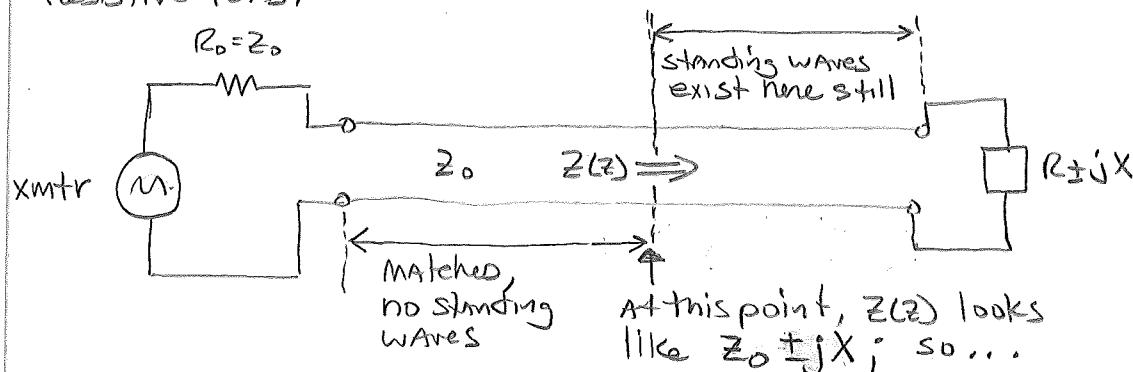


Back to the Antenna/transmitter matching problem.

Our antenna presents a complex impedance $z = R + jX$. Along the feedline, the impedance changes however.

What if we could find a point along the feedline where the rest part of the impedance was equal to the z_0 of the line?

If we could cancel the reactive or imaginary component of the load with a X_L or X_C the cable would see z_0 from that point back to the transmitter, providing it with a resistive load.

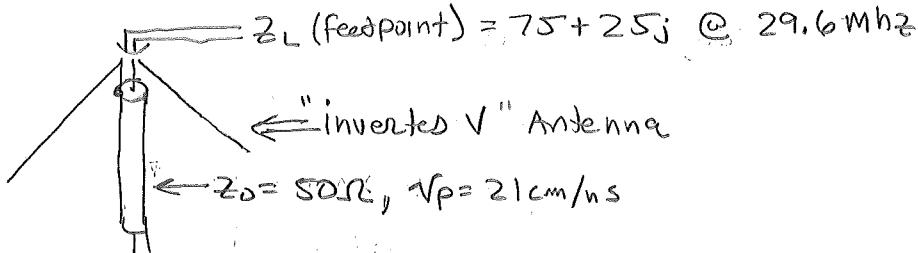


ADD $+jX$ if $-jX$ exists or
 $-jX$ if $+jX$ exists.

Do standing waves matter? Yes. Loss on the cable with standing waves can be excessive due to $I + V$ extremes.

Greater mismatch causes greater variations in $V + I$. The loss mechanism is I^2R loss with $I + V$ dielectric leakage with V .

Why not just match at xmtr end? Standing waves will exist over more of the cable causing greater loss.



Find the two closest points to the antenna along the line where the real part of the impedance Z(z) is equal to Z₀, 50Ω.

At any point on the feedline,

$$Z(z) = Z_0 \left[\frac{Z_L - jZ_0 \tan(\beta z)}{Z_0 - jZ_L \tan(\beta z)} \right] \quad \text{At any } z \quad (-l \leq z \leq 0)$$

so,

$$\begin{aligned} Z(z) &= 50 \left[\frac{(75 + j25) - j50\varsigma}{50 - j(75 + j25)\varsigma} \right] = 50 \left[\frac{(3 + j) - j2\varsigma}{2 - j(3 + j)\varsigma} \right] \quad \text{where } \varsigma = \tan(\beta z) \\ &= 50 \left[\frac{\overset{\text{real}}{3 + j(1 - 2\varsigma)}}{\underset{\text{real}}{(2 + \varsigma)^2} - \underset{\text{imag}}{j3\varsigma}} \right] \quad \beta = 2\pi/\lambda \\ &\quad \lambda = \frac{V_p}{F} = \frac{21 \times 10^8}{29.6 \times 10^6} = 7.095 \text{ m} \end{aligned}$$

$$\text{Re}\{Z(z)\} = R_c \left\{ 50 \left[\frac{3 + j(1 - 2\varsigma)}{(2 + \varsigma)^2 - j3\varsigma} \right] \left[\frac{(2 + \varsigma) + j3\varsigma}{(2 + \varsigma) + j3\varsigma} \right] \right\} \quad \begin{matrix} \text{(mult by complex conjugate)} \\ \text{to separate out the} \\ \text{complex + real parts} \end{matrix} \quad (6\varsigma^2)$$

$$= R_c \left\{ 50 \left[\frac{6 + 3\varsigma + j9\varsigma + 2j - j4\varsigma + j\varsigma - 2j\varsigma^2 + j^2/3\varsigma - 6j^2\varsigma^2}{(2 + \varsigma)^2 + (3\varsigma)^2} \right] \right\}$$

$$= R_c \left\{ 50 \left[\frac{6 + 6j\varsigma + 2j - 2j\varsigma^2 + 6\varsigma^2}{(2 + \varsigma)^2 + (3\varsigma)^2} \right] \right\}$$

$$= R_c \left\{ 50 \left[\frac{6(1 + \varsigma^2) + j(6\varsigma + 2 - 2\varsigma^2)}{(2 + \varsigma)^2 + (3\varsigma)^2} \right] \right\} = 50 \left[\frac{6(1 + \varsigma^2)}{(2 + \varsigma)^2 + (3\varsigma)^2} \right]$$

Now find the point(s) z where the real portion of Z(z) is equal to 50Ω,

$$\text{Re}\{Z(z)\} = Z_0 \text{ is where } 50 = 50 \left[\frac{6(1 + \varsigma^2)}{(2 + \varsigma)^2 + (3\varsigma)^2} \right]$$

$$1 = \frac{6 + 6\varsigma^2}{4 + 4\varsigma + \varsigma^2 + 9\varsigma^2} = \frac{6 + 6\varsigma^2}{10\varsigma^2 + 4\varsigma + 4}$$

$$10\varsigma^2 + 4\varsigma + 4 = 6 + 6\varsigma^2$$

$$4\varsigma^2 + 4\varsigma - 2 = 0$$

$$2\varsigma^2 + 2\varsigma - 1 = 0 \Rightarrow \varsigma = .366, -1.37$$

Solves via octave

So we have the two solutions $\delta = .366, -1.37$

We defined δ as $\tan(\beta z)$ where $\beta = \frac{2\pi}{\lambda}$, so

$$\begin{aligned}\delta &= \tan(\beta z) = \tan\left(2\pi \frac{z}{\lambda}\right) \quad (\lambda = \frac{v_p}{f} = \frac{21 \text{ cm/sec}}{29.6 \text{ MHz}}) \text{ previous page} \\ &= \tan\left(2\pi \frac{z}{7.09}\right) \\ \delta &= \tan(.886z)\end{aligned}$$

choosing $\delta = -1.37$ we get:

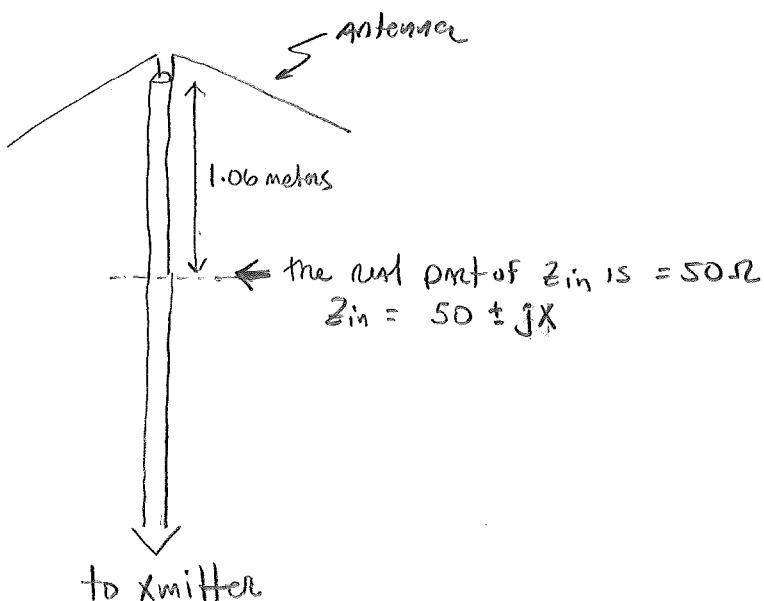
$$-1.37 = \tan(.886z)$$

$$\tan^{-1}(-1.37) = .886z$$

$$-.94 = .886z$$

$z = -1.06 \text{ meters}$ \Leftarrow this is where the matching element is placed to cancel out the reactive component.

Now, we must find what the reactive component is @ -1.06 meters from the load.



The other possible solution for $G = .366$

$$G = \tan(\beta z) \text{ where } \beta = \frac{2\pi}{\lambda} \text{ so where } \gamma = \frac{21 \text{ cm/sec}}{29.6 \text{ MHz}} = 7.09 \text{ m}$$

$$G = \tan(.886z)$$

$$\text{now let } G = .366 \dots$$

$$.366 = \tan(.886z)$$

$$\tan^{-1}(.366) = .886z \text{ meters}$$

$$z = 0.396 \text{ m} \dots \text{huh?... positive } z \text{ is past the load!}$$

Move backwards 0.5λ from load ...

$$0.5\lambda = \frac{7.09}{2} = 3.545 \text{ m}$$

$$-3.545 \text{ m} + .396 \text{ m} = -3.149 \text{ meters or}$$

$$\frac{-3.149}{7.09} = -444 \text{ J}$$

- we will find this to be correct later using smith charts

- this solution is however further away from the antenna.

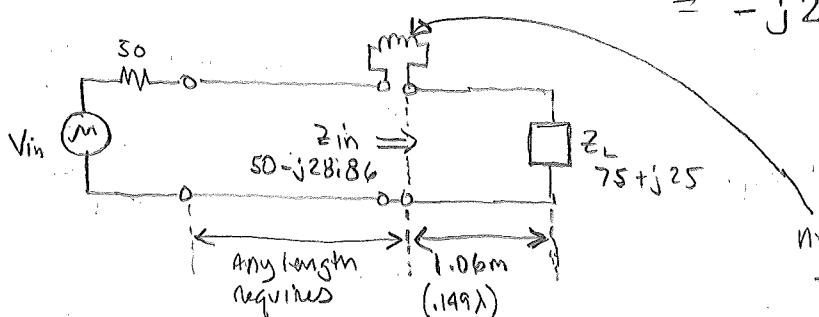
First, find the imaginary component of the impedance (@ -1.06 meters)

$$Z(z) = Z_0 \left[\frac{Z_L - jZ_0 \tan(\beta z)}{Z_0 - jZ_L \tan(\beta z)} \right] \quad \text{And from the previous part of the problem,}$$

$$Z(z) = 50 \left[\frac{\underbrace{6(1 + \beta^2)}_{\text{real}} + j(\underbrace{6\beta + 2 - 2\beta^2}_{\text{imms}})}{(2 + \beta)^2 + (3\beta)^2} \right]$$

the imaginary part is:

$$\begin{aligned} \text{Im}\{Z(z)\} &= 50 \left[\frac{j(6\beta + 2 - 2\beta^2)}{(2 + \beta)^2 + (3\beta)^2} \right] \quad \text{now where } \beta = \tan\left(\frac{2\pi}{7.69} \cdot (-1.06)\right) \\ &= 50 \left[\frac{j(6(-1.367) + 2 - 2(-1.367)^2)}{(2 - 1.367)^2 + (3(-1.367))^2} \right] \\ &= 50 \left[\frac{-9.9394}{17.219} \right] = 50[j0.57724] \\ &= -j28.862 \quad (\text{capacitive}) \end{aligned}$$



@ 1.06m from the load, Z_{in} looks like

$$Z_{in} (1.06m) = 50 - j28.862$$

Need this to be

$+j28.862$ to cancel capacitive reactance

$$X_L = 2\pi f L$$

$$28.862 = 2\pi (2\pi \times 10^6) L$$

$$L = 155.2 \text{ nH} \quad \left\{ \begin{array}{l} \text{matching inductor} \\ \text{to be added} \end{array} \right.$$

$$\left\{ \begin{array}{l} j25 \text{ e } 29.6 \text{ MHz} \Rightarrow \\ X_L = 2\pi f L, L = \frac{25}{2\pi f} = 134.5 \text{ nH} \end{array} \right\}$$

What inductance is at the load?

Use in simulation

(stub-lumped SP)

Instead of a lumped element, we could (and usually do) use a T-line stub.

So we need a $+j28.862$ element
For a shorted stub:

$$Z = jZ_0 \tan(\beta l) \quad \beta = \frac{2\pi}{\lambda} \quad (Z_{in} \text{ for shorted } T\text{-line})$$

$$\frac{28.862}{50} = \tan\left(2\pi \frac{l}{\lambda}\right)$$

$$.5772 = \tan(.8858l)$$

$$\tan^{-1}(.5772) = .8858l$$

$$.5235 = .8858l$$

$$l = .591 \text{ meters or}$$

$$\frac{.591}{7.09} = .0833\lambda \text{ shorted stubs}$$

An open stub:

$$Z = -jZ_0 \cot(\beta l)$$

$$\frac{28.862}{50} = \cot(\beta l)$$

$$.5772 = \cot(.8858l)$$

$$\cot^{-1}(.5772) = .8858l$$

$$\frac{1}{\tan^{-1}(.5772)} = .8858l$$

$$1.91 = .8858l$$

$$l = 2.157 \text{ meters or } \frac{2.157}{7.09} = .304\lambda \text{ open ended stub}$$

λ for
2916 MHz &
 $\sqrt{\mu} = 21 \text{ cm/m}$

Gee, I wonder if there is an easier way!

Mar 01, 10 10:50

stub_lumped.sp

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*Inverted V antenna at 29.6Mhz that represents a complex impedance of 75+25j
 *uses matching with lumped element, shorted and open stubs
 *stub is positioned 1.06 meters from the load

*transmitter with 50 ohm output
 $V_{in} = 0 \text{ ac } 1.0 \sin(0 \ 1.0 \ 29.6e6)$
 rsrc vin tl_in 50

*arbitrarily long (about 20 meters) piece of coax
 $t1 \text{ tl_in } 0 \text{ tl_j1 } 0 \ z0=50 \text{ td}=100\text{ns}$

*1.06 meter long coax is 0.149 lambda
 $t2 \text{ tl_j2 } 0 \text{ tl_out } 0 \ z0=50 \ F=29.6\text{Meg} \ NL=0.1495$

*insert matching inductor at the 1.06 meter point
 lmatch tl_j1 tl_j2 155nH

*insert matching shorted coaxial stub at the 1.06 meter point

*t3 tl_j1 tl_j2 tie1 tie1 z0=50 F=29.6Meg NL=0.0833

*r90 tie1 0 10Meg

*insert matching open coaxial stub at the 1.06 meter point

*t3 tl_j1 tl_j2 tie1 tie2 z0=50 F=29.6Meg NL=0.304

*r90 tie1 0 10Meg

*r91 tie2 0 10Meg

*complex load 75+25j at 29.6Mhz
 rload tl_out join_load 75
 lload join_load 0 134.5nH

$$i_{in} = \frac{V_{in} - V_{tl_in}}{50} ; V_{in} = V_{tl_in}$$

$$Z_{in} = \frac{50(1+i_{in})}{V_{in} - i_{in}}$$

.control
 set hcopydevtype=postscript
 *set hcopydev=kec3112-clr
 set hcopypscolor=true
 set color0=rgb:f/f/f
 set color1=rgb:0/0/0
 ac lin 100 10M 50Meg
 plot vm(vin) vm(vin,tl_in) vm(tl_in) vm(tl_j2)
 hardcopy temp.ps vm(tl_in) vm(vin,tl_in)
 .endc
 .end

