On the Subject of Baluns

S & T treat baluns on pp. 180-187, Sect. 5.3 "Feeding Wire Antennas" (read this!)

Kraus treats "matching problems" on pp. 734-745. Discussion on baluns is mostly contained on pp. 741-745, Sect. 16.11.

Balanced to Unbalanced transformers

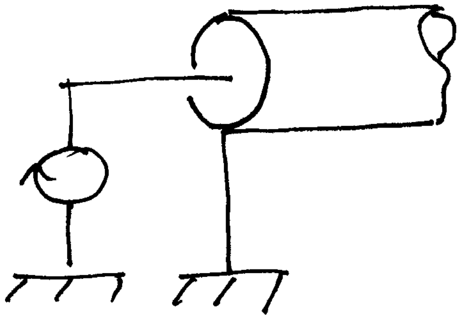
or BALUNs

Why needed ?

What are they?

How do they work?

Most typical example of an unbalanced system is coaxial cable.

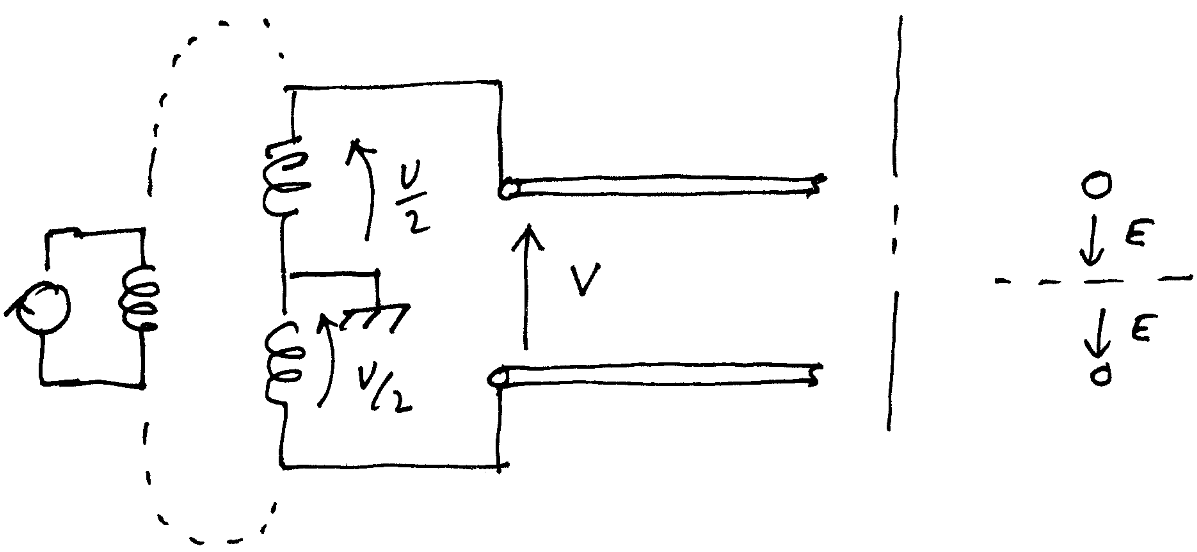


Unbalanced because all potentials are of same sign* w.r.t reference potential "⏚"

(*instantaneously, at a given location)

/...

Contrast ~~this~~ above with



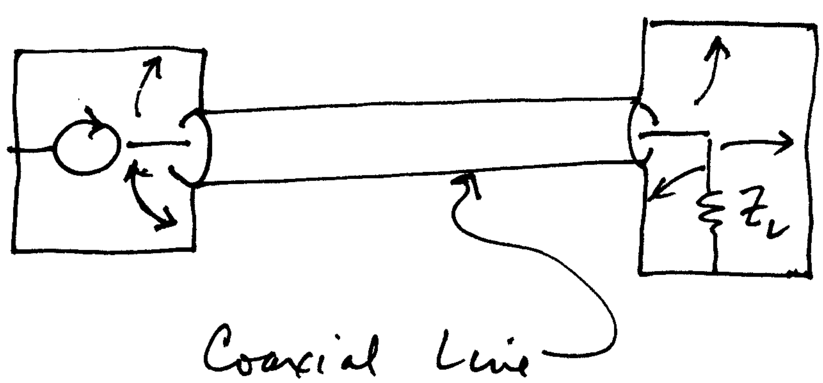
Symmetrical w.r.t. ⏚, said to be

But some antennas are "balanced," while others are "unbalanced."

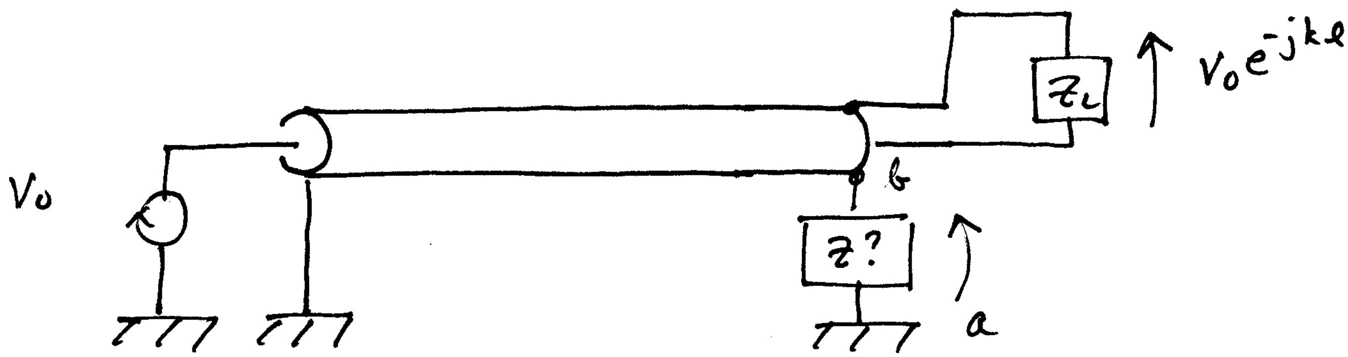
How to connect balanced and unbalanced systems?

Unbalanced Systems occur "naturally" – in active devices, e.g.

They can be completely shielded



Consider,



$$V_{ab} = \int_a^b \bar{E}\cdot d\bar{s} = \int_a^b (-\nabla\phi - j\omega\mu\bar{A})\cdot d\bar{s}$$

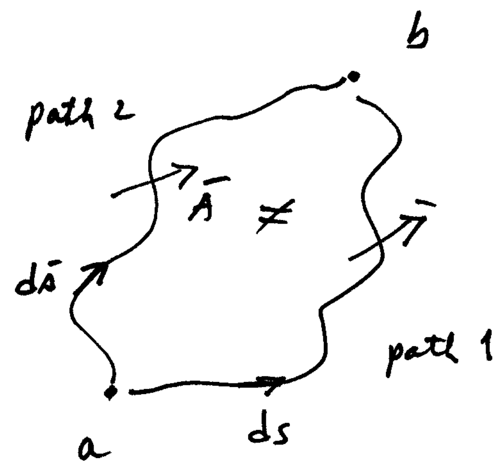
$$= -\int_a^b \nabla\phi\cdot d\bar{s} - j\omega\mu\int_a^b \bar{A}\cdot d\bar{s}$$

/...

16-8

$$V_{ab} = \underbrace{\phi_a - \phi_b} - j\omega\mu\int_a^b \bar{A}\cdot d\bar{s} \neq 0$$

$\nabla\phi$ is conservative field $= 0$ when integrated around a loop.

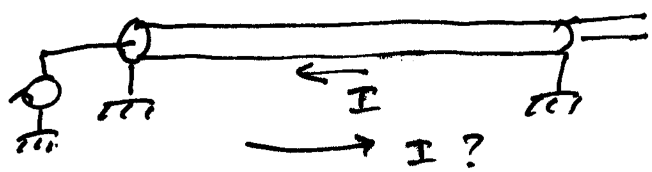


$$V_{aa} = 0 - j\omega\mu\oint_a^a \bar{A}\cdot d\bar{s}$$

$\int_a^b \bar{A}\cdot d\bar{s}$ depends on path of

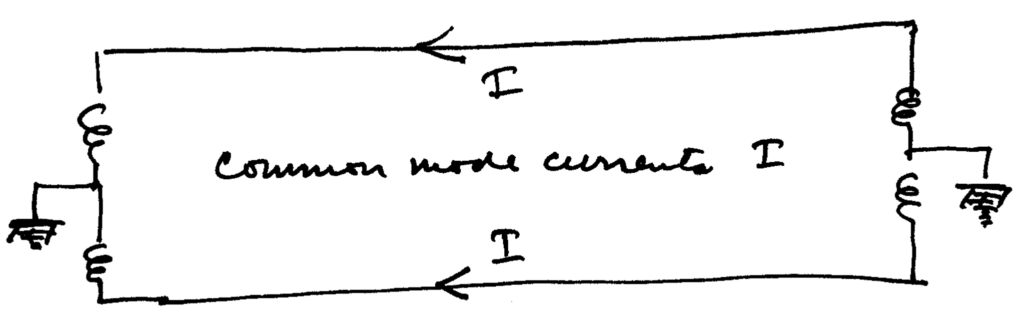
$$= -j\omega\mu\int \nabla\times\bar{A}\cdot d\bar{s}$$

So, in the presence of $\bar{A}$ (or $\bar{B}$), external to a coaxial conductor, currents can flow on the outside of the outer conductor as the result of "induction." That is, induced potential differences on different parts of the conductor result in currents necessary to maintain $\bar{E}_{tang} = 0$. Since $V_{aa} \neq 0$, this can occur even when the conductor (the outer coaxial braid, e.g.) appears to be "grounded."

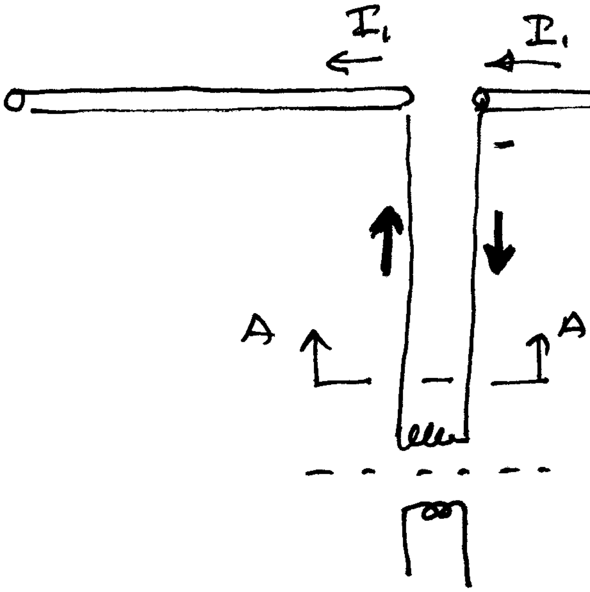


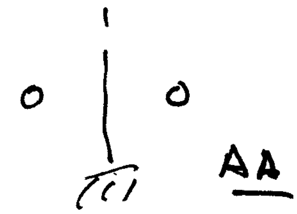
N.B. The circuit need not close through an external connection, however.

Aside: Similar phenomena can occur on balanced lines.



Symmetrical antenna



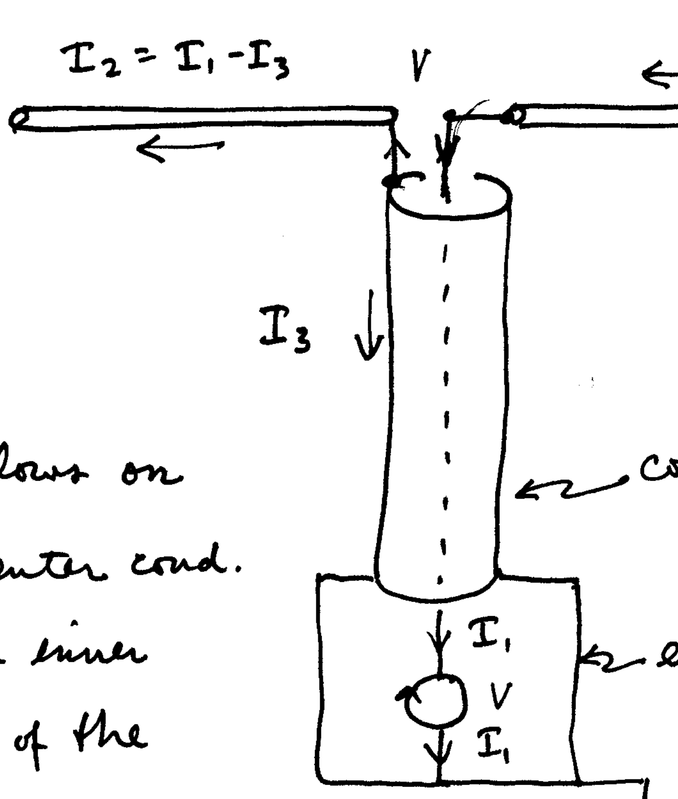


symmetrical transmission line.

Balanced system

No Problem

Symmetrical Antenna – Unbalanced Line

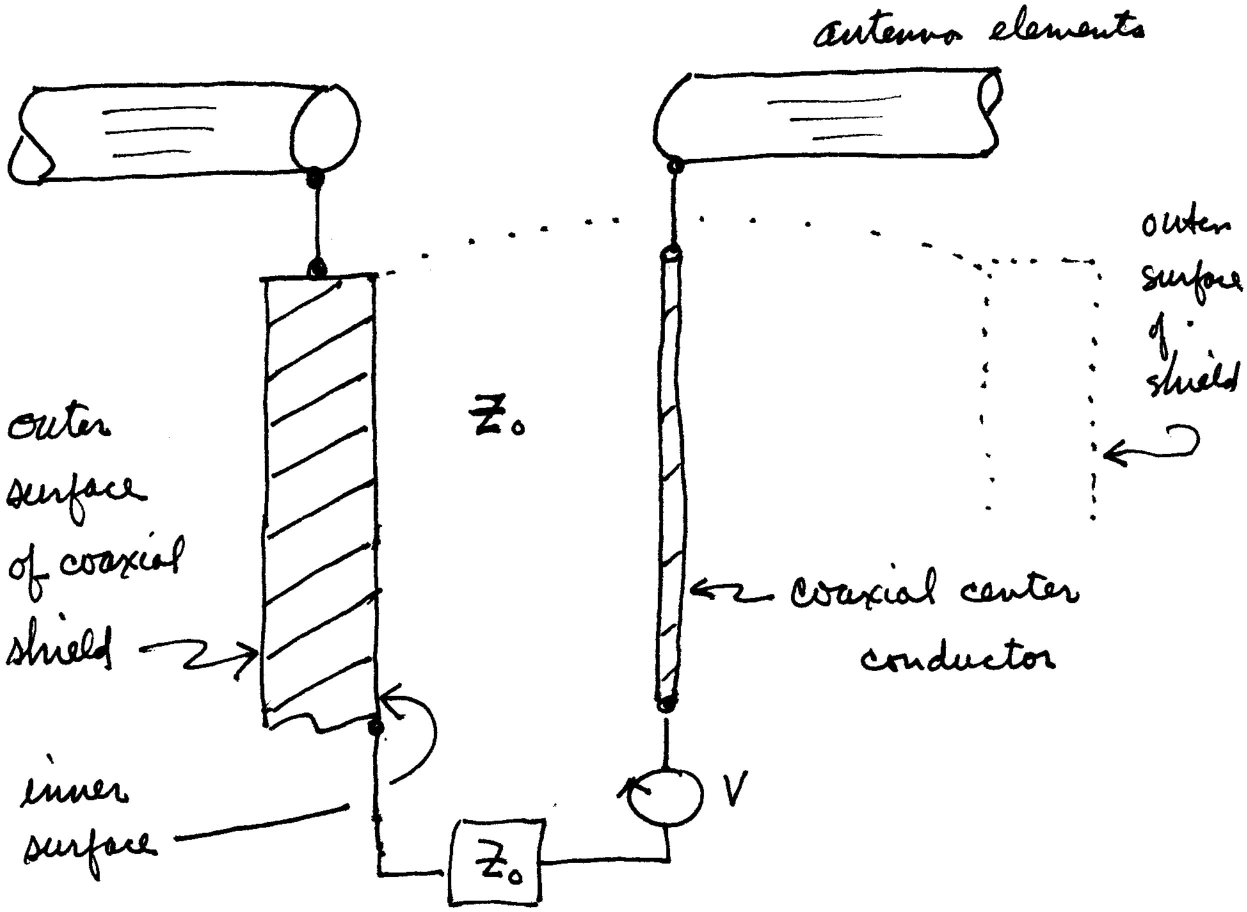


coaxial line – enclosed.

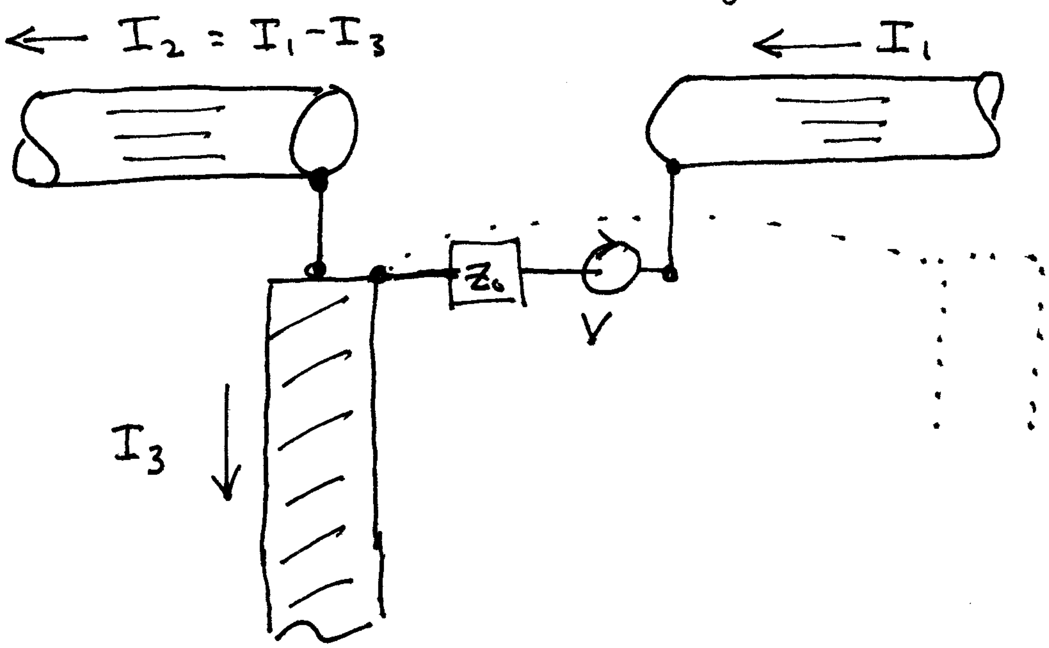
enclosed source

I_1 flows on both center cond. and the inner surface of the

Here is an exaggerated sketch of the situation at the antenna feed point...

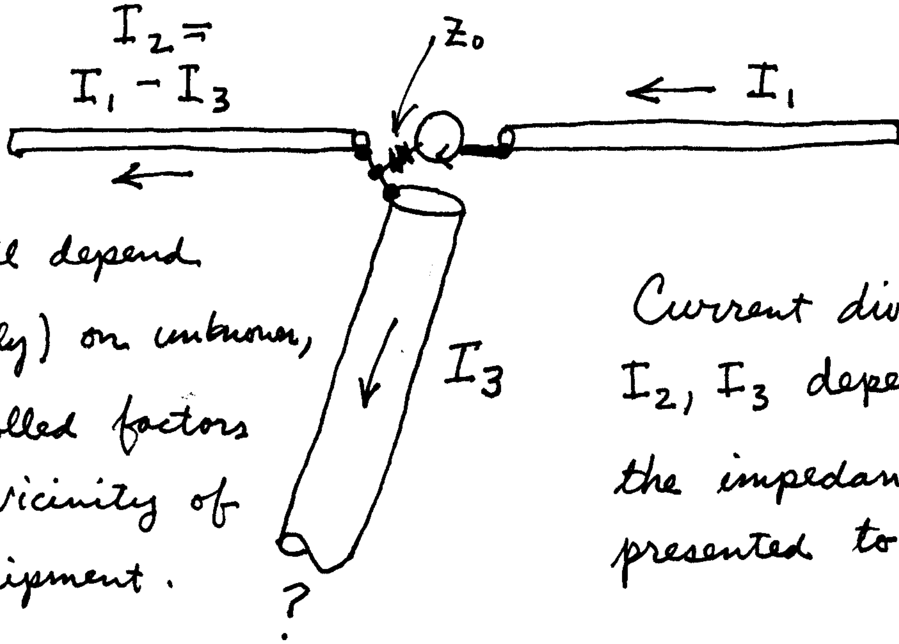


Owing to the properties of a matched transmission line this is equivalent to...



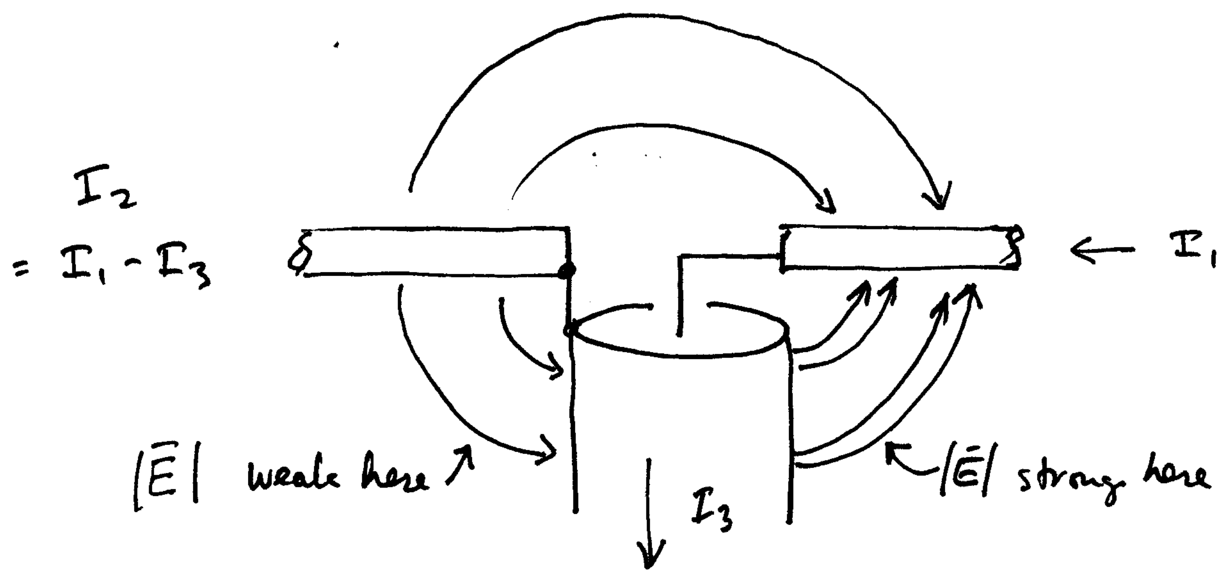
Another way to think of this —

At the feed point we have, in effect ...



I_3 will depend (typically) on unknown, uncontrolled factors in the vicinity of the equipment.

Current division between I_2, I_3 depends on the impedance presented to the source.



Why?

Radiation results from I_1, I_2, I_3

$I_1 \neq I_2$, $I_3 \neq 0$ corrupts pattern and

Pattern problems important for both transmitting and receiving.

Uncontrolled flow of currents is (or can be) dangerous in high power equipment.

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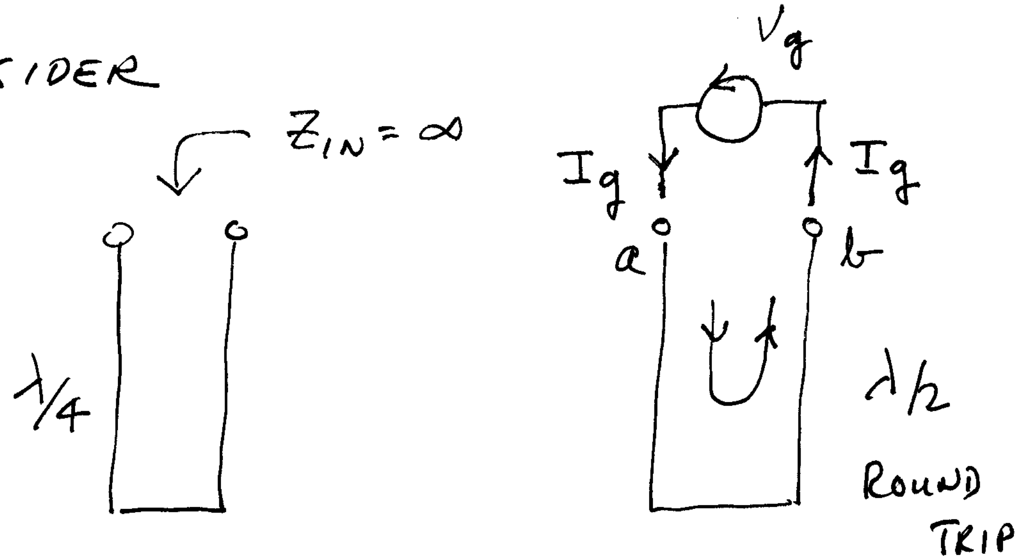
How to BLOCK I_3?

CONSIDER



<u>WHEN PHASE REVERSAL IS CONSIDERED</u>

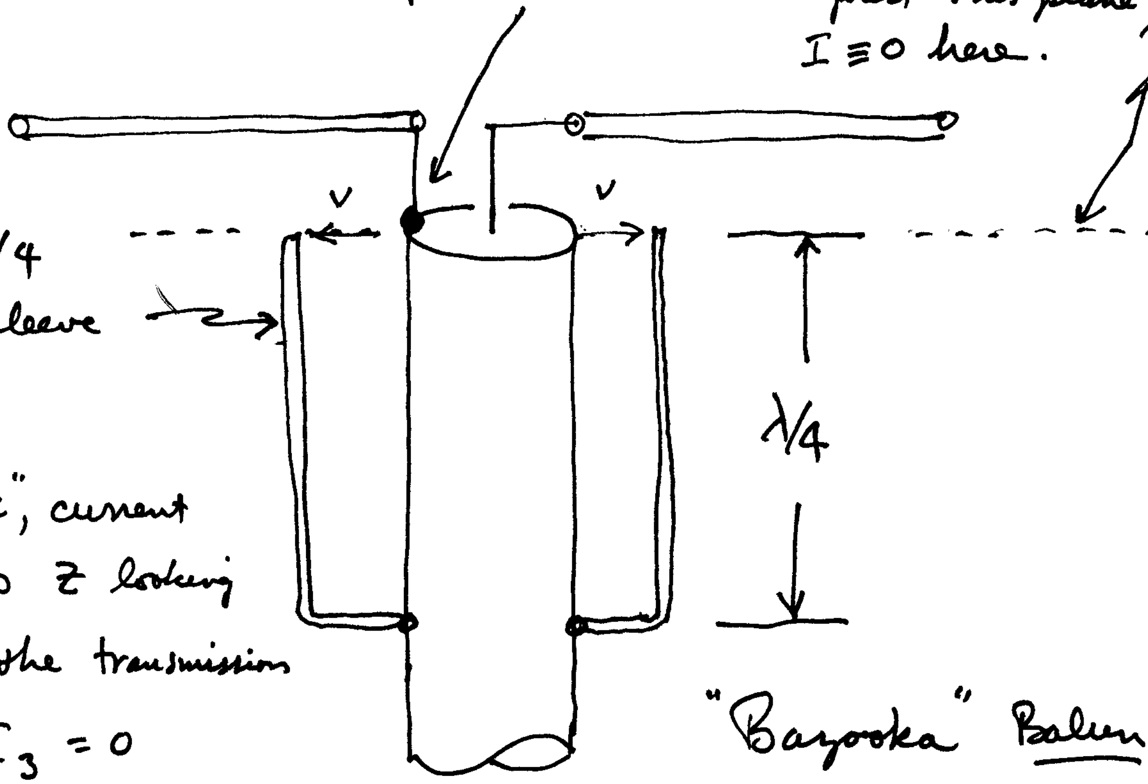
$\lambda/2$ path from $a \rightarrow b$ and vice versa cancels I_g at feed point!

$\lambda/4$ transformer can be applied to antenna problem.

point "c"

No net current past this plane $I \equiv 0$ here.

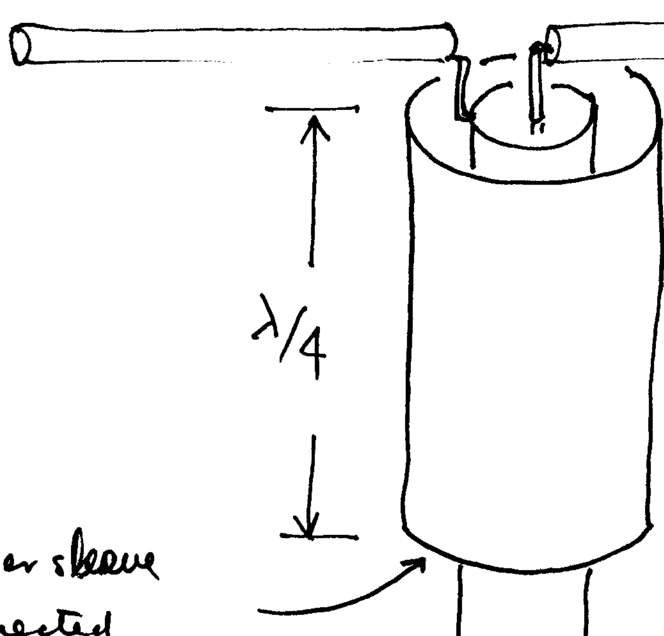
added $\lambda/4$ coaxial sleeve



At point "c", current sees an ∞ Z looking back down the transmission line. $I_3 = 0$

"Bazooka" Balun

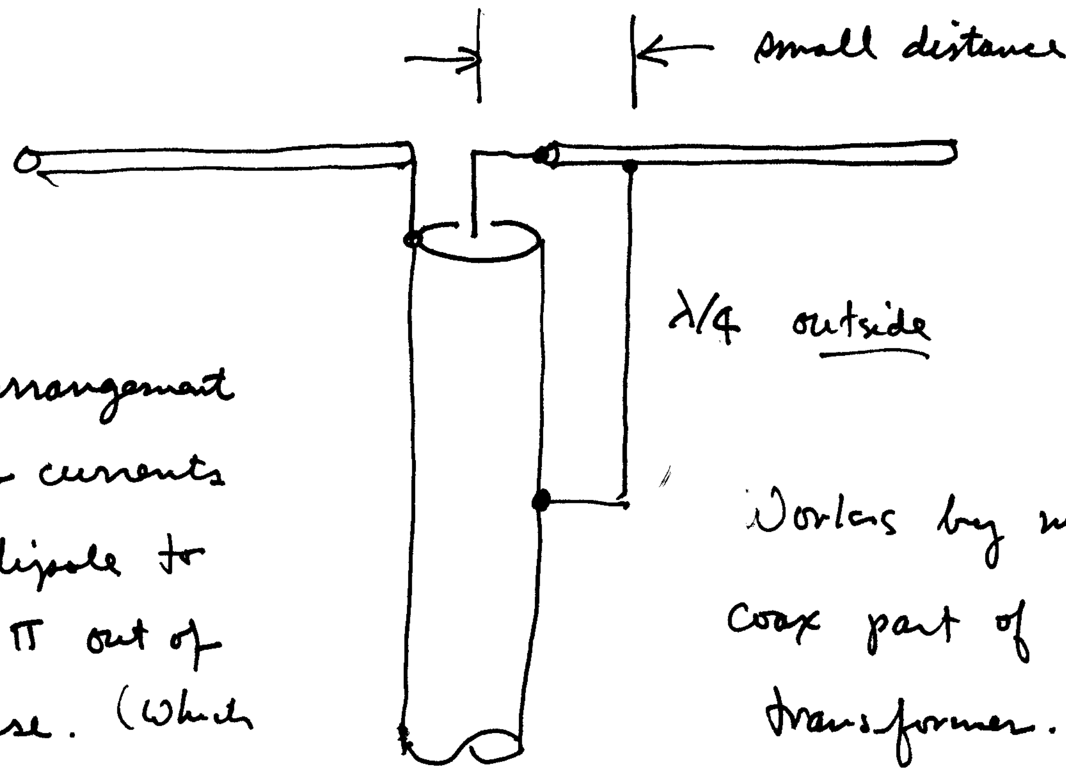
Perspective View of the Bazooka Balun



Balun is an additional coaxial sleeve fitted over the original coaxial

Outer sleeve connected

Alternative



This arrangement forces currents on dipole to be π out of phase. (Which means in phase in our context!)

Works by making coax part of λ/4 transformer.

Called 1:1 Balun

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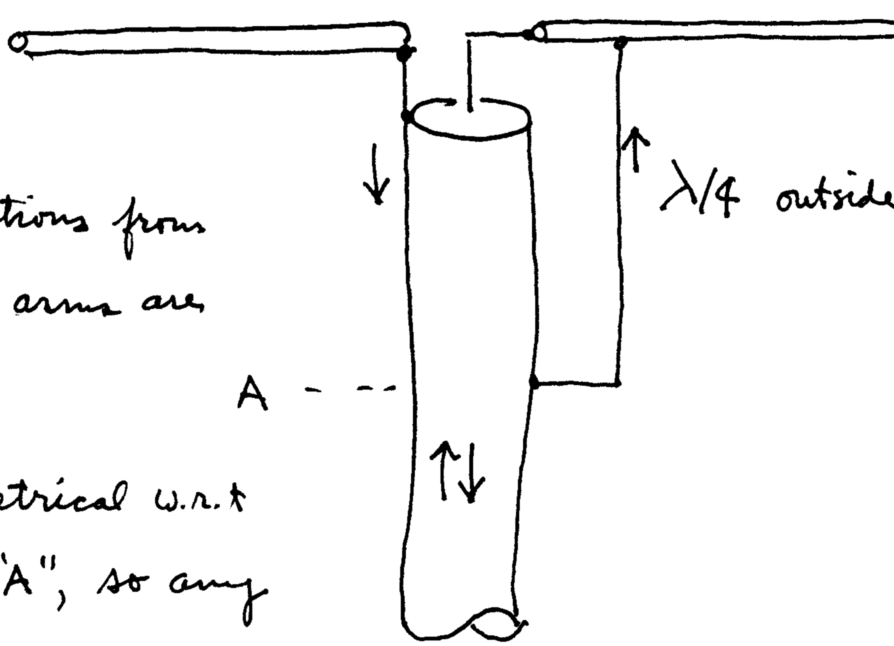
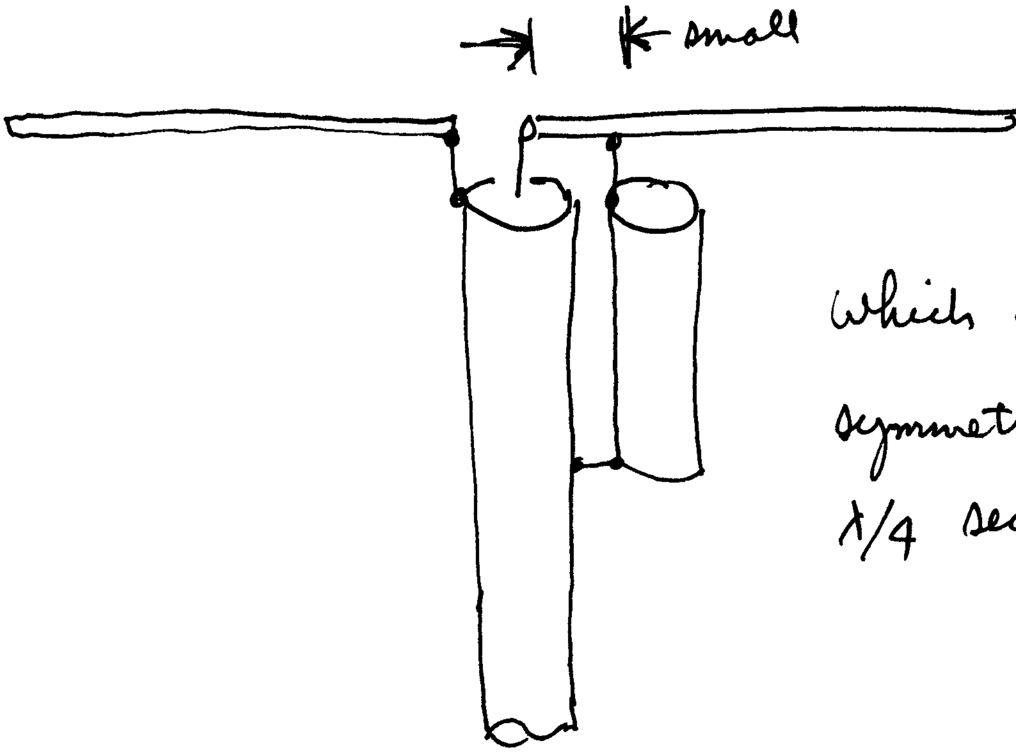


Connections from dipole arms are symmetrical w.r.t level "A", so any induced currents on

1:1 Balun sometimes realized as ...



Which gives better symmetry in the $\lambda/4$ section.

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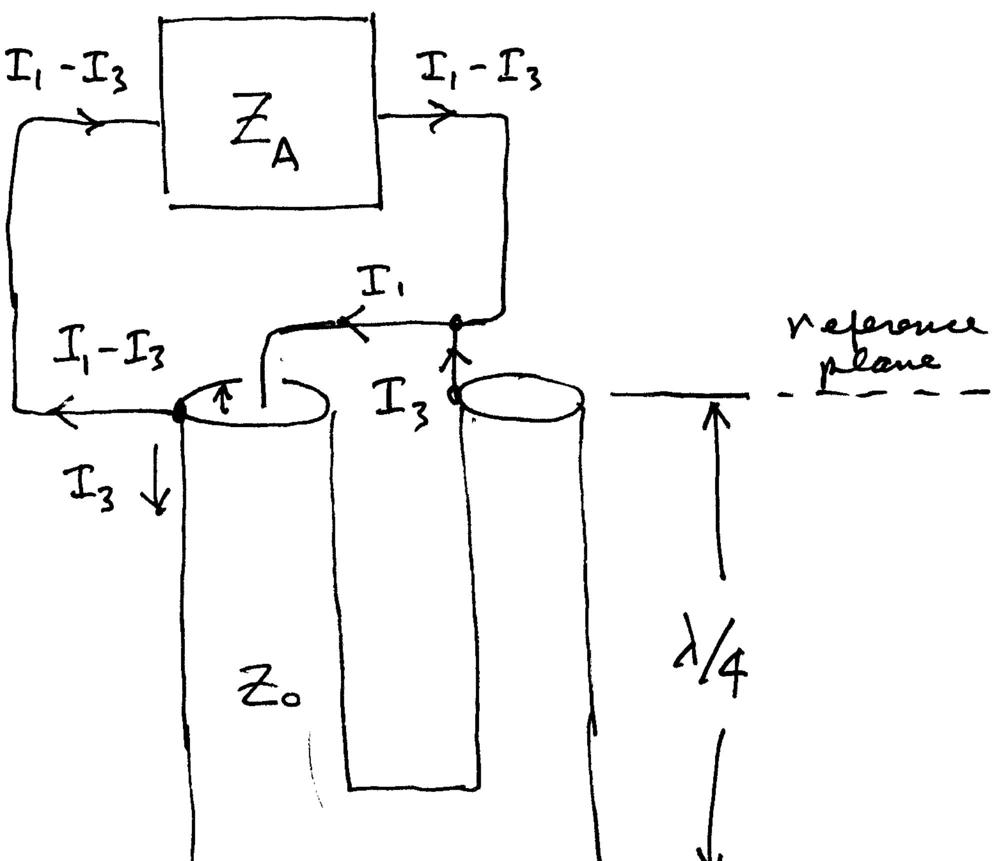
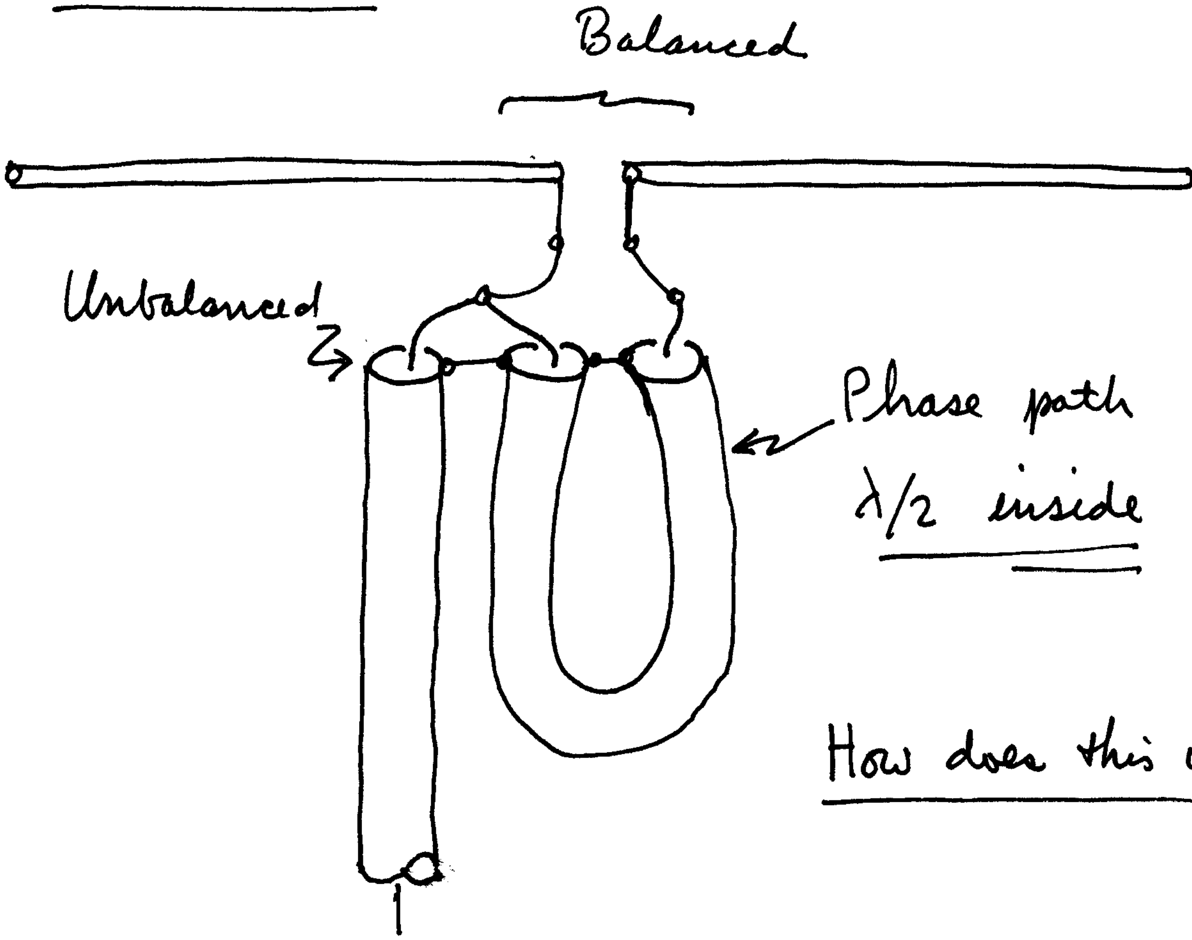
What about 1:1 Balun? (For match $Z_A = Z_0$)



A. No net current can pass down the line beyond the $\lambda/4$ section

B. $I_3 = 0$ because $\lambda/4$ section is ∞ Z at

4:1 Balun



How does this work??

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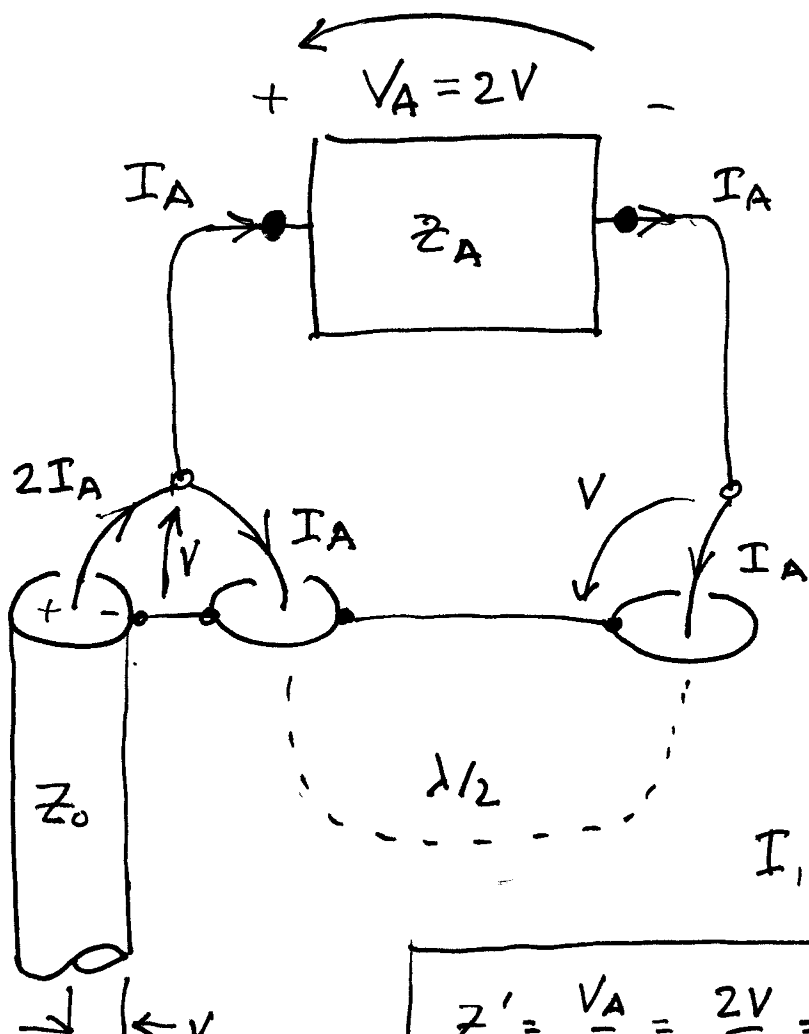
$Z_0 = \frac{V}{I}$



Currents on antenna elements are forced to be equal (I_A) by λ/2 phasing

I, V reverse in λ/2

$$\boxed{Z' = \frac{V_A}{\ldots} = \frac{2V}{\ldots} = 4\,Z_0}$$

Disadvantage of practical examples is that

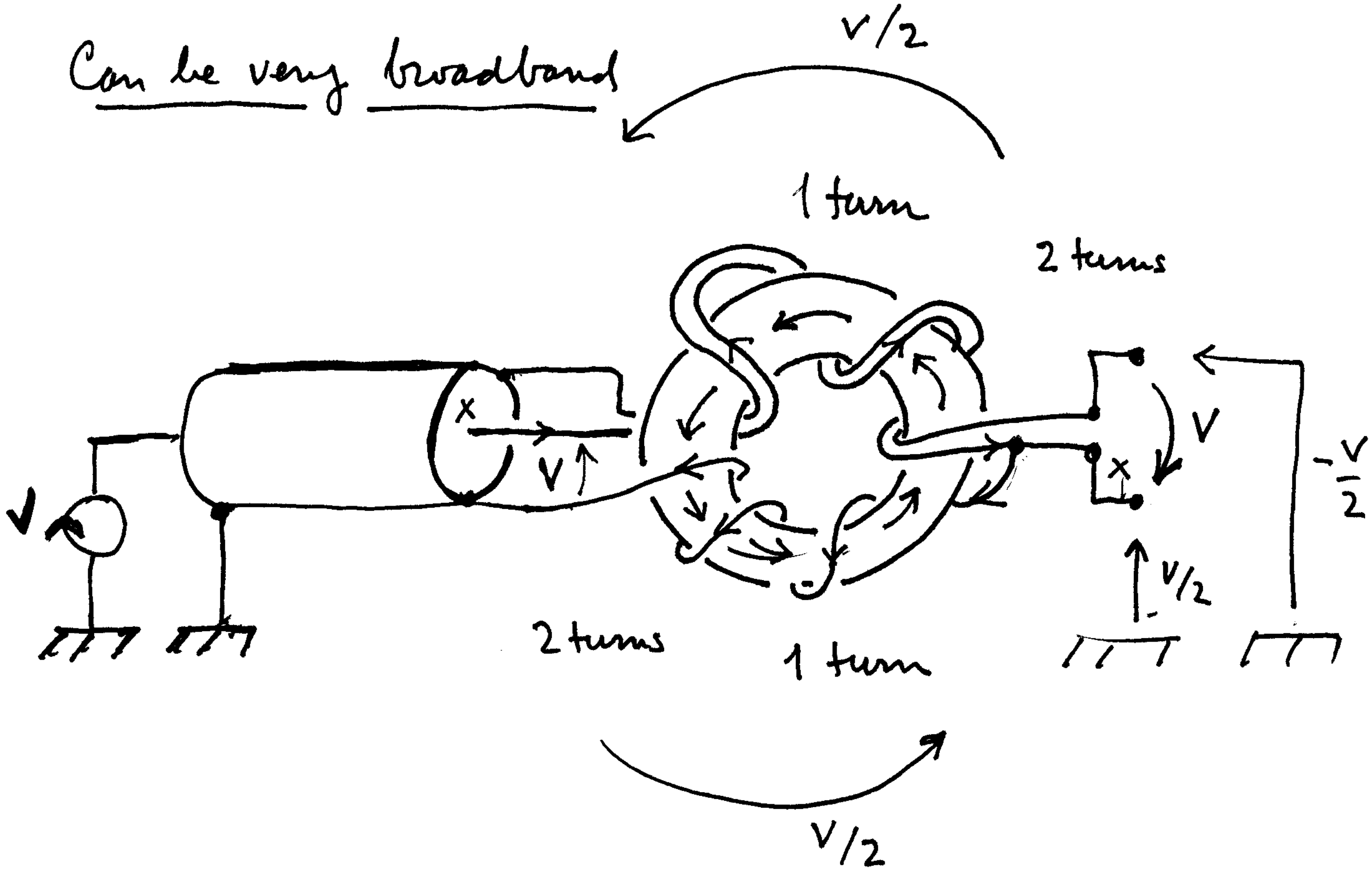
they are all narrow band. (They depend on specific phasing structures implemented w/ transmission lines.

Broad band solutions can be realized w/ circuit type elements.

See below

/..

Can be very broadband



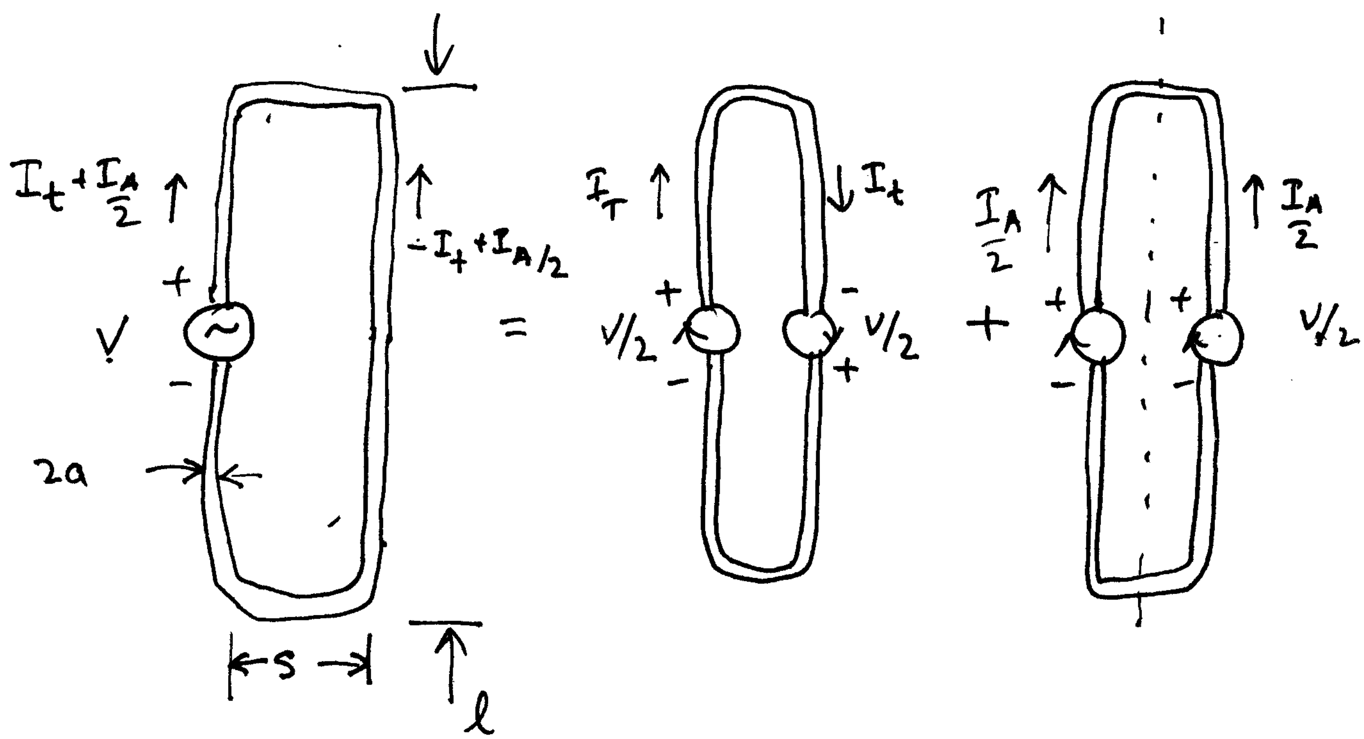
Non-linear → harmonics

Lossy

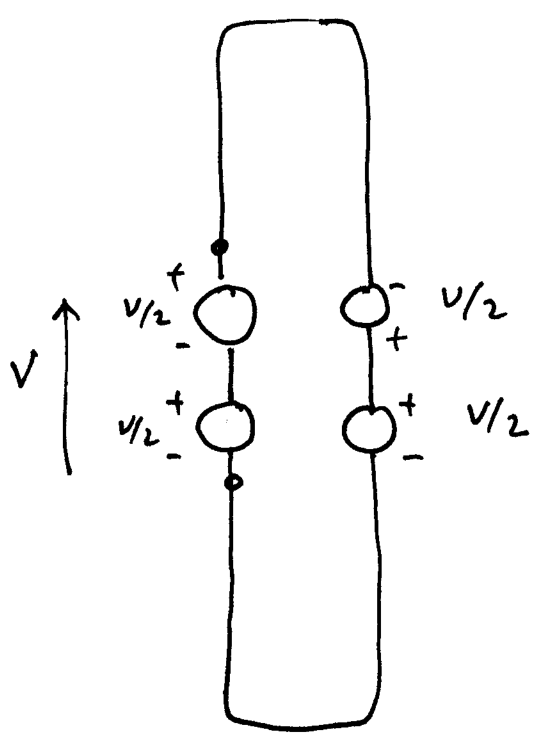
Other examples of Z transformation.

Folded Dipole

$s, 2a \ll l\ ,\ l \approx \lambda/2$



16-30



V/2 — transmission line generators

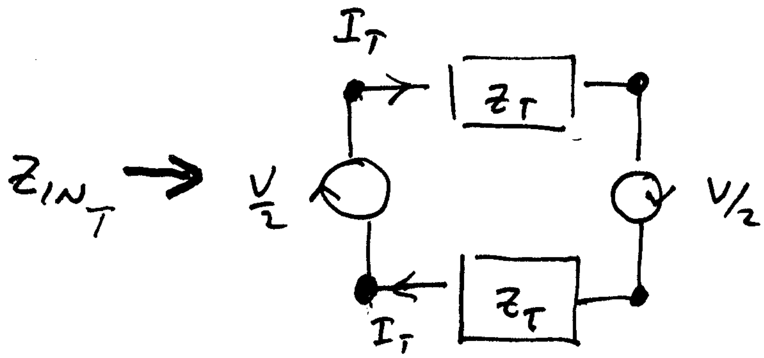
V/2 — antenna mode generators

How can this be analyzed?

Use superposition!

For <u>transmission line mode</u> $\quad Z_T = j\, Z_0 \tan\left[\beta\, \ell/2\right]$

An equivalent circuit is



$$Z_{IN_T} = ? \qquad I_T = \frac{2 \cdot V/2}{2\, Z_T} = \frac{V}{2 Z_T}$$

$$Z_{IN_T} = \frac{V}{I_T} = 2\, Z_T$$

For <u>antenna mode</u>, I_A is approximately that of a single dipole with excitation $V/2$

$$I_A \simeq \frac{V/2}{Z_D} = \frac{V}{2 Z_D}\ ; \quad Z_D = \text{dipole input impedance}$$

$$Z_{IN_D} \simeq \frac{V}{I_A} = 2\, Z_D$$

Input Z doubled! Why? Voltage required to drive a given current is doubled by close

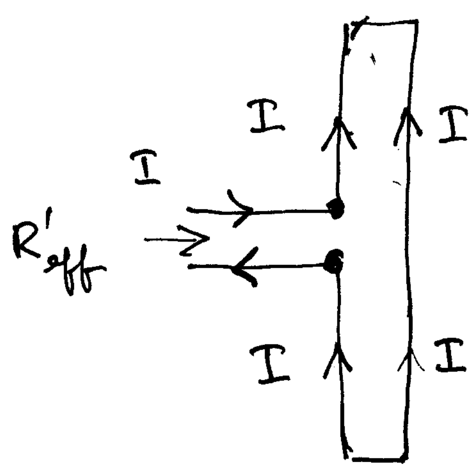
So what is input Z for the whole thing?

$$Z_{IN} \simeq \frac{V}{I_T + \frac{1}{2} I_A} = \frac{V}{\frac{V}{2Z_T} + \frac{1}{2}\frac{V}{2Z_D}} = \frac{4 Z_T Z_D}{2 Z_D + Z_T}.$$

$$\left.\begin{array}{l} Z_{IN} \longrightarrow 4 Z_D \\ \text{when } Z_T \to \infty, \\ \text{which occurs when } l \simeq \lambda/2 \end{array}\right\}$$

So input impedance is quadrupled!

An alternative view, valid at resonance is as follows:



Effective radiating current is $2I$, so the radiated power has increased by $\times 4$.

$$\underbrace{\frac{1}{2} R'_{eff} I^2}_{\text{folded dipole}} = \underbrace{4 \cdot \frac{1}{2} R_{eff} I^2}_{4 \times \text{simple dipole}}$$

$$R'_{eff} = 4 \cdot R_{eff}$$

Summary - for Folded Dipole

$$Z_{IN} \simeq 4 Z_D \qquad (l = \lambda/2)$$

$$Z_{IN} \simeq 4(73 + j42) = 292 + j168 \ \Omega$$

Resonate this by trimming, $Z_{IN} \simeq 300\Omega$, which matches $300\ \Omega$ twin line.

Such dipoles generally are more broadband than straight dipoles. Why?? Think about this.

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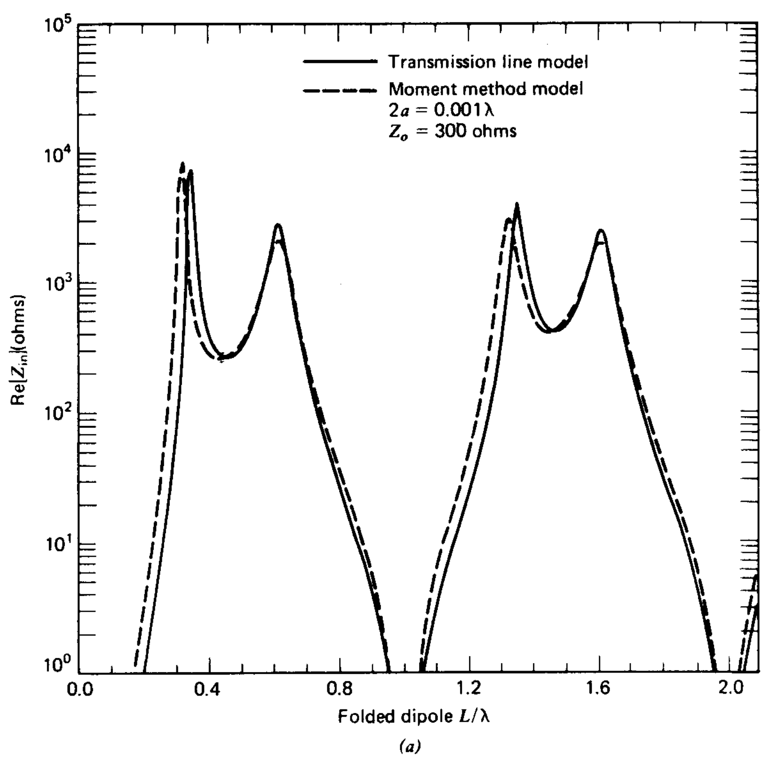

(a)

Figure 5-15 Input impedance of a folded dipole. The solid curves are calculated from the transmission line model. The dashed curves are calculated from more accurate numerical methods. The wire radius a is

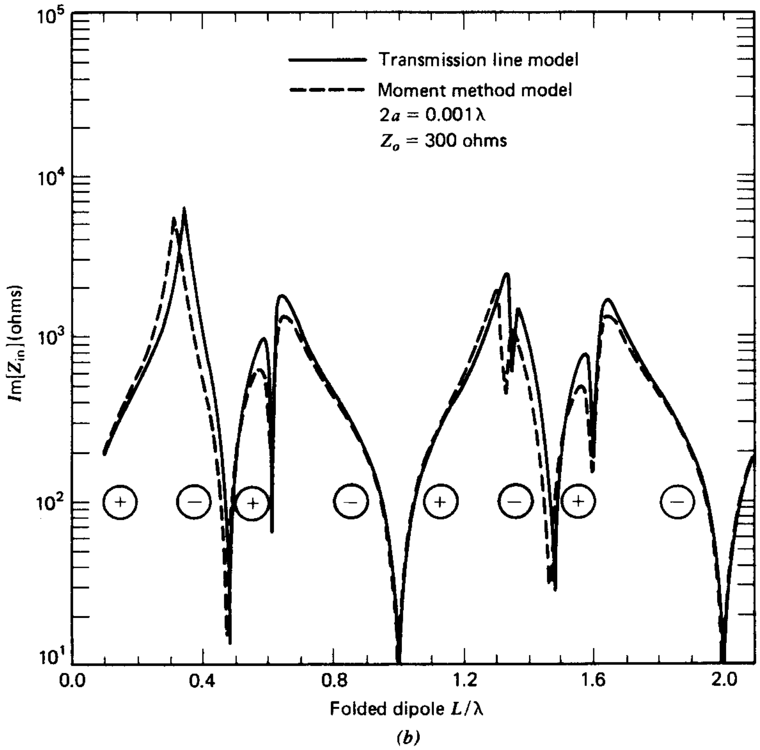

Figure 5-15 (*b*) Input reactance.

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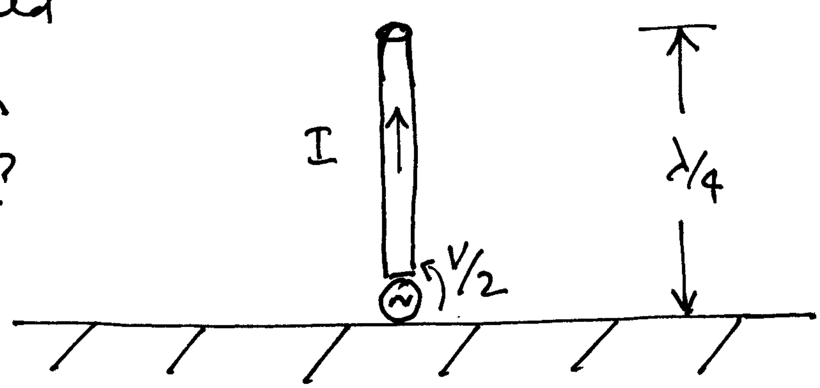
Above the conducting plane we only need

Has field strength changed? (No!)

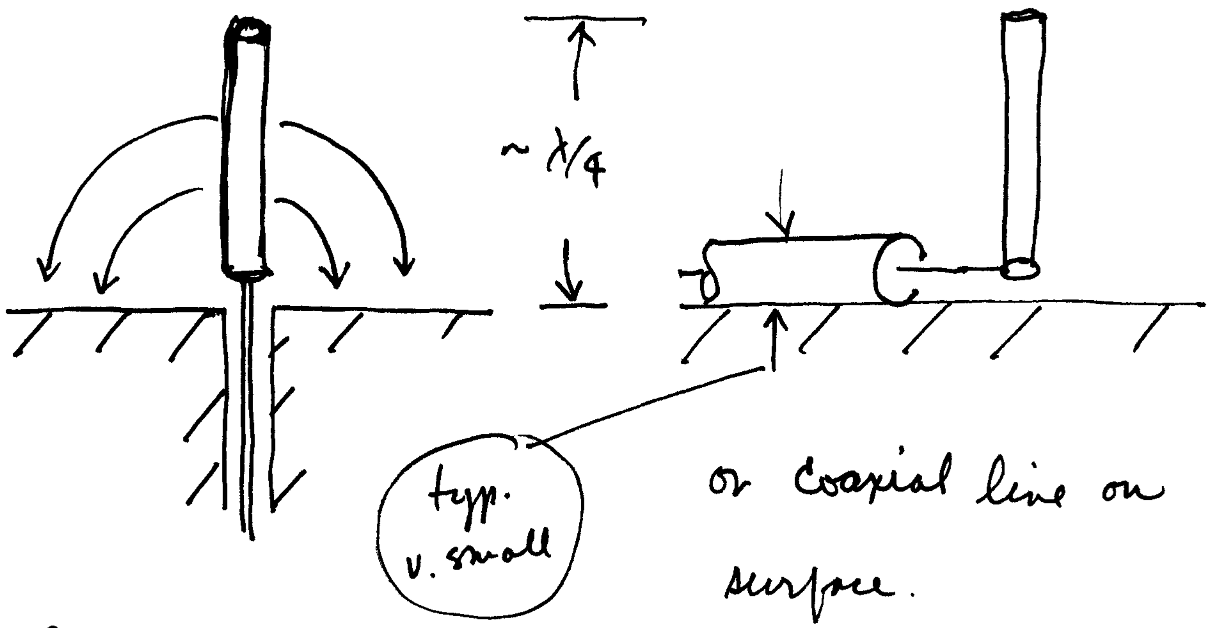


Monopole, vertical, "stub"

Has Z_{IN} changed? (Yes!) $Z_{IN} \simeq \frac{73}{2} \simeq 36\,\Omega$

Has input power changed?

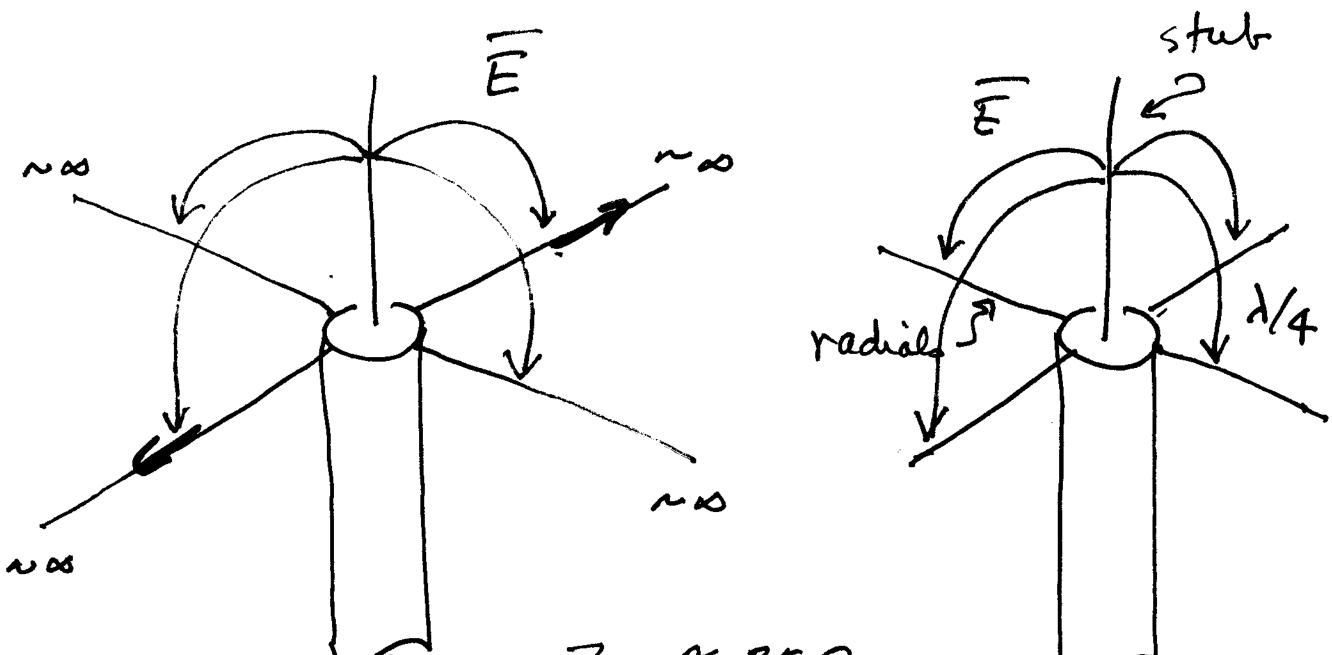
Ways to couple this to a T. Line



Coaxial line from interior

or coaxial line on surface.

As a practical matter, a full ground plane is not required (in many cases)



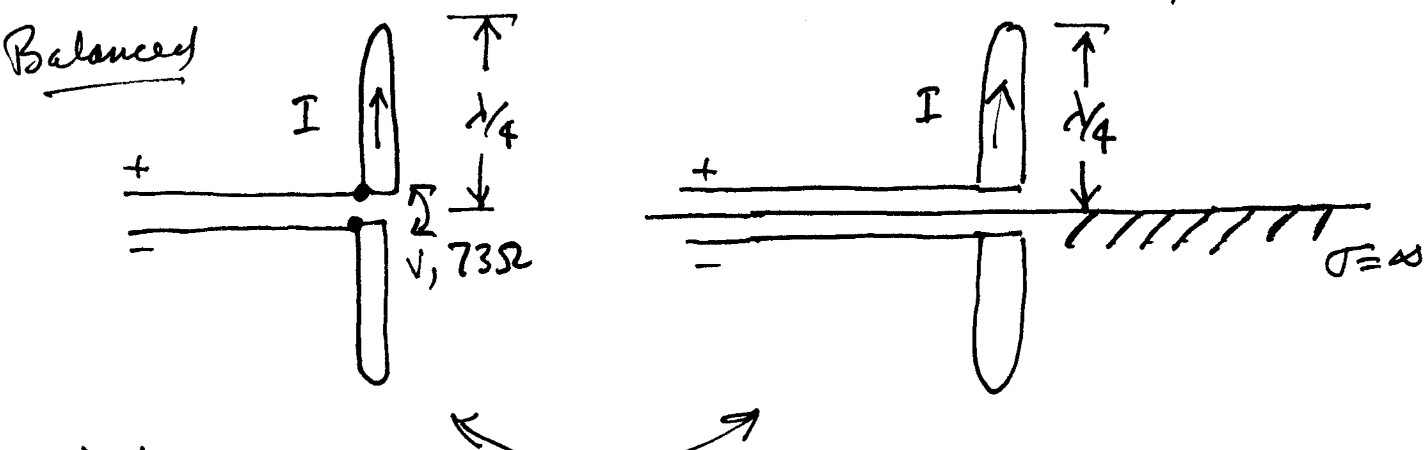
Other examples of feed structures & methods

Consider vertical dipole

$\theta = \frac{\pi}{2}$, $E_r = 0$

$E_\theta \neq 0$

$H_\phi \neq 0$



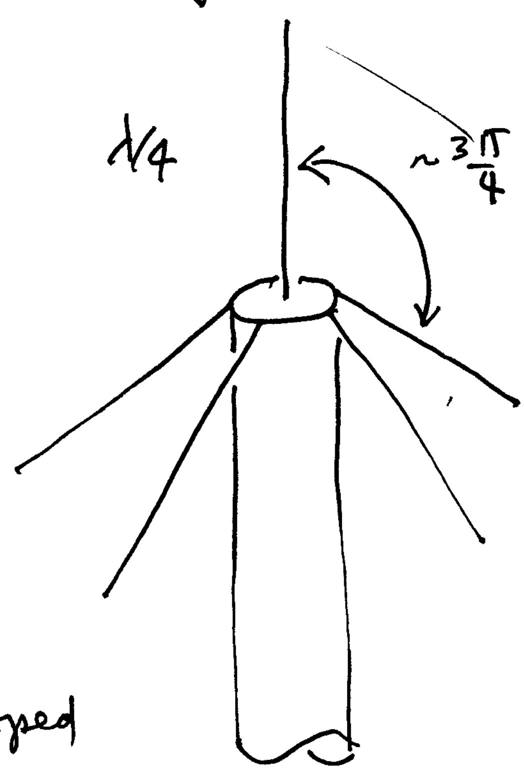
in free space

are fields different in these two cases.

with conducting sheet inserted

/...

/... An extremely common antenna looks like this

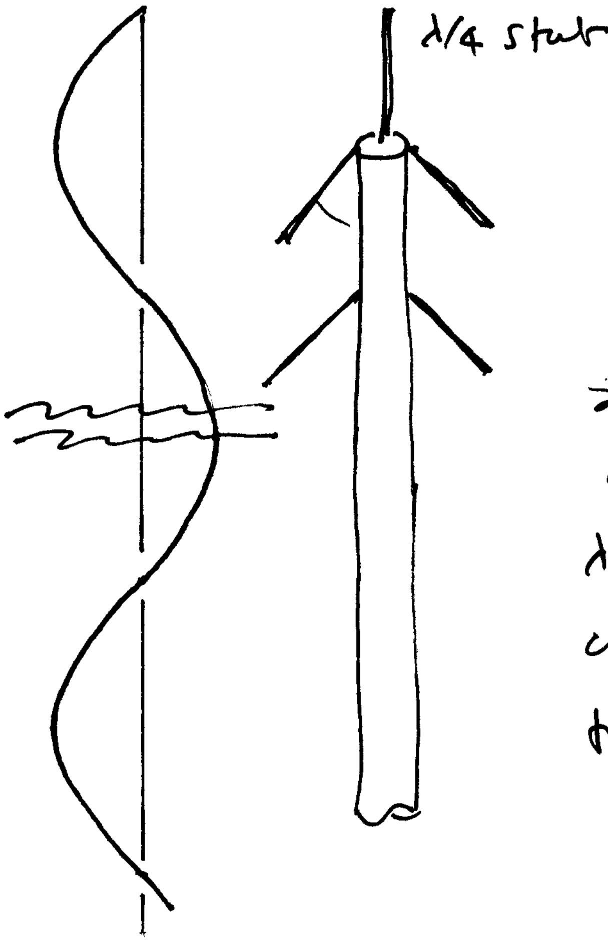


drooped radials

Drooping the radials increases the input Z since the structure (sans transmission line) approaches more closely a $\lambda/2$ dipole. A reasonable match to a 50Ω cable is obtained for on the transmission line.

Drooped stubs can function approx. as $\lambda/4$ choke – similar to bazooka balun.

Approx. current distribution



natural I_{max} about here

second set of radials at about this level – $\lambda/2$ below feed point – chokes off current on transmission line / support structure.