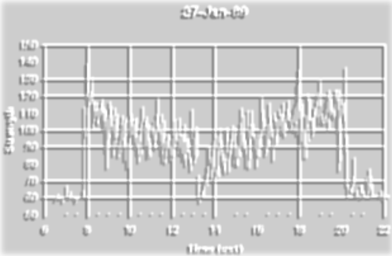
Solar Flare detection by Shortwave Radio



KJ SMITH 1991

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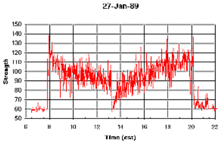


This is the tale of a project long in the making, nurchered over three years of thinking and patience, of persistant attention, and finally of research and discovery. I hope it will facinate and inspier the reader as much as it did myself.

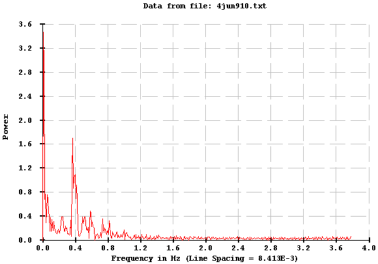
The object of this study was to observe solar flares via shortwave radio. The technique, described in an article by Mr. John Hudak, (Sky and Telescope, Nov. 1984), involves monitoring the shortwave signal of a distant beakon and looking for a characteristic fadeout signature indicative of a solar flare. The equipment utilized in the article included a shortwave receiver and a chart recorder. I was interested in this project and had the necessary receiver, but no chart recorder so things merely stewed in my mind. It would not be easy or practical to purchase a chart recorder for a single purpose. Instead I considered ways of utilizing a Commodore 64 computer for the purpose of recording the data.

Things stood that way for three years until one day while shopping with my family I picked up a Radio Electronics magazine quite on a lark. Reading it later at home I was quite stunned to find an article by Dr. Frank Maloney which described a scanner controller project for use with a Commodore 64. Two circuits were presented of which, one was an interface between the radio automatic gain control (AGC) and a C64 computer "paddle" port. I suspected that the

small compared to the 15MHz carrier. On top of that is a second interesting beat in the amplitude with 40 to 50 second period or about 0.02Hz (also seen on the power spectrum).

Voila! No noise at all, just signal everywhere.

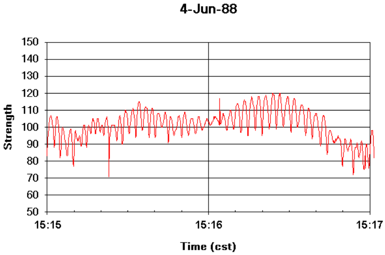
Supplemental Records



Power spectrum of the data collected on 04 June, 1998. The data was converted to the frequency domain via a Fourier transform.

Fin.

seen the characteristic signature of signal fading. There are in fact two periods of fading superimposed, one of about 50 seconds, the second about 5 seconds. The fading has the typical rounded crests and sharp drop to the separating nodes. This pattern results from the beat amplitude of two or more interfering signal frequencies.



characteristic signature of signal fading

The second chart is from a run of only seven minutes giving about a tenth second interval between readings. There the fading signature shows with about 50 beats over the two-minute interval shown. Fading generally results from the interference of the same signal arriving from two paths at the receiver. A power spectrum of the data shows a strong peak around 0.4 hertz corresponding to the dominant beat (25b/m or 0.4b/s). For a beat to be set up the signals traveling along separate paths, (presumably a single hop and a double hop) they must not merely be arriving slightly out of phase but also with a difference in frequency of 0.4Hz. That shift is extremely

unit would work as well with my Yaesu 7700 shortwave receiver and there followed correspondence with Dr. Maloney. He was a great help and in fact he had the same radio. The circuit had one major drawback from my perspective, it was battery operated and I was proposing to make regular observations of 15 plus hours duration. Finally the solution came in the form of a modification by my clever brother in Seattle allowing the interface to run off the 11vDC power supply or the radio itself.

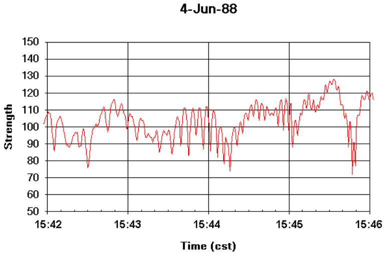
With the hardware in place after my years of waiting, I was ready to go to work. September 1987 was only a year past the minimum between sunspot cycles 21 and 22 and the solar activity was still fairly low, but picking up rapidly. My goals included both detecting flares and a more general one of observing radio propagation variation from minimum to maximum in the sunspot cycle, a project therefor lasting several years. In actual fact I gathered data weekly from September 1987 until July of 1991. Each Friday early I would switch on the computer and radio and, with a homebrew Basic program, monitered WWV's signal at 15MHz.

A technical note on the interface. The device works by taking the variable voltage output of the receiver's AGC circuit, accessable easily from the rear of the unit, and converting it to a variable resistance. The Commodore 64 computer gameport could read both joysticks and the even-then obsolete game "paddles" which worked on resistance. The computer read the resistance and converted it to digital values, a built-in analog to digital interface.

A true confession, while I can ponder for hours the possible physical reasons behind a discontinuity in the data, I personally get little pleasure from soldering two wires together. With modern pentium PC computers its probably best just to purchase a manufactured A/D circuit and concentrate on the science. My own C64 retired soon after the end of this study in 1991.

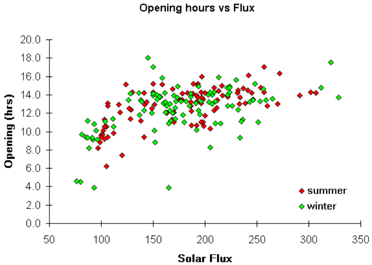
The "Grass", Noise Revealed

Some final words and observations concerning the "grass", the noise on the records with the very high frequency. Hidden within that noise lies some interesting signals and an interesting message. This "noise" seen on the records is in fact just more signal, but at a higher frequency than I have been presenting. The following charts were made on 04 June, 1988. They were taken specifically to look at the high frequency content of the signal. It should be noted that in both charts the signal strength scale remains exactly the same as in all the previous charts so the amplitude of the "noise", the range from crest to node is quite significant when compared to the daily variations being measured.



characteristic signature of signal fading

In the above case I gathered a standard 3200 points over 29 minutes with no filter giving a half-second period between points. The chart shows four minutes of data and on it can be otherwise. Increased ionization levels increase the signal absorbtion as well. Also, times of high solar activity bring instabilities in the earth's geomagnetic field. Both of these effects have an important impact on signal strength.



Solar activity (flux) vs length of openings

Solar activity (flux) on the other hand does indeed improve the conditions in terms of the length of the openings, especially for levels of flux above about 120. This is logical when considering the overall increased ionization levels. While the increased ionization may actually hurt signals by increasing absorbtion and causing greater geomagnetic instability, it does make for longer openings. Next: The "grass", noise revealed..

Some Definitions

Sunspot Number
This is a measure of the number and area of both individual sunspots and sunspot groups. Naturally this is based on visual observations from a number of observatories, the data reduced and averaged. Sunspot numbers were introduced in 1848 by the Swiss astronomer J.R. Wolf and have been calculated, with caution, back to around 1610 making this the longest continuous record of solar activity available. Sunspot numbers range from lows near 0 to highs over 200 during maximums of solar activity.

Solar Flux
In many ways similar to the sunspot number, and well correlated, the solar flux index is a measure of solar radio flux at a frequency of 2800MHz, or 10.7 cm as it is commonly called. This measure was introduced in 1947 at Ottawa, Canada and has obvious advantages over the sunspot number in that it does not rely on visual, often subjective observations.

K indices (K, Kp)
Quasi-logarithmic index of geomagnetic activity relative to quiet levels for a local recording station. These measurements are taken over a 3-hour period and reported on a scale of 0 to 9. Planetary (Kp) values are determined from data from 12 to 13 stations worldwide. This indice was begun in 1949 at the Institut für Geophysic, Göttingen University, Germany.

A indices (a, A, ap, and Ap)
Indices derived from the K index but converted to a linear scale as follows:

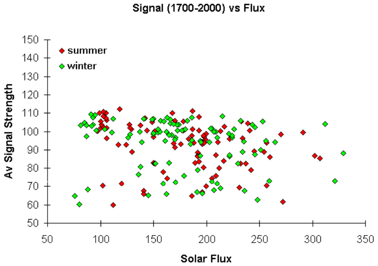
K	0	1	2	3	4	5	6	7	8	9
a	0	3	7	15	27	48	80	140	240	400

The Ap, or planetary A index is an average daily report which I have commonly used to indicate geomagnetic conditions. The equavelant values are defined thus:

Ap	Condition
0-7	Quiet
8-15	Unsettled
16-29	Active
30-49	Minor Geomagnetic Storm
50-100	Major Geomagnetic Storm
>100	Severe Geomagnetic Storm

Signal Strength by Solar Activity

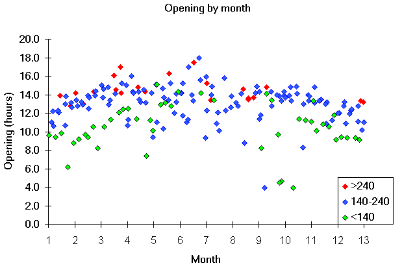
The following charts show the relationship of solar flux to signal strength and to the length of time for an opening for propagation along a circuit. Color coding provides an indication of the variation due to season as seen in the previous section. In this case I have distinguished "summer" from "winter" data on thess charts in the following way: Winter = October to March, Summer = April to September.



Plot of signal strength averaged over the midday period 1700 - 2000UT

Plot of signal strength averaged over the midday period 1700 - 2000UT (11-13 CST).

For both summer and winter seasons I see a weak but real inverse relationship of decreasing average signal strength with increasing solar flux. It has often been stated that propagation improves during times of high solar activity, this data suggests



opening hours versus season

When plotting the length of time of the openings by season the situation is reversed with longer openings showing a weak but real preference to the summer season. This results principally from the longer time of ionizing radiation on the ionosphere, but in this case moderate to high levels of solar flux can add one to two hours of additional opening per day. I agree with the oft-stated general conclusion that winter is the best time for long distance communication by HF radio, but given the scatter I would temper that by addressing more closely the question of solar activity. Next: Signal strength by solar activity..

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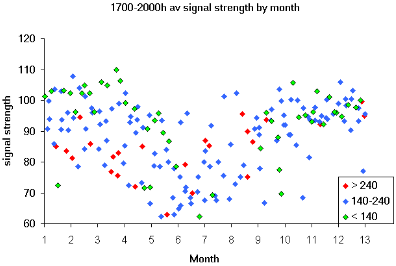
Solar Flares

The study of solar flares is driven by both practical as well as scientific reasons. Flares are explosive eruptions of energy on the surface of the sun. These releases are the most powerful form of solar activity and occasionally have severe impact on terresterial communications and power distribution. Tight magnetic fields associated with active reagions on the sun form sunspots. These magnetic fields become twisted and kinked, storing tremendous amounts of energy. The process that causes the flare energy release is not well understood, and no predictive model exists which allows scientists to know in advance when or where a flare will erupt.

The energy released in a flare occures over the full spectrum of wavelengths from the radio to visible, to ultraviolet and x-ray. By far the major release of energy is in the shorter wavelength ultraviolet and x-ray regions. Ultraviolet energy radiates away from the sun at the speed of light and, upon impacting the earth's ionosphere 8 minuts later, rapidly ionizes all levels disrupting communication. Charged particles released in the outburst take longer, arriving about 1 to 4 days after a major flare. They interact with the earth's magnetic field causing further communications disruptions and auroral displays.

Fortunately, flares last only a short time, up to several hours in their extended, or "main" phase after the initial burst. Given their terrestial effects and short duration, flares have long been a welcome challenge to amateurs observing at both visible and



signal strength versus season

This chart, already presented in section 3.2, clearly shows that the summer season does not provide the same signal strength that can be found in winter. In general summer openings have low signal strength and greater variation from day to day. Overall they are less dependable. The chart distunguishes data collected under conditions of different levels of solar flux, (low flux in green to high flux in red). Curiously, there is a clear association between the strongest signals and the lowest levels of solar flux.

Signal Strength by Season

After spending some four years collecting and analysing propagation data, it is reasonable to have a few observations concerning the subject. I have often read general statements concerning propagation versus time of year and solar cycle, so how did this study compare? Keep in mind that the entire data set is from a single circuit, Ft. Collins, Colorado to Houston, Texas, and that it is for a single frequency, 15.000 MHz. While it cannot be generalized to all HF radio, it provides a good test under semi-controled conditions. Another assumption that is implicit in all this data is that the transmitted power remained constant over the whole period. I will make that assumption while noting that I did not ever confirm it to be true.

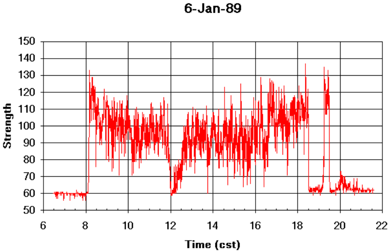
The following charts addresses the question of signal strength and opening hours versus season. Color coding provides an indication of the variation due to solar flux, but this will be explored more in the next section.

radio wavelengths. Visible-light observers generally monitor the sun in Hydrogen-alpha light where the flares shine brightest. Radio observation has traditionally utilized the very low frequency band. According to Mr. Hudak, (Sky and Telescope, 1984) this method requires a radio-quiet observing site, something simply not available to most amateurs today. This report describes observations using his method of shortwave fadeout to detect flares. In addition, the data gathered reveal several other interesting phenomona which I describe as well.

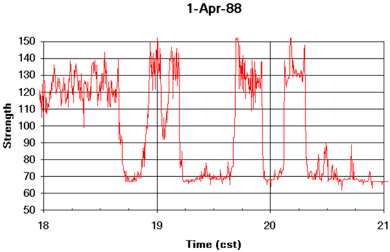
Earth's Ionosphere

The density and composition of the earth's atmosphere changes with height above the surface. From the sun, solar ultraviolet radiation impacts the upper atmosphere, ionizing the atoms there in the process of being absorbed. As the density of the atmosphere falls to very low levels the time it takes for ionized electrons and their atomic nuclei to recombine becomes sufficiently long to form a persistant ionized zone. This zone of ionized particles is called the earth's ionosphere. Due to the chemistry of the atmosphere, density variations, and varying energy levels in the ionizing ultraviolet radiation, the ionosphere forms distinct zones or layers which have been given the rather unimaginitive names of D, E, F1 and F2 with increasing height above the earth.

With the complex interplay of the different factors involved, the ionosphere varies considerable with time. Regular variations form from the diurnal rotation of the earth bringing differents parts of the atmosphere under the radiation effects of the sun, and from seasonal changes, and from the regular change in solar energy associated with the sunspot cycle. Other more random variations result from interactions of the earth's magnetic field with the charged particles in the ionsphere, and from disturbances to the magnetic field by solar activity. Its behavoir also varies by latitude, with polar, mid-latitude, and low-latitude regions all behaving in characteristic ways.



06jan89
Major flare at 1805UT, (1205 CST). Also note the evening signal dropout and return.

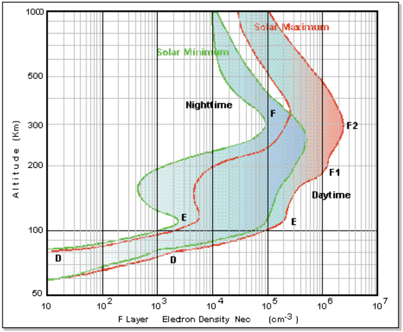


record for 01 April, 1988, detail

The above view focuses in on 18 to 21 CST showing more detail in the features. They clearly represent moments where the ionoshpere electron density is passing repeatedly through the critical density for propagation. These features show a sinusoidal variation in electron density with a period between 25 and 30 minutes, (from drop to drop). I interpret the variations as density waves propagating in the ionosphere. A test of this would require one or preferable two other beakons being monitored at a close frequency to see whether the same features appear offset in time. Note also on the first chart that there are two signal loss periods between 9 and 11 CST as well, more evidence of unsettled conditions in the F layer that day.

Similar features appear on other records already presented in this article such as 06 January, 1989.

The early study of the ionosphere involved measuring its density variations and electrical properties. Most work was done in conjunction with radio studies and radio waves remain the primary way to probe its structure. Studies focus on its variability and the nature and causes of disturbances. In the process much has been learned about the solar-terrestial connection. With a communications receiver and an inquiring mind, anyone can reach above the sky and touch the near-space environment.



Daytime to nighttime electron concentrations which constitute the midlatitude Ionosphere. Graph with variation between solar minimum and solar maximum curves. (from Tascione, 1988)

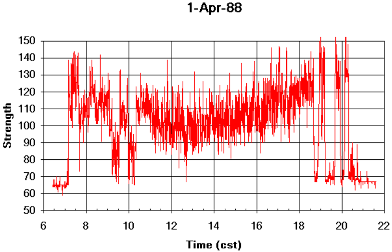
Radio Wave Propagation

Because the different levels in the ionosphere are electrically conducting, they interact with electromagnetic radio waves bending them in much the same manner that glass or water bends light. The refractive index of a layer in the ionosphere depends on its electron density and has an effect on waves according to their wavelength. Levels with higher electron densities (higher altitudes where recombination is slower) have lower refractive indices. As a wave passes up from below into such layers they get refracted, or bent back down towards the lower electron density layers. The amount of bending depends on the incident angle and the frequency of the wave. Higher frequencies are less affected. Finally, in passing through conducting layers, energy in the wave vibrates the electrons thus transfering some energy into the layer and being partially absorbed in the process.

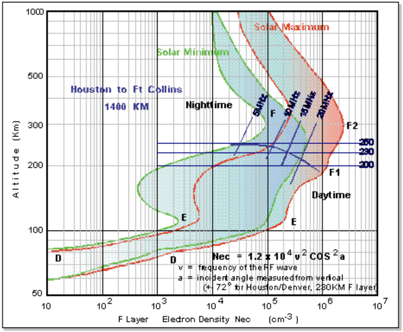
For much of the radio spectrum the frequencies are simply too high to be refracted back to the earth given the range electron densities which exist and propagation angles required. This is not true in the HF band of frequencies between a few hundred hertz and about 30 megahertz. There a delicate balance exists where, depending on the natural variations in density of the ionsphere, radio waves may be either refracted back to the earth or passed out into space. For the case of vertical incidence and a given ionospheric density there is a critical frequency above which no reflection will be received. Inversly, you can say that for a given frequency there is a "critical"

Density Waves

On a number of records I found interesting features which were not easily explainable. The record below for 01 April, 1988 shows a series of falls and jumps in signal strength between 18 and 21 CST. Similar features can occur on the morning side as well as the evening side, but seldomly near midday.



record for 01 April, 1988



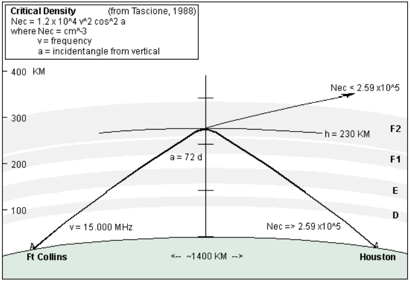
Electron density versus altitude as per section 2.2. This chart shows lines of criticality for different transmission frequencies on the Houston - Ft. Collins circuit. As the ionosphere ionizes in the morning or recombines in the evening, the density passes critical in the altitude range of 220 to 250 Km. Note that the F-Layer density never falls below critical for 5MHz, but does affect 10 through 20MHz. The November 1988 test was somewhere between solar minimum and maximum. (from Tascione, 1988)

density needed to return reflections. The relationship between the three parameters (Nec = electron density (cm^-3), v = frequency, and a = incident angle measured from vertical) is given by the following expression, (Tascione, 1988):

Nec = 1.2 x 10^4 v^2 cos^2 a

It should be noted that this expression is for the critical situation only. Where the angle is approximately known based on the circuit geometry and the frequency is known precisely, the density calculated will be the lowest density that, below which, no return (reception) will be possible. A radio wave of a given frequency therefor will continue to travel upwards into an ionsphere layer until it reaches the elevation where the density rises to the "critical" level (Nec) and the wave will be turned back to earth.

For most HF radio communication the main reflecting layer is the F layer situated between 200 to 300 KM altitude. The D and E layers are generally too weakly ionized to be of much importance except during the day over shorter distances. Ionization, although falling, persists through much of the night in the F layer as well. Intense ionization of the F layer causes it to warm and split into a second, higher, level during the day, returning to a single layer at night. There are also seasonal variations on the theme. The E layer, about 100-150 KM up, can persist into the night to some extant and in addition there are occasional "clouds" or masses of E level ionization which can drift causing sporadic radio openings when the right geometries exist. The D layer at about 80 to 90 KM is only useful for propogation during the day recombining quickly after sunset. In the negative sense, it absorbs signals passing through it to or from the F layer.

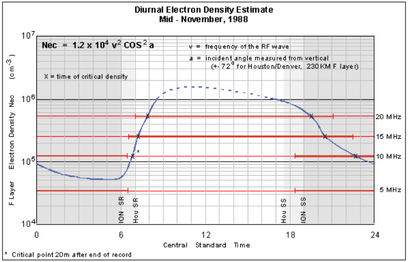


Graphical presentation of the relationships between the frequency, ionosphere electron density, and propagation incident angle measured from vertical are given in the expression:
Nec = 1.2 x 10^4 v^2 cos^2 a ...(from Tascione, 1988)

For the given circuit parameters:
v = 15.000 MHz
a = 72 d ...(h = 230 KM)

Then the Critical ionosphere density from the formula is
Nec = 2.59 x 10^5 cm^-3.

For densities lower than that value the signal will pass out of the ionosphere into space. For densities above that value the signal will continue to propogate, but with increasing absorbtion on this circuit.



curve of the diurnal change in ionosphere density

The plot shows that the ionosphere goes through a morning period of fairly rapid ionization peaking perhaps around 10am CST (1600UT). Then the process stops and reverses, going through a slower recombination period in the evening and into the night until near ionosphere sunrise the process again reverses and repeats the rapid ionization. This plot in fact compares quite well to published mid-lattitude ionosonde data such as Olivier and others, 1988. It is even possible, where circumstances permit, to see more rapid ionospheric variations as described in the following section. Next: Density waves..

Supplemental Records

Poor Man's Ionosonde

My reading suggested a solution to the ionization problem described in the previous section. This solution dispenced with the notion that the jump in signal strength was caused by some jump in F layer ionization. It can be found in the relationship between the main parameters affecting propagation: Nec - electron density (cm^-3), v - frequency, and a - incident angle measured from vertical. The expression is as follows:

Nec = 1.2 x 10^4 v^2 cos^2 a

If this expression were true, then it was simple to devise a test to confirm it. If the ionization truly proceeded at a much slower rate, it should affect different radio frequencies at different times, in a regular manner. The beacon, WWV, transmits as previously stated at several frequencies, 2.5, 5.0, 10.0, 15.0, and 20.0 MHz. With this beacon, I could maintain the same basic circuit geometry. In mid November, 1988 I conducted a series of recordings at 5.0, 10.0, 15.0, and 20.0 MHz which, when plugged into the above expression gave me discreet electron densities.

F Elev	Angle a	Frequency			
		5 MHz	10 MHz	15 MHz	20 MHz
250	71	3.34+E4			
240	71		1.24+E5		
230	72			2.59+E5	
220	73				4.26+E5

The signal jump would give me the exact time that the F layer passed the calculated critical density. The following chart is my curve of the diurnal change in density, a sort of "Poor-man's" ionosonde.

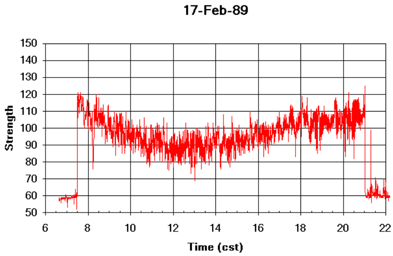
Daily Record

My study utilizes the WWV time standards beacon at Ft. Collins, Colorado. That transmitter emits at 2.500, 5.000, 10.000, 15.000, and 20.000 MHz. I monitor the 15 MHz signal which provides a strong signal at my station in Houston, Texas. 10MHz openings last longer into the night but would be useless for flare detecting at that time as the sun has set! I use a Yaesu FRG7700 receiver which is not terribly expensive and extremely stable once it has warmed up.

The interface between the receiver and computer uses a voltage to ohms converter which proved very acceptable but, being a resistance device, was suseptable to temperature induced drift. In Houston that was generally only a problem in the spring or fall where large changes in day to day temperature are typical in the Gulf of Mexico's battle against the continent for dominance of the climate of the region. I made occasional calabrations as necessary to the interface and kept the base level within a narrow range. The following list gives the correspondence between the digital signal strength readings presented on the charts and the radio's S-meter output:

S-meter	Computer
S0	60
S3	79
S5	90
S7	101
S9	112
+10db	132
+20db	157

record of 17 feb, 1989

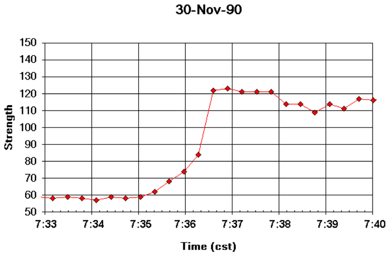


The above record shows a fairly "classic" responce for a 15 hour run. In all my runs regardless of duration I collected 3200 samples only. That was an expedient to simplify the programming, keep the record within the memory limits of a Commodore 64, and have a simple multiple of the high-resolution screen's 320 pixel width. For a nominal 15 hour run that translates to about one record each 17 seconds which is more than sufficient for the project. In addition, I actually sampled continuously between saves and read the average of many readings for each saved record. Even then, there is considerable fading and short second to minute scale noise which accounts for the "grassy" surface.

Note also two important features of the record, the very sharp discontinuities at the beginning and end of the "opening", and the general sag or lower strength of the signal at mid-day. More on the discontinuities later, the sag itself is due to increased absorbtion by the lower D layer at it reached full ionization near midday and dissipates by the afternoon. There

electron density, radio frequency, and incident angle which I explained in section 2.3. The answer to the problem presented itself quite simply: My circuit, Ft. Collins to Houston had a fairly fixed geometry (if you assume a constant 230 Km height for the refracting region, close but clearly not constant), and a single radio frequency of 15 MHz. The only variable then is the F layer density which goes critical at about 2.6 x 10^5 cm^-3. Below that density there can be no propagation. As the F layer ionizes, quite slowly perhaps, it passes that critical density and causes the sudden jump in strength seen on my records.

Pretty neat.. If you gather data and think about a thing, you are bound to learn something facinating. The above relationship quickly suggested to me the experiment described in the following section.



Record for 30 November 1990, detail

At the time I had the idea that the rise in signal strength in the morning, (and drop in the evening) was associated directly with the ionization of the reflecting F layer. As the layer ionized under the rising sun the signal would pick up. The records though could not be interpreted in that manner. As I thought about it, I realised that there were two problems with my theory: First, I noted the curious fact that sunrise on the F layer, and therefor ionization, took place up to one or two hours prior to the morning jump in signal strength (and vise versa in the evening). If the rise in strength was caused by a rise in ionization, why didnt it occur earlier? Secondly, the duration of the jump, sometimes in just seconds was far too rapid. The volume of refracting space in the ionosphere was simply too large to be illuminated by sunrise and ionize so rapidly.

Thinking about this problem sent me to the textbooks and literature. There I learned about the relationship between the

is an assymetry to the opening as well with a longer period of strong signal in the evening than in the morning. I attribute this to the geometry of the Houston-Ft. Collins curcuit with Ft. Collins being to the west. By the time the F layer ionizes in the morning at a point halfway between Houston and Ft. Collins, the lower D layer is already ionized, conversely, in the evening there is still a couple of good hours remaining for the F layer after the D has dissipated.

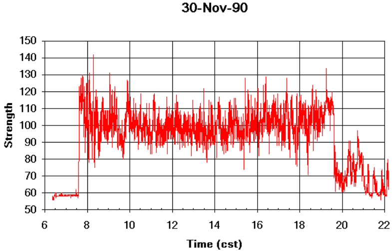
Base level, (S0) on this record is 58, the solar flux that day was quite high at 239 and the geomagnetic field was quiet. The resulting record is pretty close to ideal which is actually quite unusual. In all, the project ran for nearly four years from just after sunspot minimum to past sunspot maximum and resulted in nearly 200 weekly records. The next section provides additional views giving a flavor of the variability possible, and why.

Seasonal Variations

The record presented in the previous section represented a nearly "ideal" winter record. I found that winter openings were generally dependable with a distinct jumps in the morning and drop in the evening, and good strong reception all day. 06 October, 1989 was another good day. It is possible to "map" the data from week to week in order to visualize how the propagation openings change with time. The following chart shows a map of signal strength contoured against time. Local Central Standard Time is on the Y-axis and calendar time on the X-axis. Each day starts at the bottom and moves up, the next day starting again at the bottom next to (to the right of) the prior one so the calendar flows to the right. Additionally, the Gray curves running along the upper and lower portions of the map indicate local Houston sunrise and sunset respectively.

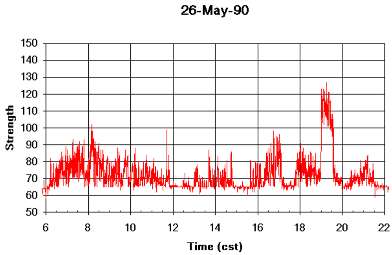
Ionization Problem

Early on in my project I encountered a problem in the interpretation of the data. Most records like the one below for 30 November 1990, showed a very rapid increase in signal strength from near 60 (S0, no reception) to a maximum of 120 or more (S9+, extremely strong).

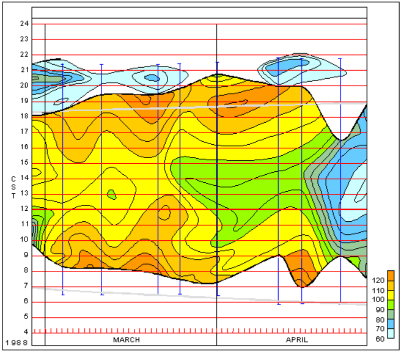


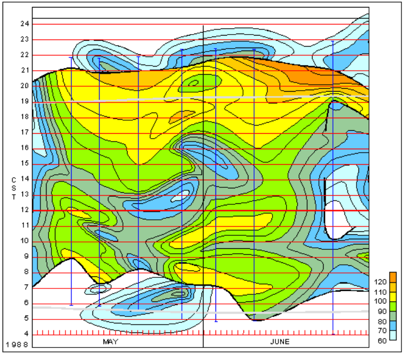
Record for 30 November 1990

The time from nothing to maximum was often under a minute or two, as shown in the detail chart below where in the minute around 7:36 am CST the signal makes its jump. (This also shows some of the tight detail available on the records which looks spikey on the normal 15-hour presentation charts).



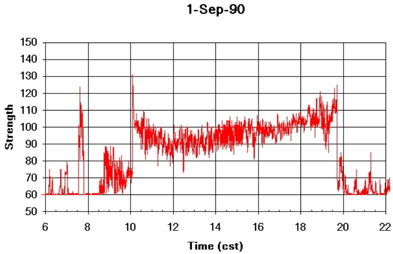
26may90
Major flare and geomagnetic storm, propagation never had much of a chance! Return..





This map shows the period of March and April, 1988. In it you see the srong morning and evening signal (in browns) and the midday sag in yellow to green. On the right the signal for the record of 22 April becomes poor, (blues). This was an active day with geomagnetic disturbances disrupting the propagation. Also in this map you can see typical evening sporadic low-level propagation after the main opening has ended, especially in early March.

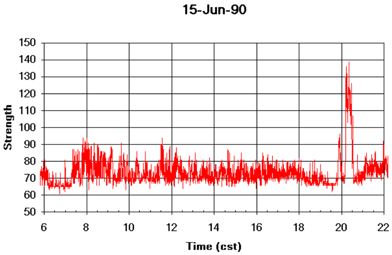
In contrast to the above "winter" view, the following map shows the doldrums of summer. It is for the period of May and June, 1988. I characterize the propagation in summer as generally longer duration, but with lower signal strength and much greater day to day variability. It is not unusual to have a good strong opening for an hour or two in the evening, but



record of 01 September, 1990

This record for 01 September, 1990 indicates that not all geomagnetic activity necessarily destroys propagation. This day with Ap=26 had conditions ranging from quiet to major storm yet the openings remain generally good. Geomagnetic storms in fact can be quite local and do not a priori indicate poor communications. Recall that my recordings only probe a small portion of the ionosphere located about halfway between Ft. Collins, Colorado and Houston, Texas.

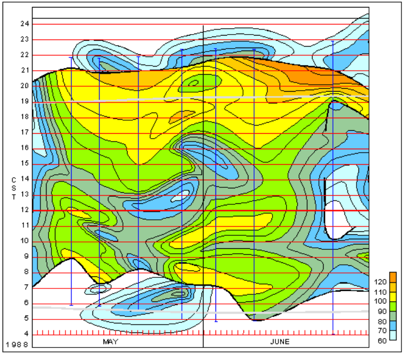
Supplemental Records



record of 15 June, 1990

Another storm ending on 15 June, 1990 in the summer season has in this record nearly wiped out the opening totally. Ap for the record also a high 47. Similarily, the flare and storm on 26 May, 1990 with an Ap=38 had terrible results for communications.

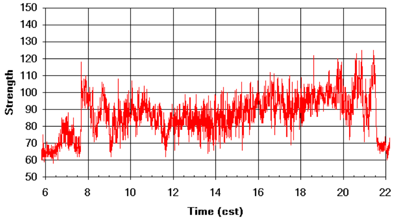
generally the records are choppy and noisy, fading is a far bigger problem.



period of June and July, 1988

On 24 June of this period there occured a major flare at 1609UT (1009CST) which closed the window for several hours.

6-Jul-90



record taken on 06 July, 1990

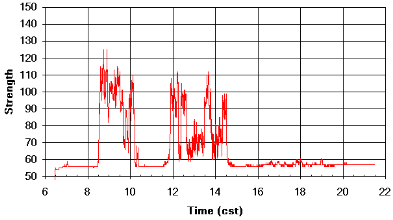
This chart shows a fairly typical (if there is such a thing) "summer" record taken on 06 July, 1990. The day had strong solar flux at 209, and the geomagnetic field was moderately quiet. Still, the signal was weak most of the day with lots of noise and levels only in the S3 - S5 (80 - 90) range. A week later on 13 July the opening made a brief appearance in the morning and then headed south all day. Good day to go fishing.

I have taken averaged hourly signal strengths for all 200 records and put them on a spreadsheet to make further analyses. The following graph shows the average strength for the midday period 1700 - 2000 UT (10am to 1pm CST) averaged together and plotted by month. That is, all february data regardless of year together, all June and so forth. Although some years may be better overall, you can clearly see the seasonal signature with good autumn to spring signal and poor summer reception.

Unsettled to Active Field Response

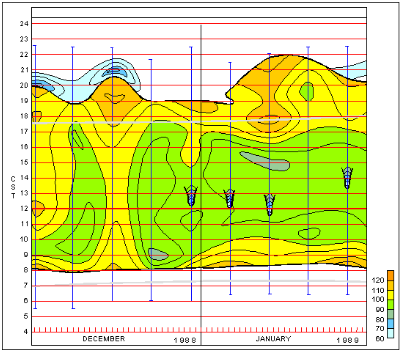
Solar activity can cause cause disruptions of the earth's magnetic field leading to choppy or poor openings. The usual cause of these disruptions is the interaction of charged particles expelled from the sun by flares with the earth's ionosphere. Being charged, they carry magnetic field lines from the sun and distort the local earth field lines. The effects are most pronounced when the sun's magnetic poles are reversed with respect to the earth's. Even when sunspot activity seems low particles can still be ejected through coronal holes and disrupt local conditions.

15-Jan-88



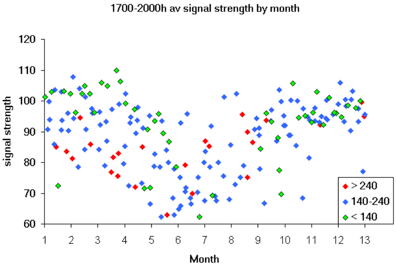
record of 15 January, 1988

This record of 15 January, 1988 was taken on the last day of a major geomagnetic storm. The planetary "Ap" value, (a measure of geomagnetic activity) was a high 45. The openings here are choppy, short lived but still with good signal strengths typical of a winter record.



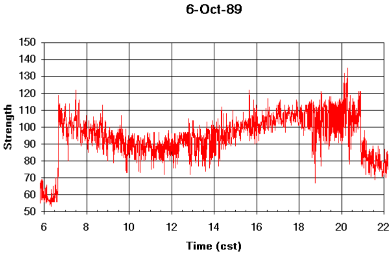
Map for the winter 88/89 which shows the typical short openings and strong signals. Major flares on 30 Dec, 88, 1802 UT (1202 CST); 06 Jan, 90, 1805 UT (1205 CST); 13 Jan, 89, 1734UT (1134 CST); and 27 Jan, 89, 1917UT (1317 CST). Solar flux during the period was understandably high hovering between 154 and 170 in early December, jumping to 180 to 290 through January 89.

average strength for the midday period 1700 - 2000 UT

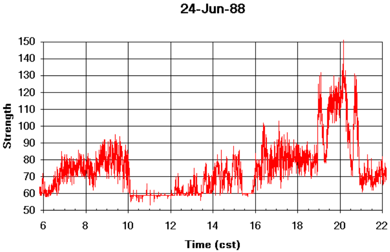


The following section shows the signature of a solar flare since finally, thats what all this is about!

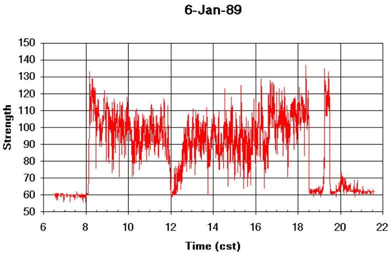
Supplemental:



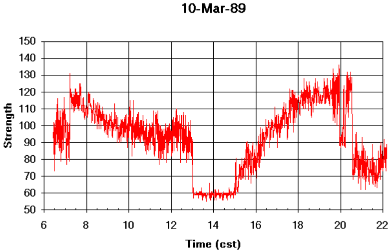
"Ideal" recording with winter responce, good opening, midday sag, and long evening period with strong signal reception.



Major flare at 1609UT (1009 CST).

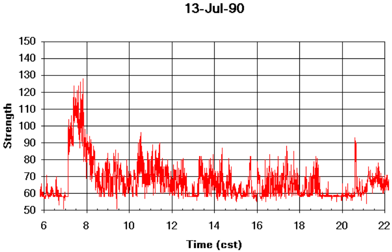


Major flare at 1805UT, (1205 CST). Also note the evening signal dropout and return.



See «http://www.ips.oz.au/background/richard/power_1989.shtmll » for a description of the event and its effects in Quebec. Next: Unsettled to active field response..

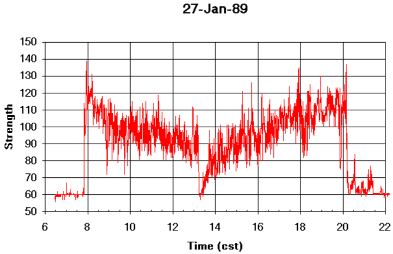
Supplemental Records



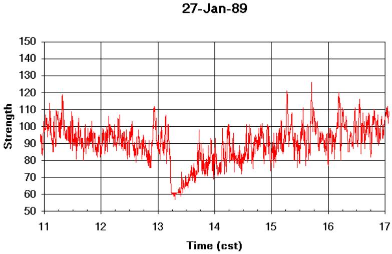
Summertime blues, solar flux good at 153, Ap=10, pretty quiet day but with lousy reception.

Flare Responce

Flares result from the sudden release of tremendous amounts of energy from the sun's surface. Some eight minutes after a flare bursts on the sun, high energy ultraviolet radiation impacts the earth ionizing all the ionosphere layers in the process. While this might be expected to enhance F layer propagation, the D layer density quickly becomes opaque to the signal causing a sudden fadeout. Depending on the duration of the flare, the fadout will last from minutes to hours and then as the ions recombine there follows a logrithmic rise back to normal. The following record of 27 January shows a classic flare signature against a clean winter record.



record of 27 January, 1989



record of 27 January, 1989, detail

The above detail shows more clearly the sudden drop followed be a rise back to the former signal level. This was a pretty typical flare, strong but not truly large. Another example of a typical flare comes from the record of 06 January, 1989. The winter and spring of 1989 was a very active period for flares and I caught them repeatedly on many records as the map for December 89 / January 90 shows. On the 10th of March, 1989 there occured a truly powerful outburst which blocked radio communications for several hours and the geomagnetic storm that followed three days later was so severe that it knocked out the power grid in Quebec, Canada, and caused wonderful auroral displays as far south as florida.
record of 10 March, 1989