Antenna Stacking! Why?

To Cover ALL the Angles!

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Using Science to Plan a Station

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

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

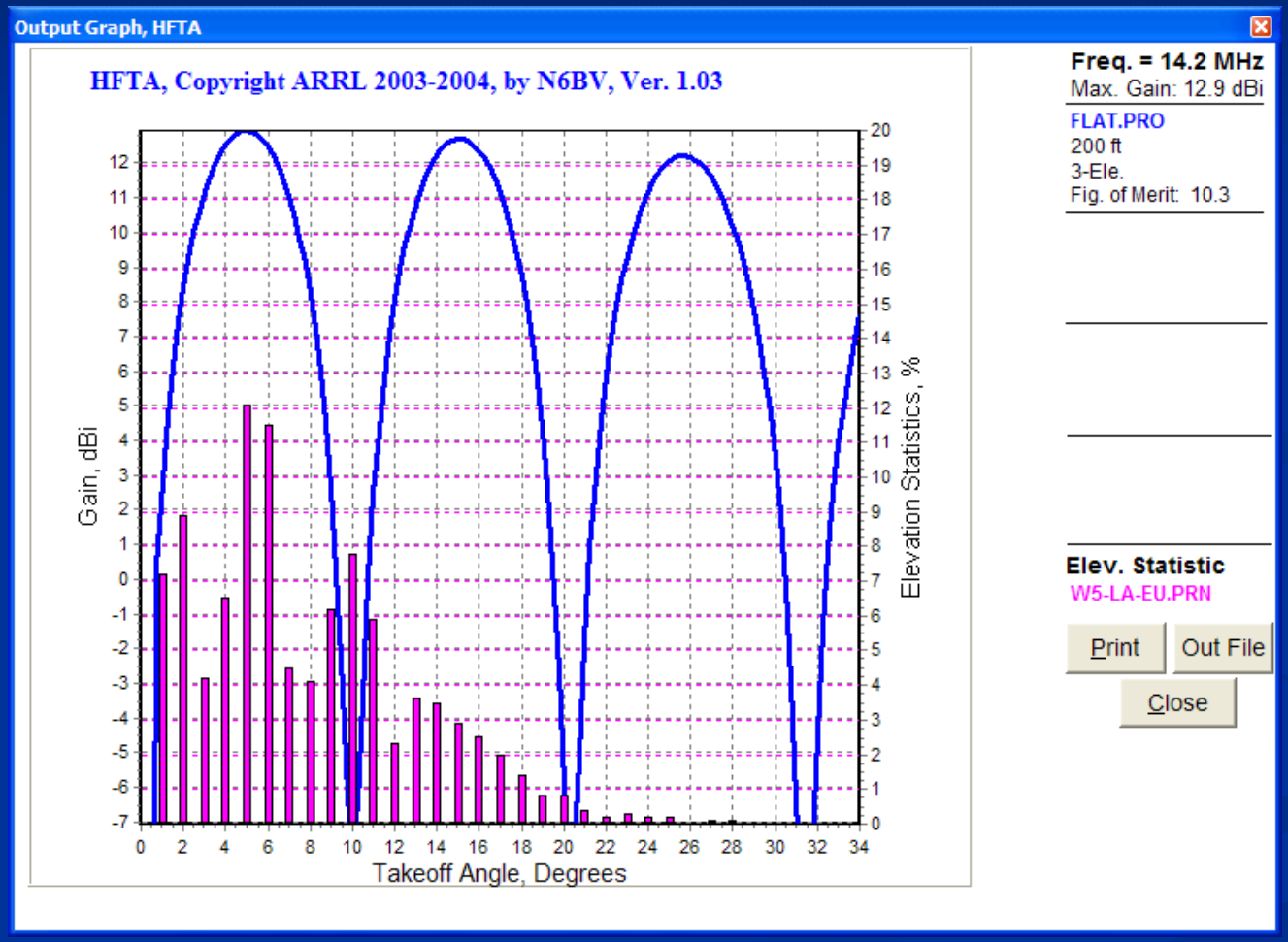
Elevation Angles

- About fifteen years ago N6BV started a detailed study at ARRL HQ on the range of elevation angles needed for communication between various QTHs around the world
- The elevation-angle files from *The ARRL Antenna Book* contain statistical averages over the entire 11-year solar cycle -- for all months of the year and for all hours of the day.

Higher is Better, Right?

- Consider a single 3-element Yagi for 20 meters
- Put it at 200 feet toward Europe
- Should be a killer antenna, right?

One Picture is Worth a Thousand Tables!

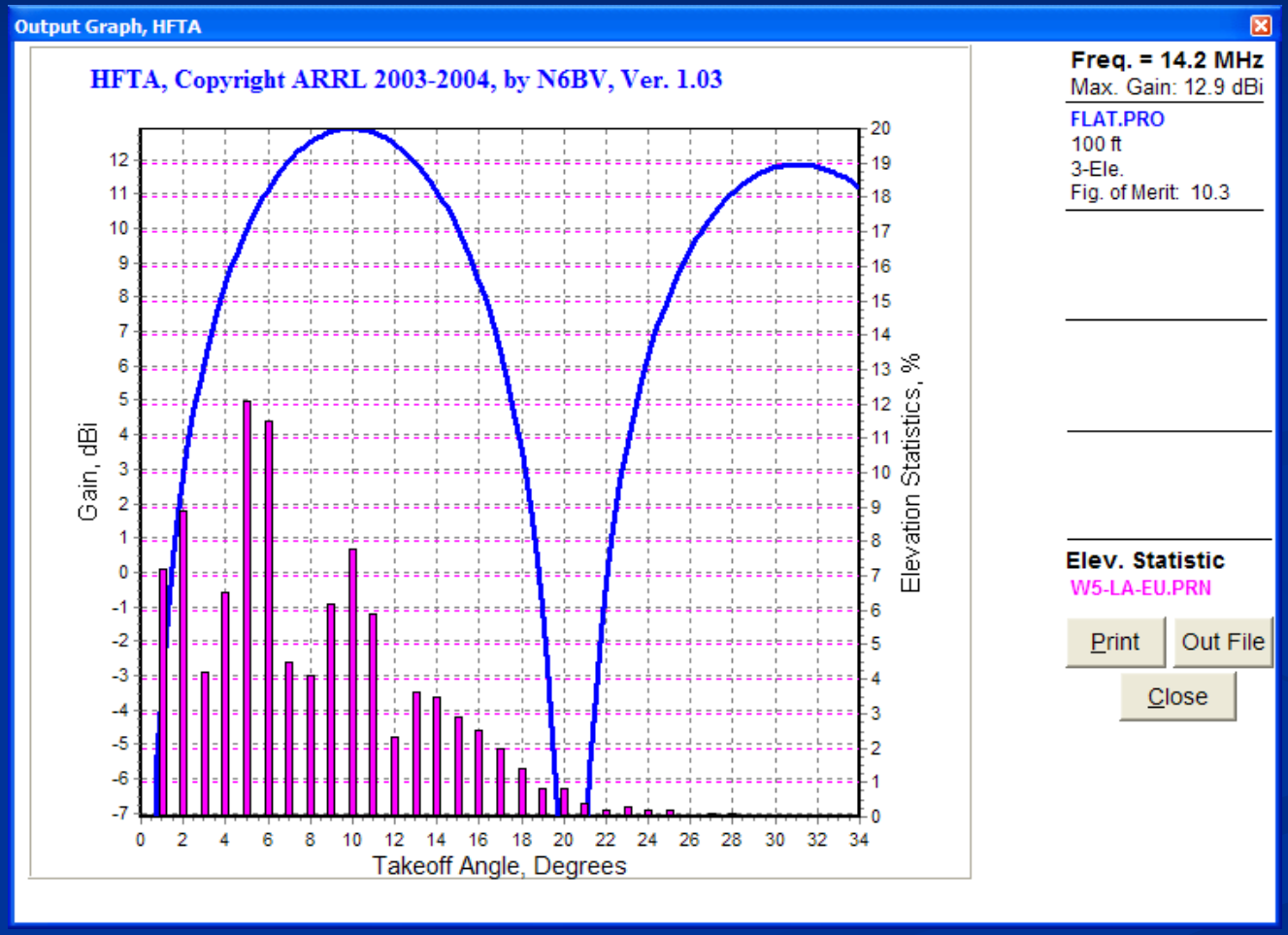


The gain is nice, but the null is a disaster.

Clearly, 200 feet is too high for Europe on 20 meters from Louisiana.

(Over theoretical FLAT ground)

Lower Anyone?

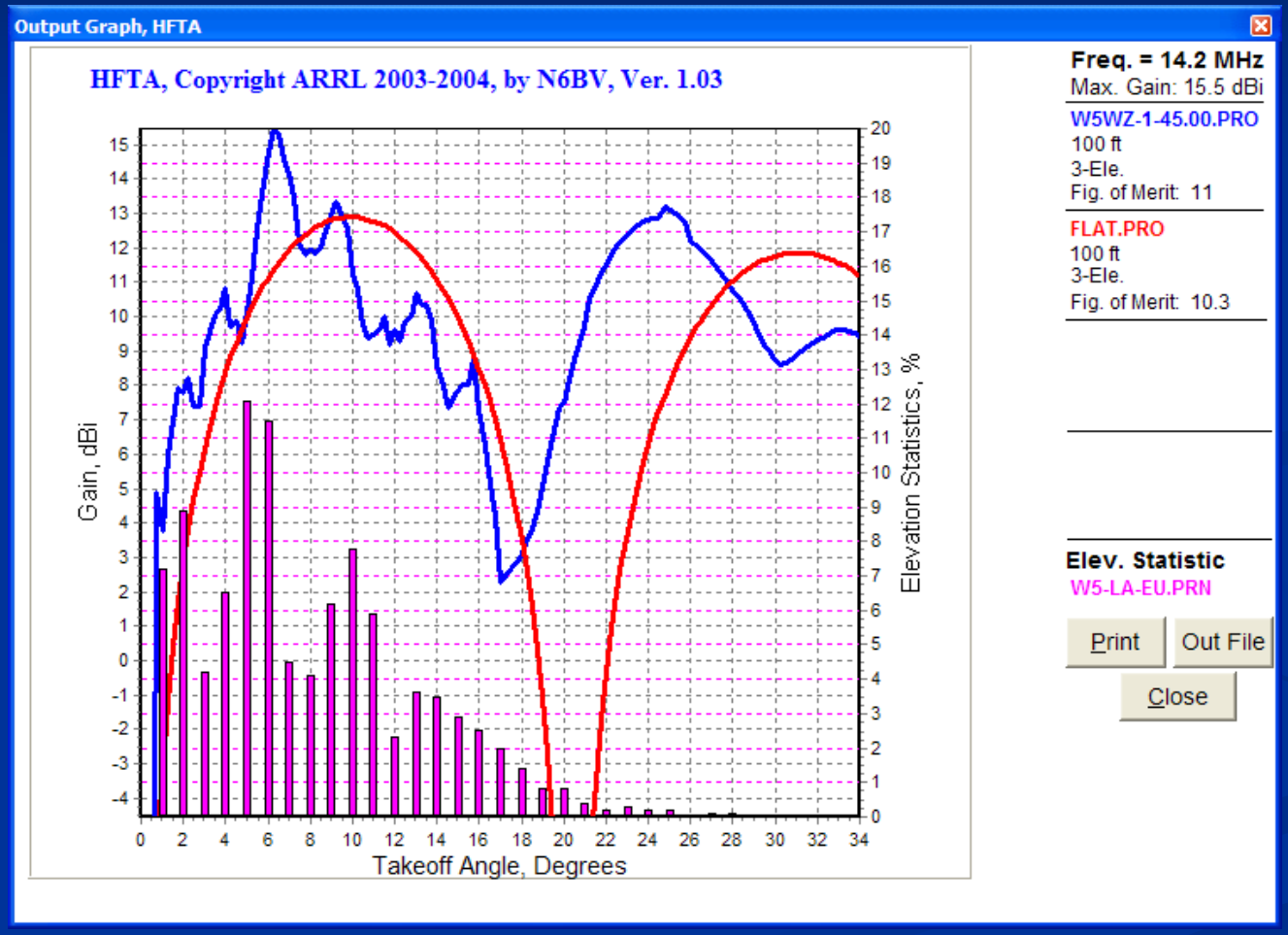


The same antenna, only this time at 100 feet

Notice the null still exists, but now is moved to an elevation angle with lower occurrence in the solar cycle.

(Over theoretical FLAT ground)

The Real World, Over Ground

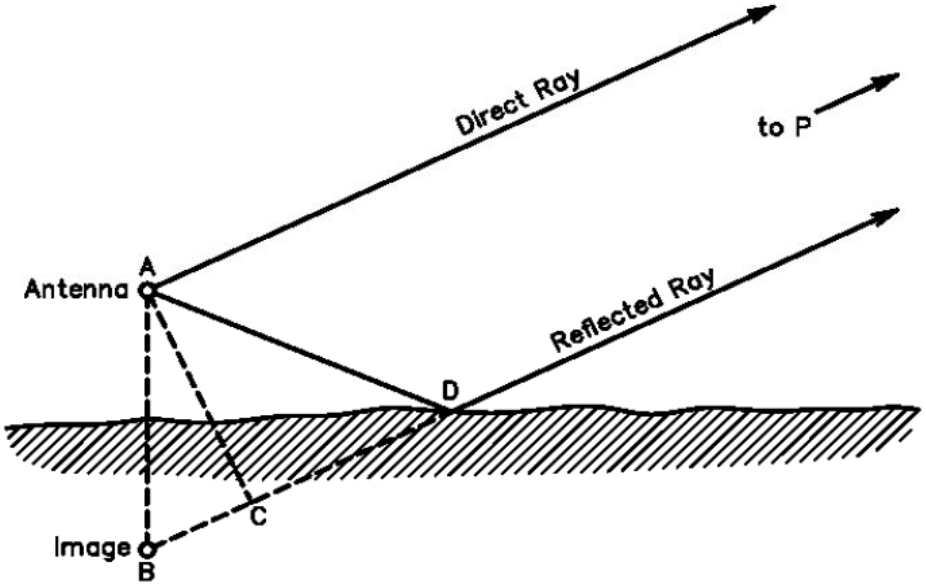


The same antenna, only this time at 100 feet over real terrain at W5WZ

Notice the null still exists, but now is less deep, due to the effect of actual terrain.

Also note the effect on peak gain by terrain.

Gain Over Ground



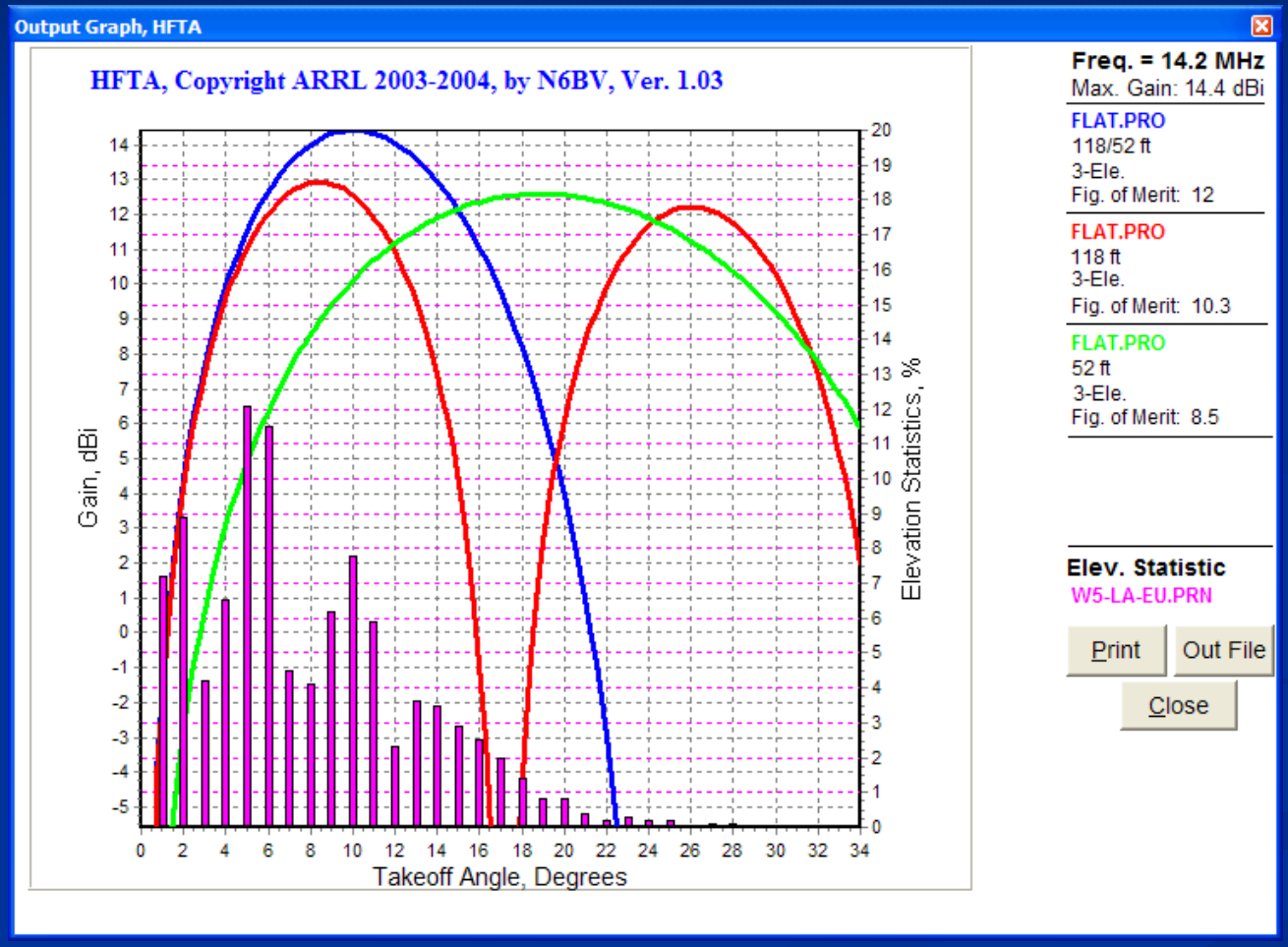
Reflections, using theory of images.

The presence of ground *profoundly* modifies the elevation pattern of any antenna compared to free space, because of vector addition of the reflected and direct rays, which travel different paths.

Really, Why Do We Stack Yagis?

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

20 meters, W5WZ to Europe (over flat ground)



Notice that all the angles are covered.

The stack at 118'/52' has the highest gain, but misses the highest elevation angles.

The 52' Yagi will cover the high angles missed by the stack.

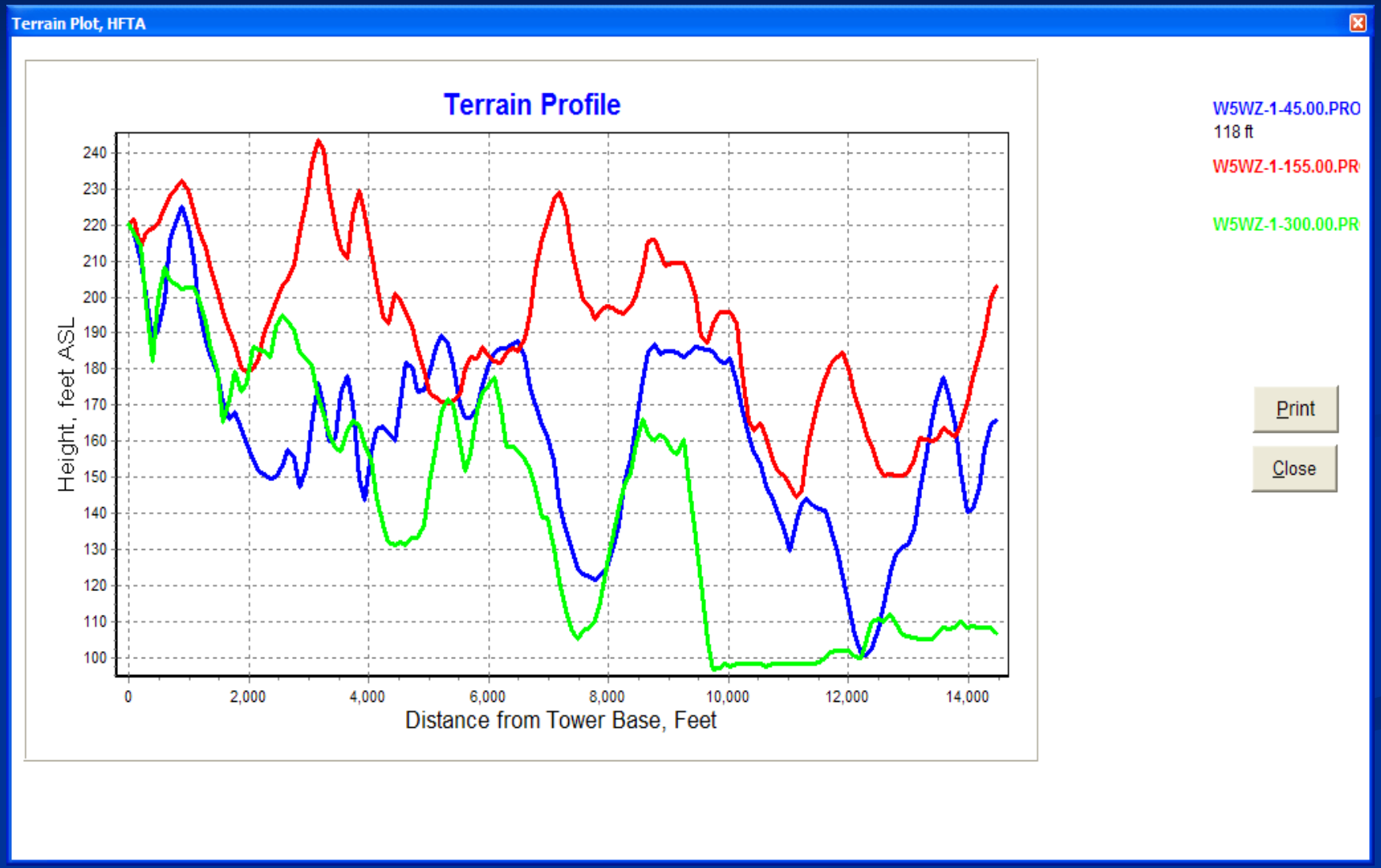
In this case, the stack clearly outperforms the top antenna alone.

However, the real world NEVER has flat ground!

Wider Elevation-Angle Coverage

- You can see that higher stacks 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. We'll look at this more later.
- By the way, a side-by-side stack will narrow down the azimuth coverage to get gain.

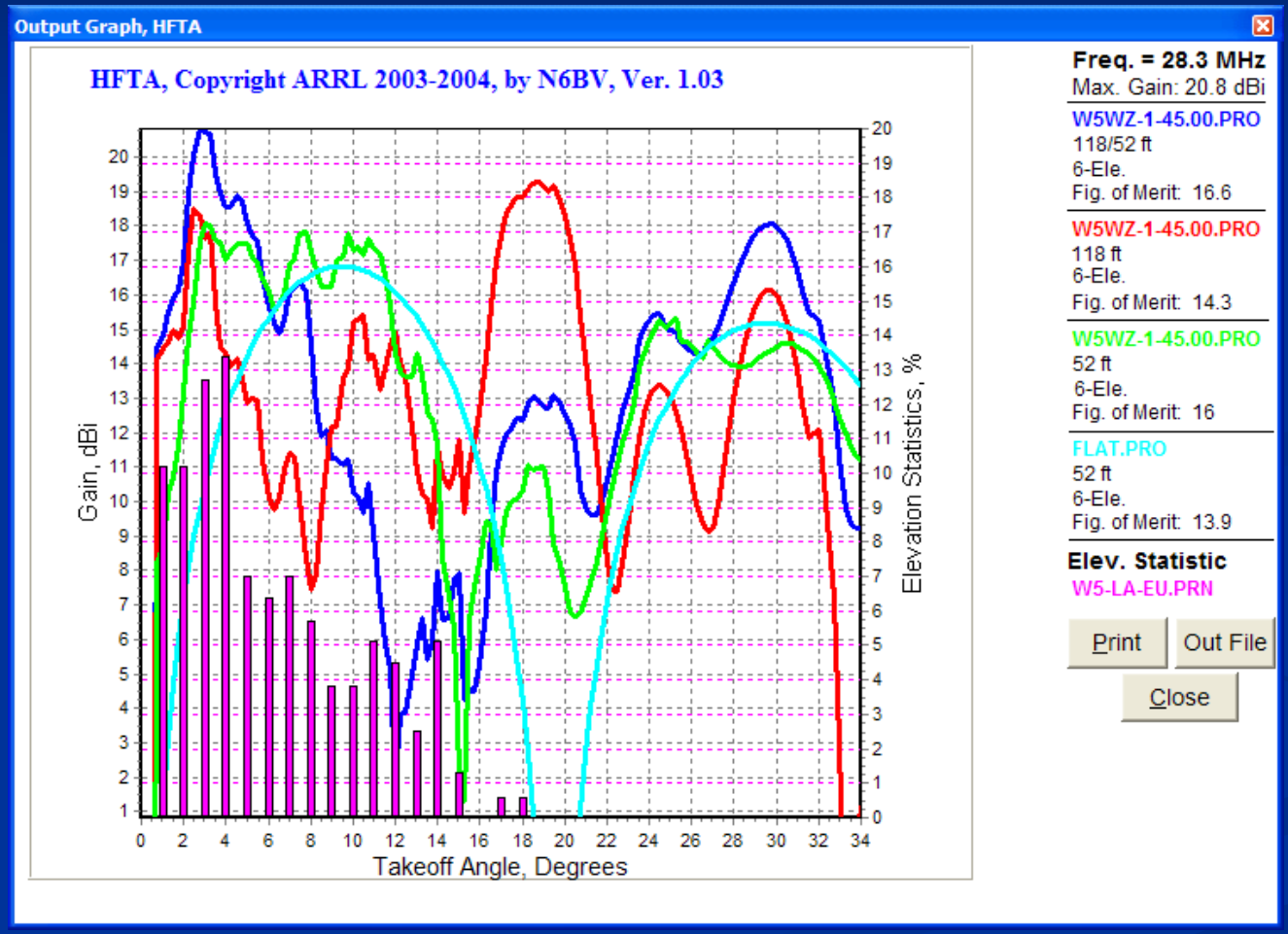
W5WZ Local Terrain, an Example



W5WZ Design Parameters

- Use the antenna on hand
  - Two Force 12 C-51XR (10, 15, 20, 40)
  - One Force 12 C-31XR (10, 15, 20)
- Feed each band separately and use a StackMatch on every band
- Recognize that stack spacing using multi-band antenna is a compromise across bands and heights; design to achieve best range of results to Europe, Japan, and S. America on all 4 bands
- Use a single tower (Rohn 55G, 116')
  - Rotate the top C-51 at 118'
  - Side mount the C-31 to Japan at 85'
  - Side mount the low C-51 to Europe at 52'

10 meters, W5WZ to Europe



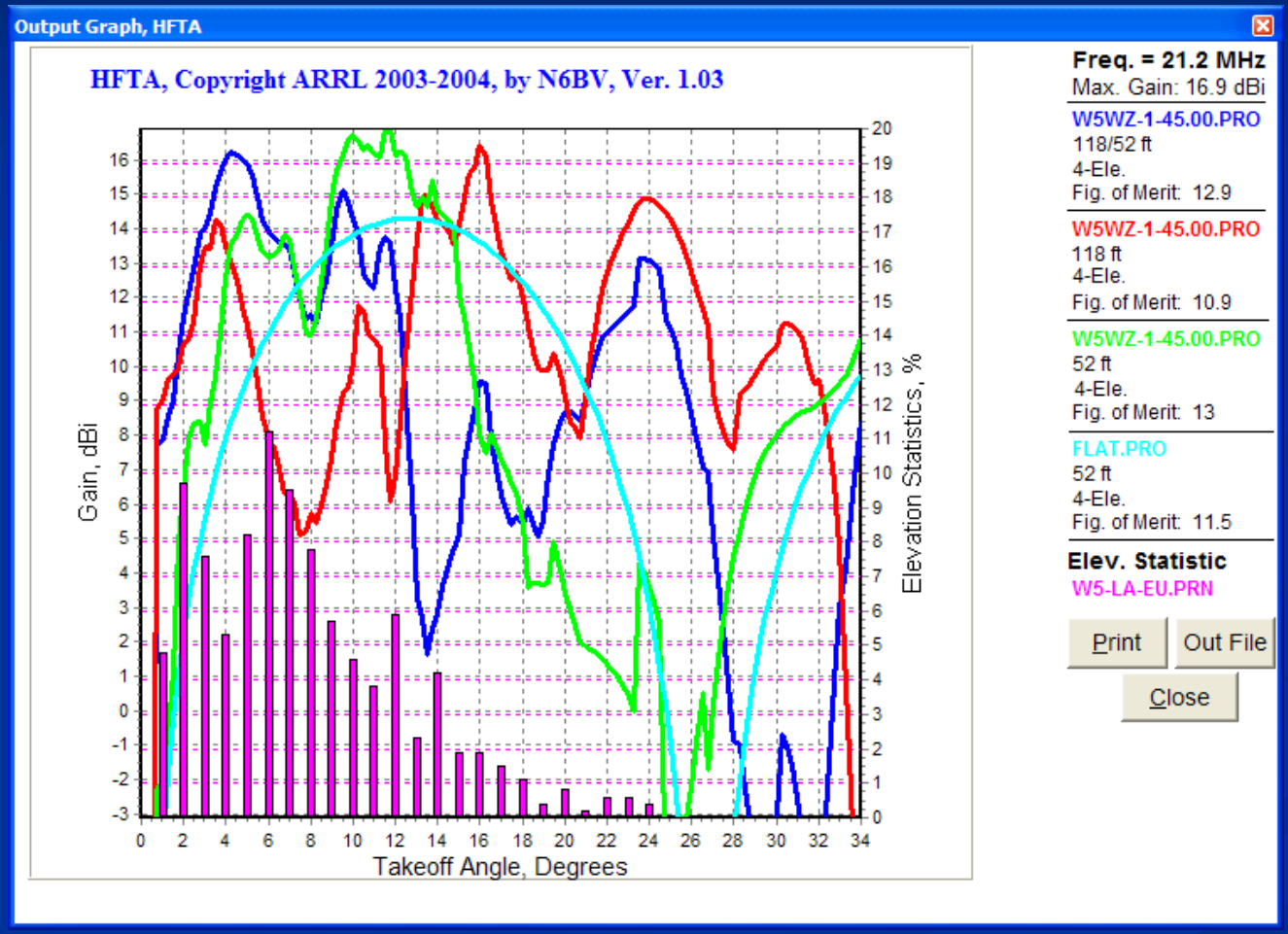
The stack provides better coverage of the low angles.

The 118' gives the highest gain of the high angles.

Between 6 & 14 degrees, the low antenna will perform best.

Notice the low antenna performance over flat ground

15 meters, W5WZ to Europe



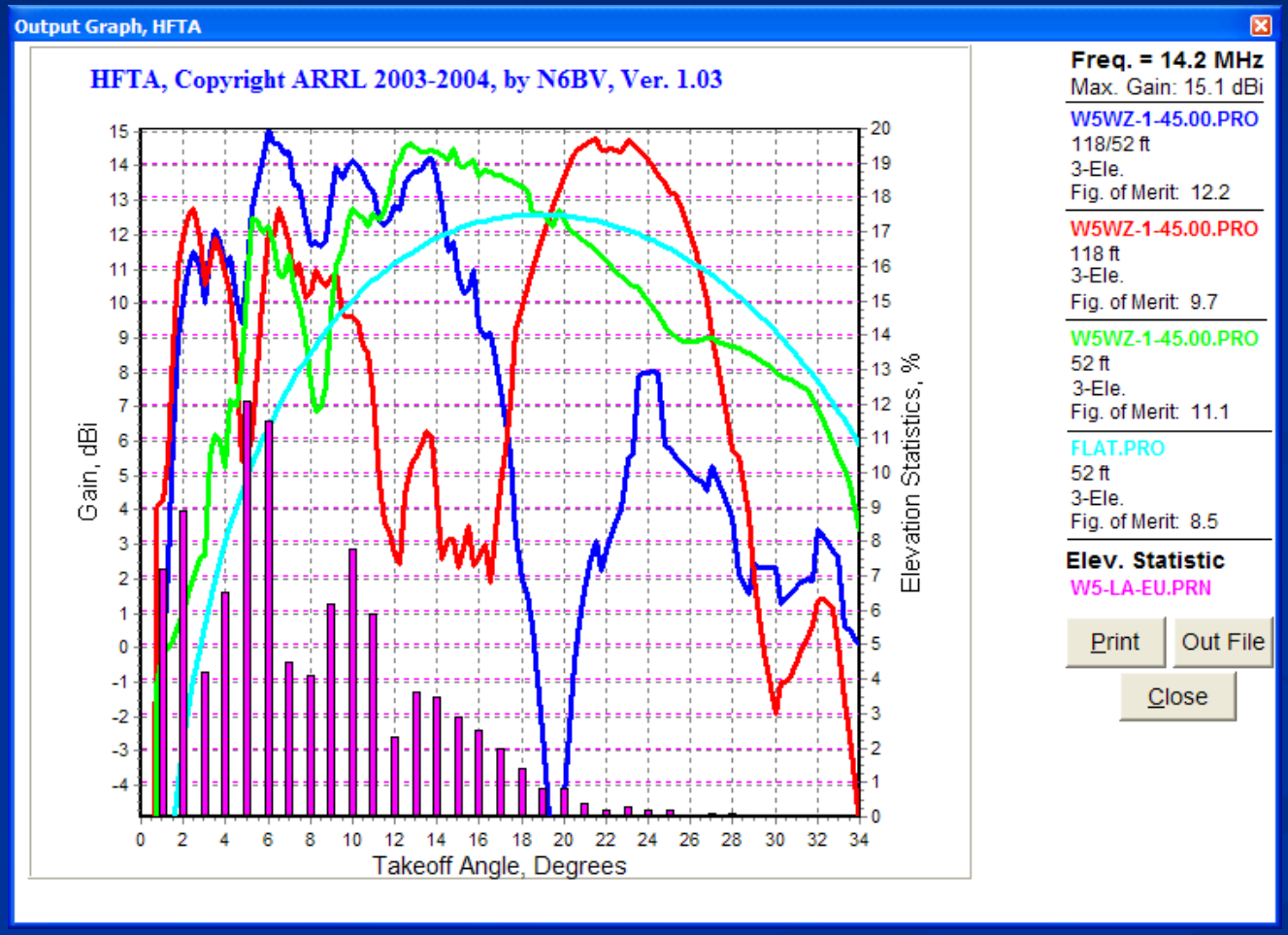
The stack again performs best at low angles.

However, from 6 to 15 degrees, the low antenna shines.

At angles higher than 15 degrees, the high antenna shines.

Again, note the performance of a single lower antenna over flat ground

20 meters, W5WZ to Europe



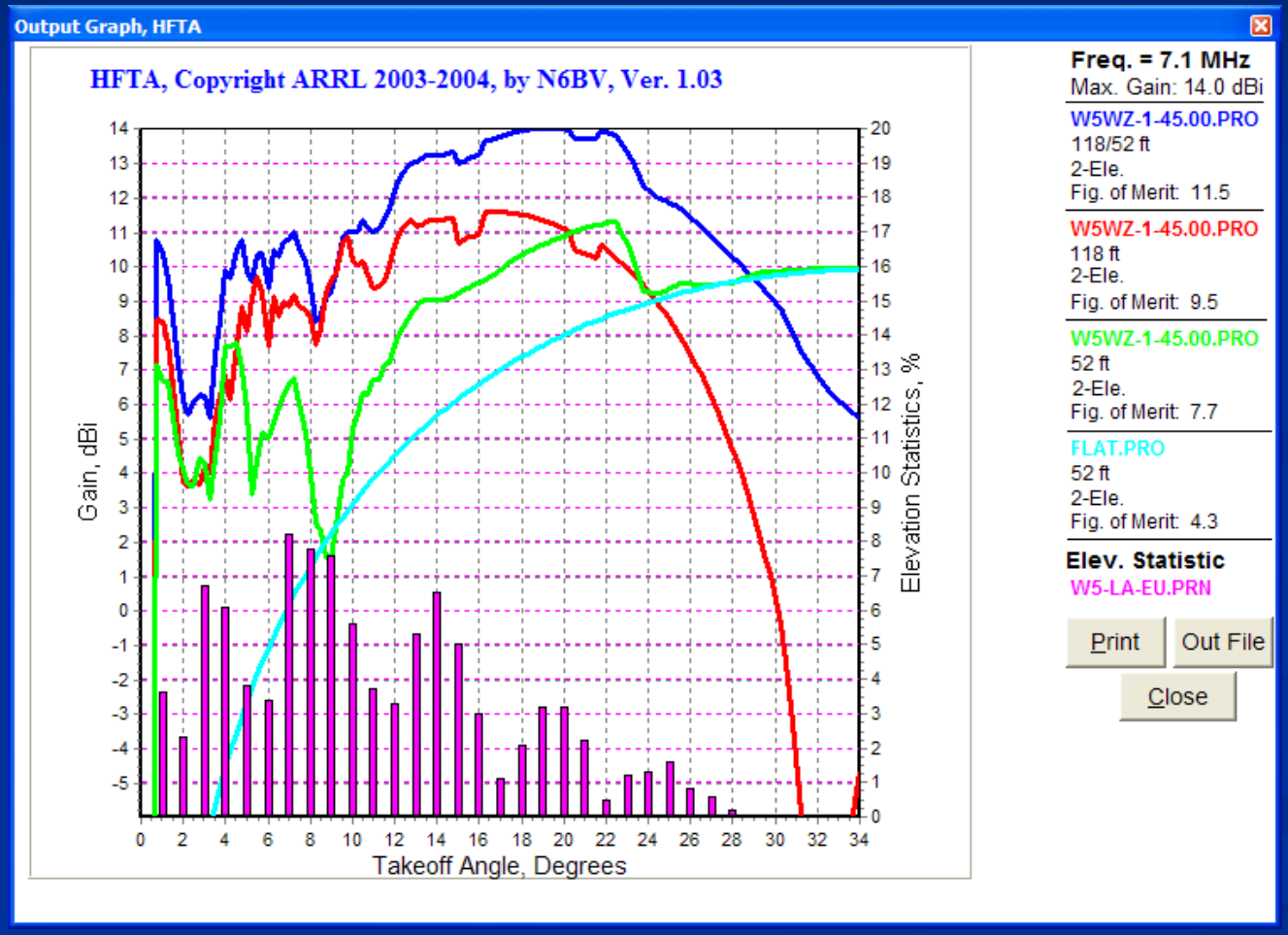
The stack again performs best at low angles.

However, from 12 to 19 degrees, the low antenna shines.

At angles higher than 19 degrees, the high antenna shines.

Again, note the performance of a single lower antenna over flat ground

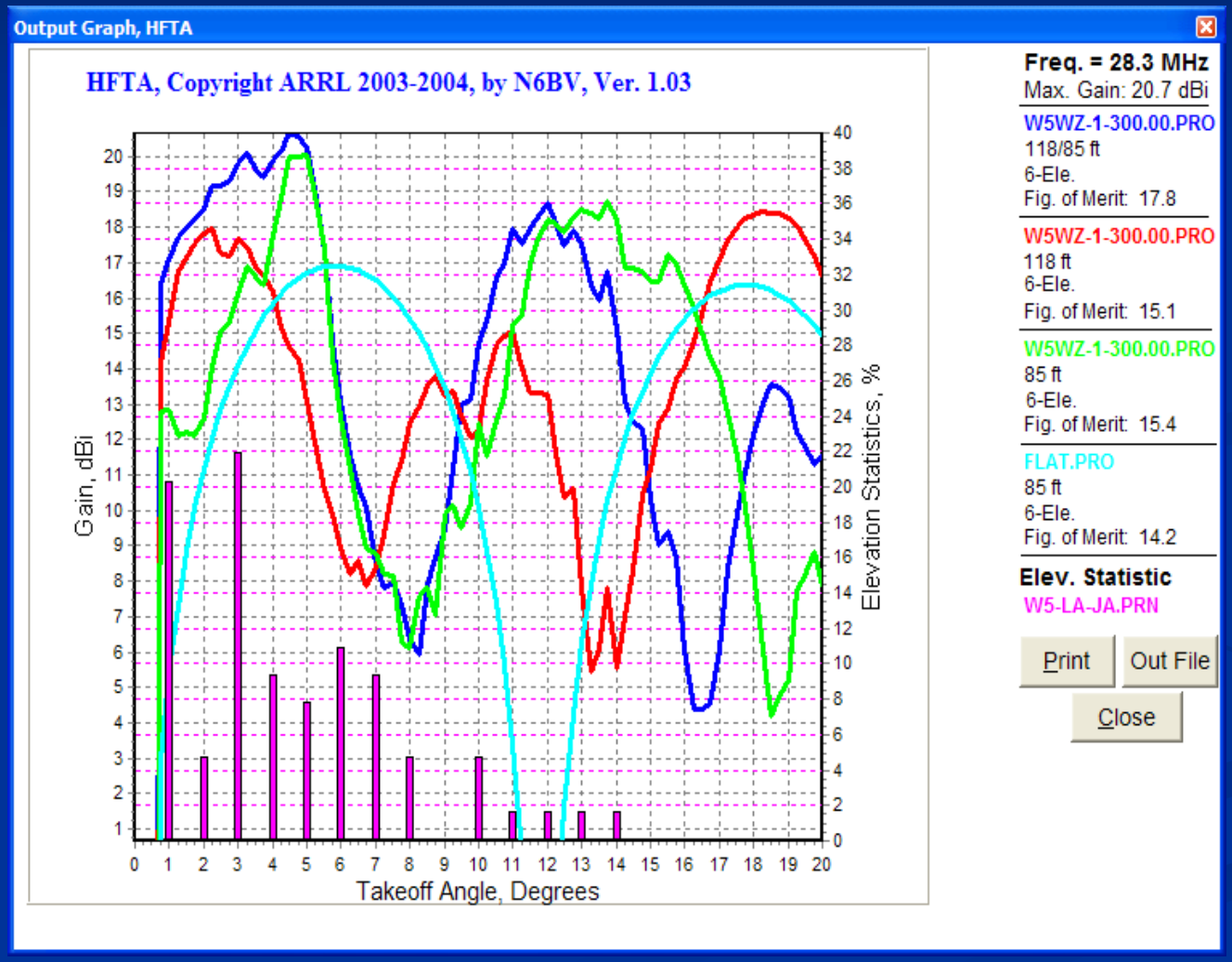
40 meters, W5WZ to Europe



Here, the stack is hands the winner for all angles.

Note the performance of the low antenna over flat ground

10 meters, W5WZ to Japan



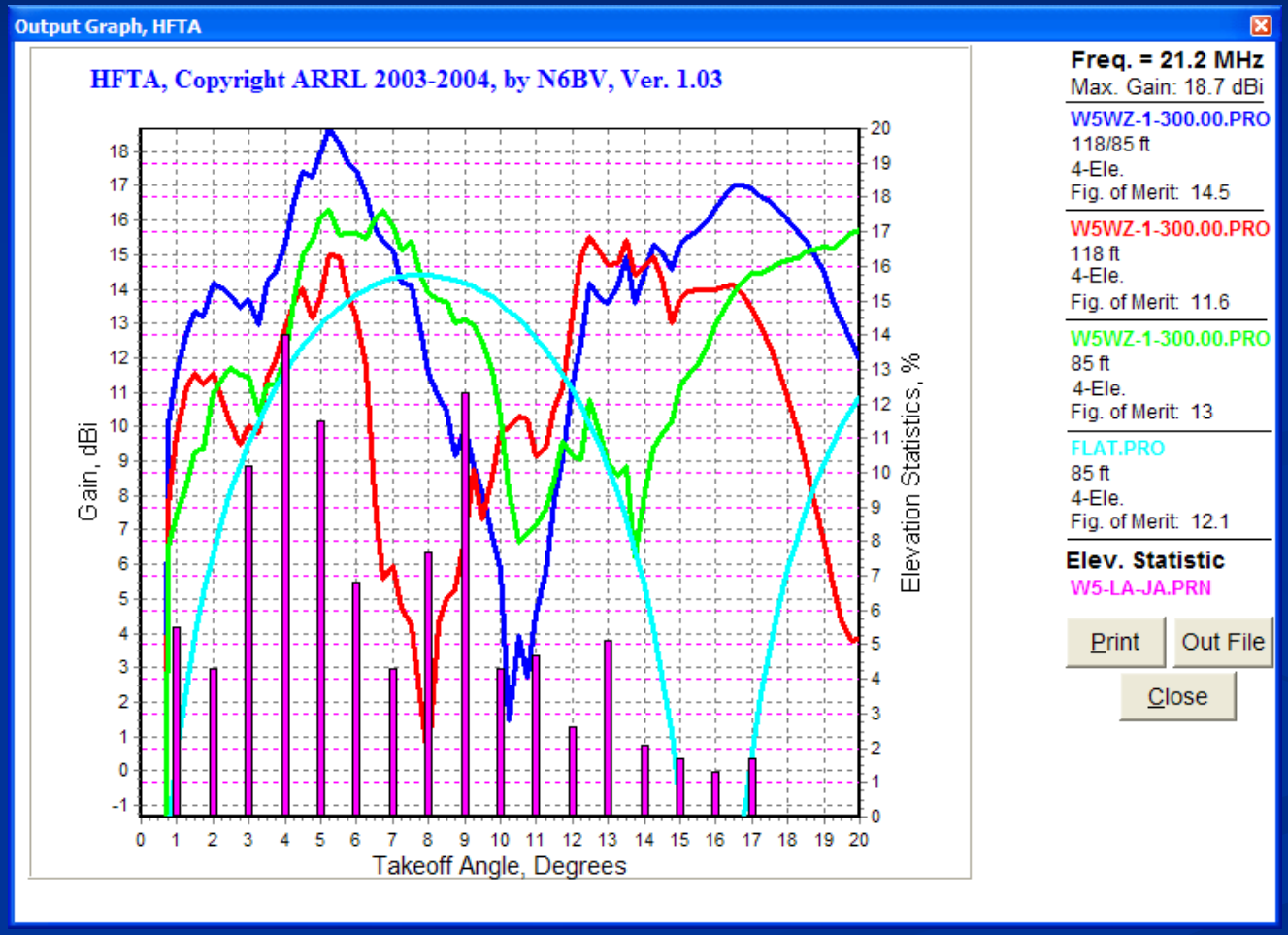
Angles from Japan are low!

Any of the antenna combinations cover all the angles, this time the stack provides max gain.

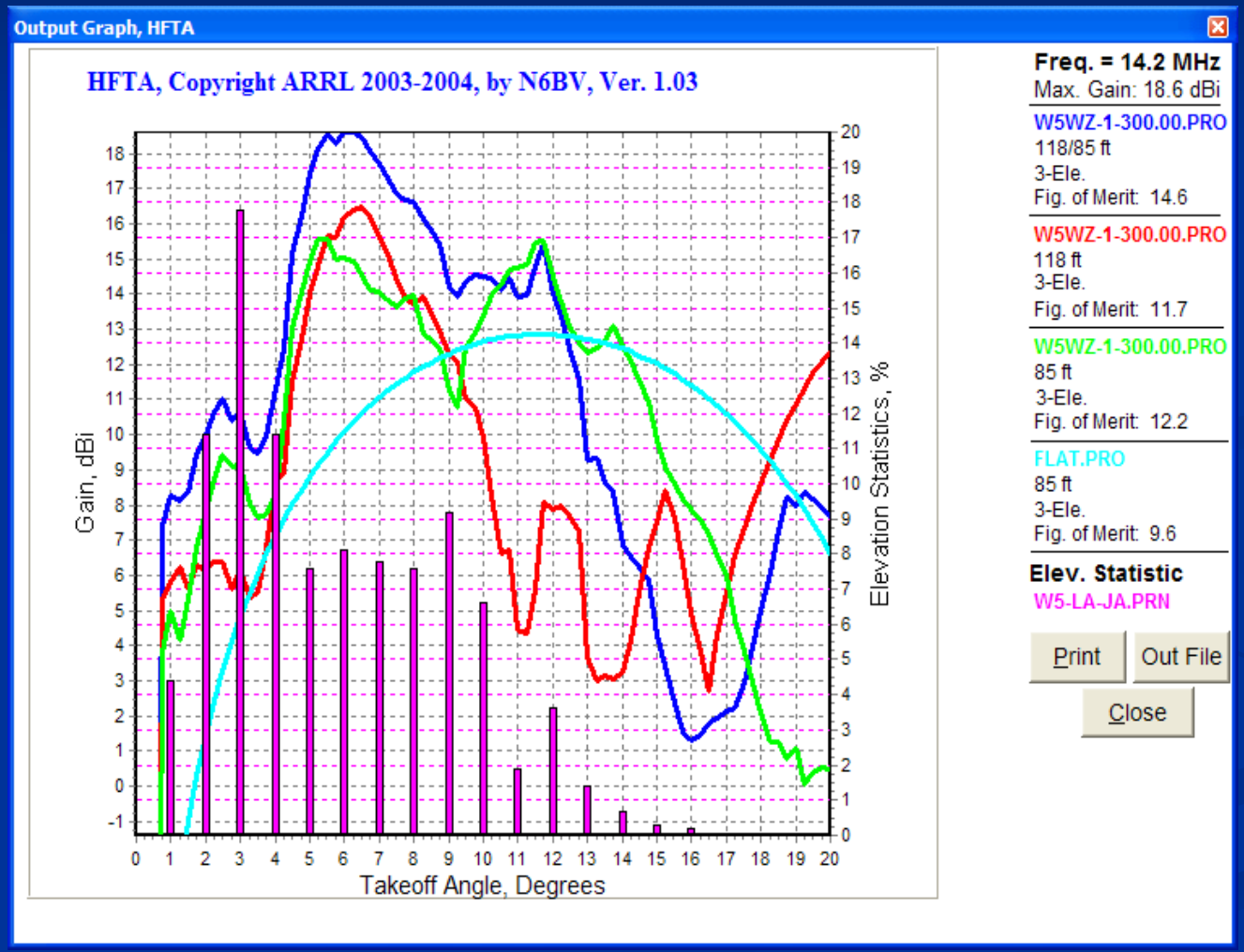
The null is cause by stack height and terrain effects.

Note the single low antenna performance over flat ground

15 meters, W5WZ to Japan



20 meters, W5WZ to Japan



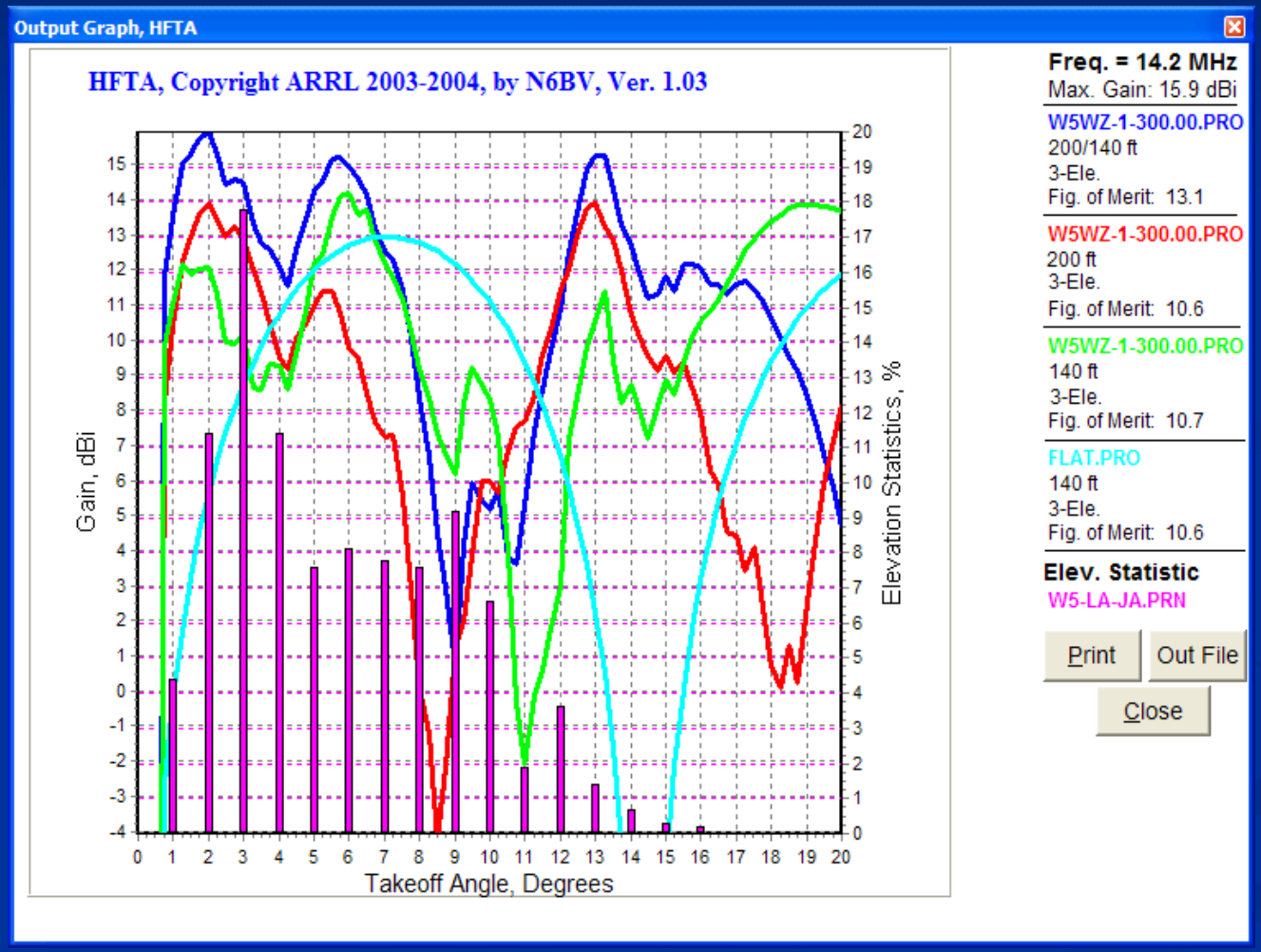
The stack shines on low angles to 12 degrees

Above 12 degrees, the low antenna performs better.

To cover angles lower than 4 degrees with 12+ dBi gain, the stack needs to be at 200'/140'

Here's a clear example of my intentional compromise

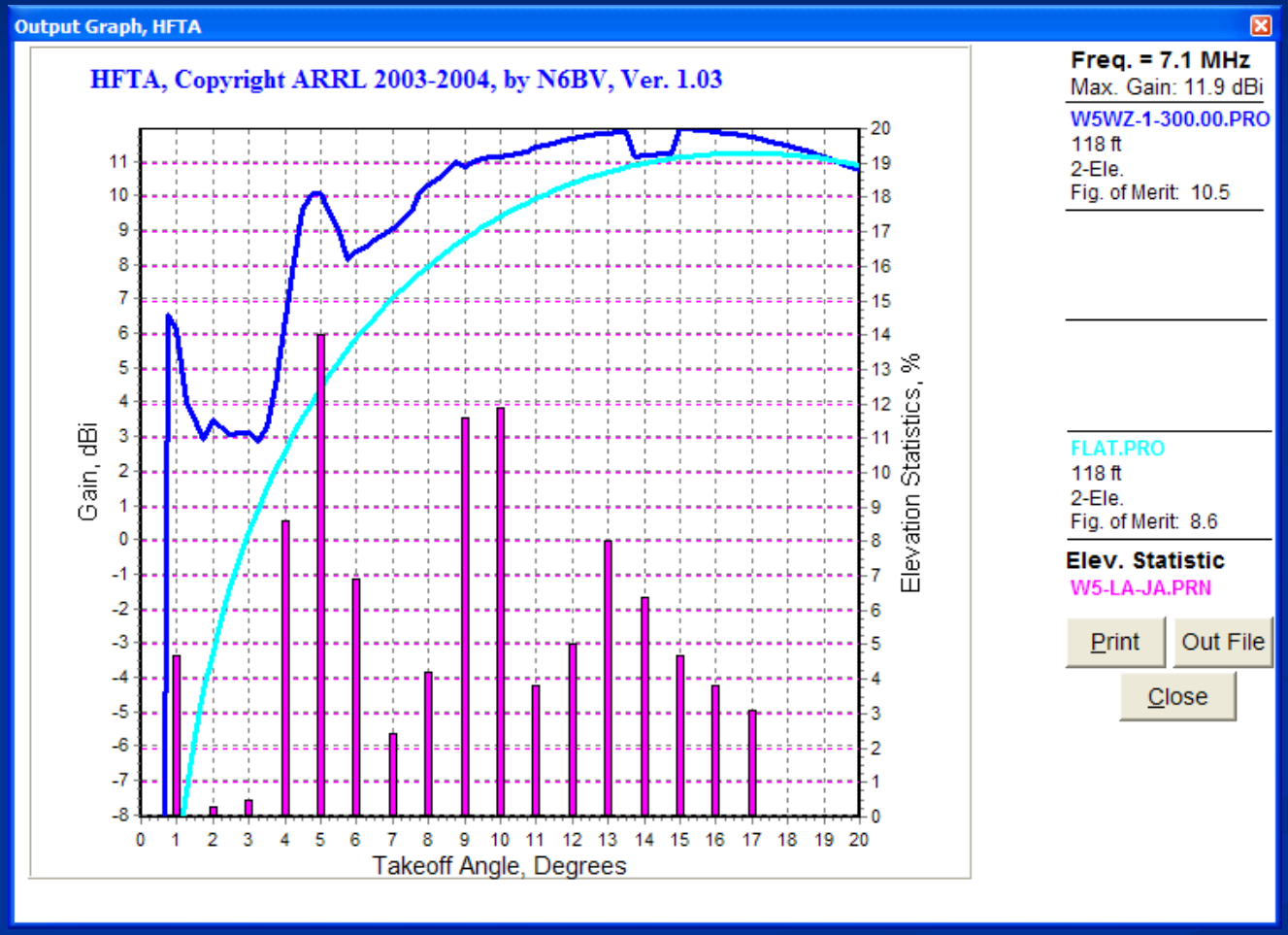
20 meters, W5WZ optimal to Japan



I was not willing to build a 200' foot tower.

Compromise of budget, safety in my back yard, and asthetics.

40 meters, W5WZ to Japan



Only the top antenna has 40m available to Japan

A single 2-element Yagi at 118' will cover all the angles on 40m.

The effect of my terrain is very obvious versus the flat ground graph.

Notice the gain enhancement versus flat ground.

Putting It All Together

- You need to know the range of elevation angles for full coverage to your target destinations.
- You should know how your antennas work under ideal conditions (free space, or flat ground).
- Then, you can analyze the effects of irregular local terrain and optimize heights, stacks or tower placement on your property.

Best Resources

- *The ARRL Antenna Book* – Get the most current edition, and use the software on the CD.
  - HFTA
  - MicroDEM
  - W6EL-PROP
  - EZ-NEC