LWA Front End Electronics Repair Guide
Ver 1.1

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1 Introduction

The front end electronics (FEE) board acts as the receiver for the two polarizations on each LWA stand. For details of the V1.8 design see Ray et al. (2009; LWA Memo 191). These can be damaged by a variety of sources such as lightning, rodents, or components fail from other unknown sources. FEEs are returned to the lab from deployment primarily as a result of station health checks flagging their spectra on one, or both polarizations as irregular. Thus, it is the job of the reader to analyze and diagnose errors in FEE performance, then repair them to working order. As a supplement to aid in these repairs the LWA FEE Ver. 1.7 documentation has been appended to the end of this memo.

Testing of FEEs that return from the site is done using the LWA FEE Test Fixture, a power supply, and a spectrum analyzer. The diagram in Figure 1 shows how to set up the testing environment for assessing the spectral response of an FEE. Input voltage is supplied by a tabletop power supply fed into a bias tee, while a broadband radio signal (RF In) is supplied by a spectrum analyzer passing through the FEE board pathway, and its response re-entering the spectrum analyzer via the bias tee connection (RF Out).

2 Order of Operations

To start the diagnosis and repair of a front end, set up a work station according to the diagrams in Figure 1 and 2. The spectrum analyzer should be set at a center frequency of about 100 MHz with a span of 200 MHz to completely cover the science band of the LWA. Next, it is important to calibrate the spectrum analyzer to ensure the test fixture supplies accurate information of FEE performance before, during, and after repairs. Start by removing all attenuators on the RF output from the spectrum analyzer and reconnect the cable without attenuation. Next disconnect the two SMA-cables from the test fixture and connect them together using a female-female SMA adapter, this would be the 'THROUGH' orientation of the system. Proceed through the magnitude transmission calibration instructions on

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the spectrum analyzer, using the corresponding 'LOAD'-'SHORT'-'OPEN' calibration tee. Once you have calibrated your system reconnect the SMA cables back to the test fixture (ensuring they are not accidentally swapped), and reinsert your attenuation onto the output RF terminal on the spectrum analyzer. LWA FEEs have approximately 36 dB of gain, so using between 36-50 dB of attenuation is required to avoid further damage to FEEs. Also, in order to prevent possible damage, set the current limit of the power supply to just over 0.25 Amps. To do this, adjust the current limit of the power supply while testing the control board just until it switches from CC, constant current, to CV, constant voltage, mode.

NOTE: Ensure that the power supply is OFF when connecting and disconnecting FEEs from the test fixture at all times.

The following order of operations is generally applicable to most cases.

1. Clean the board using a toothbrush, microfiber towel, and isopropyl alcohol. Next inspect the board for obvious signs of damage to component casings, bad solder connections, or indications of burns on the board.

2. Place FEE into test apparatus being careful not to force the board onto the screws if the fit is snug. Screws are easy to bend slightly for better fit, destroyed FEE terminals are not so easy to fix.

3. Power the board then inspect the band-pass response on a spectrum analyzer to check for irregularities. You may reference the response by comparing to Figure 3., or by first placing the 'Control Board' on the fixture and saving the response in Trace Memory on the spectrum analyzer.

4. Different wave forms may indicate a variety of components errors.

   4.1 If the general shape of an FEE response is correct, but not at the correct dB level, it may be a single amplifier is bad.

   4.2 If the shape is steady, but randomly shows drops in power, it may be a capacitor problem (a capacitor discharging earlier than it should).

   4.3 If there is no response, this is likely a problem with the Voltage Regulator (U3), the amplifiers (U1, U2, U4), or both.

5. Whatever the shape, if it does not match the control board included as a part of the repair kit, one or more components must be replaced. The easiest way to do this, as mentioned in the Introduction, is to measure the resistance of various components using a digital multimeter. Then comparing the values read across components to either the included table, or the control board values.

6. One of the easiest checks is diode D1, next to the voltage regulator; it should read $\sim 1000\Omega$. If it is broken, it will likely read close to $\sim 10\Omega$.

   6.1 If it reads somewhere below 1000Ω, but well above 10Ω (say 800Ω), it may still be fine. Try proceeding to further steps and returning to this step after checking the other components outlined here.

6.2 Note that it is important that D1 is in good working order, or assumed to be based on the impedance, to avoid potentially damaging other parts down the line in power cycling the boards.

7. Arguably the most common parts that fail are the amplifiers; the Gali-74s (U1, U2) should have matching impedance measures of $\sim 700\Omega$, and the Gali-6s (U4) should read $\sim 300\Omega$.

   7.1 A good starting place is to check the impedance of all 3 amplifiers on a side, then seeing which parts report incorrect values.

   7.2 If the Gali-74s seem to match, but they are below what they should be, start by replacing the Gali-6.

   7.3 Otherwise replace the parts that report incorrect impedance, checking the board on the test fixture after each new part replaced.

   7.4 NOTE: Amplifiers will register a higher impedance value out of the package than when measured on the board.

8. After replacing those, check the resistance of the Voltage regulator (U3), and replace if need be.

9. Next, check the capacitors nearby the Voltage regulator (C1 and C10), again replacing if need be.

This should fix most of the boards that come back from the field. Approximately 85% of the time (or more) the two amplifiers are to blame, the remaining 15% of repairs cover the voltage regulator, capacitors, small diodes, and inductors. These rough estimates are based on repairing FEEs over the past few years that have returned to the lab from LWA-SV and LWA1.

However, if it does not fix your board, look around the board again for any signs of damage. The small diodes (D2-D5), for example, can get blown dissipating incoming surges and can affect how the board functions. Another rarer problem could be the C11 capacitor next to the Gali-6. Beyond these fixes outlined, if the board is still not functioning as expected you will have to do some sleuthing to find the problem. A good starting place would to checking for poor soldering connections. Solder may not be completely connected (or connected poorly), so try checking that as well as checking for shorts. This would occur where soldered connections may be in contact with other pins on a part, particularly for the amplifiers as they are typically replaced in the lab most often. If you suspect a part may be shorted, but you aren't sure if the solder is actually connecting the 2 pins (connection points), there is a continuity setting on the multimeter that looks like a wavefront. Continuity mode will beep if the two points are connected, you can sanity test this by just touching the probes together. This is especially useful on small pins that require the microscope to solder.

2.1 Summary of Problems and Impedance Table

Common Problems:

- Amplifiers need replacing (Gali-6 and Gali-74)
- Diode D1 needs replacing

Less Common Problems:

- Voltage regulator needs replacing
- Capacitors connected to Voltage regulator need replacing (C1 and C10)

Rare Problems:

- Tiny Diodes need replacing (D2, D3, D4, and D5)
- Capacitor next to Gali-6 needs replacing (C11)
- Inductor (L1 or L2) needs replacing.

LWA FEE Part Repair Table		
Board Designation	**Part Name**	**Impedance (Ω)**
C1	Tantalum Capacitor	500, 500k if measured from ground
C10	Tantalum Capacitor	400
D1	Schottky Diode, 40V 2A	1000
D2-D5	Diodes	270k
U1, U2	Gali-74 MMIC Amp.	700
U3	Voltage Regulator (+)	480k
U4	Gali-6 MMIC Amp.	300
L1, L2	Inductor	7

Table 1: List of components that commonly require repair on returned LWA Front End Electronics and their proper probe impedance values. Impedances listed above are intended to serve as a guide and actual measurements on the board should be given appropriate fudge room. Impedance values are to be measured across the part unless stated otherwise; some will also read as overload if measured the wrong way.

3 Soldering to Fix Components

Replacing components on the FEE board required using the soldering station tools for desoldering broken parts, cleaning the connection points, and soldering a new part. Commonly replaced parts can be found in drawers within the lab (that should be labelled I might add -CAT), and can be identified either by labels on the part itself or in the LWA FEE Version 1.7 documentation. There is no perfectly correct formula for replacing parts on these units, but work will mostly revolve around using a soldering iron, heat gun, tweezers, utility knives, and other small hand tools. Other aids at the soldering station include a microscope for smaller parts, a ring light, a small suction vice, and a special FEE repair stand to stabilize the boards in soldering (asymmetry in SMA connection ports on one side can make them tippy when working on a flat surface). The small sections to follow will provide some tips and tricks compiled by previous LWA FEE repair technicians for commonly replaced parts. Also note that heating FEE components with the heat gun or soldering iron may affect their relative impedance, so allow boards to cool completely before re-evaluating a board after repair. **Please be mindful of where you place your hands and tools when working with heating elements!**

Amplifiers:

1. Place FEE into small vice or FEE table mound. Please do not force the board on to the screw mounts if the fit is tight

2. You can peel back the plastic outer shell of amplifiers using a utility knife and heat gun to access the inside shell. (Note: try not to pull too hard or lever on the outer shell too hard or you may damage the board contact point or nearby components)

3. Next, you can use a soldering iron to heat up the chip underneath the shell and peel it off with a utility knife, tweezers, or a steel probe. It should slide off easily, if not continue to heat the chip for longer.

4. When resoldering, try to keep the amplifier flat against the board. You should only need to solder on the three pins and back grounding.

Voltage Regulator:

1. This will require the heat gun to remove.

2. To solder a new regulator, start by putting the regulator flat against the board, then soldering the three legs.

3. When they are firmly in place, solder the back of the regulator to the big connector. Sometimes it is easiest to place the board vertically in the vice (perpendicular to the table surface), adding a line of solder along the back panel, then soldering it onto the contact point.

Capacitors:

1. These tend to be pretty flush with the connectors, leaving little room to heat up with the soldering tool. However, they generally have a strip of metal running from the bottom of the capacitor up into either end.

2. You can use the soldering tool on these strips to heat up the solder material for removal or connecting.

3. These may also be much easier to unsolder and resolder using the heat gun. If you put a little solder material on the board's connection points, then hold the capacitor in place with the tweezers (the long ones will likely keep your hands safer from the hot air), you can heat gun until the capacitor starts to sink into the solder material. Hold in place for a moment or two after removing the heat gun and the capacitor should be snugly in place.

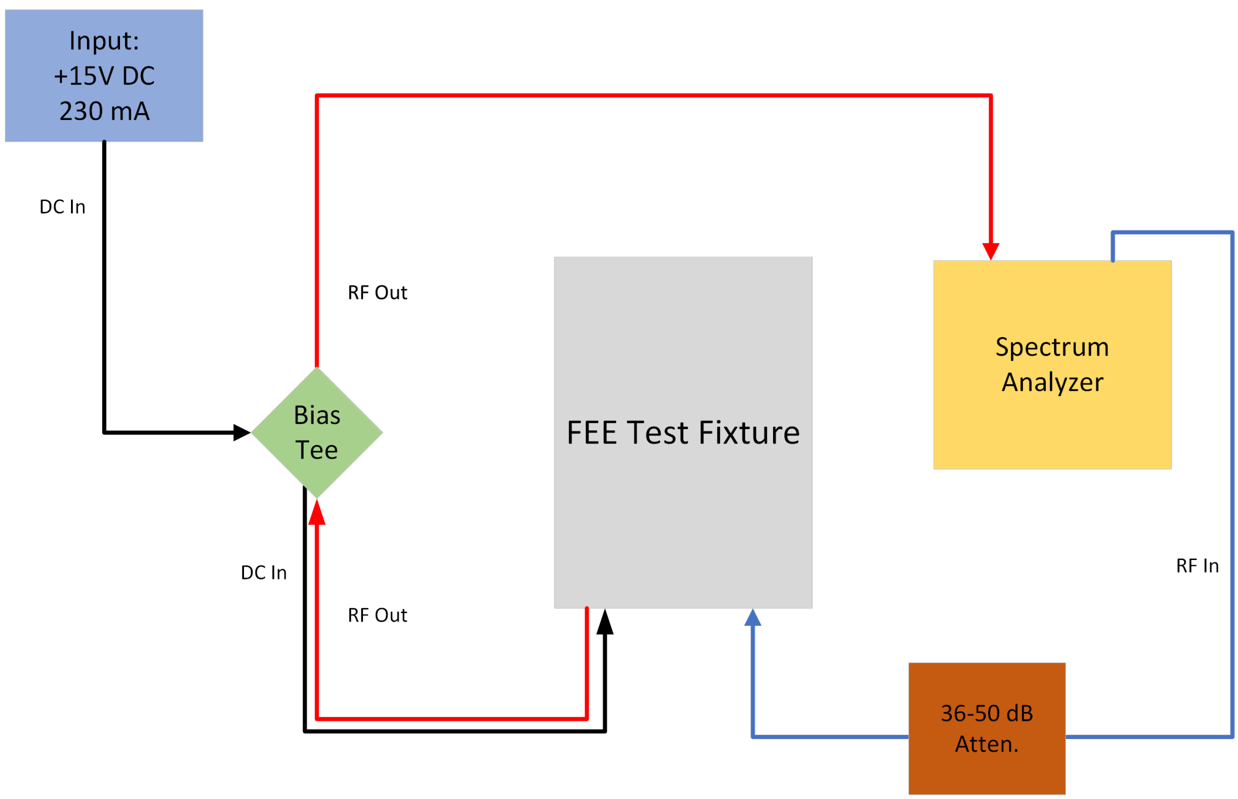

Figure 1: Diagram of LWA FEE Test Fixture and required peripheral diagnostic equipment. Here DC voltage is indicated by black lines, the input signal is on blue lines, and FEE response follow red lines.

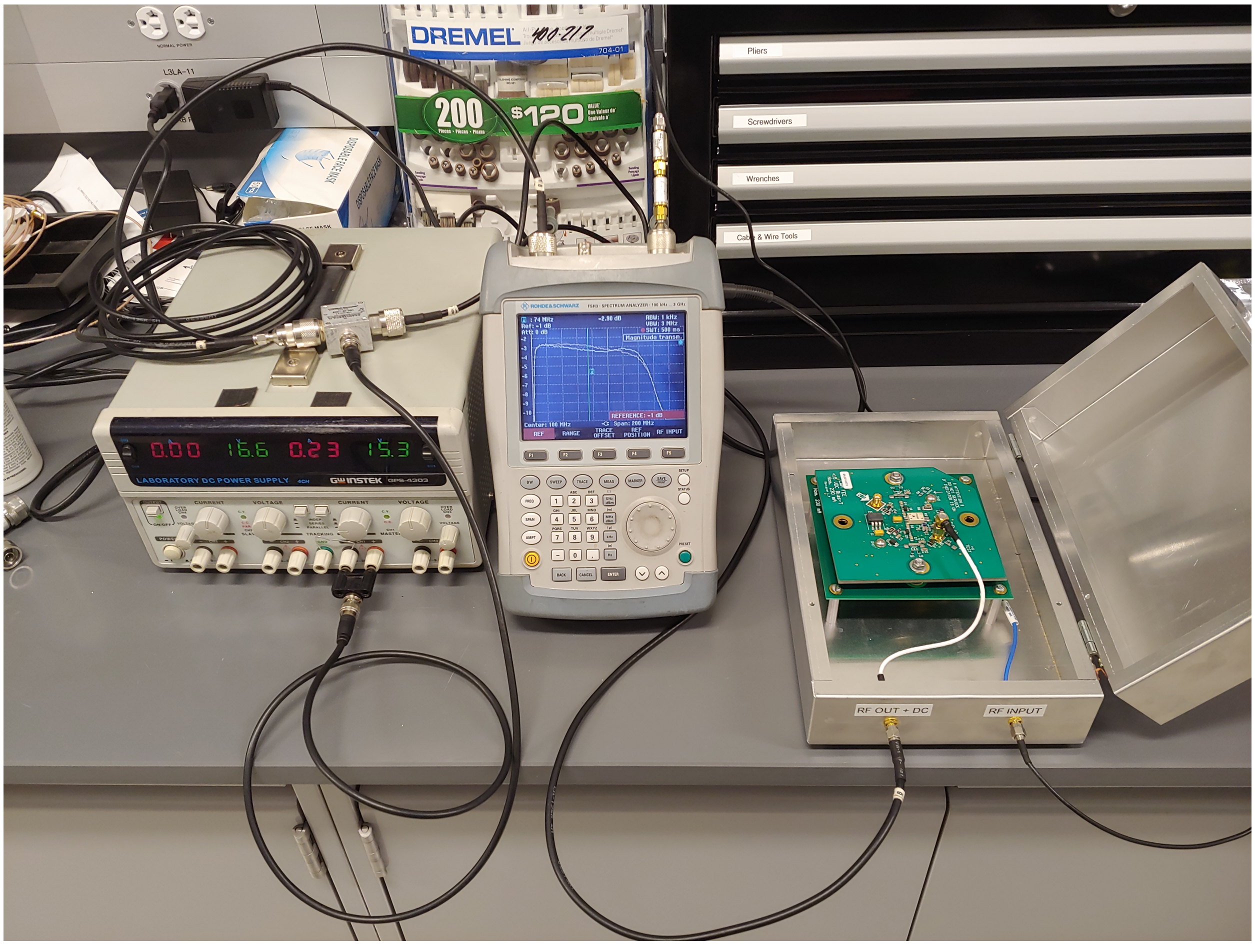

Figure 2: Lab implementation of the diagram seen in Fig 1. Starting on the left is the DC input power supply with bias tee connector sitting on top of it, Spectrum analyzer showing a trace memory bandpass, and on the right is the LWA FEE Test Fixture with the 'Control' board connected. For illustrative purposes the test enclosure is open, howerver in practice the enclosure would be closed to prevent RF-leakage interfering with testing.

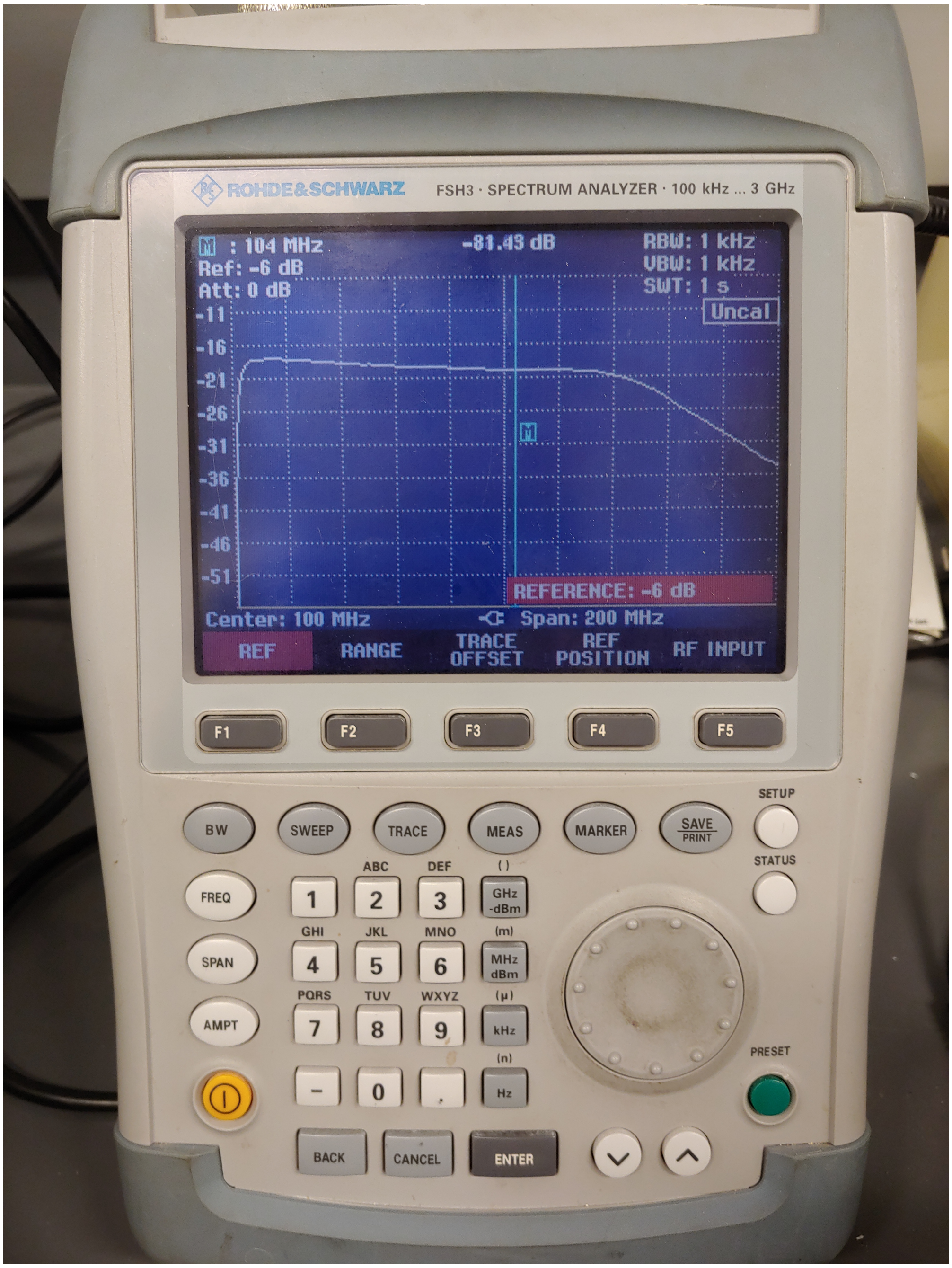

Figure 3: Spectral response of an optimally performing FEE board as measured using the set-up in Fig. 1. Coverage of the LWA FEE bandpass is displayed at a center frequency of 100 MHz with a span of 200 MHz. In this particular case, 47 dB of attenuation is applied between the spectrum analyzer and FEE fixture.

NRL Engineering Memo #FEE0022
Brian Hicks
March 17, 2009

LWA FEE Version 1.7

I. **Introduction**

This document presents a description of version 1.7 of the LWA FEE. An updated schematic, PCB layout, and bill of materials are provided that supersede earlier versions.

II. **Modifications to Circuit Design**

A schematic representing the most recent revision (1.7) of the LWA FEE is given in Figure 1.

An updated bill of materials is presented in Appendix A.

The following changes have been made:

1. L3 has been replaced with a component from Coilcraft (1008PS-472KLB) that is rated for higher current (900mA). The previous part was subject to long availability lead times and was marginally acceptable in terms of current rating. Suspicious failures of the previously specified part were observed.
2. The inductors used in the bias networks (L1, L3, and L4) of the 'Gali' amplifiers have also been changed to a component from Coilcraft (1008CS-472XJLB). The new part is more readily available and less expensive than the previous component ($0.81 versus $0.20, each). A PCB layout change was not required.
3. The diameter of the holes in the feedpoint pads has been changed 0.270" to freely accommodate 1/4-20 studs suggested by Burns Industries.
4. To prevent mixing up polarizations, one polarization (N-S) is now clearly delineated with a white outline and white arrow that will match the white jacket or heat shrink on the cable for that polarization.
5. An LED (D8) has been added to indicate when the FEE is powered. Text has been added to the silkscreen to warn against servicing the FEE when it is powered.
6. The coupling capacitors (C4, C7) at the feedpoints have been changed from 0.1 µF to 1000 pF.
7. Final assembly instructions and manufacturing details for dual polarization FEEs can be found in EM-FEE0023.

III. **PCB Layout**

The revised PCB layout for version 1.7 of the FEE is provided in Figure 2.

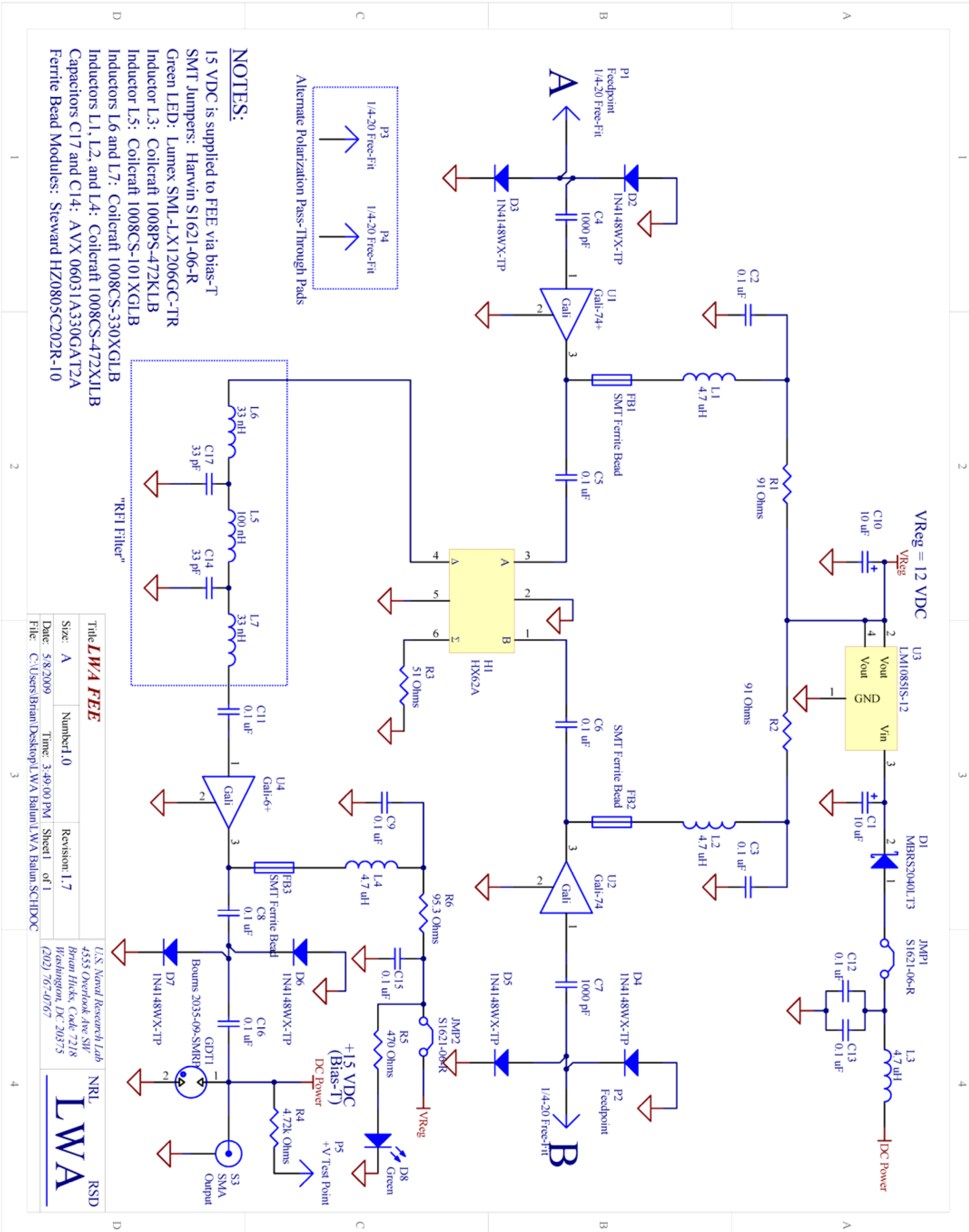

Figure 1 – Updated Schematic of the LWA FEE (Version 1.7)

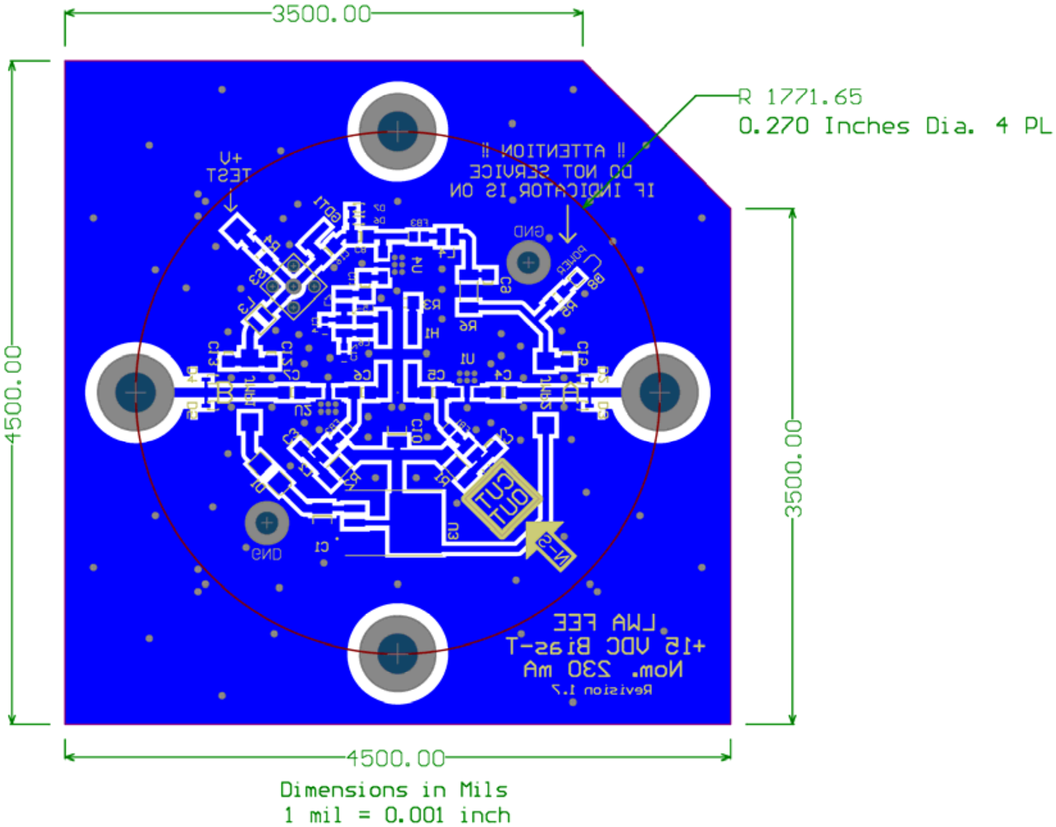

Figure 2a – FEE PCB Layout: Component Side (Version 1.7)

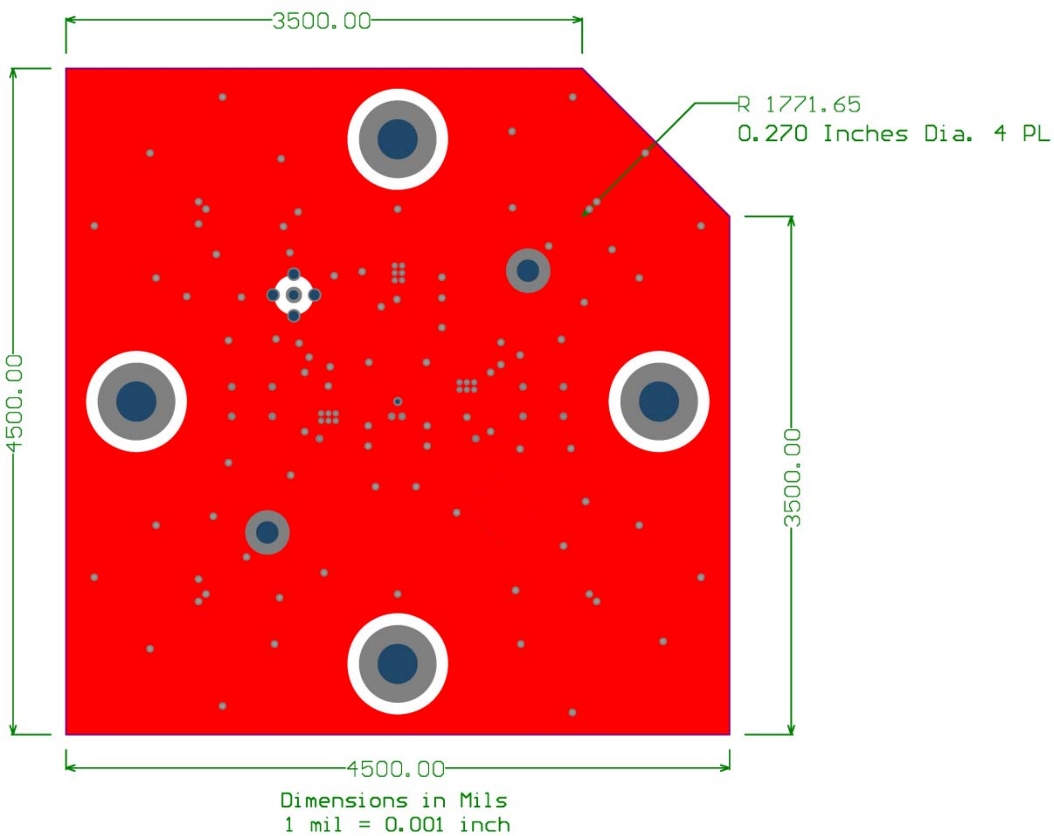

Figure 2b – FEE PCB Layout: Top Side (Version 1.7)

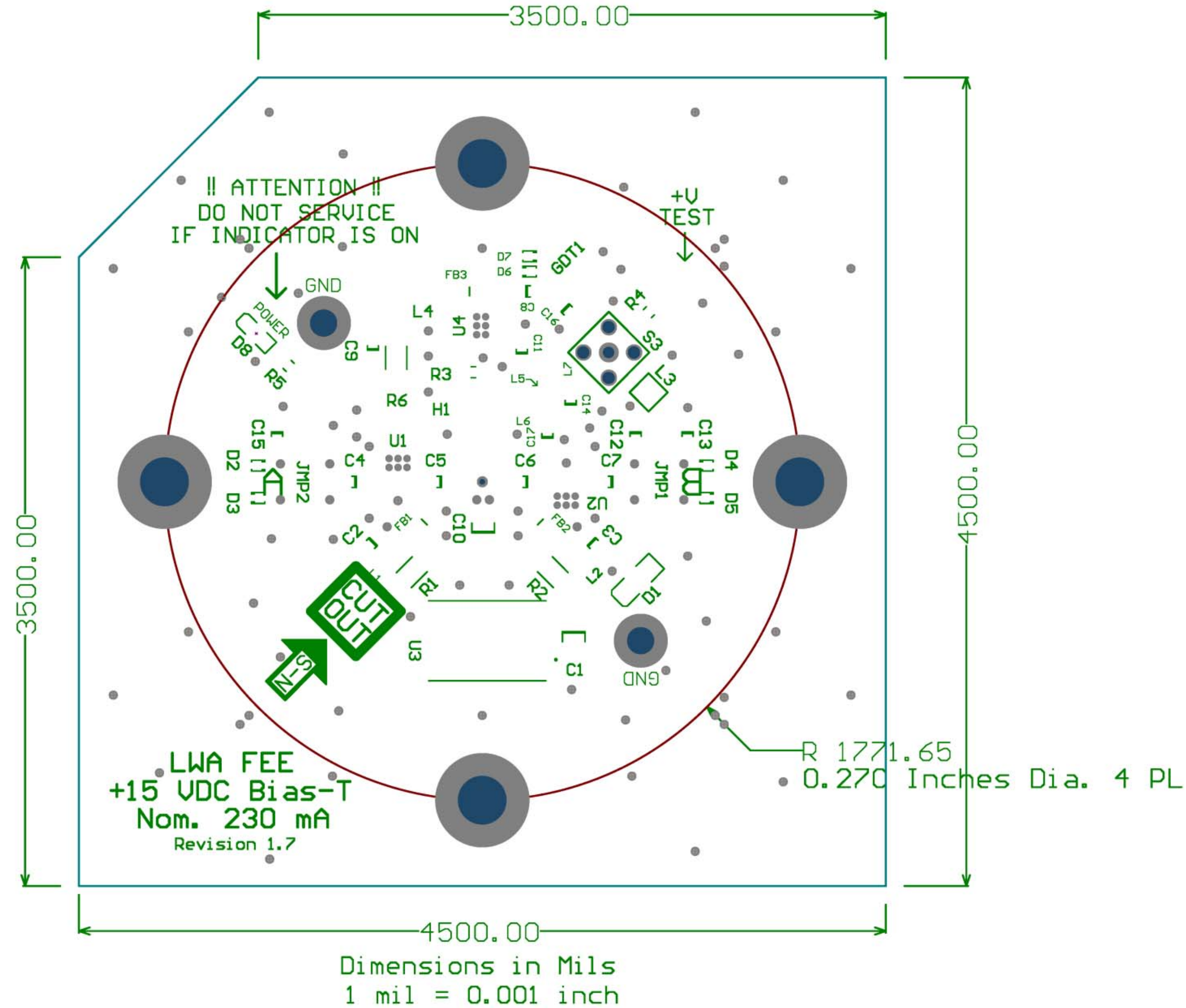

Figure 2c– PCB Layout: Dimensioned with Mirrored Silkscreen (Version 1.7)

Bill of Materials
LWA FEE
3/25/2009

Designation	Value	Tolerance	Type	Manufacturer	Manufacturer's Part Number	Digi-Key Part Number	Package Style	Unit Cost	Quantity	Extended	Cost Bracket (*)	
L1, L2, L4	4.7 µH	5%	Inductor, Ceramic Core	Coilcraft	1008CS-472XJLB	Coilcraft Direct	1008	0.2	3	0.6	>2000	(Note 1)
L3	4.7 µH	10%	Inductor, Power, High SRF	Coilcraft	1008PS-472KLB	Coilcraft Direct	1008	0.7	1	0.7	>750	(Note 2)
L5	100 nH	2%	Inductor, Unshielded	Coilcraft	1008CS-101XGLB	Coilcraft Direct	1008	0.37	2	0.74	> 1000	
L6, L7	33 nH	2%	Inductor, Unshielded	Coilcraft	1008CS-330XGLB	Coilcraft Direct	1008	0.37	2	0.74	> 1000	
C1, C10	10 µF	20%	Tantalum Capacitor	Nichicon	F931E106MCC	493-2388-1-ND	SMT-C (6.0 x 3.2 mm)	0.332	2	0.664	>250	
C4, C7	1000 pF	10%	Capacitor, Ceramic, X7R	Panasonic - ECG	ECJ-3FB2J102K	PCC2291TR-ND	1206	0.06	2	0.12	>3000	
C2, C3, C5, C6, C8, C9, C11, C12, C15	0.1 µF	10%	Capacitor, Ceramic, X7R	Panasonic - ECG	ECJ-3VB1E104K	PCC1883TR-ND	1206	0.056	9	0.504	>4000	
C14, C17	33 pF	2%	Capacitor, NPO	AVX	06031A330GAT2A	478-5136-1-ND	603	0.13	2	0.26	>1000	
R1, R2	91 Ω	5%	Resistor, 1 Watt	Panasonic	ERJ-1TYJ910U	PT91XCT-ND	2512	0.191	2	0.382	>1000	
R3	51 Ω	5%	Resistor, 1/4 Watt	Panasonic - ECG	ERJ-P08J510V	P51ALCT-ND	1206	0.042	1	0.042	<4000	
R4	4.72k Ω	5%	Resistor, 1/4 Watt	Panasonic - ECG	ERJ-8GEYJ472V	P4.7KEDKR-ND	1206	0.09	1	0.09	>10	
R5	470 Ω	5%	Resistor, 1/4 Watt	Panasonic - ECG	ERJ-8GEYJ471V	P470ECT-ND	1206	0.09	1	0.09	>10	
R6	95.3 Ω	1%	Resistor, 1 Watt	Panasonic	ERJ-1TNF95R3U	PT95.3AFCT-ND	2512	0.28	1	0.28	>1000	
U3	LM1085IS-12-ND	N/A	Positive Voltage Regulator	National Semiconductor	LM1085IS-12	LM1085IS-12-ND	TO-263-3	1.25	1	1.25	>500	
U1, U2	Gali-74	N/A	MMIC Amplifier	Mini-Circuits	Gali-74	Must Buy Directly	DF782	1.85	2	3.7	>1000	
U4	Gali-6	N/A	MMIC Amplifier	Mini-Circuits	Gali-6	Must Buy Directly	DF782	1.39	1	1.39	>1000	
H1	HX62A	N/A	180 degree hybrid	Tele-Tech, Corp.	HX62A	Must Buy Directly	TT-HX62A	20	1	20	>500	
D1	MBRS2040	N/A	Diode, Schottky, 40 V, 2A	ON Semiconductor	MBRS2040LT3G	MBRS2040LT3GOSCT-ND	SMB (5.59 x 3.81)	0.16	1	0.16	>500	
D2, D3, D4, D5, D6, D7	1N4148	N/A	Diode	Micro Commercial Co.	1N4148WX-TP	1N4148WXTPMSCT-ND	SOD323	0.06	6	0.36	>1000	
D8	Green LED	N/A	LED, SMT 1206	Lumex	SML-LX1206GC-TR	67-1357-1-ND	1206	0.1	1	0.1	>500	
FB1, FB2, FB3	Ferrite 1.5A, SMD	N/A	Ferrite, 1.5A	Steward	HZ0805C202R-10	240-2396-1-ND	240-0805	0.05	3	0.15	>500	
S3	SMA, Straight	N/A	SMA Connector	Emerson Network	142-0701-201	J500-ND	SMA	2.55	1	2.55	>500	
GDT1	2035-09	20%	2 Pole Gas Discharge Tube	Bourns, Inc.	2035-09-SM-RP	2035-09-SM-RP-ND	SMT	0.66	1	0.66	>1500	
JMP1, JMP2	S1621-06-R	N/A	SMT Jumpers	Harwin	S1621-06-R	Buy Through Harwin Dist.	SMT Jumper	$0.08	2	$ 0.16	>2000	
									Total Cost:	$ 35.69		

* Parts only cost for a single polarization balun.
* Price and availability verified on 3/25/2009

Note 2: High tolerance (5%) is incidental, component was selected on basis of: Max current (260 mA), Min SRF (90 MHz), and Max DCR (4 Ohms).
Note 2: Suffix B indicates "less than a full reel", full reels are availale.

Appendix A – Updated Bill of Materials: LWA FEE Revision 1.7