Storm Detection by Radio

By Michel Berlie-Sarrazin

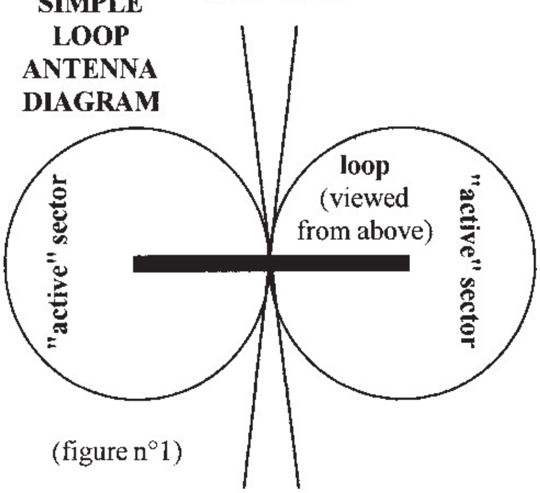
All of you know 162 MHz NOAA weather channels, but your long wave (LW) and/or medium wave (MW) receiver can also help you to determine if storms or lightning are approaching your house. The following technique is a rule of thumb, since static levels depend on a wide number of things, including time of day, frequency, intensity of the storm, sensitivity of the radio, the antenna being used, etc.

If you can receive the LW band, choose an empty channel around 150 kHz, and listen to it for one minute. Can you hear faint static? If not, there are no storms within a 200 km (125 miles) radius. Should the opposite occur, there is at least one. If static becomes louder, set your radio to a long or mediumwave station of a known distance from your location. If the static continues to be audible, the storm belt continues to approach. You can choose successively closer stations and track the storm as it approaches.

Once you hear distinct static from a station less than 50 km (30 miles) away, the storm will be visible on the horizon. It is high time to disconnect your external antenna if you use one. Do not forget that a direct lightning on this antenna could destroy your receiver, reduce your home to ashes, and badly injure or kill you. Be very careful.

❖ Local Storm Bearing

If you have a frame antenna or a ferrite one, you can try to take a bearing of the position of the source of static as you do when rotating the receiver or the frame antenna to eliminate an unwanted signal. Do not forget, however, that: (1) Storm clouds are rather wide phenomenona; (2) It is more difficult to goniometer (direction-find) sporadic sounds than continuous signals. So, don't expect more than a coarse locating, although still useful. Do not forget the remaining 180 degree directional ambiguity.



(figure n°1)

❖ Other Weather Phenomena

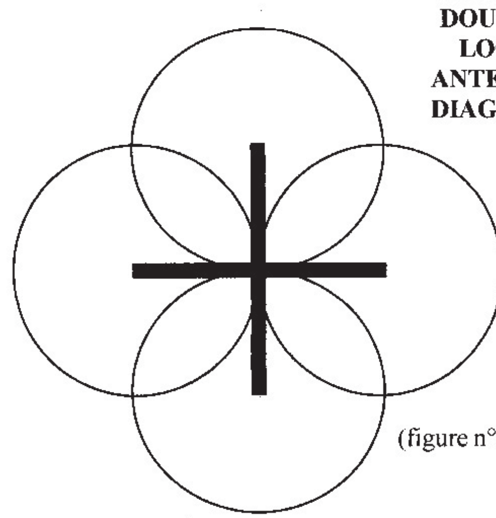
Storms are not the only meteorological phenomena you can pick up with your receiver. Here are other ones to detect on long and medium waves:

Strong creaking sounds [like breaking twigs]: nearby storms
Slight whistling: hailstorm in the proximity.
Sharp crackings [like a whip; quite faint and not very frequent]: spring frost or notable temperature lowering
Numerous crackling [like a wood fire; together with repeated loud and burning out creaking sounds]: large atmospheric depression and storms
Propagation improvement: approach of rain, fog, or snow.

❖ Distant Storm Detection

The applications we have discussed so far can be enjoyed by users of low or medium-priced portable LW/MW receivers. The following part deals with very long distance detection and requires good to excellent VLF tabletop receivers, plus a loop antenna which is a project for experienced experimenters.

Your receiver must include the VLF band (or the addition of a Datong or Palomar VLF converter), with good sensitivity and quiet internal circuitry (including the display). You should live away from man-made static such as high voltage cables and neon or fluorescent lighting. Your home should be as free as possible from uncontrolled jamming devices as dimmers, TV sets and VCR, refrigerator and air-conditioner with questionable suppressors. Above all, turn off personal computers and especially their video monitors.



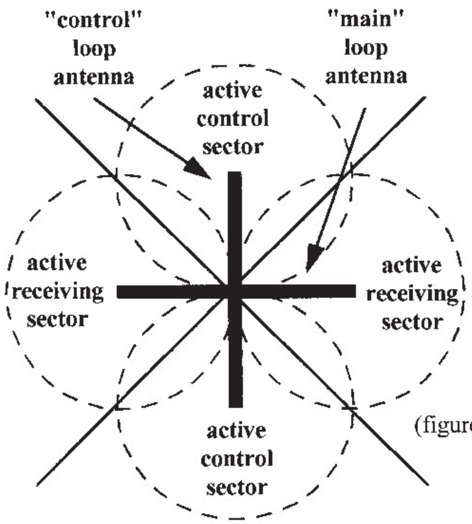
(figure n°2)

Before we start hunting storms up to halfway around the world, just few useful reminders:

Lightning strokes are powerful natural transmitters. Their continuous electromagnetic waveband extends from ultraviolet radiations to VLF, including visible light, infrared light, EHF, SHF, UHF, VHF HF, MF, LF. Each element of the electromagnetic pulse propagates more or less a long way according to its wavelength: a few kilometers or tenth of kilometers with the visible light and VHF to EHF radio components; hundreds of kilometers with HF and MF; and all around the earth with specific VLF frequencies.

Electromagnetic pulses can travel so far because at these wavelengths the ground and the lower ionosphere layers (E and D layer) make up a natural electromagnetic duct with a specific low pass filter effect. The season (winter or summer) and the presence or absence of the sun (day or night) play a variable part concerning the tuning of this low pass filter (according to the frequency under consideration).

It is possible to detect, to locate, to date, and to measure the intercontinental lightning activity using a good VLF receiver, a special antenna, and a recorder (graph plotter or computer). From France it is an easy job to listen to storms taking place in Africa, North America (central and south), Central America, South America



(figure n°3)

SECTORS DIAGRAM

(north of the Equator, Amazonian basin) and West India sea areas, to take their bearing and estimate their distance.

If you live in the eastern half of the USA, intercontinental results will most likely be similar. From the western coast of the U.S. you should expect to detect South American, Indochinese, Malay and Australian storms.

The sensitivity of the pair (receiver and antenna) must be at least 300 to 100 microvolts. The best working frequency will be around 30 kHz. A total range between 10 kHz and 100 kHz will be useful. The antenna directivity will be as narrow as possible.

❖ The Highly Directional Loop Antenna

You probably will not be surprised that the heart of the system is a special antenna. How is it special? As you know, the standard frame antenna is a directive one with two narrow "dips" (at right angles with the frame plane) where sensitivity is sharply reduced. Over most of the 360 degrees the sensitivity remains nearly unchanged.

This time this is the opposite: two narrow receiving sectors and two huge "dead" sectors. Furthermore, you have the ability to set the width of the receiving sectors. Interesting, isn't it? With a few modifications the antenna is also usable in LW/ MW broadcast DXing.

First, let me note that I found the information in a very old French Meteorological Services memo dated from 1936 and published by the Air Department. This pamphlet details the theory and the practical use of static receiving and recording devices, the results of their use, and their interpretation. Of course, back then the receivers all used tubes.

The core principle is the use of two coaxial loop antennas arranged at right angles. Connected as specified they interact in such a way that the two "active" sectors of the receiving loop are very narrow and under the control of the auxiliary loop. By playing with the auxiliary loop, you control the width of the active sectors of the first one. This width of sectors is also dependent on the intensity of the incoming signal.

This kind of aerial is known under the name of "Bellini & Tosi" radiogoniometer, or Cranwell system, both derived from early Robinson or Jeance systems dating from 1918.

❖ How Does It Work?

As a sketch is better than a hundred words, I invite you to glance at figure 1. This is the diagram of directivity of an ordinary loop antenna with very wide active sectors and two narrow "blind" or "dead" sectors. The latter are useful to suppress unwanted signals and to find the direction of a transmission.

Now, if we superimpose another diagram of directivity – one of a new loop antenna, set axially at right angles to the first – we get the result in figure 2. Let us suppose the horizontal loop is the main (receiving) antenna and the vertical one is the control (auxiliary) loop. If we (electronically) subtract the signals picked up with the control loop from the signals picked up with the main loop, we define two narrow receiving sectors (figure 3).

How is this possible? Figure 4 provides a straightforward explanation. If a signal is in the S1 position it is both in the middle of a dead sector of the control loop and in the middle of an active sector of the main loop. When you subtract 0 (the intensity level of the signal in the control loop) from 1 (intensity level of the signal in the main loop), you get 1. So it is received perfectly without attenuation.

With the S2 signal, the situation is the exact opposite. This signal is in the middle of a dead sector of the main loop, also in the middle of an active sector of the control loop. When you subtract 1 (intensity level of the signal in the control loop) from 0 (intensity level of the signal in the main loop), you get 0 (arithmetically but not algebraically speaking). The signal is zapped totally.

Between these two extremes you will find all the intermediate degrees of signal attenuation.

❖ Inevitable Mathematical Formulas

It is possible to predict these attenuations mathematically. Let us begin with the simplest (single loop antenna).

$\rho = M \times \cos\theta.$

If a signal is rated 100 µV when arriving in the plane of a loop antenna, it is rated only 86.6 µV when arriving at 30° off this plane (Cosine 30° ≈ 0.866). A 13.4 % attenuation (about – 1.25 dB).

The same signal is only 70.7 µV when arriving at 45° off the plane of the loop antenna (Cosine 45° ~ 0.707). A 29.3 % attenuation (about – 3 dB).

When a dual loop antenna is used, two choices are possible to combine the signals:

- Subtract one signal from the other before the detection.
- Subtract one signal from the other after their detection.

The corresponding formulas are:

$\rho = M \times \cos\theta - M \times \sin\theta = M \times (\cos\theta - \sin\theta) = M \times \sqrt{2} \times \cos(\pi/4 + \theta).$

$\rho = M \times |\cos\theta| - M \times |\sin\theta| = M \times (|\cos\theta| - |\sin\theta|).$

If a signal is rated 100 µV when arriving in the plane of a double loop antenna, it is rated only 36.6 µV when arriving at 30° off this plane (Cos 30° minus Sin 30° = 0.866 – 0.5 = 0.366). That provides a 63.4 % attenuation (about – 8.7 dB). Compare this with the single loop antenna (13.4 % of attenuation, or – 1.25 dB).

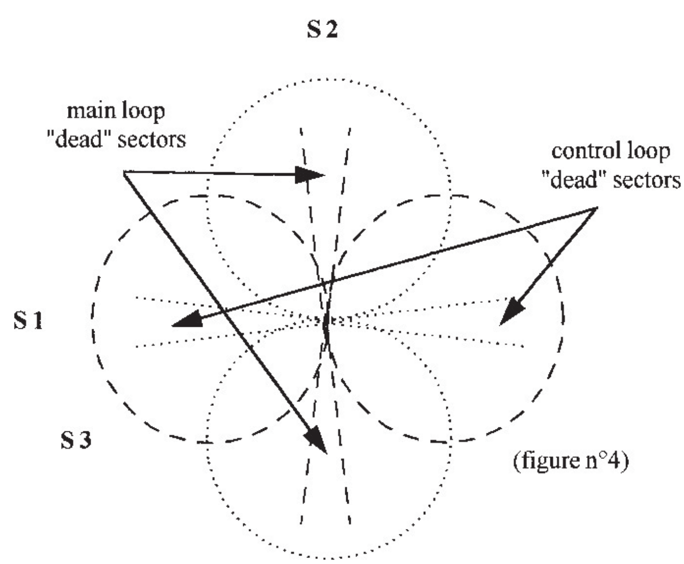
The same signal is rated 0 µV when arriving at 45° off the plane of the loop antenna (Cosine 45° minus Sine 45° = 0.707 – 0.707 = 0), for a 100 % attenuation. Again, compare this with the single loop antenna (only 29.3 % of attenuation, or – 3 dB).

❖ Adjustable Selectivity

So, what do you think? A rather impressive performance, in my opinion. But it can do more! Up to this point we have considered two identical (sensitivity, size, gain...) loop antennas. But if we begin to modify parameters, things change greatly.

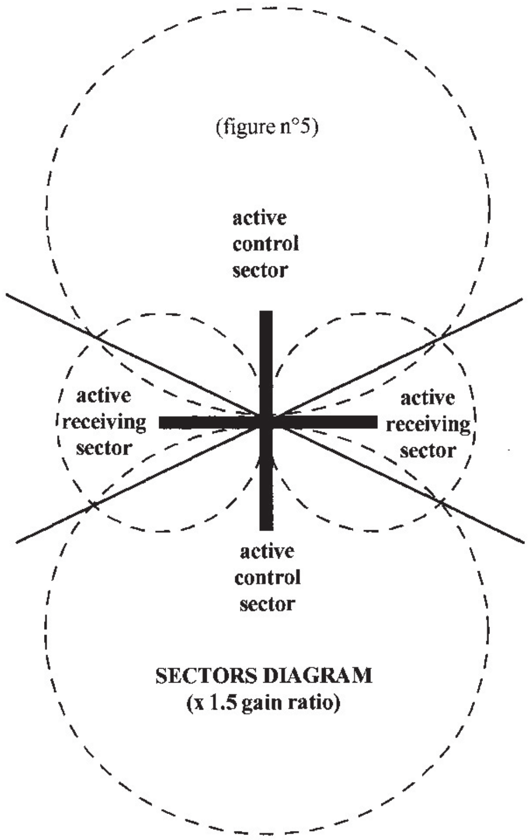
Let the control loop gain be 1.5 times the main loop gain. Let's use the first formula, always with a 100 µV signal arriving 30° off the plane of the double loop antenna.

$100 \times [(\cos 30°) - (1.5 \times \sin 30°)] = 11.6$ µV gain, or 88.4 % attenuation (more than – 18 dB)



(figure n°4)

THREE CASES OF RECEPTION



Once again, compare with the single loop antenna (13.4 % of attenuation, or – 1.25 dB). The active sector of the main loop has been narrowed definitely by the increase of the control loop gain.

Obviously, you can widely modify the performance of such an antenna according to the respective gains of the two loops (control and receiving). The end result will vary according to their sizes, the amplifying power of auxiliary electronic circuitry, and the ratio factor of the mixing stage.

To sum up, there are different scenarios, according to the electronic circuitry used. Let's cite a few of them:

If you increase the gain of the control loop you narrow the active sectors of the main loop (you increase the selectivity). In other words, to be received as well, a signal with a given level must be in a more acute angle from the main loop plane than before the increase.

If you reduce the gain of the control loop you widen the active sectors of the main loop (you reduce the selectivity), and an incoming signal needs a less acute angle of arrival to be received.

If you increase the gain of the main loop, you increase its sensitivity to faint signals (up to the limit of the internal or local noise floor). Indirectly you have also widened its active sectors (you have reduced its selectivity). It resembles figure 2, but with a better maximum sensitivity.

If you decrease the gain of the main loop, you decrease its sensitivity to faint signals. Indirectly you have also narrowed its active sectors (you have increased its selectivity). It resembles figure 1, but with a lower maximum sensitivity.

If you increase simultaneously and equally the gain of the two loops, you increase the sensitivity of the main loop without modifying its selectivity.

If you decrease simultaneously and equally the gain of the two loops, you decrease the sensitivity of the main loop without modifying its selectivity.

You can also decrease or increase each gain independently, according to your receiving needs and with a wide range of results.

Author's Note: All the data and performance put forward are those claimed by the quoted book, or supplied by theoretical calculations. To confirm the results, however, will require building the loop and performing on the air tests. However, it is not unreasonable to expect reality to come close to theory.

❖ Notes for Construction

Construction requires basically the same precautions as other high performance loop antennas. The two loops and their respective circuitry need to be shielded perfectly each against the other. An absolute balancing of the loops must be made. The output of each loop needs to be connected to true symmetrical electronic input circuitry, with the help of a balanced/unbalanced/balanced (symmetrical/asymmetrical/symmetrical) link if necessary.

The book quoted provides some data but no complete electronic diagram: the square loop is 1.3 m (4 feet 1/4") on each side, wound with 80 turns of copper wire, and coupled with a 2000 pF (yes: 2 nF) capacitor.

Thanks to the appropriate formula (see loop antennas chapter in *ARRL Antenna Book*), we can calculate its inductance: L ≈ 20 mH (selected coil length = 15 cm, side length = 130 cm, 80 turns). Distributed capacitance is C = 78 pF.

Coupled with its 2 nF capacitor (the distributed capacitance being omitted), the working frequency is: 25 kHz. With an adjustable capacitor C = 2/0.2 nF, we get a VLF frequency range Δ F = 25/80 kHz. With a 12/2 nF adjustable capacitor the VLF frequency range becomes: Δ F = 10 kHz/25 kHz.

We can also calculate the resistance of the coil R ≈ 12 Ω (monostrand 24 AWG), then the theoretical Q factor at the resonance (F = 30 kHz) Q = 263.

If we consider this Q factor = 263, a working frequency F = 30 kHz, and a standard receiver bandwidth Δ f = 2 kHz, the theoretical sensitivity will be S = 0.56 μV/m. Even with a Q factor = 10 (a poor one), the theoretical sensitivity will be S = 2.8 μV. The formulas necessary for these calculations are explained in *Loop antennas design and theory*, a National Radio Club publication.

In practice (given shielding and link coupling losses, not to mention other ones) the real sensitivity will be 3 times to 10 times lower than calculated: between 2μV and 6μV (Q = 263) and between 9 μV and 30 μV (Q = 10). The fact remains that these new values are acceptable.

It seems to me the best way to get the subtraction between the signal from the main and the control loop is to use operational amplifiers capable of handling dynamic and frequency (10 kHz to 100 kHz) ranges. As regards coil winding, multistrand (Litz) wire is worth a try.

Although succinct, the information included in this chapter gives you sufficient clues to make your experimental VLF/LF highly directional antenna provided that you have some loop antenna and operational amplifier experience. Otherwise, just wait a bit; I am sure that other readers of this text will not take a long time to fill in the gap and present us their product in a forthcoming *Monitoring Time* issue!

❖ Some Applications

What are some applications of the highly directional loop antenna? Of course, to DX elusive stations in spite of blockbuster signals and various interference. Also to use goniometric techniques to locate transmitters (with the help of another receiving station equipped in the same way).

Using a personal computer, suitable freeware or shareware polar printing utility, and remote control of the bearing of the antenna, you can make a panoramic receiver. If the loop antenna is made to rotate 360 degrees with a small motor, you can get a radar-like picture on the screen of your computer where bearings of transmitters (on a given frequency) are directly displayed. Better yet, you can make your receiver and the loop antenna automatically tunable on a given frequency range, and get the true bearing of all the transmitters currently on the air in this waveband.

Returning to the storm warning application, with the same equipment (with or without the sweep ability) you have a panoramic VLF/LF radio analyzer of natural transmitters – lightning and thundershowers.

A last tip to solve the mechanical problem of a 360 degree rotating loop antenna and its four connections (two for each loop). The book suggests using circular concentric channels filled with mercury and traveled by loop contacts. But mercury is a highly poisonous chemical element, and probably prohibited. Instead of mercury, why not make the whole setup (loop antennas, electronic circuitry, receiver...) rotate as one unit instead, and use a UHF (or infrared) low power data link to the personal computer port?

If the performance put forward in this article is confirmed by readers and future users, this loop antenna deserves good care. Its main advantage compared with other well-known loop antennas lies in its narrow and controllable receiving sectors – an important criterion in the opinion of expert DXers. Through the modification of its coil impedance, the loop can be adapted to wavebands from ELF (a few kHz) up to MF (500/1700 kHz BCB).