Antenna Improvements to Improve Your Competitiveness in Contests

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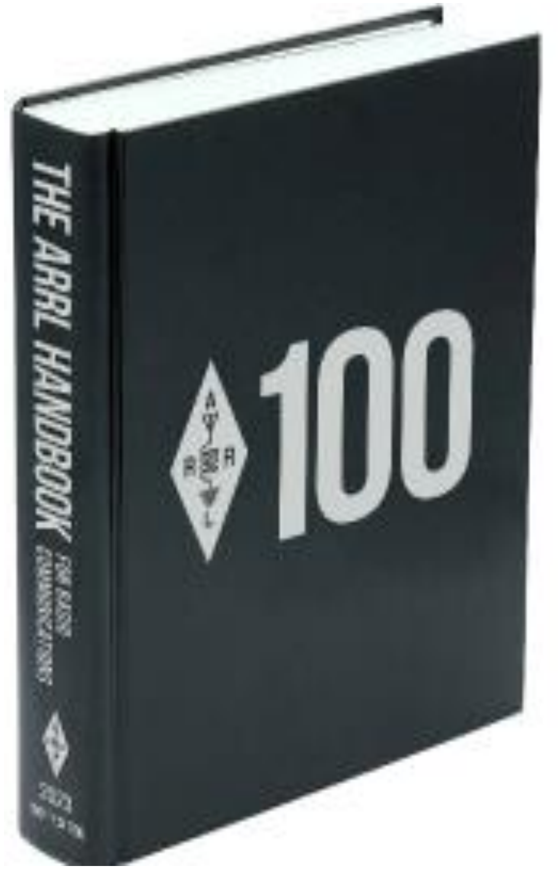
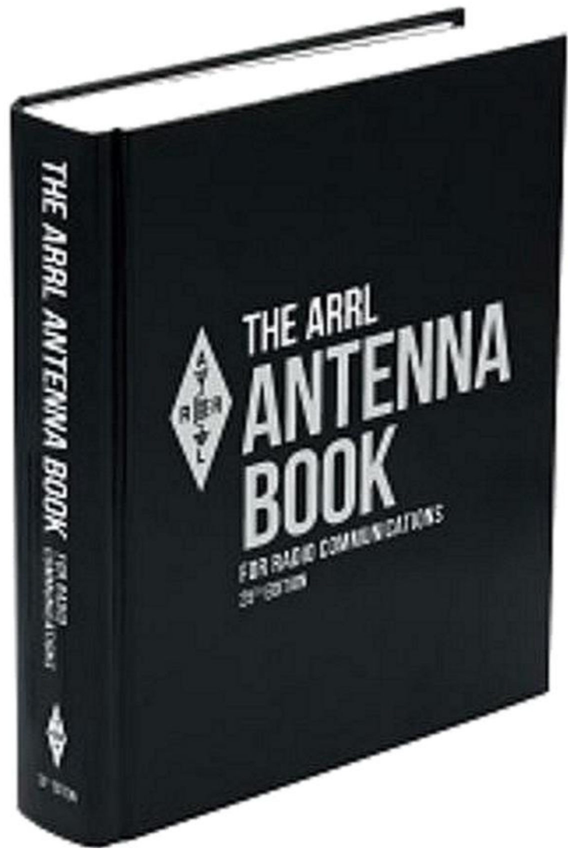
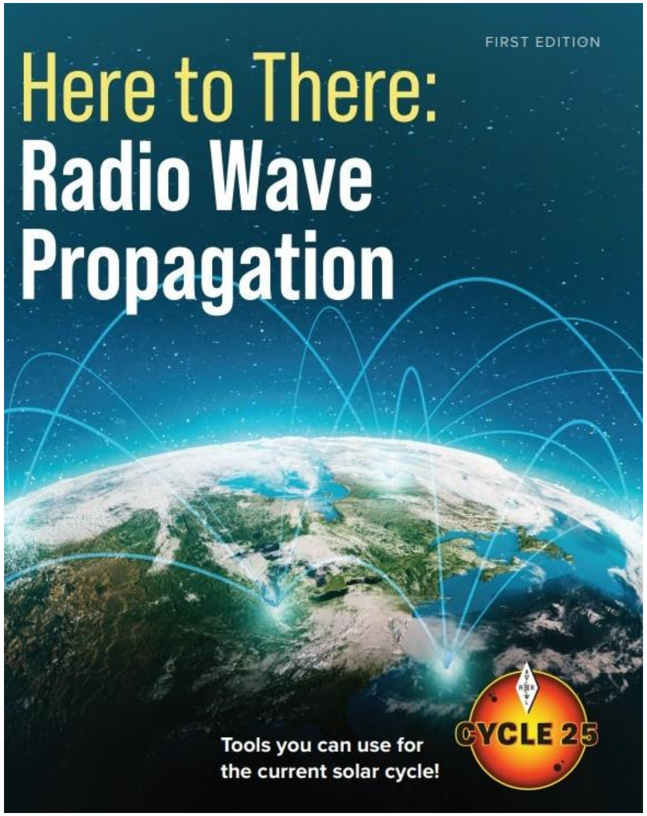
The Three Most Valuable Investments to Greatly Improve Your Understanding of Antennas and Propagation







handbook.arrl.org

home.arrl.org/action/Store/Product-Details/productId/2012451093

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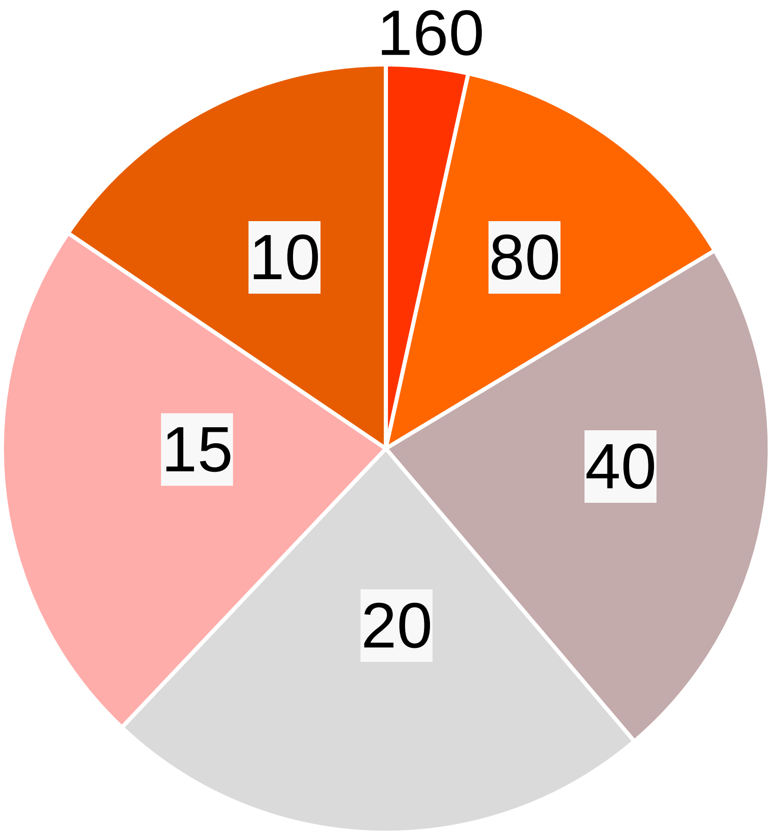
CW DX Contest QSOs
Per Band Near Solar Maximum



10 and 15 meter QSOs are much more important near solar maximum
80 meter QSOs and 160 multipliers continue to be very important

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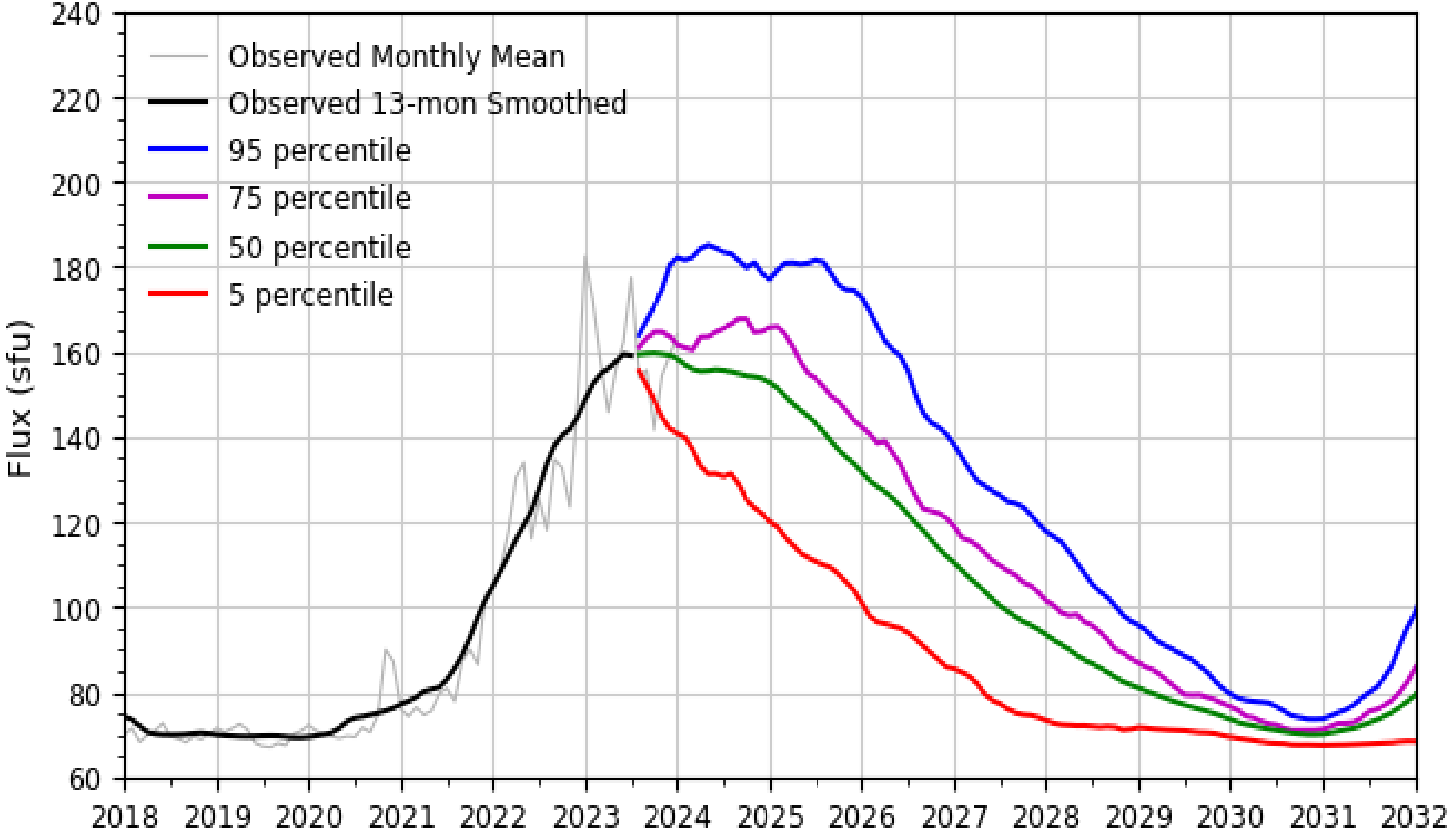
Solar Cycle 25 Solar Flux Index Forecast
NASA Marshall Space Flight Center – 6 Feb 2024



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nasa.gov/msfcsolar

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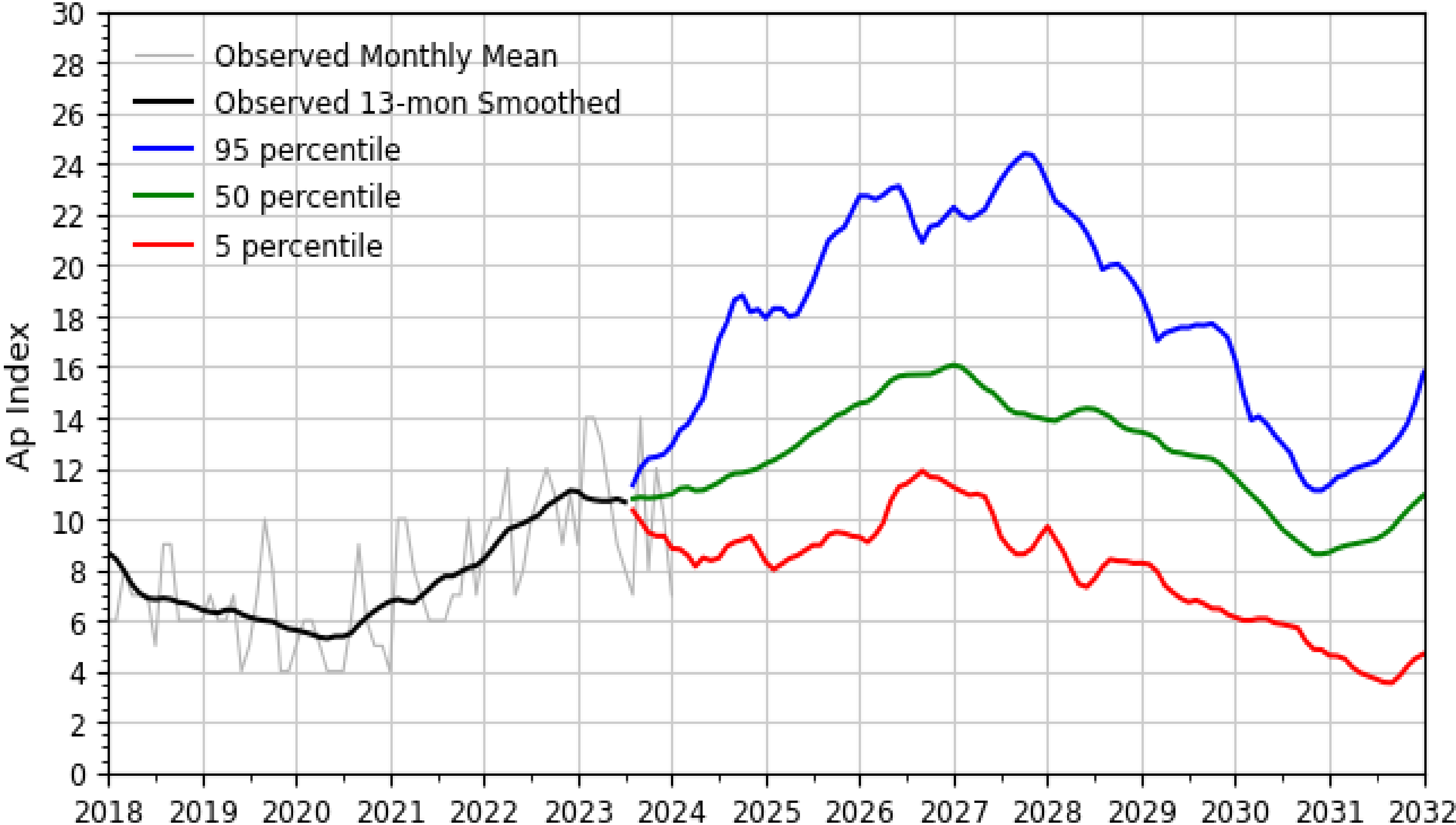
Solar Cycle 25 Ap Index Forecast
NASA Marshall Space Flight Center – 6 Feb 2024



nasa.gov/msfcsolar

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HF Propagation Trends Through Solar Minimum in 2031

- Solar maximum propagation conditions began in Dec 2022
- Solar maximum is likely to occur during 2024
  - but solar maximum propagation continues through 2026
- More frequent disturbed propagation conditions will begin during 2024
  - will slowly become less frequent after 2026
- Excellent 10 meter worldwide propagation through 2026
  - will begin to decline after 2026
- Excellent, reliable 15 meter worldwide propagation
  - will begin to decline after 2027
- The slow decline to solar minimum will begin by 2027
- Solar minimum propagation is likely to begin by about 2029

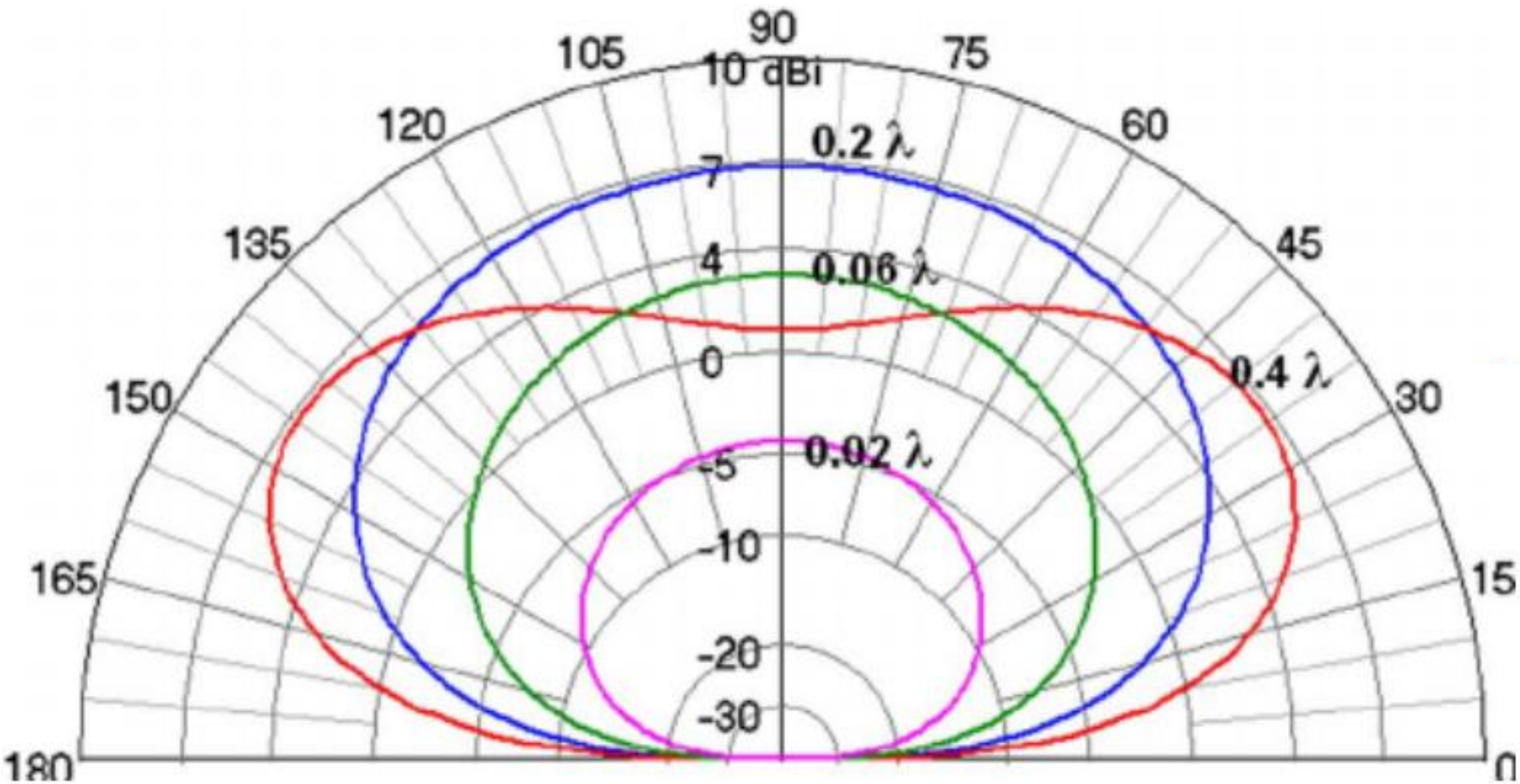
Identify and Prioritize Antenna Improvement Goals to Improve Your Competitiveness

- Identify your realistic achievable personal goals for your selected contests, entry categories and competition region
  - first place regional, national or world winner, or
  - consistently placing among the top three competitors, or
  - consistently placing among the top ten competitors, or
  - consistently improving your scores relative to your peers
- Understand your realistic constraints that limit your achievable antenna improvements
  - available physical space for towers and antennas
  - available time for achieving your goals
  - available funds for achieving your goals
- Achieve a balance between your goals and constraints
- Prioritize your goals in order of improving your competitiveness

<u>During and After</u> Every Contest Prepare Notes Documenting Your Antenna Strengths and Weaknesses Compared to Your Peer Competitors

- Identify every aspect of antenna performance and reliability that was a competitive strength compared to your peers
- Identify every aspect antenna performance and reliability that was a competitive weakness compared to your peers
- Identify improvements that your peer competitors <u>can't match</u>
- Identify every opportunity for antenna improvement that would have improved <u>your score</u> in this contest, <u>in priority order</u> by:
  - estimated score improvement from each improvement
  - degree of difficulty in achieving each improvement
  - practicality of achieving each improvement
  - impediments to achieving each improvement
  - expense to achieve each improvement

6 dB of Ground Gain for Horizontally Polarized Antennas at Least 0.2 Wavelengths High



Its extremely difficult to achieve 6 dB of ground gain with vertical polarization

6 dB of "Free" Ground Gain

- Horizontally polarized dipoles, Yagis or quads
  - easily produce 6 dB of very important ground gain over almost any soil
  - *must be installed at an appropriate height*
  - terrain must be reasonably smooth and free of large obstructions
  - *nearby antennas for the same band and tribanders can destroy ground gain, antenna gain and directivity*
- Vertically polarized antennas can achieve nearly 6 dB of ground gain
  - but only over highly conductive soil such as a salt marsh W1KM K3ZM
- Competitive DX contest stations require high horizontally polarized 40 through 10 meter antennas especially during solar minimum
- Stacked Yagis provide additional gain by suppressing unwanted high angle radiation and redistributing power into useful lower angles
  - *if installed at proper heights and spacings to obtain useful stacking gain*
  - a Stackmatch allows selection of the optimum elevation angle

Horizontal antennas easily produce 6 dB of ground gain when installed at proper heights

Antenna Elevation Angles and Heights Near Solar Maximum

- **10 meters** - early morning through sunset world wide DX band
  - most DX propagation is at **5 to 10 degree** elevation angles **50 to 100 ft**
  - marginal DX paths require angles **well below 5 degrees** **above 100 ft**
- **15 meters** - sunrise to early evening worldwide DX band
  - most DX propagation is at **5 to 15 degree** elevation angles **50 to 120 ft**
  - marginal DX paths require angles **well below 5 degrees** **above 120 ft**
- **20 meters** - 24 hour very crowded competitive worldwide DX band
  - most DX propagation is at **5 to 20 degree** elevation angles **50 to 180 ft**
  - marginal DX paths require angles **below 5 degrees** **above 180 ft**
- **40 meters** - evening and night very crowded competitive DX band
  - most DX propagation is at **10 to 25 degree** elevation angles **70 to 200 ft**
  - marginal DX paths require angles **below 10 degrees** **200 ft**
- **80 meters** - less reliable and weaker DX signals than recent years
  - use efficient antennas covering angles from **10 to 25 degrees** **100 to 200 ft**
- **160 meters** - less reliable and weaker DX signals than recent years
  - **vertical antennas** almost always provide ***much better*** 160 meter performance

Increased sunspot activity requires competitive 15 and 10 meter antennas

Competitive 160 Meter Antennas are Almost Always Vertically Polarized

- Vertical, inverted-L, T, and umbrella antennas
  - *almost always* provide much better DX performance than horizontally polarized antennas at distances beyond 1500 miles
- Nearby tall towers and antennas can significantly degrade the gain and directivity of vertical antennas
  - antenna pattern degradation
  - increased ground losses
- Efficient radial systems are essential to achieving the full performance potential of vertical transmitting antennas

Verticals *almost always* provide much better DX performance than horizontal 160M antennas

High Performance Transmitting Antennas for 160 Meter DX

- 125 foot vertical: the gold standard 160 meter DX antenna
  - ***well spaced from all nearby tall towers and antennas***
    - at least 140 ft from towers over 80 feet tall supporting large HF Yagis
    - optimum performance with spacing much greater than 140 feet
  - at least 30 to 60 shallow buried 125 foot radials
    - or at least two (preferably more than 4) elevated 125 foot radials
      - but only if 30 to 60 shallow buried 125 foot radials are not possible
    - the K2AV folded counterpoise is a good alternative for small lots
- Inverted-L, T and umbrella verticals are good alternatives
  - 50 feet or higher (as short as 35 feet with degraded performance)
  - supported by a tower, mast or trees
- or a corner fed delta loop or corner fed inverted-U antenna

High Performance Transmitting Antennas for 80 Meter DX

- Horizontal dipole at least 70 to 100 feet high
  - higher is better
- 65 foot vertical
  - install at least 30 to 60 shallow buried 65 foot radials
    - or at least two (preferably four or more) elevated 65 foot radials but only if shallow buried radials are not possible
  - ***very susceptible to degradation by nearby tall towers***
    - at least 70 feet from towers over 40 feet tall supporting a Yagi antenna
    - optimum performance with much more than 70 foot spacing
- Inverted-L, T and umbrella verticals are good alternatives
  - as little as 25 feet tall -- supported by a tower or trees
  - install at least 30 to 60 shallow buried 65 foot radials
    - or elevated radials
    - or a K2AV reduced size counterpoise for a small lot
  - or a corner fed delta loop or corner fed inverted-U

80 Meter 4-Square Vertical Array

very competitive high performing alternative to a high 80 horizontal antenna

- A four square vertical array is very competitive with high horizontally polarized Yagis and quads
- *Install at least 70 feet from all towers*
  - much more than 70 foot spacing will significantly improve its performance
- Use at least 60 shallow buried 65 foot radials under each vertical
- A 4-square is also an excellent receiving antenna

Horizontal Polarization on 80 Meters Easily Achieves 6 dB of Ground Gain

- Horizontal dipole or inverted-V dipole about 50 feet high
  - superb antenna for domestic contests: Sweepstakes and Field Day
  - a good DX antenna for distances up to about 5000 miles
- Horizontal dipole or inverted-V dipole at least 70 feet high
  - outperforms a single 65 foot vertical installed over all but the most conductive soils such as a salt marsh
- Use a vertical antenna if you cannot install a dipole or inverted-V dipole at least 70 feet high
  - 65 foot vertical, inverted-L, T or umbrella with at least thirty 65 foot radials
  - or a corner fed delta loop or a corner fed inverted-U
  - ***verticals are very susceptible to degradation by nearby towers***
- Four-square vertical array
  - very competitive with high horizontally polarized antennas
  - at least sixty 65 foot shallow buried radials under each vertical

High Performance 40M Antennas

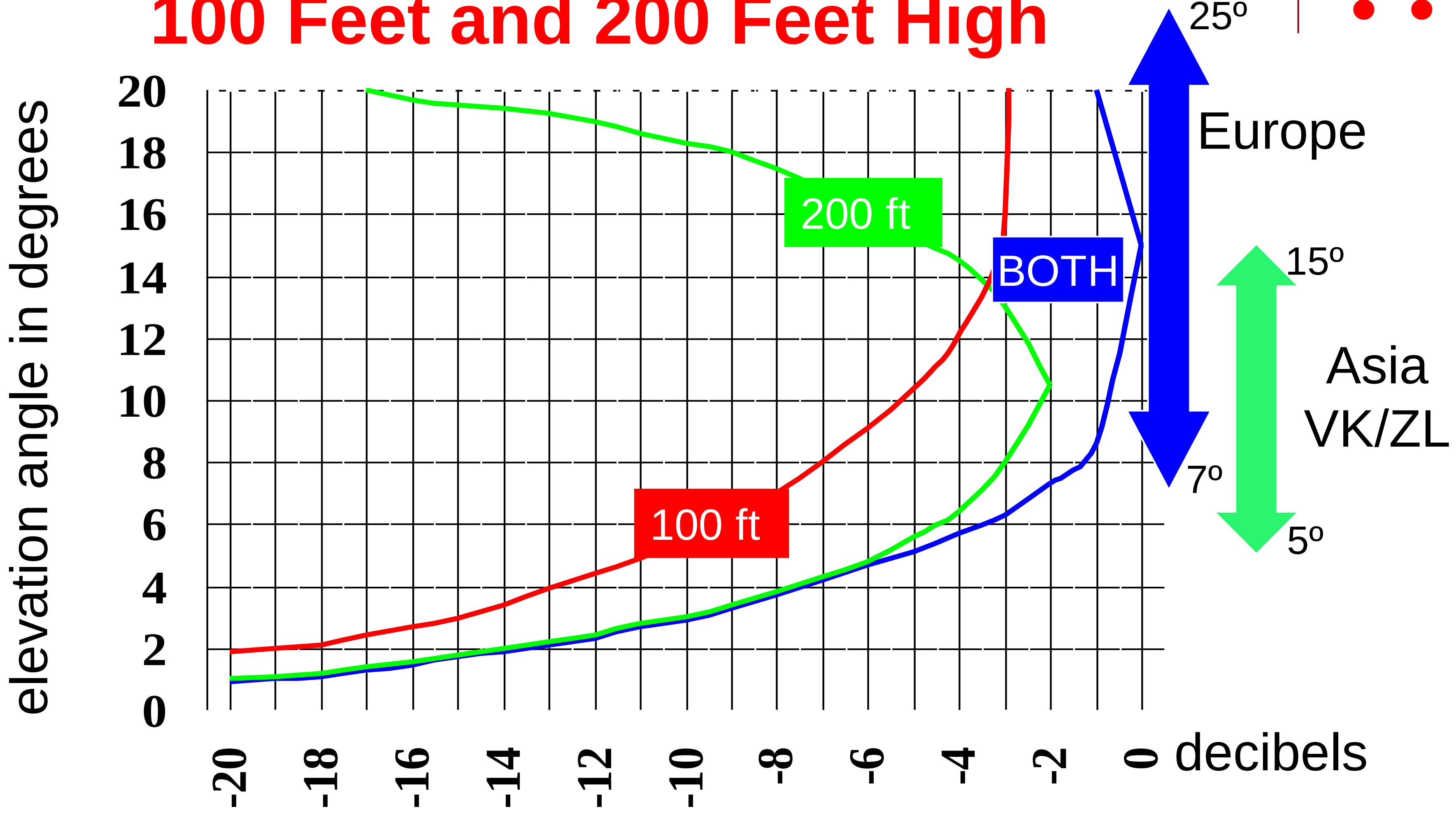
- Horizontal dipole at least 70 feet high
  - 13 to 45 degree elevation pattern half power (-3 dB) beamwidth
  - otherwise use a vertical or a four-square vertical array with 30 to 60 radials
- Higher gain: 2 element “shorty 40” Yagi at 70 to 100 feet high
  - 10 to 30 degree elevation pattern half power (-3 dB) beamwidth
  - significant improvement over a simple horizontal dipole for DX
  - a Cushcraft XM-240 at 100 feet high is very cost effective
  - a Moxon Yagi is an excellent broad bandwidth low VSWR alternative
- Highest gain: full size 3 or 4 element monoband Yagis
  - single Yagi at least 140 feet high
  - two stacked Yagis on a 200 foot tower and a Stackmatch
    - ***selectable*** 6 to 30 degree elevation beam patterns at -3 dB points
  - this antenna is often too high for Caribbean and northern South America
  - but don’t underestimate the high cost and complexity of a full size 40M Yagi!

Elevation angles from 5º to 25º are needed

Stacked 3 Element 40 Meter Yagis

48 Foot Booms

100 Feet and 200 Feet High



Elevation angles from 10º to 25º are needed

Cushcraft XM-240
2 Element 40 Meter Yagi

The most popular "Shorty Forty" Yagi

dxengineering.com/parts/csh-xm240

40 Meter Moxon

VSWR less than 1.4:1 from 7.0 to 7.3 MHz

22 foot boom and 48 foot elements

Two stacked Moxons on a 140 foot tower are fully competitive with a much more expensive full size 3 or 4 element Yagi

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www.k3lr.com/engineering/moxon

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W3KRQ's Homebrew Full Size 3 Element 40 Meter Yagi in 1959

Contesters and DXers built many 3 element 40M Yagis
W3GRF W3KRQ W3MSK (W3AU) W8JIN and many others

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Stacked 40 Meter 4 Element OWA Yagis at K9CT

k9ct.us/contest-antennas/40-m

40 Meter 4-Square Vertical Array

- A 4-square vertical array is good alternative to a Yagi
  - if you cannot install a “shorty 40” Yagi at least 70 feet high
- Install at least 60 shallow buried 35 foot radials under each vertical
- *Install at least 40 feet from all towers*
  - more than 40 foot spacing will significantly improve its performance
- A 4-square is also an excellent 40 meter receiving antenna

High Performance 20M Antennas

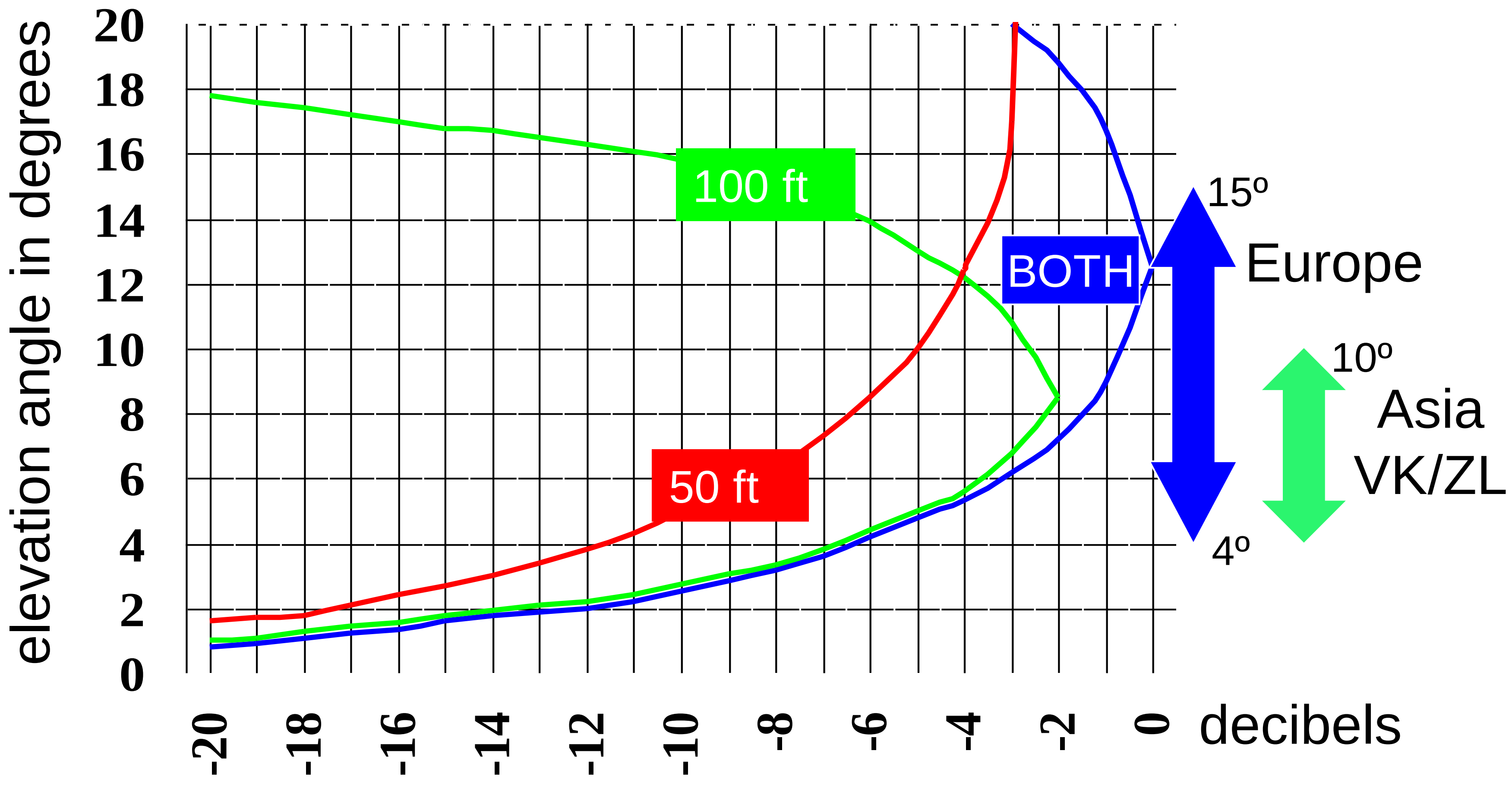
- A horizontal Yagi or quad is ***always*** the best choice
  - if you can install your antenna at least 35 feet high
  - 13 to 45 degree elevation beam pattern at -3 dB points
- Moderate gain: small tri-band Yagi, hex-beam, Moxon or quad
  - a small Yagi at least 50 to 70 feet high will produce good DX results
  - 10 to 30 degree elevation beam pattern at -3 dB points
- High gain: full size tri-band Yagi, small monoband Yagi or quad
  - at least 70 to 100 feet high
  - 7 to 20 degree elevation beam pattern at -3 dB points
- Highest gain: stacked large 20 meter monoband Yagis
  - 100 to 140 foot tower with two stacked Yagis and a Stackmatch
  - 170 to 200 foot tower with three stacked Yagis and a Stackmatch
    - *selectable* 3 to 25 degree elevation beam patterns at -3 dB points
  - stack switching (a “Stackmatch”) provides high payoff at low cost

Elevation angles from 5º to 20º are needed

Stacked 5 Element 20 Meter Yagis

48 Foot Booms

50 and 100 Feet High



Elevation angles from 5º to 15º are needed

Array Solutions Stack Match

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The Stackmatch revolutionized the performance and flexibility of stacked Yagi antennas

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High Performance 15M Antennas

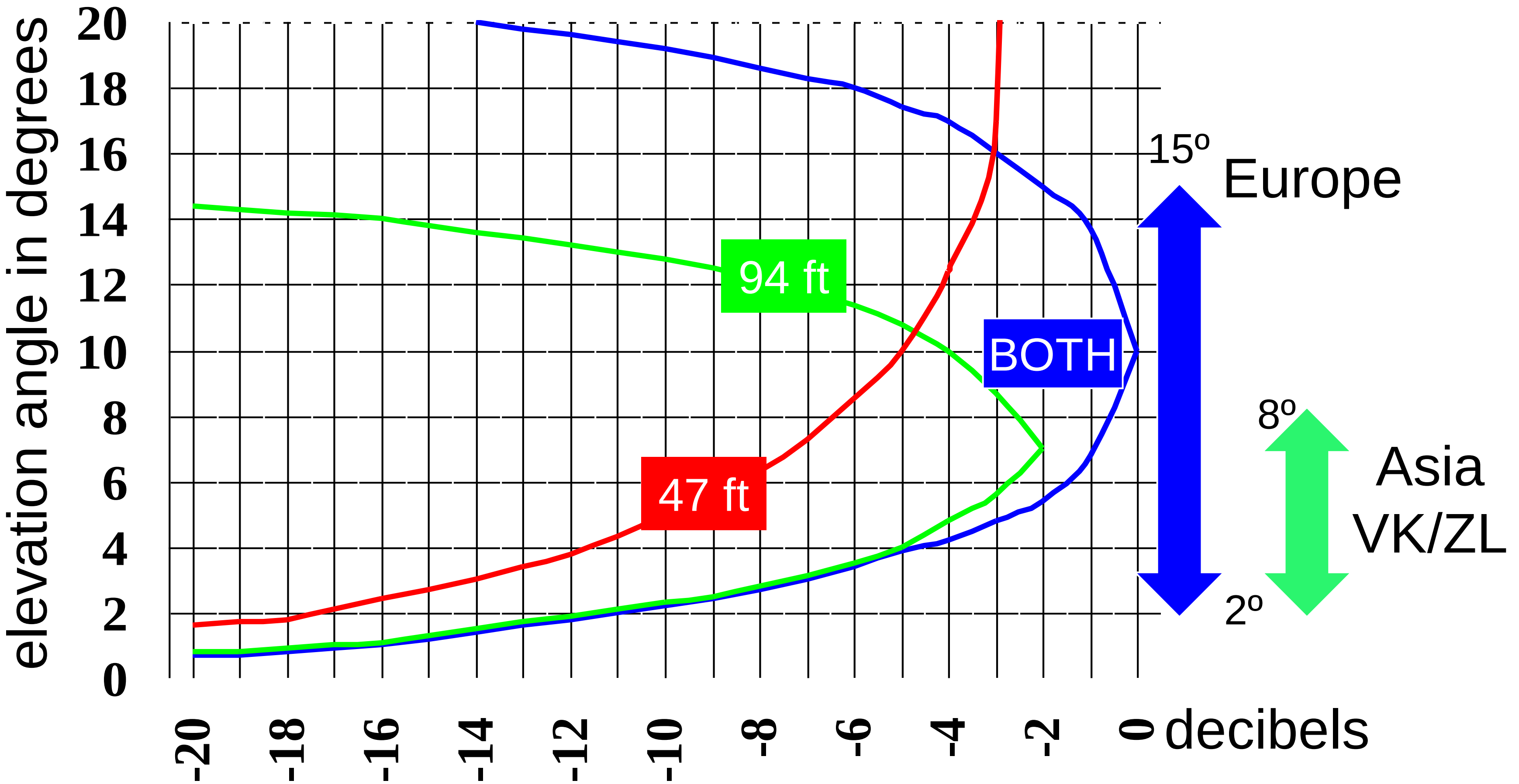
- A horizontal Yagi or quad is *always* the best choice
  - if you can install your antenna at least 25 feet high
  - 13 to 45 degree elevation beam pattern at -3 dB points
- Moderate gain: small tri-bander Yagi, hex-beam, Moxon or quad
  - a small Yagi at least 50 to 70 feet high will produce good DX results
  - 7 to 20 degree elevation beam pattern at -3 dB points
- High gain: full size tri-band Yagi, small monoband Yagi or quad
  - at least 70 to 100 feet high
  - 5 to 15 degree elevation beam pattern at -3 dB points
- Highest gain: stacked large 15 meter monoband Yagis
  - at least a 90 foot tower with two stacked Yagis and a Stackmatch
  - at least a 120 to 140 foot tower with three stacked Yagis and a Stackmatch
    - *selectable* 5 to 25 degree elevation beam patterns at -3 dB points
  - stack switching (a “Stackmatch”) provides high payoff at low cost

Elevation angles from 5º to 15º are needed

Stacked 6 Element 15 Meter Yagis

48 Foot Booms

47 and 94 Feet High



Elevation angles from 5º to 15º are needed

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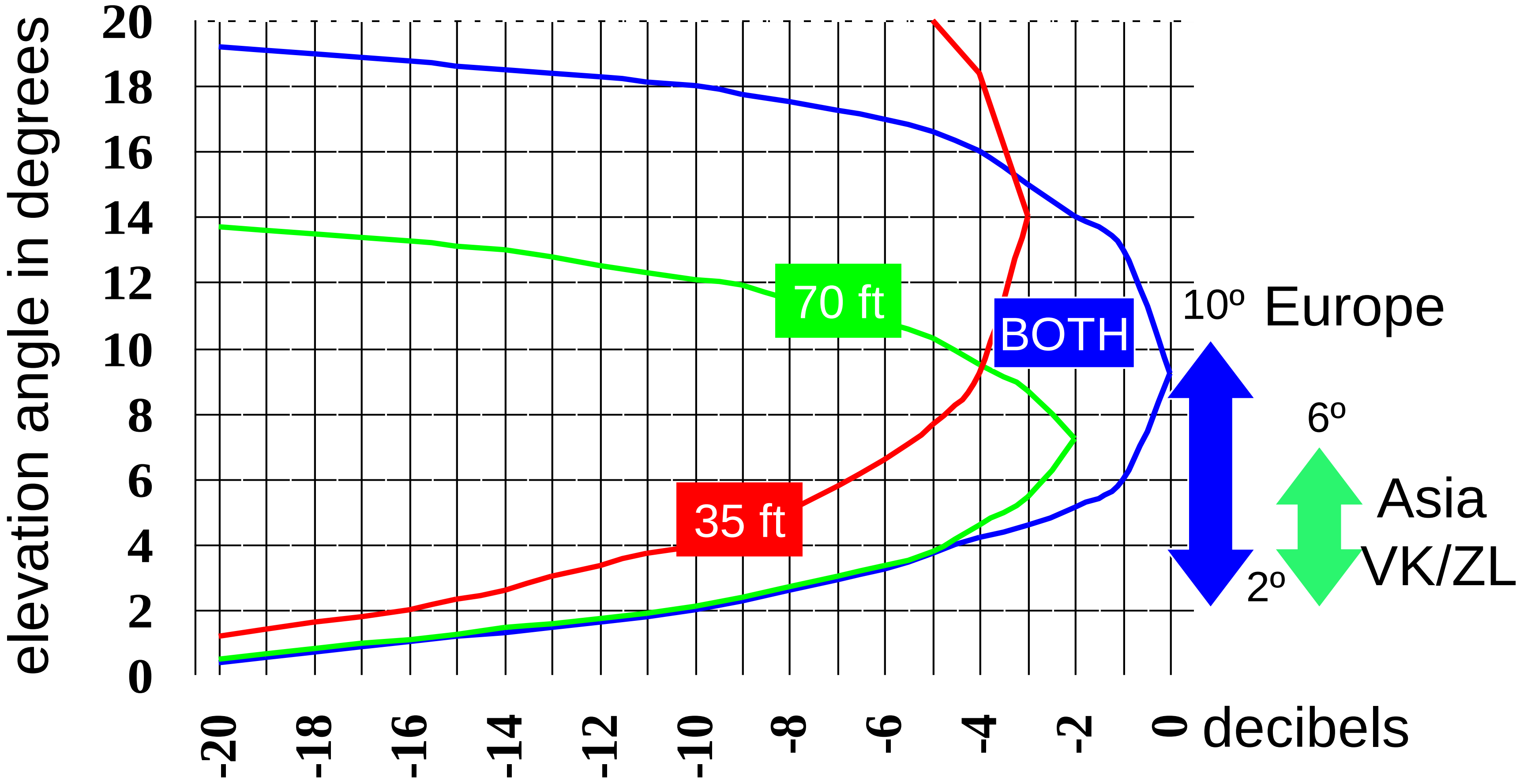
High Performance 10M Antennas

- A horizontal Yagi or quad is always the best choice
  - if you can install your antenna at 20 feet high or higher
  - 13 to 45 degree elevation beam pattern at -3 dB points
- Moderate gain: small tri-bander Yagi, hex-beam, Moxon or quad
  - a small Yagi at least 35 to 50 feet high will produce good DX results
  - 7 to 20 degree elevation beam pattern at -3 dB points
- High gain: full size tri-band Yagi, small monoband Yagi or quad
  - at least 50 to 70 feet high
  - 5 to 15 degree elevation beam pattern at -3 dB points
- Highest gain: stacked large 10 meter monoband Yagis
  - at least a 70 foot tower with two stacked Yagis and a Stackmatch
  - at least a 90 to 100 foot tower with three stacked Yagis and a Stackmatch
    - *selectable* 4 to 20 degree elevation beam patterns at -3 dB points
  - stack switching (a “Stackmatch”) provides high payoff at low cost

Elevation angles from 5º to 10º are needed

Stacked 6 Element 10 Meter Yagis
36 Foot Booms
35 and 70 Feet High



Elevation angles from 5º to 10º are needed

Competitive Single Tower Stations for the Years Near Solar Maximum

- 50-60 foot tower and a small rotator (e.g., HyGain Ham-IV)
  - small tribander, Hex-beam or quad
  - 40 and 80 meter dipoles and a 160 meter inverted-L

- 70-80 foot tower and a medium rotator (e.g., HyGain T2X)
  - Cushcraft XM-240 two element 40 meter Yagi
  - large tribander such as the SteppIR 4 element Yagi
  - 80 meter dipole and a 160 meter inverted-L

- 100-140 foot tower and a large rotator (e.g., M2 Orion)
  - Cushcraft XM-240 two element 40 meter Yagi
  - stacked monoband Yagis such as the HyGain LJ series on ring rotators
  - 80 meter dipole and a 160 meter inverted-L

High Performing Single Tower Station
K9RS

JK 402
120 ft

JK Mid-Tri
110 ft

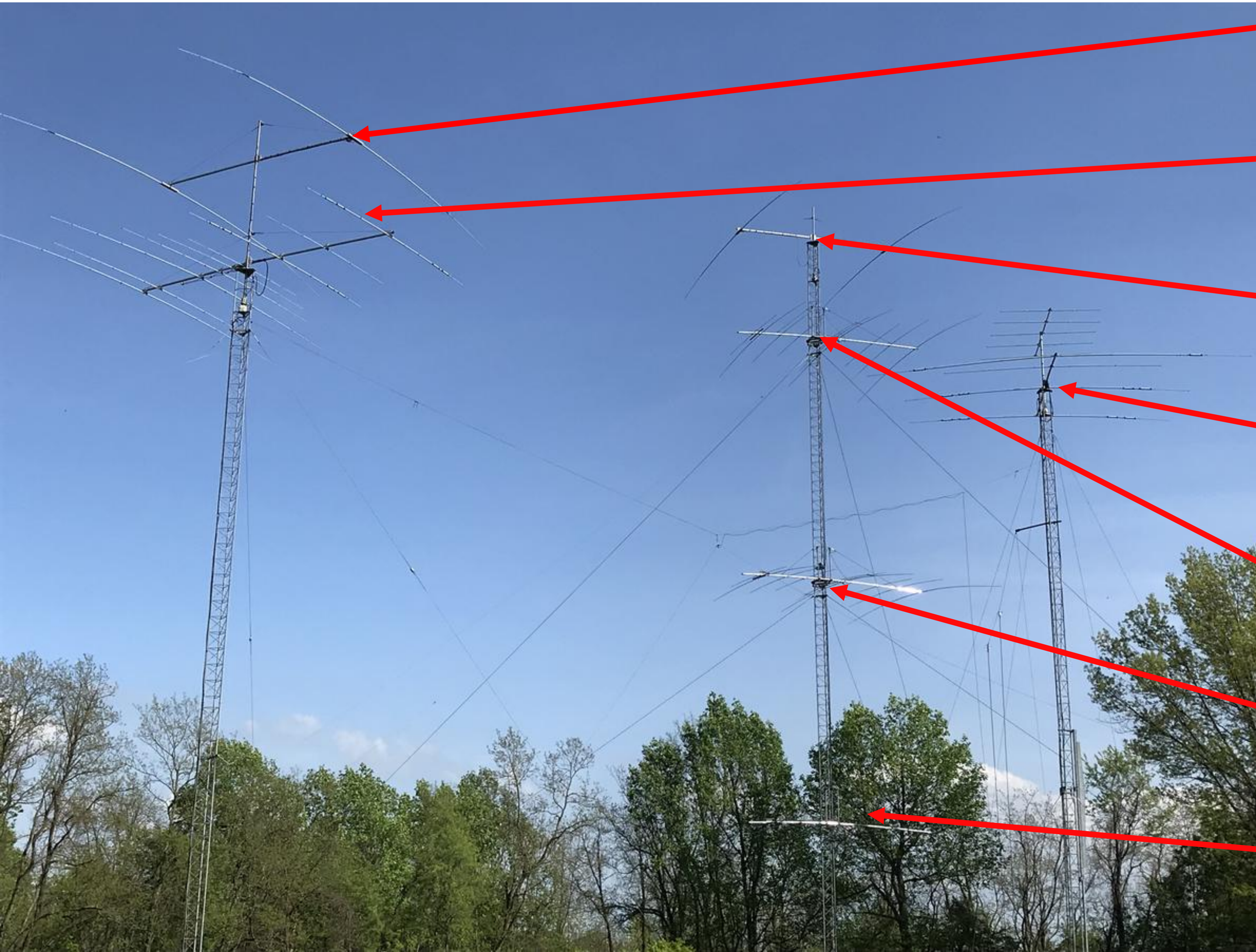
JK Mid-Tri
75 ft

Multi-Tower Antenna Systems

Designing a multi-tower station with acceptable degradation is an antenna modelling challenge

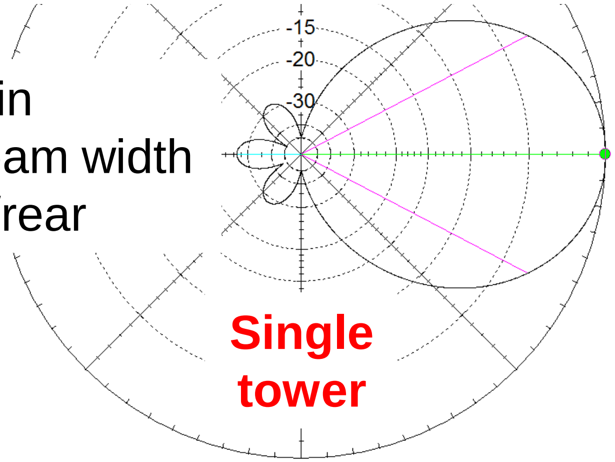
- Placement of Yagis and the relative location of the towers to minimize degradation is critical to achieving high performance
  - in most cases multiple *Triband Yagis* and multiple Yagis for the same band should be installed *on only one tower*
  - placing Yagis covering the same band *on multiple towers* requires detailed antenna modelling and very large spacing between towers
- An excellent two tower station with minimal degradation:
  - tower one: 40 meter Yagi and 10 meter stacked Yagis
  - tower two: 20 and 15 meter stacked Yagis
- An excellent three tower station with minimal degradation:
  - tower one: 40 meter Yagi and 10 meter stacked Yagis
  - tower two: 20 meter stacked Yagis
  - tower three: 15 meter stacked Yagis

High Performing Three Tower Station
AA3B



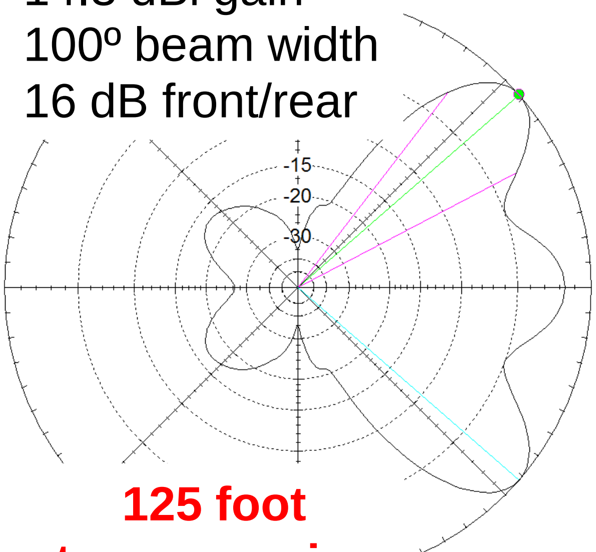
20 Meter 6 Element Stacked Yagi Array Pointing Through an Identical Array

17.8 dBi gain
55º 3 dB beam width
27 dB front/rear



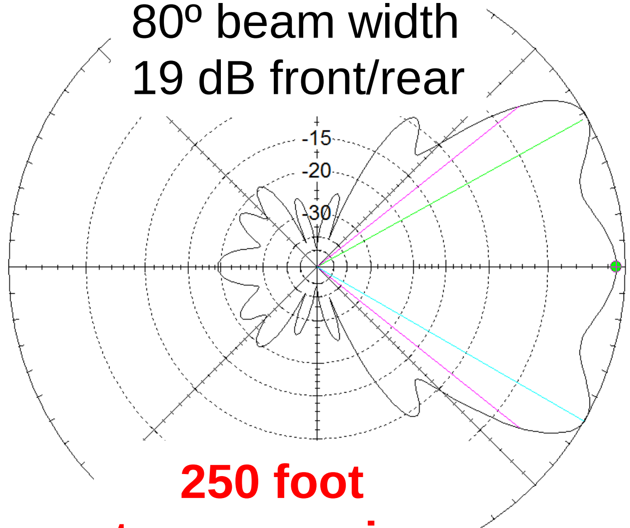
Single tower

14.3 dBi gain
100º beam width
16 dB front/rear



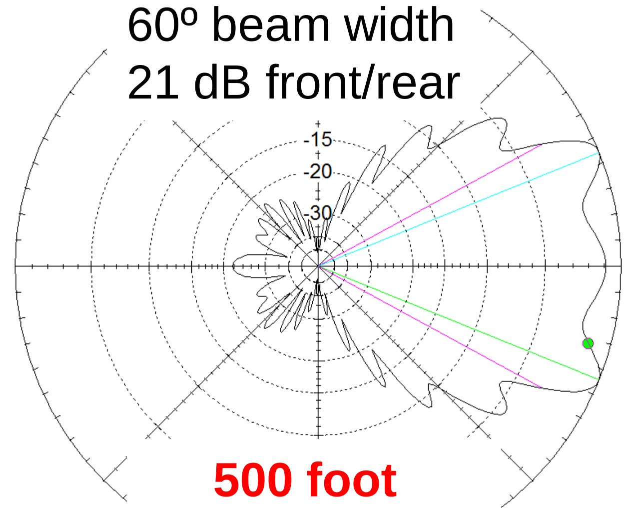
125 foot tower spacing

15.7 dBi gain
80º beam width
19 dB front/rear



250 foot tower spacing

16.5 dBi gain
60º beam width
21 dB front/rear



500 foot tower spacing

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Single Operator Antenna Improvement Ideas for the Years Near Solar Maximum

- Antenna improvements are almost always more effective and less expensive than any other station improvement
- Improved antennas can significantly improve both transmitting and receiving performance
- Receiving antennas make a big improvement on 160 and 80 meters
- A digital wattmeter allows you to monitor transmitter and antenna performance during contests

SO2R Antenna Improvement Ideas in Addition to Single Op Improvements for the Years Near Solar Maximum

- Monoband antennas
  - multiple triband antennas can cause excessive cross-band interference that requires expensive bandpass filtering
  - multiple triband antennas can cause excessive antenna performance degradation

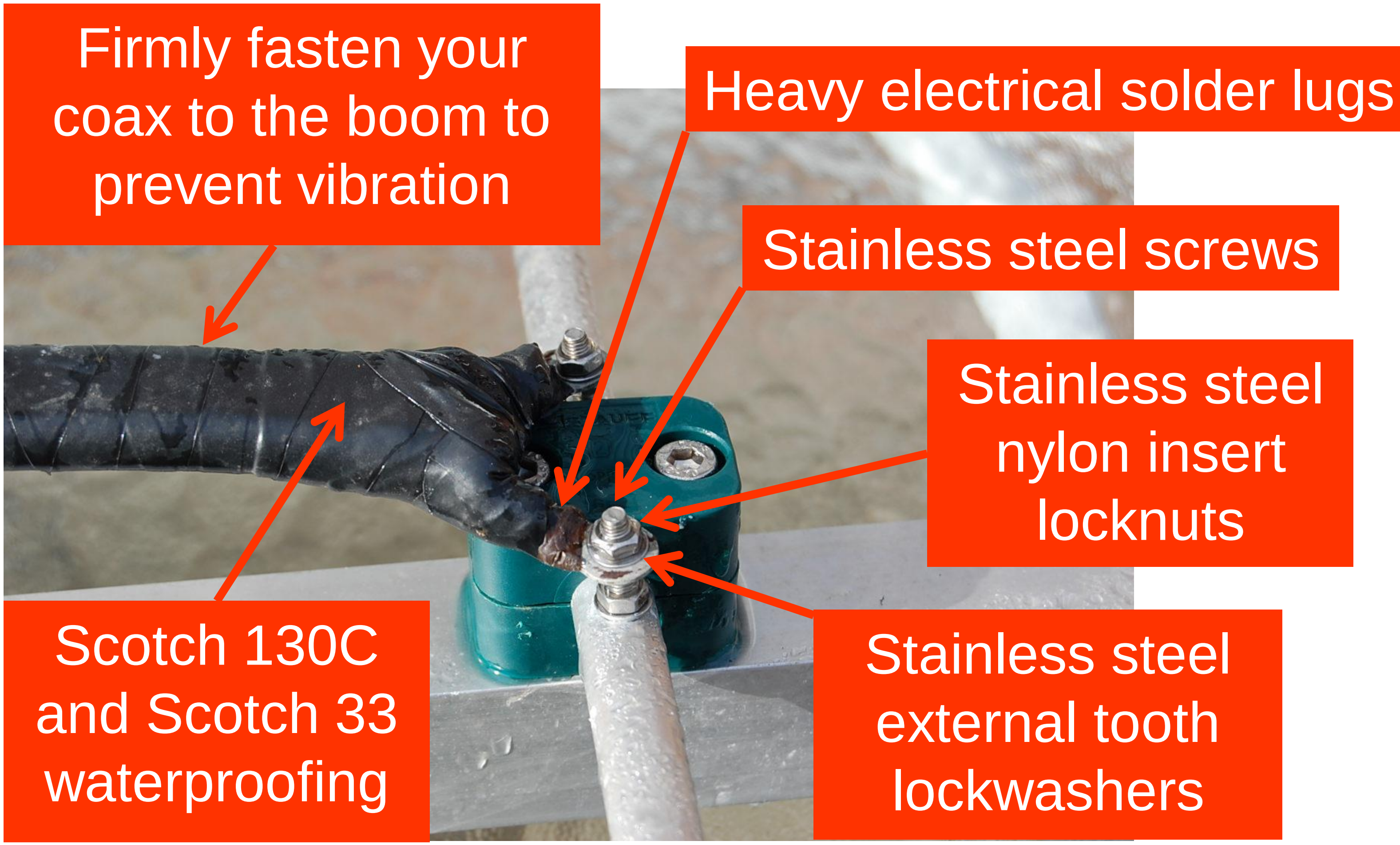
- In-band receiving antennas
  - A 50 foot high 2 or 3 element tribander is an excellent in-band receiving antenna
  - allows SO2R or multi-op operation in the same band
  - must use transmitter interlocks to make it impossible to transmit two simultaneous signals on the same band

When Good Antennas Go Bad…
common antenna system design errors

- Yagi director installed very close to the tower face
  - spacing *less than one tower diameter* shortens effective director length
- 80 meter dipole installed too close to a 40 meter Yagi
  - improper coaxial cable length makes an 80 meter dipole operate like two 40 meter dipoles tightly coupled to the 40 meter Yagi
- 10 and 15 meter Yagis installed too close to each other
  - use 10 foot minimum spacing unless you model their interactions
- 15 meter Yagi pointed through -- or mounted too close to -- a full size 40 meter Yagi
- Conductive guy wires degrading Yagi antenna performance
- 160 and 80 meter vertical antenna performance degradation caused by installing them too close to towers
- Multiple triband Yagis or multiple Yagis for the same band installed on two or more towers without detailed modelling

Antenna Feedpoint

Waterproof and Shakeproof Connections



Performance Evaluations
Inspections
Preventive Maintenance

- Maintaining consistent competitive antenna performance
  - antenna performance evaluations
  - tower, foundation and guy wire inspections
  - guy wire, guy hardware and ground anchor inspections
  - rotator inspections
  - coaxial cable inspections and performance measurements
  - coaxial connector inspections
    - PL-259 shell tightness
    - SO-239 center pin contact pressure

Well Before Your Next Contest Evaluate Your Antenna Strengths and Weaknesses Relative to Your Peers

- Evaluate your transmitting antenna strengths and weaknesses on every band relative to your peers
  - antenna and feedline performance and reliability
- Evaluate your receiving antenna strengths and weaknesses on every band relative to your peers
  - antenna and feedline performance and reliability
- Identify opportunities to improve your transmitting and receiving antenna and feedline performance and reliability
  - understanding the capabilities your peers is very helpful
- Prioritize your list of antenna improvement opportunities
  - prioritize in order of improving your competitiveness

Execute Your Antenna Proof of Performance Checklist Well Before Every Competitive Contest

- Prove that all of your antennas, rotators and feedlines are working properly
  - improve and update your checklist regularly
  - record all performance measurements
- Never enter a competition with unproven antennas
- Prove that all of your antennas, feedlines, towers and rotators are working reliably
  - far enough in advance so you can make necessary repairs well before the contest

Execute Your Tower Inspection Checklist Months Before a Competition

Helps You Avoid Mid-Winter Failures, Reliability Problems and Safety Issues During Your Next Contest

- Measure all guy wire tensions (7 to 15% of breaking strength)
- Inspect guy wires, guy hardware and guy anchors for damage
- Inspect tower plumb and twist
- Inspect your tower base for standing water and
  - corrosion, settling and cracks at the tower-to-concrete interface
- Regularly blow all debris from tower bases to avoid corrosion
- Inspect rotator performance and play
- Inspect the tower for wind damage especially after major storms
- Pay special attention to damaged, loose, missing or corroded:
  - diagonal and horizontal trusses, welds and hardware
  - especially adjacent to guy attachments

At least annual inspections are essential to owning and operating a safe and reliable tower

Tower Inspections and Maintenance Will Help You Avoid Mid-Winter Failures and Reliability Problems During Your Next Contest

- Measure all guy wire tensions (7 to 15% of breaking strength)
- Inspect guy wires, guy hardware and guy anchors for damage
- Inspect tower plumb and twist
- Inspect your tower bases for standing water and
  - corrosion, settling and cracks at the tower-to-concrete interface
  - Use a blower regularly to remove all debris from tower bases to avoid corrosion
- Inspect rotator performance and play
- Inspect your tower for wind damage after every major storm
- Pay special attention to damaged, loose, missing or corroded:
  - diagonal and horizontal trusses, welds and hardware
  - especially adjacent to guy attachments

At least annual tower inspections are essential to your safety

Execute Your Antenna Inspection Checklist Months Before a Competition Helps You Avoid Mid-Winter Failures and Reliability Problems During Your Next Contest

- Inspect coax cable for cuts, cracks, damage and moisture intrusion
  - deteriorated jacket, cuts, chaffing and especially worn rotator loops
  - water intrusion at electrical and physical attachments to antennas
  - deteriorated or inadequate cable attachments to the tower
- Compare coax cable losses and TDR displays to last inspection
- Compare antenna VSWRs to prior measurements
- Inspect connector water proofing and PL-259 tightness
- Inspect rope wear -- its much easier to replace rope before it fails
- Inspect antenna wire for wear and connections to feed lines
- Repair or replace unreliable, failing or overloaded rotators
- Inspect antennas, feed lines and connectors for lightning and wind damage
- Inspect antennas, feed lines and rotators for lightning and wind damage

Annual inspections are essential to antenna, rotator, coax and control cable reliability and performance

When Good Antennas Go Bad…

common coaxial cable errors

- Improperly installed connectors
- PL-259 connectors not gently wrench tightened ¼ turn
- Obsolete N connectors with floating pins
  - if you must use N connectors… use *only* captive pin connectors
- Connectors inadequately protected from water and moisture
  - connectors on towers should be mounted horizontally not vertically
- Coax not securely fastened to the tower
- Coax not electrically bonded to the top and bottom of the tower
- Inadequate waterproofing of the coax connection to the antenna
- Coaxial cable shield exposed to rain at the antenna connection
- Undetected rodent damage to coaxial cable jackets and more

Reduce Coaxial Cable Loss and Improve the Reliability of Your Coaxial Cables and Connectors

- Coaxial cables longer than 300 feet are often used in larger stations
- Andrew Heliax is an ideal choice for lengths up to:
  - 10 meters: 600 feet of LDF5-50A or 300 feet of LDF4-50A
  - 15 meters: 700 feet of LDF5-50A or 350 feet of LDF4-50A
  - 20 meters: 900 feet of LDF5-50A or 450 feet of LDF4-50A
  - 40 meters: 1200 feet of LDF5-50A or 600 feet of LDF4-50A
- Be cautious of the windload and weight (including ice load) of large Heliax cables mounted on light duty towers
- Failure to adequately protect connectors from water intrusion is a very common cause of coaxial cable deterioration
- Coaxial cables must be securely attached to your tower

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Improving the Reliability of Your Coaxial Cable Connectors

- N and UHF connectors are the most common choices
- No significant loss in either N and UHF connectors at HF
- No significant difference in the VSWR of N and UHF connectors at HF
- High quality silver plated UHF connectors provide much more center pin mating force than N connectors
  - eliminates cross-station interference and connector failures from potentially unreliable N connector center pin mating force
  - avoid saving a few dollars on cheap unbranded hamfest connectors
- Avoid use of adapters, but if necessary be sure they are name-brand silver plated adapters, not nickel plated
- Use a wrench to gently tighten UHF connectors just 1/4 turn
- Inspect center pin mating pressure of SO-239 connectors

The Gold Standard PL-259 Connector
Amphenol 83-1SP

www.dxengineering.com/parts/aml-83-1sp-6

newark.com/amphenol-rf/83-1sp/rf-coaxial-uhf-plug-straight-50ohm/dp/59K0534

This is the worst place to save money
in a competitive contest station

Coaxial Cable Connector Waterproofing

Cover your connectors with two <u>50% overlapped</u> layers of Scotch 130C linerless rubber splicing tape stretched to 50% of its original width, sticky side <u>facing out</u>

Cover the Scotch 130C with two <u>50% overlapped</u> layers of Scotch 33+ or Scotch 88 vinyl electrical tape