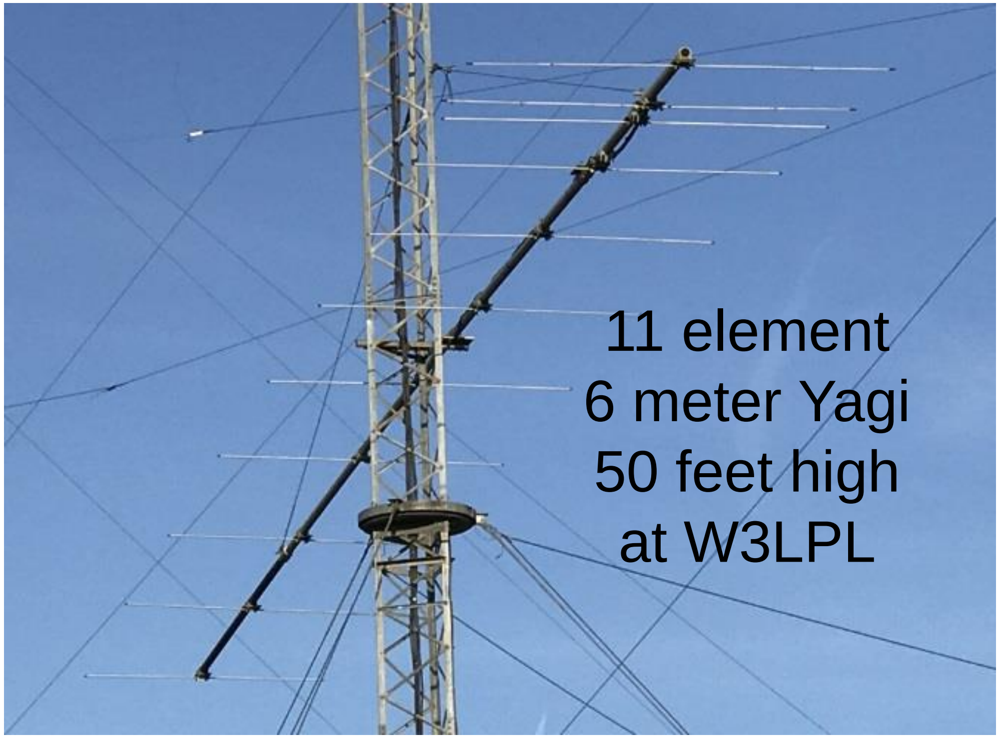
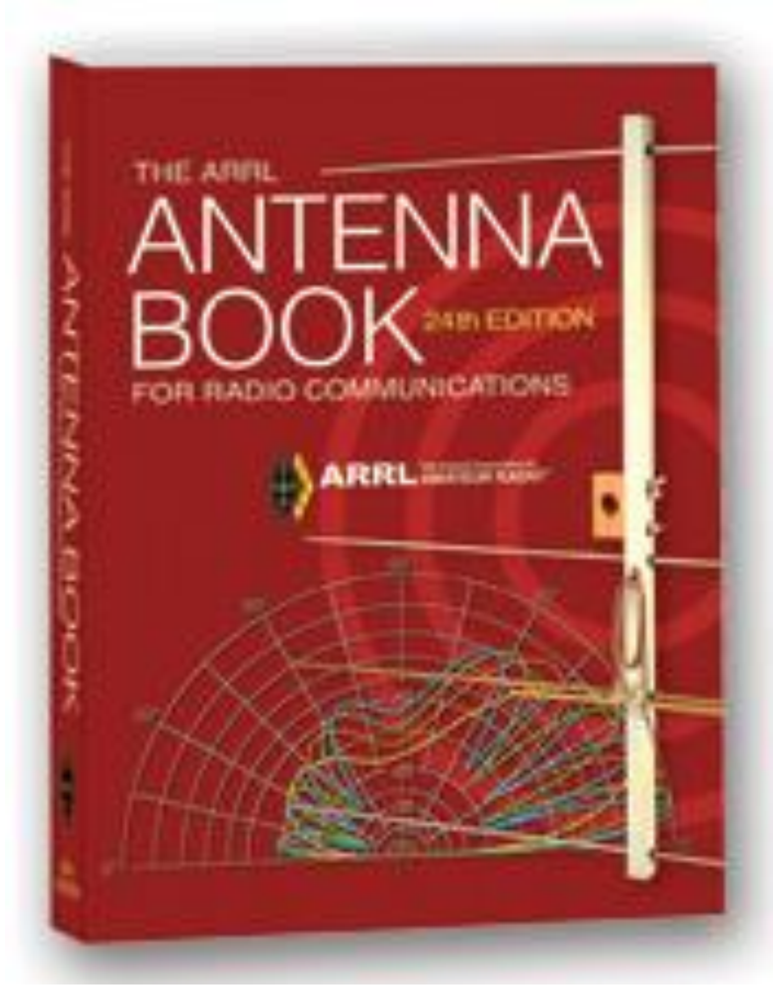
Selecting, Constructing, Operating and Maintaining High Performance 6 Meter Yagis



Frank Donovan
W3LPL
donovanf@erols.com

The Most Valuable Investment for any Antenna Builder

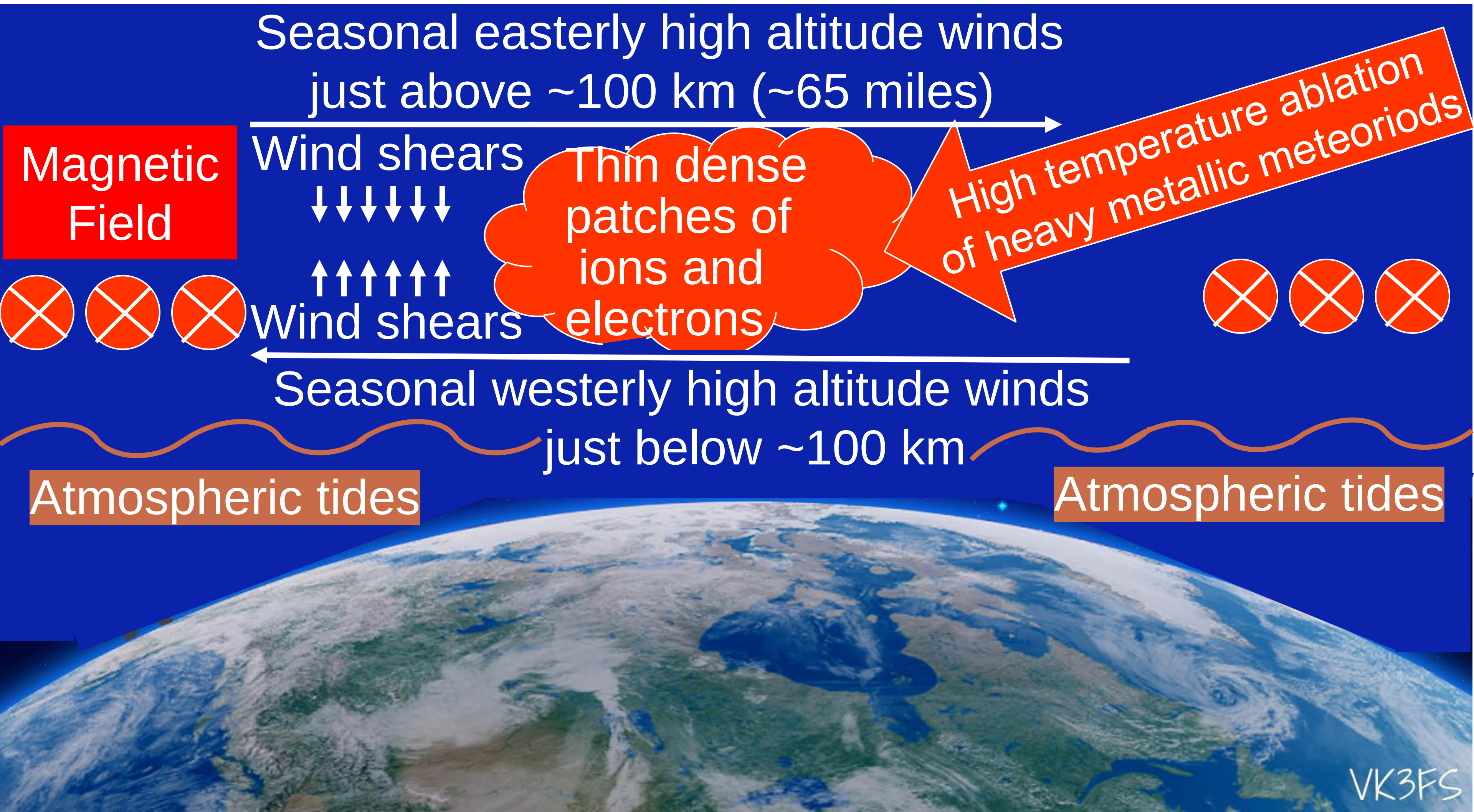


www.arrl.org/shop/ARRL-Antenna-Book-Softcover

What Causes Sporadic-E (E_s)?

The daily influx of dust-like metallic meteoroids is ionized by high temperature ablation not by solar radiation

Electrons and ions are concentrated into thin dense patches by wind shears, atmospheric tides and other forces



Single Hop E_s Propagation

by far the most common E_s propagation

Typically about 1400 to 2000 km (800 to 1200 miles)

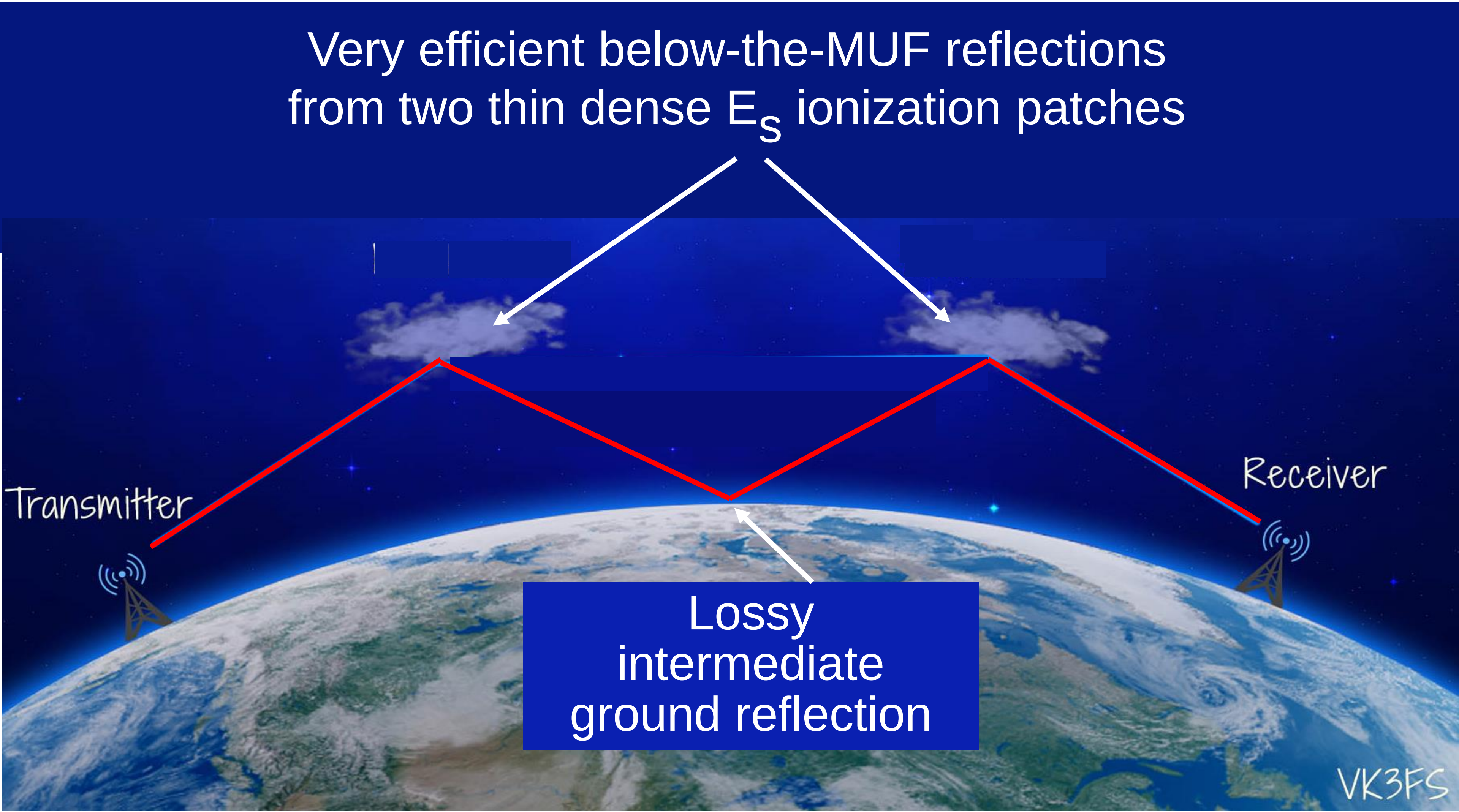
Occasionally 800 to 2400 km (500 to 1500 miles)

Very efficient below-the-MUF reflection
from a thin (only about 1 km thick)
dense E_s ionization patch
at about 100 km (~65 miles) altitude

Double Hop E_s Propagation

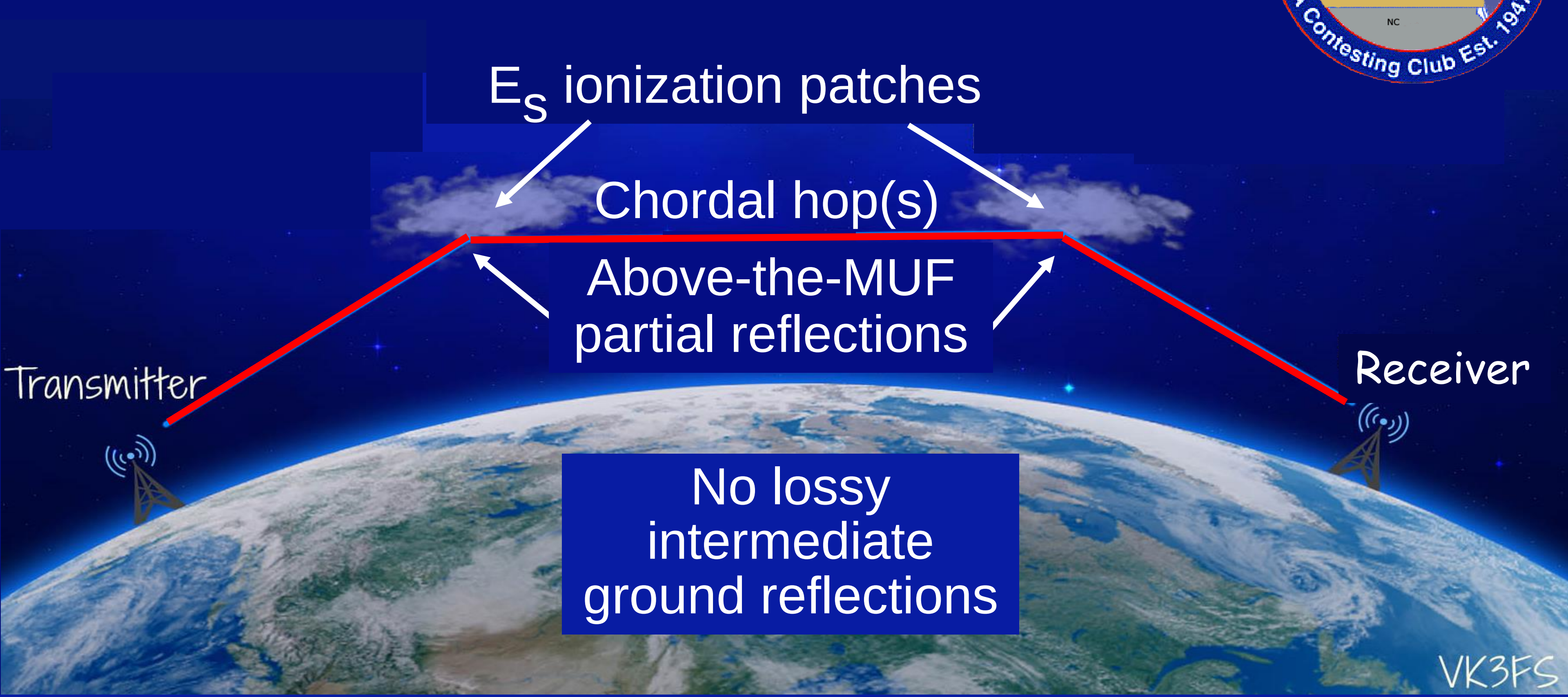
Typically about 2800 to 4000 km (1600-2400 miles)

Occasionally as little as 2000 km (1200 miles)



Above-the-MUF Partial Reflections via Chordal Hops between E_s Patches

2000 km (1200 miles) to 10,000+ km (6000+ miles)

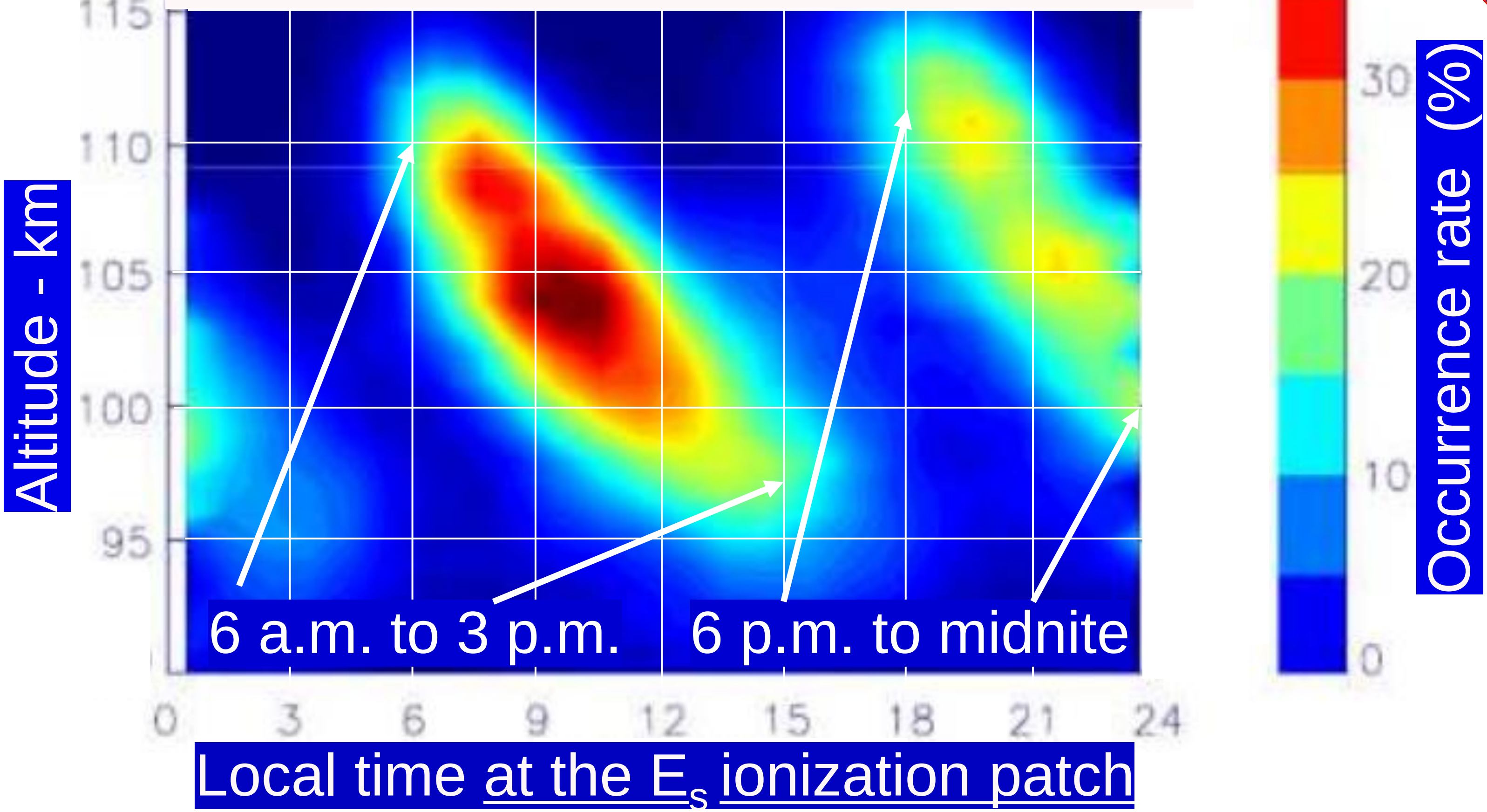


E_s ionization patches are often capable of efficient above-the-MUF partial reflection at higher frequencies than reflections returning to Earth

Partial reflections may propagate between two or more E_s ionization patches via chordal hops with no lossy intermediate ground reflection

E_s Ionization Patch Occurrence Rates

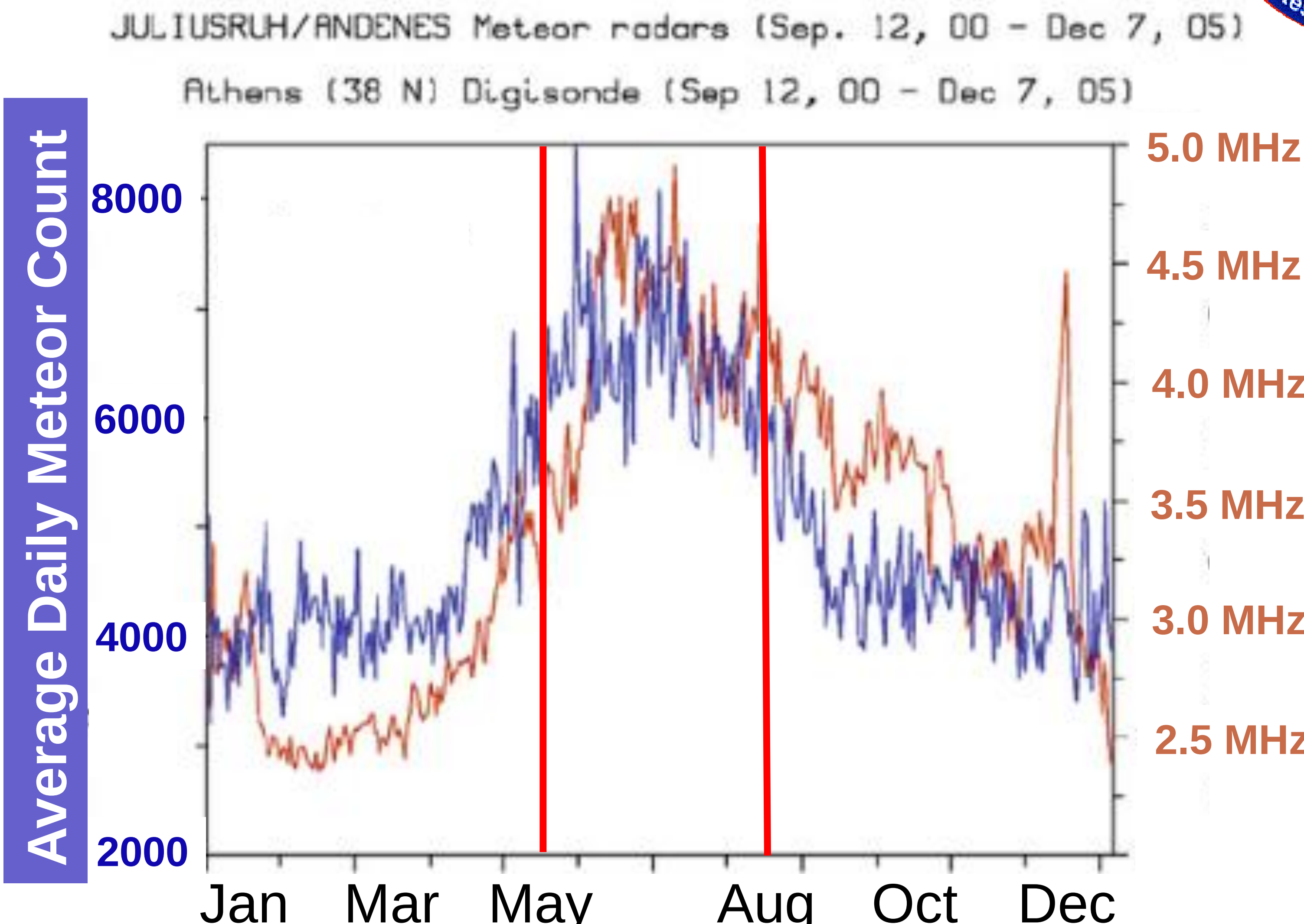
at 50-55º North Latitude



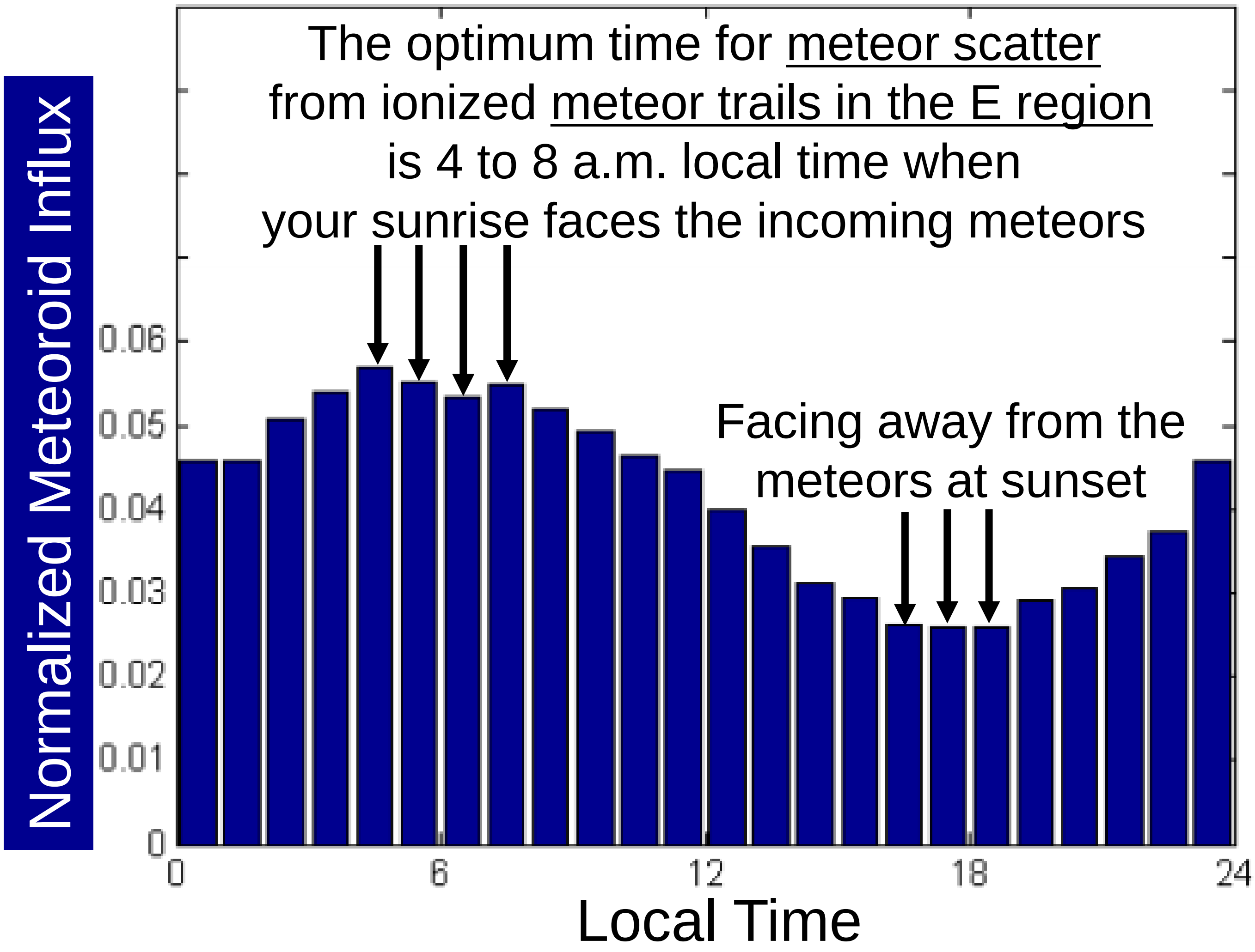
June and July upper atmosphere wind shears cause distinct morning/afternoon and evening/night peak E_s occurrence rates

Image credit: GFZ German Research Centre for Geosciences

Increased Meteor Count at Northern Latitudes from Mid-May to Mid-August Correlates to the E_s Vertical Incidence Critical Frequency (F_oE_s)



Electrons and ions ablated from background meteoroids persist for many hours to a day after the 4 to 8 a.m. peak meteoroid influx



6 Meter E_s Propagation
Basic Characteristics

Typical propagation ground footprint	Several thousand square miles to about ten thousand square miles or more
MUFs	>50 MHz MUFs every day in June and July -- but not everywhere and every day --
4000 to 10,000+ km propagation	Many days in June and July - a few days in late May and early August - a few days in late December/early January
Preferred antenna	3 to 6 (or more) element horizontal Yagi
Preferred heights	50 to 60 feet high (70 feet only for DXing)
Compromise height can be degraded by many small buildings and dense forests within 1000 feet	25 feet high: about 3 dB worse at 1000 km about 6 dB worse at 2000 km compared to 50 feet high

Easily Observed Variability
of Northern Hemisphere E_s Propagation

Monthly E_s occurrence	Every day in June and July - but not everywhere and every day Many days in May and August Some days in December and January Very infrequent in February and March
Daily E_s peak occurrence	6 am to 3 pm and 6 pm to midnight local time during June and July
E_s patch locations	Extreme E_s patch location variability
Day-to-day	Extreme E_s patch location variability
Day-to-night	June and July E_s propagation occurs from just before sunrise to just after midnight at the location of the E_s ionization patch
Short term	Seconds, minutes, hours, morning-to-evening

Antenna Heights and Elevation Angles for 6 Meter E_s Propagation

(thanks K9LA)

Antenna Elevation Angles	Single Hop E_s Distance	Required F_oE_s (MHz)	Approx E_s MUF (MHz)	Optimum Antenna Height	Occurrence
Below 5º	1400-2300 km	9-10	45	70 feet	Frequent
5º to 8º	1200-1400 km	10-11	50-55	50 feet	Very Frequent
8º to 12º	800-1200 km	11-13	55-65	25 feet	Not Frequent
12º to 15º	700-800 km	13-15	65-75	17 feet	Rare

E_s vertical incidence critical frequency (F_oE_s) does not often exceed 12 MHz

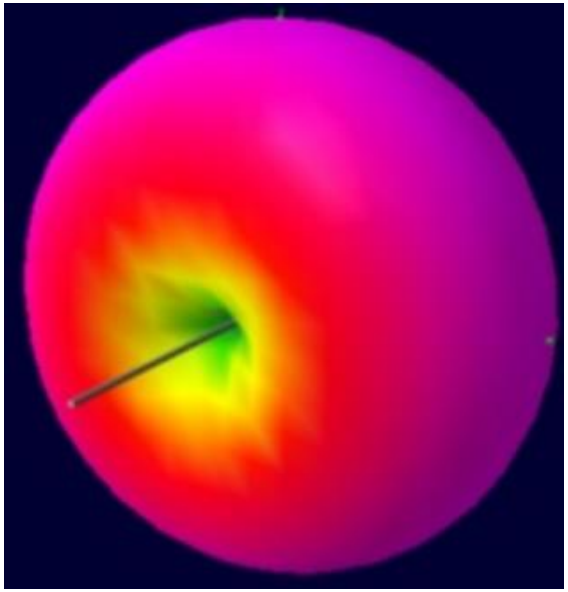
Multi and chordal hop E_s occurs very frequently below about 5º elevation angles

Yagis more than about 100 feet high are much too high for most E_s propagation

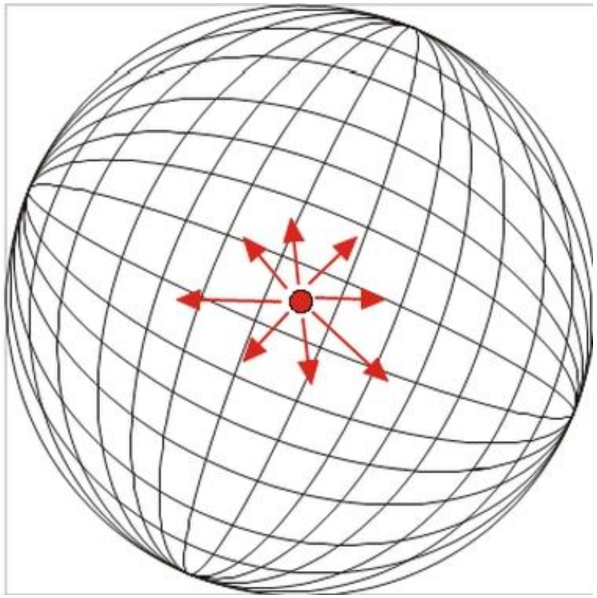
Few QSO partners have useful antenna response below about 3º elevation

https://k9la.us/Jul18_Elevation_Angles_Required_for_6m_Sporadic_E.pdf

The Reference Antenna for Yagi Antenna Gain (dBd) in this Presentation is the Half Wavelength Dipole in Free Space



Half Wavelength Dipole
in free space



Theoretical Isotropic Radiator

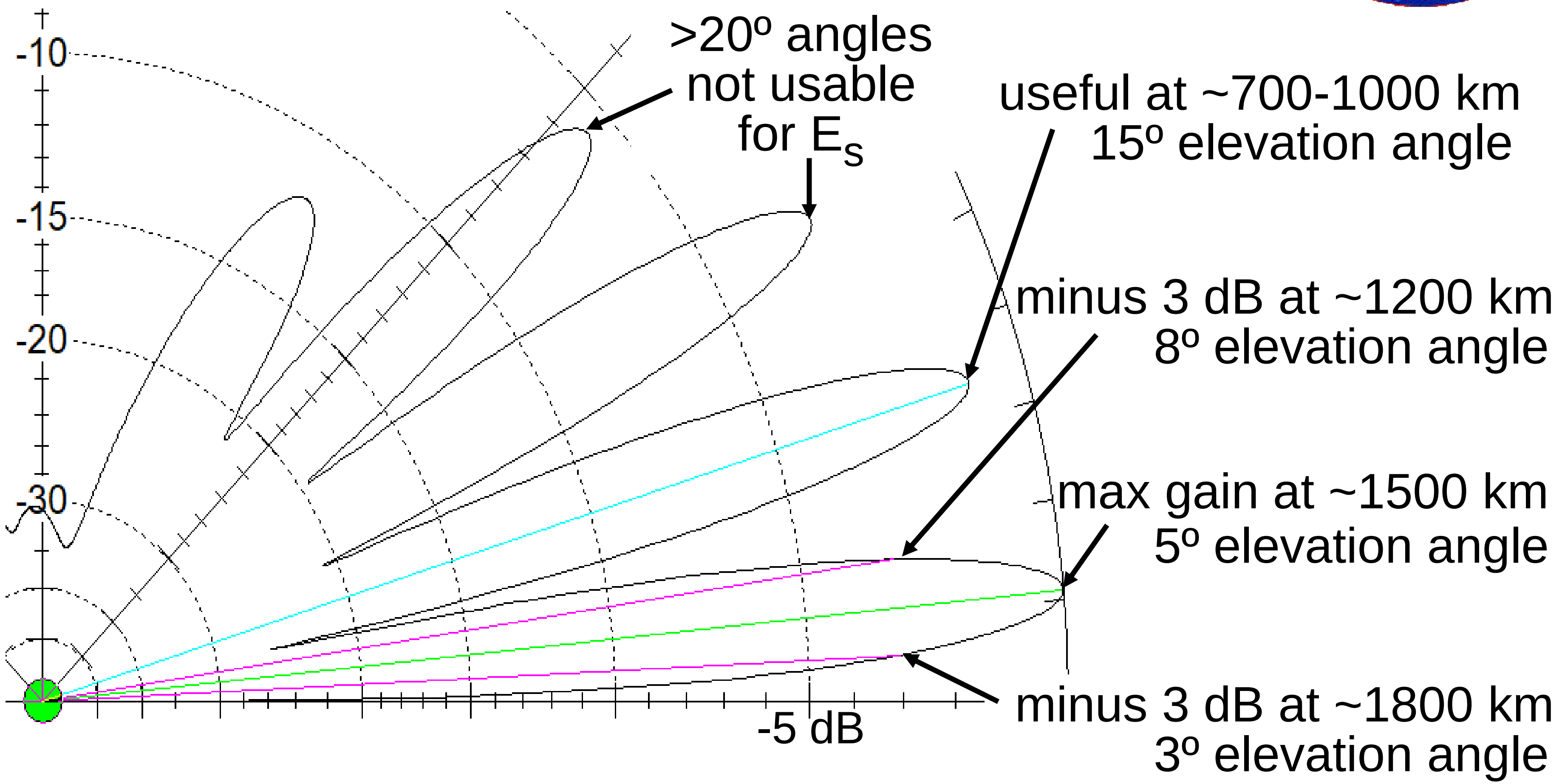
A half wavelength dipole in free space has 2.15 dB gain over an isotropic radiator

Elevation Pattern

5 element 6 meter Yagi   50 feet high

Excellent height for almost all E_s

Degraded by dense housing within 1000 ft



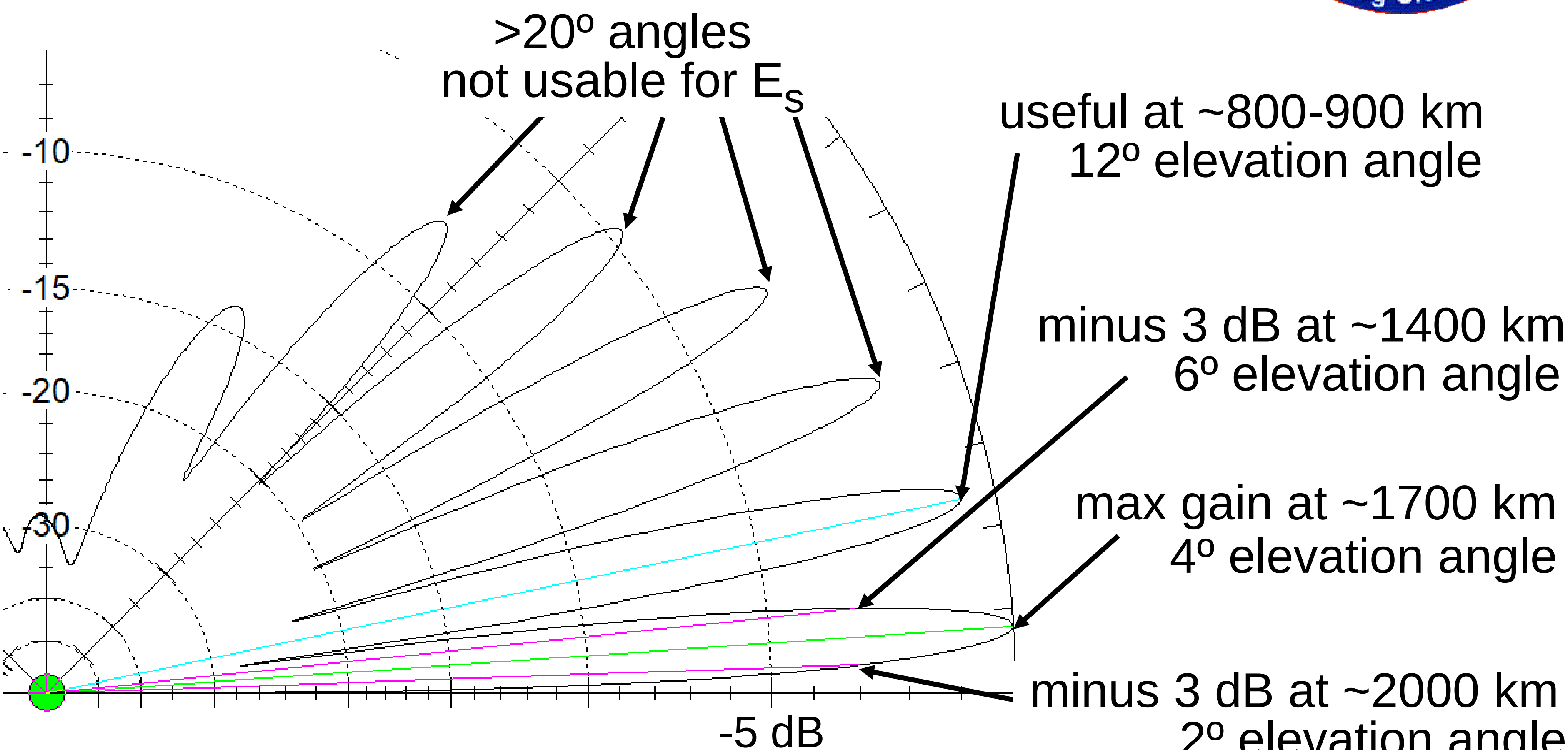
Elevation Pattern

5 element 6 meter Yagi 70 feet high

1 to 2 dB better for E_s DX than 50 feet high

Minor degradation by dense housing

Degraded by a deep null at 6 to 10º elevation



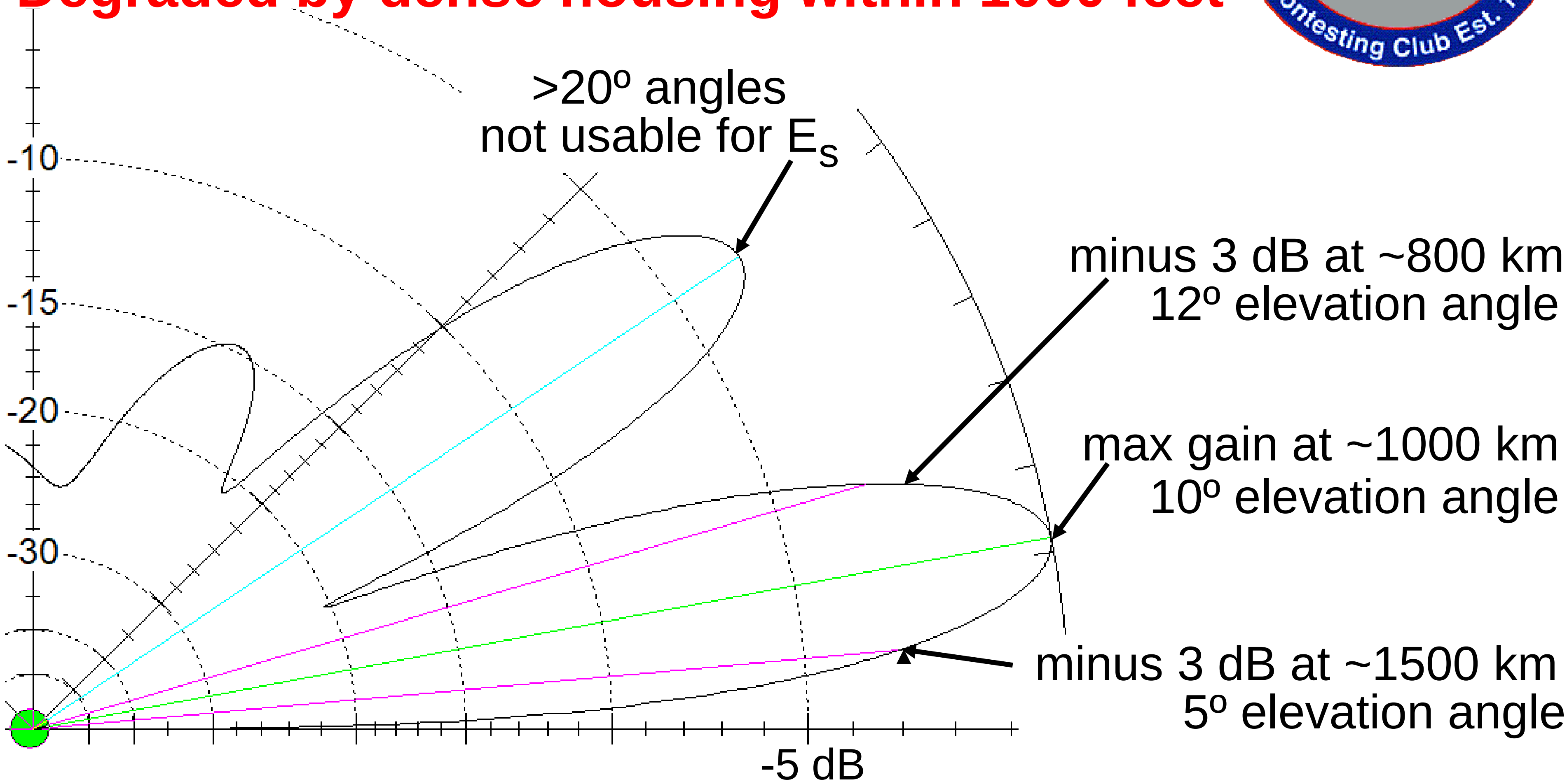
Elevation Pattern

5 element 6 meter Yagi 25 feet high

Adequate height if can't be higher

Only 3 to 6 dB worse than 50 foot height

Degraded by dense housing within 1000 feet

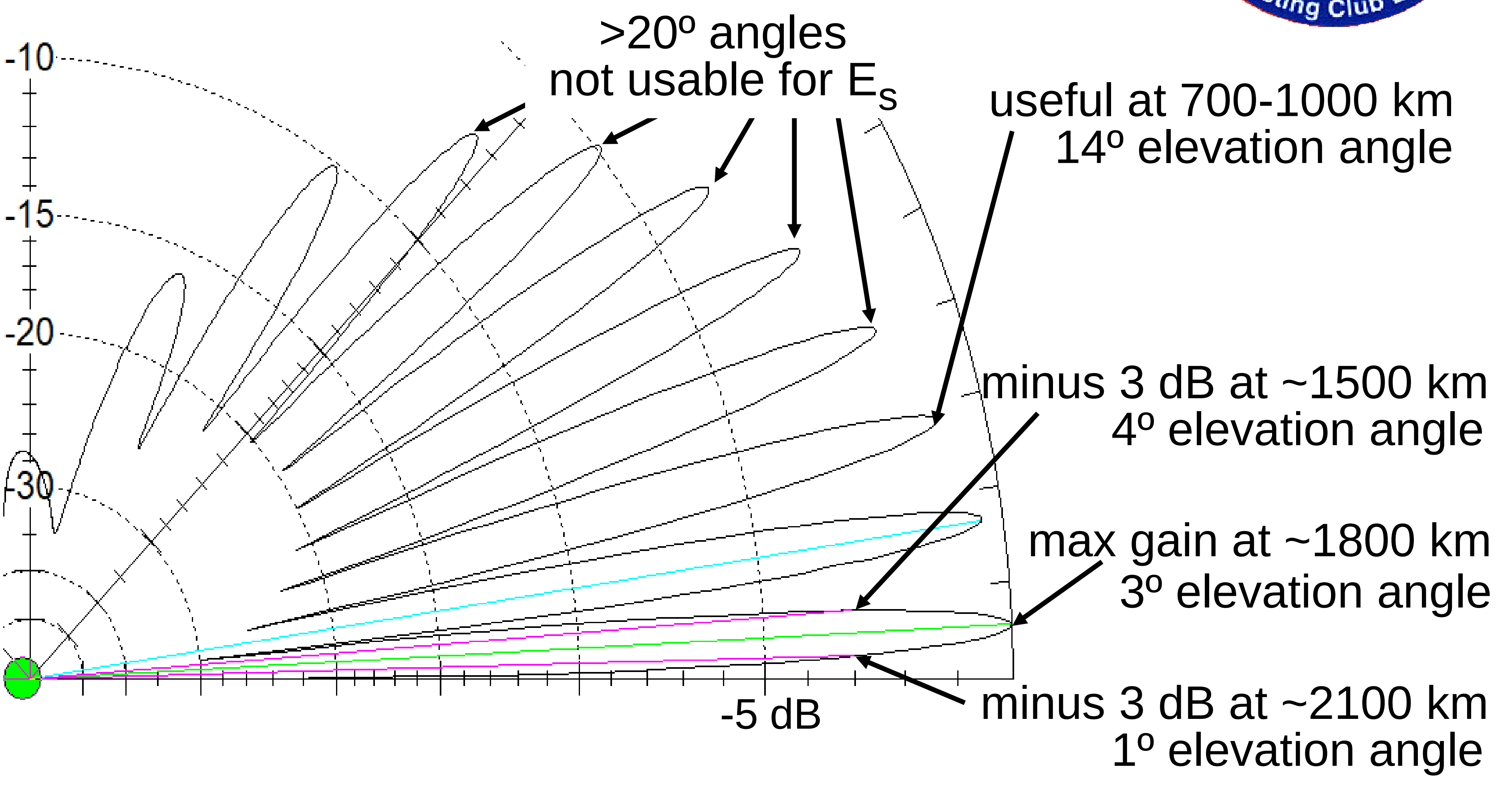


Elevation Pattern

5 element 6 meter Yagi 100 feet high

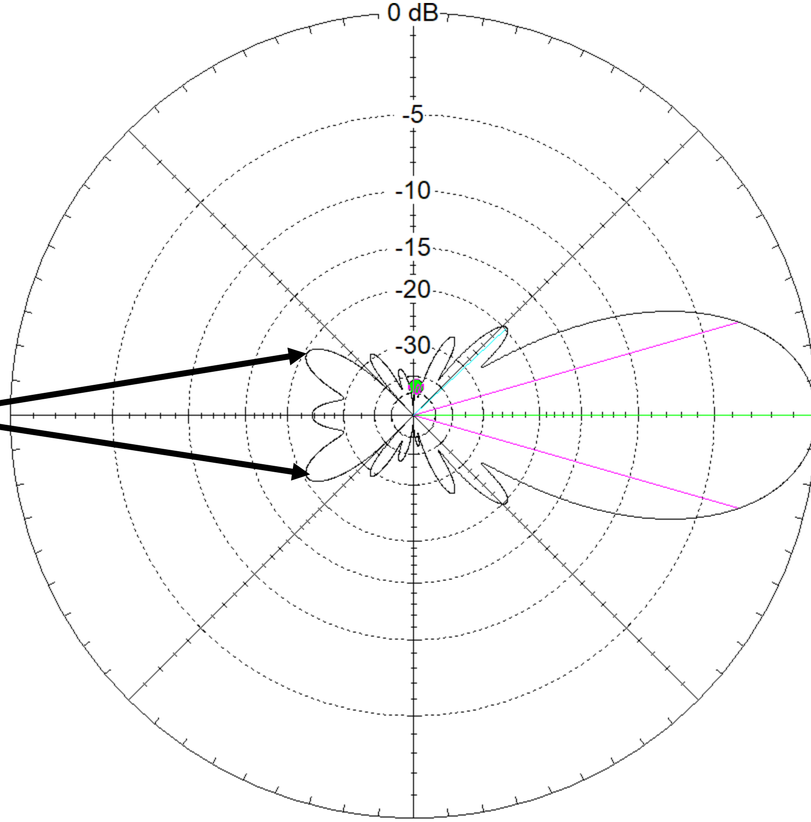
Unwanted deep null at 4 to 7º elevation

Too high for most E_s propagation



Front to Rear (F/R) Ratio

Maximum signal from the rear of the antenna

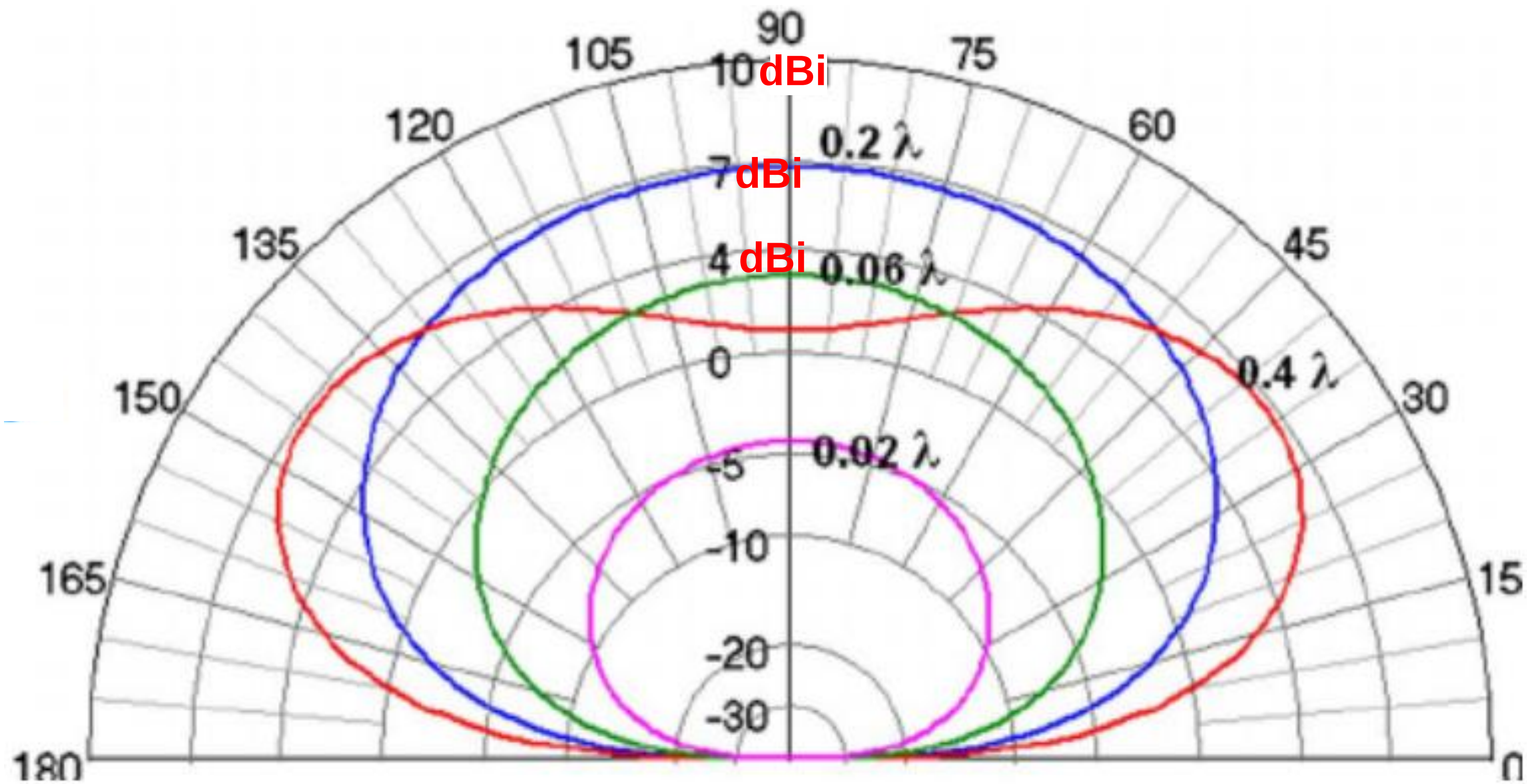


Maximum signal from the front of the antenna

rear ← → front

6 dBd Ground Gain of a Horizontal 1/2 Wave Dipole with Minor Irregularities in the Reflection Zone

Terrain irregularities: <25% of antenna height
Buildings: <25% of antenna height
Forest: <25% of antenna height
Obstructing less than 5% of the reflection zone

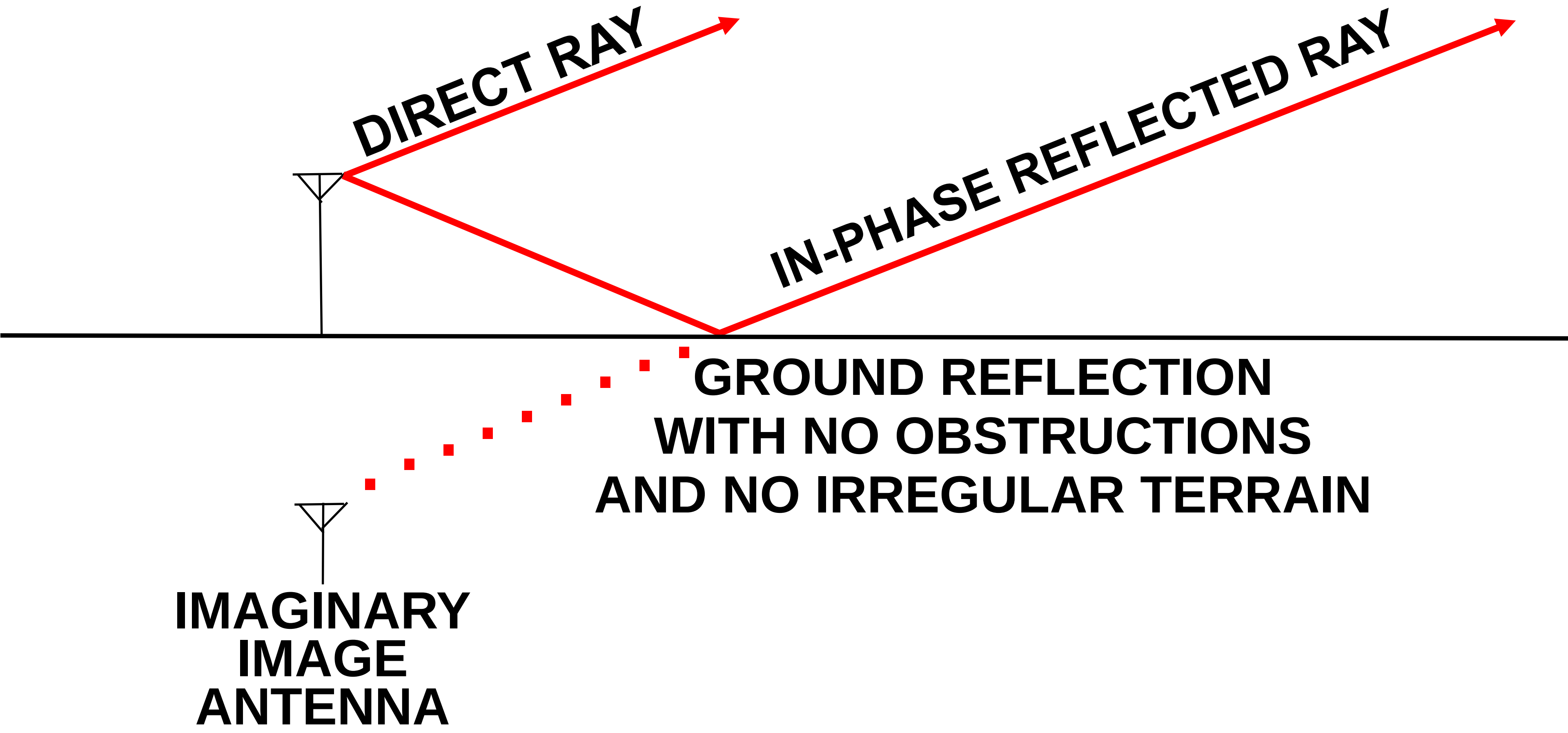


A horizontal half wave dipole at least 0.5 wavelength high with relatively smooth terrain and few tall buildings in the reflection zone has 6 dBd gain over a horizontal dipole in free space

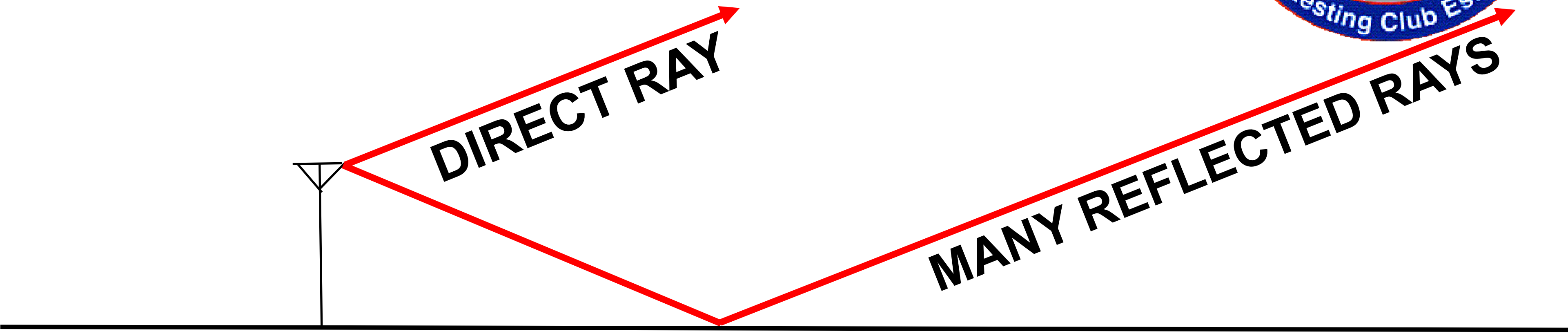
The Classic “Image Antenna” Model

an accurate model for
computing peaks and nulls
in antenna elevation patterns

Assumes an ideal reflection zone
with no obstructions or irregular terrain



What is the Actual Reflecting Zone in front of my antenna?



How large is it?

What shape is it?

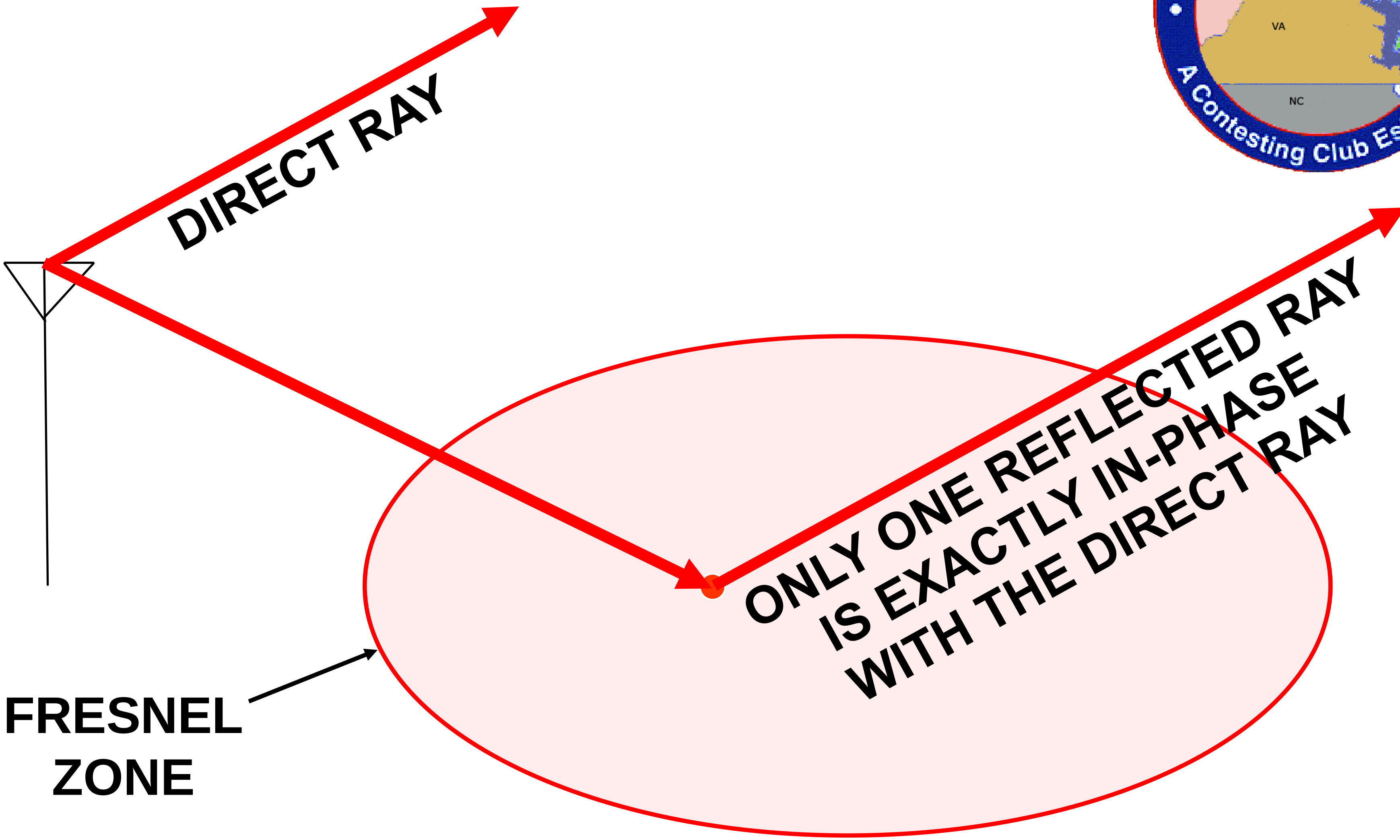
How far in front of my antenna is it?

How much do obstructions degrade the reflection?

How much does irregular terrain degrade the reflection?

The Fresnel Zone

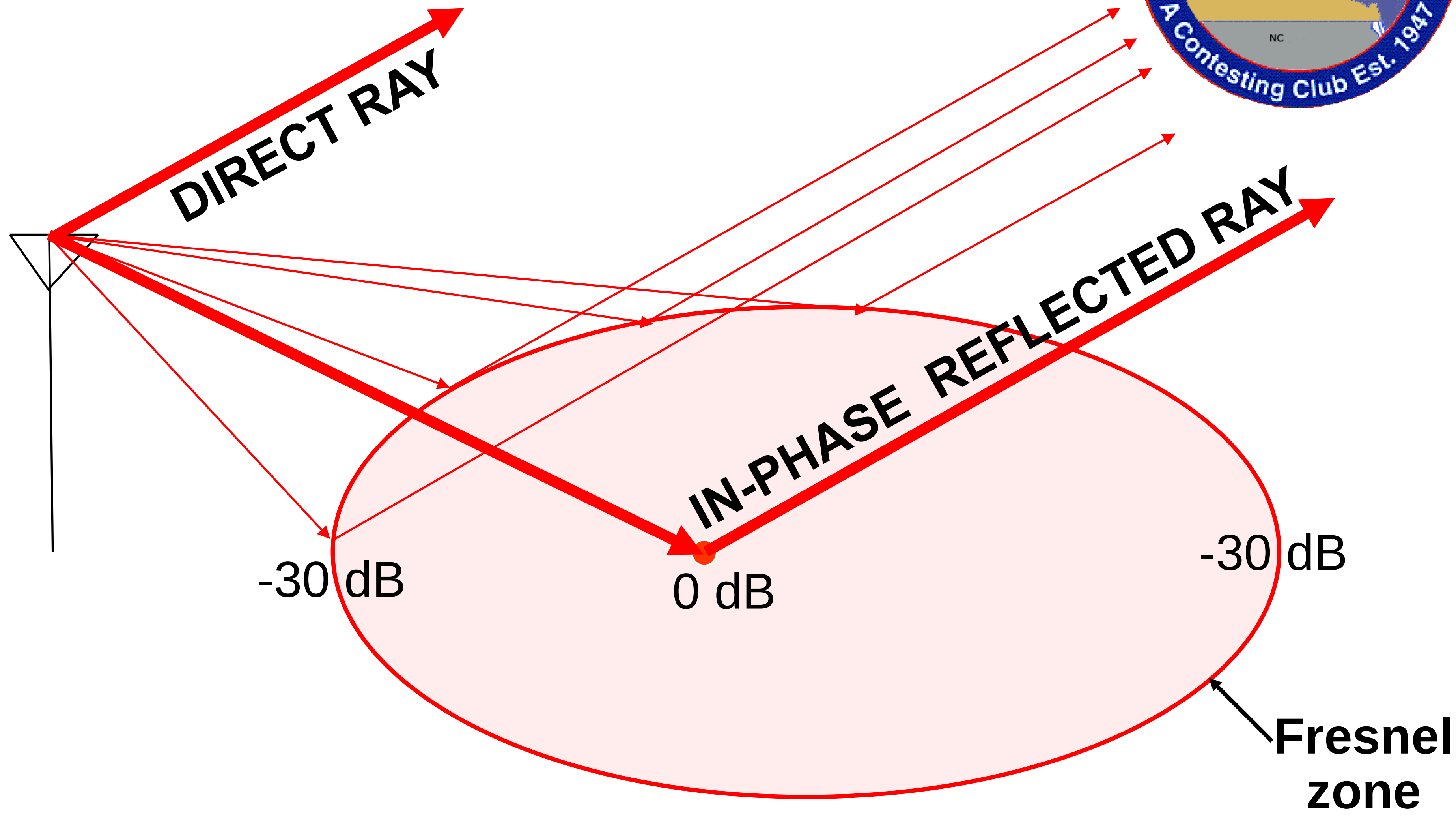
By definition includes every ground reflection within +/- 90^{o} of the phase of the direct ray



https://ia801604.us.archive.org/5/items/sitingcriteriafo139utla/sitingcriteriafo139utla.pdf

The Fresnel Zone

Reflections near the edge of the Fresnel Zone form the <u>first deep null</u> in the elevation pattern
but do not form the peak of the low angle lobe

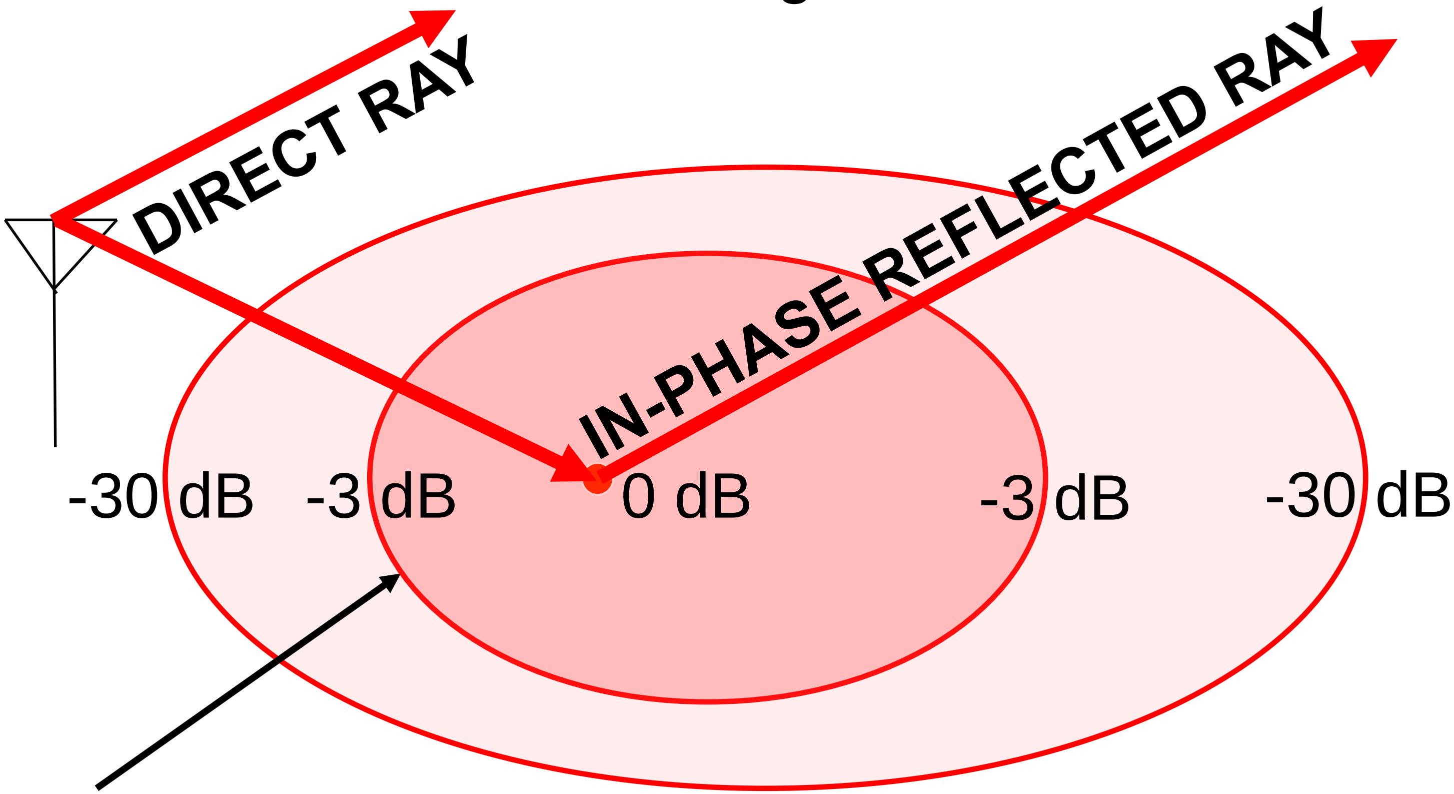


The -3 dB Ground Reflection Zone

Roughly the middle half of the Fresnel zone

Ideally the reflection zone should not be obstructed

- **buildings and forests occupy < 5% of the zone**
- **buildings and forests < 25% of antenna height**
- **irregular terrain < 25% of antenna height**

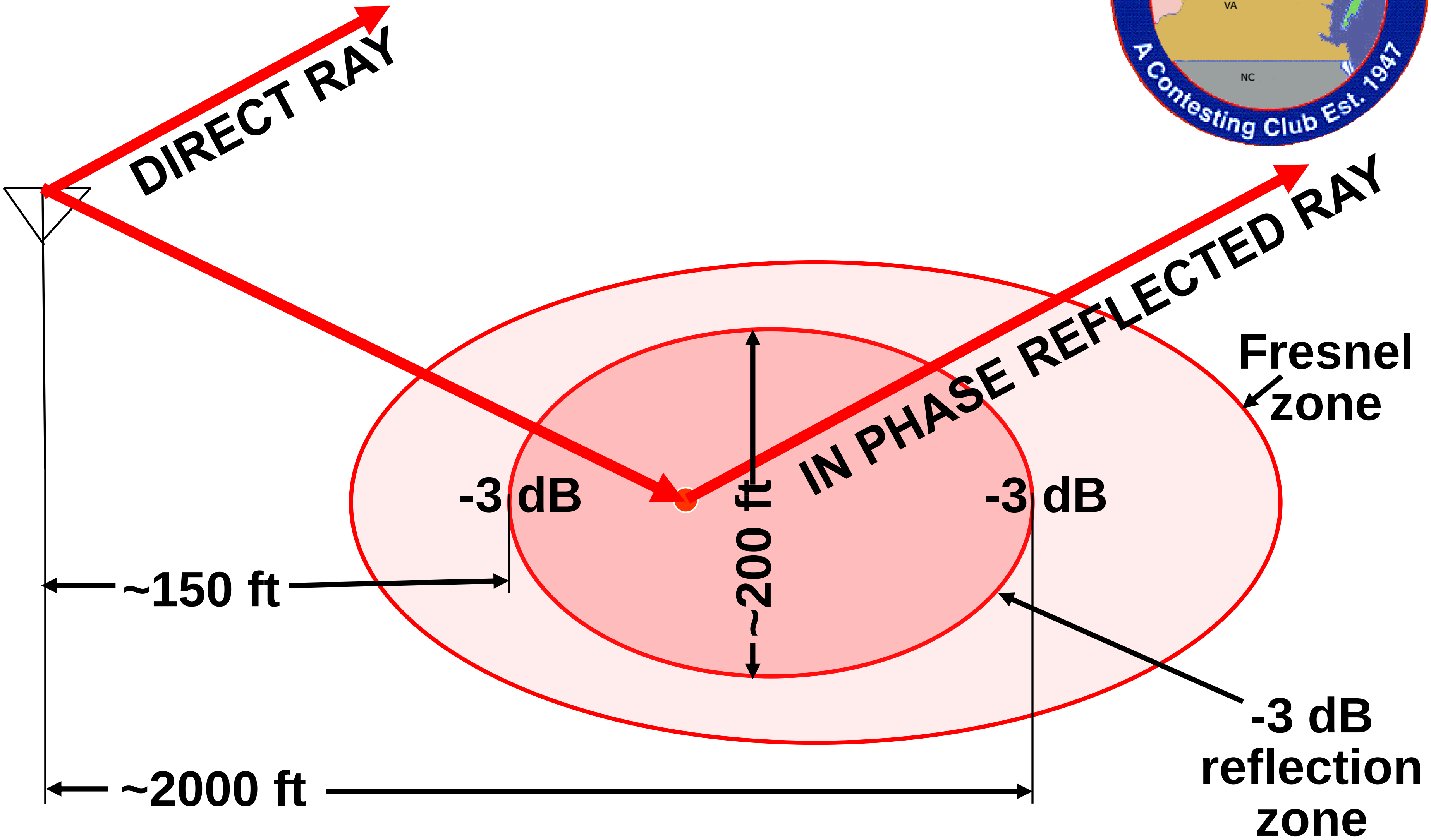


Roughly the middle half of the Fresnel zone forms most of the -3 dB contour of the antenna's low angle lobe

-3 dB Ground Reflection Zone

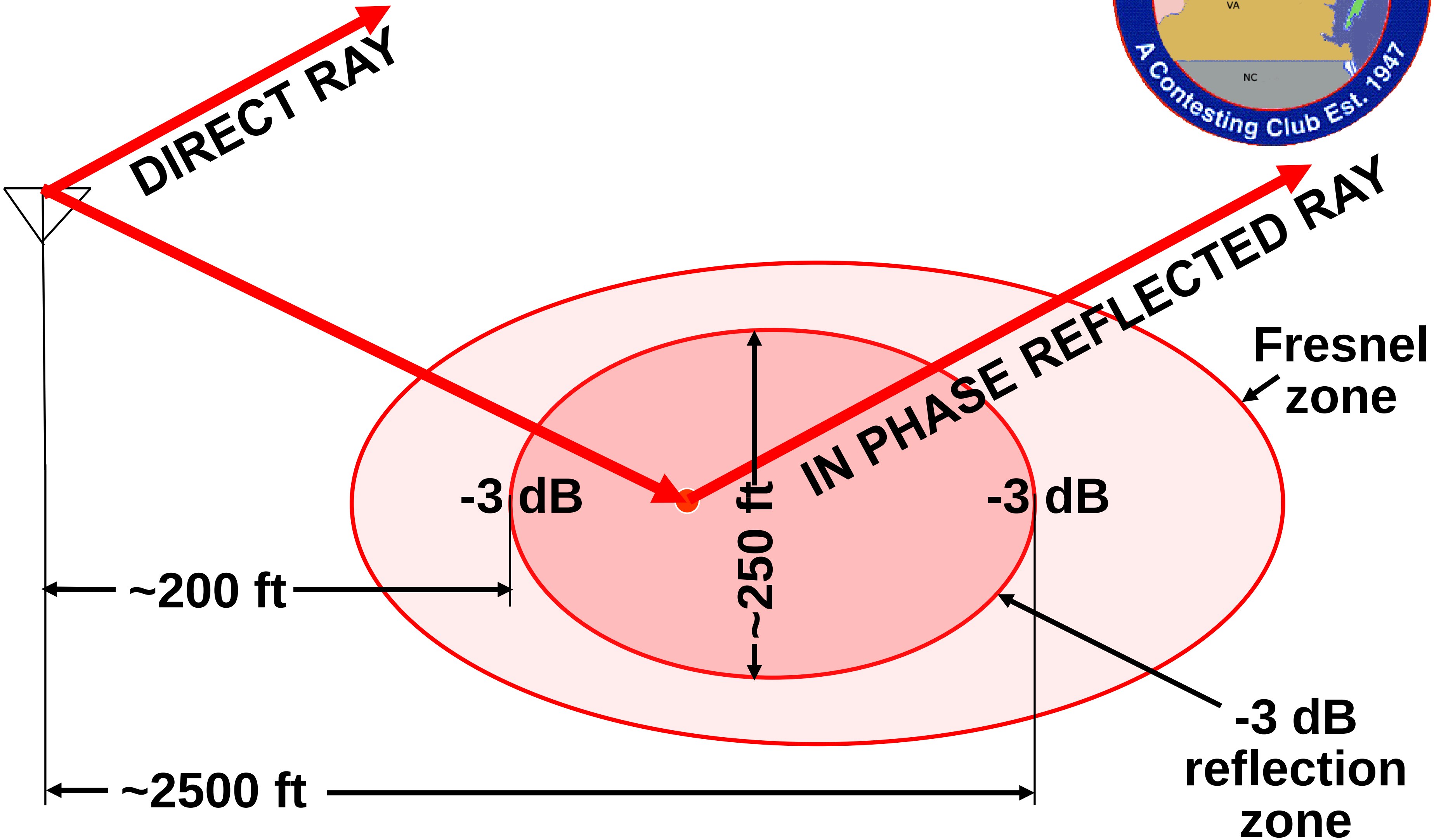
6 meter Yagi 50 feet high

5º elevation angle



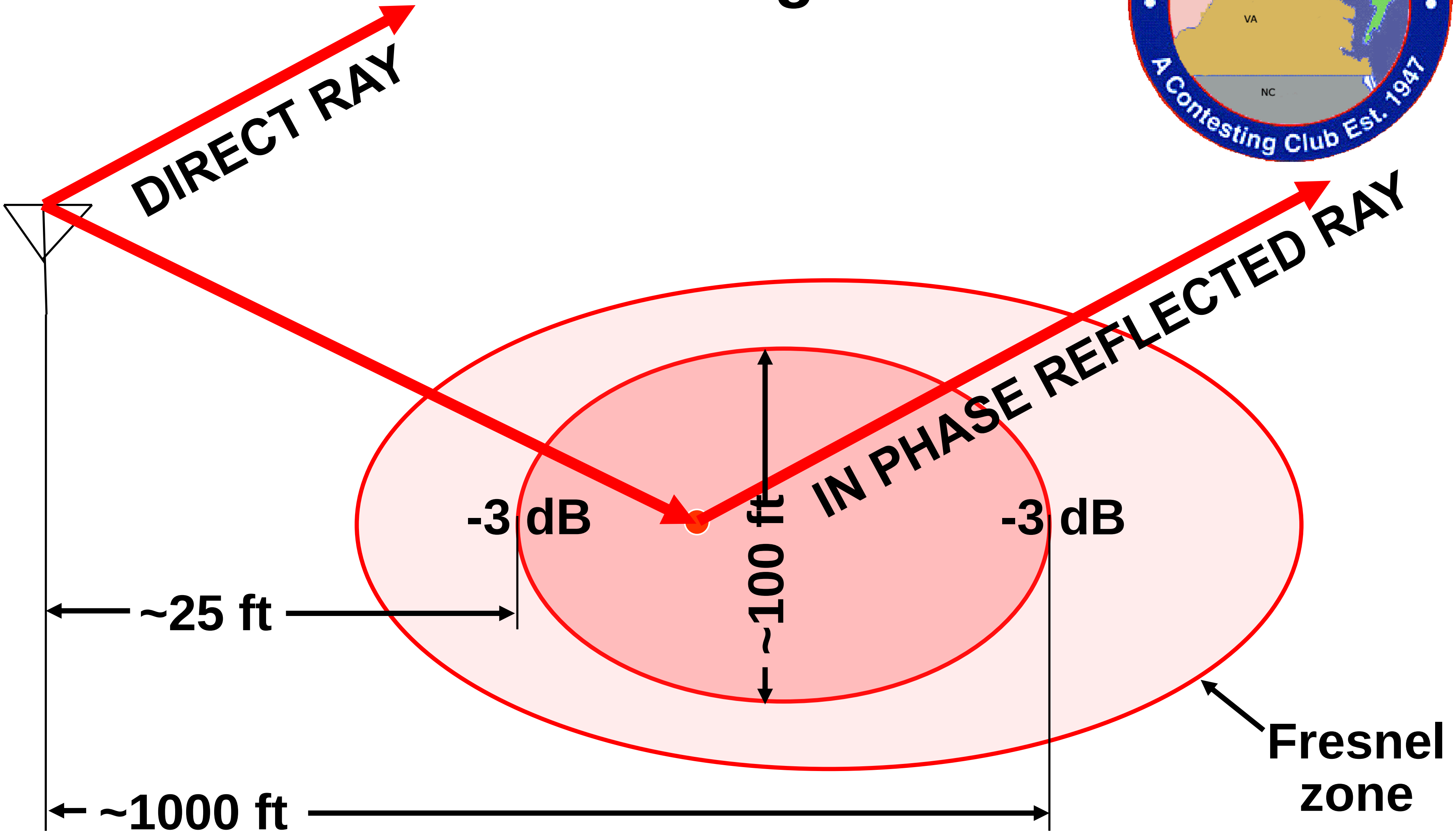
-3 dB Ground Reflection Zone

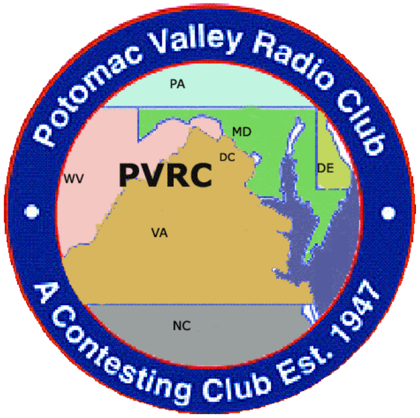
6 meter Yagi 70 feet high
4º elevation angle



-3 dB Ground Reflection Zone

6 meter Yagi only 25 feet high
10º elevation angle



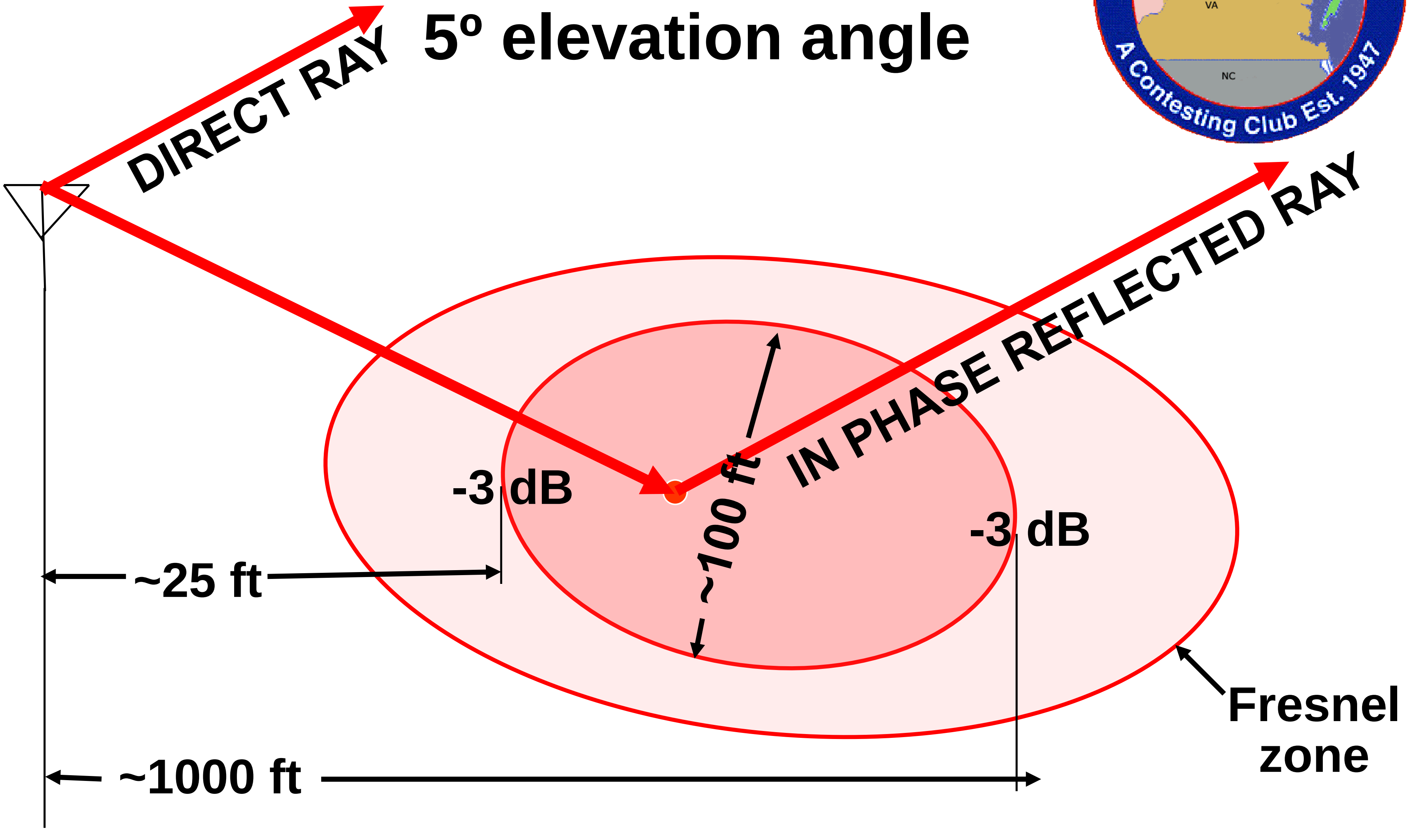


Sloping Terrain -3 dB Reflection Zone

6 meter Yagi 25 feet high

~100 ft of sloping terrain over 1000 ft

5º elevation angle



High Performance Short Yagis

light weight and small wind area

Gain and front-to-rear ratio

Source: VE7BQH charts (December 2021)

Type	Elements	Gain dBd	Front to Rear Ratio	Boom Length	Cost
M2 6M3	3	6	13 dB	7 ft	$299
EAntenna 50LFA4	4	7	**21**	10	$260
Directive Sys JX5-50	5	8	17	13	$240
YU7EF EF0605C	5	8	**24**	14	-
G0KSC 4.4m 5LFA	5	8	19	14	$225+
EAntenna 50LFA5	5	8	**21**	14	$300

www.dxmaps.com/ve7bqh6.html

M2 6M3 Lightweight Yagi

3 Element T-matched Yagi

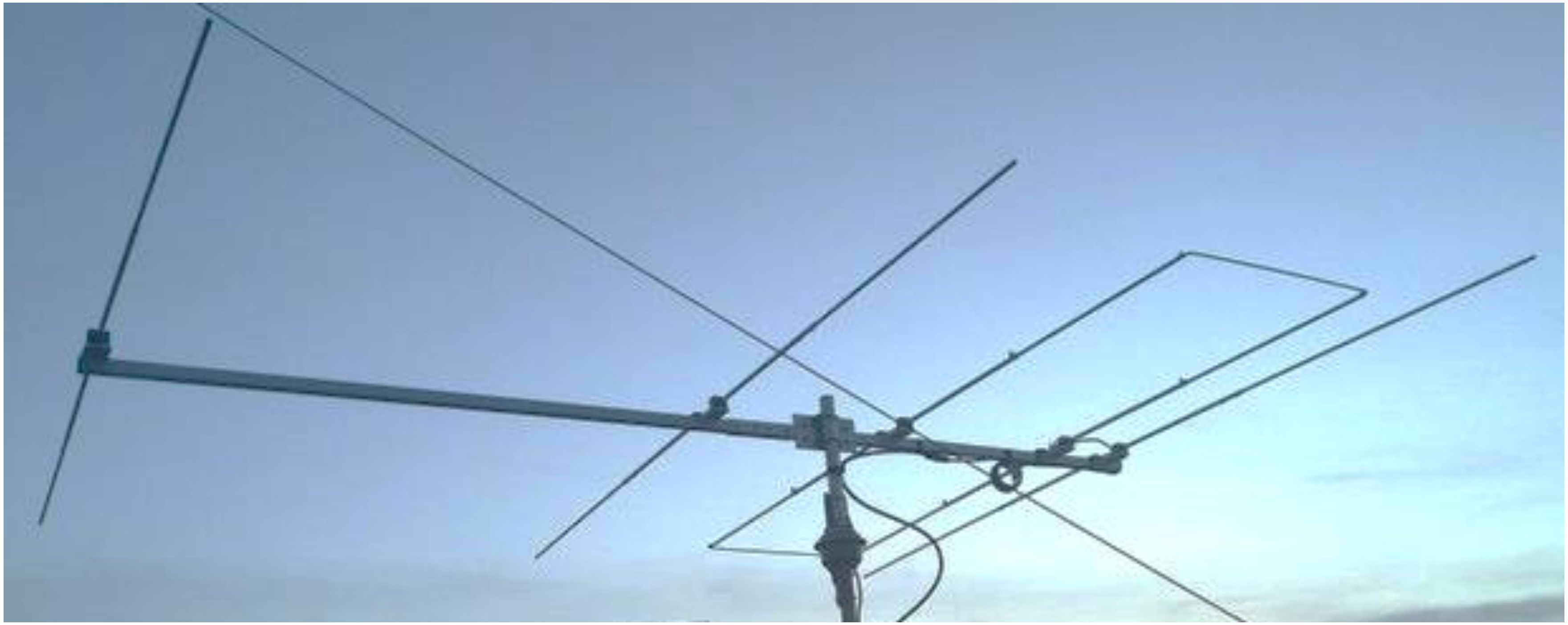
7 Foot Boom   6 Pounds

6 dBd Gain   13 dB F/R Ratio

www.m2inc.com/content/PDF%20MANUALS/6MANTS/6M3MAN03-W.pdf

EAntenna 50LFA4

4 Element Loop Fed Yagi
10 Foot Boom 13 Pounds
7 dBd Gain   21 dB F/R Ratio



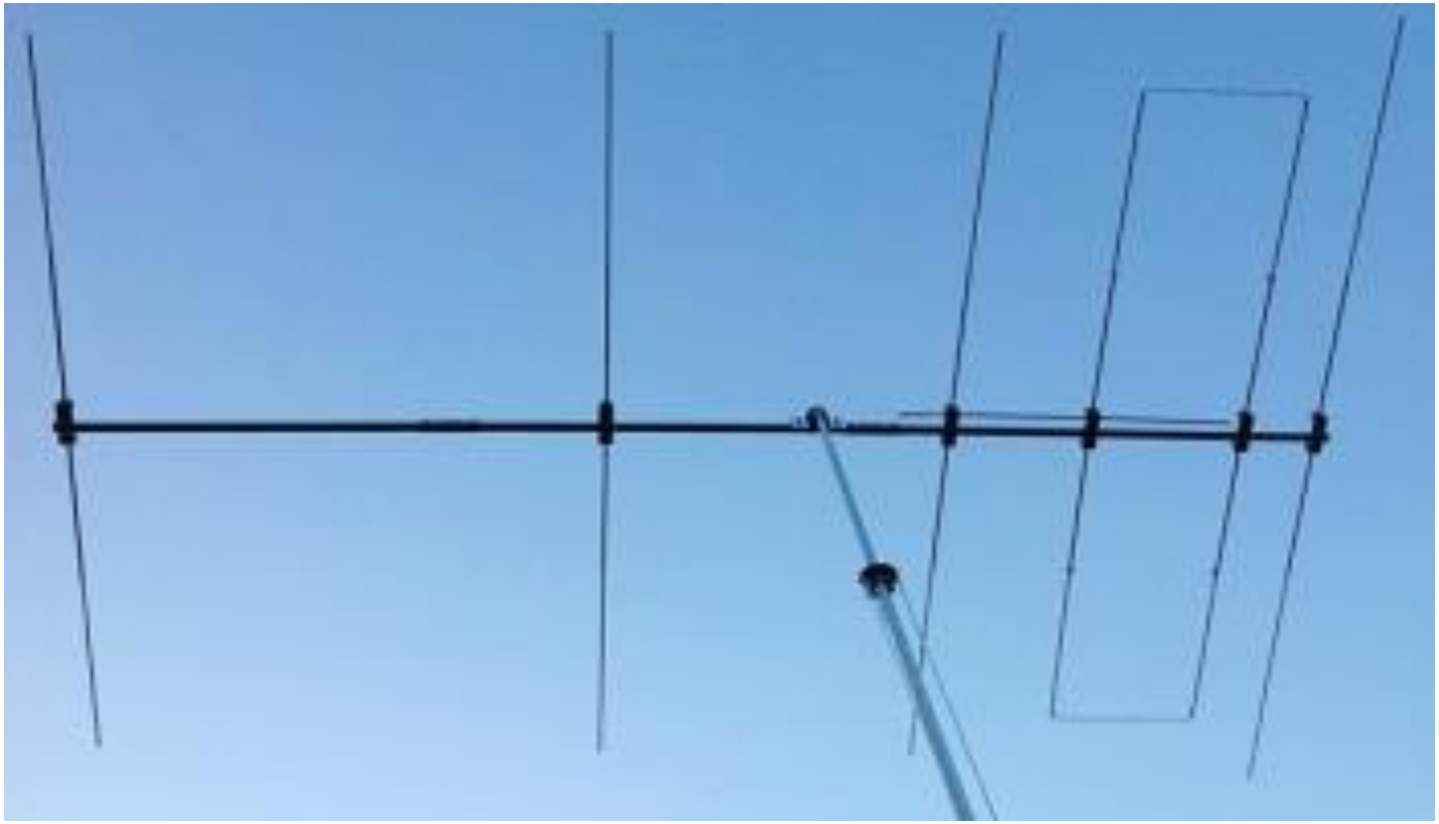
www.dxengineering.com/parts/ean-r2010106

EAntenna 50LFA5

5 Element Loop Fed Yagi

14 Foot Boom 17 Pounds

8 dBd Gain   21 dB F/R Ratio



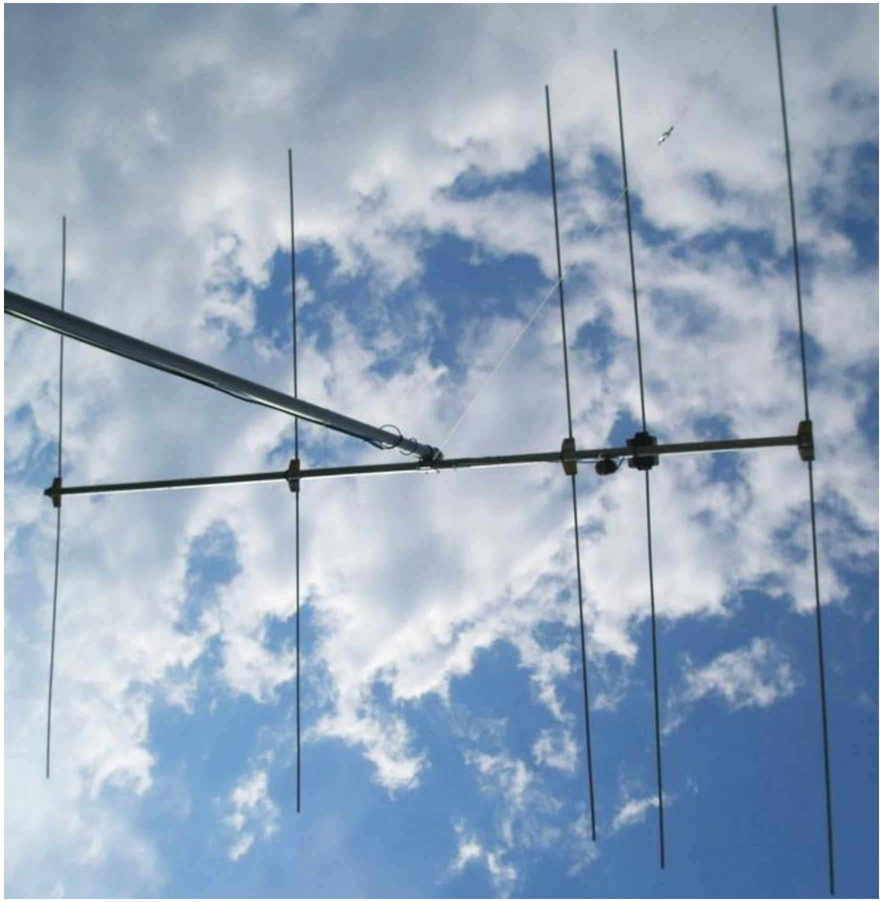
www.dxengineering.com/parts/ean-r2010102

YU7EF EF0605C

5 element split dipole feed Yagi

14 Foot Boom 17 Pounds

8 dBd Gain 24 dB F/R Ratio



www.yu7ef.com/ef0605c.htm

G0KSC 5LFA

5 Element Loop Fed Yagi
14 Foot Boom 13 Pounds
8 dBd Gain   19 dB F/R Ratio

www.g0ksc.co.uk/50mhz-lfa-yagis/5el-44mtr-boom-lfa.html

Higher Performance Long Yagis

Long boom LFAs improve front-to-rear ratio

Gain and front-to-rear ratio

Source: VE7BQH charts (December 2021)

Type	Elements	Gain dBd	Front to Rear Ratio	Boom Length	Cost
G0KSC 6.2m 6LFA	6	9	30 dB	21 ft	$406+
Innov 6.83m 6LFA	6	10	27	22	$447+
EAntenna 50LFA6	6	10	27	23	$460
G0KSC 8.9m 7LFA	7	11	25	29	$554+
EAntenna 50LFA7	7	11	26	31	$500
M2 6M7JHV	7	11	21	31	$525
Innov 8LFA	8	11	29	39	$812+

www.dxmaps.com/ve7bqh6.html

G0KSC 6LFA

6 Element Loop Fed Yagi
21 Foot Boom 14 Pounds
9 dBd Gain   30 dB F/R Ratio

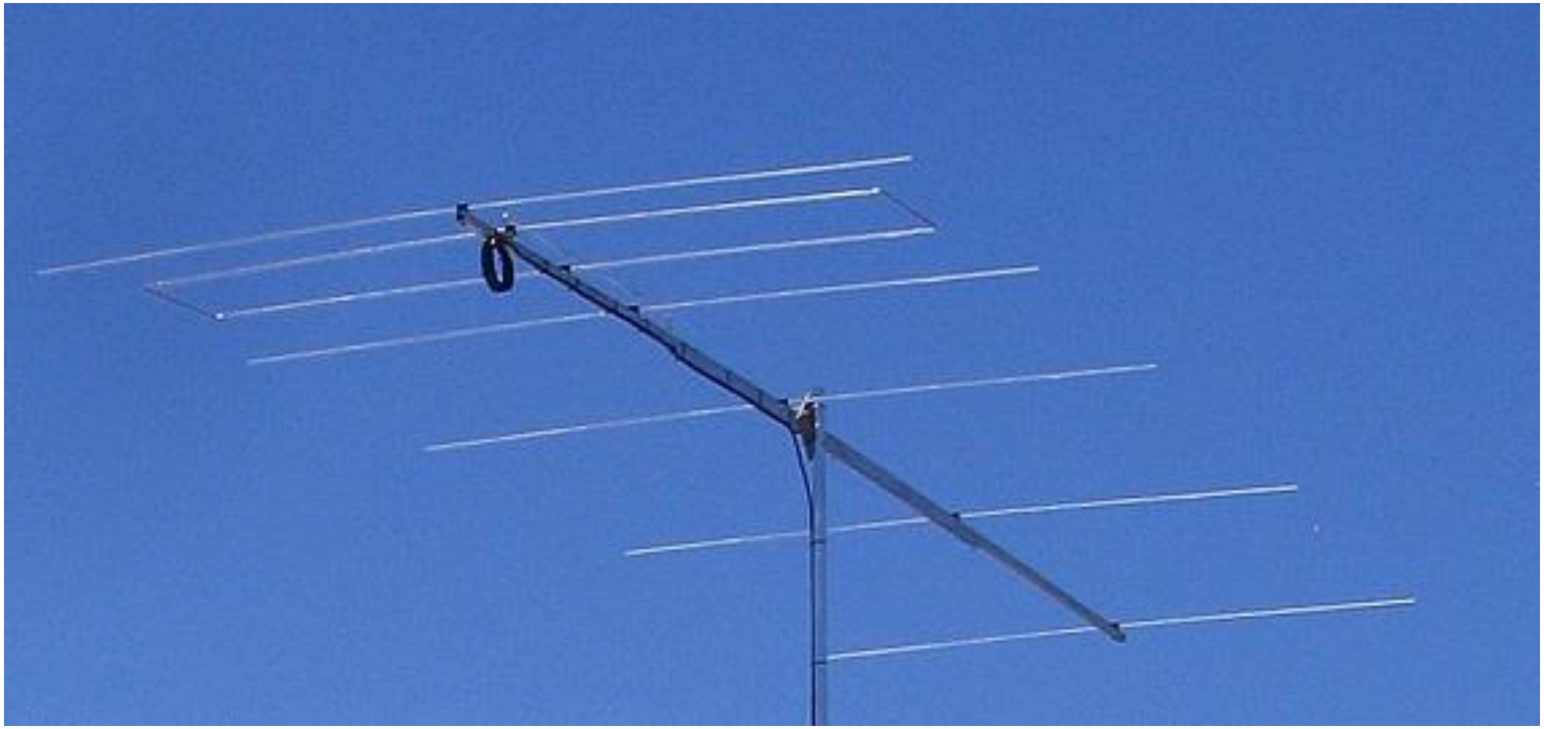
www.g0ksc.co.uk/50mhz-lfa-yagis/6el-64mtr-boom-lfa.html

InnovAntennas 6.83m 6LFA

6 Element Loop Fed Yagi

22 Foot Boom 14 Pounds

10 dBd Gain   27 dB F/R Ratio



www.g0ksc.co.uk/50mhz-lfa-yagis/6el-64mtr-boom-lfa.html

Eantennas 50LFA6

6 Element Loop Fed Yagi
23 Foot Boom 30 Pounds
10 dBd Gain   27 dB F/R Ratio

www.dxengineering.com/parts/ean-r2010108

G0KSC 8.9m 7LFA

7 Element Loop Fed Yagi

29 Foot Boom 33 Pounds

11 dBd Gain   25 dB F/R Ratio

www.g0ksc.co.uk/7el-low-noise-lfa.html

Eantennas 50LFA7

6 Element Loop Fed Yagi

31 Foot Boom 50 Pounds

11 dBd Gain   26 dB F/R Ratio

www.dxengineering.com/parts/ean-r2010111

M2 6M7JHV

7 Element T-matched Yagi

26 Foot Boom 18 Pounds

11 dBd Gain   21 dB F/R Ratio

https://static.dxengineering.com/global/images/instructions/msq-6m7jhv.pdf

InnovAntennas 8LFA

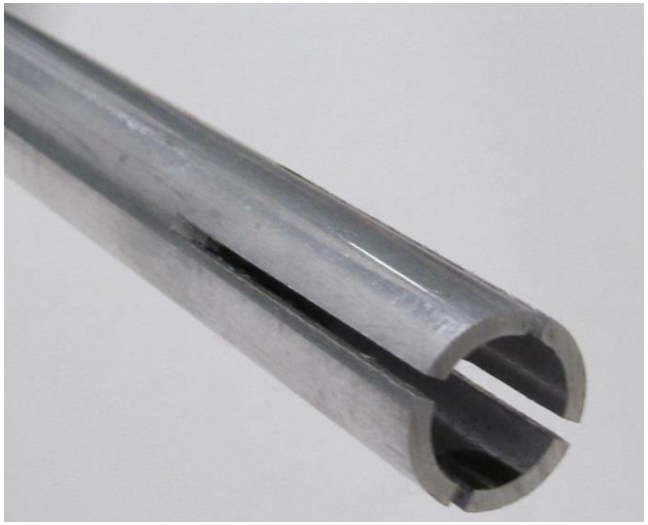
8 Element Loop Fed Yagi

38 Foot Boom 40 Pounds

11 dBd Gain   29 dB F/R Ratio

www.innovantennas.com/en/shop-page/190/3/vhf-uhf-ham-radio-antennas/50mhz-yagis-all/8-element-50mhz-lfa2-yagi-11-67mInnovAntennas%20shop.html

Yagi Element Construction



Center of each Yagi element:

6 feet of 0.5” diameter x 0.058” wall aluminum tubing

www.dxengineering.com/parts/dxe-at1205

Tips of each Yagi element:

2 feet of 0.375” diameter x 0.058” wall aluminum tubing

www.dxengineering.com/parts/dxe-at1189

Protecting Yagi Element Joints

Anti-Sieze and Anti-Corrosion Lubricant

Assures RF conductivity
Prevents oxidation and corrosion
No long-term drying and caking like many other lubricants
Easy Yagi element disassembly
Effortless cleaning of parts

www.dxengineering.com/parts/jtl-12555

Yagi Boom Construction

12 foot boom: Two 6 ft x 1.5” o.d. x 0.058” wall aluminum tubing
www.dxengineering.com/parts/dxe-at1488

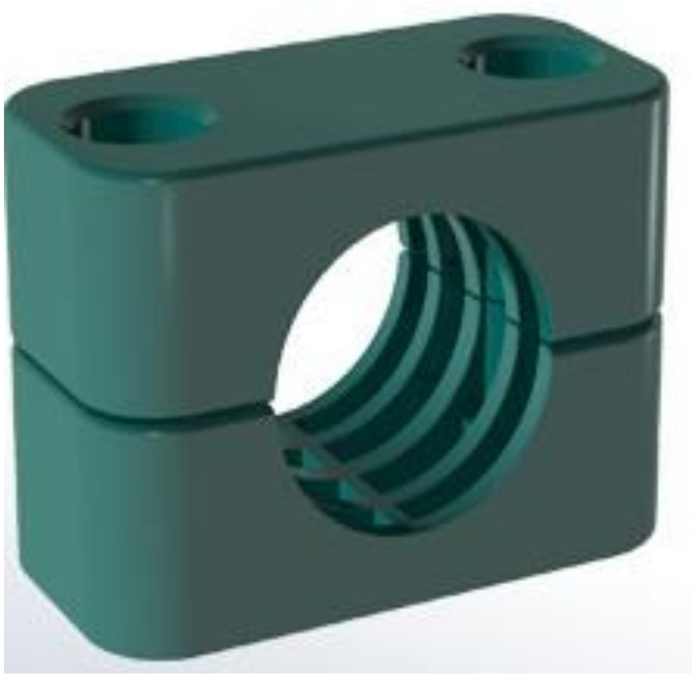
18 foot boom: Three 6 ft x 1.5” o.d. x 0.120” wall aluminum tubing
www.dxengineering.com/parts/dxe-at1311

24 foot boom: Four 6 ft x 2” o.d. x 0.058” wall aluminum tubing
www.dxengineering.com/parts/dxe-at1492

Square aluminum tubing makes precise element mounting easier
use 1.5 inch square tubing for a 12 foot boom
use 2.0 inch square tubing for a 24 foot boom
www.metalsdepot.com/aluminum-products/aluminum-square-tube

Stauff Clamps

For mounting Yagi elements to a horizontal plate attached to a boom

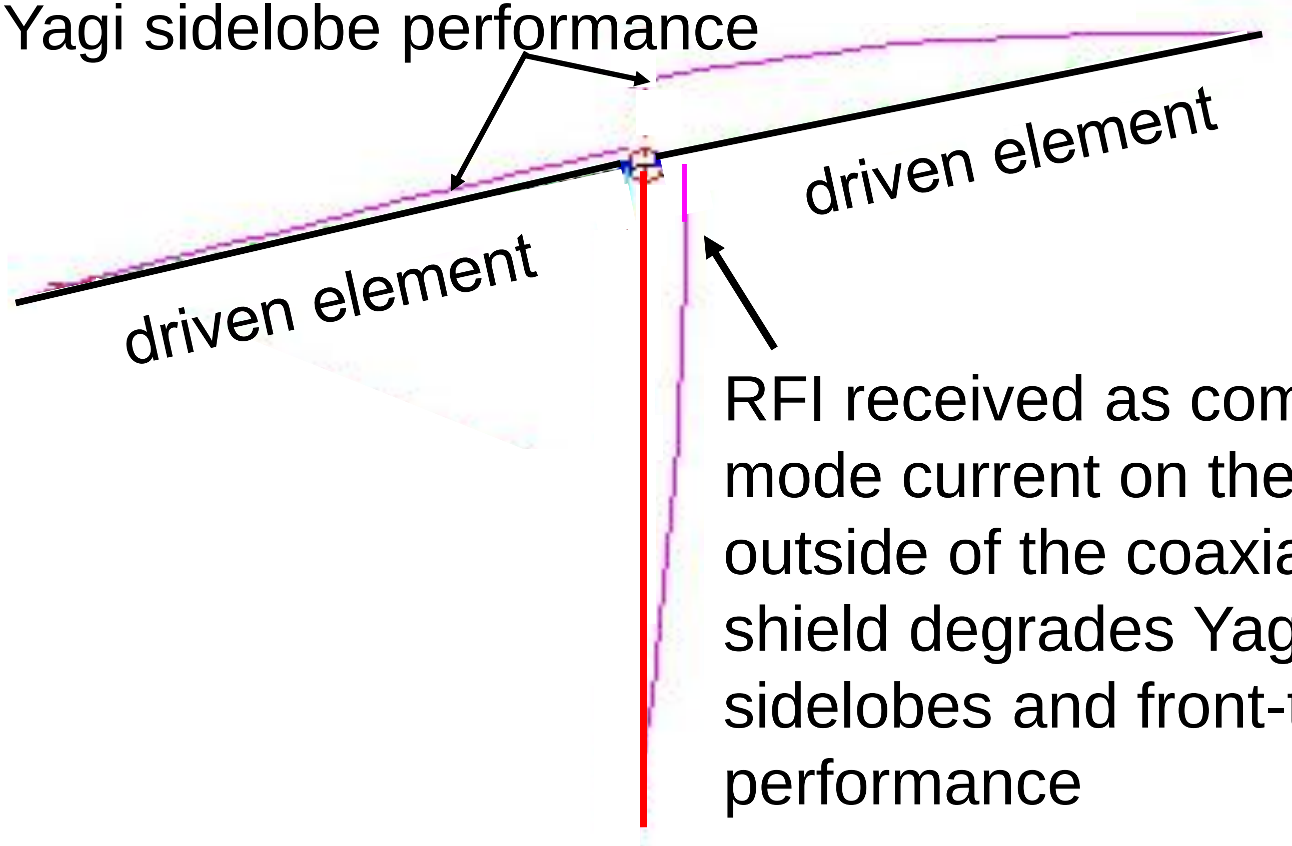


www.wilson-company.com/product/30127pp/two-bolt-heavy-duty-clamp-body-only

RFI Suppression Choke

necessary at the feed point of a Yagi balanced driven element

Unbalanced driven element current degrades Yagi sidelobe performance

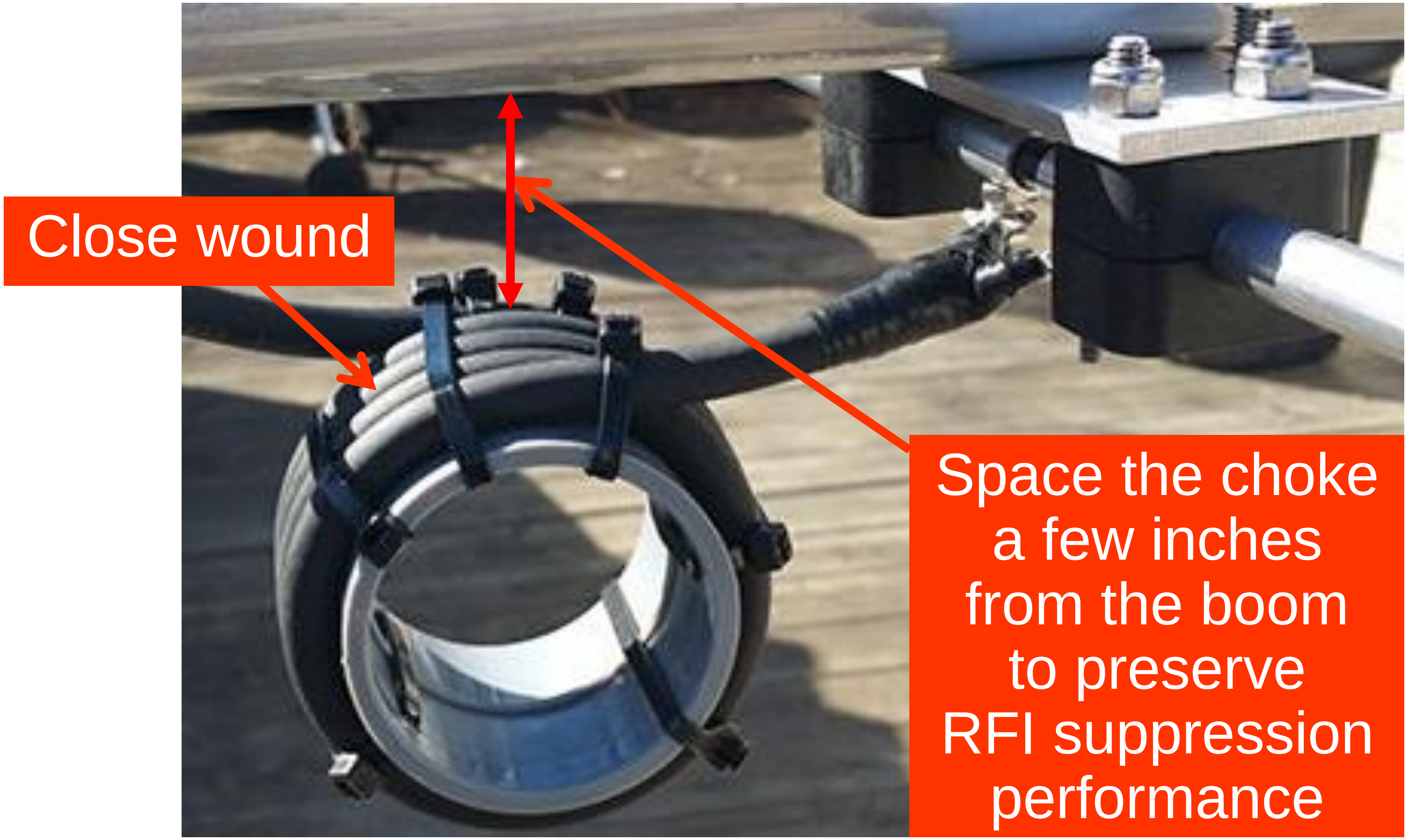


RFI received as common mode current on the outside of the coaxial cable shield degrades Yagi sidelobes and front-to-rear performance

www.innovantennas.com/en/baluns-why-do-i-need-one.html

RFI Suppression Choke

Coiled RG-213 coaxial cable suitable for quiet RFI environments



Four turns of RG-213 wound on a 2.5 inch diameter form

The builder must measure for choke resonance near 50 MHz

RFI Suppression Choke

20 mix-31 round cable ferrite cores installed over RG-213

Suitable for moderate RFI environments

Space the choke a few inches from the boom to preserve RFI suppression performance

DX Engineering DXE-CB31-500-10 ferrite cores

www.dxengineering.com/parts/dxe-cb31-500-10

www.innovantennas.com/index.php?option=com_content&view=article&id=3&Itemid=189&lang=en

RFI Suppression Choke

five mix-31 clamp-on ferrite beads optimized for severe RFI environments

before installation

audiosystemsgroup.com/ChokesVHF.pdf

Low Loss Coaxial Cable
Really pays off on 6 meters

RG-8X	40 feet *per dB*
RG-213	60 feet *per dB*
LDF4-50A	200 feet *per dB*
LDF5-50A	400 feet *per dB*

LDF4-50A has one dB less loss than RG-213 at a cable length of only 85 feet

LDF4-50A has two dB less loss than RG-213 at a cable length of only 170 feet

LDF5-50A has one dB less loss than LDF4-50A at a cable length of 475 feet

Reliable 6 Meter
Coaxial Cable Connectors

N and UHF connectors are commonly used

- both have insignificant measurable loss

High quality silver plated PL-259 UHF connectors

- much more reliable center pin mating force than N connectors

Common N connector failures caused by pin installation errors

- unreliable mating caused by insufficient pin length and pin pullback
- damage caused by excess pin length and axial pin misalignment

Captive pin N connectors solve N connector reliability issues

- assures the necessary +/- 0.020 inch (+/- ½ mm) pin depth tolerance
- assures axial pin alignment and centering
- prevents pin pullback

Avoid using adapters as much as possible

- use only name-brand silver plated adapters
- never use nickel plated or “astro-plated” connectors and adapters
- never use cheap import “no name” adapters and connectors

Wrench tighten your all of your PL-259 connectors (~1/4 turn)

Avoid saving a few dollars on cheap unbranded coaxial cable connectors and adapters

Amphenol 83-1SP
PL-259 UHF Male Connector

Shell is labeled exactly:
Amphenol 83-1SP

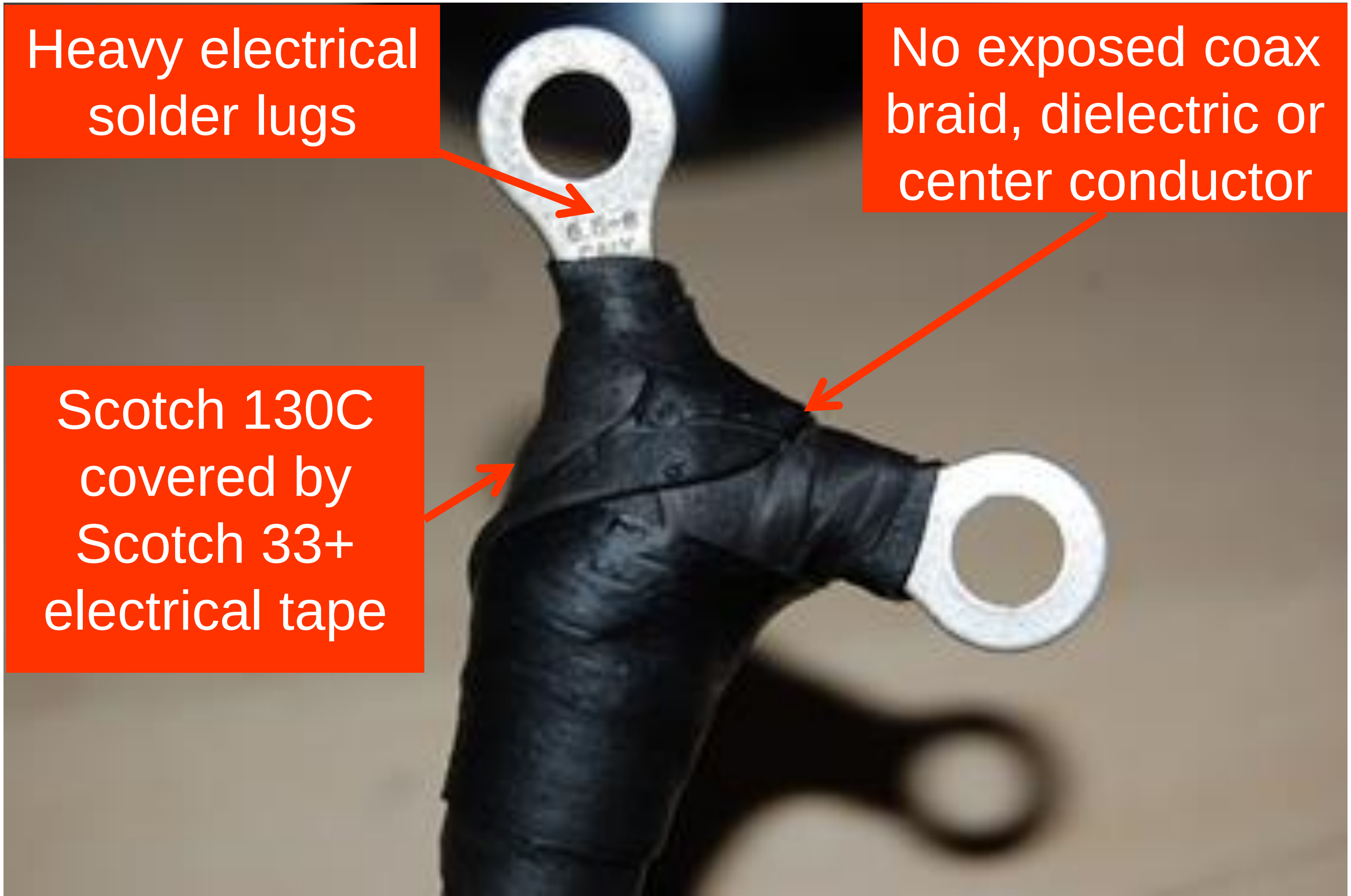
Silver Plated Center Pin

Silver Plated Body

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

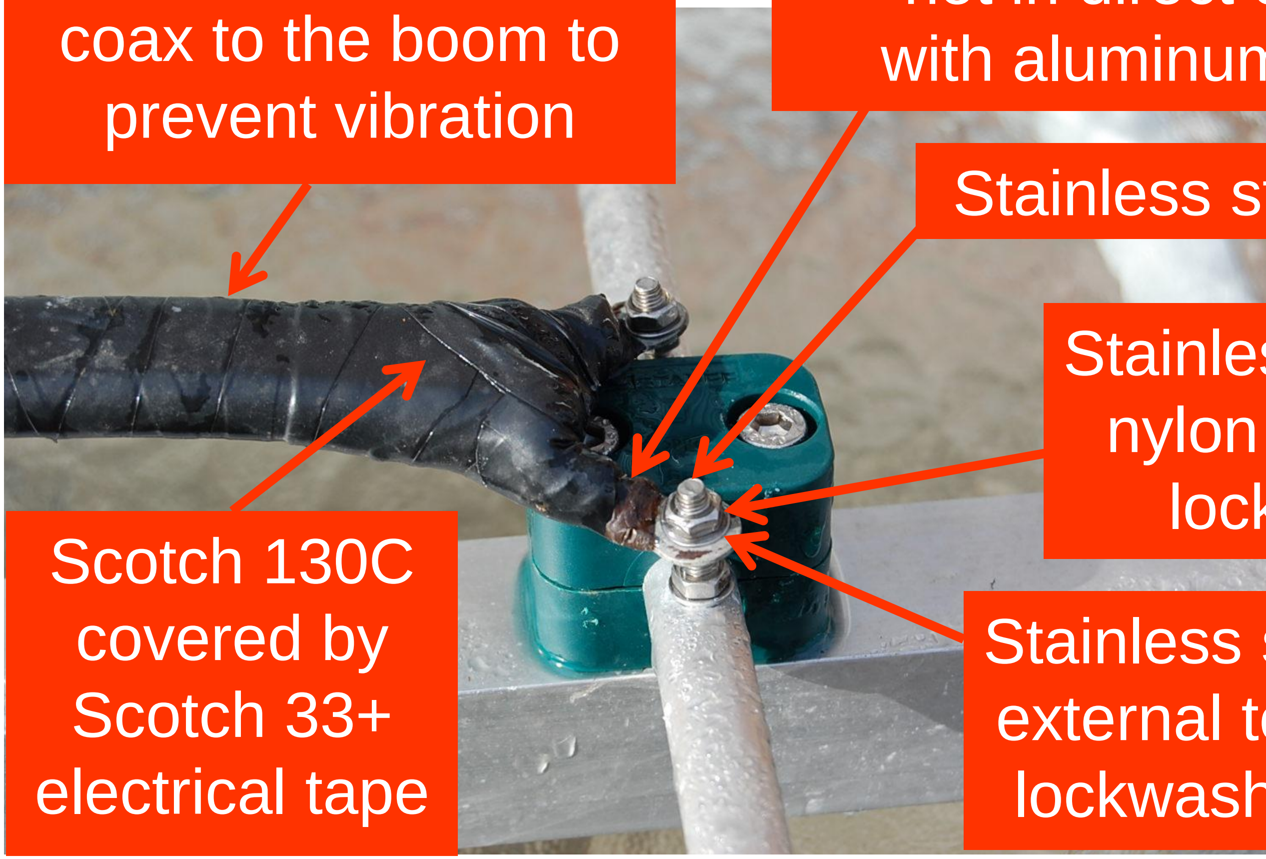
The Amphenol 83-1SP is an excellent connector for 6 meters

Waterproofing the end of RG-213 coaxial cable



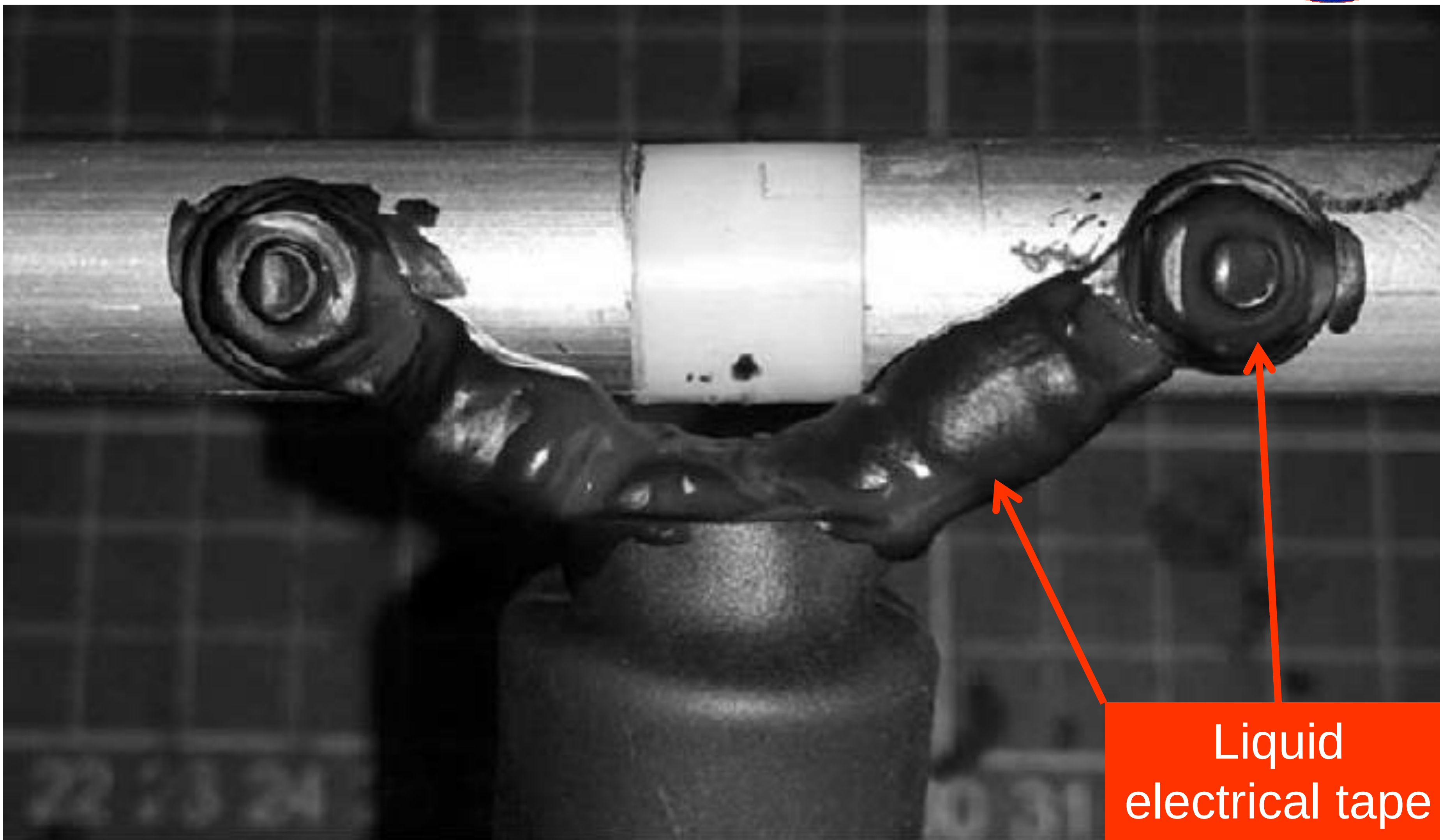
Yagi Driven Element

Waterproof, shakeproof and corrosion resistant driven element connections



Driven Element Connections

Waterproof and Corrosion Resistant



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

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

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

www.homedepot.com/p/3M-Scotch-Super-33-3-4-in-x-66-ft-Electrical-Tape-06132-8/300666852