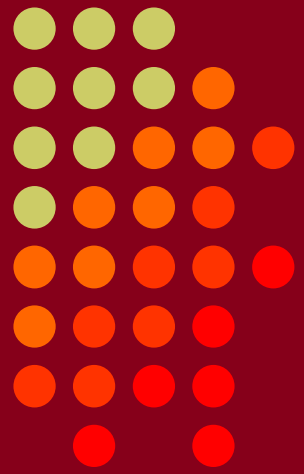
# Competitive Transmitting Antennas for Solar Maximum

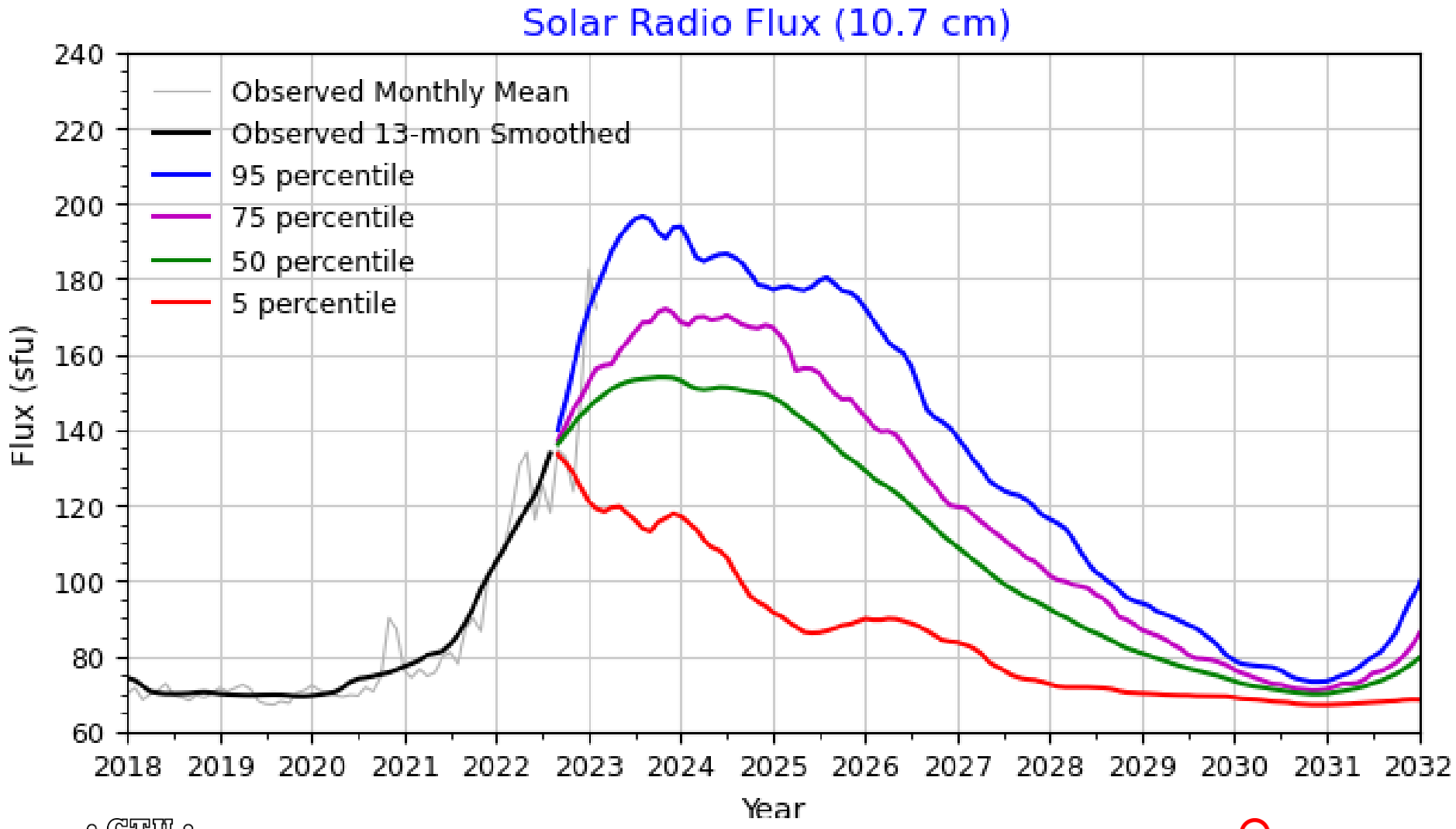
- What's important as solar maximum nears?
- When will it arrive and how long will it last?
- Vertically polarized 160 meter antennas
- Horizontally polarized 80 to 10 meter antennas
- Single Yagi stations
- Stacked Yagis
- Multi-tower stations
- When good antennas go bad…



• CTU •
CONTEST UNIVERSITY

ICOM

# Solar Cycle 25 Solar Flux Index Forecast
# NASA Marshall Space Flight Center
# 2 Mar 2023

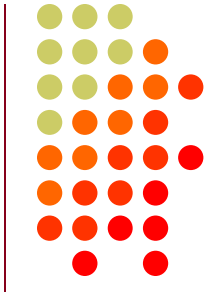



CONTEST UNIVERSITY

www.nasa.gov/msfcsolar

ICOM

# How Propagation is Affected Over the Next Five Years as Solar Maximum Arrives Next Year Then Starts to Decline About 2 Years Later



Solar maximum propagation conditions began in January 2023

Solar maximum is likely to occur next year

10 and 15 meter worldwide DX will persist later into the night for at least the next 2 years

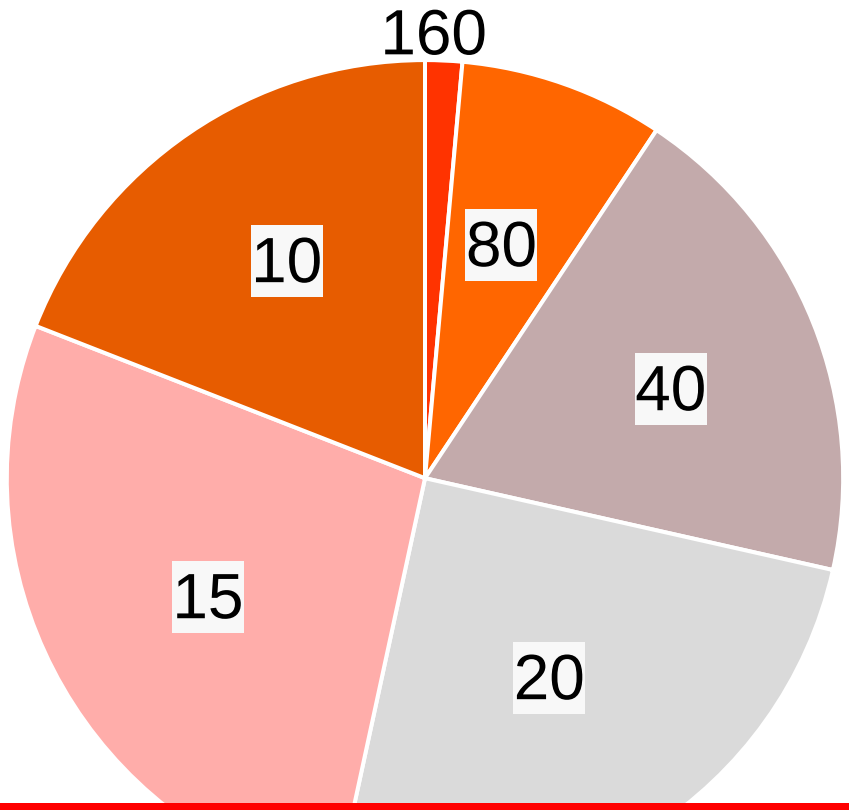
Excellent 10 meter worldwide propagation will continue for at least the next 3 years

Disturbed geomagnetic conditions will become much more frequent next year, persisting for about 7 years

10 meter propagation starts to slowly decline in about 4 years

15 meter propagation starts to slowly decline in about 5 years

# Relative Number of CW DX Contest QSOs Per Band as Solar Cycle 25 Nears Solar Maximum




10 and 15 meters have become much more productive near solar maximum
40 and 20 continues to be very productive near solar maximum
80 is less productive near solar maximum
160 is much less productive near solar maximum

# Transmitting Antenna Elevation Angles as Solar Cycle 25 Nears Solar Maximum

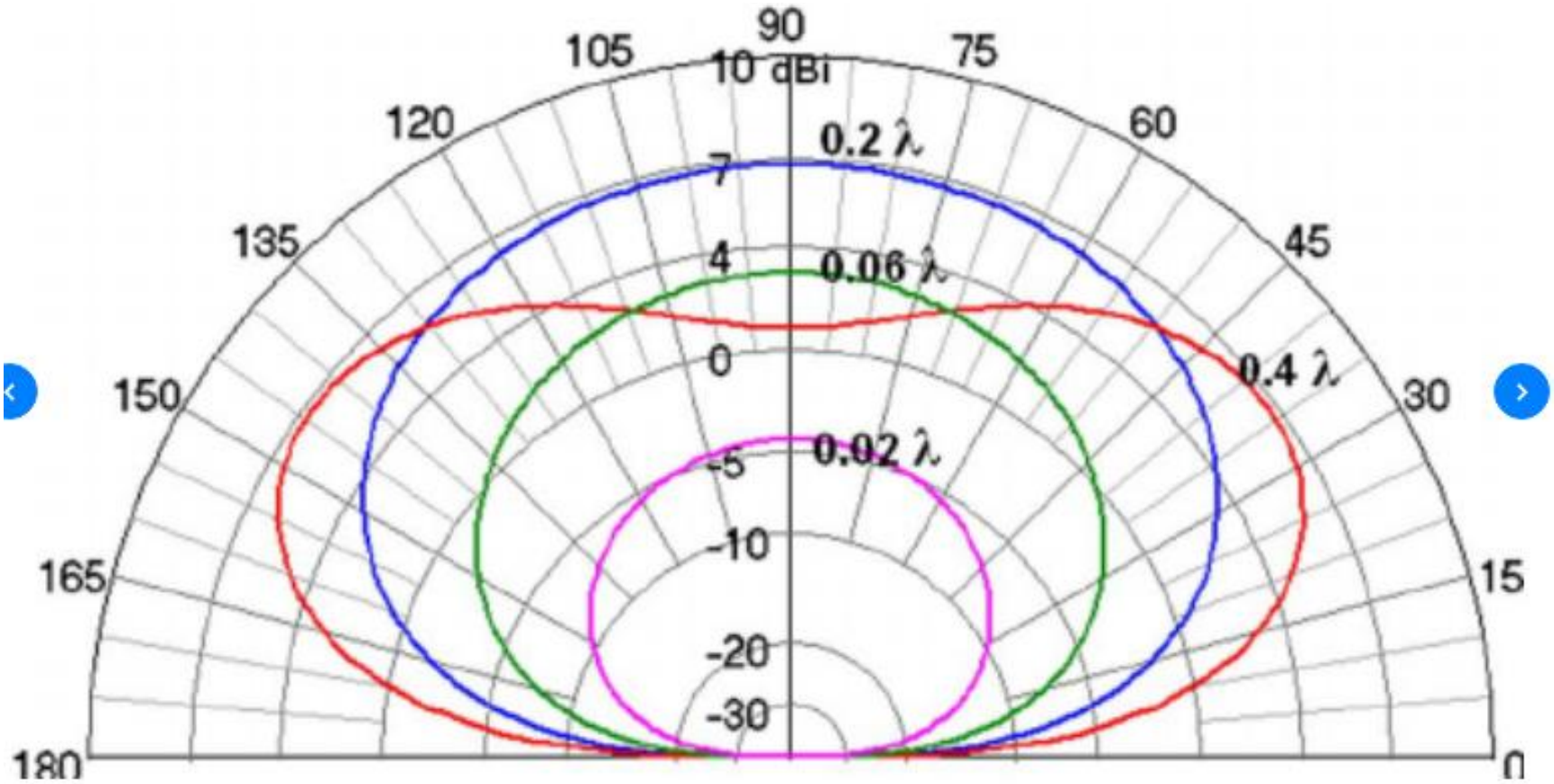
- **10 meters** - early morning to post-sunset worldwide DX band
  - most DX propagation is at low elevation angles **5 to 10 degrees**
  - marginal DX paths require very low elevation angles **well below 5 degrees**
- **15 meters** - pre-sunrise to hours after sunset worldwide DX band
  - most DX propagation is at low to mid elevation angles **5 to 15 degrees**
  - marginal DX paths require very low elevation angles **well below 5 degrees**
- **20 meters** - 24 hour very crowded competitive worldwide DX band
  - DX propagation covers low, mid and high elevation angles **5 to 20 degrees**
  - marginal DX paths require low elevation angles **below 5 degrees**
- **40 meters –** pre-sunset to post-sunrise worldwide DX band
  - requires a broad range of elevation angles **10 to 25 degrees**
  - marginal DX paths require low elevation angles **below 10 degrees**
- **80 meters** - post-sunset to sunrise less reliable, weaker DX band
  - use very efficient antennas covering a broad range of angles **10 to 25 degrees**
- **160 meters** - much less reliable, mostly weak signal DX band
  - **vertical antennas *almost always*** provide much better DX performance

CTU CONTEST UNIVERSITY

Competitive stations near solar maximum need very effective 15 and 10 meter antennas

ICOM

# 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**

CTU CONTEST UNIVERSITY

ICOM

# 6 dB of "Free" Ground Gain

- Horizontally polarized dipoles, Yagis or quads
  - easily provide 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
  - *but nearby antennas can destroy ground gain, antenna gain and directivity*
- Some vertically polarized antennas achieve nearly 6 dB of ground gain
  - but only over highly conductive soil such as a salt marsh or ocean front
- Competitive DX contest stations require high horizontally polarized 40 through 10 meter antennas for low angles to Japan and Asia
- Stacked Yagis provide additional gain by suppressing unwanted high angle radiation and redistributing the power into low angles
  - *if installed at proper heights and spacings to obtain significant stacking gain*
  - a Stackmatch allows selection of the optimum elevation angle

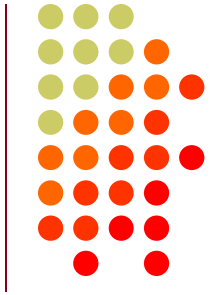
Horizontal antennas easily achieve 6 dB of ground gain when installed at proper heights

# Vertical Polarization for 160 Meters

- 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

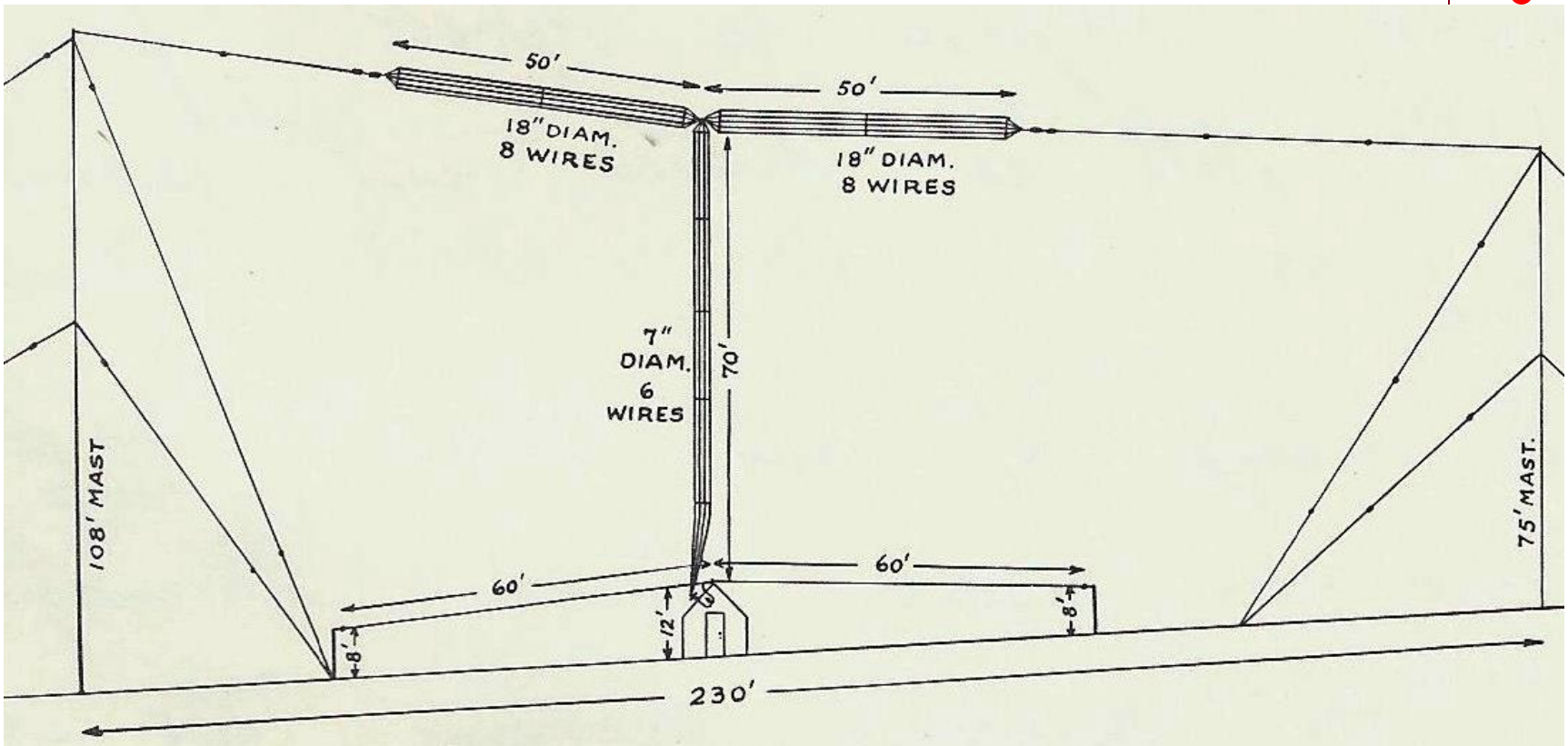
Verticals *almost always* provide much better DX performance than horizontal 160M antennas

# 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 four or more) elevated 125 foot radials
      - but only if 30 to 60 shallow buried 125 foot radials are not possible
    - a K2AV folded counterpoise is a good alternative for small lots
- Inverted-L, T and umbrella antennas are good alternatives
  - 50 feet or higher (as short as 35 feet with reduced performance)
  - supported by a tower, mast or trees
- or a corner fed delta loop or corner fed inverted-U antenna

# Cage T-Vertical Used by 1BCG at about 1500 kHz during the 1921 Transatlantic Tests

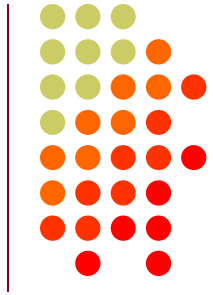



By far the strongest North American signal heard in Europe during the 1921 Transatlantic Tests

# 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 50 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 for each vertical

# High Performance Transmitting Antennas for 80 Meter DX

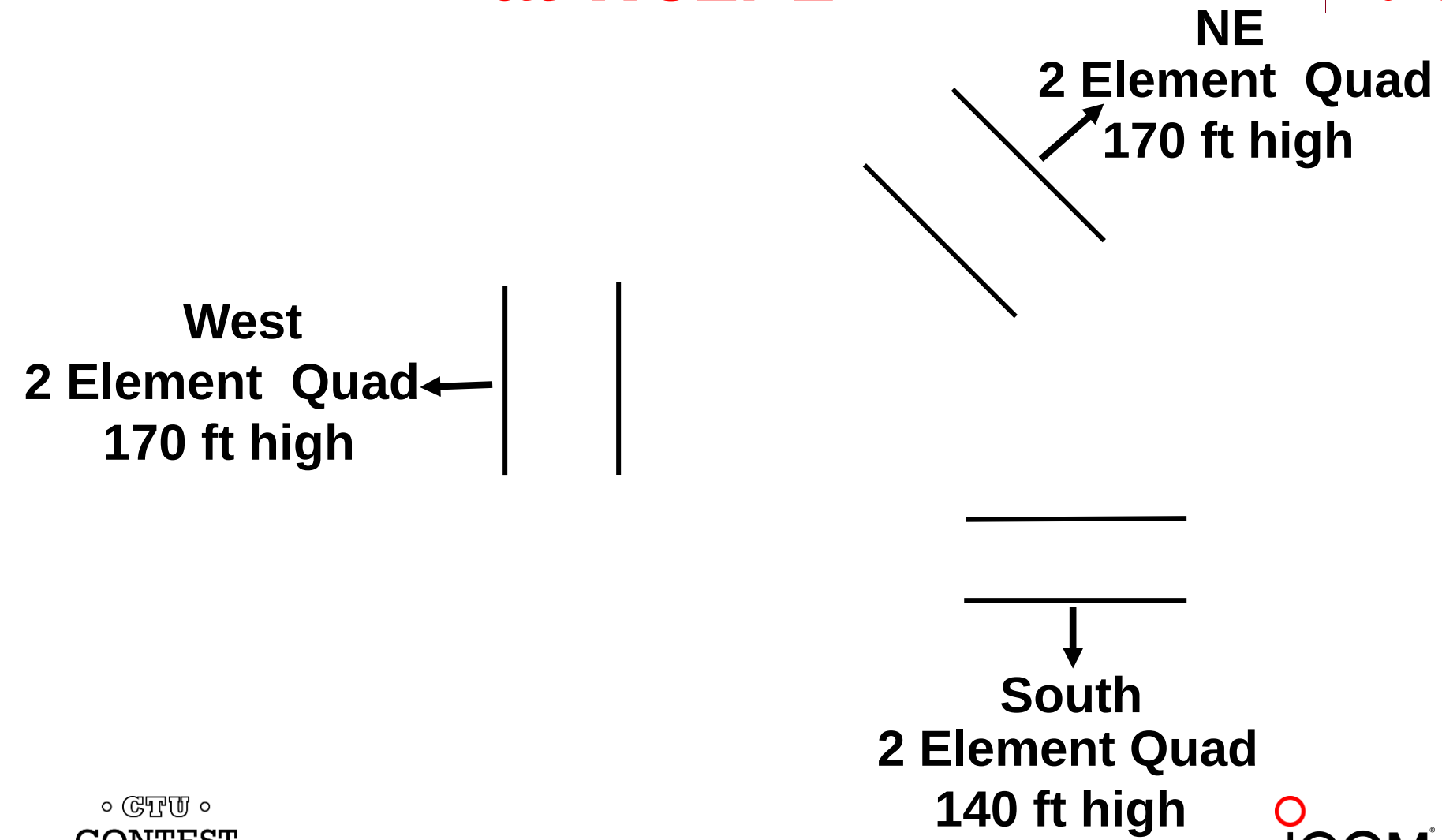


- Horizontal dipole at least 70 to 100 feet high
  - higher is better
- 65 foot vertical
  - install at least 30 to 60 shallow buried 65 foot radials
    - or at least two (but preferably four or more) elevated 65 foot radials
      - only if shallow buried radials are not possible
  - ***verticals are very susceptible to degradation by nearby tall towers***
    - at least 70 feet from towers more than 40 ft 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 vertically polarized corner fed delta loop or corner fed inverted-U

# K3ZO (SK) Installed his 3 Element 80 Meter Yagi at 140 Feet in 1984

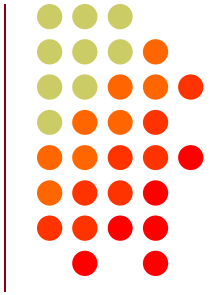
K3ZO's success with this 3 element Yagi changed my thinking about 80 meter antennas for DX

# 80 Meter Horizontally Polarized Transmitting Antenna Layout at W3LPL



# 80 Meter 4-Square Vertical Array

## very competitive high performance alternative to a high 80 meter horizontal antenna



- A four square vertical array is very competitive with high horizontally polarized Yagis and quads
- *Install at least 70 ft from towers more than 40 ft tall*
  - 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

# Comtek 4-Square Controller


dxengineering.com/search/brand/comtek

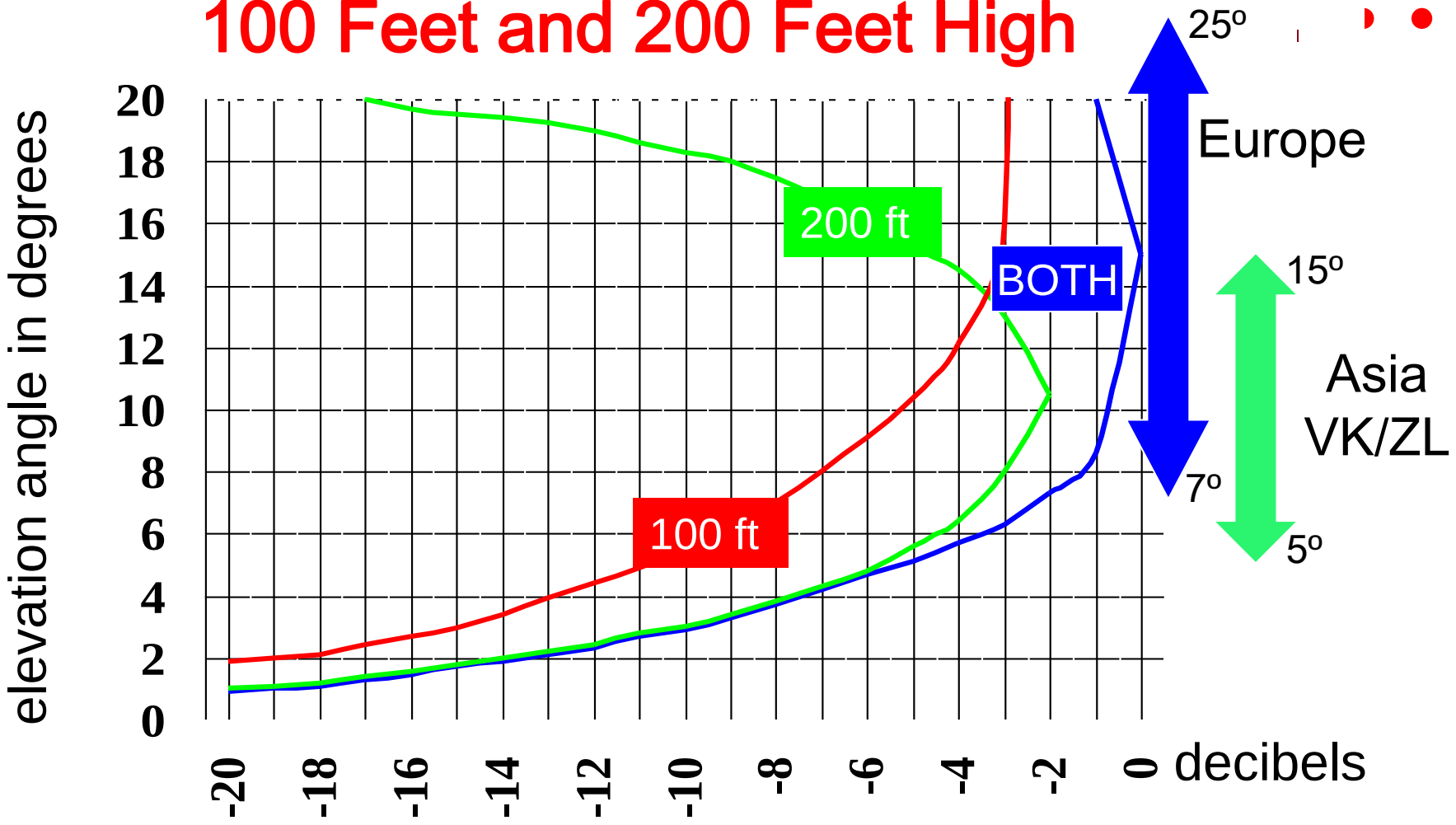
# High Performance 40M Antennas

- Horizontal dipole at least 70 feet high
  - 13 to 45 degree elevation pattern at -3 dB points
  - otherwise use a vertical or a four-square vertical array with 30 to 60 radials
- Higher gain: 2 element “shorty 40” Yagi at least 70 to 100 ft high
  - 10 to 30 degree elevation pattern at -3 dB points
  - significant improvement over a simple horizontal dipole for DX
  - a Cushcraft XM-240 at 100 feet high is very cost effective
  - a 2 element Moxon 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 5º to 25º are needed

# The First Known 40 Meter Rotatable Yagi
# 2 Element Full Size Yagi at 60 Feet
# Constructed by W9LM in 1950

Shortly after testing his new 40 meter Yagi, W9LM removed his 40 meter phased verticals

# Cushcraft XM-240
# 2 Element 40 Meter Yagi

The most popular “Shorty Forty” Yagi

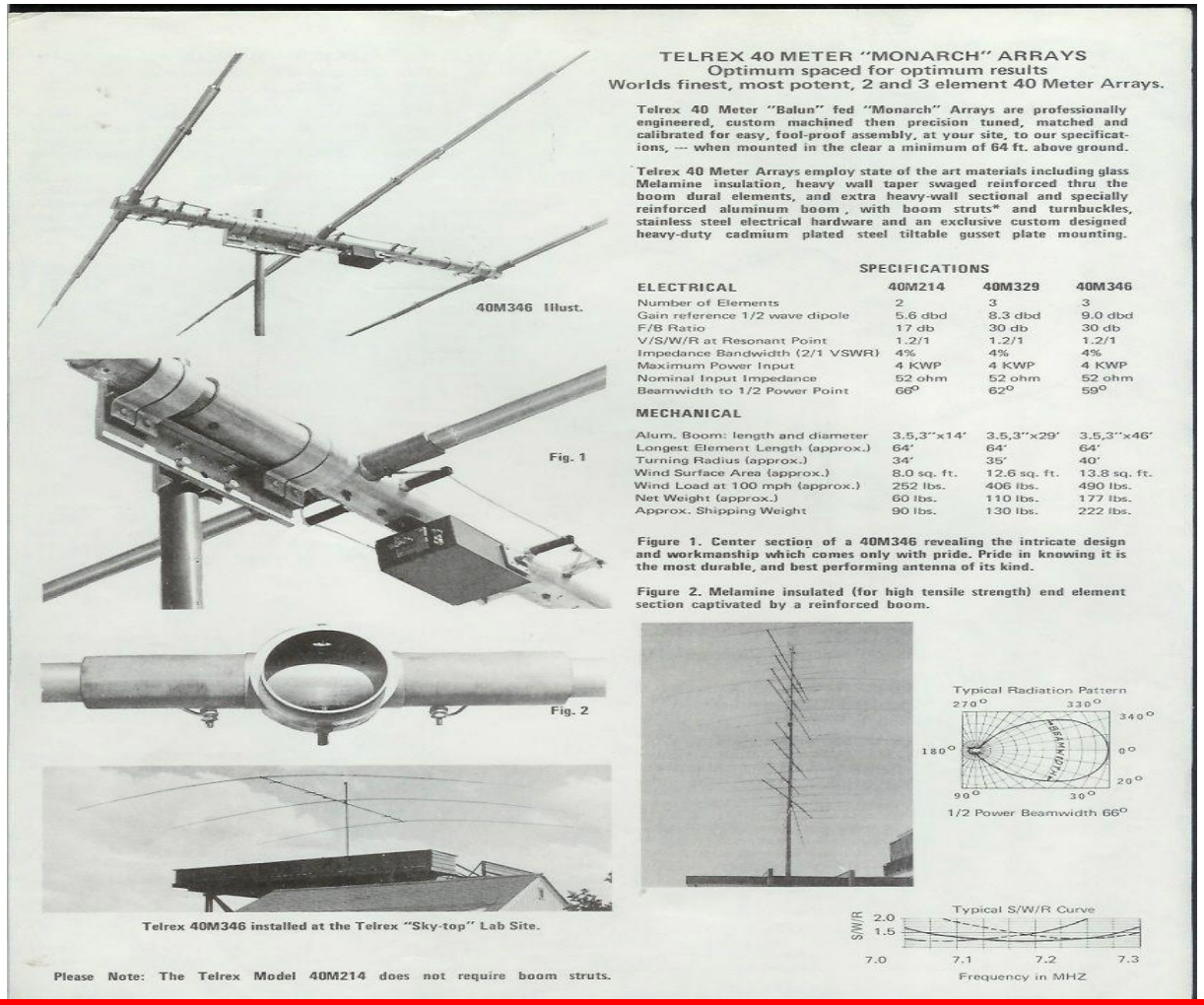
dxengineering.com/parts/csh-xm240

# 40 Meter Moxon

VSWR less than 1.4:1 from 7.0 to 7.3 MHz
22 foot boom and 48 foot elements
with no loading coils

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

# Telrex (near) Full Size 3 Element Yagi Revolutionized 40 meter Dxing in 1955



TELREX 40 METER "MONARCH" ARRAYS
Optimum spaced for optimum results
Worlds finest, most potent, 2 and 3 element 40 Meter Arrays.

Telrex 40 Meter "Balun" fed "Monarch" Arrays are professionally engineered, custom machined then precision tuned, matched and calibrated for easy, fool-proof assembly, at your site, to our specifications, --- when mounted in the clear a minimum of 64 ft. above ground.

Telrex 40 Meter Arrays employ state of the art materials including glass Melamine insulation, heavy wall taper swaged reinforced thru the boom dural elements, and extra heavy-wall sectional and specially reinforced aluminum boom, with boom struts* and turnbuckles, stainless steel electrical hardware and an exclusive custom designed heavy-duty cadmium plated steel tiltable gusset plate mounting.

40M346 Illust.

Fig. 1

Fig. 2

Telrex 40M346 installed at the Telrex "Sky-top" Lab Site.

Please Note: The Telrex Model 40M214 does not require boom struts.

SPECIFICATIONS

| ELECTRICAL | 40M214 | 40M329 | 40M346 |
|---|---|---|---|
| Number of Elements | 2 | 3 | 3 |
| Gain reference 1/2 wave dipole | 5.6 dbd | 8.3 dbd | 9.0 dbd |
| F/B Ratio | 17 db | 30 db | 30 db |
| V/S/W/R at Resonant Point | 1.2/1 | 1.2/1 | 1.2/1 |
| Impedance Bandwidth (2/1 VSWR) | 4% | 4% | 4% |
| Maximum Power Input | 4 KWP | 4 KWP | 4 KWP |
| Nominal Input Impedance | 52 ohm | 52 ohm | 52 ohm |
| Beamwidth to 1/2 Power Point | 66° | 62° | 59° |
| **MECHANICAL** | | | |
| Alum. Boom: length and diameter | 3.5,3"x14' | 3.5,3"x29' | 3.5,3"x46' |
| Longest Element Length (approx.) | 64' | 64' | 64' |
| Turning Radius (approx.) | 34' | 35' | 40' |
| Wind Surface Area (approx.) | 8.0 sq. ft. | 12.6 sq. ft. | 13.8 sq. ft. |
| Wind Load at 100 mph (approx.) | 252 lbs. | 406 lbs. | 490 lbs. |
| Net Weight (approx.) | 60 lbs. | 110 lbs. | 177 lbs. |
| Approx. Shipping Weight | 90 lbs. | 130 lbs. | 222 lbs. |

Figure 1. Center section of a 40M346 revealing the intricate design and workmanship which comes only with pride. Pride in knowing it is the most durable, and best performing antenna of its kind.

Figure 2. Melamine insulated (for high tensile strength) end element section captivated by a reinforced boom.

Typical Radiation Pattern
270° 330° 340° 180° 0° 20° 90° 30°
1/2 Power Beamwidth 66°

Typical S/W/R Curve
S/W/R 2.0 1.5
7.0 7.1 7.2 7.3
Frequency in MHZ

W0MLY W1FZ K2DGT K2GL K2LWR WA2SFP(W2PV) W8FGX W8VSK W9EWC

CTU CONTEST UNIVERSITY

ICOM

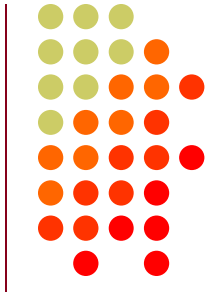
# W3KRQ's Homebrew Full Size 3 Element 40 Meter Yagi in 1959

Contesters and DXers built many 3 element 40M Yagis
W3GRF W3KRQ W3MSK (W3AU) W4BVV W8JIN

# 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 receiving antenna

# High Performance 20M Antennas

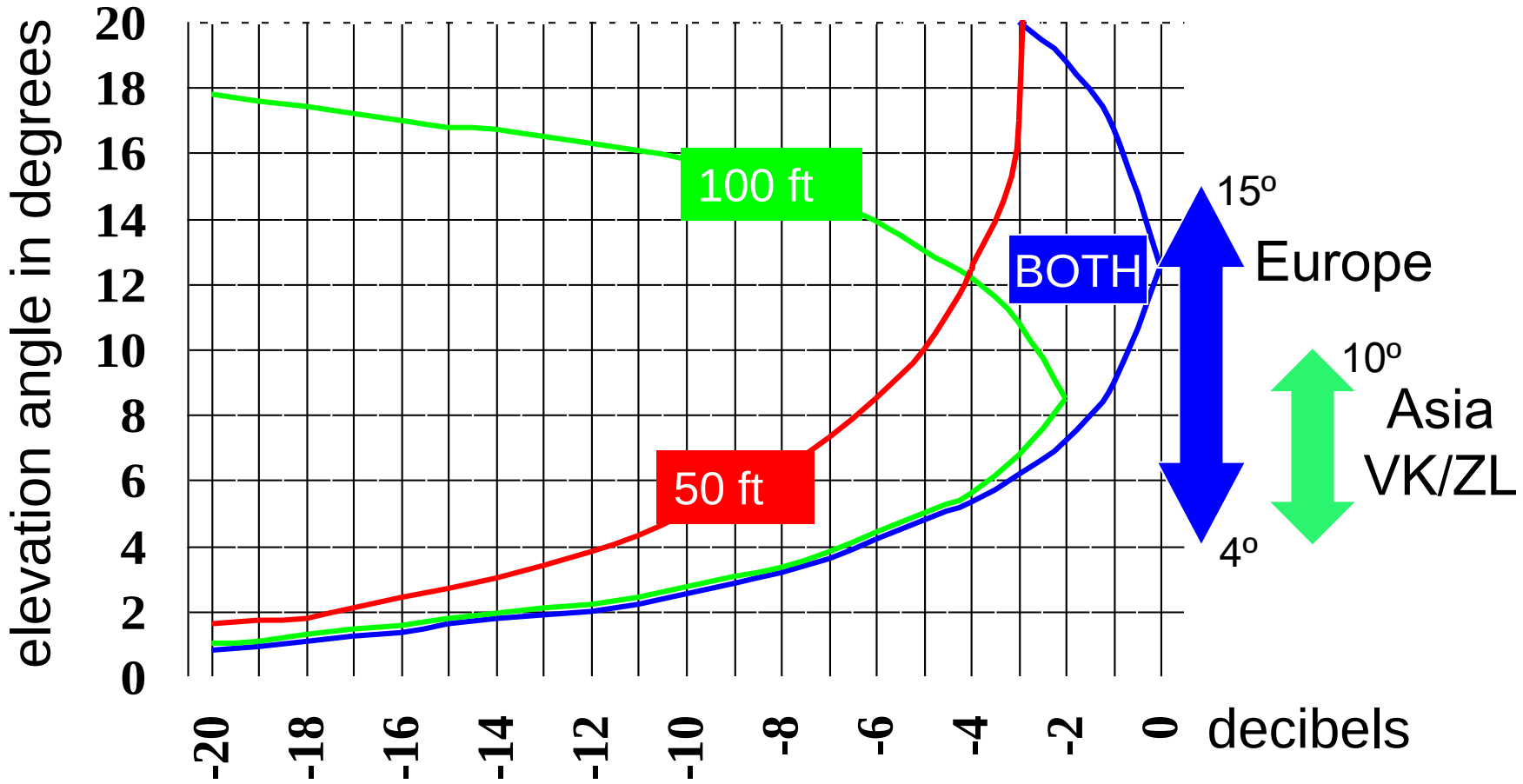
- A horizontal Yagi or quad is *always* the best choice
  - if you can install your antenna at least 35 feet high
    - 13 to 45 degree elevation beam pattern at -3 dB points
- Moderate gain: small tri-band Yagi, hex-beam, Moxon or quad
  - a small Yagi at least 50 to 70 feet high will produce good DX 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

CTU CONTEST UNIVERSITY

Elevation angles from <5º to 20º are needed

ICOM

# Stacked 5 Element 20 Meter Yagis
## 48 Foot Booms
## 50 and 100 Feet High

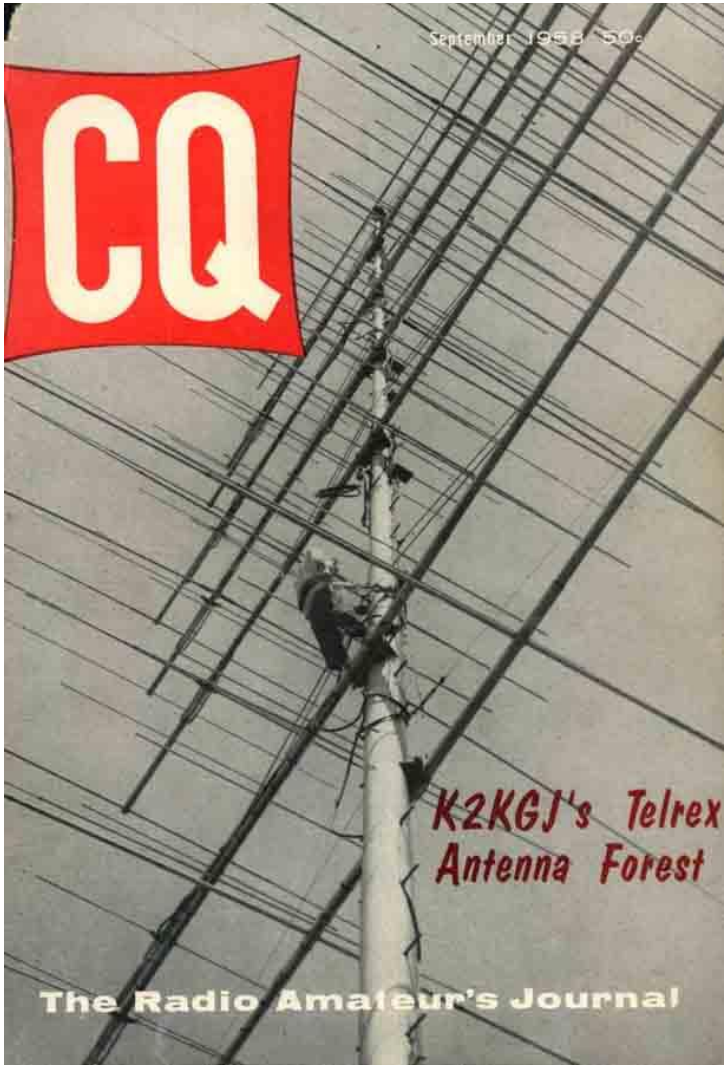



CTU CONTEST UNIVERSITY

Elevation angles from <5º to 15º are needed

ICOM

# Telrex 20, 15 and 10 meter stacked Yagis revolutionized competitive HF antennas in 1955



# Array Solutions Stack Match

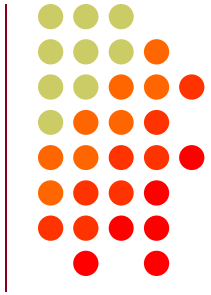

**The Stackmatch revolutionized the performance and flexibility of stacked Yagi antennas**

CTU CONTEST UNIVERSITY

www.arraysolutions.com/Products/stackmatch.htm

ICOM

# High Performance 15M Antennas



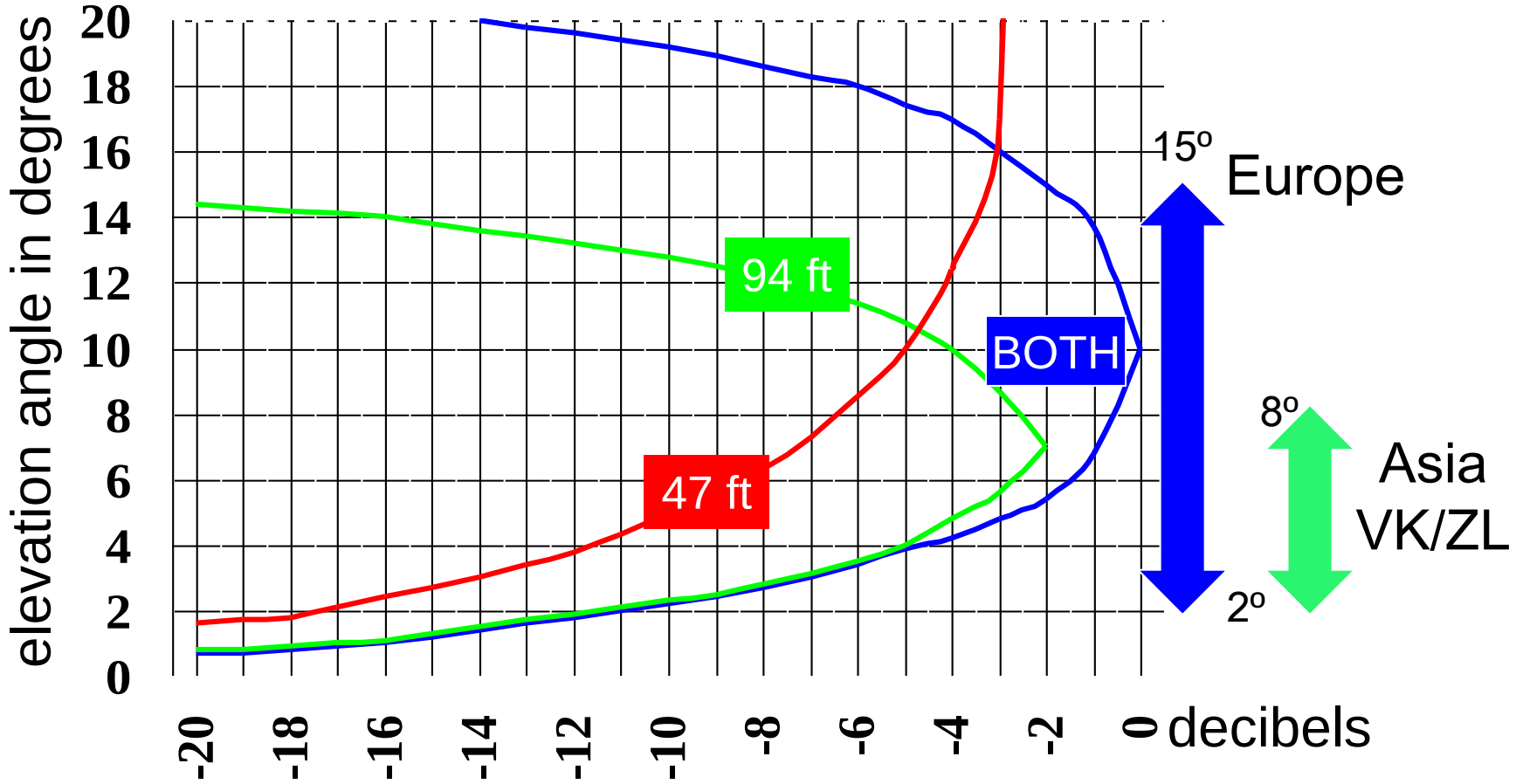
- A horizontal Yagi or quad is *always* the best choice
  - if you can install your antenna at least 25 feet high
    - 13 to 45 degree elevation beam pattern at -3 dB points
- Moderate gain: small tri-bander Yagi, hex-beam, Moxon or quad
  - a small Yagi at least 50 to 70 feet high will produce good 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

CTU CONTEST UNIVERSITY

Elevation angles from <5º to 15º are needed

ICOM

# Stacked 6 Element 15 Meter Yagis
## 48 Foot Booms
## 47 and 94 Feet High




Elevation angles from <5º to 15º are needed

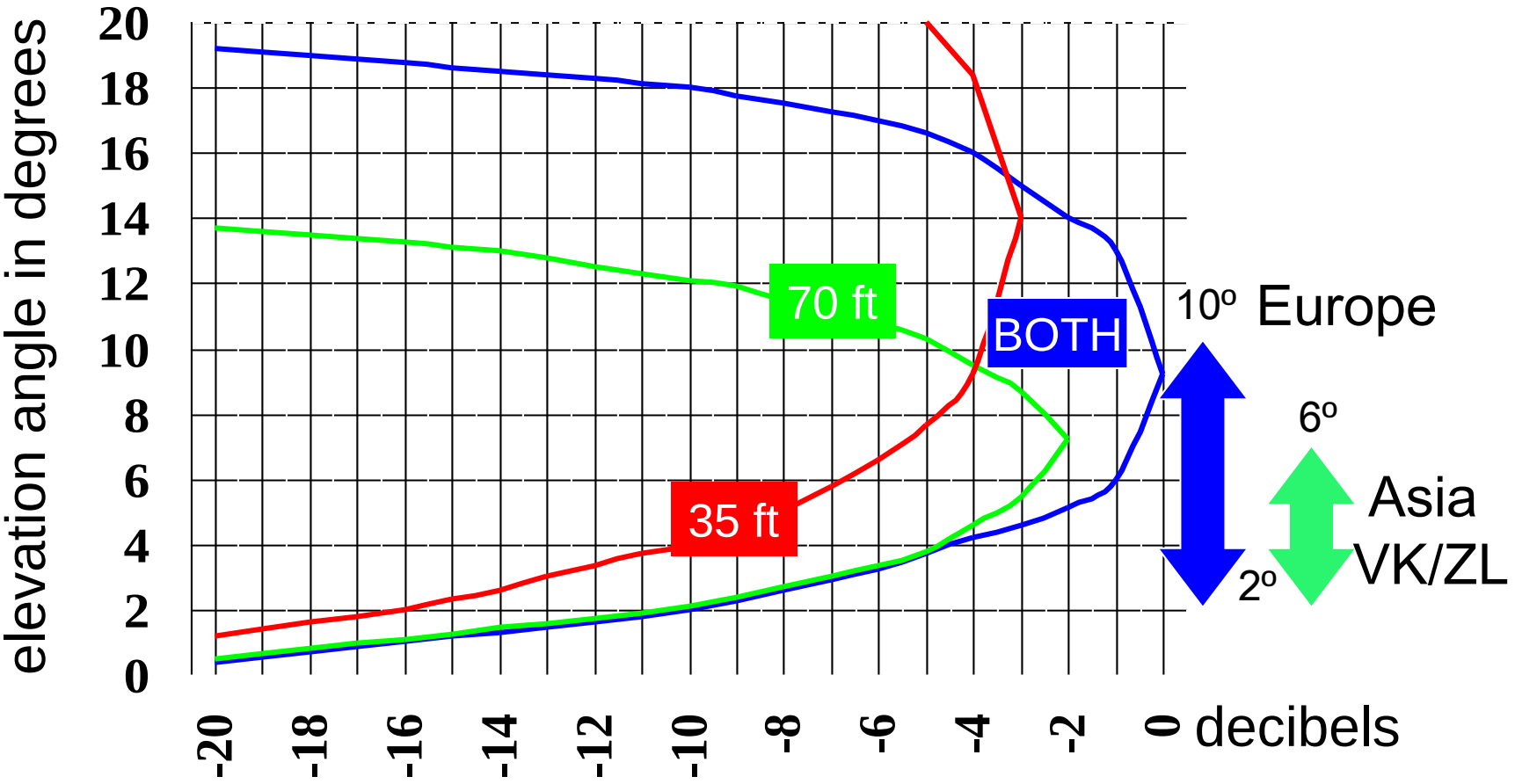
# High Performance 10M Antennas

- 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



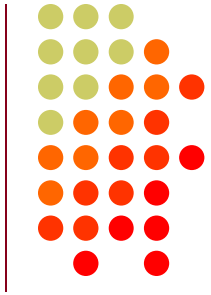
Elevation angles from <5º to 10º are needed

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




Elevation angles from <5º to 10º are needed

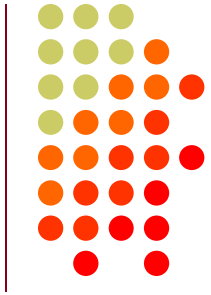
# Competitive One Tower Antenna Systems



- 50 to 70 foot tower and a small rotator (e.g., HyGain Ham-IV)
  - small tri-band Yagi, Hex-beam or quad
  - 40 and 80 meter dipoles and 160 meter inverted-L
- 70 to 90 foot tower and a medium rotator (e.g. HyGain T2X)
  - Cushcraft XM-240 two element 40 meter Yagi
  - large tri-band Yagi such as the DX Engineering Skyhawk
  - 80 meter dipole and 160 meter inverted-L
- 100 to 140+ foot tower and a large rotator (e.g., M2 Orion)
  - Cushcraft XM-240 two element 40 meter Yagi
  - monoband Yagis such as the Hy-Gain LJ series on ring rotators
  - 80 meter dipole and 160 meter inverted-L

# Multi-Tower Antenna Systems

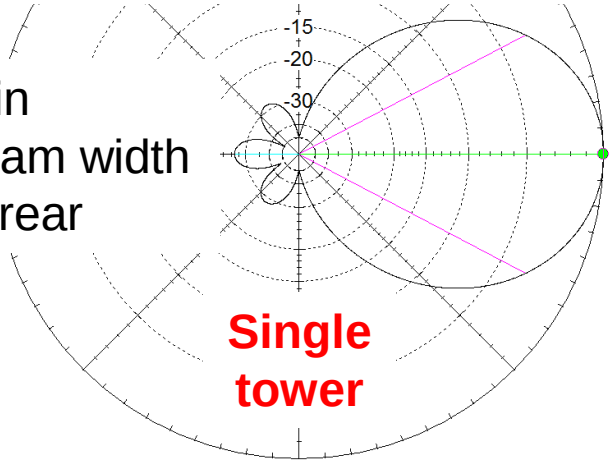
## Designing a multi-tower station with acceptable degradation from multiple antennas and close spaced towers is an antenna modelling challenge



- 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
- An excellent design for two towers with minimal degradation:
  - tower one: 40 meter Yagi and 10 meter stacked Yagis
  - tower two: 20 and 15 meter stacked Yagis
- An excellent design for three towers 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

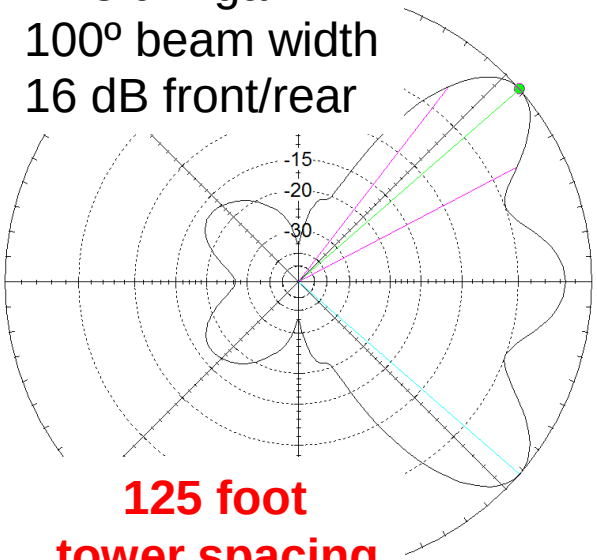
# 20 Meter 6 Element Stacked Yagi Array Pointing Through an Identical Array

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



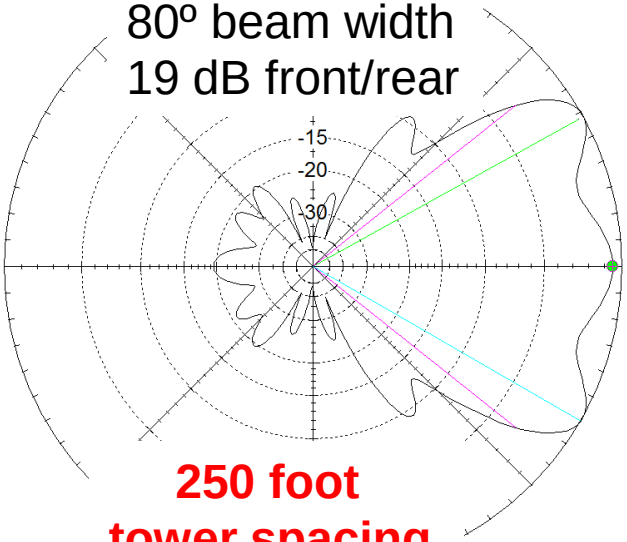

**Single tower**

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



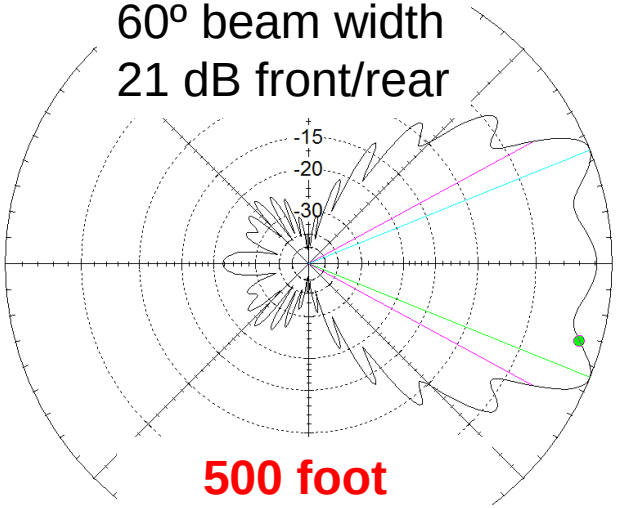

**125 foot tower spacing**

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



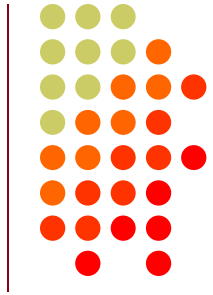

**500 foot tower spacing**

CONTEST UNIVERSITY

ICOM

# When Good Antennas Go Bad…

## antenna system design issues



- Yagi director installed too 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 or 15 meter Yagi
  - A bad choice of coaxial cable length makes an 80 meter dipole operate like two 40 meter dipoles tightly coupled to the 40 or 15 meter Yagi
- 10 and 15 meter Yagis installed too close to each other
  - use 10 foot minimum spacing unless you model their interactions first
- 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

# When Good Antennas Go Bad…

## common coaxial cable issues

- 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 not adequately 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 worse

# Amphenol 83-1SP
# PL-259 Connector

Shell is labeled exactly:
Amphenol 83-1SP

Silver Plated
Center Pin

Silver Plated
Body

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



This is not a good place to save a few dollars

# Waterproof your Connectors!



Cover your connectors with two 50% overlapped layers of Scotch 130C self-vulcanizing linerless rubber splicing tape

- stretched to 50% of its original width
- sticky side facing out

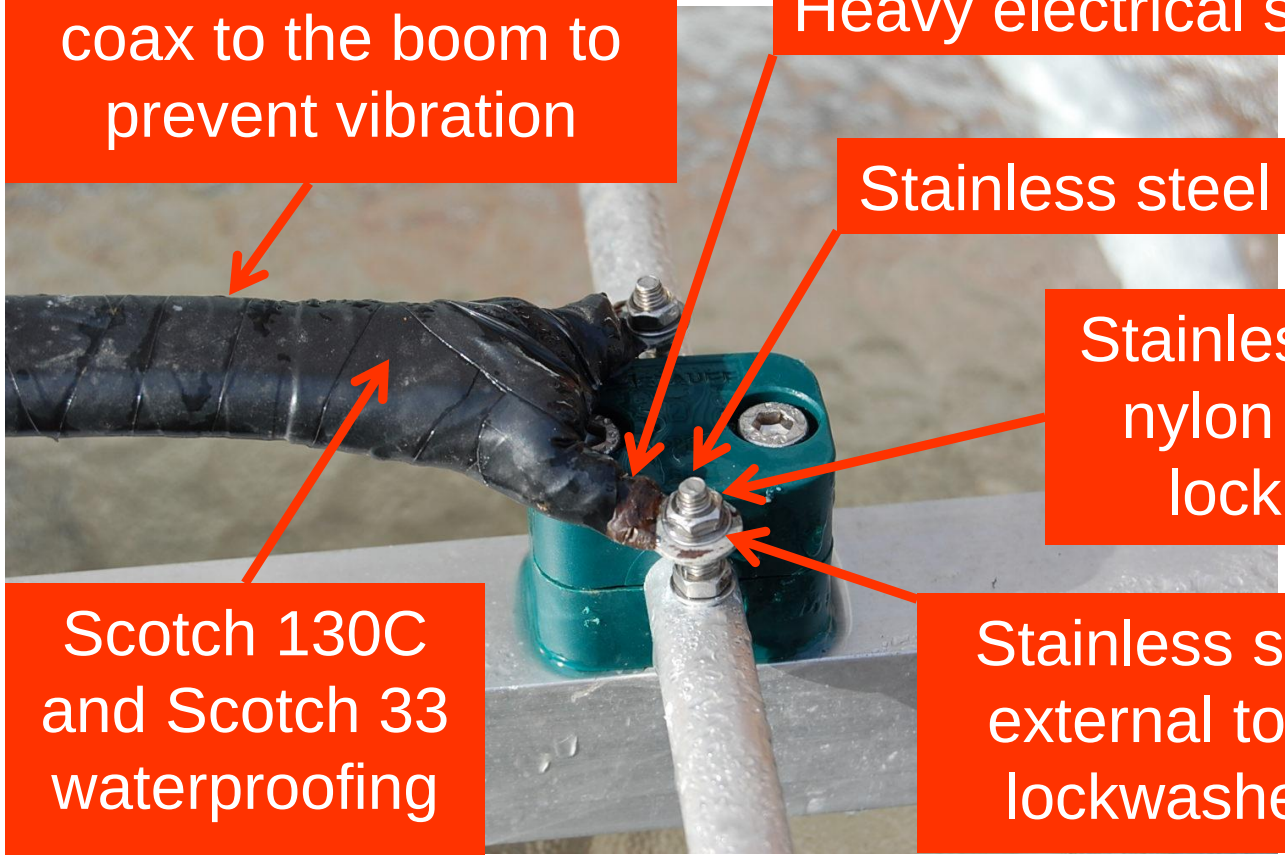
homedepot.com/p/3M-Scotch-3-4-in-x-30-ft-Linerless-Rubber-Splicing-Tape-41717-BX-10/205523418

Cover the Scotch 130C tape with two 50% overlapped layers of Scotch Super 33+ vinyl electrical tape

homedepot.com/p/Scotch-Super-33-3-4-in-x-66-ft-x-0-007-in-Vinyl-Electrical-Tape-Black-6132-BA-10/304653556

# Antenna Feedpoint

## Waterproof and Shakeproof Connections



# When Good Antennas Go Bad…

## Performance Evaluation, Inspections, and Preventive Maintenance

- Maintaining 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
    - a time domain reflectometer is an excellent investment
  - coaxial connector inspections
    - PL-259 and SO-239 center pin engagement pressure
    - Tighten all PL-259s just enough so they can't be removed by hand