

Summary of the Research Corporation's early association with Grote Reber, 1950-1957.

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GROTE REBER, Electrical Engineering.
Chicago, Illinois, December 22, 1911.
B.S., Illinois Institute of Technology,
1933. Radio engineer, Stewart Warner and
Belmont Radio Corps, Chicago, 1933-47;
member of staff, radio division, Bureau of
Standards; 1947-51; general physical
scientist, 1951-53; private research, radio
astronomy, 1953 --

Reber is the pioneer of radio astronomy. His early work, undertaken with a radio telescope he designed and built in his back yard at his own expense, confirmed the earlier observations made by Jansky of Bell Labs relative to the existence of "cosmic static," and extended them greatly in actually mapping discrete sources. He demonstrated that a completely new field of astronomical research existed.

Research Corporation's first contact with him was the following letter: (November 6, 1950)

Your recent article entitled "How Firm a Foundation" in Physics Today has interested me greatly. I can appreciate the view that experimental physics has become lopsided in the direction of atomic research. Some of my friends have commented that the Physical Review had degenerated to a journal of nuclear physics.

Since 1937 I have been interested in certain experiments which, even today, are of no economic importance. The enclosed reprint is the last of a series of papers describing my findings. This work was supported by me at my home in Illinois until three years ago when I joined the government in this city (Washington). Since then, I have attempted to interest various government organizations in underwriting further experiments. Because the work is without military significance, no civil servant administrator can find any "practical" aspect to "justify" a government laboratory spending funds. Perhaps this is as it should be. In any case, it forces me to look elsewhere for the necessary backing if I expect to continue this work in the future.

It seems dubious that your organization would be interested in this type of research, which is really astronomy. However, I would appreciate an opportunity to meet you in New York and go over my ideas for an hour or so. It is apparent that you have had considerable experience and are a person of wide contacts. Thus, you may be able to suggest an effective plan for promoting further research along this line.

There followed a get-together in the course of which he outlined some of his recent work and ideas developed outside his then-current Bureau of Standards employment. Brushing aside as economically infeasible his complete detailed design for a 450-foot diameter steerable antenna, he elaborated on his study of the feasibility of an interferometer type of instrument which would utilize as one element a large rotatable antenna at a high point commanding as nearly as possible 360 degrees horizon visibility of water, with the water surface comprising the second element. He had learned that Kole Kole Hill, atop Haleakala Mountain on the island of Maui not only nearly satisfied these requirements but had been used previously for other purposes which provided it with an access road. He proposed to complete his tentative design for the antenna construction and, if arrangements could be made, lease the property and go to work on a novel observatory for high-resolution study of radio stars at about ten megacycles. This would entail his giving up his Bureau of Standards job, and he didn't have quite enough money to swing the installation on his own. He estimated its cost at about \$15,000, and was seeking this amount as a grant. Other astronomers, radio and otherwise, endorsed his plans but

suspected the decimal point on the dollars would have to be moved a place or two to the right.

Apparently a sympathetic ear was all Reber needed to trigger him into action. Without waiting for any assurance of support (I had taken a sketchy version of his plans to the Advisory Committee in March, where action was justifiably deferred), he took off in early April for Hawaii, ostensibly on vacation from the Bureau, to survey the possibilities at first hand. They were so promising that by May 24, 1951, he wrote the following letter (from Wailuku, Maui):

Thank you for your letter of the 2nd. Circumstances here seem quite favorable for conducting the proposed experiments. I have found the people in authority to be interested, if not understanding, and very cooperative. Consequently I have been able to secure a lease upon Kole Kole hill on top of Haleakala mountain. A photograph of this location is enclosed.

Further inquiry indicated that these experiments seem to be within my financial capability. Consequently I have decided to go ahead. Presently I am securing bids on foundation work and making field trips in search of bamboo. For structural purposes bamboo must be allowed to cure in a dry place for about six months before use. Tests to destruction on a half dozen samples cut three years ago and allowed to stand outdoors showed tensile and compressive strengths of 10,000 to 13,000 pounds per square inch. The modulus of elasticity varied between 1.9 and 2.4×10^6 . These values are quite high for wood.

Enclosed is a photo of a model which I constructed to show the type of movable framework for supporting the antenna wires horizontally. The bottom rectangle will be of steel pipe. All the superstructure will be bamboo. The over-all dimensions at the tips of the antenna spars will be 216 feet long, 63 feet wide and 50 feet high. Metal parts such as pipe, plate, rail, wheels and motors I have been fortunate in securing early delivery upon. So far I haven't located a suitable diesel power plant but expect to in the near future.

My plans are to stay here another six to eight weeks until the foundations are in and the bamboo has been cut. Then I will return to the states for a few months to follow up procurement. After I am sure everything is here, I expect to return in the fall and finish the job. While I am in the states I will call on you in New York to advise you of my progress. In the meantime, I will be happy to have you relay the above information to the Advisory Committee on June 13. I am sorry that I cannot be there in person.

and, on May 31:

Thank you for your letter of the 29th. Early in March it became evident that my contacts here were able, willing and ready to give me a lease on Kole Kole. It seemed imperative for me to come out and secure the lease now. In six months, no one could foresee what might have transpired to cause a change in their thinking. If, for any reason, Kole Kole slipped thru my hands the whole business would be off because there is no other suitable mountain with a road to the top. That was the primary reason for my trip. However, after being here a bit, another rather pressing set of circumstances became apparent.

I had made an investigation into the weather upon the top of Haleakala. By some extrapolation and guessing I deduced that the five months of November thru March would be unfit for outdoor work. Once in April I ran into a winter storm on Kole Kole. It was exceedingly miserable and surpassed my expectations. Inquiry at the Ranger Station showed such weather to be quite common early in the year, although the particular storm I hit was unseasonably late. After this experience, it became evident that if foundations were to be built, they should be done this summer or else the whole business would have to be put over a year.

At this point I went into a huddle with myself on finance. The entire program would take the major part of my funds but it looked like a good gamble so I decided to go ahead. If I couldn't get reimbursed, I wouldn't go broke. If I could recover the funds at a later date, so much the better. As things stand now, I expect to push on with the foundations and the cutting of the bamboo. That is about all I can accomplish from this end on this trip.

While I don't want the above to be construed as an attempt to railroad you people into this, I would still like to secure your support at a later date. Whether or

not this is possible, I don't know. Perhaps I can turn over the paid bills to you, in which case the program becomes one of the Research Corporation. Perhaps you can only support future and operating expenses. In view of the fact that you do not make grants to individuals, perhaps the simplest thing is to join the Research Corporation (if this be acceptable). I believe once we discussed forming a subsidiary corporation. Perhaps none of the above is any good. I merely bring these up as suggestions.

Upon my return I'll know more exactly what everything is going to or has cost and all the circumstances surrounding this venture. In the meantime, I'll be pleased to have you take up the matter with the Advisory Committee on the 13th and await with interest their reactions.

The Advisory Committee recommended a grant of up to \$15,000 for the support of Reber's work at its meeting on June 13, 1951. The grant was to be contingent upon some sort of institutional affiliation for Reber so as to avoid the granting of personal funds. In August, Reber made tentative arrangements with a trade school on Maui, and proposed grants of \$3,000 per year for three years to operate the observatory. He stated that he would assume the costs of permanent equipment, along with his own personal expenses. Meanwhile, helped by "two tough-looking Portuguese from Mahawas" and a variety of rented, borrowed and purchased equipment, construction had gone ahead. We were still bogged down on incidental details of suitability of his affiliation, which evidently worried us much more than it did Reber.

Letter of October 22, 1951:

Thank you for your letter of the 19th. I have not forgotten you and everything is going quite well. Enclosed is a photo taken two months ago. Since then the rail arrived and has been set in a smooth bed of mortar. By

some manipulations we got it within 1/4" of round and 1/8" of flat. The trucks for corners of turntable also have arrived; been assembled and installed. The whole turntable is now in process of being welded into one piece.

The electric power plant has been installed and operates but has not been wired up. The building has also been rehabilitated but no heating facilities have been installed. At present rate of progress the turntable should be in operating shape about the middle of November. Thus it seems I'm going to beat the bad weather and get all the outdoor work completed.

The situation on bamboo is gradually being resolved. The pieces 6" diameter and smaller I can secure from Japan at a moderate price. Through a friend in Borneo I have placed an order for pieces 8" diameter. Presently I am negotiating to purchase 10" and 12" diameter pieces from India. All this should be here next spring when I return.

Unfortunately I have not done much more about a sponsor. However, I wish to say that the percentage fee, to which you object, was my idea and not that of Maunaolu College. It merely seems to me that any organization which is charged with the bookkeeping and correspondence should get something for clerical help. My friend Mr. Robert Bruce, who is manager of EMI and trustee of the college, informs me that he will personally take care of this matter if necessary. There are other organizations here who might act as sponsor such as the Rotary Club, but it is really just the same people who own and run this island. That they are doing a good job is obvious from the wealth of the economy.

My plans for return are still vague. However, I will be at Wheaton, Illinois for Christmas and will attend the meeting of the American Astronomical Society in Cleveland the 26th through 29th. Perhaps a good time to see you would be right after New Year's. I'll write again soon.

Research Corporation's Executive Committee approved the Maui Vocational School arrangements on January 10, 1952, the initial \$3,000 grant was proffered on January 16 and forwarded January 28. The next note of progress is March 9:

I arrived out here (Wailuku, Maui) earlier this week and made a trip up the mountain. Everything was in good

order just as I had left it with nothing broken or stolen. The last half mile of road up to Kole Kole hill which is cinder had been graded with large sweeping turns wide enough for two cars. I thought this a very nice gesture.

The Vocational School has extended to me such services as I need. The future appears bright and it is evident the Island people are doing whatever they can to assist this venture.

Presently, I have a lot of calculations and drawings to make before it will be possible to start fabricating the members which go above the turntable. Thus it may be two or three months before I have anything new to report. In the meantime, I will be pleased to answer any letters you may wish to send. Thank you again for the grant and I hope we can use it to maximum effect.

In September:

Now seems to be a good time to write. Enclosed are some pictures. The photography is not good but they will give an idea of how things are progressing.

Last spring when the bamboo idea fell through there were two alternatives. The first was to throw together some type of temporary framework and try for results at the earliest possible date. The second was to redesign the members in the form of open trusses and hollow columns to be made from redwood. A few estimates showed the whole framework could not be so constructed in the few months available. Thus it was decided to go ahead with the center part which is now finished. Next year the rest of the members will be fabricated and the entire framework completed.

In the meantime I expect to put up the long spars which will be made out of local bamboo cut last December. It is not the best, but will be satisfactory for the time being. Thus the structure will be suitable for hanging up antenna wires in a month or so, even tho on a reduced scale from the original plan.

Recently I have received word that a signal generator which I ordered last January is now ready for delivery. Thus I should be able to get all the electronic equipment functioning by late November. Fortunately from here on, the work will be mostly indoors, so the coming bad weather should not have appreciable effect on progress.

I want to thank you for your letter of August 18th with enclosures and the additional check for carrying along this work. It should be adequate until we get into more construction next spring.

The meeting in Australia was apparently a success. I had several visitors both before and after the meeting so I secured a good idea of how things are being done elsewhere. After adding it all together, I am further satisfied that this experiment at Kole Kole is on the right track. However, if the most is to be made of it, the work can't be rushed. Fortunately this is unnecessary as we are not competing with anyone.

The Weather Bureau and the Pineapple Research Institute have provided me with a variety of instruments, so now we are getting weather data regularly from the highest station in the Islands. I also take pictures twice a day of the tops of the clouds on the windward side of the island. The camera and film are supplied by the meteorologists of the Hawaiian Sugar Planters Association. These people are interested in rain making. All in all, things are going along nicely. Fortunately I've been able to get along well with the Island people and have had little difficulty securing labor, etc.

While I am averse to publicity in general, because we have nothing to sell to the public, it seems impossible to shut it off altogether. The people of the Islands have somewhat of an inferiority complex plus a tremendous sense of local pride. This carries down even to the level of inter-island rivalry. I have attempted to interest them in this venture and to be myself a Mauian. Thus from time to time these experiments will receive publicity. In any case I'll do my best to see that Research Corporation is included, and the whole matter kept within the bounds of reason. I may seem apprehensive on this matter. Unfortunately, it was one of the headaches I encountered and which I had practically no control of at NBS.

Your comment about Harvard and the National Science Foundation leaves me curious. I'd be greatly interested to learn what phase of these matters Harvard thinks is worth exploiting and what their program is to be. Or is it just money??

The following two paragraphs of a letter from the Maui school commissioner are interesting at this point:

"I have been watching Mr. Reber and his work for some time and I can tell you I am amazed at what he has accomplished in such a short time and with so little money. He is an indefatigable worker. To fabricate the framework for his antenna, haul it 60 miles, and erect it at an altitude of 10,000 feet, with the help of a few men and do it for so little is just beyond comprehension.

"I know nothing of his scientific accomplishments but I do know what costs are in Hawaii. I can assure you that your organization is getting full value, plus, for every cent you are contributing toward this experiment."

In February, 1953, Reber reported that, weather permitting, measurements would be started soon. He also commented on a visit from E.G. Bowen of the CSIRO, Australia, in the course of which he learned of a start by the Australians on a very similar project, initiated at about the time he had gone to Hawaii. The Australian start, after considerable expense, had been held in abeyance when Reber's plans became known.

On March 30, the following note:

It is with pleasure I am writing to tell you at long last results are in hand. Under auspicious circumstances the effect of the curvature of the earth can be seen and there appears to be an abundance of sources to study.

Perhaps it will not be too long before some new information upon the universe is forthcoming. Now the main effort is the gathering of data.

In April, Reber turned down an invitation to address a radio astronomy session of the National Academy of Sciences in

favor of keeping his observations going. On request, however, he prepared a paper and some slides which Merle Tuve undertook to present in his name. His line of thought developed in a letter April 20:

It seems that I take a dim view of speech making compared to those who organize conventions. My reluctance to go to Washington is not merely the expenditure of several hundred dollars to make a 20-minute talk, which does seem rather out of proportion; but also, travel is hard work and I do not feel equal to making a long junket at this time.

I have settled with Tuve on the basis of sending a number of slides and a manuscript. It is my intention to make the same offer to Bok. As I explained to him, the AAAS affair seems poorly thought out. Certainly, a Saturday morning the day after Christmas will be inconvenient to everyone not residing in Boston.

As you know, Radio Astronomy started in this country over 20 years ago. Jansky was not a very pushing type of person and he suffered from poor health. However, he did go around making addresses to various societies without any visible success. As he explained to me one time, the electrical engineers were not interested because they didn't know any astronomy and couldn't find anything useful in the subject. The astronomers were not interested because they didn't know any electrical engineering and considered their present techniques adequate for studies of the universe. My subsequent experiences confirmed these reactions.

It now appears that our savants have discovered radio astronomy through the efforts of the British and Australians. This bears out a statement by Kettering to the effect that: The best way to get the inventions of General Motors laboratories into G.M. cars was for Chrysler or Ford to start using them.

My outlook on life has changed a bit in the past year. Back in the states I used to rush around as it sometimes did some good. Out here such procedure is absolutely futile. Thus, each day I do what I can and what isn't done waits until tomorrow or the next day. Hawaii is a pleasant place, especially if one gets out of Honolulu. Perhaps you can make an excuse to come out here for a couple of weeks next autumn when the tourist rush is over. I'll write again when something interesting occurs.

July, 1953, brought the first comment on scientific progress, as excerpted here:

Scientifically, we are progressing, but rather slower than I had hoped. With the coming of summer and a more dense ionosphere, the auspicious days for observations at 20 megacycles have dwindled to practically zero. Recently, I changed the operating frequency to 30mc. This increased the number of useful days. However, all the sources except the two in Cygnus and Cassiopeia are now fainter. A few have disappeared. As the interference fringes get closer together at higher frequency the angular size of the source tends to fill in the pattern. When the diameter of the source is the same as or larger than the distance between fringes the interference pattern disappears altogether. With the return of autumn the observing conditions should improve and I expect the best conditions to prevail next winter. We will then be at the bottom of the solar activity cycle so the ionosphere will be most transparent. From this point of view the timing of this program has been near perfect.

Before coming out here I investigated the characteristics of the ionosphere as deduced from the soundings made by the ionosphere station at Kihei, Maui since 1944. This technique gives an idea of the condition of the bottom half of the ionosphere directly overhead. By applying suitable theories one can deduce the characteristics of the ionosphere at the horizon. 20mc seemed like a very safe frequency all year round. Actually the ionosphere has turned out to be much more opaque than any theory could predict. Apparently the top half of the ionosphere is composed of many small blobs which rapidly change in size, position and time. These scatter the celestial wave and introduce a type of fading known as fluctuations. The above explanation is mostly a guess. As more data are collected the nature of this matter will become clearer. So far it has been the limiting circumstance of the whole investigation.

Some time ago I began a study of the bending of a radio wave in the lower atmosphere. The bending was computed from a large number of radiosonde observations taken at Honolulu. It so turns out that this study is along the same lines as an investigation by Strand. I have sent to him my results as far as they have gone to date. He intends to present them along with his at the Boulder meeting of the American Astronomical Society next month.

Haleakala volcano is very old and classified as dormant. The only known lava flow occurred at Makena about 1750, just before the arrival of Cook. Recently, two friends and I dug some carbonized roots of a large Banyan tree from under a lava flow at Ulupalakua. I am negotiating to get a carbon date on this material. An interesting Hawaiian legend also is associated with this flow. If a date can be secured, the age of the flow will be known and some idea obtained upon how long these islands have been inhabited.

I'll write you again when something else interesting turns up.

In September, a more detailed study followed:

By now sufficient data has been secured and experience gained to form some judgment on this whole endeavour. All is not good. An unexpected and presently unexplained phenomenon of nature has been encountered; namely, nighttime absorption in the ionosphere. During the day the ionosphere is very complex containing many layers and absorbing regions. With the setting of the sun the D, E and F_1 regions quickly disappear leaving only the F_2 region.

F_e may be defined as the limiting frequency of entry of a celestial ray or the limiting frequency of exit of a terrestrial ray. The value of F_e varies with the condition of the ionosphere and the angle of incidence of the ray. Cosmic static frequencies below F_e will be returned to space while terrestrial signals will be returned to earth making long distance communication possible.

Conventional theory of the ionosphere indicates a small amount of absorption at F_e . The absorption decreases to a negligible amount at $0.9F_e$, as shown on the attached sheet. Thus nighttime communication via the F_2 layer will be very good as has been amply confirmed by experience. Conventional ionospheric sounding techniques can only provide information about the lower part of the ionosphere at frequencies less than F_e . Thus nothing is known about the top part of the F_2 layer. However, since the conventional theories appear to explain its performance at frequencies less than F_e , it seemed a fair assumption to expect the theories to be borne out at frequencies greater than F_e . The crux of the whole matter is that this assumption is grossly in error.

Nearly all of my observations have been between midnight and dawn at frequencies between $1.5F_e$ and $2.5F_e$. Under these conditions the absorption should be negligible. Thus the ionosphere should be transparent to cosmic static and act like a prism introducing a small amount of bending to the ray. Such bending should cause the source to rise slightly early and set slightly late. At no time has this bending been observed. Whenever the ionosphere is sufficiently present to provide the expected bending a great amount of absorption is also present which soaks up the celestial ray. If these normal conditions existed at all times, nothing whatever would have been secured and the whole enterprise could be written off as a complete failure. However, at infrequent intervals holes appear in the ionosphere and the cosmic static wavefront comes thru without attenuation or bending just as if no ionosphere were present. These are the auspicious circumstances mentioned in my note of March 30. As is often the case, beginners have all the luck! These holes are of small size as they last for only a few minutes of time and are confined to a few degrees of azimuth. For instance, two sources may rise only 30 minutes of time and 20° of azimuth apart. Cosmic static from one may come thru a hole beautifully while the other source probably will be obliterated entirely. Because of these holes it is possible to make some estimate of the actual absorption as shown on the attached sheet. If the hole persists long enough a few loops of the interference pattern are secured. The above explains part of the results.

There are two sources in Cygnus and Cassiopeia which are markedly stronger than any of the others. Their intensity is sufficient so that at least small amounts of energy may be detected most nights. No interference pattern is secured, merely random and incoherent fluctuations. These variations of intensity are probably due to the random adding and subtracting of multipath transmission thru the ionosphere and not due to variable absorption. Whenever absorption exists (most of time) it is of great amount and appears quite constant. No doubt you have watched the sun set on a clear horizon. It takes about 3 minutes from the time the lower edge just touches the horizon to the time the upper edge disappears. Quite the same thing happens on the Cygnus source a number of nights. However, instead of 3 minutes the phenomenon is all over in about 3 seconds! By examining the shape of the curve it is possible to compute the angular size of the object as about $1/2$ minute of arc and get some estimate of the distribution of surface brightness. On a good night the phenomenon is rather spectacular. The trace will be running along with

considerable random fluctuations. Then a sudden drop will occur and the trace will again run along but now perfectly smoothly as the source of energy causing the fluctuations is gone.

In between these two rather different types of results are all gradations and combinations with absorption. Some of the above sound promising. Actually they are picayune compared to what I had hoped to achieve. The more nights I spend on top that volcano getting nothing the more chilled my enthusiasm becomes. So far I have found no way of predicting or estimating when a good night will be. At one time I thought they were associated with magnetic storms, but now I'm not at all sure. Even if they were, it wouldn't be satisfactory because such storms are unpredictable.

Last month Dr. F.W.G. White was here for a day. He is an ionosphere expert of some standing, formerly of Cavendish and now on the board of CSIRO in Australia. I went over the whole business with him in some detail. He was much interested in the ionospheric aspect of the results. Apparently the absorption must be above the normal F_2 layer which is inaccessible to terrestrial means of investigation. There are two hints which confirm my findings. During magnetic storms the height of the F_2 layer rises greatly and all terrestrial signals become very weak and fade rapidly. Thus it seems that temporarily the F_2 layer gets up into the absorbing region and produces poor radio communication conditions. The other hint is that during some moon-echo tests in Australia, no echoes could be secured when the moon was near the horizon. They put this down to inadequate antenna systems when actually it was probably due to absorption. White had no suggestion as to any mechanism to account for the absorption because nobody knows what is above the F_2 layer which is far beyond the reach of V rockets.

We discussed the sea interferometer experiments of his laboratory. Unfortunately, there isn't any good comparison because everything is so different. They are operating from heights of only 2 or 3 per cent of my altitude which provides much poorer resolution. Their operating frequencies are on order of 10 to 20 F_e which appears to greatly reduce the absorption. Perhaps most important they are at a different place on the earth. White suggested the absorption might be much worse near the equator than in temperate regions. He had no reason, merely a hunch.

I also wrote to Harry Wells of DTM-CIW about this night time absorption and asked for an explanation. His reply indicated that he had no idea what I was trying to tell him, much less provide any explanation. Perhaps I have stumbled upon a discovery of sorts; to me a bad one.

We can't move the mountain nor lower the apparatus. However, the operating frequency can be raised. During the next month or so I expect to change things around to operate at 5 to 7 F_e . Perhaps the results can be improved from poor to fair. In any case the above discussion points up a number of things.

(1) I've walked into a set of circumstances over which I have small understanding and little control.

(2) What is going to be learned from this adventure is more related to the ionosphere than to astronomy.

(3) Improved results are probably going to be secured at higher frequencies instead of lower. This is in reverse direction to my fundamental interests as outlined by my letter of May 22, 1952.

(4) Unless something remarkably and unexpectedly new turns up there is no point to making further capital expenditures out here. Costs should be limited to operations.

My plans are to operate the installation thruout the winter, first at 5 to 7 F_e and then at 10 to 15 F_e if time and conditions warrant. By next spring I should have quite a collection of results under a variety of conditions. Summer is the poorest season because the ionosphere is most dense. In the spring it is my intention to pack up my data and take an extended trip to Australia. Maybe some good ideas will be forthcoming. If not, one more winter of observations out here should push the results far into the region of diminishing returns and finish the project. Labor, while poor, can be hired for a price. Intelligent help is quite impossible to secure. Consequently, this adventure depends entirely upon me for the design, construction and operation of apparatus plus interpretation of results. I have thought of trying to import some good help. In view of the mediocre results secured so far this does not seem warranted. . . .

During the winter I expect to get into shape for publication a number of subsidiary articles. Perhaps a paper on the results will also be suitable by spring. This rather lengthy letter should give you some idea of how things are going plus the status of my present thinking.

And in November, a brighter note:

Your letter of October 1st was very welcome and I was much tempted to take a month out and return to the states. Unfortunately, these conferences are at an inconvenient time. As explained, last summer's observations were pretty poor. However, with the return of the equinoxes there has been a marked improvement in observing conditions which now approach those of last spring. Out of four runs last night two gave excellent data, one fair and one blank. This is, so far, an all time high for one night's results. From the very beginning I thought the best season of the year would be November thru February. Apparently this belief is correct. Right now on this venture I am where I had hoped to be a year ago. All the bugs have been removed from the installation and I can go up to Kole Kole with a good expectation that everything will function. It is my intention to make the most of the next three or four months and get as much data as possible. By mid-March I intend to fold up for the summer and take the long projected trip back to the states.

I have sent the manuscript to Bok for his conference and have arranged with Dr. John Kraus of Ohio State, whom I know quite well, to give the talk. I want to stop and see him for a few days next spring.

Jesse Greenstein is arranging a confab for early January. I will send him something also. Unfortunately, the more time I spend on this sort of thing the less I can spend securing results. These people don't realize that getting a few drawings and slides made is a major operation out here; and I do most of the operating!

followed by acquiescence to a trip home:

After reading over your letter of the 20th I have decided to change my mind. My past conditioning upon conferences has been the many interminable and futile gumbeatings I was obliged to be part of when I worked for NBS. Perhaps there is more to the affair in Washington than I originally thought. Unfortunately, I cannot overcome the suspicion that all the recent enthusiasm about radio astronomy in this country is directly associated with the fact that the National Science Foundation now has some funds to dispense.

A short study of ionospheric characteristics shows that we are still on the down grade of the solar activity

cycle. Thus next winter should be as good or perhaps even better than this winter for getting data. Consequently, taking a couple of weeks out won't be too serious. I have arranged the following schedule.

During the visit here, Reber discussed a new idea which had been developing in his mind as result of some speculative theorizing of a Dutch physicist on modes of propagation of electromagnetic radiation through the ionosphere. He was convinced that one of these would find a "hole" in the ionosphere at latitudes near the geomagnetic poles and believed that a location in southern Tasmania would approximate the necessary conditions. With some cautious encouragement from me, this developed further after his return to Hawaii in January:

Out here the situation is gradually becoming clearer as the data accumulates. The major controlling factor seems to be turbulence in the very topmost parts of the ionosphere above the F₂ layer. The roughness of the bottom of this region manifests itself as Spread-F to the ionosphere sounders. All the data taken at the Kihei, Maui ionosphere station since its inception in 1944 has been analyzed for Spread-F. The results will appear in the June 1954 issue of the Journal of Geophysical Research. The way out of the difficulty is to raise the frequency gradually in steps of about 1-1/2 to 1. Since this can be done at any time, there is no particular urgency in regard to season or year. My lease on Kole Kole runs for two more years and can be renewed.

Recently I received letters from Pawsey and his theoretician Bracewell. They take a very dim view of the Tasmania venture and would like to wash their hands of it. Reading between the lines, it is evident they are wound up in other matters more interesting to themselves. The main difficulty seems to be that they can't find any experimental or theoretical evidence to bear upon the subject one way or the other. Bracewell thinks it might work at the geomagnetic pole. Magnetically, Hobart is only 14 degrees from the south magnetic pole, so this part seems a fair guess. Pawsey thinks it would be a good idea to analyze somebody else's data on atmospherics

and try to find a sidereal component. I think this is a good idea too, provided somebody has taken some data worth analyzing. As I explained to you, the phenomenon should only appear in a certain range of frequencies, at very limited places at auspicious times. Furthermore, the antenna used should be most susceptible to downcoming waves. All previous data has been taken using vertical antennas which have a null overhead and are predominantly sensitive to waves coming in at low angles. Pawsey also states that to the best of his knowledge no data on atmospherics have been taken anywhere in Australia.

To my way of thinking, this is precisely the kind of a situation which ought to be investigated because it seems nobody really knows anything concrete about it. Obviously the first step is to get some data worth analyzing. In spite of his discouraging letter, Pawsey invites me to come and visit them anyhow. This I intend to do and then find my way over to Tasmania. Bowen agreed to provide me with letters of introduction so I should make out all right. Bowen and Mills are going to stop here towards the end of February, at which time I will go over the whole thing with them in detail. Then I intend to leave here early in March. The return is uncertain, but I'll probably get back in October. Another set of observations can then be started at Kole Kole using higher frequencies as explained above.

Again, in May:

As you have probably guessed, my negotiations with the Australians broke down. Mills showed up as expected but Bowen found reasons to bypass this place. Sometimes it is possible to find out more from the men than from the bosses who hesitate to say what they really think. Mills' statement of the situation was that Bowen's outfit (Division of Radiophysics) expected to confine their activities to Sydney and did not wish to dissipate their resources in Tasmania. If I wanted to find something to do in Sydney, they would take care of all expenses, etc. If I insisted on the Tasmania business I would have to provide all the funds and equipment and make the arrangements and carry out the work. The most they could offer was laboratory facilities in Sydney.

Further inquiry developed that I stepped into a bad political situation. The Division of Radiophysics is one of several organizations which are competing for CSIRO funds. Two of the other institutions to which CSIRO dispenses money for scientific work are the Commonwealth

Observatory and the University of Tasmania. In view of all the above, it seemed more profitable to deal directly with the people in Tasmania. Therefore I opened up another contact in Hobart. Peculiarly enough, they have been doing ionospheric experiments which are closely related to what I propose. Enclosed is a letter from Ellis on the subject. According to his analysis the elevation of the hole in the ionosphere can be adjusted merely by changing the frequency. If this be true, it is a very useful property as large areas of the sky may be scanned without moving anything mechanical. You will also note that in Hobart there appear to be others than the hewers of wood and the drawers of water. At times I am convinced that the large majority of the people here are incapable of even these elementary tasks. It is really marvelous how, when sufficiently primed by federal funds, a backward area can take on the trappings of progress and still remain backward! In any case, I expect to follow up the Hobart negotiations and go down there next autumn for about eight months.

Mills and I spent a day going over my data. Oddly enough, he seemed to think my results to be quite fair. Perhaps this was just salve. In any case, his opinion was that the work should be continued at higher frequencies where the ionospheric effects were less. This was the same conclusion I had already reached. Last February I shut down on 30mc and for six weeks changed over to 50mc. Presently I have a month's observations in hand. The ionospheric difficulties are still present but much less so. At times the vagaries are absent altogether for limited periods at night and beautifully regular interference patterns are secured. The daytime results are still worthless, however. It is my intention to continue observations at 50mc for the next few months. When I am able to secure the necessary material, I expect to change over to 100mc. This will probably be in July or August. Thus some further improvement in results should be forthcoming before I take off for Australia.

I believe this brings you up to date on how matters stand out here. Please return the letter from Ellis when you have finished with it.

And in July:

Considerable water has gone over the dam since last May, so it is time to write again. Early in June I was able to engage the assistance for the summer of an above average Portuguese young fellow. He has turned out to be

a good operator and doesn't mind working atop the mountain in the early hours of the morning. I hope to be able to use his services until school starts in September.

Also in June I changed over to 100mc frequency. Together, we have amassed a considerable amount of data in the past month and a half. 100mc is substantially better than 50mc and some useful results can now be secured during the day. However, the faint sources must still be observed at night. While the sample of data is still rather small to form a judgment upon, it is clear that the results secured here are much less reliable than the results secured in Australia using the same technique and the same frequency of 100mc. Thus my suspicions of the past year seem confirmed that the tropics are not the place to do radio astronomy experiments. The cause of the situation is not totally clear, but is associated with a much greater depth and turbulence of the upper parts of the ionosphere near the equator.

My intentions are to leave the installation here intact and to return at a later date for observations at 200mc and 500mc. While such observations were not originally contemplated, it seems that they should be made in order to get a complete picture of the situation over the largest possible frequency range 20 to 500mc. These high frequency observations can be made at any time as the solar activity cycle will have no effect. Also the expense involved should be limited to the purchase of some additional electronic equipment and operations costs. No new construction will be necessary. Unless something startling is turned up the adventure at Kole Kole may then be considered closed.

The Australian adventure is gradually shaping up. Enclosed is a letter from Dr. Hogg (please return it). I will be working under their auspices at their field station near Hobart. As you can see, they appear quite interested and wish to be helpful. My plan is to leave here October 17 aboard the RMS Orion of the Orient line. The Orion arrives in Sydney on November 1. With me will go twelve cases of scientific apparatus which should include everything I need. Only poles will have to be set up and wires strung at Hobart. I expect to be making observations sometime in December. The best time for this kind of observations are the months March thru August. Thus adequate time should be available. . . .

Over the past two years a lot of meteorological data has been secured. I have engaged the services of a retired

professor at Maunaolu College to analyze this data. While it has nothing to do with radio astronomy, I am of the opinion that if data is worth taking it is worth organizing to see what has been caught. The results should be of scientific interest as no long run of data has ever been taken before at such a high altitude over the central Pacific Ocean. A couple of scientific papers will be forthcoming eventually on this subject. So far, I have written four subsidiary papers. When reprints are available, I will send copies to you. I believe it best to hold back the radio astronomy results until a complete picture can be secured. Also I want to consult with the Australians and compare our findings.

As you probably guessed, now that I am beginning to understand the phenomena available here at Kole Kole, I am beginning to lose interest in the situation and am anxious to get on with the next experiment.

The Hawaiian work was suspended in October on this note:

It is about time to cast off here. Enclosed are some reprints. The main results of the studies here are:

1. The earth's atmosphere is bulged out along the equator in the form of a ring or thick disk about 40° wide.
2. Some of the celestial radio sources are multiple. The one in Cassiopeia is probably a cluster.
3. There are daily oscillations in the pressure of the earth's atmosphere with periods of 24 and 8 hours (but not 6 hours) in addition to the well known one with a period of 12 hours. All three oscillations exhibit characteristic annual variations of amplitude and phase.
4. The diurnal cycle of humidity atop the mountain is exactly opposite in phase to the humidity cycle at sea level.

Aside from item 2, these findings have little to do with the original purpose of coming to Hawaii. The meteorological data will probably be published in Pacific Science by the University of Hawaii. I am taking all of my cosmic static chart recordings with me and expect to analyze them in detail at Hobart. On the basis of this analysis, I will decide whether or not it is worthwhile making more observations at Kole Kole and if so, just what. Presently, I am rather weary. The existing results will ultimately be published in more detail.

Because the proposed measurements in Tasmania are so different from those being made here, nearly all new electronic apparatus had to be built or purchased. Due to long delays in procurement, I was unable to finish my apparatus and about six weeks work remain at Hobart. Some of the things were impossible to secure in America, so I bought them in England. They are being shipped direct from London to Hobart. I expect to set up as simply as possible to see whether or not anything can be secured. If positive results are forthcoming, then more elaborate antenna systems may be erected. The general picture of what is possible in Tasmania should be available by July 1955 and I expect to leave there in August.

Now that the British have a large mirror, the idea of such a device emerges from the crackpot and attains respectability. When Mills was here he described to me the promotion at Cal. Tech. DuBridge wants to build a large mirror out of fibre glass because this material has a high ratio of strength to weight. This idea is a midconception because if enough material is provided and the structure properly proportioned to reduce the bending to a small value, then the structure will be overly strong. Actually the material should have a large ratio of modulus of elasticity to weight. Steel and aluminum are by far the best of the common materials.

Back in 1948 and 1949, I designed a mirror with the characteristics on the attached sheet. Unfortunately, the time was not right for its promotion. If you think you can sell it to someone, I'll be pleased to have you try. Berkner is a pretty effective kind of a fellow. Maybe he would like to undertake it. I believe that I showed you the model once. It and the engineering to support it are now in the attic at 212 W. Seminary Ave., Wheaton, Illinois.

A note of his passage through Sidney (November 18, 1954):

Considerable time I spent at CSIRO looking at their results and discussing them. In nearly all aspects their findings are what might be termed conventional. However, there is one source in Cygnus which rises far north. It acts differently than all the others. Scintillations are pronounced, absorption often great and it usually rises late. All these phenomena are similar to what I have observed in great profusion in Hawaii. They merely wrote these off as anomalies. However, it seems apparent that the hypothetical ring around the earth actually is

of sufficient depth to extend several degrees above the northern horizon at 35° S latitude. Thus they were in fact observing Cygnus thru the ring. Apparently this ring is only 30° or 40° of latitude wide. By pure chance I happened to get located under one edge at Hawaii. If I had been close to the equator probably very little of anything would have been secured. Farther north in the states the ring would only manifest itself as anomalies near the southern horizon. The subject is worthy of study.

I also spent considerable time at IPS where they have an immense file of ionospheric data from all over to far in the past. I made sample counts of Spread-F at various places. It differs widely and in some way is related to geomagnetic latitude and longitude. I intend to follow this up at my next opportunity. Will write again.

And settling at Hobart (December 16, 1954):

I have permission to use the laboratories and shops of the University to complete my apparatus. The initial try will be made at the IPS field station near Cambridge. This place turned out to be not too good as an airport is only a mile away and a high voltage power line goes by one side of the property, plus quite a few dwelling houses within a half mile. Consequently, I have secured permission to use the far half of Seven Mile Beach. This place is about 15 miles east of Hobart in the wilderness. Access is by road to near end of beach and then out along beach. Thus I should have ample room ($3\frac{1}{2}$ miles) to put up any kind of antenna.

I find quite an interest in radio astronomy here. One of the lecturers in Electrical Engineering has just returned from a year in Cambridge, England, working with Ryle. Newstead is now setting up to do radio astronomy experiments here. He is quite a theoretician. Also Ellis who is in charge of the ionosphere station is starting some radio astronomy studies closely related to my ideas. We will work together. If this hole experiment can be made to function, big mirrors will be obsolete. The hole in the ionosphere is about $1^{\circ} \times .8^{\circ}$. Also the position of the hole can be moved up and down by changing the frequency. Thus one merely sets up an antenna to look in general direction of hole, adjusts frequency for right altitude and lets time pass. The hole sweeps over sky with ionosphere as screen to exclude everything else. Simple, if it works! We will know in a few months.

In March, further indication of impact on Hobart:

Many thanks for your recent letter. I have been so busy with my problems here that I have not been able to worry properly about what is going on in America.

I secured possession of my boxes two days before Christmas. Most of the following two months were used up in getting the apparatus in working order. We made some measurements late in February and early March which seemed encouraging. Then a lot of disturbances started on the power line near our place at Cambridge. About ten days were spent with the fellows of the Wireless Branch of the Post Office Department trying to find the trouble. We never did locate the source but were able to show that the disturbance came in from a long distance and ended up on the Cambridge branch of the line. Last week I got the Hydro Electric Commission to pull down some of this high tension line and the trouble seems to have gone away. We may still have to pull down the low tension, but that remains to be seen. In any case, I am about ready to make some more observations.

The proposed operation at Seven Mile Beach was given up because it would take too long to set up poles and get organized. However, the offer is still open and we can go out there later for a more pretentious installation if our Cambridge results seem to warrant it.

After I got your letter I started to draw up a memorandum on mirror design. Then on the 19th I received a letter from Emberson stating that a meeting was to be held on the 25th. Unfortunately it was not possible to get all this material in order on that short a notice. Consequently, I am sending it to you. When you have gone over it, you may send it on to him for consideration at some future meeting. This is about the best I can do for the boys from here. They will have to struggle with all the details at close hand.

Will write again when I am sure of my findings. Enclosed is a reprint from Nature.

And in June, indication of developing results which exceeded his expectations, followed in July by this letter:

Many thanks for your letter of June 27th and enclosed large mirror specification. Quite obviously there are no takers as that spec is merely pleasant thoughts. Before

any bidders will appear someone will have to figure out how many pieces of iron and how long and how big, where the holes go, plus provide an index of how the puzzle goes together.

Observations here are about finished for this year. The ionosphere critical frequencies are rising fast and the celestial sources have moved forward to early evening so they are nearly out of range. Now Ellis and I have to collect our thoughts and try to understand what has been caught. We intend to send a short paper to the radio astronomy conference at Manchester late in August and write a synopsis for Nature.

An electromagnetic wave may have right hand or left hand circular polarization corresponding to the ordinary and extraordinary ray in the southern hemisphere. The direction of travel may be dominantly across or parallel to the earth's magnetic field corresponding to transverse or longitudinal propagation. Thus there are four possible modes: Ordinary Transverse O, Extraordinary Transverse X, Ordinary Longitudinal Z and Extraordinary Longitudinal L modes. Each of these modes may traverse the entire ionosphere if proper conditions exist. The O hole is the one all our success has been had with. It forms a thin slit along the magnetic meridian which opens each evening and closes at dawn. The Z hole is the small hole about a degree in diameter I referred to in a previous letter. Presently the most suitable frequencies fall in the broadcast band at night, so no results have been secured. The X hole is a rather wide ellipse perpendicular to the magnetic meridian. It depends upon ionosphere critical frequencies and strength of the earth's field. Not much has been done on this. However, the necessary conditions have been observed on old ionosphere records so it does exist. The L hole is a rather larger round hole probably existent down to very low frequencies where the earth's field is strong and nearly vertical. Fortunately, it is independent of critical frequencies, so it is not affected by the solar activity cycle. We have a few measurements but rather inconclusive as our antennas are too poor.

The solar activity cycle appears to be starting to rise, so the auspicious circumstances of the past few months may not be repeated for several years. However, the L mode is independent of solar activity, so it seems a suitable subject to continue these studies upon. Presently, I am investigating the possibility of getting very much larger antennas set up at Seven Mile Beach. If this can be done in time, I expect to return here next

year for additional studies. The O, X and Z holes will continue to be present. However, with a rising period of criticals it is unwise to start building anything because by the time the installation is completed the ionosphere conditions may be such as to make the installation inoperative. These holes can best be studied on a large scale during a period of decreasing solar activity. Thus it is well to pass them up for the next few years.

Enclosed is a financial statement. The second item is a reasonable estimate of part of my expenses. Living is not so cheap here as in Hawaii. If possible, I would appreciate an additional \$3,500, which should be ample funds to continue this year and perhaps provide a down payment on a more elaborate installation at Seven Mile Beach.

Word has arrived here about the small artificial moon project. I will be much interested to learn what the trajectory is near the equator as I have a hunch there is much more atmosphere out there than is commonly supposed. Enclosed are a few more reprints on this subject in case you wish to pass them around. Incidentally, it must have been a good one as I received several requests from Europe for copies.

A note in August provides an interesting sidelight:

I forgot to say a few things about the money. The first sum was sent direct to the bank. This turned out to be a bit of a tactical error due to inexperience.

Now that I've had a chance to find out how things are, I would suggest that the check be drawn to me. I will then be able to negotiate it at a marked advantage to both of us. I find that only fools deposit dollars in banks. Many other eager customers are available including the CSIRO itself!

A couple of paragraphs from a letter in September forecast the developments:

During the past couple of weeks I have gotten some positive results at 500kc (600 meters). This energy seems to be arriving via the extraordinary longitudinal mode which I have rechristened the Y mode as it is rather similar to the Z mode in operation. Now with the Y hole a proved thing these celestial radiations may be traced

down much farther in frequency. The lower frequency limit is unknown as there is no theory on this matter. Apparently the only limitation at present is the size of the antenna structures which may be constructed.

At these low frequencies the antenna height should be several hundred feet and lengths of a couple of thousand feet. Consequently it is not economically feasible to erect suitable man-made supports. However, this country abounds with hills and valleys. Thus, as next year's experiment I intend to swing some light cables across suitable ridges about a half-mile apart. Most of my present electronic apparatus may be used with some modifications.

Reber was persuaded to return here again at the end of 1955, writing as follows in November:

Monday I start on the long trip back to America. I have paid my respects to the Chancellor of the University and I will stop for a couple of days in Canberra to visit the Commonwealth Astronomer and thank him for his cooperation. The past year has been very successful and two good papers on the results have been written. One entitled "Celestial Radio Waves Near One Megacycle" has been sent to the Australian Journal of Physics. The other entitled "World Wide Spread F" has been sent to the Journal of Geophysical Research. Both have been accepted for publication.

All in all, the arrangement here has been very satisfactory except for the unending irritation related to matters of supply, even down to getting two dozen sheets of semi-log graph paper. The economic situation here is difficult to understand and I wouldn't have believed it if I hadn't lived a year here gaining first hand knowledge.

As you will recall, he gave us a short dissertation on his operations at the January, 1956 meeting. He visited several of the radio astronomy centers on this continent and headed back for Tasmania by the eastern route which enabled him to stop at several of the European centers.

From Hobart in April, the following line of thought developed (Reber had asked us to get some recording tape for one of his friends at the University):

The Teledeltos Tape arrived down here shortly after I returned and Mr. Newstead is very happy with it. Like many other things in Australia, it is nominally available through an agent. However, unless the agent is a good politician he cannot get any dollar credits, so he has no merchandise to sell. This situation is now even finding its way into items bought with Sterling Pounds. It seems the whole monetary situation is gradually decaying. This morning's paper quotes Commonwealth bonds of various issues just above 50%. These and various other things indicate that I should fold up here permanently as soon as I've completed the present group of experiments.

This year's experiments are to examine and try to detect for certain the Y hole in the ionosphere. This matter was discussed somewhat in my letters of 16th September and 31st July, 1955. The general scheme is to find a north-south valley about 1/2 to 3/4 mile wide and 400 to 600 feet deep. Then hang some long steel cables across the valley and install the electronic equipment in a shelter at the bottom of the valley. Nearly everything is either in hand or for delivery during the next six weeks. Measurements should begin late in June and I should have satisfied myself on this matter by the end of July. Then I plan to pack everything up and come back to American shores by boat.

Australia would be a much nicer country if it were easier to do business. Down here they have the British system of free enterprise which really is monopoly. Naturally, business operations are sluggish, expensive and inefficient. Since the people don't know anything else, their only recourse is to favor socialism. On some things this has been tried but the results are also bad. Aside from a very few who have resided in America, no one really understands why productivity is so low. All the above, in some respects, explains the basis for social unrest.

Enclosed are three copies of a reprint about some of my results in Hawaii. Recently I learned that another article of mine entitled "World Wide Spread F" will appear in the June issue of Journal of Geophysical Research.

Thanks again for past favors. I hope the new National Radio Astronomy facility is rapidly taking shape. Presently I have no particular plans after I leave here. However, we can better discuss the future when it is not so far away.

His letter of August, 15, 1956, brings us to the observation stage:

It pleases me to report that some results are now in hand. I started making observations about 5 P.M. on the 12th and the apparatus continues to run automatically since then. On the basis of the very limited evidence presently available it seems to be a success. However, things have taken so long that I'm now about 2 1/2 months behind schedule; thus I will be here for several more months until this whole set-up can be given a fair trial. If these results are what I think (or hope) it seems that this Y hole is the small round one about a degree across which I mentioned a year or more ago.

The weather has continued bad. Last night I folded up about midnight in a blizzard and finally got back to town about 1 A.M. Kempton is inland about 30 miles north of Hobart at an elevation of 800 feet. I park my Holden car on the edge of the road about a mile from my installation. The farmer has loaned me one of his tractors upon which I have installed an electric starting system and lights plus a big box to carry my stuff. The tractor is kept under a big Norfolk pine tree. I then drive the tractor down into the bottom of the valley and park it outside of my shed. A cord runs from shed and plugs into a receptacle on the tractor which has an oversize battery. This provides light at night. A good kerosene heater provides warmth. A kerosene stove may be used to cook hot soup or heat soldering irons, etc. Altogether, the set-up is about as good as I can organize without expending a huge amount of time and money.

The antennas are two east-west wires each 2200 feet long and 300 feet high above the center of the valley. They form the center parts of spans respectively 3660 feet long at south and 3920 feet long at north. These parallel wires are about 1000 feet apart in a north-south direction. For comparison the main span of the Hudson river bridge is 3500 feet. While this valley is rather inaccessible, the choice seems to be a good one as it is very quiet electrically. Wires are buried in the bottom of the valley. These connect the down leads and tuner boxes under

the center of the 2200 foot sections with the building which is in the middle of the whole affair. All this construction in a sea of mud is what took so long. This year is one of the very wettest on record. By June 30 quite a bit more than the normal annual rainfall had already come down and the wet season was just beginning. The creek at the bottom is swollen most of the time and it was necessary to lay down tiles and put in a dozen loads of rock to form a kind of bridge. Last night the water was running over the top of rocks a foot deep but the tractor got through OK. At one place we ploughed a trench about 400 feet long up a slight slope. The water seeped out of soil all along trench so that at bottom there was a stream 3" deep and 6" wide. Atop one hill 360 feet high we put down another trench six feet long and 2 feet deep to bury an anchor log. In a half hour there was nearly an inch of water in this trench. The hills must be saturated to the very summit.

No kangaroos are around and the rabbits are about extinct but quite a number of small animals such as bandicoots and devils inhabit the place. They are respectively similar to mongoose and skunk in appearance and size but don't have a scent and both have a pouch like a kangaroo. They are harmless. The birds are magpie (big black and white crow), plover and two varieties of parrots. These are green birds with red and yellow markings. They feed on clusters of red berries which are abundant. However, they don't peck at the berries like ordinary birds. The parrot stands on a branch with one foot. He then breaks off a bunch of berries with his bill and transfers these to his other foot. Holding the cluster of berries in his claw like a bunch of grapes he bites off one berry at a time and spits out the seed before going on to the next berry. The whole procedure is rather a human performance. Most parrots stand on left foot and hold berries in right claw. Thus they are right handers.

Recently I learned that Bok is taking over the job of Commonwealth Astronomer. He seems to be a good choice as he is being well received. There is to be a welcoming gathering and symposium on radio astronomy in Sydney during the first week in September which I expect to attend.

Some details of observations and a look to the future appear in the letter of October 19, 1956:

Thank you for your letter of the 29th of August. During the past two months a considerable amount of data has been secured and experience obtained. As usual Mother Nature is not simple in her manifestations. It is now apparent that there are several phenomena acting irregularly and independently and sometimes simultaneously.

During the day, radiation comes in from a large fuzzy patch perhaps 30 degrees in diameter centered about 40 degrees south of the zenith. This source is quite feeble, very steady and always there. The intensity may or may not change slightly with the seasons. The source may or may not be present at night. Its apparent temperature is on the order of 1000 degrees. Its cause and significance are unknown and is an unexpected discovery entirely out of the blue. During the day a few feeble and irregular atmospheric are normally present, but this radiation from the south is a characteristic thermal hiss quite different from atmospheric.

The first two hours after dawn nearly always show a distinct minimum when the apparent temperature drops to about 300 degrees. This is an absorption phenomena which wipes out the southern daytime source. The absorption also wipes out the atmospheric and, for an hour or so, things are exceedingly quiet. Its time for occurrence definitely follows the sun, but whether or not there are changes in magnitude or duration with the seasons remains to be seen. No similar effect occurs at sunset. Again this is an ad-hoc discovery of unknown cause and significance.

Shortly after sunset a nighttime source of radiation appears about 25 degrees north of the zenith. It is probably less than 5 degrees in diameter and very strong with an apparent temperature of 100,000 degrees or more. Because of this intense nighttime source it is not possible to determine whether or not the daytime southern one is still present using existing antennas. This northern source is the one I was looking for, so I was very happy to find something about where predicted. Last August this source showed a maximum intensity of 10^5 degrees about 10 P.M. Then a gradual smooth decline all night to 10^4 degrees before dawn. Now, two months later it is rather weaker all night with a broad minimum about 3 or 4 A.M. and then flat or a gentle rise to dawn. This change in shape I was also expecting. If my predictions are correct it indicates sidereal structure. This cannot yet be proved as it may be merely some kind of a seasonal effect.

During periods of great solar activity the sun throws out large quantities of charged particles which reach the earth in a day or so. They fall primarily on the polar regions. In severe cases they cause an absorption phenomenon known to radio communications as "polar black out." The 520kc energy from the nighttime source seems rather susceptible to this kind of thing, which is a further indication that the nighttime source is really of celestial origin. During a severe polar black out the northern source is extinguished and the general level falls to daytime values. Thus it appears the large southern source is still there at night. Unfortunately, I've never chanced to be out there in person to manipulate the direction finding gear when one of these polar black-outs occurred. With approaching summer, the nights are getting shorter and atmospheric conditions are becoming worse. However, it appears that useful data can be secured all year round.

Finally, there is the phenomenon of precipitation static as distinguished from atmospheric static. Precipitation static is a coarse frying noise associated with rain, snow and hail. There is not any thunder or lightning. This year continues to be an exceedingly wet one with a lot of storms sweeping in out of the southwest. At times precipitation static reaches fantastic levels even before a rain drop or snow flake comes down. These great occurrences are beyond anything I've ever encountered elsewhere. The field strength at 520kc are on the order of a volt per meter. This obliterates all broadcast stations. Fortunately, such affairs only happen a couple of times a month and last for only an hour or less. However, the lesser cats of the same breed are very frequent and ruin about half of the recordings. During the day they may only be heard for a few miles but at night they must have some effect if they occur anywhere in Tasmania. This precipitation static is really the limiting feature of the whole investigation. Last year was quite dry and the few records obtained then did not show any such difficulty. Fortunately, every rain storm does not make precipitation static. In any case, I've gotten the wireless branch of the PMG and the Weather Bureau interested so something may come out of this bother yet. After encountering a couple of great occurrences and noting the details, I'm convinced that precipitation static is the source of the radio waves from Jupiter discovered by the Carnegie fellows. You might mention this to Scherer when you see him.

Now for the future, which is quite vague. After having gotten this far it seems worthwhile to continue.

More data should be secured to elucidate these various matters. Also better data would be desirable, particularly in regard to the direction finding and measurement of angles. These can only be done in a crude way with two antennas. More would be better. Since the farmer seems to still be happy to have me around, I've decided to swing two more spans across the valley. Most of the material can be secured in a couple of months, so about the first of the year the quality of the data at 520kc should improve. Also the question arises about what kind of phenomena will be encountered at still lower frequencies. Fortunately my antennas have another natural resonance about 170kc. Consequently I am building further electronic apparatus to make measurements at this frequency. Between these two developments, it seems I'll be quite busy for the next few months.

Please remember me to your board of directors at the next round table meeting. Unfortunately, with all this going on here I probably won't be able to get back next January. However I'll keep you advised of progress. Enclosed are a few reprints of my last year's work and some fotos of my present installation.

The approach to a finale on the southern hemisphere is the most recent word:

The purpose of this letter is to ask you to send down here via air mail 25 sheets of Keuffel & Esser number 359-71 graph paper. This is 3 cycle semilog by 10 lines to the inch in orange on thin transparent paper. The ink and cable connectors arrived OK. Thanks very much.

I've enough data to work up now, but not enough graph paper. This experiment has been a success and I've found what I was looking for. There is a strong celestial component coming down through a hole about five degrees in diameter close to 25 degrees north of the zenith. This hole has two trap doors. The one at the bottom is "D" region absorption about 60 miles up and keeps the hole closed during the day. The trap door at the top is caused by an infinity in the propagation of a longitudinal wave. This trap door closes or opens depending upon whether or not more or less material surrounds the night side of the earth at a distance of some 1500 miles.

Also it develops that auroral particles are capable of creating Cherenkov radiation in the region just below the infinity. With the present increase of solar activity

there is more and more material surrounding the earth and more auroral particles. Thus the trap door is remaining closed an increasing amount of the time and the Cherenkov radiation is becoming more frequent. Obviously these kinds of experiments should be put off for a few years until the solar activity quiets down.

I intend to continue observations until the winter solstice and then fold up. The results will be written up before then and sent to the Journal of Geophysical Research. All my apparatus will be packed up nicely in good wooden cases and put in storage here for use at a future day. I expect to return by boat in early August and will stop in Hawaii to see what circumstances are there.

I will keep you advised of my progress. My future plans are quite open. If you know of something interesting to do, please pass on whatever turns up.

The financial record, up to the March, 1957 authorization for commitment of up to \$5,000 additional, shows \$27,550.78 charged to the Reserve for Grants during this nearly seven-year period.