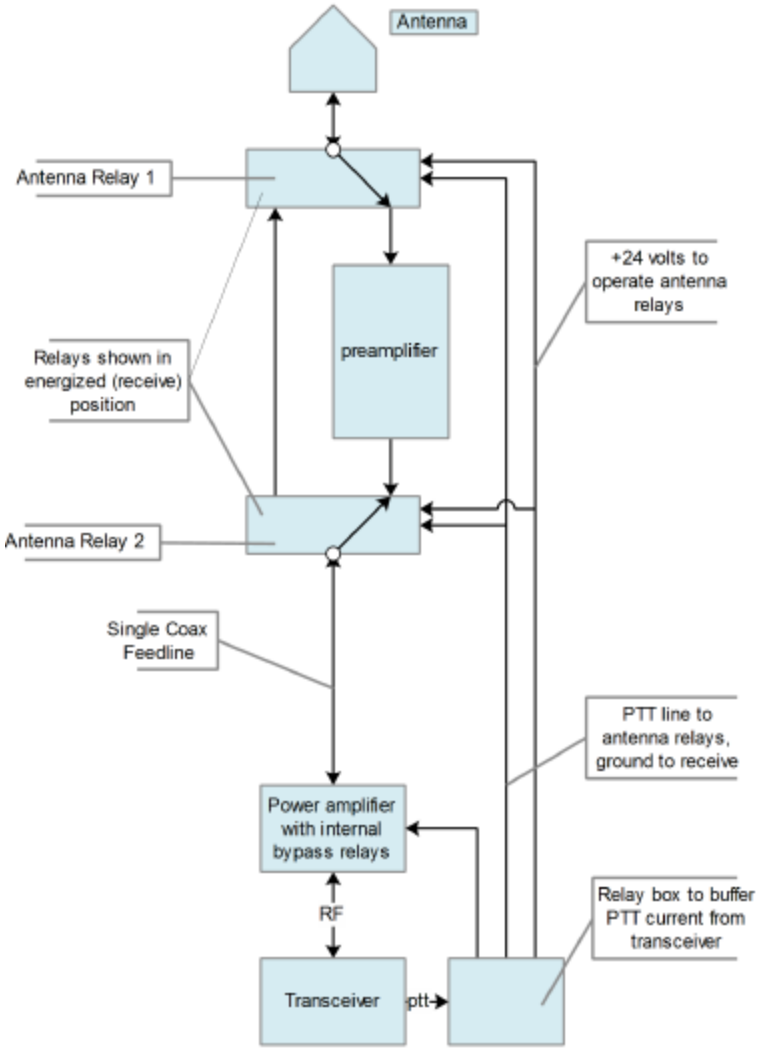
Sequencing for VHF stations

From time to time I see questions and comments on the various reflectors and chat pages, about the best way to protect equipment via sequencing. Having some experience in the matter I thought I would write something up.

First, why do we need sequencing. Well if you have a simple setup where you just have a transceiver connected directly to an antenna, you don't need to sequence. But with more complicated setups you almost always do. There are two crucial pieces of equipment that need to be protected, your external antenna relay and your external preamplifier.

The normal setup for a well performing VHF station is a transceiver, possibly a transverter, an external power amplifier, an external (to the radio) antenna relay, and an external preamplifier. This will be more complicated if the power amplifier has a set of internal relays to bypass the amplifier. The radio has a PTT output line that we use to operate the antenna relay and key the amplifier. Also, if only one transmission line is in use, a second antenna relay is required on the tower, to switch the coax feed from the output of the preamp, to the main antenna relay when it is in the transmit position. Both relays are operated at the same time. See the diagram below.

Note that this is wired so the antenna relays are energized to receive. This is necessary for safe remote relay operation. In transmit the relays are not on. This means that if relay power is lost for any reason while transmitting, the relays will not switch, and your equipment is protected. Also when you power down your station, the preamp will not be connected to the antenna, so it will be safer from any nearby lightning strikes.



Many lower power amplifiers have a feature called RF sensing. This can be used to key the amplifier automatically, without having to connect a wire to 'hard key' the amp. This is a bad idea! I will discuss that issue in a bit, but for now only consider the situation where you hard key the amplifier.

When we want to start transmitting, we grab the mic, press the PTT button and start transmitting.

If there is no sequencing, the transceiver starts making power immediately. At the same time the antenna relay is switching and the power amplifier is keyed. Since it takes a little time for the antenna relay to switch, what happens is that

power is sent up the coaxial line before the relay has finished switching. This can cause 2 problems.

1. Since there is RF power on the coax line, the relay will generate a spark across the contacts when it closes. This is called 'hot keying' and must be avoided in nearly all cases (except when doing it with very low power – a few watts at most).
2. If you have a single feedline going up the tower then the rf will be sent into the output port on the preamp, for a split second every time you key up. If you are not running a lot of power, you may get away with doing this for a while, but eventually you will damage the preamp, the relay, or both.

So how do we solve the problem. A sequencer is a device that you connect to the PTT output of you radio. It has several output lines that send the PTT signal to your amplifier, your antenna relay, and anything else that needs to be operated from the PTT line. It is arranged so that each output line is keyed sequentially so that everything is not keyed at once. The output lines are usually numbered, 1 through 4 if there are 4 outputs. So, first line 1 is activated, then 2, etc. When the PTT from the radio is released, the sequencer operates in reverse, releasing #4 first, then 3, etc. Most sequencers have switches or relay options to allow an open or a closed contact, for each line, when activated. Also, most sequencers will have a way to adjust the timing between each output. A good way to set it up initially is slow. Then when you are sure everything is working as you planned, you can shorten the time to where you want it. Normally I set the total time to a little under ½ second. Here is a simple setup for each stage:

1. PTT from radio applied
2. Line one activated, operates just the antenna relay.
3. Line 2 operated, keys the amplifier.
4. Lines 3 and 4 activate but are not used in this setup.
5. PTT from radio released.
6. Lines 4 and 3 are deactivated.
7. Line 2 is released, turning off the amplifier.
8. Line 1 is released, switching the antenna relay back to the receive position.

Now you can see that the antenna relay should not be hot switched. The amp is not turned on until after the relay has operated. But there is a problem. Initially

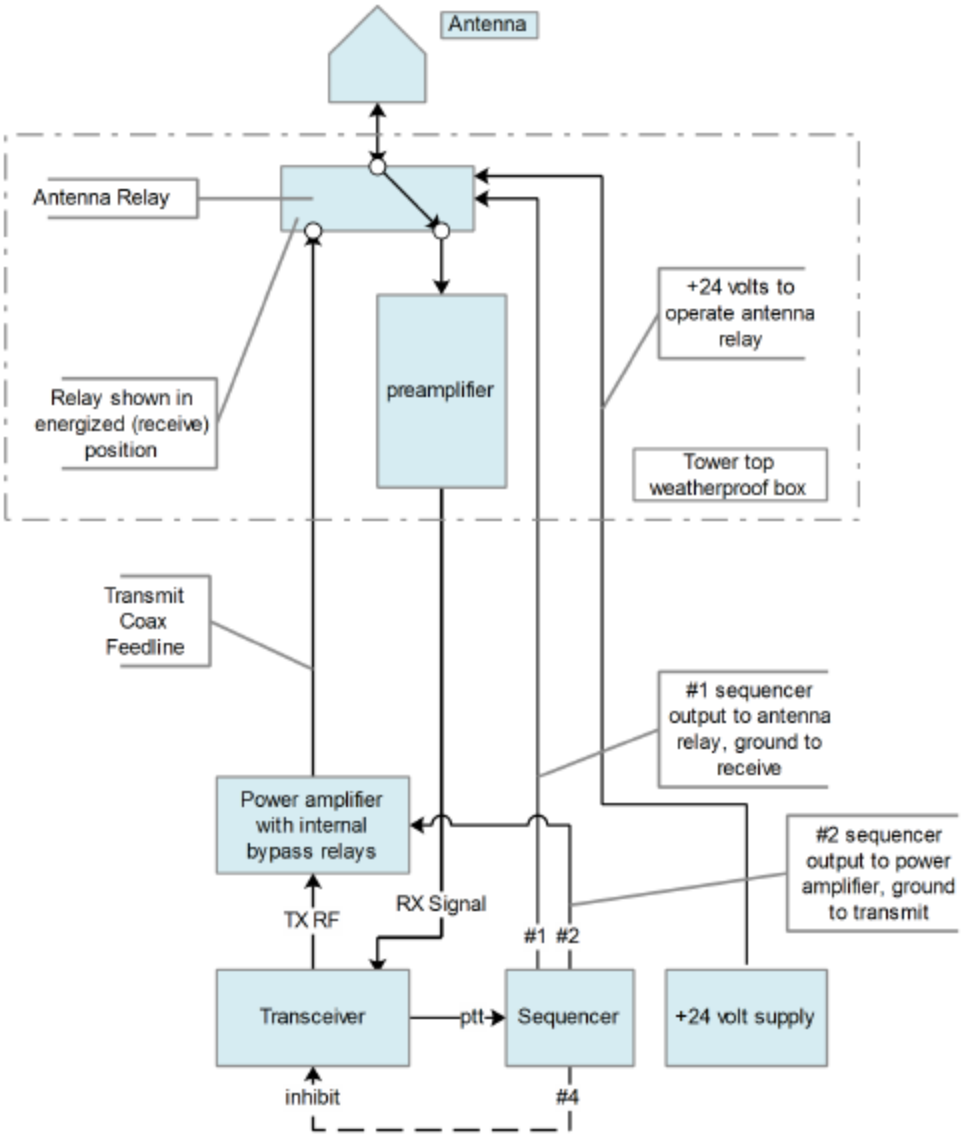
the radio started making power immediately, before the sequencer could operate. This is where the RF sensing feature of a power amplifier is bad. The amp can start making power before the sequencer tells it to turn on! So, in all but a simple, low power situation, RF sensing should not be used. Hard key the amplifier and disable the RF sense. Some amplifiers have the ability to disable the RF sensing, but in many cases one would have to actually disconnect the RF sense mechanism inside the amplifier. This problem is normally only present with what we call 'brick' amplifiers, solid state amps that generate up to a few hundred watts. Tube amplifiers and high power, solid state amps normally do not have RF sensing.

Ok, so we have done away with RF sensing, but there is another problem. Most 'brick' amps, and many high power amps have bypass relays. This is needed so that the receive signal can pass through the amp on the same coaxial line that is used for transmitting. It can also be useful when the amplifier is turned off if you only want to run low power. But now what happens when you key the radio? The RF from the radio immediately passes through the bypass relays on the amplifier and is applied to the antenna relay, before it switches. Again, the relays will be hot switched and the preamp can be damaged.

So, what is the fix for this. Well there are several possibilities. For many years I have used two feedlines up my tower. The main line is only used for transmitting. The other, smaller, line is only for receive. The small coax is connected directly to the output of the preamp, so no relay is needed there. In the shack the receive coax goes directly to the receive input to the radio, or transverter. (In most cases the radio will have to be modified to provide a separate coaxial connection for receive only.)

This provides a couple of improvements. Only one antenna relay is now needed, switching the antenna from the transmit line, to the preamp during receive. So, there is never any possibility of damaging the preamp by applying RF to its output port. (Another advantage is that it is now possible to apply your receive signals to more than one receiver at the same time.)

Notice how much simpler the tower top circuit is now. See Diagram below.



Now if the drive requirements for your power amplifier are low, it won't matter much if power goes through the bypass relay for an instant when you first key up. The antenna relay can handle being hot switched with a few watts. But these days most HPAs need 40 or more watts drive to produce full output. That is enough power to destroy that expensive antenna relay over time. One solution is to remove the bypass relays and use the amplifier all the time. I did that for years with my tube amplifier. How it works is that the RF power is always applied only to the input of the amp, and so the amp will not pass or make power until it is keyed; so all is well. But what if you want that bypass feature? Well there have been a number of solutions to that problem suggested and that is the main

reason I decided to write this article. My assertion is that there is only one fool proof way to handle this situation. First let me address a solution that is often proposed and used.

Many times I have seen the suggestion to not let the radio key the PTT line. Instead, key the sequencer directly with the microphone PTT line (or foot switch) and then let the sequencer key the radio when everything else has finished switching. Sounds great, right? Yes, it will work in the simple case where you are only operating in voice modes and you never key the radio any other way. But what happens if you want to use CW VOX or even voice VOX. Now there is no way to key the sequencer if it is not connected to the radio PTT. If you never use VOX maybe you are ok, but what if VOX gets turned on by mistake. It happens, and when your radio keys up via VOX the sequencer is totally bypassed. In fact it never comes on. So, in the single coax system, your power is applied to the output of the preamp and it blows – immediately! The same thing would happen if you press the MOX or send button on your radio. Especially if you were in FM mode, full power from the radio will be applied.

So, I find this approach of keying the sequencer directly, dangerous. What else can be done?

There are still a couple of solutions that are completely safe. One is called 'transmit inhibit'. This is a connection to your radio that, when asserted, will prevent the radio from producing RF power even when it has been keyed. A few transceivers have such a line, but most will require some kind of modification, or special external circuit to make a TX Inhibit function. More on that later. Now let's look at the sequencing:

1. PTT activated from the radio. No RF output because TX inhibit is asserted from the last stage of the sequencer.
2. Line 1 is activated, operating the antenna relay.
3. Line 2 activates the amplifier.
4. Line 3 not used.
5. Line 4 de-asserts the TX inhibit line to the radio and RF starts being produced.
6. PTT from the radio is released.

7. Line 4 from sequencer is released, putting radio back into TX inhibit mode. RF stops.
8. Line 2 is released unkeying the amplifier.
9. Line 1 is released switching the antenna relay back to receive.

Look back at the diagram above, at the bottom there is a dashed line that shows the transmit inhibit line connected from the sequencer to the radio.

Now, no matter how you key your radio, nothing can damage your expensive, hard to work on, tower mounted relays and preamplifiers.

Ok, so how do you implement TX inhibit. Well, the radio may need to be modified if that function is not available natively. But one solution that can work is to use the ALC input line on the radio. That line is normally connected to an external amplifier so it can reduce transmit power if the peak signals from the amplifier are too high. It usually works by applying a negative voltage to the ALC input line, reducing power. But if you apply a sufficient amount of negative voltage, the radio will not make any power at all. So, if you wire your system to apply negative voltage from the sequencer to the ALC input during receive, and remove it during transmit, you have a TX inhibit line. That will work fine, but there is one possible problem - the ALC time constant. In my Kenwood TS-2000 it took about 2 seconds to discharge the ALC timing capacitor once -7 volts had been removed from the ALC input. That is way too slow for most operators to contend with. Other radios seem to have faster acting ALC and so this scheme may work much better for them. I had to find another solution.

After much investigation of the schematics and service manual I finally found a trace called VTXB that supplied +7 volts to the lower level circuits during transmit. I cut the trace and put an NPN transistor across the cut. Now when I supply + voltage to the base of the transistor the transmitter comes on (if PTT was asserted). But the PTT circuit and everything else still work normally. So now I have a fool proof system. No matter what I do, I cannot cause power to hit my relays or preamps before everything is in transmit mode.

Most other radios likely have some similar circuit that can be exploited to provide a TX inhibit and I believe that is the best way to go. I only wish that manufacturers of all amateur radio transceivers would provide that function.

For those who use transverters, there is another option. You can provide a small antenna relay on the VHF output of the transverter. The relay switches the output to a small load resistor when the sequencer is in receive condition. Then the last stage of the sequencer switches the transverter output back to the amplifier. This will only work for low power transverters, but it is a very effective solution and does not require modification of the transceiver.

In the final configuration, here is the sequencing of my station:

1. PTT from radio applied to sequencer.
2. Line 1 of sequencer disables my manual polarity switch for the two meter crossed Yagis (so I cannot accidentally switch polarity when transmitting).
3. Line 2 of sequencer switches the antenna relay to the transmit position.
4. Line 3 of the sequencer keys the power amplifier.
5. Line 4 applies voltage to the TX inhibit line to the TS-2000, enabling RF power.
6. PTT from radio dropped.
7. Line 4 from sequencer removes voltage from the TX inhibit, stopping radio from making power.
8. Line 3 unkeys the power amplifier.
9. Line 2 puts the antenna relay back into the receive position.
10. Line 1 enables my manual polarity switch (used for EME operation).

I should note that with the TX inhibit line I could likely just turn everything except the polarity control on and off at the same time, only needing 3 positions on the sequencer. But the sequencer makes connection to control lines for all the external equipment easy, and I like the safe feeling of controlling exactly how things are working.

There is one more thing I should mention about antenna relays. It is not part of the sequencing discussion but should be noted. It is essential to place a small, power silicon, diode directly across the coil connections of all relays. Failure to do so will allow a large reverse EMF (voltage), that is generated when the relay is de-energized, to feed back into your equipment and cause damage. Never use a DC relay without this protection.

73 to all and I hope this article will help.
Russ K2TXB