Propagation and Antenna Selection for Contesting

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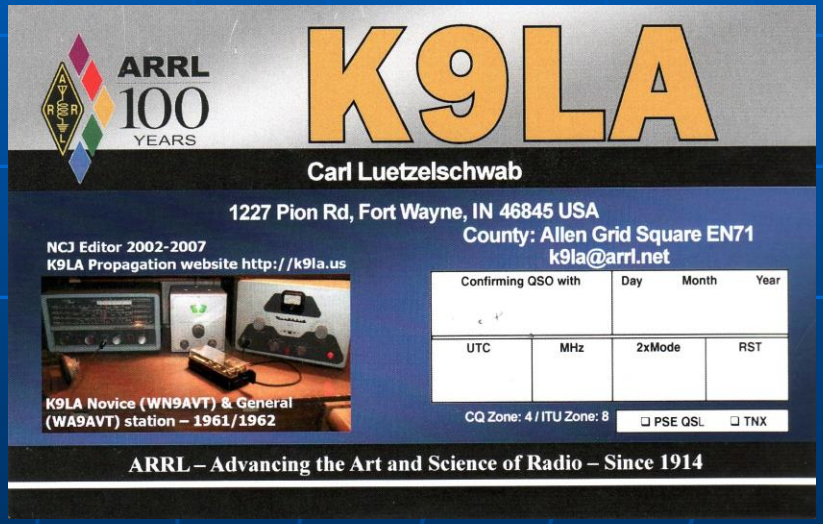
The title of this presentation is a very broad subject. We will focus on one specific issue - the required elevation angles – a parameter that's often ignored. Addressing this issue usually leads to stacking Yagis. We'll see why stacking is needed, the advantages and a real-life example.

Who Is K9LA?

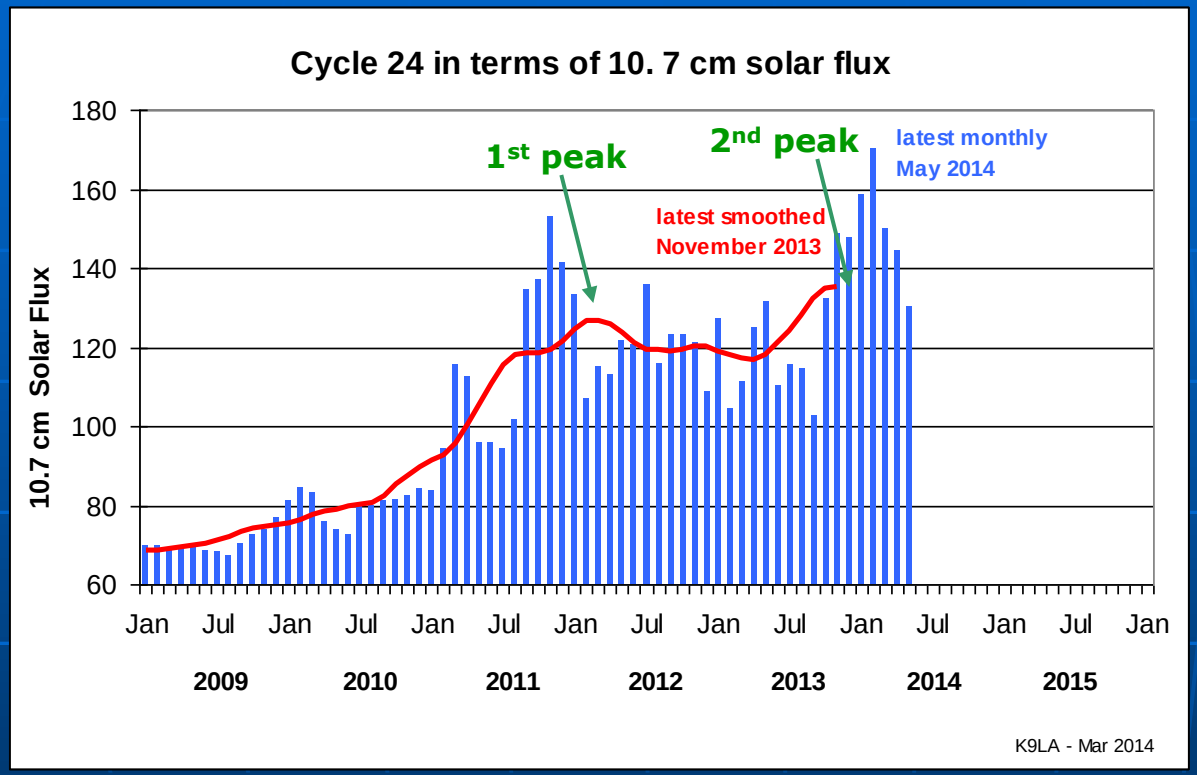
- Licensed in October 1961 as WN9AVT
- Selected K9LA in 1977
- Enjoy contesting, DXing, propagation, antennas and vintage equipment
- NCJ Editor 2002-2007
- Top of the Honor Roll
- Recently retired RF design engineer
  - Designed solid-state power amplifiers for Motorola and Raytheon (formerly Magnavox)



Topics

- Quick update on Solar Cycle 24
- My first contest antenna and its limitations
- My first Yagi and its limitations
- Elevation angles
- Stacking
- ZF2AH

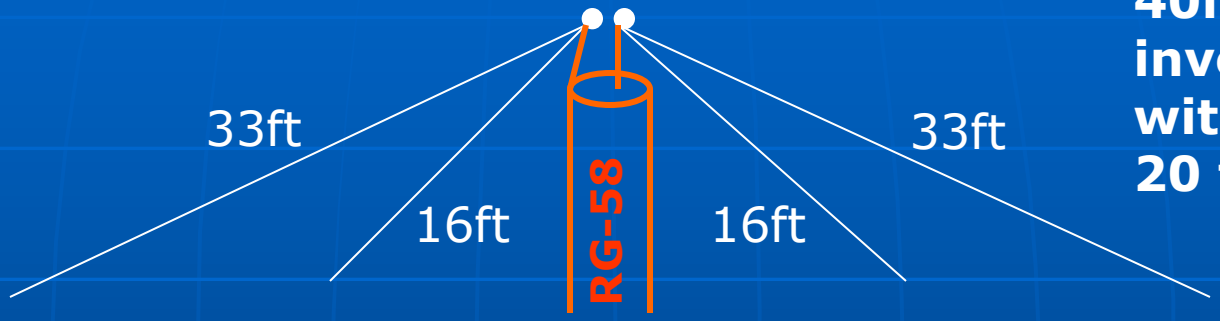
Solar Cycle 24 Update



Here's a fact if you're ever on Jeopardy – the time period between peaks is called the Gnevyshev gap

- First peak in early 2011
- Second peak (even better) likely in Dec 2013 or early 2014
- Second peak will continue good propagation on the higher bands (15m and 10m) for the fall and winter contests

My First Contest Antenna



40m/20m inverted-vee with apex at 20 feet

- Covered a DX band and a domestic band
- Simple and pretty much maintenance free
- Pretty much omni-directional
- Gradually realized I needed to be more competitive in the antenna arena
  - Inverted-vee does not have gain nor rejection like a Yagi

My First Yagi

- When I transferred with Motorola to Ft Worth in 1979, I put up Rohn 25 tower with a Cushcraft A3
- No consideration for elevation angle coverage
  - Tower height (40 ft) was what the city of Bedford allowed on our lot
- Subsequently, the book "Yagi Antenna Design" made me aware of the importance of elevation angles

“Yagi Antenna Design”

- Authored by Dr. James L. Lawson, W2PV
- Series of articles in *Ham Radio* in early 1980
- Book published by the ARRL in 1986
- This book started the antenna modeling effort
- Chapter 5: Effects of Ground
  - “Distances beyond 1600 km via the F2 region are covered by elevation angles from 3 to 17 degrees”
    - W2PV was a big M/M - focused on DX contesting

“All the Right Angles”

- The next step after W2PV was using IONCAP to better define the elevation angles needed
- Authored by Dean Straw, N6BV in 1993
- Purpose was to perform “a detailed study of optimum elevation angles for HF propagation throughout the world”
- Data has been updated over the years
- Latest data is on the ARRL Antenna Book CD (22nd Edition)

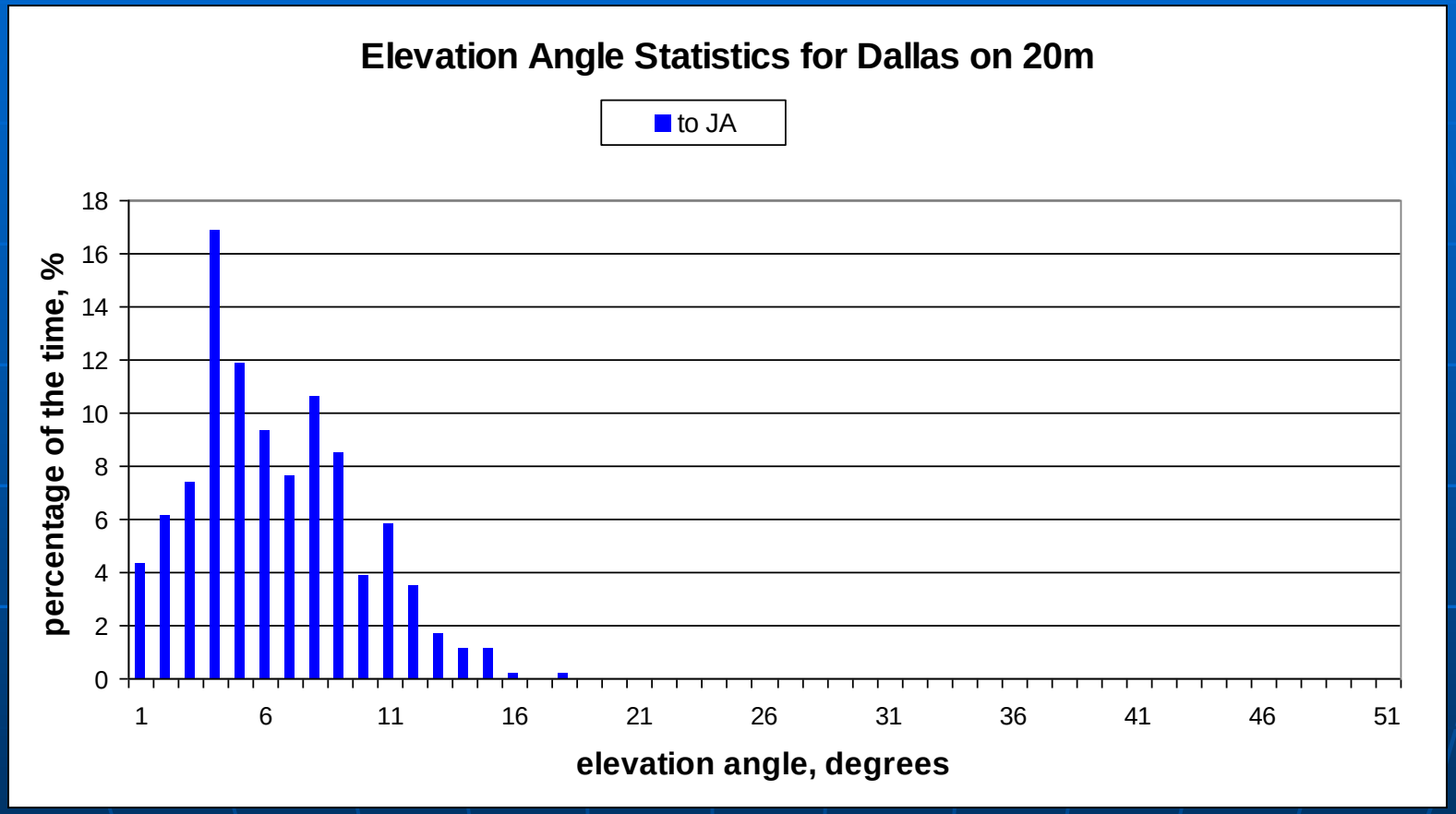
Sample Elevation Angle File

Dallas, Tx to Far East

Elev	80m	40m	30m	20m	17m	15m	12m	10m
1	10.2	18.1	12.4	4.3	9.4	13.3	18.7	12.9
2	3.7	6.5	24.2	6.1	4.3	3.0	7.1	15.3
3	1.0	1.0	9.8	7.4	5.9	8.0	7.7	5.9
4	2.0	0.2	3.0	16.9	9.7	10.2	8.4	15.3
5	7.7	4.4	1.7	11.9	14.0	11.0	11.6	10.6
6	7.2	13.3	3.8	9.3	6.5	11.0	11.6	9.4
7	5.0	8.1	14.7	7.6	7.5	5.7	10.3	5.9
8	3.7	2.5	8.5	10.6	8.1	4.5	7.1	7.1
9	8.5	2.1	4.3	8.5	9.9	7.2	5.2	2.4
10	6.0	10.0	2.1	3.9	6.5	8.7	1.3	7.1
11	6.7	8.5	4.1	5.8	3.8	4.5	1.9	0.0
12	7.0	4.7	4.3	3.5	4.0	2.7	3.9	5.9
13	6.5	3.5	3.2	1.7	4.3	3.0	1.9	1.2
14	6.2	5.4	1.3	1.1	3.5	2.3	1.3	1.2
15	9.0	4.1	0.6	1.1	1.3	3.0	1.9	0.0
16	5.2	4.6	1.5	0.2	0.8	1.1	0.0	0.0
17	4.2	3.1	0.6	0.0	0.5	0.8	0.0	0.0
18	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

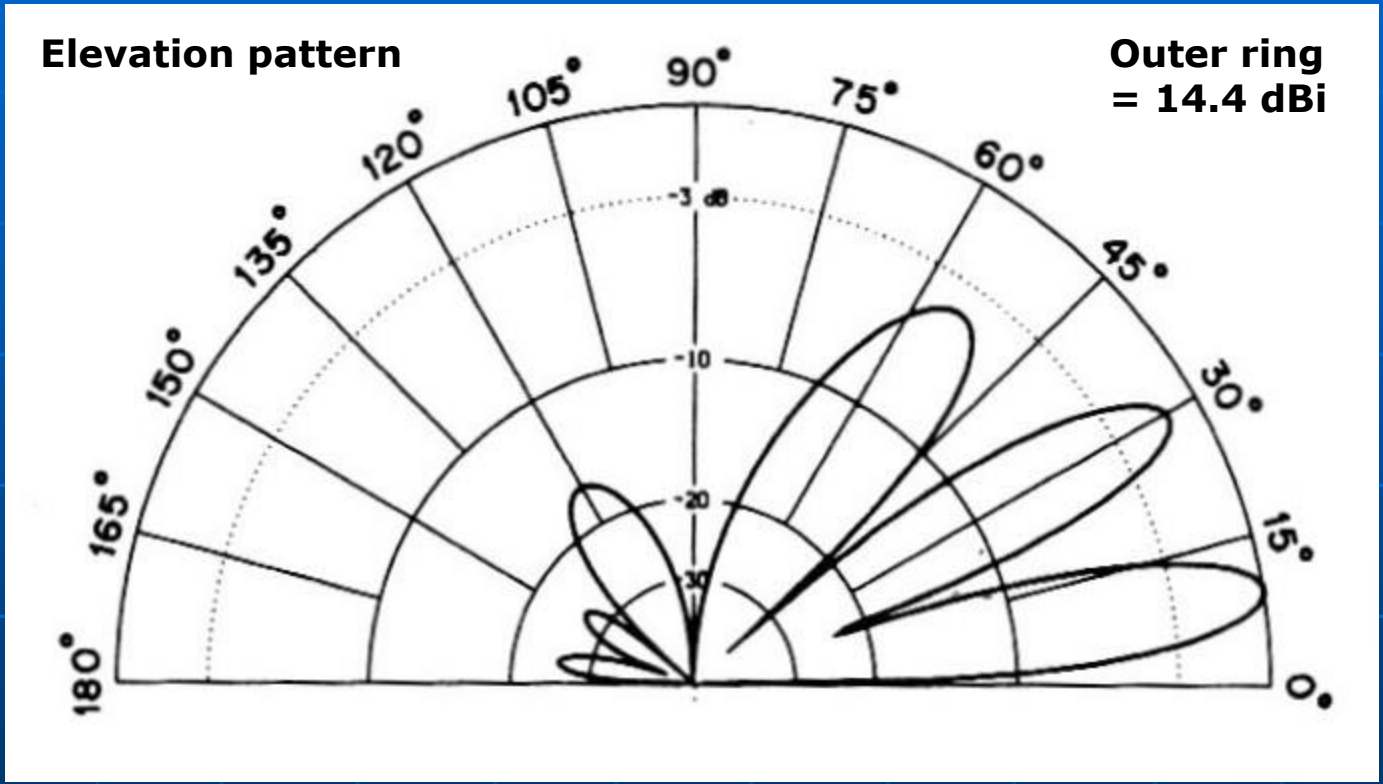
Value is the percentage of the time that the indicated elevation angle occurs

Plot the 20m JA Elevation Data



- Pretty much agrees with W2PV's estimate
- Now let's look at antenna elevation patterns

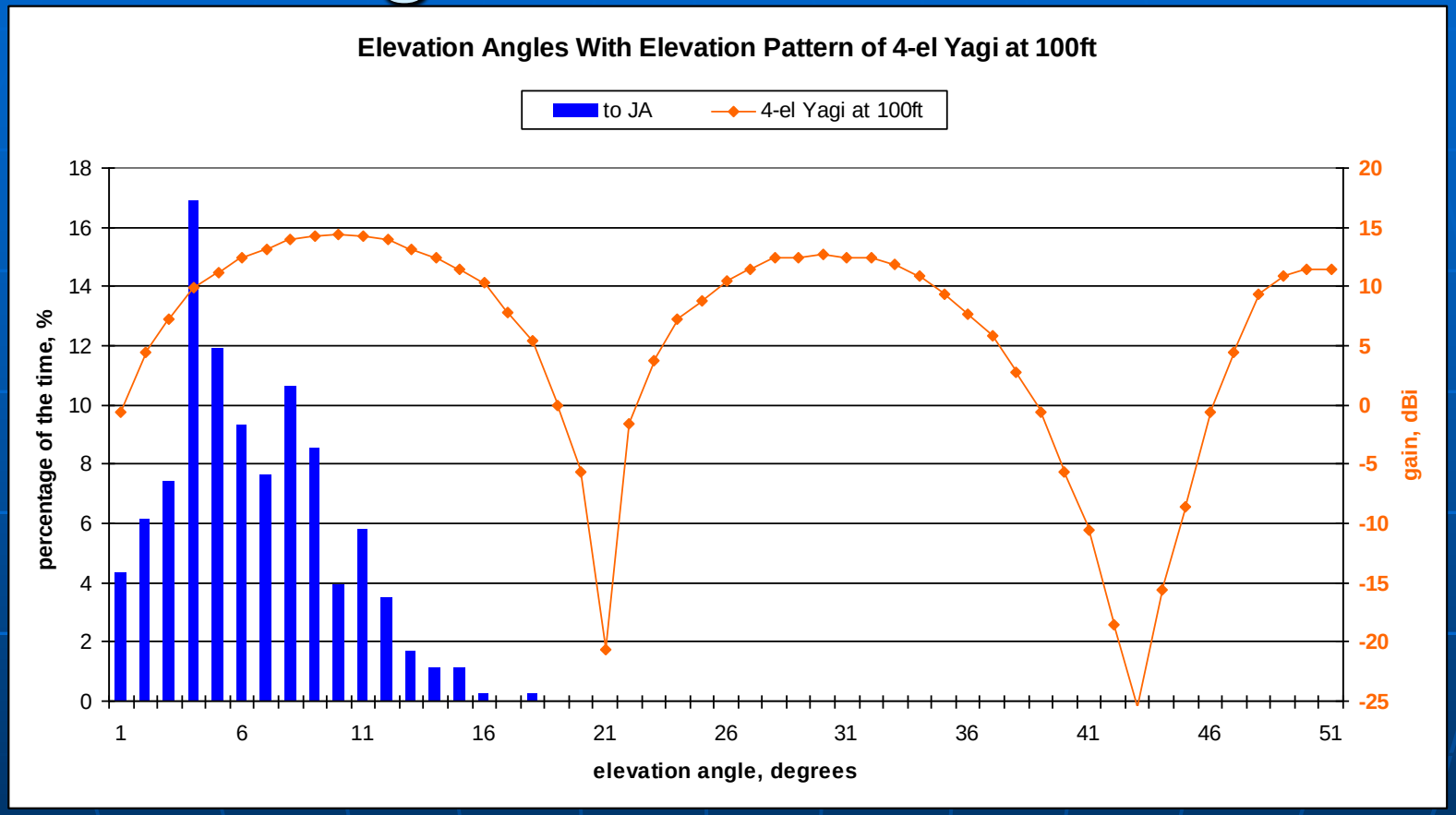
4-el 20m Yagi at 100 ft



- Dipole has 2.1 dB gain over isotropic = 2.1 dBi
- 4-el Yagi has ~6.7 dB gain over dipole = 8.8 dBi
- Ground reflection gain is ~5.6 dB = 14.4 dBi

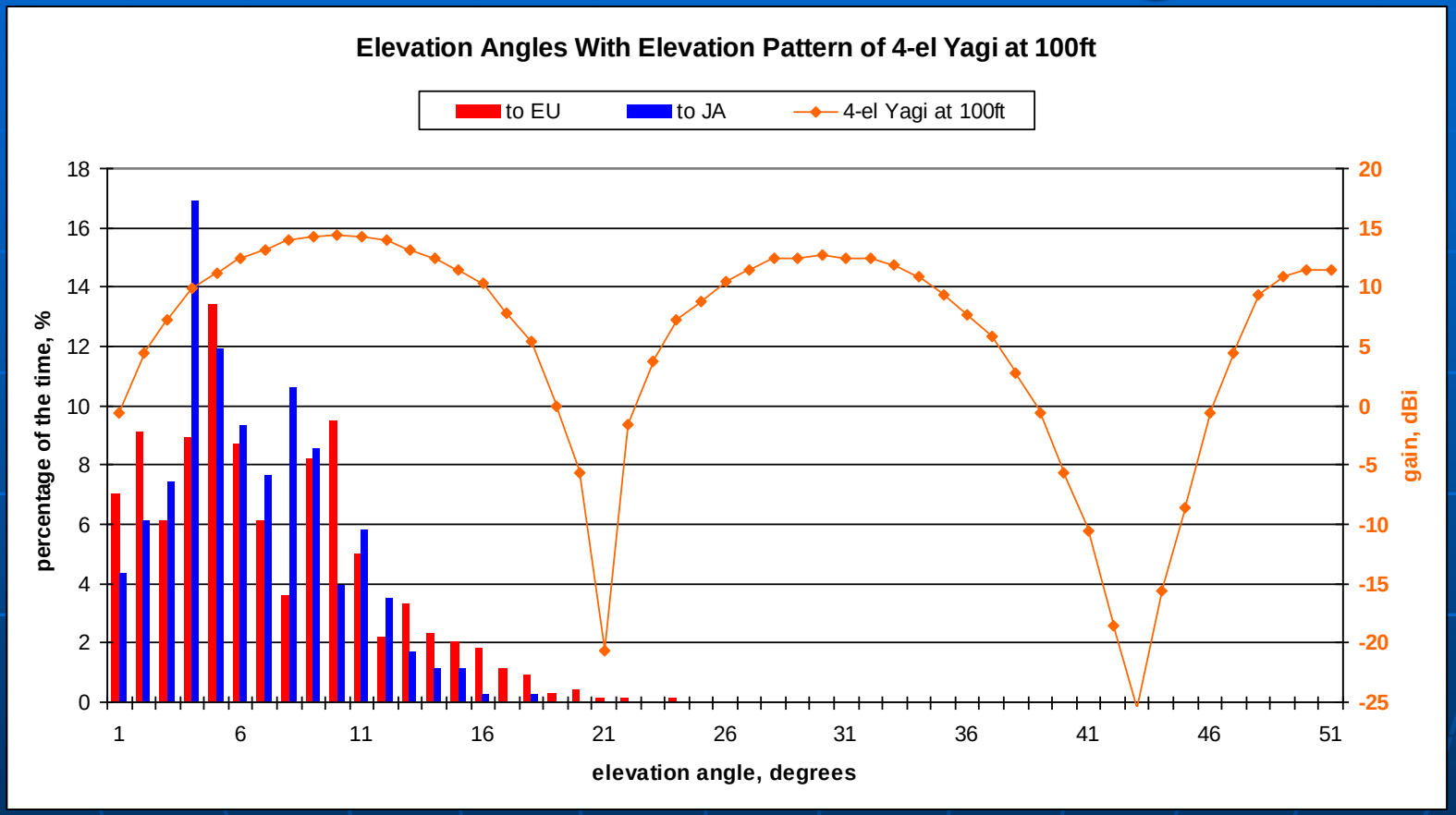
- Let's convert this polar plot to a rectangular plot
- Then we'll superimpose the elevation pattern rectangular plot onto the elevation angle rectangular plot

Elev Angles Plus Elev Pattern



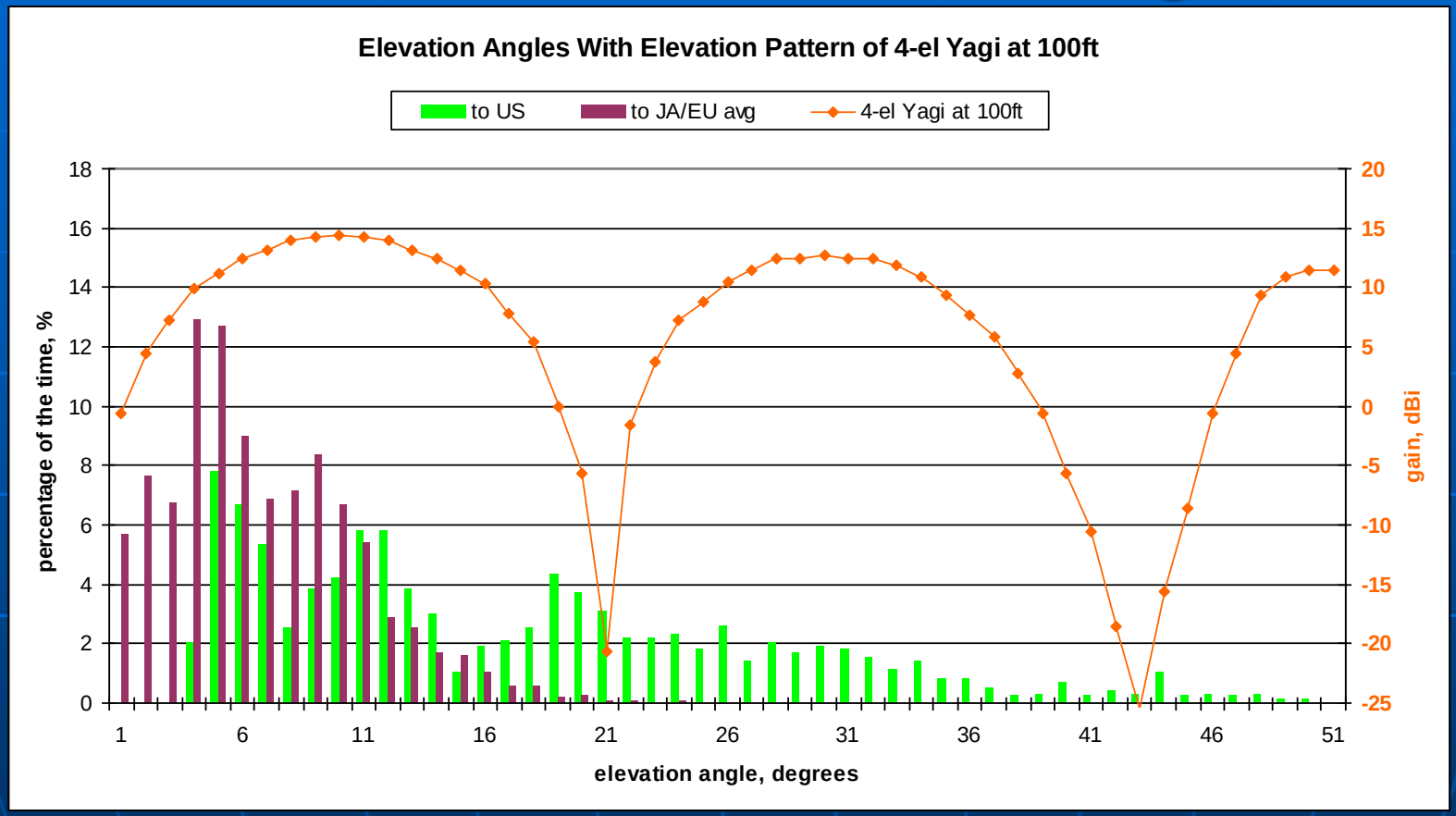
- The 100ft antenna covers the JA angles fairly well
- Somewhat higher would help the lowest angles

Add EU Elevation Angles



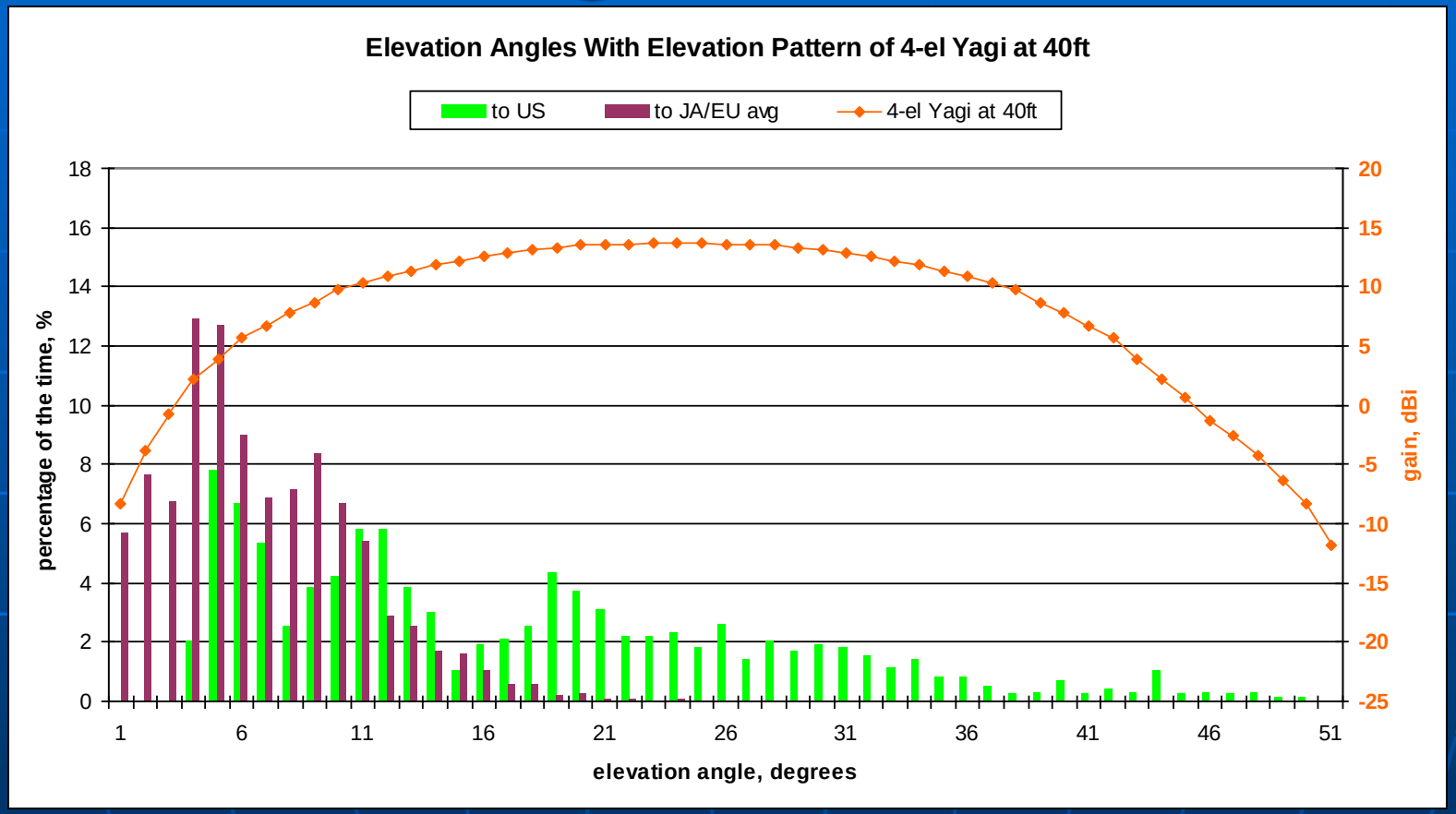
- The 100ft antenna covers EU angles fairly well – but could be higher
- Let's add US elevation angles – but Excel can't plot three data columns and one data line, so I averaged the JA and EU elevation angles

Add US Elevation Angles



- US (closer in QTHs) needs much higher elevation angles
- We have a problem - two nulls in the needed higher angles
- One solution - move the antenna down to 40 feet

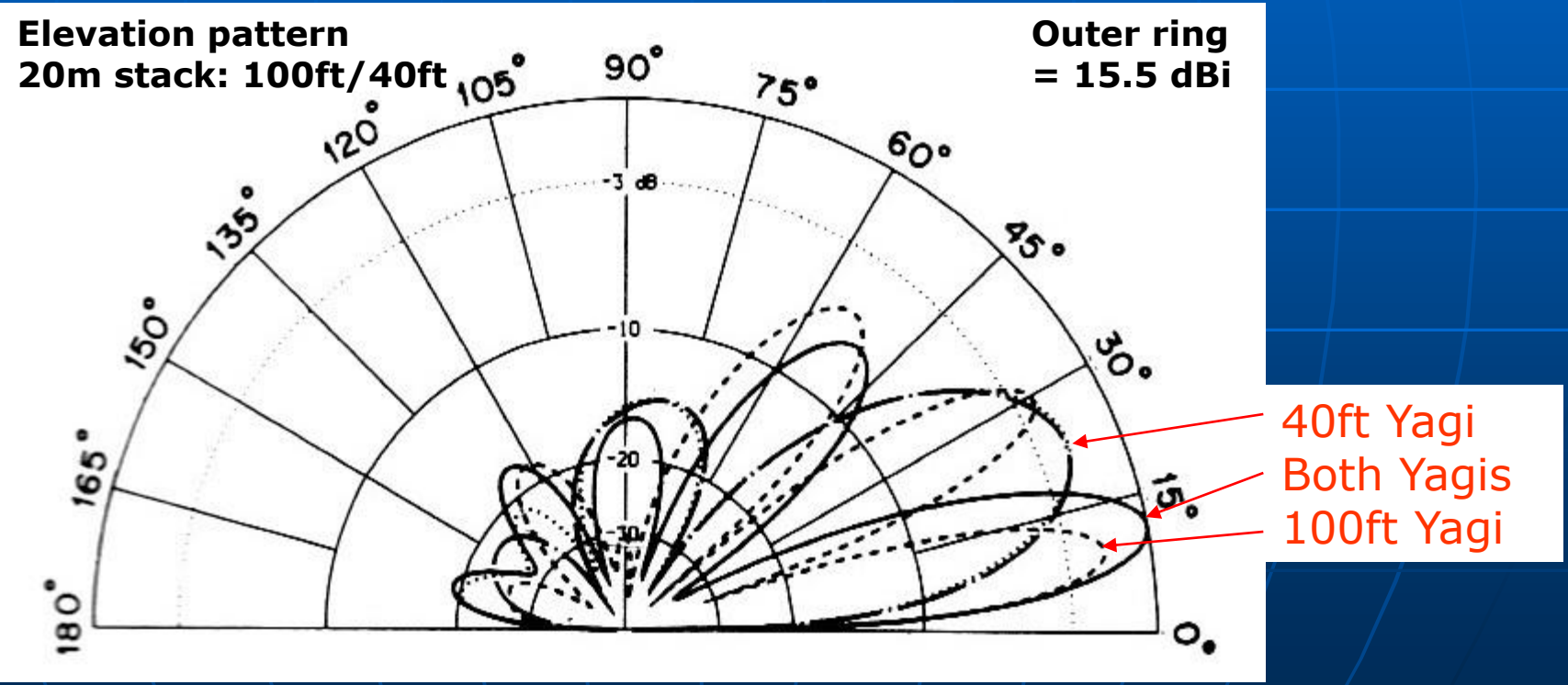
Move Yagi Down to 40 ft



- Yagi at 40ft covers the higher elevation angles very well
- But we give up more than an S-unit at the lower elevation angles
  - **For example, at 2° the difference between 100ft and 40ft is 9 dB**

Best Solution

- Put one at 100ft (long distance targets) and one at 40ft (closer-in targets)
- Employ a Both-Upper-Lower switch



Elevation Angle Summary

- Theoretical results say we need to cover a wide range of elevation angles
  - How good are the elevation angle data?
    - Over the years there have been a handful of studies that have measured arrival elevation angles
      - Measured results tend to confirm the theoretical results
- Likely to require more than one antenna
  - Many US stations have a low antenna fixed on the Caribbean
- How far you want to go depends on how competitive you want to be

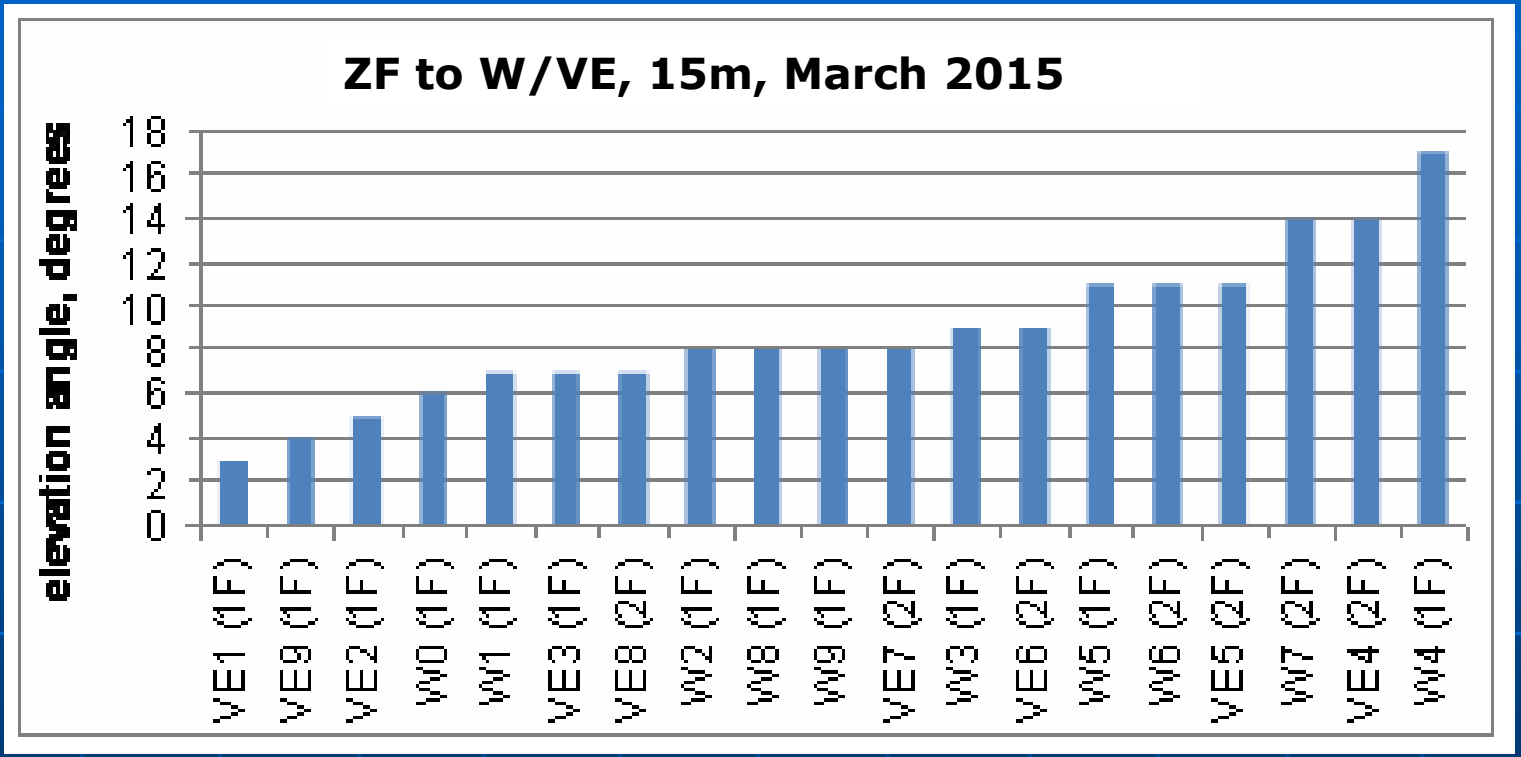
The Purpose of an Antenna

- To put the most energy at the proper azimuth angle
- To put the most energy at the proper elevation angle
- To put the most energy into the proper polarization
  - Electromagnetic waves at HF that propagate thru the ionosphere are circularly polarized
    - Ordinary and extraordinary waves – rotate opposite
      - Would have to provide for both for best results
  - I believe horizontal polarization is the best compromise on the higher HF bands

A Real-World Example

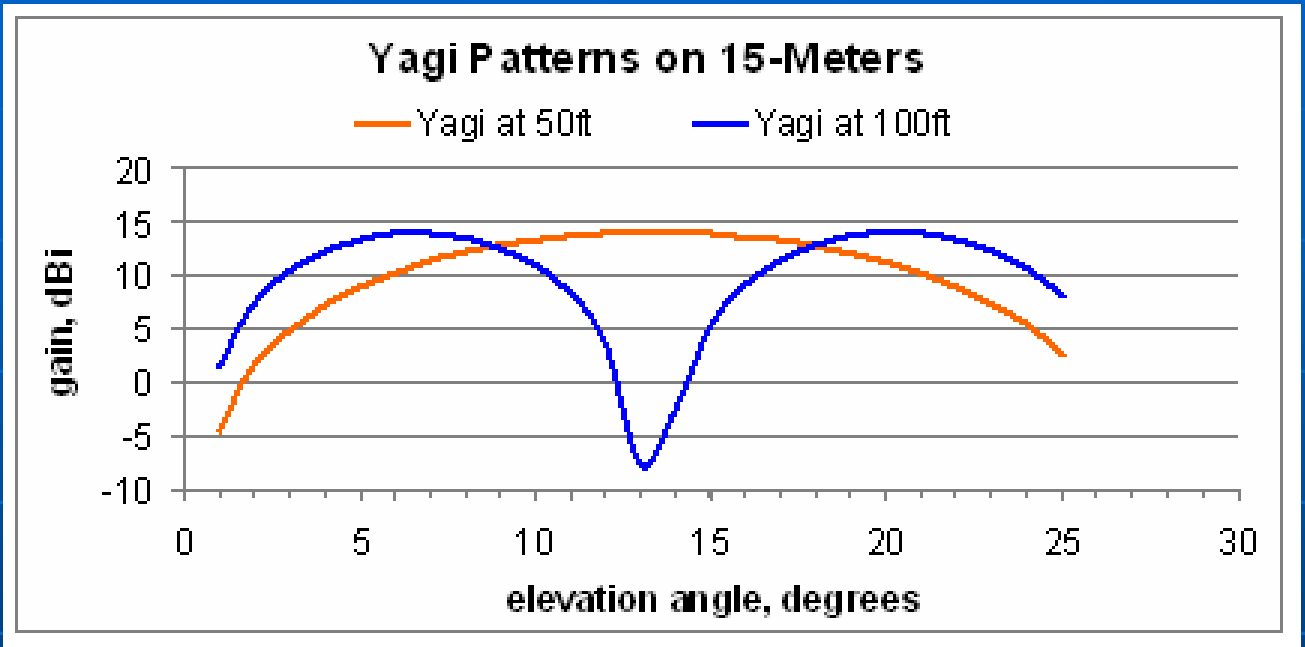
- Joe W6VNR has won ARRL DX PH as ZF2AH on five bands
  - 10m in 2000, 20m in 2004, 80m in 2008, 160m in 2009, 40m in 2012
- No one has ever won all six bands from the same QTH
  - K1UO has won 80m, 40m, 20m, 15m, 10m
- Joe plans 15m in March 2015
  - D44TD beat him in 2003 by 3.7%
  - FY5KE beat him in 2013 by 6.2%
  - PY is usually stiff competition, too

Needed Elev Angles from ZF



Need to cover 3-17 degrees for W and VE

15m Antennas at the CARS Station

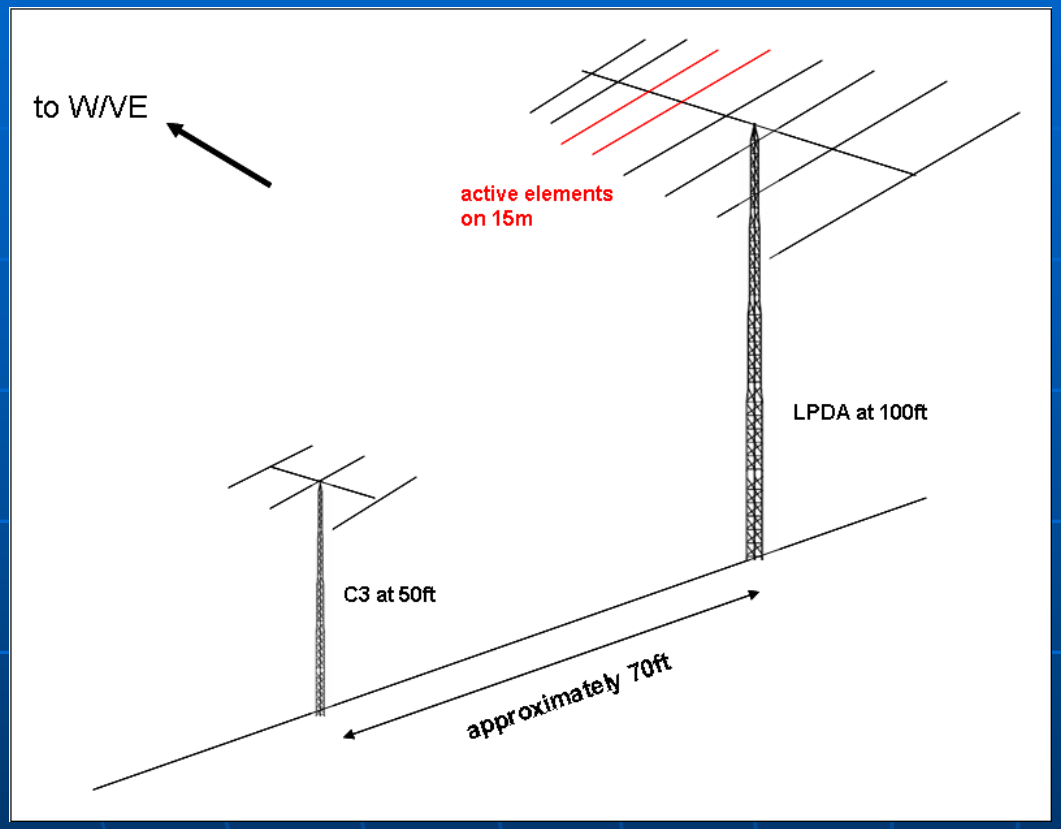


Cayman Amateur Radio Society

- Mosley LPDA (7-30 MHz) at 100 ft
- FORCE-12 C3 at 50 ft

- LPDA at 100 ft good for the low angle 1-hop paths
  - But it has a null at several important higher elevation angles
- C3 at 50 ft good for the higher angle 2-hop paths and the higher angle close-in 1-hop paths
  - But the C3 gives up > one S-unit at the low elevation angles

CARS Antenna Details

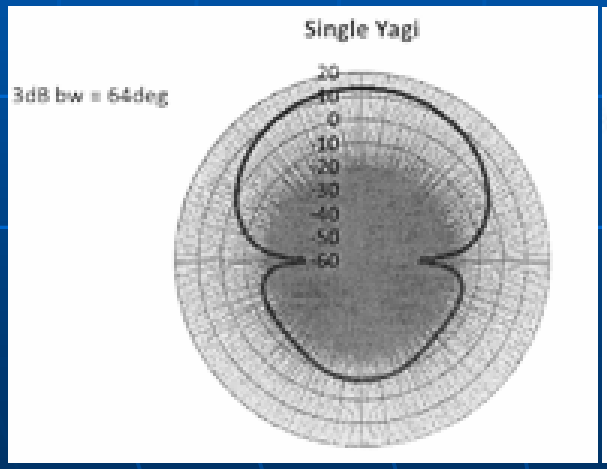


- This is not a conventional vertical stack of Yagis
- And it's not a conventional horizontal stack of Yagis
- Makes it tougher to get the system right
- Fortunately the antennas are tip-to-tip when pointed towards W/VE
  - Minimizes interaction between antennas

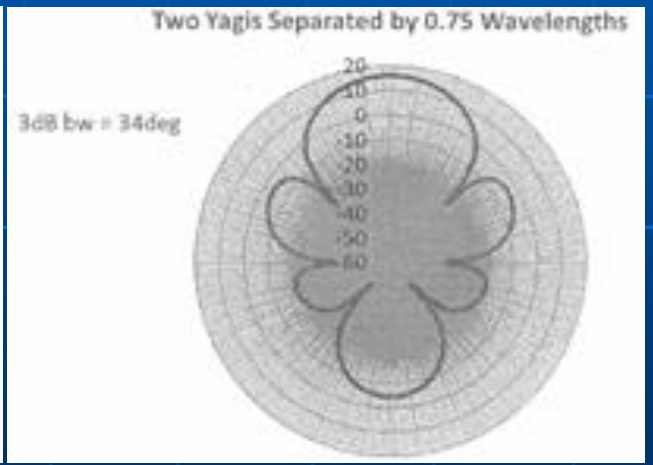
- I told Joe to buy a StackMatch and he tried it in 2013
- 'Both' did not work as good as direct on the USA with the LPDA at 100 feet, then switching antennas to accommodate the local Florida and close-in stations with the lower C3 antenna

Why He Had Problems

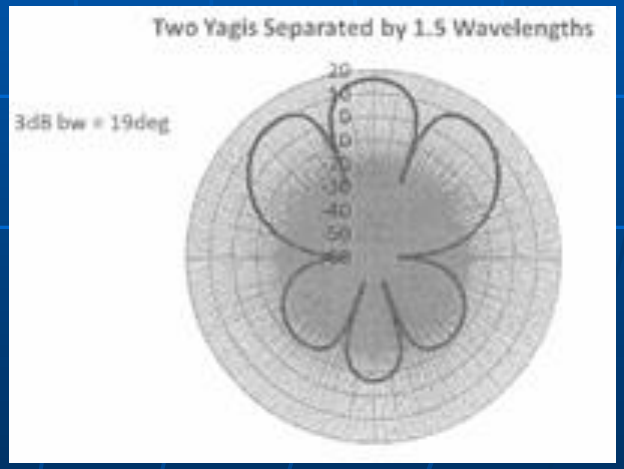
- The horizontal spacing is too large
  - Main lobe narrows up considerably and two side lobes form
  - Puts two nulls in the forward direction



single Yagi
3dB bw = 64 deg



two Yagis, .75λ
3dB bw = 34 deg



two Yagis, 1.5λ
3dB bw = 19 deg

Why He Had Problems – con't

- Used coax lengths as-is (unknown electrical length)
  - Antennas probably not fed in-phase
- Active elements of the LPDA on 15m not at the tower
  - Additional phase shift

For ZF2AH in March 2015

- Existing CARS antenna placement scenario not good for 15m improvement
- I think the best solution is to put another Yagi on the tower with the LPDA
  - 3-el Yagi likely best to match the LPDA performance
  - Mount the new Yagi at the proper height for a good 15m stack
- Vary the length of coax to one antenna to maximize US signals
  - I assume this will correct for the 15m portion of the LPDA being "ahead" of the new Yagi
- Keep BIC (butt-in-chair) as much as possible

Q & A

- Any questions about the Sun?
- Any questions about propagation?
- Any questions about stacking antennas?
- Any questions about polarization?

- Enjoy the rest of HamCom!

Carl K9LA