# 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 2 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 3 and 4 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 5 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 12 and 13). The top view, with component identities, is shown in figure 18. Figure 14 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 16 and the completed PCB assembly in figure 1.
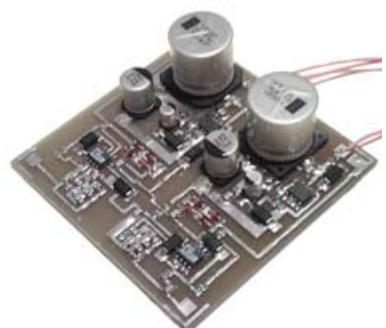


Figure 1 - The completed SM LR PCB

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 2 - Lightning Location by Triangulation


Figure 3 - The author's Lightning Map
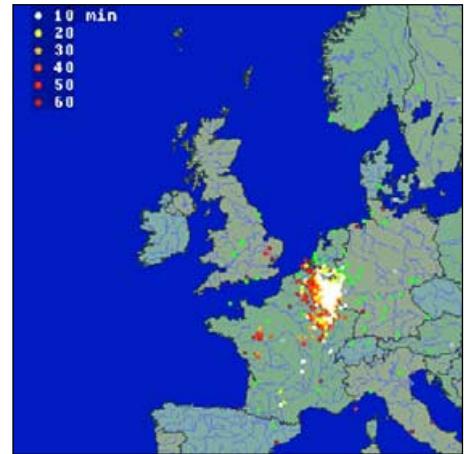

Figure 4 - The *Blitzortung* Lightning Map


Figure 5 - The Copper-Pipe Loop Antenna
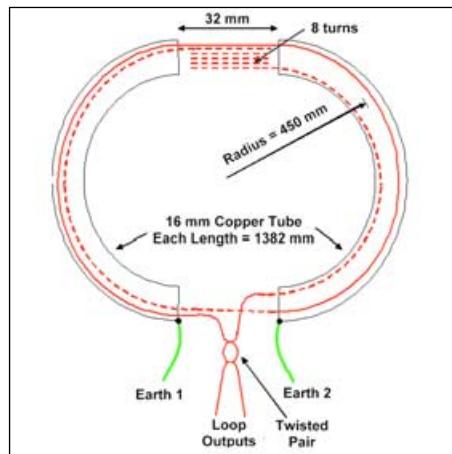

Figure 6 - Schematic: Copper-Pipe Loop Antenna
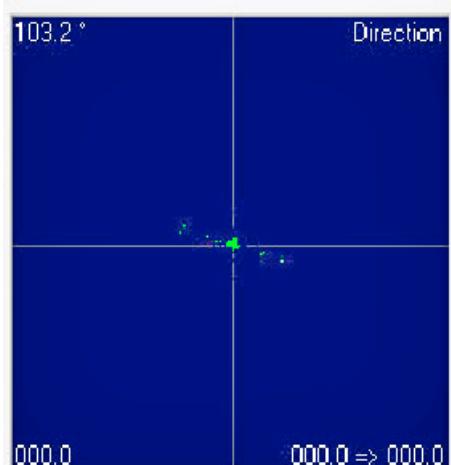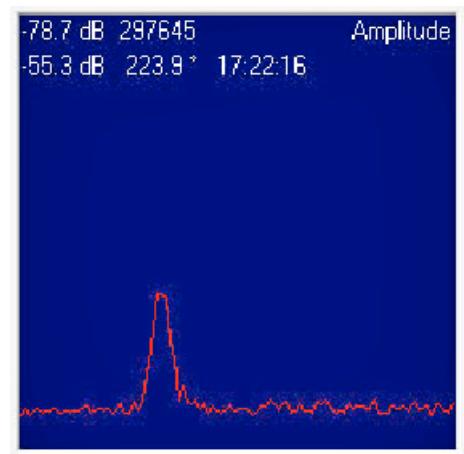

Figure 8 - A strike detected
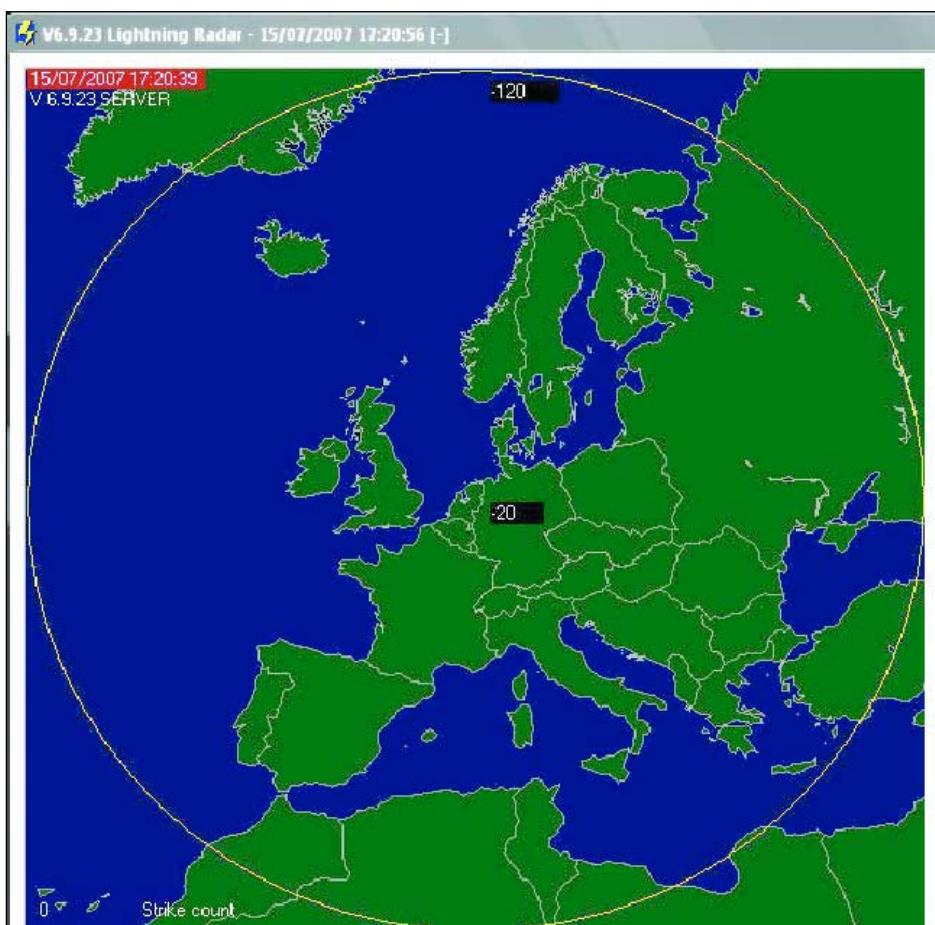

Figure 7 - The initial radar screen shown when first running LR
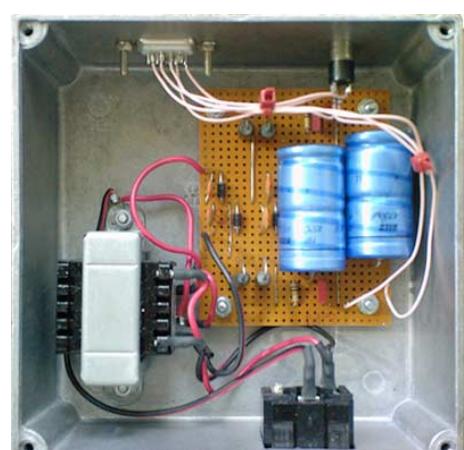

Figure 9 - The prototype PSU

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 15 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 9 (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 10.



Figure 10
The completed PSU PCB

The circuit diagram (figure 15) 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 7). 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 11 (these values are a good starting point).

If lightning strikes are being received you should be seeing the sort of patterns shown in figure 8; if not, and you get a
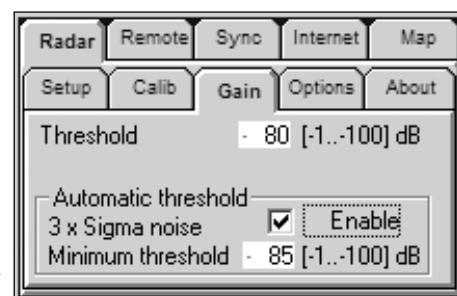


Figure 11 - The LR gain settings dialogue

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 22 to 23 show screen dialogues from the  LR program which illustrate good starting settings.
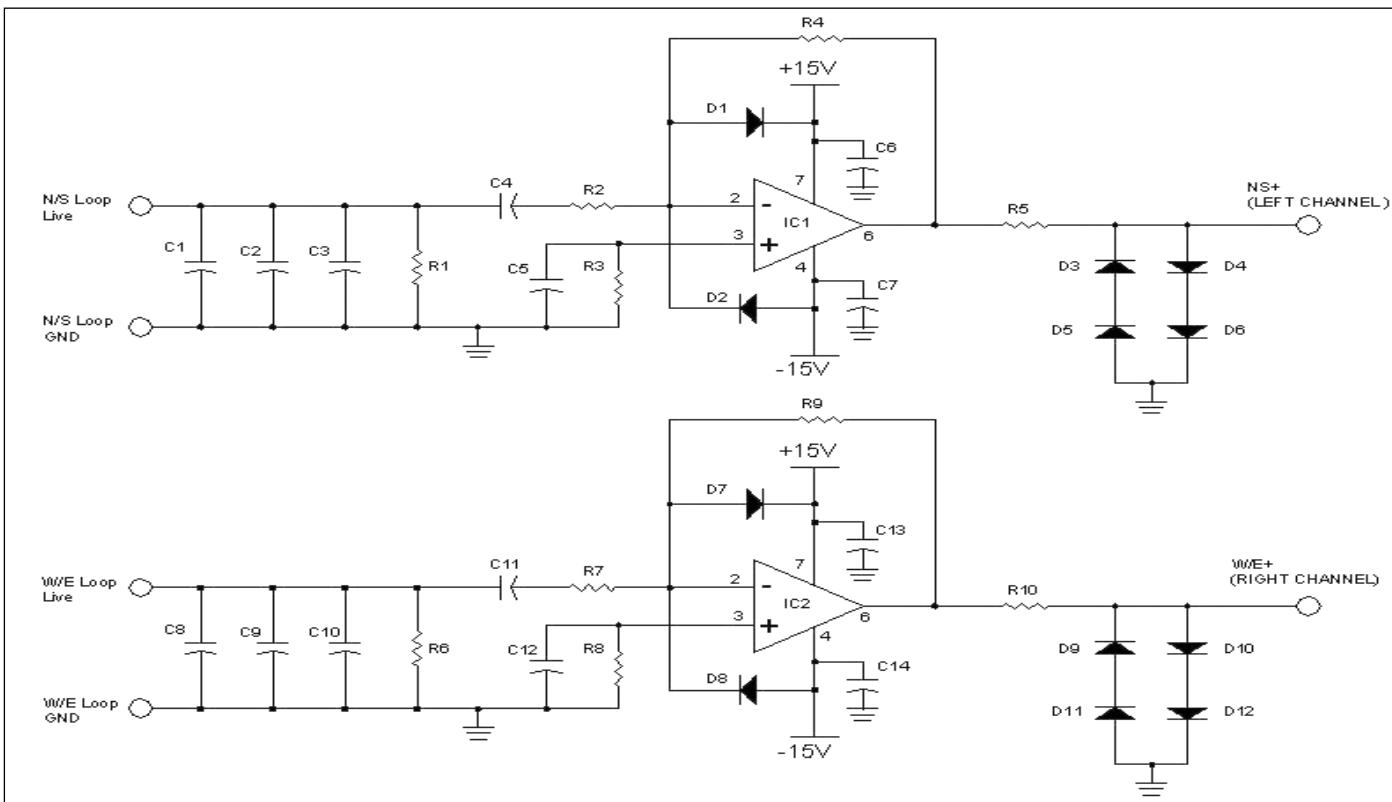
Figure 12
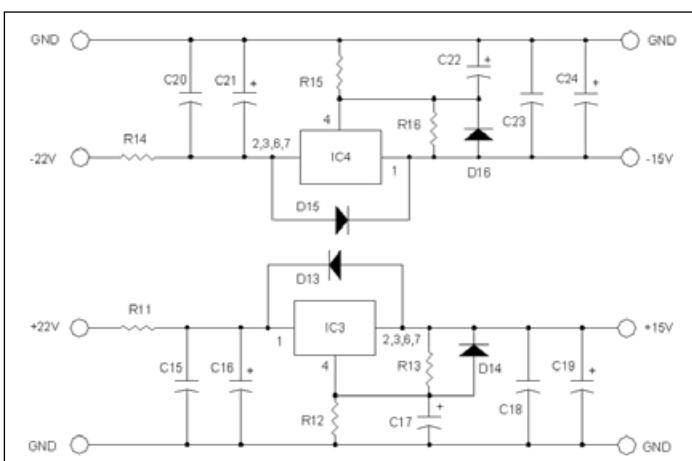


Figure 13
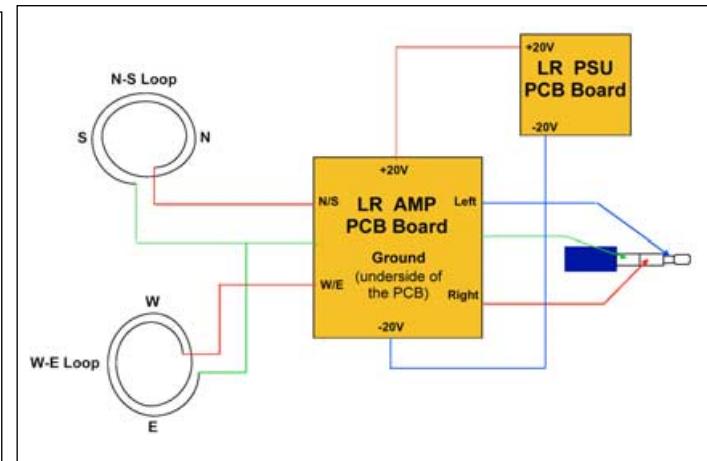


Figure 14 - The wiring of the LR and PSU modules to the PC and antenna.
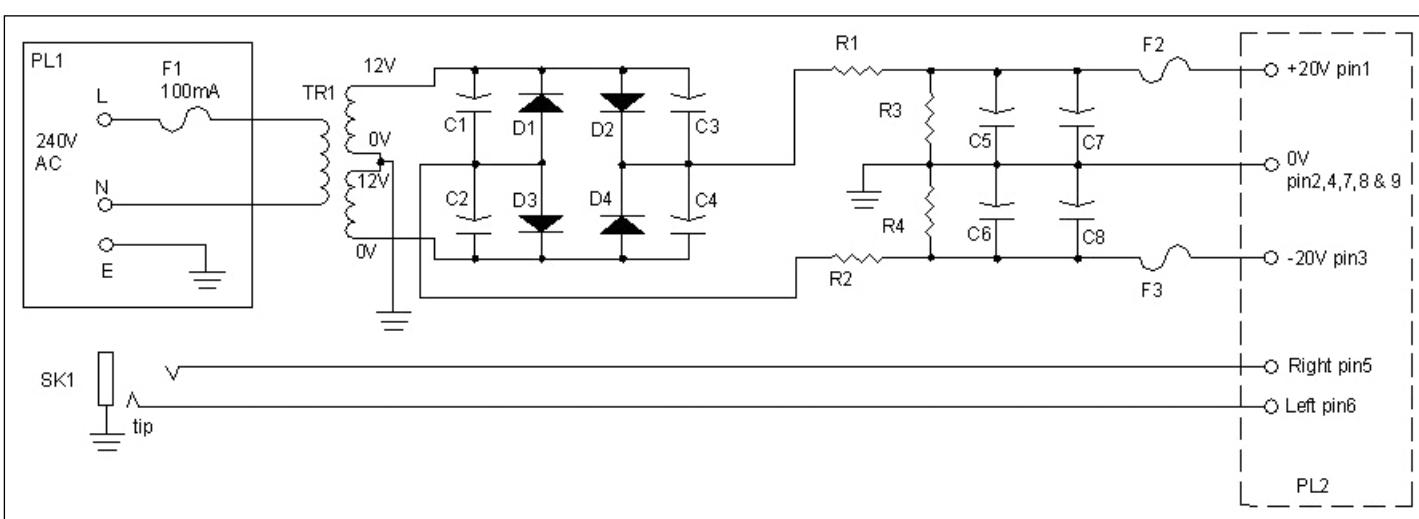


Figure 15 - The PSU section circuit diagram. The components are mounted on a small PCB in a diecast box.
The 100 mA Fuse (F1) is part of the IEC mains input plug, SK1.
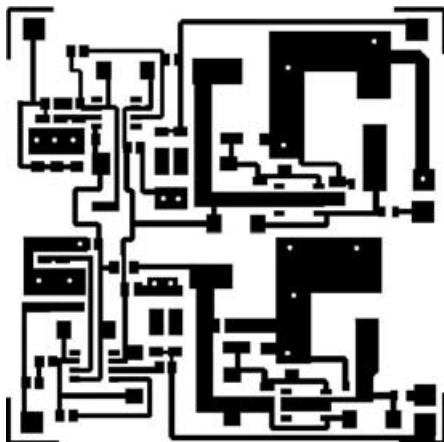
**Figure 16** (Actual size)
The PCB foil track side of the LR SM PCB (the reverse of the PCB is continuous copper ground-plane). There are 17 via thru holes, which are made by drilling a 0.8 mm diameter hole and linking the top track to the rear ground-plane using thin strips of copper tape (or tinned copper wire). PCB size is 58mm by 58mm.
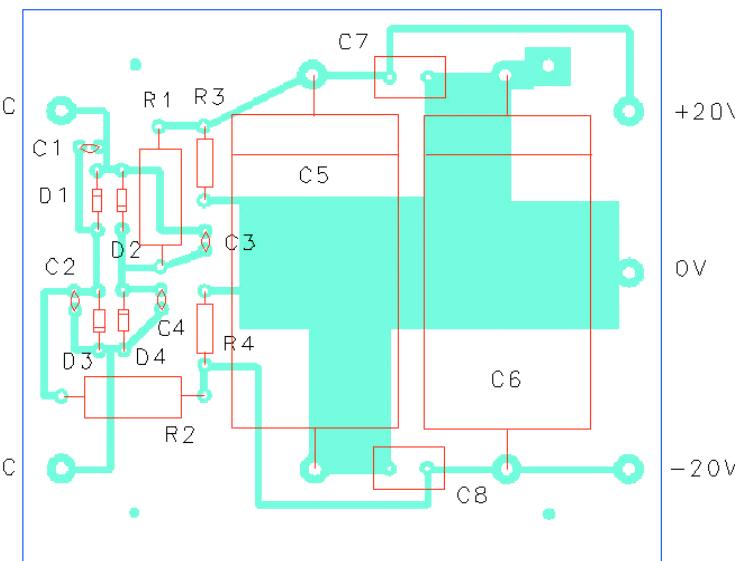


**Figure 17**
The component positions for the PSU PCB section (actual size). Note the line on C5 and C6 signifies the positive end of the capacitor.
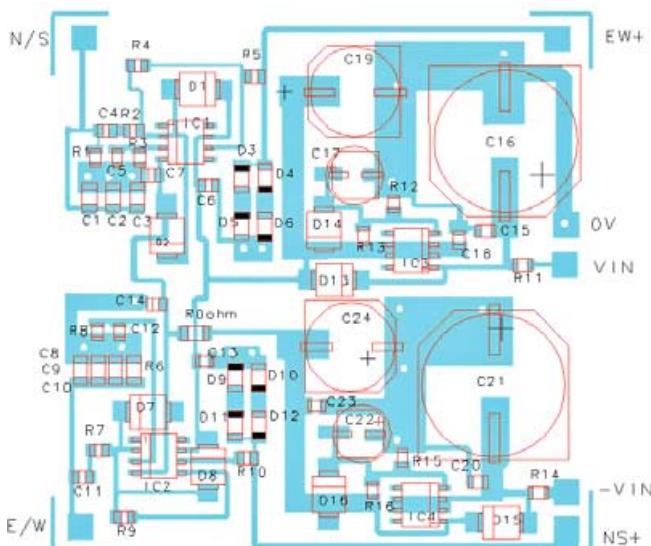


**Figure 18**
The PCB component schematic (actual size)
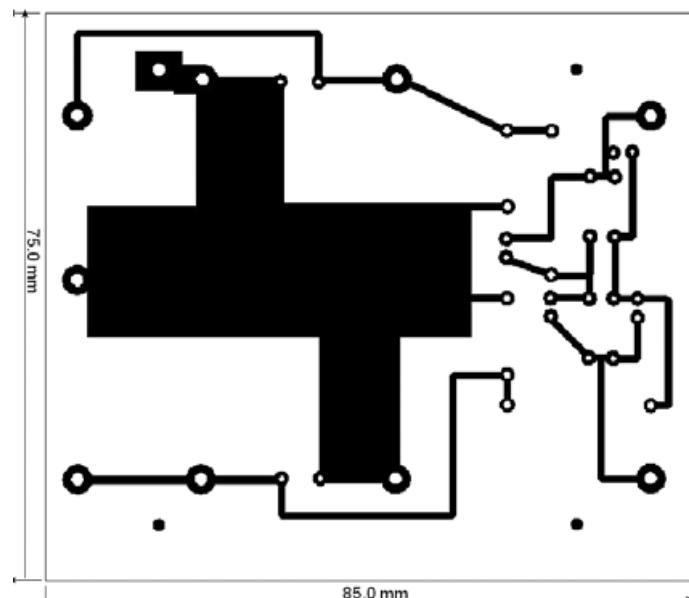


**Figure 19**
The PCB foil pattern (actual size) of the PSU section. This is what you need to <u>see</u> on the copper clad side of the PCB.

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## Internet Settings

This dialogue (figure 24) 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

    send "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 in a very compact design that can be
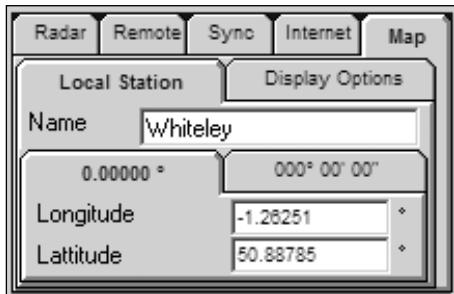
Figure 20 - Enter the coordinates
of your Station Location


Figure 21 - Selecting a high-pass filter, which
helps to eliminate spurious sources
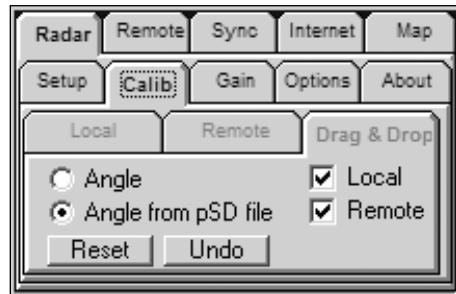

Figure 22 - Calibration Settings
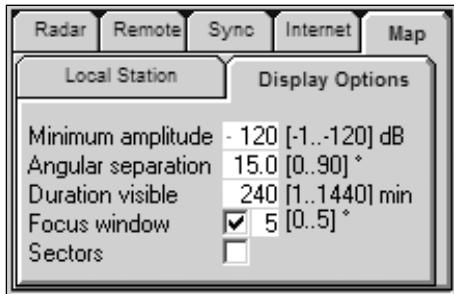

Figure 23 - Display Options

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 24 - Internet Settings

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