Design Notes

Avoidable disasters and active antennas

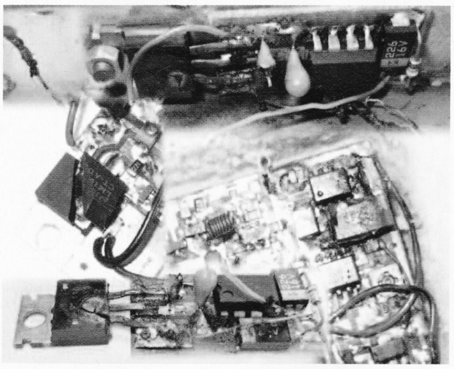

PHOTO 1: Montage of typical damage resulting from a sustained overvoltage on the input to regulator chips. These were all the result of a power supply fault triggered by a lightning-induced transient.

CARNAGE! Fred Zappa, 2E9ZAP **[1]** made a big mistake. For convenience, "because it was to hand", he used an old 2A, 0 – 50V bench-type adjustable power supply set at 12V to power his masthead mounted 24GHz transverter. Everything worked well enough for a long time until a recent thunderstorm. He writes, "... [there was] a blinding big flash and a mighty bang and a crack /fizz which sounded like it came from my mains sockets, although that might have been the electric field collapsing after the strike. The neighbour had his cordless phone go down plus an external TV camera. I did first wonder if it had struck my mast and his ensuing damage was the strike dissipating through his ground. There was no evidence of any damage to the mast at all, so must have been a nearby ground strike...

"I got the mast down and found the remains of my 24GHz system following the lightning (see **Photo 1**). It looks like all the three-terminal regulators have gone, leaving some rather messy remains to clear up. I just hope they blew to open circuit and saved what was downstream. Looks like the scenario has been that the shack 12V PSU serving the 24G may have been hit by either a mains spike or discharge down its mast lead on the LV side, leading its output to soar to 50V or more when regulation failed. This in turn took out the three-terminal regulators. Awful smell too!"

The PSU was an old design with several pass transistors in parallel. The induced transient caused one to fail short circuit and allowed the full rectified input at more than 50V to get to the load. It is not known whether the transient arrived on the mains input cable or on the DC lead going up the mast, or even as a kilovolt spike across both. Whatever happened, it was enough to damage the PSU and cause one device to fail short circuit – with the knock-on consequences. Fred continues, "... the output fuse also blew but it seems to have perhaps taken some time. I did smell burning at the time but the PSU has no ON light so didn't realise it was off until some minutes later, by which time the damage had been done."

LESSONS LEARNT. The lighting strike itself only appears to have caused minor damage to the PSU, causing a single pass transistor to go short circuit. But the ensuing overvoltage destroyed all the voltage regulators further down the chain. Both LM317 and 78xx types are rated for inputs up to about 30V, so the 50V killed them. It is fortunate that in some cases these must have then failed open circuit, protecting more delicate circuitry further down the chain. In other cases it appears that tantalum capacitors may have worked as voltage clamps, preventing voltage levels rising too high, although blowing themselves apart in the process. It does appear as if some of the more sensitive, expensive and exotic microwave semiconductors have survived, although several were damaged or degraded in performance. Most damage was to the power supply regulators and decoupling capacitors.

So what has been learnt? Firstly, for semi-permanent installations, never use an adjustable PSU that can ever deliver a voltage significantly above the maximum input allowed for any downstream equipment. This includes all equipment with its own power supply regulators. Even if it never gets damaged, there may come a point when the voltage setting control is tweaked accidentally. Provide an overvoltage clamp or trip on all PSUs and set this at a safe maximum, just above the working voltage. Do not rely on output fuses to protect downstream equipment; the PSU mentioned could easily supply 50V at 2A forever when fully working. If equipment is to be left on continuously, add extra circuitry to kill the mains input if the output goes under or over voltage – this is a commonsense safety precaution against any nasties and is best implemented with a latching relay system on the PSU mains input. And do include LEDs on the PSU to indicate input and output volts are present and correct!

When masthead equipment is in use, provide transient suppression components such as Transorbs and firmly bond all grounding cables and 0V points together. That way, if transients do get induced, everything 'jumps' together. And finally, if you smell burning – switch off! **[2]**.

ACTIVE ANTENNAS. An active antenna offers a convenient solution for a small sensitive receive-only system in the VLF to HF range, 0 – 30MHz. The principles behind active antennas (sometimes referred to as voltage probes) and their correct installation is not always fully appreciated. An arbitrarily short metal probe is placed at a certain height above ground where the electric, or E-field, component of any radio signal induces a voltage in the probe. The magnitude of the induced voltage is given by the field strength of the signal in volts per metre multiplied by the height of the bottom of the probe above ground. Note that the length or shape of the probe does not inherently affect the induced voltage, although it does affect efficiency, as we'll see shortly.

The probe is now connected to the input of an amplifier with a very high input impedance, a voltage gain of unity but with a high current gain – such as that shown by emitter or source follower circuits. The amplifier has to be installed at the base of the probe, with its reference connection going to ground vertically underneath. The induced voltage on the probe is then transferred to the output port, which can feed down coax or other suitable RF feeder to a receiver. In theory, the input to the receiver, in (micro)volts is now pretty close to the field strength multiplied by height of the probe. But it's not quite that simple.

The impedance of the probe consists of a very high resistance in parallel with a few (tens of) picofarads of capacitance. To all intents and purposes for an electrically short probe the resistive part can be considered infinite so the impedance of the probe now appears as a small capacitor with respect to ground. We'll assume 10pF as a working value for now. Consider the 80m band.

TABLE 1: Mini-Whip antenna specifications.

Frequency range	10kHz – 30MHz
Power	12 – 15V at 50mA
2nd order output intercept point	> +70dBm
3rd order output intercept point	> +30dBm
Maximum output power	> -15dBm
Dimensions	100mm x 40mm diameter

At 3.7MHz, 10pF has a reactance of 4.3kΩ. At 137kHz this rises to 116kΩ. To avoid undue losses, the amplifier input impedance must be appreciably greater than this to avoid the voltage being divided down. FET source followers are nearly always used, followed by at least one, and sometimes two more stages of current gain. Making the probe capacitance as high as possible with a large area also helps, as the resulting source impedance is lower. Making the probe longer is not always a good idea. At the upper frequency end, where a long probe no longer appears electrically short, large signals could appear that cause overloading. In practice, short and fat is the rule. Or at least moderately short.

The circuit of **Figure 1** shows the circuit diagram of the Mini-Whip antenna **[3]** designed by Roelof Bakker, PA0RDT. This is typical of such designs; this particular one is simple to build and has proved itself time and time again amongst operators on the 137 and 500kHz bands. It is used extensively by the receive only 'grabber' stations monitoring those frequencies. The probe itself consists only of a piece of copper, half the PCB, just 30 x 45mm in size. A J-FET source follower presents very high input impedance with only a few pF in parallel, and 1MΩ input bias resistors ensure the input impedance is of this order. A medium power RF transistor run at several tens of mA serves as output buffer driving the 50Ω line. DC power is supplied up the coax from a bias tee situated at the far end. The performance achieved, shown in **Table 1**, is impressive.

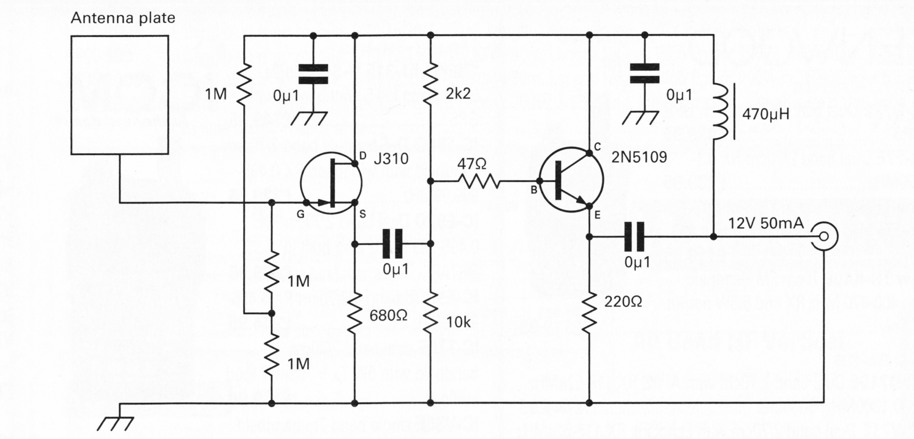

FIGURE 1: Circuit diagram of the PA0RDT Mini-Whip active antenna covering LF to HF.

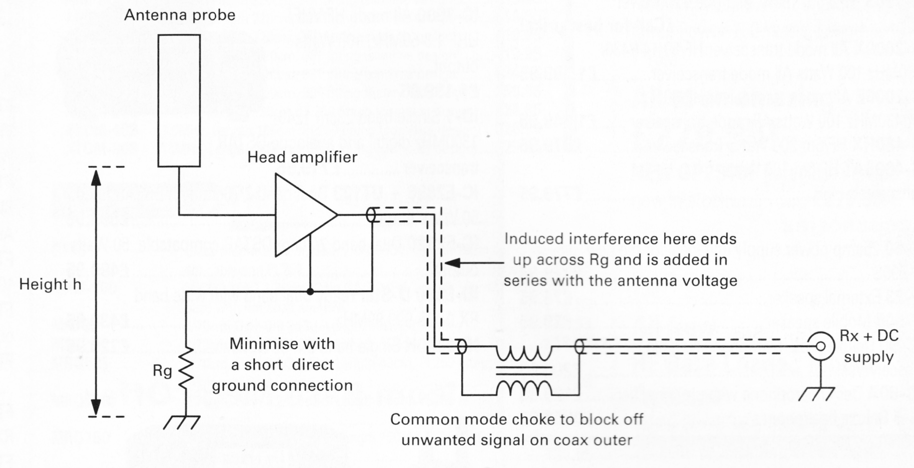

FIGURE 2: Typical installation of a voltage probe antenna showing the interference injection mechanism and decoupling to minimise its effects.

INSTALLATION GUIDELINES.

Active antennas respond to electric fields and this means they are particularly susceptible to locally generated E-field interference, which is generally a short range phenomena. There are two important criteria that must be met when installing such an antenna to minimise unwanted pickup. First, mount it away from electrical wiring and any locally generated interference sources. In practice, this means at the end of the garden, away from the property. Indoor or loft mounted versions are certainly not advisable. A long run of coax is quite acceptable, as the power gain provided by the head amplifier is more than adequate. Secondly, the common, or ground connection of the amplifier must be firmly connected to ground directly underneath the probe.

Consider what happens if local interference is imposed on the outside of the coax – exactly the situation that will happen as it passes indoors next to interference generating equipment. Refer to **Figure 2**, which shows a typical installation. Unwanted signals will travel along the outside of the coax until they reach the head amplifier. If the far end is not perfectly grounded, as shown by the resistance Rg, the unwanted signal voltage will be imposed across Rg, which is effectively in series with the probe, so the unwanted signals will enter the receive chain. As perfect grounding is almost impossible to achieve in practice, extra isolation against common mode local interference can be added by a common mode choke in the feeder. One way is by winding many turns around a ferrite core. Burying the cable to give additional decoupling will also help. Several users have resorted to transformers for common mode isolation, with a battery for remote power isolated from the mains supply. One user resorted to optical coupling, although I suspect the linearity of the analogue voltage / optical conversion process was not too good.

In any practical design, measures ought to be taken to provide protection against static and high voltages on the probe with its high input resistance. A direct connection to the J-FET is not always a good idea; an input capacitor for DC blocking is often included, along with a spark gap or neon tube to discharge high voltages, as well as a bleed resistor. Depending on how low a frequency response is desired, a high pass filter is often included somewhere in the circuit to reduce any 50Hz hum levels to below those that could cause any non-linearity. Having said all that, the PA0RDT whip is being used successfully by several of the group of amateurs experimenting at 9kHz.

INDEX PROJECT.

See **[4]** for an index of subjects covered in past Short Circuits and Design Notes. An index for past Data columns is also available.

INPUT WANTED.

Can I have your ideas please? For too long this column has been written around designs and experiences either by myself, gleaned from published works or colleagues' experiences. I would like to receive some of YOUR ideas and experiments, your projects and experimental work, your experiences, catastrophes and successes (and failures). All contributions to the address at the top please.

WEBSEARCH

[1] Name and callsign have been changed to protect the innocent and avoid embarrassment.
[2] If you smell burning switch off, but do try not to black out half a city! See www.g4jnt.com/Hams_Hall_Investigation_Report.pdf
[3] PA0RDT Mini-Whip antenna – www.radiopassioni.it/pdf/pa0rdt-Mini-Whip.PDF
[4] Index for Design notes – www.g4jnt.com/DesignNotesIndex.pdf and for Data – www.g4jnt.com/DataColIndex.pdf