SEARCHING FOR PULSES

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ABSTRACT

Searching for pulses has fascinated SARA members for many years. This paper presents an analysis of the problems in finding pulses and some solutions.

BACKGROUND

Many years ago, in 1983, some of our members noted strange pulses in their recordings. Bob Sickels, who was Editor of the Journal of the Society of Amateur Radio Astronomers at the time, named them High Energy Pulses, or HEP for short. Bob tried unsuccessfully to get the attention of the astronomical community. For some time, there was a group of SARA members looking for these pulses.

I recall Bob Sickels built a primitive detector for High Energy Pulses, based on a Commodore 64 computer and an 8-bit A/D converter. The computer read the converter from time to time and printed the results. A flag was added when the computer found a High Energy Pulse. The program was not too fast. It was written in BASIC. I do not think he ever connected the unit to his telescope.

The following year, Gene Greneker wrote two articles on this topic. (See References). He suggested methods for detecting the pulses and determine their extraterrestrial origin. He offered a monetary reward to the first member to make a positive determination.

Several years later, the astronomical community discovered what was labeled "Gamma Bursts". These are very intense pulses detected first in the gamma ray spectrum. Later, it was found that these Gamma Bursts are usually accompanied by bursts of radio frequency radiation.

Looking for these pulses has always captivated the imagination of SARA members. I know of the efforts made by our President, Chuck Forster. He recorded the output of his interferometer for more than a year. Katrina Koski, a high school student, made an analysis of this data trying to correlate the observations with known gamma ray activity.

There is currently a SARA Gamma-Ray Project, headed by Jeff Lichtman, trying to develop interest on the members for this type of observation. Jeff coordinates these efforts and correlates the observations.

DETECTING PULSES

Detecting pulses, other than by chance, is very difficult. The main reason is that the pulses are short. A duration on the order of 2 to 4 seconds is reported as typical. All the procedures used by the amateurs conspire to hide these pulses. Consider three factors, sampling rate, sampling procedure, and integration.

Most amateurs sample their telescopes at not more than one sample every ten to fifteen seconds. The probability that the sample coincides with a pulse is below one in five. If the pulse happens during the idle time of the telescope (what Chuck Forster calls the computation time), no trace of the pulse appears in the record.

With respect to the sampling procedure, most amateurs sample as mentioned above. The computer is idle or making computations for ten seconds. At the end of this time, it takes a sample. It saves the sample and return to its computations. While the computer is computing, it is not looking at the telescope. Worst is the situation with strip chart recorders.

To compensate for the lack of attention of the strip chart recorder or the computer, the telescope has an integrator. The function is to accumulate, or average the signal for a period of time. The output of the integrator represents the average of the signal for the past few seconds. The secondary purpose of the integrator is to smooth out irregularities, pulses among them. Consequently, the integrator reduces the effect of pulses on the output of the telescope.

The equipment we normally use is not designed to detect pulses. Better said, it is designed to eliminate pulses. For a pulse to pass through the integrator it has to have very high amplitude and a substantial duration. The probability of detecting a short pulse that happens just in front of our antenna is quite low. There are more problems for the detection of pulses. They are not regular. They come from any direction of space. Then, the probability of a pulse happening in the beam of our antenna is low, but not zero.

The worst problem for the detection of pulses is the presence of terrestrial pulses of all amplitudes, duration, forms, and directions. Thus, after detecting a pulse, it is necessary to determine if the pulse came from space or from our neighbor lawn mower.

FINDING THE PULSES

It is not too difficult to see a pulse when you analyze a strip chart recording or a computer graph. The problem is that this requires going through masses of data. A better procedure is to let the computer determine when a pulse has occurred and store the pertinent information.

Gene Greneker makes suggestions in his second article [2]. He suggests comparing each measurement with the previous one to see if the signal is increasing. He lets the computer wait for the signal passing a threshold, getting to a maximum, starting its way down until it gets back below the threshold. Timing data is collected during this process.

This procedure can be used only if the signal is very clean. The signals I have seen have noise. It will be necessary to add integration to remove the noise. This integration distorts the pulse.

I have experimented with many different strategies for detecting the pulse automatically. Some of my experiments include averaging a number of past samples to determine a trend that is not affected by the noise. I tried to detect the peak of the signal. I tried to set a constant threshold for the signal. I tried a threshold above the average. I used a multiple of the average as threshold. None of these methods work reliably as the samples are taken. The basic problem is that these computations take too long. The sampling rate becomes so slow that no pulse can be seen.

Another set of experiments were performed by taking a sample, say two minutes at a fast rate. After the sample is taken, the values are analyzed to see if there is a pulse. I have used the same strategies as above.

The main reason why these experiments do not work is that the signal varies very much. There are times where the signal from both telescopes are almost constant for several days. Other times the signal from one or both telescopes vary wildly. A strategy that detects pulses when the signals are calm produces hundreds of hits when the signals are wild.

The best overall results seem to be obtained by sampling the signal for a short period of time. Two minutes seems to give the best results. The signal is analyzed at the end of this period, using a threshold that depends on both, the average of the signal and a value above it. In any case, the pulse is defined by a number of consecutive samples above the threshold.

THE EQUIPMENT

The detection of pulses depends on the equipment in use. This does not mean that you need top of the line equipment. On the contrary. A moderate antenna works better that a high gain one because it covers more of the sky. My setup is formed by two telescopes, one working at 435 Mhz and the other at 1300 Mhz. The antennas point to the same place of space. They both point South with the same elevation. You probably recall the equation Gene Greneker gives in his article [2]. Using the same DM of 100, these frequencies produce a time differential of almost two seconds.

The 435 Mhz receiver is built with ARR [3] modules that provide amplification, conversion and detection. A DC processor permits to remove the steady state value. No integration is used.

The 1300 Mhz receiver is built with PC Electronics equipment [4] for Amateur TV. A VCR is used as amplifier and detector, followed by a similar DC processor.

The two DC processors feed their signals to an XT-type computer which has two A/D converters. These are flash converters, that can be sampled up to 15 million times per second. The precision is only six bits. The precision of the measurements is increased by taking 1024 samples and adding them to a 16-bit value. The measurements are made as simultaneous as possible by taking samples alternatively from the two converters. This process, for both converters, takes on the order of one thirtieth of a second. So, it is possible to have 30 samples per second from each telescope.

ANALYSIS

I have been working on this problem for some time. I have come up with a procedure that increases the possibilities of detecting a pulse, if it happens in the beam of my antenna. I have identified the data that makes the observations valid. My solution is based on several ideas I want to analyze.

I am a firm believer of continuous sampling. This means that instead of computing or waiting for several seconds and sampling one value, I prefer to sample all the time and stop only to save the accumulated value. It has many advantages even in normal work. It is a form of integration inside the computer. It also increases the precision of the measurements. My system has the computer sampling continuously and saving the sum from time to time.

The pulses are of short duration. We should have little or no integration in the hardware of the unit. It was mentioned that the purpose of integration is to smooth out pulses. If your location is noisy, you might need integration, but not too much.

Given the short duration of the pulses, it is necessary to sample very fast. The idea is to catch the pulse. It is also interesting to catch its form. This requires a sampling rate of several samples per second, I use 30 samples per second. This means, sampling continuously for one thirtieth of a second and saving the sum of the values as fast as possible.

At 30 samples per second you accumulate records faster than you can count them. My values have 16 bits each. This means that I accumulate 60 bytes per second, or 3600 bytes per minute. This is over 5 megabytes of data per day from each telescope!

Chuck Forster samples once every ten seconds. He once sent me a record for over a year. It was some four megabytes. This procedure produces that much data in a day. Looking at this data takes forever. Your equipment produces data faster than you can look at it and determine if there is a pulse.

My solution is to teach the computer to recognize pulses. The problem is how. One of my programs accepts values for duration and amplitude. The computer collects data for 2 minutes. Gets the average of the 3600 values. It adds the given amplitude to get the threshold. If it finds the requested number of consecutive values above this threshold, it stores the record. The record is destroyed otherwise. Imagine I call for 30 samples. This requires the signal to be continuously above the threshold for a full second. The records really have 7200 values, each with 16 bits. 3600 values from the 432 Mhz and 3600 from the 1300 Mhz telescopes. The records from each telescope are analyzed separately. If any one suggests a pulse, the full record is saved.

Another program has a similar starting but it uses four times the average as the threshold. Another program starts the same way. After the record is completed, the average and the peak values are found. If the peak is at least four times the average, the record is saved. Many such experiments have been performed.

It is not clear at this moment which strategy gives best results. A constant threshold is defeated when the signal goes up for several hours. The same happens with a constant value above the average. When the average is high, adding the constant value overflows and no comparison can be made. A threshold that is a multiple of the average is defeated when the average is very low, close to zero. Any small variation produces a hit. Using only the peak and the average gives hits with very sharp pulses, typical local noise. All the examples shown on the graphs presented below were obtained with a threshold formed by a constant value above the average. The requirement of having a certain number of consecutive samples above the threshold eliminates sharp noise pulses.

Combining these requirements, I use now a threshold of twice the average plus a constant. This eliminates the problem when the signal goes up for long periods of time. Notice that in this case no pulse can be detected because it overflows the converter. This strategy eliminates the problem of a very low average. A number of consecutive samples should be above the threshold. I try to keep the output of the telescopes quite low, close to zero.

In any way, I get a record only when there is a pulse, whatever the strategy used for detecting it. This procedure permits loosing some pulses that start in one record and end in the other. The computation time is very short. Much shorter than the duration of the pulses. No pulse can happen while the computer is not looking. This method does not assure that the pulse is centered in the record. It is possible to get longer records, say 10 minutes, analyzing them every two minutes. When a pulse is detected, it is centered and the record stored. I have not decided if it is worth.

Finally, when the computer stores the file, it also stores all the data I consider pertinent. My name, address, telephone, geographical coordinates, equipment at each frequency, starting and ending time, position of the Sun, sampling rate. The criteria for identifying the pulse is also included. Notice that many of these values need to be recomputed if the pulse is artificially centered on the record.

In this way, I end up with a few short records of the data that is of interest, with all the required documentation. In order to speed up the operation, I use what is called a RAM disk. This is a part of memory that acts as a disk. All the programs as well as the records are stored practically in memory.

DISPERSION

The purpose of making simultaneous measurements at two frequencies is to determine if the pulses are of extraterrestrial origin. (See Greneker's second article for details). Different frequencies travel at slightly different speeds.

By plotting the signals from the two telescopes on the same graph, it is possible to determine the time differential between the arrival of the pulse at the two frequencies. This tells us if the pulse is terrestrial or extraterrestrial. This also tells us how far from us the pulse originated. It was mentioned that a pulse coming from the vicinity of the center of the Galaxy will have a dispersion of almost two seconds. A pulse in only one frequency is probably terrestrial interference.

RESULTS

The results of the program depend very much on the strategy you use for detecting pulses. That is, the values you enter as duration and amplitude. Since the pulses we search for are normally 2 to 4 seconds long, I use one to two seconds for the duration. This means, 30 to 60 consecutive samples. The value of amplitude added to the average is arbitrary. Using a low value produces hits for every variation in the signal. Using a high value makes the computer ignore valid pulses.

The values to use depend on your equipment and the location of your telescope. The best way is to experiment. Run the telescope in the normal mode, without integration, and observe the trace. This will show you how much the signal from your telescope varies.

The most difficult parameter to determine is the gain of the amplifier. Too much gain produces large variations in the output. Too low gain does not show any variations. The experiment above permits you to adjust the gain until you get satisfactory results. I use a fairly low gain. I expect the pulse to be intense, at least in one frequency.

One very important characteristic of the amateur looking for pulses is patience. You are looking for an uncommon phenomena. You cannot expect it to happen the first time you turn your telescope on and run the program. The best procedure is to let the system run continuously for days at a time. Check the clock of the computer so your time marks are accurate.

With respect to the results I got so far, the only I can say is that I have some records that seem to indicate pulses of extraterrestrial origin. I am still adjusting the gains and the program to improve the results. I think there is much yet to be done.

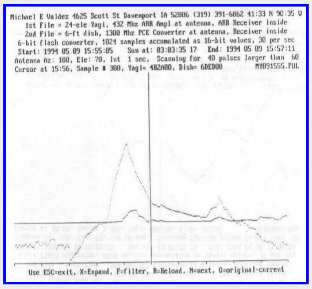
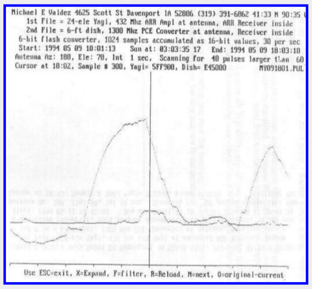
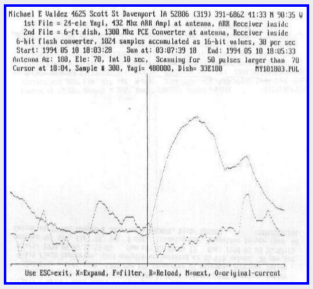
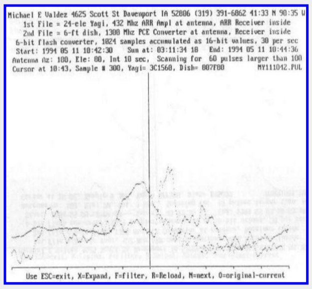
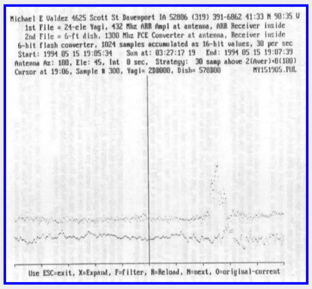
One interesting result that has been observed so far is that there are a number of low energy pulses with the characteristics of extraterrestrial pulses. The term low energy is relative. What I mean is pulses at the level of all the other noise around my observatory. It is not uncommon to see such pulses producing displaced traces for the two frequencies in use. Most pulses attributable to local noise produce simultaneous traces in the two frequencies.

THE GRAPHS

Some preliminary examples are presented on the graphs that accompany this article. These graphs come from a program to analyze the records. Note the header printed at the top of the graph. All that data is included as part of the file. The only exception is the last line with the data at the cursor. You can identify which plot is the Yagi (435 Mhz) and which the Dish (1300 Mhz) by the value measured at the cursor. In all the graphs the cursor is at the center.

All these records were produced by the program that expects consecutive values above the threshold. The legend "Scanning for 60 pulses larger than 100" means that the program stored the record because there were 60 values at least 100 units above the average.

These graphs plot the data by averaging every six values into a dot. The original data has 3600 points for each record in about 120 seconds. Each dot on the graph represents one fifth of a second. Each tic at the bottom scale represents about 12 seconds.

Click on a graph to see it full size.

FURTHER WORK

It was mentioned above that I consider there is much work to be done to improve the results and the reliability of the observations. Note that all the required data is in my records. If I get a pulse, it is properly documented. I do not know if I am getting all the pulses that come my way. This depends on the strategy for identifying a pulse. This is an area where much work must be done.

The reason for publishing these preliminary results is exactly this. It is possible that somebody else might come up with a strategy for identifying the pulses that works better than what I have tried.

Another area where more work needs to be done is in the equipment. I plan to try a vertical antenna. Naturally, I will not know where the pulses come from but it might give a better idea of how many pulses really happen. My equipment is still too noisy. I also have interfering signals. I need to improve in this area.

CONCLUSIONS

Although it is not easy to detect pulses, by using the right equipment you can increase the possibilities of detecting one. It is important to emphasize that you do not need top of the line equipment. The pulses are strong. You do not need to have two frequencies, although it helps. See Greneker's article [2] for the use of a single telescope.

It seems logical to mention that this type of work is quite interesting. The main reason is that a procedure of this type produces results of value. For this to be true you need to record all the necessary documentation. With a little care, you can obtain results that will improve the image of the amateur radio astronomers, in general.

HELP

This work is computer intensive. I will be very happy to help any SARA member who wishes to develop a system similar to mine. I will also be happy to help anybody who has different ideas and wishes to implement them.

In order to customize the programs to your needs, I require detailed information on your hardware. The most important data refers to the connection of the A/D converter to the computer. The type and speed of the converter affect the program. The computer does not need to be very fast. I use an XT-type computer. A fast A/D converter helps. I use what is called a flash converter. It gives only six-bit values but it can be sampled at 15 million samples per second. The computer cannot sample this fast. The use of this converter simplifies very much the hardware and software.

Other values that affect the program are the type of computer you use, the flexibility you wish to have in adjusting the thresholds, the strategy you wish to use to detect the pulses. If you have a modem, I can modify the program as often as you wish and you can read it over the phone.

REFERENCES

[1] Greneker, G.: "The High Energy Pulse: Within the Solar System or Galactic Origin", Journal of the Society of Amateur Radio Astronomers, August 1984, pp 8-18.

[2] Greneker, G.: "Determining the Origin of the High Energy Pulse (HEP) using Automated Dispersion Receiving Techniques", Journal of the Society of Amateur Radio Astronomers, November 1984, pp 4-12.

[3] Advanced Receiver Research ARR, Box 1242, Burlington, CT 06013 (203) 582-9409.

[4] P. C. Electronics, 2522 Paxson Lane, Arcadia, CA 91006- 8537 Tom (W6ORG) and Maryann (WB6YSS) O'Hara (818) 447-4565.

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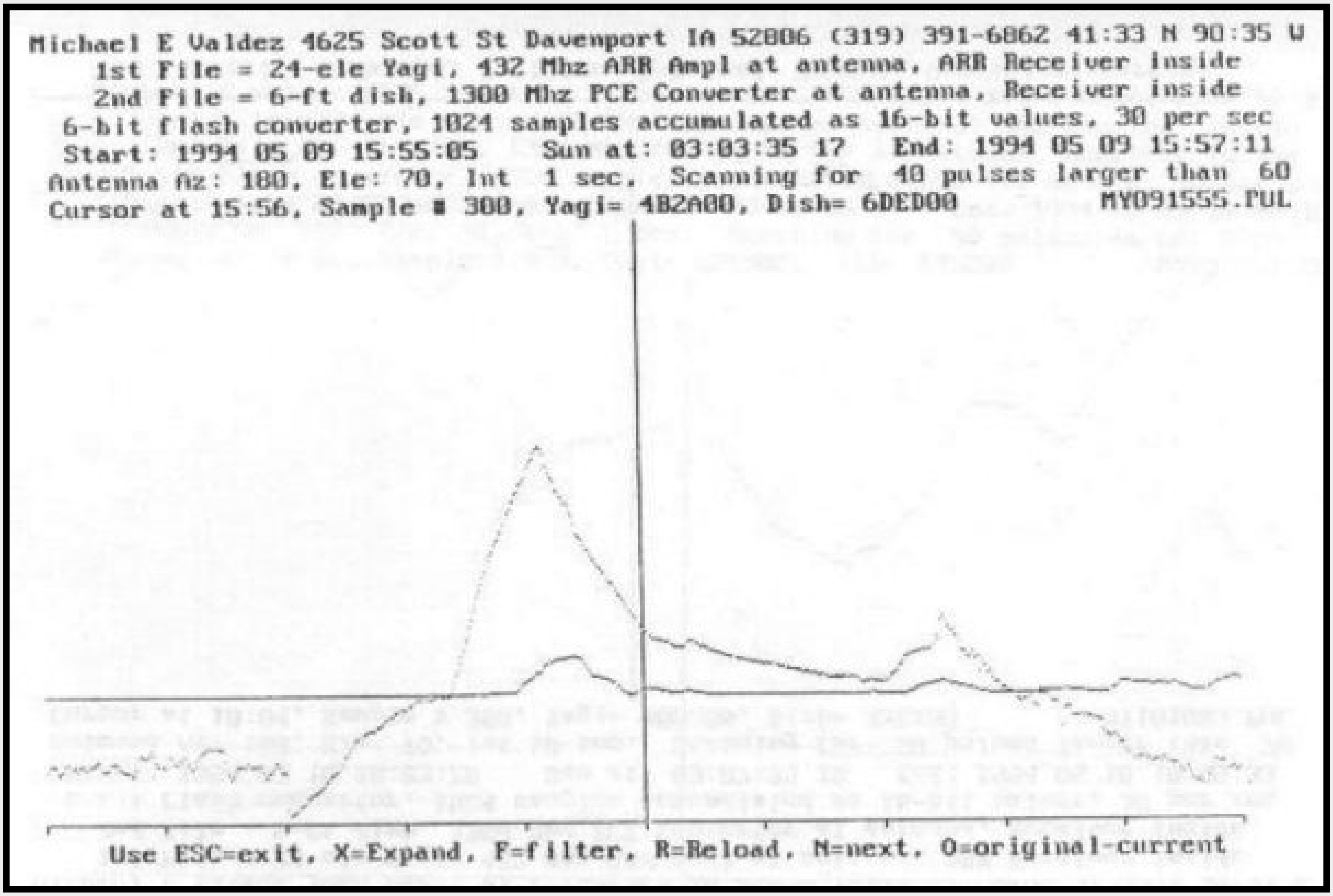

PULSE GRAPH #1
The last line of the heading indicates the value of each plot at the cursor.
The cursor is the vertical line at the center of the graph.
Thus, the dish plot is the top one at the center, and the Yagi is the lower one.
Note the pulse to the right (after) the cursor, which arrived at the same time in both frequencies. This is local interference.

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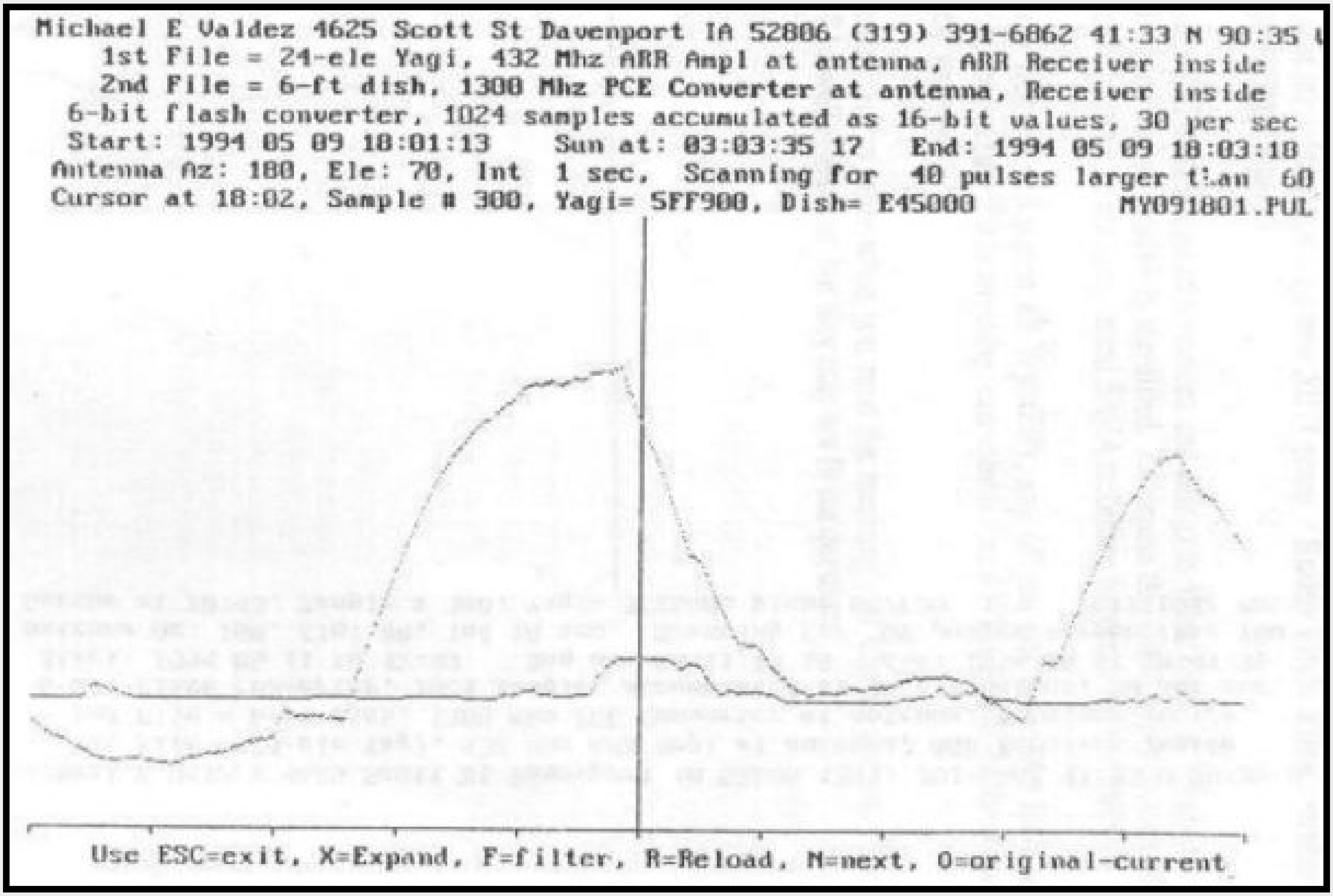

PULSE GRAPH #2

The last line of the heading indicates the value of each plot at the cursor.

The cursor is the vertical line at the center of the graph.

Thus, the dish plot is the top one at the center, and the Yagi is the lower one.

Note the pulse to the right (after) the cursor, which arrived at the same time in both frequencies. This is local interference.

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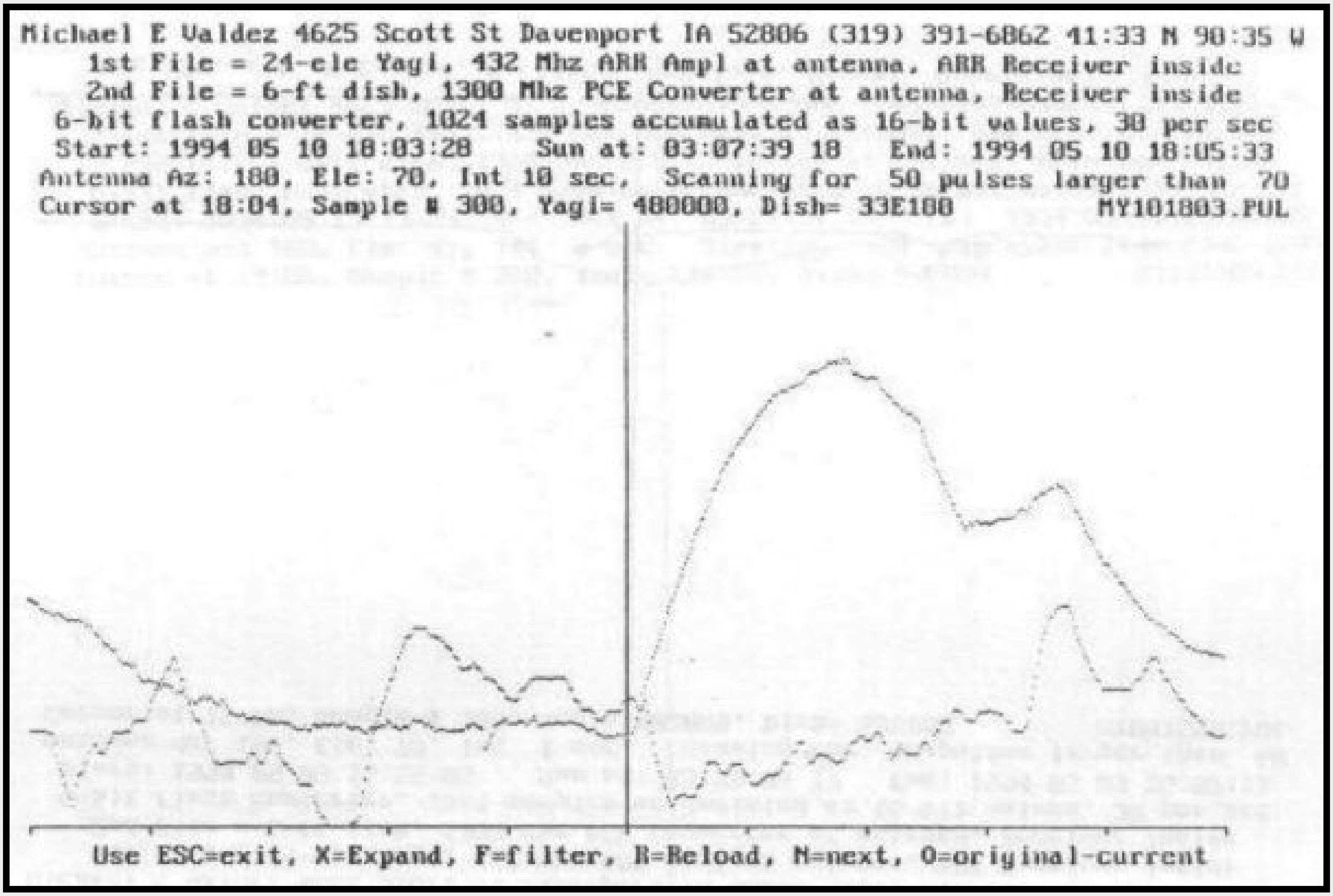

PULSE GRAPH #3

The last line of the heading indicates the value of each plot at the cursor.

The cursor is the vertical line at the center of the graph.

Thus, the dish plot is the bottom one at the center, and the Yagi is the top one.

Note the noise at the lower frequency (Yagi).

There is a very well defined double pulse to the right of the cursor. Note the dispersion.

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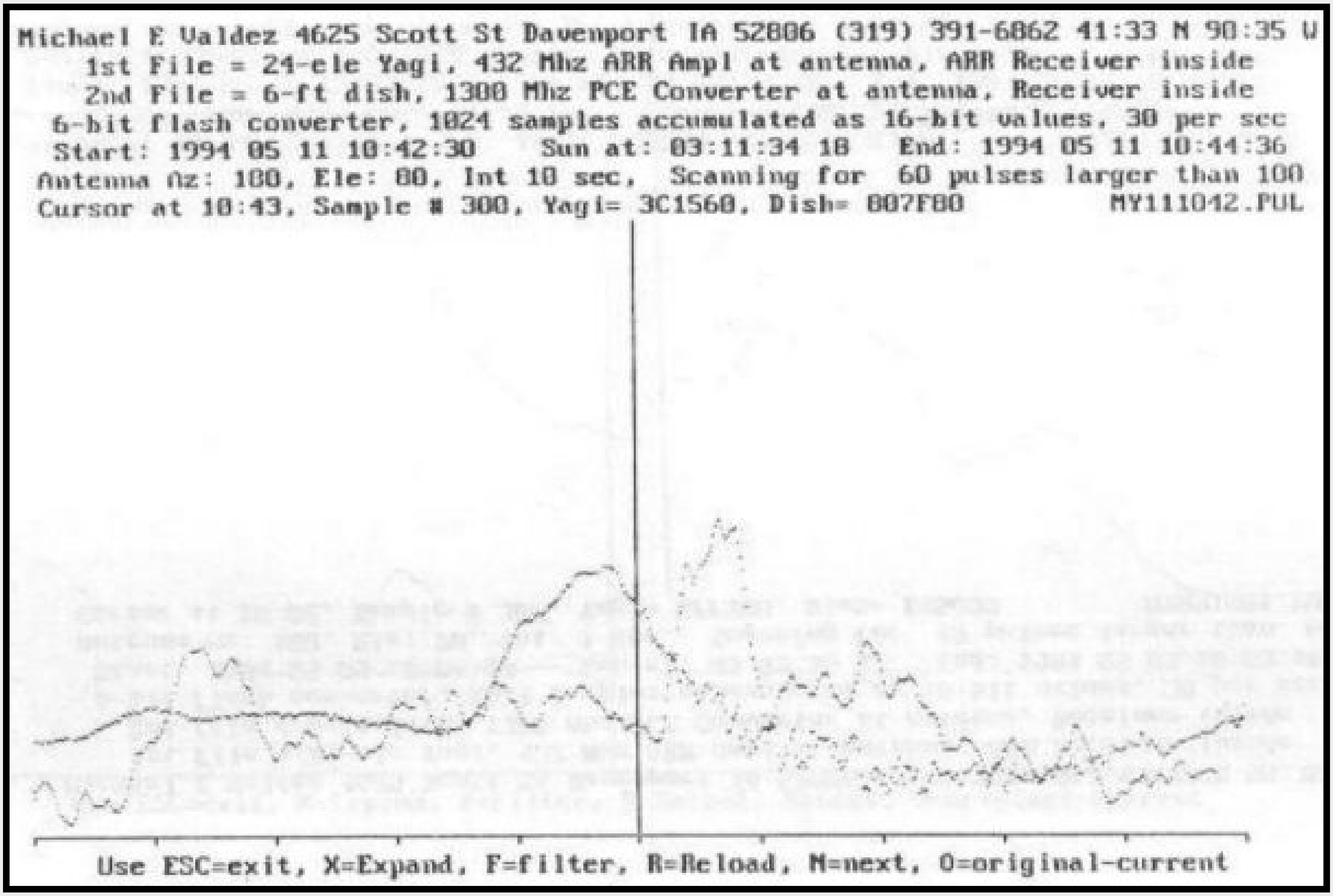

PULSE GRAPH #4

The last line of the heading indicates the value of each plot at the cursor.
The cursor is the vertical line at the center of the graph.
Thus, the dish plot is the top one at the center, and the Yagi is the bottom one.
Another noisy graph.
Note the two well defined pulses to the right of the cursor.
The second one is multiple. It has lower amplitude. It might not be pulses but noise.

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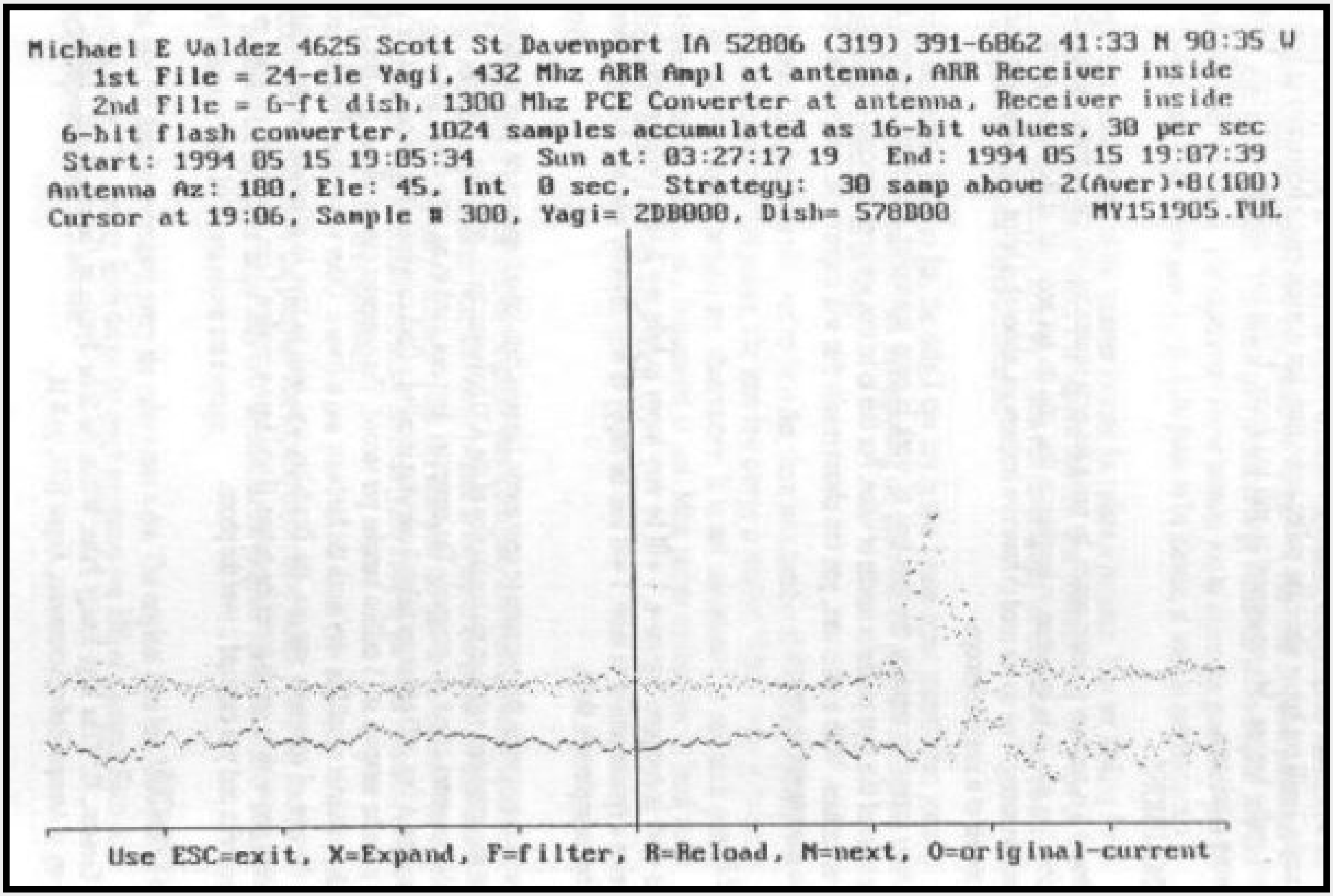

PULSE GRAPH #5

The last line of the heading indicates the value of each plot at the cursor.
The cursor is the vertical line at the center of the graph.
Thus, the dish plot is the top one at the center, and the Yagi is the bottom one.
Nice pulse to the right of the cursor. Note the dispersion.

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