Inexpensive HF Through 148Mhz Mast-Mounted Preamp Bypass Relay Board

Part I: Useful Applications & Validation

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Ref: https://www.nf4rc.club/how-to-docs/satellite-mast-mounted-preamp-protection-board/

Introduction: How This Can Help Defeat Coax Loss

Modern HF to VHF receiver front ends often provide adequate to excellent front-end noise figure. However, *every dB of coaxial cable loss between the antenna and the receiver front end adds directly to the effective noise figure of the receiver*.   For this reason, a lot of satellite- and weak-signal-operators want a low-noise preamp right at their antenna, boosting the signal.

But they aren't the only ones.   Our EOC has *hundreds* of feet of coaxial cable between our tower-mounted antennas and our operating position, easily adding 5+ dB of loss and adding considerable "deafness" to our VHF stations.   A mast-mounted preamp would do wonders!

Field Day: When operating multiple transmitters in close proximity, as in a disaster radio camp or a Field Day competition, receiver desensing is a real problem, and one solution is a **remote receiving antenna**, at least 200 feet and possibly 900 feet away (per the Field Day rules).   Even using RG8, 900 feet of coaxial cable at 30 MHz is about 9dB of loss!   So there are multiple situations where one might want a remote preamplifier, and some of those situations require protection of the preamplifier from transmitted energy.   A good review of the usage of antenna-end preamplifiers can be found here: https://www.qsl.net/zl3dw/pdf/Masthead Mounted Preamplifiers and Noise Figure.pdf

What is already commercially available?

For VHF/UHF satellite communications participants, there are a limited number of specially designed mast-mountable preamplifiers that allow for protection from transmitted energy.   One such device is the MHP series of German-manufactured low now amplifiers, retailing upwards of $600. (https://www.wimo.com/en/ssb-electronic-mast-preamp-6m-4m-2m-70cm)   M2 offers their 2m mast mounted preamplifier for $376, with switching to protect the preamp during transmit (https://www.m2inc.com/FG2MPA).   The ICOM AG-25 and AG-35 mast-mounted preamplifiers are discontinued. The Advanced Receiver Research products were much more reasonably priced 10+ years ago but not certain they are still available (https://www.eham.net/reviews/view-product?id=7972)   There were some issues with waterproofing.   There may be other preamplifiers available that I haven't found.

Those are some pretty pricey preamps!   After destroying a less-expensive model, I discovered very inexpensive low-noise GaAsFET preamps (such as $20 https://www.amazon.com/dp/B07T59B9C5). Add in an external filter and some means of transmitter-protection and you would have a very inexpensive high quality preamp!

I designed such a system for frequencies up to the 2-meter band.   The goal of this investigation was to test an externally keyed (via coaxial cable-delivered "bias-Tee" voltage) relay system of much lower cost, using inexpensive (Omron) relays, a low pass filter, and a wideband inexpensive mass-produced GaAsFET $20 preamplifier.

Some transceivers can provide a coaxial-cable DC signal ("bias T") to activate (and possibly power) a mast-mounted preamplifier.   This design is based on sensing that signal, possibly using either it or a separate +12V to power the relays.

A subsequent article will provide additional construction details.

Note: Sequencer Required
To avoid hot-switching relay contacts and likely damage to the preamplifier, a **sequencer system** is needed to delay the arrival of real RF transmitted power somewhat later (e.g. 30-50mSec) after the DC bias voltage is removed, to move the relay board into "transmit" configuration. Expensive commercial versions of sequencers are also available off-the-shelf.   In a separate development, an Arduino-based sequencer is being developed to control the ALC input of ICOM-type transceivers.

Low Cost
Presuming that the board can be obtained as part of a group purchase for approximately $10 each, the components needed for this board are likely under a total cost of $30.   As mentioned above, the wideband preamplifier is approximately $20, and the low pass filter utilized was one portion of a Comet CF-146 "duplexer" available for $55 (https://www.dxengineering.com/parts/cma-cf-416a)   A suitable multi-section lumped constant or other low pass filter could easily be constructed at even less cost (but filters can be tricky!).   Some waterproof container (possibly a plastic box) would be needed, but the entire system should be possible for less than $100.   Unfortunately this current design is not suitable for 70cm; a later development may solve that problems.

The basic schematic of the preamplifier bypassing board is shown below.

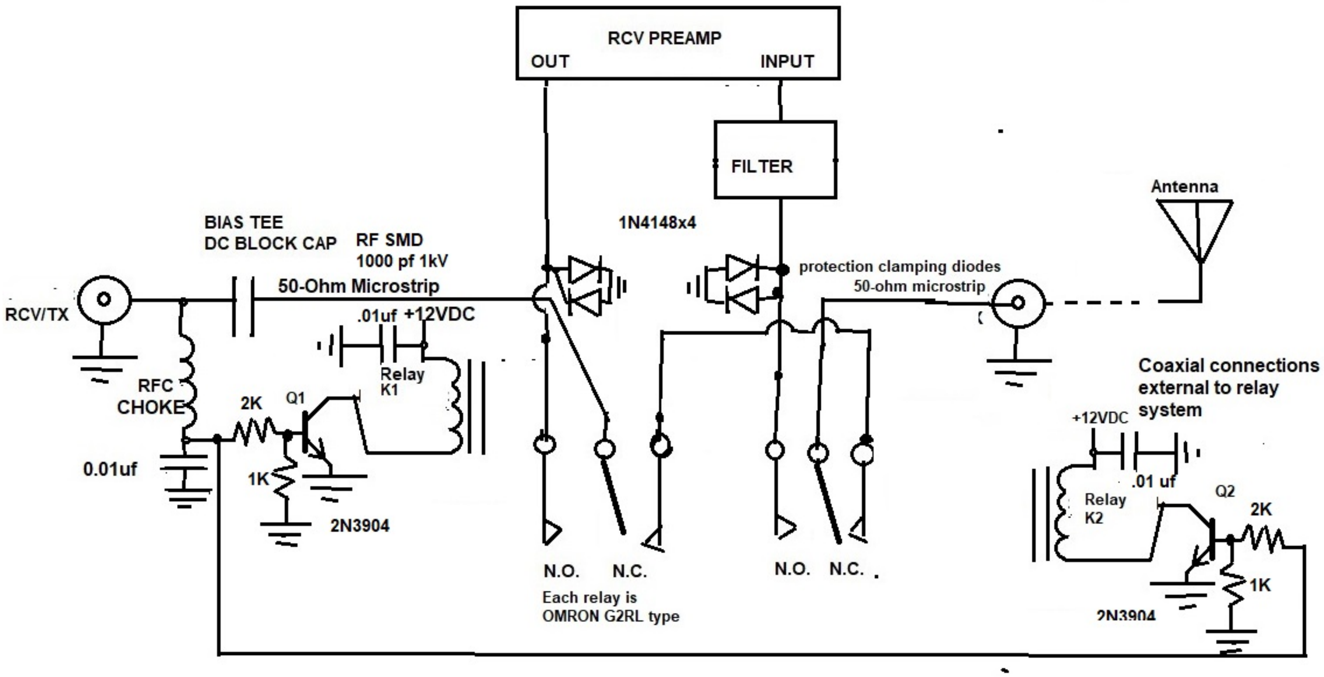
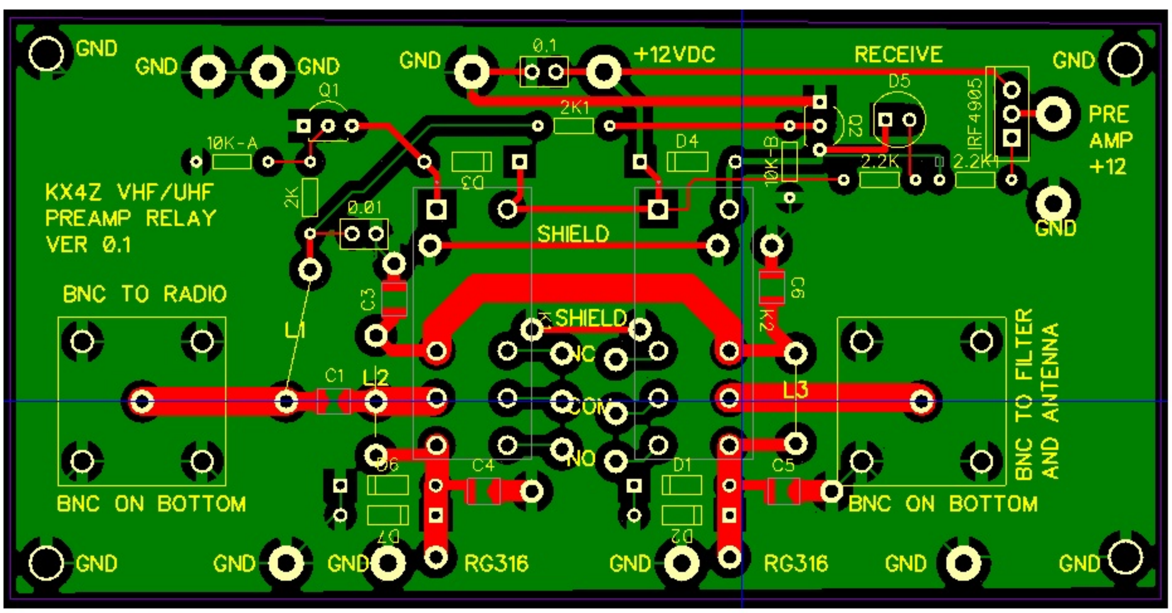


Figure: Basic schematic of Preamplifier Bypass Board. The low pass filter is necessary to protect from nearby 70cm power and to prevent oscillation of the preamp.

A photo of the layout of the board is shown in the next figure, laid out including an effort at a 50-ohm microstrip line for the transmitted signal from input to output. (RED = top trace; GREEN = bottom trace or grounded copper pour).



4.8" x 2.425"

Figure: Two-layer layout of the preamplifier bypass board.

This design attempts to use inexpensive general purpose Omrom G2RL-2-DC12 $3.32 low-profile relays to switch RF energy at up to 148 MHz. These are available from mouser.com as: https://www.mouser.com/ProductDetail/653-G2RL-2-DC12

W6PQL's Pioneering Work

Jim Klitzing, W6PQL, has written and experimented quite extensively on VHF and UHF communications and equipment construction. He made crucial measurements on these relays (and others) which were instrumental in this effort. That excellent work can be found at: https://w6pql.com/using_inexpensive_relays.htm I simply adopted several of his suggestions and other VHF/UHF printed circuit board design techniques, although I'm quite the beginner. Following Jim's suggestions, the board allows for surface mount capacitors at relay terminals that might further reduce the SWR seen by the transmitter, at C3, C4, C5, C6. At this time, I haven't utilized those potential improvements.

For possibly the best performance, the BNC connectors are mounted on the underside of the board; the 1N4148 and other components are mounted with the shortest possible leads right at the board surface, and the relays were mounted flush at their contact end, and raised approximately 1mm at their coil connection end to give slight vertical clearance to the transmitter microstrip transmission line.

Control

An impressed DC voltage of approximately 10V on the center conductor of the input coaxial cable will move the board into "RECEIVE" condition. Removing that voltage causes the board to bypass the preamplifier and go into "TRANSMIT" condition. Relays are not instantaneous and the protection provided by just the 1N4148 diodes before relay settling provides 36dB of isolation, is inadequate to protect the board and/or preamplifier from damage. A proper sequencer should be used to delay arrival of actual RF energy by 30-50 milliseconds or more to allow for relay settling.

1. Transmit SWR and Losses

The board, as tested, did not include any of the 5pf contact-to-ground mica capacitors recommended by W6PQL to reduce SWR at 144MHz. At one point a 3pf was attached to the output normally closed contact to ground with an apparent decrease in the (tiny) throughput loss, so it is likely that his improvement would work, but for simplicity none were included in this test.

Loss at 144 MHz was measured compared to a double-female BNC connector used to normalize a Siglent spectrum analyzer to 0dB. When reconnected to the BNC connectors of the board, using the inexpensive Omron relays, the loss at 144MHz was 0.14dB, which is equivalent to 3.2% of input power (into a 50 ohm load).

SWR @ 144 MHz: With a suitable 50-ohm 25W dummy load attached via BNC to N connector adapter at the antenna end of the board, the input SWR (at the radio end) was measured by a calibrated nanoVNA at <= 1.1 throughout the 135-145 MHz region. This is the most accurate measurement I have available, and might be reduced further by adding in 3-5 pf surface mount capacitors to ground from some of the relay contacts, as suggested by W6PQL.

The bias tee series capacitor is a 1000 pf 1kV KEMET surface mount "1210"-sized capacitor using COG dielectric said to have very low equivalent series resistance.
https://www.mouser.com/ProductDetail/80-C1210C102JDGAUTO Each such capacitor is $1.79.

Power testing was accomplished with an available approximately 50-ohm dummy load capable of handling significant power, manufacturer unknown, and using a TYT MD9600 FM transceiver rated for 50W output, at 144.990 MHz. Full power was maintained for 60 seconds with no observable change in input SWR on an available unknown-accuracy VHF/UHF wattmeter/SWR meter. **No component showed any trace of warming to observation or touch.** I was satisfied by this test that the bias T capacitor was sufficient and that losses on the board were truly negligible.

2. Preamp Isolation From Transmitted Energy

During TRANSMIT, the input and output of the preamp connections are both "grounded" and disconnected from the transmission pathway. The "grounding" of the lines to the preamp is certainly not perfect, nor is the isolation by the inexpensive relay perfect, because of radio frequency capacitive and inductive effects of even small conductor lengths, and proximity of relay contacts. In order to protect the preamp from the <=50 watts of 144MHz transmitter energy (approx 47dBm) we need significant isolation -- and the board provides on the order of 36dB isolation to both ports at two meters.

Each port is protected by a pair of 1N4148 small signal diodes, to ground, in each direction. Theoretically these will conduct around 0.7V and protect against signals rising above 10dBm.

50Watt Power Test

The inexpensive (< $20) preamplifier in use is rated at 0.6 dB NF and 16dB gain at 5V power supply. https://www.amazon.com/dp/B07T59B9C5 Its specifications do not note the maximum safe applied RF, but 10dBm is a common level and 0.7V is well below the damage level for many semiconductors.

With the preamplifier wired into the relay board with a low pass filter (see below) on its input port, and the board in "transmit" condition (hence, not powering the preamplifier), the full RF power from the 50watt FM transmitter was against passed through the board to a suitable dummy load for 60 seconds. Following this test, the spectrum analyzer tracking generator was used to supply a signal of approximately -50dBm and the normal amplification by the preamplifier was again observed, as allowed by the low pass filter throughout its bandpass. This test suggested there was no apparent damage to the preamplifier for 60 seconds of 2-meter energy through the board.

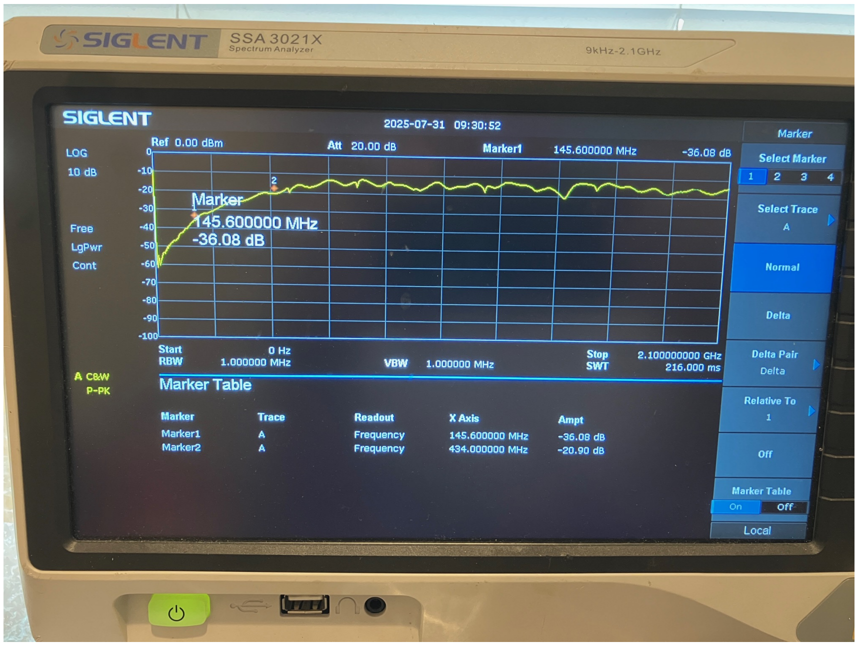


Figure: Isolation between preamp coaxial connectors and transmit pathway (1MHz-2.1 GHz) -- both input and output are similar. This shows the isolation of the preamp from the transmit pathway at two meters is approximately 36dB, but the isolation declines markedly at higher frequencies.

> **<u>WARNING: Insufficient protection at 70cm</u>**
> While the 2-meter isolation is adequate to get the power heading to the preamp down into the 10mW level (approx 0.7 Vrms -- tripping the protection diodes), the isolation from transmitted signal path to preamplifier input/output connections, at 70cm, is inadequate.   Attempts to correct this were unsuccessful and instead brought in new problems.   So this inexpensive Omron relay in this configuration aren't suitable for 70cm usage.   (It is likely that an improved, and more costly relay, with 40dB isolation, will allow usage at 70cm; see a later article for details.)

3. Feedback & PreAmp Stability

The input and output connections to the preamp must have sufficient isolation to prevent oscillation, even with the gain (16dB) of the wideband GaAsFET preamp. *Unfortunately, the feedback loop around the preamp has insufficient isolation (approx -13dB) just below 1GHz and oscillation (and likely damage, as I experienced in testing) will result if a low-pass filter isn't used right at the input of the $20 preamp.*   I used the low-pass side of a simple $50 Comet duplexer for this purpose, with good success.

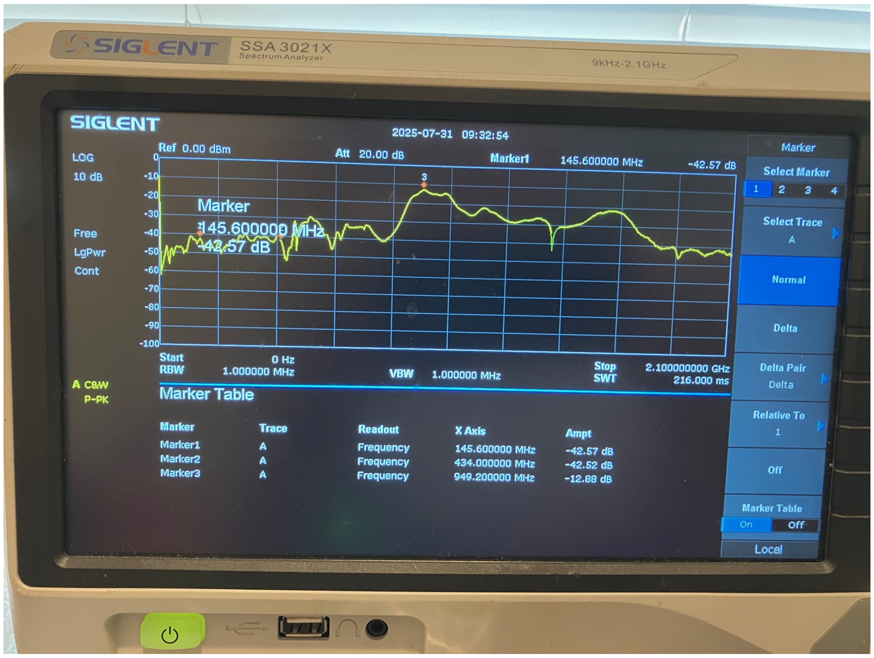


Figure: Spectrum Analyzer used to measure gain(loss) around the feedback loop via the connections to the preamp. This test shows a risk of preamp oscillation just below 1GHz, because the remainder of the feedback loop has a loss < 16dB.

Preamp Performance With LPF

To prevent oscillation, the low-pass filter side of the duplexer was inserted at the input side of the preamp. Tracking generator output measuring about -45 dBm was utilized at the antenna connector. The signal at the output of the preamp demonstrates approx 16dB gain within the low pass filter range, and no oscillations (with filter in place).

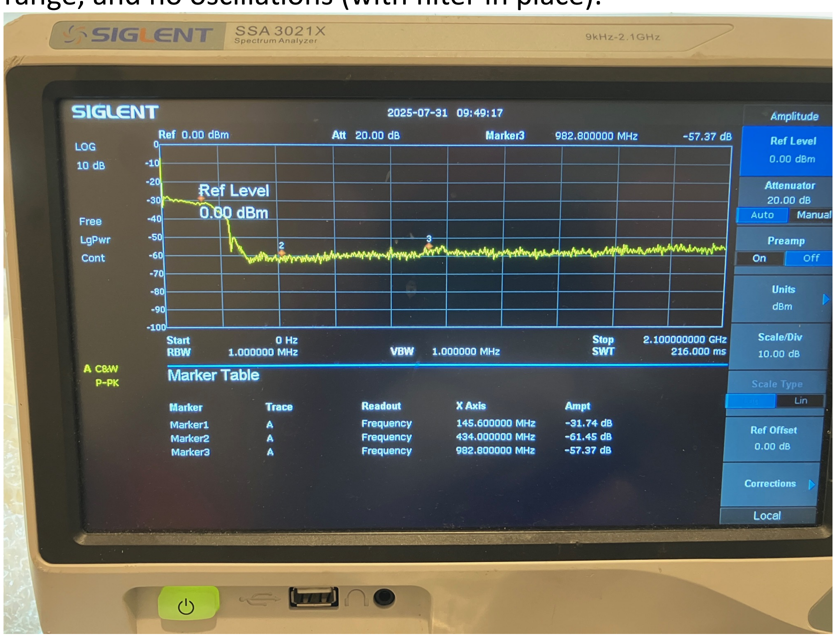


Figure: With the LPF at preamp input (inside the possible feedback loop), the system is quite stable with no oscillations visible to 2.1 GHz. The gain of the preamplifier of approx 16dB is visible.

Conclusion

These measurements demonstrate that the 2M Preamplifier Bypass board has

1. adequate transmit performance with low SWR and low loss;
2. adequate protection of the preamplifier board from transmitted energy; and
3. with proper placement of a low pass filter, adequate and stable performance of the wide band preamplifier to improve system receiver performance.

This is a much lower cost solution for mast-mounted weak-signal HF- 2meter communications, than some commercially available systems. A subsequent article will provide construction information.