NAAPO (North American AstroPhysical Observatory)

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THE NORTH AMERICAN ASTROPHYSICAL OBSERVATORY - - A NON-PROFIT ORGANIZATION DEDICATED TO EDUCATION AND RESEARCH IN RADIO ASTRONOMY. WITH HEADQUARTERS IN CARE OF:

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RO and NAAPO MILESTONES NOTED

The past two months have seen very interesting and exciting events in the life of the Radio Observatory and the consortium set up to operate the observatory. This issue of NAAPOnews carries articles describing events which singly and in serial occurrence seemed to be routine and of little impact. When played upon a broader canvas and viewed from the context of the bigger history of the Radio Observatory and the consortium we get the feeling that many of our long sought goals are coming into sight.

We record herewith the move of the PDP 11/23 computer and associated peripherals into the focus room following about 4 years of development, construction and programming on the OSU campus. Many man-hours of labor and struggle have gone into this project. Most has been entirely volunteer labor. Much was

learned and we are still on the upswing of the learning curve.

Of course, the move to the focus room means that we can again process real data from beyond the earth. Shortly after the equipment was unloaded it was plugged into the power receptacle and fired up. Casual miracle No. 1 occurred and the system began operating without a pause. Though program bugs will be showing up for months just asking to be corrected, this performance by the hardware speaks eloquently for the magnificent job done by those responsible for building, packing and moving the pieces from the eighth floor of Dreese Labs at OSU 25 miles to the focus room at the Delaware site.

The Radio Observatory staff was pleased to honor THE Grand Old Man of Radio Astronomy, GROTE REBER, during his four day visit to central Ohio as he makes his way back to his southern hemisphere observatory in Tasmania. History has such a facility for slipping unnoticed from our grasp that it is a real thrill to be able to encounter the true pioneer in any field and hear from his own memory the tales of times we will never be able to experience again on our own.

Several other projects will have their completion reported in this issue. A disc-cone antenna for monitoring noise interference at the observatory site has been completed. Donation of a complete IBM PC/XT with hard disc and much usable software has put the MicroGroup back into the production mode. The addition of a donated desktop publishing system software package has meant that the editor must revert to the learning mode and try to get things going in a timely fashion. There always seems to be a lot more to learn just around the corner.

With apologies for delays in publication, your editor asks that you read on, react to what you read and consider the possibility of sending a letter to the editor or comment to the other readers. We will try to keep everyone in touch with what each of you may be thinking about our common concerns with operating world class observatories on small but extremely valuable donations.

WORKING SESSION
5 March 1988

Those Attending: Bolinger, Huck, Dixon, van Horne, Barnhart-L, Backus, Mitchell, Hobe, Barnhart-P, - and visitors from St. Vincent's College, Latrobe, PA - Bro. James Tines, John Coletti, Cheryl McLaughlin, Anita Leiden, Michael Simco, Daniel Klinek, Harry Morrison, (Prof. of Computer Science), Gordon MacIntosh, (Prof. of Physics), Bill Amatucci, Dan Caugherty, Dave Stillman.

ANNOUNCEMENTS:
DIXON announced appointment of TOM van HORNE as Chief Observer at the Radio Observatory. Among his duties will be the coordination of focus room activities and data management from the telescope.

Huck has been asked to be patient about contracts for various services. All is not lost.

Barnhart-L reports the completion of the disc-cone antenna for noise monitoring at the site. All that is needed now is an RF connector which is standard and therefore available. Delivery will be soon.

A brief summary of the GROTE REBER visit the early part of the week was presented. It is very important that we maintain our perspective on history and the origins of the field. We get the feeling that it is important to honor, entertain and be entertained by the great pioneer of radio astronomy. A mere 50 years ago, less than

the age of some of us in this room, REBER was the only person in the world doing radio astronomy. It was a lonely and frustrating time for him as the astronomical world slowly awoke to the value of using another 10 octaves or so of the electromagnetic spectrum to enhance its perception of the universe.

REBER was particularly happy to tour Big Ear where he had lived for a couple years while a visiting investigator at the invitation of JOHN KRAUS. He found the trailer he lived in - now filled with overflow equipment, - and was interested in noting the barber shop across the Olentangy River to which he would walk on occasion is no longer there. He was very grateful to BOB DIXON for a thorough and enlightening briefing on the current operation and status of the radio observatory.

Status Reports:
Observatory Site - The move from Dreese Lab seems to have left the 11/23 in good mechanical condition. It fired right up when plugged in and the task of debugging began right away. It has been impossible to completely test the data collection program without real input to the system. Many bugs are creeping out of the operating codes and mutating into fascinating gremlins. DIXON reports his long distance phone bill is growing by leaps and bounds. This will now become a significant part of the budget for some time to come.

Focus room routines are being worked out for the security check personnel and the observers. Protocols will be posted on electronic mail and in the focus room as they are developed.

Movement of the flat has not yet been achieved. We still have a problem with the upper brake mechanism on two towers. This will become a priority task in the next few weeks.

Headquarters - BARNHART-P reports the 'end of term drag-down' has delayed the last two issues of NAAPOnews. There is no guarantee the situation will change much in the near future. He is frantically seeking to recruit business management and journalism/public relations interns to help ease the managerial and publishing load.

A revitalization of the MicroGroup is under way. We are now well set up with hardware and taskes to do with the hardware. We now need programmers and I/0 specialists to do the tasks.

Dreese Lab - Bolinger reported that little besides the all-sky camera project is going on at Dreese. Most of his time off the camera project is spent at the radio telescope.

Following the business meeting a brief version of the RO road show was presented for the benefit of the visitors. Following an introduction to the history and performance of the observatory DIXON presented a capsule account of the SETI project.

BOLINGER described the all-sky radio camera project and the progress made so far. van HORNE then described his review of the archive SETI data and the way in which he has begun to pull out the Search Strategy 9 events and track down the possible sources.

After the rather intense session of indoctrination they took a tour of the Radio Observatory and Perkins Observatory. DIXON provided an on-the-spot account of the history and meaning of the Flag of Earth. The day in Ohio for the visitors from Pennsylvania ended with a sumptuous meal at the local truck stop.

Next meeting: 19 March 1988 10 am at Big Ear.

SCIENCE 2000 AT OTTERBEIN ON SECOND ROUND

Enclosed with this copy of the newsletter you should receive a flyer announcing the second annual Science 2000 seminar held at Otterbein College. The topic this year is taken from the title of Richard Teresi's book "The Three Pound Universe". The topic is not a cosmological subject, but the human brain and the way we have come to understand some of the functioning and characteristics of this squishy blob of stuff located generally between our ears.

Those readers who are within the short commute of Westerville should consider attending all or part of the seminar. The people involved as presenters are renowned and from all indications quite entertaining lecturers. If you are interested in the luncheon be sure to return your reservation card. Feel free to post this announcement where all can see.

REBER REMEMBERS

Many memories were stimulated by GROTE REBER as we attended receptions, luncheons and an opportunity to transport him back to his hotel on Sunday afternoon. I grew up as an optical astronomer, with only a passing knowledge of GROTE REBER and the birth of radio Astronomy.

I was particularly interested in exploring with him his views on how science is done and how he managed to accomplish so much without the kind of support traditional science has come to expect as a divine right. His answer carried us into a conversation, about archeology, mistakes, the willingness to be wrong, and above all the exercise of curiosity.

At the luncheon honoring him, GROTE mentioned -- quite pointedly -- that at the time he was struggling most mightily against the forces of 'establishment' astronomy in trying to get the message of his discoveries before the scientific community, the only member of the astronomical community interested enough to come look at his equipment after his 1940 ApJ article was a young astronomer from Yerkes Observatory. Following that visit PHIL KEENAN wrote the first theoretical article on the subject of possible sources of radio emission from the interstellar medium.

Not only was it appropriate that Dr. KEENAN was in the audience that day, but I felt a particular twinge of pride that I have the privilege of having been a student of Dr. KEENAN, one of the first astronomers to appreciate what radio astronomy might have to offer to the over-all understanding of the universe. He is indeed as much a pioneer in this respect as was EINSTEIN for providing the first practical application of PLANCK'S almost totally ignored quantum hypothesis.

It is fun to associate with greatness!

PEB

NEW FRIEND OF NAAPO SURFACES

NAAPO headquarters received a call this week from STEVEN DOUGLAS, a High School teacher at St. Ignatius H. S. in Cleveland. He is a resident of Oberlin, Ohio and as a physicist interested in astronomy he became aquainted with JOE SNYDER at Oberlin College. Joe shared a copy of NAAPOnews and STEVEN decided he has some hardware we might make use of on the project. I invited him to the working session this Saturday with promise of tours of all astronomical facilities within one mile of Big Ear.

We look forward to welcoming STEVEN to our meeting.

11/23 MOVES WELL

On 30 January a scarcely awake crew of non-movers met at the loading dock of DREESE LAB intending to transport the PDP 11/23 from the eighth floor of Dreese 25 miles to the focus room at the Radio Observatory. Barnhart-P obtained a truck. The only one with a hydraulic lift gate was 30 feet long. This amounts to a length comparable to the length of the focus room.

The moving crew was as ably headed by CLIFF COLLINS, moving expert for the IRCC at OSU. We were politely informed that AT&T never move computers in the winter. Since we were not supposed to know that we went ahead with the move.

BOLINGER, JANIS, DIXON, FISHER, van HORNE and HUCK heaved and hoed the heavy stuff while BARNHART-P untangled the acid rotted rope he had brought to tie things down. RON came through with several lengths of nylon twine (rope was scarce) which we applied with diligence and trepidation. When all was loaded, the inept truck driver dropped the right rear wheel off the first curb he came to. It was a LONG truck. We at least tested the tie-down technique effectively.

Arrival at the radio Observatory was about 45 minutes ahead of schedule. Unloading was accomplished in reverse order of loading and two tables were moved into the focus room so none of the terminals or disc pacs would have to sit on the floor.

Upon receiving power the circuits all started working like they knew what they were doing. Bugs in the program began to appear. These are being skooshed effectively by DIXON from his living room. It is the understanding of those that know that the telephone stand upon which his modem rests is an IBM 1130 recently saved from a mouse inhabited focus room. May he program in peace.

EDITOR GETS NEW PLAYTHING - - IS IT GOOD?
WHO ARE we KIDDING?

Into each life some rain must fall. Into my hands a desk-top publishing program fell. There are problems with such gifts. First, it is hard to keep your hands off them. Second, to learn how to use it I elected to publish this issue of the NAAPOnews on it HA!

First I had to create a dummy file that does nothing but let me use a [word expunged from the newsletter]. (It is a nice self censoring machine.) Then through the process of very hard knocks, I come to discover that a PC with 1.2 meg of RAM is worthless unless the programs you use know how to access the extra megabyte of RAM. Twice I lost complete pages of text after grinding them slowly out of my deteriorating personal memory banks. I think I have developed three new ways to curse microprocessors.

WORKING SESSION = = 20 FEBRUARY 1988

I was in Washington, D. C. attending a conference of Physics Department Chairs. DIXON presided and I'm sure got a lot done. I can not find the memo he sent to me describing the meeting nor the accomplishments. You may be lucky - PEB

LEWIS SCHOLARSHIP AWARDED AT OTTERBEIN

Some months ago a scholarship was established through NAAPO at Otterbein College to be granted to a promising student(s) majoring in Physics who is willing to commit time and energy to work at the Radio Observatory during the undergraduate years. The selection process for this scholarship is difficult, particularly prior to having the student on campus. There is some hope that the scholarship may, in the future, be useful as a tool to recruit freshmen to the campus.

The first recipient of the Everette G. Lewis Scholarship is Otterbein Freshman RICHARD HOBE. It is not always easy to convince college freshman to make such early commitments, but encouragement to this honor student seems to have paid off. We will now explore the excitement, drama and hard work that goes into scientific research.

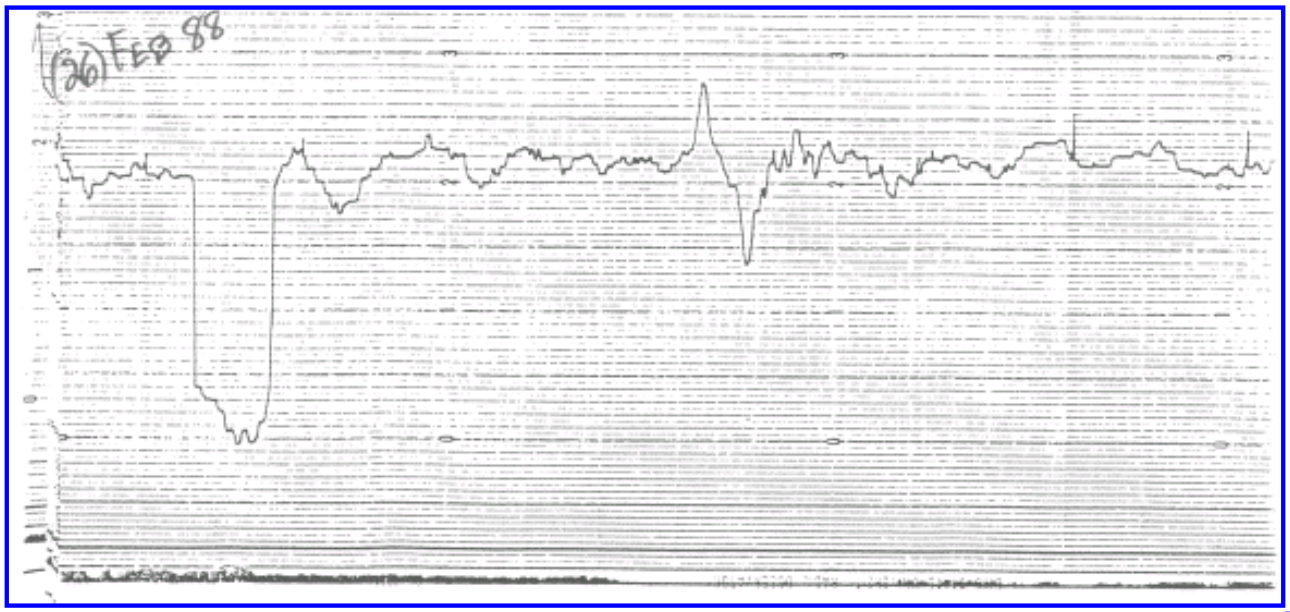
Named to honor the father of 'SKIP' LEWIS, a friend and generous donor to the effort to save Big Ear and NAAPO, the scholarship will provide support for deserving students and a corps of dedicated seekers after answers to leading questions about the universe. We congratulate RICK on his award and wish him the best in the years to come.

COORDINATOR'S CORNER

It has not been an easy few weeks working up to this newsletter. My conscience does not let me rest when there are things I know must be done. I have been a real fish out of water this term teaching a class in introductory functions. It is a fun class to teach and I am able to see much progress on the part of students. It is the non-students that give me the fits. [When ask[ed], "How many students do you have in your class?" I am tempted to answer, "About one in six!"] I have become convinced that we must operate on the spiral learning system. Round and round, over and over -- then they will be able to do something. So much of what we anticipate they have learned before simply is not there.

I am most frustrated ot the slow process of learning about publishing program. It has so many neat things, yet somehow I am going to have to tell it there is 1.2 Mbytes of RAM in there, so quit limiting yourself to 256 K and then dumping all my hard earned information. Till next time.

HERE IS A SAMPLE OUTPUT OF CONTINUUM NEAR 1420 MHz SHOWING A TYPICAL RADIO SOURCE PASSING TWO HORNS.



Click the above image to obtain a larger version of it.

How to calculate FFT's

by
William H. Mook

[Note. Because the text for this article contains so many formulas that don't convert well into HTML (i.e., browser readable format), I have chosen to display below (and in a larger version) an image of this article (which was originally found on page 6 of the newsletter). No OCR (optical character recognition) was done. (Jerry Ehman, webpage editor)]

How to calculate FFT's

by
William H. Mook

A discrete fourier transform (DFT) is a computation which converts a series of sampled values into a series of frequency values. The DFT formula is written as follows:

$$F(u) = \frac{1}{N} * \sum_{x=0}^{N-1} f(x)\ e^{-i2\pi ux/N} \qquad u=0,1,2,\ldots,N-1 \qquad [1]$$

where F(u) is the frequency at point u
N is the total number of samples
$f(x)$ is the sample at point x
$e^{-i2\pi ux/N}$ is the Euler represenation of the sine and cosine functions of a complex number
Σ is the summation sign

The notation for formula [1] can be simplified if you use the definition below in your equations:

$$W_N = e^{-i2\pi/N} \qquad [2]$$

Substituting [2] into [1] you obtain a simplified version of the DFT:

$$F(u) = \sum f(x)\ W^{ux} \qquad u=0,1,2,\ldots,N-1 \qquad [3]$$

where the summation is understood to be over the range of x's from 0 to N-1. Formula [3] gives you N different frequency values F(u) when you plug in N different samples $f(x)$. If you analyze [3] you'll see that for every N values of $f(x)$ you'll need to perform N^2 computations. When N points are converted to N frequencies in this way it is called an N-point transform of the input data.

To make the DFT practical for use in digital filters you must simplify the computation. This was first done in 1965 by use of the *Fast Fourier Transform* (FFT). The FFT decomposes the N-point DFT into sums of smaller and smaller DFT's thus reducing the total number of computations from N^2 computations to:

$$N * \log(N)/\log(2) \qquad [4]$$

computations. So clearly FFTs are superior to DFTs in performing real-time signal processing.

To perform a FFT begin by breaking a complete DFT into even and odd parts as follows:

$$F(u) = \sum_{\text{even } x} f(x)\ W^{ux} + \sum_{\text{odd } x} f(x) W^{ux} \qquad [5]$$

Then rewrite the even and odd x's in terms of a single integer r.

$$F(u) = \sum_{r=0}^{N-1} f(2r) W_N^{2ru} + \sum_{r=0}^{N-1} f(2r+1) W_N^{(2r+1)u} \qquad [6]$$

If you examine this formula you'll see that the r's have replaced the x's and that the range of summation is half that of the previous summation in [3]. You can now simplify equation [6] further by simplifying the W's, as shown below:

$$F(u) = \sum_{r=0}^{(N/2)-1} f(2r)\ (W^2)_N^{ru} + W_N^u * \sum_{r=0}^{(N/2)-1} f(2r+1)(W^2)_N^{ru} \qquad [7]$$

So you have now reduced an N-point DFT into two N/2 point DFTs. You have reduced the total number of computations to one quarter of that needed for the full N-point DFT. By repeating this process you obtain a FFT. Also by looking at equation [7] note that we have doubled the frequencies in each of the half-DFTs left, but have factored out a W from the odd part. A FFT program will end up with individual data points multiplied by W's of various frequencies to obtain a complete transform. Keeping track of which frequencies get multiplied by which data points and which data points get added to each other is what we'll look at next.

Remember the W really means the Euler form of sine and cosine. This means you can write a relationship between W's as follows:

$$W^2 = (e^{-i2\pi/N})^2 = e^{-i2\pi/(N/2)} = W_{N/2} \qquad [8]$$

Plugging equation [8] into equation [7] gives you equation [9]:

$$F(u) = \sum_{0}^{(N/2)-1} f(2r)(W_{N/2})^{ru} + W_N^u * \sum_{0}^{(N/2)-1} f(2r+1)(W_{N/2})^{ru} \qquad [9]$$

So an N point DFT become two N/2 point DFTs , which can be broken into 4 N/4 point DFTs and so on, for any N that is equal to an integer power of two.

For example, if you write only the 'even' portions of an eight point FFT you come up with the following equations:

$F(u) = G(u) + (W_N)^u * H(u)$ two four point FFTs

$G(u) = G_1(u) + (W_{N/2})^u * G_2(u)$ four two point FFTs

$G_1(0) = f(0) + (W_{N/4})^0 * f(4)$ even point of G_1

$G_1(4) = f(0) + (W_{N/4})^4 * f(4)$ odd point of G_1

To maintain a simple program it is convenient to arrange the data points - the $f(x)$'s so that the adding and multiplying operations can be applied successively. This is accomplished by a *bit reversal* process. You write down the x-value or index of point $f(x)$ as a binary number and reverse the order of the bits. This automatically sorts the f's into the proper even and odd sequence to apply a simple add an multiply routine to them to obtain the N-point FFT frequency outputs.

Since you can write higher frequency W's as multiples of lower frequency W's you can organize the W's for computation as well. Also it turns out that the odd W's are the negatives of their paired even W's.

The table below gives all of the operations needed for an eight point FFT, this includes W calculations, point reordering, and additions:

Data	Bin.	Rev.	Reord.	*	+	*	+	*	+	Freq.
$f(0)$	000	000	$f(0)$	1	$f(0)+f(4)$	1	$f(0)+f(2)$	1	$f(0)+f(1)$	F(0)
$f(1)$	001	100	$f(4)$	W 0	$f(0)-f(4)$	1	$f(1)+f(6)$	1	$f(4)+f(5)$	F(1)
$f(2)$	010	010	$f(2)$	1	$f(2)+f(6)$	W 0	$f(0)-f(2)$	1	$f(2)+f(3)$	F(2)
$f(3)$	011	110	$f(6)$	W 0	$f(2)-f(6)$	W 2	$f(1)-f(6)$	1	$f(5)+f(6)$	F(3)
$f(4)$	100	001	$f(1)$	1	$f(1)+f(5)$	1	$f(1)+f(3)$	W 0	$f(0)-f(1)$	F(4)
$f(5)$	101	101	$f(5)$	W 0	$f(1)-f(5)$	1	$f(5)+f(7)$	W 1	$f(4)-f(5)$	F(5)
$f(6)$	110	011	$f(3)$	1	$f(3)+f(7)$	W 0	$f(1)-f(3)$	W 2	$f(2)-f(3)$	F(6)
$f(7)$	111	111	$f(7)$	W 0	$f(3)-f(7)$	W 2	$f(5)-f(7)$	W 3	$f(6)-f(7)$	F(7)

References

1. **Brigham, O, "The Fast Fourier Transform" Prentice Hall, 1974.**

2. **Blahut, R. E, "Fast Algorithms for Digital Processors", Addison Wesley, 1985.**

3. **Rabiner, L. and Gold, B, "Theory and Application of Digital Signal Processors", Prentice Hall, 1975**

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E-mail Webmaster

Designed by Jerry Ehman
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