A Transceiver Front-End Protector in High Signal Level Environments
Phil Salas AD5X (ad5x@arrl.net)

Introduction

Protecting a transceiver's receiver front-end from high level signals is a real consideration when operating in a multi-station contest environment. Here, the close proximity of a high power transmitter on one antenna can result in a potentially damaging RF signal being applied to a receiver on a nearby antenna. When the bands are different, external band-pass filters resolve the problem. But if the transmitter is on the same band, a band-pass filter won't help and receiver damage can occur.

Receiver/Transceiver Protection Technique

A receiver protection technique that has been around for years is to use a small incandescent lamp in the receive path followed by shunt back-to-back diodes. The lamp provides minimal mismatch and insertion loss under normal receive conditions, but acts as a current limiter and fuse under high-signal conditions. The silicon diodes theoretically limit the receiver voltage to 1.4Vpp, or +7dBm at 50 ohms. Therefore I decided to pursue an external lamp/diode overload protection technique for transceiver use that could handle the output of any transceiver up to 400 watts RF power.

The transceiver front-end protector solution is shown in Figure 1, and the parts list is given in Table 1. The transceiver's amp-key output enables an Omron G6A-234P-DC12 relay which switches out the protector when transmitting. This relay handles up to 3-amps, so it will handle 450 watts at 50 ohms. It also switches in less than 5ms so it is QSK-compatible. And it only requires 16ma when keyed so it adds little to the transceiver's amp-key current sink requirement. The 12VDC/150ma lamp has a 9-ohm cold resistance and snaps into a standard ¼" fuse holder and is easily replaced should it burn out. The 1N4454 diodes limit the signal at +11dBm as measured with a MiniCircuits PWR-6GHS+ NIST-cal'd power sensor. The 75V gas discharge tube adds additional high voltage and impulse protection to the receiver front-end. The 8.2pf capacitor and two 10pf capacitors compensate for wiring, relay and lamp inductance.

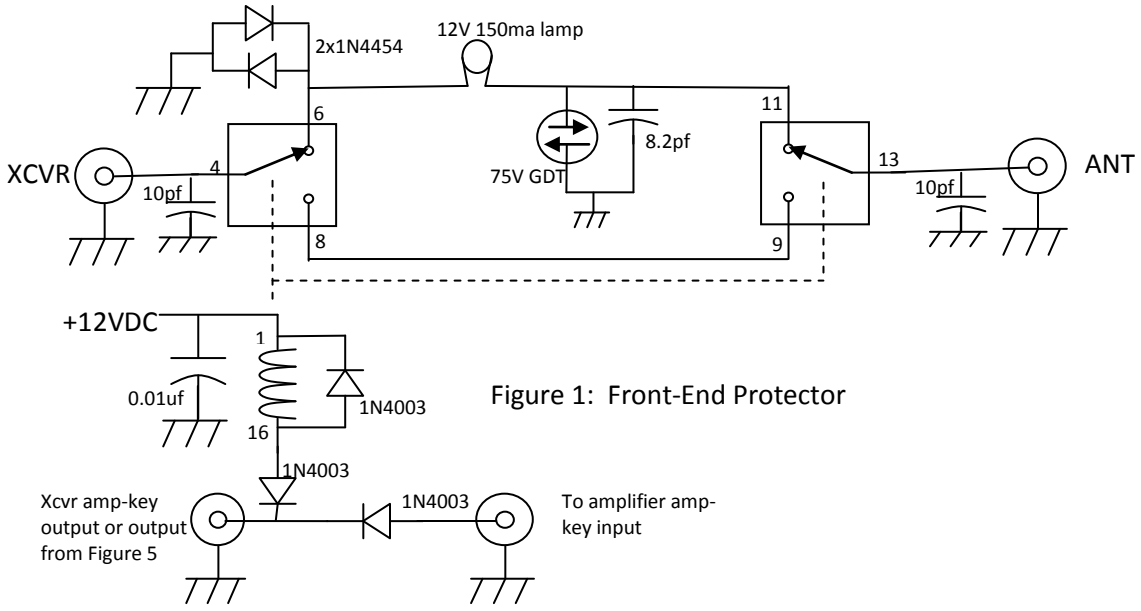

Figure 1: Front-End Protector

Building this is pretty easy. Hot-glue the relay upside down in the aluminum box, plug-on the IC-socket, and directly wire to the connectors and socket pins. Cut-off IC socket pins 2, 3, 5, 7, 10, 12, 14 and 15 as these pins are unused, and this makes the relay wiring easier.

Table 1: Figure 1 Front-end protector parts list

QTY	Description	Mouser part number	Price each
3	1N4003 diode	863-1N4003G	$0.05
2	1N4454 diode	583-1N4454-T	$0.07
2	10pf 500V capacitor	140-500N2-100J-RC	$0.10
1	8.2pf 500V capacitor	140-500N2-8R2D-RC	$0.10
2	RCA jack	161-0253-EX	$0.95
1	2.1x5.5mm DC jack	163-1060-EX	$0.88
1	DPDT signal relay	653-G6A-234P-DC12	$4.67
1	16 pin DIP socket (machine pin)	535-16-3518-10	$1.37
1	12V 150ma cartridge lamp	560-GF780	$1.88
1	Fuse Holder	576-03540101ZXGY	$1.06
1	75V Gas discharge tube	652-2057-07-BLF	$0.74
1	Project Box 3.25x2.125x1.625”	537-000-P	$6.63
4	Rubber Feet	517-SJ-5003BK	$0.11
2	UHF connector	601-25-7350	$2.11
2	#4 solder lugs	534-7325	$0.21

Unfortunately the Figure 1 front-end protector does not interface directly with the HSEND amp-key output of my IC-706MKIIG transceiver. And as a CW operator, I operate mostly full break-in. Therefore I incorporated the buffer/keying circuit shown in Figure 2. This circuit requires less than 2ma of amp-key drive, interfaces with any transceiver, and adds about 5ms relay turn-off delay (JMP2) for transceivers that prematurely unkey the amplifier (like ICOM IC-706/7000 transceivers do). It also adds a +12V keying interface option (selected by JMP1) for Kenwood radios. Finally, it will key any amplifier with an open circuit keying voltage of up to 80VDC and a keying current of up to 500ma. Table 2 gives the additional components needed.

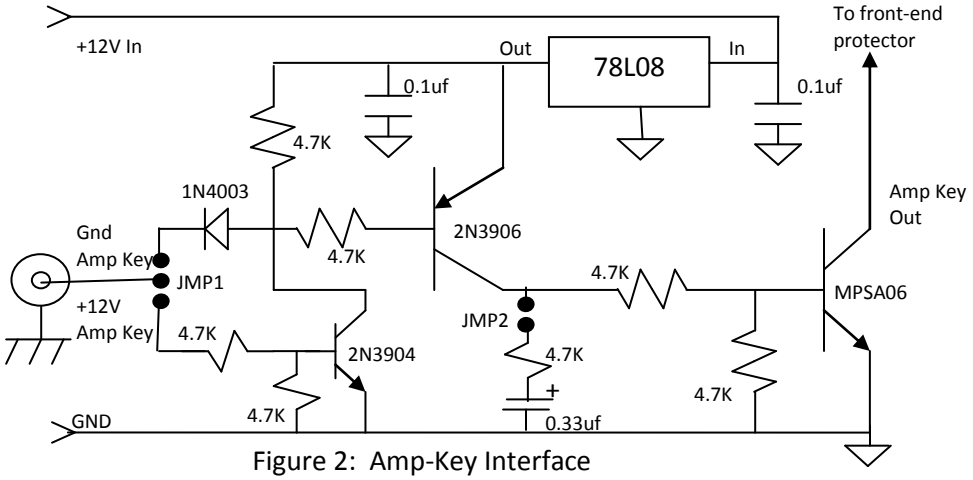

Figure 2: Amp-Key Interface

While everything can be built on a perf-board, a printed circuit board makes assembly much easier due to the number of components. For those who wish to go this route, prototype pc boards are available. Figure 3 shows the printed circuit board component locations.

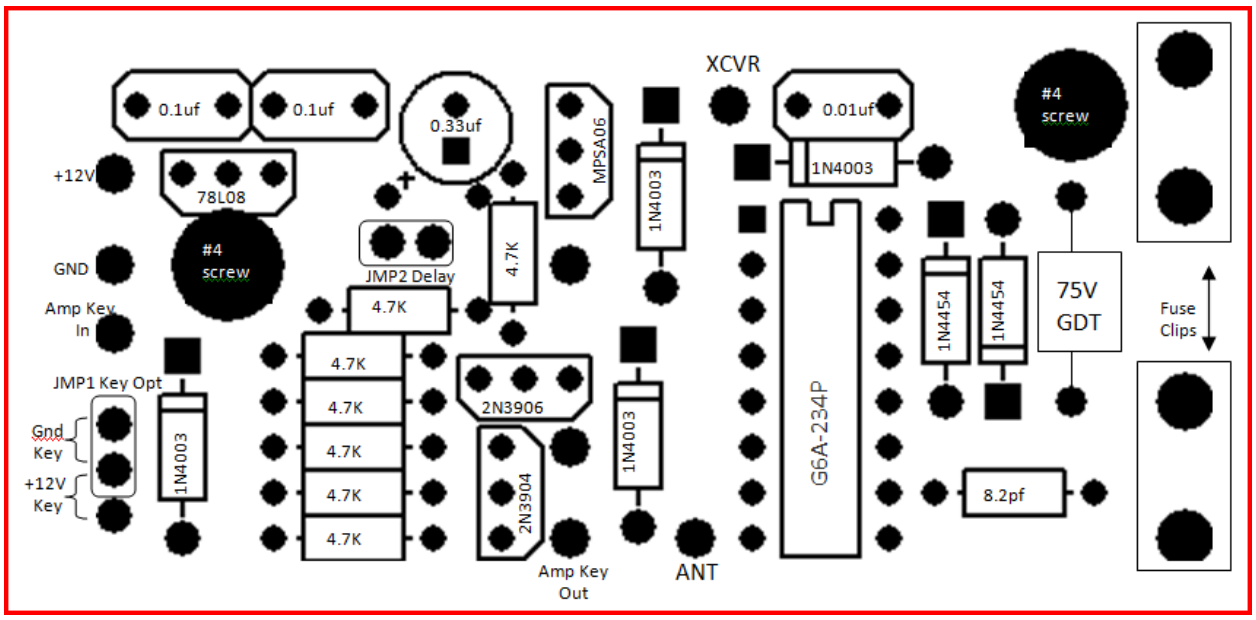

Figure 3: Component locator for the printed circuit board assembly

Table 2: Additional Parts List for Transceiver Front-End Protector Keying Interface

QTY	Description	Mouser/Part Number	Price ea.
1	0.33uf elec. Capacitor	647-UVZ1HR33MDD	$0.09
2	0.1uf 100V capacitor	581-SR211C104KAR	$0.16
1	MPSA06 transistor	512-MPSA06	$0.23
1	78L08 regulator	863-MC78L08ACPG	$0.21
1	2-pin header	538-90120-0122	$0.19
1	3-pin header	538-90120-0123	$0.25
2	Jumper	538-15-29-1024	$0.18
1	1N4003 diode	863-1N4003G	$0.05
1	2N3904 NPN Transistor	512-2N3904TA	$0.05
1	2N3906 PNP Transistor	512-2N3906TA	$0.05
7	4.7K resistor	660-MF1/4LCT52R472J	$0.05
2	0.25” long #4 threaded stand-off	636-160-000-006R032	$0.26
2	Fuse Clips, PC mount	534-3510	$0.21
2	4-40 x 9/16” screws, nuts and split lockwashers for pcb mounting		
4	4-40x3/8” screws, nuts and split lockwashers for UHF connector mounting		
1	PC Board – Contact AD5X for pc board pricing and availability		

The 10pf compensating capacitors are soldered from the input and output UHF connectors to the solder lug grounds. Figure 4 is an internal view of the completed unit. Figures 5 and 6 show the input and output connectors. Labeling was done with Casio black-on-clear labels.

Figure 4: Internal view

Figure 5: Transceiver side

Figure 6: Antenna side

I took some data on the final unit to verify performance. Figure 7 shows the transmit path performance, and Figure 8 shows the receive path performance from 1.8-54 MHz. Transmit insertion loss is negligible (0.06dB maximum on 6-meters) and SWR is less than 1.1:1. The receive path insertion loss is only about 1dB on HF, and less than 2dB on 6-meters. The receive SWR is constant at about 1.2:1 from 1.8-54MHz, consistent with the 9-ohm cold resistance of the bulb in series with the 50 ohm termination. Incidentally, I used an Array Solutions VNAuhf for these measurements. This instrument puts out -13dBm, which is well below the diode saturation level. Keep diode saturation in mind if you use another VNA or antenna analyzer to make similar measurements.

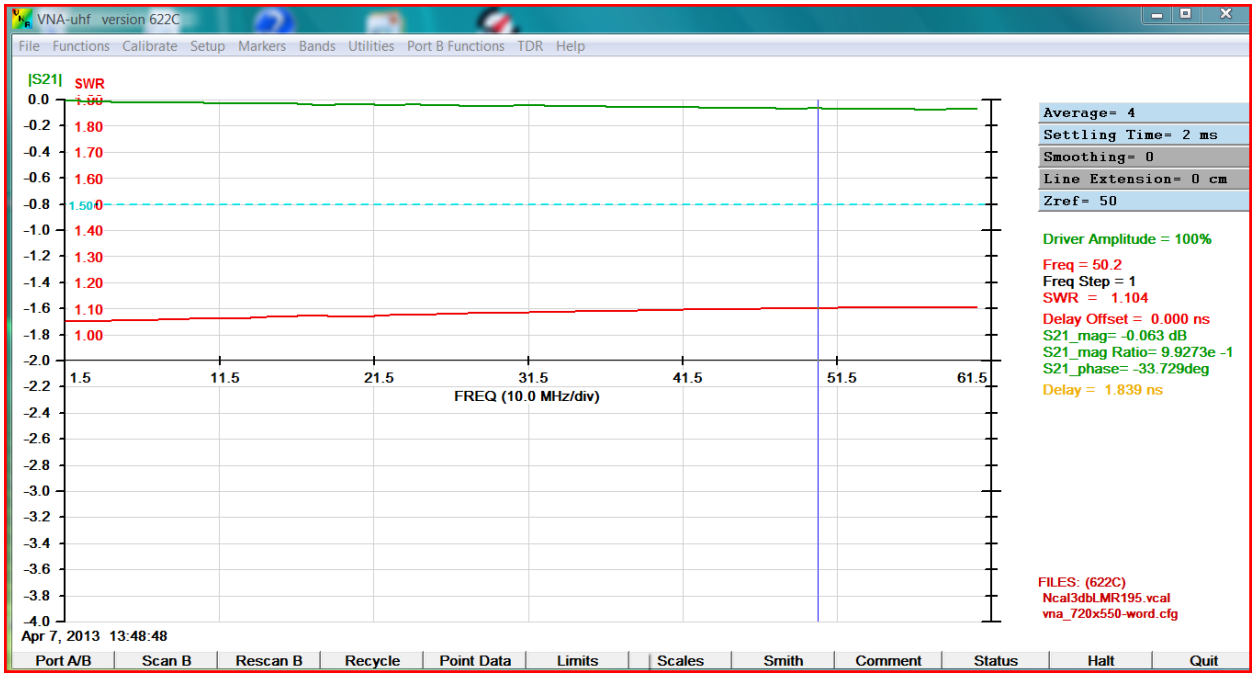

Figure 7: Transmit path SWR and insertion loss

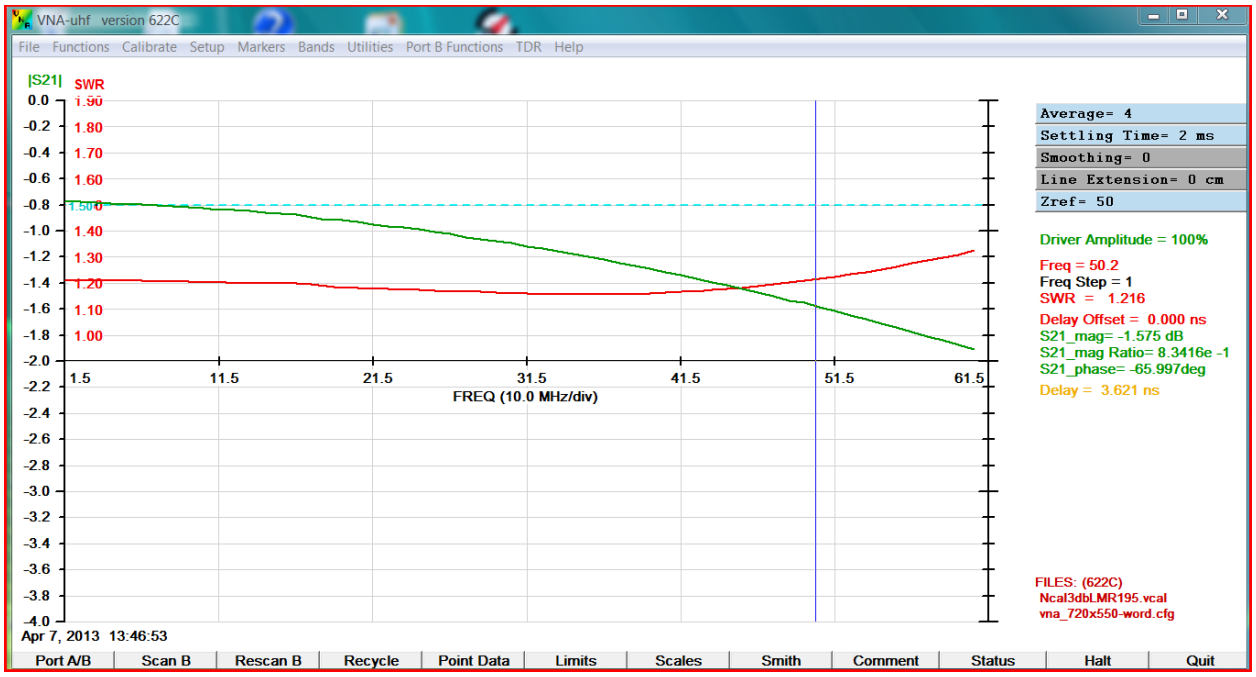

Figure 8: Receive path SWR and insertion loss

Connecting the Transceiver Front-end Protector

The transceiver front-end protector connects at the transceiver's RF output port. The transceiver's amp-key output plugs into the amp-key IN on the front-end protector. If an amplifier is used, the front-end protector RF output feeds the amplifier's RF input, and an amp-key cable connects from the front-end protector's amp-key OUT to the amplifier's amp-key input. Figure 9 shows the interface wiring.

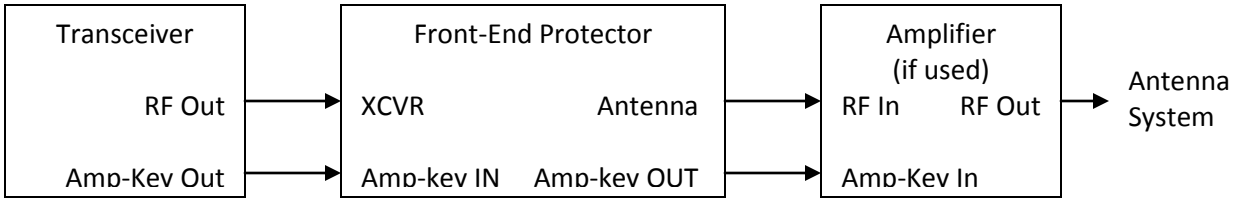

Figure 9: Front-End Protector Connection Block Diagram

Some final observations

I tested the unit up to 5-watts average input power. At 1-watt the bulb glows dimly. However at 5-watts the bulb is VERY bright – and I suspect is close to burning out. Of course, 5-watts is a very hot level. But the lamp does its job, and if it burns out it is easily replaced.

While receive path SWR it quite good under normal conditions, I was curious about the SWR during limiting. The results are shown in Table 3. As you can see, the lamp does a good job of preserving input SWR even at very high input power levels, though this is not really important.

Table 3: SWR at high power levels

Power (PEP)	SWR
1W	1.2:1
2W	1.3:1
5W	1.6:1
10W	1.8:1

Finally, remember that not only will there be some distortion of the desired signal during clipping of the high level signal, the desired signal will also be reduced by the amount of limiting that occurs on the high level signal.

Conclusion

I've described a receiver front-end protector for transceivers that may be subjected to high receive signal levels in multi-transmitter, multi-antenna environments. This unit will interface with any transceiver and it will even operate under full break-in CW conditions. And if you just need receiver (not transceiver) protection, you can simply build the Figure 1 circuit without the relay, and phono- and DC-power jacks.