Solid State Kilowatt Amplifiers

A tutorial on how to annoy your neighbors with modern LDMOS transistors

Which bands will we explore here?

- 2m, 222MHz and 70cm
- 6m (winter 2013/14)
- HF through 6m (spring 2014)

Can You Build One of These?

Sure, why not?

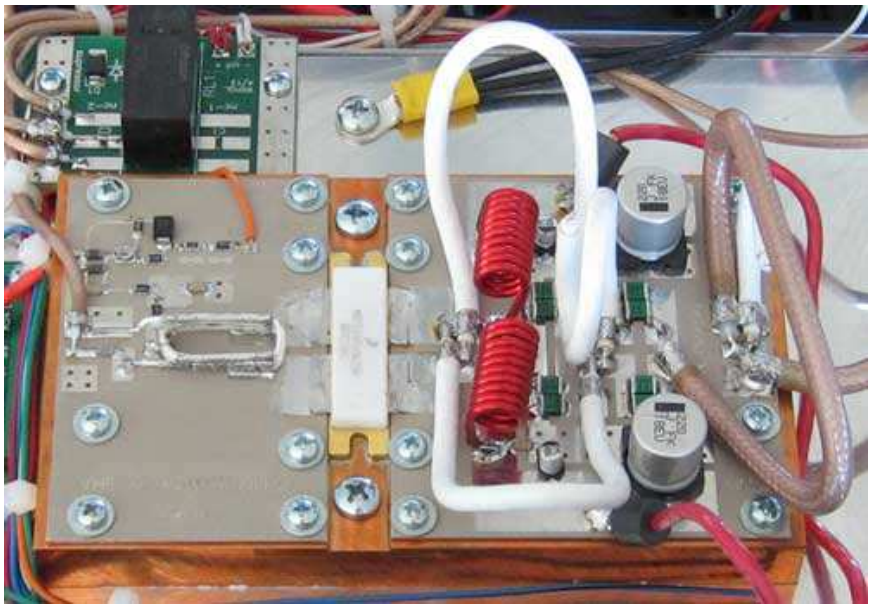
Another version

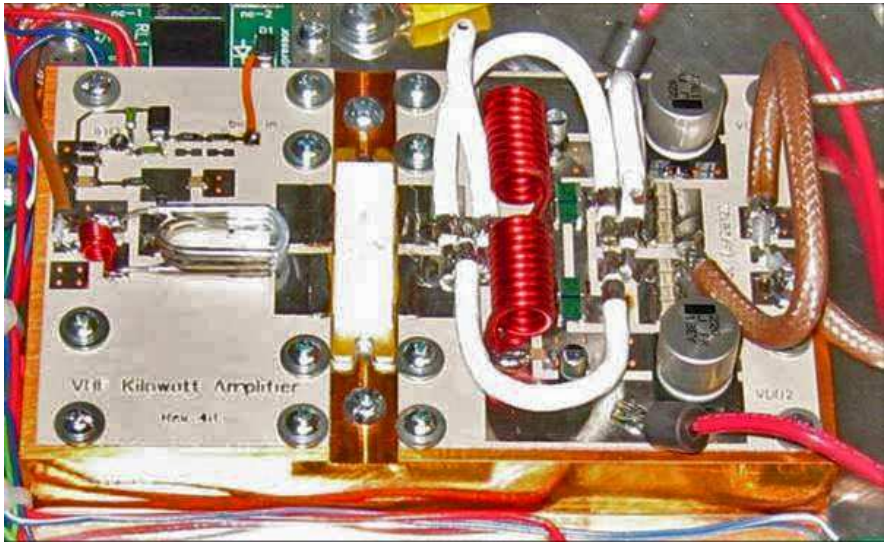
BIG LDMOS devices are available

At “reasonable” cost

- Freescale and NXP (Phillips)
  - MRFE6VP1K25H - 1.25kw (Freescale) HF to ~300MHz
  - MRFE6VP5600H – 600w (Freescale) HF to 450 MHz
  - BLF578XR -1.25KW (NXP) HF to ~300MHz
  - BLF184XR – 600w (NXP) HF to 450MHz (new device, unverified)

Measured Performance



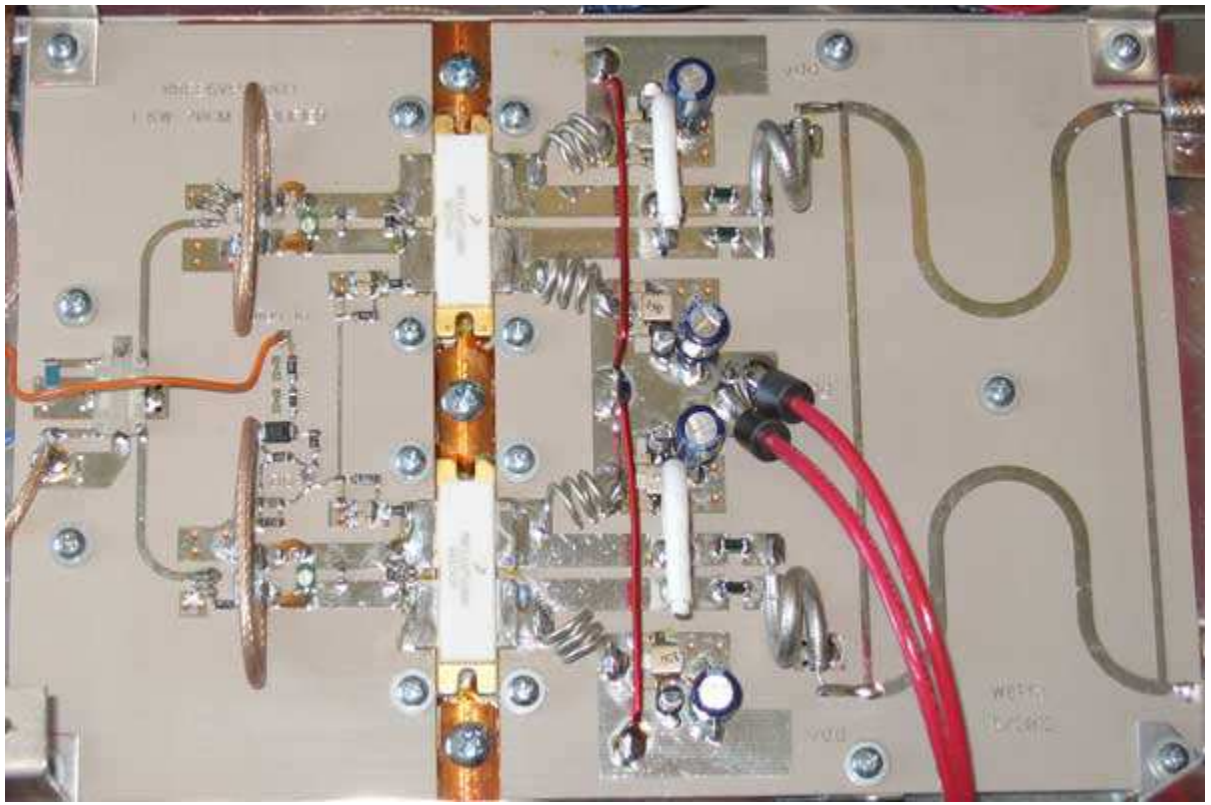


- 6m, 2m and 222MHz
  - 1.25kw part produces 1kw at P1db, and up to 1.35kw at P3db
  - Efficiency is >70% at P1db

Measured Performance

70cm

- 1.25kw part produces ~350w with low efficiency
  - 600w part produces 500w at P1db with 53% efficiency
  - Two of the 600w parts produce 1kw at P1db with 53% efficiency



Where to Find Design Info

- Manufacturer reference designs
- Dubus magazine
- QST and QEX magazine
- Web sites
  - www.w6pql.com
  - F1JRD
  - Many others

Critical Parts

1. LDMOS distributors
   - Newark Electronics www.newark.com (Freescale)
   - RFMW Limited http://www.rfmw.com/ (NXP)
   - Digikey www.digikey.com
   - Mouser www.mouser.com
   - Richardson RFPD www.richardsonrfpd.com (Freescale)

Critical Parts

High power RF capacitors

- Metal Micas
  - Mouser
  - Digikey
  - Communication Concepts www.communication-concepts.com/
- SMT micas (CDE MC series)
  - Mouser
- Coaxial matching capacitors
  - Self-made

More Critical Parts

Inductors and transformers

- Communication Concepts
- Mouser
- Self-wound RF chokes and transformers

Coax (special stuff, 10, 12, and 25 ohm)

- Communication Concepts
- RF Elettronica www.rfmicrowave.it
- EBay (50 Ohm RG401,RG402, RG316, RG142)

More Critical Parts

Terminations

- Richardson RFPD
- RFMW Limited (Florida RF labs terminations)
- EBay

High power RF resistors and attenuators

- Richardson RFPD (ATC attenuators)
- Newark (Johanson attenuators)
- Mouser (high power resistors for attenuators)

More Critical Parts

Relays and transfer switches

- RFPARTS (www.rfparts.com) - Tohtsu, Dow Key
- Surplus Sales of Nebraska - Tohtsu, Dow Key
- EBay
- WWW.W6PQL.COM (input relay board)

PC boards

- Communications Concepts
- RFHAM
- WWW.W6PQL.COM

More Critical Parts

Copper spreaders

- RFHAM
- WWW.W6PQL.COM

Aluminum heat sinks

- www.heatsinkusa.com
- WWW.W6PQL.COM (fully machined to accept spreaders)

Cabinets and panels

- www.frontpanelexpress.com

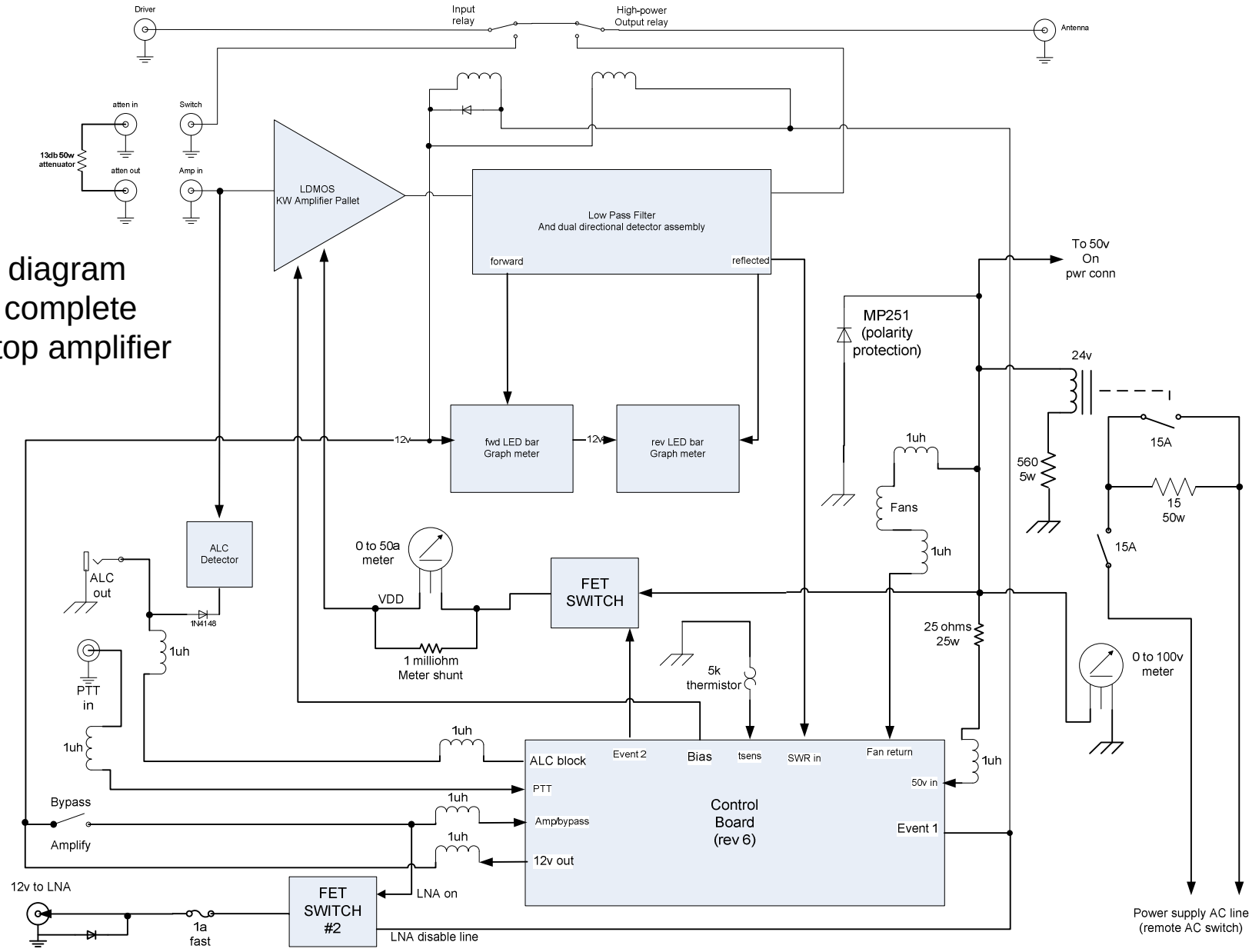
Design Cautions

1. All bands
   - Use good quality PC board substrate
   - Matching components (capacitors)
     - Best capacitor for matching is coaxial
   - Instability due to low frequency gain
     - Gate components
2. Bias stability (thermal drift)
   - LDMOS IDQ thermal drift
     - Use of thermistors for stabilization

OK, you have an RF Deck

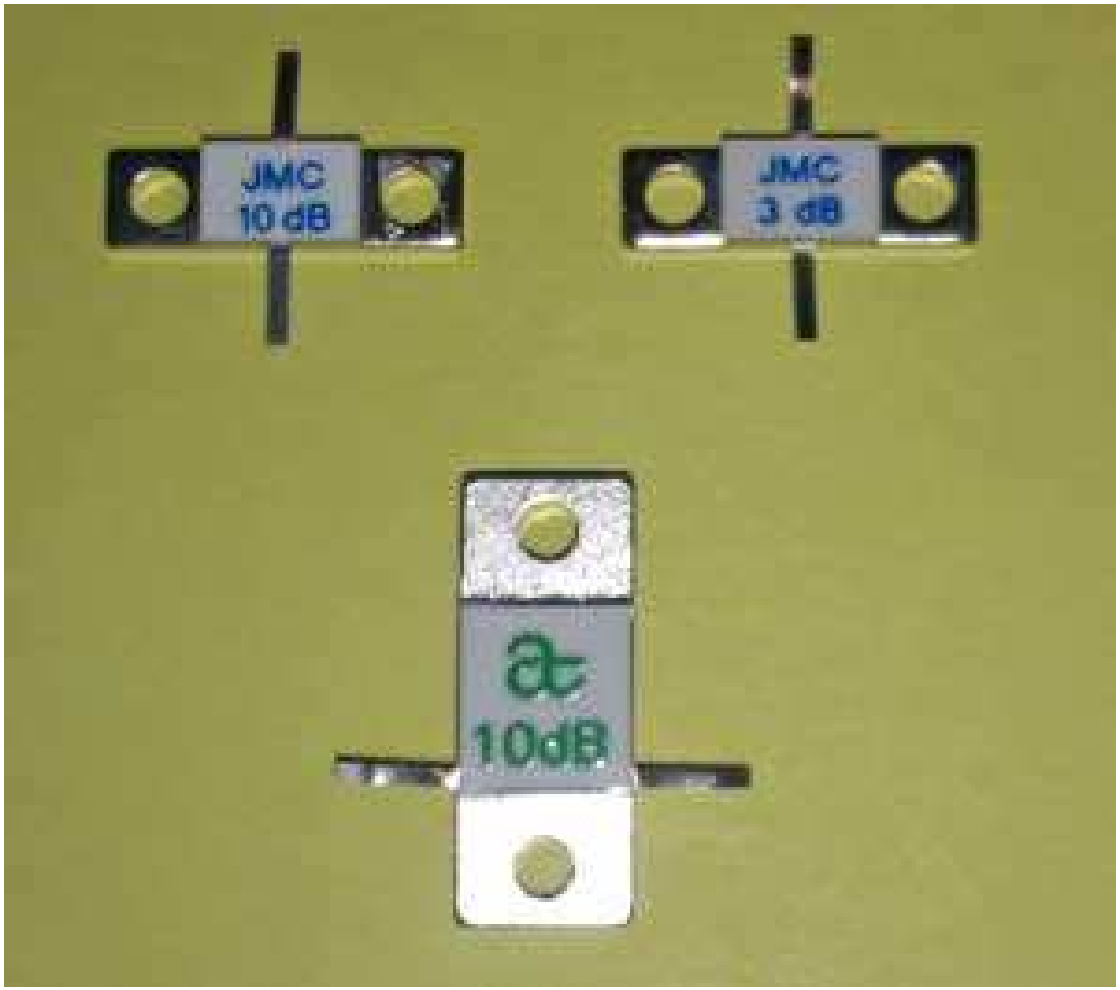
Now what?

Block diagram
For a complete
Desktop amplifier

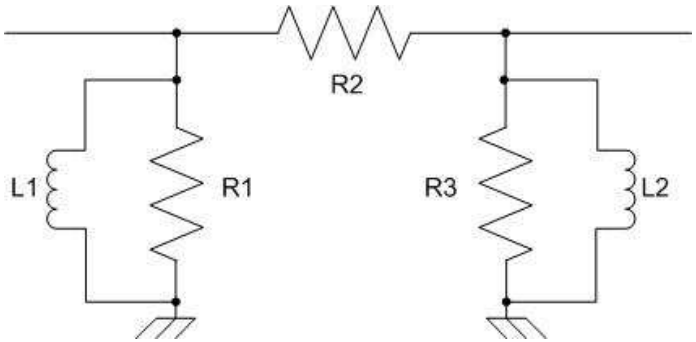


Flange-Mount Attenuators

- Available in 3,6,10,20 and 30 db packages (availability varies)
- Made by ATC and Johanson
- 100 watt package
- Requires transistion boards



A more flexible option



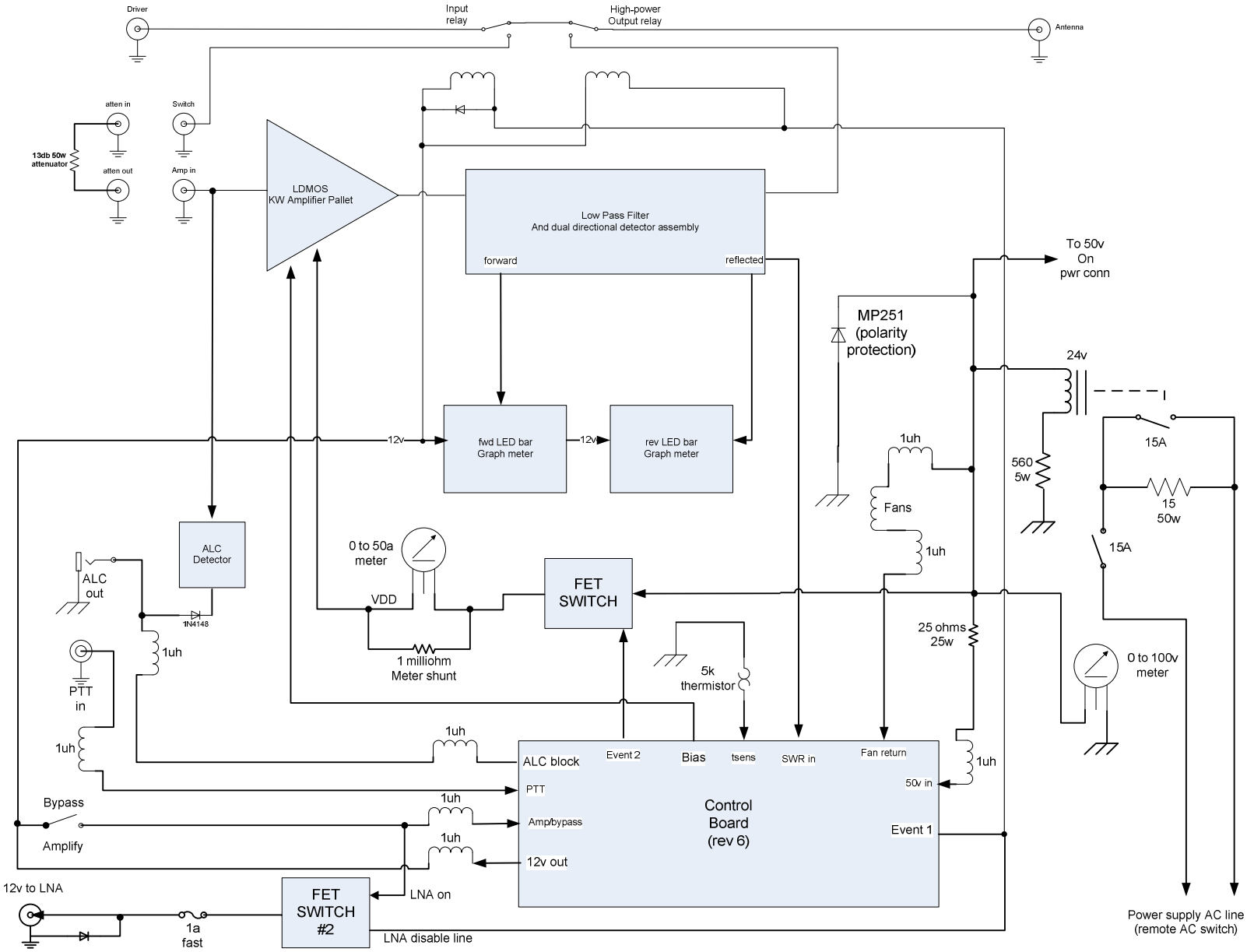
Attenuator setup

432 MHz	3db	6db	10db	13db	16db
R1	300 – 15w	100 - 15w	100 – 30w	75 -30w	
R2	15 -15w	50 – 15w	75 – 15w	100 – 15w	
R3	300 -15w	Not used	100 – 15w	75 – 15w	
L1	27nh	3 turns #22 3mm dia, space-wound input inductor; position across R1 terminals near body	8.5nh inductor 3 turns #22, 3mm id, 8mm long; position across R1 terminals near body	8.5nh inductor 3 turns #22, 3mm id, 8mm long; position across R1 terminals near body	
L2	27nh	33nh	27nh	27nh	

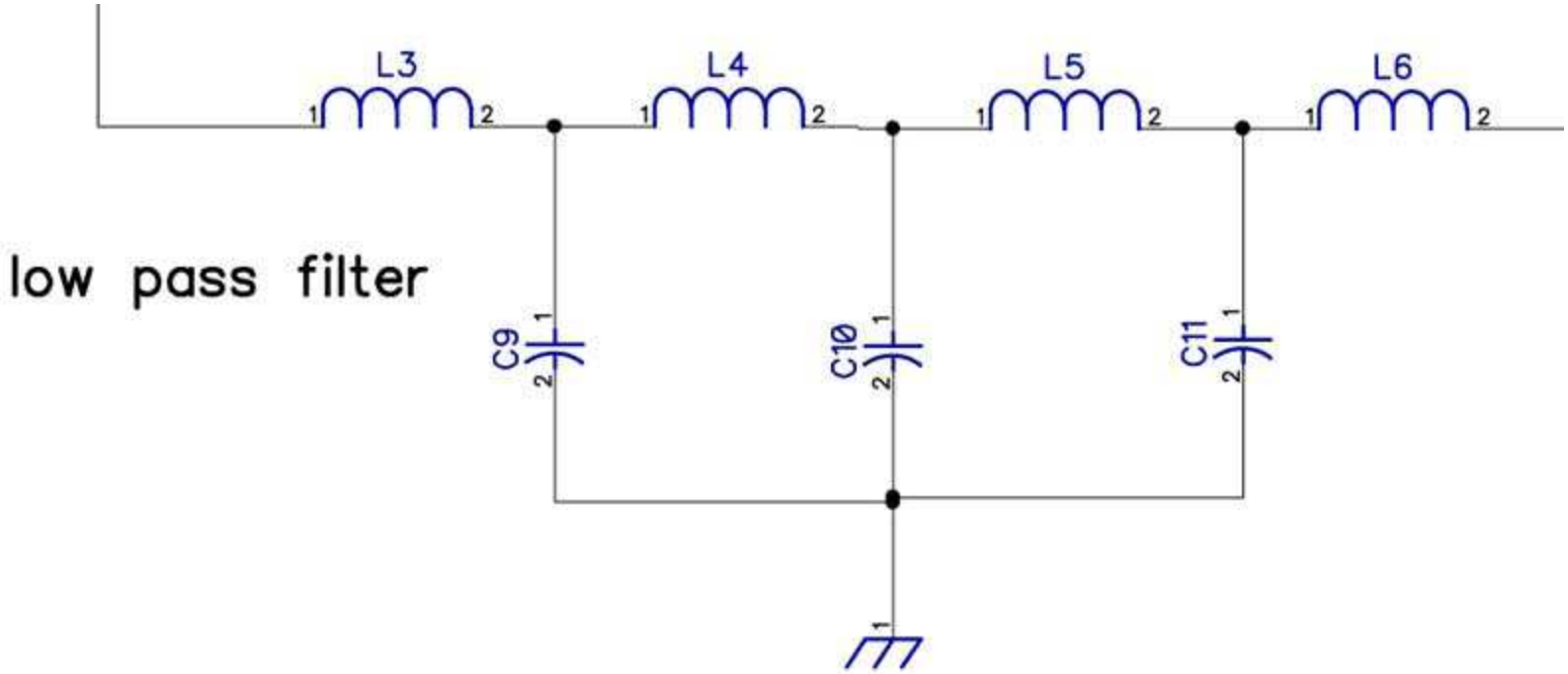
222 MHz	3db	6db	10db	13db	16db
R1		100 – 15w			
R2		50 -15w			
R3		Not used			
L1		120nh			
L2		220nh			

144 MHz	3db	6db	10db	13db	16db
R1	300 – 15w	100 – 15w	100 – 30w	75 -30w	75 – 100w
R2	15 -15w	50 -15w	75 – 15w	100 – 15w	150 – 30w
R3	300 -15w	Not used	100 – 15w	75 – 15w	75 – 15w
L1	330nh	270nh	220nh	220nh	120nh
L2	330nh	560nh	330nh	330nh	270nh

50 MHz	3db	6db	10db	13db	16db
R1	300 – 15w	100 – 15w	100 – 30w	75 -30w	75 – 100w
R2	15 -15w	50 -15w	75 – 15w	100 – 15w	150 – 30w
R3	300 -15w	Not used	100 – 15w	75 – 15w	75 – 15w
L1	Not used	Not used	Not used	Not used	Not used
L2	Not used	Not used	Not used	Not used	Not used


Driver
Input relay
High-power Output relay
Antenna
atten in
Switch
13db 50w attenuator
atten out
Amp in
LDMOS KW Amplifier Pallet
Low Pass Filter And dual directional detector assembly
forward
reflected
To 50v On pwr conn
MP251 (polarity protection)
24v
12v
fwd LED bar Graph meter
12v
rev LED bar Graph meter
1uh
Fans
1uh
560 5w
15A
15 50w
15A
ALC Detector
ALC out
1N4148
0 to 50a meter
VDD
1 milliohm Meter shunt
FET SWITCH
5k thermistor
25 ohms 25w
0 to 100v meter
PTT in
1uh
1uh
1uh
ALC block
Event 2
Bias
tsens
SWR in
Fan return
PTT
50v in
Bypass
Amplify
1uh
1uh
Amp/bypass
Control Board (rev 6)
Event 1
12v out
12v to LNA
1a fast
FET SWITCH #2
LNA on
LNA disable line
Power supply AC line (remote AC switch)

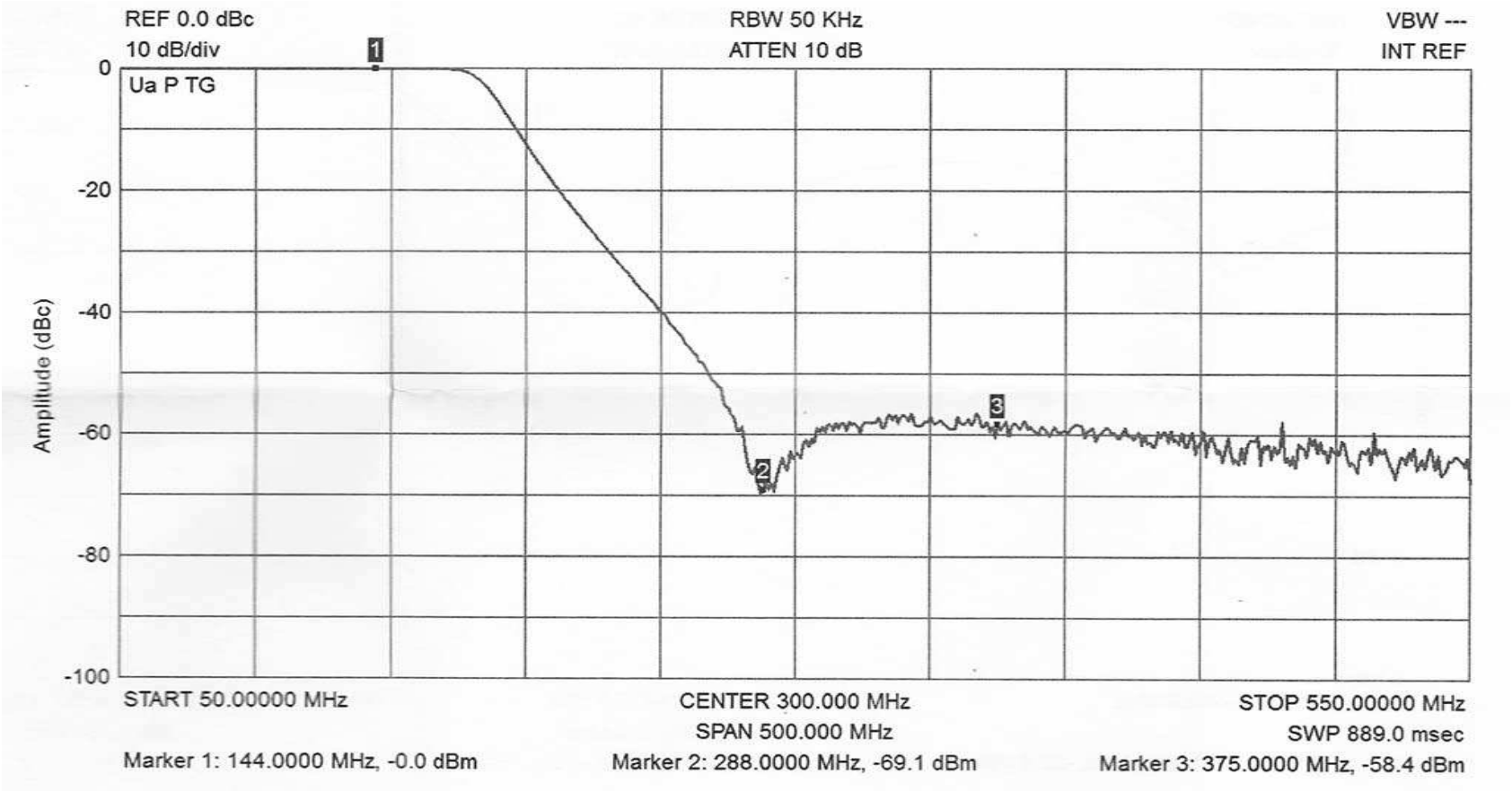
Low Pass Filter



Low Pass Filter

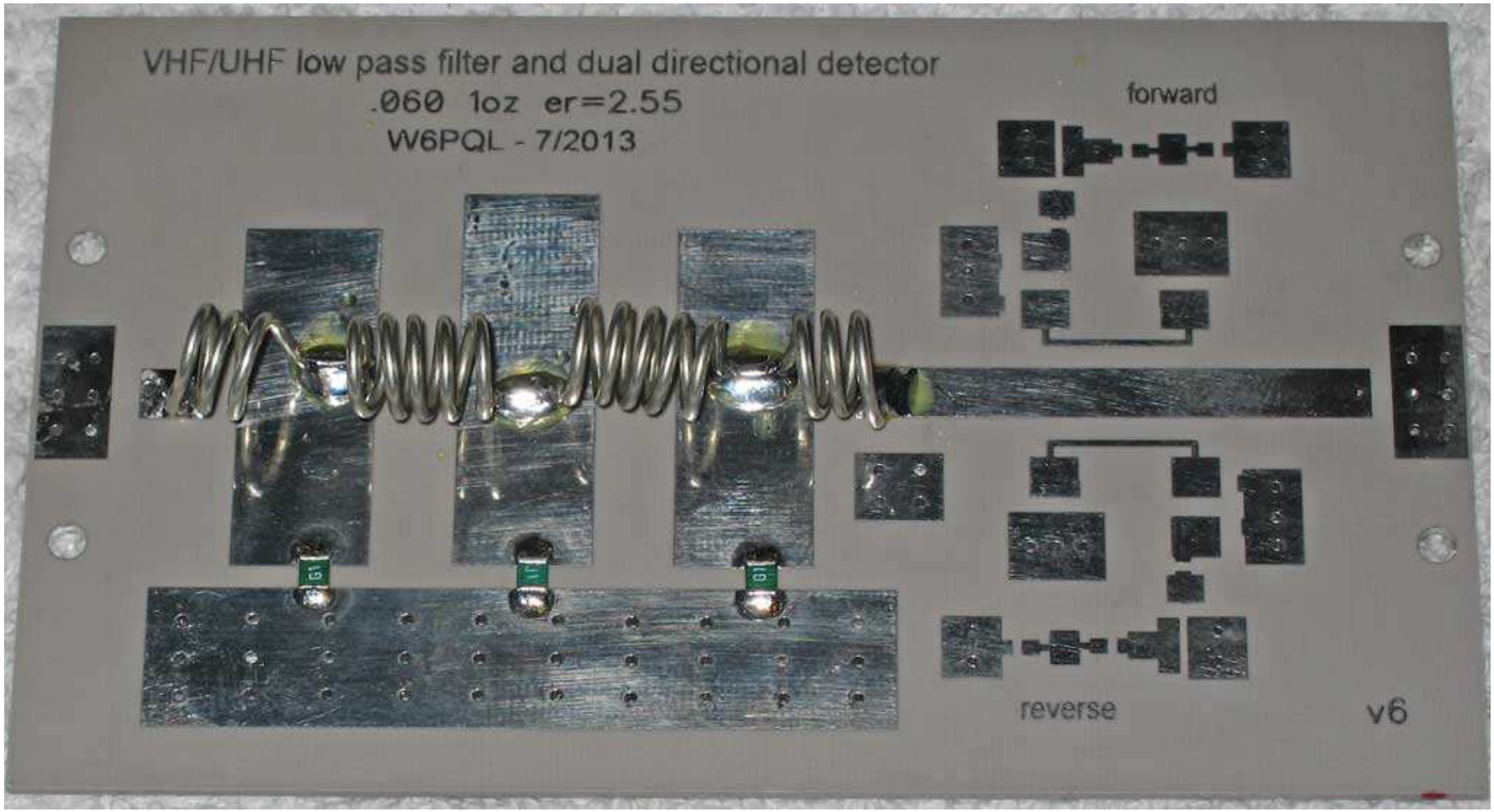
Filter Passband

2m setup



Low Pass Filter

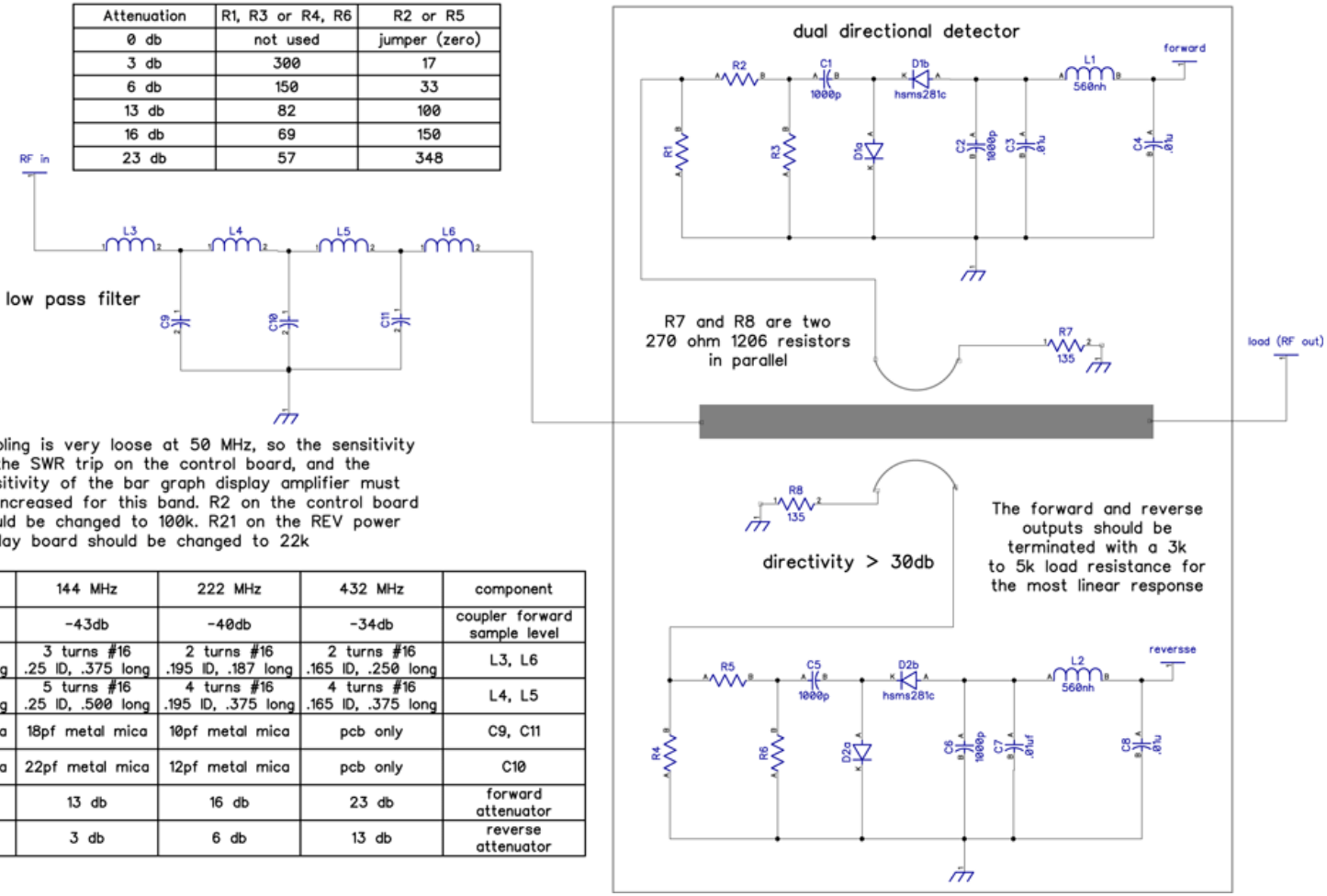
with dual directional detector



Low Pass Filter

1 KW LPF and dual directional detector assembly - total insertion loss is < 1/10 db (7-2013 version)

Attenuation	R1, R3 or R4, R6	R2 or R5
0 db	not used	jumper (zero)
3 db	300	17
6 db	150	33
13 db	82	100
16 db	69	150
23 db	57	348



coupling is very loose at 50 MHz, so the sensitivity of the SWR trip on the control board, and the sensitivity of the bar graph display amplifier must be increased for this band. R2 on the control board should be changed to 100k. R21 on the REV power display board should be changed to 22k

50 MHz	144 MHz	222 MHz	432 MHz	component
-53db	-43db	-40db	-34db	coupler forward sample level
2 turns #16 .50 ID, .375 long	3 turns #16 .25 ID, .375 long	2 turns #16 .195 ID, .187 long	2 turns #16 .165 ID, .250 long	L3, L6
5 turns #16 .50 ID, .625 long	5 turns #16 .25 ID, .500 long	4 turns #16 .195 ID, .375 long	4 turns #16 .165 ID, .375 long	L4, L5
50pf metal mica	18pf metal mica	10pf metal mica	pcb only	C9, C11
80pf metal mica	22pf metal mica	12pf metal mica	pcb only	C10
3 db	13 db	16 db	23 db	forward attenuator
0 db	3 db	6 db	13 db	reverse attenuator

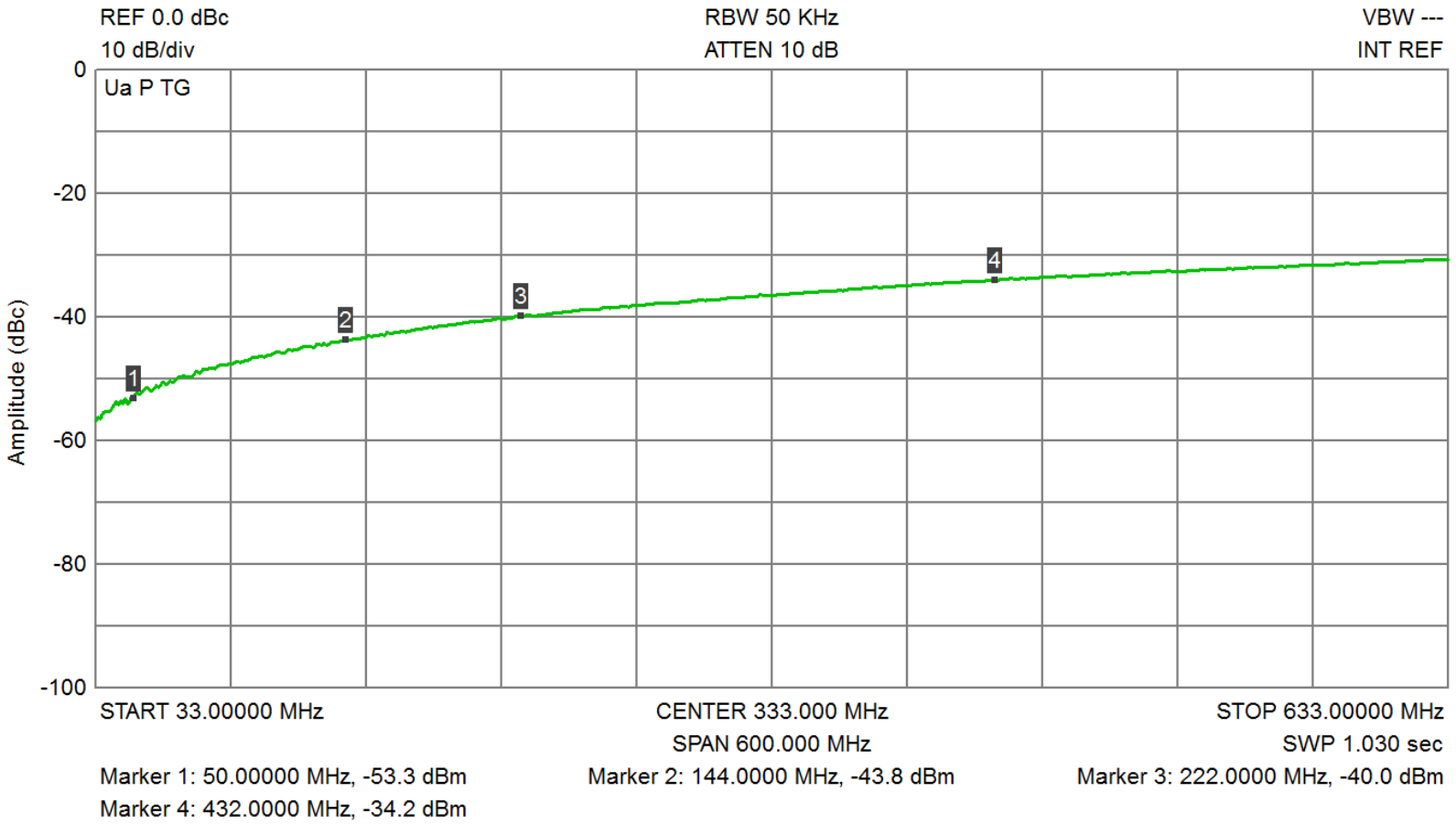
Low Pass Filter

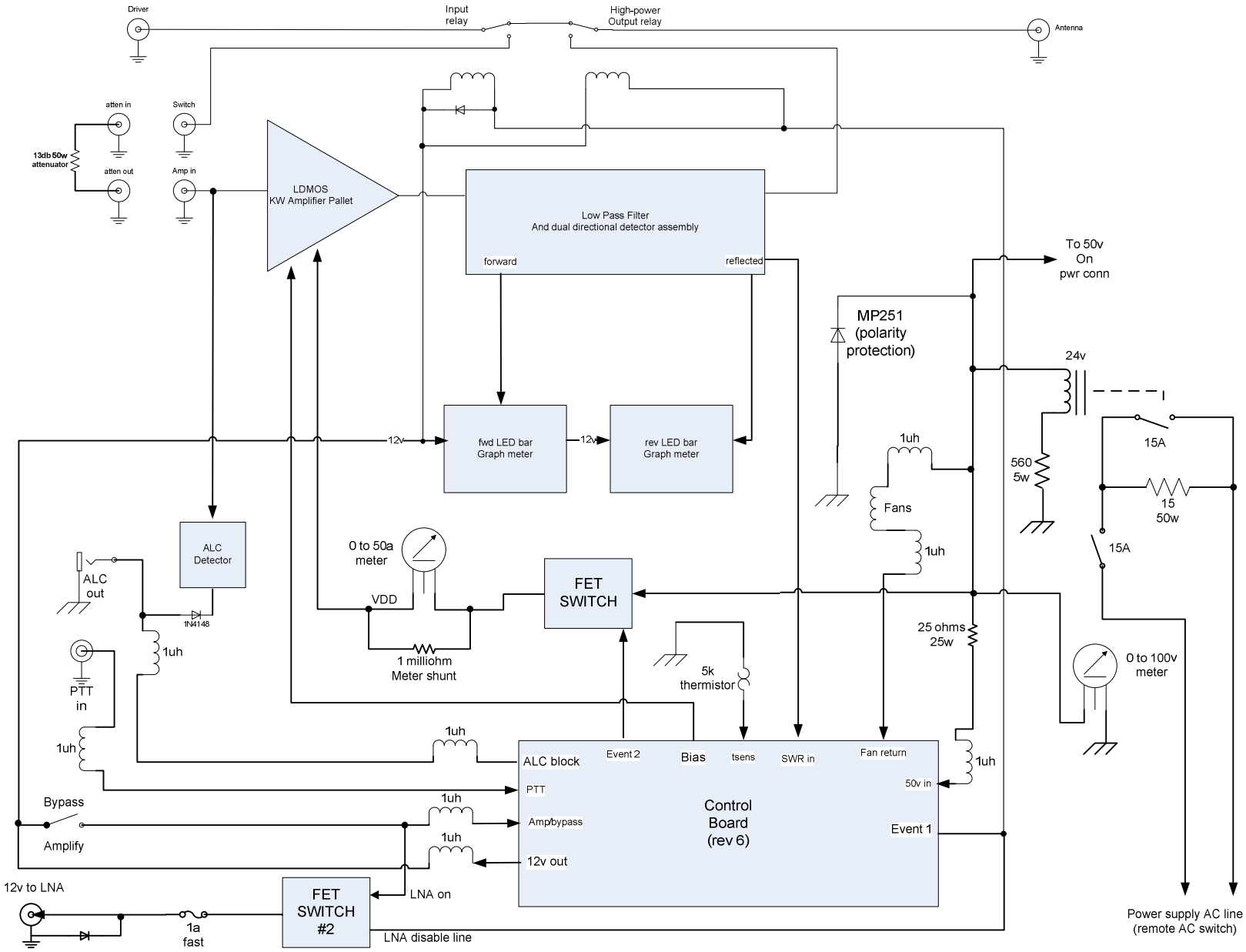
with dual directional detector

1. Coupler will sample both forward and reflected power levels
2. Each band can be configured for correct signal levels
   - On-board attenuators set the correct signal levels for the detector diodes

Coupler Response

coupling across VHF/UHF bands




Driver
Input relay
High-power Output relay
Antenna
atten in
atten out
13db 50w attenuator
Switch
Amp in
LDMOS KW Amplifier Pallet
Low Pass Filter And dual directional detector assembly
forward
reflected
To 50v On pwr conn
MP251 (polarity protection)
24v
12v
fwd LED bar Graph meter
rev LED bar Graph meter
1uh
Fans
560 5w
15A
15 50w
ALC Detector
ALC out
1N4148
0 to 50a meter
VDD
1 milliohm Meter shunt
FET SWITCH
5k thermistor
25 ohms 25w
0 to 100v meter
PTT in
ALC block
Event 2
Bias
tsens
SWR in
Fan return
50v in
PTT
Amp/bypass
12v out
Control Board (rev 6)
Event 1
Bypass
Amplify
12v to LNA
1a fast
FET SWITCH #2
LNA on
LNA disable line
Power supply AC line (remote AC switch)

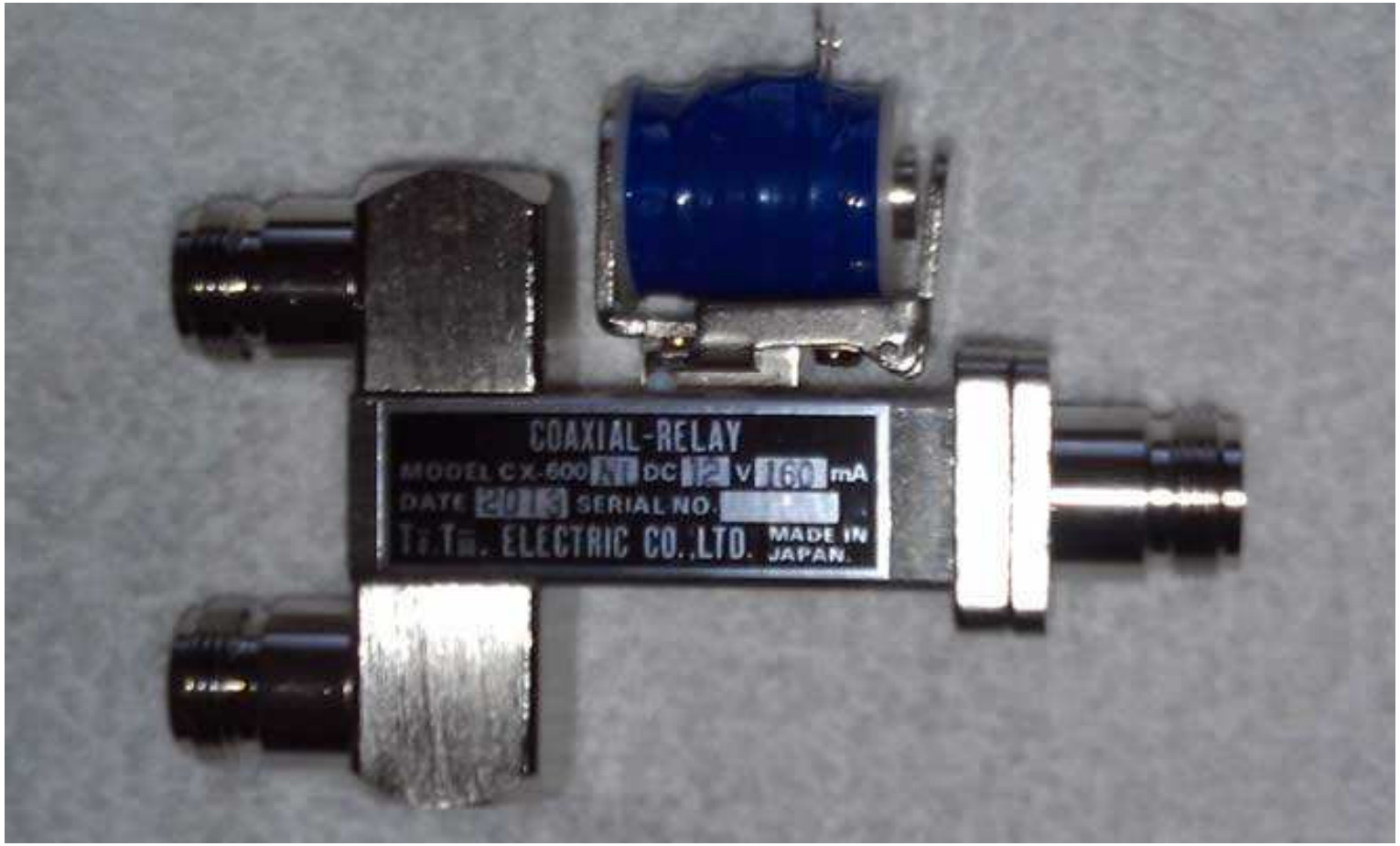
Antenna Relays (output)

Transfer switch
Dow Key model 412

SPDT model 402

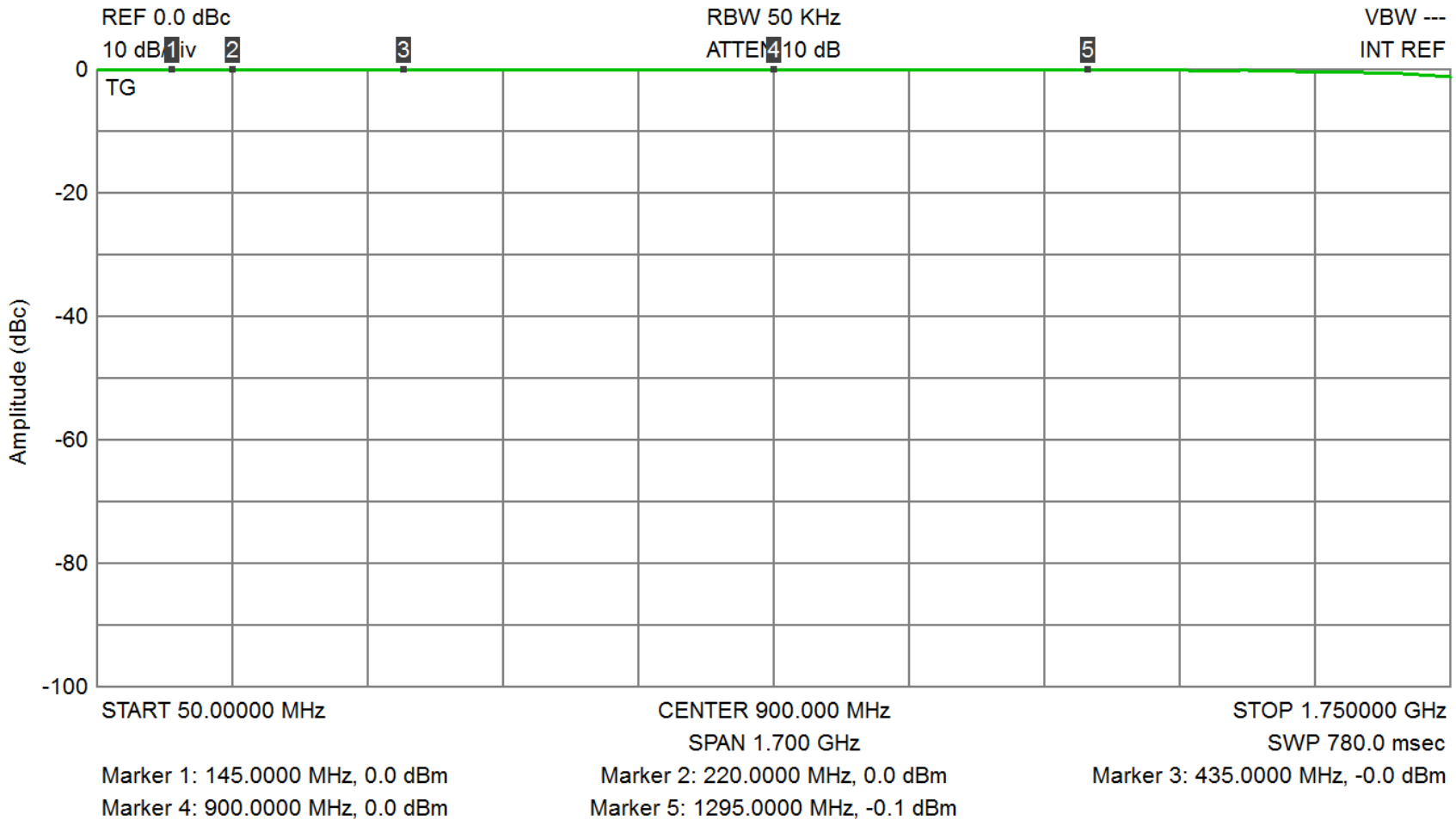
Antenna Relays (output)

SPDT – Tohtsu model CX600NL



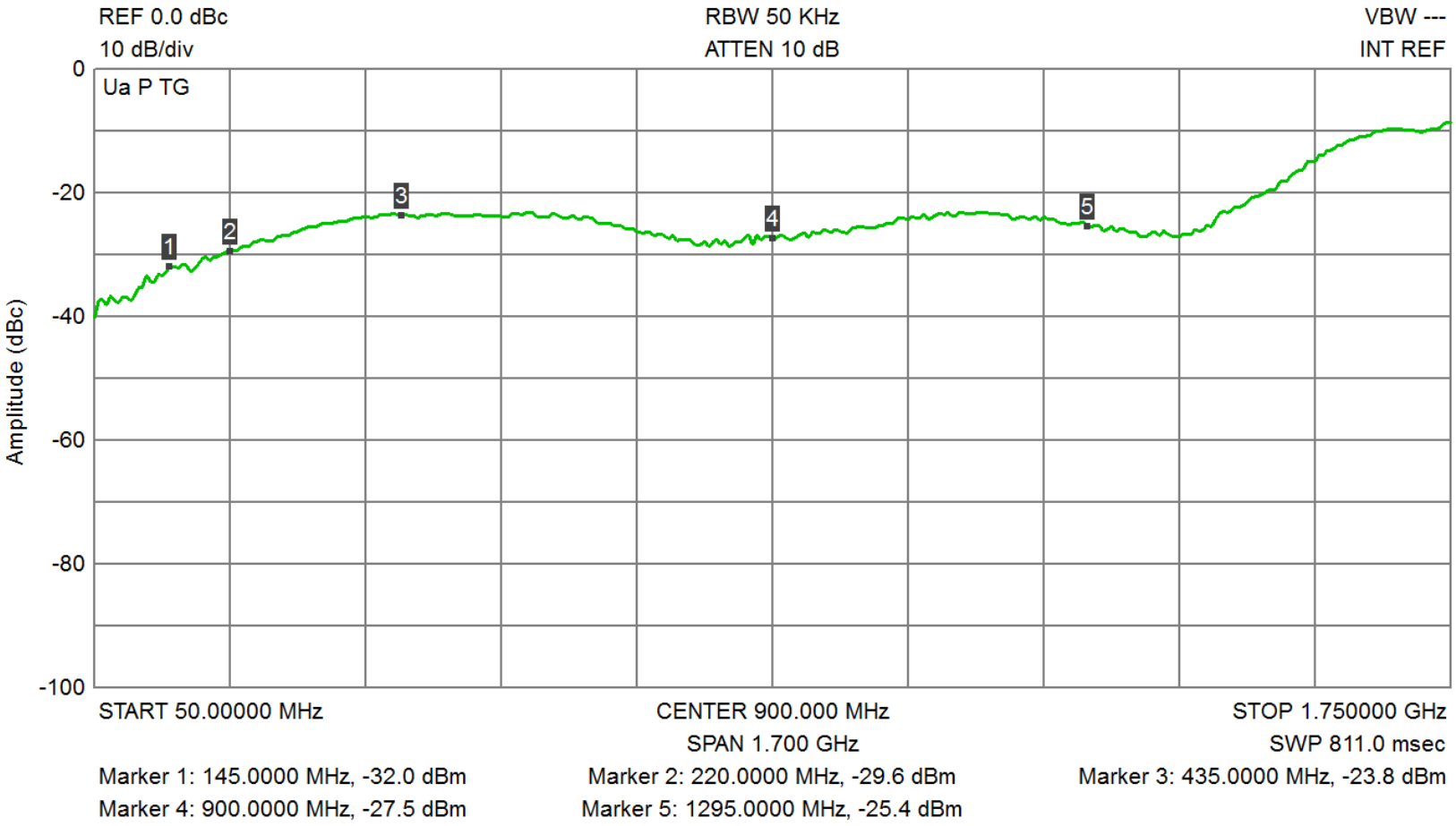
Relay Measurements (CX600NL)

insertion loss



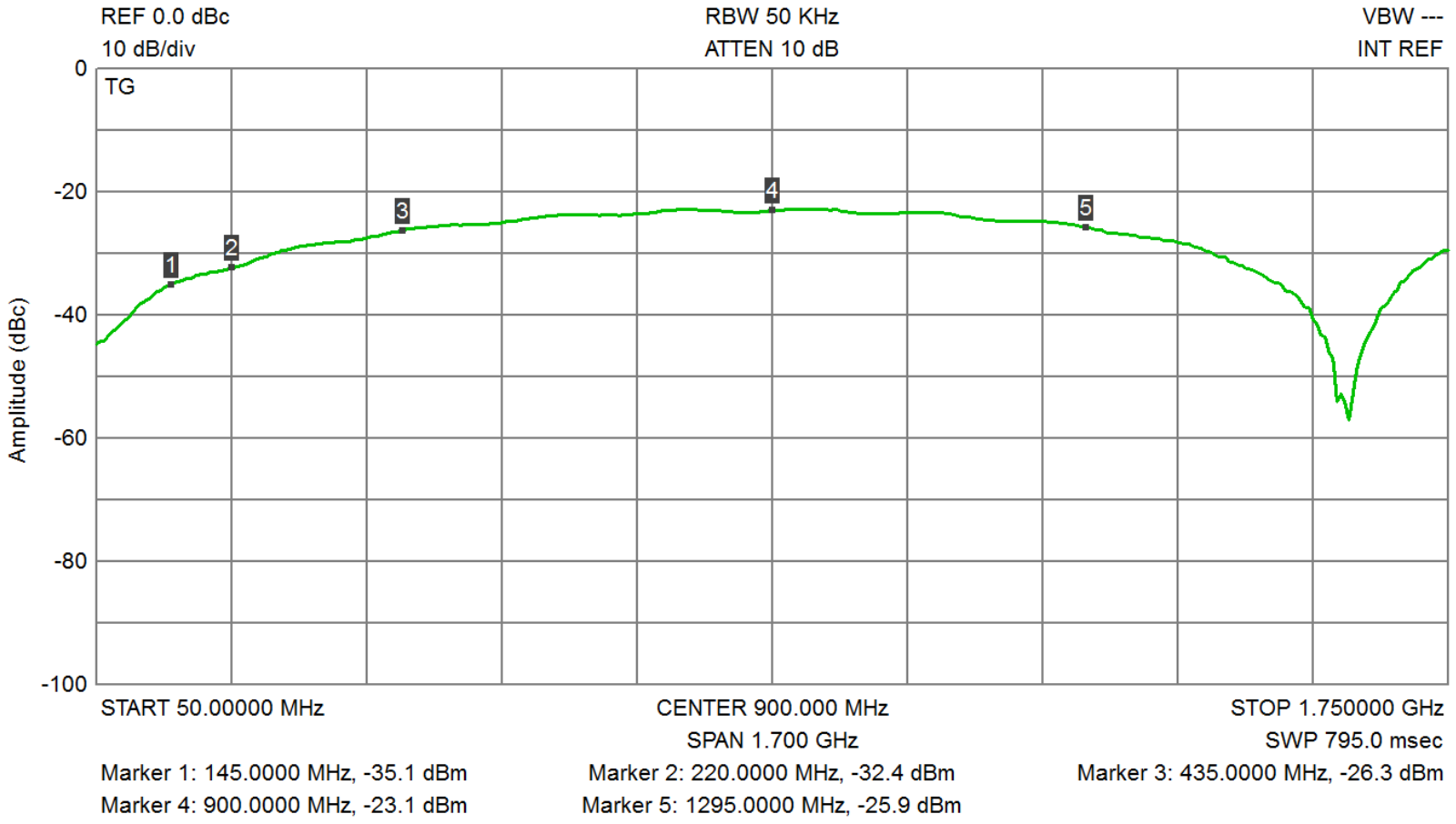
Relay Measurements (CX600NL)

return loss

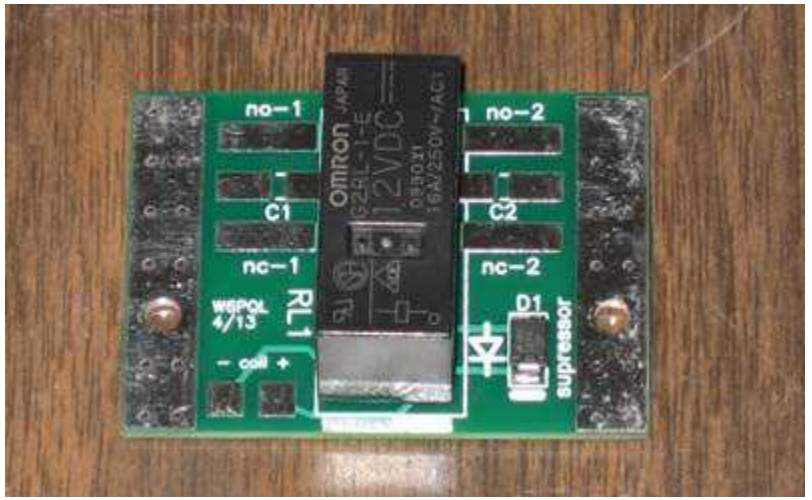


Relay Measurements (CX600NL)

isolation

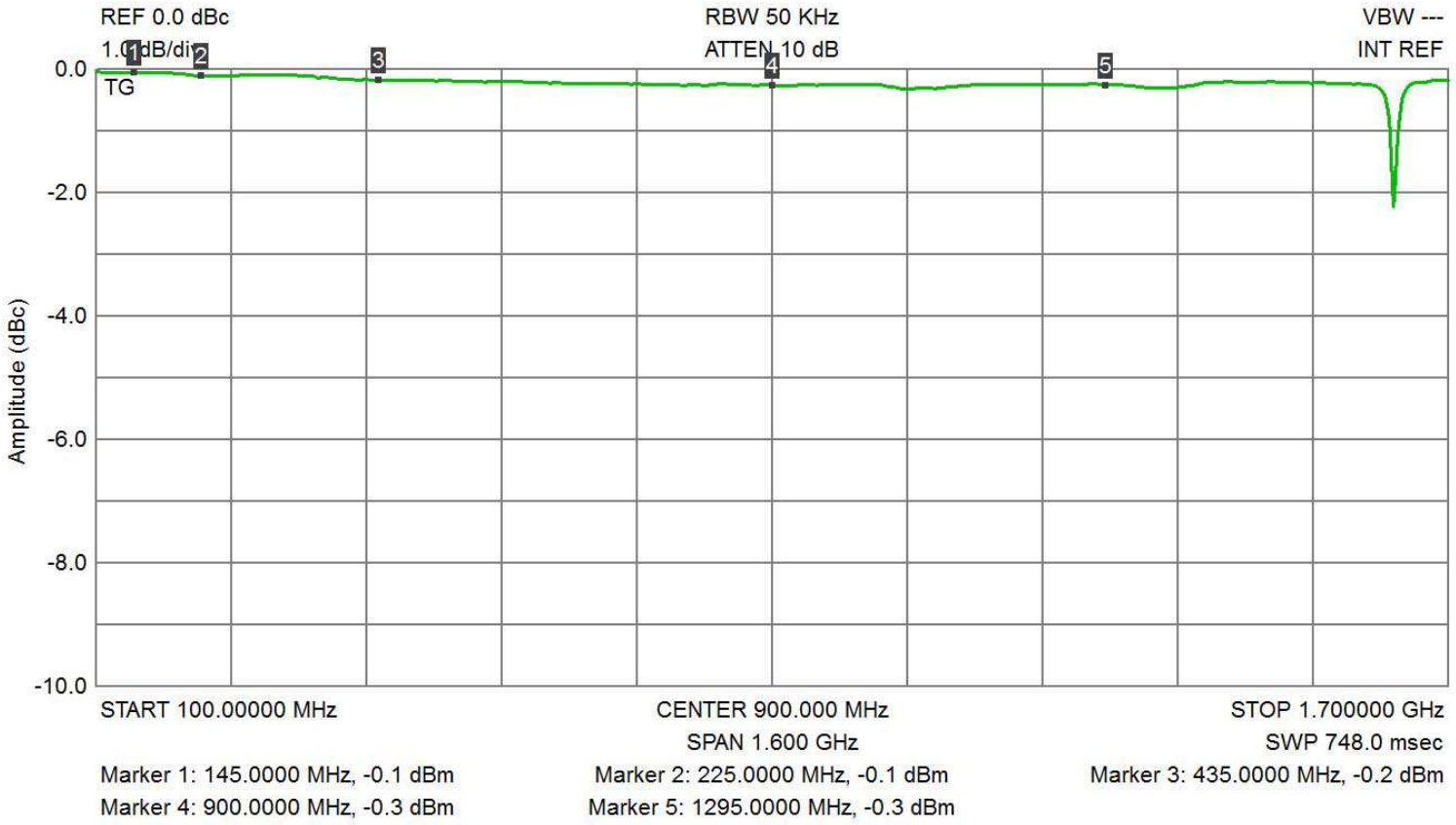


Antenna Relays (input)



Relay Specs (CX120A)

insertion loss



Relay Specs (CX120A)

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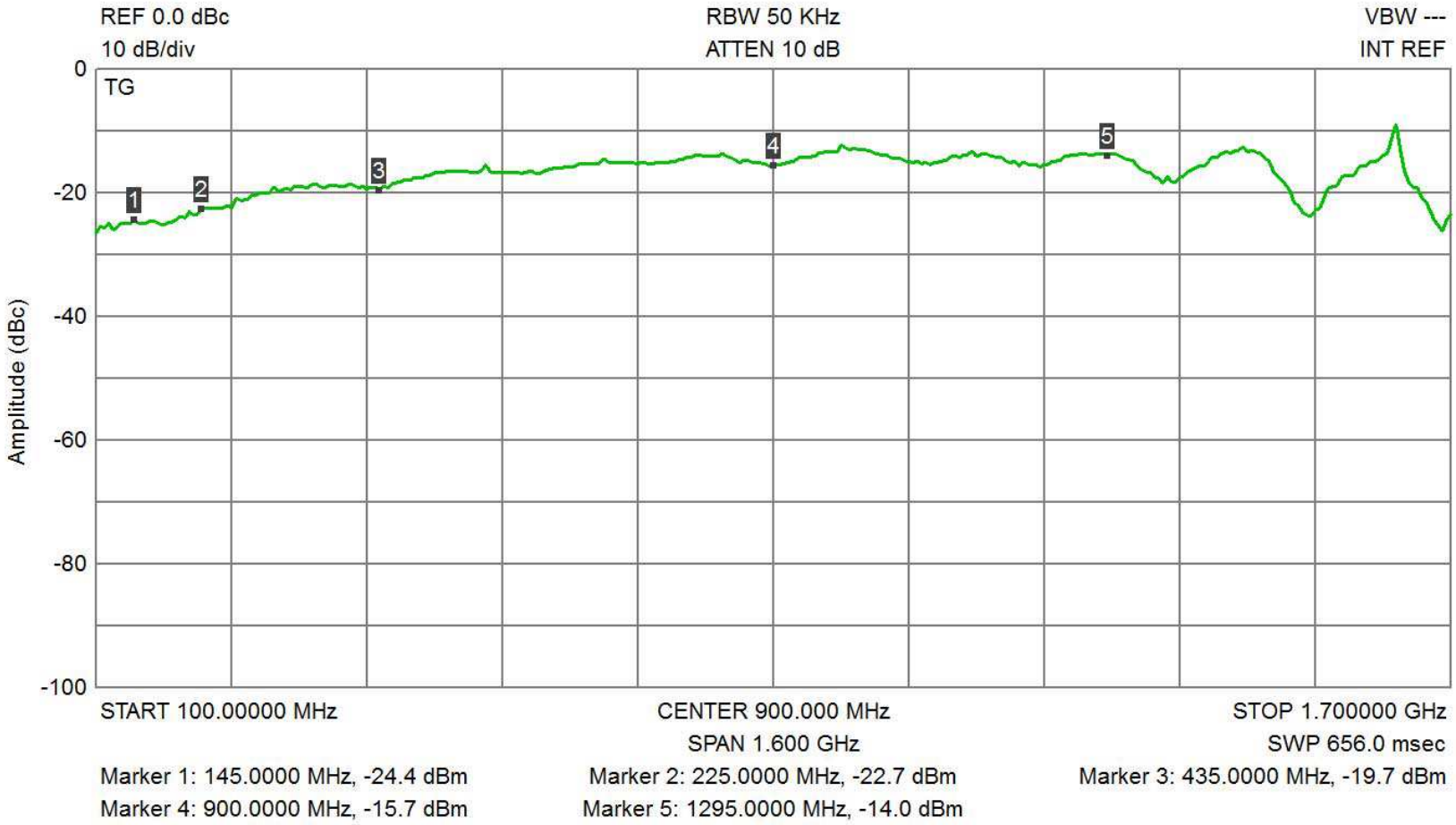

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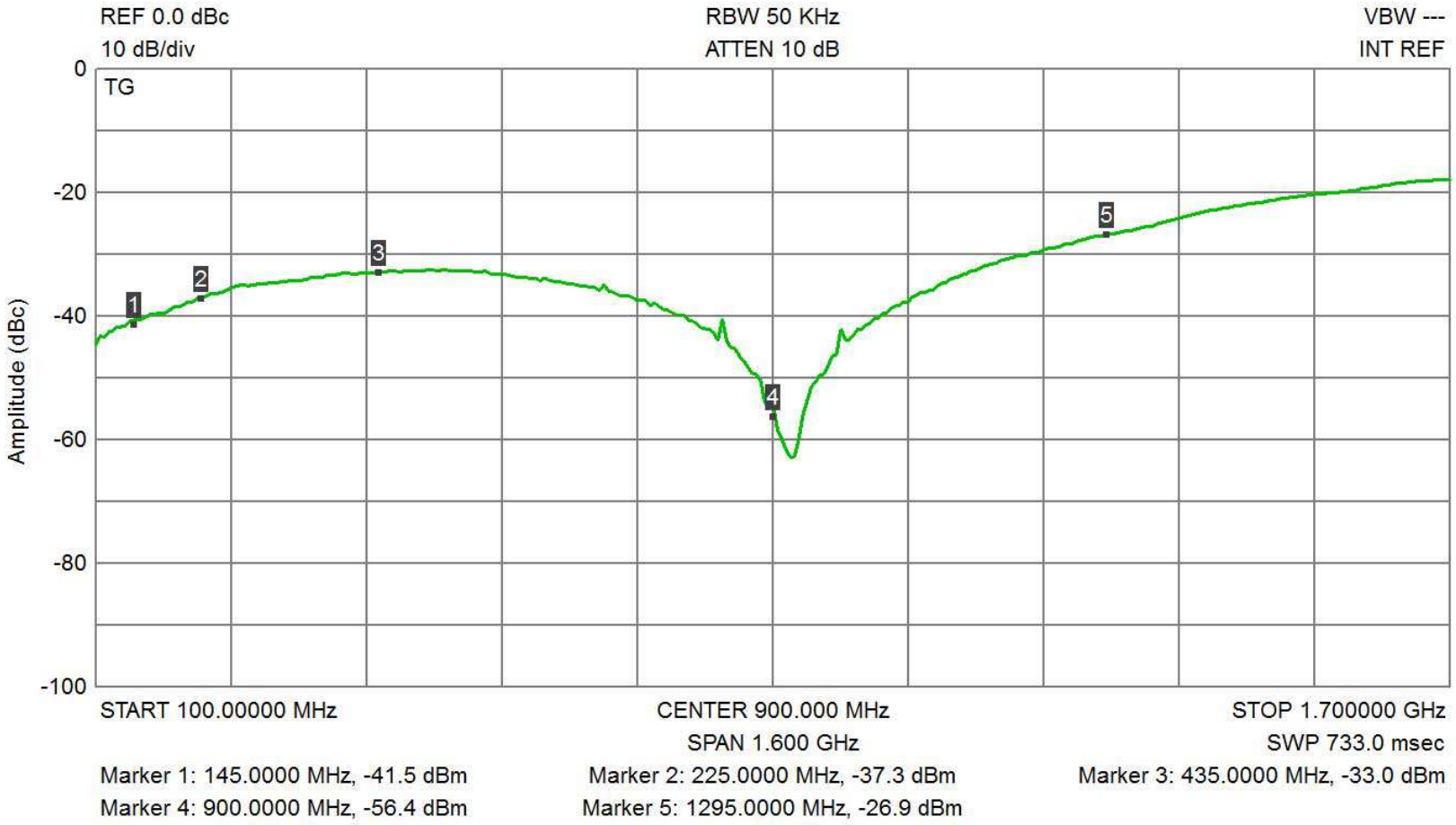

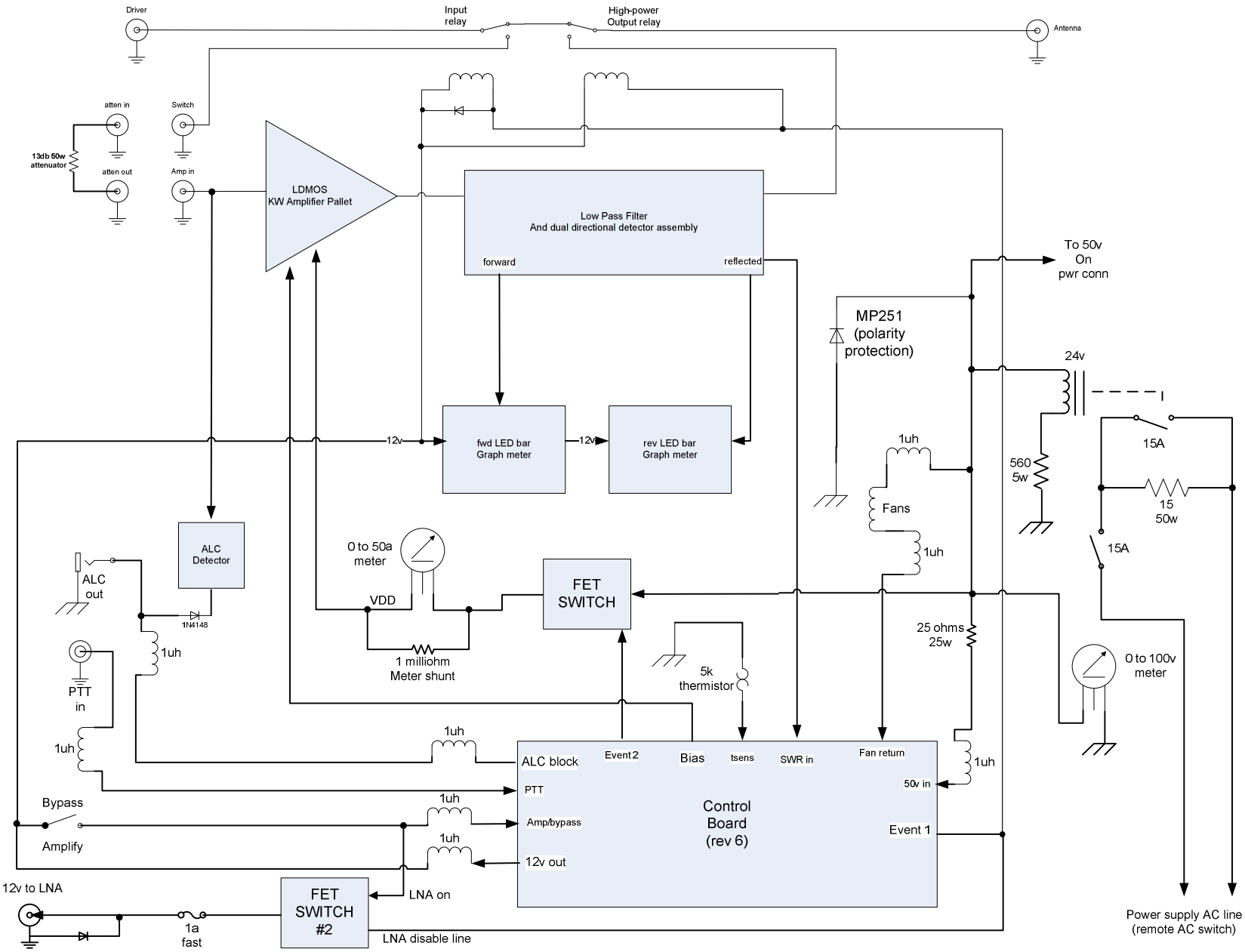
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ALC Detector
ALC out
1N4148
0 to 50a meter
VDD
1 milliohm Meter shunt
FET SWITCH
5k thermistor
25 ohms 25w
0 to 100v meter
PTT in
1uh
1uh
1uh
ALC block
Event 2
Bias
tsens
SWR in
Fan return
1uh
PTT
50v in
Bypass
Amplify
1uh
Amp/bypass
Control Board (rev 6)
Event 1
1uh
12v out
12v to LNA
FET SWITCH #2
LNA on
1a fast
LNA disable line
Power supply AC line (remote AC switch)

Control Board Functions

- Sequencer
  - Prevents hot-switching the antenna output relay
- DC power gate
  - VDD and bias (event 2)
- Fan control
- Reverse power lockout (high VSWR)
- Over-temp lockout
- Sequenced LNA power feed and drive power gating if required (event 3)

Coming soon to a band near you

- K2OP – 160 thru 6m
  - 650w on 160m
  - 1kw+ on 75m thru 10m
  - 950w on 6m
  - Broadband transformer design

Very complex switching and filtering, as you can imagine

- Harmonic content is as high as -9dbc on some bands
  - Thus, a complex output filter is required…the prototype is working well now
    - Combination LPF and diplexer