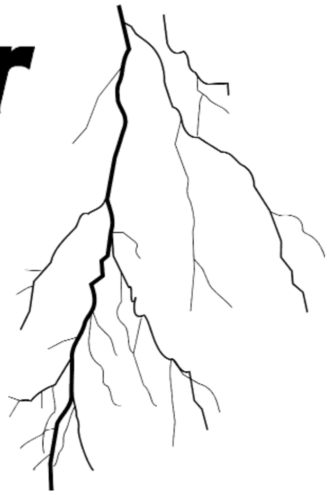
DIY Lightning Radar



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Having a general interest in the weather, I have always been fascinated by storms, and particularly the lightning associated with them. There are professional lightning detectors, the most well known being the *Boltek* system, which provides a radar-like display of the surrounding location and the position of lightning strikes. However, this system can cost around £300 and I wondered if there was a 'simple' DIY solution? A quick search on the Internet led me to Daniel Verschueren's *Lightning Radar Project* site at

http://users.edpnet.be/DanielV37/Detecteur3/

featuring a Lightning Radar (LR) based on a design and concept by Frank Kooiman

http://members.home.nl/fkooiman/lightning/

I have to say that these guys have developed the hardware and software for this project and I owe them much thanks for helping me to set up my own LR station. The purpose of this article is to describe the principal behind LR, the hardware required (including a surface mount design I have developed) and the setting up and use of the software.

The Concept

The LR system antenna consists of two loops with a resonant frequency of approximately 10 kHz; these are mounted 90° apart so that one can point north/south and the other east/west. Lightning strikes produce a distinct 'signature' that can be recognised by a software algorithm which eliminate spurious sources like car ignitions and central heating switches. The low frequency RF lightning signal arrives at the antenna and, depending on the direction, will generated a voltage in each loop.

Each antenna loop is connected to a simple circuit containing an op-amp, with the gain set close to 100, which is in turn connected to the line input of a PC soundcard. The specially written software can sample the signal arriving at the soundcard, decide whether it is a lighting strike, and if so, the direction from which it arrived. Also, depending on the signal amplitude, it can calculate how distant the strike was.

Unfortunately, using just two antennas gives rise to a 180° phase ambiguity in the received lightning signal. To overcome this problem, Frank's software is able to link up with another station (via the Internet) and, using a clock synchronisation routine, employing triangulation to pinpoint the direction of the lightning strike. This triangulation method has an accuracy of one degree. Figure 1 shows how two 'linked' stations can use triangulation to pinpoint the location of a lightning strike. It will only work if the two PC's have their clocks synchronised so that they detect the strike at the same time.

My system has been up and running for a few months now and when it is properly set up can give very accurate results. The latest software additions allow connection to the *Blitzortung* network [1]. Figures 2 and 3 show a comparison between my LR and the corresponding Blitzortung map. As you can see there is a very good correlation between the lightning strike maps which show a storm over Belgium.

The Copper-Pipe Loop Antenna

For a more robust and waterproof design, Daniel designed the copper-pipe loop antenna and figure 4 shows my more sturdy version. You can find all the constructional details for this antenna on his website when you click the '*Hardware*' button.

I have built this antenna myself, specifically for an outdoor location. The antenna is made from four lengths of 15 mm copper tube bent into semicircles and mounted at each end in PTFE blocks. Connecting wire is then fed through the openings in the top and bottom blocks into the copper pipes to form each of the two loops. A diagram showing one of the twin loops is shown in figure 6. Note that the ends of each winding are twisted together (twisted pair) but, if fairly short, less than 15 cm, then the wires can be left free.

The diameter of the loop is 900 mm and each semicircular element is 1382 mm in length. A 1 µF capacitor connected across the winding of each loop should resonate the antenna to the correct frequency (around 10 - 11 kHz).

The PTFE blocks are fitted in the 32 mm wide gaps. Details on manufacturing the PTFE blocks and more information on this antenna can be found on Daniel's '*Hardware*' page.

Hardware Electronics

The electronics for the LR are very simple and consist of two identical low noise op-amp circuits each with a gain of 100. The op-amps require a dual voltage supply of ±15 V from a PSU sited indoors and fed to the op-amp circuit at the antenna.

The PSU Design

If the whole system is to be sited indoors, in a loft for example, then the circuitry could be easily built on *Veroboard* using leaded components. The surface mount (SM) design described below is based on Daniel's circuit. To simplify the build of the system, I designed a surface mount version of Daniel's LR design (figure 9 and 10). The top view, with component identities, is shown in figure 11. Figure 13 shows the system connections to the PC via a stereo 3.5 mm plug. Connection between the PC/PSU and the antenna-mounted LR PCB was made via four individually screened audio leads.

Note that the SM circuit is built on double-sided standard FR4 PCB board with the underside ground-plane remaining intact to allow earth connections. The earth connections of the component side are completed by drilling a 0.8 mm hole through the board and linking the two layers with a piece of copper tape or wire. The PCB layout is shown in Figure 7 and the completed PCB assembly in figure 8.

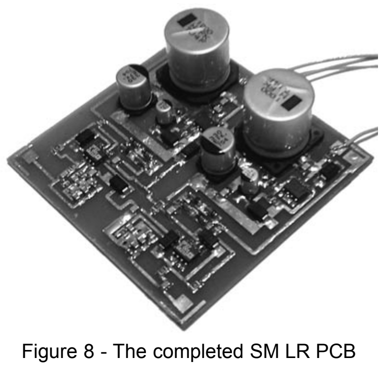

Figure 8 - The completed SM LR PCB

Most of the parts are easily sourced through component suppliers like *Maplin* and *Farnell*. Table-1 (page 36) lists the parts for the amplifier-regulator section. The values of R4 and R9 are set to 100k which gives each amplifier a gain of 100,

Figure 1 - Lightning Location by Triangulation

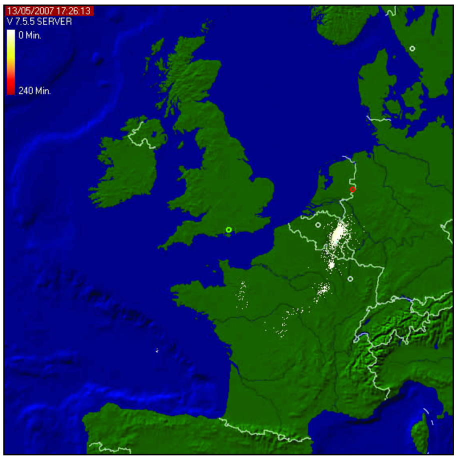

Figure 2 - The author's Lightning Map

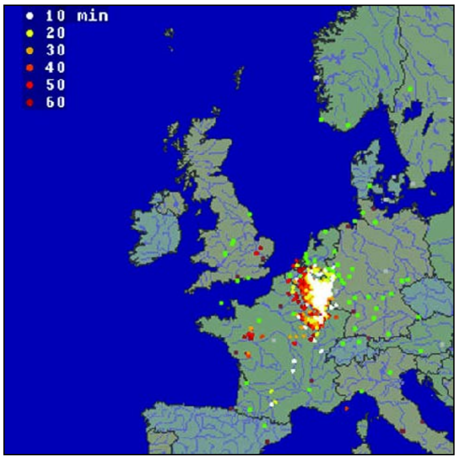

Figure 3 - The *Blitzortnung* Lightning Map

Figure 4 - The Copper-Pipe Loop Antenna

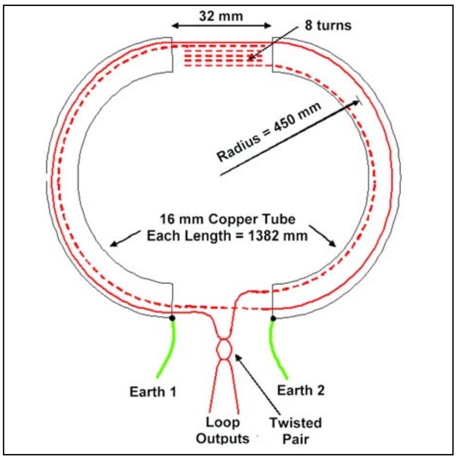

Figure 6 - Schematic: Copper-Pipe Loop Antenna

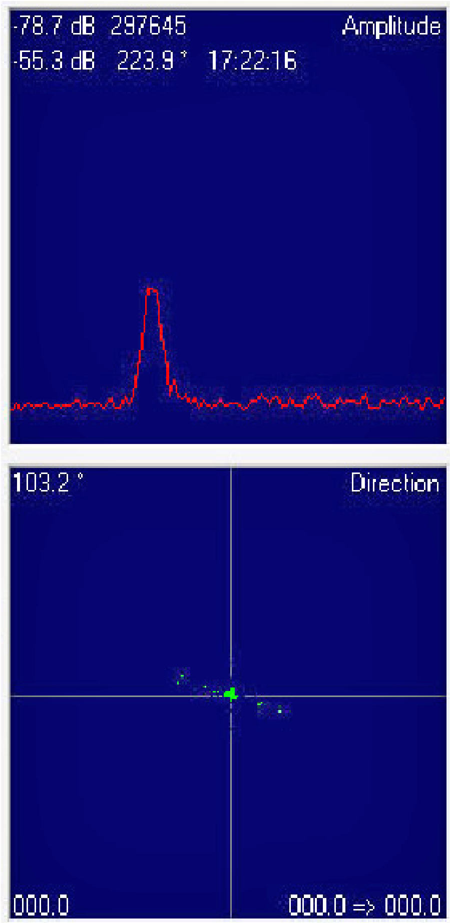

Figure 20 - A strike detected

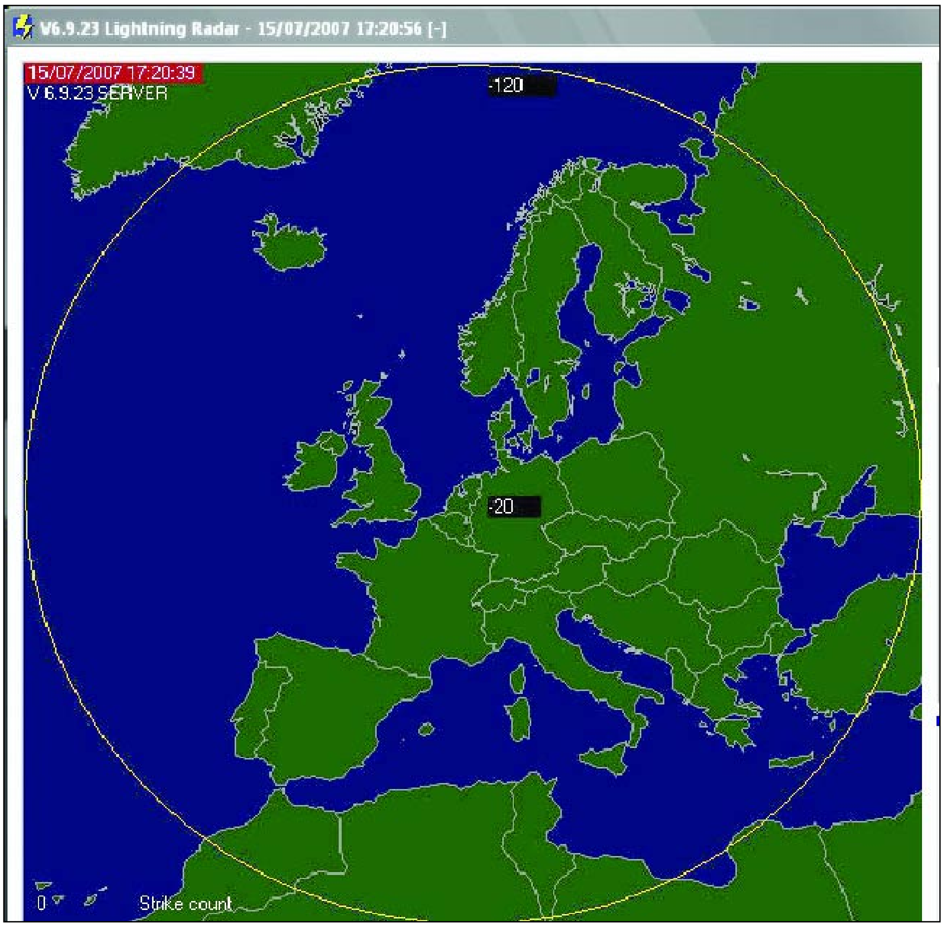

Figure 18 - The initial radar screen shown when first running LR

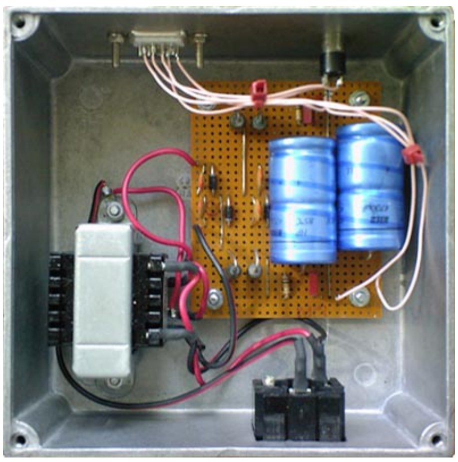

Figure 14 - The prototype PSU

which seems to be a pretty optimum value. No alignment is required with this design. However, it is very important that the PCB is thoroughly sprayed with a conformal coat of lacquer to ensure it is absolutely waterproof. I am hopeful that a populated and tested LR Antenna amplifier PCB assembly will be available from the *GEO Shop*.

The PSU Circuit

The PSU provides an unregulated ± 20V to the LR circuit board sited at the antenna. The circuit diagram is shown in figure 12 and the parts lists in table-2 (page 36). The transformer has two 12-0V windings that are wired to give ± 20 V a.c. The rectifier components are mounted on a small PCB. My prototype, which used a simple *Veroboard* layout, is shown in figure 14 (a PCB has been designed for future builds). The voltage outputs are connected to a 9-way *Cannon* plug (top left) and this connector is used to receive the right and left channels from the antenna PCB. In addition, a 3.5 mm stereo socket connected to the *Cannon* socket is located at upper right so that the strike pulses from the LR circuit can be fed into the PC soundcard. The audio cable to the PC is connected to this socket. The IEC mains connector, with fuse, is at the bottom right. As a precaution, two additional fuses have been added to the +20 V and –20 V outputs in case of cable shorts.

It's a good idea to fit fuses all round, especially as our new dog decided to chew through the LR cable causing one of the rectified voltages to short—and resulting in a very hot PSU unit.

There is no requirement to use the PSU design given here. Some LR operators have simply used two mains unregulated power supplies. Such a power supply suitable for this application is *Maplin's* 24 V, 500 mA unit (order code *N88AT*).

There will still be a need for a small box, the purpose being to provide a socket for the LR data/PSU cable, sockets to connect the two PSUs and a 3.5 mm jack socket to permit an audio connection to the PC.The wiring inside this box connects the PSU and jack sockets to the LR data/PSU cable socket (the aforementioned 9-way *Cannon* socket).

The PSU PCB

As described above, the original PSU section was built on *Veroboard*. My latest design uses a single-sided PCB measuring 85 x 75 mm; the component side is shown in figure 16 and the foil side in figure 17. (The 4 fixing hole positions are 65 x 65 mm). The PCB is mounted in a die-cast box with the mains fed through a fused IEC connector. The a.c. mains is wired to the primary of the transformer. You must ensure that any exposed connections are insulated with heat-shrink sleeving. Make sure that the secondary transformer connections are made correctly, so that the rectified voltage outputs of the PCB are approximately +20V and –20V. The completed PCB assembly is shown in Figure 15.

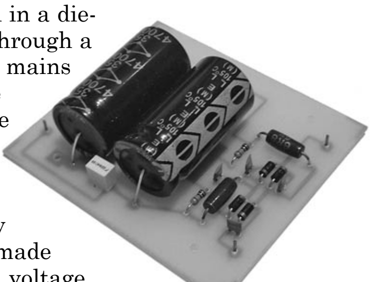

Figure 15
The completed PSU PCB

The circuit diagram (figure 12) shows the suggested *Cannon* pin connection numbers to be used. Two pins on the connector supply the audio from the LR amplifiers and connect to the stereo 3.5mm audio connector. You also require a lead to link the PC to the LR amplifier. I used 4-core screened cable (*Farnell* 389-4745) although you could in fact use twin screened audio cable as the current taken by the LR is very small.

The 'Lightning Radar' Software

The software written by Frank determines whether a strike has occurred and uses triangulation with another station to plot the strike on a map. The audio output cable connects to the soundcard 'Line' input (usually denoted by a green connector). Ensure that the line is activated and set it to maximum using Windows sound recording options. Also, if you have a firewall running (software and/or router), you must make sure that port 4711 is free. This will enable the LR software to communicate with another station; otherwise, there will be no triangulation process and the plotted strike direction will be meaningless.

Once you have constructed the hardware, it is time to install and set up the *Lightning Radar* software, which can be downloaded from.

http://members.home.nl/fkooiman/lightning/index.htm#5

Click menu item No 6 at the top of this page ('Software Downloads'), which takes you to the 'Download Lightning Radar Software' section near the foot of the page. Click the link to download the current full version, *V.6.7.25Setup.zip* and install it. The program is constantly being updated and you may also also download and install the latest update patch, currently *V 7,12,5.zip*, which should be saved into the existing application folder. Note that these version numbers may well have been updated by the time you read this.

If you experience difficulties obtaining the software, feel free to email me and (***john@jps.myzen.co.uk***) and I can forward copies to you

Initial Startup

This section assumes that you have the latest version of the software installed. The screenshots below refer to version 7.12.5. When first running LR it will open with a default radar screen (figure 18). Set the centre value to –20 and the outer value to –120.

An instruction manual on how to generate your own radar map can be found at

http://users.edpnet.be/danielv37/Detecteur3/Forum

Download the file '*Step 6 - How to build a map.pdf*'.

Setup Gain

You need to ensure that a signal is being received by the soundcard and that the level is set correctly in LR. To start with, connect the LR audio lead to the 'Line' input of the soundcard, not the 'MIC' input and use Windows *sndvol32.exe* utility to ensure that the recording level of the 'Line' input is set to maximum.

Next, select the LR gain window and insert the details shown in figure 19 (these values are a good starting point).

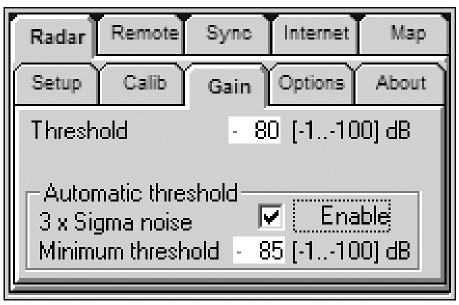

Figure 19 - The LR gain settings dialogue

If lightning strikes are being received you should be seeing the sort of patterns shown in figure 20; if not, and you get a flat line all the time or nothing at all, then either the lightning radar is faulty, there is a broken wire, or there is a problem with the soundcard setup.

Note: A small utility called *Sound Input* should be running, showing a blue bar for 'bu' at about 10% and green bars for 'vl' and 'vr' at about 1%.

General Settings

Figures 21 to 24 show screen dialogues from the LR program which illustrate good starting settings.

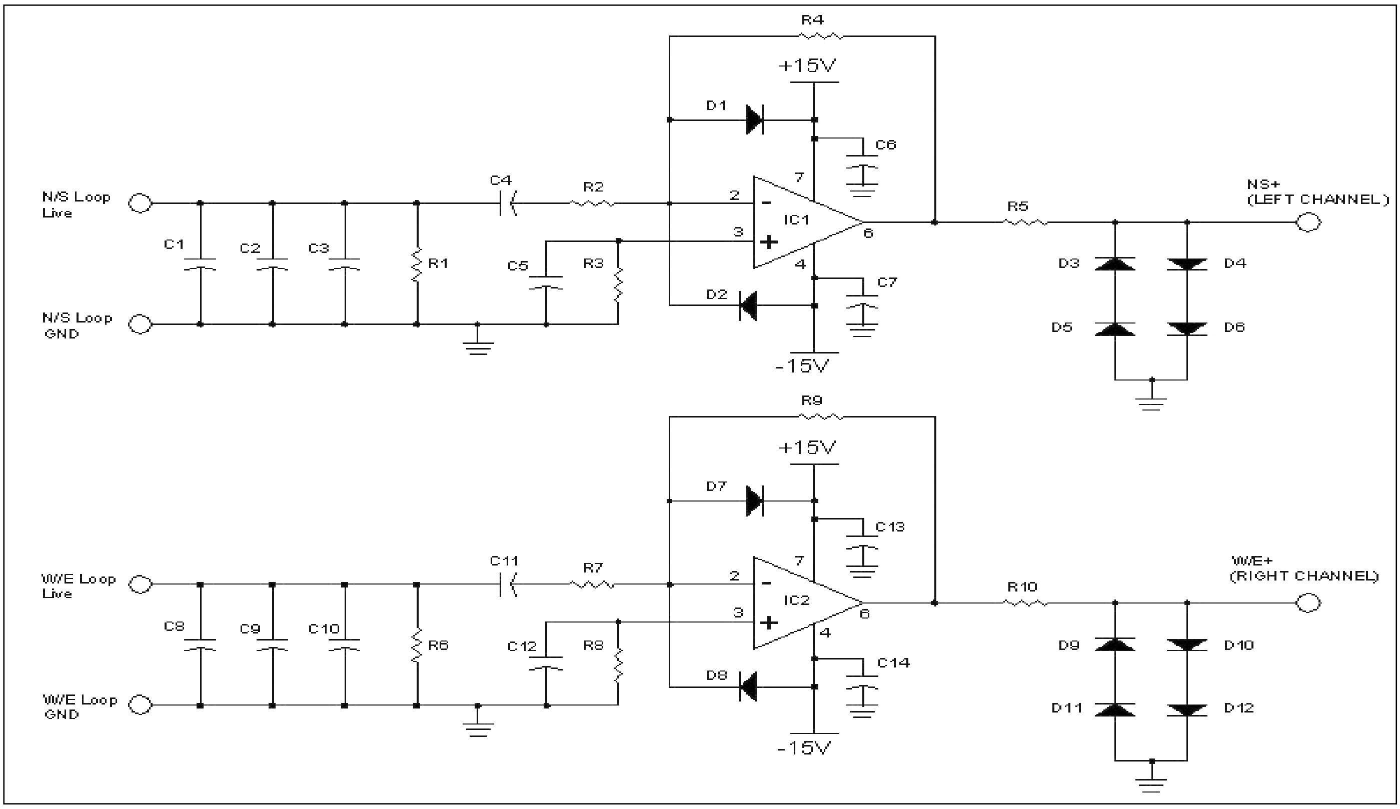

Figure 9

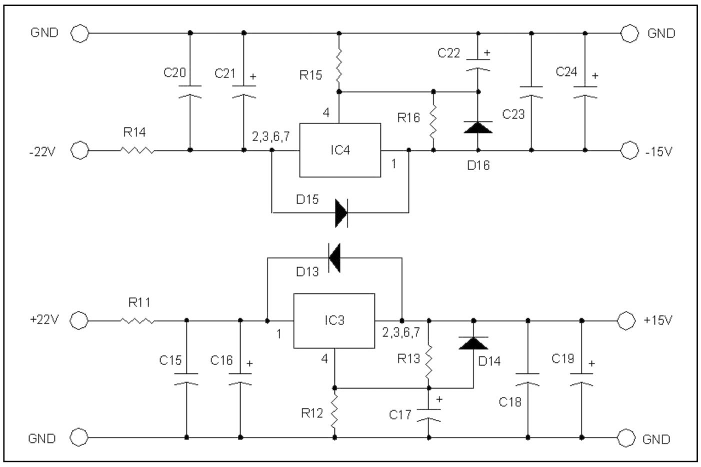

Figure 10

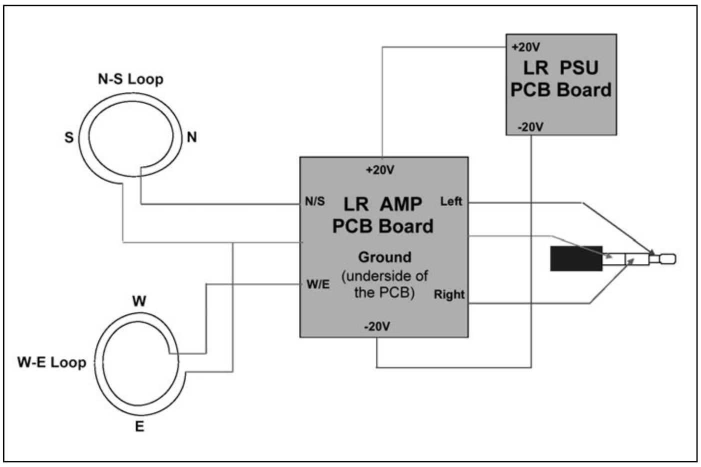

Figure 13 - The wiring of the LR and PSU modules to the PC and antenna.

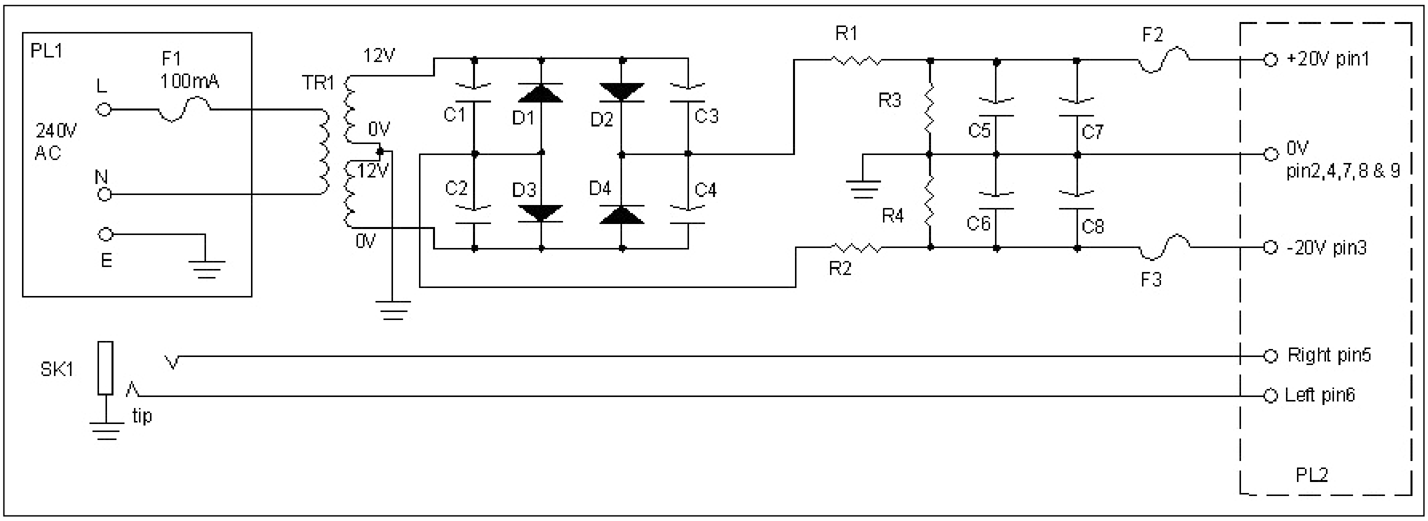

Figure 12 - The PSU section circuit diagram. The components are mounted on a small PCB in a diecast box.
The 100 mA Fuse (F1) is part of the IEC mains input plug, SK1.

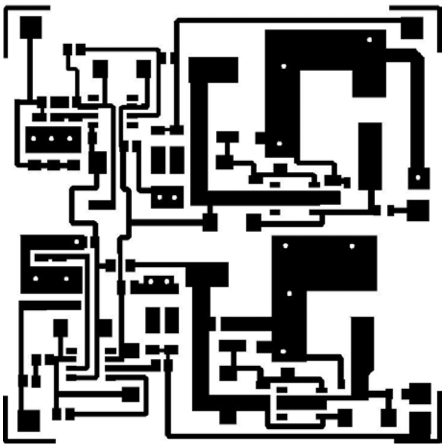

Figure 7 (Actual size)
The PCB foil track side of the LR SM PCB (the reverse of the PCB is continuous copper ground-plane). There are 17 via thru holes, which are made by drilling a 0.8 mm diameter hole and linking the top track to the rear ground-plane using thin strips of copper tape (or tinned copper wire). PCB size is 58mm by 58mm.

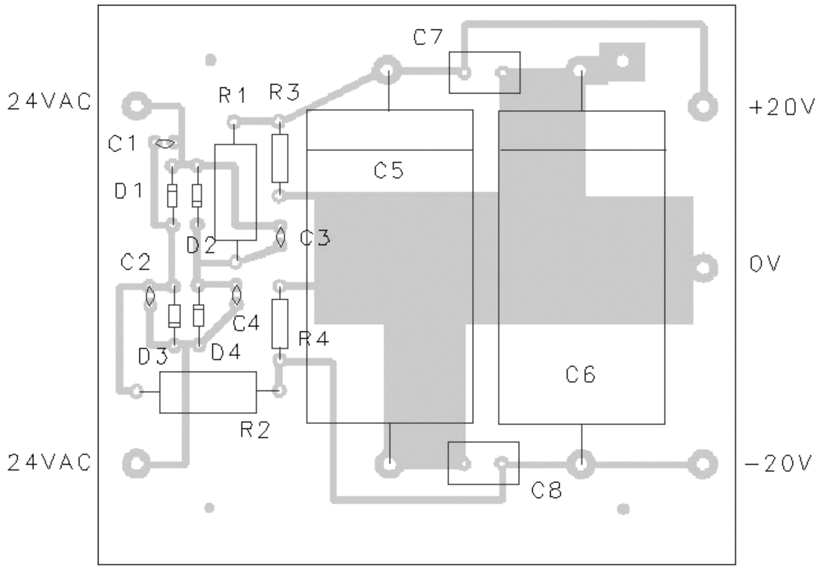

Figure 16
The component positions for the PSU PCB section (actual size).
Note the line on C5 and C6 signifies the positive end of the capacitor.

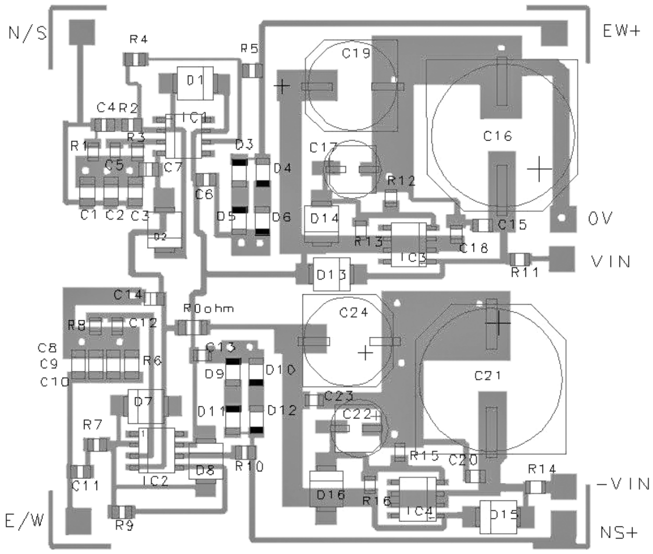

Figure 11
The PCB component schematic (actual size)

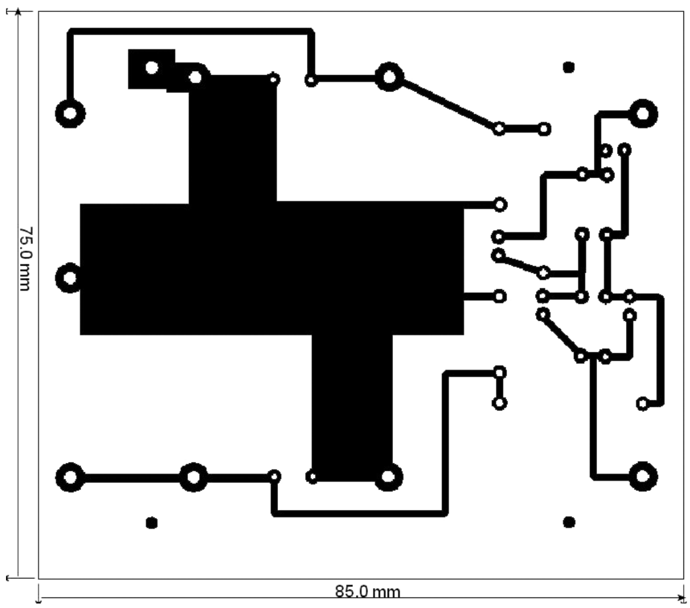

Figure 17
The PCB foil pattern (actual size) of the PSU section. This is what you need to see on the copper clad side of the PCB.

Internet Settings

This dialogue (figure 25) allows data to be uploaded from the user's own FTP site to Daniel 's website. First, enter your FTP site address in the '*FTP to*' field, then edit the file '*Publish.cmd*', found in the LR folder.Initially, it looks like this:

```
<username>
<password>
send "picture5.png"
send "picture4.png"
send "picture1.png"
bye
```

Enter your FTP username between the angle-brackets in the topmost field and the corresponding password between the second set of angle-brackets.

Next, add the instruction '*cd Lightning_radar/*', the address of the folder **on your FTP site** to which you intend to upload the pictures. This must be followed by the instruction 'binary' to establish the mode of transmission. Finally, just prior to the 'bye' command, add a line such as

put "C:\Program files\
LightningRadar\Data\picture8.png"

```
<ftp.username.isp.co.uk>
<mypassword>
cd Lightning_radar/
binary
send "picture5.png"
send "picture4.png"
send "picture1.png"
send "C:\Program Files\
   LightningRadar\Data\picture8.png"
bye
```

Your edited '*Publish.cmd*',file should now look something like the above. This script will upload your plots on to Daniel's website.

Forum

Although the software does not possess a full help file, there is a forum to assist would-be LR builders at

http://foudre.chasseurs-orages.com/viewforum.php?f=45

Conclusions

This article describes the construction of a simple lightning radar capable of results similar to commercial systems like *Boltek*. Although SM components can be somewhat fiddly to use, they do result

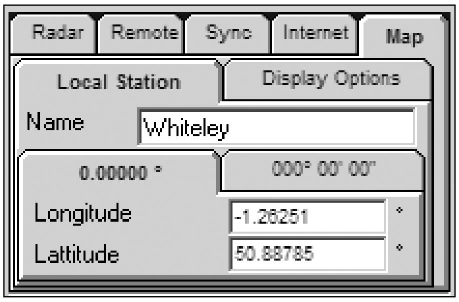

Figure 21 - Enter the coordinates of your Station Location

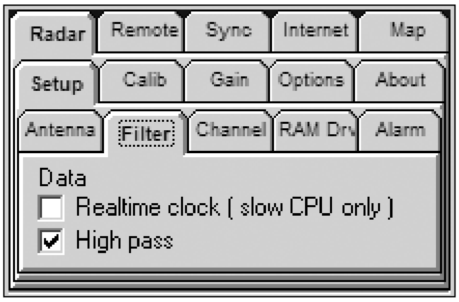

Figure 22 - Selecting a high-pass filter, which helps to eliminate spurious sources

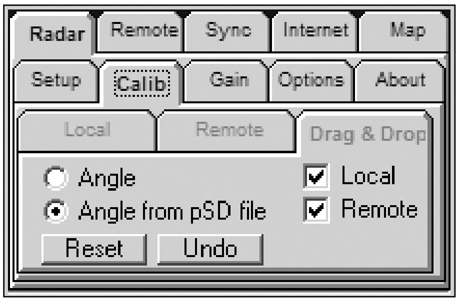

Figure 23 - Calibration Settings

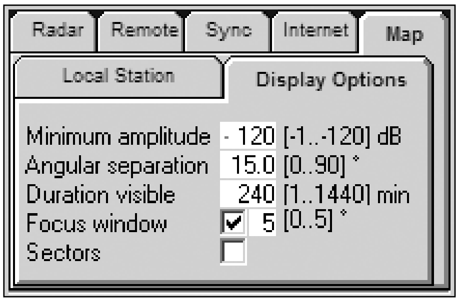

Figure 24 - Display Options

The *Minimum amplitude* matches that entered on the radar diagram; *Duration visible* is the number of minutes to show the strike before erasing it; *Focus window* uses software to pinpoint clumps of strikes; *Angular separation* is a parameter that can be varied to remove spurious strikes.

Figure 25 - Internet Settings

in a very compact design that can be housed within a box at the antenna. In addition, I found that using an SM design made it at lot easier to waterproof the active antenna circuit (by spraying the completed PCB with *Conformal Coat*), So far, my unit has survived the very wet weather experienced during the 2007 summer.

The author of the software is continuing to develop it, removing bugs and adding extra functionality (most recently, a link to the *Blitzortung* storm site [1]. The latest version now has a drop and drag feature under the calibration menu. The user can locate a local storm (either from the *Blitzortung* site or a local *Boltek* site) and drop and drag the corresponding storm on to the correct position on their own LR map.

Reference

1 Blitzortung - *http://www.blitzortung.org*

Component	Quantity	Part type	Part Package	Part Source
R1, 2, 5, 6, 7, 10	6	1k Resistor	0805 SMT	
R3, 8	2	10k Resistor	0805 SMT	
R4, R9	2	100k Resistor	0805 SMT	
R12, 15	2	1k1 Resistor	0805 SMT	
R13, 16	2	100R Resistor	0805 SMT	
R11, 14	2	10R Resistor	0805 SMT	
R 0 ohm (figure 11)	1	0 ohm link	1206 SMT/wire link	
C1, 2, 8, 9	4	470nF Capacitor	1210 SMT	
C3, 10	2	150nF Capacitor	1210 SMT	
C5, 12	2	1nF Capacitor	0805 SMT	
C4, 11	2	10nF Capacitor	0805 SMT	
C6, 7, 13, 14, 15, 18, 20, 23	8	100nF Capacitor	0805 SMT	
C16, 21	2	1000µF, 35V Capacitor	SMT Case J16 (Range FK Panasonic)	Farnell 9695982
C17, 22	2	10µF, 50V Capacitor	SMT Case D (Range FK Panasonic)	Farnell 1244410
C19, 24	2	330µF, 25V	SMT Case F (Range FK Panasonic)	Farnell 1244418
D1, 2, 7, 8, 13, 14, 15, 16	8	Schottky 60V, 1A	SMT Case SMB	Farnell 4213038
D3, 4, 5, 6, 9, 10, 11, 12	8	1N4148	SMT	RS
IC1, IC2	2	OP27GSZ	SMT SOIC-8	Farnell 942612
IC3	1	LM317LM	SMT SOIC-8	Farnell 9488537
IC4	2	LM337LM	SMT SOIC-8	Farnell 9485945

Table 1 Parts list for the antenna amplifier PCB

Component	Part type	Suggested Part Source
T1	12-0, 12-0 Transformer 6VA each winding	Maplin N01CF
F1	100mA, 20mm fitted into IEC chassis socket SK1	Maplin GJ72P
F1, 2	100mA, 20mm fuses and chassis sockets	Maplin GJ72P & GU73Q
PL1	IEC mains plug and fuse holder	Maplin FT37S
SK1	3.5mm Stereo Jack socket	Maplin FK03D
PL2	9-way D-sub plug + lock posts	Maplin RK60Q & FP31J
SK2	9-way D-sub socket & Hood	Maplin RK61R & KE94C
D1-D4	1N4007	Maplin QL79L
R1, 2	Resistor 6.8 ohms, 5 W	
R3, 4	Resistor 100k, 0.25 W	Maplin M100K
C1-C4	Capacitor Ceramic 100pF, 100V	Maplin WX56L
C5, 6	Capacitor Electrolytic 4700uF, 35V	Maplin AT24B
C7, 8	Capacitor Polyester 220nF, 100V	Maplin BX78K
	Diecast case, PCB, Nuts, Bolts etc	
	4-core screened cable	

Table 2 - Parts list for the PSU section