Dr. Whitham

ANALYSIS OF MICROSEISMIC NOISE EXPERIMENT IN A GEOTHERMAL AREA (MEAGER CREEK)

by

George A. McMechan

SEISMOLOGICAL SERVICE OF CANADA

INTERNAL REPORT 77-3

Division of Seismology and Geothermal Studies

Earth Physics Branch

Department of Energy, Mines and Resources

OTTAWA

February 1977

A spectral study has been made of ground noise, related to the Meager Creek geothermal area, which was recorded on vertical short period seismographs during 1975. The recording sites are shown in Figure 1.

There are some studies in the literature which describe the types of spectral features that are associated with other known geothermal areas which are used as a guide in the present study.

Some of the effects which have been previously observed are:

1) In New Zealand, there is a continuous high level background noise associated with geothermal activity (Clacy, 1968).
2) In California, this noise peaks in the region of 1-3 Hz (Clacy, 1968; Douze & Sorrells, 1972). See Figure 2.
3) Studies in Yellowstone Park (Iyer & Hitchcock, 1974; Nicholls & Rinehart, 1967) indicate that there are cyclically fluctuating changes in the 2-8 Hz region that correlate with geyser activity (Figure 3). They indicate that the high frequency energy is related to shallow depth phenomena (e.g. steam vents) and the lower frequency, to deeper circulation.

It is important to differentiate between geothermal ground noise and the usual effects of site characteristics (e.g. bedrock vs alluvium (Frantti, 1963)). This can be done by considering the stationarity of the background noise and its frequency content. Site characteristics refer to the response of the material beneath the recorder. A signal must be present for a response to occur, and such noise is therefore dependent upon the type of local excitation. The classic example is wind noise. It is clearly non-stationary. The only non-stationary noise that has been observed in relation to geothermal activity is in cases where violent geysers or steam vents are visible. As mentioned above, high frequency ground noise is associated only with such activity, and is therefore expected to be absent in the Meager Creek area.

In view of the above information, and the geological setting of the Meager Creek anomaly (Rogers et al., 1976), any seismic noise anomaly associated with this area is expected to occur in the 1-5 Hz range, and to be fairly stationary in time.

Any consistent background noise of this character should be easily visible on the short period records made during the field programs in the Meager Creek area. Rogers reported that this is not observed in a visual inspection of the records. In order to confirm this visual analysis, maximum entropy spectra have been computed for typical 30 second record length intervals at various locations and conditions. The results appear in Figures 4 to 8. The first 3 are for Meager Creek records in the anomalous area, and the last 2 are for the control stations at Pemberton and Gold Bridge. No consistent significant differences in spectral amplitudes or shapes are apparent.

No stationary pattern of seismic noise increase related to Meager Creek is detected, either visually or computationally. The non-stationary phenomena that were observed were clearly related to site conditions (e.g. soil vs bedrock or a nearby creek, or a helicopter, or wind (see Figure 9)). Some seasonal variations were noted by Rogers, particularly related to cold temperatures and the presence of snow - these however, are essentially discrete events, not a continuous background effect.

In making spectral comparisons of records obtained at the anomaly with those away from it, it is not necessary to use temporally contemporaneous records because:

a) the effect, if present, should be stationary in time, and,

b) the distance between stations is large enough that contemporaneous records would never exhibit the same energy due to the finite time of travel of a disturbance between stations.

The general features of the spectra in Figures 4 to 8 are similar partly because the interest here is only in the relative, broad-band, frequency content of the records. The maximum entropy wavelet length was, therefore, chosen to define the frequency of dominant energy, not detailed spectral structure. A significant shift in the position and width of the spectral peak would be observed if the characteristic energy was different at the Meager Creek site than at the outside sites. This difference is not observed.

The 'noisy' Meager Creek record has a lower spectral peak value than the 'average' and 'quiet' records (see Table 1) because the noise observed was not in the 0 to 5 Hz range which is of interest here.

A similarity in position of the peaks labelled 1 to 4 on Figure 3 with those on Figures 4 to 8 was noted. This coincidence is probably fortuitous. In Figures 4 to 8, these secondary peaks are not stable. They are sidebands of the main peak and can be made to disappear by reducing the length of the maximum entropy operator.

The above observations are consistent with the general features of the Meager Creek anomaly. This experiment indicates that surface manifestations of geothermal activity at this site are many orders of magnitude less than those of areas where commercial geothermal reservoirs have been found (California, New Zealand, Italy, Iceland).

This study indicates that, at this site within the Meager Creek geothermal anomaly, seismic noise studies are not a viable diagnostic tool, although this conclusion should not rule out the studying of additional data if the research project continues at another site in this region or others.

Relative max spectral values in 0-5 Hz range

Meager	noisy	7.38
	average	9.6
	quiet	9.2
Gold Bridge		7.6
Pemberton		13.6

TABLE 1

In the table above we see that Gold Bridge is just as noisy as Meager, and Pemberton is even noisier.

REFERENCES

Clacy, G.R.T. 1968. Geothermal and ground noise amplitude and frequency spectra in the New Zealand volcanic region, J.G.R., 72, 5377-5383.

Douze, E.J. & G.G. Sorrells. 1972. Geothermal ground noise surveys, Geophysics 37, 813-824.

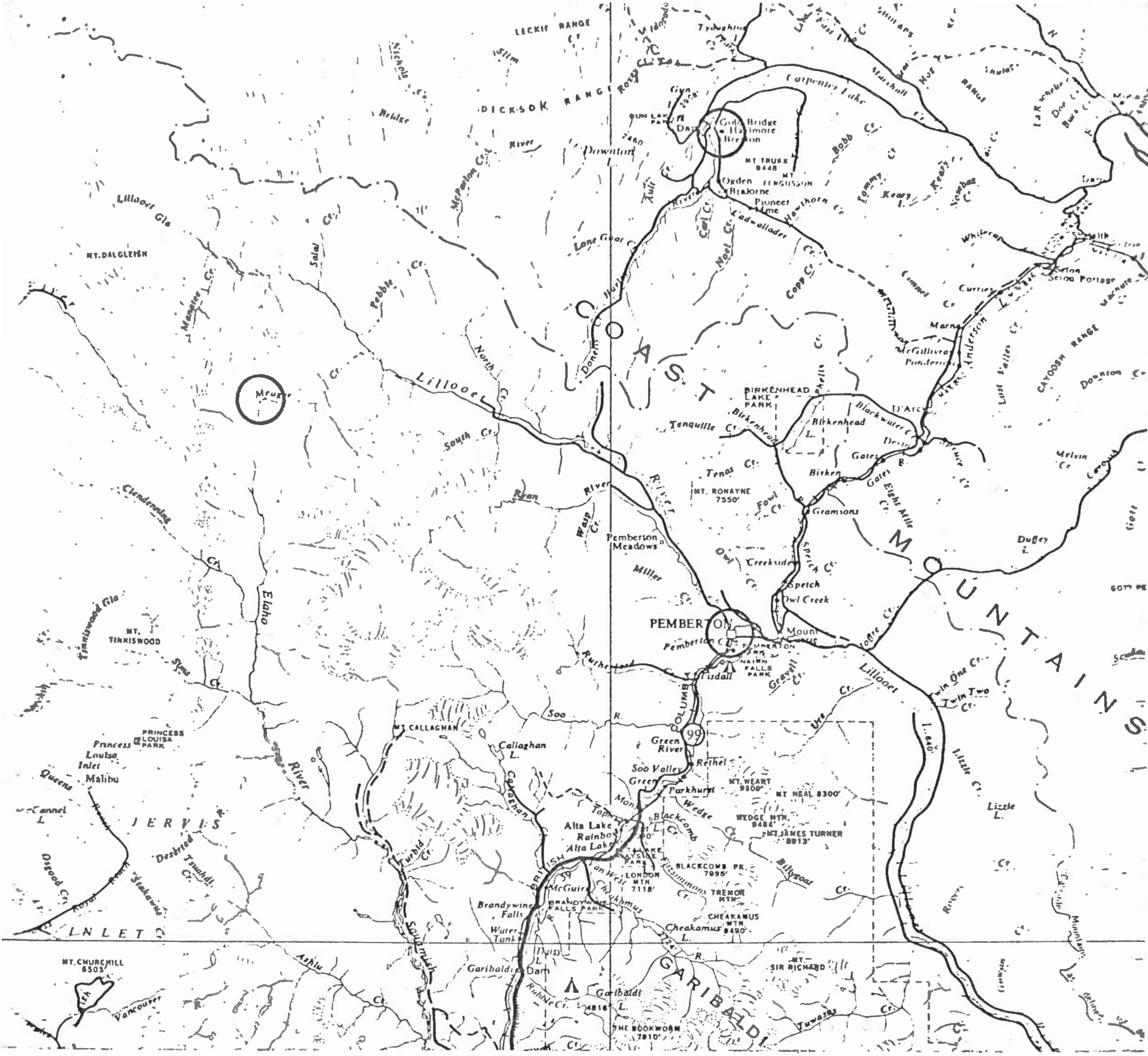
Francatti, G.E. 1963. The nature of high frequency earth noise spectra, Geophysics XXVIII, 547-562.

Goforth, T.T., E.J. Douza, & G.G. Sorrells. 1972. Seismic noise measurements in a geothermal area, Geophysical Prospecting 20, 76-82.

Iyer, H.M., & T. Hitchcock. 1974. Seismic noise measurements in Yellowstone National Park, Geophysics 39, 389-400.

Nicholls, H.R. & J.S. Rinehart. 1967. Geophysical study of geyser action in Yellowstone National Park, J.G.R., 72, 4651-4663.

Rogers, G.C., L.K. Law, G.A. McMechan, H. Dragert, & G. Shore. 1976. Geophysical investigations of the Meager Creek geothermal area - a progress report (abstract), Eos. Trans. A.G.U., 57, 90.



LECKIE RANGE
DICKSON RANGE
Downton
Carpenter Lake
Gun
Gold Bridge
Haylmore
Minto
MT. TRUAX 9448
Ogden
Bralorne
Pioneer Mine
Cadwallader Cr.
Hawthorn Cr.
Bobb Cr.
Lillooet Gla
MT. DALGLEISH
Pebble Cr.
Salal Cr.
Lone Goat Cr.
COAST MOUNTAINS
North Cr.
Lillooet
Meager
South Cr.
BIRKENHEAD LAKE PARK
Birkenhead L.
Birkenhead
Tenquille Cr.
Blackwater Cr.
D'Arcy
Gates
Birken
Tenas Cr.
MT. RONAYNE 7550'
Gramsons
Fowl Cr.
Clendenning
Ryan
River
Wasp Cr.
Pemberton Meadows
Miller
Owl Cr.
Creekside
Spetch
Owl Creek
Elaho
MT. TINNISWOOD
PEMBERTON
Pemberton Cr.
NAIRN FALLS PARK
Tisdall
Rutherford
Soo R.
Twin One Cr.
Twin Two Cr.
MT. CALLAGHAN
Callaghan L.
Green River
Rethel
Soo Valley
Green
Parkhurst
MT. WEART 9300'
MT NEAL 8300'
WEDGE MTN. 9484'
MT. JAMES TURNER 8813'
Wedge Cr.
Blackcomb
PRINCESS LOUISA PARK
Princess Louisa Inlet
Malibu
Queens
JERVIS
Alta Lake
Rainbow
Alta Lake
LONDON MTN. 7118'
BLACKCOMB PK. 7998'
Fitzsimmons
TRENOR MTN.
Billygoat
McGuire
Brandywine Falls
BRANDYWINE FALLS PARK
Cheakamus
CHEAKAMUS MTN. 8490'
Cheakamus L.
Water Tank
INLET
MT. CHURCHILL 8503'
Ashlu
Vancouver
Garibaldi
Dam
Daisy L.
Garibaldi L.
GARIBALDI
THE BOOKWORM 7910'
MT. SIR RICHARD
Duffey L.
CAYOOSH RANGE
Anderson
Seton Portage
Lizzie L.
Squamish

Fig 1

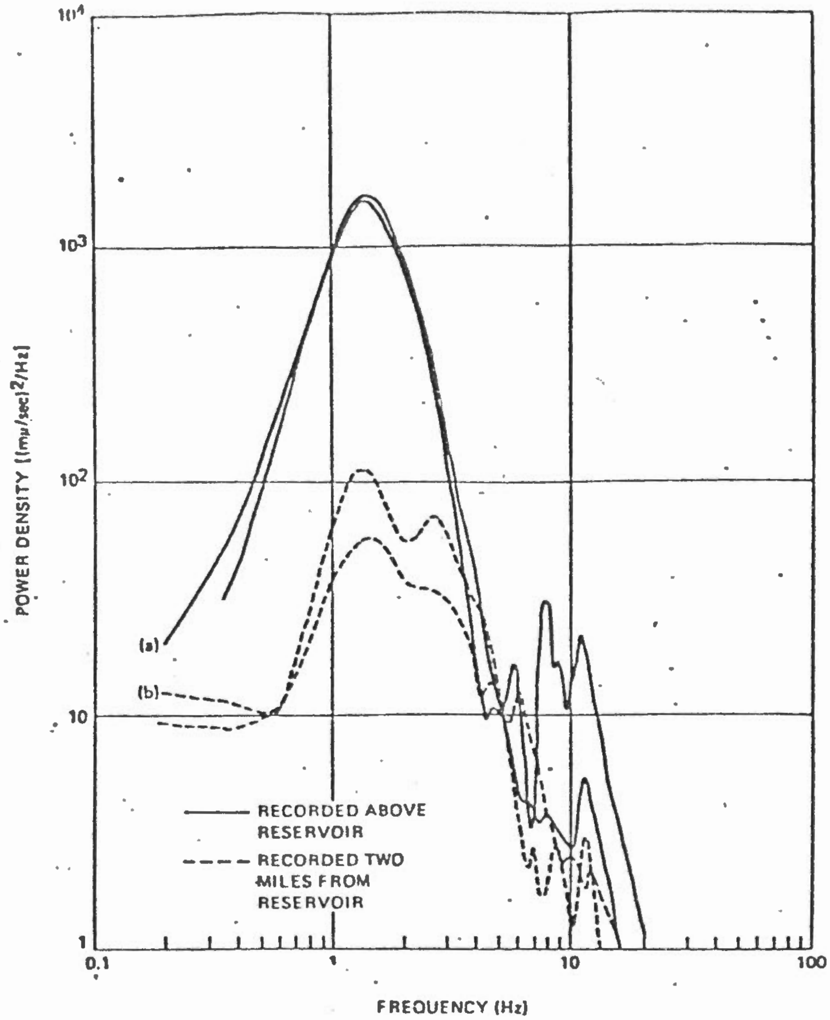


FIG. 3. Power density spectra of the noise inside and outside the ground-noise anomaly.

from Clacy (1968).

Fig 2

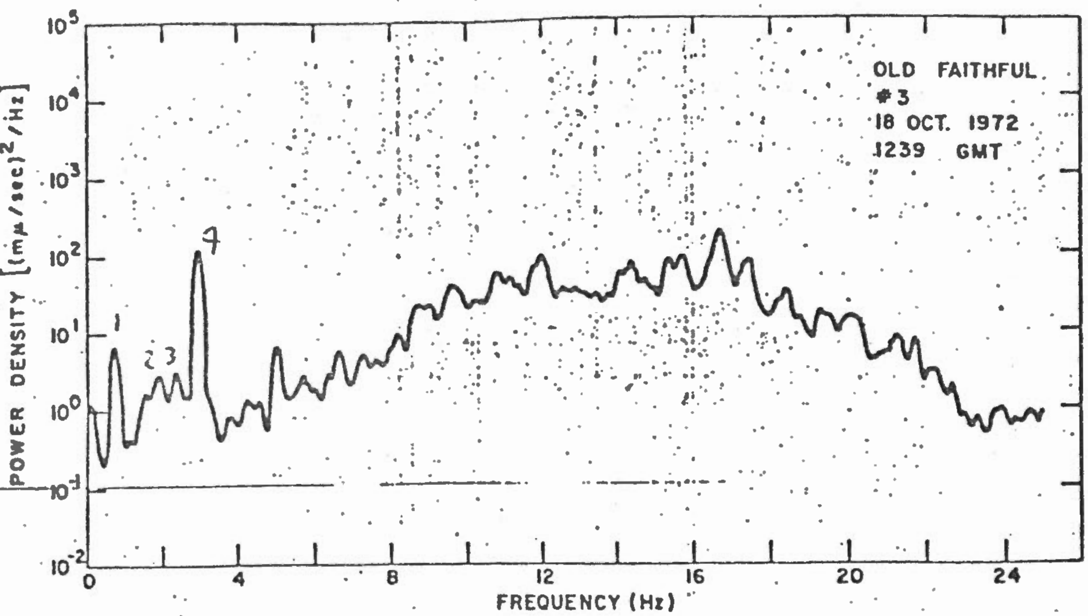


FIG. 10. Spectrum of seismic noise (smoothed using a 15-point window) recorded near Old Faithful after an eruption when amplitudes were low.

hz band, and the low-frequency plots do not show any correlation with the eruption cycles. The amplitude level in the 2–8 hz band is of the order of that found in the region of Old Faithful Geyser (see Figure 1b). Hence, it is our belief that the high-frequency noise near Old Faithful is generated by the boiling and steam bursts near the top of the geyser cone, whereas the low-frequency noise is generated deeper by convection associated with the geothermal system.

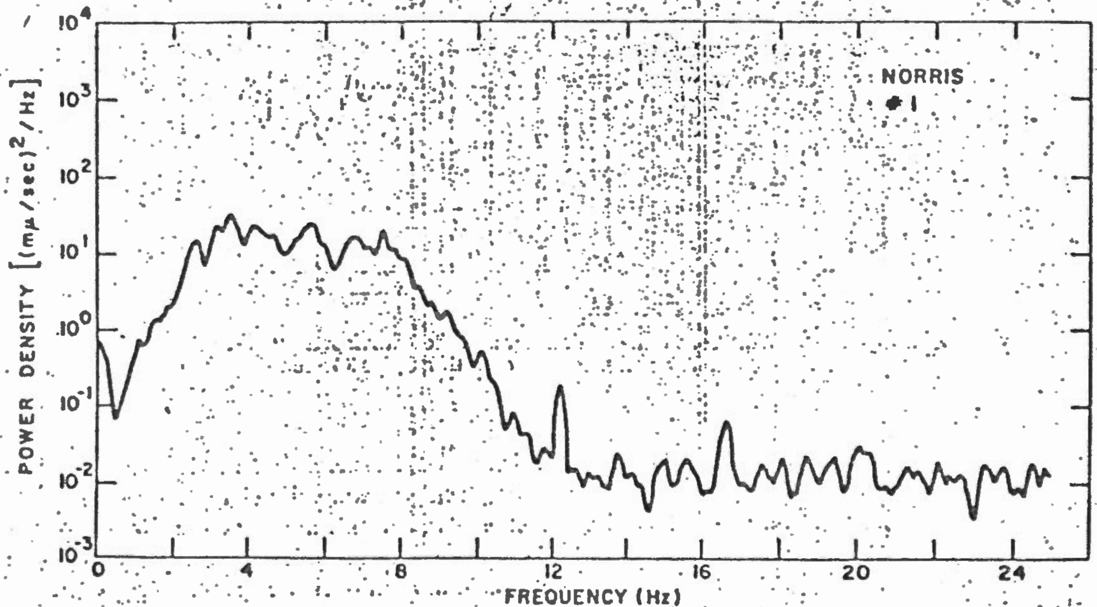
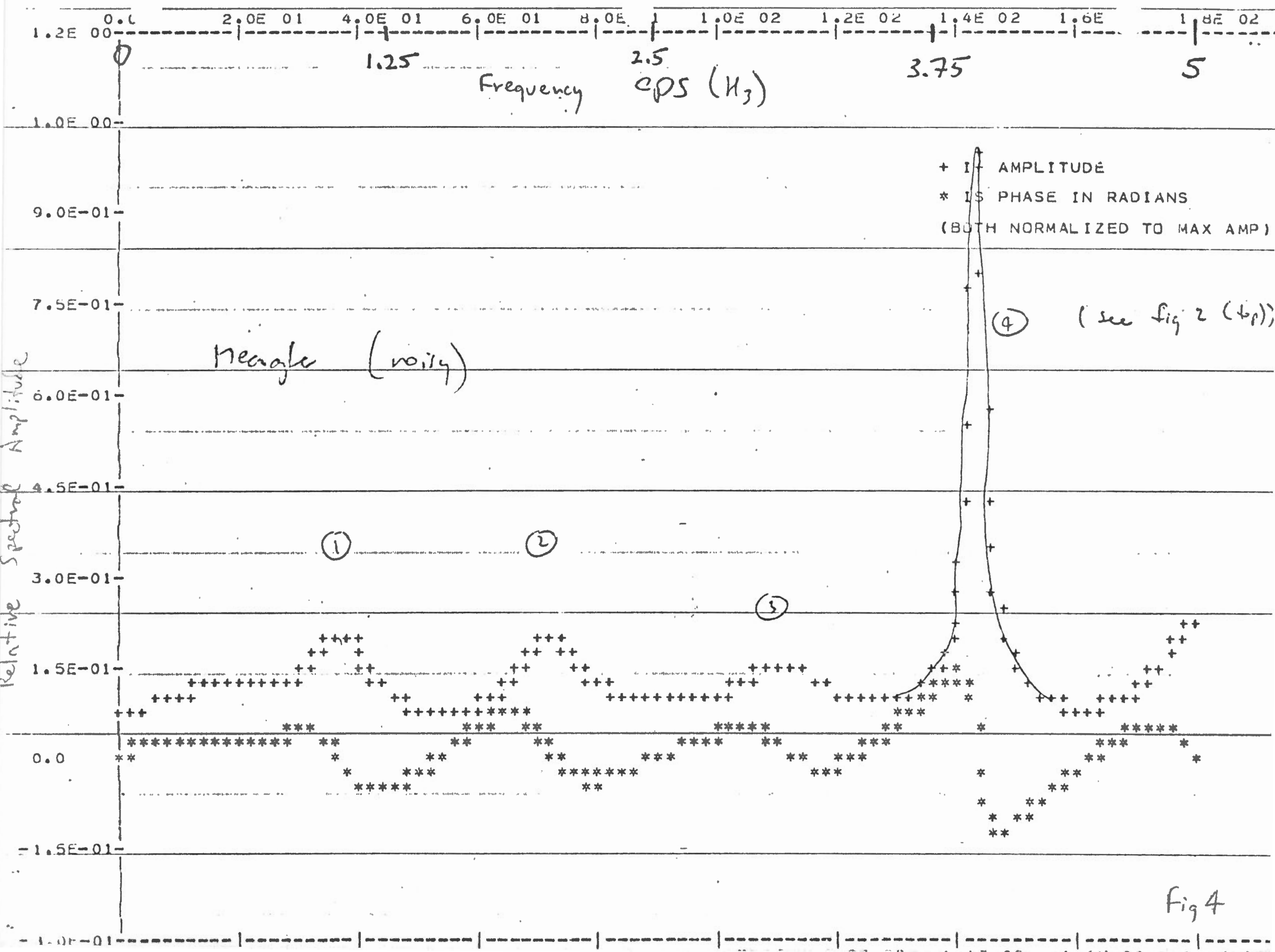
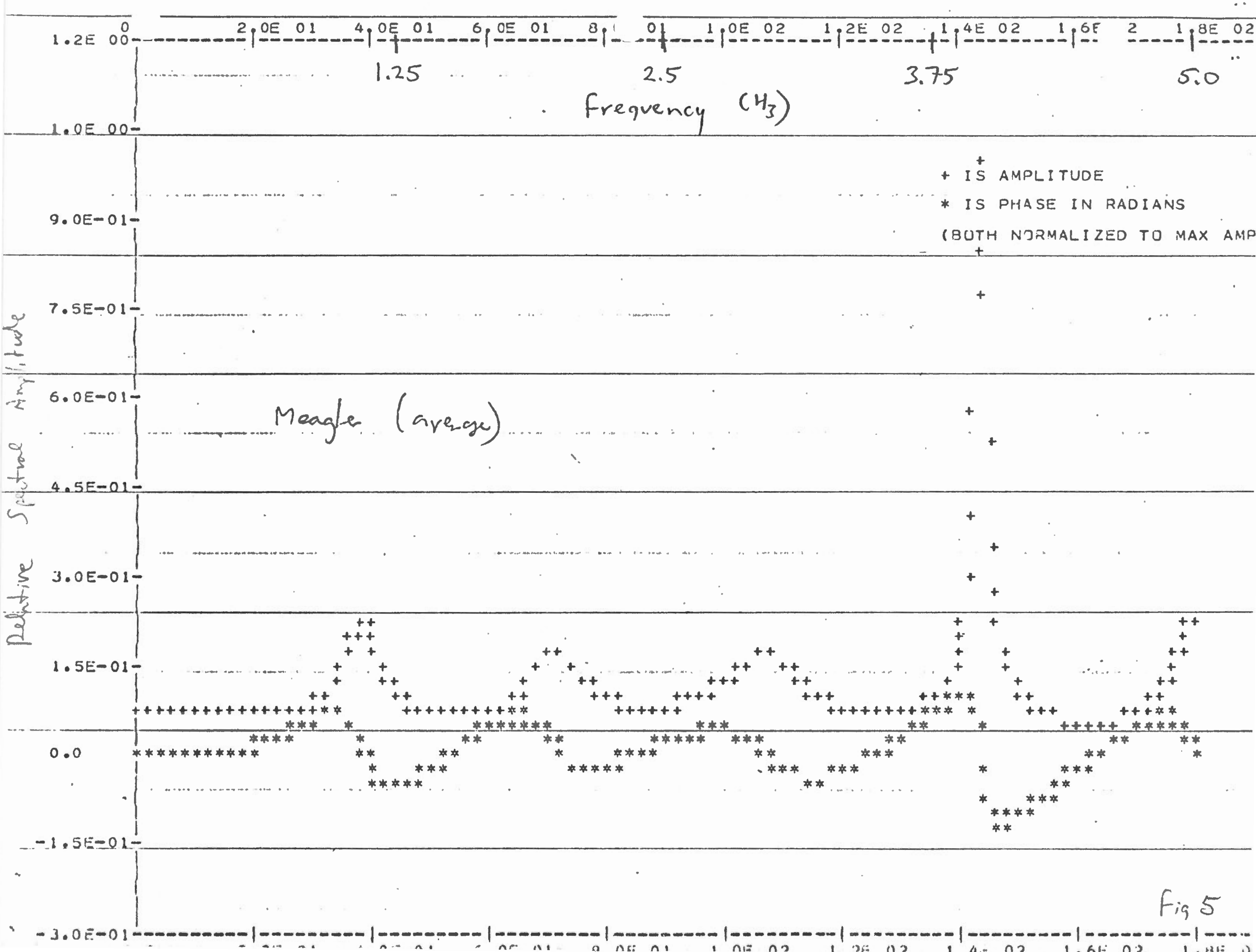


FIG. 11. Spectrum of seismic noise (smoothed using a 15-point window) recorded by channel 1 of the Norris array.

from Douje & Sorrells (1972)

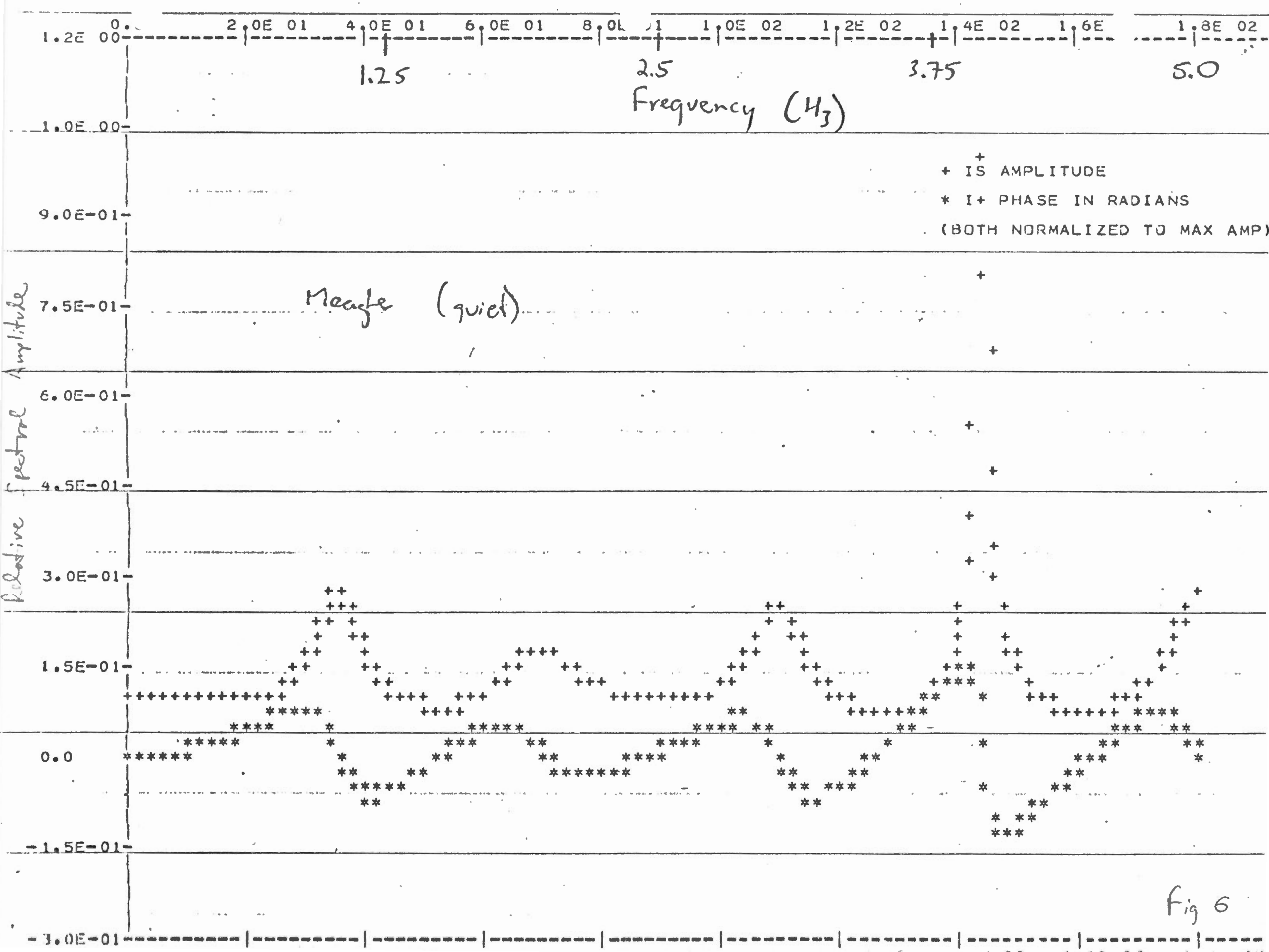
Fig 3


Frequency cps (Hz)
+ IS AMPLITUDE
* IS PHASE IN RADIANS
(BOTH NORMALIZED TO MAX AMP)
Relative Spectral Amplitude
Meagle (noisy)
(see fig 2 (tp))
Fig 4



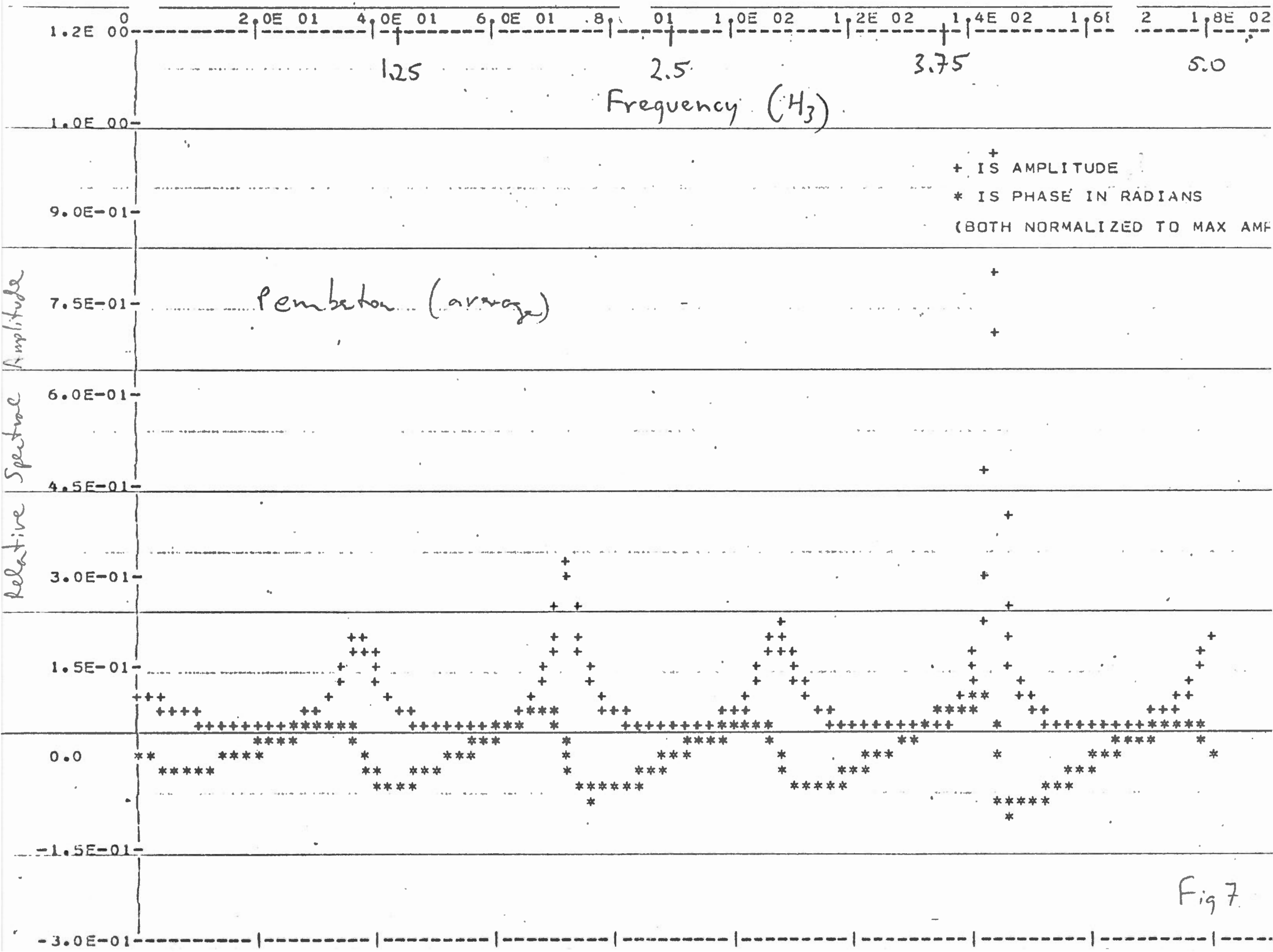
1.2E 00
1.0E 00
9.0E-01
7.5E-01
6.0E-01
4.5E-01
3.0E-01
1.5E-01
0.0
-1.5E-01
-3.0E-01
2.0E 01
4.0E 01
6.0E 01
1.0E 02
1.2E 02
1.4E 02
1.8E 02
1.25
2.5
3.75
5.0
Frequency (Hz)
+ IS AMPLITUDE
* IS PHASE IN RADIANS
(BOTH NORMALIZED TO MAX AMP
Meagle (average)
Relative Spectral Amplitude

Fig 5



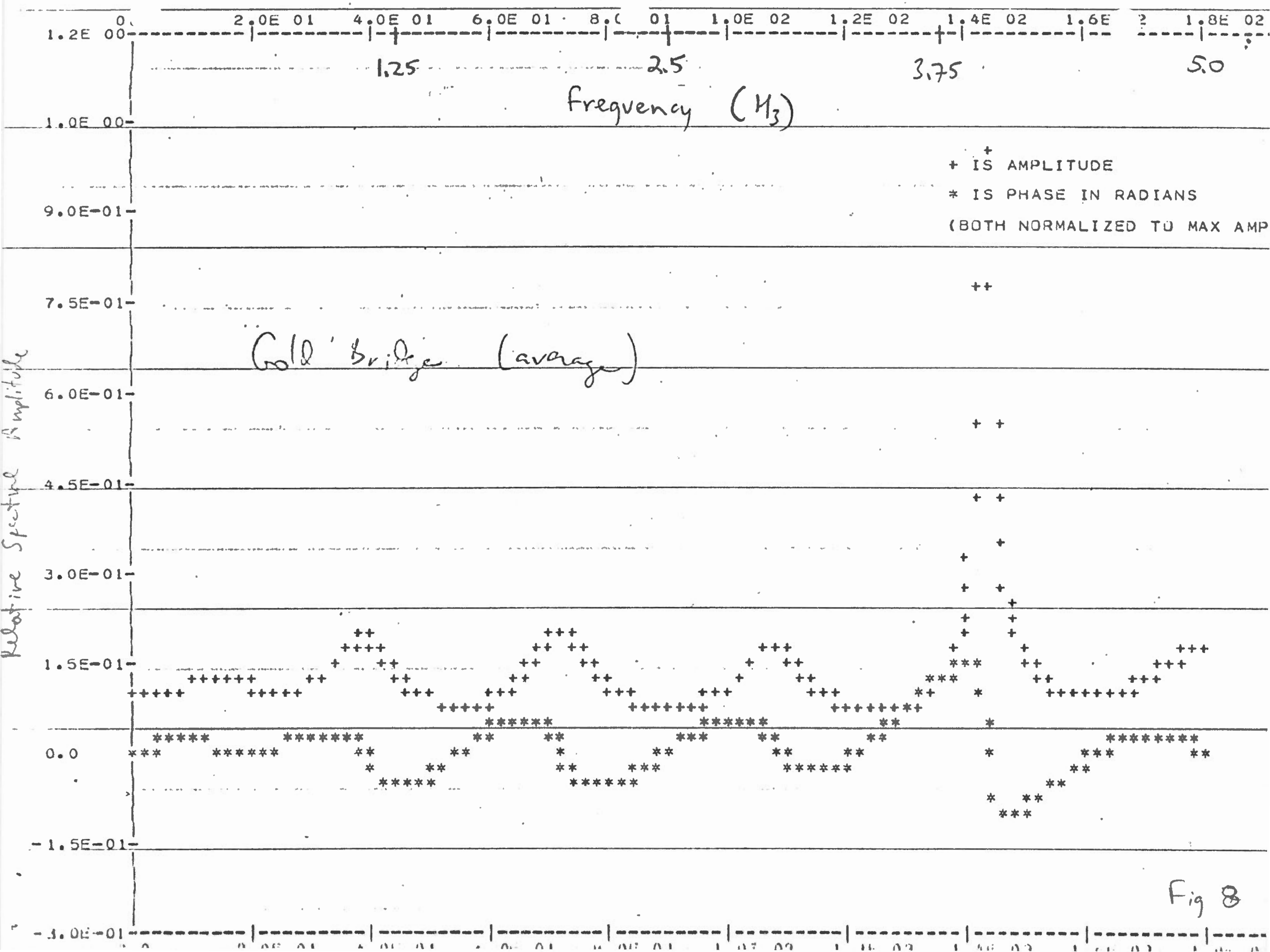
+ IS AMPLITUDE
* I+ PHASE IN RADIANS
(BOTH NORMALIZED TO MAX AMP)
Frequency (Hz)
1.25
2.5
3.75
5.0
Relative Spectral Amplitude
Meagle (quiet)
1.2E 00
1.0E 00
9.0E-01
7.5E-01
6.0E-01
4.5E-01
3.0E-01
1.5E-01
0.0
-1.5E-01
-3.0E-01
2.0E 01
4.0E 01
6.0E 01
1.0E 02
1.2E 02
1.4E 02
1.8E 02

Fig 6



Frequency (Hz)
1.25
2.5
3.75
5.0
0
2.0E 01
4.0E 01
6.0E 01
1.0E 02
1.2E 02
1.4E 02
1.8E 02
1.2E 00
1.0E 00
9.0E-01
7.5E-01
6.0E-01
4.5E-01
3.0E-01
1.5E-01
0.0
-1.5E-01
-3.0E-01
+ IS AMPLITUDE
* IS PHASE IN RADIANS
(BOTH NORMALIZED TO MAX AMP
Pemberton (average)
Relative Spectral Amplitude

Fig 7



Frequency (Hz)
1.25
2.5
3.75
5.0
+ IS AMPLITUDE
* IS PHASE IN RADIANS
(BOTH NORMALIZED TO MAX AMP
Gold Bridge (average)
Relative Spectral Amplitude
1.2E 00
1.0E 00
9.0E-01
7.5E-01
6.0E-01
4.5E-01
3.0E-01
1.5E-01
0.0
-1.5E-01
-3.0E-01
2.0E 01
4.0E 01
6.0E 01
1.0E 02
1.2E 02
1.4E 02
1.6E
1.8E 02

Fig 8

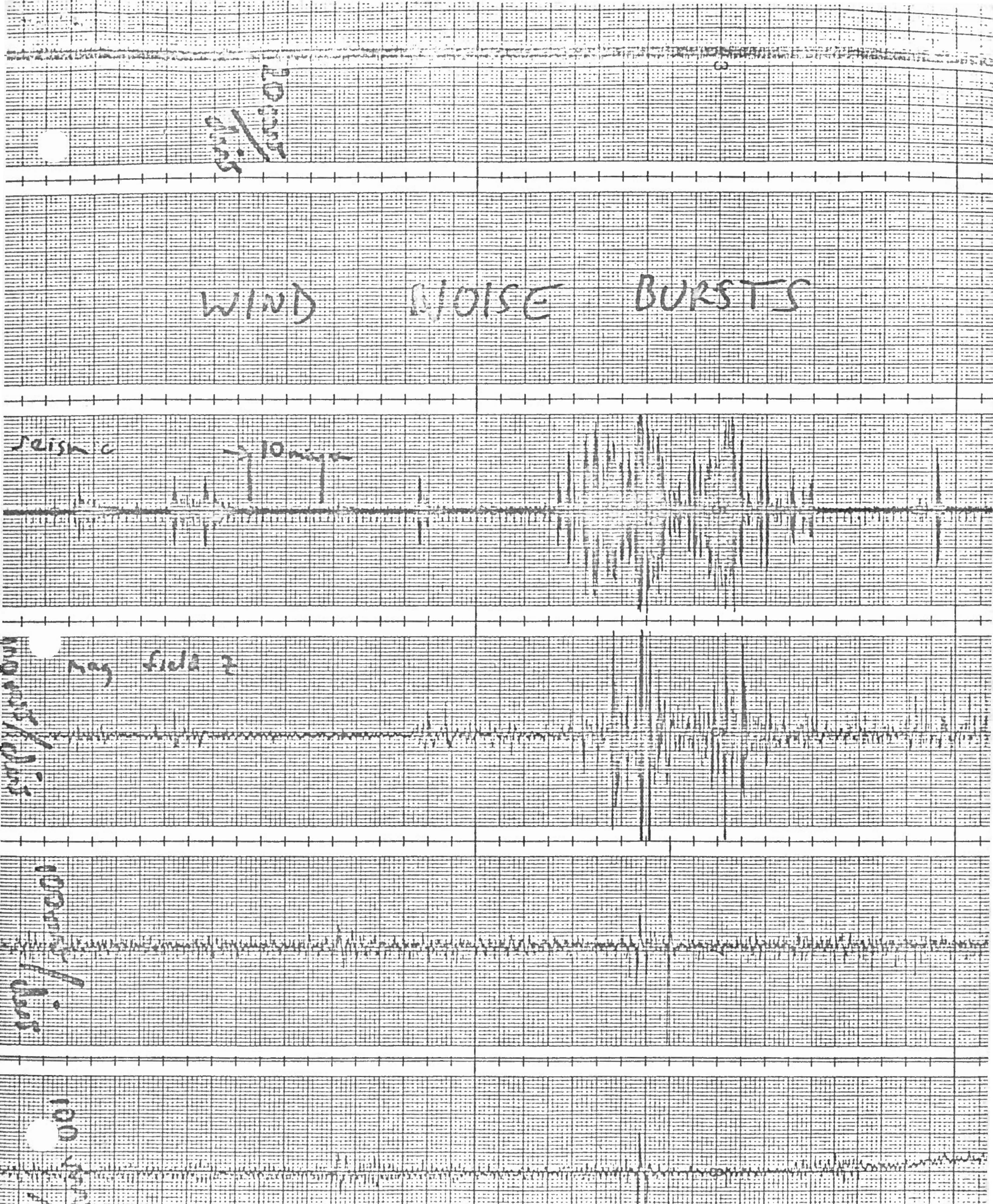


Fig 9