Stacking of VHF Antennas

A Helpful Reference for a Novice

ERAÜ XVIII Talvepäev 2016

By ES3RF January 23th, 2016

Questions to be Answered

- What are the reasons for stacking antennas?
- Would building a bigger antenna be better than stacking?
- If we stack, what order of gain increase can we expect?
- Is it better to stack vertically or horizontally?
- How far apart do we stack the antennas?
- How do we manage the phasing requirements?
- How do we manage the matching requirements?
- Is ot possible to use open wire feedline for stacking?
- How to stack antennas for different bands onto one mast

Why stack Antennas?

- Greater gain (compared to boom length increase)
- Decrease the beamwidth (in the plain of stacking only)
- Noise cancellation (less side lobes, narrower main lobe)
- Less boom length, stronger mechanically

Consideration For a Single band Increase in Gain

- Do I use a longer antenna or stack a shorter one?

  - 2.35 db gain for 2x boom length increase

    - Advantage or disadvantage?

  - 2.7 to 2.9 db gain for stacking 2 antennas

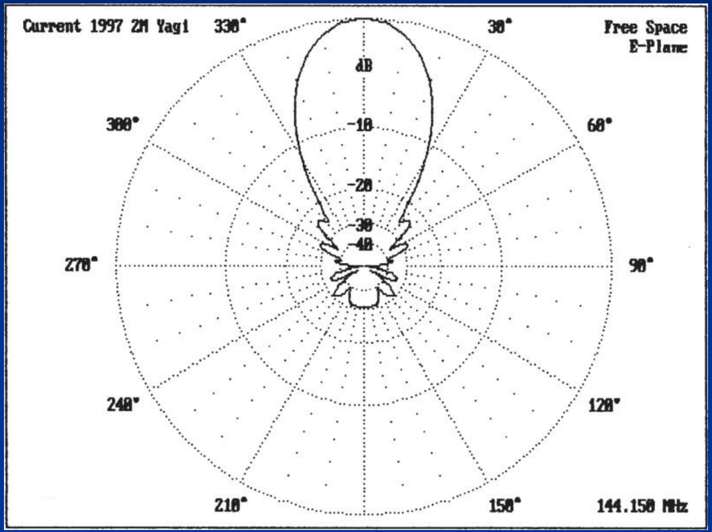
- Space available
- Maine lobe beamwidth
- Stacking distance optimization

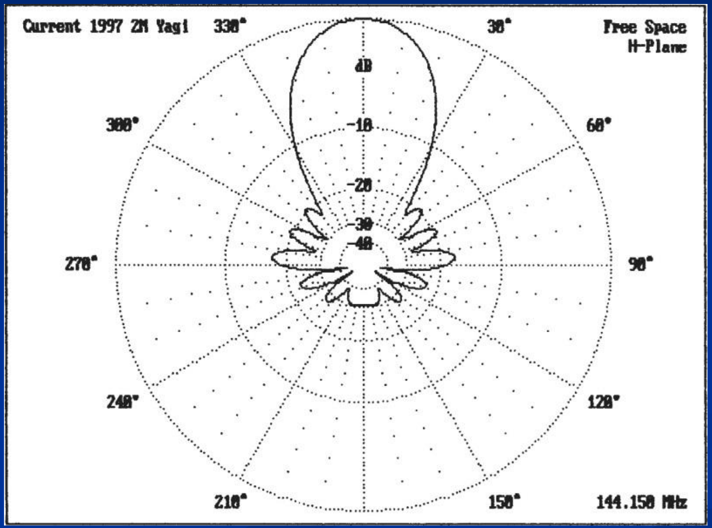
Super Long Yagi

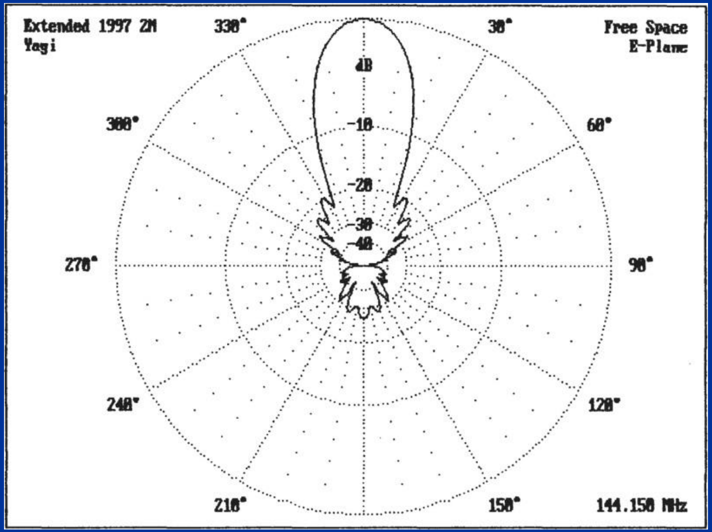
- **VC1T Team antenna**

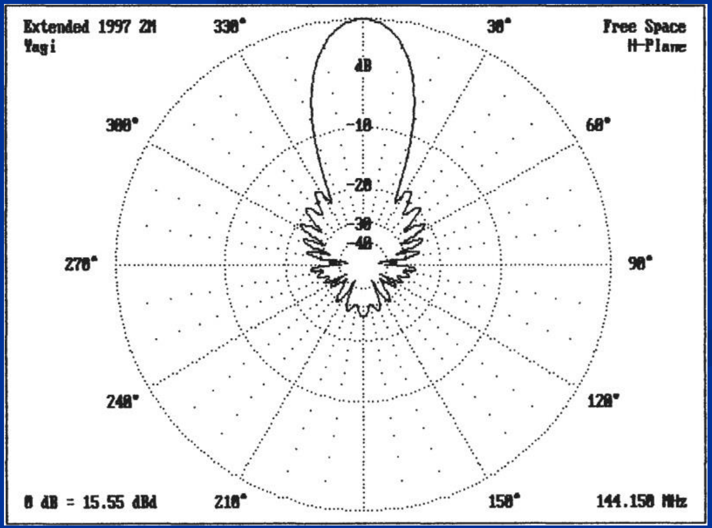
- **Constructed by VE7BQT**
- **Antenna:** 43 el on 2 stand Kevlar cord
- **Lenth:** 30 meters (reflector to director #41)
- **Height:** 6 to 8.5 meters above ground
- **Forward Gain:** 23.9 dBd
- **Front to Back Ratio:** 32dB
- **Front to Side Ratio:** 25 dB (270°)
- **Horizontal Main Lope Width:** 15.6° at -3db points
- **Vertical Main Lobe Thickness:** 4.6° at -3db points.

6 m long boom, 13 el. 144 MHz yagi, gain 12.7 dbd
versus
12 m long boom, 18 el. 144 Mhz yagi, gain 15.5 dbd









Horizontal or Vertical Stack?

- Horizontal stack:

Narrow in E-plane, wide in H-plane

- Vertical stack:

Narrow in H-plane, wide in E-plane

What is Aperture?

- Effective antenna area

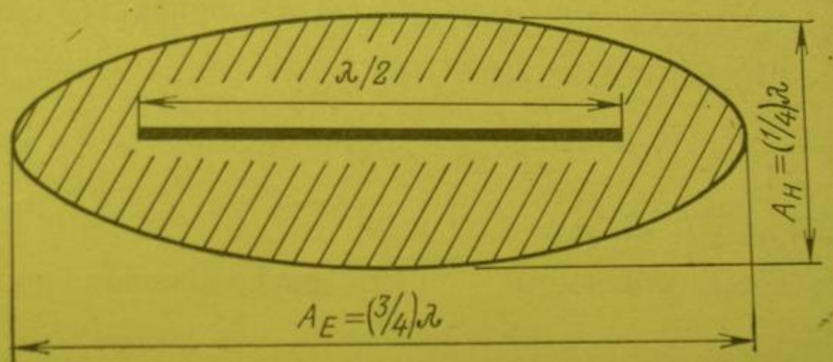


Рис. 2.62. Эффективная площадь раскрыва полуволнового диполя

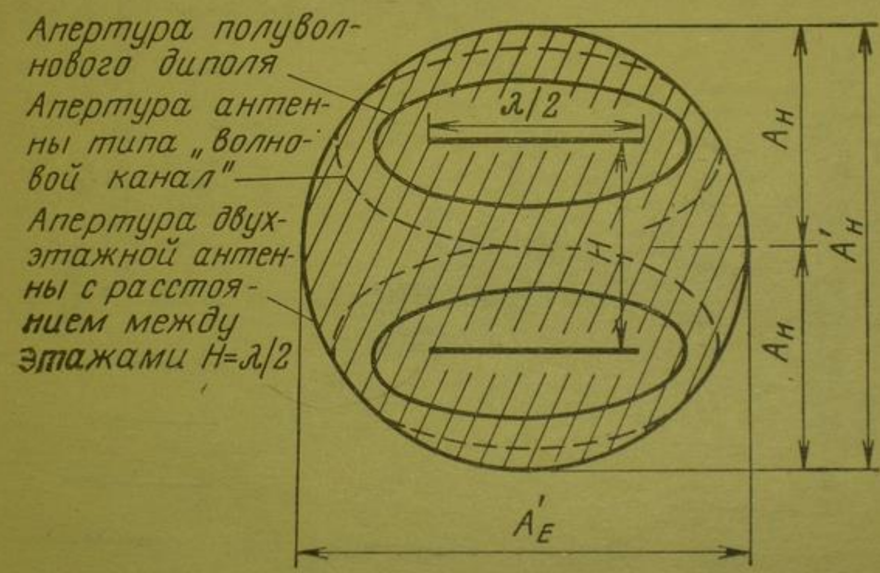


Рис. 2.63. Совмещение апертур двух антенн, отстоящих друг от друга на расстояние λ/2

$$A_E = \sqrt{A_{эфф}\,\alpha_E/\alpha_H}; \qquad A_H = \sqrt{A_{эфф}\,\alpha_H/\alpha_E}.$$

How far apart we stack?

DL6WU Stacking formula for Long Yagis

(good only for yagis of more than 10 elements and boom length greater than about 2 wavelengths)

D=W/2*sin(B/2))

where: D = stacking distance

W = wavelength, same units as D

B = beam width (radiat. angle) between -3db points

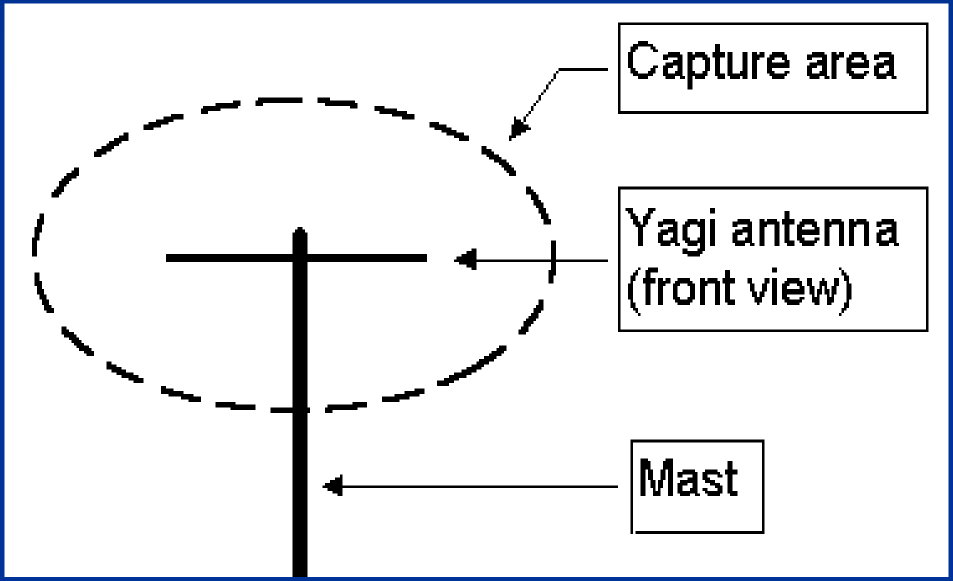
use vertical beamwidth for vertical stacking

use horizontal beamwidth for horizontal stacking

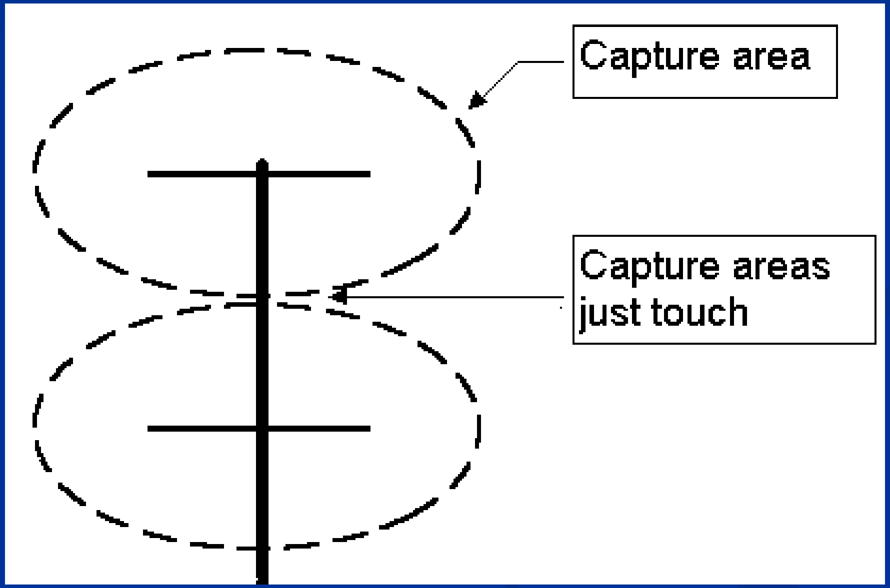
How far apart do we stack?

Capture Area or Effective Aperture

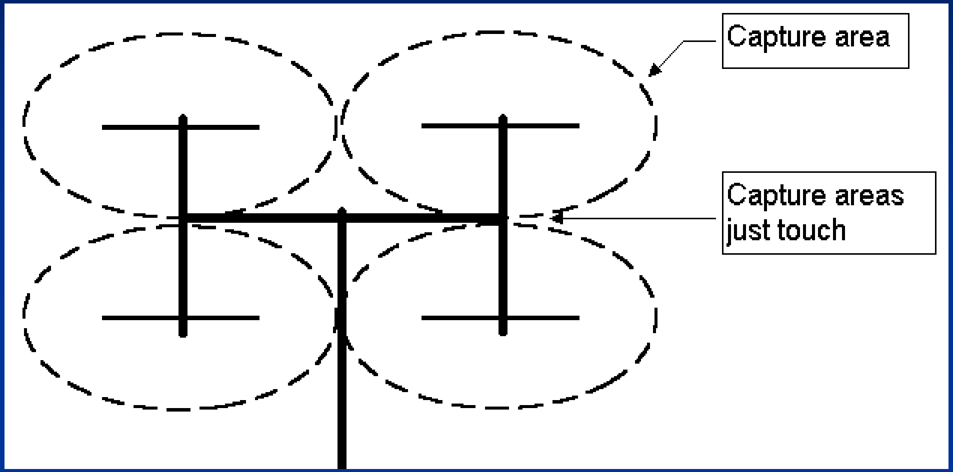
- Capture area of single yagi



- More capture area = more gain



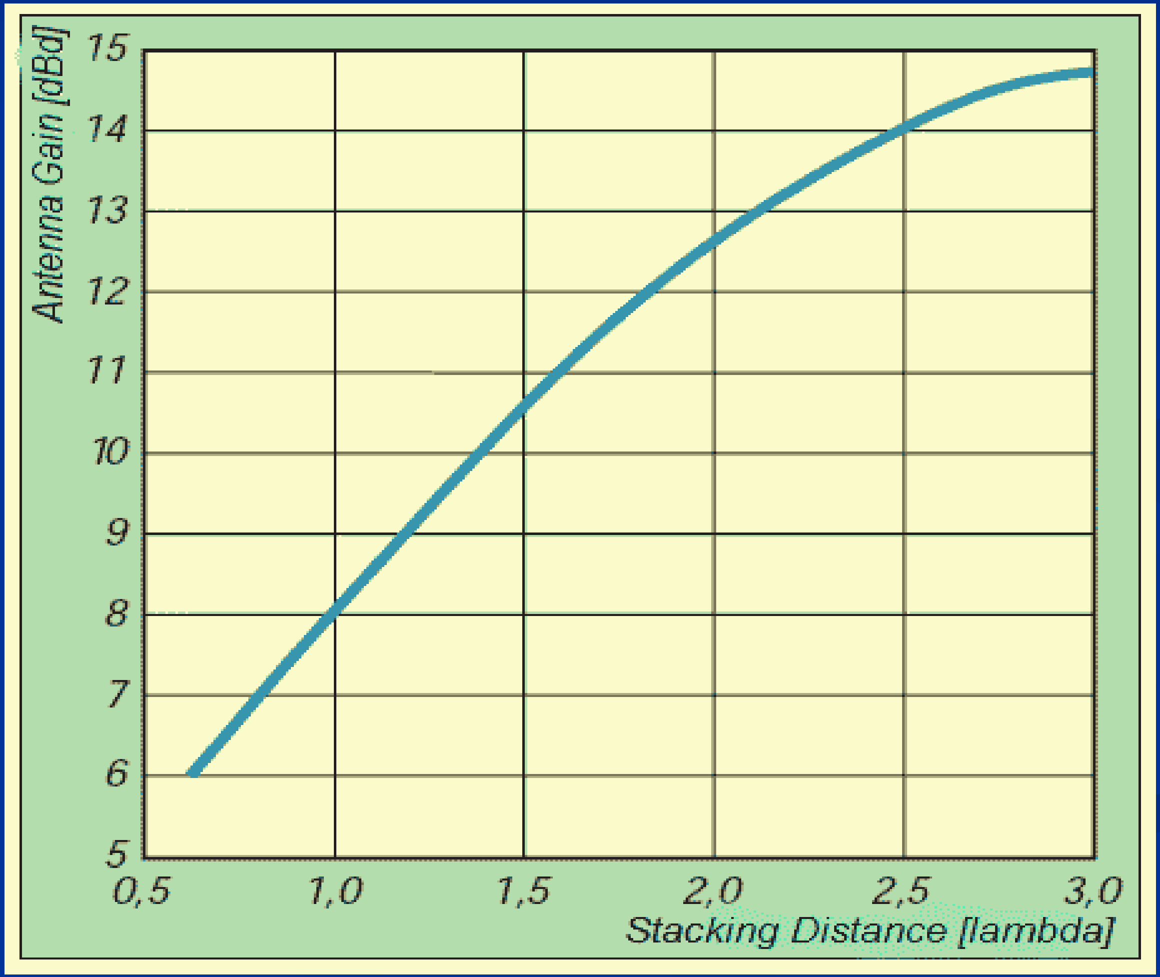
Points to know



- Capture areas just touch in both the vertical and horizontal directions.
- The horizontal spacing is greater than vertical, because the capture areas are elliptical
- The horizontal cross-arm of the H-frame is in the same plane as the yagi elements, but interactions are minimized, because the cross-arm is outside of the capture area

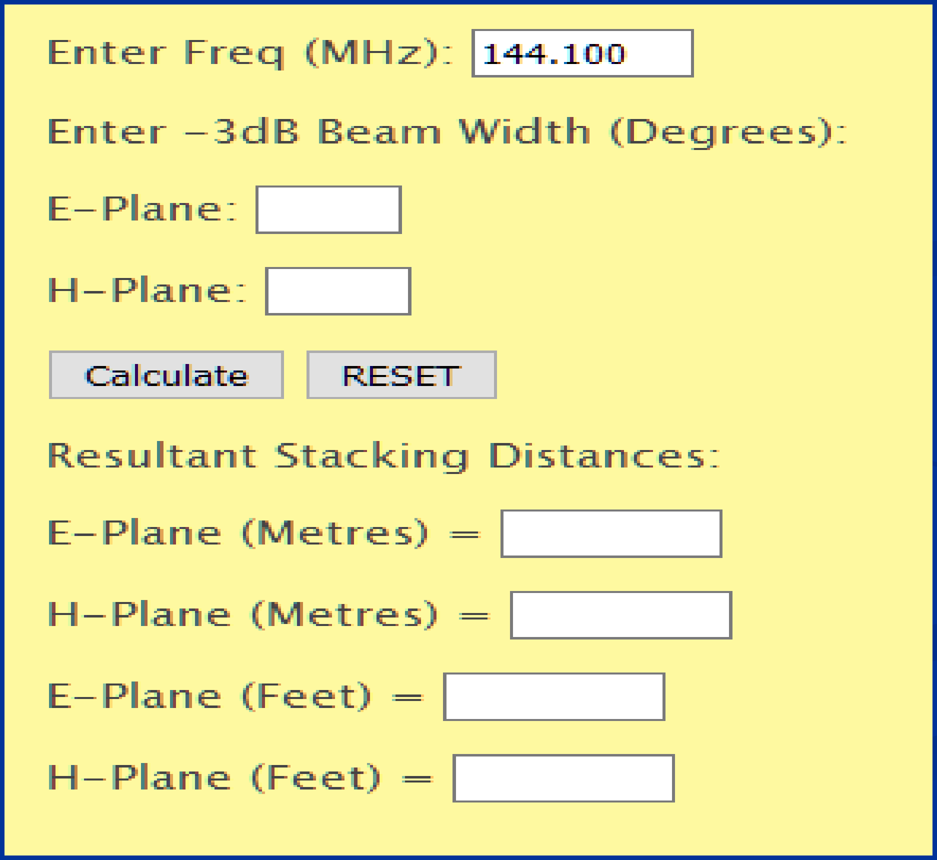
Stacking distance

- The gain (dBd) of a single Yagi versus the stacking distance (lambda) by DK7ZB



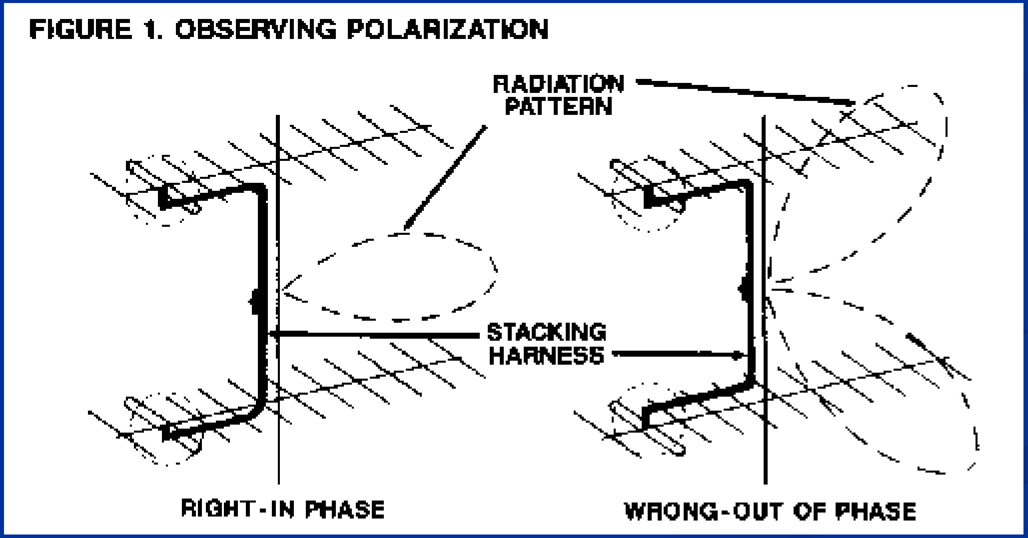
G4CQM stacking distance online calculator

- **Enter the -3dB Beam Width (Degrees) information found on each yagi design page…**
  (http://g4cqm.www.idnet.com/antennadesigner/Stacking-Yagis.htm)

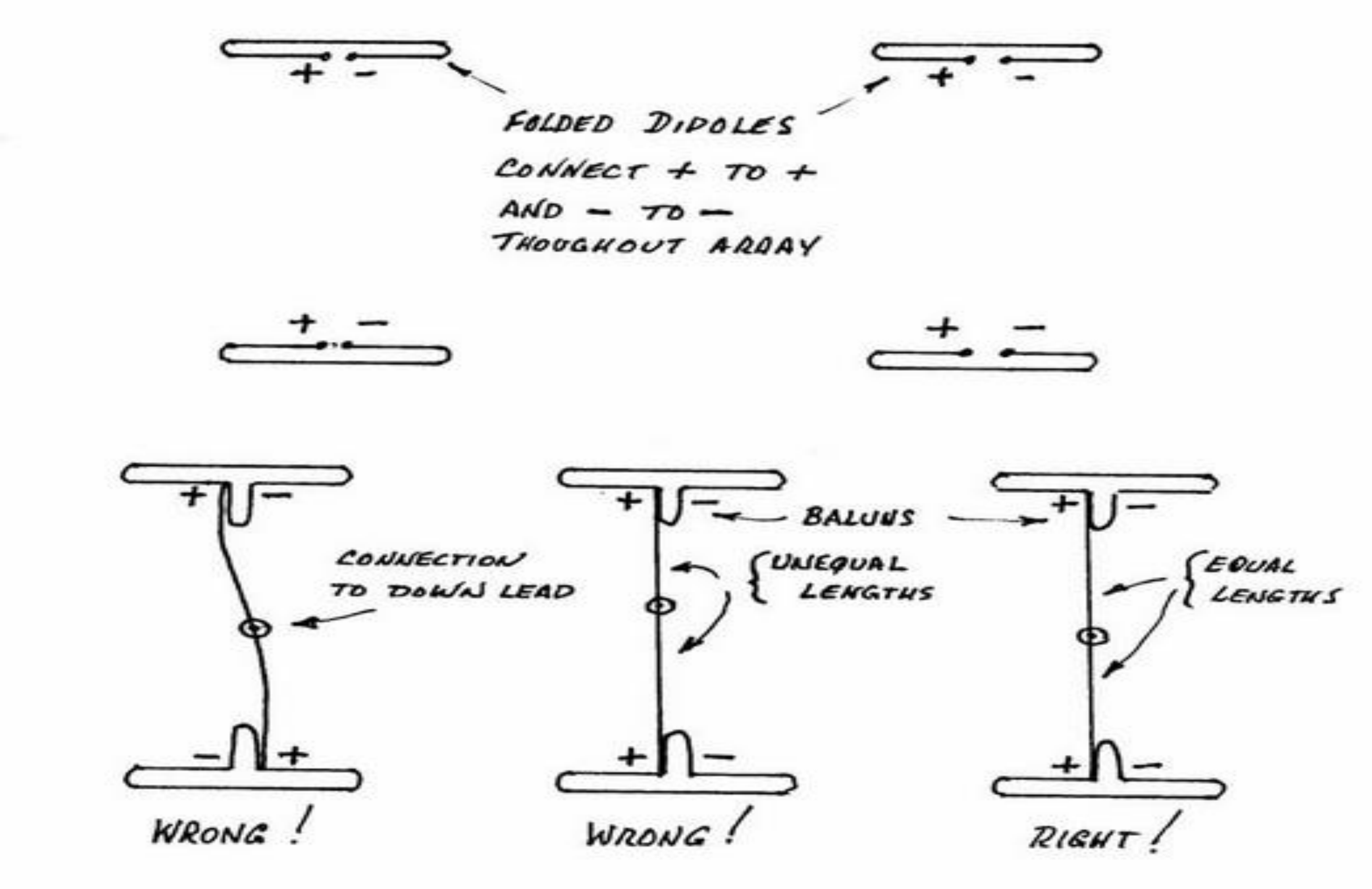


Phasing yagis

- It simply means that looking at the stack as a receiving antenna, signals from all dipoles must be in phase at the feeder junction to the line to the shack!

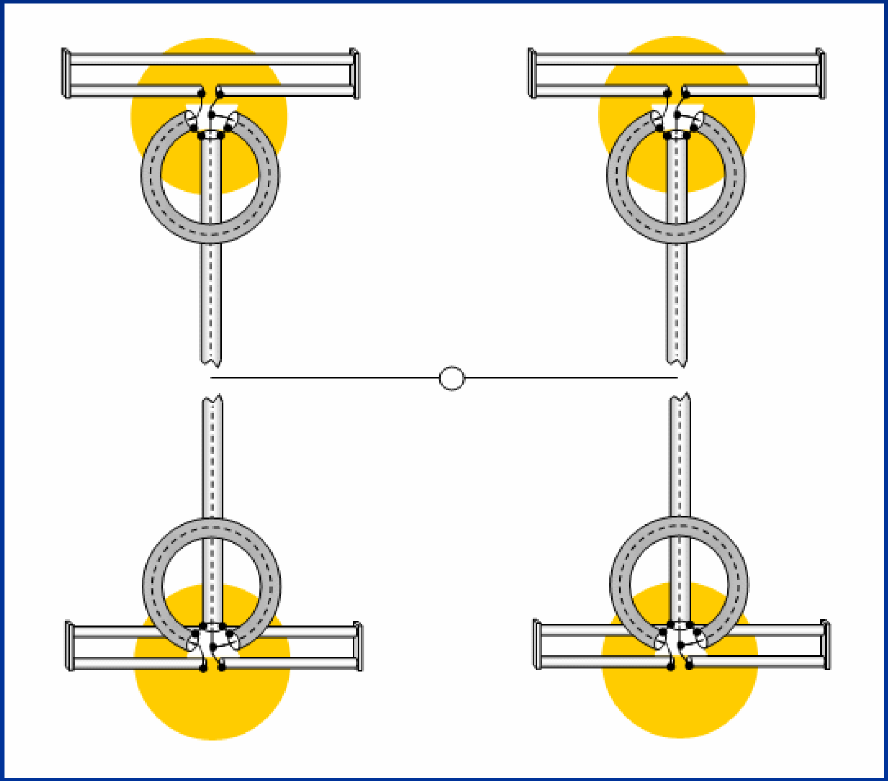


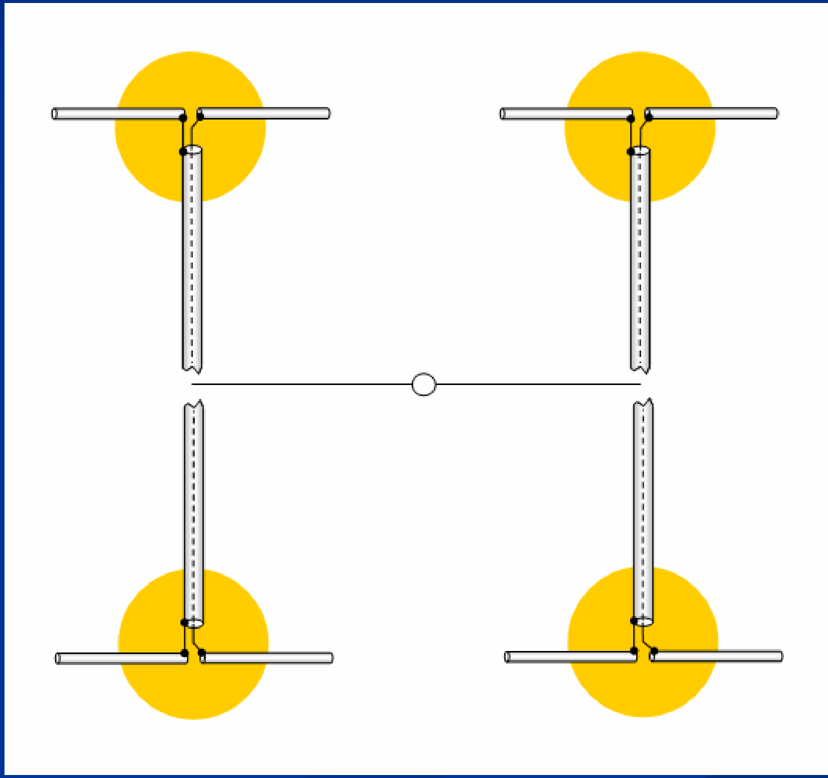
Phasing yagis



Phasing yagis

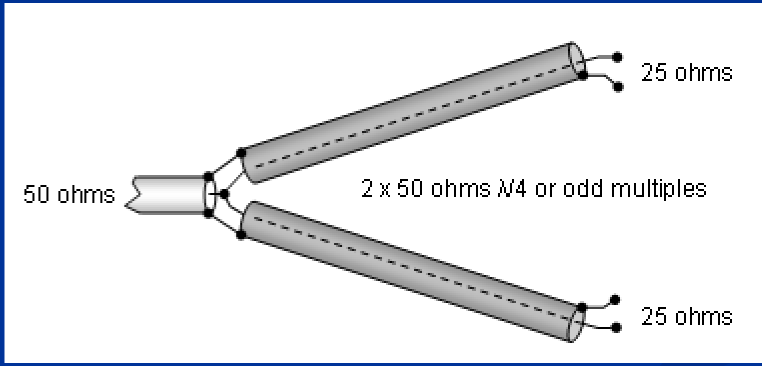
- Folded and Straight Split Dipoles in phase

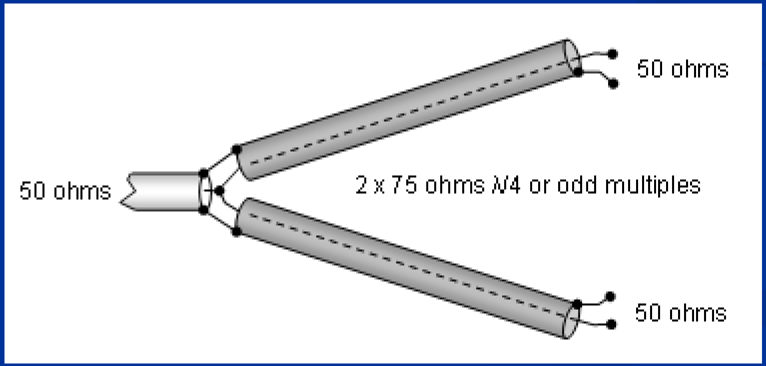




Matching and Feeding of Stacked Yagis

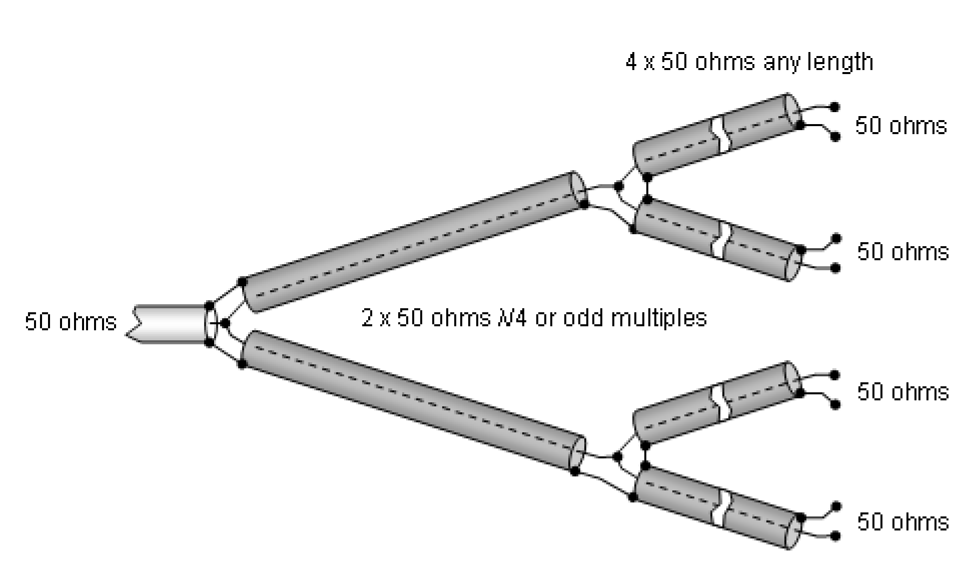
- Matching Transformers from coaxial cables for 2 Yagis





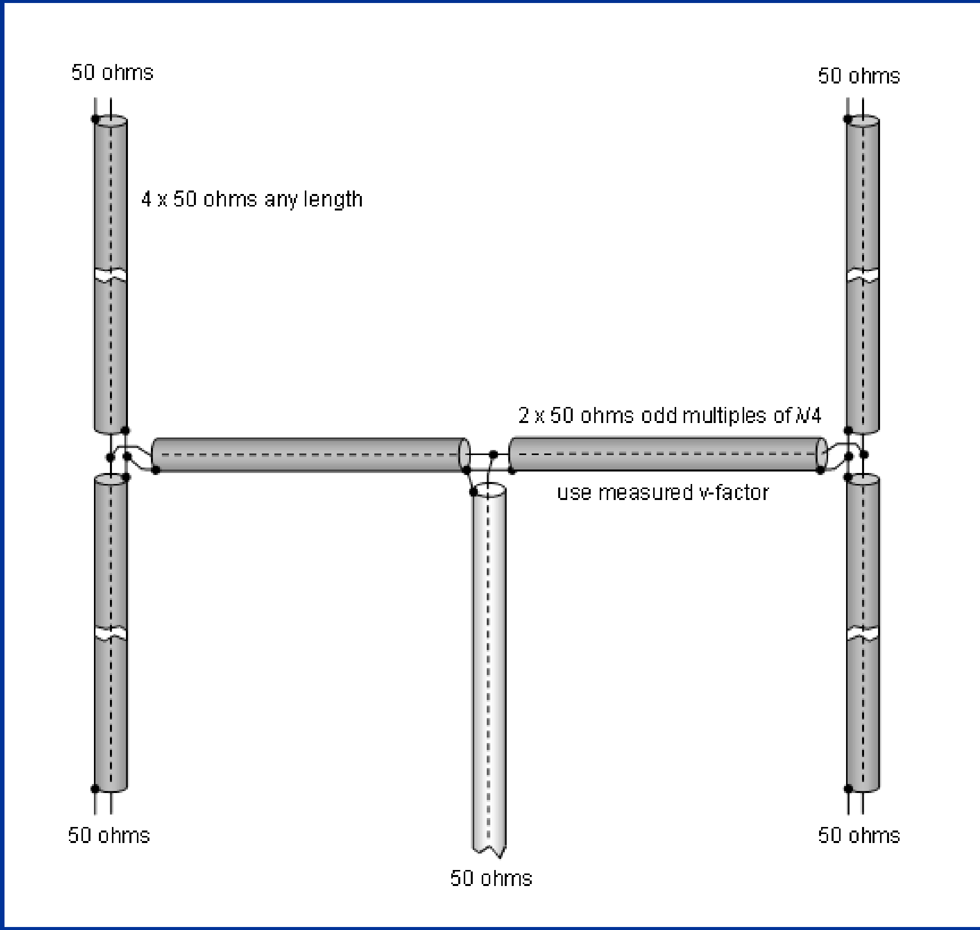
Matching and Feeding of Stacked Yagis

- Matching Transformers from coaxial cables for 4 Yagis



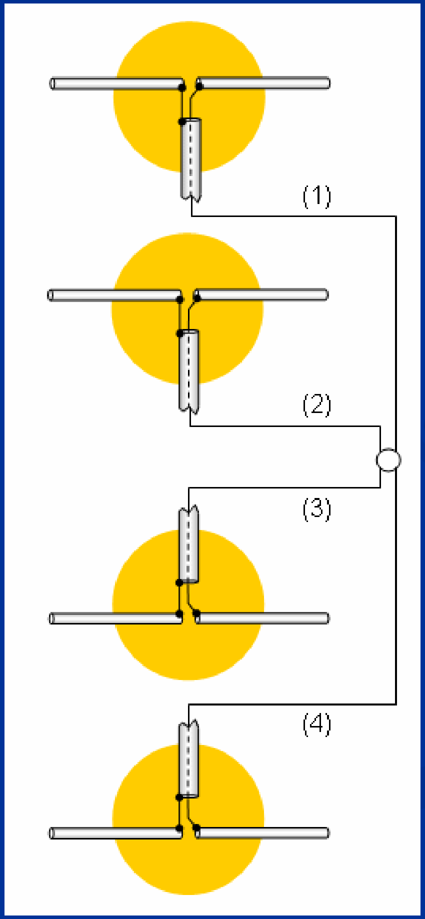
Matching and Feeding of Stacked Yagis

- Antennas in typical H-frame configuration



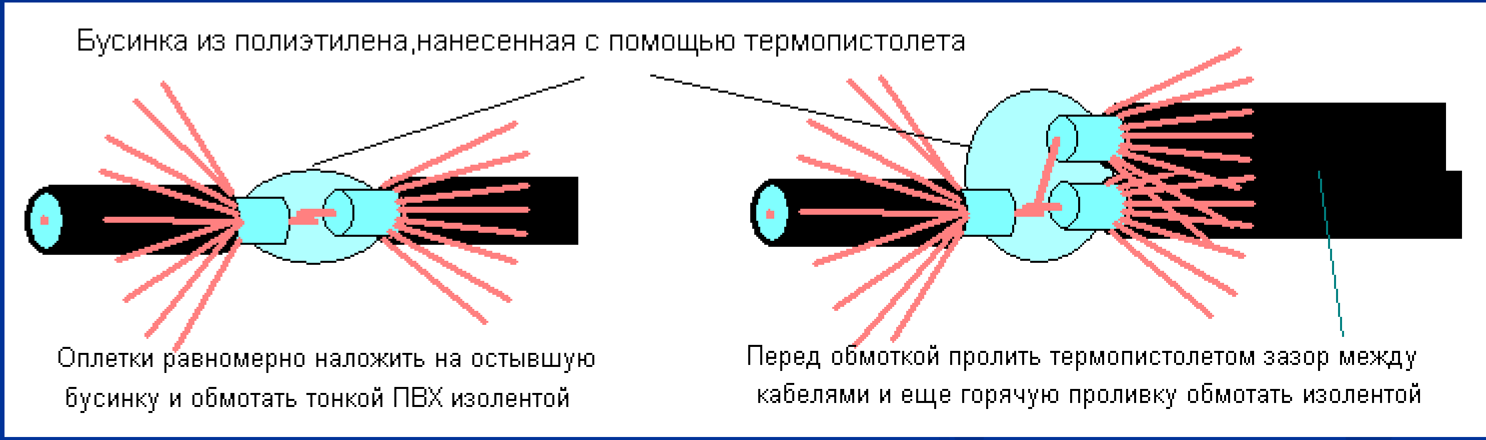
Matching and Feeding of Stacked Yagis

- 4 yagis, vertically stacked in phase. All feeding coaxials (1,2,3 and 4) should be equal length



Matching and Feeding of Stacked Yagis

- Join cables by soldering



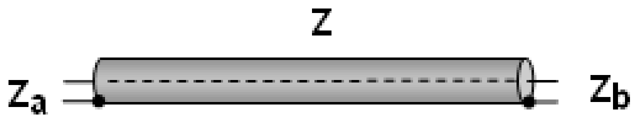
Coaxial Power Transformers (Splitters)

- Home made splitters.
- **The basis of the power splitters/combiners is a construction of a square tube for the outer conductor and a round tube for the inner conductor. It forms a quarter wave coaxial impedance transformer.**

Splitters Design

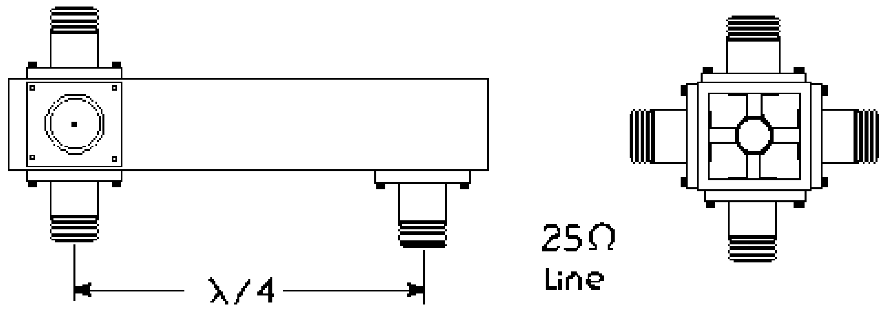
- Main feeder line is coaxial cable 50 ohm (Za)
- 2 x 50 ohm antenna (Zb) = 25 ohm
- 3 x 50 ohm antenna (Zb) = 16.7 ohm
- 4 x 50 ohm antenna (Zb) = 12.5 ohm
- To determine ¼ wave line between Z1 and Z2:

$$Z = \sqrt{Z_a \cdot Z_b}$$

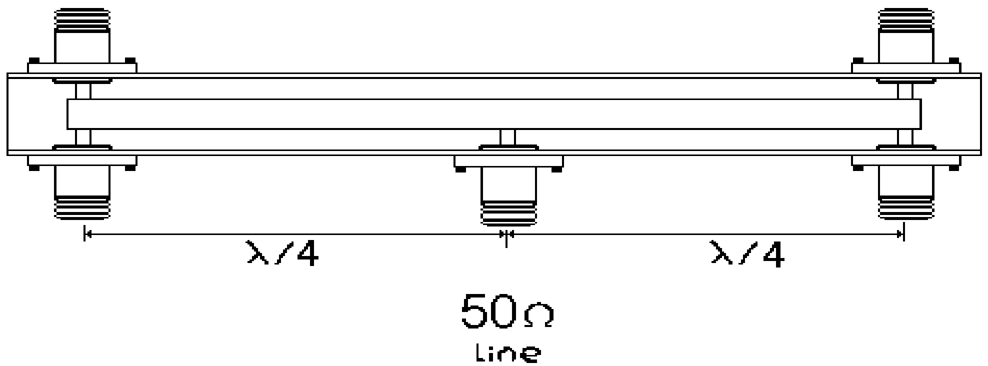


Types of power splitters

Quarter-wave four way splitter



Half-Wave four way power splitter



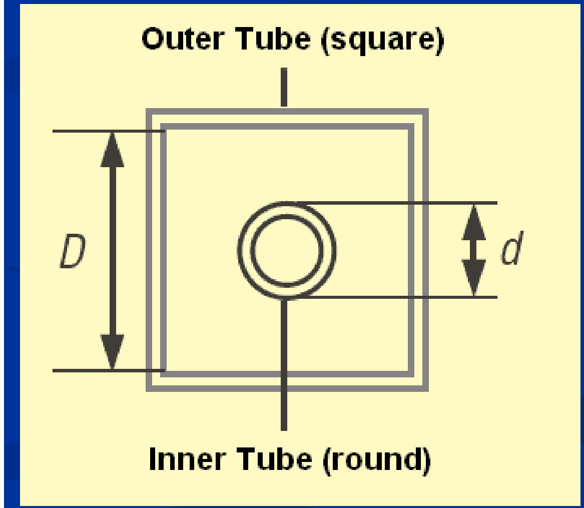
Splitters design (formulas)

- Square or round tube (Dint) for outside conductor
- Tube or wire (d) for inside conductor
- N-type connectors

$$\text{velocity factor } \nu = \frac{1}{\sqrt{\varepsilon_r}} \qquad \varepsilon_r\ (\text{dielectricums material})$$

$$Z_{round} = \frac{1}{\sqrt{\varepsilon_r}} \cdot 138 \cdot \log_{10}\left(\frac{D}{d}\right)$$

$$Z_{square} = \frac{1}{\sqrt{\varepsilon_r}} \cdot 138 \cdot \log_{10}\left(1.08 \cdot \frac{D}{d}\right)$$



Splitter in principle

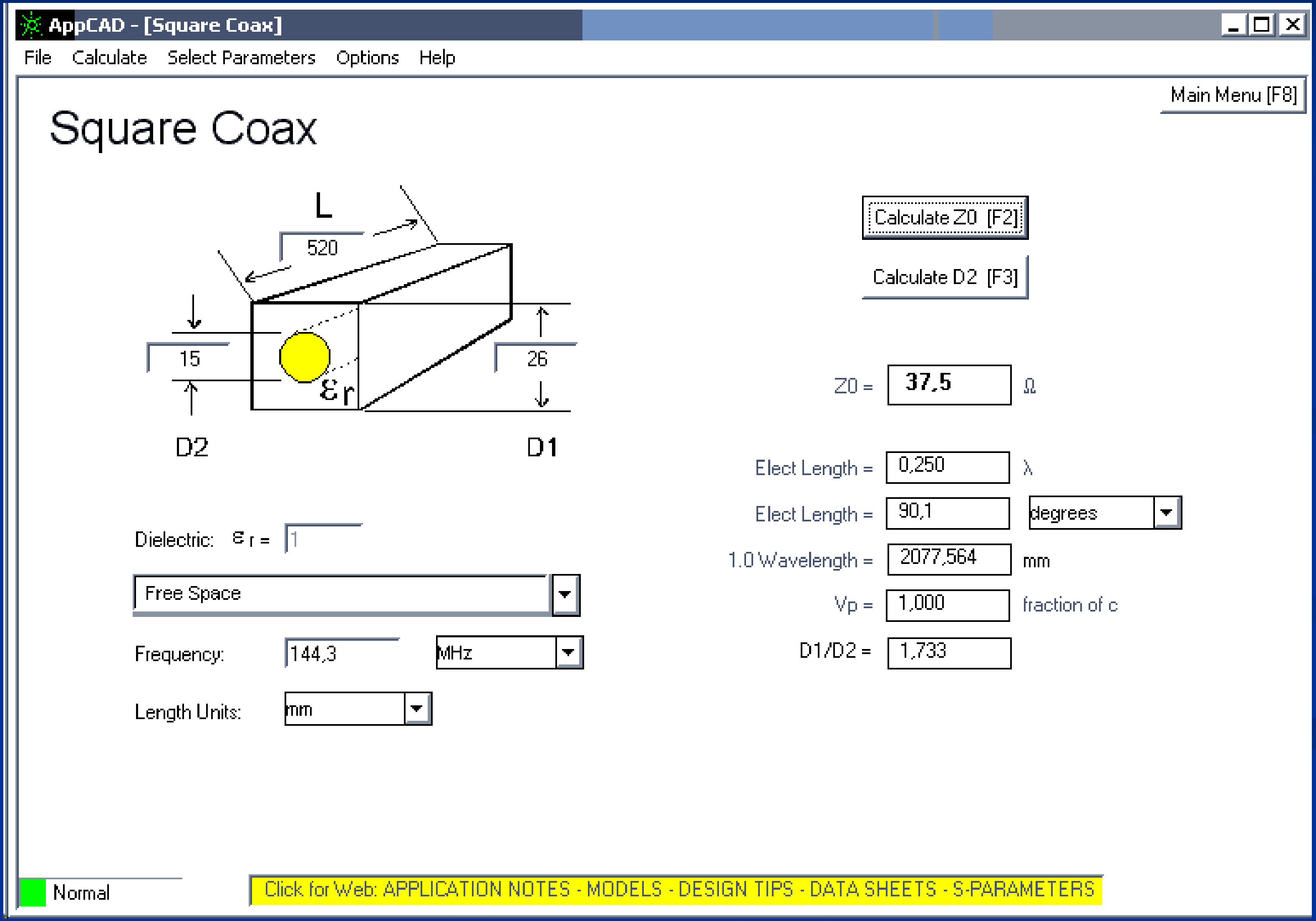
- Splitter is a construction from outer and inner conductors, which are forming ¼ wave coaxial impedance transformer.
- The relation of D/d influences the resistance/impedance of the splitter.
- Impedance transformation will be made with lengths of lambda/4
- A halfwave splitter consists of two ¼ wave splitters in parallel

Splitters design

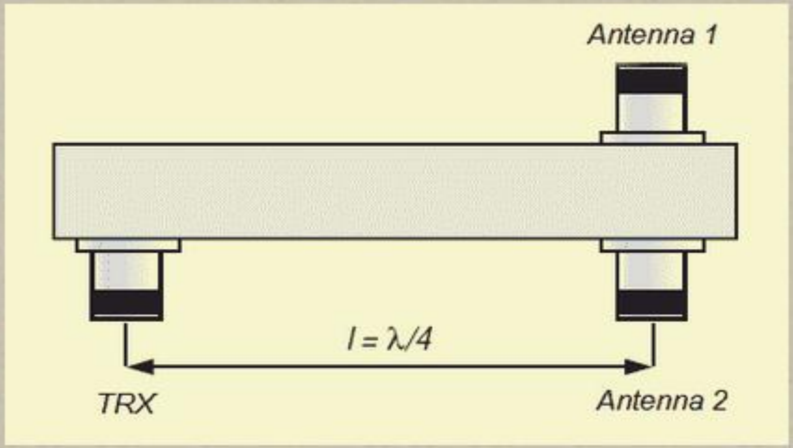
- The freeware“AppCad” can be downloaded from http://www.hp.woodshhot.com

Splitters design

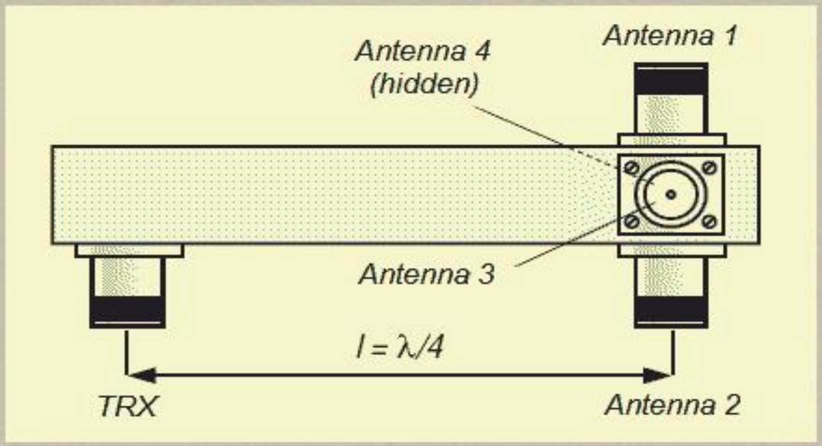
- AppCad's screenshot



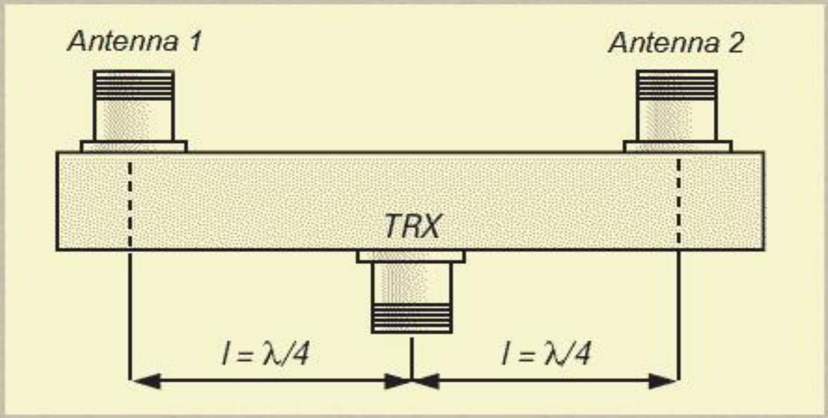
Types of power splitters



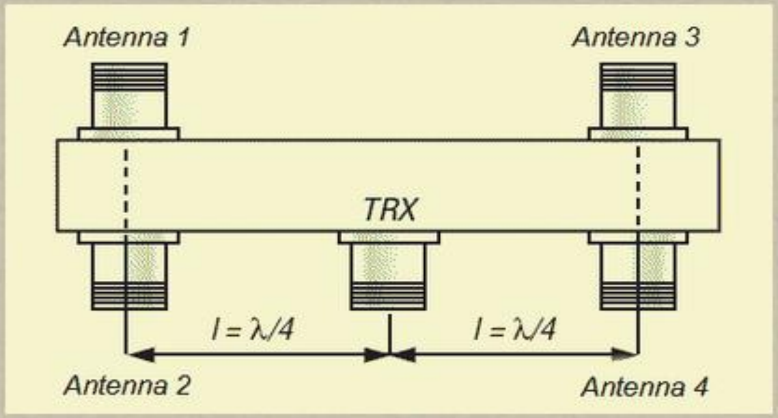
The λ/4-power splitter (2-way) = Type 1a



The λ/4-power splitter (4-way)= Type 1b



The λ/2-powersplitter (2-way) = Type 2a



The λ/2-powersplitter (4-way) = Type 2b

Splitter dimensions

- Calculated by AppCadd:

Attributes of the Power Splitters

Type	Ways	Length	Z_E	Z_A	Z_0
1a	2x	λ/4	25 Ω	50 Ω	35,4 Ω
1b	4x	λ/4	12,5 Ω	50 Ω	25 Ω
2a	2x	λ/2	50 Ω	100 Ω	70,7 Ω
2b	4x	λ/2	25 Ω	100 Ω	50 Ω

Lengths of the inner Tubes (d) for the Bands 2m, 70cm and 23cm

Amateurband	Principle	Length inner tube
2 m	λ/4	520 mm
70 cm	λ/4	173 mm
23 cm	3λ/4	189 mm

Table 1: λ/4-Splitter , 2-way, Type 1a, needed Z=35,4 Ω

Type	Square	Inner (D)	Round Tube (d)	Z
1a	30x2 mm	26 mm	15,5 mm	35,6 Ω
1a	29,5x2,4 mm	24,7 mm	15 mm	34,4 Ω
1a	23,5x1,5 mm	20,5 mm	12 mm	36,6 Ω
1a	19,5x1,5 mm	16,5 mm	10 mm	34,6 Ω
1a	30x2 mm	26 mm	15 mm	37,5

Table 2: λ/4-Splitter , 4-way, Type 1b, needed Z=25,0 Ω

Type	Square	Inner (D)	Round Tube (d)	Z
1b	25x2 mm	21 mm	15 mm	24,7 Ω
1b	19,5x1,5 mm	16,5 mm	12 mm	23,7 Ω

Stacking with open wire feedline

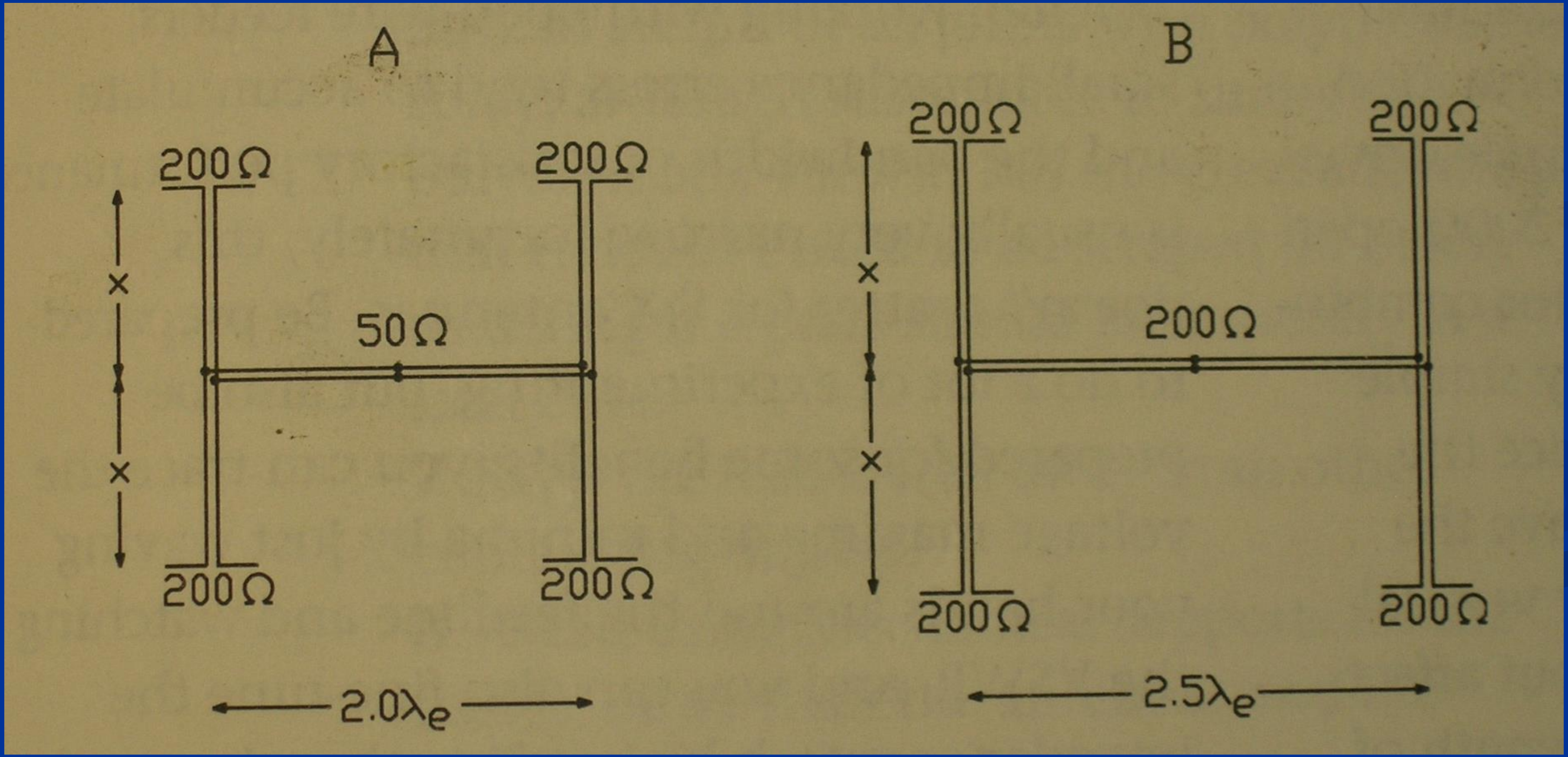
- The advantage that open wire lines have over Coaxial cable feeds is twofold:

  -Firstly the feeds provide better receive performance due to the lower losses between the antenna and the Pre-amp.

  - Secondly, they are unlikely to suffer from the ingress of water or condensation in the same way that coax does in damp climates.

Stacking with open wire feedline

- A – for a shorter yagis, which need 1.9 - 2.2 lambda horizontal distance.
- B – for a longer yagis and for groups of 4 yagis, which are need 2.2 – 2.9 lambda horizontal distance.



Stacking with open wire feedline

- The basic formula for calculation:

$$Zo = 276 \times \log(2D/d)$$

Where: D = the pitch spacing of the wires
d = diameter of wires

- For calculations also the AppCad software can be used

- To achieve a 200 ohm nominal impedance using 4.76mm diameter wires the pitch spacing would be 12.6mm. The lines are spaced using accurately machined PTFE spacers, these control the characteristic impedance of the lines so the pitch must be accurate.

Stacking with open wire feedline

- Designed by G4RGK for 8 x DJ9BV yagis

G4RGK array

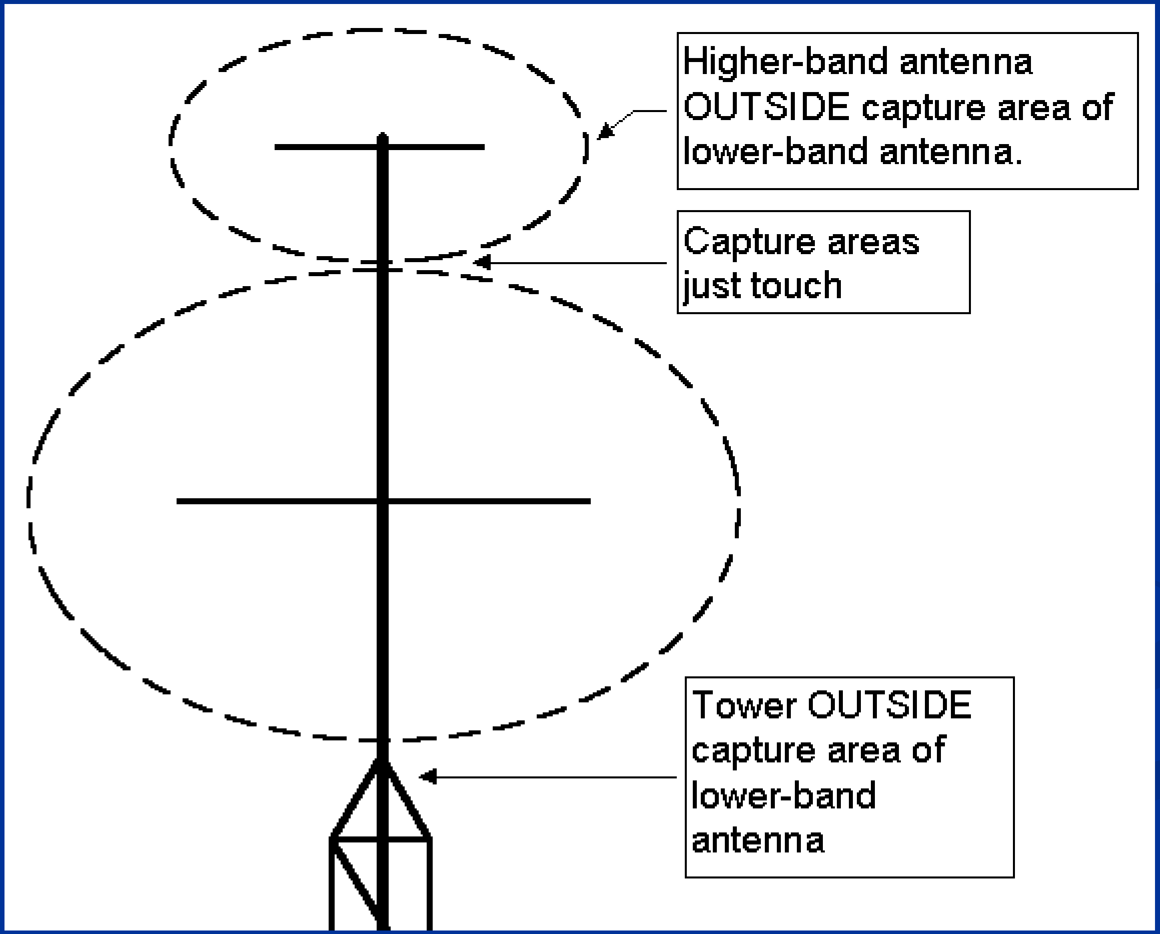
- Here is used Method (A) for group of 4 yagi and Method (B) for groups of 2 x 4 yagis

Stacking with open wire feedline

- I1NDP
- DL1APV

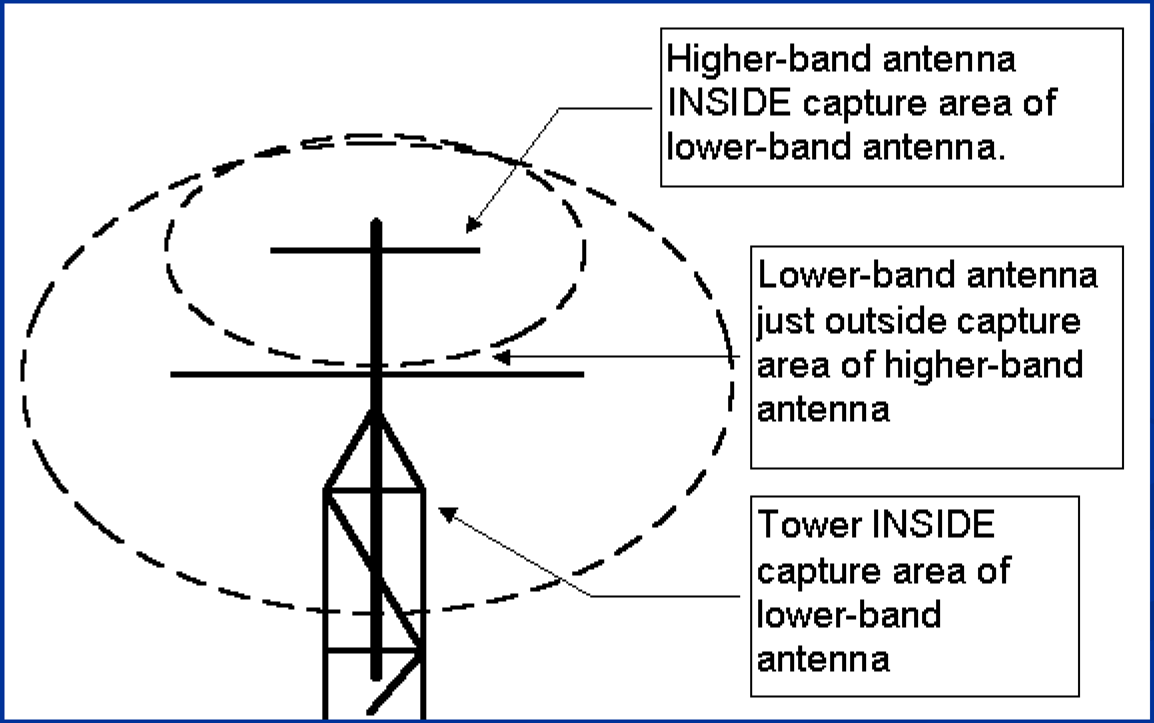
Antennas for Different Bands… the Principle

- The "Christmas tree" – poor mechanically



Stacking Antennas for Different Bands

- The absolute minimum configuration - closer stacking result serious loss of performance



Stacking Antennas for Different Bands

- Check the vertical stacking distance that the manufacturer recommends for **two of the same antennas**. This distance is the height of the capture area!
- The minimum clearance distance (for antennas on lower bands, same polarization) is **one-half** of the stacking distance for two of the same antennas
- **Example:** The manufacturer recommends that you stack two identical 144MHz yagis 3.3 m apart. That means that you shouldn't mount one of these yagis any closer than (3.3/2) = 1.65 meter above a lower-band antenna such as a 50MHz yagi or HF tribander.

VE7BQH 144 MHz antenna chart

TYPE OF ANTENNA	L λ	GAIN (dBd)	E (M)	H (M)	Ga (dBd)	Tlos (K)	Ta (K)	< H Plane > F/R (dB)	1st SL (dB)	2nd SL (dB)	Z (ohms)	VSWR Bandwidth	G/T (dB)
+KF2YN Boxkite4	0,43	11,10	3,50	2,00	16,80	3,9	225,7	23,4	22,0	none	50,4	1.12:1	-4,59
G4CQM 6	1,00	9,46	2,60	2,17	15,44	7,9	249,7	18,9	17,1	none	56,7	1.83:1	-6,38
+KF2YN Boxkite6	1,04	12,47	[illegible]	3,00	18,25	4,6	263,1	26,5	22,9	24,8	49,9	1.20:1	-3,80
Vine 6 FD	1,10	9,69	2,64	2,21	15,67	8,2	238,4	24,1	18,4	none	48,3	1.18:1	-5,95
G0KSC 6LFA	1,13	9,69	2,60	2,19	[illegible]	4,0	236,9	24,5	19,8	none	49,3	1.04:1	-5,96
DD0VF 6	1,16	9,73	2,63	2,22	[illegible]	[illegible]	[illegible]	23,7	16,4	none	27,2	1.07:1	-5,94
*DD0VF 6	1,16	9,73	2,30	2,30	[illegible]	[illegible]	[illegible]	23,7	16,4	none	27,2	1.07:1	-6,16
M2 2M7	1,28	9,96	2,65	2,26	[illegible]	[illegible]	[illegible]	18,6	16,4	none	41,3	1.10:1	-5,96
*M2 2M7	1,28	9,96	2,21	2,03	15,20	4,3	240,1	18,6	16,4	none	41,3	1.10:1	-6,45
+KF2YN Boxkite7	1,32	13,34	4,17	3,40	19,30	5,2	245,5	26,8	23,6	24,5	52,7	1.06:1	-2,40
+YU7XL 8 Hybrid	1,34	10,50	2,79	2,50	16,40	3,2	251,6	19,8	17,1	none	199,9	1.13:1	-5,46
*YU7XL 8 Hybrid	1,34	10,50	3,00	2,43	16,43	3,5	247,7	19,8	17,1	none	199,9	1.13:1	-5,36
+G0KSC 7LFA	1,39	10,62	2,84	2,49	16,53	1,8	248,9	20,4	16,1	none	48,0	1.19:1	-5,28
*G0KSC 7 LFA	1,39	10,62	2,60	2,20	16,20	1,8	233,6	20,4	16,1	none	48,0	1.19:1	-5,34

Stack of 4 yagi

Reference

- **GM3SEK's Amateur Radio Technical Notebook**
- **DG7YBN –** Low Noise Yagis http://dg7ybn.de/
- G4CQM - Yagi antenna designer.
  http://g4cqm.www.idnet.com/
- **DK7ZB** - Fundamental Knowledge for stacking
  http://www.qsl.net/dk7zb
- **VK2ZAB**, Gordon McDonald – synopsis of talk in Sydney
- Antenna performance table by VE7BQH
- The VHF-UHF DX Book