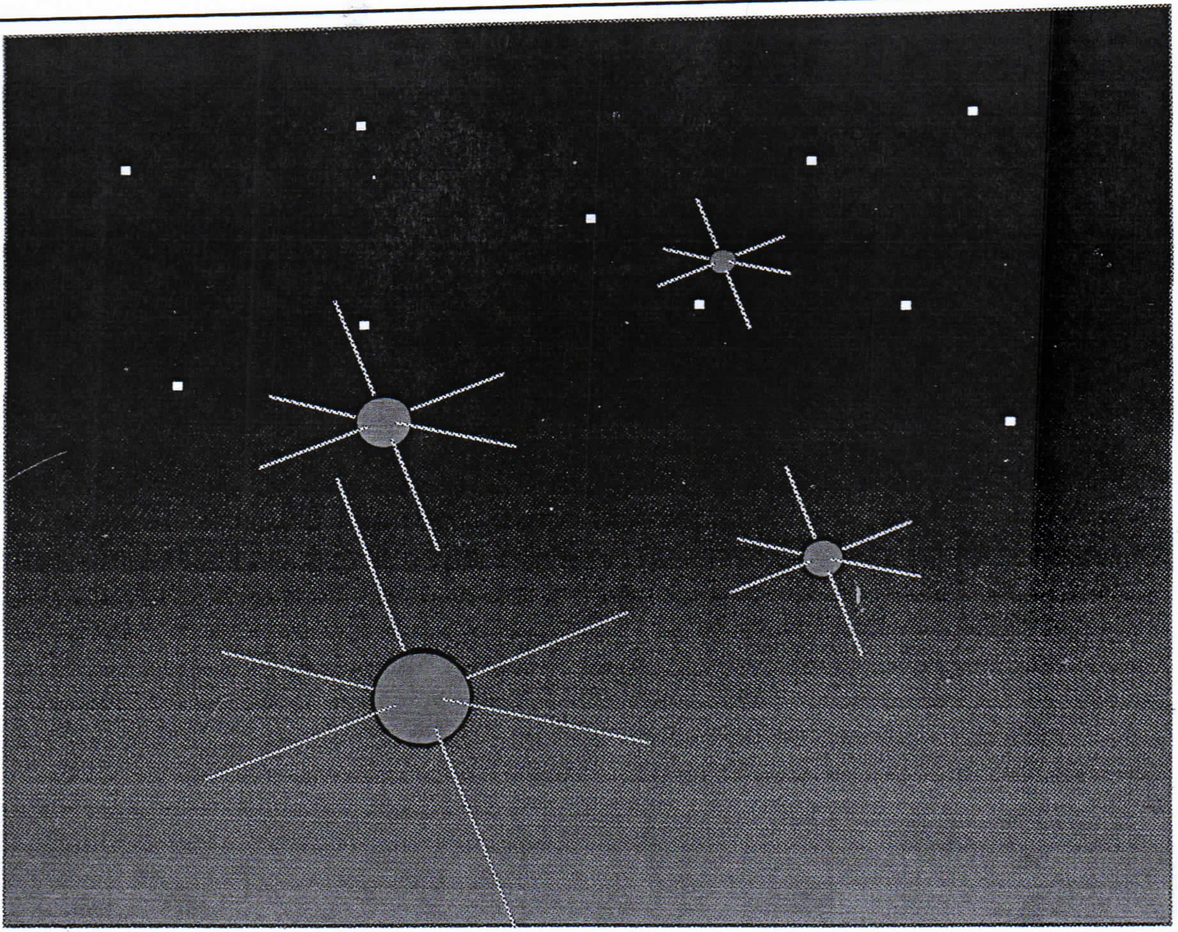


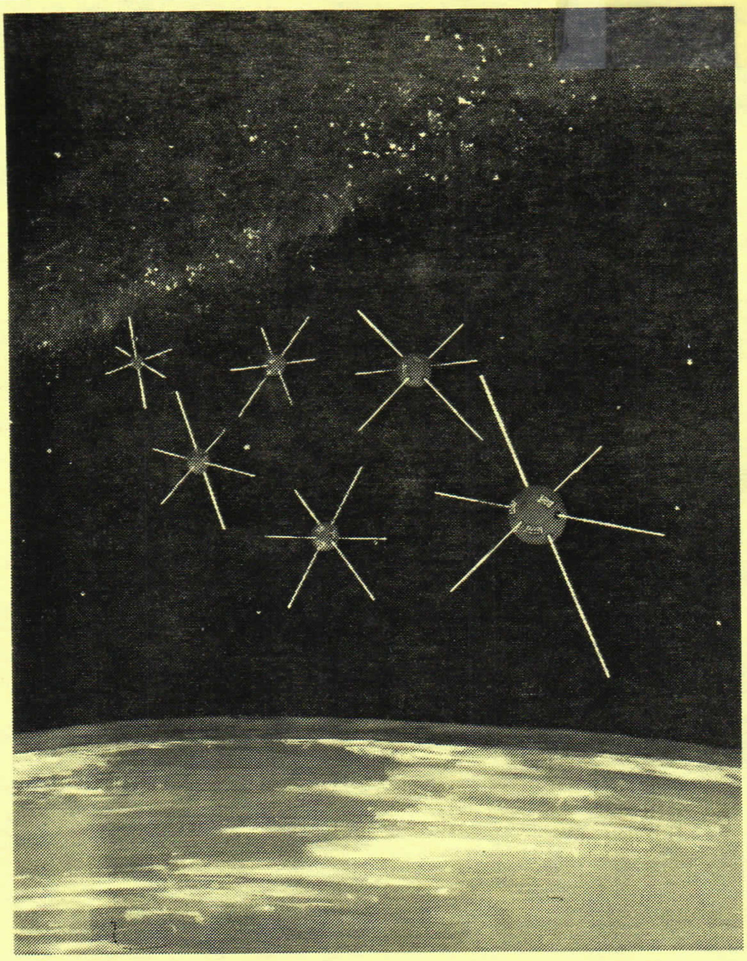
LOW FREQUENCY ASTROPHYSICS FROM SPACE

A Workshop held to explore the scientific motivations for placing a high resolution, low frequency (1-30 MHz) synthesis array outside of the Earth's ionosphere.

8-9 January 1990 Crystal City, Virginia

Sponsored by NRL in collaboration with GSFC and JPL

PLEASE POST



***Workshop Announcement
and
Call for Papers***

Low Frequency (1-30 MHz) Astrophysics From Space

The lowest radio astronomy frequencies are inaccessible from the surface of the Earth. They represent a regime where high resolution, high sensitivity observations from space can open a new window for astronomy and bring it to a fundamental physical limit. Still lower frequencies cannot be observed from within our Galaxy due to interstellar absorption. Extending observations down to this last limit will thus provide great scientific rewards in many areas of astrophysics. Also, exciting serendipitous discoveries have always accompanied the opening of new realms of frequency, resolution and sensitivity in astronomy.

Goals and Approaches

The possibility for placing long baseline, low frequency interferometric arrays in near Earth orbit or on the Moon has developed a new interest in the scientific problems needing exploration with high resolution at radio frequencies near and below the ionospheric cutoff (1-30 MHz). However, as a component of further development of the program, it is necessary to elaborate the scientific goals and targets of such telescopes in more detail. To explore this, the workshop will bring together scientists from the many relevant areas of astrophysics to discuss applications in

Interstellar and Interplanetary Scattering, Pulsars and the ISM
Galactic and Extragalactic Surveying, Cosmic Rays
Spectral Lines from the Largest Atoms, SNRs and HII regions
The Sun and the Solar System, Fossil Galaxies and Old Electron Populations
Quasars and the Structure of Radio Galaxies, Source Counts and Cosmology
Coherent Emission Processes, Absorption Phenomena and Energy Loss Mechanisms

The workshop will also provide input to NASA and to the National Academy of Sciences' Astronomy and Astrophysics Survey Committee for the Decade 1990-2000 ("Bahcall Committee"). All presentations will be compiled into a published proceedings.

REGISTRATION & INFORMATION PACKET

When:	January 8-9, 1990 immediately preceding the winter AAS meeting
Where:	The AAS meeting center at the Marriot Crystal Gateway hotel in Crystal City, VA
Contact:	Namir Kassim or Kurt Weiler at NRL Code 4131, Washington, DC 20375-5000
E-Mail:	(span) 11334::KASSIM (internet) KASSIM%SSD0.DECNET@NRL.ARPA
Registration:	To help defray some of the meeting expenses there is a registration fee of $75.

Scientific Organizing Committee:

K. Weiler (chair)	(NRL, USA)
J. Baldwin	(MRAO, UK)
A. Bridle	(NRAO, USA)
J. Burns	(NMSU, USA)
G. Dulk	(UCO, USA)
W. Erickson	(U. of Tasmania, AUS)
K. Johnston	(NRL, USA)
M. Longair	(ROE, UK)
V. Radhakrishnan	(Raman Inst., India)
B. Rickett	(UCSD, USA)
G. Swarup	(TIFR, India)
J. Taylor	(Princeton, USA)

Local Organizing Committee:

N. Kassim (chair)	202-767-0668	(NRL)
M. Claussen	203-767-0670	(NRL)
A. Fey	203-767-2377	(NRL)
R. Fiedler	202-767-0644	(NRL)
M. Kaftan-Kassim	202-767-0668	(NRL)
K. Weiler	202-767-0292	(NRL)
B. Dennison	703-961-5186	(VPI)
D. Jones	818-354-7774	(JPL)
M. Desch	301-286-8222	(GSFC)
M. Kaiser	301-286-5461	(GSFC)

LFAS Workshop Schedule

Day 1

Time	Activity/Talk	Speaker	Title
0730	COFFEE AND ROLLS AVAILABLE		
0845	Opening Remarks	K. Weiler	
0900	Introduction	K. Johnston	"The Need to go to Space"

Session I: Instruments I

Chair: Ken Johnston

Time	Activity/Talk	Speaker	Title
0930	Invited	M. Kaiser	"The Radio Astronomy Explorer Mission"
1000	Invited	K. Weiler	"A Low Frequency Space Array"
1030	Invited	J. Burns	"The Lunar Observer Radio Astronomy Experiment (LORAE)"
1100	COFFEE		

Session II: Instruments II

Chair: Dayton Jones

Time	Activity/Talk	Speaker	Title
1115	Invited	H. Smith	"Very Low Frequency Interferometry from the Moon"
1145	Contributed	T. Kuiper	"A Simple Low-cost Array on the Lunar Near-side for the Early Lunar Expeditions"
1200	Contributed	J. Basart	"A Very Low Frequency Array for the Lunar Far-side"
1215	Read	A. Bridle	Papers by G. Reber and W.C. Erickson
1245	Invited	D. Jones	"Tradeoffs Between Science and Array Complexity"
1315	Contributed	T. Gergely	"Status of Low Frequency Radio Astronomical Allocations at the 92nd World Astronomical Radio Conference"
1330	LUNCH		

LFAS Schedule: Day 1 (continued)

Time	Activity/Talk	Speaker	Title
Session III: Solar System			
Chair: George Dulk			
2:00 1430	Invited	G. Dulk	"Solar Radio Astronomy at Kilometer Wavelengths"
1500	Contributed	N. Gopalswamy	"Some Problems in Low Frequency Solar Radio Physics"
1515	Invited	M. Desch	"The Planetary Sources: Signal and Noise"
1545	Contributed	B. Jackson	"Broad-band Kilometric Images of TKR from ISEE-3"
1600	Contributed	B. Dennison	"Low Frequency Propagation in the Earth's Magnetosphere"
1615	Contributed	T. Carr	"Low Frequency Monitoring of Jupiter from Earth Orbit"
1630	COFFEE BREAK		
Session IV: SNe, SNRs, and Ionized Gas in the ISM			
Chair: Ron Reynolds			
1645	Invited	R. Reynolds	"The Electron Temperature and Emission Measure of Ionized Hydrogen in the Diffuse ISM: Free-Free Absorption at High Galactic Latitudes"
1715	Contributed	N. Kassim	"HII Regions in Absorption at Low Frequencies: What do they tell us?"
1730	Invited	R. Chevalier	"Low Frequency Radio Emission from SNe and SNRs"
1800	Invited	H. Payne	"Low Frequency Spectral Lines from the Cold ISM"
1830	END		
1830	Cocktails		
1900	Banquet	V. Radhakrishnan	"Some Random Thoughts"

Salon C Grand Ballroom

Sheraton Ballroom A

LFAS Schedule: Day 2

Time	Activity/Talk	Speaker	Title
0730	COFFEE AND ROLLS AVAILABLE		

Session V: Pulsars, Scattering in the ISM, and Galactic Surveying

Chair: John Baldwin

Time	Activity/Talk	Speaker	Title
NB 0815	Invited	S. Spangler	"Low Frequency Angular Broadening and Diffuse Interstellar Plasma Turbulence"
0845	Contributed	Y. Gupta	"Refractive Interstellar Scintillation at Low Frequencies"
0900	Invited	J. Cordes	"Low Frequency Interstellar Scattering and Pulsar Observations"
0930	Invited	T. Phillips	"Recent Low Frequency Observations of Pulsars from the Arecibo Observatory"
1000	Invited	J. Baldwin	"Low Frequency Galactic Surveying"
1030	Invited	N. Rees	"The New Cambridge 38 MHz Radio Survey: 1 Steradian at 4 arcmin resolution and sub-Jansky Sensitivity"
1100	COFFEE		

Session VI: Topics in Extragalactic Low Frequency Astrophysics I

Chair: Malcolm Longair

Time	Activity/Talk	Speaker	Title
1115	Invited	M. Longair	"Cosmic Rays and the Galactic Background Radiation"
1145	Invited	W. Webber	"Cosmic Rays in the Galaxy and their Implications for Very Low Frequency Radio Astronomy"
1215	Invited	W. Kundt	"Known and Expected Sources of Low Frequency Radiation"
1245	LUNCH		

LFAS Schedule: Day 2 (continued)

Time	Activity/Talk	Speaker	Title

Session VII: Extragalactic Low Frequency Astrophysics II

Chair: Phil Kronberg

Time	Activity/Talk	Speaker	Title
1345	Invited	D. Harris	"Extrapolating Electron Spectra to the Lowest Energies"
1415	Invited	P. Kronberg	"Radio Emission from Intergalactic Gas and the Implications for Low Frequency Radio Astronomy"
1445	Invited	T. Jones	"In and Around Radio Lobes at Low Frequencies"
1515	Contributed	K. Lind	"The Comparison of Numerical Simulations to Radio Maps of Jets"
1530	COFFEE		

Session VIII: SUMMARY SESSION

1600 Panel Discussion

Chair: Kurt Weiler

Panel Members:
J. Baldwin
A. Bridle
J. Burns
R. Chevalier
J. Cordes
G. Dulk
K. Johnston
D. Jones
P. Kronberg
M. Longair
V. Radhakrishnan
H. Smith

1700 END OF MEETING

6/12/89

Greetings Bill:

Thanks for your note of 1st. Yes, I agree that travelling 11,000 miles to give a 10 minute talk verges on the ridiculous. Send both our papers to Alan Bridle. I don't think these space fellows are going to get anywhere during our time. The vast size of antennas is just not commensurate with the technology.

Grote

Grote Reber
Bothwell 7030

Hectometer and Kilometer Radio Astronomy

Grote Reber

The two main reasons for doing low frequency radio astronomy observations are:

A. It provides a technical challenge both as to equipment and to understanding and use of earths atmosphere.

B. The radio sky at hecto and kilometer waves is very different from radio sky at meter waves and down. Consider this first.

The radio sky is similar to optical day sky; bright all over with brightest near galactic poles. This <u>apparent</u> temperature rises from 6×10^4 degrees at 19.7 mhz (1a) to 10^7 degrees at 1.6 mhz (2) at south galactic pole. The nomenclature is bad. There is nothing out there with any such temperature. The intensity merely appears that way if there were. The source of these radiations is probably encounters between free electrons and protons in intergalactic space (3). I call them free-free transitions. Others refer to it as bremsstrahlung or braking radiation. However the matter, it is clear the phenomena are not thermal.

According to thermodynamics people, the universe is running down. However the universe has been around a long time. It seems probable some phenomenon, not thermodynamic, is winding it up. This phenomenon is probably associated with above high intensity background. Such is probably electro-dynamic. I have discussed this in some detail (1b). During 1952 I built a small electrostatic motor. It ran nicely when supplied with energy having a continuum of periods. No non-linear devices such as rectifiers were used (1b). This is one aspect of cosmology which deserves more investigation. In fact, the whole expanding universe theme is peppered with difficulties (4). Such seem to say there is a fundamental error of interpretation of the evidence. The red-shifts have nothing to do with relative motion (5). In my opinion, the exciting frontier of future radio astronomy is in the nearly unexplored region of waves longer than 100 meters (3mhz).

Being an observer and technician, I am most interested in the equipment. I will concede that observations above the ionosphere are desirable. However the RAE-1 satellite (6) demonstrated this is no panacea. The ionosphere is leaky and does not shield satellite from man-made emissions. These are of great intensity and completely swamped the radio astronomy receivers. Accordingly, satellites circling the earth are out. The difficulty will probably extend as far as the moon, and beyond. To secure really quiet location to do low frequency radio astronomy, the observer must be on back of moon(7). Such may eventuate by middle of next century, long after my time.

The possibilities here on surface of earth have not been properly exploited, much less exhausted. During northern winter 1986/7, I made exploratory observations at 2.1 mhz using an old antenna array just west of Ottawa. The north galactic pole has same high intensity as south galactic pole. There is a 30% decrease of intensity when antenna beam crosses plane of Milkyway north of Cygnus. These results are reassuring. Then an ice storm brought most of antennas down. Solar activity was rising. Time had run out. Nothing more was done.

Operating an ionosonde is a popular scientific sport. It is being indulged in at scores of places around the earth. This data is analysed for maximum critical frequency. Such is important to predict high frequency radio communication. I've examined some of this data for low critical frequency, particularly Ottawa Canada, Boulder Colorado, and Wallops Virginia. During solar activity minimums of 1970s and 1980s, critical frequency drops below 2.0 mhz at Ottawa 5.5 times as often compared to Boulder and 7.1 times compared to Wallops. This confirms the Alouette satellite data. There is a marked valley in F region electron density near 45° latitude in south eastern Canada. The ionosondes at Winnipeg and StJohns have been shut down. I am requesting copies of hourly values for f_oF_2 for appropriate years. So far nothing has come to hand.

A similar valley crosses over Tasmania. It was used to map southern sky during solar minimum of mid 1960s with appropriate maps (3). These showed that the ionospheric hole at 2.1 mhz opened for at least a few hours every winter nite. The hole stayed closed all nite for about three weeks near summer solstice. Some winter nites the hole was open 10 and even 12 hours. Beautiful clear charts showing great detail were secured. The absorption in ionosphere was sensibly zero. On clear nites the traces would reproduce within accuracy of measurement, about two percent. The single beam could be set anywhere in North-Zenith-South plane from celestial equator to south celestial pole. A map of southern sky was developed (3). The antennas were broadbanded from 1850 to 2450 khz. By modern standards the receiver is archaic, using 1.4 volt tubes. However the battery supply provided excellent gain stability.

The main equipment deficiency was having only one beam. It could be changed in direction by a complex system of taps on feed lines. These took better part of half a day to change. When a good nite happened, only one trace was secured. To take advantage of these occasions, a picket fence of beams along the meridian from equator to pole should be available. Such would greatly speed up a sky survey. Accordingly a new set of receivers and fixed phase shifters have been constructed. These provide 25 beams. No outside or inside adjustments are needed.

Everything is fixed. The antenna looks at 25 different directions simultaneously. However this arrangement cannot be used for transmitting, as was possible with original setup. The main thing needed now is an antenna array of large dimensions, at an optimum place to be prepared for solar activity minimum of mid 1990s.

I've examined swinging the beam east/west. This can be done. In fact a single beam can be made to track an object in the sky at any place within some 50° of zenith. As mite be expected, the complexity goes up by leaps and bounds. All in all, I recommend more attention be paid to ground based installations. The satellite and moon stuff is very expensive, long drawn out, and of dubious performance. Just pie in the sky.

References.

1. "Hectometer Cosmic Static"; Grote Reber; IEEE Transactions on Military Electronics, July-October 1964, (a) fig 1, p 258; (b) p 262.

2. "A 1.6 mhz Survey of Galactic Background Radio Emission"; G.R.A. Ellis and M. Mendillo; Australian Jnl. Phys., Vol 40, 1987, p 707.

3. "Cosmic Static at 144 Meters Wavelength"; Grote Reber; Jnl. Franklin Inst., Jan 1968, vol 285, p 1-12.

4. "Early Moments of Our Universe"; Hubert Reeves; Jnl. Royal Astro. Soc. Canada, August 1989, vol 83, p 223-231.

5. "Intergalactic Plasma"; Grote Reber; IEEE Transactions on Plasma Science, December 1986, p 678-682.

6. ""Radio-Astronomy-Explorer-Satellite-1"; R.R.Weber, J.K.Alexander, R.G.Stone; Radio Science, 1971, vol. 6, p 1085

7. "Scientific Instrumentation of the Radio-Astronomy-Explorer-Satellite-2"; J.K.Alexander, M.L. Kaiser, J.C.Novaco, F.R.Grena, R.R.Weber; Astronomy and Astrophysics, 1975, vol 40, p 365-371.

20th November 1989

Grote Reber

Grote Reber
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From: EXOS%"munnari!physvax.utas.oz.au!BERICKSON@uunet.uu.net" 5-JAN-1990 01:12
To: ABRIDLE
Subj: RFI Paper

Return-path: (munnari!physvax.utas.oz.au!BERICKSON@uunet.UU.NET)
Received: from cv3 (NRAO.EDU) by cvax.CV.NRAO.EDU
id 0000151D002 ; Fri, 5 Jan 90 01:11:21 EDT
Return-Path: (munnari!physvax.utas.oz.au!BERICKSON@uunet.UU.NET)
Received: from uunet.uu.net by NRAO.EDU (3.2/DCW-2n)
id AA18273; Fri, 5 Jan 90 01:14:32 EST
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id AA07098; Fri, 5 Jan 90 01:13:12 -0500
Received: from munnari.oz.au by murtoa.cs.mu.OZ.AU (5.5)
id AA29164; Fri, 5 Jan 90 17:10:04 EST
(from BERICKSON@physvax.utas.oz for uunet!abridle@nrao.edu)
Received: from physvax.utas.oz (via ditmela) by munnari.oz.au with SunIII (5.61+IDA+MU)
id AA14198; Fri, 5 Jan 90 17:09:58 +1100
(from BERICKSON@physvax.utas.oz for abridle@nrao.edu)
Message-Id: (9001050609.14198@munnari.oz.au)
Received: by physvax; Fri, 5 Jan 90 16:33:42 east
Date: Fri, 5 Jan 90 16:33:42 east
To: abridle@nrao.edu
X-Vms-Mail-To: ACSNET%"abridle%nrao.edu@munnari.oz"

Dear Alan, 5 Jan 1990

I assume that you have received the papers that I sent you. If not, Namir has copies of them.

I have had a look at the ISEE-3 data and I'd like to make some small changes/additions to the "Solar and Jovian Emission", "Conclusions" and "Acknowledgemnts" sections of my paper. The modified sections follow.

Solar and Jovian Emission

Ionospheric shielding will be effective only on the sunlit side of the earth, where solar emission may interfere with observations. Type III solar bursts are the most common. These bursts have average durations at w1 MHz of about ten minutes; at w10 MHz their durations are a few minutes or less. They occur at a typical rate of several per hour at solar maximum and at average intervals of many hours at solar minimum. Weak bursts are a few decibels above the Galactic background on low gain antennas; strong bursts are 30-60 db above background.

Jovian bursts can be intense but they are short-lived, they occur during predictable periods, and come from a definite direction. They may be a nuisance but it should be possible to cope with any problems that they present.

NEW

I have examined the statistics of these bursts using ISEE-3 data spanning a period of solar maximum from launch and positioning at the inner libration point, L1, in September, 1978, until the spacecraft left L1 at the end of 1982. The spinning dipoles of the spacecraft provided a rudimentary direction-finding capability which indicated that almost all of the observed bursts came from the direction of the sun. At the three highest ISEE-3 frequencies, the percentages of the time when the radiometer outputs exceeded the Galactic background by 3, 6, and 10 db are given in Table 1.

TABLE 1

Frequency	1980 kHz	1000 kHz	513 kHz
3 db above background	10.4q0.8%	20.7q1.4%	43.1q2.2%
6 db above background	3.9q0.4%	9.5q0.9%	26.9q1.9%
10 db above background	1.6q0.2%	4.0q0.4%	13.7q1.2%

These data indicate, for example, that if a system were to operate at 1980 kHz, and all data were to be discarded when the level of solar emission exceeded the Galactic background by 3 db, it would be necessary to discard only about 10% of the data. Solar bursts have shorter durations as the frequency increases, so observations at frequencies above 1980 kHz should suffer from less data loss due to solar interference. It would be necessary to develop interference excision routines to remove the effects of solar emission near or below the Galactic Background level.

[Interference Levels Harmful .... section here]

Conclusions

In the 1 to 10 MHz range ionospheric effects make high-angular resolution (warc-minute) observations from the Earth's surface virtually impossible and it is necessary to go to space. At satellite altitudes near the Earth, terrestrial sources generate noise levels millions of times above the level of interference harmful to observations with a low-frequency space array. This interference is both narrow band and broad band noise. It is essentially impossible to filter or excise interference to such levels.

Near solar minimum, sensitive observations up to a few MHz may be possible from Earth orbit on the sunlit side of the Earth where the ionosphere should provide sufficient shielding from terrestrial interference. Near solar maximum it may be possible to work up to 10 MHz from the sunlit side, at least during selected periods. Interference due to solar bursts does not appear to be a particularly serious problem. Even near solar maximum, solar emission should seriously effect less than ten percent of the observations.

In the 10 to 30 MHz range sensitive observations from space near the Earth are probably impossible because ionospheric shielding will be ineffective. In this case, Earth-based observations utilizing terrain shielding are far more practical. The problems associated with ionospheric refraction in Earth-based observations can be attacked with modern self-calibration techniques that have proven to be highly effective at higher frequencies. This approach is far more feasible than an attempt to cope with the interference levels at satellite altitudes.

The interference levels at the near side of the Moon will be about a thousand times lower than those at typical satellite altitudes. This reduction in levels may make relatively sensitive observations possible if effective interference rejection techniques are developed.

The far side of the Moon appears to be the only location near the Earth that is sufficiently shielded from terrestrial interference to permit observations without interference rejection systems. In the distant future, when the severe communication and logistical problems associated with the lunar far side are solved, it is the most promising site for low-frequency radio astronomy.

Acknowledgements

This paper is based on a report prepared for the Jet Propulsion Laboratory (JPL Publication 88-30). I wish to acknowledge very helpful discussions with Mike Kaiser, Bob MacDowall, and Bob Stone at GSFC, with Dayton Jones, Tom Kuiper, Mike Mahoney, and Mike Janssen at JPL and with Hilary Cane. However, this is not to dilute my responsibility for all errors and omissions. The ISEE-3 data was provided to me by Bob Stone and Bob MacDowall of the Radio Astronomy Group at GSFC.

Thanks very much. Bill