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312 W. Seminary Ave.
Wheaton, Illinois

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Dear Mr. Langer:

I expected to answer your letter before this but work has not progressed as rapidly as hoped for.

Relative to the last paragraph of your letter, I am not connected with any laboratory at present. This enterprise is a purely private venture conducted at my home in Wheaton. Ever since Jansky publised his first paper in Dec. 1932 I have been turning the matter over in my mind. For the past year negotiations have been conducted toward getting someone to build the necessary apparatus. Everyone seemed afraid to take on the work or stated an exhorbitant price probably becuase of the peculiarity of the requirements or uncertain amount of labor involved. Finally the situation boiled down to doing it myself if were going to be done. Consequently I have obtained a leave of absence from the radio industry where I have been employed as engineer for the past several years to carry out this work.

I agree with you that high sensitivity is of utmost importance. There is however a limit to what can be done along this line of attack. After the gain of the first tube in an amplifier has been increased to cover shot effect and plate circuit noise the final limit to ampli-

fication is the thermal agitation noise of electricity in the first circuit. Only two means then are available to work on the problem. One is to reduce the absolute temperature of this circuit which includes the antenna coupled to it. The other is to increase the efficiency of the circuit by tuning and then by using parts of lower loss. The practical limit of power detectable at present is about 10^{-17} watt representing 1 microvolt across 10^{5} ohms.

This limiting amount of power is dependent on the following relationship.

$$P = 7.13 \cdot 10^{-49} \; v^3 \; T \; A \; \theta^2 \text{ watts}$$

where

v is resonant frequency in cycles per second

T is absolute temperature of radiator (black body radiation assumed)

A is area of collector in sq. cm.

θ is resolving power in circular degrees.

This assumes a flat top transmission shape of zero attenuation to $\pm 10\%$ v and infinite attenuation at all other frequencies. The response of tuned circuits involving various electrical parameters to black body radiation has been worked out but not tested. Since the resulting mathematics are very complex the above simplified version is adequate to represent an average single tuned circuit for the present.

After reading Jansky's works several times it seems remarkable he got anything at all using a band width of only 0.13%. To me this ap ears unnecessarily small and for the present a very useful improvement in sensitivity can be obtained merely by increasing the acceptance band.

The factor A should be made large.

The other points of interest center around θ. From a sensitivity point of view it should be large (part of Jansky's results are due to this fact). From an information point of view it should be small. Its value will be determined from the mechanical details of the collector.

For this work one fundamental change is necessary in the collector used by Jansky. The axis of rotation should be changed 90° so his R.A. motion becomes a motion in declination. It would be desirable to provide both but this hopelessly complicates the matter and the daily rotation of the earth will supply a satisfactory movement in R.A.

The collector may be either of two fundamental types. The first depends upon the phase interference of waves on wires. The second utilizes optical principles. The second only gives much hope of small resolving power. Which type is preferrable to use seems to depend upon frequency with about 1 meter wavelength as the dividing line. The directivity (square root of the resolving power) is proportional to the linear dimensions of the collector in wavelengths. At long wave lengths this makes for a very large structure. Unless the array (radio term for multi-wire antenna) consists of several curtains a large part of the energy of the oncoming wavefront may pass thru; in other words it will not be a sink of wavepower. A combination of these things make an efficient collector of 15 meter energy a really gigantic affair which is nearly impossible to put upon pivots. A couple of new long wire type

antennas, namely the V of RCA and the rhombic of Bell Tel. offer a compromise as they are relatively simple but the real way out of the dilemma is to use an idea described by C. C. Southworth, Page 1502 Sept. 1930 IRE. While it doesn't reduce the size of the array any it eliminates the necessity of turning it on a declination axis. For an array of end on coplaner horizontal dipoles the horizontal directivity (in R.A.) is dependent upon the number of end on dipoles and their spacing. Similarly the vertiole directivity (in declination) is dependent upon the number of tiers of dipoles used. Supplying each dipole with a second a quarter wavelength behind it forms couplets. This changes the acceptance of the array from bidirectional to unidirectional. Now advancing or retarding each successive tier of couplets by a certain small electrical angle will vary the direction of wave acceptance electrically and thereby eliminate the motion in declination. The above paper gives a very detailed exposition on directive antennas made up of stacked dipoles and the relative cost and performance in respect to size. Excepting the above mentioned V and rhombic types directive antennas are quite selective and do not perform well much off resonance. With the above ideas in mind it becomes appearant any thorough investigation of extraterrestrial radiation using wire type collectors will entail a tremendous outlay in time and money.

The first trials of optical collectors used a paraffin lens reinforced with a wooden lattice. This was given up due to excessive weight of an appreciable size lens. If

a light thin lenz is to be used the mounting will be heavy due to long focal length and conversely. Finally I decided to build a large sheet metal parabolic saucer. This work is underway now. It consists of an assembly something like a horizontal drum concrete mixer in that there are two large circular tracks turning on wheels mounted on top of concrete piers. The drum is cut axially thru the center and a sheet metal mirror mounted upon this plane. The four points which are terminus of the circular track support arms going to the focus. Arrangement is made to tilt to within 10° of the southern horizon. Thus all the celestial sphere from the north celestial pole to -38° declination can be covered. The saucer will be approximately 30 feet in diameter and have a 20 foot focal length. So far the piers have been set, the wooden and steel pieces for the frame completed and the steel wheels and bearings ordered. The cradle or frame should be erected in two weeks. The entire machine should be in operating shape about the 15th of August.

Whether or not the machine is adequate remains to be determined. From a physical point of view it seems large. At a wavelength of 10cm it is only equal to an apperture of .05mm in yellow light. On a wavelength basis it is equal to an array of 58000 dipoles.

Your letter stated some difficulty was encountered by extraneous noises. These will be reduced proportionately to the increase in directivity (assuming even distribution of noise in respect to direction). While the location here

is quite urban I don't dexpect much difficulty from noise as a recent development on the transmission of electromagnetic waves down tubes supplies a very efficient high pass filter. This particular device determines the maximum resolving power by the aperture of the tube, approximately one half wavelength. It is possible to check the polarization of the received energy by varying the orientation of the detecting dipole in the tube. My experiments will be conducted between one meter and one centimeter wavelength.

Returning to the longer waves and wire type collectors I would suggest you contact some of the commercial radio companies, A.T.&T., RCA and Mackay. They have quite formidable outlays of directive antennas for communication with South America at Bolinas, San Diego, Palo Alto, San Francisco, etc. Nothing like those facilities exist in the middle west. Possibly you can arrange to obtain a loan of the use of one suitable for this type of investigation. Not being too optomistic they might even help you fix up a phasing arrangement mentioned above.

I hope that this long monograph has not bored you completely and that it will give you some idea of my thoughts upon the subject.

Yours truly,

Grote Reber