Repeating Jansky's Experiment

NRAO - Green Bank, 1995-1996

With ringleaders :

Darrel Emerson, Sue Ann Heatherly, Frank Ghigo , Glen Langston,
Ron Maddalena, Dana Balser

Participation and help from

Naomi Bates	David Gordon	Mike Holstine
Harley Carpenter	Don Gordon	Jay Lockman
Carl Chestnut	Ron Gordon	Bob Simmons
Ramon Creager	Wes Grammer	Tom Wilson

and special assistance by
Grote Reber

Jansky Memo Series No.10
June 2008

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Abstract of the presentation at the 188th Meeting of the American Astronomical Society. Madison, Wisconsin, June 1996.

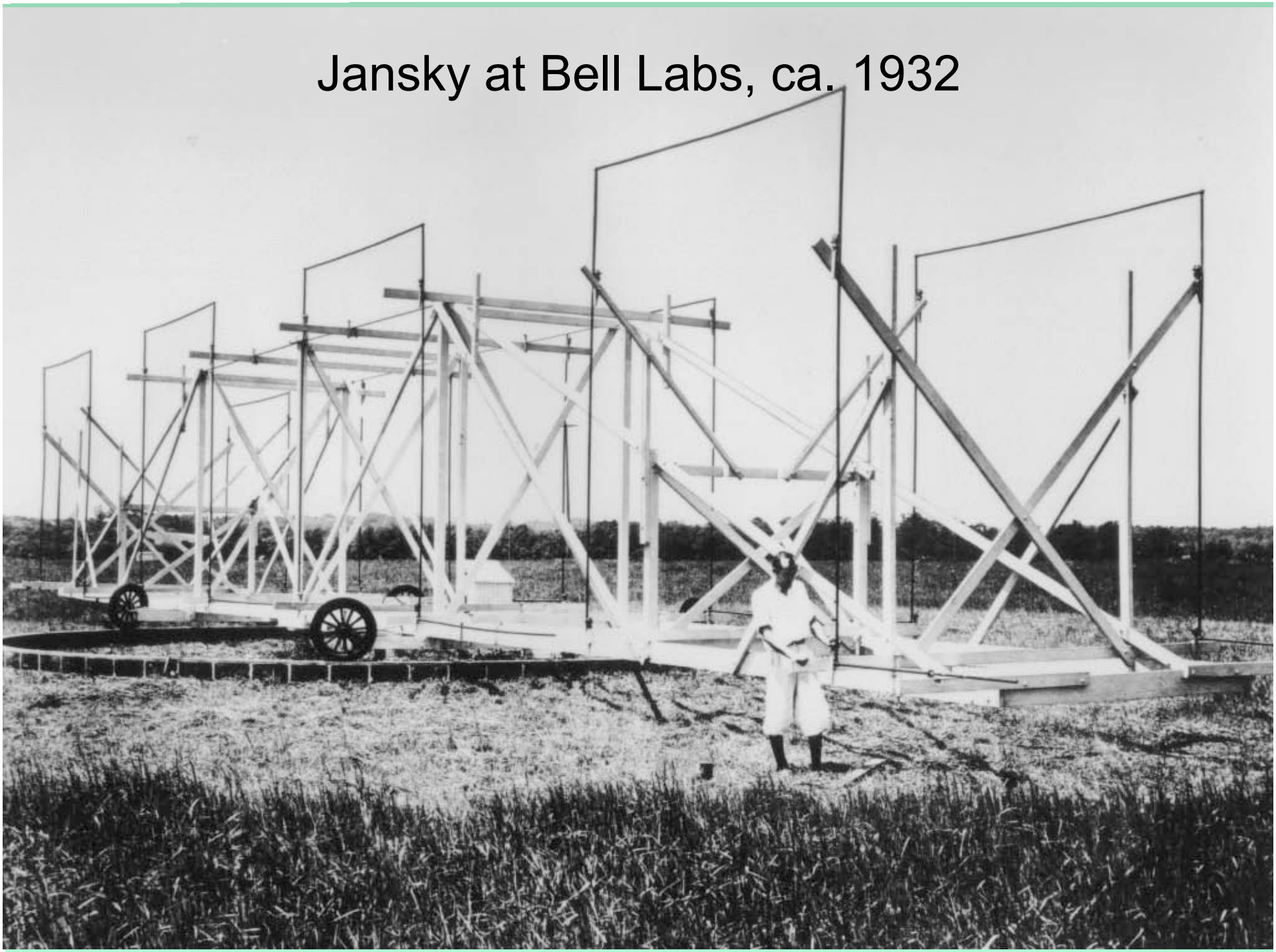
A replica of Karl Jansky's "merry-go-round" antenna at the National Radio Astronomy Observatory* in Green Bank, West Virginia is being refurbished to make it a usable radio telescope. Although receiver and data acquisition systems have been added which are more modern than Jansky's, the antenna itself, including the feed and drive system, are very similar to those used by Jansky.

The antenna is capable of mapping the whole accessible sky every day with a *25* degree beam at *20* MHz. Since very little wide field mapping has been done at this frequency since Jansky's day, it is potentially interesting to look for possible changes that may have happened in the past *60+* years to the flux densities of the brightest sources and the galactic emission.

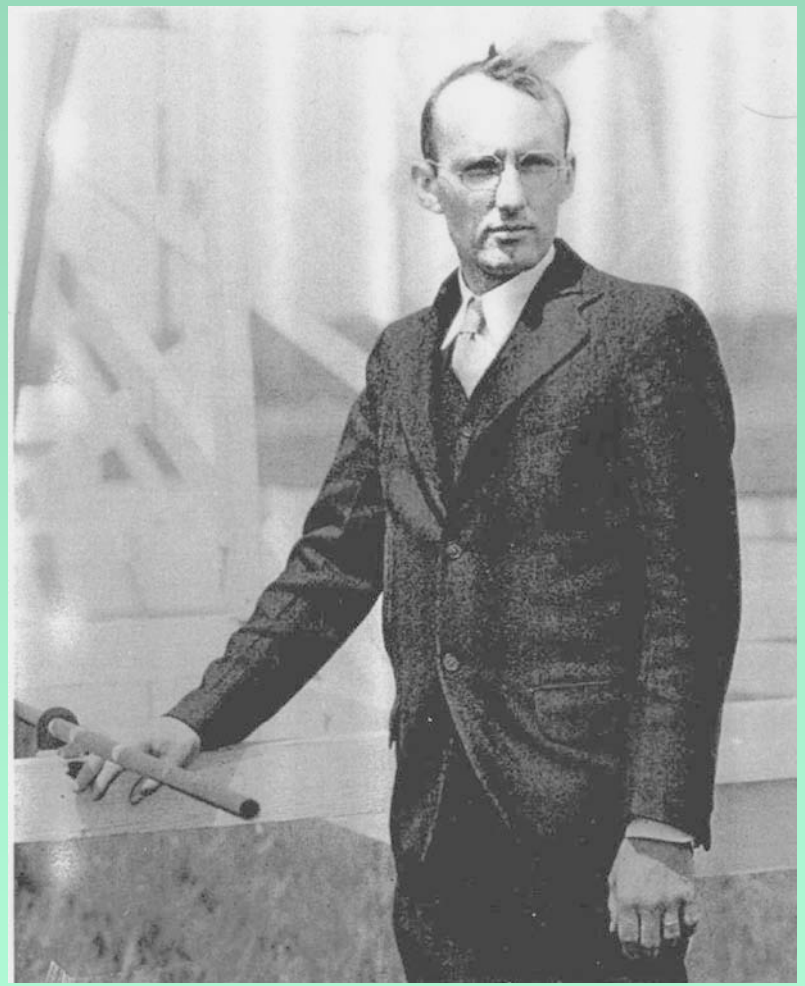
These observations take advantage of the current solar minimum, during which *20* MHz observing is often possible. When the refurbishment project is complete, the antenna may be used on a continuing basis for student projects in the teacher enhancement institutes that NRAO hosts. The progress to date on this project will be summarized, and preliminary observations will be presented.

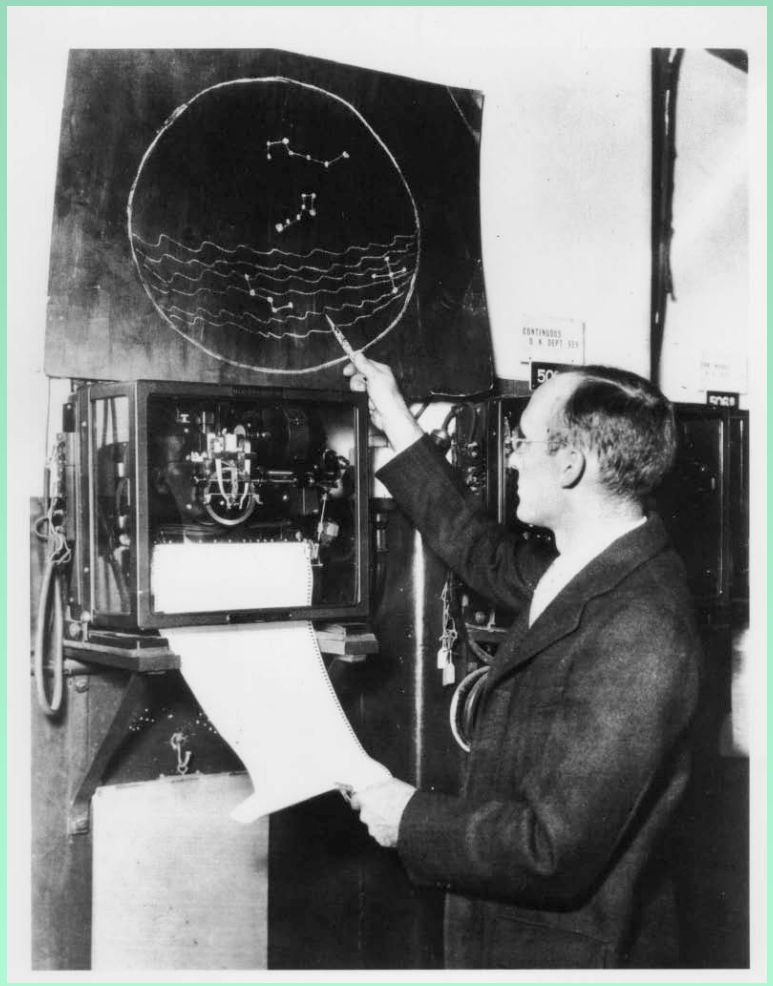
* *The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.*

Jansky at Bell Labs, ca. 1932



Our favorite pictures of Karl





Replicating Jansky's Antenna

It was Grote Reber's idea to build a copy of Jansky's antenna and locate it at the entrance to the National Radio Astronomy Observatory in Green Bank, West Virginia, as an historical monument.

His insistence that it be an accurate replica resulted in a usable antenna with similar properties to the original. The replica was completed in September of 1964.

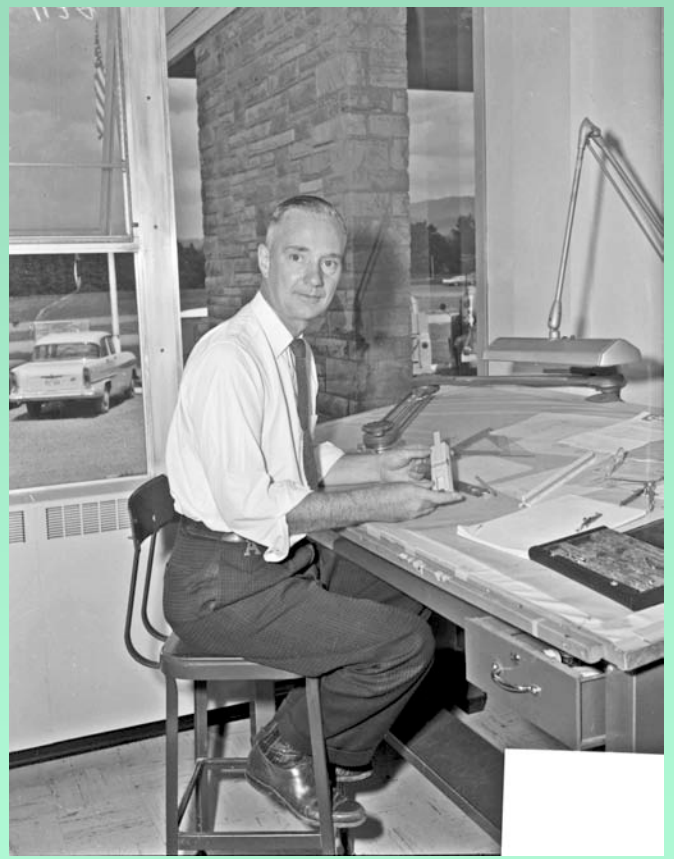
Reber's Account:

From Grote Reber, J.Roy.Astron.Soc.Canada 1988, vol.82, 110.3, p.93,
"A Play Called the Beginning of Radio Astronomy"

Intermission. Many years later, when supervising the reconstruction of my dish (see Act 2) at Green Bank on the left side of the front entrance, it occurred to me that it would be appropriate to have a full-size reproduction of Jansky's merry-go-round on the right side.

I contacted George Southworth, who was a contemporary of Jansky at Holmdel. He brought the idea to the attention of people at Bell Laboratories. They concurred and started things in motion. Peculiarly enough, the same man was still in charge of the carpenter shop that built the original nearly thirty years earlier, and all the drawings were still available.

By 1960, more experience had been gained and the head of the shop wanted to make the reconstruction different and better than the original. After some persuasion, he finally agreed to make it the same as the original.



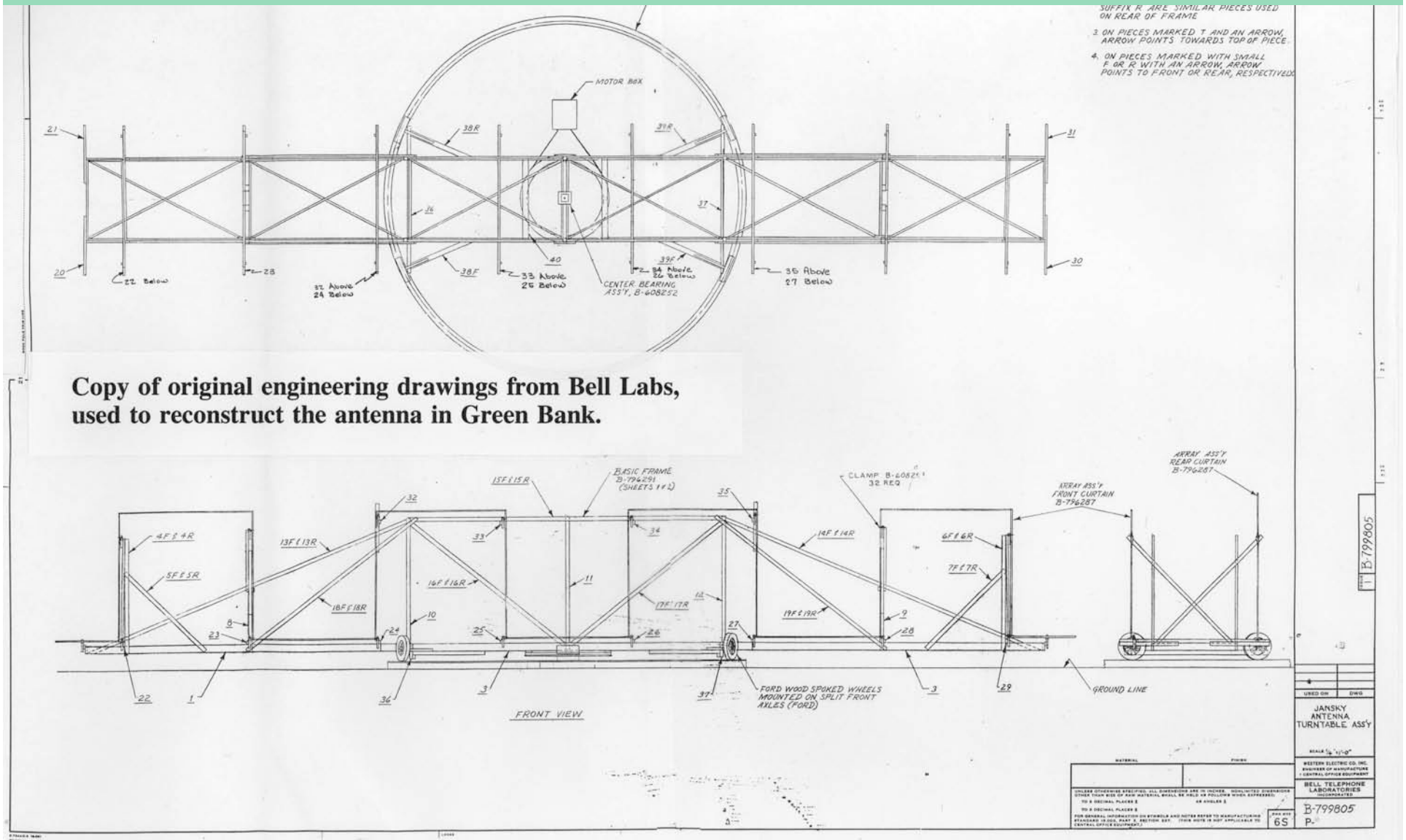
Reber's account, continued

The only piece of the original which could be found was the speed-reducing gear box (now installed at Green Bank).

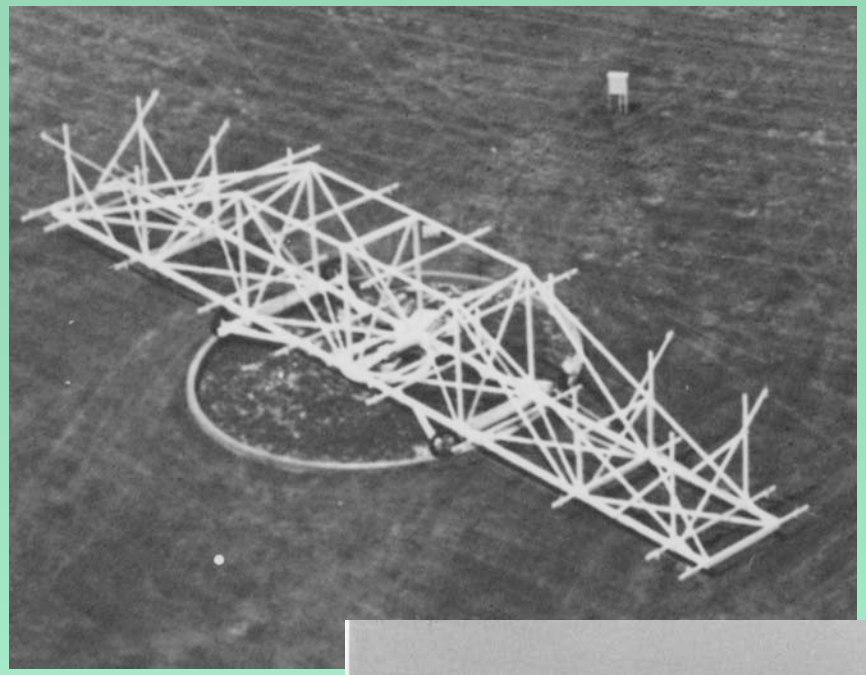
The original merry-go-round was mounted on front wheels and axles of Ford Model-T cars. Such were plentiful in car junkyards during the 1930s. By 1960 they were long gone.
I decided to advertise in the Marlinton, West Virginia. newspaper because some might still be lying around farm barnyards. Much to my surprise, an ample supply was readily available. What to do about tires and tubes? Consultation with a Sears catalogue produced the needed items.

Later I learned from A.C. Beck that the original used hard rubber tires from Model-T trucks. Unfortunately, such went out of style many years ago. Accordingly, the reconstructed merry-go-round has pneumatic instead of solid tires, a relatively minor departure from authenticity.

Copies of the Drawings from Bell Labs, and Reber's Correspondence, are stored in the NRAO Archives in Charlottesville, VA



Copy of original engineering drawings from Bell Labs, used to reconstruct the antenna in Green Bank.



Views of the reconstructed antenna, Green Bank, 1960s

Renovation: 1995-1996

The replica of Jansky's antenna, after 30 years, was deteriorating. Some of the wooden structure was rotting, and some of the brass conductors had broken. At the urging of one of us (D.Emerson), it was decided to put it back into working order.

Due to the solar minimum, now [1995-6] is the best time for several years to come for a clear view of the sky at 20 MHz.

The renovation effort began in the summer of 1995.

Structure

The first job in the renovation was to repair the wooden structure. Some of the wooden beams were replaced and the whole structure was painted.

Broken brass pipes were replaced, and a half-wave copper pipe was added below the lower central part of the antenna to be part of the matching network.

--thanks to Harley Carpenter and the Gordons of the NRAO carpentry and mechanical shops.

Drive chain

The chain drive had not been used for years, and the chain could not be located. It was found that a Harley-Davidson motorcycle chain was the right size.

Three motorcycle chains joined end-to end were used. The same motor and gear system used by Jansky is still being used. A gear tensioning idler was added.

Tires and Wheels

Surprisingly enough, it is still possible to order tires for a model T !

A set of new tires was bought to replaced the old ones.

Replacing some of the broken wooden spokes in the wheels was done by the observatory carpenter, who made new ones on a lathe.

Grote Reber Visits

Grote Reber visited Green Bank in the summers of 1995 and 1996.
Some aspects of that visit were described by Sue Ann Heatherly in
"Travels With Grote", which was published in The Green Bank Tattler of September 1996,
and also reprinted in "But It Was Fun: the first forty years of radio astronomy at Green Bank",
page 500, published by NRAO, 2007.

Grote's contributions to the Jansky antenna refurbishment are described in these excerpts from Heatherly's "Travels with Grote"

> ``In 1995 a bunch of us at NRAO decided it would be fun to re-do Jansky's experiment. Since then, the ``Jansky Fellers,'' as we call ourselves, have been using the antenna more-or-less as is. The antenna was refurbished somewhat so that it could rotate under motor control, but Fellers had to be present to bang the chain back on the gear every few minutes! Even worse, every two rotations, the antenna had to be stopped so that the Fellers could untangle coax cables which got wrapped around the center post. "

Grote advises *

``The Fellers had hoped to interest Grote in making some observations with the antenna this summer. But he took one look at our set-up and said it was a mess! And it was. Under Grote's supervision, a coaxial slip joint was installed which allows the antenna to be rotated while connected to a receiver without tangled coax lines. This was no easy feat since it required drilling through about 18 inches of concrete (special thanks to Harley Carpenter). "

* From "Travels with Grote" by S.A.Heatherly

The Rotating Coaxial Joint

Grote gets results

``Grote Reber instigated reconstruction of the gear box which was absolutely necessary in order to keep the chain on the gears and not tear the motor up. The shop guys and mechanics did a beautiful piece of work there, by the way.

Grote accomplished in 3 weeks what the Jansky Fellers had not thought possible at all. It might have something to do with having the name Grote Reber, but I think his tactics had something to do with it.

If Grote decided something had to be done, then we did it. Now! If he needed a part machined he might just wait in the machine shop till it was ready. Or he would sit on the Jansky Antenna and wait while I (or Carl Chestnut, or Dave Vandevender or H. A. Taylor or whoever) went to do his bidding.

You can't just sneak off to coffee while Grote Reber is sitting in the hot sun waiting for your return."

* From "Travels with Grote" by S.A.Heatherly

The Gearbox and chain drive

Always an experiment to be done *

``For Grote, there was always an experiment waiting to be done, even in idle moments.

While sitting out on the Jansky Antenna waiting for me to come back with a wrench, or in his office waiting for a letter to be typed, Grote would conduct experiments with whatever was at hand.

Example: for several days while out at the Jansky Antenna, Grote counted the cars that went north and south on Route 92. He noticed that more cars went north than south, and thought that was odd. By expanding his observations to other times during the day, Grote was able to report that it ``evened out"!

Another example: Grote made numerous tests on Sue Shears' [the electronics department secretary] calculator. He found out that an average time of 28 seconds elapses between the last entry you make and the time it automatically shuts off."

* From "Travels with Grote" by S.A.Heatherly

The Matching Network

The counterpoise and matching network used by Jansky were missing. We added a half-wave counterpoise 5 inches below the central element, as shown in Jansky's paper.

Jansky used a matching network of two tuned circuits magnetically coupled. Darrell Emerson measured about 30 ohms at the feed point and recommended that we use the much simpler approach of connecting a *50* ohm coax directly to the driven element with the shield to the counterpoise, providing a good, although not perfect, match.

Jansky's Matching Network

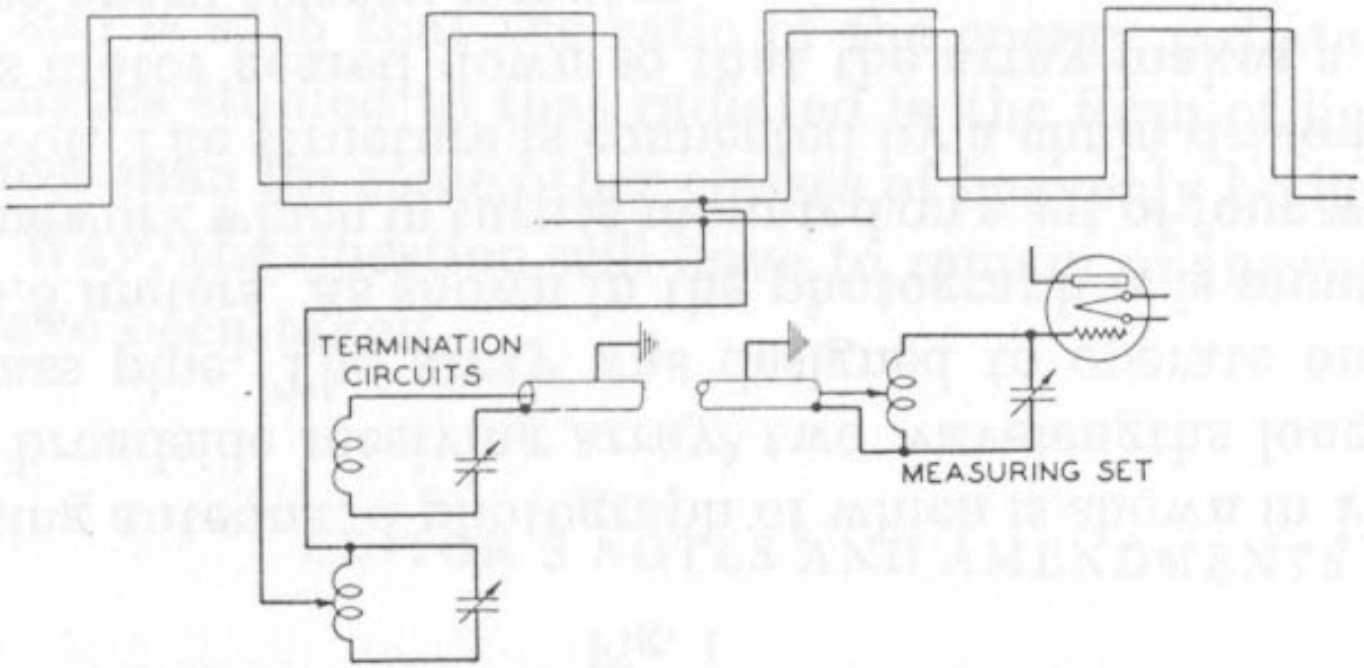
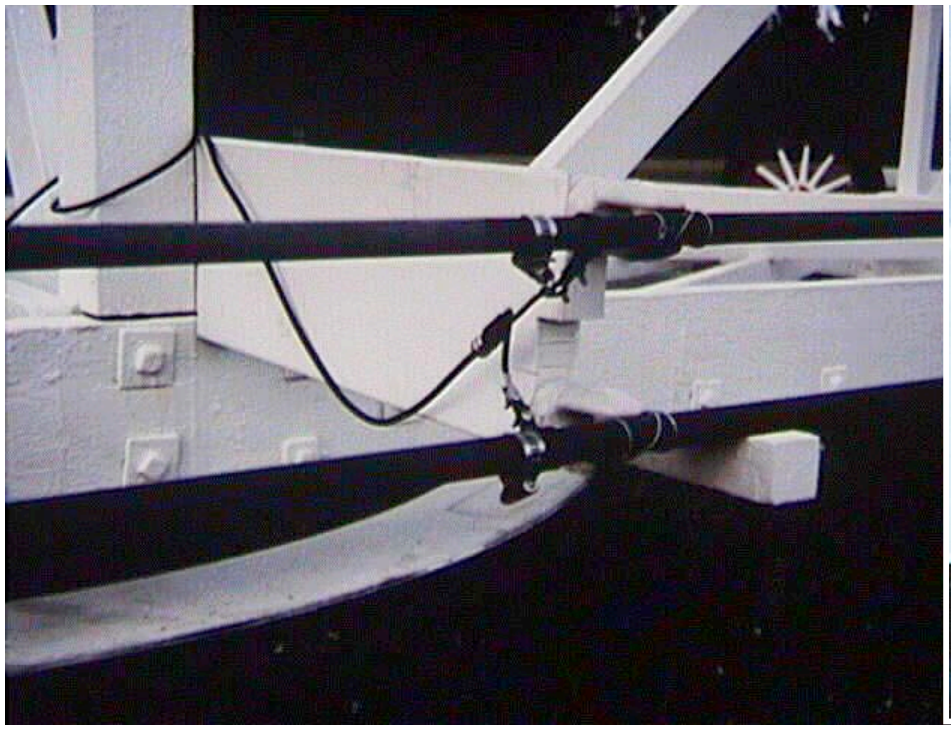


Fig. 4—Schematic diagram of array, termination, and pipe transmission line.

Our simplified matching network



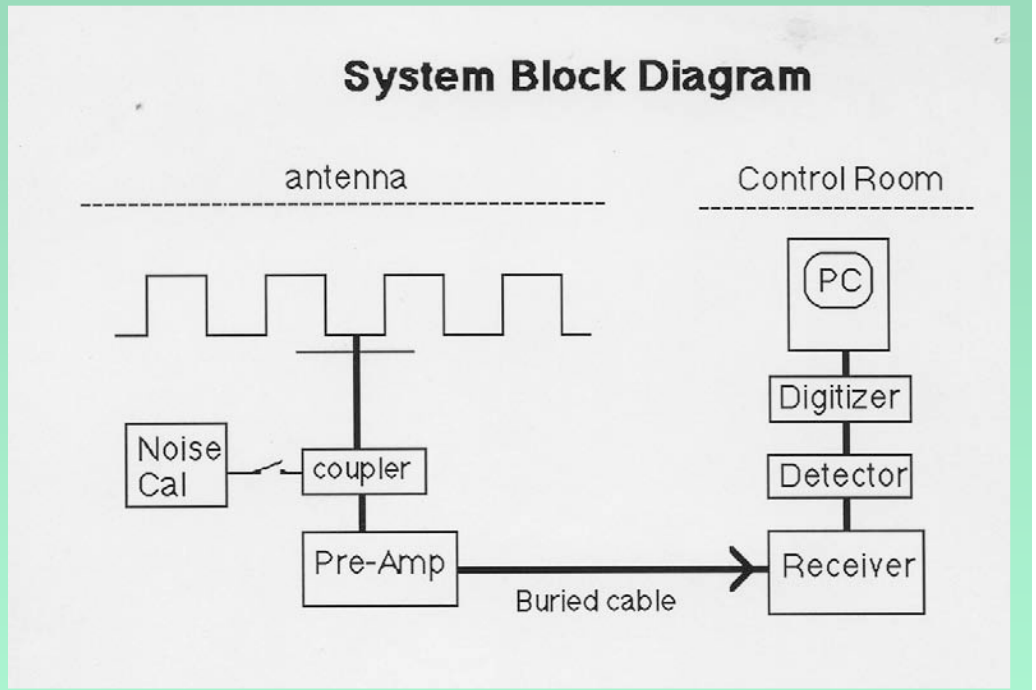
Additions

Amplifiers and a recording system of somewhat more recent vintage than the original were added.

Preamplifier
A preamplifier with switchable noise calibration generator was built in-house and installed at the antenna to overcome losses in the cable leading into the control room.

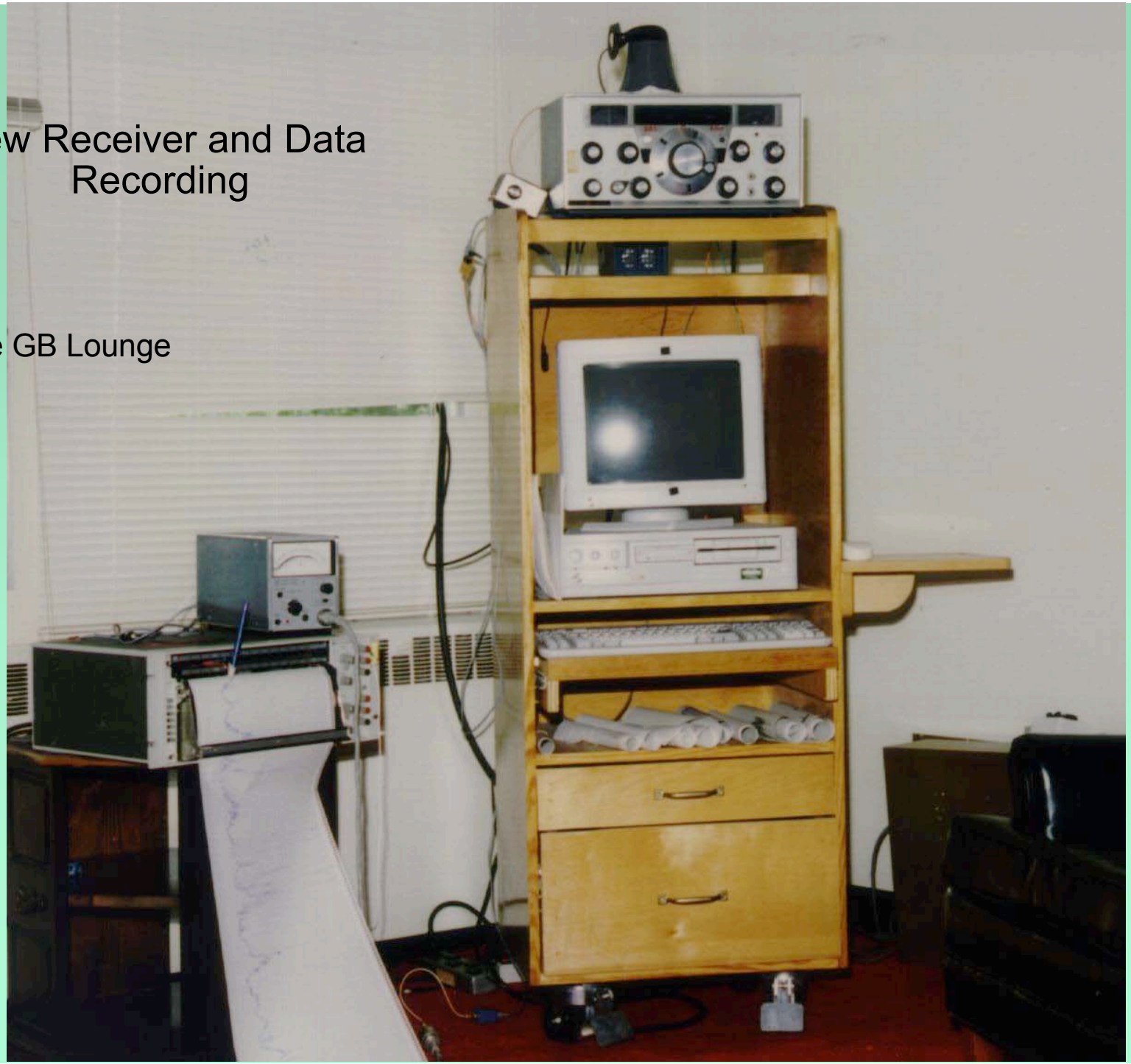
Receiver
A WWII surplus Signal Corps.Hallicrafters receiver was used for the observations recorded here.

Recording system
A square-law detector and 8-bit digitizer were built by summer students, A data acquisition program runs on an IBM-type PC which can sample data at intervals from *55* ms to 60 seconds, with option to do median filtering in order to surpress interference spikes from vehicles.

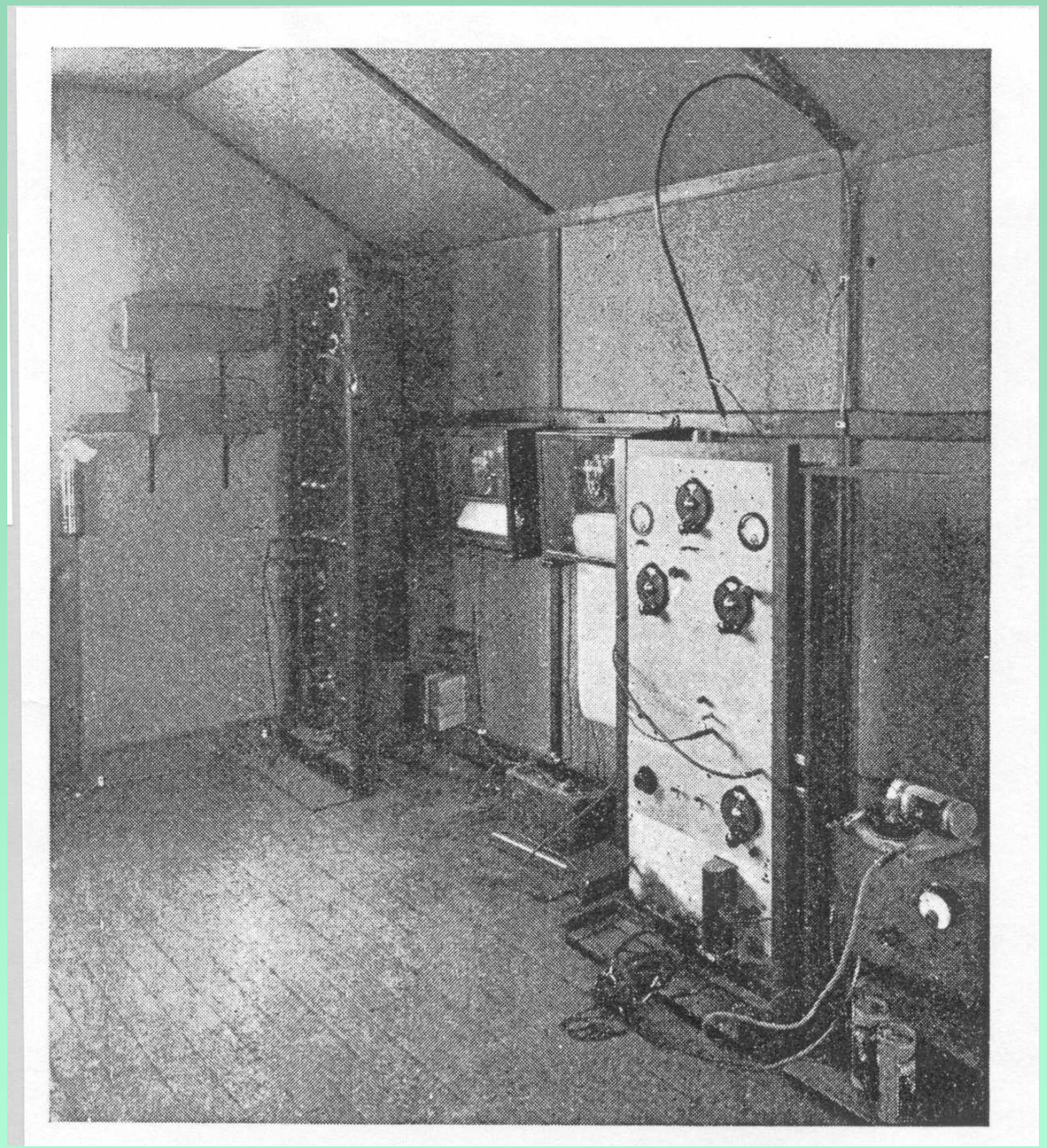


New Receiver and Data Recording

In the GB Lounge



Original Control Room,
at Bell Labs, ca.1932



New control room

The closest building to the Jansky antenna is the observatory residence hall/ cafeteria building. The receiver and data recording system were placed in the upstairs lounge. The lounge has a fireplace, comfortable chairs, couches, and liquor cabinet, making it quite a more congenial control room than the rather Spartan building Jansky used.

New Back end, and some of the Jansky "Fellers"

Left to right: Glen Langston, Frank Ghigo, Dana Balser, Sue Ann Heatherly, 1996

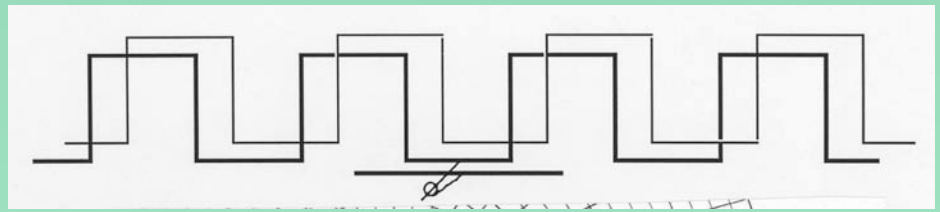
The "Jansky Fellers", summer 1996.

Left to right: Frank Ghigo, Dana Balser, Naomi Bates, Glen Langston, Sue Ann Heatherly, Ron Maddalena

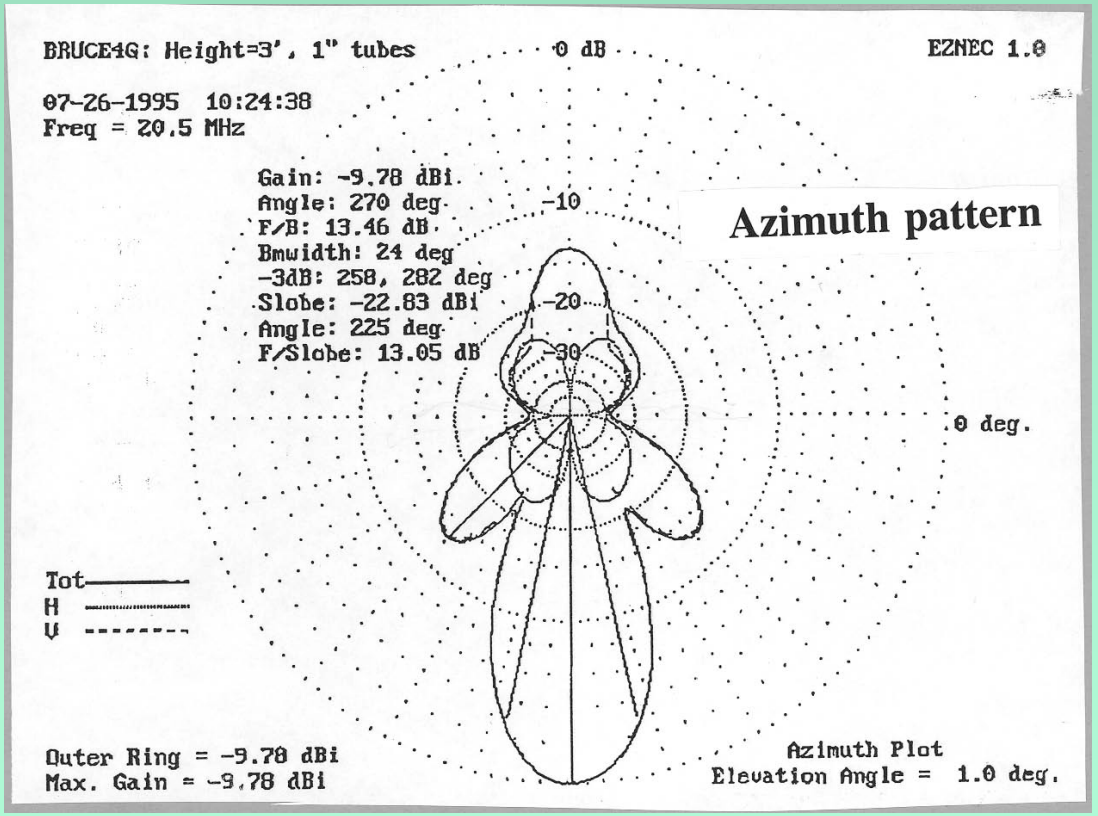
End View

The Beam Pattern

Darrel Emerson calculated the beam profiles for this antenna, which is a two-wavelength long Bruce-type array. Each 12-foot segment is a quarter wavelength.

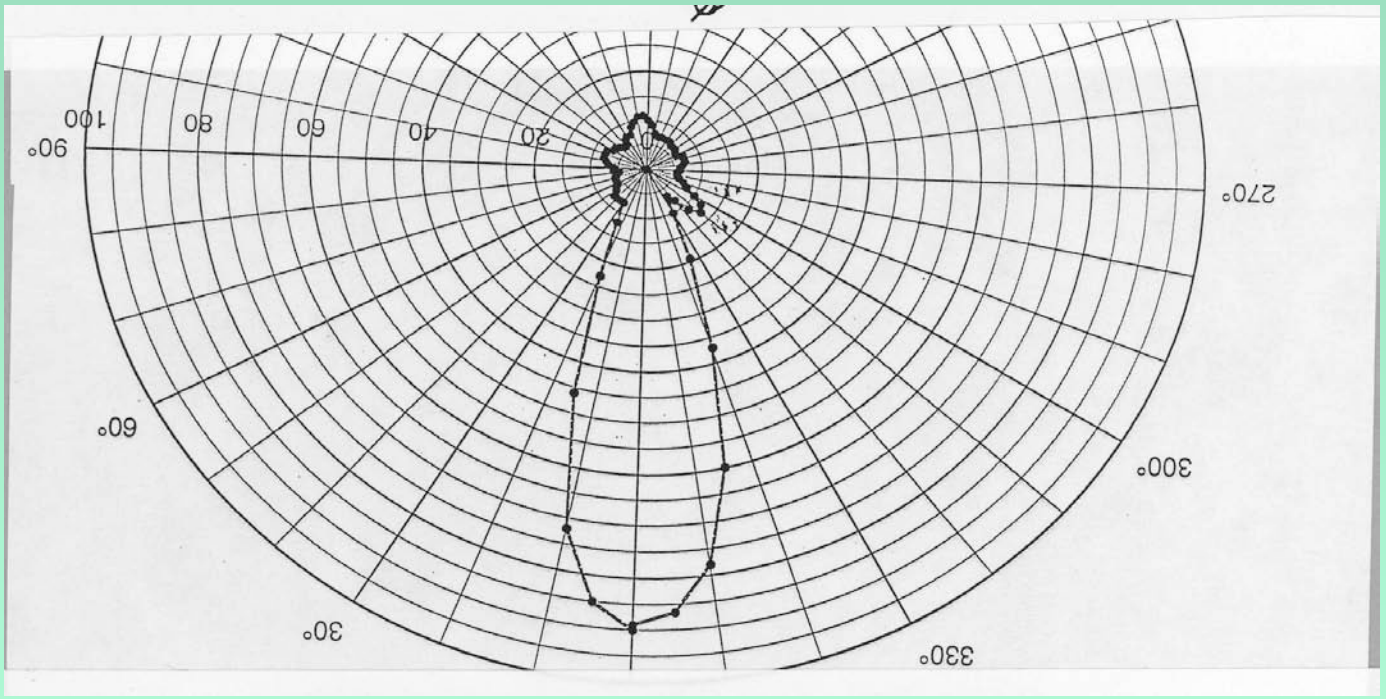


The rear element is a reflector producing a uni-directional beam. The beam sweeps the horizon as the antenna rotates, at an elevation of 25 degrees.



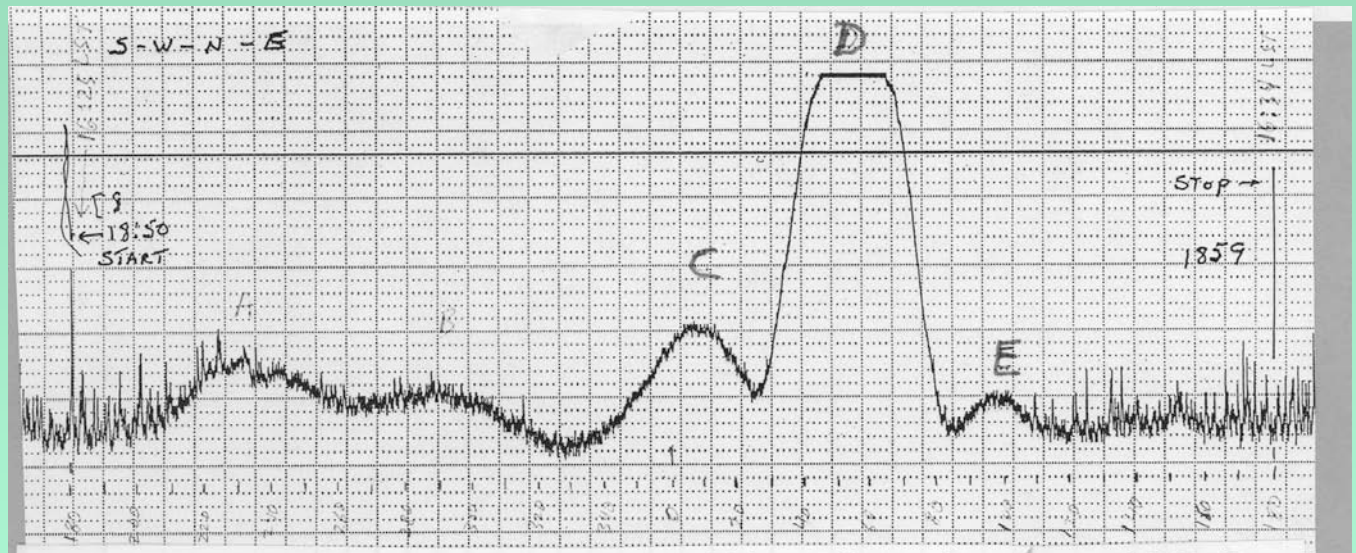
Measuring the Azimuthal pattern

To measure the beam pattern, a small hand-held 20 MHz transmitter was the test source, positioned about 300 meters from the antenna while the antenna rotated through 360 degrees, resulting in this plot. The sidelobes show considerable asymmetry.



A scan through the plane

Another way to see the azimuthal beam pattern is to observe a scan through the galactic plane. The asymmetric sidelobes are seen here as well as in the previous slide.



Scan through galactic plane (D) at longitude ~ 120 deg
Sidelobes at 45 degrees are seen at C and E.

The vertical beam pattern.

The measurement of the beam pattern in the vertical plane presented difficulties. How could we hoist a transmitter high enough ?

The same hand-held transmitter used for the azimuthal measurements was again used, and was hoisted by a bunch of helium filled balloons. Several attempts were made. A complicating factor was the difficulty of holding the bunch of balloons steady enough over a reference mark.

After a few unsucessful attempts, we were successful early one morning when the wind was very calm. Two of us positioned the balloons, while two others sighted from different directions to make sure they were over the mark.

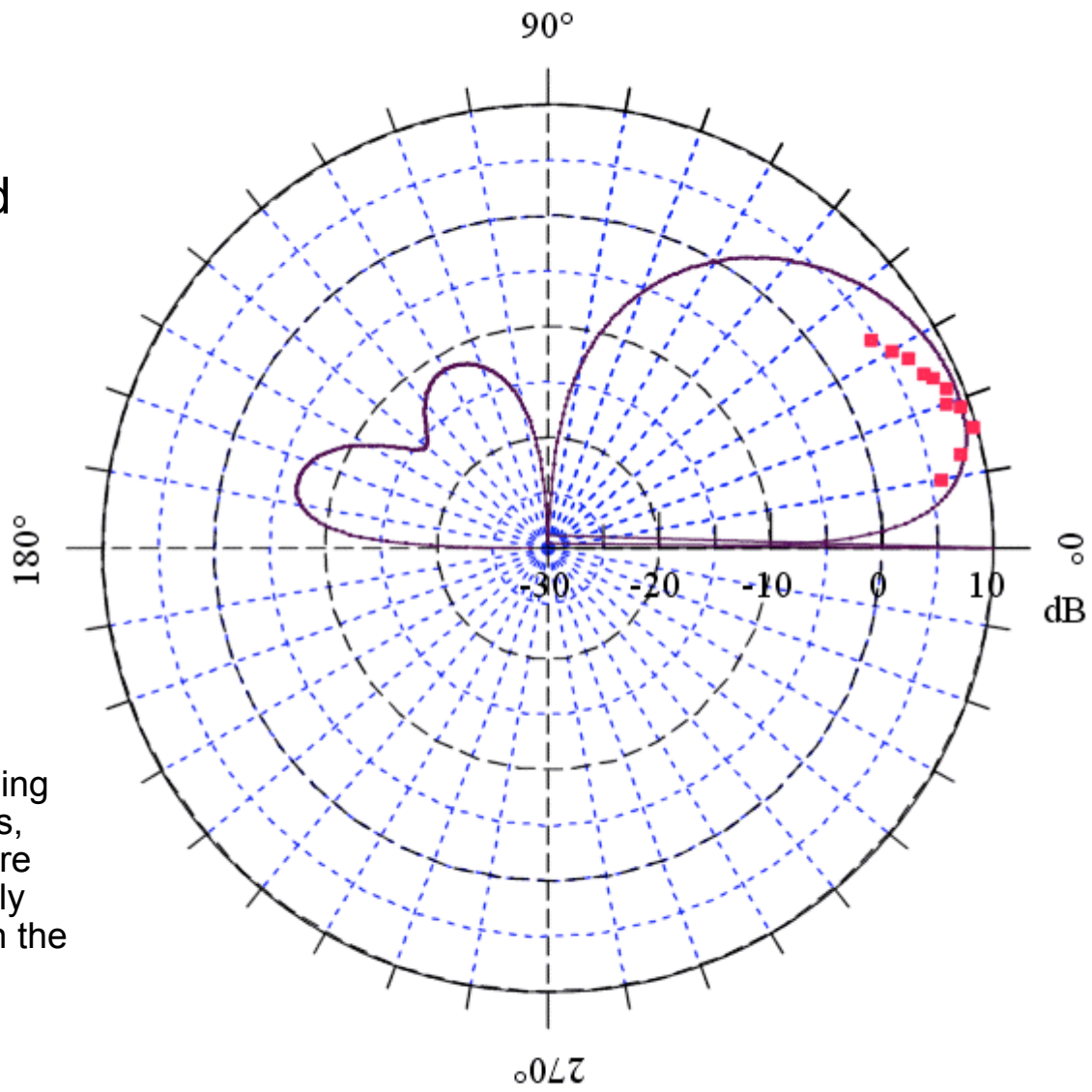
Preparing for the vertical beam measurement

Left to right: Frank Ghigo (behind balloons), Grote Reber, Sandy Heatherly, Patrick Heatherly, Bob Vance, unidentified (behind Bob).

Hoisting the transmitter

Carl Chestnut (L) and Darrel Emerson position the transmitter.

Vertical beam pattern: calculated and measured.

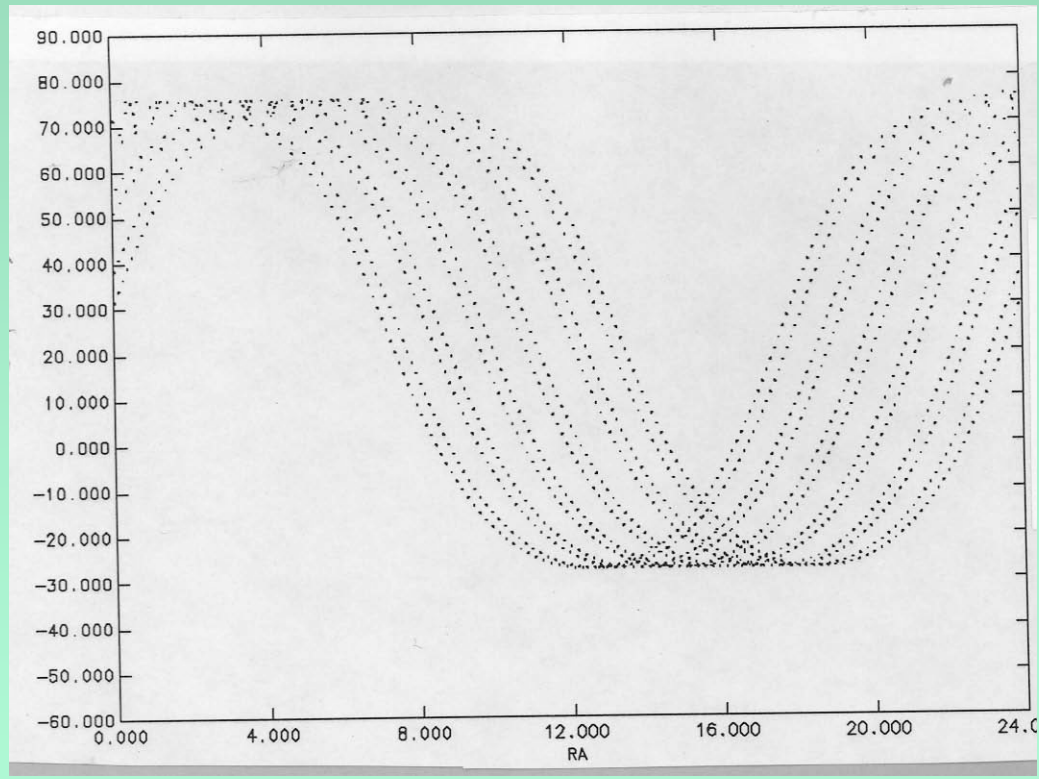


Considering the difficulties in positioning the bunch of balloons, the measurements are probably in sufficiently good agreement with the calculations.

Observing Method

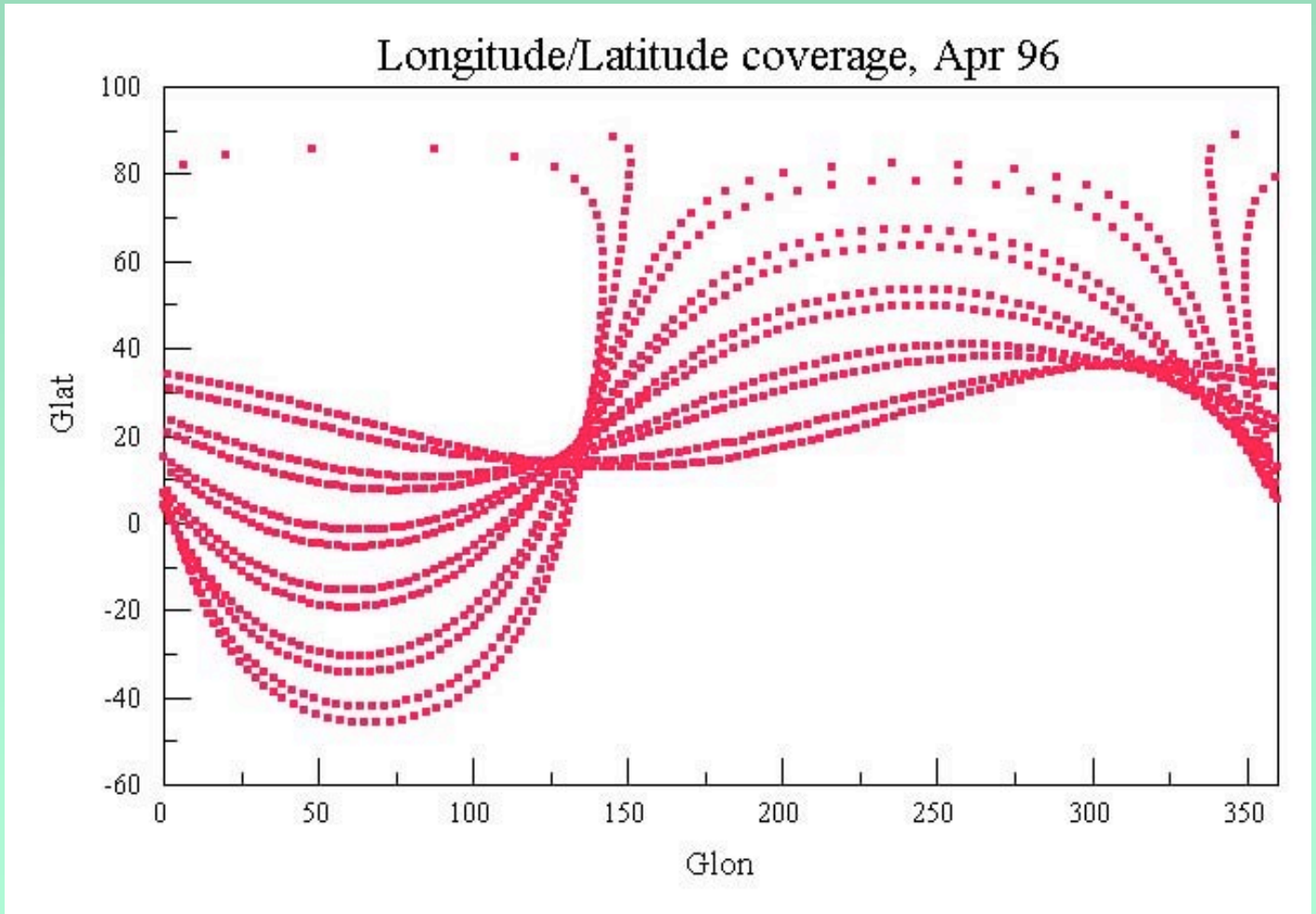
The antenna makes a complete rotation every 20 minutes. The observing method that Jansky used, and that we also tried to use, was to collect data continuously as the antenna rotated for several hours.

Rotations in azimuth produce tracks in Right Ascension (RA) and Declination (Dec), similar to those shown here.



Sky sweeps, Galactic

Each 360 degree sweep in azimuth produces curves in Galactic Longitude and Latitude such as are shown here.



Observing Session

Test observations were made on April 4-5, 1996. The ionospheric MUF was below about 8 MHz for the whole session. Observing was very operator intensive because the chain had a tendency to slip off the gear, so had to be pushed into alignment frequently.

After two 20-minute rotations the feed cable had to be disconnected and unwound. The dedicated group tended the antenna over a 10 hour period, obtaining data from 12 complete rotations of the antenna.

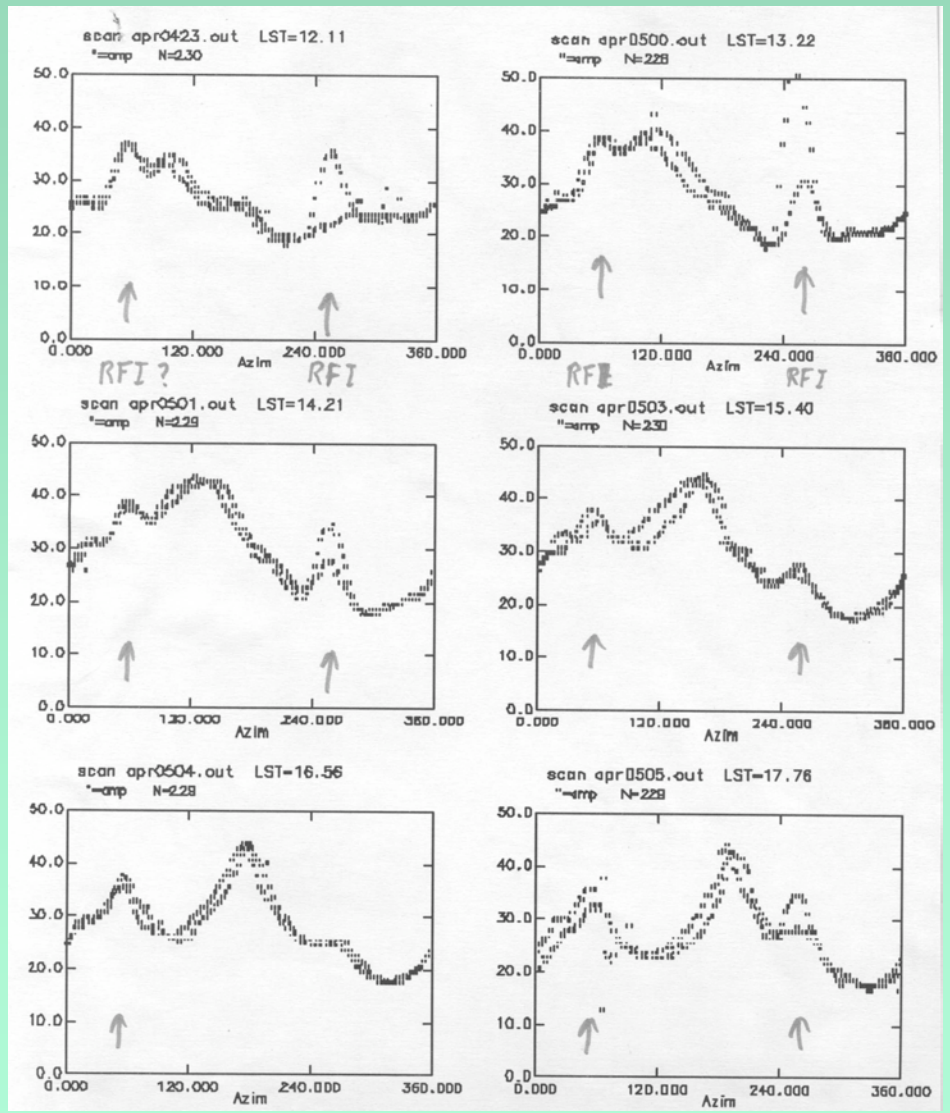
[This was before the mechanical improvements directed later in the summer by Reber.]

These plots show Amplitude vs Azimuth for twelve rotations (2 per plot).

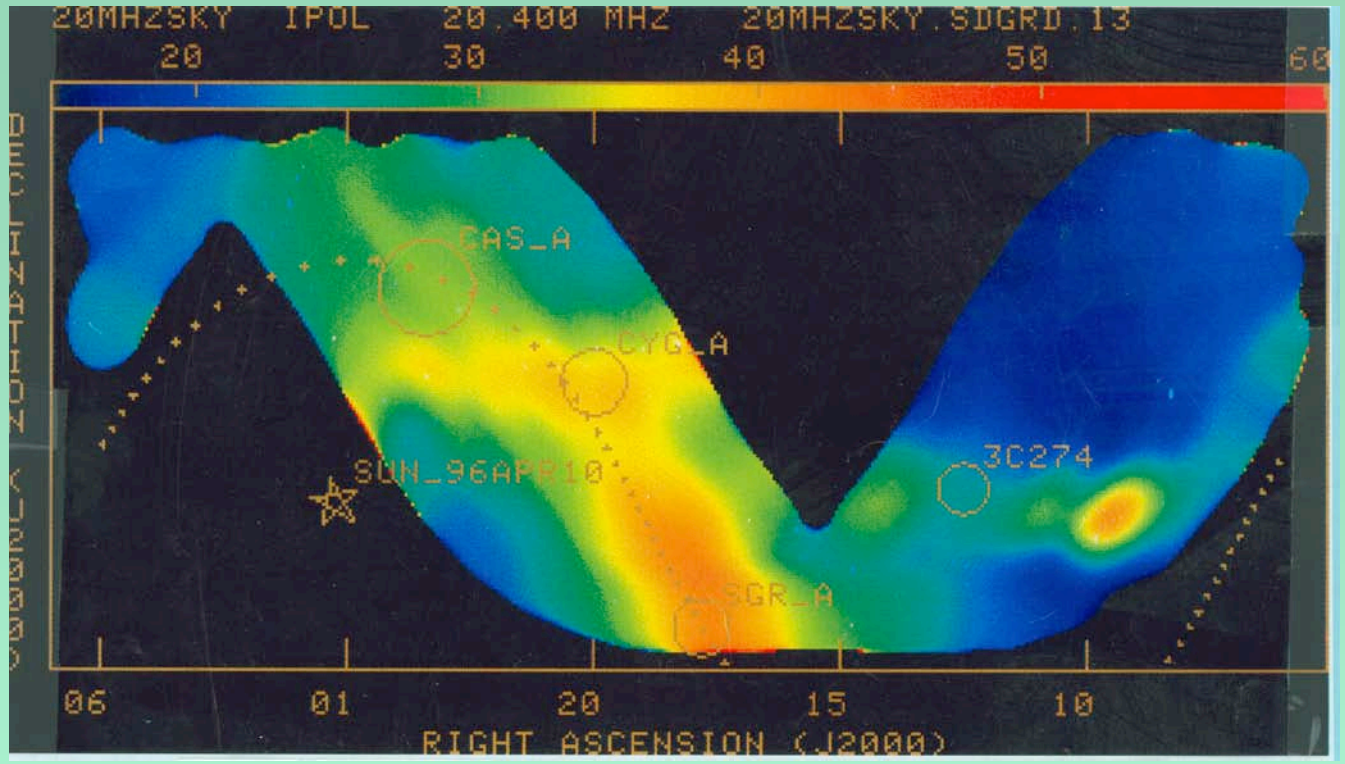
Possible interference, noted by arrows, comes always at constant azimuth.

Strong variable interference at az=255 deg is from the direction of the Observatory kitchen, perhaps a cycling refrigerator.

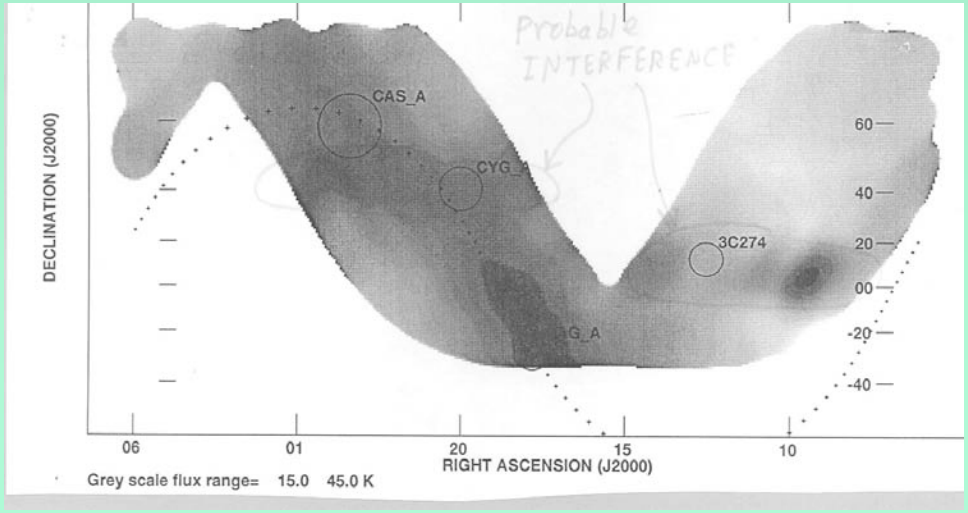
A more steady source at az=55 deg is from the direction of the Director's residence.



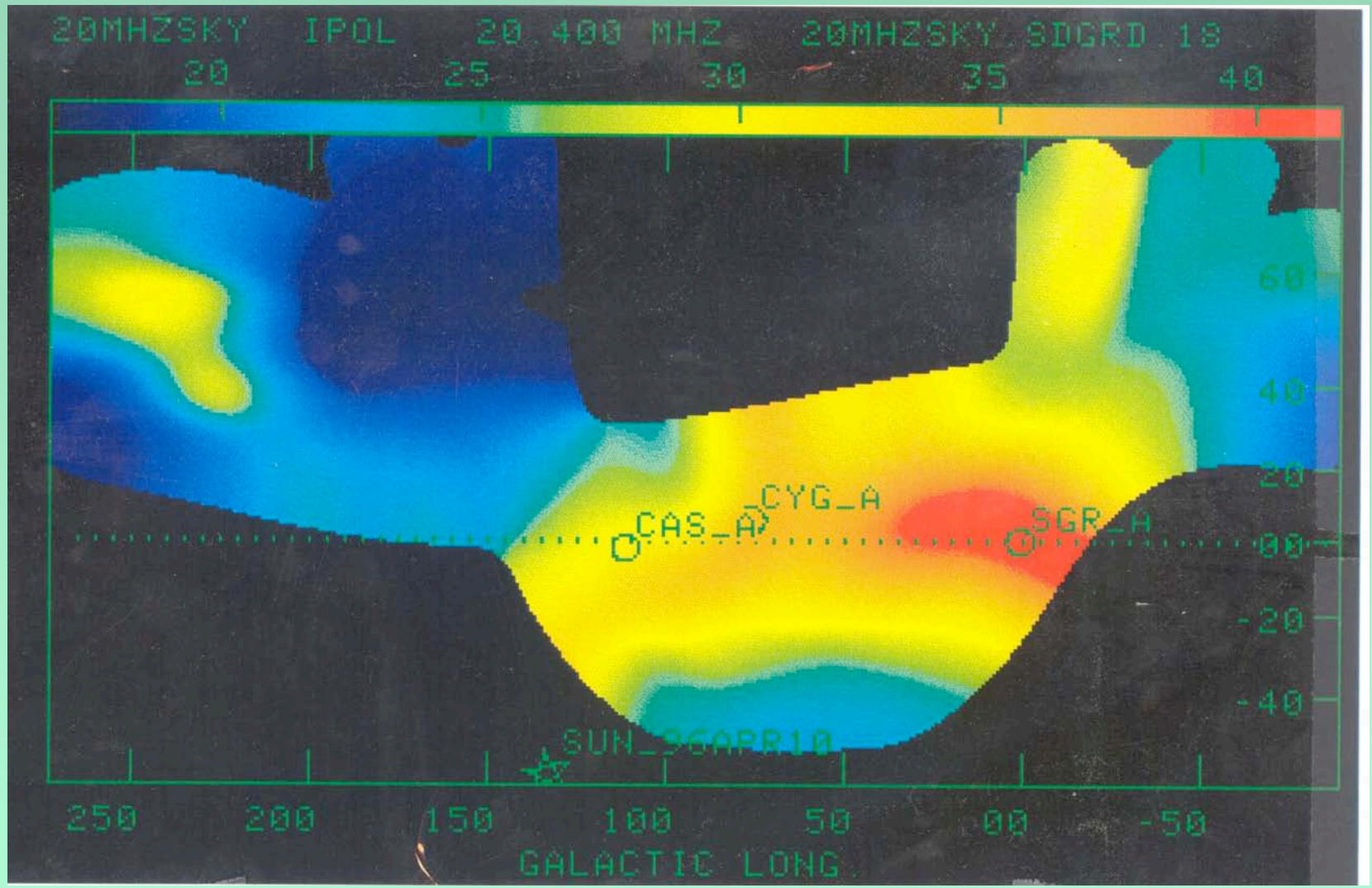
Sky Image in RA/DEC coordinates



The all-sky image is made by gridding the individual scans. The Galactic Plane shows clearly. Probable interference sources are indicated below.



Contour Map in Galactic Coordinates



Comparison with Sullivan's analysis of Jansky's 1933 Observations

W. T. Sullivan has re-analyzed Jansky's 1933 data, estimated the brightness temperature scale, and presented it as a contour diagram in Galactic Coordinates.

(see Sky&Telescope, Aug.1978, p.101; and "Classics in Radio Astronomy", Reidel 1982.)

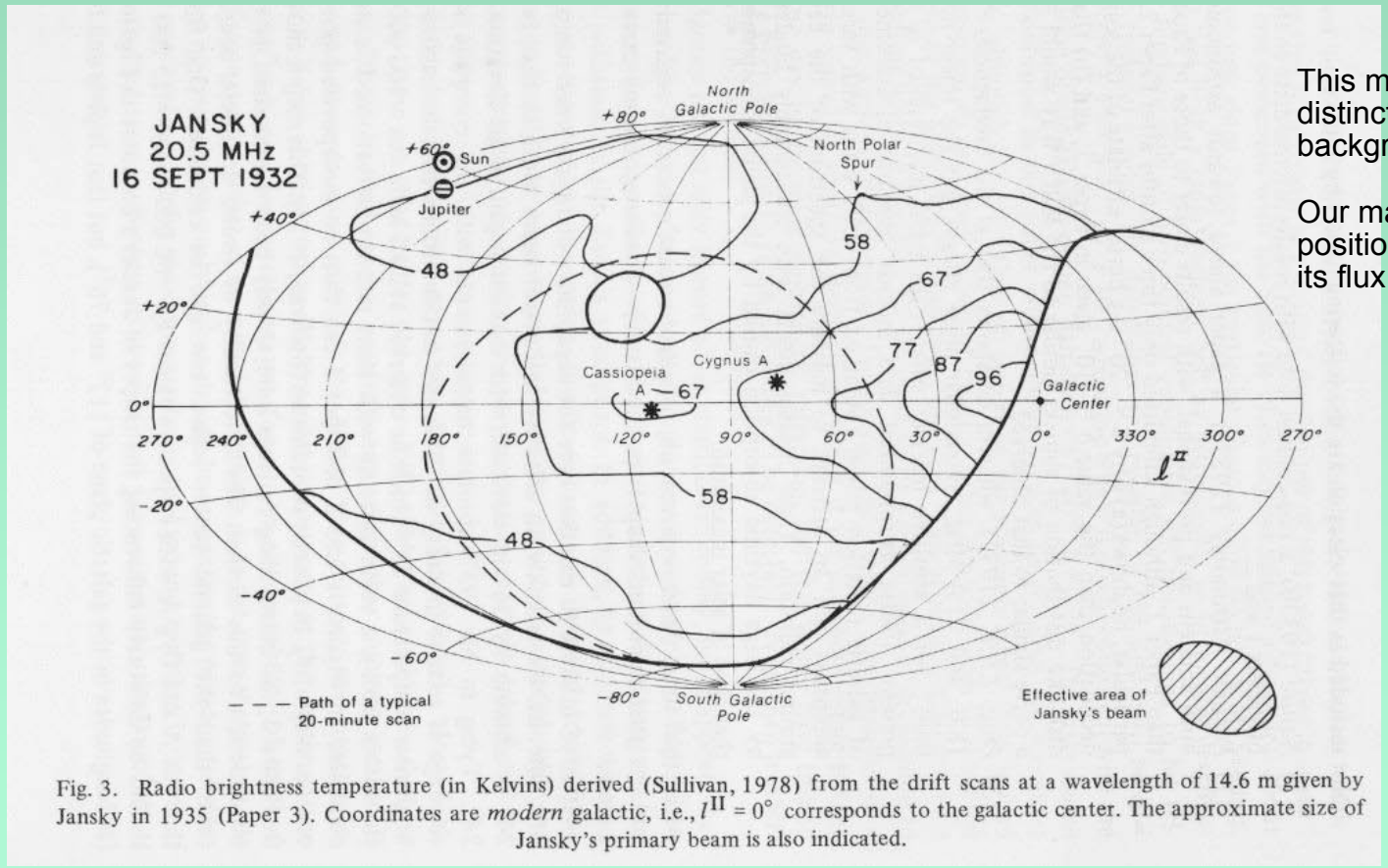


Fig. 3. Radio brightness temperature (in Kelvins) derived (Sullivan, 1978) from the drift scans at a wavelength of 14.6 m given by Jansky in 1935 (Paper 3). Coordinates are *modern* galactic, i.e., $l^{II} = 0°$ corresponds to the galactic center. The approximate size of Jansky's primary beam is also indicated.

Contours labelled in units of 1000 Kelvins.

This map shows Cass A as a distinct peak above the galactic background.

Our map shows no peak at the position of Cass A, consistent with its flux decreasing with time.

Conclusions *

The galaxy can be observed and mapped using the Jansky antenna replica. The observations are consistent with a significant decline in flux density of CAS-A over 60 years.

Future Work *

With a goal of accurately mapping the sky at 20.5 MHz, we plan to make several improvements.

Improvements to the chain drive alignment and addition of a rotating coaxial joint will permit operation of the antenna without constant operator attention.

Calibration procedures will be developed so that sky brightness can be measured accurately.

Correction for ionospheric refraction and absorption will be included in post-processing.

Additional observing sessions over the next year will help to distinguish interference from celestial sources.

* From the AAS poster presentation of June 1996.

So, what happened?

What can be said from a perspective 12 years later?

Nothing more happened after the summer of 1996. Why? Several reasons come to mind.

The only one of the items under "Future Work" that was accomplished was the installation of the rotating coaxial joint and the improvements to the alignment of the chain and drive system. But even with those improvements, the chain slipped off the gear after a few hours. The alignment was never improved enough to allow continuous long-term trouble-free operation.

The goals of proper calibration and data processing procedures were never realized.

The end of the solar minimum meant that surveys of the galaxy were no longer possible in the years following 1996.

It became clear that it was going to take a lot more effort to make the Jansky antenna easy to use and reliable. Combined with the problems with properly distinguishing the galaxy from ionosphere and local interference, the Janksy "Fellers" just ran out of steam and returned to work on more pressing matters.

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