UFO DESIGN 101

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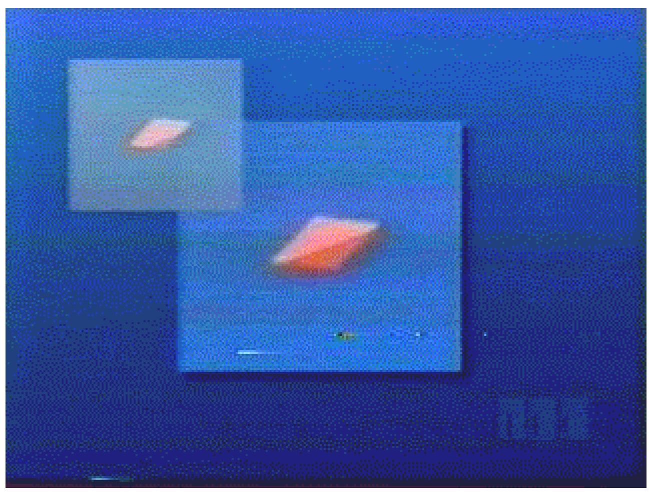
Sturgeons Law – 95% of all information is garbage.

1 Introduction

I have had one experience with UFO sightings. Several years ago, my wife and I were driving in Oregon when I noticed the cumulus clouds seemed to be “Florescent”. We were looking at the clouds when we both saw a double pyramid object (pyramid bases glued together and apexes orientated vertical to the earth) emerge between clouds. It was silver and I estimate 50 feet in height and width. I believe the object is a craft being developed by our Government. (This is more credible than an extraterrestrial origin). Last month, I discovered a book giving a mathematical derivation based on Quantum Mechanics which lays a foundation for an engineering design of the craft. I have dabbled in an approach which is solely my own and have no idea whether it is valid. I have spent only several weeks of my spare time on this so be kind with mistakes. I would like to build the model described herein but my wife is afraid it will implode our house. Maybe someone reading this in cyberland will try.



Photograph from "The Learning Channel" documentary.

The proposed design is based on mathematical foundation work pioneered by Jerry Bayles (Reference 1 is at "electrogravity.com"). I realize there are many details in designing a craft of this nature. My effort will focus on a possible propulsion system in hopes to inspire others to fill in the details. My approach is based from Chapter 7 of Jerry’s book, “Electro-Gravitation As A Unified Field Theory”. According to Jerry’s calculations, a quantum macro-particle is constructed by rotating a standing wave current in circular fashion near the speed of light. Phasing non-radiating transmission line standing waves in a circular geometry can produce the simulated current. I will attempt to produce this simulated current with existing technology in an effort to lay groundwork for others to expand upon.

This entire writing depends on the reader buying into two concepts. The first concept is that subatomic particles can be modeled as rotating standing waves. The second concept is that subatomic particles under certain conditions can act together as one large particle (Bose-Einstein condensate). If the reader is unwilling to buy into these concepts then read no further.

The idea that particles exist as harmonically coupled circular electromagnetic waves is consistence with matter-energy equivalence, particle-wave duality, de Broglie wavelength of electron orbits to name a few. The universe is a very wave like place. In addition, at temperatures near absolute zero, atoms are super-cooled to a point where a considerable portion of them settle into their single, lowest quantum energy state. Under these conditions, each atom's physical characteristics of position and velocity effectively merge with those of other atoms. Relative to the microcosmic atomic scale, the atoms behave as a "macro-atom". This is exemplified by recent experiments that used this phenomenon to slow the speed of light to less than 38 mph.

This design adopts the philosophy that a non-radiating rotating standing wave phased so the net current flows in the opposite direction of the applied voltage polarity will emulate positive particle flow producing a reverse polarity diverging electrogravity field. Atoms (the craft) contained within the rotating standing wave will be de-polarized with respect to atoms residing outside the wave. In addition, phasing the voltage/current relationship of the rotating standing wave (equivalent reactance) will result in changes of electrogravitational force relationships as described in the next section.

2 Electrogravitational Force Calculation

The following equations for the electron Electrogravitional Force (EGF) are derived in Reference 1 and will not be reproduced here. See the Electrogravity web site at "electrogravity.com" for detailed derivations. The following equations are used as the basis of the craft design in this paper.

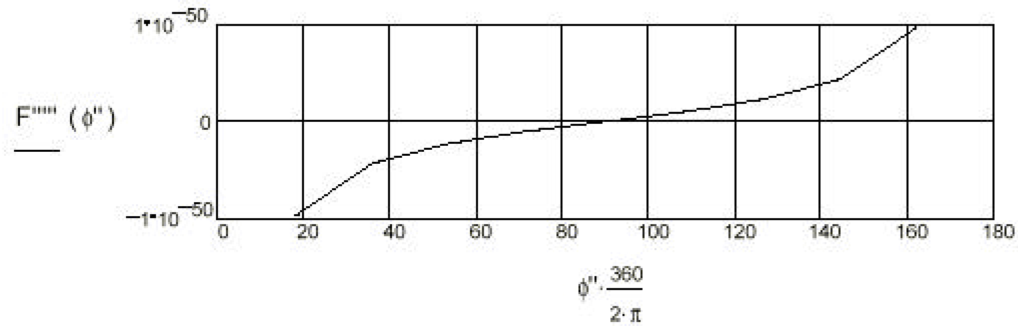
An electron’s Electrogravitational Force, Chapter 7 Equation (234) of "Electrogravitation As A Unified Field Theory" expressed in terms of quantum inductive and capacitance reactance is:

$$F''''(\phi'') := \left[\frac{X_L \cdot e^{j \cdot \left(\frac{\pi}{2}\right)} \cdot \left(i_{LM}\right)^2}{\omega_{LM} \cdot r_x} \cdot A \cdot B\right] \cdot \mu_o \cdot \left[\frac{\cot(\phi') \cdot \cot(\phi'') \cdot X_L \cdot e^{j \cdot \left(\frac{\pi}{2}\right)} \cdot \left(i_{LM}\right)^2}{\omega_{LM} \cdot r_x} \cdot A \cdot B\right]$$

Where $\cot(\phi')$ is the quantum inductive reactance angle reciprocal and $\cot(\phi'')$ is the quantum capacitive reactance angle reciprocal. The quantum capacitive reactance angle is +9° for an electron. Reference 1 calculates this in detail using quantum nuclear constants. The electron calculated EGF is:

$$F''_{eg} = -1.982973070535905 \cdot 10^{-50} + 2.428361421636938 \cdot 10^{-66} i \cdot \frac{henry}{m} \cdot newton^2$$

The minus real term is attraction force attributed to gravity. Plotting EGF vs. quantum capacitive reactance as a function of ϕ'' (see Reference 1) shows the tangent nature of the electron electrogravitational force:



A very interesting occurrence happens at φ > 90°. The negative real term changes sign to a positive repulsive force. At φ = 171°, repulsion force is approximately equal to the normal electron attraction force (180° – 9°). At φ very near 180° (see Reference 1), the calculated EGF is:

$$F_{\delta g} = 2.57715439257088 \cdot 10^{-35} - 3.155999643923548 \cdot 10^{-51} i \quad \cdot \frac{\text{henry}}{\text{m}} \cdot \text{newton}^2$$

Note the electron's EGF is 15 orders of magnitude greater than at φ = 171°. In fact, φ = 180° implies an EGF of ∞. Equation (234) reveals EGF is independent of quantum reactance magnitude and depends only on the reactance phase angle. A phase of 0° implies an attraction force of ∞. The tangent asymptotic nature at 0° and 180° degrees begs the question can quantum reactance phasing be used as a sling shot effect to propel electrons (or a macro-particle) near the speed of light? Electron quantum reactance can not be easily altered due to the particle's size and physical constants of nature. However, if the physics of an electron could be emulated in a macroscopic way, reactance phasing would allow extreme velocities to be obtained with nearly zero system power input. This is a very exciting concept. Theoretically, a flashlight battery powered spacecraft could easily leave the solar system! Phasing the reactance between attraction/repulsion will steer a spacecraft using nearby large gravitational bodies (suns). If this seems fanatical, consider the attributes of a black hole or the energy released from a gram of U^{235}. Nature is forceful.

3 Transmission Line Geometry

Consider Figure 1. Here a standard electronic printed circuit board micro-strip transmission line is described.

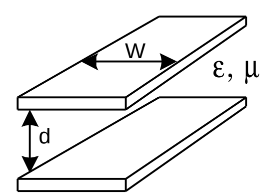


Figure 1. Strip Line diagram showing two conductors of width W, separation d, permittivity ε and permeability μ.

The equation describing the strip line's characteristic impedance Zo is:

$$Zo = \sqrt{\frac{m}{e}} \cdot \frac{d}{W}$$

Notice that for a selected permittivity and permeability, the characteristic impedance Zo is simply the ratio of d/W. Now consider the micro-strip geometry of Figure 2.

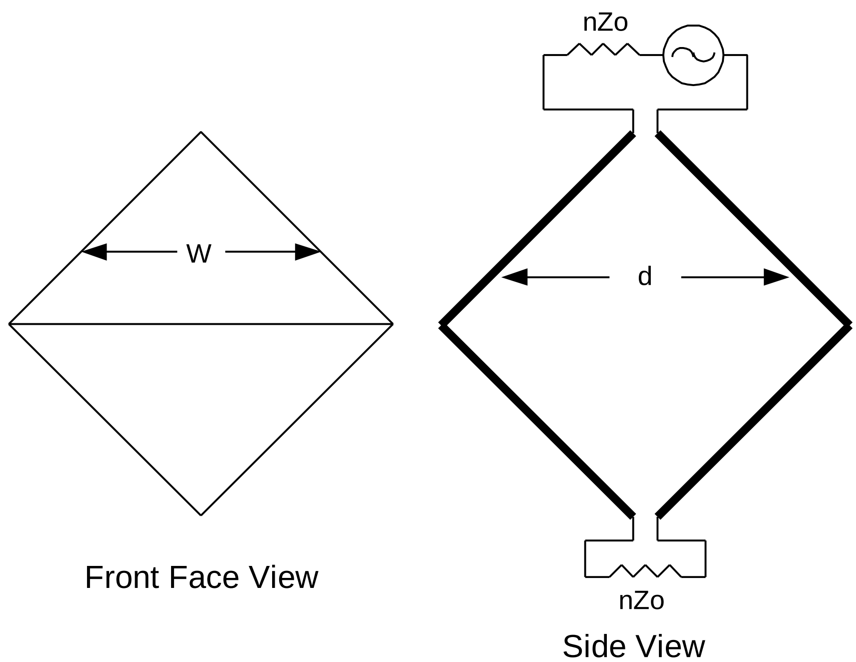


Figure 2. Transmission Line consisting of conductive triangular sheets. Notice the ratio of W/d is constant.

Zo for this strip transmission line is constant and is ≅ 377 ohms using the Zo equation with d/W = 1.0, ε and μ for copper and air. As the line surface area widens, the separation distance increases maintaining a constant d/W ratio. (Also note the capacitance C = area/separation is constant). Beneficially, this micro-strip should be a well-behaved transmission line. Note the following attributes:

- ✓ The surface length from apex to apex is the transmission line length.
- ✓ A four-sided craft would consist of two electrically separate transmission lines.
- ✓ Terminating each line at both ends in an integer multiple of Zo results in a standing wave.
- ✓ For length equal to the wavelength, at the near and far ends, current is minimum and voltage is maximum.
- ✓ For length equal to the wavelength, at the center of the line (right angle bend), current is maximum (crest).

A Transmission Line will support a standing wave without radiating the wave's energy. This is similar to an electron orbit forming a standing wave orbital around a nucleus. The electron standing wave orbital is required to prevent the electron from radiating energy and eventually falling into the nucleus. An electron standing wave has no net velocity change (due to the even multiple wave periodicity) and therefore no energy radiation. A transmission line circular standing wave will exhibit the same characteristics as the electron orbital. Basically, the standing wavelength is in the same size scale magnitude as the transmission line mass size. The transmission line mass (the craft) surrounded by the rotating standing wave will behave as a single atomic macro-particle exhibiting quantum mechanical behavior. Large densities of atoms (the earth) will exert forces on the emulated macro-particle identical to forces exerted on single micro-particle (electron).

4 Craft Design

For this example I will simplify the design by using only two transmission lines to form the craft's outer shell. More lines may be used tending to "round" the craft into a circular shape. Also note a change in height does not change the d/W ratio (see

Appendix A). The craft can be stretched vertically to form a classic “cigar” shape or horizontally to form a “saucer” shape. In addition, multiples of Zo termination values are used to reduce the craft’s size to a demonstration model. Figure 5 depicts the craft’s outer appearance using only two transmission lines.

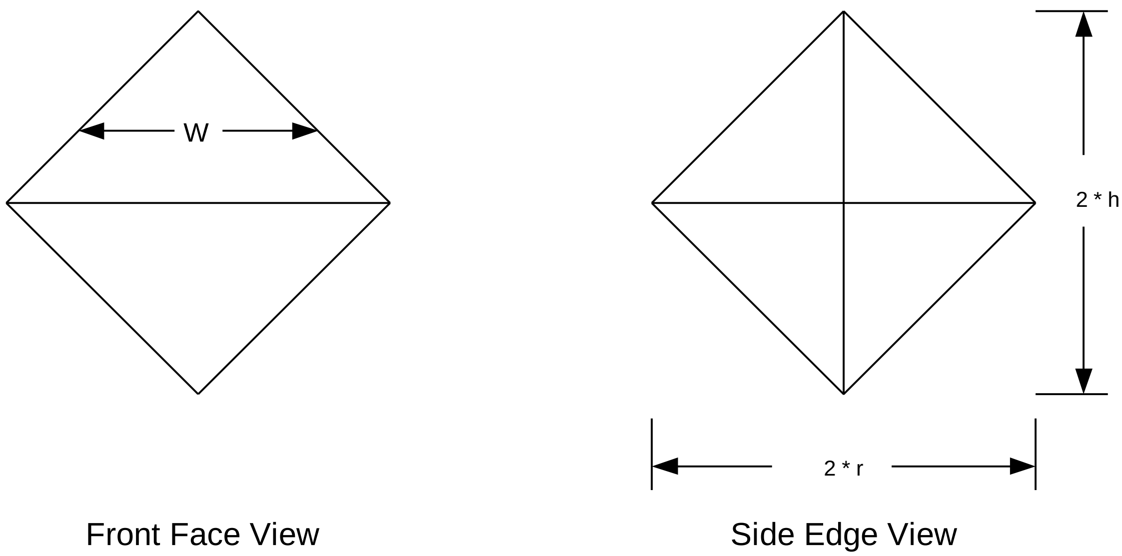


Figure 3. Symmetrical transmission line craft geometry.

For a craft 50 feet in height and 50 feet in center diameter, each micro-strip face height is 30.6 feet yielding a total line wavelength (λ) of 61.2 feet. Assuming transmission line phase velocity to be the speed of light c, f = c/61.2 feet or 32 MHz. This means applying a 32 MHz sine wave to our transmission line 61.2 feet in length, one of the line’s face center will build a standing wave current maximum at opposite face centers flowing in opposite directions. Now we phase shift the sine wave by 90 degrees (delay line) and apply it to the second micro-strip line. Its face center currents will be 90 degrees out of phase with the first line’s face currents. These phased currents form a simulated current ring flowing in a radial direction around the craft’s outside surface with a maximum value at the craft’s center.

We now have control of the simulated current and need to alter the inductive and capacitive reactance (cot(ϕ) terms) as described by Jerry in Chapter 7 page 123, Equation 236 of his book. Equation 236 states if tan(ϕ) = 0 (reactance is such that the voltage and current phase is 180 degrees) the electrogravitational repulsion force becomes infinite. This condition occurs when the signal’s voltage and current applied to the transmission lines is 180 degrees out of phase. Equation 236 also indicates the magnitude of repulsion is a function of the reactance phase terms only and not the simulated current magnitude (1/tan(180°) = 1/0 = infinite).

For the craft design (demonstration model) described herein, an integer multiple of Zo will be selected to form a harmonic multiple standing wave. This technique effectively reduces the craft physical size while maintaining a relative low drive signal frequency. It will be seen later, a low drive signal frequency is important in maintaining stable control electronics.

Figure 4 describes the trigonometry relationships of a face’s upper (or lower) triangular section. Three parameters are pre-selected by the designer; number of craft faces, craft vertical apex to apex height and craft horizontal apex to apex width. Remaining parameters are calculated from the equations. Table 1 lists results for a craft with several height/width dimensions. The last two table entries are for a multi-facetted craft having “cigar” and “saucer” shapes respectively.

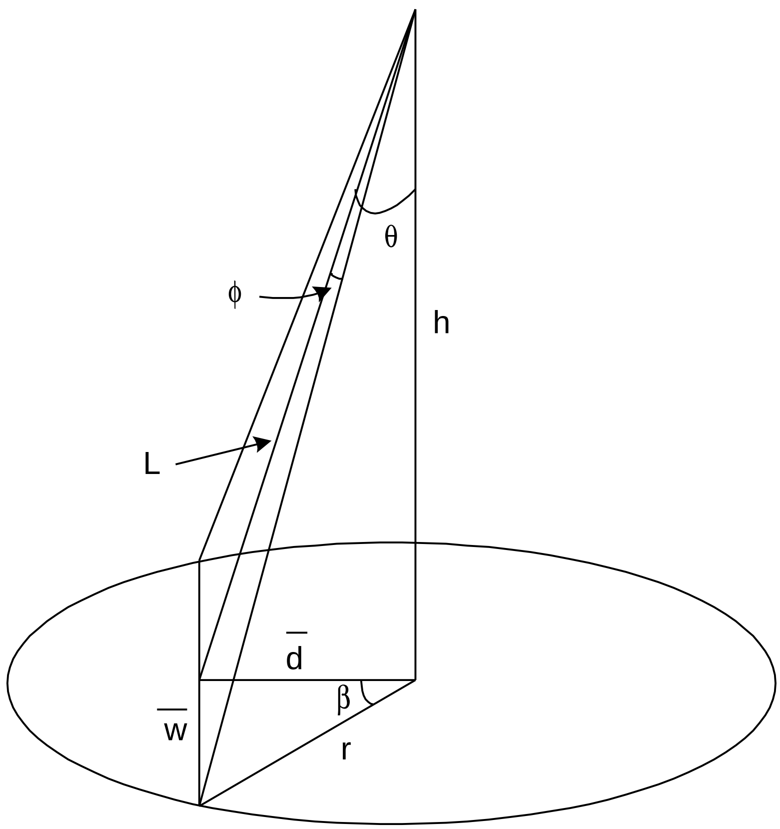


Figure 4. Geometrical representation of craft’s upper face sheet.

From Figure 4 and design criteria:

n ≡ even number of equal craft faces,

Craft width = 2·r,

Craft height = 2·h,

W = $2 \cdot \overline{w}$, (Eq 1)

D = $2 \cdot \overline{d}$, (Eq 2)

Zo = function($\frac{d}{W}$), (Eq 3)

$\frac{d}{W}$ ≡ constant, (Eq 4)

λ = 2·L, (Eq 5)

f = $\frac{Vp}{l}$. (Eq 6)

Select:

n , r, h.

Calculate:

$\beta = 360/n,$ (Eq 7)

$\overline{w} = r \cdot \sin\beta,$ (Eq 8)

$\overline{d} = r \cdot \cos\beta,$ (Eq 9)

$\tan\beta = \text{constant},$ (Eq 10)

$L = [h^2 + \overline{d}^{\,2}]^{1/2},$ (Eq 11)

$\theta = \tan^{-1}\left(\frac{\overline{d}}{h}\right),$ (Eq 12)

$\phi = \tan^{-1}\left(\frac{\overline{w}}{L}\right),$ (Eq 13)

$f = \frac{Vp}{2 \cdot L}.$ (Eq 14)

Zo is the transmission line characteristic impedance,

Vp is the transmission line propagation velocity,

λ is the transmission line wavelength,

f is the drive signal frequency,

W is the dimension defined by Figure 2,

d is the dimension defined by Figure 2.

For d/W $\equiv$ constant, h is an independent variable of Zo, h changes λ only.

No Faces	Height	Width 2r	d	W	THETA(D)	PHI(D)	L	LAM	Freq Hz	Zo Ω
4	2	2	1.41	1.41	35.26	39.23	1.22	4.90	4.0049E+08	377.32
4	4	4	2.83	2.83	35.26	39.23	2.45	9.80	2.0025E+08	377.32
4	6	6	4.24	4.24	35.26	39.23	3.67	14.70	1.3350E+08	377.32
4	8	8	5.66	5.66	35.26	39.23	4.90	19.60	1.0012E+08	377.32
4	10	10	7.07	7.07	35.26	39.23	6.12	24.49	8.0098E+07	377.32

4	12	12	8.49	8.49	35.26	39.23	7.35	29.39	6.6749E+07	377.32
4	14	14	9.90	9.90	35.26	39.23	8.57	34.29	5.7213E+07	377.32
4	16	16	11.31	11.31	35.26	39.23	9.80	39.19	5.0061E+07	377.32
4	18	18	12.73	12.73	35.26	39.23	11.02	44.09	4.4499E+07	377.32
4	20	20	14.14	14.14	35.26	39.23	12.25	48.99	4.0049E+07	377.32
4	22	22	15.56	15.56	35.26	39.23	13.47	53.89	3.6408E+07	377.32
6	24	6	5.20	3.00	12.22	13.73	12.28	49.11	3.9949E+07	653.54
8	6	24	22.17	9.18	74.86	46.26	11.49	45.94	4.2707E+07	910.94

Table 1. Craft dimensional parameters for varying height and width.

For this design basis we will select a four sided, 20 foot high by 20 foot wide symmetrical craft. This results in a 40 MHz drive signal frequency as shown in Table 1. Selecting transmission line terminating impedance's of eight times Zo ($8 \cdot 377 = 3016\Omega$), a standing wave of 320 MHz is produced on the craft's surfaces. This effectively reduces the demonstration model craft's dimensions to more manageable 2.5X2.5 feet. This is close to the smallest craft size obtainable without transcending into more complex higher frequency control system electronics.

5 Craft Transmission Line Electrical Parameters

Figure 5 shows the electrical schematic representation of the craft's transmission line outer shell for two sides. The drive signal voltage and current are phased by an angle θ. This phasing is produced by the control system electronics and is determined by a single potentiometer adjustment.

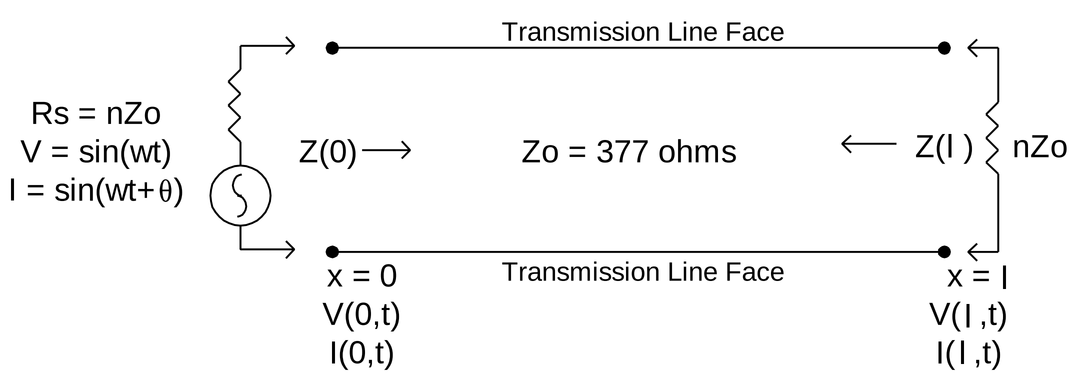


Figure 5. Schematic representation of a transmission line terminated in n multiples of Zo.

Partial differential equations describing the voltage and current distributions as a function of time and line length are:

Transmission Line Differential Equations:

$$\frac{\partial V}{\partial x} + ZI = 0 \qquad \frac{\partial I}{\partial x} + \frac{V}{Z} = 0 \qquad \text{(Eq 15)}$$

Solutions are:

$$V(x,t) = \sin(wt)\left[e^{-jw\sqrt{LC}x} + \frac{Z_L - Zo}{Z_L + Zo} e^{-jw\sqrt{LC}(2\ell - x)} \right] \qquad \text{(Eq 16)}$$

$$I(x,t) = \frac{\sin(wt + q)}{Zo}\left[e^{-jw\sqrt{LC}x} - \frac{Z_L - Zo}{Z_L + Zo} e^{-jw\sqrt{LC}(2\ell - x)} \right] \qquad \text{(Eq 17)}$$

$$\lim_{Z_L \to \infty} \frac{Z_L - Zo}{Z_L + Zo} = 1 \qquad \text{(Eq 18)}$$

$$Vp = \frac{1}{\sqrt{LC}} = f\,l \qquad w\sqrt{LC} = \frac{2p}{l} \qquad w = 2pf \qquad \text{(Eqs 19)}$$

where:

t = time,

ℓ = length from signal end of the line,

Zo = line characteristic impedance,

Z_L = line termination impedance,

L = line inductance,

C = line capacitance,

Vp = line phase velocity,

θ = voltage to current phase angle.

Terminating the line in integer multiples of Zo produces drive signal harmonic multiple standing waves as described below.

Reflection coefficient at x = 0:

$$r_0 = \frac{Z_L - Z_O}{Z_L + Z_O} e^{-j2w\sqrt{LC}\ell} \qquad \text{(Eq 20)}$$

$$w\sqrt{LC} = \frac{2p}{l} \qquad \text{(Eq 21)}$$

For $Z_L = 2 \cdot Zo$ (Load is twice Zo):

$$r_0 = \frac{2 \cdot Z_O - Z_O}{2 \cdot Z_O + Z_O} \cdot e^{-j2w\sqrt{LC}\ell} = \frac{1}{3} \cdot e^{-j2w\sqrt{LC}\ell} = \frac{1}{3} \cdot e^{jf} \qquad \text{(Eq 22)}$$

$$f = -2w\sqrt{LC}\ell \qquad \text{(Eq 23)}$$

$$|r0| = \frac{1}{3} \qquad \text{(Eq 24)}$$

V_{max} occurs at:

$$f + 2w\sqrt{LC}x = 2np \quad where \quad n = 0, \pm 1, \pm 2, \cdots \qquad \text{(Eq 25)}$$

$$-2w\sqrt{LC}\ell + 2w\sqrt{LC}x = 2np \qquad \text{(Eq 26)}$$

$$2w\sqrt{LC}(x - \ell) = 2np \qquad \text{(Eq 27)}$$

$$x - \ell = \frac{2np}{2w\sqrt{LC}} = \frac{np\,l}{2p} = \frac{n\,l}{2} \qquad \text{(Eq 28)}$$

V_{max} occurs at x = 0 and $\frac{n\,l}{2}$ down the line.

A frequency f_{in} will create a line standing wave of $2 \cdot f_{in.}$

For $Z_L = 8 \cdot Zo$:

$$r_0 = \frac{8 \cdot Z_O - Z_O}{8 \cdot Z_O + Z_O} \cdot e^{-j2w\sqrt{LC}\ell} = \frac{7}{9} \cdot e^{jf} \qquad \text{(Eq 29)}$$

V_{max} occurs at $\frac{n\,l}{8}$ where $n = 0, \pm 1, \pm 2, \cdots$

$$\text{VSWR} = \frac{1 + \frac{7}{9}}{1 - \frac{7}{9}} = 8 \qquad \text{(Eq 30)}$$

A drive signal frequency f_{in} will create a line standing wave of $8 \cdot f_{in.}$

V_{max} occurs at $\frac{n\,l}{8}$ where $n = 0, \pm 1, \pm 2, \cdots$ and I_{max} occurs at $\frac{n\,l}{16}$ where $n = 0, \pm 1, \pm 2, \cdots$ down the line. I_{max} occurs in the craft's center as shown in Figure 6.

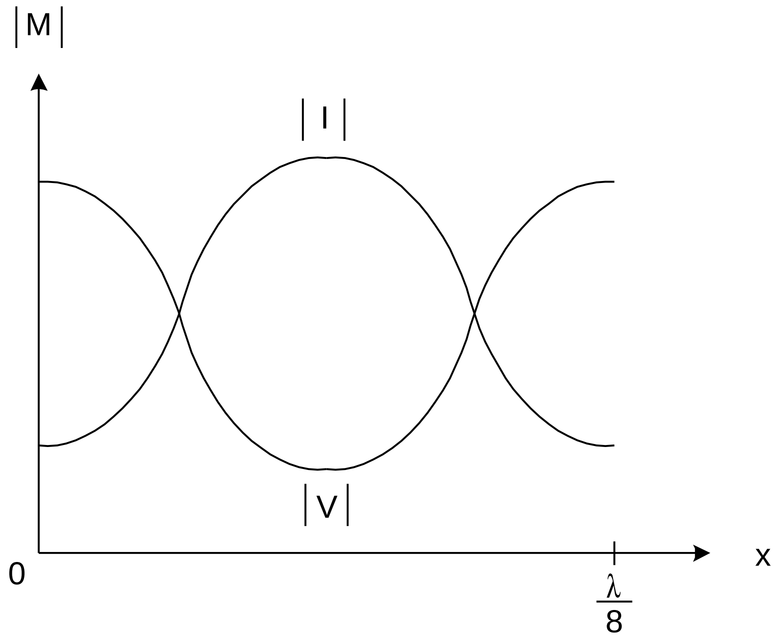


Figure 6. Voltage/Current distribution plot for a transmission line terminated in 8·Zo.

For an ideal transmission line, capacitance, inductance and phase velocity are easily calculated:

$$C = e \cdot \frac{W}{d} \qquad \text{(Eq 31)}$$

$$L = m \cdot \frac{d}{W} \qquad \text{(Eq 32)}$$

$$Vp = \frac{1}{\sqrt{me}} = c \qquad \text{(Eq 33)}$$

$$Zo = \sqrt{\frac{m}{e}} \cdot \frac{d}{W} \qquad \text{(Eq 34)}$$

where d and W are defined in Figure 2. Table 2 lists the calculated transmission line parameters for this design. Note – Appendix A equations for resistance and capacitance with a trimmed START dimension of zero are equal to ∞. This is due to the infinitely small width and separation dimensions obtained mathematically at the apex. Practically, this is not obtainable and selecting a START dimension of 0.1 inch eliminates the problem.

HEIGHT	WIDTH	H	LAMBDA	L	W	w bar	THETA
feet	Feet	Feet	feet	feet	Feet	feet	degrees
2.5	2.5	1.25	3.06	1.53	1.77	0.88	35.26

PHI	START	FREQ		FEED PD	T/4	90D LEN	
Degrees	Inches	Mhz		nsec/in	Nsec	inches	
39.23	1.00E-01	4.0049E+07		0.102	6.24	61.40	
3S DEPTH	DC RES						
Feet	Ohms						
1.03E-04	4.84E-02						
TL LEN	TL R	TL CAP	TL IND	Zo			
Feet	Ohms/ft	F/ft	H/ft	ohms			
3.06	1.58E-02	2.70E-12	3.84E-07	3.77E+02			
M	Ohms/m	F/m	H/m				
9.33E-01	5.18E-02	8.85E-12	1.26E-06				

Table 2. Transmission line parameters calculated for a 2.5ft by 2.5ft craft.

6 Electronic Control System Block Diagram

Figure 7 illustrates the craft electronic control system's objective of a rotating standing wave simulated radial current. It is important for the reader to distinguish between the drive signal's voltage to current phase produced electronically and the craft surface 90° delay line phase. The drive signal's voltage to current phase is produced by an electronic phase bridge and applied to all craft surfaces via the two transmission lines. The 90° delay line phase produces the craft's simulated radial current from the above phased drive signal.

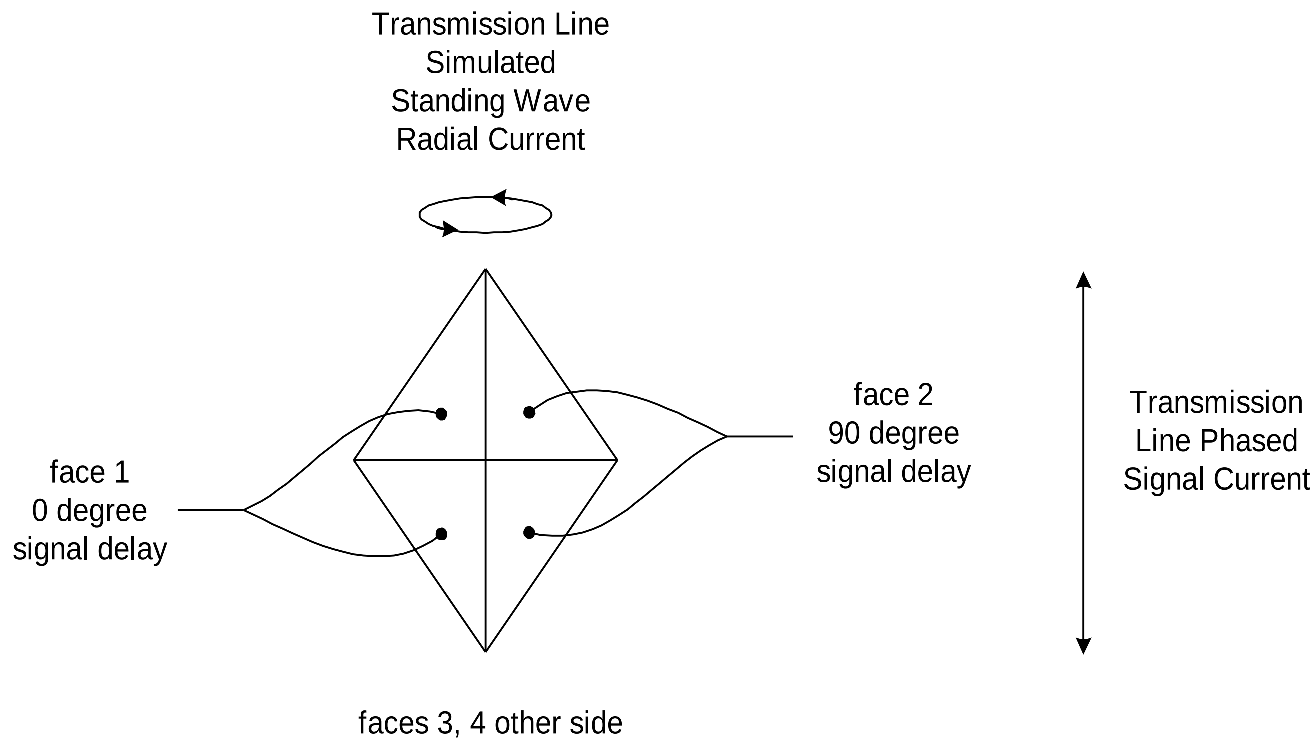


Figure 7. Simulated Radial Current produced by 90° delay line phasing the electronically V-I phased drive signal.

Figure 8 gives a pictorial block diagram of the craft's electronic control system. The block diagram shows a control system acting much like a phase-locked-loop only feedback is provided by VSWR measurements instead of digital dividers. For a λ line length, voltage will be maximum and current minimum at the line's ends when the correct drive signal frequency and line termination values are present. Terminating the transmission lines with multiple Zo impedance will cause the standing waves to build to large voltages. Therefore, measuring voltage for control system feedback may not be practical. Current measurements using a non-invasive current loop coil may be the better choice. Unfortunately, current probe limitations include bandwidth and signal-to-noise issues. For this design, voltage measurement feedback will be used.

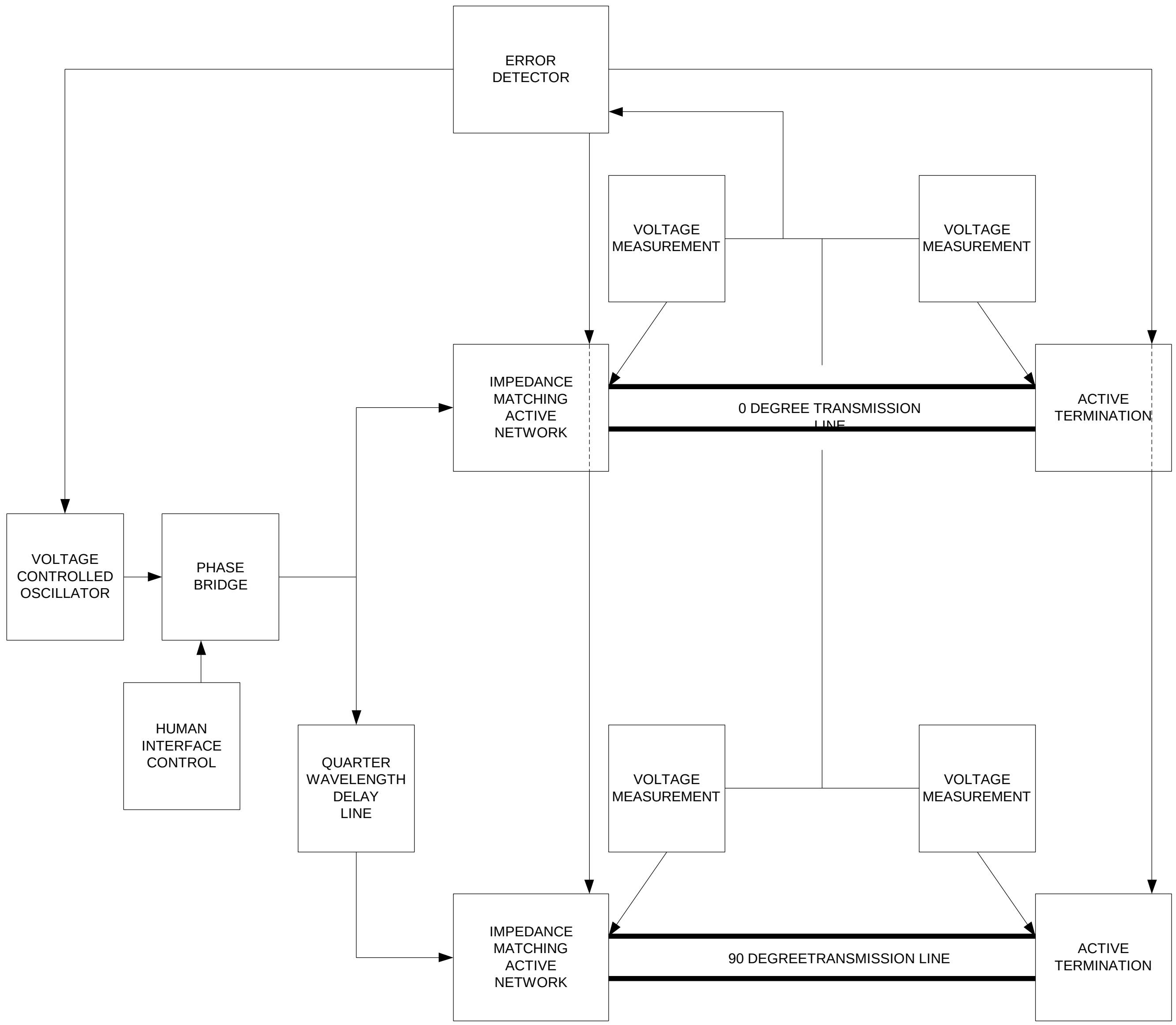


Figure 8. Standing Wave Control System Block Diagram

The block diagram shows a voltage controlled sine wave oscillator driving a differential balanced buffer connected to a phase shift bridge. The phase bridge voltage to current phase is determined by the craft's operator by a potentiometer controlled MOSFET biased as a variable resistance. Another differential buffer isolates the phase bridge and drives coaxial feed and delay lines to the craft's transmission line sides. The buffer's bandwidths are 500 MHz so no major phase shift should occur at the model's drive signal frequency of 40 MHz. The 0° coax feed line is as short as possible and the 90° coax feed delay line length is $\lambda/4$ plus the 0° line length. A time domain reflectometer (or equivalent measurements) will yield exact termination values and line lengths for precise calibrations of phase and minimum SWR. Notice the entire signal drive circuit is isolated from signal ground.

A "Tee" impedance matching network (see Appendix A) converts the 50Ω feed line impedance to the required $8 \cdot 377\Omega$ transmission line impedance. The MOSFET's adjust the output side of the Tee impedance to compensate for transmission line propagation delay changes (temperature expansion, air density etc.). Craft transmission line load terminations are also MOSFET's in an effort to maintain an exact $8 \cdot Zo$ termination impedance at both ends. The VCO frequency is also adjusted for environment variations to maintain a line length frequency of $\lambda/8$.

Measured DC feedback voltages from each transmission line ends are applied to a microprocessor programmed as a proportional controller. The microprocessor's 12-bit ADC inputs digitize the measured VSWR rectified DC voltage levels and create analog output voltages to control the MOSFET's via pulse width modulation outputs connected to low pass filters. Switched capacitor low pass filters provide low MOSFET gate voltage ripple. The low pass filter analog output voltages control MOSFET substrate resistances for maximum VSWR voltage measurement signals. This corresponds to a best match of system variables for the desired VSWR. Proportional controller MOSFET control voltage dynamic ranges are restricted to Zo values of 7.5·Zo to 8.5·Zo. This prevents the controller from locking on to an incorrect integer multiple of Zo.

7 Electronic Control System Phase Bridge

A key part of the craft's control system design is drive signal voltage to current phase control. Figure 9 shows a phase shift bridge used by the control system. Making the reactive component capacitive or inductive allows a zero to positive or negative 180° phase shift. This circuit can shift phase very close to 180° without going past 180°. SPICE simulation reveals changing the variable resistor shifts the voltage to current phase (with out changing the magnitude) as needed for the proposed circuit. ***Caution – If the equations are correct, the craft will create a gravity attraction instead of repulsion if the reverse phase is applied. This could possibly implode the immediate environment causing sever damage to the craft's surrounding area.***

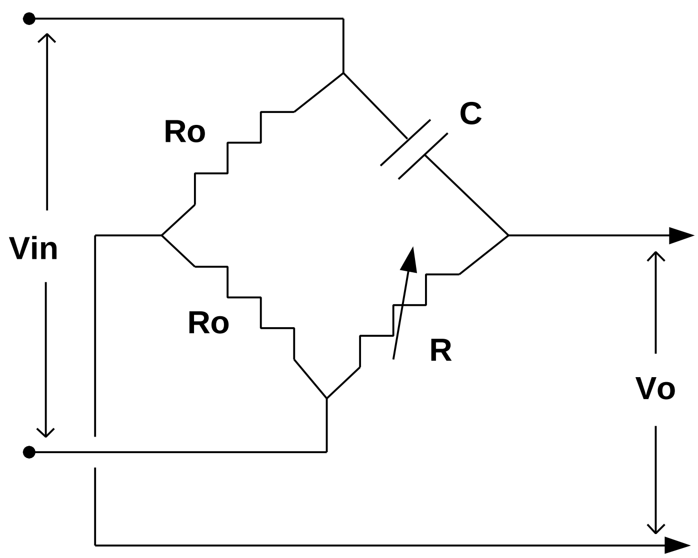


Figure 9. First order all pass phase bridge schematic.

Phase Bridge Equations:

$\theta = -2 \cdot \tan^{-1}(\omega RC)$ (Eq 35)

$R = 0, \theta = 0$

$R = 1/(\omega C), \theta = -\pi/2 = -90°$

$R = \infty, \theta = -\pi = -180°$

$\theta = 2 \cdot \tan^{-1}(\omega RL)$ (Eq 36)

R = 0, $\theta = 0$

R = $1/(\omega L)$, $\theta = \pi/2 = 90°$

R = ∞, $\theta = \pi = 180°$

Freq	C	R	Theta
4.00E+07	1.00E-09	0.85	2.4105608805E+01
		1.00E+04	1.7995438234E+02

Table 3. C or L value needed for a 24 to 179.99 phase shift dynamic range.

An important consideration for control system stability is RC break frequencies due to circuit component internal capacitance and circuit board stray capacitance. At 40 MHz, break frequencies must occur at least a factor of two (a decade is preferred) to prevent their associated phase shifts from corrupting the phase bridge output phase. Assuming a drain to source MOSFET substrate capacitance of 35pF, a substrate resistance of 3016Ω (termination resistance for 8·Zo) gives an approximate break frequency of 1/(RC) or 330 KHz. The reader should realize why it is important to keep the craft drive signal frequency as low as possible. For a large-scale craft, signal drive frequency can be made lower and therefore less prone to circuit capacitance effects. Control circuit resistance values need to be kept well below 10KΩ.

8 TEE Impedance Matching Network

For this design, resistive "Tee" impedance matching networks are employed to match the feed coax transmission lines to the phase bridge buffer amplifier output and the feed coax lines to the craft transmission line sides. Resistor value equations are derived in the Appendix A. Table 4 lists a range of values for matching the 50Ω coax feed lines to the 8·Zo craft transmission lines. Signal attenuation occurs with each Tee network.

Rs	RL	R3	R1	R2	Zin	Zout	ATTN
50	3016	2	48.00	1010.84	50.00	3016.00	0.50
50	3016	4	46.01	1008.96	50.00	3016.00	0.50
50	3016	6	44.02	1007.16	50.00	3016.00	0.50
50	3016	8	42.03	1005.44	50.00	3016.00	0.50
50	3016	10	40.05	1003.80	50.00	3016.00	0.50
50	3016	12	38.07	1002.24	50.00	3016.00	0.50
50	3016	14	36.10	1000.76	50.00	3016.00	0.50
50	3016	16	34.13	999.36	50.00	3016.00	0.50

50	3016	18	32.16	998.03	50.00	3016.00	0.50
50	3016	20	30.20	996.79	50.00	3016.00	0.50
50	3016	22	28.24	995.63	50.00	3016.00	0.50
50	3016	24	26.28	994.54	50.00	3016.00	0.50
50	3016	26	24.33	993.54	50.00	3016.00	0.50
50	3016	28	22.39	992.61	50.00	3016.00	0.50
50	3016	30	20.44	991.76	50.00	3016.00	0.50
50	3016	32	18.50	990.99	50.00	3016.00	0.50
50	3016	34	16.57	990.29	50.00	3016.00	0.50
50	3016	36	14.64	989.68	50.00	3016.00	0.50
50	3016	38	12.71	989.14	50.00	3016.00	0.50
50	3016	40	10.78	988.68	50.00	3016.00	0.50
50	3016	42	8.86	988.29	50.00	3016.00	0.50
50	3016	44	6.95	987.98	50.00	3016.00	0.50
50	3016	46	5.03	987.74	50.00	3016.00	0.50
50	3016	48	3.12	987.58	50.00	3016.00	0.50

Table 4. Values of Tee resistors to match 50 ohms and 3016 ohms (8·Zo).

9 Control System Proportional Controller

Figure 10 depicts the proportional controller's output MOSFET control voltage transfer function. The point of this figure is transmission line end voltages are maximized when oscillator frequency and line termination impedance values are at optimum.

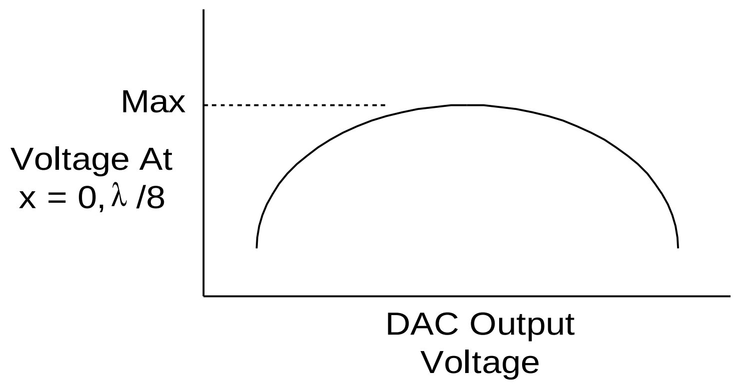
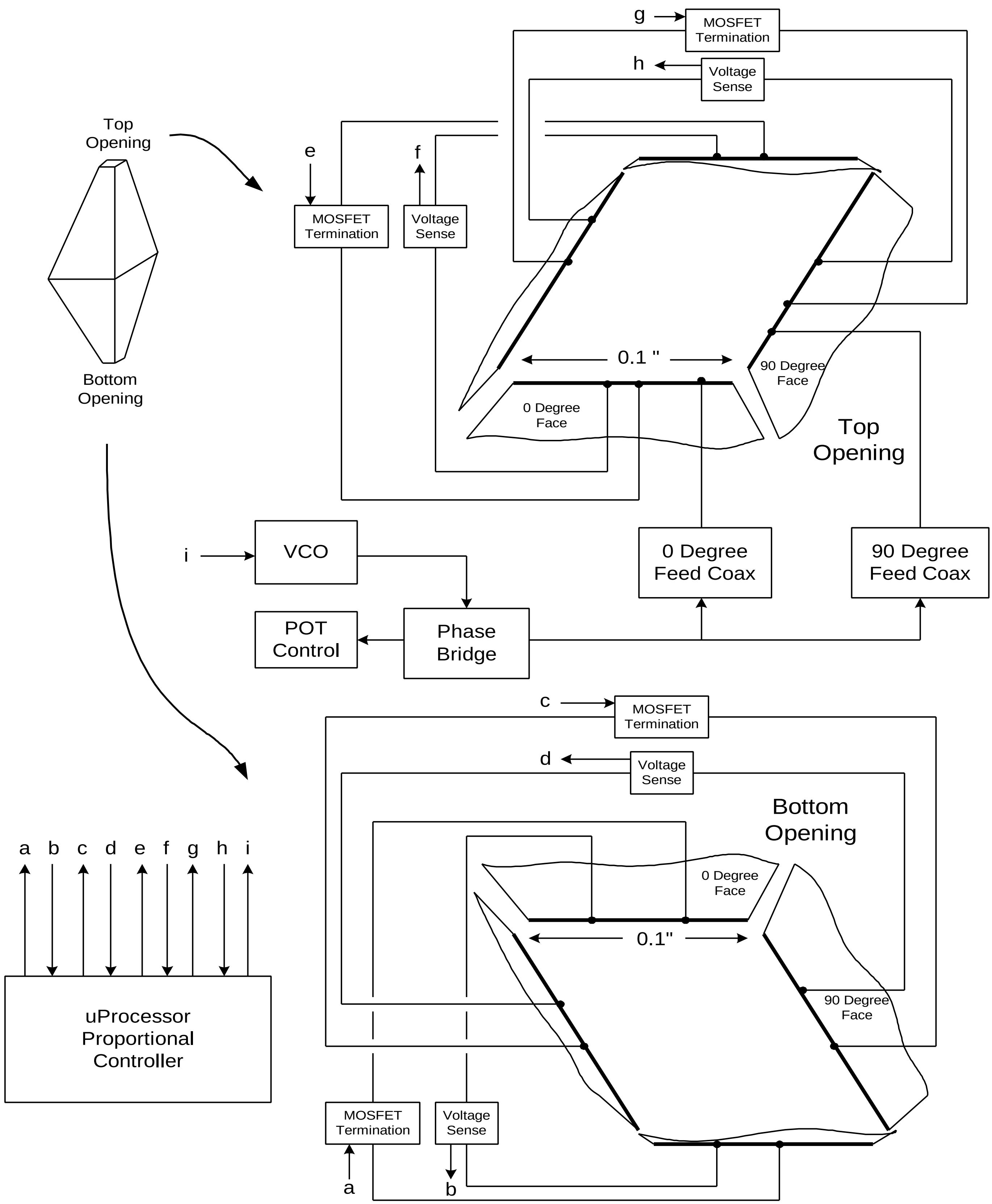


Figure 10. Proportional control diagram for standing wave control.

10 Craft End Connections

Figure 11 details how craft transmission line terminations and VSWR voltage measurements are connected. Both craft vertical apexes are trimmed back to allow a small flat edge for wire connections. Appendix A transmission line parameter calculations include this trimming as a general case.



g
MOSFET Termination
h
Voltage Sense
Top Opening
e
f
MOSFET Termination
Voltage Sense
0.1 "
90 Degree Face
0 Degree Face
Top Opening
Bottom Opening
i
VCO
0 Degree Feed Coax
90 Degree Feed Coax
POT Control
Phase Bridge
c
MOSFET Termination
d
Voltage Sense
Bottom Opening
a b c d e f g h i
0 Degree Face
0.1"
90 Degree Face
uProcessor Proportional Controller
MOSFET Termination
Voltage Sense
a
b

Figure 11. Transmission line top/bottom connections for termination and voltage measurement.

11 Appendix A

This Appendix calculates a non-perfect “lossy” transmission line’s skin effect depth, resistance, capacitance and inductance. These parameters were used to SPICE the line termination characteristics. Mathematical formula for the impedance matching Tee circuits used in the control system electronics are also described.

Transmission Line Skin Depth Equations:

$$d = \frac{1}{p s m V p} \qquad \text{(Eq 1A)}$$

$\sigma = 1$ for Cu @ 72° F,

$\mu = \pi \cdot 4(10)^{-7}$ for Cu,

Vp is phase velocity.

Choose copper thickness $\geq 3 \cdot \delta$ to ensure good conduction.

$3 \cdot \delta$ = minimum thickness $\geq \dfrac{0.65}{\sqrt{f(Hz)}}\ feet$. (Eq 2A)

Transmission Line Resistance Equations:

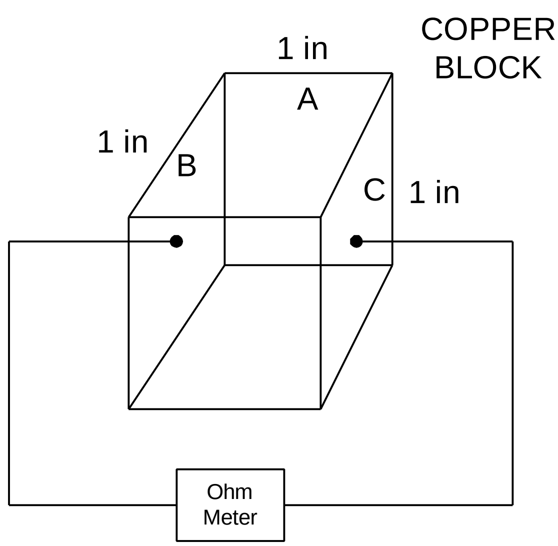


Figure 1A. Conductance measurement for a copper cube with an ohmmeter.

$R_{TL} \propto A$,

$R_{TL} \propto 1/B$,

$R_{TL} \propto 1/C$,

$$R_{TL} = \frac{kA}{BC}. \qquad \text{(Eq 3A)}$$

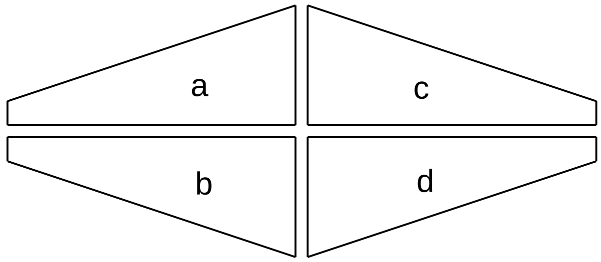


Figure 2A. Transmission line face broken into four parts.

- ✓ A = L, B = 3·δ.
- ✓ Calculate R_{TL} for one face part (a)
- ✓ Adding (b) will half R_{TL}
- ✓ Adding (c) and (d) will double R_{TL} so (a) = (a,b,c,d)
- ✓ Return (opposite) side will double R_{TL} so R_{TL} = 2·R(a)

Start equals trimmed apex so wires can be attached. For this design, assume START = 0.1 inch.

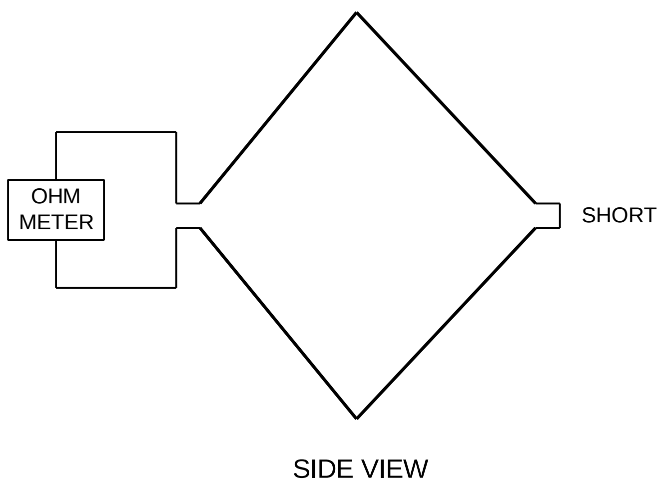


Figure 3A. Transmission line DC resistance ohm meter measurement.

R_{TL} is value measured by the ohmmeter of Figure 11.

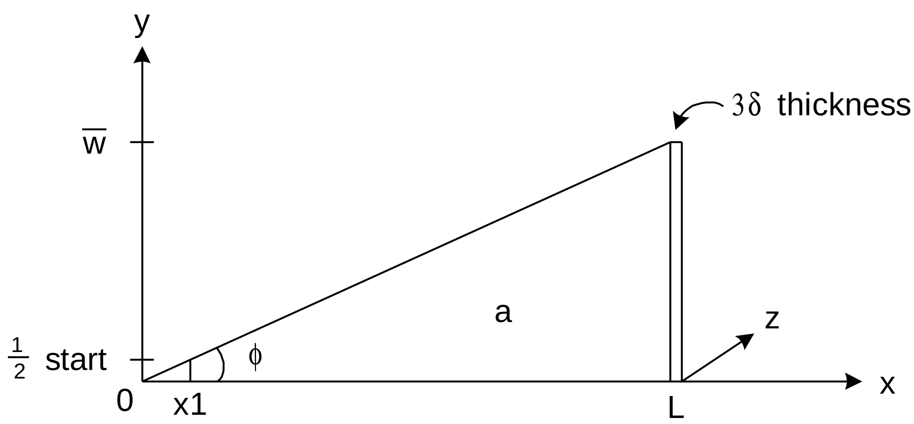


Figure 4A. Geometric representation of craft face segment.

Equation of straight line through the origin is:

$$y = \frac{x\bar{w}}{L} = C \qquad \text{(Eq 4A)}$$

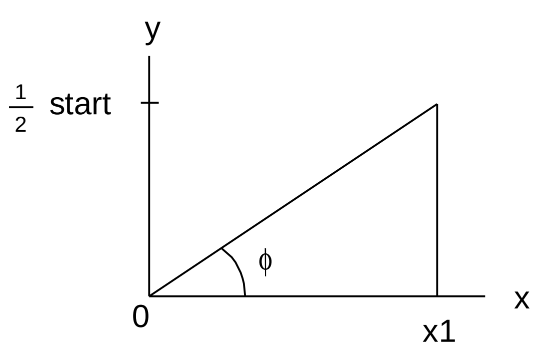


Figure 5A. Geometric representation of trimmed part of segment.

$$x1 = \frac{START}{2 \cdot \tan f} \qquad \text{(Eq 5A)}$$

where "START" is the trimmed edge widths at each vertical apex for wire attachment.

$$R_{TL} = \frac{2 \cdot 6.7\times10^{-7} \cdot L^2}{3 \cdot d \cdot \bar{w}} \int_{x1}^{L} \frac{dx}{x} = \frac{1.34\times10^{-6} \cdot L^2}{3 \cdot d \cdot \bar{w}} \left(\log(L) - \log\left(\frac{START}{2 \cdot \tan f} \right) \right) \qquad \text{(Eq 6A)}$$

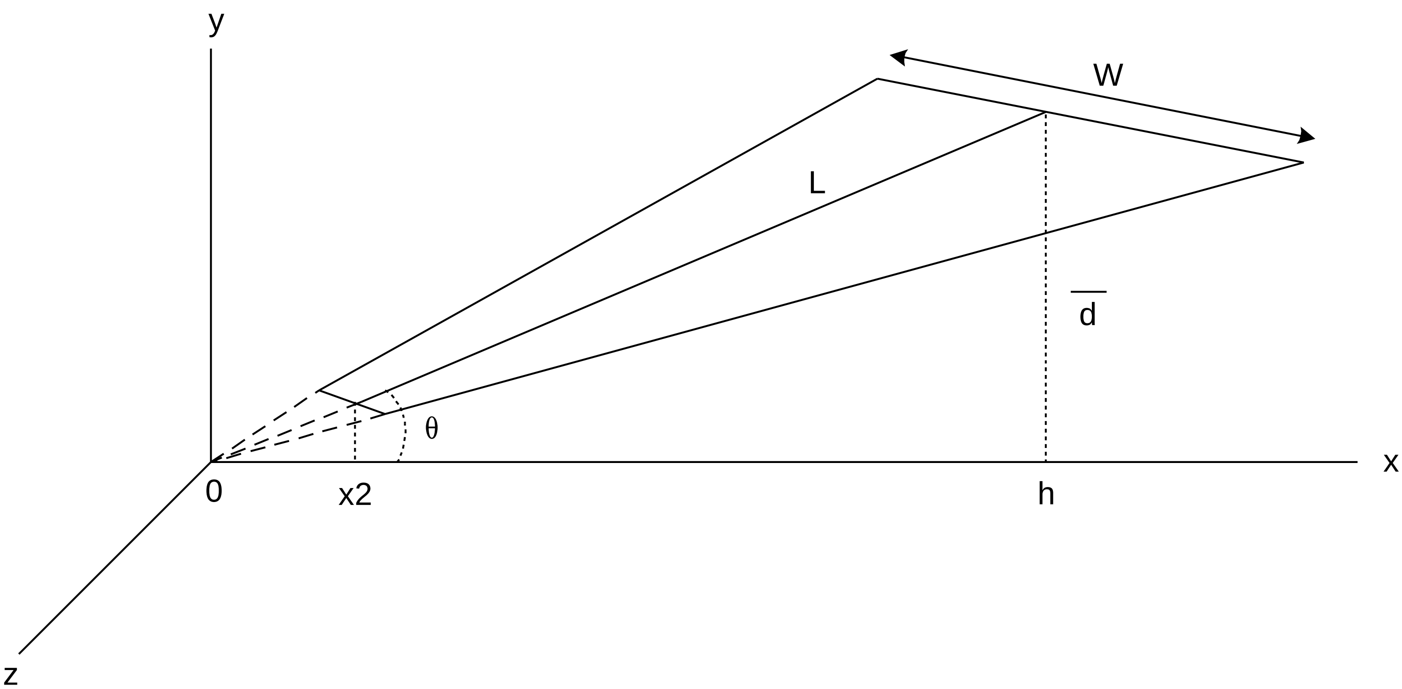


Figure 6A. Geometric representation of half face sheet.

Transmission Line Capacitance Equations:

A′ = face area

d′ = face separation

μ = 1.000536 for air ≈ 1.0

β = 8.85pF/m = 0.225pF/in = 2.7pF/ft

$$C_{TL} = \frac{A'b}{d'} \qquad \text{(Eq 7A)}$$

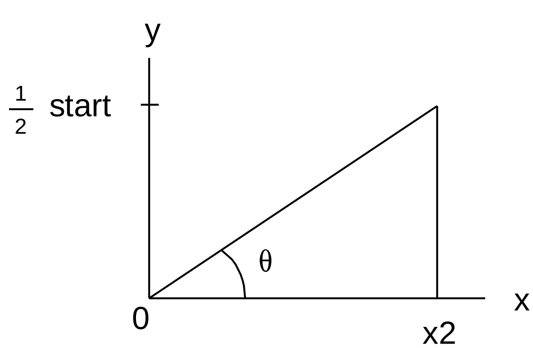


Figure 7A. Geometric representation of trimmed edge.

Since the ratio of W/d = 1, w = d and START for angle ϕ equals START for angle θ.

$$x2 = \frac{START}{2 \cdot \tan q} \qquad \text{(Eq 8A)}$$

$$y = d' = \frac{2 \cdot \overline{dx}}{h} \qquad \text{(Eq 9A)}$$

$$C_{TL} = \frac{nA'b}{2 \cdot \overline{d}} \int_{x2}^{h} \frac{dx}{x} = \frac{hA'b}{2 \cdot \overline{d}} \left(\log(h) - \log\left(\frac{START}{2 \cdot \tan q} \right) \right) \text{ in pF} \qquad \text{(Eq 10A)}$$

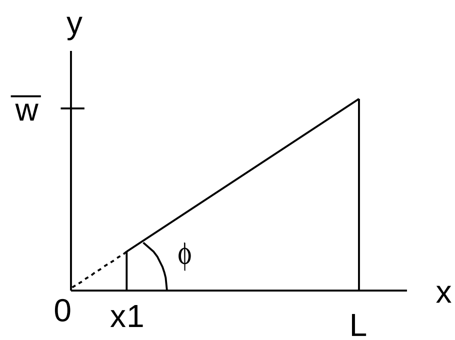


Figure 8A. Geometric representation of trimmed edge.

$$y = \frac{\overline{w}}{L} \cdot x \qquad \text{(Eq 11A)}$$

$$A = \frac{2 \cdot \overline{w}}{L} \left[L^2 - \left(\frac{START}{2 \tan f} \right)^2 \right] \text{ in inches}^2 \qquad \text{(Eq 12A)}$$

Transmission Line Inductance Equations:

$$L_{TL} = Zo^2 \cdot C_{TL} \qquad \text{(Eq 13A)}$$

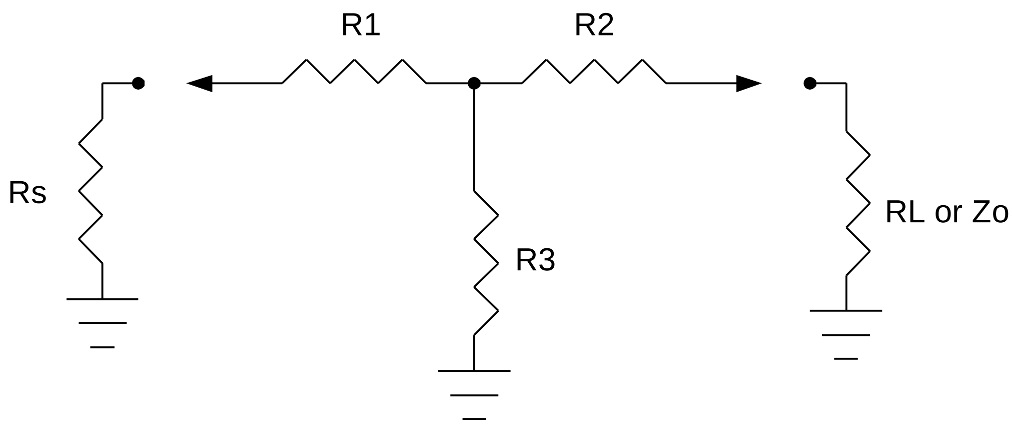


Figure 9A. Impedance matching TEE circuit.

Matching TEE Resistor Equations:

RS and RL are known. Select R3. Solving for R1 as a function of R2 and R3, let:

A = (R1·RL - R1·R3 + F)/(R1 + C)

B = RS·R3 + RL·RS – R3·RL

C = RS + R3

D = R3 + RL

E = RS – R3

F = RL·R3 + RL·RS – R3·RS

then:

$R1^{2}\cdot(RL\text{-}R3 + D) + R1\cdot(F + C\cdot D - RL\cdot E + R3\cdot E - B) = B\cdot C + F\cdot E$ (Eq 14A)

is a quadric equation with:

$a_0 = B\cdot C + F\cdot E$

$a_1 = (F + C\cdot D - RL\cdot E + R3\cdot E - B)$

$a_2 = (RL\text{-}R3 + D)$

solution is:

$$R2 = \frac{-a_1 \pm \sqrt{a_1^2 - a_2(-a_0)}}{2 \cdot a_2}$$ (Eq 15A)

R1 = A (Eq 16A)

12 Appendix B

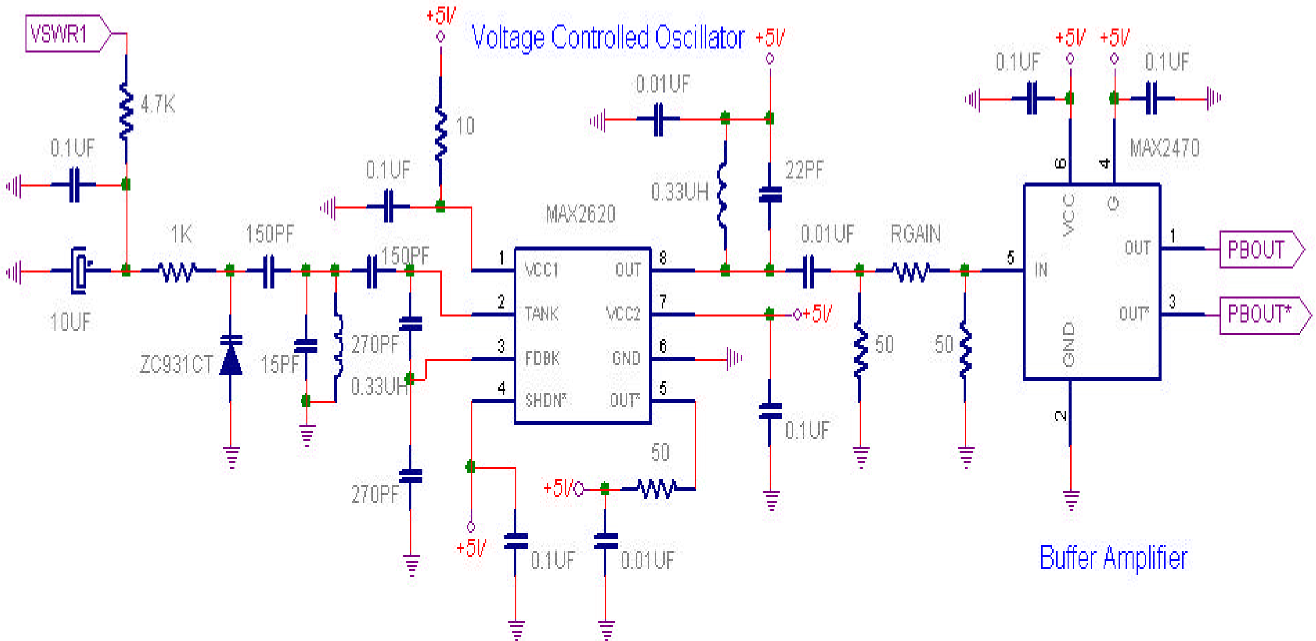


Figure 1B. Voltage controlled oscillator driving a single ended input, differential output buffer amplifier.

Figure 1B represents a voltage controlled oscillator circuit and output buffer amplifier. The varactor variable capacitance diode determines the oscillators output frequency from the proportional controller's DC voltage output. Controller output voltage dynamic range is limited to 39 MHz < f_{out} < 41 MHz to prevent the oscillator from locking to a multiple harmonic of the 40 MHz fundamental. The buffer amplifier's high impedance input isolates the oscillator to prevent frequency and voltage amplitude variations due to external loading. Differential outputs drive the all pass phase bridge circuit described next.

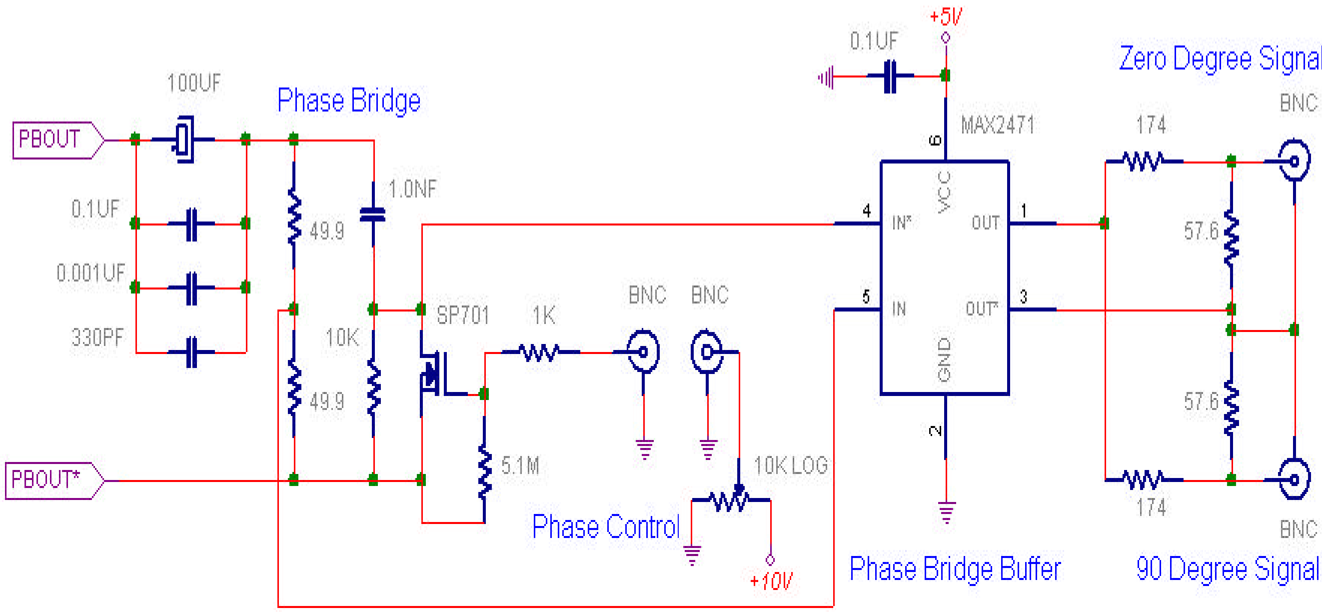


Figure 2B. All pass phase adjustment bridge driving a differential input, differential output buffer amplifier.

An all pass phase bridge (see Figure 9) allows the operator to shift voltage to current phase with a single potentiometer. The capacitor value of 1.0 nanoF varies phase from 21° to 179.99°. For a capacitance bridge, current leads voltage by the phase angle. The MOSFET substrate resistance ranges from 0.8Ω to > ten megohms. The 10K parallel resistor limits the high range resistance to below the stray capacitance break frequencies. The MOSFET can be replaced by a 10K carbon (not wire wound) pot if leads are kept short.

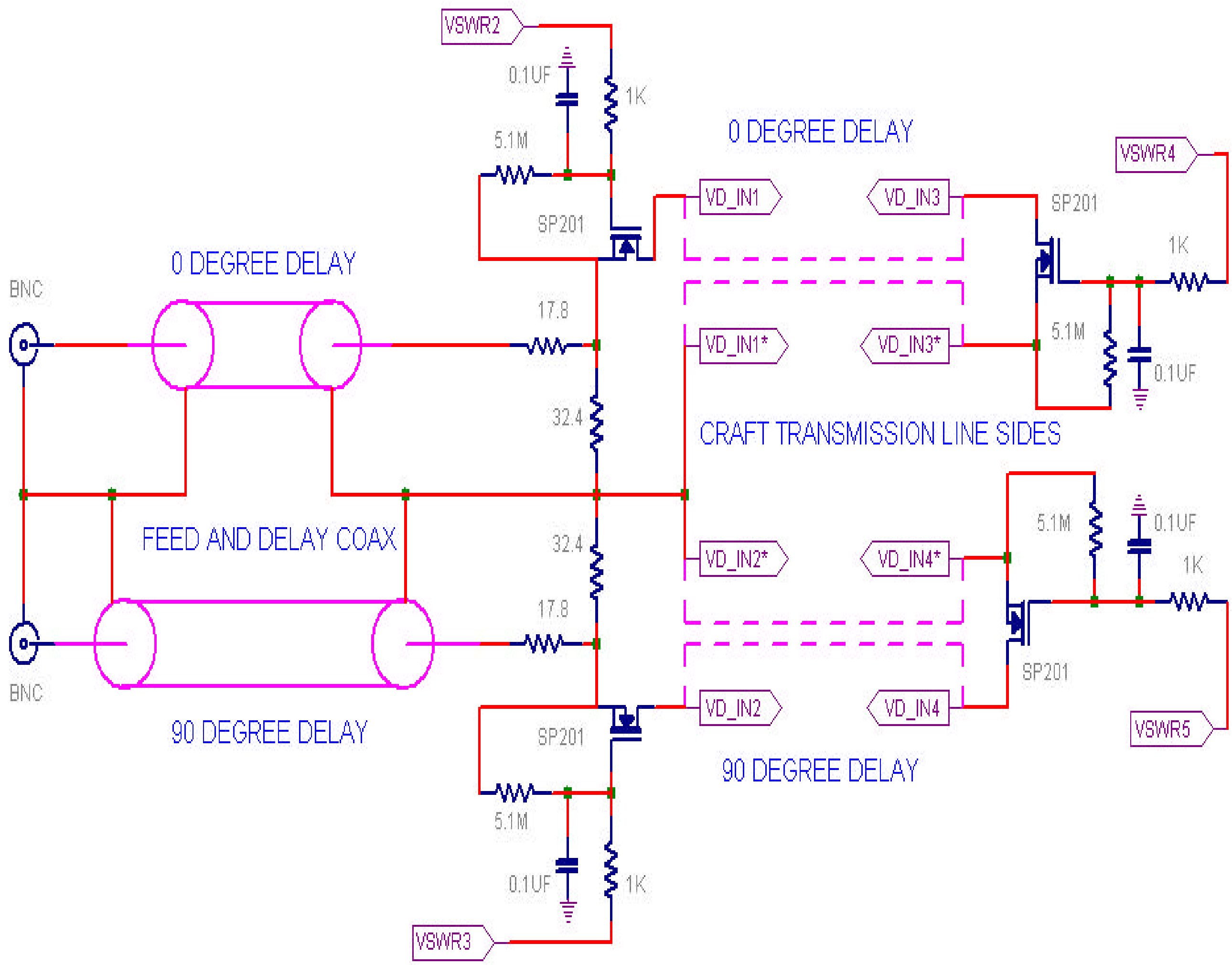


Figure 3B. Coax cables feeding the phased voltage-current signal to the craft's transmission line sides.

Fifty ohm shielded coax cables connect the phase bridge buffer output Tee network to the craft's transmission line sides. The Tee networks matche the buffer's output impedance to the craft's transmission line impedance. Tee variable resistance MOSFETs are controlled by the proportional controller's feedback voltage outputs. In addition to signal feed, the 90° coax provides a λ/4 quadrature signal delay to the craft's second transmission line to achieve a simulated radial current flow.

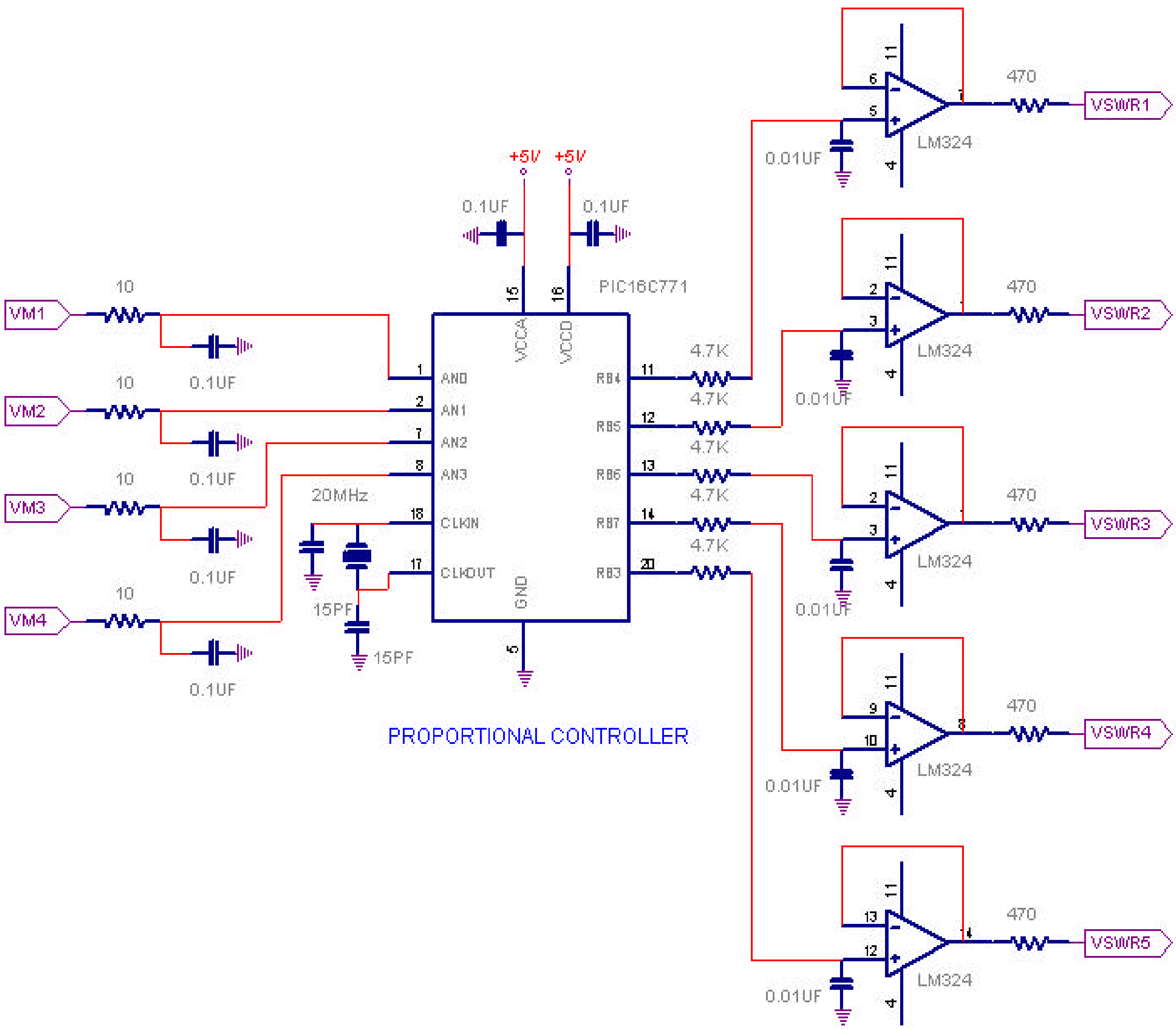


Figure 4B. Proportional microprocessor controller adjusts the four VSWR MOSFET devices and the drive signal VCO frequency.

A microcontroller provides system control in relation to the VSWR transfer function characteristics illustrated by Figure 10. Running a proportional control algorithm, the controller accomplishes the following tasks:

- ✓ Digitizes the four VSW measurements provided by the circuits of Figure 5B.
- ✓ Calculates derivatives for the inputs and determines the error from a zero slope reference.
- ✓ Adjust pulse width duty cycles of the five outputs to achieve filtered DC feedback voltages corresponding to near zero slopes.

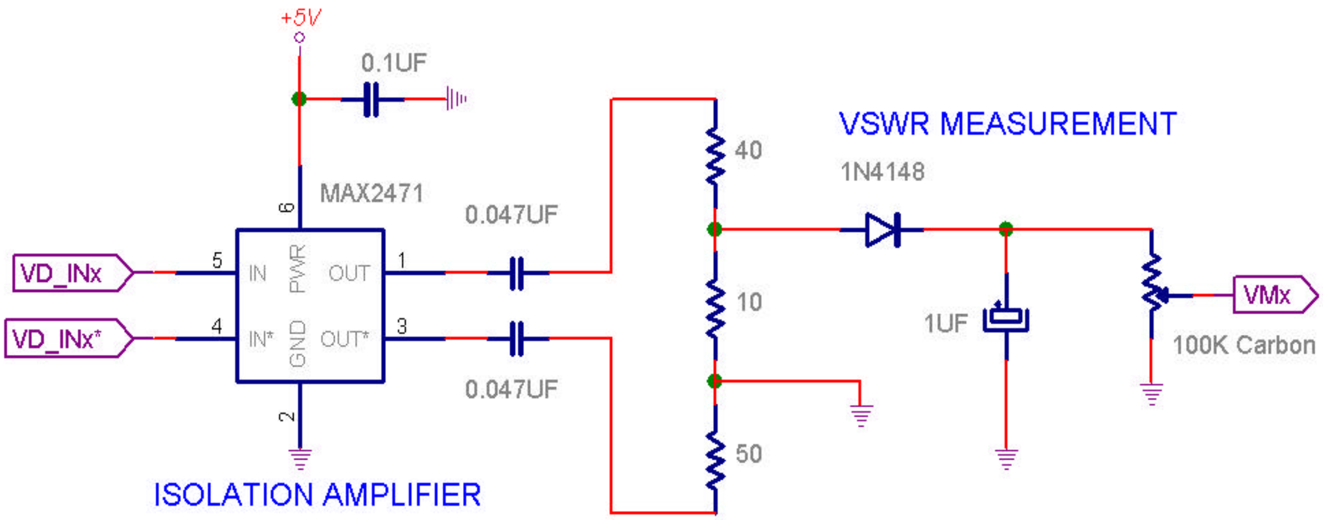


Figure 5B. One of four voltage standing wave measuring circuits connected to the transmission line source and end points (x=0 and x=ℓ).

The circuit of Figure 5B differentially measures the VSW across the craft's transmission line source and end points VD_INx and VD_INx*. Figure 6 details the transmission line's voltage distribution as a function of length. Voltage is maximized at the line's end points when the standing wave is optimized. Differential measurements minimize electrical influences on the line's voltage and current standing waves. The non-inverting output is terminated, rectified, filtered and voltage level adjusted. The inverted output is terminated and not used. VD_OUT of the four circuits is connected to four of the proportional controller's ADC inputs as shown in Figure 4B.