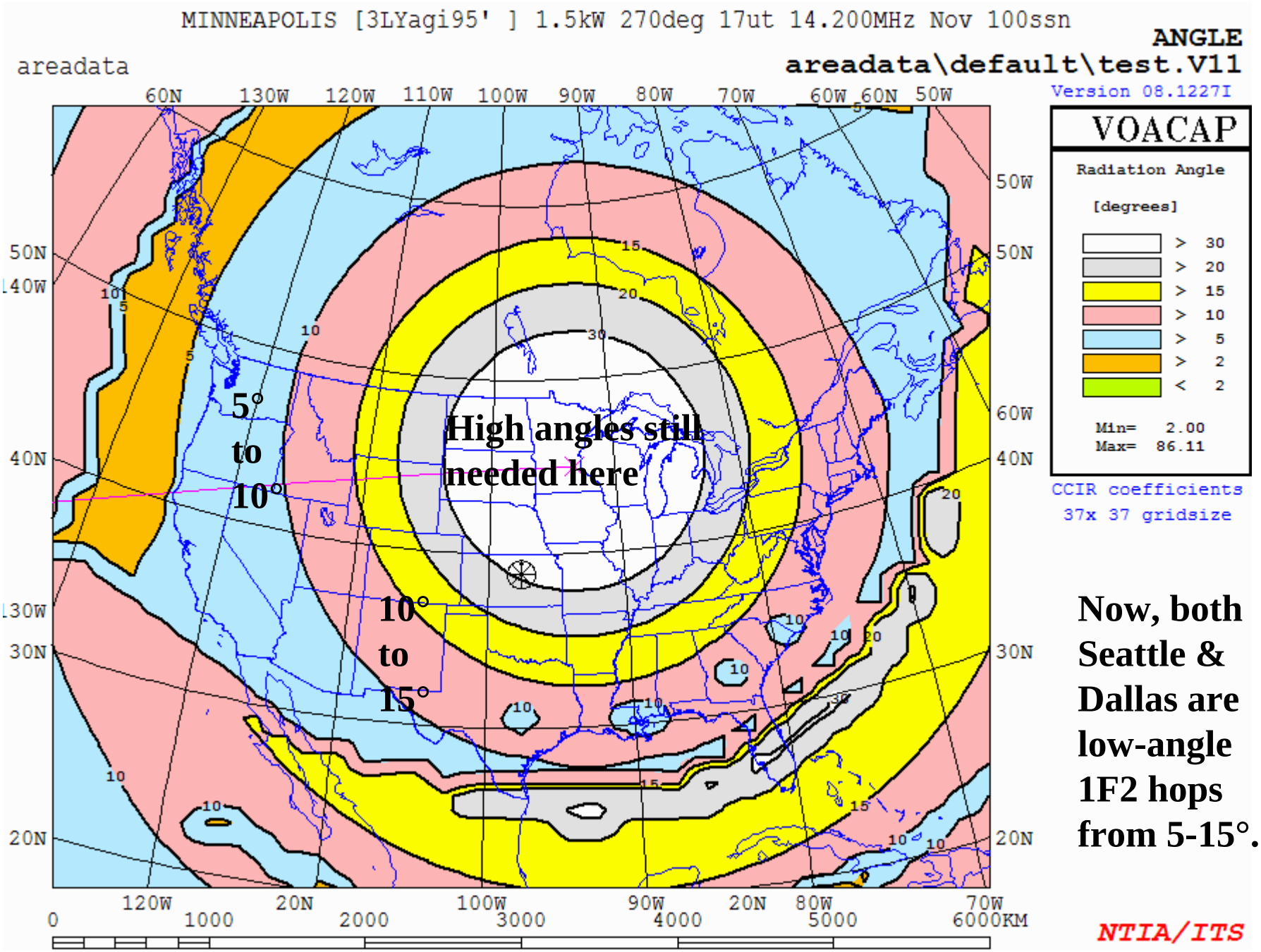
300 feet looks about right…!

Now, Consider the “Black Hole,” from Minnesota

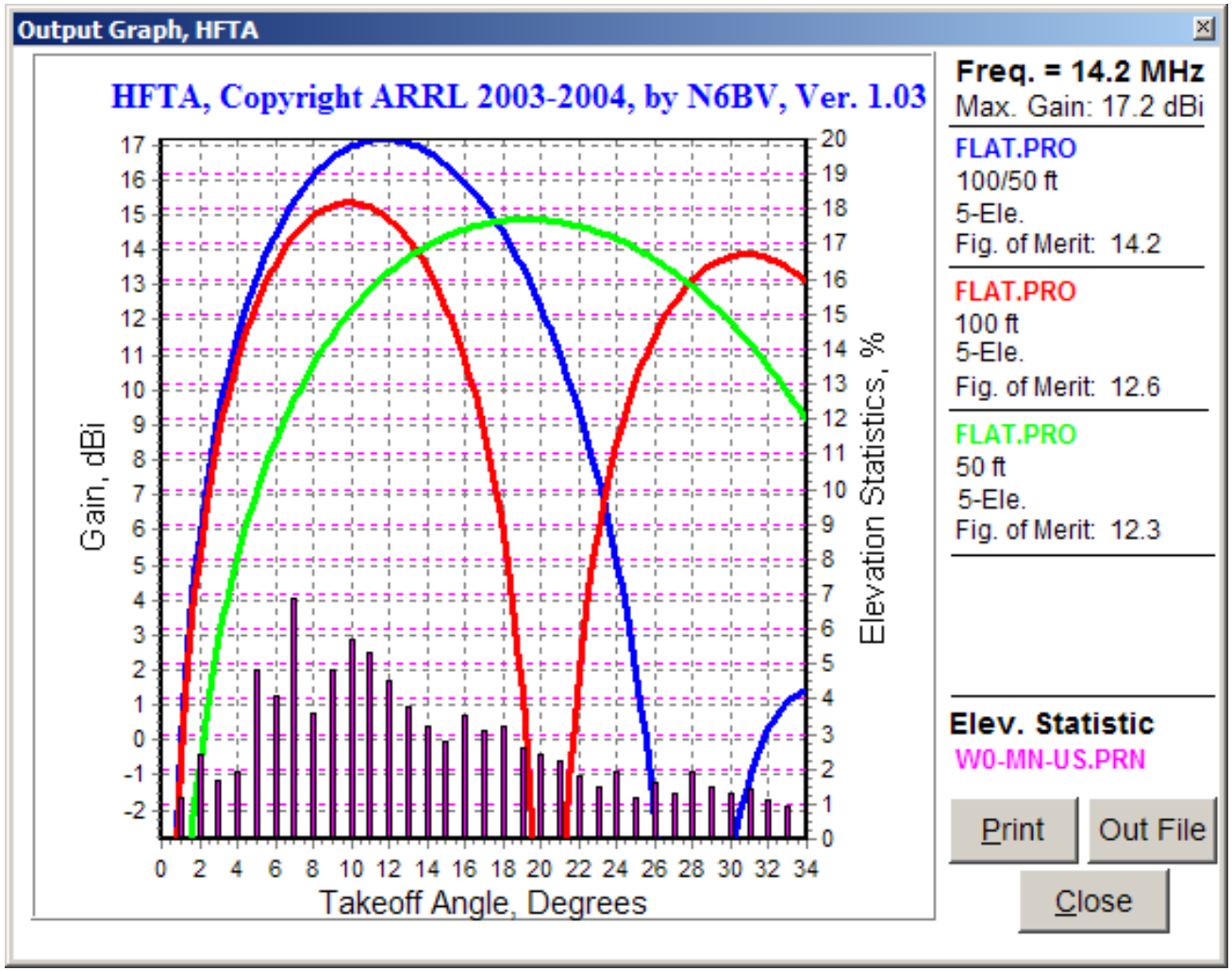
- Are high antennas in the Midwest good *only* for DX?



Signals for a 95' 3L20 Yagi, a pretty high antenna


MINNEAPOLIS [3LYagi95'] 1.5kW 270deg 17ut 14.200MHz Nov 100ssn
ANGLE
areadata
areadata\default\test.V11
Version 08.1227I
VOACAP
Radiation Angle
[degrees]
> 30
> 20
> 15
> 10
> 5
> 2
< 2
Min= 2.00
Max= 86.11
CCIR coefficients
37x 37 gridsize
5° to 10°
High angles still needed here
10° to 15°
Now, both Seattle & Dallas are low-angle 1F2 hops from 5-15°.
NTIA/ITS

Angles Needed from MN to All of USA

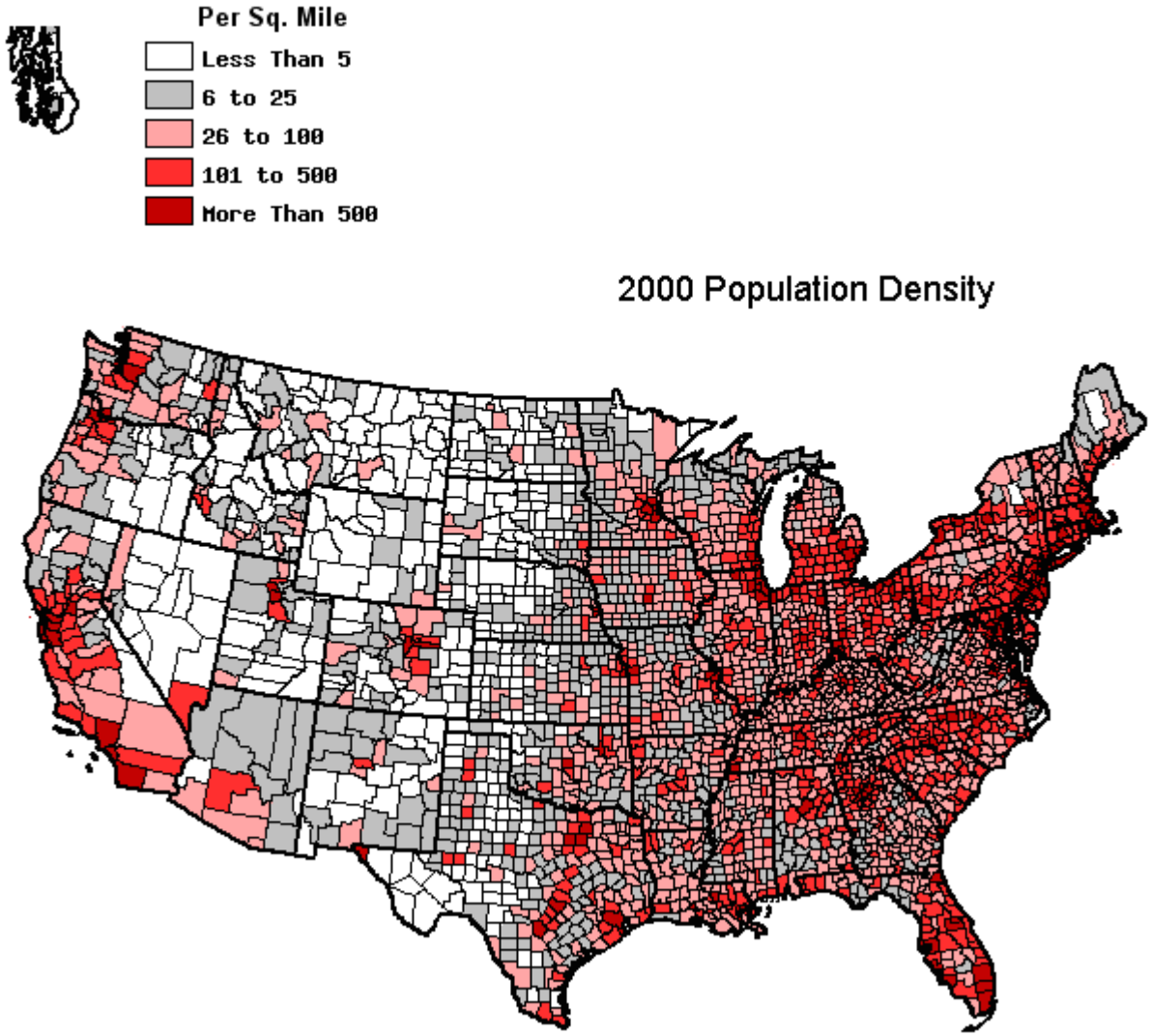


From the Midwest to the USA, a 100/50’ stack wouldn’t be too high to cover the wide range of domestic angles.

What About NVIS?

- On 40 and 80 meters, *Near-Vertical Incidence Skywave* (NVIS) techniques may be useful for close-in QSOs into heavily populated areas.

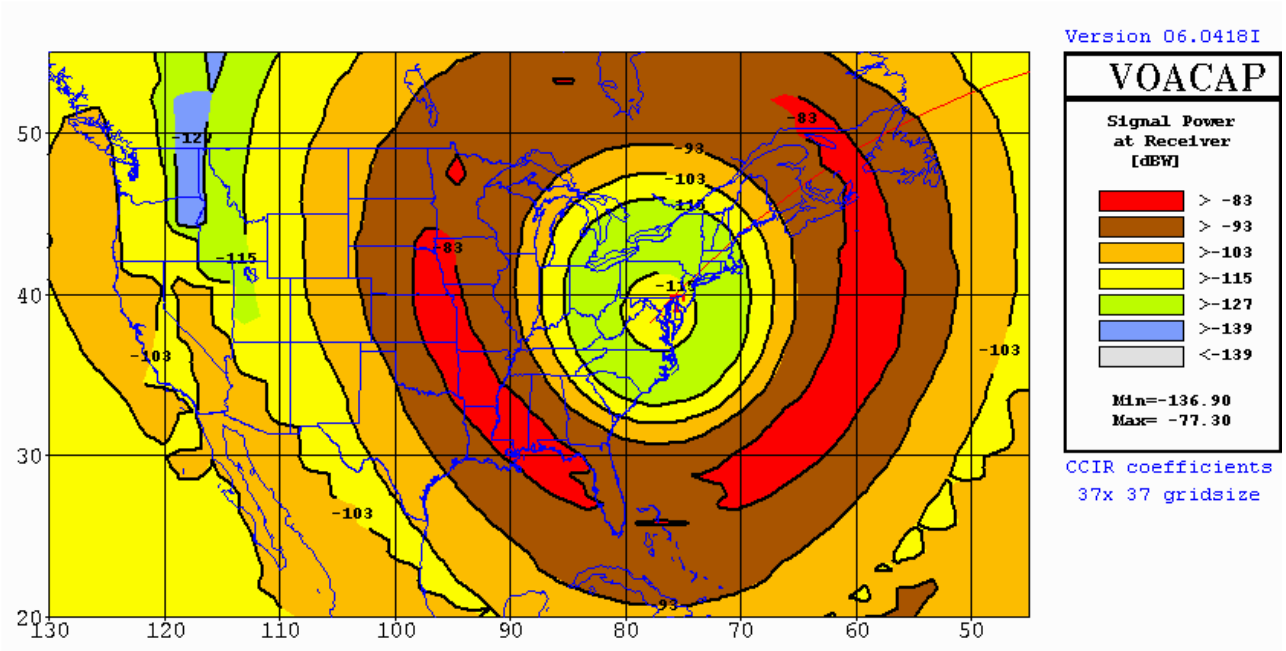
Coverage – Most Populous Areas



US Census 2000 Data

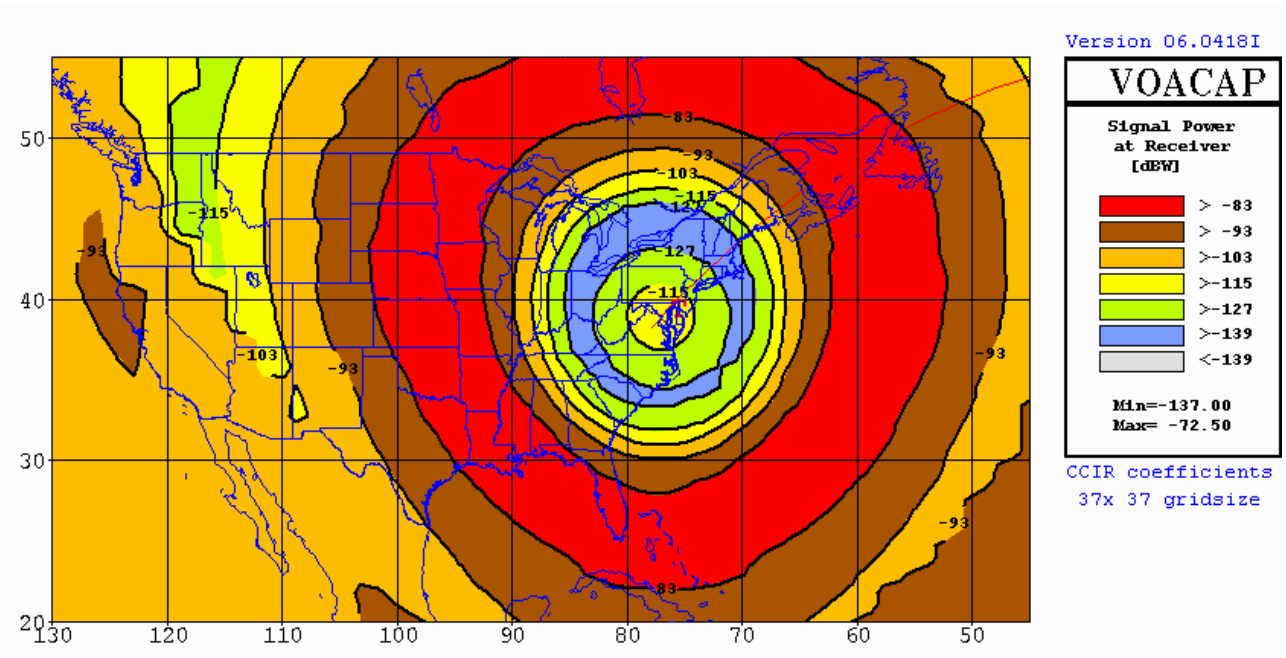
What About NVIS?

- On 40 and 80 meters, *Near-Vertical Incidence Skywave* (NVIS) techniques may be useful for close-in QSOs into heavily populated areas.
- Low antennas on 40 meters are particularly interesting from the East Coast and the Midwest, with their high population densities.
- The overall population density in the West is relatively low. But San Francisco to Los Angeles is high-angle and NVIS can help before 40 “goes long” in the early evening.



40 meters from W3

For 35’ dipole on 40 meters; November, SSN = 20, 04 UTC

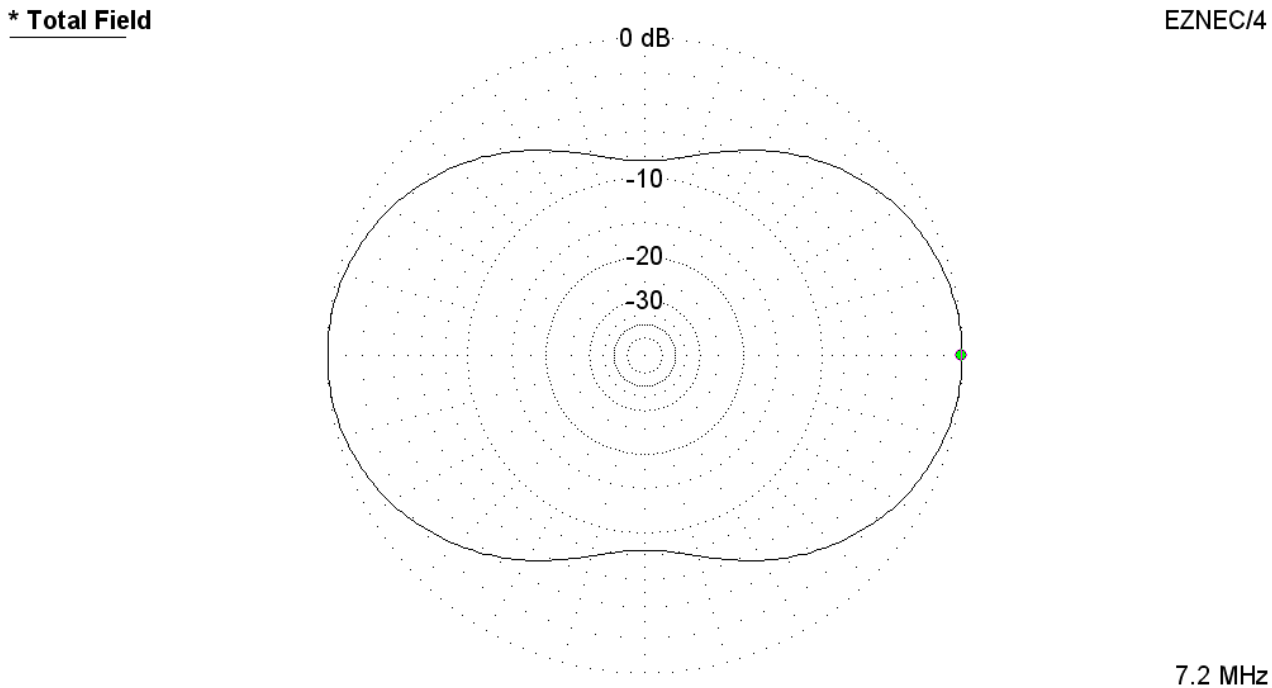


For 100’ dipole

Note how blue skip zone is larger – right into New England…

Low Dipoles on 40 Meters

- Low dipoles on 40 meters don't really have huge azimuthal nulls in coverage. You don't really have to worry much about pointing them.



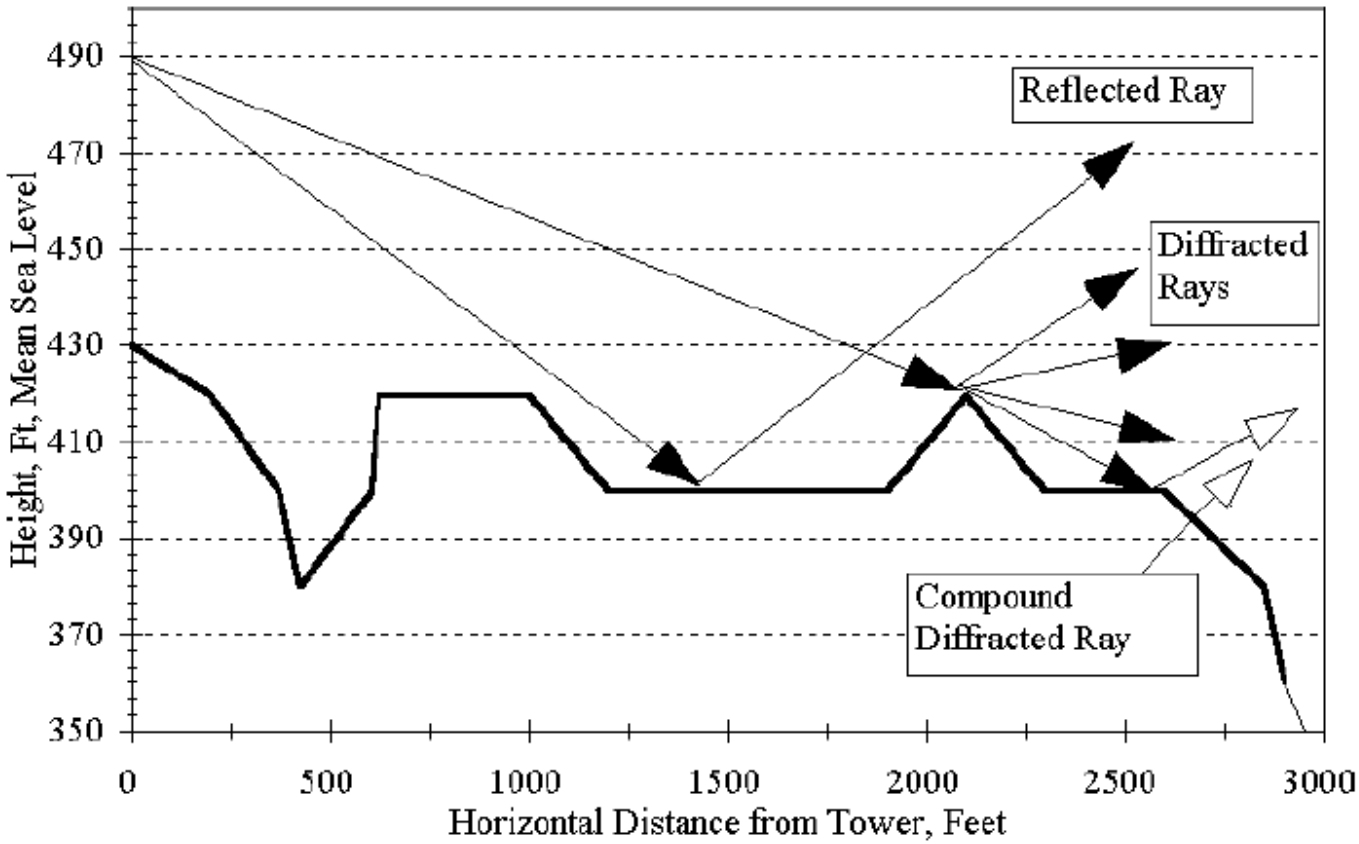
Antennas for Domestic Contests

- So far, all the scenarios have involved antennas over flat ground.
- But real terrain is a lot more bumpy…

The *HFTA* Program

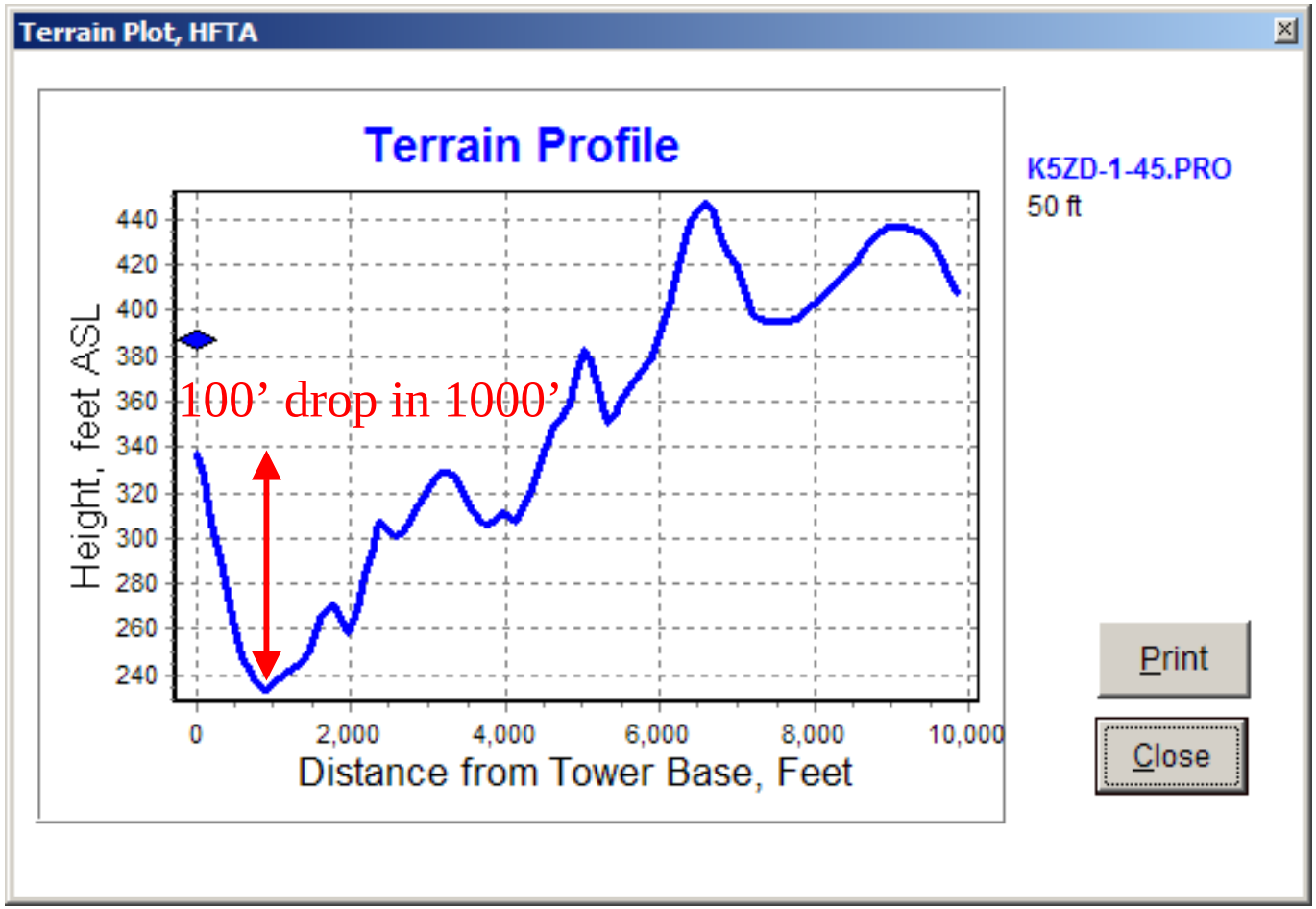
- *HFTA* is a ray-tracing program.
- Consider it like a rifle, shooting bullets in steps of 1/4° from +45 ° to –45°, and watching how the bullets interact with the ground terrain.
- *HFTA* calculates reflections and diffractions over the terrain.

An Example, Some Rays



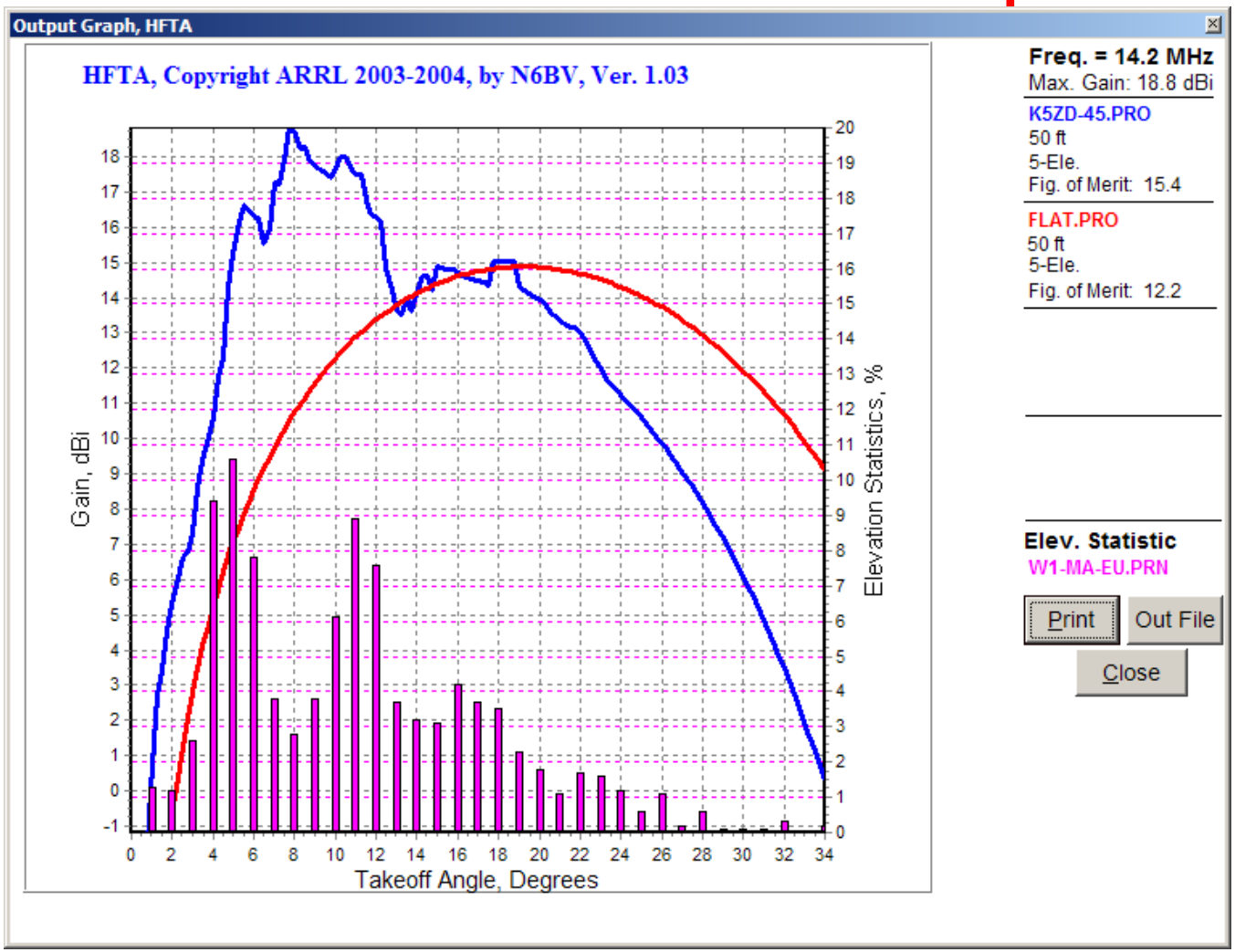
Complex ray-tracing off N6BV/1 terrain towards Japan.

Local Terrain, an Example



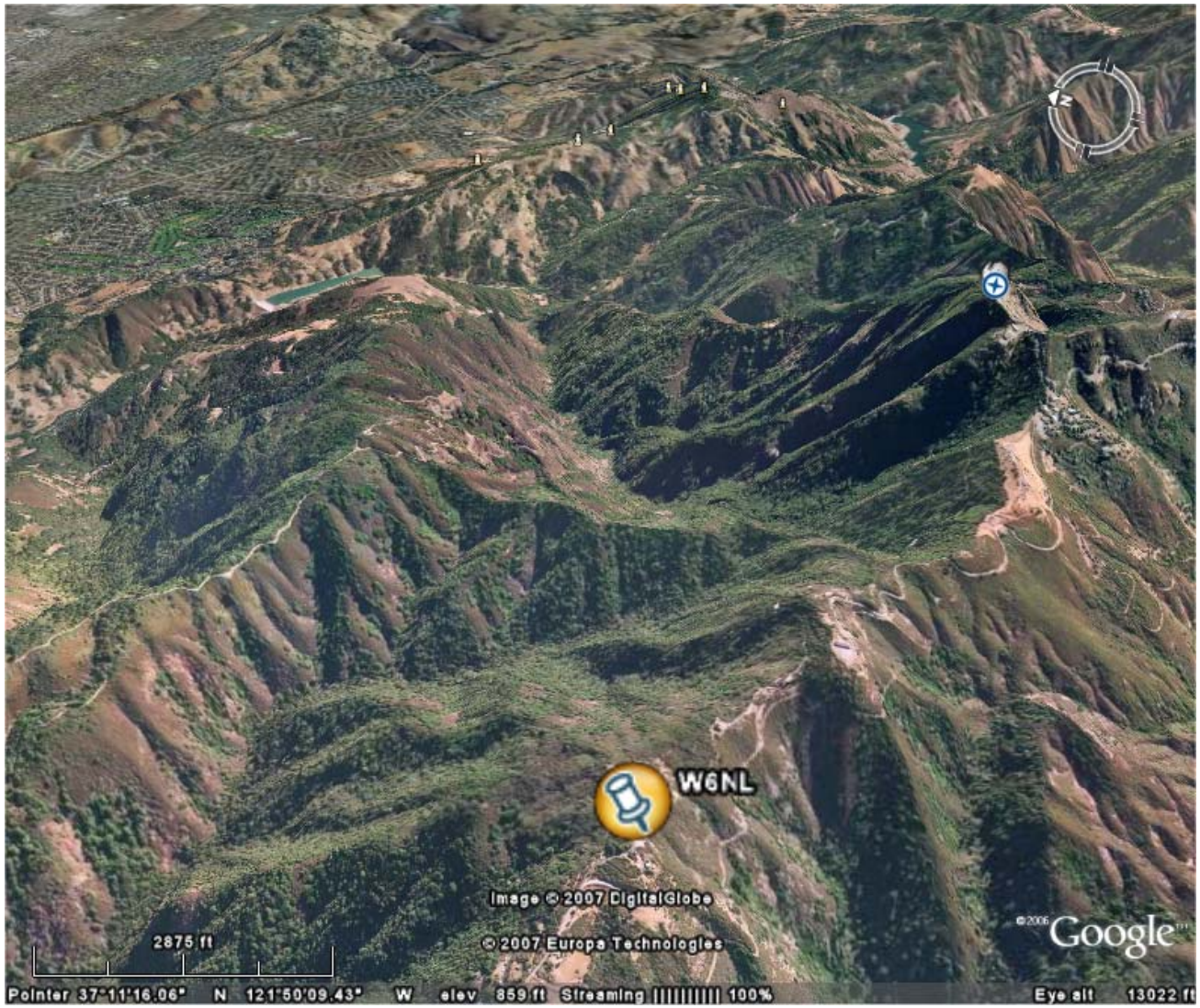
Terrain at K5ZD/1 in Massachusetts, towards Europe.

K5ZD Towards Europe

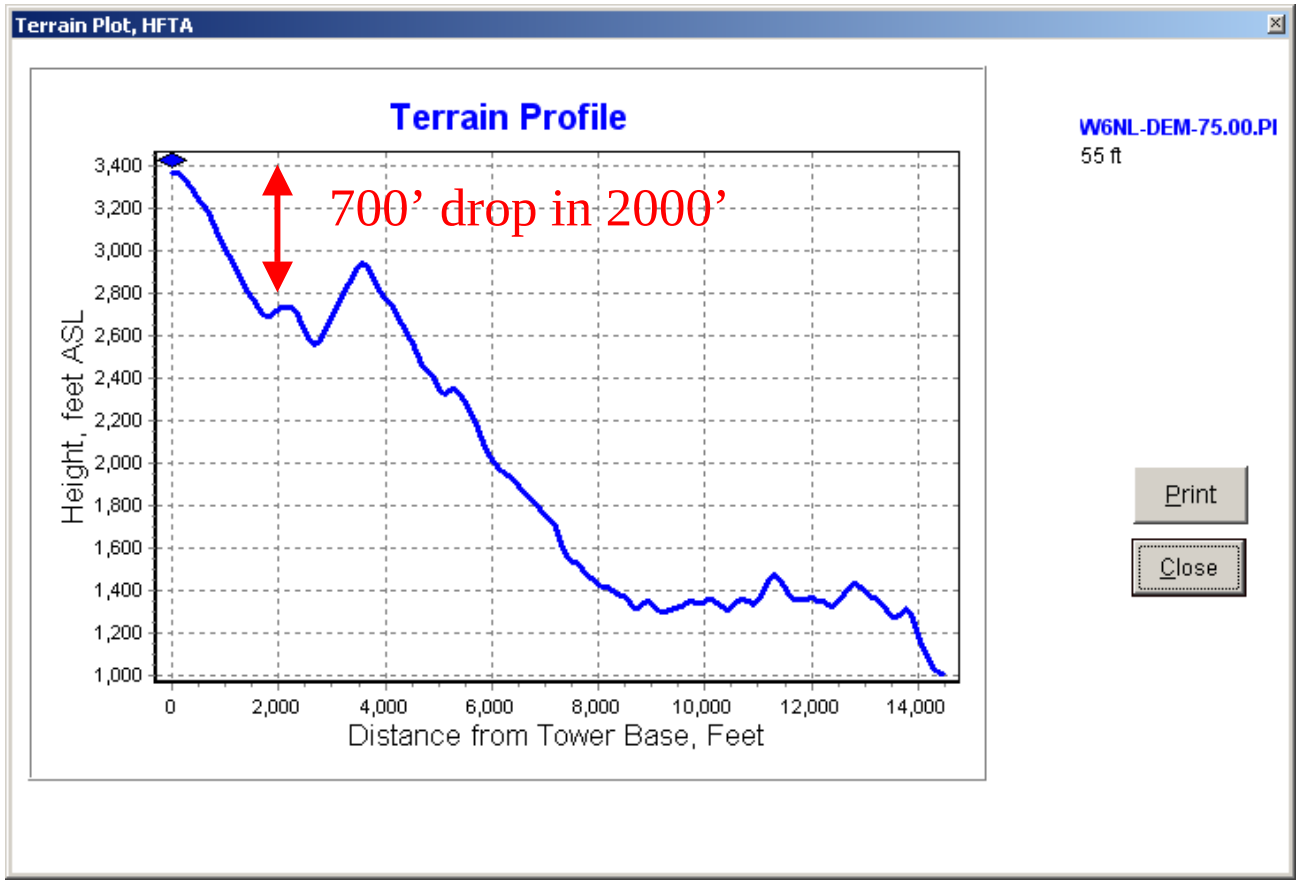


K5ZD's steep terrain has a major effect compared to a flatland antenna!

W6NL Towards the USA



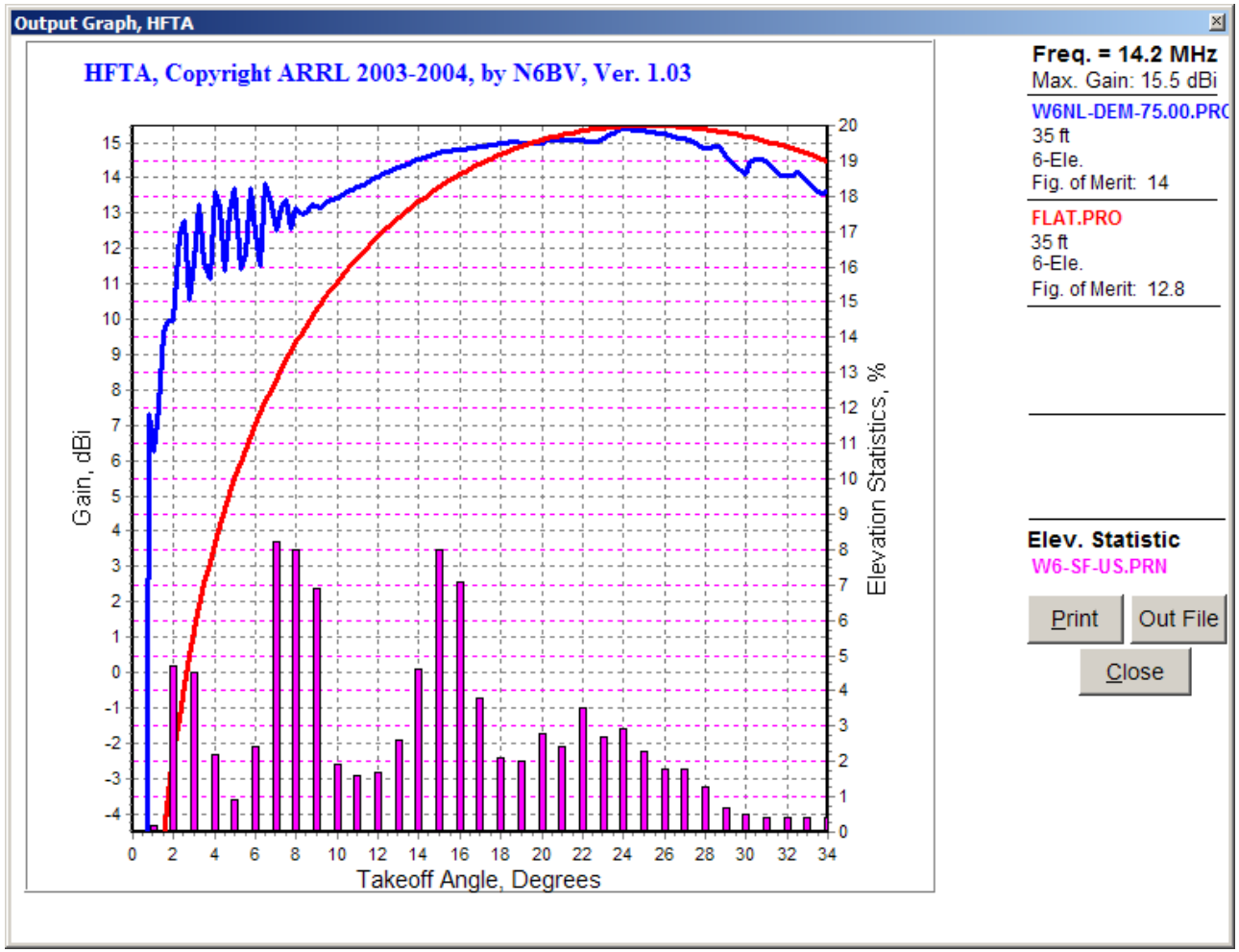
W6NL's Terrain Towards USA



Terrain at W6NL's place in Los Gatos, CA, towards USA.

Because of steep slope this QTH is only good for DXing, right?

W6NL — Covering All the Angles



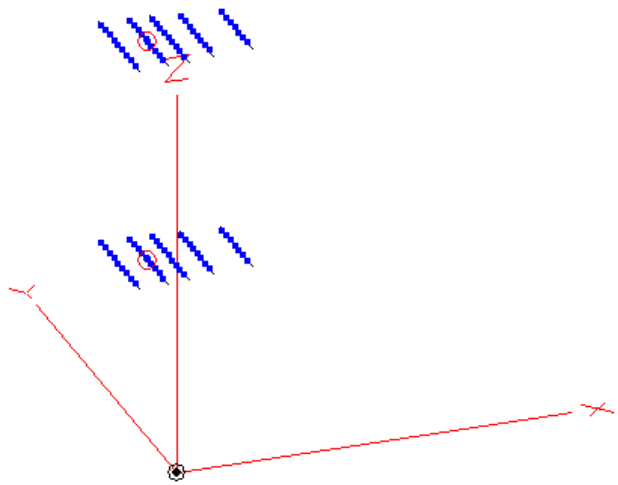
A 35-foot high 20-meter antenna covers low and high angles well at W6NL for USA (and for DX too)!

How Can You Achieve High and Low Angles Suitable for Both Domestic and DX Contests?

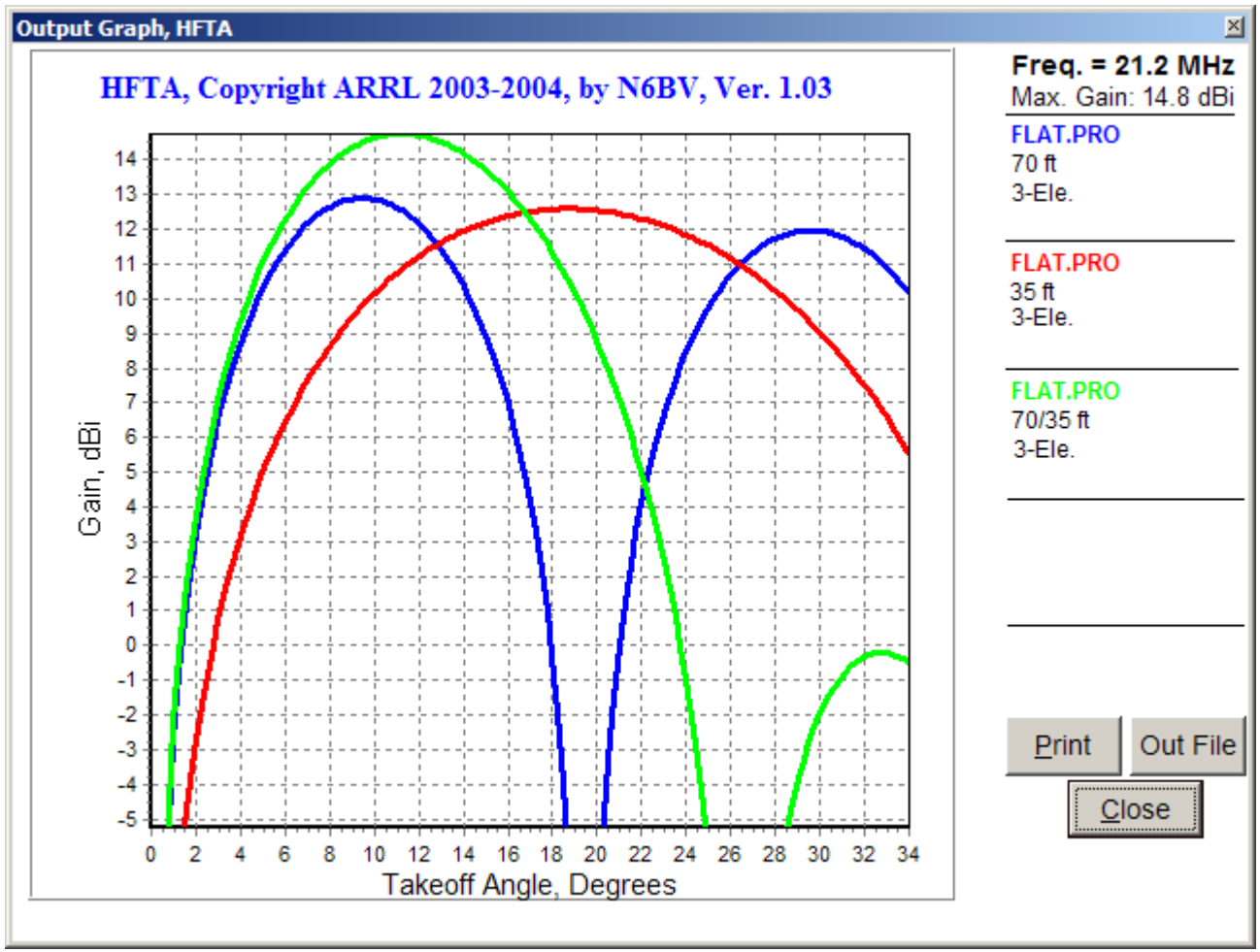
- Higher is sometimes better, but not always.
- The usual approach is to use vertically stacked Yagi antennas.
- Stacking isn't the only way, but it is one of the most popular ways among modern contest stations.

Why Do We Stack Yagis?

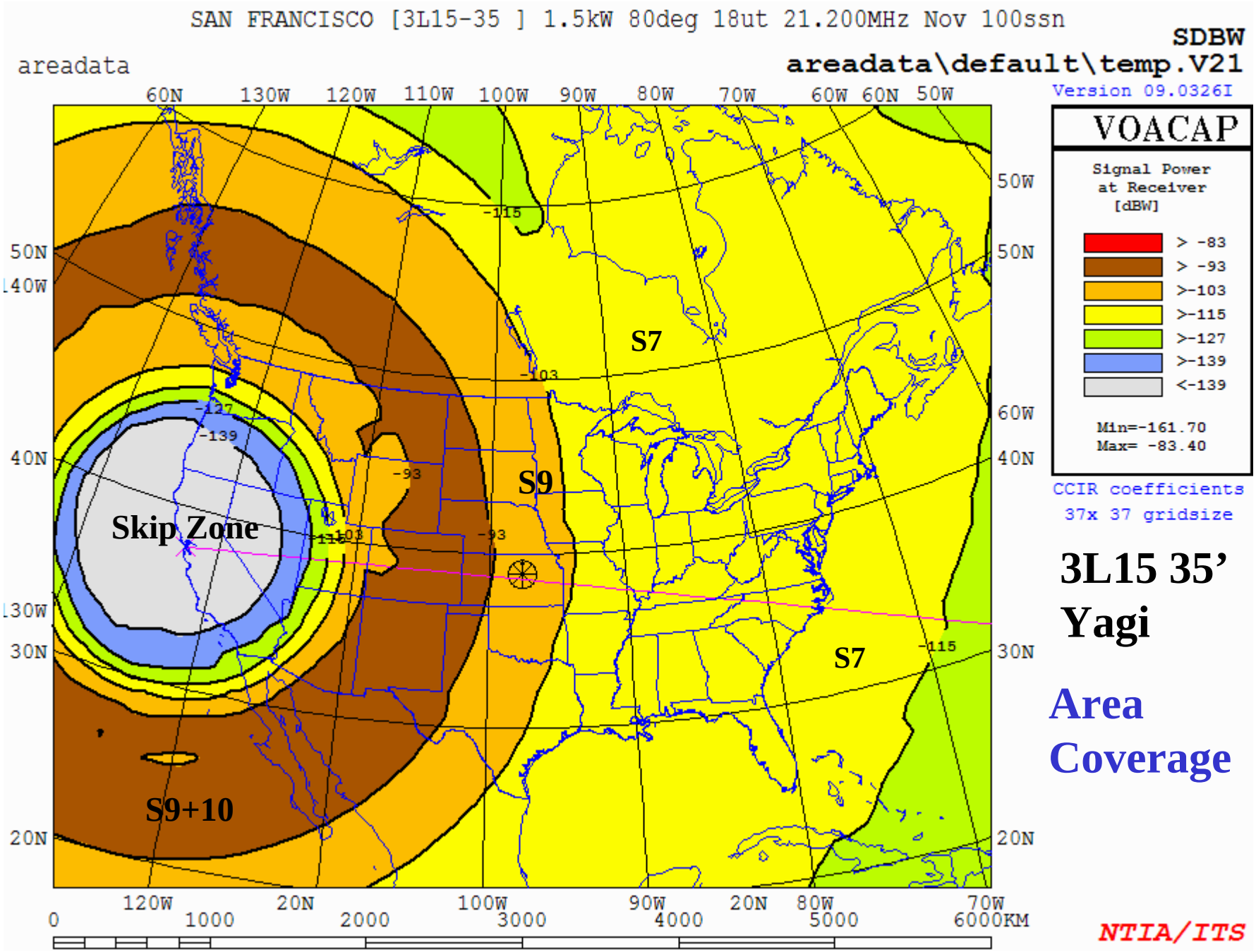
- For more gain
- To widen elevation coverage
- For azimuthal diversity
- For less fading

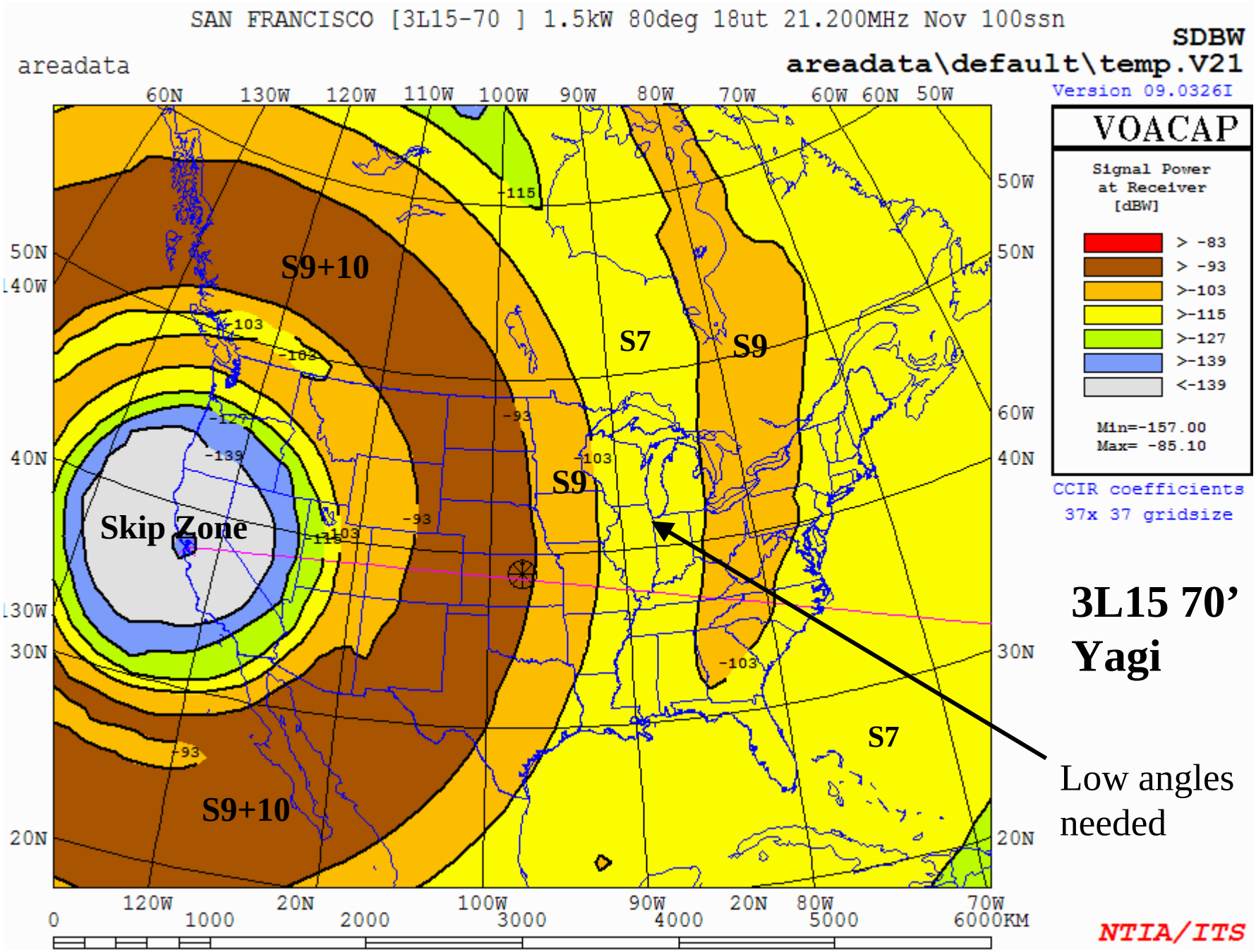


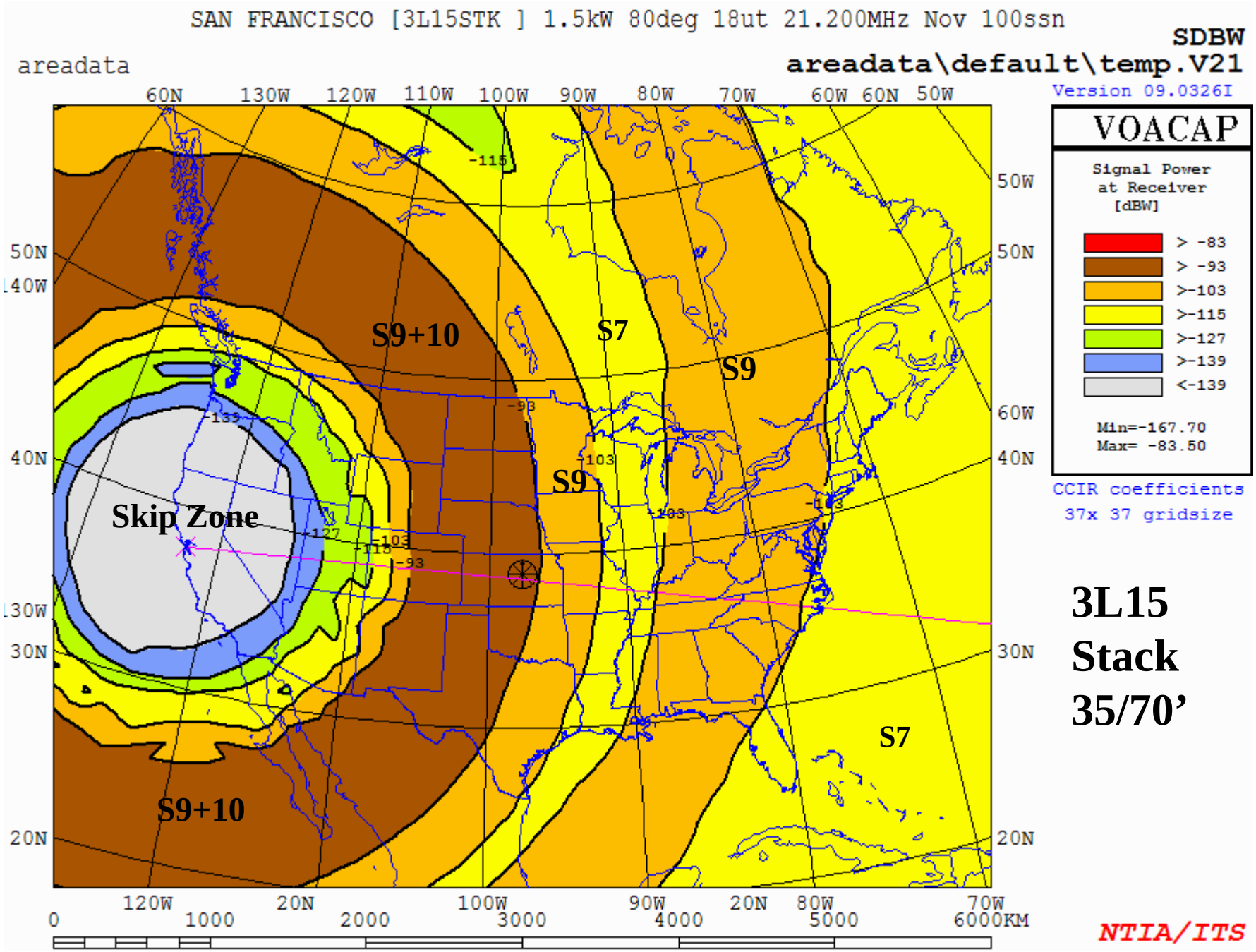
Stacking Gain

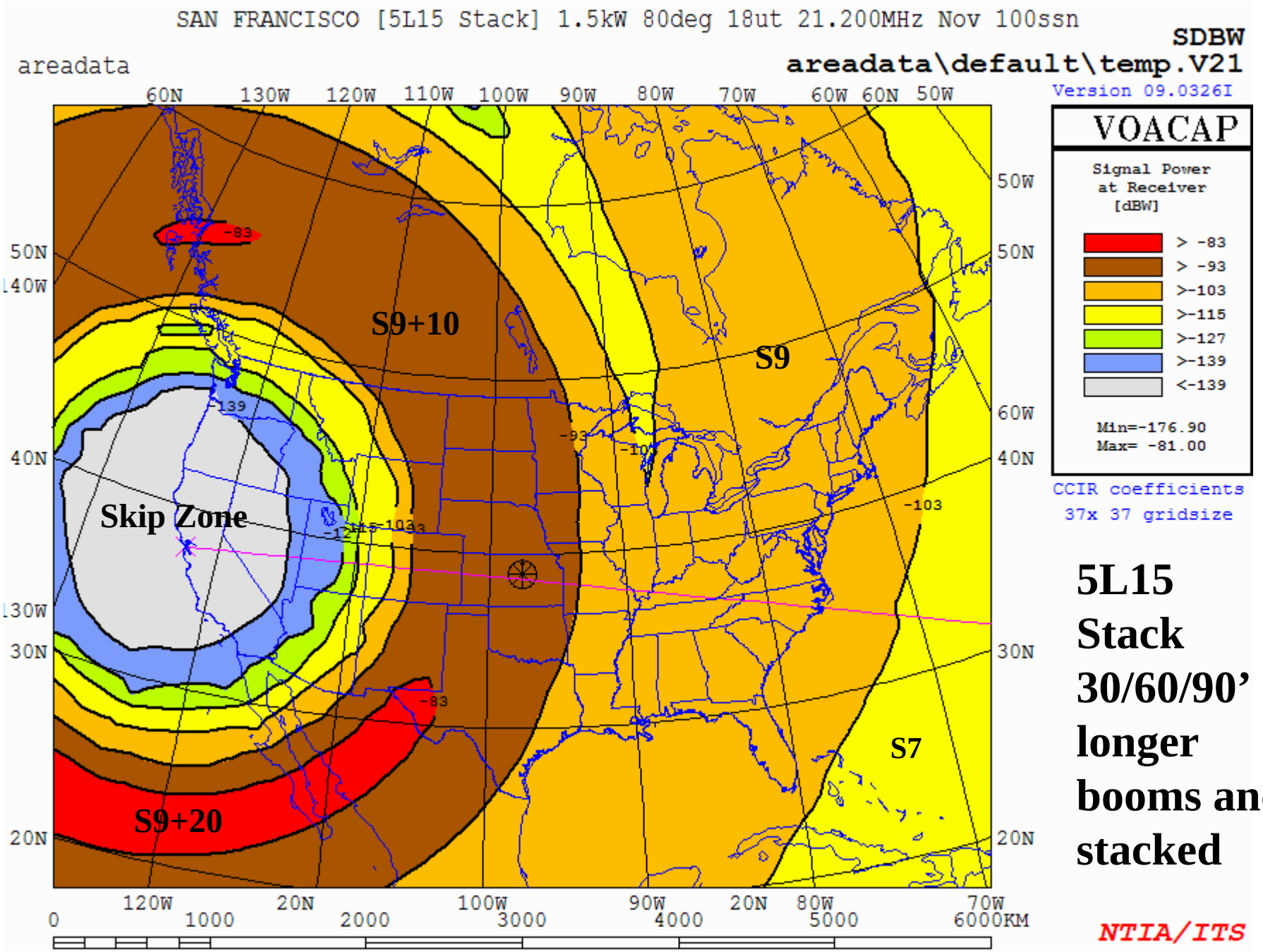


What's the Area Coverage like?

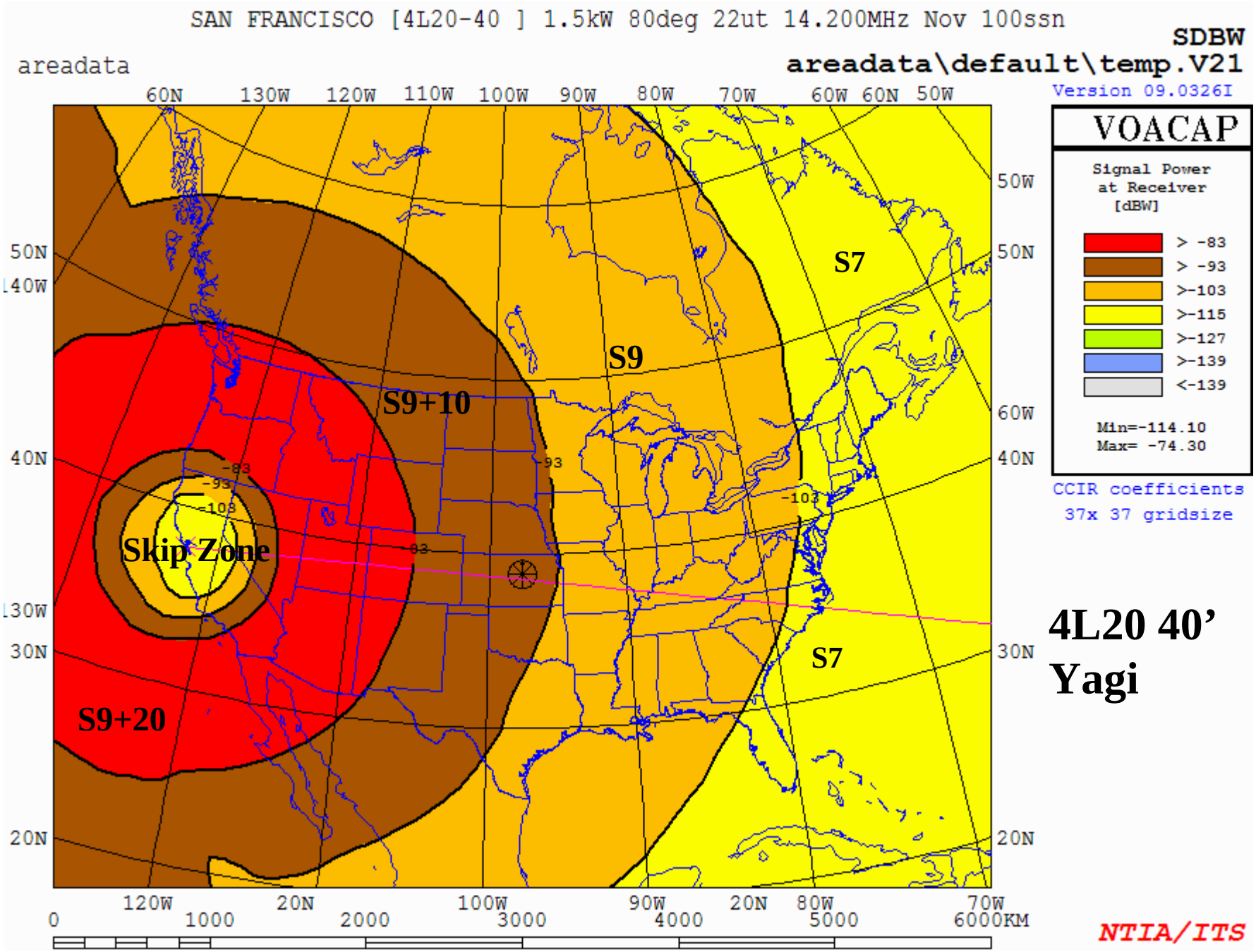

SAN FRANCISCO [3L15-35] 1.5kW 80deg 18ut 21.200MHz Nov 100ssn
areadata
SDBW
areadata\default\temp.V21
Version 09.0326I
VOACAP
Signal Power at Receiver [dBW]
> -83
> -93
>-103
>-115
>-127
>-139
<-139
Min=-161.70
Max= -83.40
CCIR coefficients
37x 37 gridsize
60N 130W 120W 110W 100W 90W 80W 70W 60W 60N 50W
50N
40N
30N
20N
S7
S9
S7
S9+10
Skip Zone
-115
-103
-93
-127
-139
0 1000 2000 3000 4000 5000 6000KM
3L15 35’ Yagi
Area Coverage
NTIA/ITS

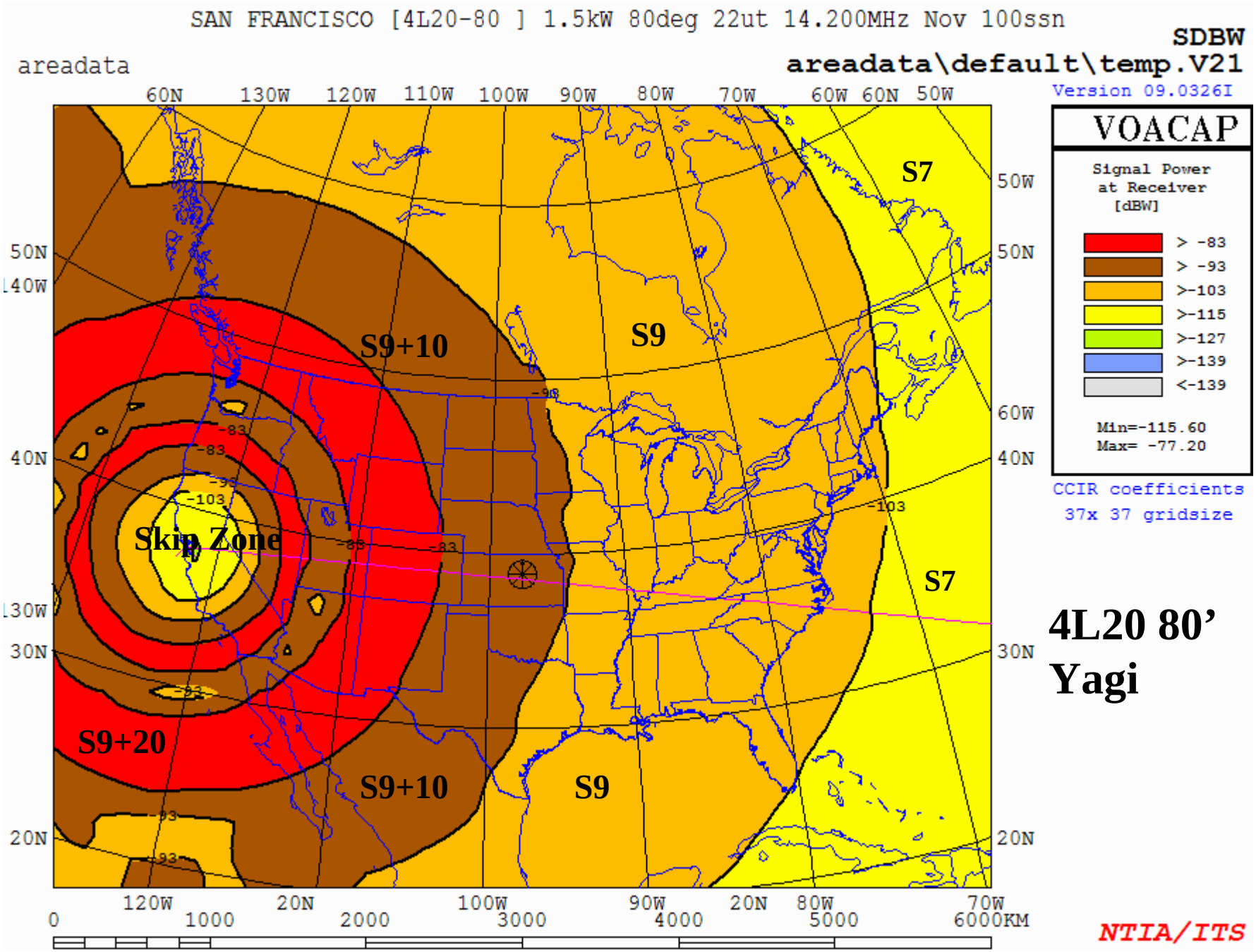

SAN FRANCISCO [3L15-70] 1.5kW 80deg 18ut 21.200MHz Nov 100ssn
areadata
SDBW
areadata\default\temp.V21
Version 09.0326I
VOACAP
Signal Power at Receiver [dBW]
> -83
> -93
>-103
>-115
>-127
>-139
<-139
Min=-157.00
Max= -85.10
CCIR coefficients
37x 37 gridsize
S9+10
S7
S9
S9
Skip Zone
S7
S9+10
3L15 70’ Yagi
Low angles needed
NTIA/ITS

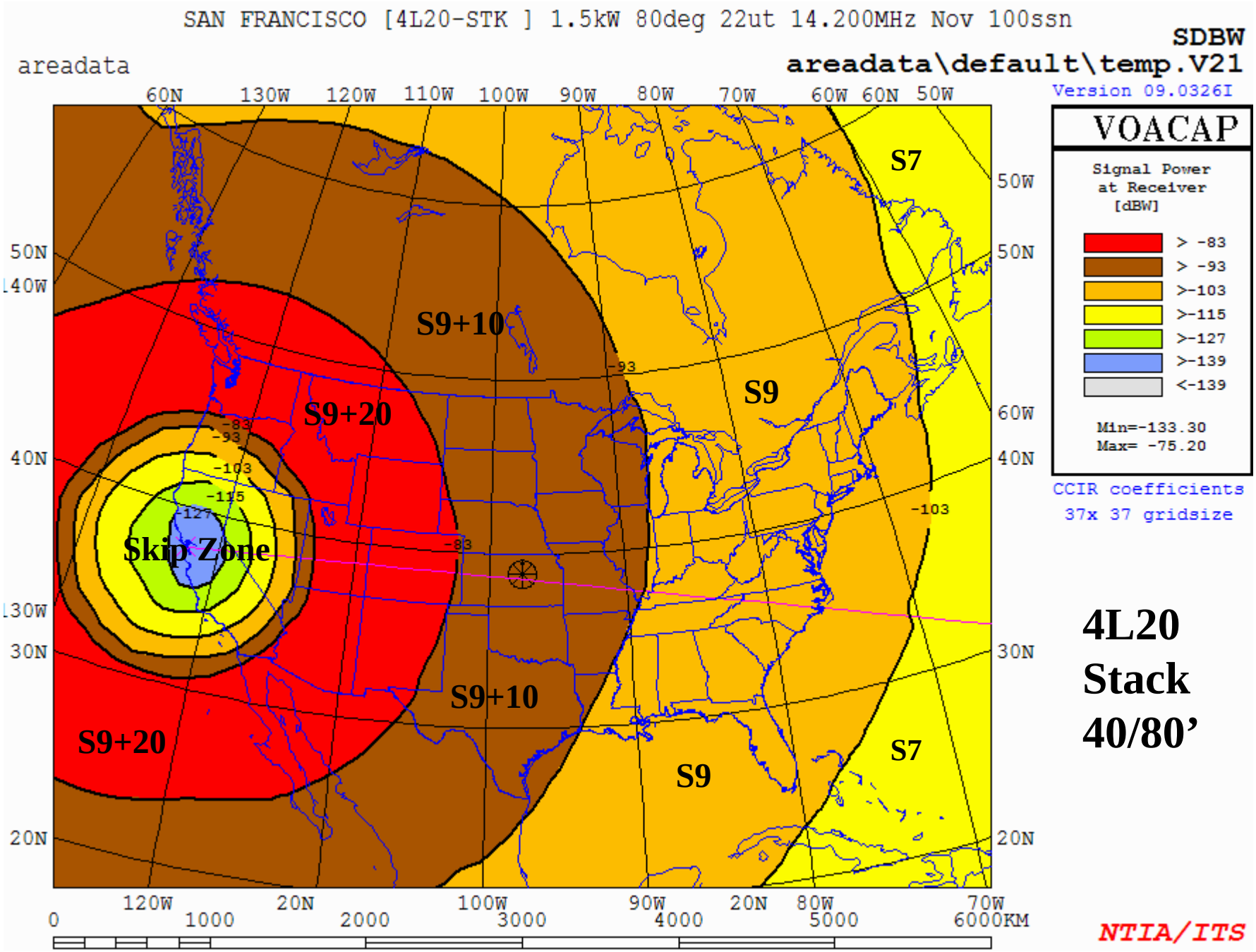

SAN FRANCISCO [3L15STK] 1.5kW 80deg 18ut 21.200MHz Nov 100ssn
areadata
SDBW
areadata\default\temp.V21
Version 09.0326I
VOACAP
Signal Power at Receiver [dBW]
> -83
> -93
>-103
>-115
>-127
>-139
<-139
Min=-167.70
Max= -83.50
CCIR coefficients
37x 37 gridsize
S9+10
S7
S9
S9
Skip Zone
S7
S9+10
3L15
Stack
35/70'
NTIA/ITS

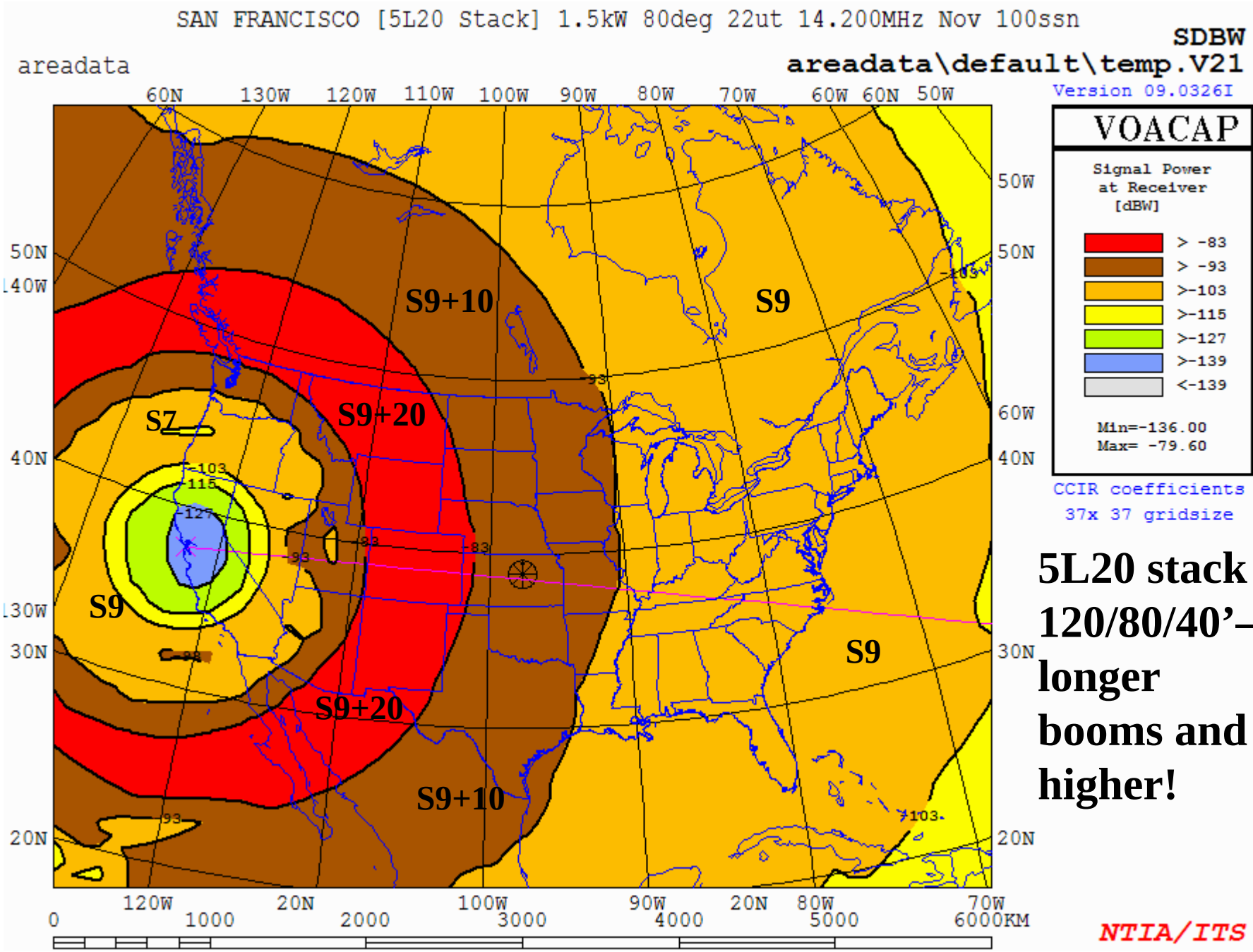


5L15 Stack 30/60/90' – longer booms and stacked


SAN FRANCISCO [4L20-40] 1.5kW 80deg 22ut 14.200MHz Nov 100ssn
areadata
SDBW
areadata\default\temp.V21
Version 09.0326I
VOACAP
Signal Power at Receiver [dBW]
> -83
> -93
>-103
>-115
>-127
>-139
<-139
Min=-114.10
Max= -74.30
CCIR coefficients
37x 37 gridsize
S7
S9
S9+10
S9+20
Skip Zone
-83
-93
-103
4L20 40’ Yagi
NTIA/ITS


SAN FRANCISCO [4L20-80] 1.5kW 80deg 22ut 14.200MHz Nov 100ssn
areadata
SDBW
areadata\default\temp.V21
Version 09.0326I
VOACAP
Signal Power at Receiver [dBW]
> -83
> -93
>-103
>-115
>-127
>-139
<-139
Min=-115.60
Max= -77.20
CCIR coefficients
37x 37 gridsize
S9+10
S9
S7
Skip Zone
S9+20
S9+10
S9
S7
4L20 80’ Yagi
NTIA/ITS

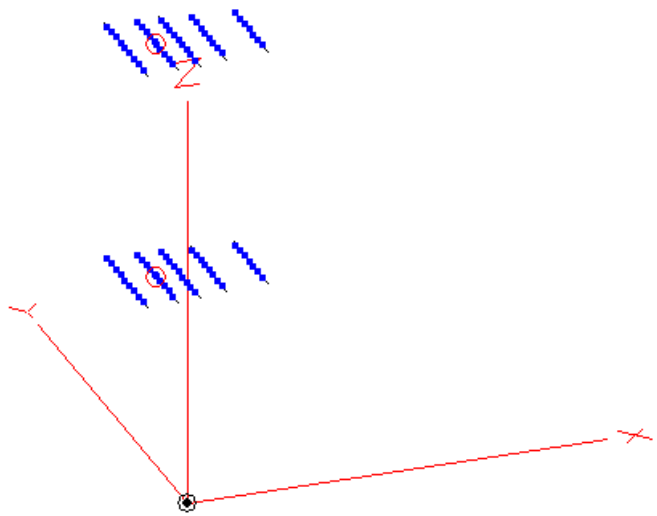

SAN FRANCISCO [4L20-STK] 1.5kW 80deg 22ut 14.200MHz Nov 100ssn
areadata
SDBW
areadata\default\temp.V21
Version 09.0326I
VOACAP
Signal Power at Receiver [dBW]
> -83
> -93
>-103
>-115
>-127
>-139
<-139
Min=-133.30
Max= -75.20
CCIR coefficients
37x 37 gridsize
S7
S9+10
S9
S9+20
Skip Zone
S9+10
S9+20
S9
S7
4L20
Stack
40/80'
NTIA/ITS



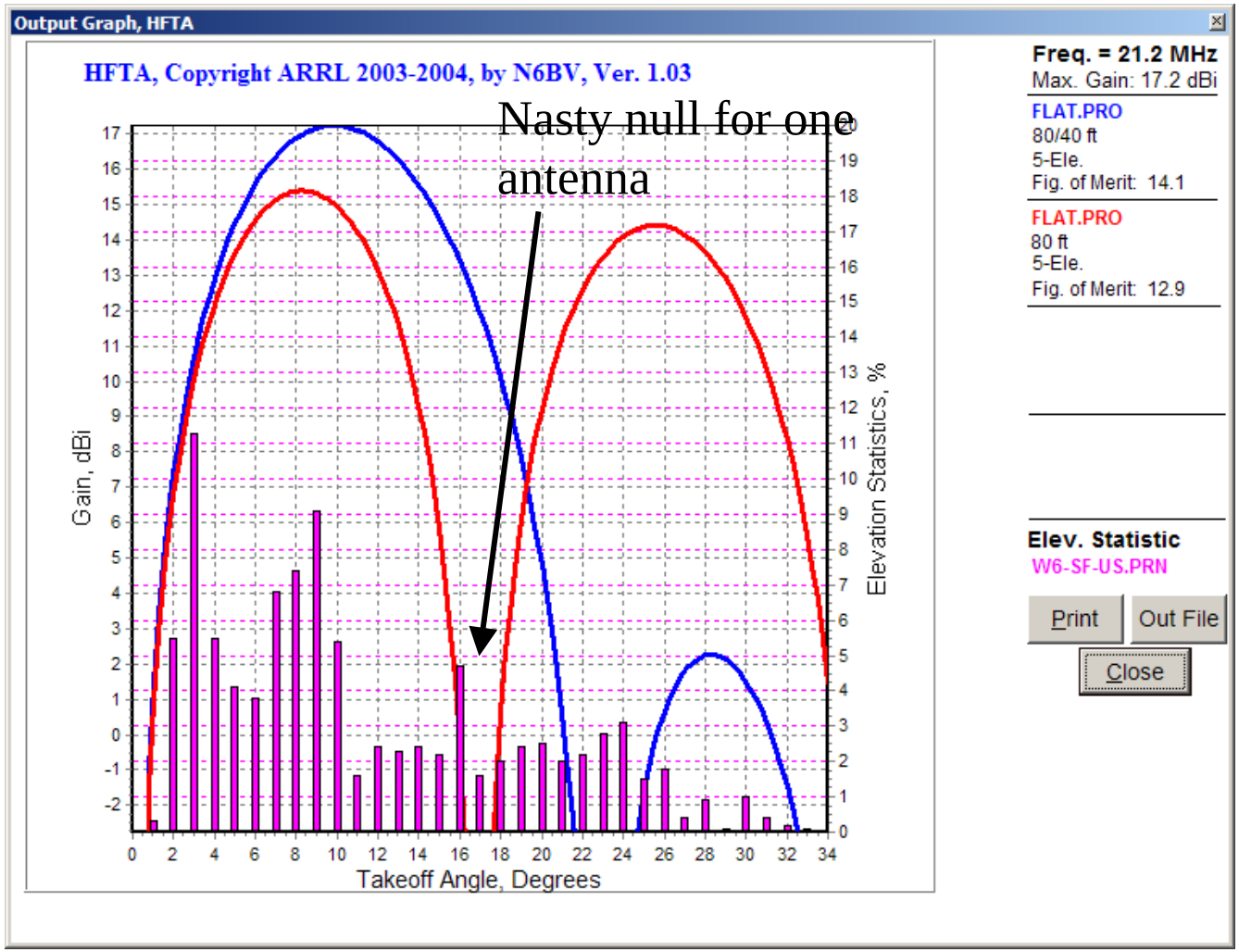
5L20 stack 120/80/40'—longer booms and higher!

Why Do We Stack Yagis?

- For more gain
- For wider elevation coverage
- For azimuthal diversity
- For less fading



15-Meter Stack at 80’/40’



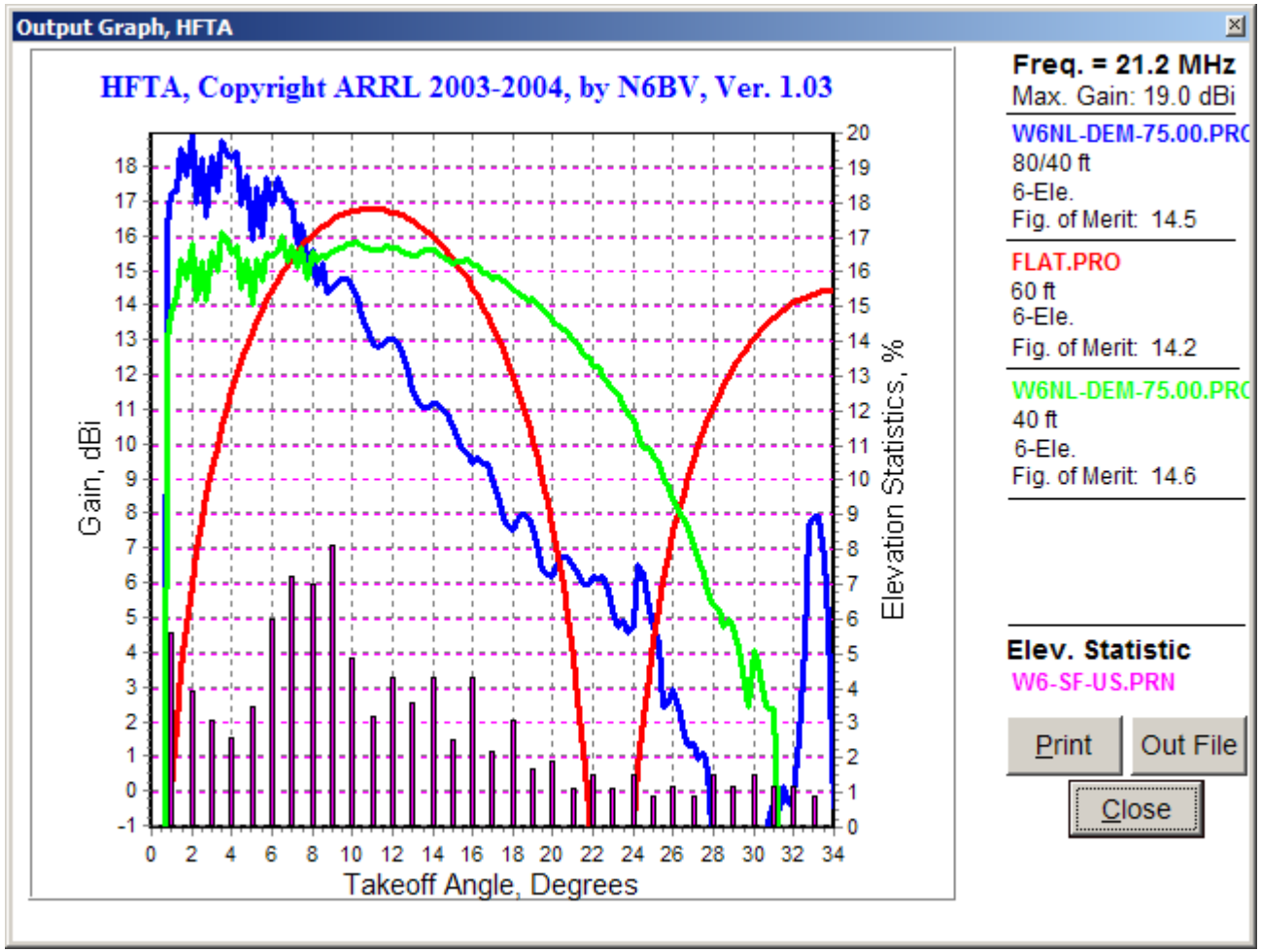
Over flat ground, for illustration.

Wider Elevation-Angle Coverage

• Higher antennas are not necessarily always better. The gain is good at low angles, but the nulls can really hurt you. You need to cover all the angles, preferably with a single stack so you don't have to switch all the time.

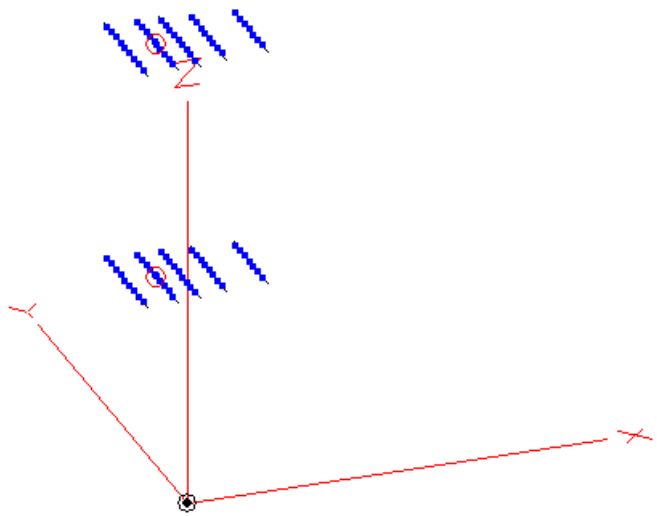
• It's easy to be too high, especially on hilltops.

Too High on W6NL's Mountain



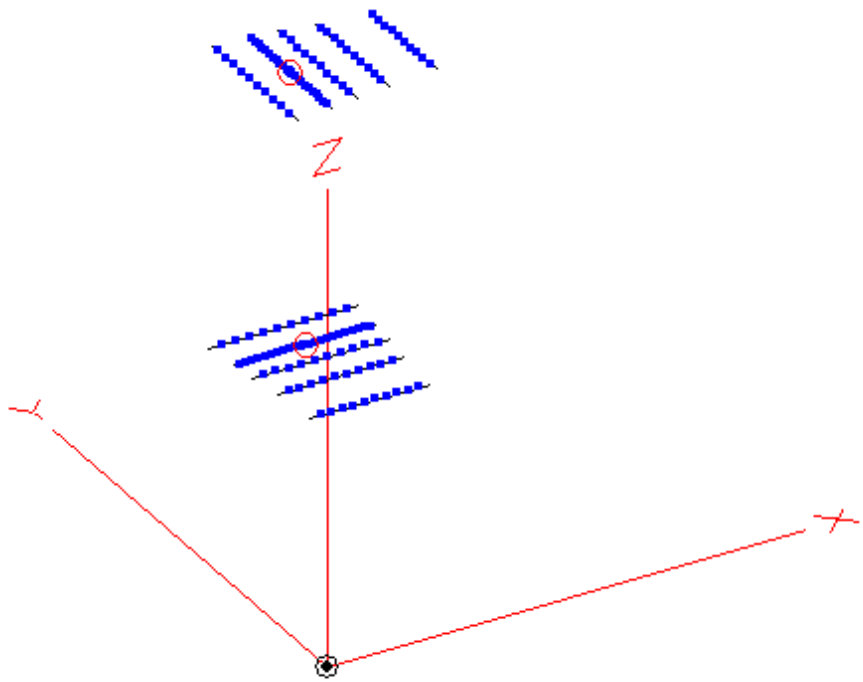
Why Do We Stack Yagis?

- For more gain
- For wider elevation coverage
- For azimuthal diversity
- For less fading

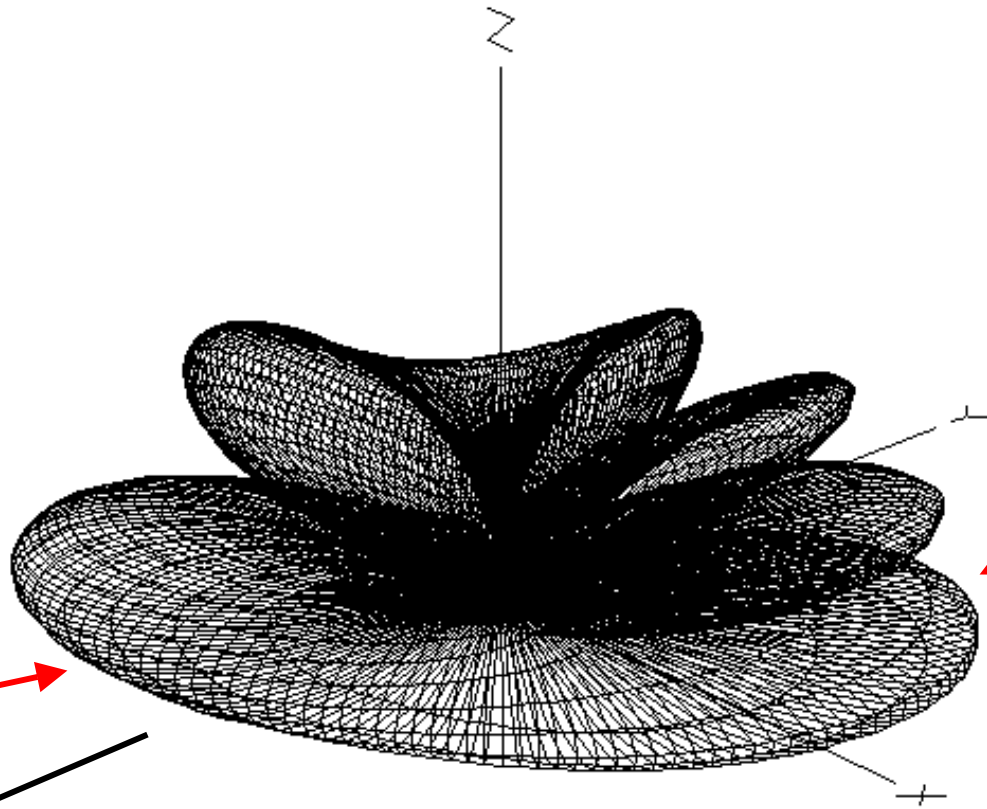


Azimuthal Diversity

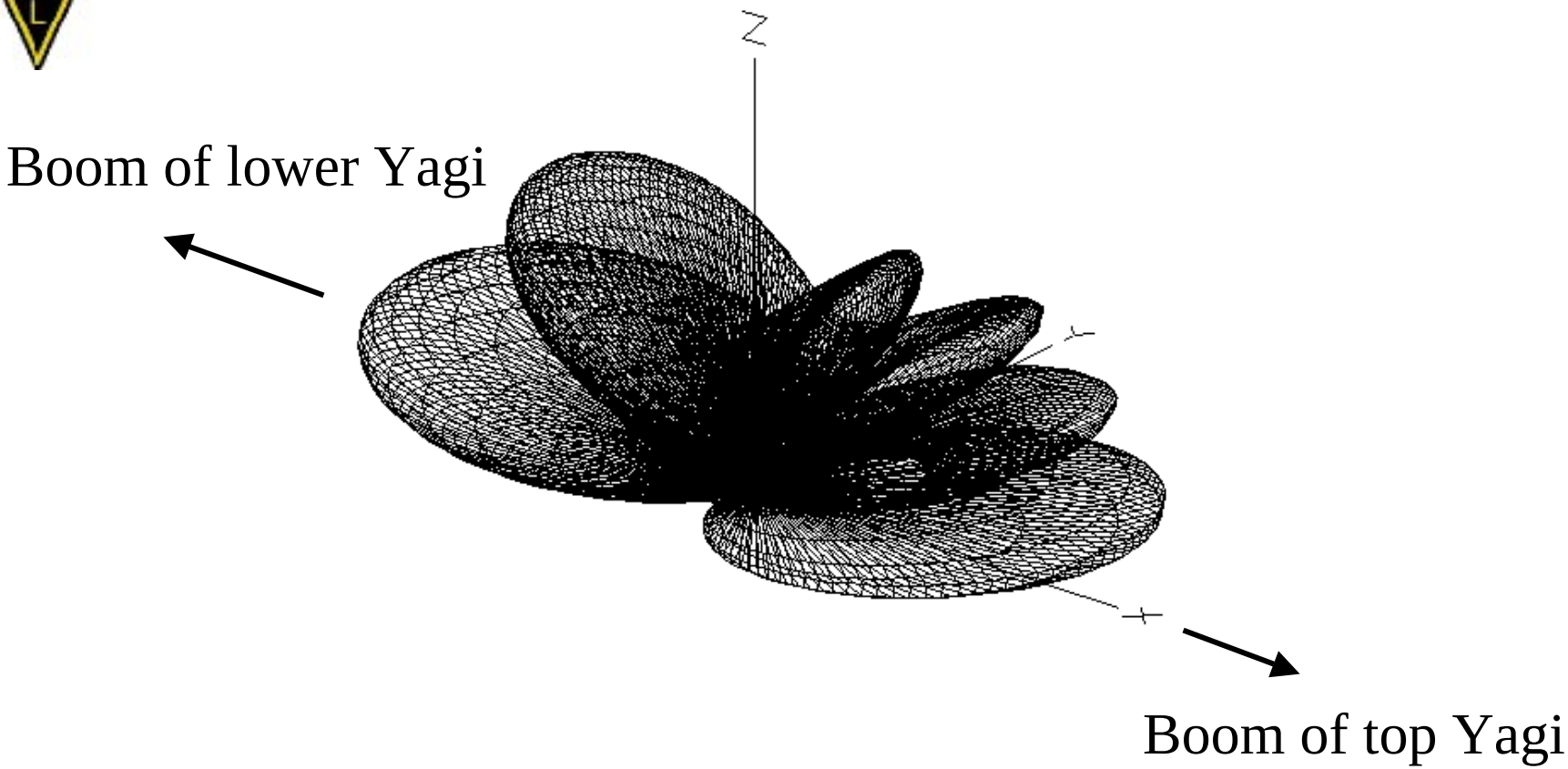
If you turn one antenna in the stack you can beam simultaneously in two directions. If you have more than two Yagis in a bigger stack you can cover even more directions at once, or you can quickly switch to one Yagi.



Azimuthal Diversity, Turned 90°



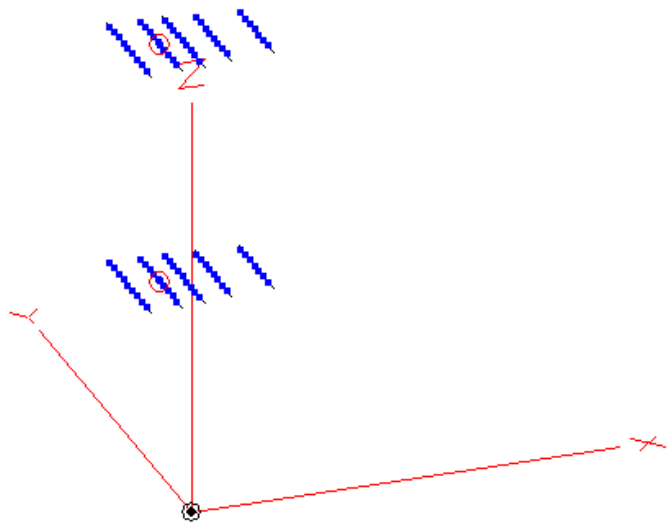
Azimuthal Diversity, Turned 180°



You may want to turn the lower Yagi rather than the top one, depending on the angles involved to the target locations.

Why Do We Stack Yagis?

- For more gain
- For wider elevation coverage
- For azimuthal diversity
- For less fading



Fading and Stacks

K2KQ has a stack consisting of a pair of small A3S tribanders at 82'/60' on Martha's Vineyard, MA. Here's what Don says about the performance:

"On all three bands, the stack is always better on NE paths than either antenna by itself. The average signal level benefits from lower and less frequent fades. Peak signal level is sometimes no better on the stack, but it is very seldom inferior."

"It's surprising how well the stack performs on 20M, considering the modest 22-ft spacing…but it consistently outperforms the top antenna alone."

-- *Don, K2KQ*.

Fading and Stacks

Stacks give:

• *Space Diversity* — even with close spacing.

• With a stack you can pull out a complete call sign as much as 5% more often than without one. Over a 48-hour contest that can make a difference!

• On SSB, often the audio sounds more “full” on a stack — this is related to less selective fading.

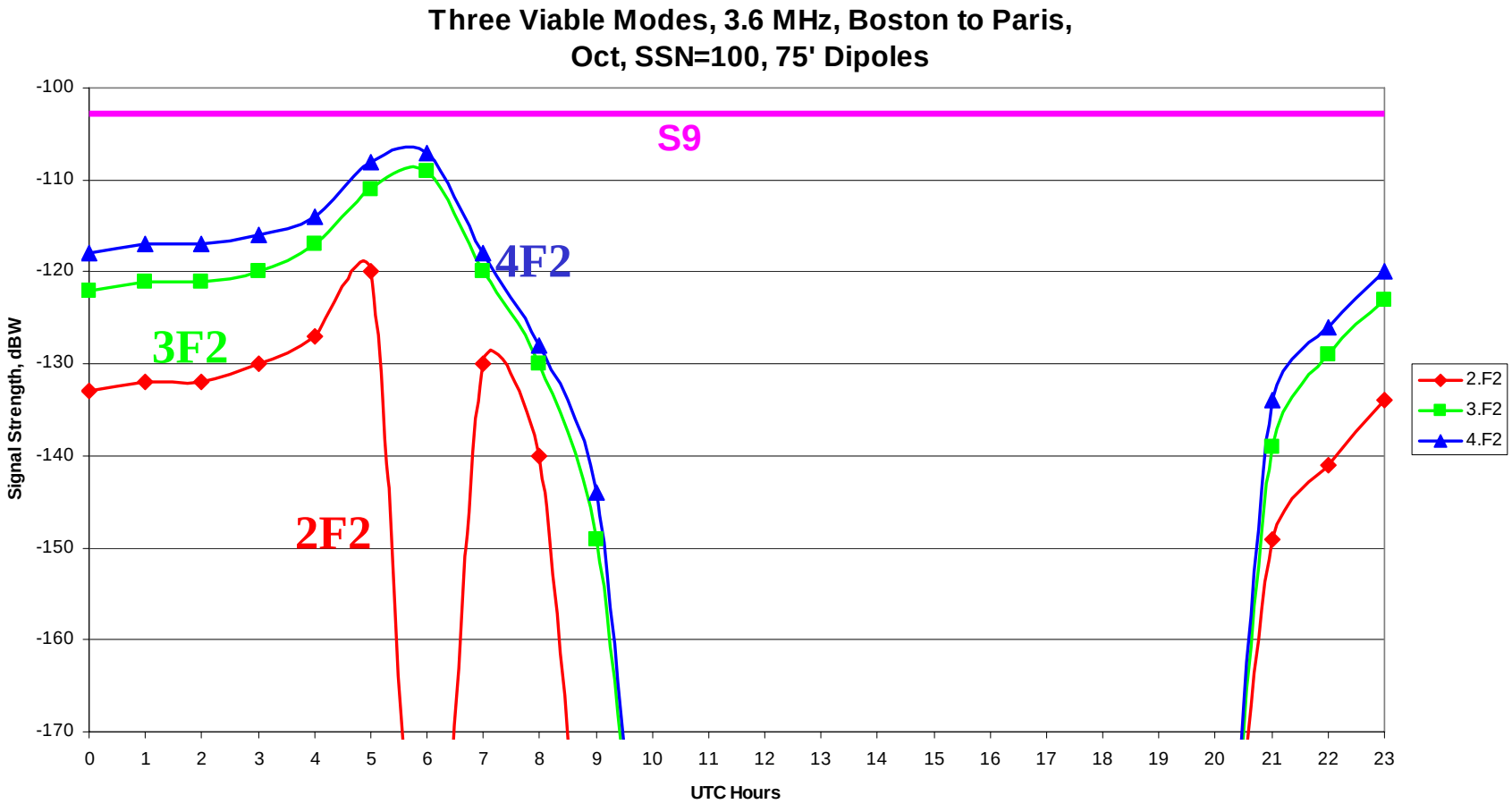
VOACAP Statistics: a Reminder

From my friend Carl, K9LA:

"Scientists had solar data and ionosonde data, and they determined that the best correlation between the two sets of data was smoothed sunspot number (or smoothed solar flux) and monthly median ionospheric parameters (f_oE, f_oF_2, hmF_2, etc).

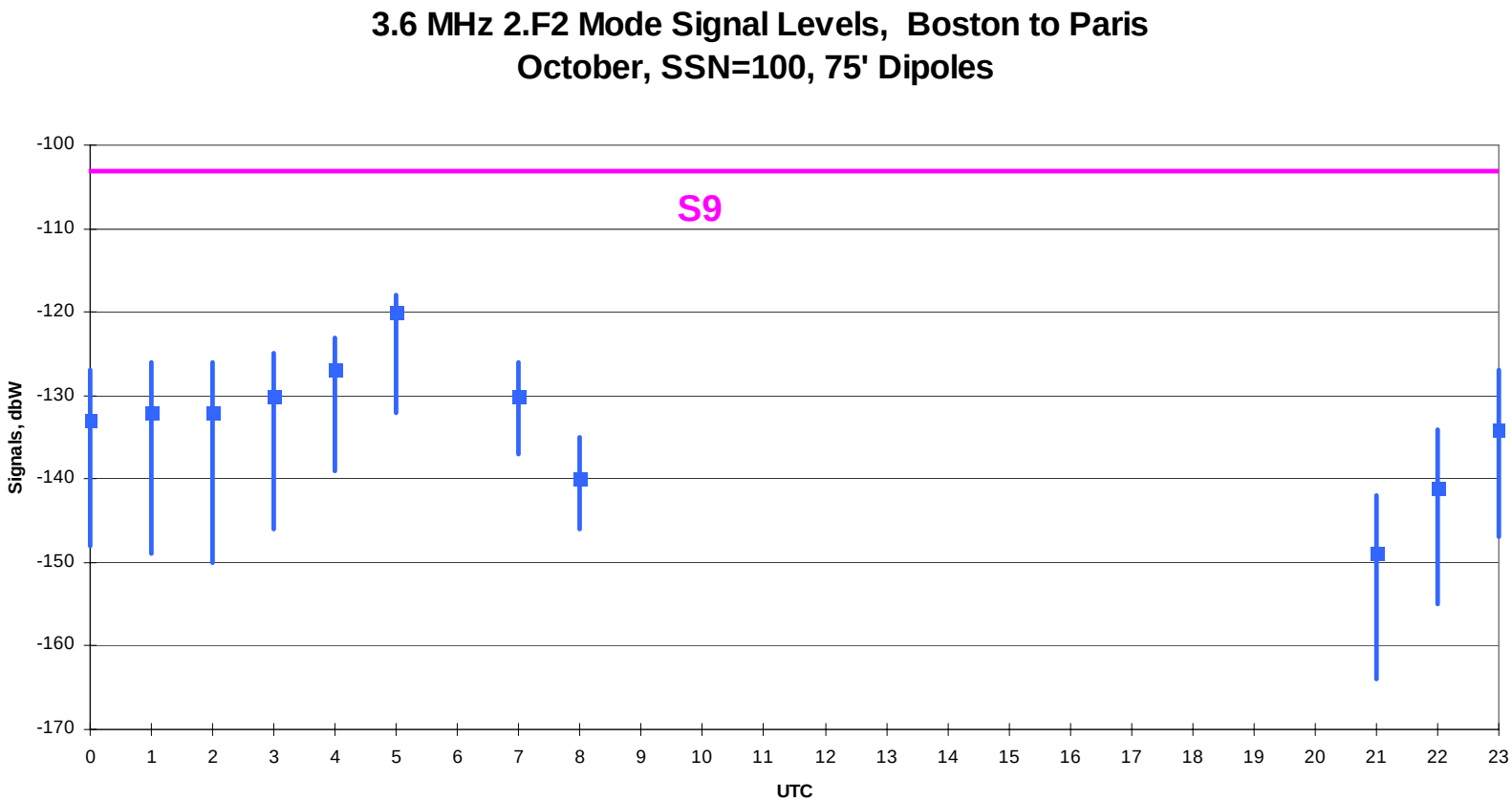
Thus our predictions (both MUF and signal strength) are statistical in nature about the median, with "median" implying 50% probability. Plugging in the daily solar flux does not make predictions more accurate."

Three Simultaneous Modes: Median Signal Strengths



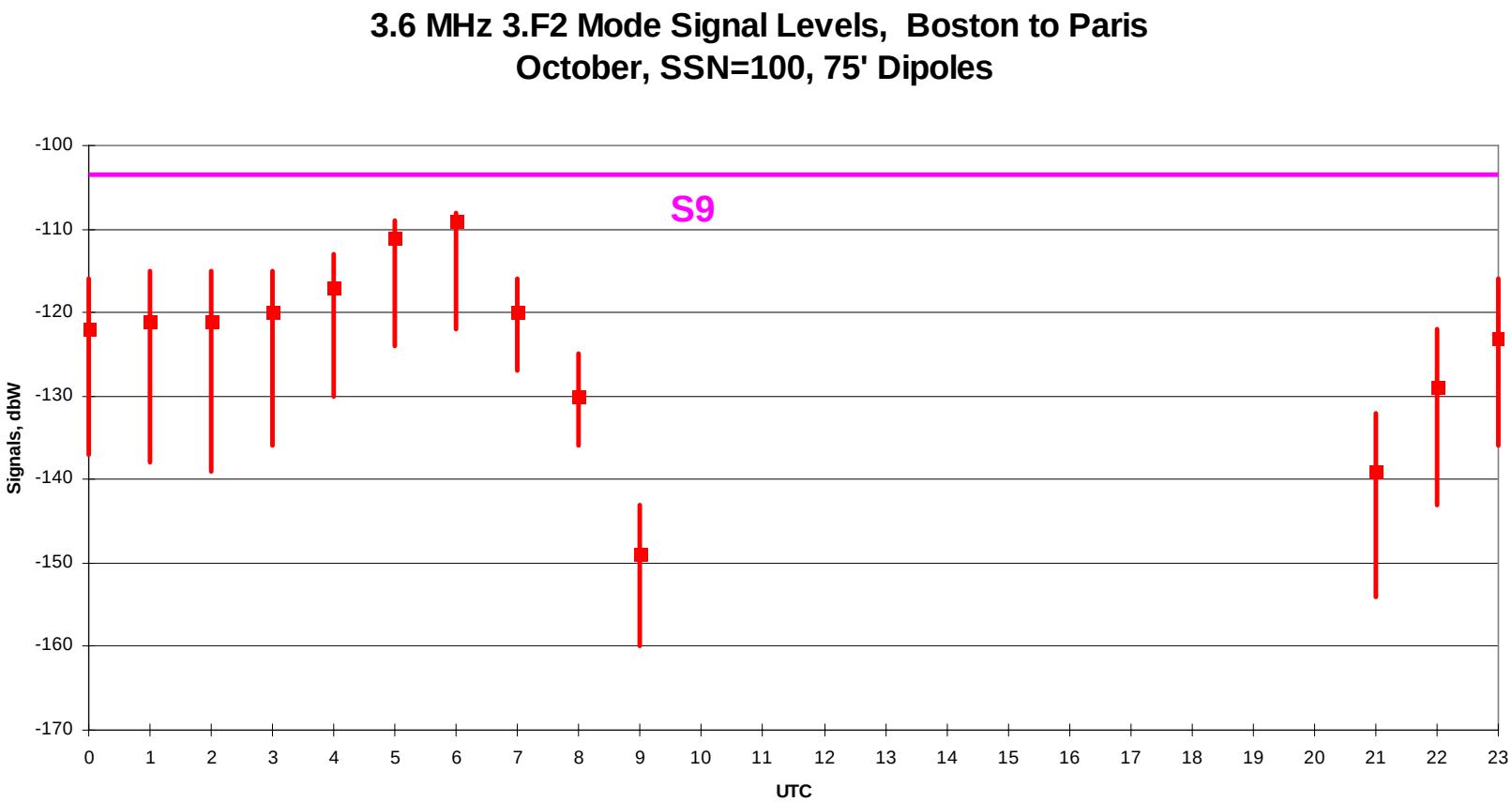
When amplitudes of various modes are close to each other and 180° out-of-phase, severe fading can occur.

2F2 Range of Signals: Statistics



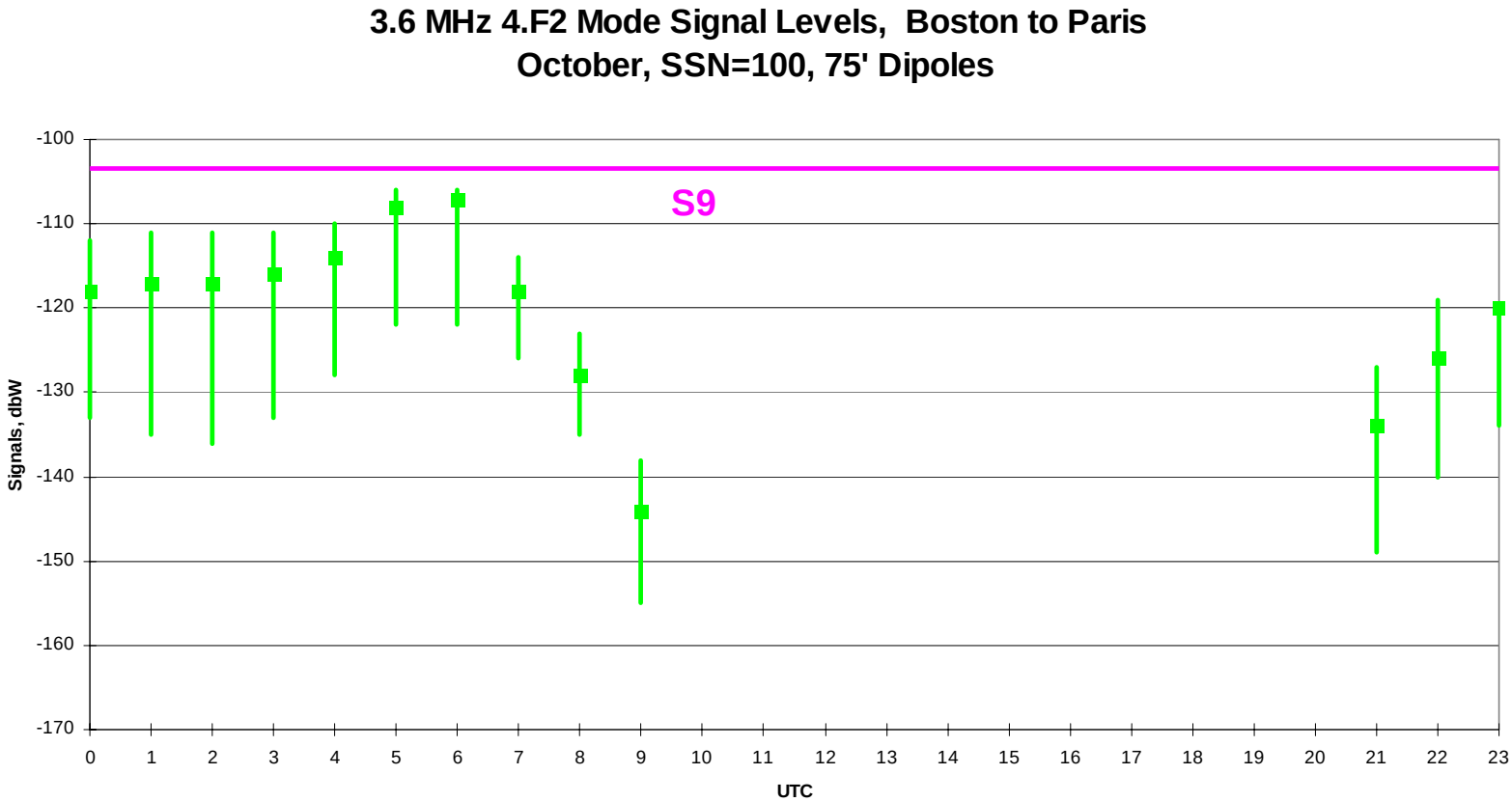
At a particular hour, the lower level occurs ≥ 90% of the time when band is open. The upper level occurs ≤ 10% of the time. Blue square is median signal power at 50% of the time.

3F2 Range of Signals: Statistics



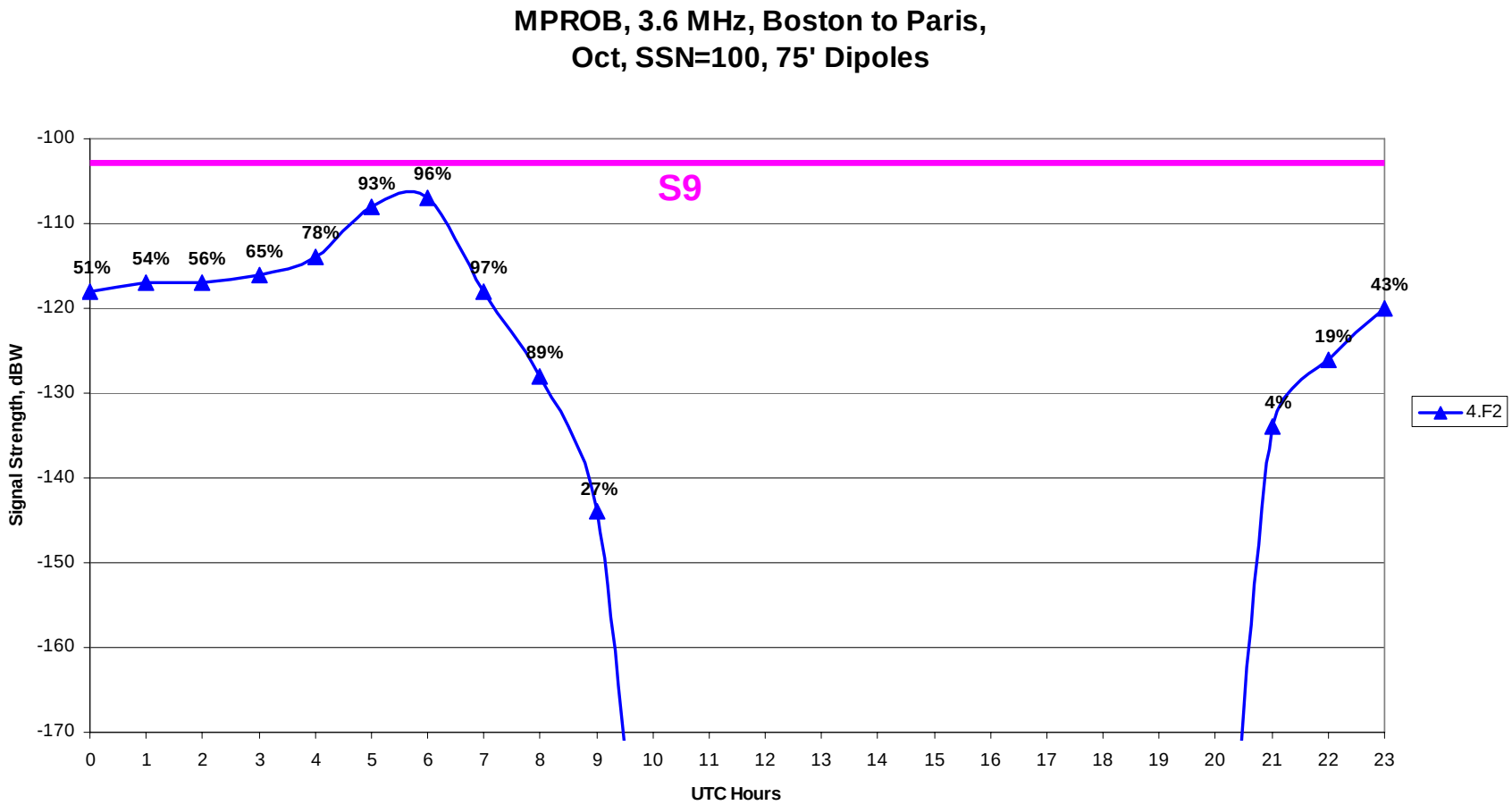
3F2 mode is stronger on this path from Boston to Paris than 2F2 mode, given antennas used.

4F2 Range of Signals: Statistics



4F2 mode is a little stronger on this path from Boston to Paris than 3F2 mode.

Fading Possibilities, MPROB "Thumbnail"



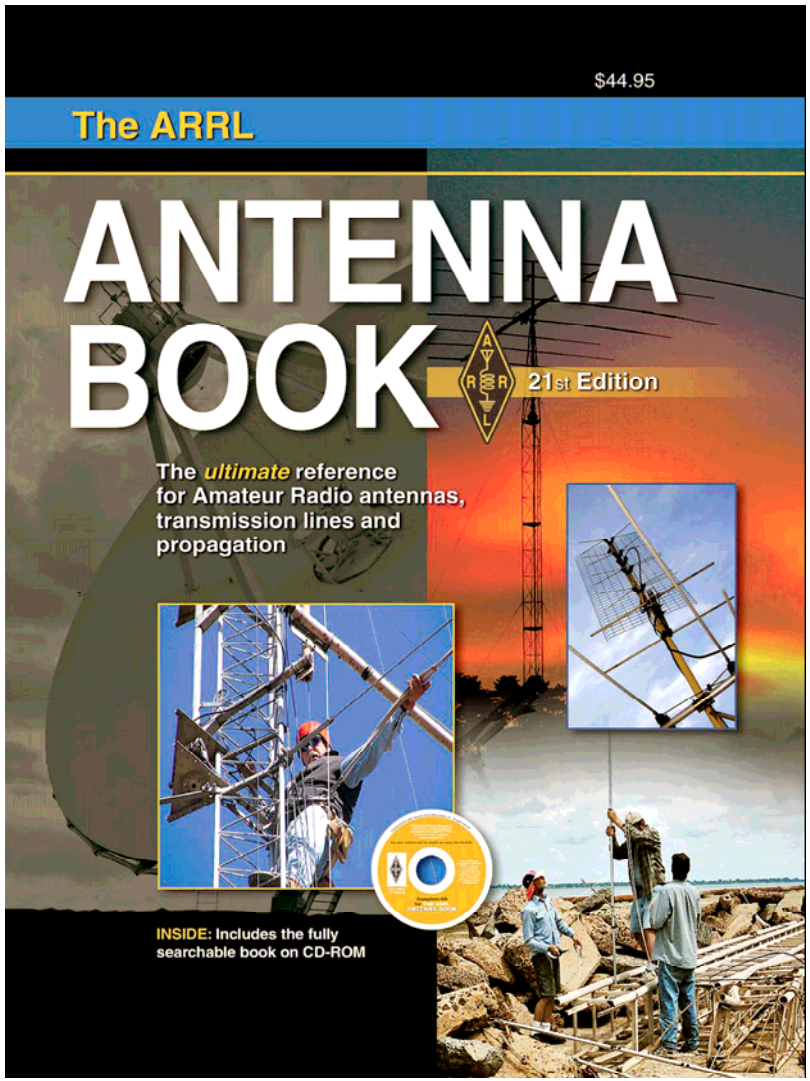
MPROB = reliability of next-most reliable mode. A higher MPROB implies increased possibility of fading.

Antennas for Domestic Contests

- Could very well be the same antennas you use for DX contesting (stacks), with some additions.
- Consider putting up a 35’ to 50’ high 40-meter dipole for close-in NVIS coverage.
- By the way, if you’re using a Four Square vertical array on 40 or 80 meters, put the “dump power” into a low horizontal dipole. You’ll be amazed.

Summary

- You must cover the full range of elevation angles to all your target destinations, domestic & DX.
- You should know how your antennas work under ideal conditions (free space, or flat ground by modeling).
- You should analyze the effects of irregular local terrain and optimize heights, stacks or tower placement on your property.
- *HFTA* is in *The ARRL Antenna Book.*



The 21st Edition of *The ARRL Antenna Book*

Jari Perkiömäki, OH6BG's Website

- Jari is a good friend. He's helped me a lot.
- His web site is at: **http://www.voacap.com/**
- Or just Google: "VOACAP". It will be 1st hit.
- This site contains many interesting articles about *VOACAP*.
- OH6BG has kindly offered to post this presentation at his site.
- Thanks also to Greg Hand for fixing MPROB in *VOACAP* and for maintaining the program.