RITZ INSTRUMENT TRANSFORMERS

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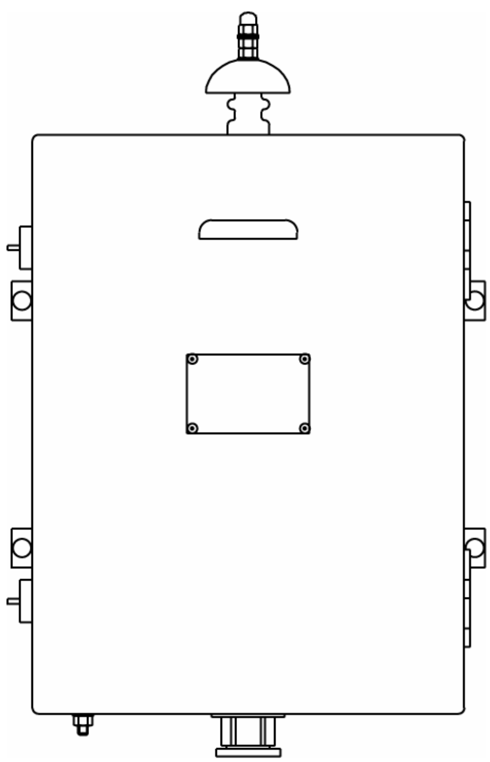
INSTRUCTION BOOK

LINE TUNER
SINGLE-FREQUENCY
PHASE-TO-GROUND COUPLING



IB-LT-SF
Revision 0
3/3/06

<u>WARNING</u>

ONLY THOROUGHLY TRAINED PERSONNEL SHOULD ATTEMPT TO HANDLE OR CONNECT TO THIS DEVICE WHEN CONNECTED TO OTHER EXTERNAL DEVICES. HIGH-VOLTAGE MAY BE PRESENT.

The instructions and safety guidelines contained in this manual and accompanying drawings and instructions are in addition to the normal safety practices established by the user and should not be interpreted to limit the user’s procedures or recognized standards.

1.0 STORAGE

The line tuner can be stored in its shipping container in a protected outdoor area, provided the area does not exceed the range of –40^{o}C to +55^{o}C (-40^{o}F to +131^{o}F)

If the unit is stored in a highly humid environment, the internal heater should be used to prevent condensation moisture from damaging the internal components.

2.0 DESCRIPTION

Line tuners provide an efficient path to transfer Power-Line Carrier (PLC) signals to and from high-voltage transmission lines and also protect the PLC equipment from voltage and current surges from the transmission line. This line tuner is designed to provide a high return loss and low insertion loss within a relatively narrow bandwidth. The single-frequency tuner consists of a series L/C circuit (formed by the coupling capacitor, the blocking capacitor, and the series inductor unit).

The following components are normally contained in a single-frequency line tuner. Refer to the line tuner schematic drawing supplied with the line tuner for exact arrangements.

2.1 Protection Unit

The protection unit consists of a grounding switch, a spark-gap, a power-frequency blocking capacitor, and, optionally, a drain coil. The drain coil is normally present in the coupling capacitor. If there is a drain coil in the coupling capacitor, it is not recommended to place an additional drain coil in the line tuner, as the losses associated with this device will be increased.

2.2 Inductor Unit

The inductor unit is adjusted to resonate with the coupling capacitance at the GMF.

2.3 Impedance Matching Transformer (IMT)

The IMT matches the characteristic impedance of the coaxial cable with the characteristic impedance of the transmission line in order maximize the power transfer between the 2 circuits.

3.0 INSTALLATION

The bottom of the cabinet should be mounted approximately four feet off of the ground and the area should allow sufficient room for the cabinet door to open fully.

The unit should not be installed in a battery room or where corrosive vapors are present.

There should be 120 VAC power available for connection to the heater and to operate required test equipment.

4.0 LEAD-IN CONDUCTORS

Two types of conductors are generally used to connect the line tuner to other equipment.

4.1 Carrier-Current Single-Conductor

This conductor is used to connect the line tuner to the coupling capacitor. No. 8 AWG stranded copper conductor, unshielded, and insulated for 5 kV with Vulkene ™ insulation should be used.

WARNING

The lead-in conductor from the coupling capacitor to the line tuner should only be disconnected after the carrier terminal on the coupling capacitor has been grounded. Normally, this is accomplished by closing the carrier ground switch on coupling capacitor voltage transformers or coupling capacitors. Failure to maintain a power-frequency ground on the coupling capacitor can result in dangerous static voltages at this point. In most coupling capacitors, a drain coil is also present to provide this ground reference.

This conductor is on the high-impedance side of the tuned circuit and thus, stray-capacitance to ground and leakage current can affect the performance of the carrier circuit. In order to minimize these effects, the conductor should be supported on insulators, using as few as possible and the conductor should be run in the most direct path possible.

The line tuner is supplied with a lead-in bushing. This bushing is either on the top or on the side of the cabinet. For the top mounted bushing (standard), the lead-in conductor should be connected to the external bushing stud using a crimp connection. For side-mounted bushings, the lead-in conductor should be run through the bushing and connected internally to the appropriate connection point.

<u>4.2 Coaxial Cable</u>

Coax cable is used to connect the low-impedance side of the line tuner to other line tuners and/or to the carrier transmitter/receiver assemblies. RG-8/U cable should be used.

The coax cable can be run in underground conduit or directly buried in the ground. The cable should be run in the most direct path possible in order to keep the cable length to a minimum.

The outer conductor of the coax cable should be grounded at the carrier equipment end only. At the line tuner end, the conductor should be fitted with the proper UHF connector or plug-type connector and connected to the appropriate terminal on the impedance matching transformer (IMT).

The IMT will accept coax cable with characteristic impedances of 50 ohms, 75 ohms, 100 ohms, 125 ohms, and 150 ohms.

5.0 DETERMINING THE THEORETICAL BANDWIDTH

The bandwidth (BW) is defined as the width of the frequency range where the return loss is higher than a specified value. The lowest frequency of the bandwidth is referred to as f_1 and the highest frequency of the bandwidth is referred to as f_2.

$$BW = f_2 - f_1$$

Since bandwidth is defined for a given return loss limit, if the return loss limit is increased the bandwidth is reduced and if the return loss limit is lowered, the bandwidth is increased.

To determine the bandwidth of a single-frequency resonant line tuner, the following parameters are required:

CC is the value of the coupling capacitance
RL is the characteristic impedance of the transmission line
GMF is the geometric mean frequency

$$(GMF)^2 = f_1 \cdot f_2$$

The formula to calculate the bandwidth is:

$$BW = 2\pi(GMF)^2 \cdot RL \cdot CC' \cdot K$$

CC’ is the effective coupling capacitance, which is a combination of the blocking capacitance (CB) and CC.

$$CC' = (CB \cdot CC)/(CB + CC) \text{ with CC and CB in } \mu F$$

The value of CB depends on the Protection Unit design, which can vary depending on how the line tuner was specified. The following table lists the CB value based on the model number of the Protection Unit. This model number is printed on the top of the Protection Unit.

Protection Unit Model	CB (μF)
301236.0001	0.10
301236.0002	0.15
301236.0003	0.10
301236.0004	0.15
301236.0005	0.10
301236.0006	0.15

Table 1 – Value of Blocking Capacitor

K is a constant based on the desired return loss limit. To determine the ‘K’ constant to use, please refer to Table 2 below. If the return loss value needed is not shown, please consult the factory for further information.

Return Loss – RL (dB)	Amplitude (dB)	K
14	0.177	0.4070
12	0.300	0.5348
10	0.500	0.6984
3	3.000	2.0000

Table 2 – Value of ‘K’ Constant

6.0 TUNING PROCEDURE

6.1 Instrumentation Recommended for Tuning

- Impedance Analyzer (HP4192A LF or similar)
- Capacitor with low dissipation factor for simulating the coupling capacitance
- Low capacitance, low inductance resistors to simulate the line and coaxial side impedances

6.2 Calculating the Values of the Components

In order to calculate the values of the line tuner components, the following parameters are needed:

- Line side characteristic impedance (RL)
- Coaxial side characteristic impedance (RC)
- Coupling capacitor (CC)
- Blocking capacitor (CB)
- Geometric mean frequency (GMF) and the lower and upper edge frequencies (f_1 and f_2) or GMF and bandwidth ($BW=f_2-f_1$)
- Return loss at the edge frequencies (Rloss)

Please note that the bandwidth is defined as the width of the frequency range where the return loss is higher than a specified value. If the specified return loss changes, the bandwidth will change as well. For instance, if the bandwidth corresponding to 10dB return loss is 250kHz, the bandwidth for 12dB return loss will be narrower.

The following designations are used in the rest of the document:

L_1 - inductance of the L unit

Since the series L-C circuit formed by the coupling capacitor, blocking capacitor and the inductance of the L unit needs to be in resonance at GMF, the inductance L1 can be calculated with the following formula:

$$L_1 = \frac{1}{4 \cdot \pi^2 \cdot GMF^2 \cdot CC'} \qquad (1)$$

where

$$CC' = \frac{CC \cdot CB}{CC + CB} \qquad (2)$$

6.3 Preparations Before Tuning

The IMT must be set to the closest line side and coaxial side impedances available. See Figure 8 and 9 for more details on the IMT connections.

The impedance analyzer should be calibrated before each use (short-circuit calibration at 100 kHz, series measurement mode, Z-phase angle mode, open-circuit calibration at 1 MHz., parallel measurement mode, Z-phase angle mode). Warm-up time for most impedance analyzers is 20-30 minutes. Consult the instruction manual provided with the impedance analyzer for details.

6.4 Tuning

Follow the steps below to field tune the line tuner. Note that in most cases the line tuners are delivered pre-tuned at the factory according to the specifications when ordered.

1. Disconnect yellow lead connecting stud E2 on the L unit and stud OUT on the IMT.
2. Reference Figure 3. Determine the RL connections (fourth column) based on the calculated value of L1 (see section 6.2). Always choose a combination with the least number of connections. For example, if the inductance L1 needs to be 250uH and you have model 301237.001 no connections are needed for the inductor part (see fourth line: 80-270uH, RL connections: none). If you have model 301237.0002, one solution would be to connect studs 2 and 3 with a red wire link (see third line: 135-500uH, RL connections: 2-3), but a better solution is the one in the fourth line (130-400uH, RL connections: none). If two neighboring studs need to be connected (for example: 2 to 3) use rigid links. If wire links are needed, use red wire and keep the wire as short as possible. Determine which studs need to be connected to the connection points E1 and E2. For instance, for model 301237.0001 and 250uH, connect stud 5 to stud E1 or E2 (whichever is closer) and stud 6 to the remainder of E1 or E2. Use red wire and keep it as short as possible.
3. Loosen the set-screws on the fine tuning knob (there are four at 90 degrees apart).
4. Make sure the hardware on every stud is tightened properly.
5. Open ground switch (see Figure 2).
6. Connect a low dissipation capacitor (for instance polyester or similar capacitor) having the value of the coupling capacitor CC to the line side bushing.
7. Set the impedance analyzer in Z-phase angle mode. Set the frequency to the GMF desired. Connect the measuring leads to the free end of the capacitor simulating CC and to stud E2 on the L unit.
8. Turn the fine tuning knob until the phase angle is 0 (minimum value on the on the measured impedance should also be reached at this point).
9. Fix the fine tuning knob with the four set screws.
10. Connect stud E2 on the L unit to stud OUT on the IMT with a yellow wire.

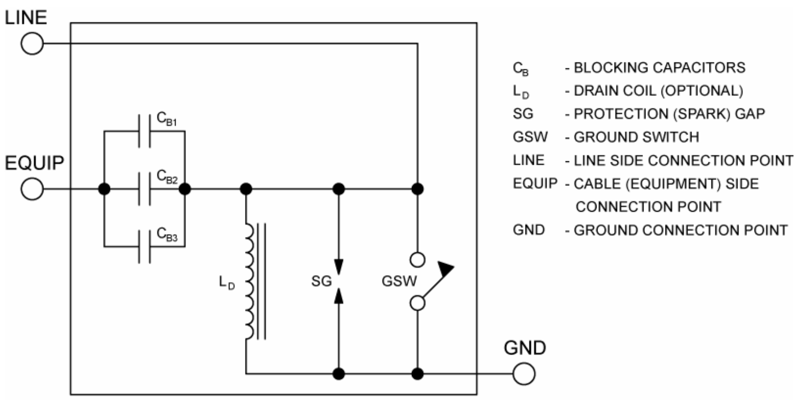
7.0 COMPONENTS AND SCHEMATICS

7.1 Protection Unit

The protection unit consists of the following devices:

- Ground Switch – grounds the incoming carrier lead-in connection from the coupling capacitor. This switch should remain open (ungrounded) during normal operation.
- Spark Gap – limits the voltage between the coupling capacitor lead-in connection and ground during a transient.
- Blocking Capacitor (CB) – limits the power frequency surge current from the coupling capacitor lead-in connection.
- Drain Coil (Optional) – provides a low-impedance path to ground for power frequency current, while presenting a high-impedance path to ground for the carrier frequency range. The drain coil is normally present in the coupling capacitor. If there is a drain coil in the coupling capacitor, it is not recommended to place an additional drain coil in the line tuner, as the losses associated with this device will be increased.

Figure 1 below shows the schematic diagram of the protection unit and Figure 2 shows the physical layout of the protection unit.



MODEL	C_{B1} [nF]	C_{B2} [nF]	C_{B3} [nF]	L_D [mH]
0001	50	50	-	-
0002	50	50	50	-
0003	50	50	-	25
0004	50	50	50	25
0005	50	50	-	100
0006	50	50	50	100

Figure 1 – Protection Unit Schematic

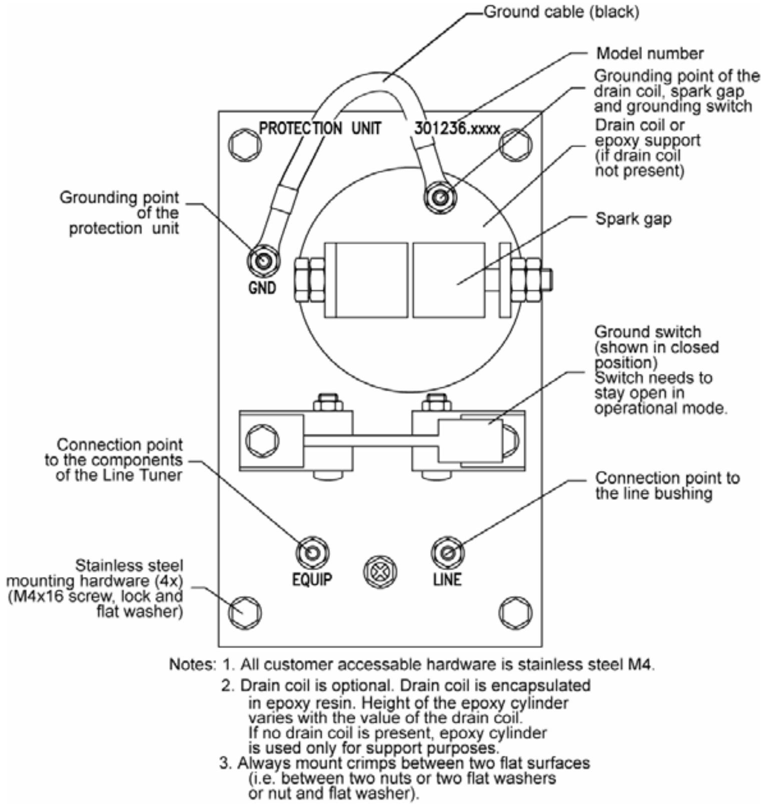
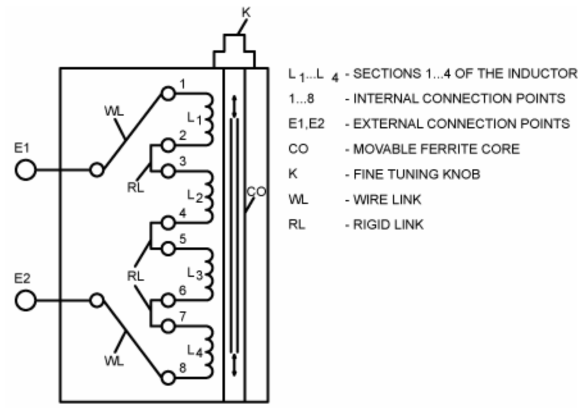


Figure 2 – Protection Unit Layout

7.2 Inductor Unit

The inductor unit acts together with the coupling capacitance to form a series LC circuit. The inductance is adjustable to resonate with the coupling capacitance at the GMF being used.

The inductance is adjustable within finite ranges. The ranges are set by making various connections between the output terminals (E1 and E2) and the internal connection points (1-8) and between the internal connection points themselves. Once the range is set, the fine tuning can be made by rotating the fine tuning knob, which moves an adjustable ferrite core inside the inductor unit. Figure 3 shows the internal connection schematic and adjustment ranges and Figure 4 shows the layout of the inductor unit.



MODEL 0001	MODEL 0002	MODEL 0003		
LE1-E2 [mH]	LE1-E2 [mH]	LE1-E2 [mH]	RL CONNECTION(S)	WL CONNECTION(S)
7-20	40-90	30-180	None	E1-1, E2-2
15-40	70-220	110-470	None	E1-3, E2-4
30-100	135-500	240-1220	2-3	E1-1, E2-4
80-270	130-400	800-2000	None	E1-5, E2-6
130-590	345-1550	1600-6200	2-3, 4-5	E1-1, E2-6
130-400	240-780	3200-15000	None	E1-7, E2-8
280-1300	420-2000	4500-23000	6-7	E1-5, E2-8
360-1700	830-4000	6200-31000	2-3, 4-5, 6-7	E1-1, E2-8

SCHEMATIC SHOWS TYPICAL CONNECTIONS AND CONNECTIONS
MAY VARY DEPENDING ON INDUCTANCE RANGE REQUIRED

Figure 3 – Inductor Unit Schematic

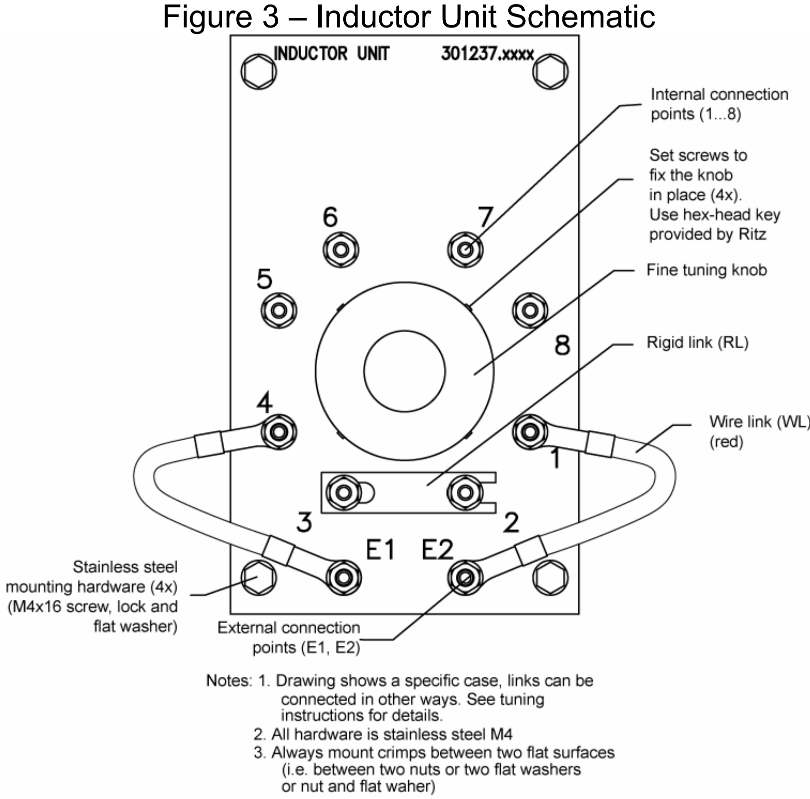


Figure 4 – Inductor Unit Layout

7.4 Impedance Matching Transformer

The impedance matching transformer (IMT) is used to match the characteristic impedance of the coaxial cable to the characteristic impedance of the transmission line in a phase-to-ground coupling application.

The cable impedance settings available are 50, 75, 125, and 150 ohms. A UHF connector is available for unbalanced connections, while binding post connectors are available for balanced connections. The cable impedance settings are made by connecting a rigid link labeled “COAX IMP” from the center terminal to the appropriately labeled terminal about the center.

The transmission line characteristic impedance selections available are 175, 210, 265, 320, 380, and 450 ohms. The line impedance settings are made by connecting a rigid link labeled “LINE IMP” from the center terminal to the appropriately labeled terminal about the center. There is an adjustment link that can be set to increase the transmission line impedance setting by 10% and this link is labeled “IMP CORR”.

Figure 8 shows the IMT schematic and Figure 9 shows the layout of the IMT.

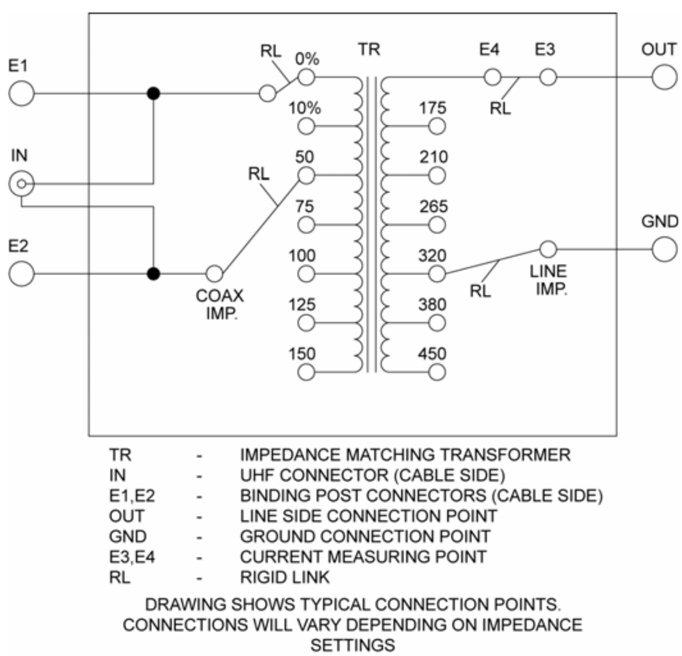


Figure 5 – IMT Schematic

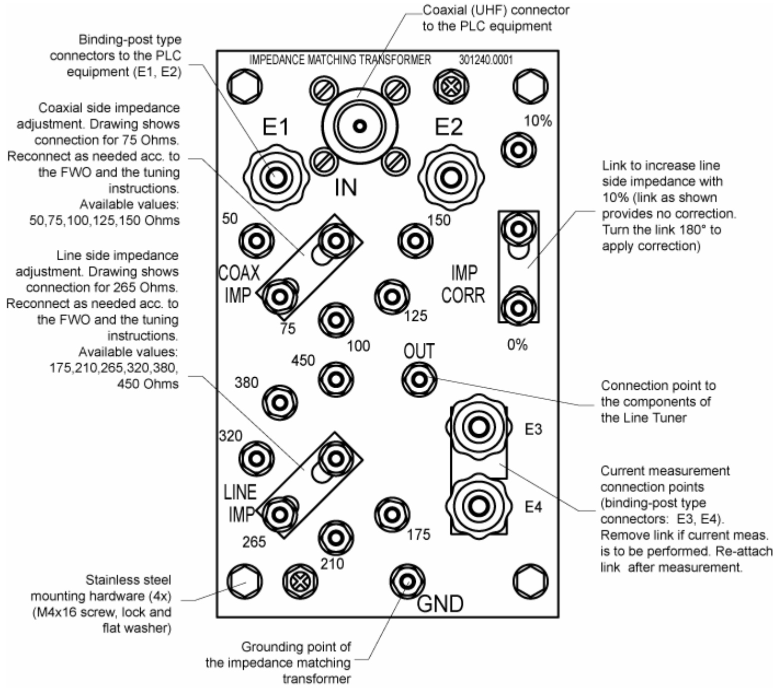


Figure 6 – IMT Layout

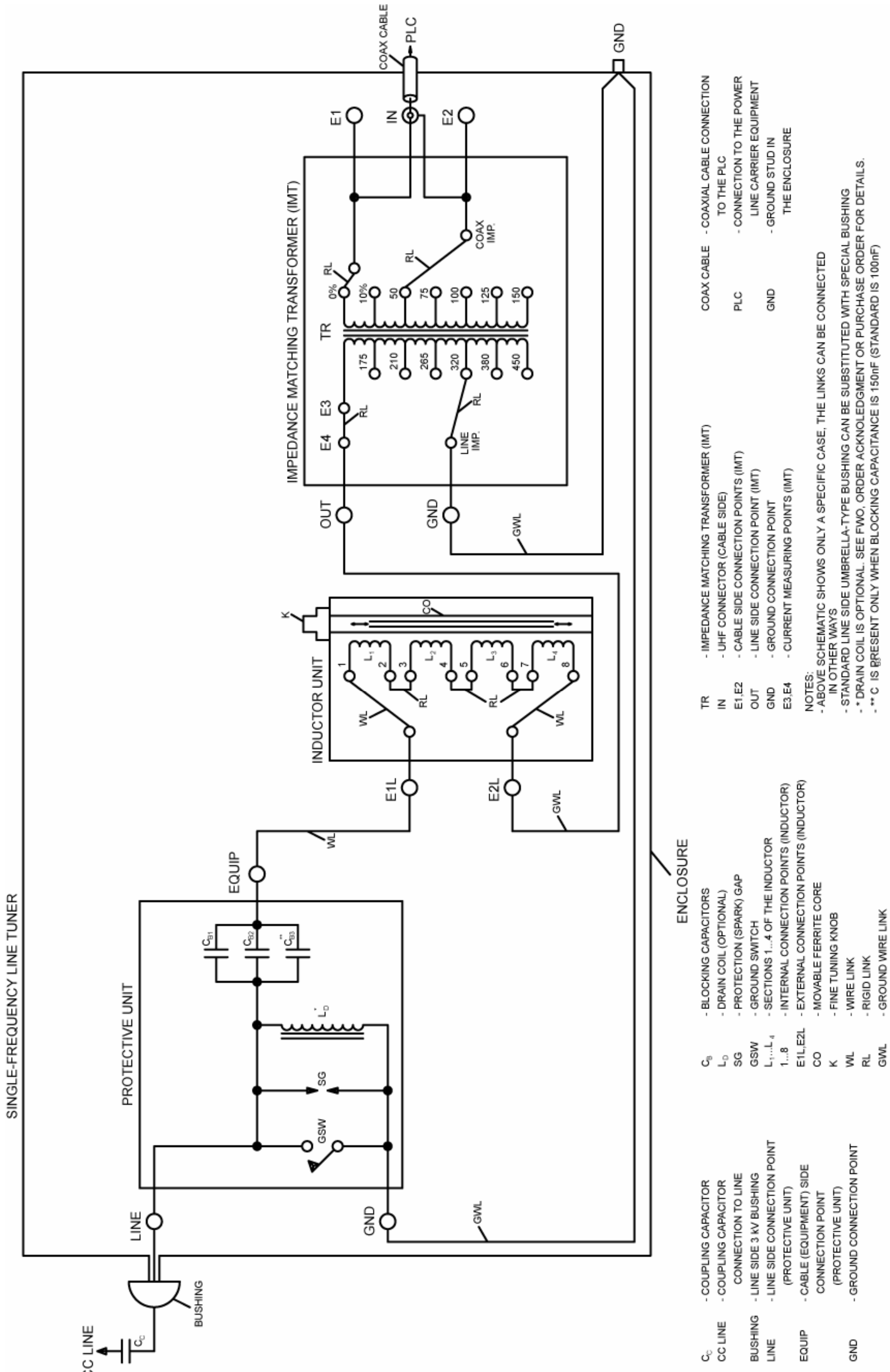
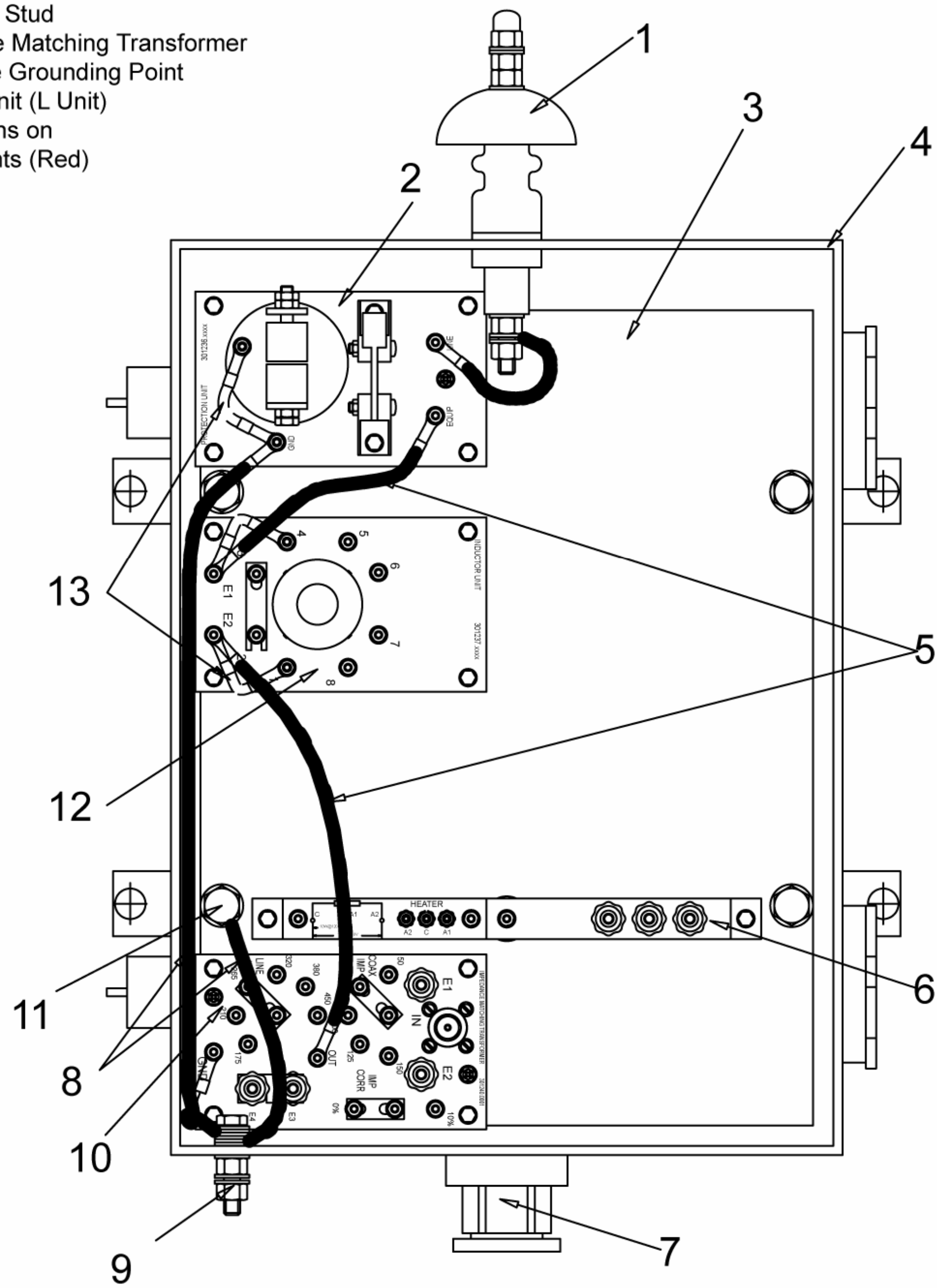


Figure 7 – Complete Unit Schematic

1. Line Side Bushing
2. Protection Unit
3. Base Plate, Aluminum
4. Enclosure, Aluminum
5. Connections Between Components (Yellow)
6. Heater (120/240 VAC)
7. 1.5” Conduit Hub For Coax Cable
8. Ground Leads (Black)
9. Grounding Stud
10. Impedance Matching Transformer
11. Base Plate Grounding Point
12. Inductor Unit (L Unit)
13. Connections on
Components (Red)



Connections on Components Mayl Change Depending on Tuning Settings
Connections Between Components Will Not Change

Figure 8 – Complete Unit Layout

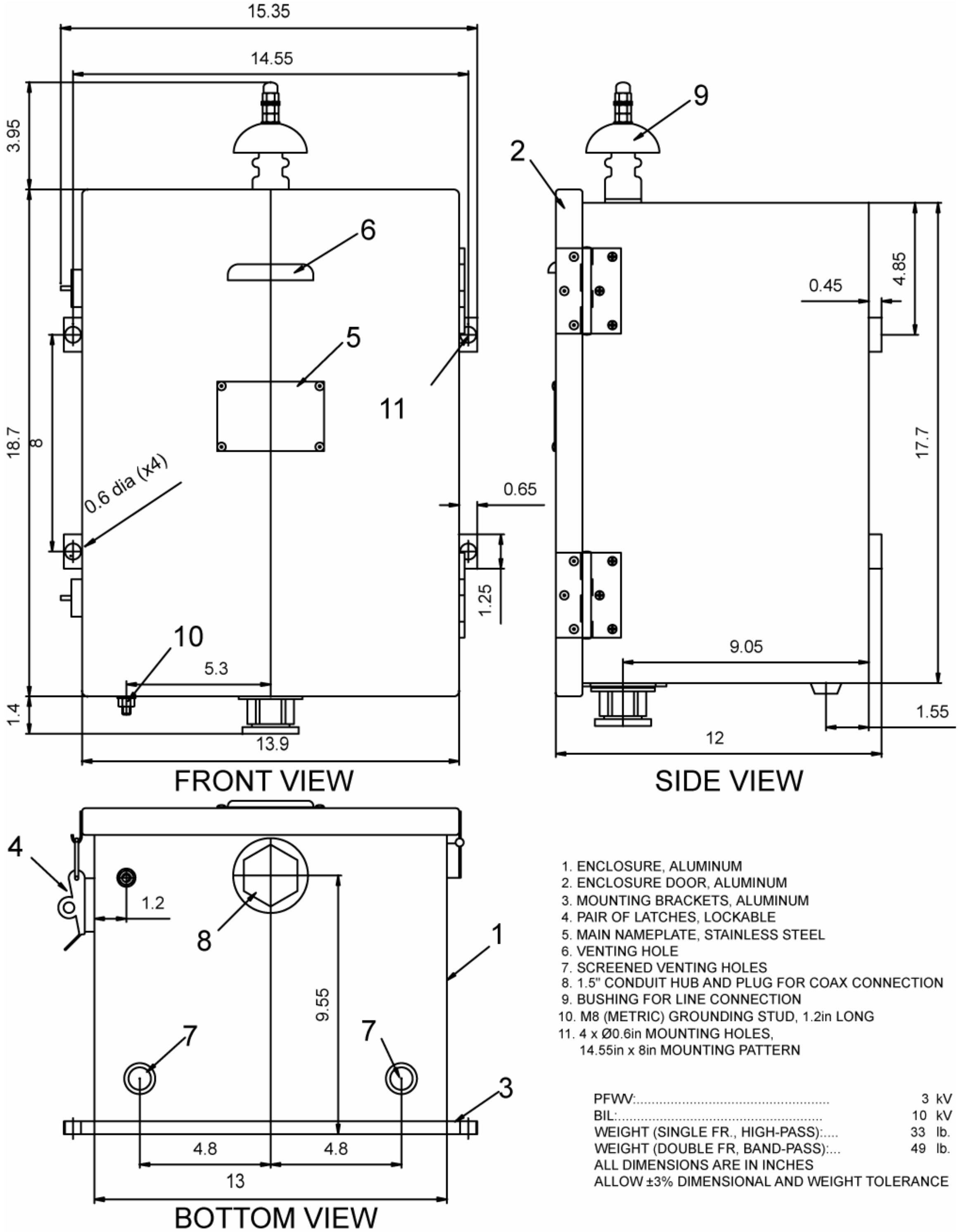


Figure 9 – Line Tuner Outline