# AN AURORA DETECTOR:
# HOW TO
# MONITOR THE EARTH'S MAGNETIC FIELD

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**Summary**

**Some background outlining auroral activity is presented. The mechanics of auroral formation is discussed, followed by some earlier magnetic field detector attempts. The current magnetometer is then presented with practical information given so that any amateur may duplicate the magnetometer with little expense and trouble. Finally, some characteristics of magnetic storms and auroral displays are presented.**

In the early 1980's, I had the good fortune to meet Ken Willis, G8VR. In the late 1980s, Ken gave me an article from an English astronomical publication that described making a simple device for detecting auroras. (Ken had graduated to VHF editor for the RSGB) I had a son in Junior High School, and thought that the article was the basis for a "dynamite" science fair project. I did convince my budding scientist to try the project, and we were both rewarded with a device that exceeded our wildest expectations. Just imagine an instrument that can be built by a 7th or 8th grade student that will measure magnetic field variations! I saw the exceptional performance of the experiment as a good way to detect magnetic storms and auroras.
There were problems with the Jam Jar Magnetometer which included:

1. A very fragile instrument that was difficult to locate in the home.
2. There was no way to collect the data other than to record the information in a notebook.

That is good for a science project, but bad for an auroral monitor!
But, the seeds were sown. I promised myself that I would look for a good alternative to the jam jar magnetometer, one that would not require constant monitoring.

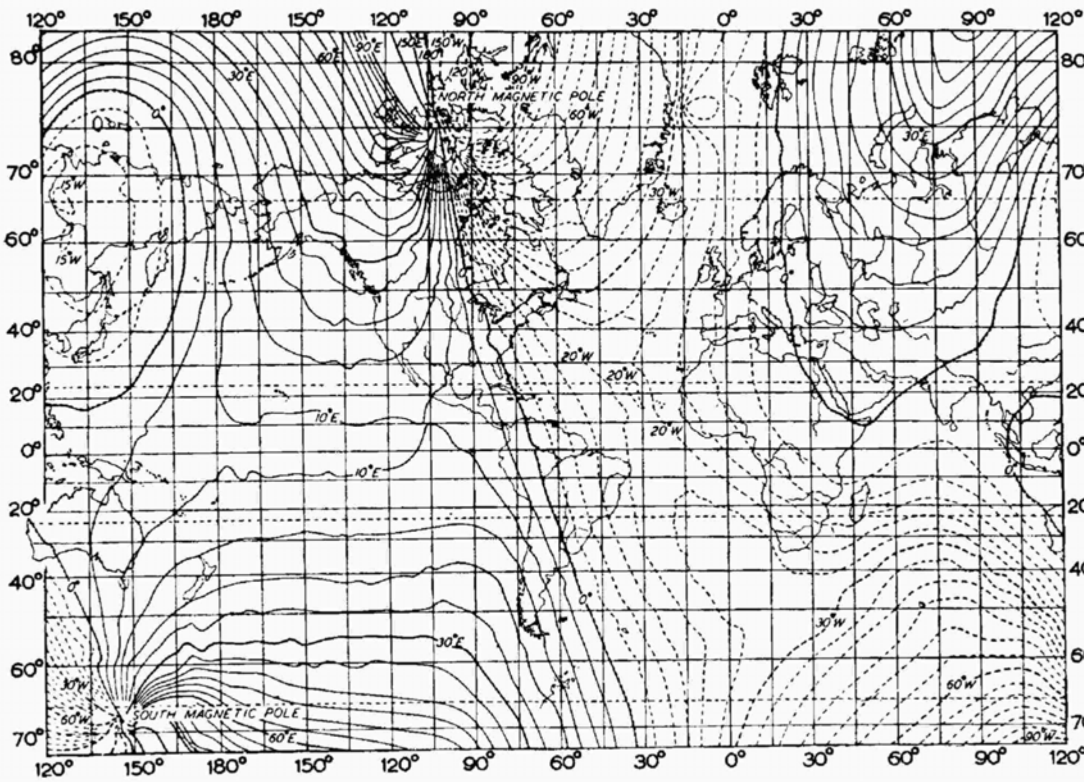
**Some Auroral Mechanics.**

Most people have some idea that auroras are somehow linked to the Earth's magnetic field. Most VHF hams know that aurora is caused by flares originating on the Sun's surface, and that the resulting aurora can produce raspy sounding contacts on the lower vhf bands with stations up to over 1000 miles away.
The Earth's own magnetic field is believed to be caused by convective currents within the Earth's molten interior acting as a self excited dynamo initiated by heat from residual radioactivity in the core. This magnetism is strong and never constant. At present, the North geomagnetic pole is located near $78^0$N and $104^0$W, west of Ellesmere Island. This is where your compass needle points! It is moving northwest at 15 km per year. A typical bar magnet may have a magnetic field of 10 gauss. The Earth's field at the surface at our latitude is 0.5 gauss. It is 0.63 gauss at the pole, and 0.3 gauss at the equator. A small portion, about 10% of the Earth's magnetic field is affected by the atmosphere, or more correctly, the magnetosphere, which can extend over a ***million*** miles into space during very energetic periods.
To get a measure of things, 1 gauss = 100,000nT (nano teslas)
1 nT=1 gamma
1 oersted= 1 gauss in air
Earth's field = 50,000 gamma (approx.) at mid latitudes

The Earth's magnetic field has distinct, measurable characteristics.
**Declination** is the variation of the direction of lines of force from true north. We all know that the geomagnetic field axis is offset from the true rotation axis by about 12 degrees. The value of declination varies with time and position on the globe. In New England it was 16

degrees West in 1950. It is now about 17 degrees West. The slow variation in the field is called the **Secular change.** Geologically speaking, the secular change is rapid and gives credence to fluid motion within the Earth's crust as a source of magnetism. For example, here are some declination values taken at London England over the past few hundred years.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| YEAR: | 1600 | 1650 | 1700 | 1750 | 1800 | 1850 | 1900 | 1950 | 1970 |
| DECLINATION: | $8^{0}$E | $1^{0}$E | $7^{0}$W | $18^{0}$W | $24^{0}$W | $22^{0}$W | $16^{0}$W | $8^{0}$W | $7^{0}$W |



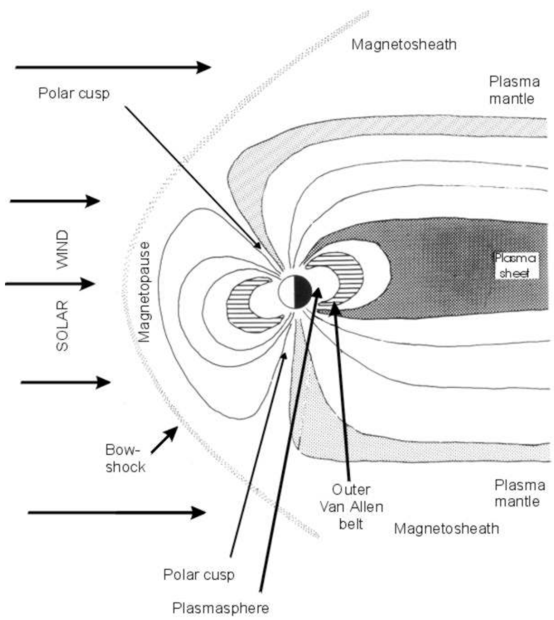

Magnetic **dip,** or **dip angle,** is a measure of the angle formed by the magnetic lines of force and the Earth's surface. The dip angle varies with latitude. Dip is 90 degrees at the magnetic pole, and 0 degrees at the magnetic equator. That is why your compass needle never looks level. It is trying to point along the dip angle as well as towards magnetic North.

There is also a **diurnal change** due to the motion and effect of the Sun and Moon. The change is great and varies over an almost 24 hour period. It is literally the tidal effect influencing the overall magnetic field. Both the Sun and Moon contribute, although the Sun's influence is the greater of the two by far, at the equator, being twenty times that of the Moon.

And, finally, there are variations that are associated with **geo magnetic storms**. This will be the primary subject in this presentation.

Auroras have been pretty scarce in the past few years while we have gone through the bottom of the sunspot cycle. The upcoming years promise dramatically increased auroral activity as the Sun "heats up". The exact mechanism for auroral formation is very complex, but needs discussion to make the connection with the magnetic field. Increased solar activity produces an increase in the solar wind expanding outwards from the Sun at speeds of from 400 – 1000 km/sec. The solar wind is comprised of electrically charged particles, or plasma, thrown out of the Sun’s gravitational force in the corona or outer "atmosphere". Flares and associated sunspots produce increases in the Solar wind. When the Solar wind "front" comes in contact with the Earth's magnetic field, or magnetosphere, many things occur. The high speed wind produces a shock wave or "bow shock" effect on the sunward side of the magnetosphere. As seen in the diagram, the magnetic field is compressed on the sunward side to about 10 earth radii., and extended on the midnight side for up to 1000 Earth radii! The magnetopause marks the edge of the Earth's magnetic field. It is here that the force of the Solar wind equals that of the Earth's magnetic field. Most of the Solar wind is deflected around the Magnetosphere, but some Solar wind plasma enters the Earth system at the Polar cusps, and travels down the magnetic lines of force in the plasma mantle and into the plasma sheet. The plasma sheet has a neutral central layer bordered by opposite charged regions on each side of the neutral sheet. A cross section through the magnetotail will show this alignment of two opposing fields of magnetic activity. Electric currents in the magnetosheath flow in opposite senses around these two lobes and meet and cancel out in the neutral sheet which lies in the equatorial plane. As seen in the noon-midnight diagram above, the field lines in the far northern hemisphere are directed sunward, while those lines in the southern hemisphere flow towards the magnetotail.

All this is getting very complicated, but interaction between the incoming Solar wind and the Earth's terrestrial magnetic field lines may result in trapping and then ejection of particles from the central plasma sheet down the magnetotail, and also into the Earth's high atmosphere there producing the aurora. Aurora is the result of an electrical discharge process powered by the Solar wind/ Magnetosphere dynamo. The fields produce rapid particle movements and collisions in the upper atmosphere.



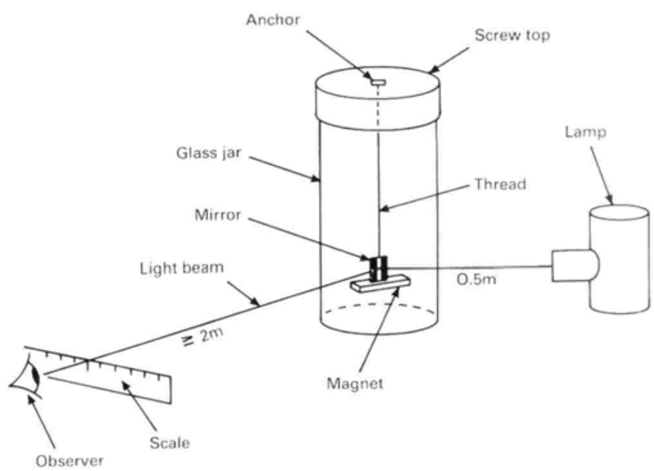

The Earth’s Magnetosphere

From:
The Aurora
Sun-Earth Interactions
By Neil Bone
Ellis-Horwood Limited
Chichester, W. Sussex, England
1991

Normally, in polar latitudes during quiet Sun periods, the auroral oval, a permanent area of auroral activity is positioned near the geomagnetic poles and skewed southerly on the midnight side of the globe and northerly on the daylight side. During periods of intense Solar wind caused by solar flares etc. the auroral ovals get quite disturbed. The horizontal component of the Earth's magnetic field after an small initial increase, can become depressed and the auroral ovals expand and descend to lower latitudes. When the auroral curtain becomes visible in more temperate latitudes, it is possible to work DX on the VHF bands.

The aurora can extend vertically from a lower limit below 100 km to a height of 1000 km. The colors seen are associated with the interaction of charged particles and atoms/ molecules of nitrogen and oxygen, the elements present in our atmosphere. Light is given off as a result of the collisions, the amount and color is related to energy levels and the atoms involved. Green atomic oxygen emission is dominant in lower elevations (100 km), while red emissions are generated with low energy collisions with oxygen in the less dense atmosphere above 150 km. Molecular Nitrogen at 1000 km can emit purple-blue emissions at certain times. It is also worth noting that there has been found a tremendous voltage potential along the auroral arcs. Some have likened our upper atmosphere to the inside of your TV sets' picture tube.

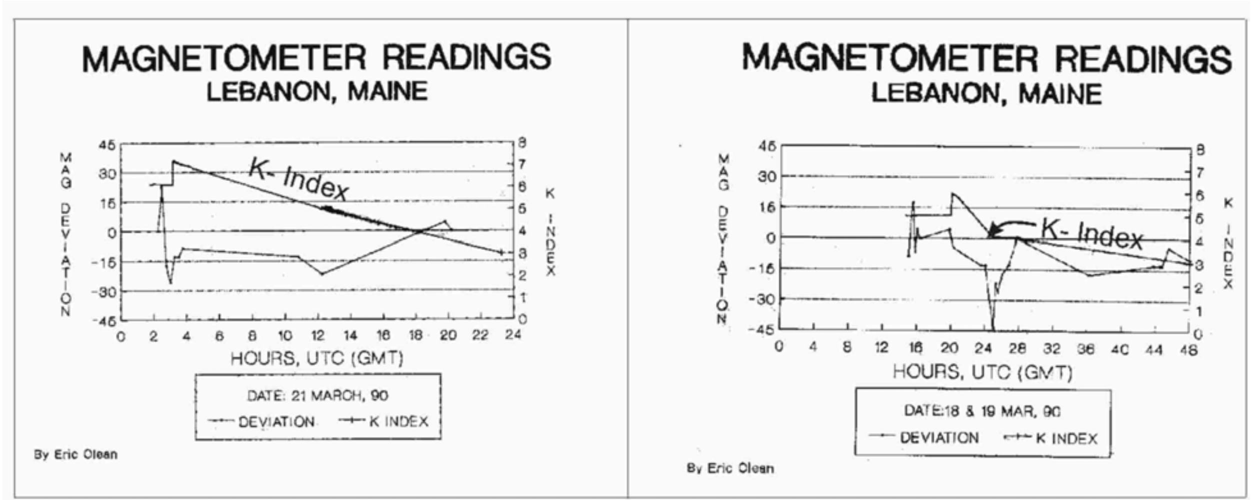
So How do you measure the magnetic field variations? The first, already mentioned device is the Jam Jar Magnetometer, popularized by Ron Livesey in Great Britain. It's operation is simple, as the figure below details. Any budding scientist can easily make one.




JAM JAR MAGNETOMETER

As mentioned previously, my son built one of these jam jars for a science fair in 1990. He recorded data sporadically for one month. He correlated his data with the WWV k index for the same period. Some results are shown below. Needless to say, the project was a success!

Doug Smilie in Scotland devised a more souped up version of the Jam Jar called a magneto-resistive magnetometer in 1991. It uses a free swinging bar magnet suspended in an oil filled container. Hall effect diode sensors located close to the poles but outside the container allow both horizontal and vertical fields to be measured. The signal output can drive a chart recorder.



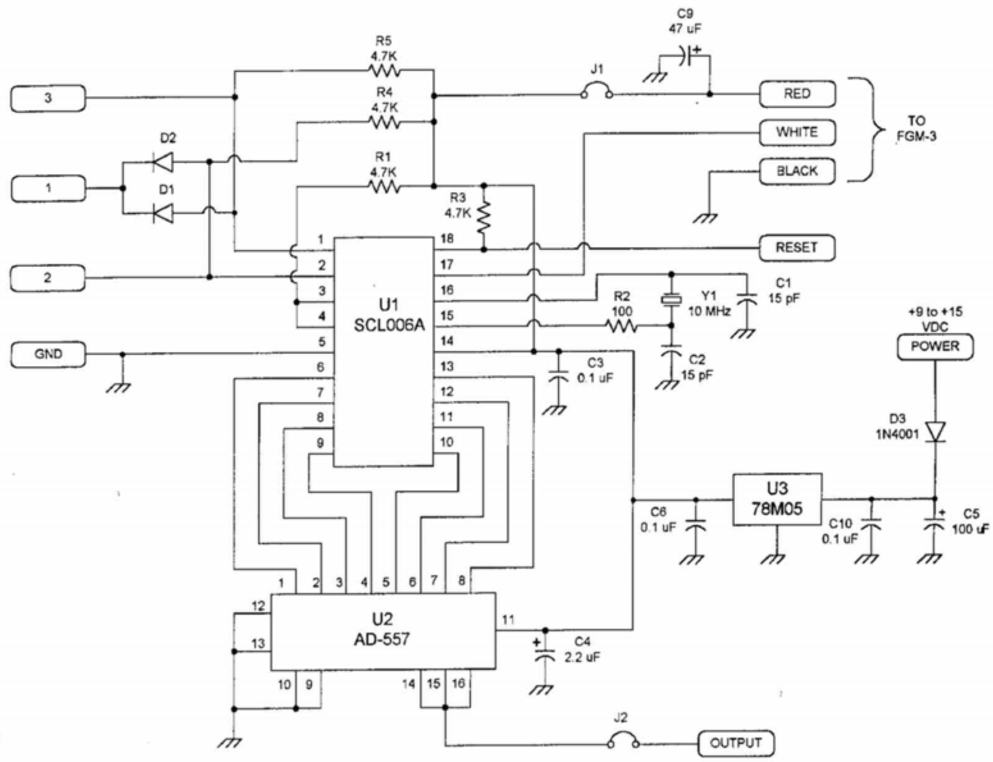

JUNIOR HIGH SCHOOL SCIENCE PROJECT GRAPHS. (1990)
An example of typical jam jar magnetometer results

A novel magnetometer design by Flodqvist also appeared in Sky and Telescope in October 1993. It detailed a phototransistor and LED pair with a compass needle suspended between them. The needle was biased to cancel the Earth's field, so that any storm activity would cause large movements of the needle and alter the light levels hitting the phototransistor. A 741 op-amp provided amplification to drive a chart recorder. It suffers from siting problems as well. It must be on firm flooring and not be touched when in use. It is a very ingenious design however!

Some time ago, I saw an article by Joseph Carr, that pointed me to a company that marketed magnetometers built in England by Speake Ltd. This article looked very interesting because it utilized a real flux gate magnetometer that did not rely on Hall effect sensors (which are very temperature sensitive). Also, the magnetometer actually measured field strength and so should be more adept at measuring the onset of geomagnetic storms than the moving vane types. I purchased the magnetometer, parts kit, and circuit board, and set out to build my own magnetometer. The schematics and all parts are available from the USA distributor, Fat Quarters Software in Murrieta, CA. The total cost will run about $85.00 if you have no junk box. Actually, if you want to get started cheaply, all you need is the magnetometer element, the FGM-3h or FGM-3, and a frequency counter. The magnetometer output is a 5-volt square wave that varies with field level. An ASIC, the SCL-006A, provided by Fat Quarters Software is a great touch and is very reasonably priced. The SCL-006A IC includes all functions to convert the magnetometer output to a BCD signal that your computer can understand. An additional D/A Converter puts you in business to drive an analog meter and chart recorder. A printed circuit board and a complete parts kit are available as well. All you have to do is put it in a case and connect power and an output meter/recorder. Talk about "simple". It can be built in an evening.

A few details about the circuitry are in order. I chose the FGM-3h flux gate magnetometer. (The more sensitive one). The FGM-3h has a linear range of +/- 15,000 gammas. The FGM-3 has a linear range of +/- 50k gammas. I think the FGM-3 is the better choice. The wider linear range is good. There is enough sensitivity with either the FGM-3 or the more sensitive FGM-3h.

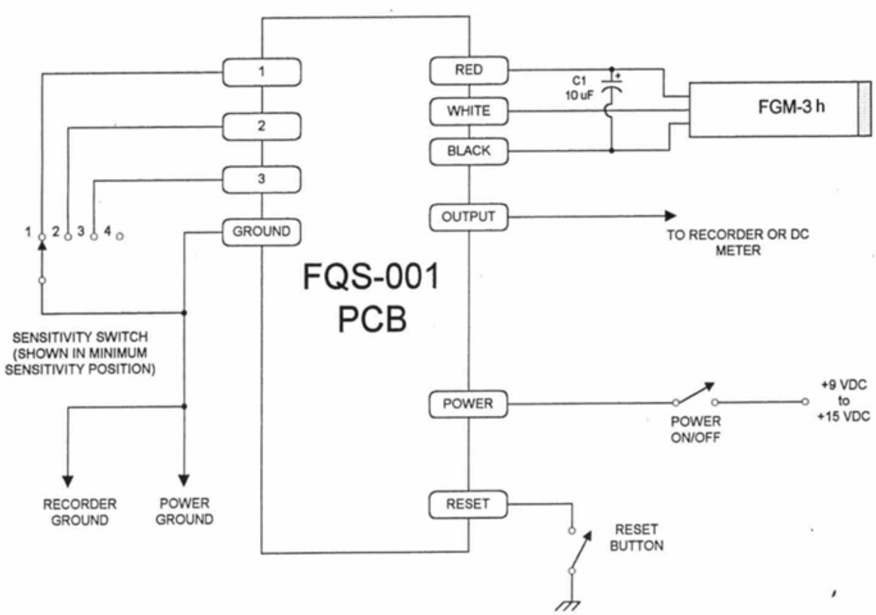
The SCL-006A ASIC contains a 10 MHz crystal oscillator and binary divider that drives a mixer to provide a down-converted frequency range of 0-1000 Hz rather than the 45-125 kHz square wave of the magnetometer. This low frequency is then run through a freq/volt converter and then output to an AD557 D/A converter. A sample is taken every second and is sent to the panel meter and chart recorder. All of this is handled by the two chips themselves. The




# FLUX GATE MAGNETOMETER SCHEMATIC
## FQS-001 Printed Circuit Board

| Switch Position | Range |
|---|---|
| 4 | +/- **75** gamma (total **150** gamma 0 to 2.5 volts) |
| 3 | +/- **125** gamma |
| 2 | +/- **275** gamma |
| 1 | +/- **500** gamma |

If you really want accurate calibration, each sensor should be calibrated.




# EXTERNAL PRINTED CIRCUIT BOARD WIRING FQS-001

circuit board is nicely made with IC sockets and goes together in rapid fashion. Note that the power supply must be double regulated to minimize drift in measuring small field changes. Use heat sinks for the three terminal regulators to minimize thermal drift voltage shifts.

The complete electrical unit was built in an old microwave power meter. (I saved only the power supply and the mirrored scale meter.) The magnetometer element was built up in a 1 1/2" PVC pipe with PVC plugs on each end and a power connector that can be taped and sealed with RTV. I remoted it outdoors and will permanently bury the unit in the back yard when I get things working as I like. Already I have ruled out the front yard as passing cars affected the magnetometer readings. The road was 75 ft away. It was interesting to note that some cars were "stealth" cars and gave no reading, but other vehicles gave good results. More investigation is needed, but I think cars like a '58 Buick with 4 portholes on the hood give good indications, while 1982 K-cars and late model Yugos give no response. (Much plastic or aluminum?) The magnetometer detected my wife leaving for work in her car, (1986 van with some "Bondo": 55 feet) so the rule is get it as far away from moving steel objects as possible. I provided a 0-1 ma meter output as well as a BNC output to drive a chart recorder or computer data port. There is also a BNC output direct from the magnetometer element so that the direct frequency of the sensor may be measured for calibration purposes.

There are many ways to monitor the output of the magnetometer. A simple meter or frequency counter may be used, but requires constant attention so as to not "miss" anything. A much better solution is to utilize a strip chart recorder or computer to collect the data. I have been using a computer and an inexpensive data collection system. Some scientific data acquisition boards for personal computers cater to the scientific community, and are quite "pricey." I found a rather inexpensive solution that provides a two channel, 12 bit, data acquisition module from DATAQ Instruments. It includes very robust software for WIN 3.1, WIN95 and 98, WINDAQ-LITE. Communication with the PC is through the serial port. The setup time is minimal. In 20 minutes I had the software installed and the hardware was collecting magnetic data! The total package convinced me to retire my trusty strip chart recorder with attendant pens and paper rolls. I can collect a year's worth of magnetic data in a one megabyte file size. In addition it is a simple matter to compress the record, or alter sensitivity after the fact. Try that with a strip chart recorder!

The best place to locate the flux gate magnetometer element is obviously out in the back yard under ground. Some people have had good success putting the unit up on a high roof away from the street and moving objects. The underground idea is better in that a more constant temperature is available there. The sensors have a variation of .03% / degree C. This is good, but you can get some temperature effects in the outdoors. The sensor dissipates 50 milliwatts and it could overheat if mounted directly in Styrofoam insulation. For above ground use outdoors, the manufacturer recommends you attach it to a large non-metallic heatsink, then encase it in sand inside a Styrofoam drink container. The idea is to get a large massive thing that will not change temperature fast. A heatsink is not required for cooling. 50 milliwatts is pretty negligible in most cases. Air-cooling is satisfactory. I packed my unit in bubble wrap, which is almost air!

In operation, the circuit updates its reading every second. The four-position sensitivity switch controls the maximum magnetic range available on the meter. The FGM-3 would have gamma ranges double those shown in the figure at the middle of page 6. Initially, with the FGM-3h magnetometer, the output would vary so much that the readings were exceeding the range of the detection circuits. I traced the problem to poor alignment of the sensor itself. I had not done a good job of orienting the unit in an East-West direction. As a result, the diurnal variations seen as the geomagnetic "tide" comes in and goes out were too great! I had to keep re-centering the plot on the paper by pushing the RESET button. The best procedure for locating the sensor, would be to align the magnetometer with the long axis pointing East-West, and measure the frequency or period. Then rotate the sensor exactly 180 degrees and check the reading again. When it is truly aligned, the field will be the same and the frequencies will be similar. After carefully re-aligning my unit, I obtained a frequency of 60.3 kHz. All this brings home the fact that the FGM-3 and the FGM-3h are both vastly more sensitive than we need to detect magnetic storms.

Most serious vhf "hams" are familiar with the Boulder K index as is transmitted at 18 minutes after the hour on WWV. The K index gives a measure of the amount of disturbance in the Earth's magnetic field. A reading of maximum deflection is taken over a three-hour period, say from 1900-2100 UTC. A composite measurement of the X and Y component of the field is taken typically and the variation from the diurnal change is tabulated. The following scale is used by the Swedish Magnetic Observatory. These are much more "energetic" than the Boulder K values. The severity of the fluctuations is related to latitude. Kiruna Sweden is above the Arctic Circle at "magnetic" latitude +65 degrees. Boulder is at +49 degrees.

| | **Kiruna** | **Boulder** |
|---|---|---|
| **K-indices** | **Deflection in nanoTeslas** | **Deflection in nanoTeslas** |
| 0 | 0-15 | 0-4 |
| 1 | 15-30 | 4-10 |
| 2 | 30-60 | 10-22 |
| 3 | 60-120 | 22-40 |
| 4 | 20-210 | 40-70 |
| 5 | 210-360 | 70-119 |
| 6 | 360-600 | 119-214 |
| 7 | 600-990 | 215-370 |
| 8 | 990-1500 | 370-500 |
| 9 | 1500+ | 500+ |

If you have been paying attention, you have seen that the diurnal variation is a rather large "signal" and that a magnetic storm will easily dwarf the diurnal variation.

In late September, 1998, the unit and chart recorder were connected and waiting for some large solar disturbance to occur, but only various perturbations in the Earth's magnetic field that are too small to cause auroras were routinely detected. On 2300 UTC on 30 September, a rather big magnetic disturbance was noted on the recorder. WWV broadcast the latest 2100Z K index as 2, An update would be done at 0018 UTC, but I knew that something happened at 2300! If it had been a big storm, I would be working DX while everyone else was watching Mork and Mindy re-runs on TV. Only later after several more hours had passed did WWV indicate minor storm levels, and a Kp of 4. At 0300 it went to Kp=5. I saw the peak at 0030 UTC! Later the next afternoon, another disturbance occurred at about 1715Z. It lasted two hours, with minor blips showing up after that. The utility of having your own geomagnetic data is incredible! Now all I need is the 2M transmitter right next to my magnetometer, instead of 1/2 mile away!

The characteristics of a typical magnetic storm and auroral display are worth discussing at this point. The transition from quiet diffused arcs in the auroral oval to a full-fledged magnetic storm can occur in a matter of minutes. Most storms consist of an initial sudden compression of the Magnetosphere as the shock wave passes the Earth. This is the SSC or ***Sudden Storm Commencement***. The compression is often followed by successive explosive processes within the Magnetosphere of one to three hours duration. These events are called ***magnetospheric substorms.*** There may be five or ten substorms within a magnetospheric storm. These substorms are believed to produce excessive amounts of plasma within the upper atmosphere trapping regions at a faster rate than can be dissipated normally, thereby causing post midnight auroral displays. Pre midnight bright auroras are the result of electric fields set up at about one Earth radius in order to enhance the flow of current required to reconfigure the Earth's magnetic field in the magnetotail. The electric field accelerates the electrons in the upper atmosphere to produce the particle collisions with the attendant light emission...the aurora!

An observer near the auroral zone may view a low diffuse glow to the poleward horizon in early evening. Only the tops of the auroral display are visible since the auroral oval is hundreds of miles to the North. As night progresses, the oval appears to extend more southerly as the Earth rotates. Remember that the maximum southerly extent of the auroral oval is at local midnight. As a storm commences, we would see a rapid expansion of auroral activity beginning with a rapid brightening of the diffuse glow, and then an extension of auroral arcs above the diffused band. The expansion begins at the local midnight portion on the Auroral oval, and this expansion pushes in every direction. A pronounced westward surge is normally viewed on the evening side of local midnight, and may occur rapidly within a 5 to 10 minute period. The surge consisting of a large scale fold travels at about 1 km/sec. expanding North and West. The areas West of local midnight typically consist of stable auroral arcs as well as the surge effects already mentioned. To the East of the local midnight point, the auroral display will usually appear as broken patches of rays, or flashes of light. The local midnight sector usually will have the greatest area of auroral displays visible soon after storm commences. The aurora may proceed overhead and may even extend to the southern horizon. This is known as the ***BREAKUP*** phase of the auroral substorm, and is the maximum expansion of the aurora. An auroral corona can sometimes be seen at the magnetic pole zenith. Then you know that the aurora is directly above you and you are looking straight up the curtains! It is an awesome sight. Maine is at magnetic dipole latitude +54 degrees, and I have seen several auroras that covered the entire sky near local midnight.

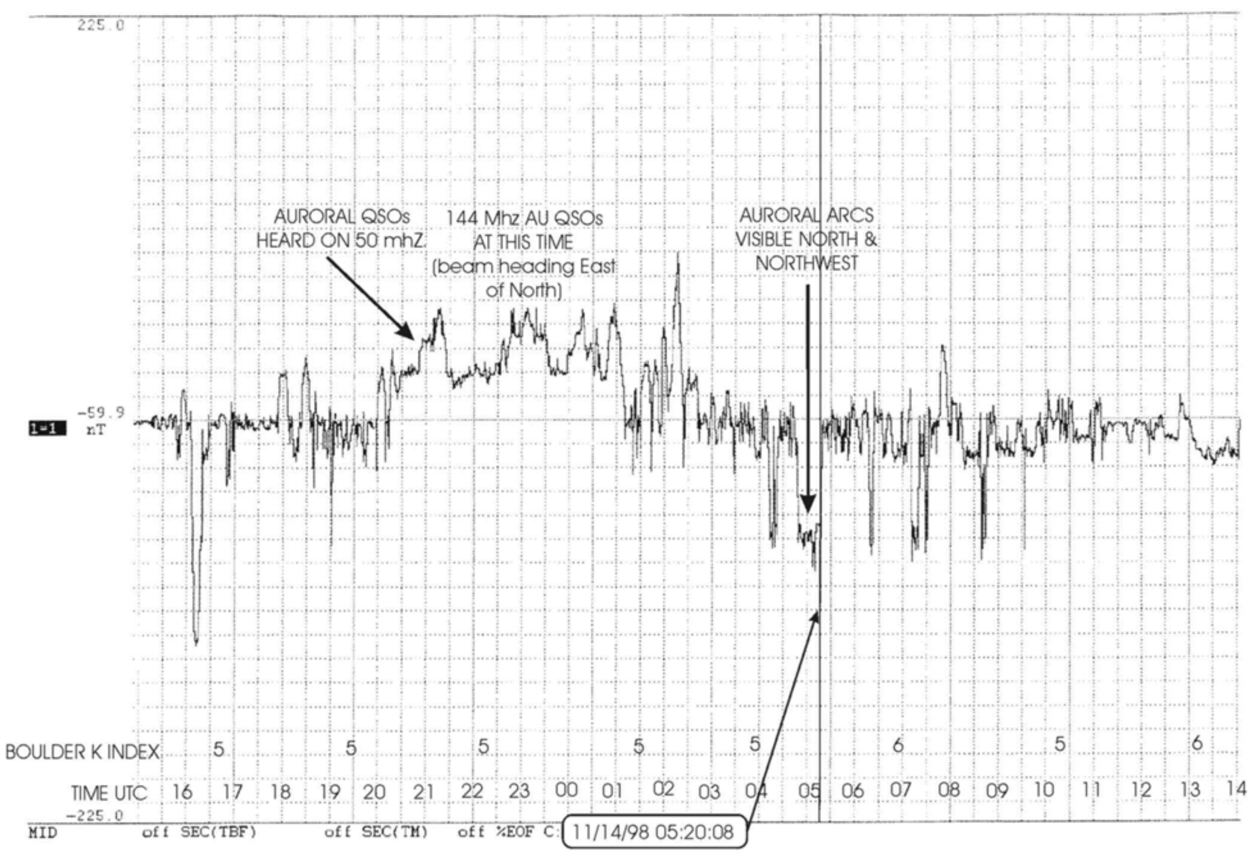
When the local midnight bulge begins to contract, the **RECOVERY** phase has begun. It is important to remember that every storm will have a different magnitude, and that a particular location on Earth can be in the auroral oval at one time and not another. We can see that each storm is influenced by the local time, at a particular spot, as well as UTC, for sudden storm commencements, sub storms, and recovery periods.

Associated with the auroral oval is the auroral electrojet, a concentrated electric current that profoundly affects geomagnetic recording instruments in its' proximity. Auroral activity will trigger huge *local* variations in the Earth's magnetic field. These will easily be measured by a flux gate magnetometer. A typical geomagnetic storm will last for a period of one , two or three days and be marked by a slight trigger of positive field, followed by a steep negative free fall of the magnetic field over a very short period of time. A slow recovery will then occur over the next few days. The rebound will be accompanied by numerous substorms appearing as smaller events superimposed on the larger (longer time) event. Northern stations closer to the auroral zone, will have larger variations than will be seen at more southerly locations.

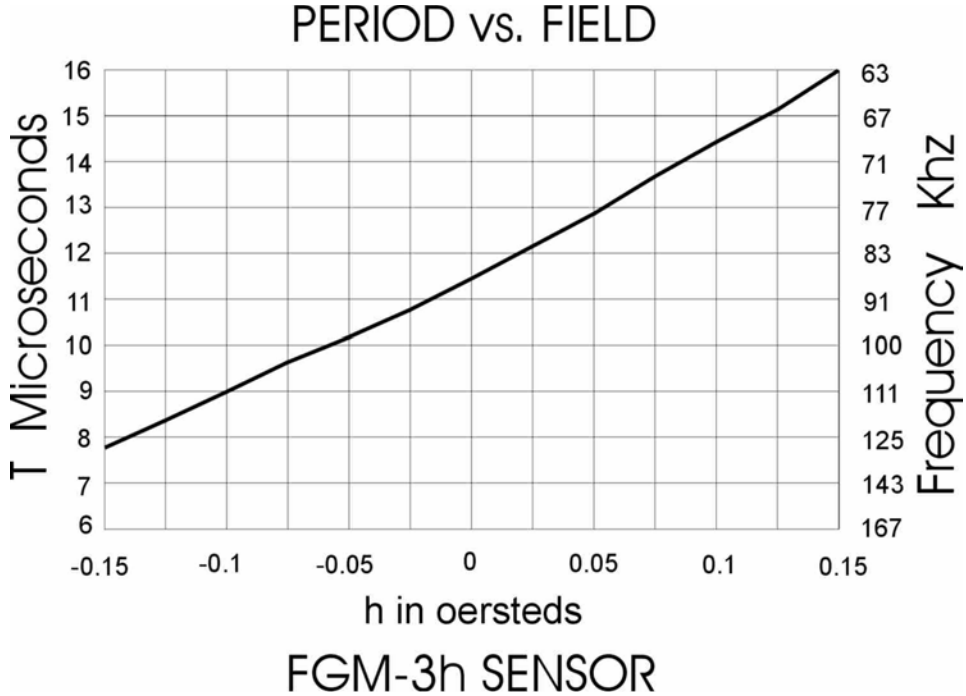
The subject of geomagnetic recording during storms is quite involved and it is immediately apparent that no two observatories will produce the same traces. Geomagnetic latitude and longitude are very important variables. The location of the auroral oval with respect to the observer is critical and the results obtained at differing points on the globe are the means, along with satellite data, to map the magnetic field variations and the position of electric currents in the magnetosphere.

As an example of a typical data recording as might be obtained with an amateur flux gate magnetometer, I have included a trace of a minor storm as detected on November 13 and 14, 1998. This sequence was notable in that the visual aurora was observed and could be correlated with the actual recorded data.

At 0100 UTC on November 14, I was able to observe a diffuse auroral glow in a band that stretched across the northern sky. There were no rayed arcs or flashing displays; just a whitish glowing band. The sky had just cleared. Previous auroral activity that night was not visible although aurora contacts were being made on 144 MHz from at least 2200 to 0200 UTC. I went out for the evening at 0100 and watched the display from my car, and then at my destination. When I was about to leave for home at midnight, I again observed the aurora, and was rewarded with a beautiful view of the same diffuse band, but now it contained rayed arcs especially to the West. They danced around rapidly from about 310 degrees to 50 degrees true azimuth. The display was not spectacular. It did not rise more than 10 degrees above the horizon, but at times it was bright green and the moving rays were beautiful. I watched it all the way home and when I arrived at 0530 UTC., the rays had disappeared. A quick check of the recording showed a pronounced dip in magnetic field that ended at exactly 0520 UTC when the rays dissipated! As can be seen, there were other, more abbreviated negative dips in the record that occurred later. At these times I am sure that ray structure (and VHF DX!) were evident. I have included the Boulder K index and the times across the bottom of the recording. It is very evident that the actual times of VHF DX correspond closely with the extreme recorded disturbances, while the K index gives only a general indication that auroral activity is possible or probable. The value of having your own data lies in the real time determination of exactly when the auroral substorm is happening. The VHF reflections from the aurora will coincide with these substorms.




So now we have accomplished the goal of assembling a true auroral detector. In fact, we have done something better, we have built a geomagnetic observatory with results that can compare with the "big guys". The only missing ingredient is a calibration of the setup. I will not go into the details, they are adequately discussed in application notes supplied with each sensor ordered. You must simply supply a known magnetic field obtained from a coil of wire wrapped around the magnetometer. The Earth's field must be canceled (align East-West) and a close wound single layer long solenoid coil of wire placed around the sensor. Supply a precise current through the coil, and measure the reaction of the sensor. Now you have an accurate calibration curve for the sensor in use. Linearity of under 1% are possible. flux accuracy can be within 5%. A period vs. frequency curve for the FGM-3h sensor is pictured below.




As can be seen from the graph, the sensor is quite linear from +0.15 oersted to -0.15 oersted. One oersted is equivalent to one gauss in air or a vacuum and $10^5$ gamma. 0.15 oersted is equivalent to $1.5X10^4$ gamma or 15,000 gammas. It should be stated that the sensor is linear with respect to period, not frequency. There are other tricks possible to improve the 5% basic linearity of the magnetic sensors, but are not needed for aurora detecting. I should mention, however that there is an extra winding in the sensor itself to apply DC bias to null out field effects, or slide the curve to a more linear portion of the scale. Of course, the less sensitive FGM-3 is linear over the wider range of +/- 0.5 oersted or 50,000 gamma. Unlike the FGM-3h, it can record the total Earth magnetic field at our latitude without saturating.

In conclusion, I can see the value of a network of amateur magnetometer stations in this country designed for early warning of auroras. (Such a condition is almost the case in the United Kingdom today) The cost is minimal. The effort is slight, and it is almost as much fun detecting the aurora as it is working new grids when the "buzz" is coming in! I am very pleasantly amazed at how slick and simple this instrument is to use. There are no things to bump and throw out of whack! The magnetometer sensor just sits there and delivers first class data day after day. I would imagine that, with a bit of experience, the practice of evaluating geomagnetic storms from the comfort of your "shack" would become quite routine. After all, you would have at your disposal an accurate measure of the exact amount of field disruption that has taken place. You could be the first one on your block to issue local K indexes to your friends and neighbors! On a serious note, the availability of such accurate indications of geo magnetic activity will usher in a new era where amateur radio VHF enthusiasts can obtain the maximum potential from auroral openings. How many times have you worked an aurora and have it fade out at 9:30 PM, then miss it later when it roars back at 11:30 pm with another sub-storm, and you miss all the good long haul contacts? Just imagine the correlation possible when you plot your QSOs against the magnetic storm trace on your recorder or computer! Now you have no excuse to miss the best parts of the storm. The magnetometer can inform you when the best periods are happening. I am convinced that we now have a fantastic tool at our fingertips, and it is up to us to derive the greatest benefits from it.

I wish to thank the following people who helped me in the development of this article. Mr. Joseph Carr, K4IPV, helped by providing the schematic drawing artwork for the magnetometer. I also thank Mr. Erich Kern from Fat Quarters Software for his help throughout the project, and Mr Ken Willis, G8VR for getting me started on this project way back when! Finally I would like to thank Dr. Roger Arnoldy, Director of The University of New Hampshire Space Science Center in Durham, NH., for his considerable constructive comments on this paper. He has studied auroras since the early 1960s, He provided much practical information necessary to put all of the facts together. Upper atmosphere physics is a challenging discipline where new discoveries are being made on a routine basis, and similarly, much remains yet undiscovered!

## Bibliography

S.I. Akasofu, Polar and Magnetospheric Substorms, Springer-Verlag, New York, 1968

S.I Akasofu, J.R. Kan, Physics of Auroral Arc Formation Geophysical Monograph #27, American Geophysical Union, 1981

Bates, D.R., F.R.S. The Earth and it's Atmosphere, Basic Books, New York, NY. 1959

Bone, Neil, The Aurora Sun-Earth Connections, Ellis Horwood Ltd, Chichester, England, 1991

Carr, Joseph J. " Experimenting with Magnetic Sensors", Electronics Now, June, 1998 pp. 49-52 and July, 1998 pp 56-60.

Davis, Neil, The Aurora Watcher's Handbook, University of Alaska Press, Fairbanks, 1992
(This is a great book written in simple and clear language)

Flodqvist, Gote, "Detecting the Polar Lights", Sky & Telescope, October, 1993, pp. 85-87

Lanzerotti, Louis J., Uberoi, Chancal, "Earth's Magnetic Environment" Sky and Telescope, October, 1988 pp. 360-362

Livesay, Ronald J. "Gleanings for ATMs: A Jam Jar Magnetometer as Aurora Detector" Sky and Telescope, October, 1989, pp426-432

Press, Frank, & Siever, Raymond, Earth, W.H. Freeman & Co. SanFrancisco, CA , 1978

Wells, Bradley, "Solar Activity and the Earth's Magnetosphere", Ham Radio, August 1987, pp. 8-15

**Parts Sources**

Fat Quarters Software (USA Distributor for Speake & Company Ltd.)
24774 Shoshonee Drive
Murrieta, CA.
Tel: 951-698-7950 Fax 951-698-7913 E-mail: efkern@earthlink.net
Web Address: http://www.FatQuartersSoftware.com

Speake & Company
6 Firs Road
Llanfapley, Abergavenny,
Monmouthshire, NP7 8SL
United Kingdom
Tel: 01600-780150 (From USA dial 011 44 1600 780150)
http://www.speakesensors.co.uk
e mail: speake@elvicta.fsnet.co.uk

Data Acquisition : Model # DI-190 or DI-150RS with WINDAQ-LITE Software
Dataq Instruments Incorporated
150 Springside Drive, Suite B220
Akron, OH. 44333
1-800-553-9006
www.dataq.com
Note: The DI-190 has been discontinued and will not be available when supplies run out. The DI-150RS will work just as well.

Note: Since this article was written, Dataq has updated the above serial port data acquisition units. The new models are:

| | | | |
|---|---|---|---|
| DI-194RS | 10 bit 4 channel +/- 10 v. | serial port module | $24.95 |
| DI-154RS | 12 bit 4 channel +/- 10 v | serial port module | $149.95 |