Why balun ?

Baluns are used when feeding antennas with unsymmetrical coaxial cables. But why exactly they are used, how good they must be and what difference it makes to use voltage balun or current balun. How bad can it be if we don't use balun.

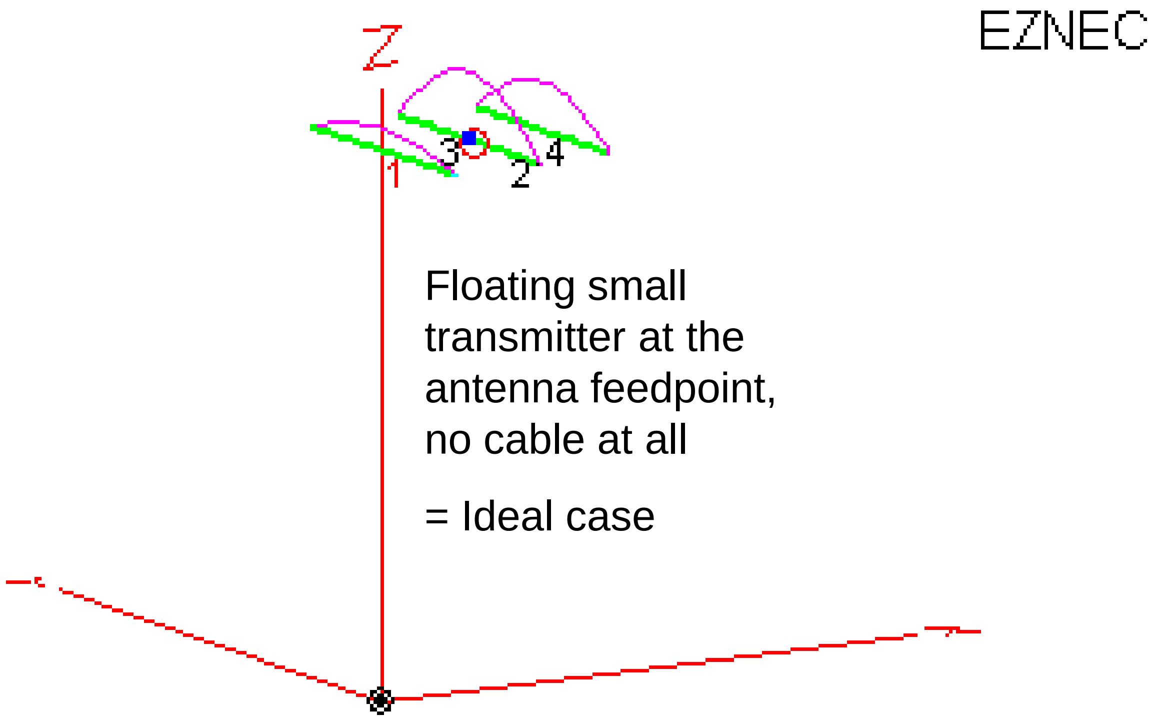
Paper on CCF & OHDXF cruise 4.1.2012

Pekka Ketonen

Case A: 3-el 20m yagi up 21m

No feed cable

Our reference



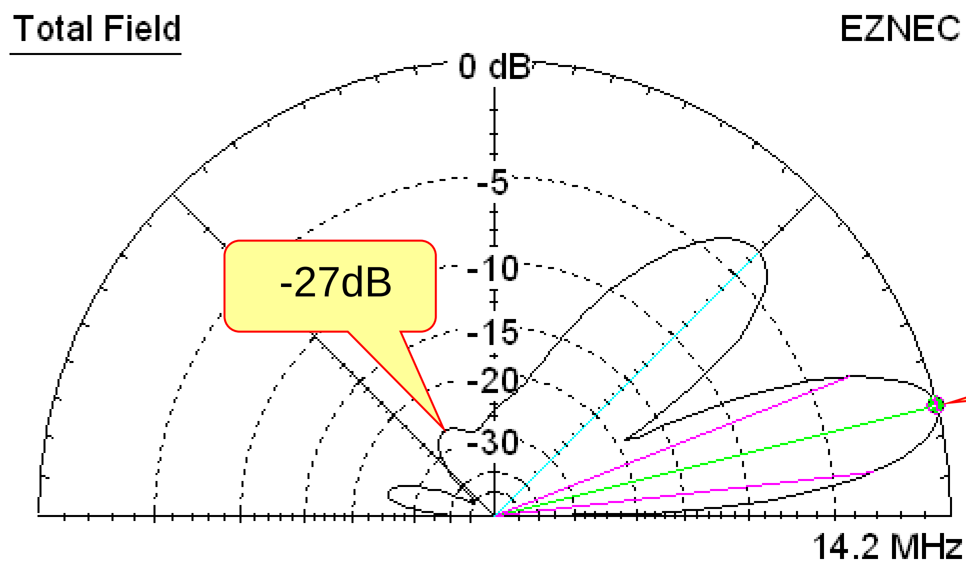
Floating small
transmitter at the
antenna feedpoint,
no cable at all

= Ideal case

Case A: 3-el 20m yagi up 21m

No feed cable

Our reference

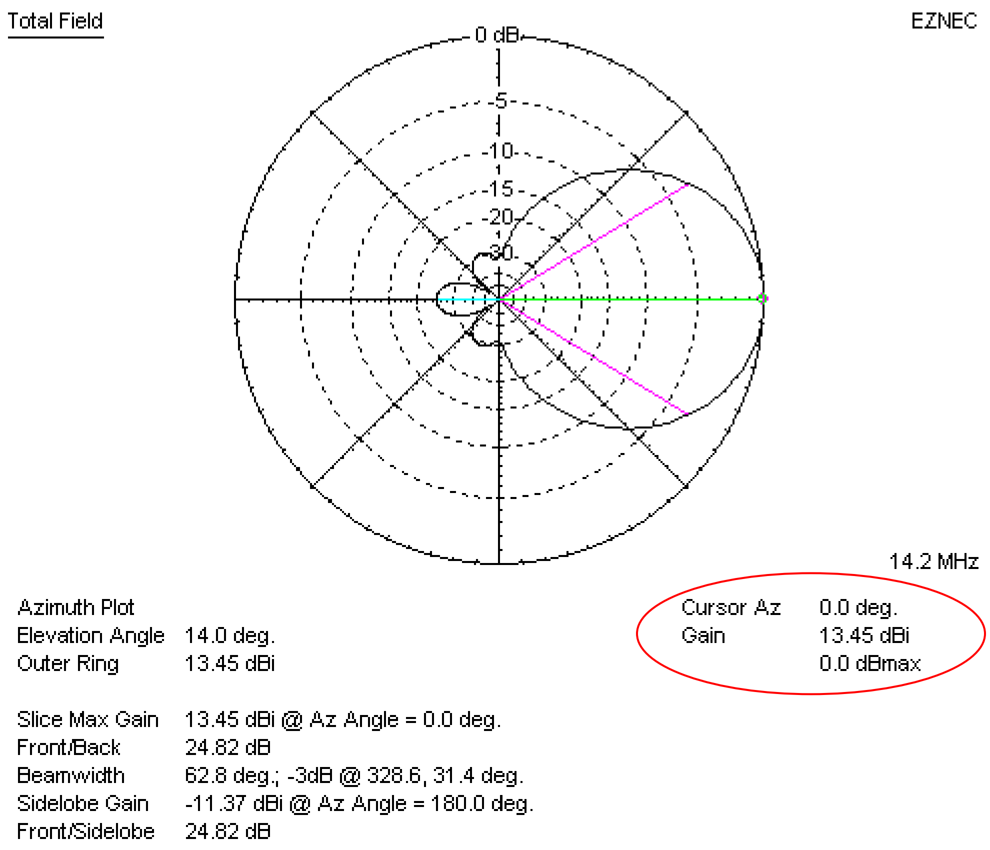


Elevation Plot		Cursor Elev	14.0 deg.
Azimuth Angle	0.0 deg.	Gain	13.45 dBi
Outer Ring	13.45 dBi		0.0 dBmax

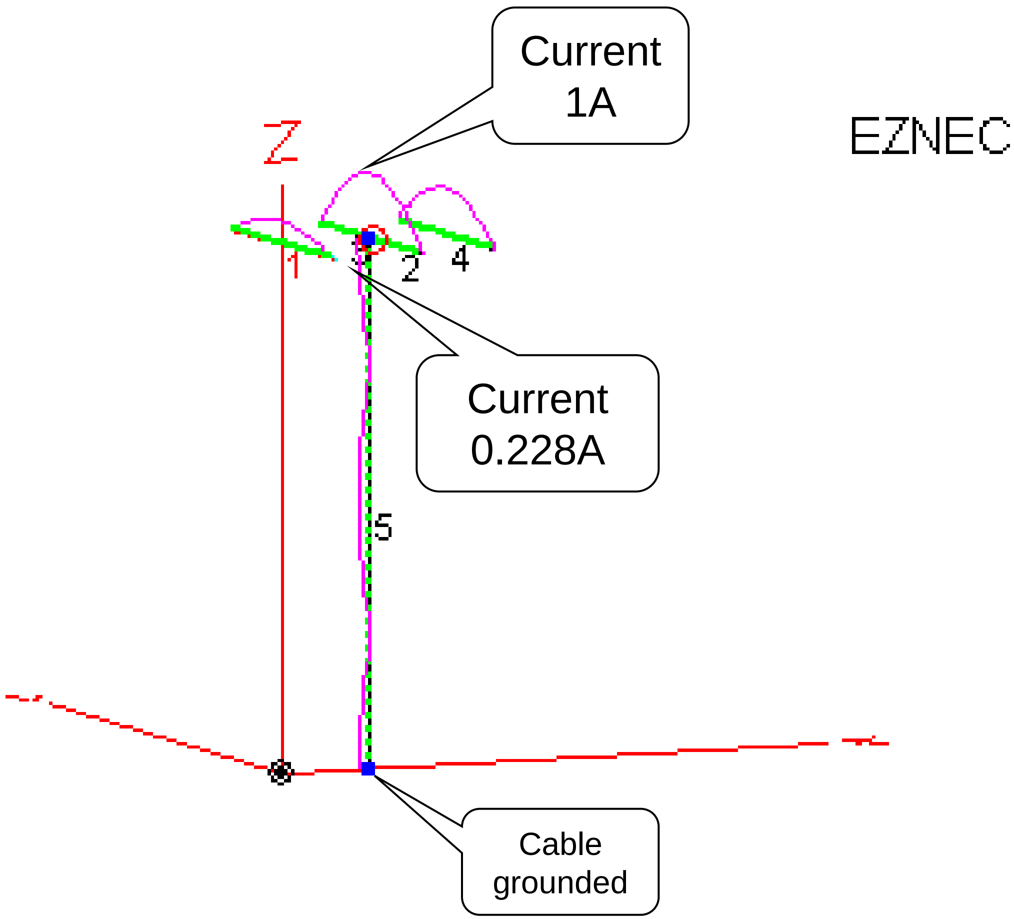
Slice Max Gain	13.45 dBi @ Elev Angle = 14.0 deg.
Beamwidth	14.6 deg.; -3dB @ 6.7, 21.3 deg.
Sidelobe Gain	10.03 dBi @ Elev Angle = 45.0 deg.
Front/Sidelobe	3.42 dB

Case A: 3-el 20m yagi up 21m
No feed cable, elevation 14 deg

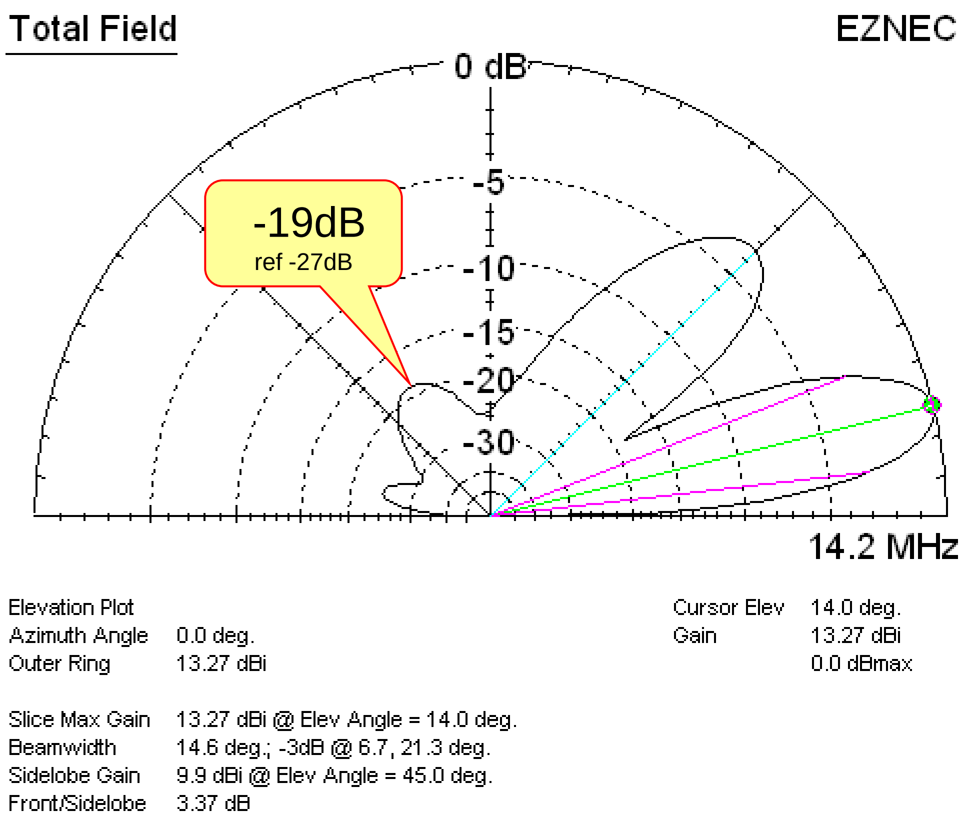
Our reference



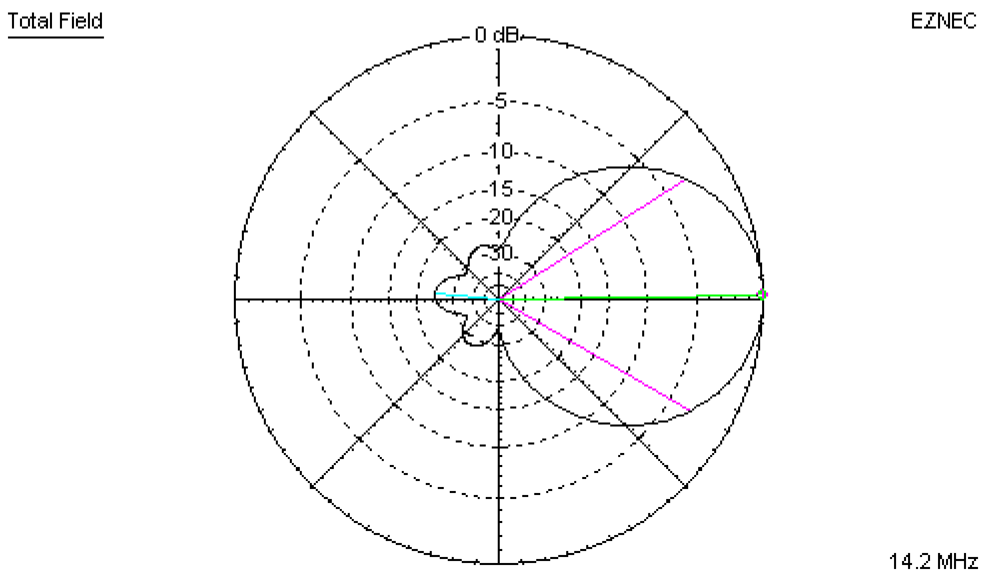
Case B: 3-el 20m yagi up 21m
Feed with coax (5), no balun



Case B: 3-el 20m yagi up 21m
Feed with coax, no balun



Case B: 3-el 20m yagi up 21m
Feed with coax, no balun



Azimuth Plot

Elevation Angle	14.0 deg.
Outer Ring	13.27 dBi

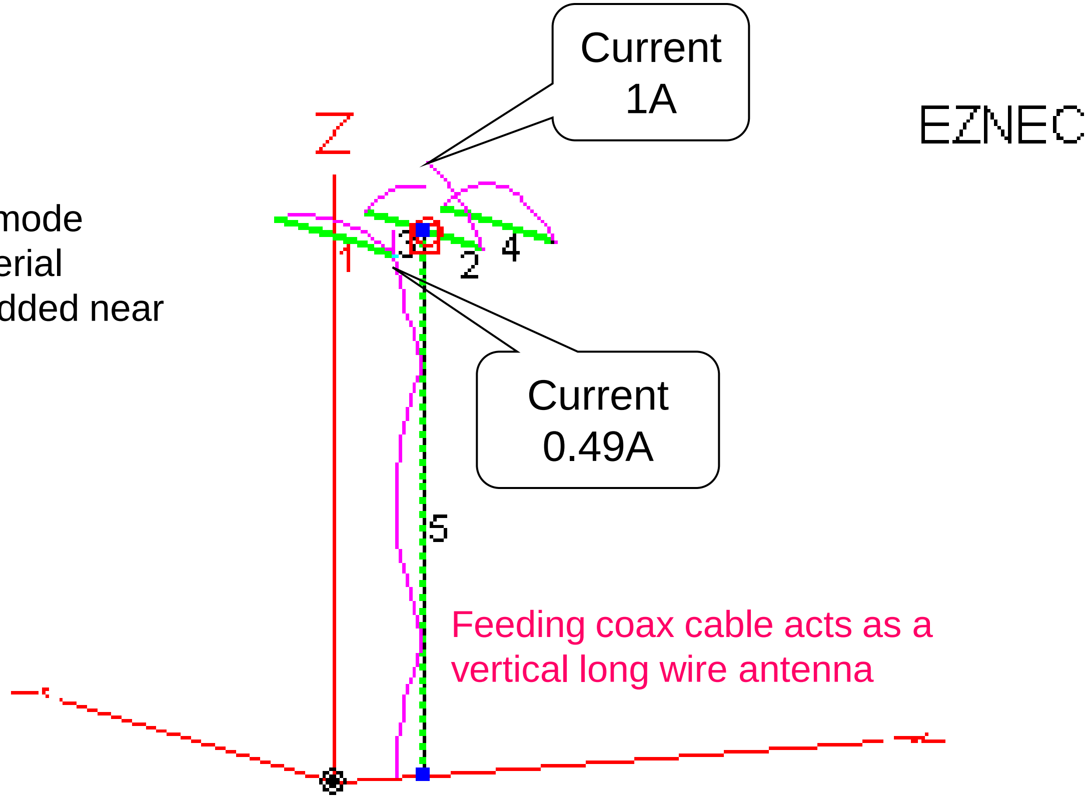
Cursor Az	1.0 deg.
Gain	13.27 dBi
	0.0 dBmax

-0.18dB

Slice Max Gain	13.27 dBi @ Az Angle = 1.0 deg.
Front/Back	24.73 dB
Beamwidth	62.8 deg.; -3dB @ 329.9, 32.7 deg.
Sidelobe Gain	-11.1 dBi @ Az Angle = 174.0 deg.
Front/Sidelobe	24.37 dB

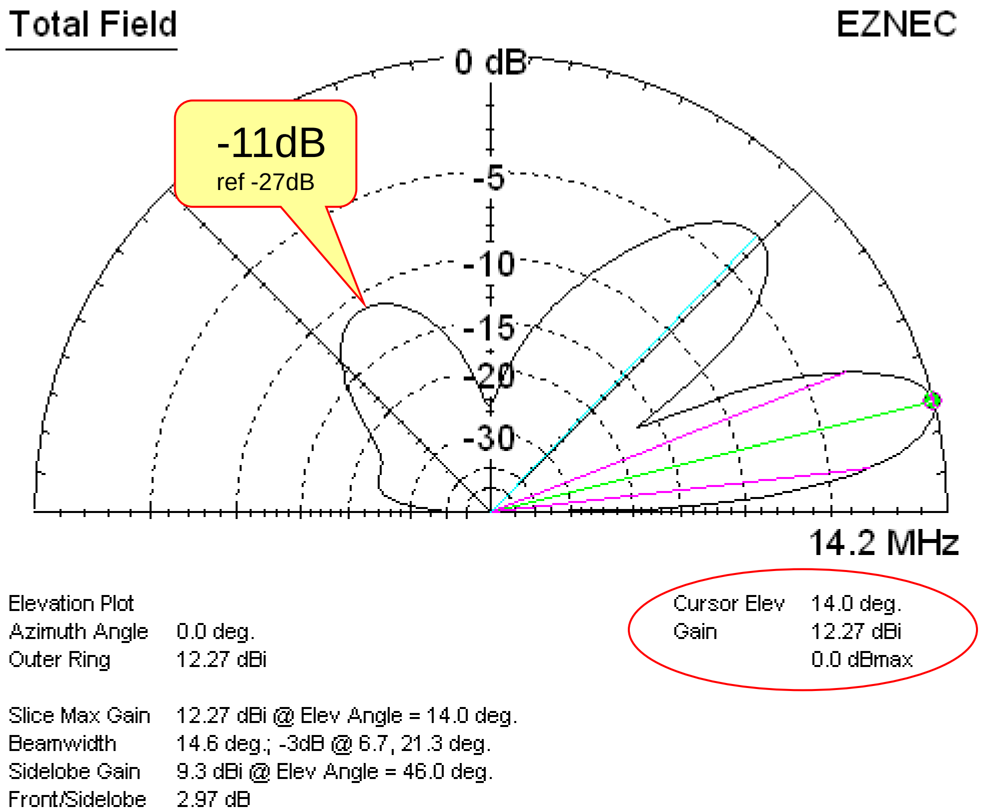
Case C: 3-el 20m yagi up 21m
Feed with coax, no balun, worst case

Coax (5) in common mode resonance, 50 ohm serial inductive reactance added near the feedpoint



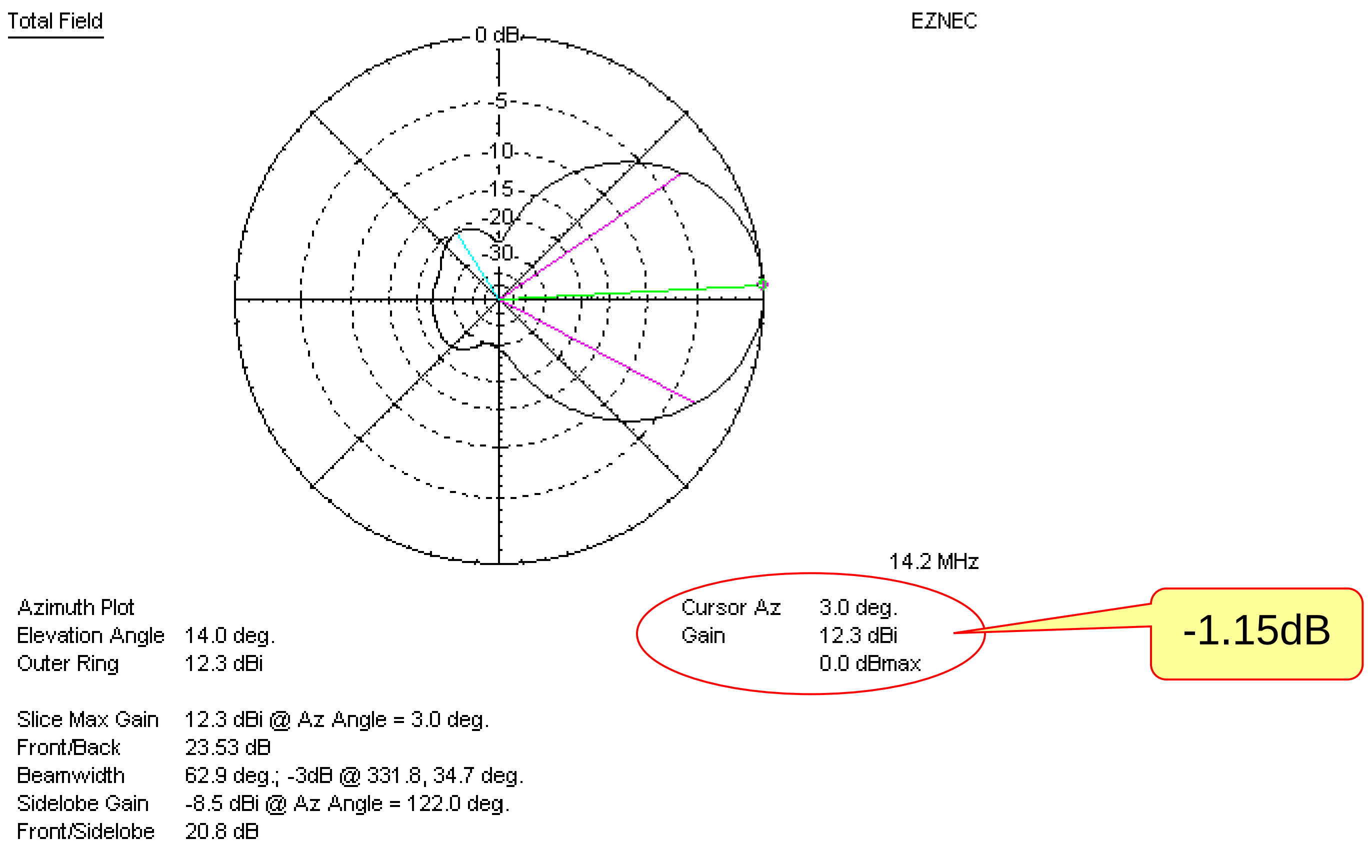
Case C: 3-el 20m yagi up 21m
Feed with coax, no balun, worst case

Coax in common mode resonance, 50 ohm serial inductive reactance added near the feedpoint



Case C: 3-el 20m yagi up 21m
Feed with coax, no balun, worst case

Coax in common mode resonance, 50 ohm serial inductive reactance added near the feedpoint



Conclusions 1
in light of the examples

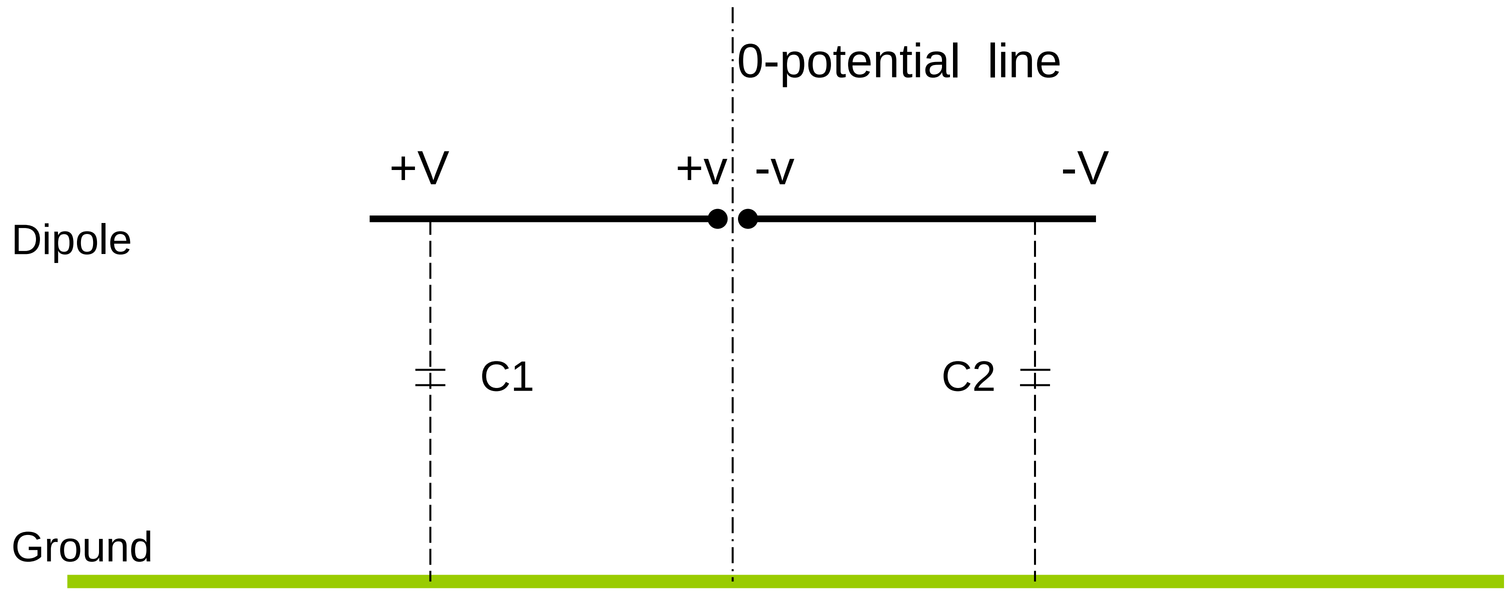
- Asymmetry and imbalance in antenna feed create a common mode voltage to coaxial feed line
- This voltage generates common mode current in the feed line
- If the feedline is made resonant so that current max occur at the feedpoint, current in the feedline can be up to 50% of antenna driven element current
- Common mode current in the feedline causes radiation
- Is such a case F/B ratio is considerably distorted, in our case from 27 to 11dB
- At the same time some forward gain is lost, in our case 1.15dB

Adding Voltage Balun

In order to hinder

common mode voltage feed to coax

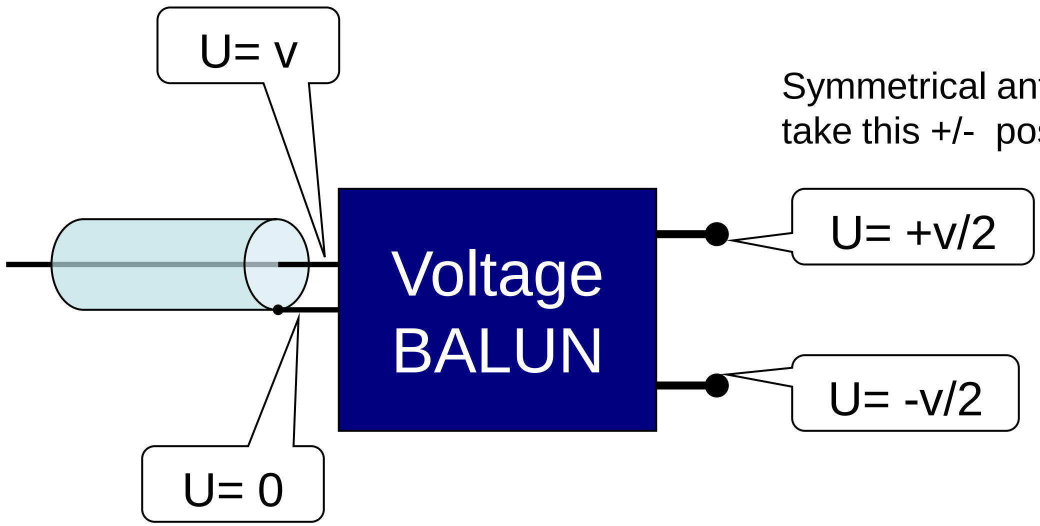
Dipole needs symmetrical feed voltage



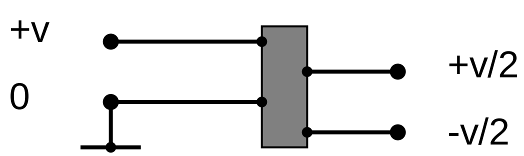
If feed to antenna is floating and C1 = C2 (symmetrical antenna), voltages settle symmetrically around 0-potential line

What is voltage balun?

BALanced to UNbalanced = BALUN



Symmetrical antenna tends to take this +/- position

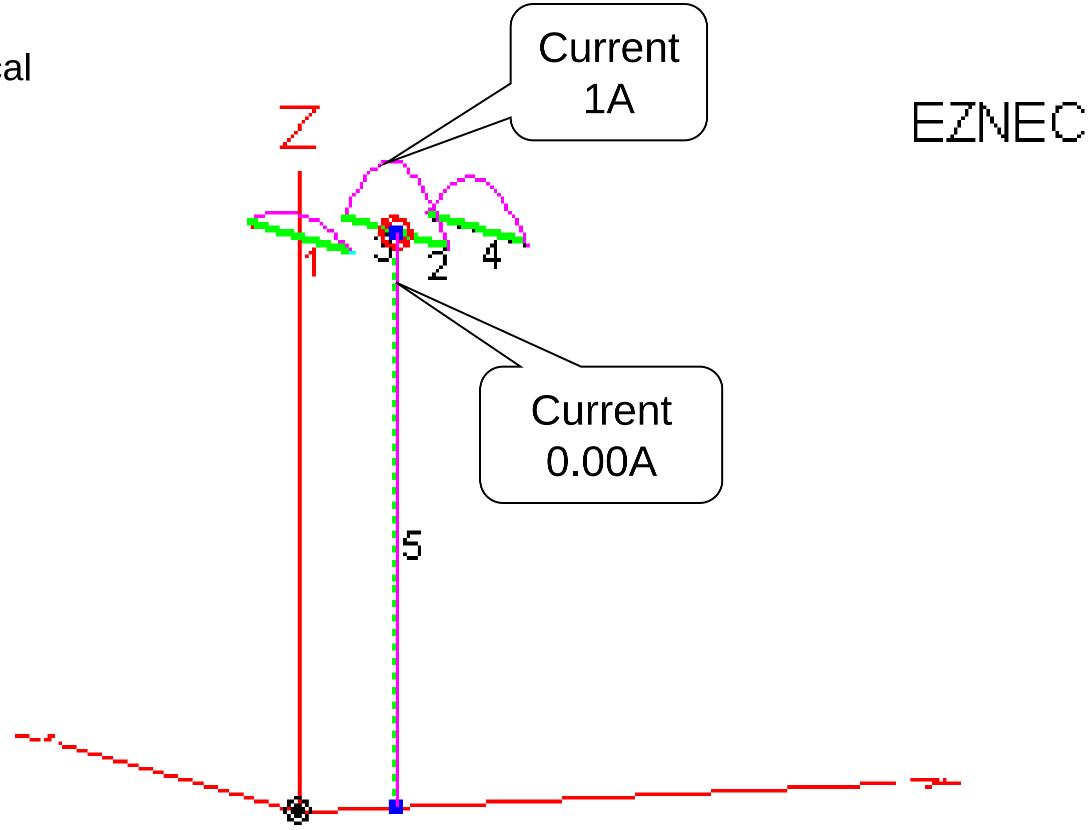


Autotransformer

No common mode current is generated as the feeding voltage is symmetrical, the same as the antenna wants naturally to be in. There is no forcing voltage difference.

Case D: 3-el 20m yagi up 21m
Feed with coax, ideal voltage balun

Antenna fully symmetrical
Ideal voltage balun



Case D: 3-el 20m yagi up 21m
Feed with coax, ideal voltage balun

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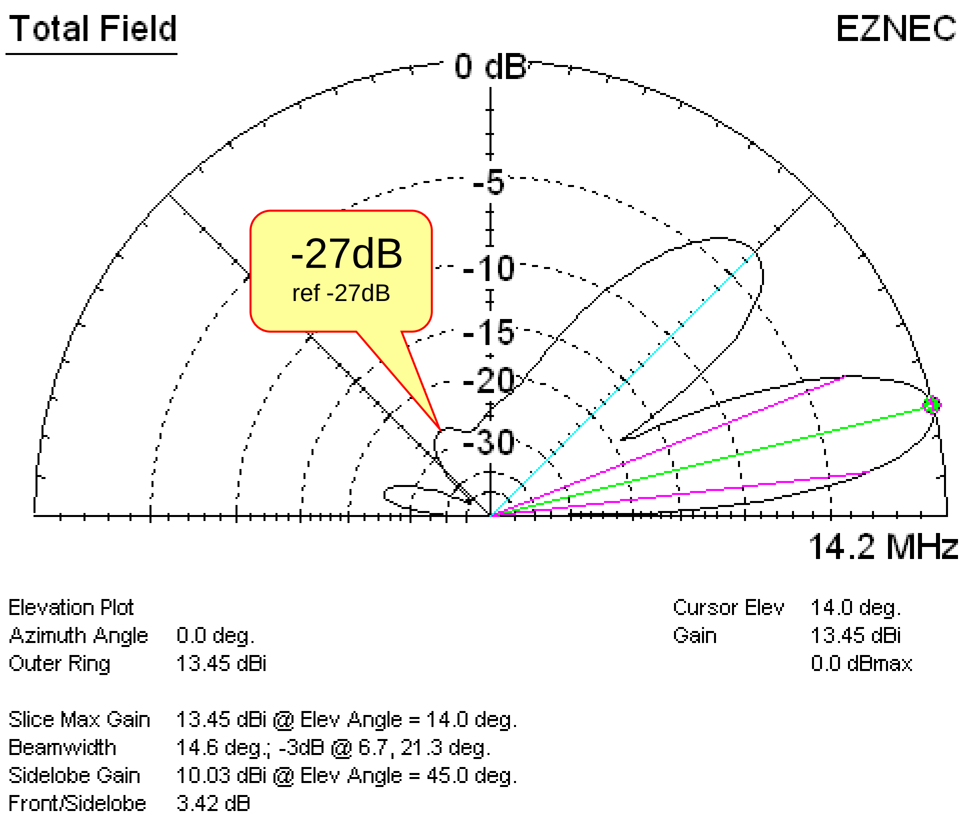
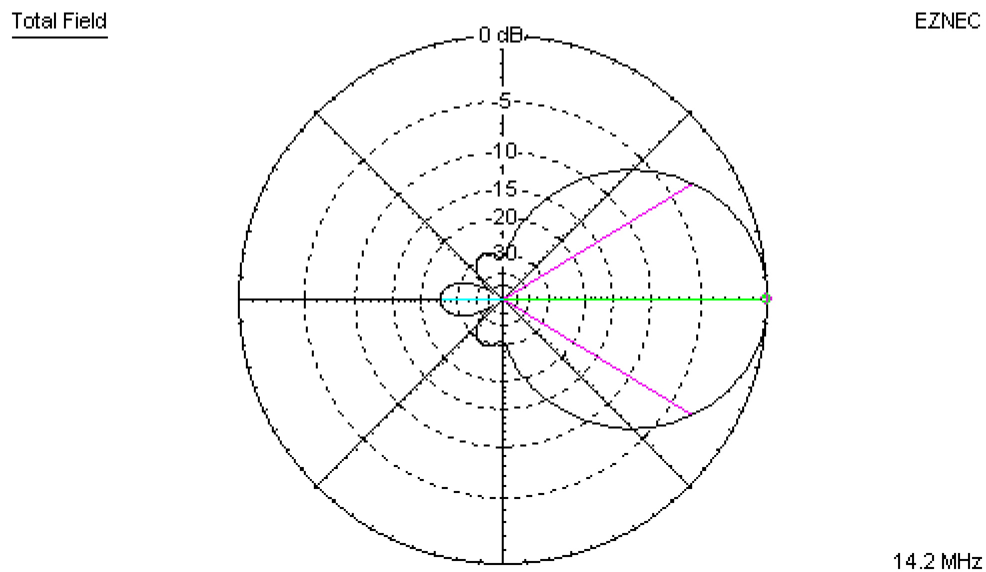


No difference to the cableless case 1a

Case D: 3-el 20m yagi up 21m
Feed with coax, ideal voltage balun

Antenna fully symmetrical
Ideal voltage balun



Azimuth Plot
Elevation Angle 14.0 deg.
Outer Ring 13.45 dBi

Slice Max Gain 13.45 dBi @ Az Angle = 0.0 deg.
Front/Back 24.82 dB
Beamwidth 62.8 deg.; -3dB @ 328.6, 31.4 deg.
Sidelobe Gain -11.37 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 24.82 dB

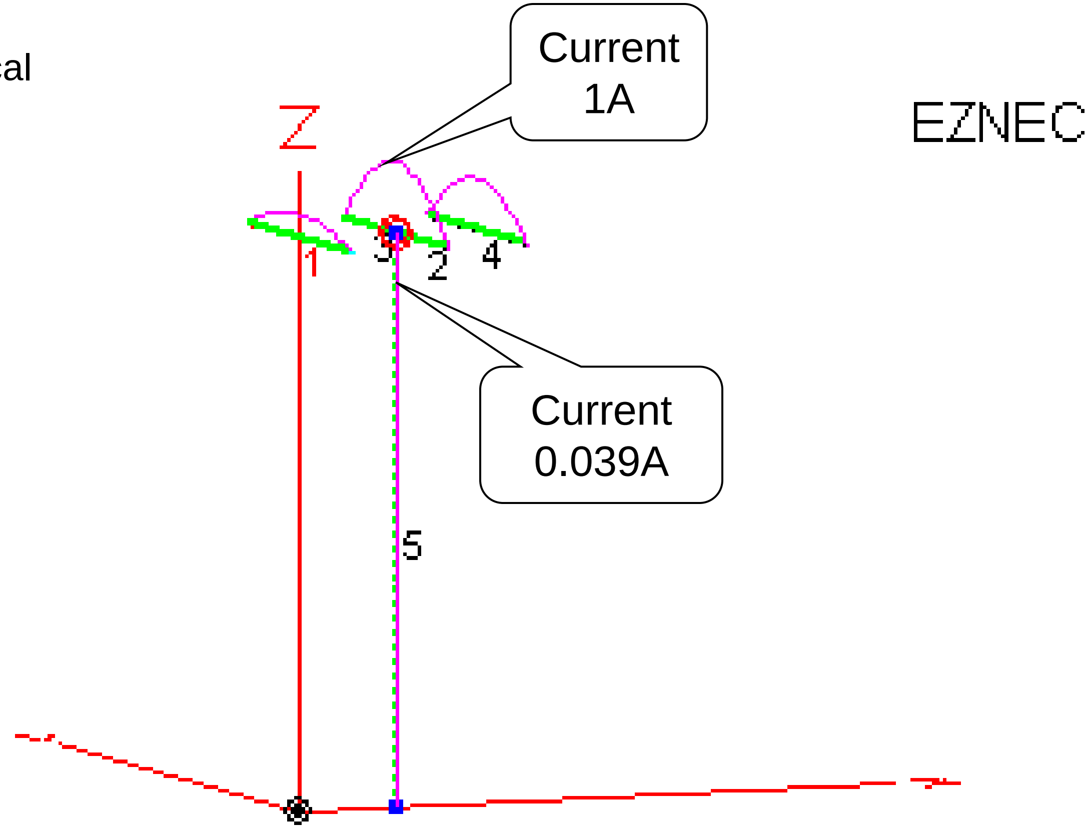
Cursor Az 0.0 deg.
Gain 13.45 dBi
0.0 dBmax

-0.00dB

No difference to the cableless case 1a

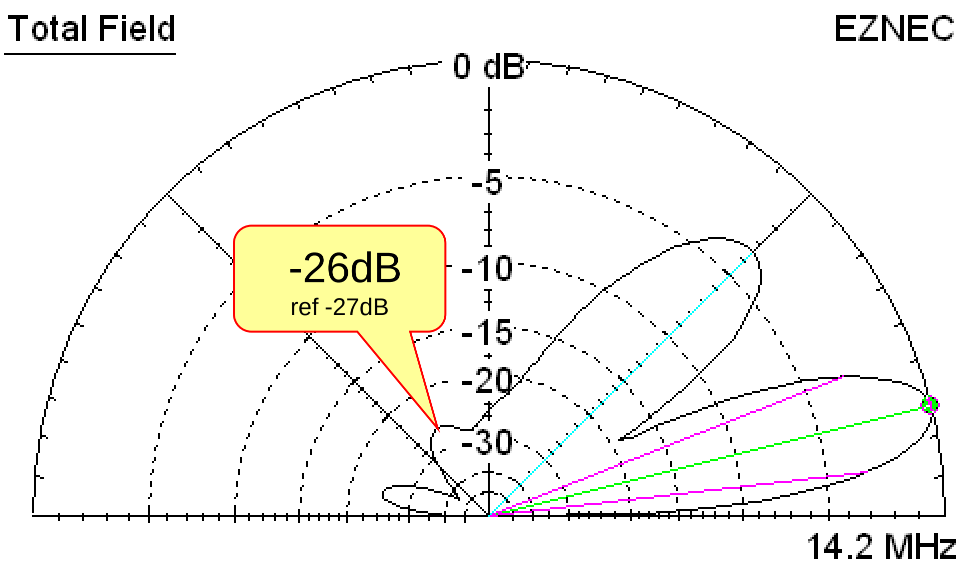
Case E: 3-el 20m yagi up 21m
Feed with coax, 3dB imbalanced voltage balun

Antenna fully symmetrical
Balun 0db/-3dB



Case E: 3-el 20m yagi up 21m
Feed with coax, 3dB imbalanced voltage balun

Antenna fully symmetrical
Balun 0dB/-3dB

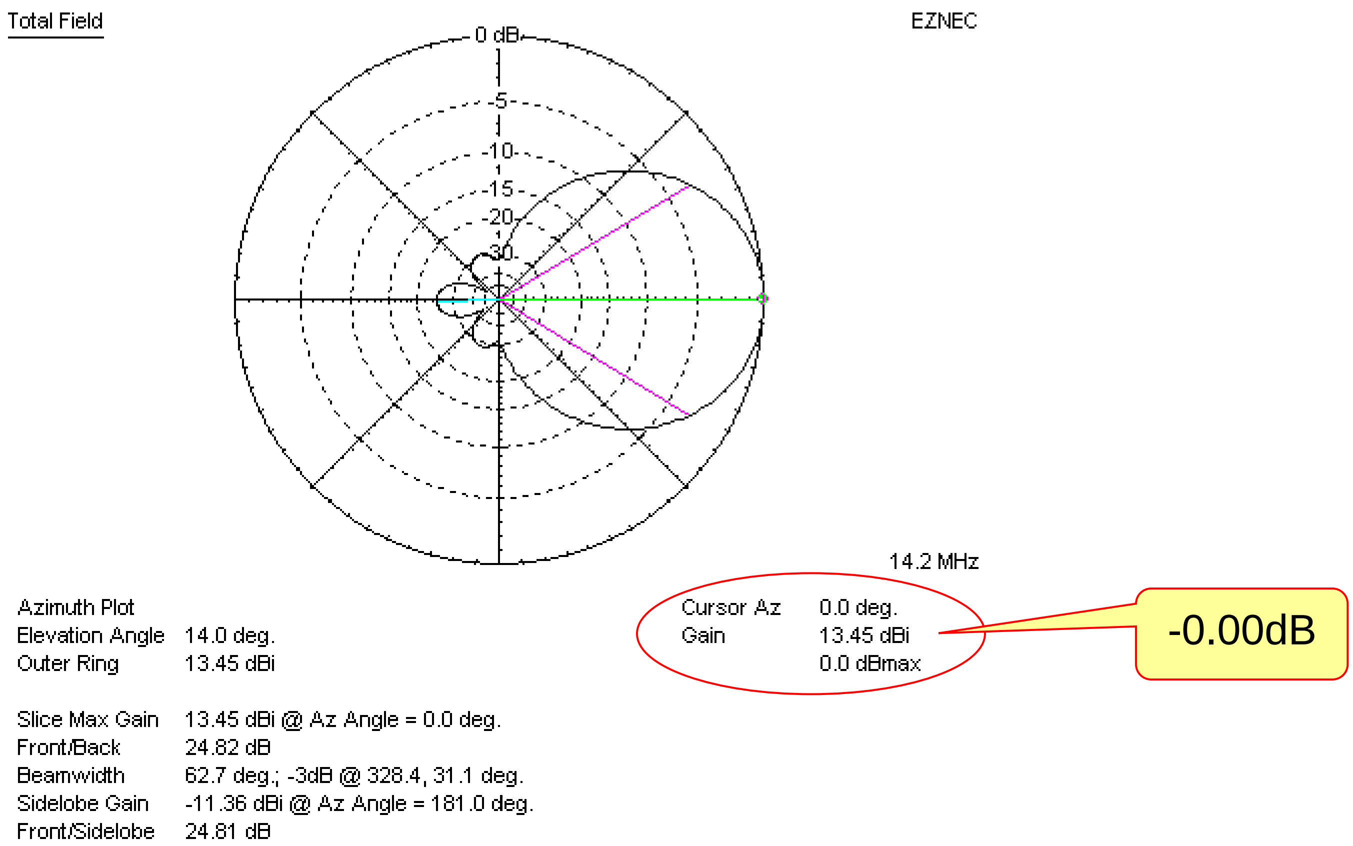


Elevation Plot		Cursor Elev	14.0 deg.
Azimuth Angle	0.0 deg.	Gain	13.45 dBi
Outer Ring	13.45 dBi		0.0 dBmax

Slice Max Gain	13.45 dBi @ Elev Angle = 14.0 deg.
Beamwidth	14.6 deg.; -3dB @ 6.7, 21.3 deg.
Sidelobe Gain	10.02 dBi @ Elev Angle = 45.0 deg.
Front/Sidelobe	3.43 dB

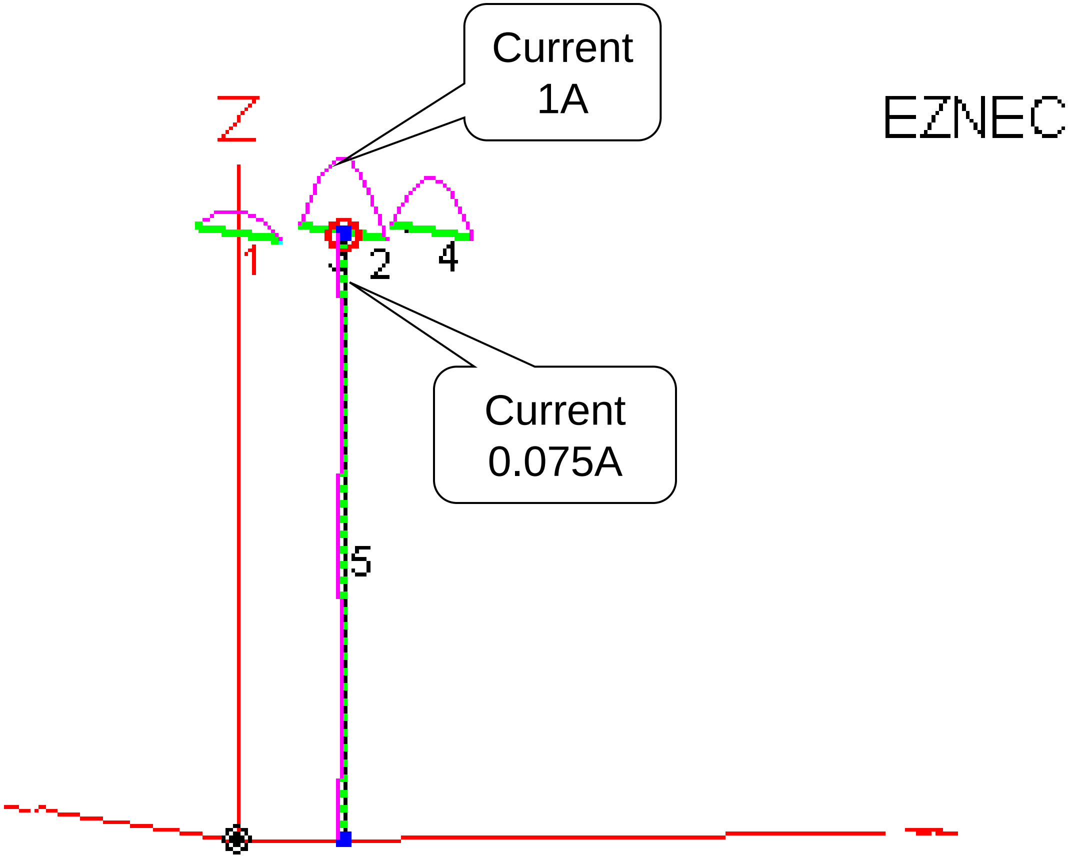
Case E: 3-el 20m yagi up 21m
Feed with coax, 3dB imbalanced voltage balun

Antenna fully symmetrical
Balun 0dB/-3dB



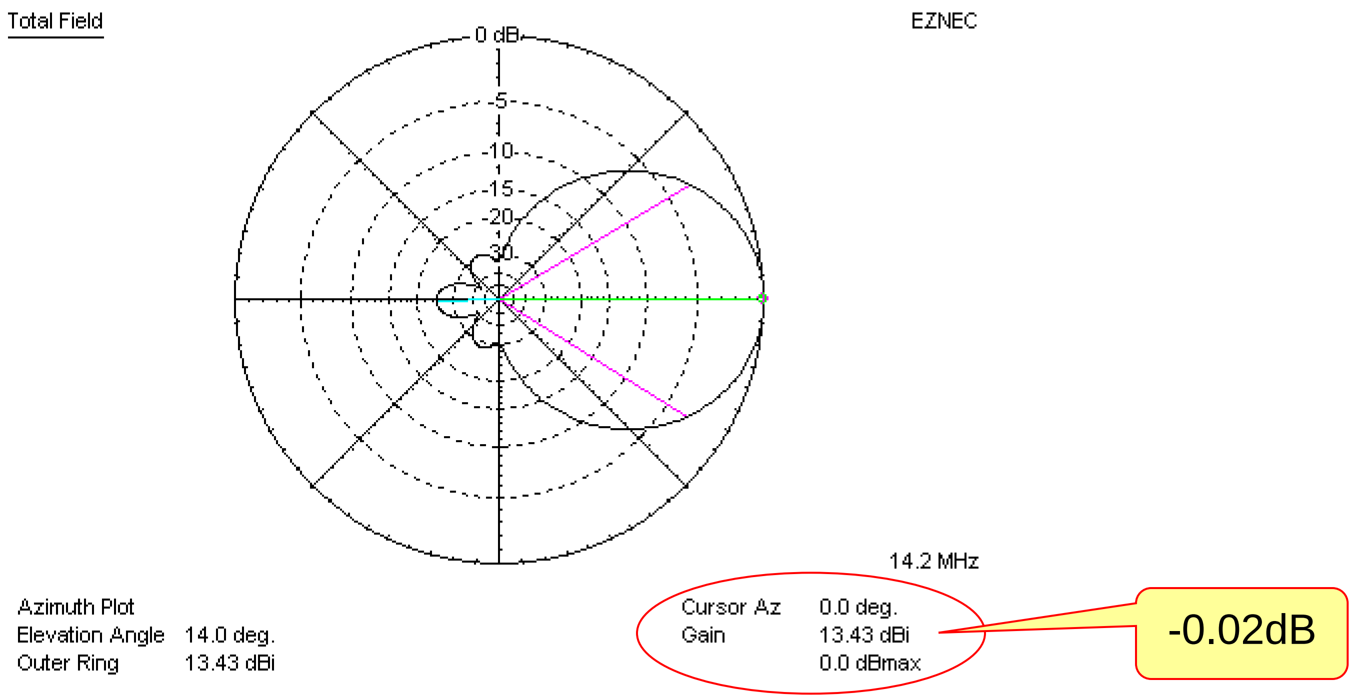
Case F: 3-el 20m yagi up 21m
Feed with coax, 6dB imbalanced voltage balun

Antenna fully symmetrical
Balun 0db/-6dB



Case F: 3-el 20m yagi up 21m
Feed with coax, 6dB imbalanced voltage balun

Antenna fully symmetrical
Balun 0dB/-6dB



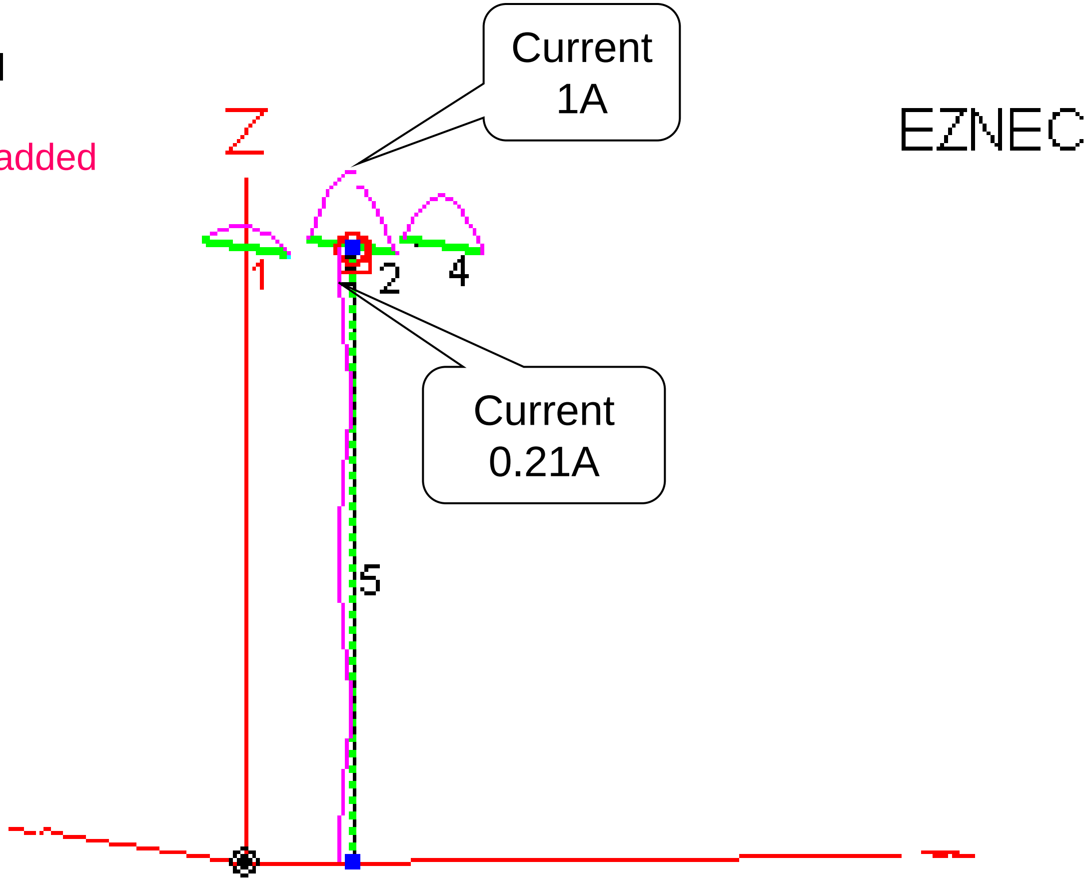
Azimuth Plot
Elevation Angle 14.0 deg.
Outer Ring 13.43 dBi

Slice Max Gain 13.43 dBi @ Az Angle = 0.0 deg.
Front/Back 24.8 dB
Beamwidth 62.7 deg.; -3dB @ 328.2, 30.9 deg.
Sidelobe Gain -11.34 dBi @ Az Angle = 181.0 deg.
Front/Sidelobe 24.77 dB

Case G: 3-el 20m yagi up 21m

Feed with coax, 6dB imbalanced voltage balun, worst case

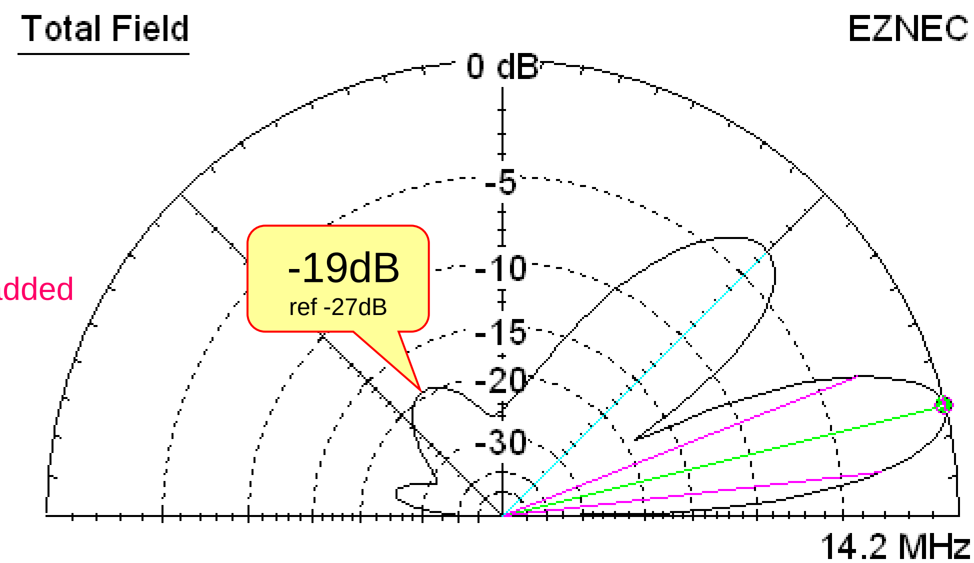
Antenna fully symmetrical
Balun 0db/-6dB
Coax in resonance, +j55 added



Case G: 3-el 20m yagi up 21m

Feed with coax, 6dB imbalanced voltage balun, worst case

Antenna fully symmetrical
Balun 0dB/-6dB
Coax in resonance, +j55 added



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 13.29 dBi

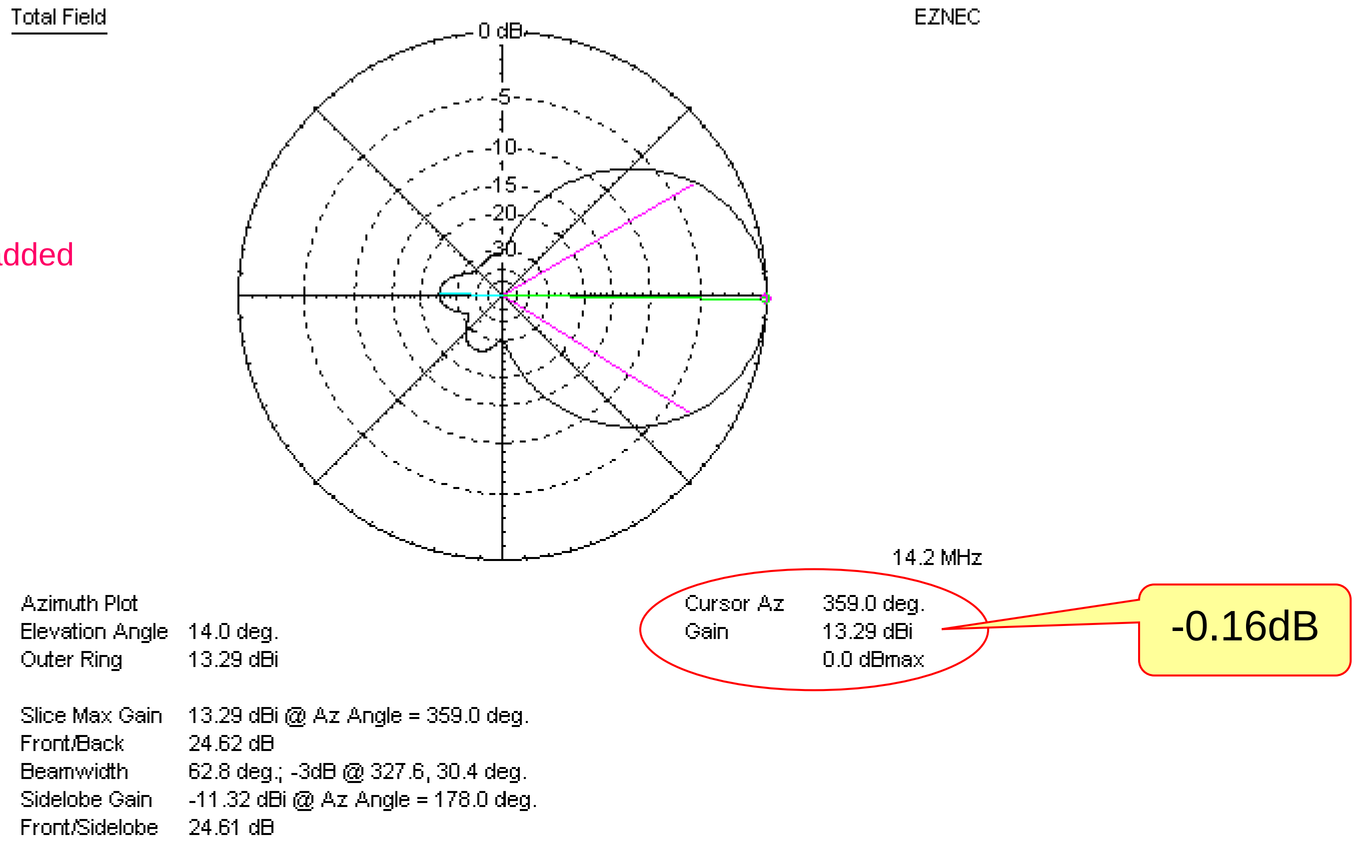
Slice Max Gain 13.29 dBi @ Elev Angle = 14.0 deg.
Beamwidth 14.6 deg.; -3dB @ 6.7, 21.3 deg.
Sidelobe Gain 9.92 dBi @ Elev Angle = 45.0 deg.
Front/Sidelobe 3.37 dB

Cursor Elev 14.0 deg.
Gain 13.29 dBi
0.0 dBmax

Case G: 3-el 20m yagi up 21m

Feed with coax, 6dB imbalanced voltage balun, worst case

Antenna fully symmetrical
Balun 0dB/-6dB
Coax in resonance, +j55 added



Conclusions 2
voltage balun

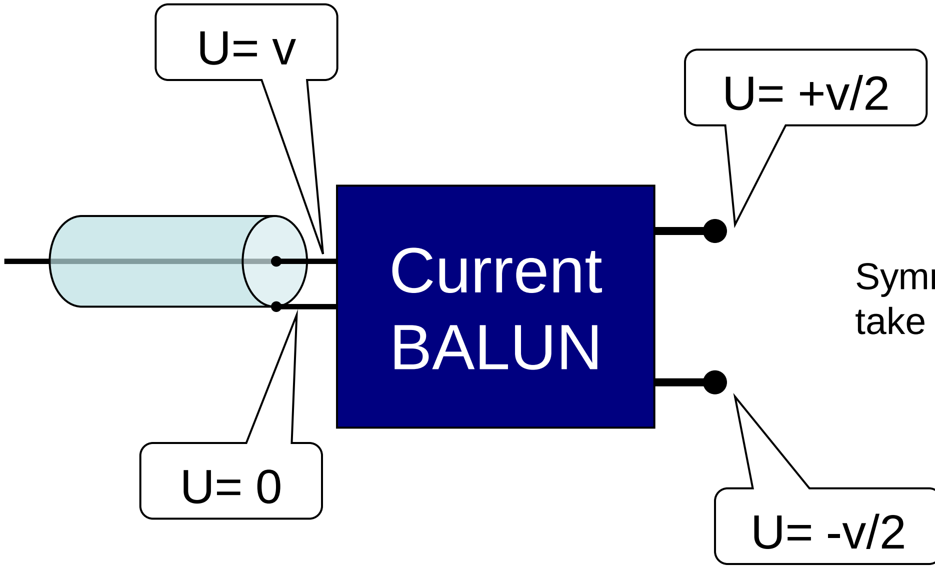
- The idea of voltage balun is to hinder common mode voltage to exist in the feed line near the antenna feedpoint
- In an ideal case: fully symmetrical antenna, ideal balun and feed line situating on the antenna centerline, no common mode current is flowing in feed line and no distortion is introduced to the radiation pattern, even the feedline would be resonant

- 3dB voltage imbalance in the balun cause only minor distortion in the radiation pattern, and can be accepted
- 6dB voltage imbalance and resonant feed line cause 8dB drop in F/B and 0.2dB in forward gain in our case, which in not acceptable.
- Voltage balun is not good with asymmetrical antennas as those antennas naturally do not want symmetrical feed voltage
  - Only current baluns are used with ¼ wave verticals

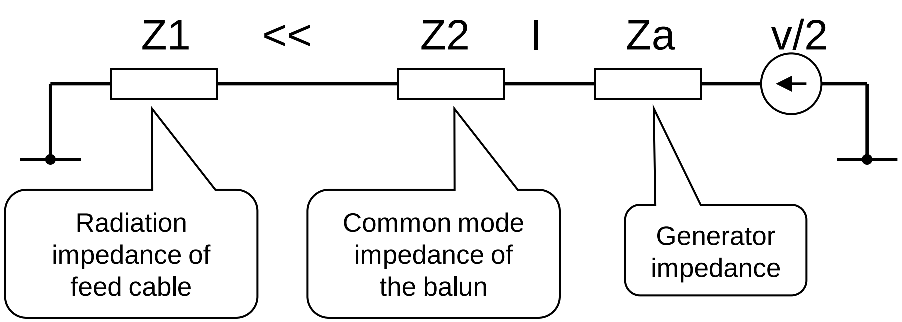
Adding Current Balun

The aim is to limit common mode current

What is current balun?



Symmetrical antenna tends to take this +/- position

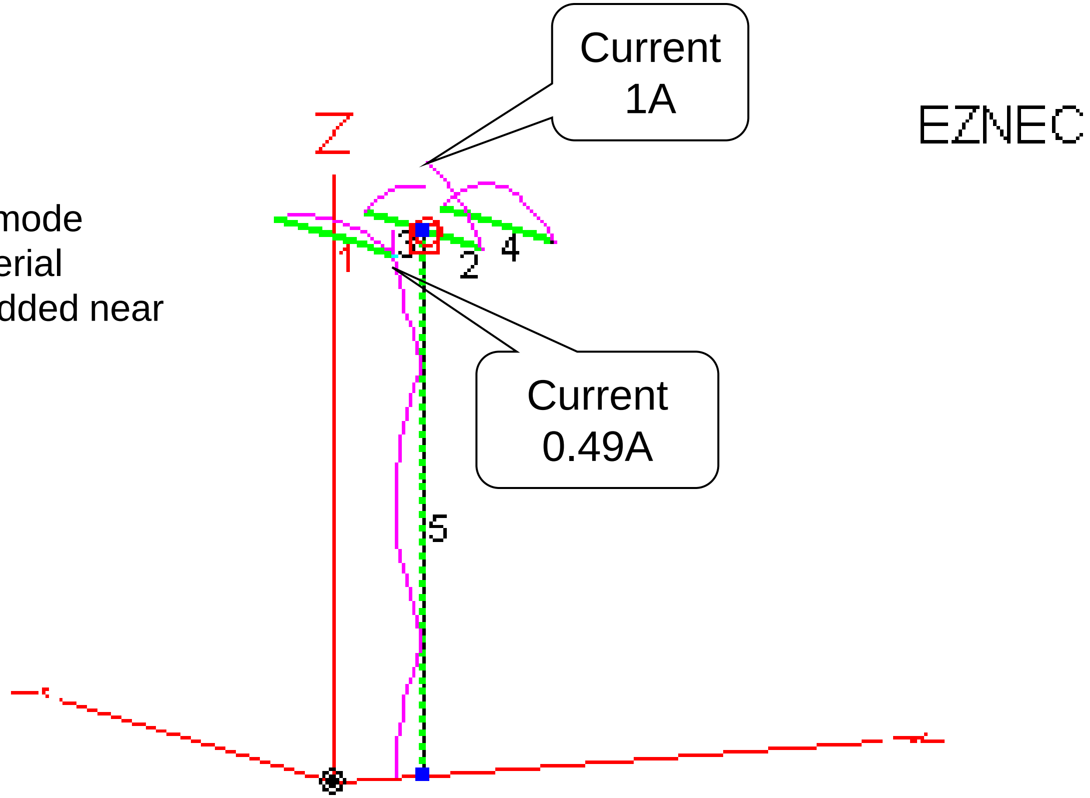


$$I = \frac{v}{2\,(Z1 + Z2 + Za)}$$

Current I gets low when Z2 is made big enough

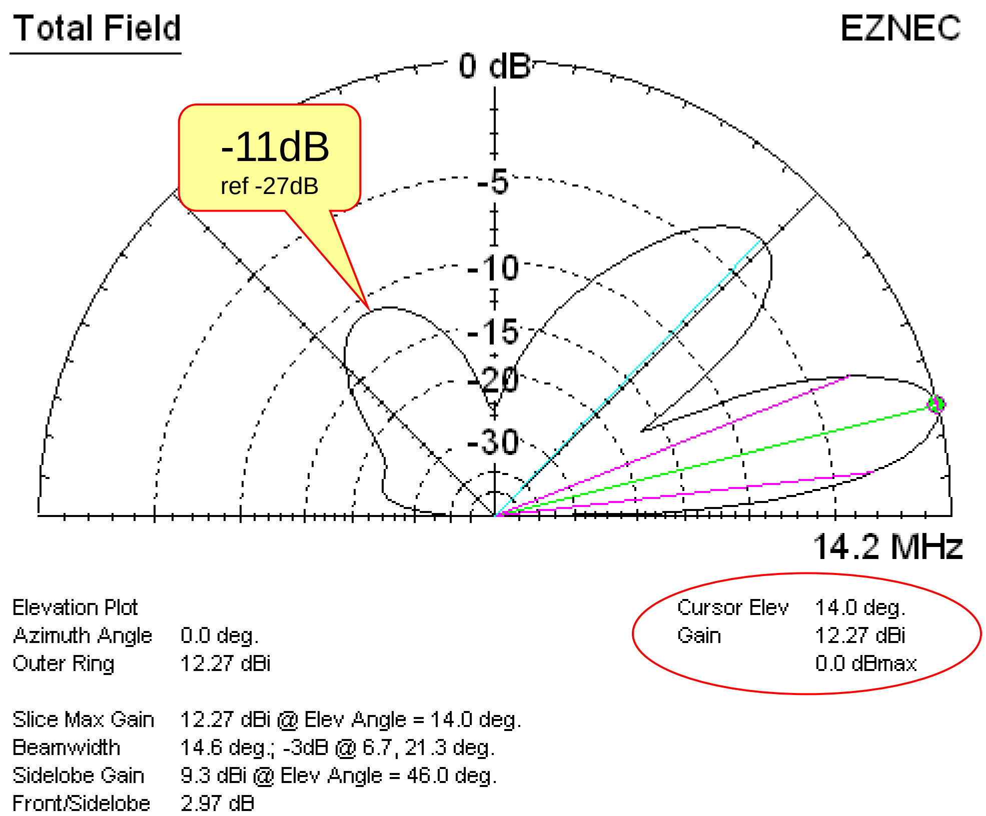
Case C: 3-el 20m yagi up 21m
Feed with coax, no balun, worst case

Coax (5) in common mode resonance, 50 ohm serial inductive reactance added near the feedpoint



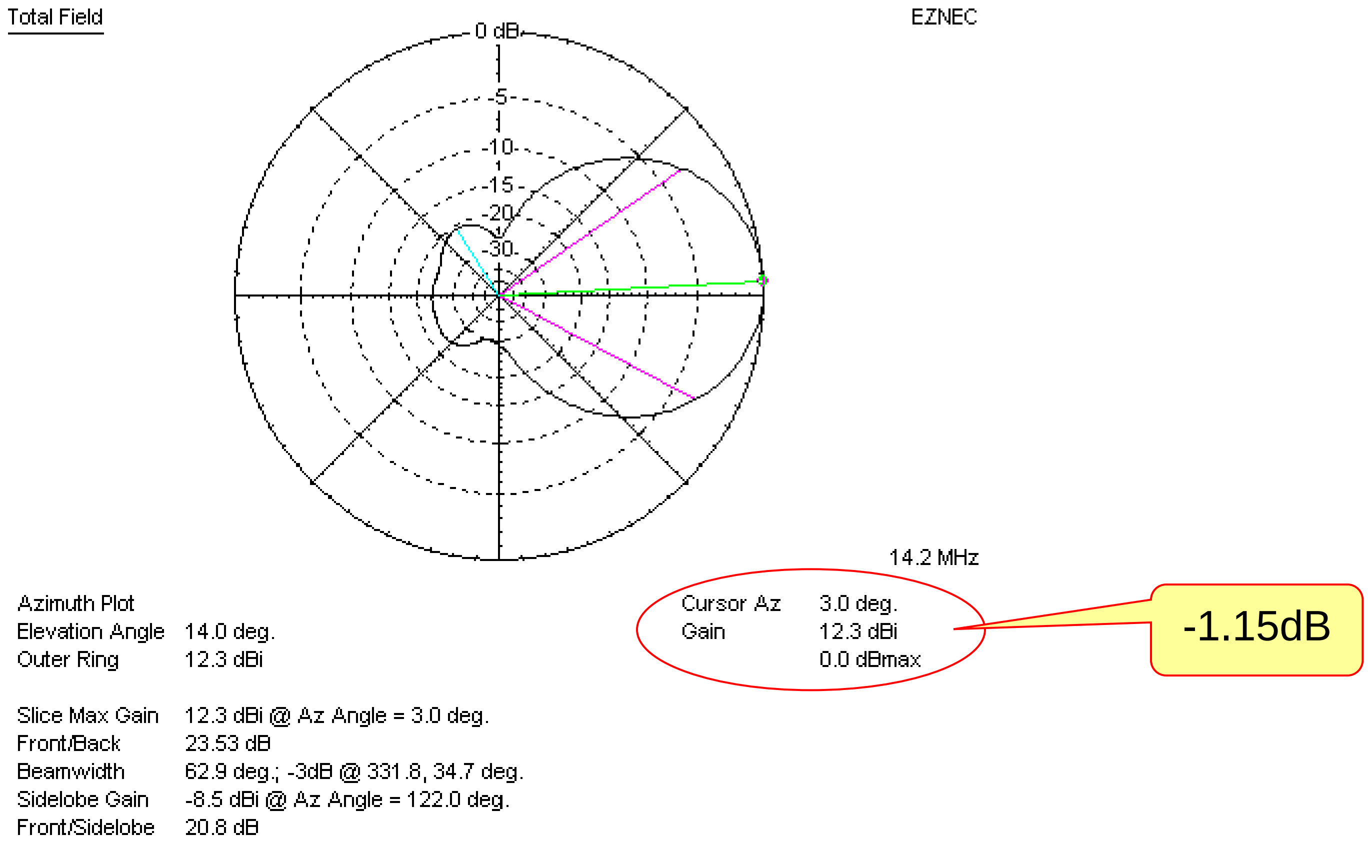
Case C: 3-el 20m yagi up 21m
Feed with coax, no balun, worst case

Coax in common mode resonance, 50 ohm serial inductive reactance added near the feedpoint



Case C: 3-el 20m yagi up 21m
Feed with coax, no balun, worst case

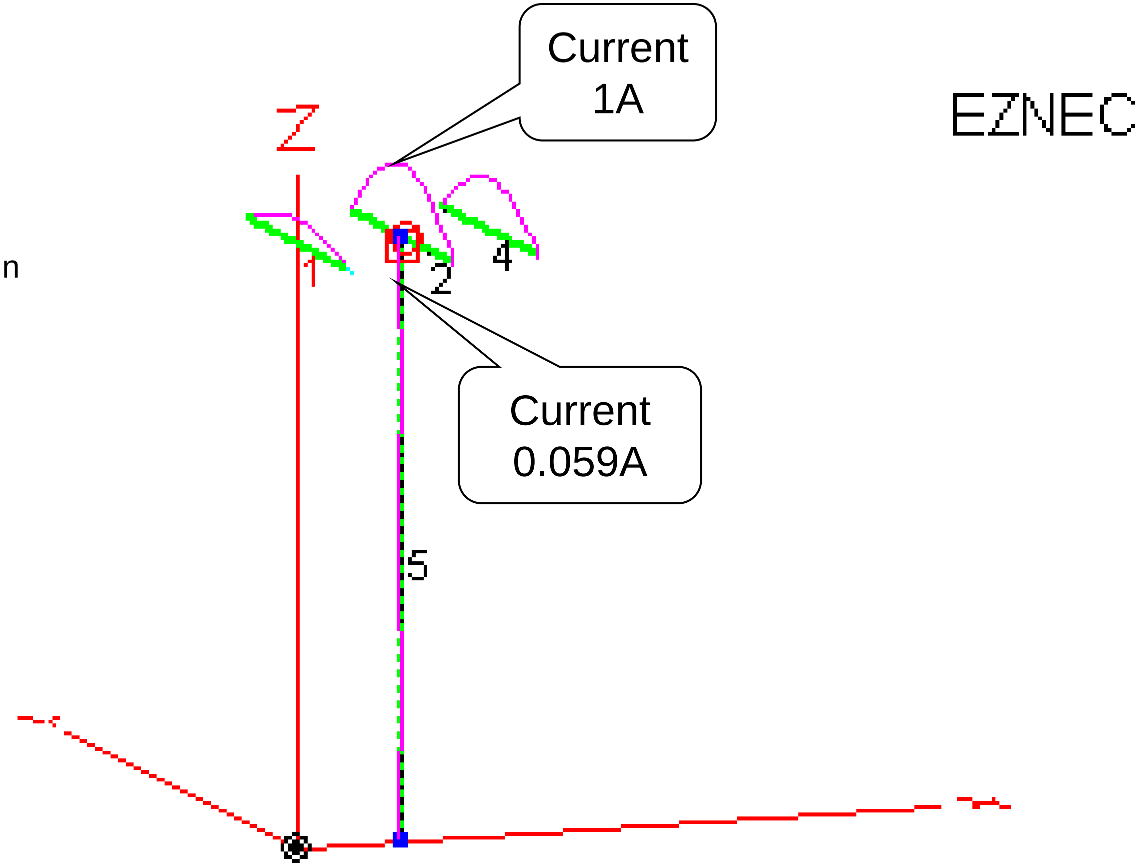
Coax in common mode resonance, 50 ohm serial inductive reactance added near the feedpoint



Case H: 3-el 20m yagi up 21m
Feed with coax, current balun 200 ohm R

At the feedpoint current balun

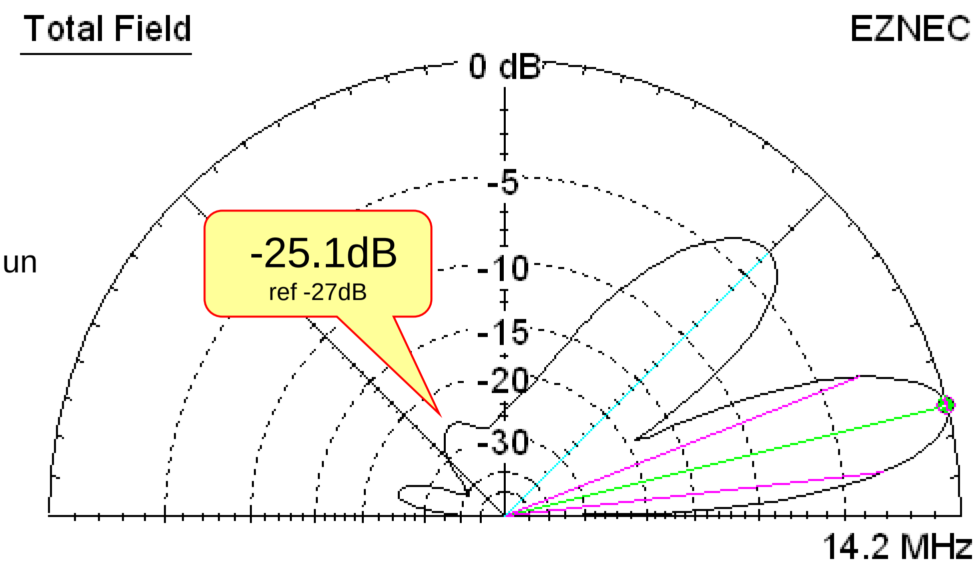
Serial impedance 200 ohm resistive



Case H: 3-el 20m yagi up 21m
Feed with coax, current balun 200ohm R

At the feedpoint current balun

Serial impedance 200 ohm resistive



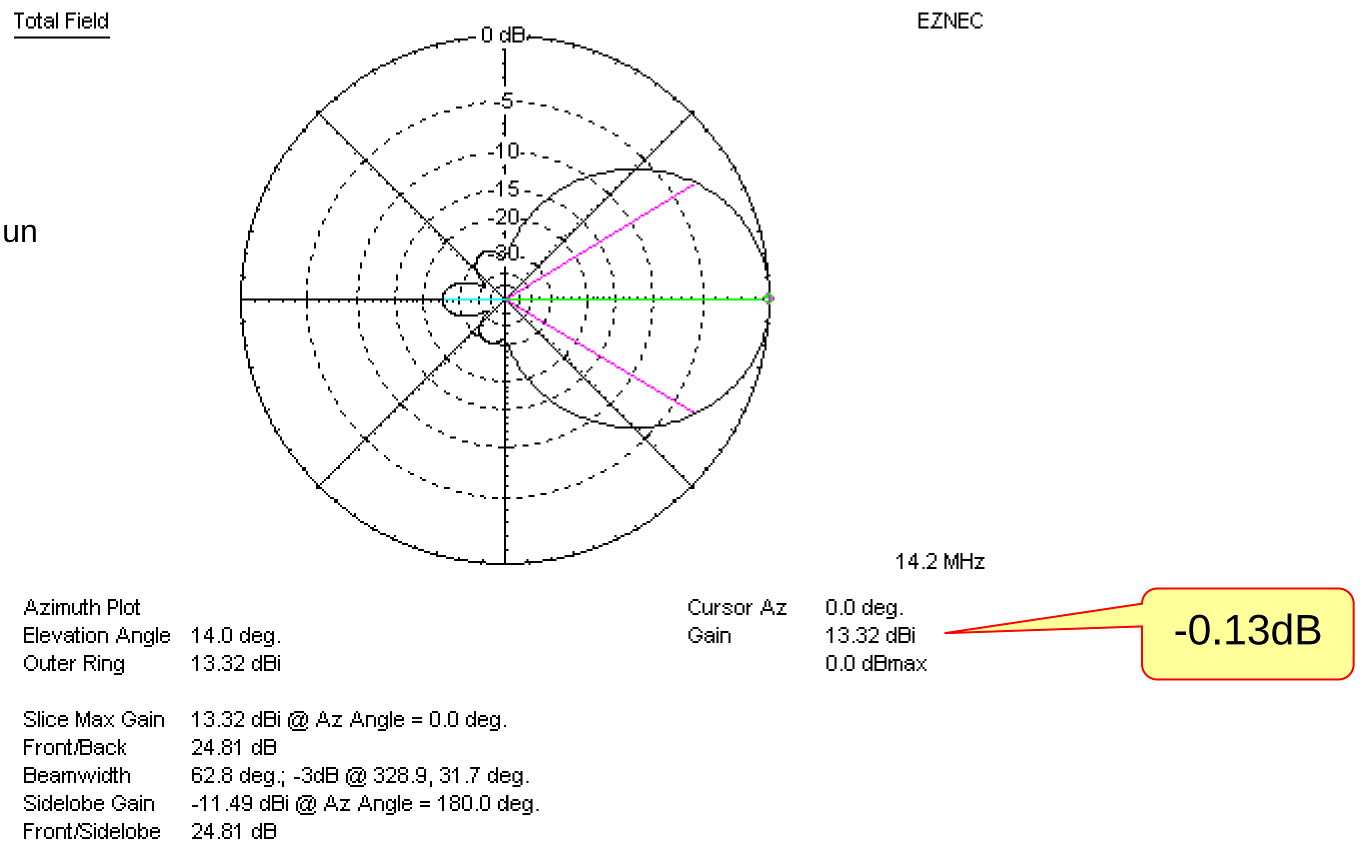
Elevation Plot			Cursor Elev	14.0 deg.
Azimuth Angle	0.0 deg.		Gain	13.32 dBi
Outer Ring	13.32 dBi			0.0 dBmax

Slice Max Gain	13.32 dBi @ Elev Angle = 14.0 deg.
Beamwidth	14.6 deg.; -3dB @ 6.7, 21.3 deg.
Sidelobe Gain	9.9 dBi @ Elev Angle = 45.0 deg.
Front/Sidelobe	3.42 dB

Case H: 3-el 20m yagi up 21m
Feed with coax, current balun 200ohm R

At the feedpoint current balun

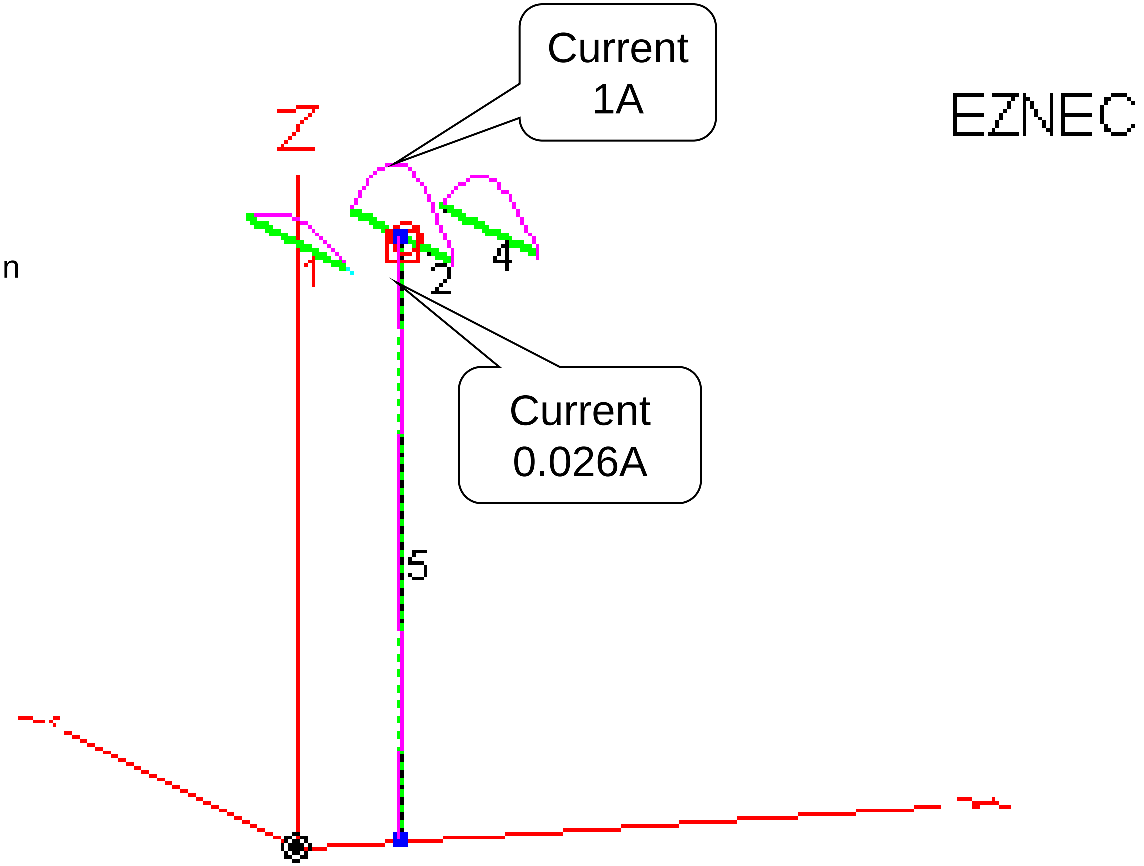
Serial impedance 200 ohm resistive



Case I: 3-el 20m yagi up 21m
Feed with coax, current balun 500 ohm R

At the feedpoint current balun

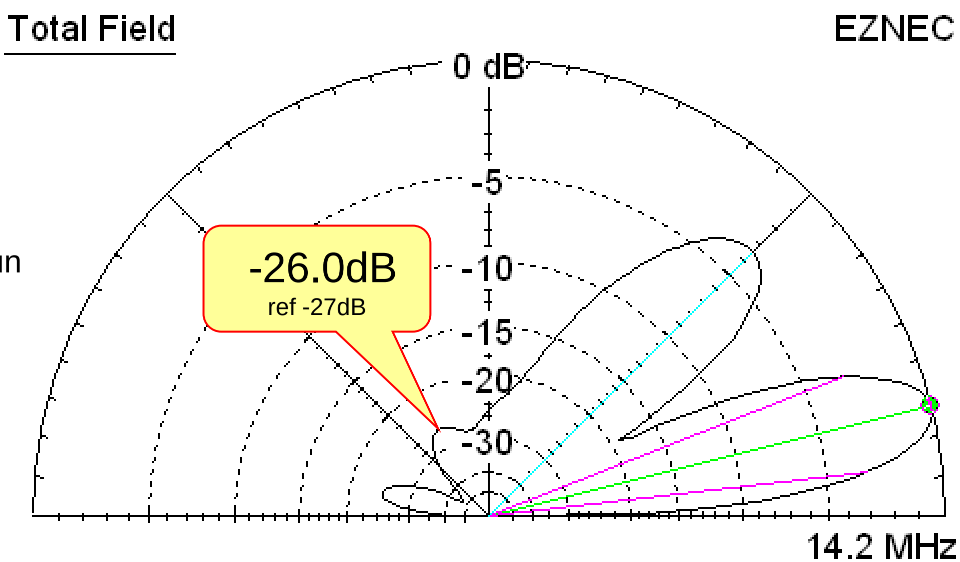
Serial impedance 500 ohm resistive



Case I: 3-el 20m yagi up 21m
Feed with coax, current balun 500ohm R

At the feedpoint current balun

Serial impedance 500 ohm resistive



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 13.39 dBi

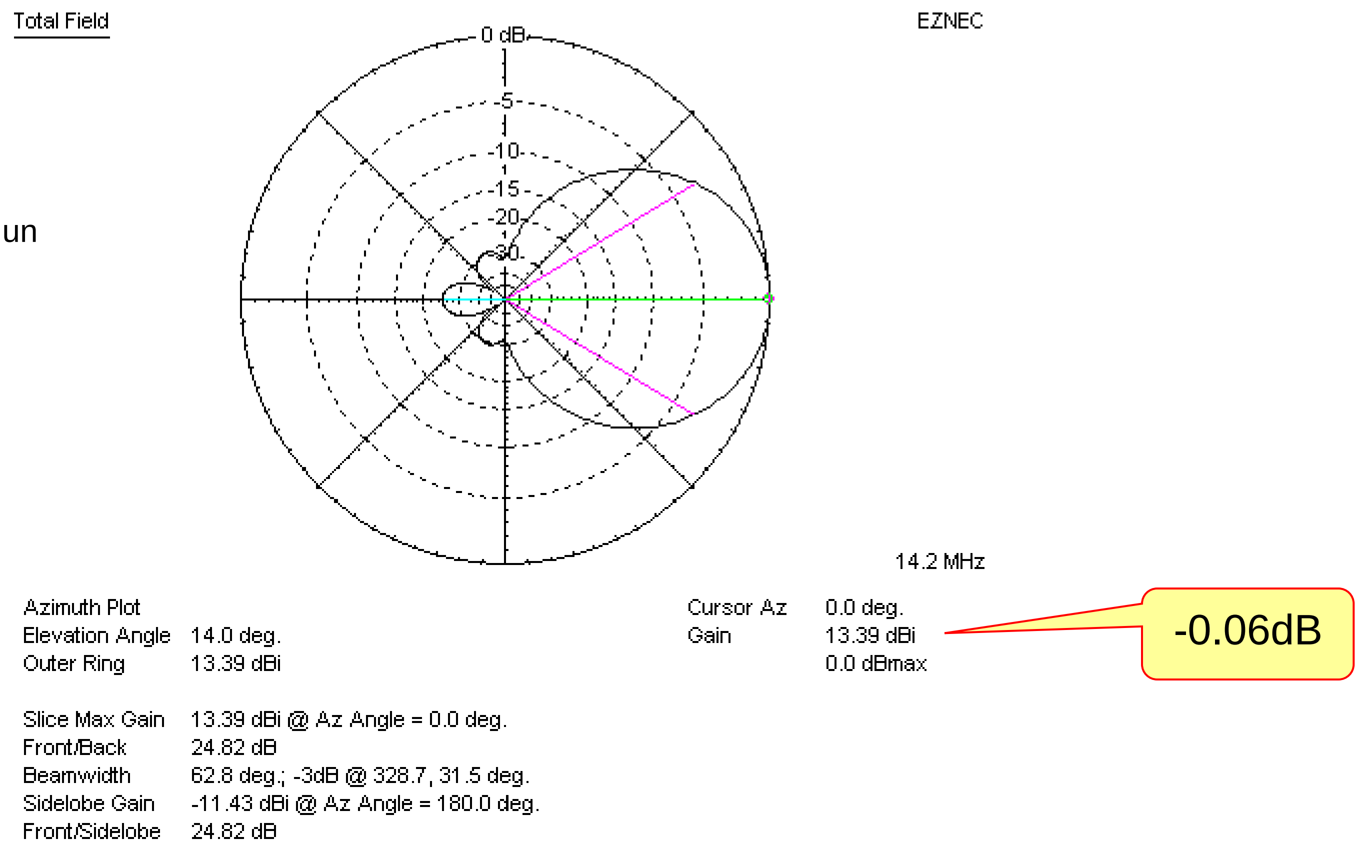
Cursor Elev 14.0 deg.
Gain 13.39 dBi
0.0 dBmax

Slice Max Gain 13.39 dBi @ Elev Angle = 14.0 deg.
Beamwidth 14.6 deg.; -3dB @ 6.7, 21.3 deg.
Sidelobe Gain 9.97 dBi @ Elev Angle = 45.0 deg.
Front/Sidelobe 3.42 dB

Case I: 3-el 20m yagi up 21m
Feed with coax, current balun 500ohm R

At the feedpoint current balun

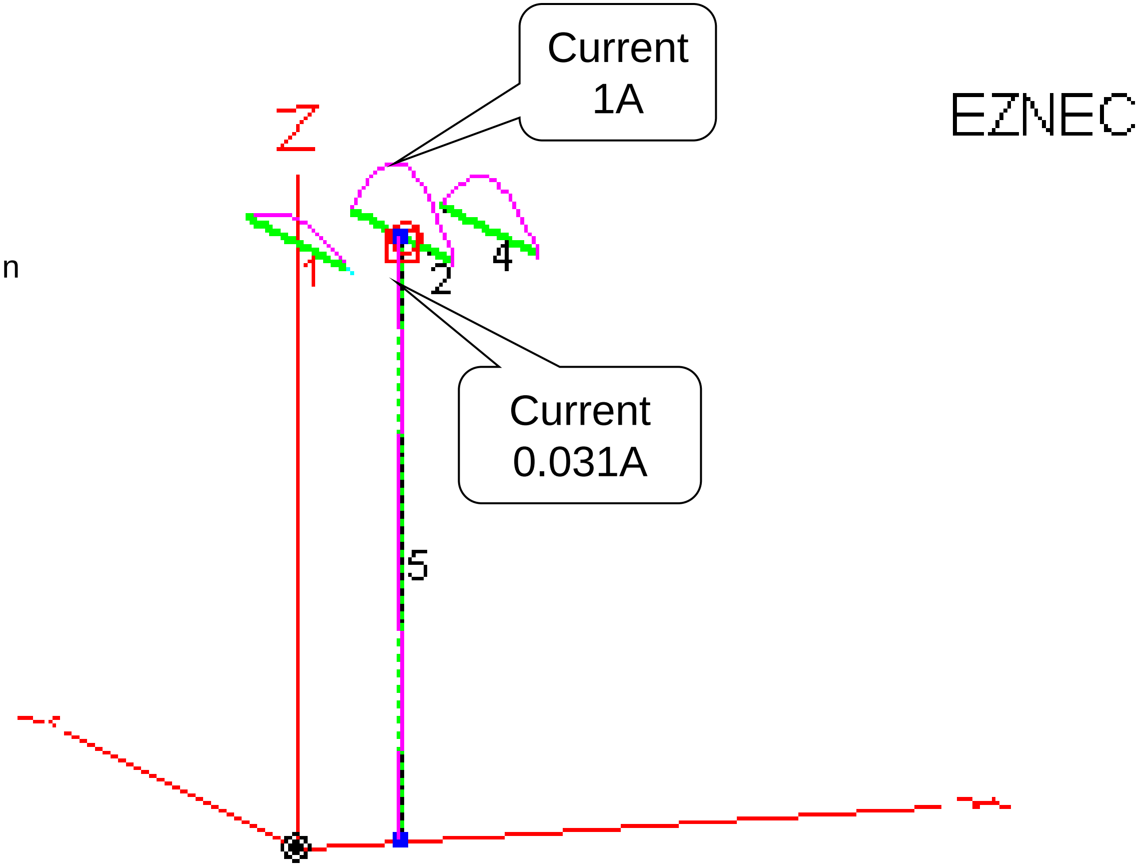
Serial impedance 500 ohm resistive



Case J: 3-el 20m yagi up 21m
Feed with coax, current balun 500 ohm L

At the feedpoint current balun

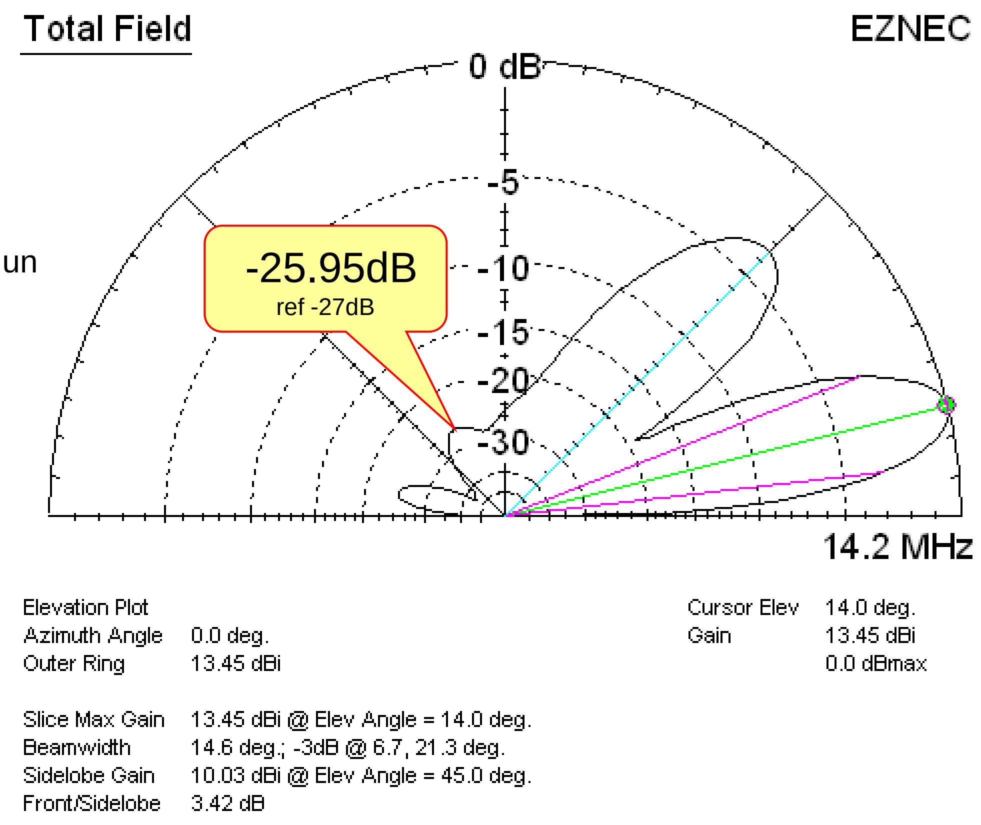
Serial impedance 500 ohm inductive



Case J: 3-el 20m yagi up 21m
Feed with coax, current balun 500ohm L

At the feedpoint current balun

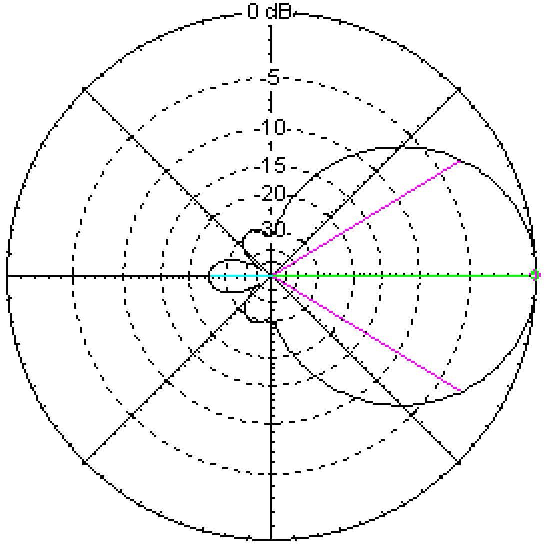
Serial impedance 500 ohm inductive



Case J: 3-el 20m yagi up 21m
Feed with coax, current balun 500ohm L

At the feedpoint current balun

Serial impedance 500 ohm inductive



Azimuth Plot	
Elevation Angle	14.0 deg.
Outer Ring	13.45 dBi

Cursor Az	0.0 deg.
Gain	13.45 dBi
	0.0 dBmax

-0.00dB

Slice Max Gain	13.45 dBi @ Az Angle = 0.0 deg.
Front/Back	24.82 dB
Beamwidth	62.8 deg.; -3dB @ 328.5, 31.3 deg.
Sidelobe Gain	-11.37 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	24.82 dB

Conclusions 3..
current balun

- The idea of current balun is to limit common mode current in the feed line, even common mode voltage exists. Current balun is a high common mode impedance.
- The most effective way to use current balun is to locate them in the current maxima.
  - One natural place is near the antenna feedpoint
- If reactive impedance is used, it shall tune the system away from resonance
  - In our example +j50ohm made the cable resonant, which shall be avoided
  - High reactance, 500ohm or more, works fine
- Resistive serial impedance works in all circumstances, but can introduce some loss to forward gain.
  - Resistance values 200-500ohm are suitable in many cases.
- Most ferrite beads provide both resistive and inductive impedance
- Current balun works fine with asymmetrical antennas too

…Conclusions 3

- Note:
  - In these examples feed cable was located symmetrically on antenna center line, as the case often is with tower installed yagi. Therefore radiation índuced currents were very small.
  - Sometimes with wire dipoles feedline cannot follow the antenna centerline and radiation induced currents in coax can become significant. In such a case current balun can be better than voltage balun. In difficult conditions multiple current baluns can be used: first one at the antenna feedpoint and others every ¼ wavelength from that. They hinder current maxima to develop.