Acta Astronautica Vol. 26, No. 3/4, pp. 201–204, 1992
Printed in Great Britain. All rights reserved

0094-5765/92 $5.00 + 0.00
Copyright © 1992 Pergamon Press Ltd

CONCLUSION OF THE SELECTED TARGET SEARCH AT THE NANÇAY OBSERVATORY†

FRANÇOIS BIRAUD
Observatoire de Meudon, 92195 Meudon, France
and
JILL TARTER
University of California Berkeley and The SETI Institute 2035 Landings Drive, Mountain View, CA 94043, U.S.A.

(*Received 29 November 1991*)

Abstract—In 1981 we began a SETI search on nearby solar type stars: in all some 344 stellar targets. Previous reports to IAF Congresses have presented work in progress. This paper presents the summary of all our observations which detected no narrowband signal from another technology but did detect several unsuspected sources of terrestrial technology and provided an excellent opportunity to evaluate the statistical nature of the observatory noise environment.

1. INTRODUCTION

A SETI program has been initiated in 1981 at the Nançay radiotelescope. It has now been completed, after six runs of observations. We were searching for narrowband signals by taking adjacent 1024 channel spectra with a digital 3-bit autocorrelator. We will give here a summary of all the observations. The net result is negative, as no signal with the expected properties could be found. Nevertheless, we investigated several instrumental problems of interest not only for the Nançay program, but for such searches in general.

A first one is the estimation of the level expected in a given channel. Some results have already been published [1]. A potential "alarm" is obtained when the observed power in a channel is well above the expected level, the probability of such deviation coming from noise along being very small (10^{-6} to 10^{-7}). In this range the first and second derivatives of the noise distribution are very large and we showed that the estimate of the expected level has to be very accurate. We chose to fit a high order (25) harmonic baseline to the spectrum. Although apparently the best in our case, this technique is not quite satisfactory, and another of its drawbacks is analysed below.

The large amount of data collected and stored (some 3×10^7 spectral elements) provided a good opportunity to analyse the noise statistics down to low levels of probability. We give below the results and discuss some related problems.

Finally, we detected terrestrial interferences showing unexpected properties. We could not spot their origin, but they are likely, if they are present everywhere, to be a major source of false alarms in SETI searches.

2. GAIN LOSS DUE TO THE REDUCTION TECHNIQUE

For each N points spectrum y ($N = 1024$) the expected baseline $\langle y \rangle$ is the nth order ($n = 25$) harmonic fit to the data. This is computed readily as the Fourier Transform of the first n points of the autocorrelation function. This is equivalent to smoothing with a sinc function. We then look for points where $y/\langle y \rangle$ exceeds a given threshold (namely 1.14, which corresponds to 5.3σ for the actual value of $B\tau = 1465$).

Let us assume that the spectrum is a constant level with a superimposed monochromatic signal of strength s. In the convolution with the smoothing function, the signal appears in the baseline as a negative going sinc function, reducing the observed amplitude. Figure 1 shows qualitatively this effect. It is easy to show that the "gain" is reduced to

$$(1 - n/N)/[1 + s(n/N)].$$

Even for small values of s, the gain loss amounts to $n/N = 2.44\%$. This might be considered as negligible, but corresponds in fact, near a threshold of 1.14 ($s = 0.14$) to a factor of 2.1 on the probability distribution of the noise. This effect stresses again how critical the estimation of $\langle y \rangle$ is.

3. SENSITIVITY TO WIDE BAND SIGNALS

Although our search was for monochromatic signals, i.e. narrower than our frequency resolution of 50 Hz, it is of interest to study the sensitivity achieved on signals spread over several channels. The

---

†Paper IAA-88-542 presented at the *39th Congress of the International Astronautical Federation*, Bangalore, India, 8–15 October (1988).

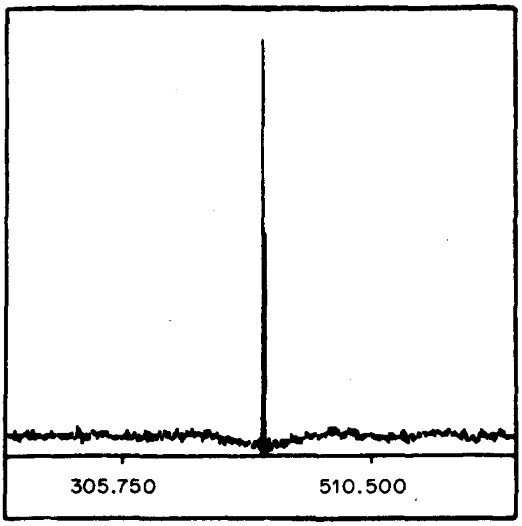

Fig. 1. Effect of the baseline subtraction. The scale is channel numbers.

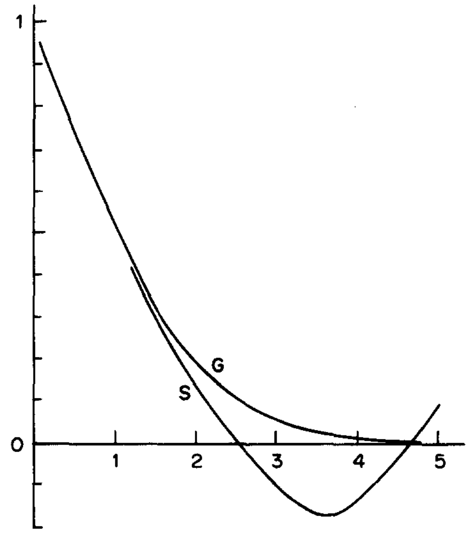

Fig. 2. Normalized sensitivity to wideband signals, as a function of the bandwidth in kHz. The two curves are for gaussian (G) and square (S) bandwidths.

procedure used to define the baseline (see above) tends to smooth them out.

The computation has been made for signals of gaussian or square spectra of various width. The results are given in Fig. 2 (the negative gain for a square spectrum means that the edges can be detected as negative going peaks). As could be expected, the sensitivity remains high to signals less than 1 kHz wide, which corresponds to 20 channels, as the smoothing is made on $n = 25$ channels.

Many OH masers exhibit lines of this width or less and could have been detected. Our search did not find any, from the 344 directions studied.

4. AUTOCORRELATOR SENSITIVITY TO MONOCHROMATIC SIGNALS

For a digital autocorrelator with a large number of channels of width b, the frequency response of a given channel centered on f_0 is close to a sinc function

$$g(f) = \sin[\pi(f - f_0)/b]/[\pi(f - f_0)/b].$$

Generally, the signal frequency does not lie at the center of a channel, and the gain is less than unity. If the signal is very strong, it is also observed in several adjacent channels: it would then be possible to figure out its actual frequency, and to correct for the gain loss. We preferred to apply a statistical correction to the observed amplitude: as the frequency can lie uniformly in $f_0 - b/s$, $f_0 + b/2$, the average gain in the central channel is

$$(1/b)\int_{f_0 - b/2}^{f_0 + b/2} g(f)\,\mathrm{d}f = (2/\pi)\,\mathrm{Si}(\pi/2) = 0.872.$$

Conversely, if a monochromatic signal is observed with an amplitude s, this amplitude should be multiplied by

$$(2/b)\int g^{-1}(f)\,\mathrm{d}f = 1.166.$$

5. SUMMARY OF THE OBSERVATIONS

The aim of the program was to observe all stars from the Royal Greenwich Observatory Catalog, of spectral type F, G or K and luminosity class V. 220 such stars, or multiple system containing such a star, could be observed from the Arecibo telescope (declination range $-1°$ to $+39°$), and 347 from Nançay ($-38°$ to $+90°$) but not from Arecibo. Of these, 344 have been observed at Nançay in at least one of the six runs, in June 81, August 84, April 87, October 87, January 88 and April 88. 249 are single stars and 95 are multiple. Finally, 26 of these multiple systems contain two stars of the desired spectral types, both lying within the telescope beam. The total number of stars studied therefore amounts to 370. Their list is given in Table 1.

During all the runs but the first one, the frequency coverage was 0.64 MHz around the HI line at 1420 MHz and 2.24 MHz around the OH lines at 1665 and 1667 MHz. The coverage was somewhat narrower during the first run, and the resolution was 100 Hz instead of 50. But all the first run targets have been reobserved later. All the stars have therefore been observed exactly in the same way and over the full frequency range, except for 12 of them for which the frequency coverage is only partial, generally due to scheduling conflicts (the Naņcay telescope being a transit one), the whole set of data is well homogeneous. More details on the observation and reduction procedures have already been published [1].

During the mass reduction of the data, we built the amplitude distribution of all points above 1.1 times the expected level (3.83σ, theoretical probability from noise alone 1.0×10^{-4}). Points above 1.14 (5.36σ, 1.4×10^{-7}) were considered as potential "alarms" and their characteristics (amplitude, frequency, etc.) stored individually. With a few exceptions they all

Table 1. List of the stars observed an Nançay. The numbers are from the RGO Catalog. (P) indicates a partial frequency coverage, the asterisk that at least one alarm occurred on this target

4A	97	211	9296	9396	577*	9611	9752
9001AB	100	216AB*	9297*	9398AB*	580A	9612A	9761*
10	9094*	9196AC	342*	9407	9514*	706	9769
9008(P)	9095*	9198*	9298*	9408	9517	9619	9770*
9009	9096	9205	348A	9409A	586AB	9622	9775*
9011	107A	9212A*	364*	475	591	9625	859AB
9012	111	9213	365	9414*	593AB	713	862
18	117	9215	9306A(P)*	482AB	602	715*	9787
23A	9014A(P)*	243*	368	483	9531	716	9789*
25A	9109	245*	9311	484	9535*	9630	9792AB
9019*	124	9217	379A	9417	9540C	722(P)	868
28	128A	249	9318*	9421	9541AB	9632	869
9020A	131*	250A	380	9424	9543A*	9642AB	870*
9024*	135	256	9320	489	610*	9648AB*	9803A*
9026	141	259*	9321*	491A	611A	9649	879*
34A	9116	267*	9325	496A	612	755	886
36*	142	9232	9326*	498*	614	9656	9808*
37	144	9234	9328	500	616	764	9812A*
40(P)*	9121	9240	392A	9432	9551	9662A	9813
42	9130AB	288A	394	9434*	9553	9663	892*
9035	155*	290	395	506	9557A	9665	9815B
49	9136	291A	397	9439	621	770	9823
9036	9139	292A*	9334	511AB	9567	9673	9824
52	157A*	9245	9336	9449	631	9678	9829
9045AB	9143*	9246*	9337*	9452*	632*	9679*	898
9052A	161*	9247	9338	517	9573	9687	9833*
9054	166A(P)	9252	407*	9453*	9576	783A	9839
9055AB	168	9253	9346	9457A*	9578	9688A	9843
58*	9154A*	9255A	420A	523	648	785*	909A
59	171	302	9353A	529*	651	788	
60A(P)	172	306	9356(P)	530	653*	790	
61	9165	9263*	9357	9463*	9582A	9699	
62	177	9264	9362A	9474B	9584AB*	9702	
9059	9168	309*	9366A*	9476A	659AB	796	
67	183	9269	432A*	544A	663AB*	9703	
69*	9174A*	9270*	9370AB	549A	664	805	
71	9176	311*	441	9481B*	667AB	9710	
75*	9178	313	444A	553	670A(P)	811	
76*	193*	314AB	446	556	675	9717A	
9061B	196*	321(P)	451	9488	684A*	819A	
9075AB	197	325A	9377A	9494B	689	820AB	
90*	198	327	453*	565	692	9721A(P)	
9077	200A	332A	454	9501	9602AB	9734A*	
95*	204*	9287A*	9386	570A	9604	9736	
9079	9186*	9291A*	9390A(P)	575AB	9608	9745*	

have been reobserved later. We will now discuss the results of these studies.

5.1. Amplitude distribution

The theoretical distribution is given by Oliver and Billingham [2]:

$$P(y) = 1 - e^{-ny} \sum_{k=0}^{n-1} (ny)^k/k!$$

It is plotted in Fig. 3, along with the observed distributions for the 1987 and 1988 runs.

For $1.10 < y < 1.12$, the observed distributions are parallel to the theoretical one, but a factor of 2–3 higher, for all 4 runs. This effect can be produced by an increase of about 5% of the noise r.m.s. above the value expected from $B\tau = 1465$. It is probably due to the digitization scheme of the autocorrelator: the video signal is digitized on 3 bits (8 levels) and the expected increase in noise is shown to be 4.6%.

For $y > 1.12$, the distributions show huge excesses of points with large deviations, and their slope is rather flat: very large deviations (the "alarms" studied below) are common. They represent real narrowband signals coming into the receiver. During part of the October 87 run, one of the IF chain local oscillator failed to slave on the rubidium standard frequency and was sweeping in frequency by some 10 kHz. Therefore, all signals incoming before the corresponding mixer (from 545 to 80 MHz) were smeared out. The corresponding distribution is also plotted in Fig. 3. It is everywhere parallel to the theoretical curve and above by a factor of about 2. This confirms that this effect comes from the autocorrelator or from the last IFs, and shows that the tail of large deviations comes from the HF part of the receiver or through the antenna.

5.2. Properties of the alarms

Our three last runs confirm the results obtained in April 87 and given by Biraud [1] and Tarter [3].

The signals are narrowband, well below 50 Hz (relative width $< 10^{-8}$), but they drift in frequency with time (up to 100 Hz, i.e. 10^{-7}, per minute), in an apparently erratic way. The amplitude also varies with time, from not detectable (< 7 K) up to 100 K in the 50 Hz band.

There are no significant variations with civil or sidereal time, nor within the limited azimuth range

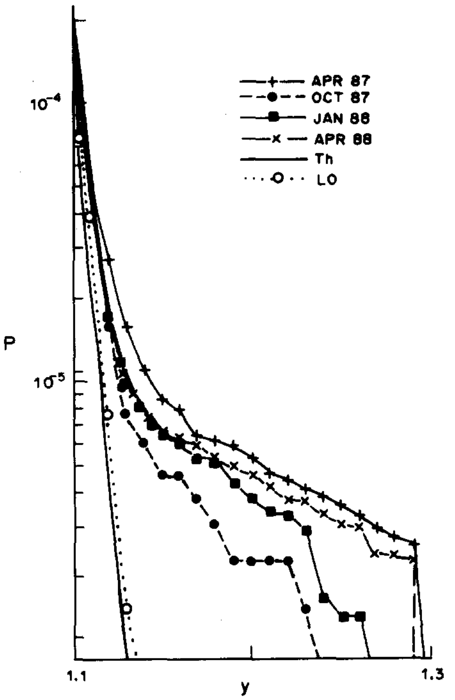

Fig. 3. Probability distributions. (Th) is the theoretical curve, (LO) the result with the swept LO. See text.

of the telescope around meridian, but a strong dependance on the elevation in the sky: the signals apparently come from low elevation angles, from the South, but mainly from the North. This seems to rule out an origin internal to the receiver. The interference stays on when all the other instruments on the Observatory grounds are turned off. It is therefore very likely that they are coming from distant transmitters.

Their frequencies exhibit a characteristic pattern, showing a few narrow "lines", especially at 21 cm (Fig. 4), near 1420.355 and 1420.410 MHz. It is particularly worrying that they are right in the protected band exclusive to radioastronomy. Of course they could be harmonics of signals outside the band. In any case they are a major trouble for this kind of search.

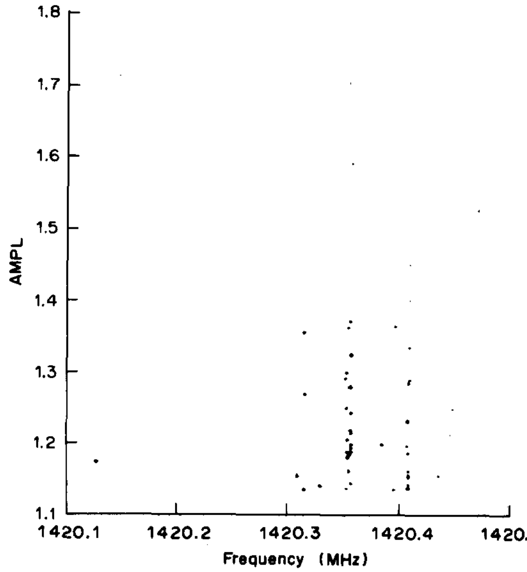

Fig. 4. Amplitude of the alarms as a function of frequency 1420 MHz.

6. CONCLUSIONS

The search conducted at Nançay since 1981 failed, as previous ones, to detect any artificial signal of extraterrestrial origin. But we got interesting results on the use of a digital autocorrelator to search for narrowband signals, and valuable data on the noise statistics and on the quality of the electromagnetic environment, at least at Nançay.

REFERENCES

1. F. Biraud, in *Bioastronomy, The Next Steps*. IAU Coll. No. 99, p. 351 (1987).
2. B. M. Oliver and J. Billingham, Project Cyclops. NASA CR 114445 (1973).
3. J. C. Tarter, to appear in Proc. of IAU Coll. No., 112, *Light Pollution, Space Debris and Radio Frequency Interference*. Kluver Press, Washington (1988).
4. J. C. Tarter, *Stockholm IAF Congress*. IAA-85-473 (1985).