Early calculations and discussions and correspondence with Ellis about low frequency observations. The experiments were performed at Cambridge during winter of 1955 and published in J.G.R. March 1956.

6-9-52

Low Frequency Studies

Below 2mc there seems very little possibility of measuring Cosmic Static because of the ionosphere. Even at vertical incidence the F_2 critical frequency practically never gets below 1mc. If lower frequencies are to be investigated it will be necessary to move the measuring equipment up above the F_2 layer either by means of a rocket or to the moon. One other possibility exists.

At very low frequencies, below 10kc the skin depth of the ionosphere may be so large that it exceeds the physical depth of the ionosphere. In this case the ionosphere becomes partially transparent and some Cosmic Static may be measured.

On page 34 of Terman is given for a conductor

$$\text{Skin depth (cm)} = \epsilon = 5{,}033\left(\frac{\rho}{\mu f}\right)^{1/2}$$

ϵ is depth in cm the current drops to 1/e of surface value
ρ is resistivity in ohms per cm cube.
f is frequency in cycles/sec
μ is permeability. $= 1$

On page 714 in Terman is given for ionosphere. without magnetic field.

$$\sigma = N \frac{e^2}{m} \frac{v}{\omega^2 + v^2} \frac{1}{.9 \times 10^{20}}$$

σ = conductivity in emu.
e = charge of electron in esu,
m = mass of electron in grams,
v = number of collisions an electron makes per second with gas molecules,
$\omega = 2\pi f$ where f is in cycles per second.
$e^2/m = 2.81 \cdot 10^{-13}$
N = electrons / cc (page 712)
Table 2 page 714 gives
$v = 8.5 \cdot 10^3$ at 200 km $v = 1.7 \cdot 10^4$ at 150 km
$v = 8.5 \cdot 10^2$ at 300 km $v = 4.3 \cdot 10^5$ at 100 km
$v = 1.2 \cdot 10^2$ at 400 km
$v = 2.8$ at 600 km
On page 25 we find 1 abohm (emu) = 10^{-9} ohm

On pages 39 + 40 of NBS circular # 462 we have from charts
$N = 10^{11}$ / cubic meter at 100 km These are ions
$N = 2 \cdot 10^{11}$ / " " " 150 km
$N = 4 \cdot 10^{11}$ / " " " 200 km
$N = 8 \cdot 10^{11}$ / " " " 300 km
$N = 16 \cdot 10^{11}$ / " " " 400 km (maximum)

On page 714 of Terman we have from table 2.

$N = 1.2 \cdot 10^{13}$ molecules/cu. cm at 100 km

$5 \cdot 10^{11}$	"	"	"	150 "
$1.8 \cdot 10^{11}$	"	"	"	200 "
$2.4 \cdot 10^{10}$	"	"	"	300 "
$3.6 \cdot 10^{9}$	"	"	"	400 "
$8.8 \cdot 10^{7}$	"	"	"	600 "

Above 300 km the gas is mostly ionized so number of electrons and molecules are substantially equal. Thus at 400 km we have $3.6 \cdot 10^{9}$/CC ions from this table and $1.6 \cdot 10^{6}$/cc from NBS graphs. This is a large discrepancy. The number of molecules/cu. meter given by Terman page 714 & NBS page 36 do not agree

Height in km	Molecules/cubic meter Terman	NBS
0	$2.7 \cdot 10^{25}$	$2.7 \cdot 10^{25}$
20	$1.9 \cdot 10^{24}$	$1.5 \cdot 10^{24}$
40	$8.6 \cdot 10^{22}$	$7.7 \cdot 10^{22}$
60	$4.2 \cdot 10^{21}$	$1.0 \cdot 10^{22}$
80	$2.1 \cdot 10^{20}$	9.6 & $9.6 \cdot 10^{20}$
100	$1.2 \cdot 10^{19}$	9.8 & $7.8 \cdot 10^{19}$
120	$4.0 \cdot 10^{18}$ approx	1.9 & $1.3 \cdot 10^{19}$

Terman states in text on page 714 that the maximum conductivity occurs at heights of 60 to 80 km in ionosphere. He means maximum losses.

The general shape of the N vs height curve is probably correct in NBS charts. There seems to be an error in the abscissa calibration. These values should be multiplied by

$$\frac{3.6\cdot 10^{9}\text{ (Terman at 400 km)}}{1.6\cdot 10^{6}\text{ (NBS charts at 400 km)}} = 2.3\cdot 10^{3}$$

Thus we have NBS adjusted

$N = 2.3\cdot 10^{8}$/cc at 100 km
$N = 4.6\cdot 10^{8}$/cc " 150 "
$N = 9.0\cdot 10^{8}$/cc " 200 "
$N = 1.8\cdot 10^{9}$/cc " 300 "
$N = 3.6\cdot 10^{9}$/cc " 400 "

The conductivity is determined by value of

$$\frac{N v}{\omega^2 + v^2}$$

If frequency = 10 kc, $\omega^2 = 3.9\cdot 10^{9}$

Height km	N/cc	v/sec	v^2	$\frac{Nv}{\omega^2+v^2}$	
100	$2.3\cdot 10^{8}$	$4.3\cdot 10^{5}$	$18\cdot 10^{10}$	$.54\cdot 10^{3}$	$= 5.4\cdot 10^{2}$
150	$4.6\cdot 10^{8}$	$1.7\cdot 10^{4}$	$2.9\cdot 10^{8}$	$.19\cdot 10^{4}$	$19\cdot 10^{2}$
200	$9\cdot 10^{8}$	$8.5\cdot 10^{3}$	$72\cdot 10^{6}$	$1.9\cdot 10^{3}$	$19\cdot 10^{2}$
300	$1.8\cdot 10^{9}$	$8.5\cdot 10^{2}$	$72\cdot 10^{4}$	$3.8\cdot 10^{2}$	$3.8\cdot 10^{2}$
400	$3.6\cdot 10^{9}$	$1.2\cdot 10^{2}$	$1.4\cdot 10^{4}$	$1.1\cdot 10^{2}$	$1.1\cdot 10^{2}$

Taking a maximum value of $1.9\cdot10^3 = \frac{N v}{\omega^2+v^2}$

$$\sigma = \frac{2.81\cdot10^{-13}\cdot1.9\cdot10^3}{9\cdot10^{20}} = .61\cdot10^{-30} \text{ emu}$$

$= 1.6\cdot10^{30}$ abohms / cm cube

$\rho = 1.6\cdot10^{21}$ ohms / cm cube

$$\text{Skin depth} = 5,033\left(\frac{1.6\cdot10^{21}}{10^4}\right)^{1/2} = 5\cdot10^3\cdot4\cdot10^4 = 2\cdot10^8 \text{ cm}$$

$$= 2\cdot10^6 \text{ meters} = 2\cdot10^3 \text{ km}$$

If this be true the thickness of the ionosphere is small compared to skin depth at 10 kc and it should be transparent vertically at this and lower frequencies. The difficulty is that there seems no good value for the electron density.

There is nothing about low frequencies in NBS circular #462. See second paragraph page 1 for statement.

At very low frequencies (Terman page 719) where the wavelength is large compared to distance a large change in index of refraction exists, there reflection occurs from the ionosphere. The situation is quite similar to a mirror (page 733), where the wave is turned back by eddy currents. If the thickness of the mirror is small and its conductivity poor, a considerable part of the wavefront will pass thru similar to the partial reflecting mirrors used in interferometers to split the light beam.

At 10 kc the wavelength is 30 km. This is comparable to the effective thickness of the bottom of the E layer, see page 714. Thus transmission is accomplished by reflection at this frequency, see page 733. Probably the ionosphere is partially transparent in the vertical direction at 10 kc. No data on vertical soundings is available. All communication takes place at relatively small angles by means of vertically polarized waves. Such waves cannot be launched vertically.

To measure 10 kc waves from vertical it will be necessary to use a very large loop or else some type of horizontal dipole. These may be hung between some large hills or mountains. Something hung across Grand Canyon might do.

6-16-52

References on Very Low Frequency Measures.

"Ionospheric Propagation of Very Low Frequencies"
Bracewell, etc. Proc. IEE, Part III, May 1951, p 221-236
This contains references to measures on lightning down to about 10kc and estimates to 3.5kc on page 222. Data on 16kc vertical reflection + absorption on page 226-227 According to figure 4 page 226 + summary (a) page 235 the reflection coefficient of the ionosphere is near unity at 16 mc. Absorption during the day reduces the conversion coefficient which is strength of wave at ground or apparent reflection coefficient. A few extra and substantiating comments are made on page 99 of March 1952 issue.

From the information outlined here the experiments show that the ionosphere will be a nearly perfect shield to Cosmic Static coming in at 16 kc. If the ionosphere becomes transparent due to skin effect the frequency is much less than 16 kc, perhaps 1 kc.

1-20-53
Wailuku, Maui
T.H.

Future Experiments
by Grote Reber

Cosmic Static should be followed down to the lowest possible frequencies primarily because of the cosmological implications as outlined in my letter of May 22nd 1952 to Schauer.

The limitation in this procedure will be the ionosphere. There is virtually no possibility of penetrating the ionosphere by means of low frequencies. See letter of October 6th 1952 by Helliwell to me. (See paragraph marked A) Thus the low frequency limit will be set by the minimum ionization on a winter night at solar activity minimum.

The lowest critical frequencies are in region of 1.5 mc. These however occur rarely even during the most auspicious circumstances above. Also it will be desirable to measure rays coming in from lower angles than the zenith. If it is desired to get down to an angle of ϕ degrees from zenith the operating frequency must be

$$f = f_c \sec \phi$$

If $\phi = 60°$, then $\sec \phi = 2.0$. Thus the lowest frequency will be at least twice fc.

Since criticals below 2 mc are quite rare even in winter and practically non existant in summer it will be necessary to choose a higher frequency. Near solar activity minimum the summer criticals on Maui were below 3.0 mc for 10% of time and below 4.0 mc for 50% of time during two hours (5 & 6 am) during 1952. This seems like the smallest length of time suitable for making observations profitable. By filling in with good hours during the equinoxes it should be possible to cover all around the sky. Thus the lowest operating frequency should be not less than two times 3 megacycles or 6 mc. At this frequency complete coverage of sky down to an angle of 60° from zenith of observer should be possible.

If the observer is located on the equator the sky could be covered from +60° to -60° declination. Thus the entire milkyway would be observable at 6 mc or higher frequency from one location.

To get to the very lowest possible frequency of 2 mc, only rays near the zenith will come in for a few hours during winter. Thus many observers at different latitudes will be needed. At northern latitudes the observer will be able to see a region of the sky about 6 to 10 hours ahead of sun when sun is between 1600 and 2000 RA. This region will be from 0600 to 1400 RA.

At southern latitudes the region will be 6 to 10 hours ahead of sun when sun is between 0400 and 0800 RA. This region will be from 1800 to 0200 RA.

At the equator there will be two regions as above where the north and south combine.

The total part of the sky thus visible will be, if $\phi = 20^0$ and $\sec \phi = 1.07$ or $f = 1.07 fc$.

Latitude of Observer.	Declination Range	R.A. Range.
$+60^0$	$+80^0$ to $+40^0$	0600-1400
$+40^0$	$+60^0$ to $+20^0$	0700-1300
$+20^0$	$+40^0$ to 0^0	0800-1200
0^0	$+20^0$ to -20^0	0900-1100
0^0	$+20^0$ to -20^0	2100 to 2300
-20^0	0^0 to -40^0	2000 to 0000
-40^0	-20^0 to -60^0	1900 to 0100
-60^0	-40^0 to -80^0	1800 to 0200

These regions cover both galactic poles and entirely avoid the milkyway. Thus such a set of observations would not be very interesting. The unsatisfactory arrangement is due to fact sun is in milkyway at the extremes of its distance from the ecliptic plus fact ionosphere is most transparent only during a few hours before sunrise in winter. Due to peculiar nature of circumstances such an experiment does not seem profitable irrespective of the expense.

(see second following paragraph marked B)

A To get to still lower frequencies there is a small possibility that an extraordinary ray of VLF cosmic static might come in along one of magnetic lines of earth to the earths polar region. Correspondence with Helliavell should be followed up to get some idea of attenuation of such a ray. The net result would not be very informative even if such a ray came in. This is because direction of ray would be determined by direction of earths field at observer and not by direction of source in space.

B Getting back to the zenith experiment, it should be possible to check the intensity of some point sources and thus carry their spectral distribution down to about 2.0 mc. Unfortunately all of the best sources lie along the milkyway and are thus out of range. Of the ones listed by Mills (Aust. Jnl Sci. Res. June 1952) only the ones in Virgo (+12°44' + RA 1228) and Triangulum (−60°45' RA 1610) seem at all possible and these are out of the above ranges of position. Thus only the faint sources are available and these would be difficult to locate in general background. Again this setup does not seem profitable as all the most interesting parts of the sky are excluded.

To make successful observations at still lower frequencies it will be necessary to get outside the earths atmosphere. However, even if it were possible to land on and observe from the Moon it is probable that not much improvement would be secured. This is because the moon probably has a small amount of atmosphere on the order of 10^{-5} that of the earth. It is much too small to be detectable by visual occultations but, seems to be present judging from Wells ionosphere observations of eclipse during September 1951, Thus the ionosphere on the moon will probably prevent any cosmic static at a frequency below 1 mc from reaching the surface of moon.

Apparently the only possibility in the foreseeable future is to measure cosmic static at the top of a rocket flight or much better, from a space station about 2000 miles above the earth. On such a space station all frequencies down to VLF could be measured. Furthermore, since there is no wind a very large antenna could be installed in form of a giant loop perhaps miles in extent.

Summing up.

A, at solar activity minimum, all the sky from +60° to -60° could be surveyed by an observer at the equator at 6 mc. The polar regions could be covered by other observers at higher latitudes if desired.

B, at solar activity minimum, parts of the sky around the galactic poles could be surveyed by several observers stationed at different latitudes at 2 mc. None of the milkyway nor any of the strong point sources would be available.

C, Near the earths magnetic poles some VLF cosmic static might leak in to the surface of the earth along lines of magnetic force down to perhaps a few kilocycles. The direction of arrival would be determined by direction of magnetic lines.

D. A space station above the ionosphere would be the best place to conduct low frequency cosmic static experiments.

E. The moon would be very little improvement over the earth as a base of operation because of the probable ionosphere about moon.

10-31-53

Australia, Winter Characteristic

Stations
near
Agonic Line
Watheroo,
Hobart

Stations
East of
Agonic Line
Townsville,
Christchurch, etc.

Stations
West of
Agonic line
(none)

12-21-53

Northern Hemisphere Sources.

Cygnus 20h RA., 40½° Dec.
Cassiopeia 23h RA, 58½° Dec

21st of Month	Source on Meridian Cyg.	Cas.
April	6a	9a
May	4a	7a
June	2a	5a
July	MN	3a
August	10p	1a
September	8p	11p

Declination	40½	58½
Field	.61	.61
Inclination	80	86
Latitude	50½	62½
Place	near Winnipeg	above Churchill

Hour	Summer Median foF2	
MN	2.9	3.9
2a	2.8	3.5
3a	2.7	3.5
4a	2.8	3.3
6a	3.5	3.9

Northern Hemisphere Sources

12-21-53

March 21st	00h on meridian at noon		
	23h on " "	11a	Cas
	20h " " "	8a	Cyg
Apr 21st	00h on " "	10a	
	23 " " "	9a	Cas
	20 " " "	6a	Cyg
June 21st	00h " " "	6a	
	23 " "	5a	Cas
	20 " "	2a	Cyg
Aug 21st	00 " " "	2a	
	23 " " "	1a	Cas
	20 " " "	10p	Cyg
Sept 21st	00h " " "	MN	
	23h " " "	11p	Cas
	20 " " "	8p	Cyg.

21st of Month	Cyg. on Meridian	Cas. on Meridian
Apr	6a	9a
May	4a	7a
June	2a	5a
July	MN	3a
Aug	10p	1a
Sept	8p	11p

	Cyg.	Cas.
Declination	40½	58½
Inclination	80	86
Lat.	50½	62½
Place	near Winnipeg,	above Churchill.
Field	.61 gauss	.61

Hour +	Summer	Median fo F2
MN	2.9	3.9
2a	2.8	3.5
3a	2.7	3.5
4a	2.8	3.3
6a	3.5	3.9

Summer 1945 123 days

Time	18	19	21	00	03	05	06	07	08
Lost Observations	6	6	6	9	8	9	8	7	7
Total Observations	117	117	117	114	115	114	115	116	116
No f_oF_2 due to Blanket E	1	1	2	2	4	1	3	2	5
Interpolated f_oF_2									
Number of Values f_oF_2									
f_oF_2 < f 10% Time									
" 25% "									
" 50% "									
" 75% "									
" 90% "									
Number of Days Spread F is — absent	112	111	109	78	73	81	97	109	104
Faint	1	2	6	21	27	26	14	5	4
Moderate	1	0	0	5	3	1	0	0	2
Strong	0	0	0	8	8	5	1	0	0
Percent of Observations Spread F is — absent	98.2	98.2	94.8	69.7	65.8	71.7	86.6	95.6	93.7
Faint	0.9	1.8	5.2	18.7	24.3	23.0	12.5	4.4	3.6
Moderate	0.9	0	0	4.5	2.7	0.9	0	0	1.8
Strong	0	0	0	7.1	7.2	4.4	0.9	0	0
Percent Time Present	1.8	1.8	5.2	30.3	34.2	28.3	13.4	4.4	5.4
Number of Days Blanket E is — Moderate	0	0	0	0	0	0	0	0	0
Strong	1	1	2	2	4	1	3	2	5
Percent of Obs. Blanket E is — Moderate									
Strong									
Percent Time Present									

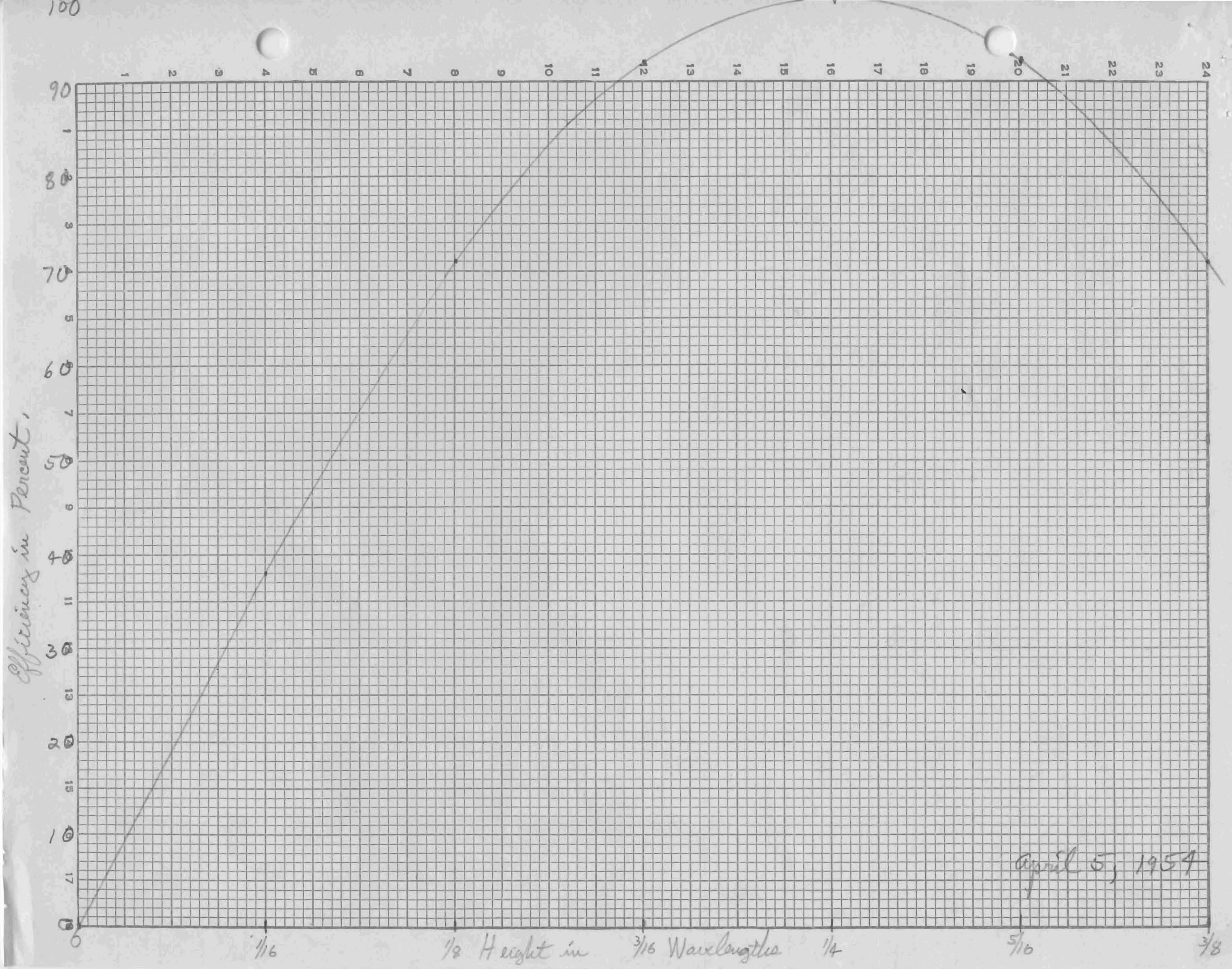
april 5, 1954

The efficiency increase linearly with height up to about 1/10 wavelength where the efficiency is 60%. Above this the increase is more gradual. Thus there seems to be no point in using a height greater than 1/10 λ. At 1/20 λ the efficiency is 30%. Below 1/20 λ the antenna may have a very large amount of reactance which will be difficult to tune out.

At Hobart the night time criticals frequently drop below 1 mc during winters near solar activity minimum. Thus it seems that an array designed for 2 mc should be operative over six or more hours many winter nights. During the day it could be used to measure the temperature of the ionosphere similar to Pawsey et. al experiments provided it was at an electrically quiet place far enough from Hobart. 2 mc also seems to be an unused frequency in Australia. Thus empty channels might be readily found.

At 2 mc the wavelength is 150 meters. A height of 1/10 wavelength is 15 meters or about 50 feet. This is a convenient height for poles. Each dipole may be a cage about 85% of λ/2 or 210 feet long. The pole spacing may be about λ/4 or 120 feet. If the array is 2 λ long east by west and 4 λ long north by south it will have dimensions 985 feet by 1970 feet. The beam width will be 30° E-W by 15° N-S. Using phase shifters the beam could be swung ± 40° from zenith. At latitude −43° this is from −3° to −83° which will cover most of southern sky.

It seems that if low frequency measures of Cosmic Static are ever to be made, they must be performed near solar activity minimum in Tasmania where the galactic center may be observed down to about 2 mc. Probably the thing should be given a whirl while the opportunity exists. No large capital layout should be made, partly because of expense, partly time and partly the speculative nature of the job.


100
90
80
70
60
50
40
30
20
10
0
Efficiency in Percent,
0
1/16
1/8 Height in
3/16 Wavelengths
1/4
5/16
3/8
April 5, 1954

sun at 06 on June 21st

06 on meridian at N

Cagey 58°E Cagey 40°E

$i = 86^0$ $\delta = 80^0$

lat 62 above Churchill lat. = 50 W

~~500~~ kc = 600 m = 1980 ft

$\lambda/4$ = 492 ft

2000 kc = $\lambda/4$ = 123 ft.

Dec 21st 00 Cp

06 MN

$225 + X = 4X$

$225 = 3X$ $\frac{225}{3} = 75$ pf min

$x = 225/3$

300 max.

pf

$L C \omega^2 = 1$ $L = \frac{1}{\omega^2 C} = \frac{1}{(6.28 \cdot .5 \cdot 10^6)^2 \cdot 300 \cdot 10}$

500

1000

Terman page 791

Horizontal ½ dipole

height	R_r	%
.05λ	8Ω	9
.1	20	22
.15	42	47
.2	70	78
.25	90	100

April 26 BTJ

Foster Fig 1

Two ½ dipoles spaced twice height

height		
0	0 0	0
.062λ	38	38
.125	70	70
.1875	.92	92
.250	1.00	1.00

50.

April 5, 1954

The results of Pawsey et. al. at 2 mc show that the night time noise level is atmospherics arriving from a vast area (p 269). The level is always high (10^4-10^7 degrees) and very variable (p 268). The man made noise has values from zero to 10^3 degrees (p. 268 + 270) during the day. It is completely lost in large atmospherics at night. These results were secured using a half wave horizontal dipole from 0.08λ to 0.18λ above ground (p 264). The observations were made at a place 40 miles from Sydney which is an industrial city of 1½ million population.

The same kind of night time conditions will be encountered at Hobart. Probably the man made noise will be no worse 11 miles from Hobart than that 40 miles from Sydney and thus be of no importance.

Obviously it will be folly to attempt to measure night time antenna temperatures much less than 10^6 degrees. Thus any schemes to detect the small amount of radiation coming thru a hole in the ionosphere by longitudinal propagation are impossible using elementary antennas. If the antenna were large enough so that the beam were same size as hole and properly steered, then the scheme might work. The array should have very small side lobes to keep out atmospherics.

According to Ellis analysis the hole phenomenon will exist even if the critical (f_o) is above the gyro (f_h) frequency. Thus the hole experiment could be conducted at any part of solar activity cycle. The only requirement is that the operating frequency (f) be less than f_h.

(over)

On the basis of the above discussion the hole experiment does not look feasible unless a very large array is used. It may be performed at any time.

An alternative experiment is to measure the Cosmic Static directly thru a transparent ionosphere at the lowest possible frequency. The array should be as large as practical and steerable. The cost of an array increases rapidly with height. The main advantage of height is greater sensitivity and ease of making the array broad band. Actually, sensitivity is of no importance as the received signals will be very large.

R.M. Foster gives information on the relative sensitivity versus height in his figure 1. The last line is the equivalent of a horizontal dipole over a perfect earth. These figures may be bisected by a vertical line thru the center representing the earth. The right hand side will now be the directivity pattern with vertical to the right. The height above earth of the horizontal dipole will be one half the spacing listed at top of respective column. The diagrams are in amplitude which corresponds to voltage. On this basis we have

Height	Efficiency	DB loss at vertical
$7/16\lambda$	.38	8.4
$3/8\lambda$	.71	3.0
$5/16\lambda$	.92	0.7
$1/4\lambda$	1.00	0.0
$3/16\lambda$	.92	0.7
$1/8\lambda$	.71	3.0
$1/16\lambda$	.38	8.4

april 6, 1954

Southern Sky Available During Winter Night

Hobart, Tasmania 43° South

0000 RA is on meridian at noon March 21st.

Time on Meridian

	Date	Dec -63°, RA 1300 Plane of Galaxy Zenith Distance 20°S	Dec -52°, RA 1600 Plane of Galaxy Zenith Distance 9°S	Dec -41°, RA 1700 Plane of Galaxy Zenith Distance 2°N	Dec -20°, RA 1800 Plane of Galaxy Zenith Distance 23°N	Dec +8°, RA 1900 Plane of Galaxy Zenith Distance 51°N	Dec +33° RA 2000 Plane of Galaxy Zenith Distance 76°N
	Jan 21st	0500	0800	0900	1000	1100	1200
	Feb 21st	0300	0600	0700	0800	0900	1000
Best Months	March 21st	0100	0400 ✓	0500 ✓	0600	0700	0800
	April 21st	2300	0200 ✓	0300 ✓	0400 ✓	0500 ✓	0600 ✓
	May 21st	2100 ✓	0000 ✓	0100 ✓	0200 ✓	0300 ✓	0400 ✓
	June 21st	1900	2200 ✓	2300 ✓	0000 ✓	0100 ✓	0200 ✓
	July 21st	1700	2000	2100 ✓	2200 ✓	2300 ✓	0000 ✓
	Aug. 21st	1500	1800	1900	2000	2100	2200
	Sept. 21st	1300	1600	1700	1800	1900	2000
	Oct. 21st	1100	1400	1500	1600	1700	1800
	Nov. 21st	0900	1200	1300	1400	1500	1600
	Dec. 21st	0700	1000	1100	1200	1300	1400

✓ = Useful Times, that is Median fo F_2 < 2.5 mc

Assume the beam can be swung N and S from zenith a distance equal to the sec^{-1} 1.5. This is 48°. Thus the sky available from 43° south is from Dec +5° down to one degree below the south pole. It is also assumed the useful times are limited to those hours when the median f_oF_2 ≤ 2.5 mc on 1952 basis.

Date	Local Time	RA span	Observing Hours
Feb 21st	0400 - 0500	1400 - 1500	2
March 21st	0300 - 0500	1500 - 1700	3
April 21st	0300 - 0600	1700 - 2000	4
May 21st	2200 - 0600	1400 - 2200	9
June 21st	2100 - 0700	1500 - 0100	11
July 21st	2100 - 0600	1700 - 0200	10
Aug 21st	0100 - 0700	2300 - 0500	7.
Sept 21st	0400 - 0500	0400 - 0500	2

Using the optimum place in the southern hemisphere the sky will be limited to δ +5° to δ -90° and RA 1400 to RA 0500. The best months are May, June and July. The best regions are 1600 to 0100. Fortunately this covers the galactic center and an appreciable region thereabout. The center (δ -25°, RA 1750) should be observable four months April 21st thru July 21st.

16-12-54

Diagonal of lot 870'

Poles 187' apart

Diagonal of lot 30 N of E & S of W

by actual measure of lot at Cambridge