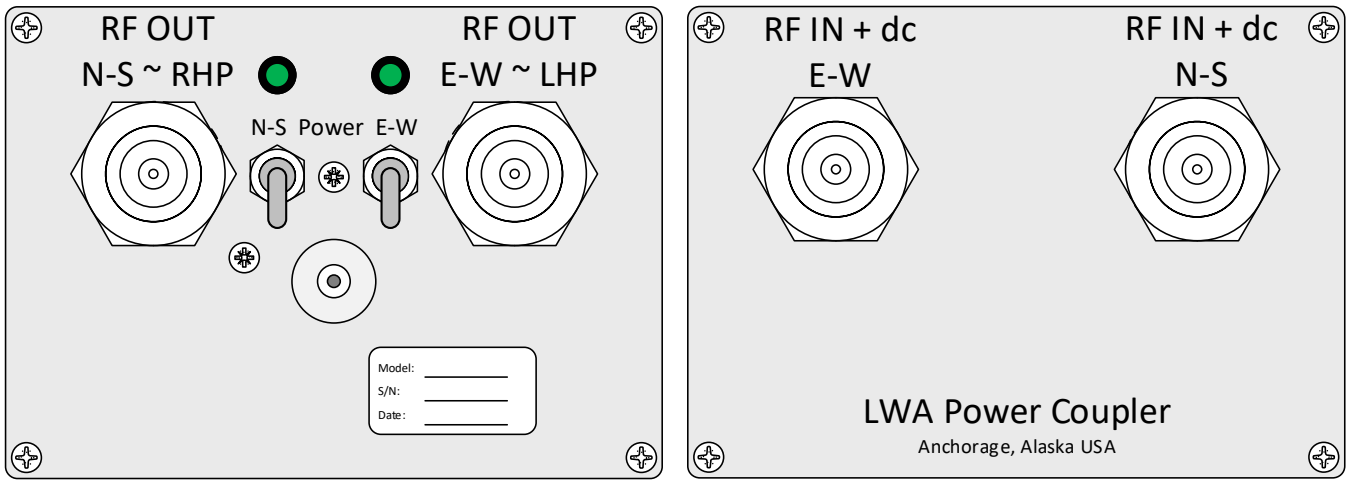
# Long Wavelength Array Power Coupler Installation and Operation

## 1. Description

The LWA Power Coupler (LWAPC) provides power to the active balun assembly in the Long Wavelength Array crossed-dipole antenna through the coaxial transmission lines. The LWAPC has two identical RF circuits and is inserted between the antenna assembly and the receivers. It optionally provides a quadrature coupler for discrimination of circular polarizations received by the linearly polarized crossed-dipoles. The LWAPC uses high-quality commercial RF modules and has the same form factor as the Callisto instrument. Two versions are available, the LWAPC-Q with a quadrature coupler, and LWAPC without a coupler. In the following, "LWAPC" refers to both models unless specifically indicated.

The LWAPC panel layouts are shown below. The front panel (left) has an input connector for power (2.1 x 5.5 mm coaxial jack) and connectors for RF to the receiver system (type N-female). If the optional quadrature coupler is not equipped (LWAPC), the RF outputs are from each of the north-south and east-west dipoles. If the optional quadrature coupler is equipped (LWAPC-Q), the outputs are right-hand and left-hand circular polarizations. The front panel also includes two power switches and LED power indicators, one for each dipole. The rear panel (right) has connectors for the RF input and dc power to the LWA antenna assembly, one for each dipole (type N-female).



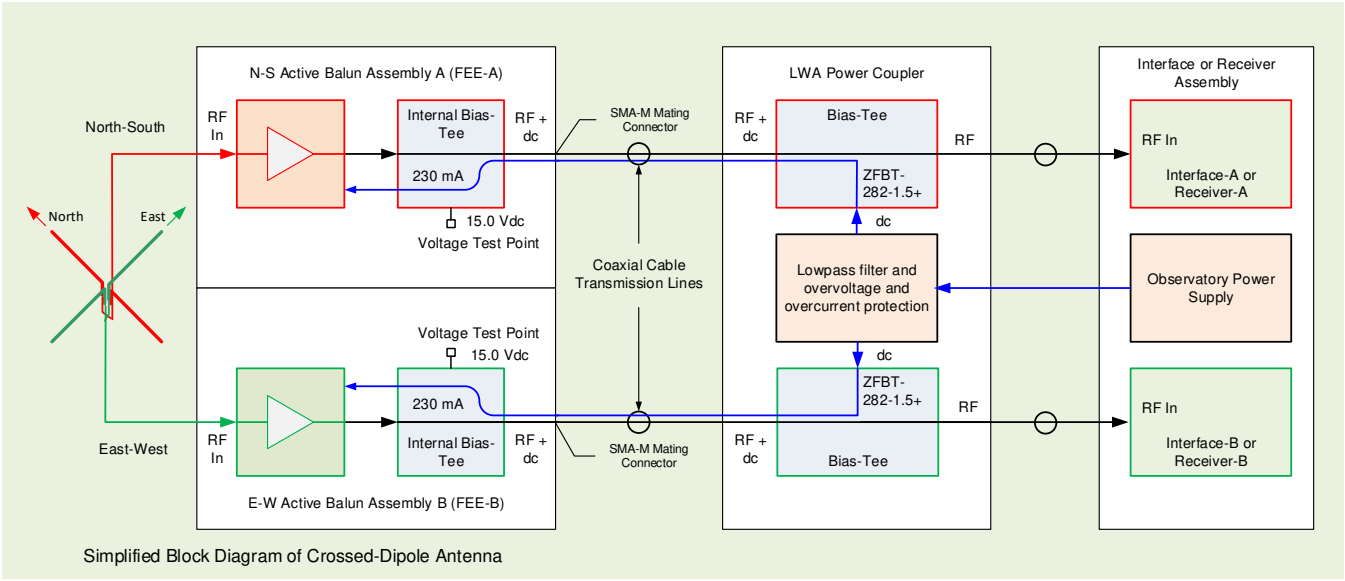

Specifications LWAPC-Q (with Quadrature Coupler) (all values nominal)

- RF input and output frequency range: 10 to 100 MHz
- RF input and output connector: Type N-female
- Insertion loss: 3.0 +2.5/–0.5 dB
- Isolation, bias-tee dc port to RF ports: ≥ 50 dB (determined by bias-tee)
- Isolation, RF IN N-S to RF IN E-W: Provisional ≥ 20 dB
- Isolation, RF OUT N-S ~ RHP to RF OUT E-W ~ LHP: Provisional ≥ 20 dB
- Return loss, RF IN: Provisional ≥ 20 dB
- Return loss, RF OUT: Provisional ≥ 20 dB
- Phase shift, RF OUT N-S ~ RHP to RF OUT E-W ~ LHP: Provisional 90 ± 3°
- Input voltage: 15 to 17 Vdc
- Input current: 500 mA maximum
- Input power connector: 2.1x5.5 mm coaxial jack (center positive +)
- Dimensions: 168 mm long x 110 mm wide x 79 mm high
- Weight: 1 kg

Specifications LWAPC (without Quadrature Coupler) (all values nominal)

- RF input and output frequency range: 10 to 100 MHz
- RF input and output connector: Type N-female
- Insertion loss: ≤ 1.0 dB
- Isolation, bias-tee dc port to RF ports: ≥ 50 dB (determined by bias-tee)
- Return loss, RF IN: Provisional ≥ 20 dB
- Return loss, RF OUT: Provisional ≥ 20 dB
- Input voltage: 15 to 17 Vdc
- Input current: 500 mA maximum
- Input power connector: 2.1x5.5 mm coaxial jack (center positive +)
- Dimensions: 168 mm long x 110 mm wide x 79 mm high
- Weight: 1 kg

The basic configuration is shown below (optional quadrature coupler not equipped).




Simplified Block Diagram of Crossed-Dipole Antenna

## 2. Installation

Equipment location

The LWA Power Coupler should be placed in an indoor environmentally controlled location with a reliable source of power. It is recommended that the LWAPC be collocated with the receivers and connected to them with short coaxial jumper cables. The LWA antenna system uses sensitive electronic circuits and it is imperative that proper electrostatic discharge (ESD) practices be used whenever handling, connecting or disconnecting anything associated with it.

Power supply

The power supply used with the LWAPC should have a regulated output, be high quality and electrically quiet with low ripple. The power supply dc output must be isolated from its ac input, and it is recommended that the ac input be 3-wire grounded type. The negative terminal of the LWAPC dc input jack is bonded to the LWAPC enclosure. All power supplies and test equipment used with the LWA antenna system, such as oscilloscopes, signal generators and multimeters, must use a common ground system.

To minimize noise conduction to and from the power supply, it is recommended that ferrite beads be placed on the power supply lead at both the LWAPC end and power supply end. Clamshell beads will allow several windings of the power leads to be wrapped around the cores. The power connector on the converter is a 2.1 x 5.5 mm coaxial jack, center positive +.

It is recommended that the power supply be rated 1000 mA at the required output voltage. The power supply output voltage (LWAPC input voltage) must be high enough to provide 15.0 Vdc at the active balun assembly voltage test point while compensating for the voltage drops in the coaxial cable transmission line and bias-tee and power components in the LWAPC. The power supply output regulation should be able to prevent the output voltage from falling below the desire value under all anticipated input and output conditions.

Note that the requirement for 15.0 V at the active balun voltage test point provides about 1.2 V margin for the active balun circuitry. The margin decreases slightly with decreasing temperature. As demonstrated below, because of the margin built into the active balun, using a power supply voltage of 15.0 Vdc may be adequate for most situations.

Example voltage drop calculations

The LWAPC power circuits include an inductor with 0.152 ohms maximum dc resistance. This inductor serves both power circuits, and the maximum current through it is nominal 480 mA, giving 0.07 V voltage drop. The individual power circuits carry a maximum current of 230 mA (no LED on PCB) or 250 mA (LED on PCB). The nominal dc resistance of each bias-tee is 0.5 ohm; therefore, the bias-tee voltage drop can be as high as 0.13 V. The resettable fuse in each power circuit has a maximum 0.77 ohm dc resistance, giving 0.19 V voltage drop. Therefore, the total voltage drop in each power circuit, not including the transmission line, is 0.07 + 0.13 + 0.19 = 0.39 V.

Assuming Times Microwave LMR-400 coaxial cable (10 mm outside diameter), the dc resistance of the center conductor is 0.0046 ohm/m and the shield is 0.0054 ohm/m, giving a total loop resistance of 0.01 ohm/m. If the cable is 100 m long the total dc resistance in the cable is 1.00 ohm, and the total voltage drop in the cable is 0.23

V. The total of all voltage drops including the LWAPC and cable is 0.39 + 0.23 = 0.62 V. With 10% additional margin (0.06 V), the required LWAPC input voltage to provide 15.0 V at the active balun voltage test point is 15.0 + 0.68 = 15.7 V. With this example configuration and to provide a 1.2 V margin at the active balun assembly, the input voltage at the LWAPC should be at least 15.7 V. If the power supply is set to 15.0 V, the margin at the active balun drops from 1.2 V to 0.5 V.

Coaxial cables and connectors

The RF connectors and cables between the LWA antenna assembly and the LWA Power Coupler must be the highest possible quality. Recommended cables have ≥ 5 mm diameter and 50 ohms impedance. Because of the relatively high gain and low noise figure of the active balun (approximately 35 dB and 2.9 dB, respectively), the cable length is not a critical parameter except where very long (> 200 m). For example, assuming 100 m of LMR-400 cable, the loss at 90 MHz will be 4 dB and the net system gain will be 31 dB. There will be no significant degradation of the noise figure.

The LWA antenna has a dual active balun assembly with SMA-F connectors. One of the connectors is marked N-S (North-South) and the other is unmarked (E-W or East-West). To reduce stress on the connectors, it is recommended that a short flexible jumper cable be used to connect the active balun assembly to the main coaxial cable if the main cable is larger than 6 mm diameter. This jumper should have an SMA-M connector on one end and N-F connector on the other end. See **section 4, External Cabling Diagram**.

Surge protection:

The LWAPC is designed for an indoor environment and does not have lightning protection (surge protection device, SPD) on its RF input ports. Therefore, it is necessary to provide lightning protection at the point where the coaxial cables from the outdoor antenna enter the building or enclosure in which the LWAPC is installed. The lightning protectors must be bonded to an earth electrode grounding system as required by local practices. Grounding (earthing) guidance may be found in the Motorola R56 document ***Standards and Guidelines for Communication Sites*** [Motorola].

**CAUTION:**
**READ AND UNDERSTAND BEFORE MAKING ANY CABLE CONNECTIONS. IF PROCEDURES ARE NOT FOLLOWED, DAMAGE MAY RESULT**

Coaxial cable connections

Coaxial cables can build up a static charge that, if allowed to discharge by connecting to equipment, may damage sensitive circuits. To avoid such damage, it is recommended that static charges be dissipated by momentarily shorting the cable connector center pin and shield before connecting to the LWA Power Coupler. This should be done carefully to avoid damaging the connector center pin. Never short the RF IN+dc port of the LWAPC. DO NOT apply power until all connections are made.

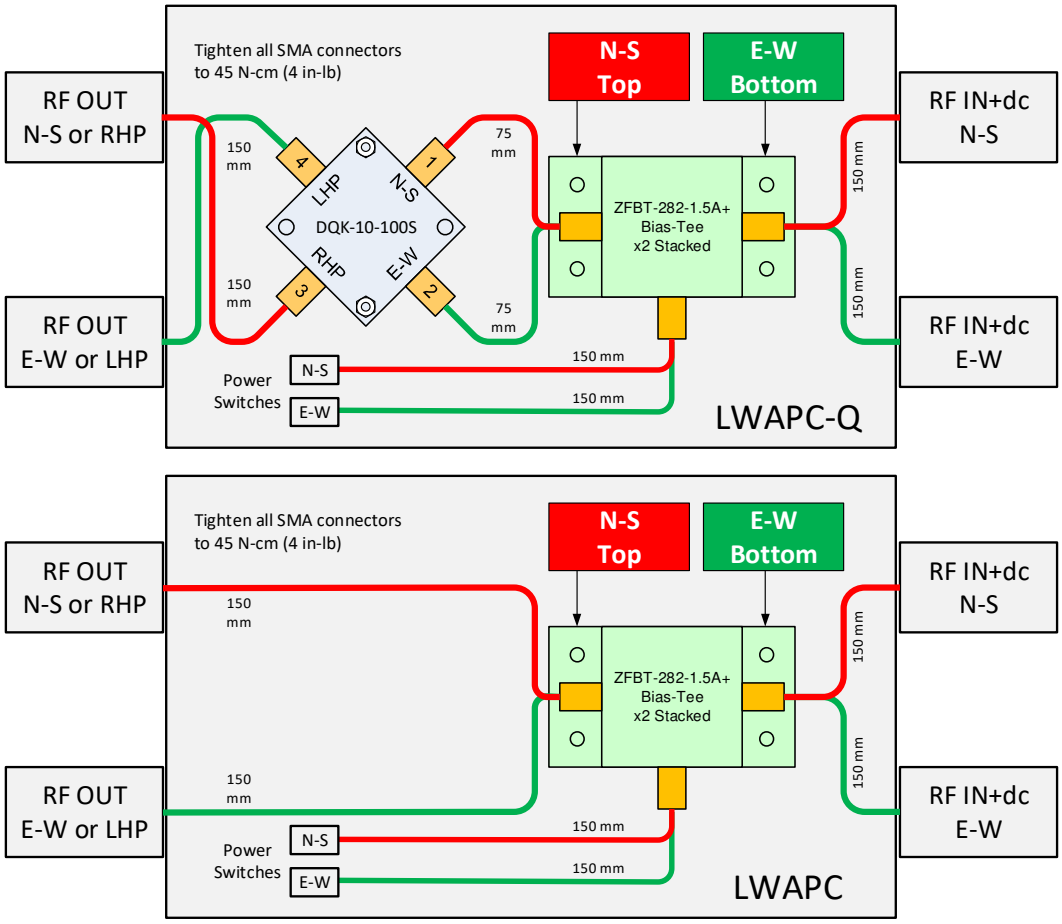
**Connection sequence**: The recommended connection sequence for the coaxial cables between the LWA antenna assembly and the LWAPC and the power is:

a. Start with all coaxial cables disconnected from the antenna and LWAPC, both LWAPC power switches in the OFF (down) position and the dc power supply disconnected from its ac power source and the LWAPC;
b. Provide a means to bond the LWAPC to an earth grounding electrode system. This bond may be provided through a coaxial cable shield and a bonded lightning arrestor assembly;
c. At the LWA antenna assembly, short the coaxial cable center conductor to its shield to discharge any static build-up and then connect to the antenna assembly
d. At the LWAPC, ensure the shield of the coaxial cable from the antenna is bonded to the earth electrode system. Now, short the cable center conductor to its shield to discharge any static build-up and then connect to the LWAPC;
e. Plug the power supply output cable connector into the LWAPC coaxial dc power input jack;
f. Connect the power supply to its ac power source;
g. Apply power to the antenna system by moving the LWAPC power switches to the ON (up) position.

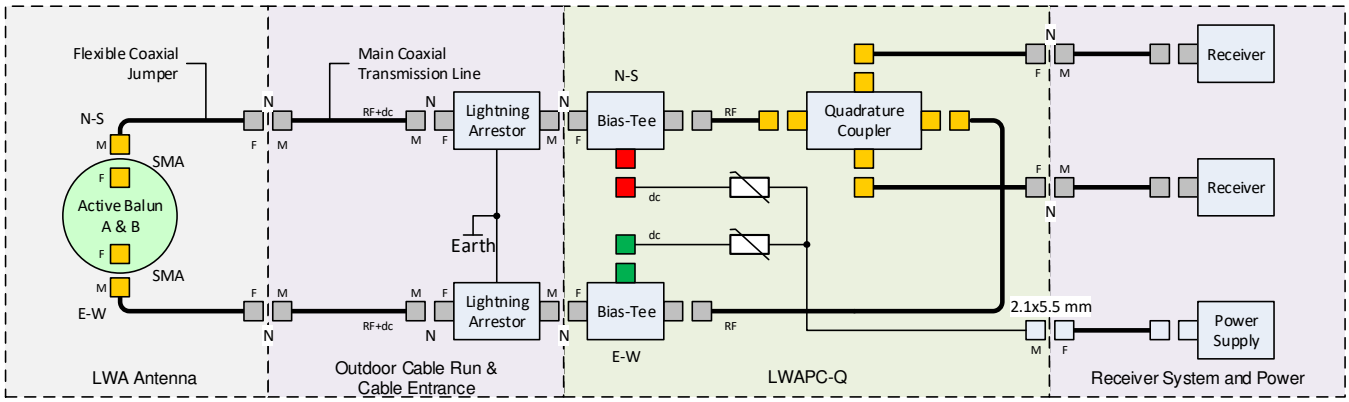
**Disconnection sequence**: The recommended disconnection sequence is the reverse of the above procedure:

a. Remove power to the antenna system by moving the LWAPC power switches to the OFF (down) position.
b. Disconnect the power supply from its ac power source;
c. Unplug the power supply output cable connector from the LWAPC coaxial dc power input jack;
d. Disconnect the coaxial cable from the LWAPC;
e. Disconnect the coaxial cable from the antenna assembly

## 3. Internal Cabling Diagram



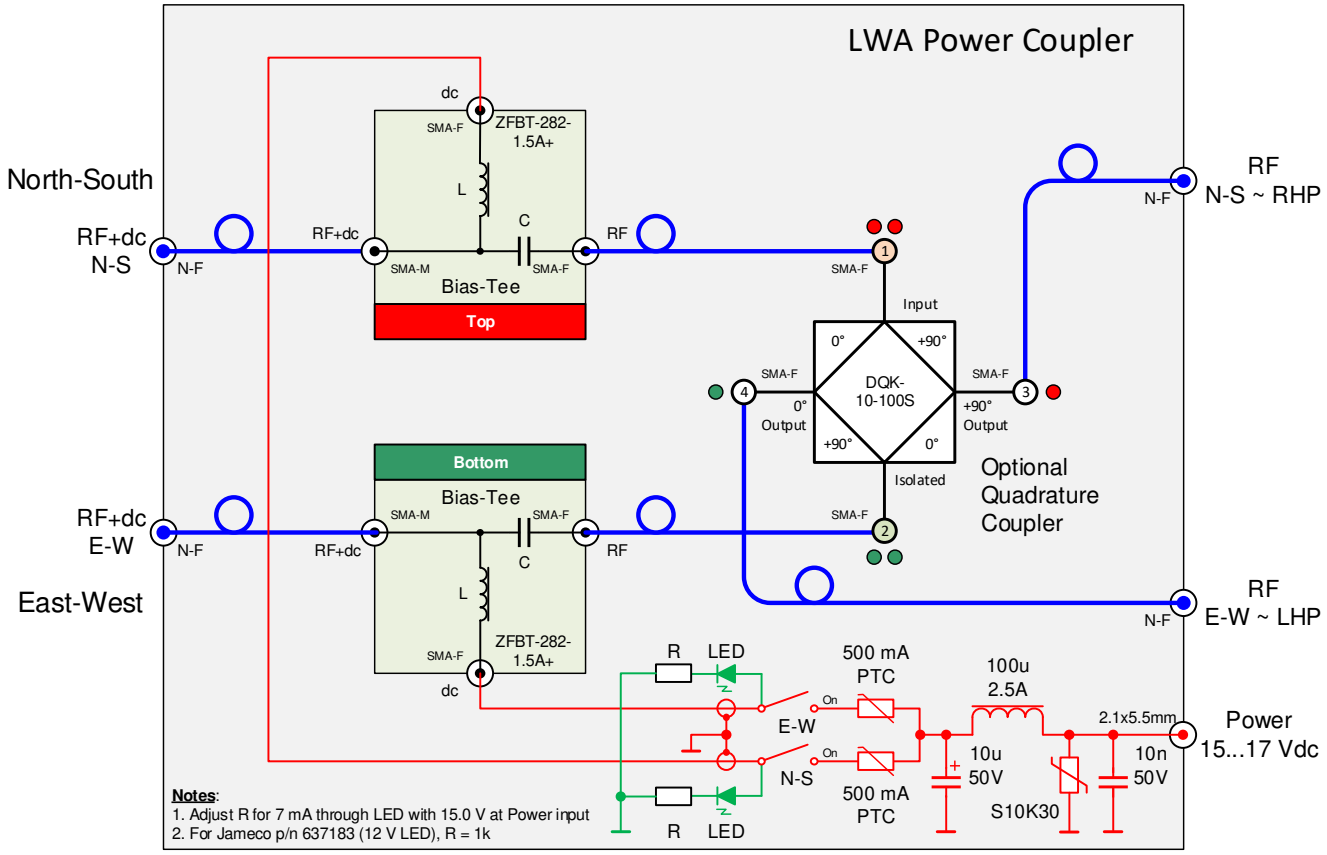

## 4. External Cabling Diagram



## 5. Circuit Description

The LWAPC consists of two identical circuits sharing a power input filter. Input power is first protected from overvoltage by a metal oxide varistor and then filtered by a lowpass filter. The LWAPC does not include input voltage polarity protection because that function is provided on each active balun. Filtered dc is fed to on-off switches through resettable fuses, one for each of the active baluns. Green LEDs indicate power state. Power is fed to each bias-tee through its dc port where it is coupled to the RF +dc port through an internal inductor for RF isolation.

The RF from each active balun connects to the RF + dc port of the bias-tee where it is coupled to the RF port by an internal capacitor. The bias-tee insertion loss is ≤ 0.5 dB throughout the LWA antenna frequency range. An optional quadrature coupler provides the necessary phase shift to derive right-hand and left-hand circular polarizations from the linear polarizations of the crossed-dipoles. The quadrature coupler introduces a nominal 3.5 dB insertion loss on each output.



## 6. Operation and Maintenance

Operation:
All RF connections should be made to the LWAPC, LWA antenna assembly and receivers before the power supply is connected and turned on. Refer to Sect. 2 for recommendations for connecting the coaxial cables.

Power is applied independently to each dipole circuit (N-S and E-W) by toggling each switch on the front panel to the UP position. Power is removed by moving each toggle to the DOWN position.

After the LWAPC has been in operation and if the coaxial cables need to be disconnected, the power switch for the affected circuit should be turned off before disconnecting the coaxial cables.

Caution: Any unused RF Output port should be terminated with a 50 ohm resistor termination rated ≥ 0.5 W and at least 10 to 100 MHz. RF Input ports carry both dc and RF and should be connected to the antenna. If one of the ports is not connected, the internal power supply for that port should be turned Off.

Maintenance:
The LWAPC requires very little periodic maintenance. LWAPC maintenance described below should be performed when performing regular maintenance on the associated receivers.

A. Monthly Preventative Maintenance
   - ☼ Brush dust off the LWAPC being careful to not disturb the connections
   - ☼ If additional cleaning of the LWAPC enclosure is required, use a damp cloth; DO NOT use any chemicals

B. Annual Preventative Maintenance
   - ☼ Check power supply voltage at active balun assembly voltage test point in the antenna, 15.0 Vdc

C. Internal RF Connections
   - ☼ If internal RF connectors are loose or removed and replaced, torque them to 45 N-cm (4 in-lb)

D. Enclosure cover
   There is no need to remove the enclosure top cover during normal maintenance; however, if it is removed, follow these steps:
   a. DO NOT skip this step: Turn off both power switches, turn off power supply and remove coaxial power plug from LWAPC.
   b. Remove the four screws in the upper corners of the enclosure end panels and carefully remove the top cover
   c. To reinstall the top cover: Note that the lower edges of the cover are offset. Align them with the lower enclosure. Insert a screw into one corner of an end panel and line up with the enclosure top. Slowly turn CCW until a click is heard, then slowly turn CW until the screw is almost fully seated. Repeat for the screws in the three other corners. When all four screws are almost seated, tighten them until snug. Do not over-tighten

## 7. References

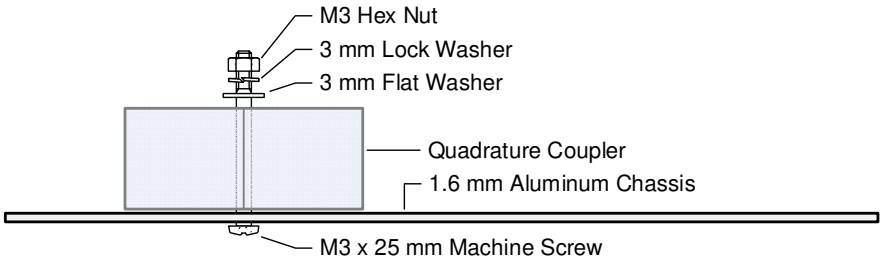
[Motorola] Standards and Guidelines for Communication Sites, Document R56, 68P81089E50-B, Motorola, 2005

## 8. Quadrature coupler installation for conversion of LWAPC to LWAPC-Q

If the LWAPC originally was purchased without the quadrature coupler and one is to be installed, follow these instructions while referring to the internal cabling diagram:

a. DO NOT skip this step: Turn off both power switches, turn off power supply and remove coaxial power plug from LWAPC
b. Carefully remove the LWAPC top cover by removing the four self-threading screws in the upper corners of the front and rear end panels
c. Remove the coaxial cables from the RF ports of the two bias-tees. Mark these cables with a piece of tape indicating upper or lower bias-tee (note: The bias-tees and connectors in some units may have red and green painted marks; if so, red = N-S and green = E-W)
d. Remove the coaxial cables from the RF+dc ports of the two bias-tees. Mark these cables with a piece of tape indicating upper or lower bias-tee
e. Remove the coaxial power cables from the front panel to the dc port of the two bias-tees. Mark these cables with a piece of tape indicating upper or lower bias-tee
f. Remove the two self-threading screws in the lower corners of the rear end panel
g. Carefully slide the chassis out of the enclosure
h. Mount the quadrature coupler with the hardware provided as follows (see drawing below): Insert the two M3x25 mm screws through the chassis from the bottom and through the coupler. Be sure the coupler is oriented as shown. Install a flat washer, split lock washer and hex nut on each screw and tighten until snug. Do not over-tighten
i. When connecting the SMA connectors in the following steps, tighten them to 45 N-cm (4 in-lb) torque
j. Install a 75 mm jumper cable on each bias-tee RF port and connect to the coupler as shown. Do not tighten the connectors until both ends are finger-tight. It may be necessary to twist the connectors for alignment; do this carefully and slowly
k. Carefully slide the chassis back into the enclosure
l. Reinstall the coaxial cables from the front panel to the RF+dc ports of the two bias-tees being sure to connect the correct port
m. Install the coaxial cables from rear panel RF ports to the quadrature coupler being sure to connect the correct port
n. Reinstall the rear end panel using the two screws removed above. Insert a screw into one corner of an end panel. Slowly turn CCW until a click is heard, then slowly turn CW until the screw is almost fully seated. Repeat for the screw in the other corner. When both screws are almost seated, tighten them until snug. Do not over-tighten
o. Check all cable connections
p. Reinstall the top cover. Note that the lower edges of the top cover are offset. Align them with the lower enclosure. Insert a screw into one corner of an end panel and line up with the enclosure top corner. Slowly turn CCW until a click is heard, then slowly turn CW until the screw is almost fully seated. Repeat for the screws in the three other corners. When all four screws are almost seated, tighten them until snug. Do not over-tighten

Side View


M3 Hex Nut
3 mm Lock Washer
3 mm Flat Washer
Quadrature Coupler
1.6 mm Aluminum Chassis
M3 x 25 mm Machine Screw

**Document information**

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Revision:
- 0.0 (Original draft started, 13 Aug 2014)
- 0.1 (Added protection and power supply details, 17 Aug 2014)
- 0.2 (Cleaned up prior to distribution, 20 Aug 2014)
- 1.0 (Distribution, 23 Aug 2014)
- 1.1 (Additional specifications and static warning, 25 Aug 2014)
- 1.2 (Added coax connection sequence, 26 Aug 2014)
- 1.3 (Updated specs, 27 Aug 2014)
- 1.4 (Numerous additions and changes, 14 Oct 2014)
- 1.5 (Minor addition, 23 Oct 2014)
- 1.6 (Added caution in sect. 6, 17 Dec 2015)
- 1.7 (Added cautions concerning cable connection and power, 11 Dec 2016)
- 1.8 (Revised voltage drop calculations for new inductor, 22 Feb 2019)