UNCLASSIFIED

AD NUMBER
AD825202
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 30 OCT 1967. Other requests shall be referred to Air Force Technical Applications Center, Washington, DC 20333.**
AUTHORITY
AFTAC USAF ltr dtd 25 Jan 1972

THIS PAGE IS UNCLASSIFIED

LARGE-ARRAY SIGNAL AND NOISE ANALYSIS

Special Scientific Report No. 4

SPACE AND TIME VARIABILITY OF THE SHORT-PERIOD LASA NOISE FIELD

Prepared by

Terence W. Harley

Frank H. Binder, Program Manager

TEXAS INSTRUMENTS INCORPORATED
Science Services Division
P.O. Box 5621
Dallas, Texas 75222

Contract No. AF 33(657)-16678

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER
Washington, D.C. 20333

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 599
AFTAC Project No. VT/6707

30 October 1967

81

LARGE-ARRAY SIGNAL AND NOISE ANALYSIS

Special Scientific Report No. 4

SPACE AND TIME VARIABILITY OF THE SHORT-PERIOD LASA NOISE FIELD

Prepared by

Terence W. Harley

Frank H. Binder, Program Manager

TEXAS INSTRUMENTS INCORPORATED
Science Services Division
P.O. Box 5621
Dallas, Texas 75222

Contract No. AF 33(657)-16678

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER
Washington, D.C. 20333

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 599
AFTAC Project No. VT/6707

30 October 1967

BLANK PAGE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONTD)

LIST OF ILLUSTRATIONS (CONTD)

SECTION I
SUMMARY

Thirteen noise samples (covering a 6-month period) were used to study the time and space variability of the LASA noise field. For every noise sample, power spectra were computed for both the output of seismometer 21 and the output of the multichannel filter system (which was applied to the noise data) at each subarray. Finally, ratios of the individual spectra to the average spectrum were obtained for each noise sample.

All seismometers in a subarray were at a depth of 200 ft, except seismometer 10 (the center seismometer) which was at 500 ft. The noise level on seismometer 10 above 1.5 cps was found to be significantly lower than the noise levels on the other seismometers. Thus, seismometer 21 (at a depth of 200 ft and near the center of each subarray) was chosen to represent the noise level at each subarray.

At the 0.2- to 0.3-cps microseismic peak, results were consistent for the 13 samples. Subarrays E4, F3, and F4 — located on the western edge of LASA in the vicinity of the Porcupine Dome — were significantly quieter sites than the average. It appears that the dome and its associated complex geology significantly attenuated the low-frequency microseismic energy. Subarrays D1, E1, and F1, which are in the northeast sector of LASA, were significantly noisier sites than the average. No explanation for their higher noise levels is known.

Variations in the peak power levels were highly correlated over all of the LASA, which implies a common source for most of the energy at 0.2 to 0.3 cps. This observation is consistent with the theory that large storms at sea are the major source of low-frequency microseismic energy.

Above approximately 1.5 cps, power levels varied considerably from subarray to subarray as well as from noise sample to noise sample. Thus, most of the energy above 1.5 cps appeared to be nontime stationary and generated in the vicinity of a subarray.

BLANK PAGE

SECTIC' II

INTRODUCTION

A. PROCESSING

This report discusses the space and time variability of short-period seismic noise over the Montana Large-Aperture Seismic Array (LASA). Thirteen noise samples were used in the analysis (Table II-1). Each subarray of each noise sample was processed with the theoretical multichannel filter (MCF) described in Special Report No. 3.[1] The MCF was designed using a disk signal model with an 11-km/sec edge velocity and a 2- to 6-km/sec noise annulus and exhibited good wavenumber response down to 0.2 cps. Power spectra of the noise out of the MCF and of the noise on seismometer 21 were computed for each subarray. Figure II-1 shows typical spectra which were obtained; the sharp peak at 0.2 to 0.3 cps was the dominant characteristic on all spectra.

Table II-1

NOISE SAMPLES USED IN THE ANALYSIS

Noise Sample	Type	Date	Time (GMT)	Unprocessed Subarrays
1	Day noise	10/29/65	21:01:02.6-21:06:48.5	D3, E1
2	Day noise	11/4/65	00:42:00.0-00:48:00.0	C1, C2
3	Noise and Aleutian event	11/10/65	04:02:56.9-04:08:40.8	B1, E2, F3
4	Night noise	11/13/65	02:05:00.0-02:11:00.0	A0, C2, F3
5	Night noise	11/25/65	01:00:00.0-01:05:00.0	———
6	Night noise	12/04/65	02:13:00.0-02:19:00.0	A0, F3
7	Night noise	12/04/65	03:07:00.0-03:12:00.0	F3
8	Day noise	12/21/65	08:41:00.0-08:46:00.0	D1
9	Night noise	1/22/66	06:57:00.0-07:05:00.0	F1
10	Noise and Greece event	2/5/66	03:02:55.4-03:11:06.3	F1
11	Day noise	4/8/66	05:18:09.3-05:26:09.0	B1, C1
12	Noise and Panama event	4/15/66	06:44:08.1-06:52:08.0	B1, F3, F4
13	Day noise	4/29/66	09:26:17.9-09:31:06.8	F1

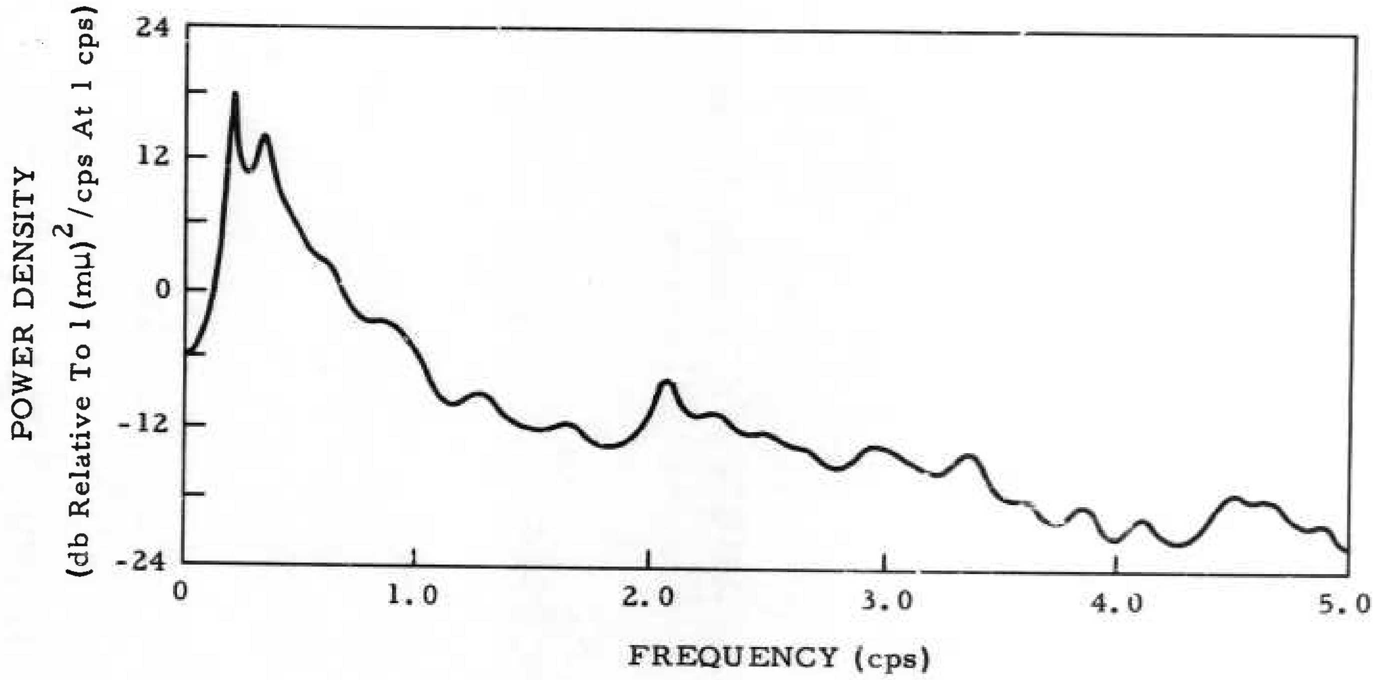


Figure II-1. Typical Noise Spectrum at LASA

B. COMPARISON OF NOISE LEVELS ON SEISMOMETERS AT DEPTHS OF 500 AND 200 FT

In choosing a single seismometer to represent the noise level at a subarray, one usually uses the center seismometer. At LASA, the center seismometer is 500 ft below ground level, whereas the other seismometers are only 200 ft deep. To determine whether there was any difference in noise level at the two depths, the spectra for seismometer 21 and seismometer 10 (the center seismometer) at each subarray were computed for one noise sample. Spectral ratios of seismometer 10/seismometer 21 were calculated, and the average ratio was computed. Figure II-2 shows the average ratio and several of the individual ratios. On the average, between 0 and 1 cps, the two seismometers had the same noise level; between 1 and 2 cps, the ratio decreased to about -4 db; between 2 and 4.5 cps, the ratio was approximately a constant -4 db. Individual ratios generally had similar shapes, although they varied from roughly no decrease to as much as a 10-db decrease above 2 cps. Thus, above 2 cps, the noise level at 500 ft generally was significantly lower than that at 200 ft. Since all seismometers except the center one were at 200 ft, seismometer 21 rather than seismometer 10 was chosen to represent the noise level at each subarray.

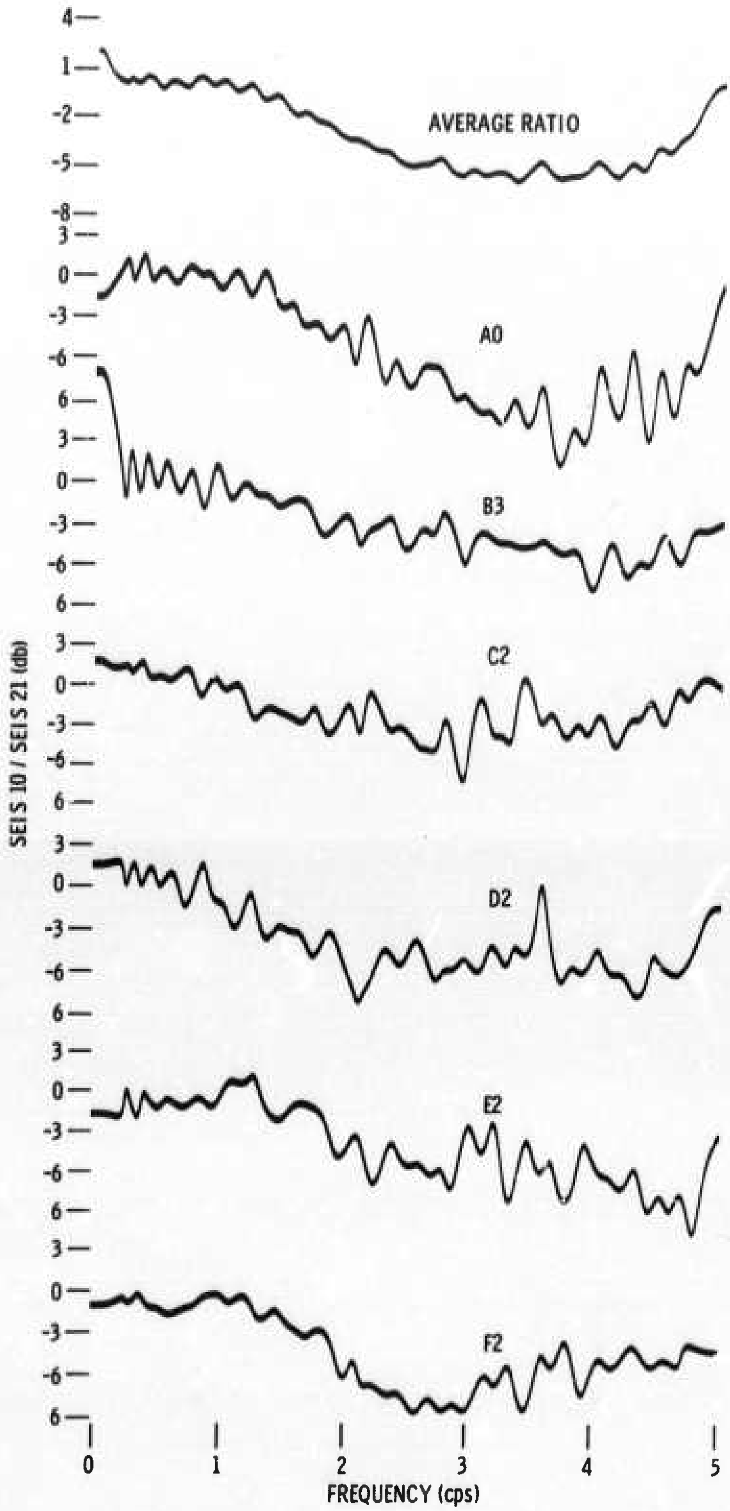


Figure II-2. Seismometer 10/Seismometer 21 Spectra Ratios

SECTION III

SPACE VARIABILITY OF LASA NOISE

To study the space variability of the LASA noise field, the seismometer-21 and MCF power spectra were averaged (using all subarrays) for each noise sample, and spectral ratios of (seismometer 21)/(average seismometer 21) and (MCF)/(average MCF) were computed. Because the spectra had been converted to decibels, the average spectra were geometric rather than arithmetic averages; i.e., the average spectra were obtained by computing

$$\overline{P(f)}\ (\mathrm{db}) = \frac{1}{N} \sum_{i=1}^{N} 10 \log_{10} P_i(f)$$

which can be written

$$P(f)\ (\mathrm{db}) = 10 \log_{10} \left\{ \left[\prod_{i=1}^{N} P_i(f) \right]^{\frac{1}{N}} \right\}$$

where the expression in braces is the geometric average of the N power spectra.

Figures III-1 through III-13 show both the (seismometer 21)/(average seismometer 21) and (MCF)/(average MCF) spectral ratios for the 13 noise samples. In general, the two ratios are about the same at each subarray. The differences that occur are usually at frequencies above 1.5 cps (e.g., subarray E2, Figure III-5; subarray E1, Figure III-6; and subarray B1, Figure III-10) and are probably due to an anomalously low (or high) noise level on seismometer 21 for that subarray.

Table III-1

NOISE LEVELS AT THE MICROSEISMIC PEAK

Subarray	Overall Performance	Noise Sample 1		2		3		4		5		6		7		8		9		10		11		12		13	
		21	MCF	21	MCF	21	MCF	21	MCF	21	MCF	21	MCF	21	MCF	21	MCF	21	MCF	21	MCF	21	MCF	21	MCF	21	MCF
A0	AV	—	hi	—	(hi)	—	—	X	X	—	(hi)	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B1	AV	(hi)	—	—	(lo)	X	X	hi	—	—	(lo)	—	—	—	—	hi	—	—	(hi)	—	—	X	X	X	X	—	—
B2	HIAV	hi	—	—	(hi)	—	—	(hi)	hi	—	(hi)	—	—	—	—	—	—	hi	hi	hi	hi	—	—	—	—	hi	—
B3	AV	—	—	lo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B4	AV	—	(hi)	—	—	—	(lo)	(hi)	—	(lo)	—	—	—	—	—	—	—	hi	—	—	—	—	—	—	(lo)	—	—
C1	AV	—	—	X	X	—	—	—	—	—	(lo)	—	(lo)	—	—	—	hi	hi	hi	(hi)	—	X	X	—	—	—	—
C2	AV	—	—	X	X	lo	—	X	X	—	—	(lo)	—	—	—	—	—	—	—	—	—	lo	lo	—	—	—	—
C3	HIAV	—	—	hi	(hi)	hi	(hi)	—	(lo)	—	—	—	—	—	—	—	—	(hi)	hi	—	(hi)	—	(hi)	—	—	—	—
C4	HIAV	hi	(hi)	—	—	—	—	—	(hi)	—	—	(hi)	(hi)	hi	—	—	—	—	—	—	—	—	—	—	—	—	—
D1	HI	hi	(hi)	hi	(hi)	(hi)	(hi)	—	—	hi	—	(hi)	hi	hi	hi	X	X	hi	—	hi	hi	(hi)	(hi)	hi	hi	hi	hi
D2	LOAV	—	hi	—	lo	—	—	lo	(hi)	(lo)	lo	(lo)	(lo)	—	—	—	lo	—	hi	—	—	—	—	—	—	—	lo
D3	AV	X	X	—	—	—	—	—	—	—	—	—	—	—	—	lo	lo	(lo)	—	—	lo	—	—	—	—	—	—
D4	LOAV	—	hi	—	lo	—	—	(lo)	—	—	(hi)	—	—	(lo)	—	—	lo	—	—	—	—	lo	lo	lo	lo	—	lo
E1	HI	X	X	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi
E2	AV	—	(hi)	—	lo	X	X	(lo)	lo	—	—	(lo)	(hi)	—	hi	—	—	—	—	(lo)	—	—	—	lo	lo	—	—
E3	LOAV	—	—	—	—	(lo)	lo	—	—	—	—	(lo)	lo	(lo)	lo	(lo)	—	—	—	—	(lo)	—	—	—	lo	—	—
E4	LO	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo
F1	HI	—	—	(hi)	hi	(hi)	(hi)	—	—	(hi)	(hi)	—	—	—	—	—	hi	X	X	X	X	—	(hi)	—	lo	X	X
F2	LOAV	(lo)	—	—	(lo)	(lo)	—	lo	lo	—	lo	lo	lo	lo	lo	—	lo	lo	—	—	—	—	—	—	hi	—	—
F3	LO	—	(lo)	lo	—	X	X	X	X	(lo)	(lo)	X	X	X	X	lo	—	lo	lo	lo	lo	lo	lo	X	X	—	—
F4	LO	lo	lo	lo	—	lo	lo	lo	lo	lo	lo	—	lo	—	—	—	(lo)	(lo)	(lo)	—	(lo)	—	lo	X	X	lo	lo

— Close to average

X Not processed

Table III-1 lists the noise level for each subarray at the microseismic peak for all noise samples and shows that

- Subarrays E4, F3, and F4 were generally low (i.e., more than 3 db below the average spectrum)
- Subarrays D2, D4, E3, and F2 tended to be low
- Subarrays D1, E1, and F1 were generally high (i.e., more than 3 db above the average spectrum)
- Subarrays B2, C3, and C4 tended to be high
- The remaining nine subarrays were generally close to average

Because of the peaked nature of the noise spectrum, the subarrays which are low at the microseismic peak are "quiet" sites in terms of total noise power; conversely, the high subarrays are noisy sites. Figure III-14 shows that the three quiet subarrays are located on the western edge of LASA. E4, which is the quietest, lies directly over the Porcupine Dome, and F3 and F4 are on its flanks. Apparently, this large feature and associated complex geology attenuate the low-frequency microseismic energy. On the other hand, the noisy subarrays are located in the northeast sector of LASA where variations in crustal structure are much less severe. No explanation for the noisy characteristics of these subarrays is known.

Between the microseismic peak and about 1.5 cps, noise levels varied both from subarray to subarray and from noise sample to noise sample. Other studies have shown that a substantial amount of the noise in this frequency band is high velocity,[2] so one might expect consistent spectral ratios from noise sample to noise sample (as was observed at the microseismic peak). However, the source of energy at the microseismic peak was consistently to the northeast,[2] but the source of energy between the microseismic peak and 1.5 cps appeared to vary. It has been shown that subarray signal amplitudes are dependent on the location of the event.[3] Thus, the variation in source location is a possible explanation of the difference in power levels from noise sample to noise sample in the 0.3- to 1.5-cps frequency band. Also, the effect of local crustal structure on the shorter wavelength energy may be partially responsible for the varying noise levels.

At frequencies above 1.5 cps, noise levels varied considerably from subarray to subarray and did not show the consistency from noise sample to noise sample as was observed at the microseismic peak. Table III-2 lists characteristics of the spectral ratios at each subarray which were observed on some (but not all) of the noise samples. There appeared to be no highs or lows common to a set of subarrays implying that, above 1.5 cps, the noise at a subarray was generated in the vicinity of a subarray.

Table III-2

CHARACTERISTICS OF SUBARRAY SPECTRA ABOVE MICROSEISMIC PEAK

Subarray	Spectral Characteristics Seen on Some Noise Samples
A0	High between 2 and 3 cps
B1	———
B2	———
B3	Slightly low above 2 cps
B4	———
C1	Small peak at approximately 2.5 cps
C2	Close to average above 0.5 cps
C3	Low above 2 cps
C4	———
D1	Close to average above 0.5 cps
D2	Large peak between 1 and 2 cps
D3	———
D4	Several sharp peaks between 3 and 5 cps
E1	Peak at approximately 2.5 cps
E2	Close to average above 0.5 cps
E3	Lows at approximately 1.5 and 2.5 cps
E4	Lows at 1.5 and 2.5 cps
F1	High between 2 and 4 cps
F2	———
F3	Low at approximately 3.0 cps
F4	Large peak at approximately 3.0 cps

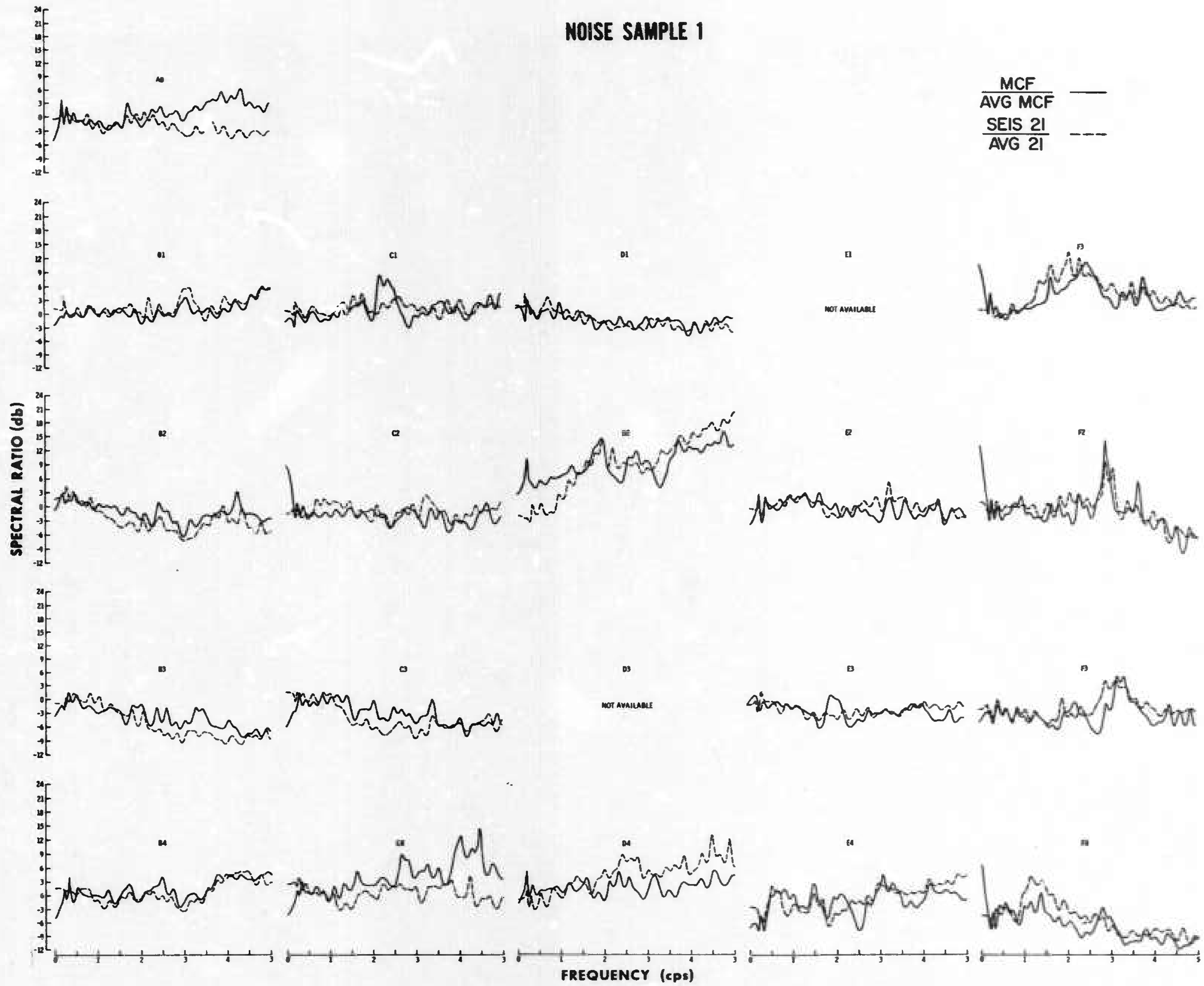


Figure III-1. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 1

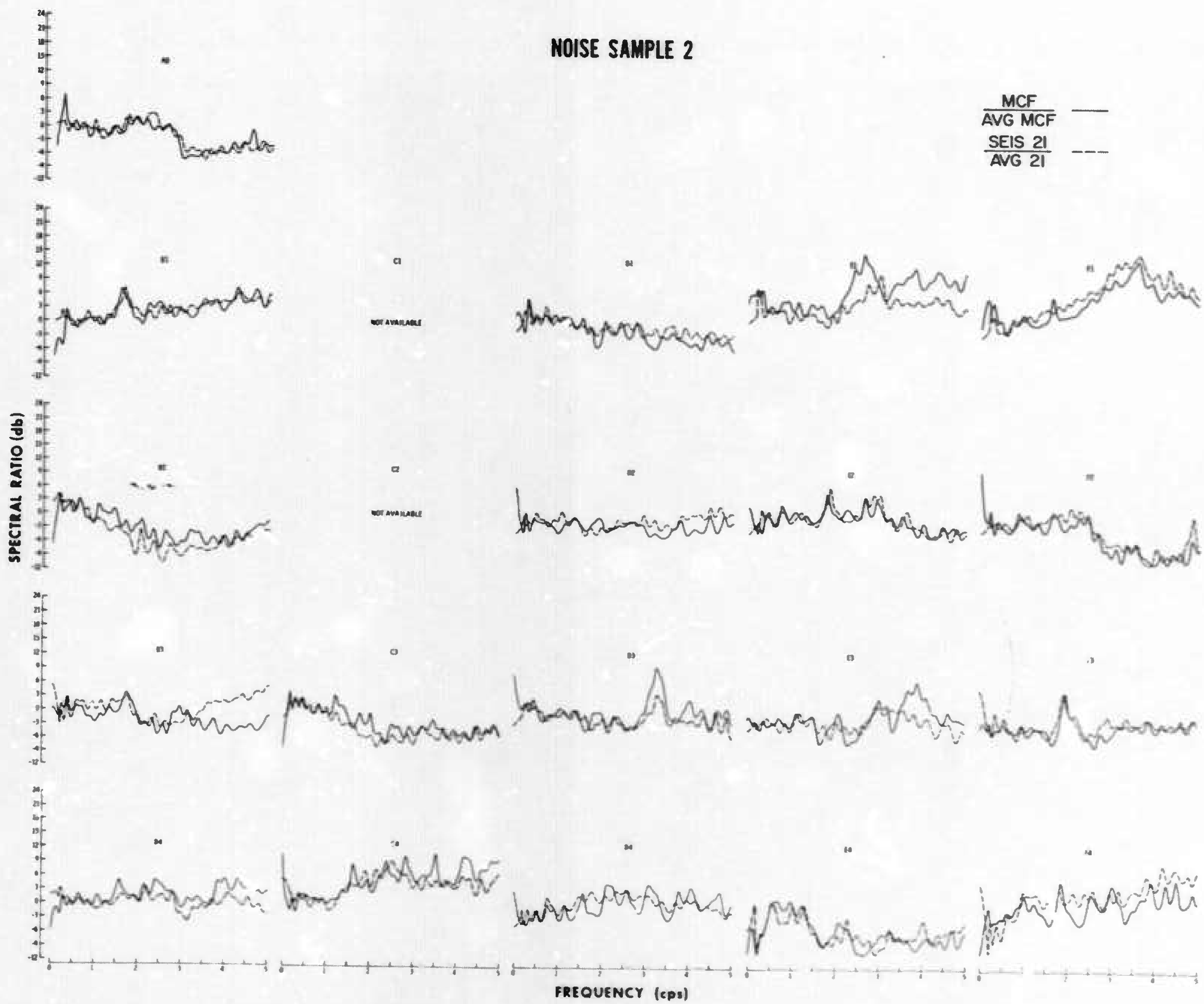


Figure III-2. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 2

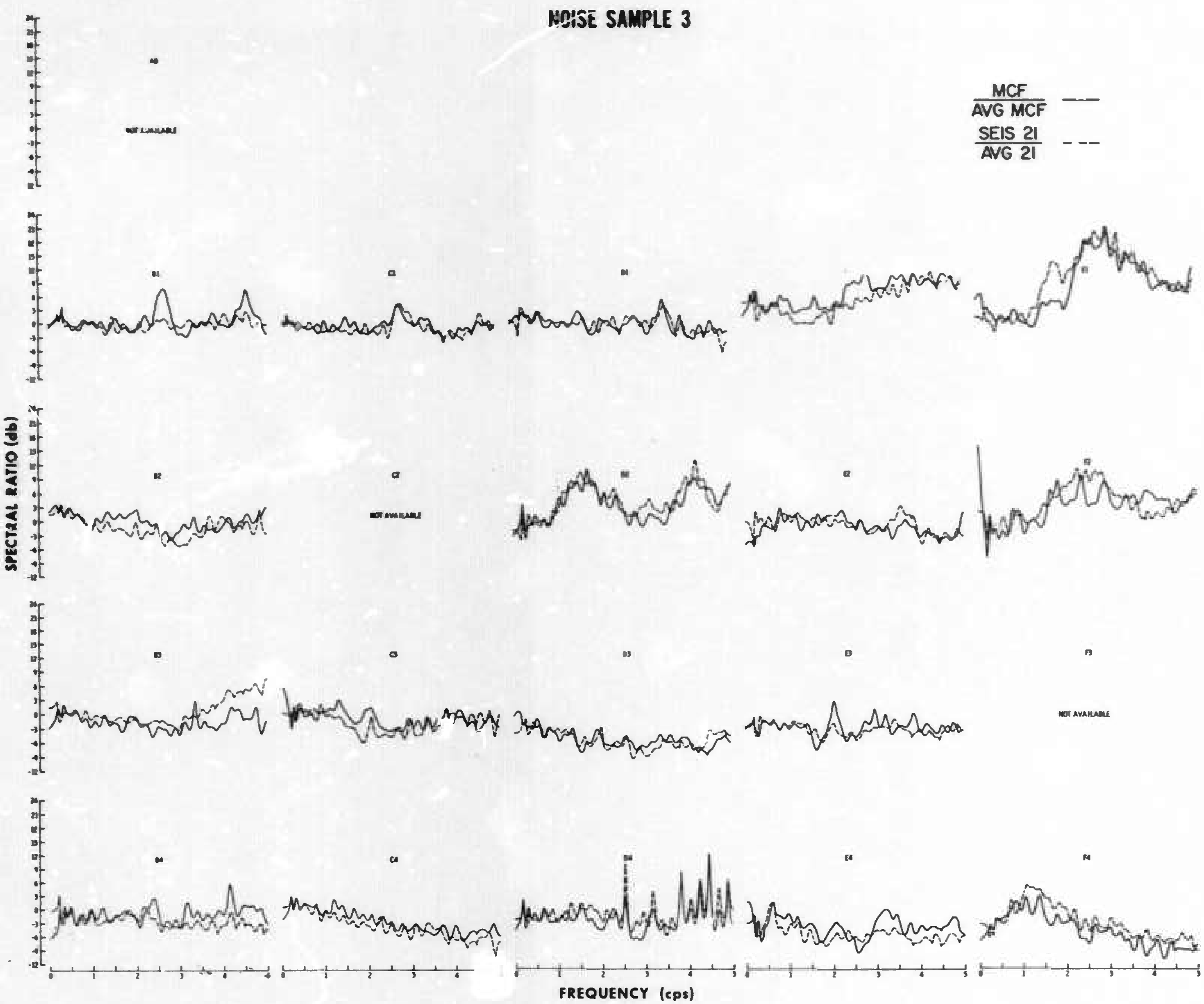


Figure III-3. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 3

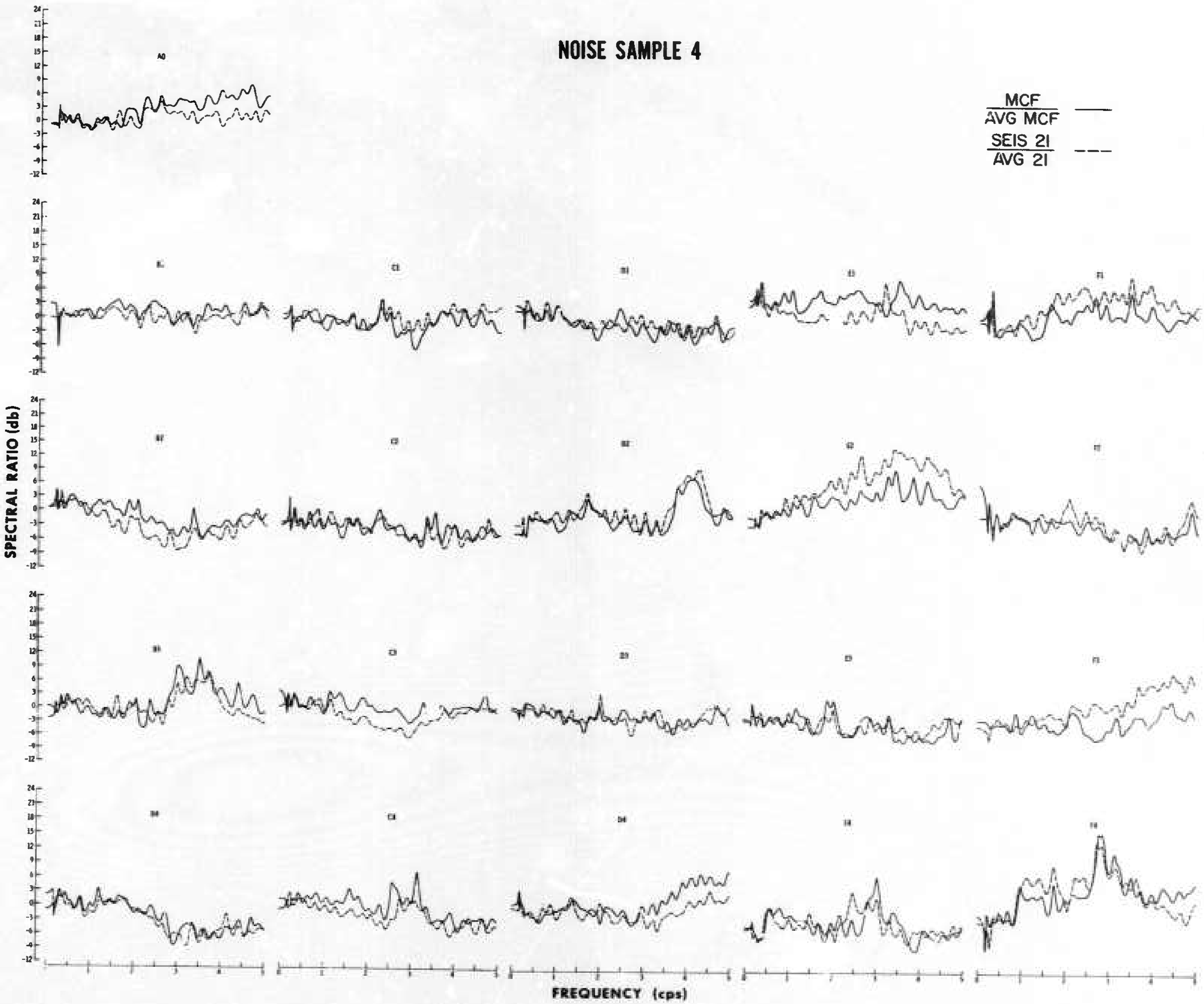


Figure III-4. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 4

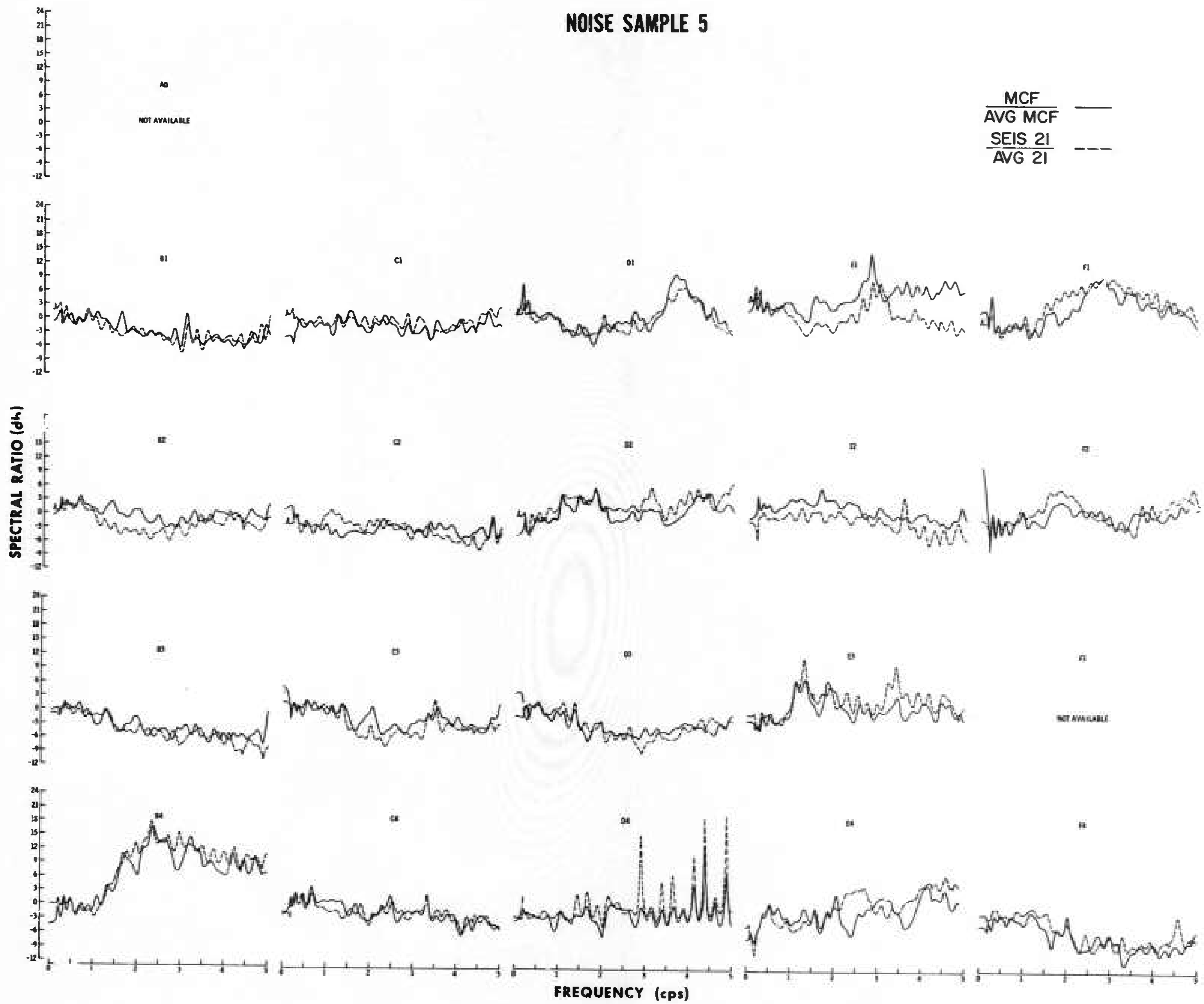


Figure III-5. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 5

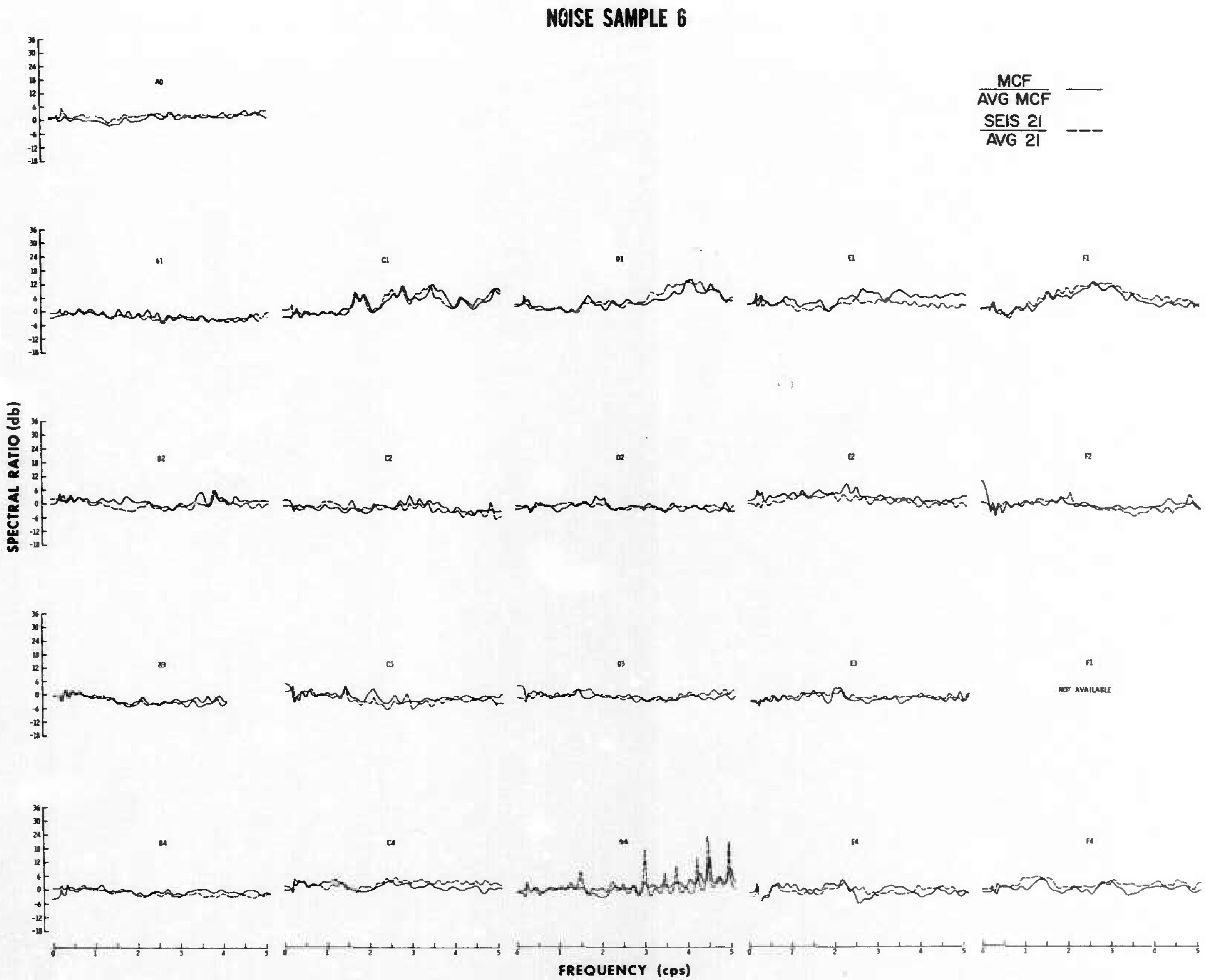


Figure III-6. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 6

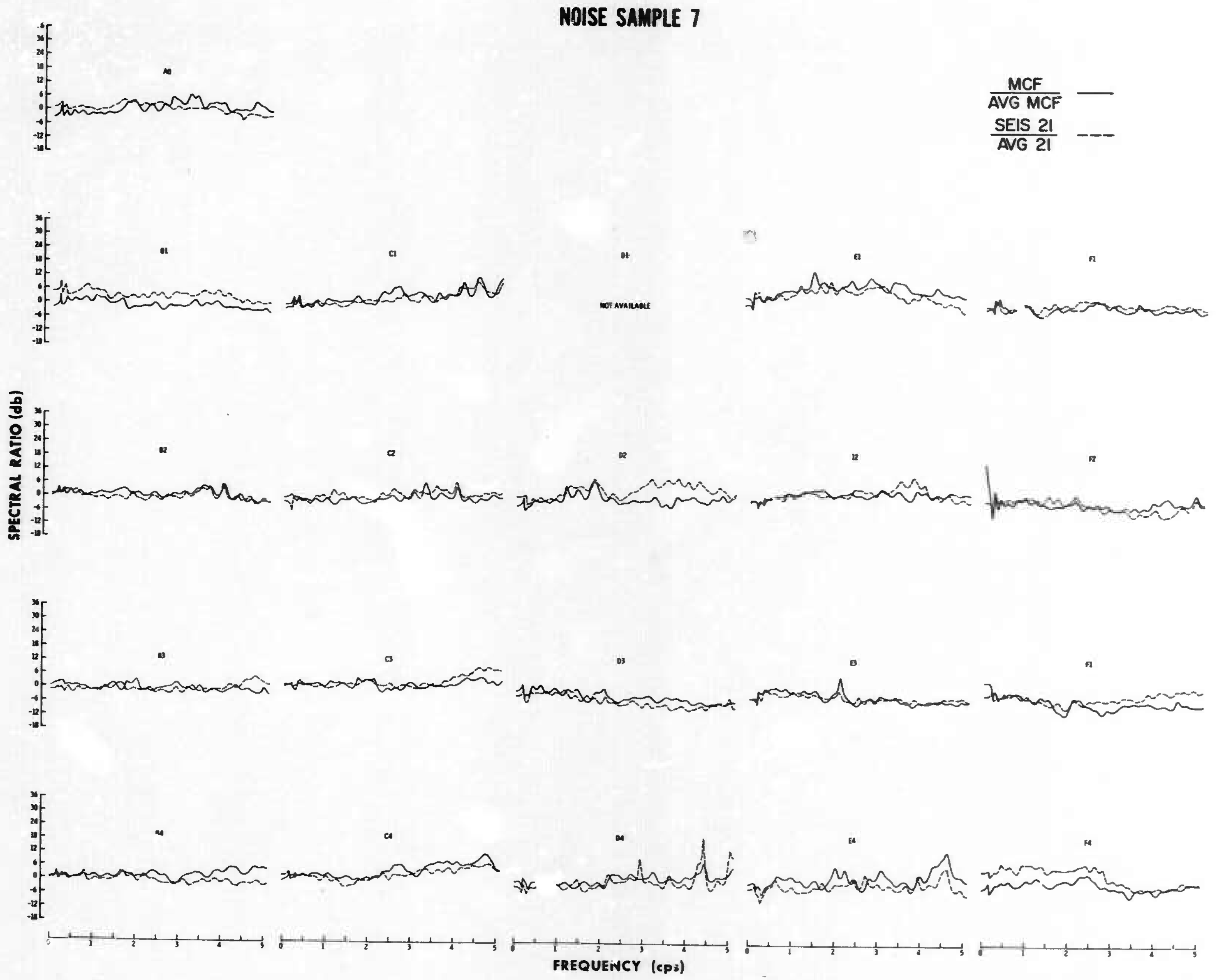


Figure III-7. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 7

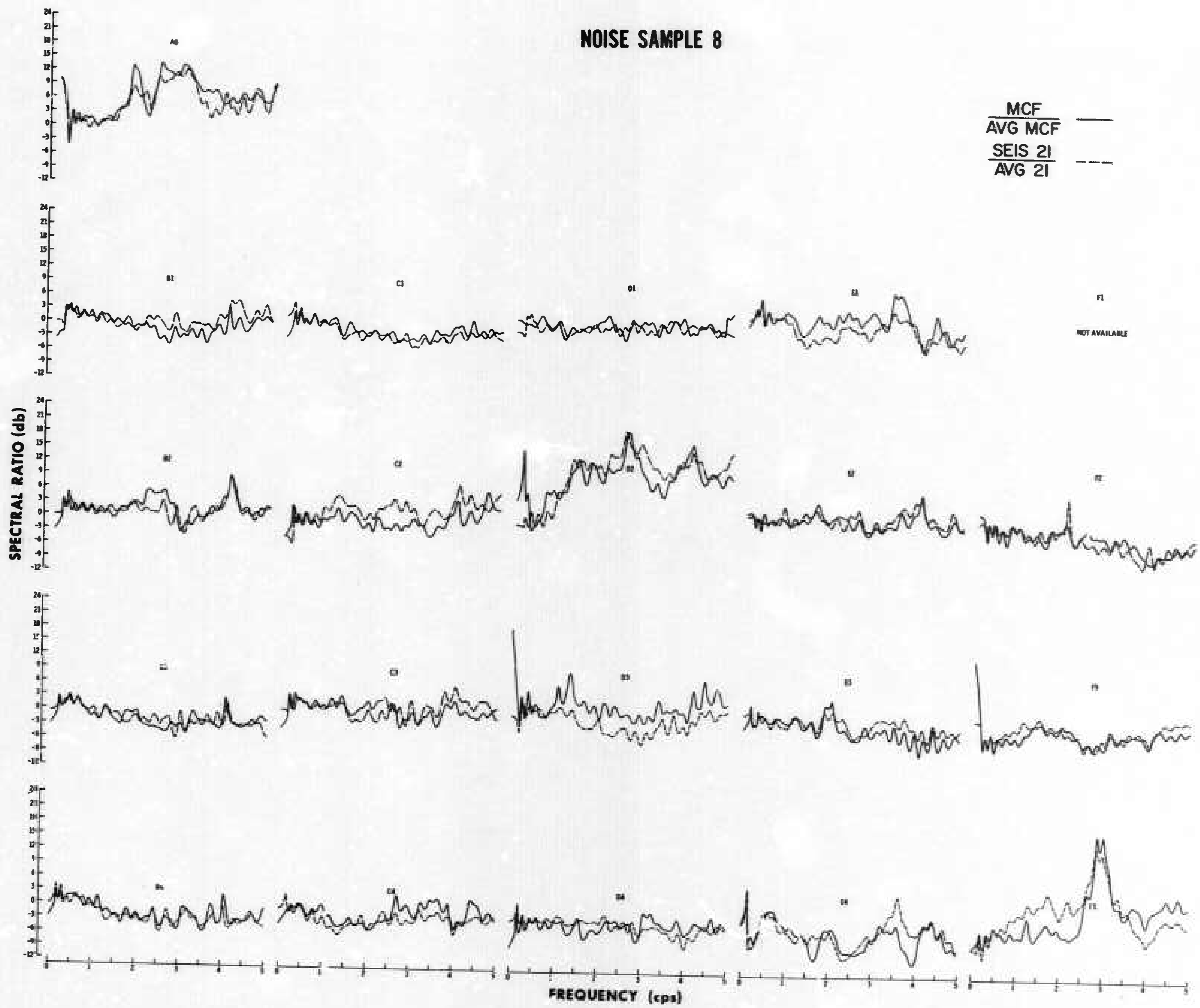


Figure III-8. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 8

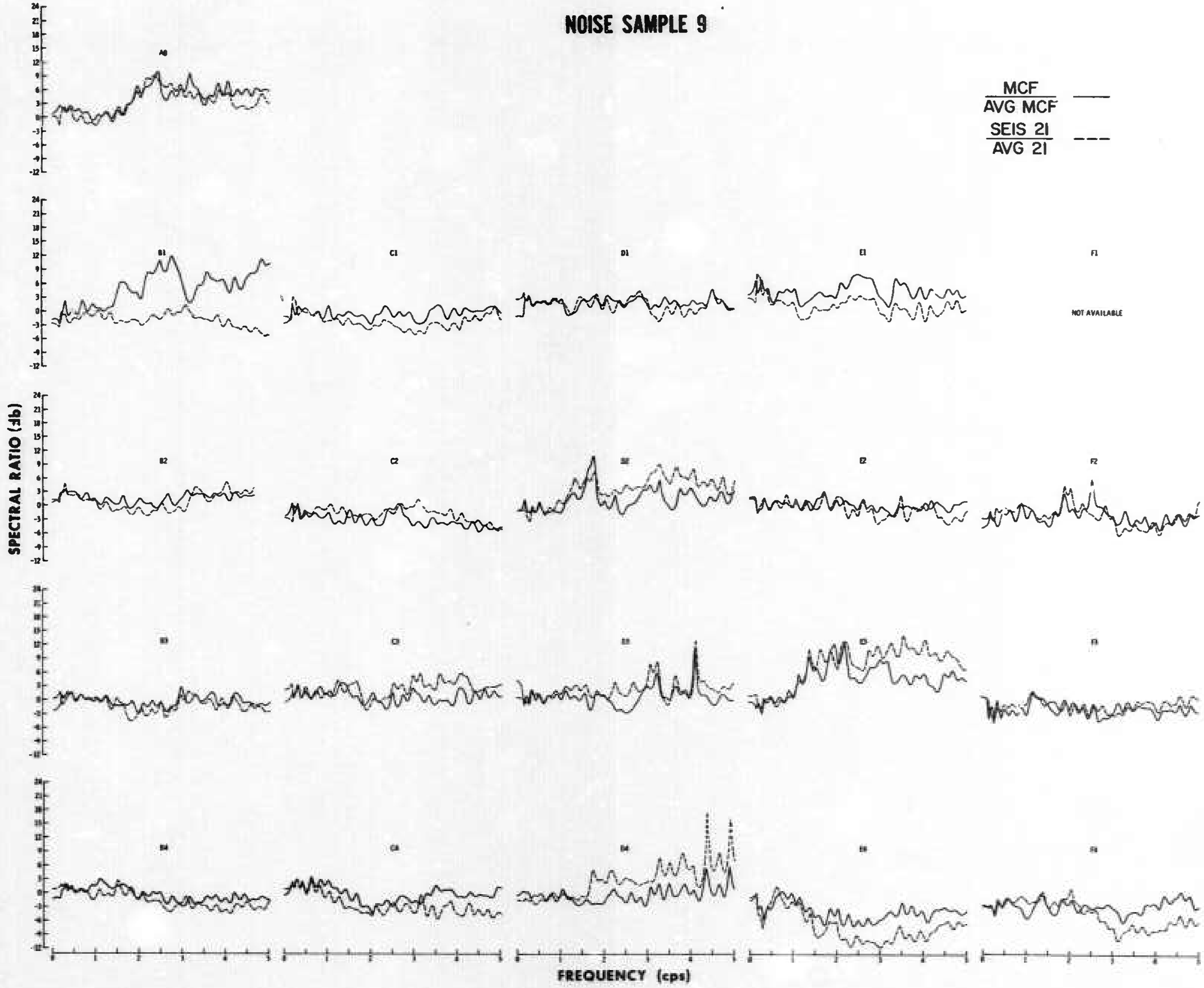


Figure III-9. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 9

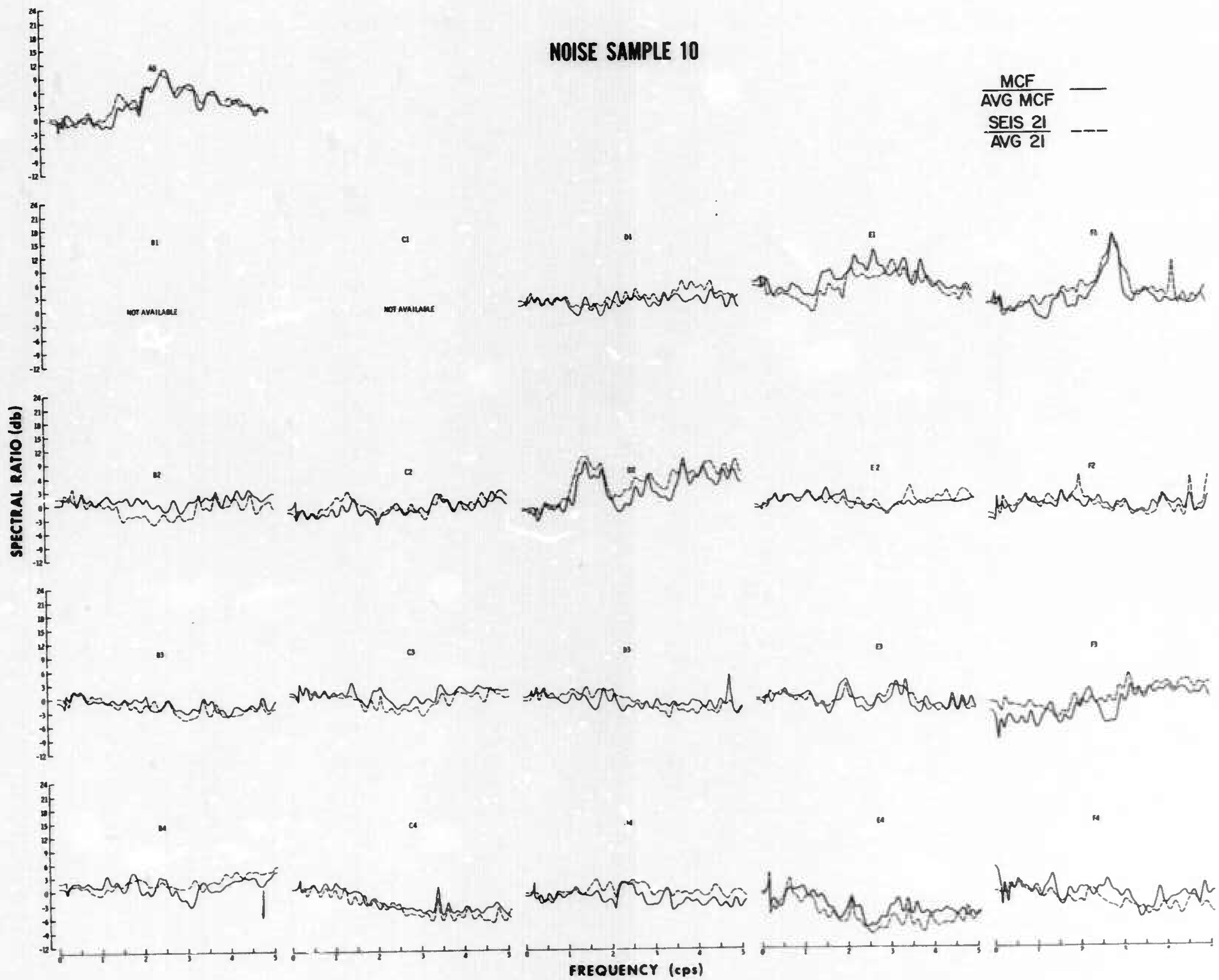


Figure III-10. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 10

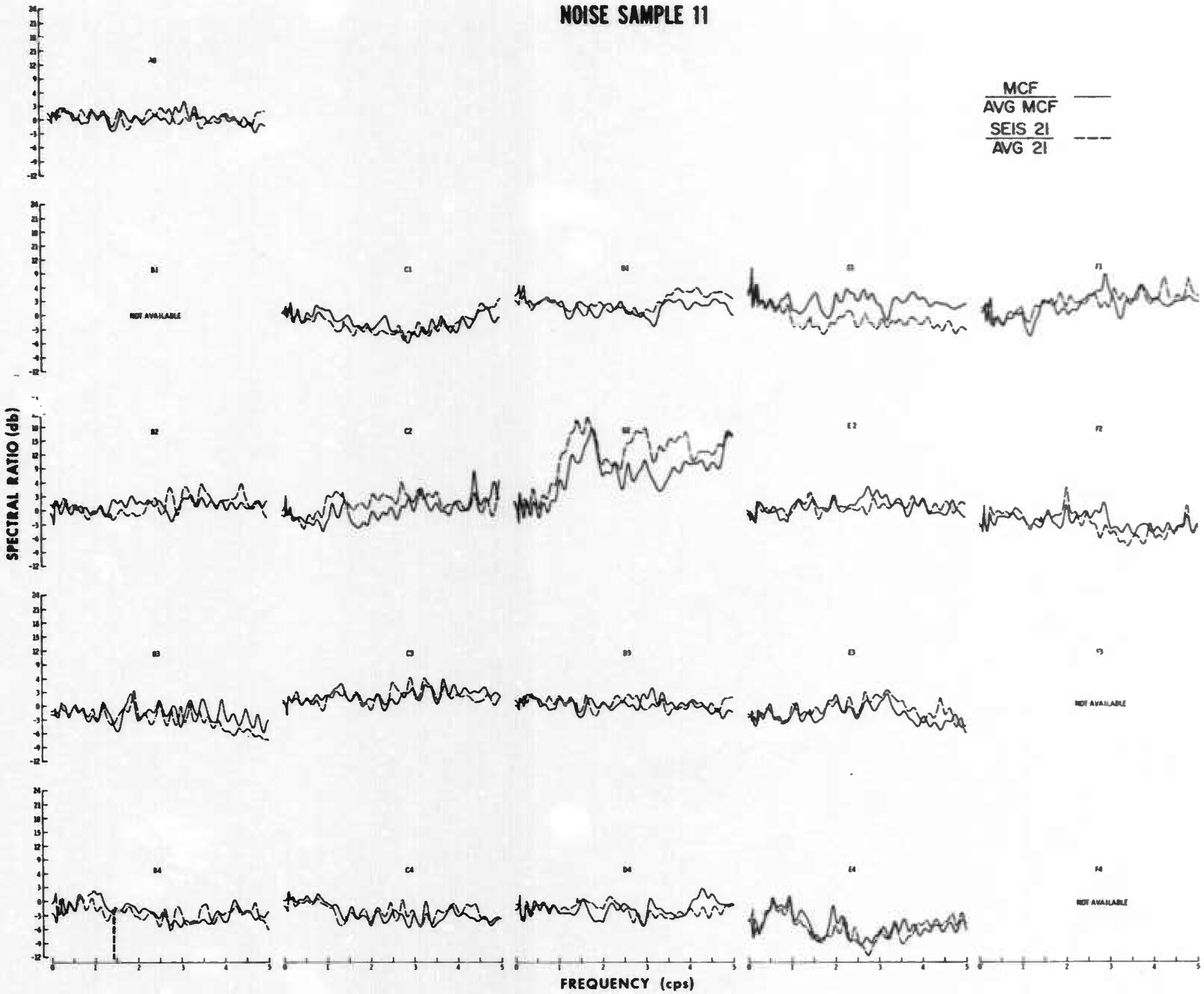


Figure III-11. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 11

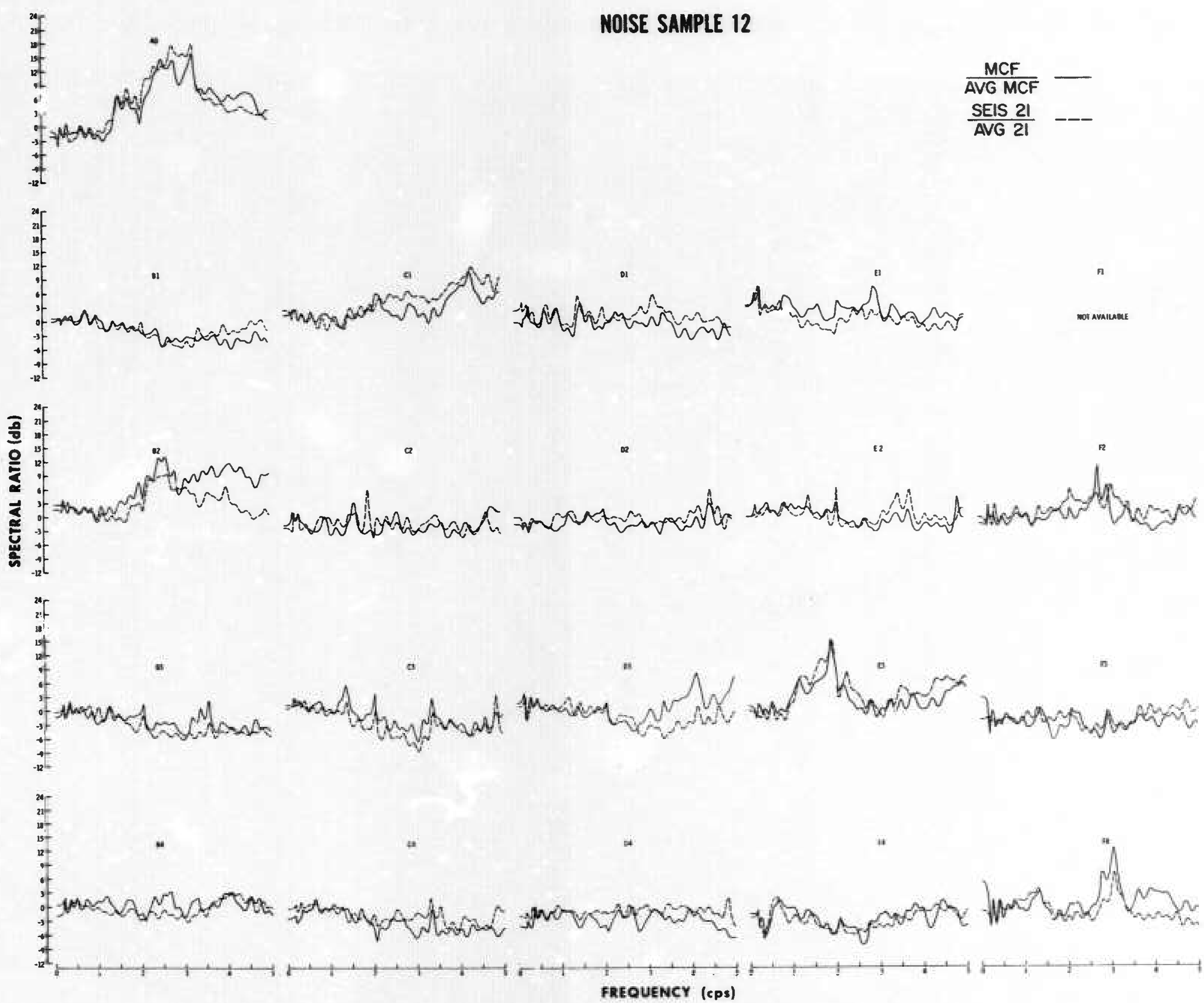


Figure III-12. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 12

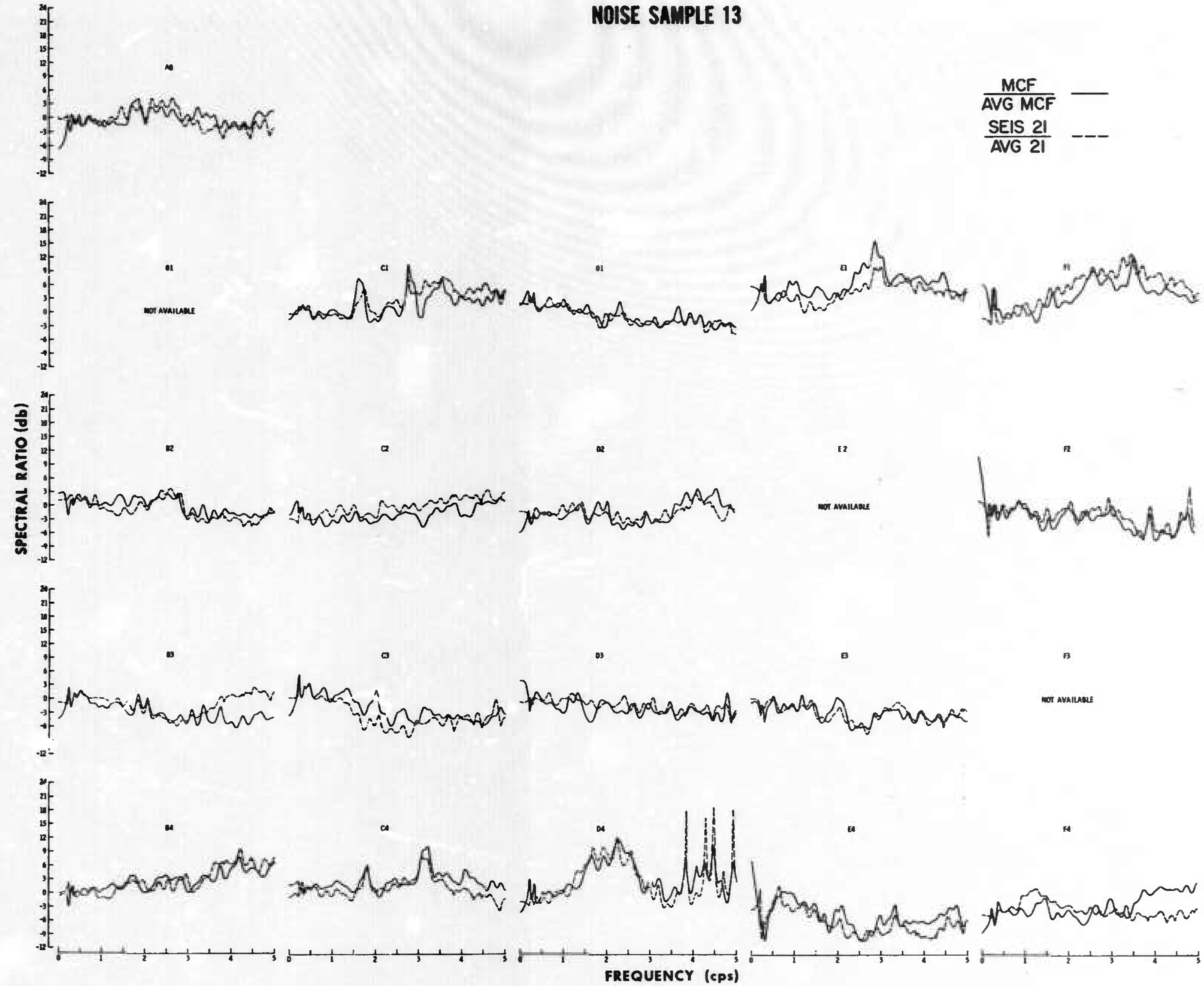
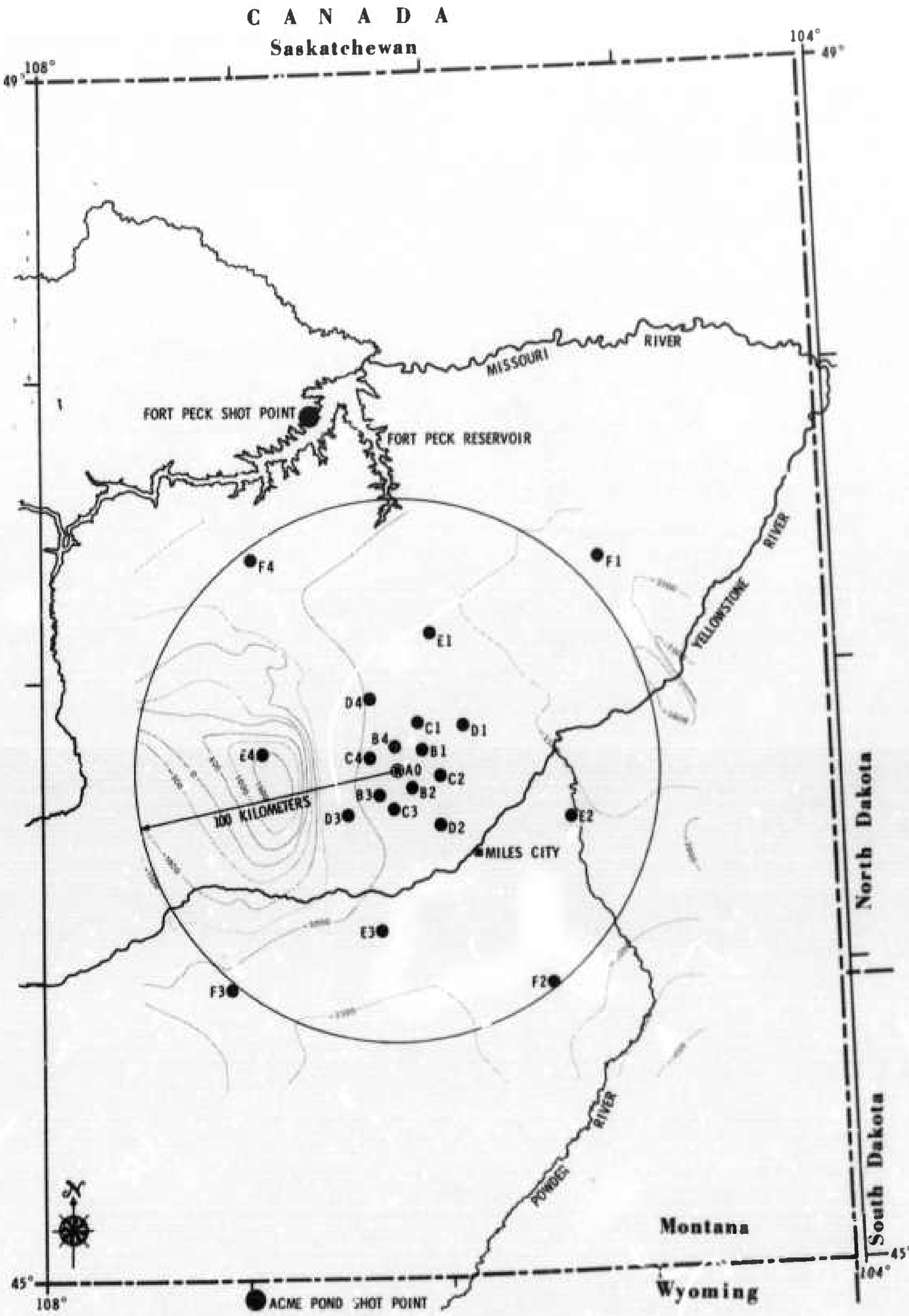


Figure III-13. Individual-to-Average Spectral Ratios for Seismometer 21 and MCF Outputs, Noise Sample 13



STRUCTURE CONTOURS ON PRESENT OR RESTORED BASE OF COLORADO SHALE

Figure III-14. Subsurface Geology at LASA

SECTION IV

TIME VARIABILITY OF LASA NOISE FIELD

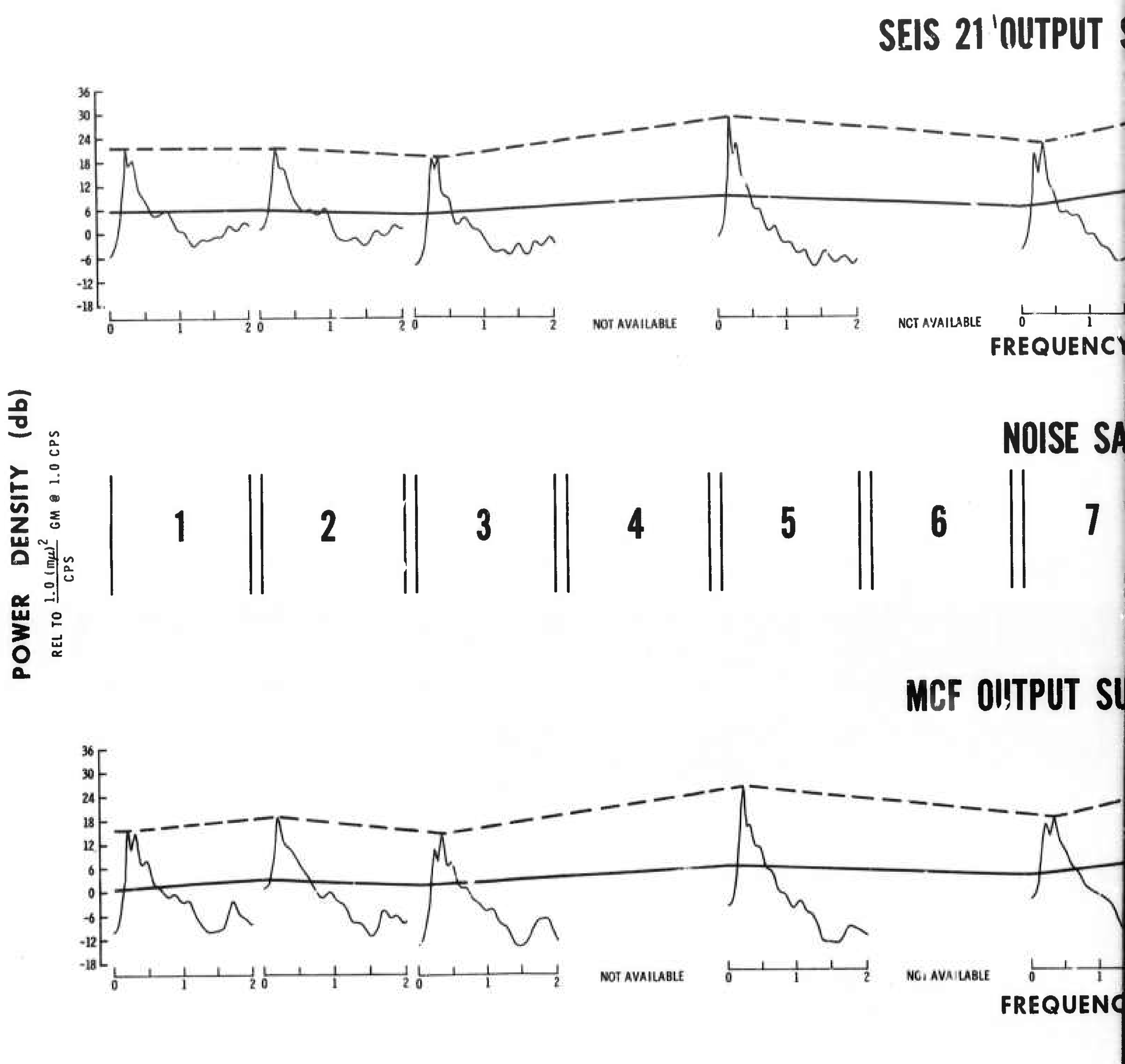
To study the long-term time variability of the LASA noise field, spectral estimates for both the single seismometer and MCF outputs at each subarray were plotted as a function of time (Figures IV-1 through IV-21). The spectra were converted to absolute units (db relative to 1 $(m\mu)^2$/cps at 1 cps) using the fact that the noise data had been equalized to 35 counts/mμ at 1 cps on the basis of the nearest (in time) 1 cps calibration information. The plots were confined to the 0- to 2-cps band because the main interest was in the microseismic peak. Dashed lines join the peak values of the power spectra; solid lines join the average power levels. The two lines are about parallel for each subarray because of the peaked nature of the spectra.

The maximum variation in the power levels was 8 to 10 db for each subarray over the 6-month period covered by the noise samples. Note that the microseismic "peak" was really two peaks — one at 2.0 cps and one at 0.3 cps — and that the maximum value of a spectrum occurred at 0.2 cps for some noise samples and at 0.3 cps for others.

Figure IV-22 shows that the variations in average power from noise sample to noise sample were similar at all subarrays. Noise samples 5 and 8 had relatively high power levels, while noise samples 9, 11, and 13 were low. The excellent agreement between subarrays was also indicated in Section III by the consistency of the spectral ratios at the microseismic peak; i.e., although the absolute level varied, the relative levels between subarrays were consistent. It is evident that a common mechanism generated most of the energy in the microseismic peak across the entire LASA. This observation is consistent with the theory that large storms at sea are the major source of low-frequency microseismic energy.[2] The far-source generation mechanism contrasts with the local generation of microseismic noise above 1.5 cps as observed in Section III.

Above 1.5 cps, the time variability can be determined from Figures III-1 to III-13. As stated previously, considerable variation from noise sample to noise sample existed at each subarray. Figures IV-23 through IV-25 illustrate the variation for three subarrays. For all three, the ratios were similar at the microseismic peak. Above 1.5 cps, B2 tended to be low; however, noise samples 3, 9, 10, 11, 12, and 13 had highs at some frequencies. D2 tended to be high, but noise samples 2, 3, and 13 were about average. F4 was quite variable. Thus, most of the microseismic energy above 1.5 cps appeared to be nontime stationary.

In summary, noise levels varied by 8 to 10 db from noise sample to noise sample at the microseismic peak; but the variation was observed across LASA, implying a common noise source for most of the energy between 0.2 and 0.3 cps. The relative levels were also consistent, with subarrays E4, F3, and F4 lower than average and B2, C3, and C4 higher. Between the microseismic peak and 1.5 cps, noise levels varied both from subarray to subarray and from noise sample to noise sample though part of the noise in this range was high velocity. A possible explanation for the variation is the variation in noise-source location as indicated by the wavenumber analysis.[2] Above 1.5 cps, the noise was nontime stationary and appeared to be locally generated (i.e., in the vicinity of a given subarray).



SEIS 21 OUTPUT S
36
30
24
18
12
6
0
-6
-12
-18
0 1 2
NOT AVAILABLE
NOT AVAILABLE
FREQUENCY
POWER DENSITY (db)
REL TO 1.0 (mμ)² / CPS GM @ 1.0 CPS
NOISE SA
1
2
3
4
5
6
7
MCF OUTPUT SU
FREQUENC

A

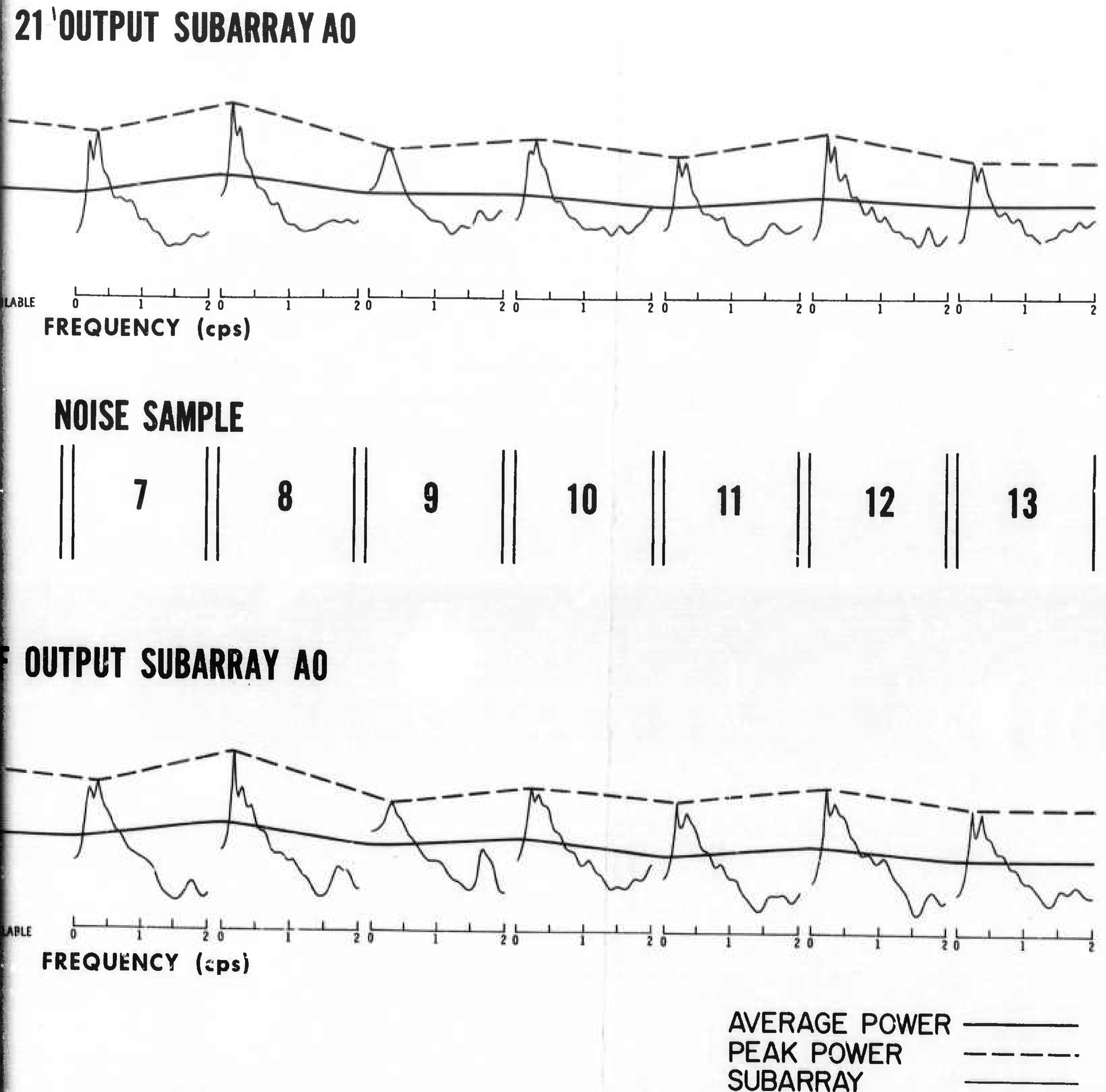
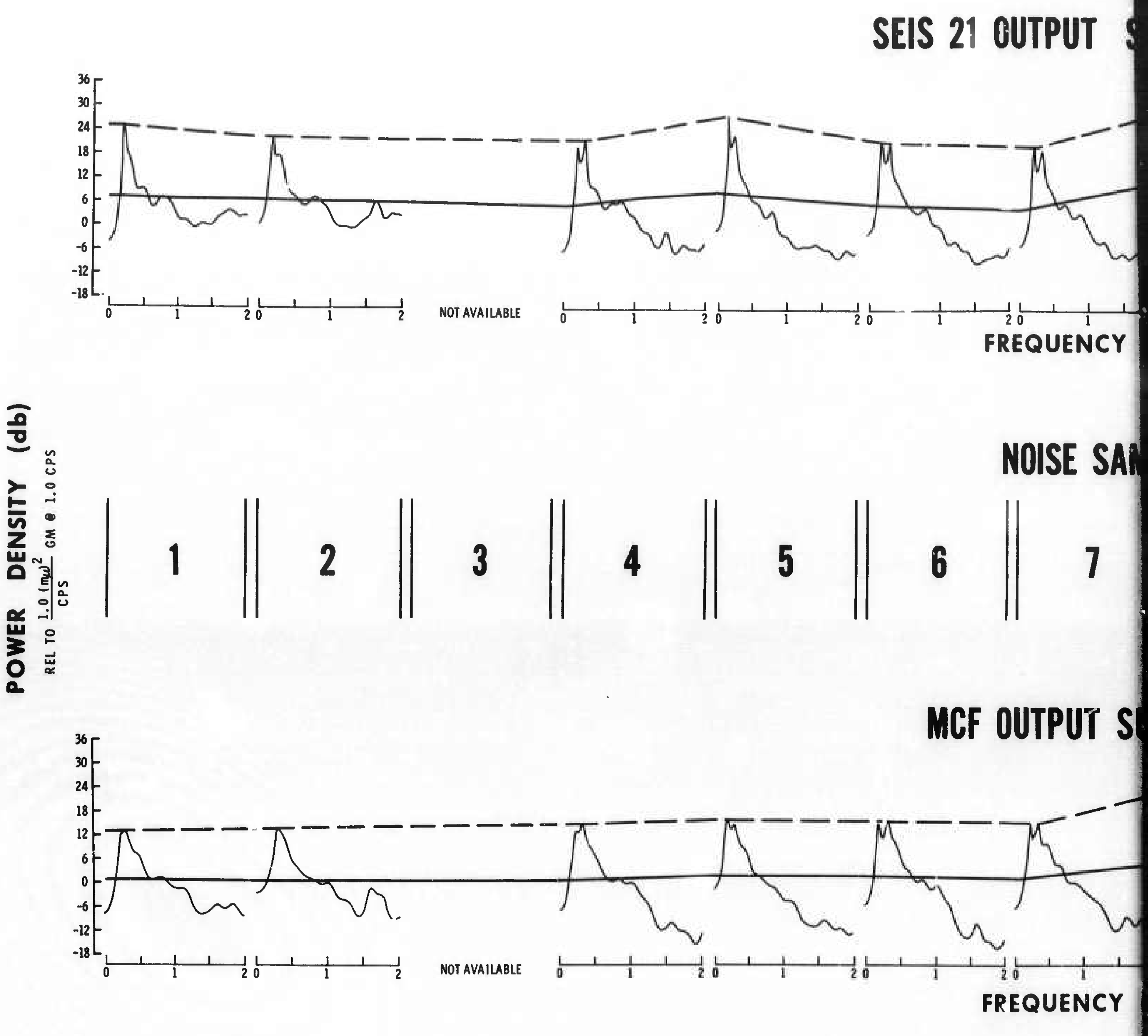


Figure IV-1. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray A0

B


SEIS 21 OUTPUT S
36
30
24
18
12
6
0
-6
-12
-18
0 1 2 0 1 2
NOT AVAILABLE
0 1 2 0 1 2 0 1 2 0 1
FREQUENCY
POWER DENSITY (db)
REL TO $\frac{1.0\ (m\mu)^2}{CPS}$ GM @ 1.0 CPS
NOISE SA
1
2
3
4
5
6
7
MCF OUTPUT S
36
30
24
18
12
6
0
-6
-12
-18
0 1 2 0 1 2
NOT AVAILABLE
0 1 2 0 1 2 0 1 2 0 1
FREQUENCY

A

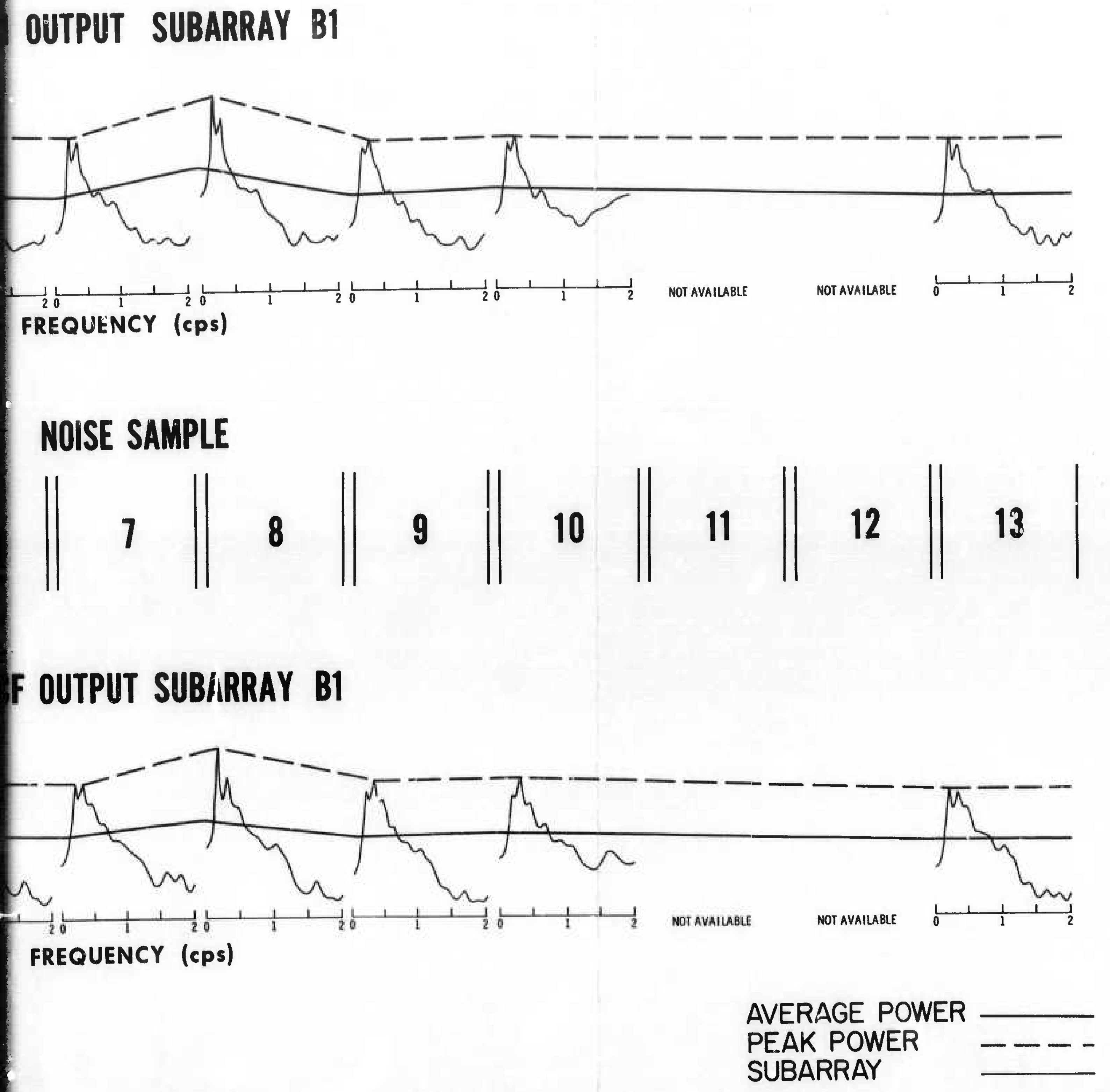
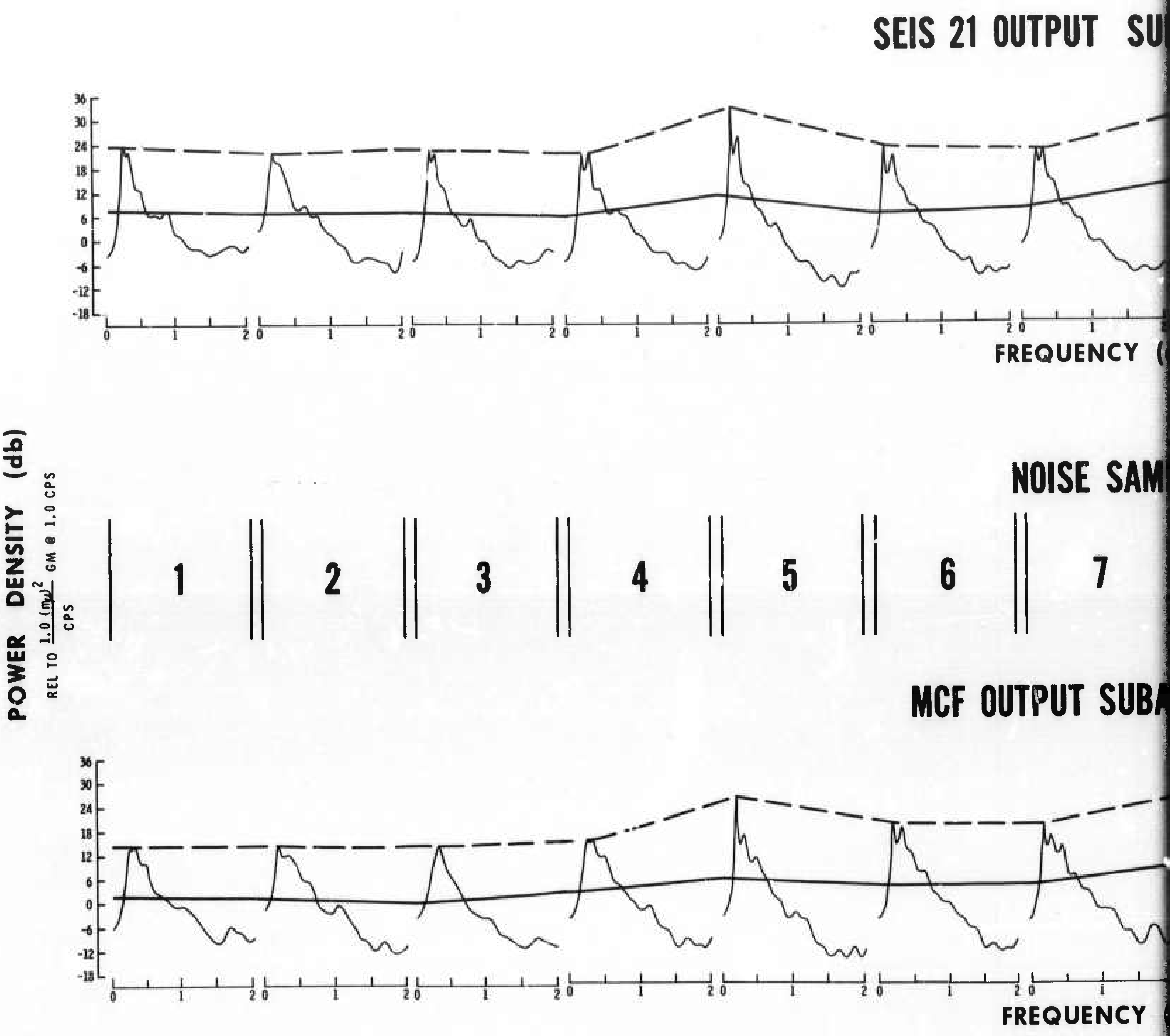


Figure IV-2. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray B1



SEIS 21 OUTPUT SU
NOISE SAM
MCF OUTPUT SUBA
POWER DENSITY (db)
REL TO $\frac{1.0\ (m\mu)^2}{CPS}$ GM @ 1.0 CPS
FREQUENCY (
FREQUENCY
1
2
3
4
5
6
7
36
30
24
18
12
6
0
-6
-12
-18

A

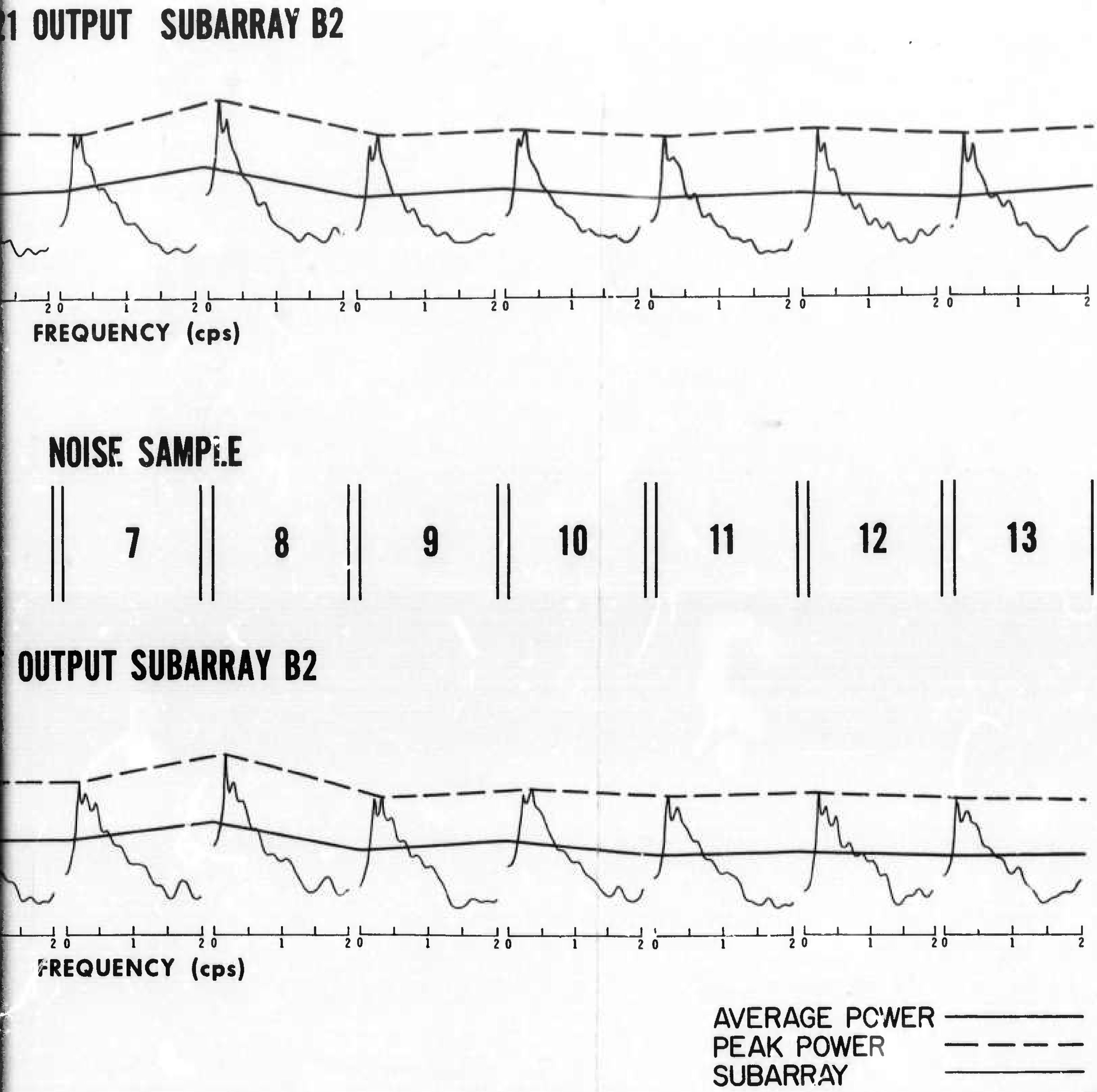
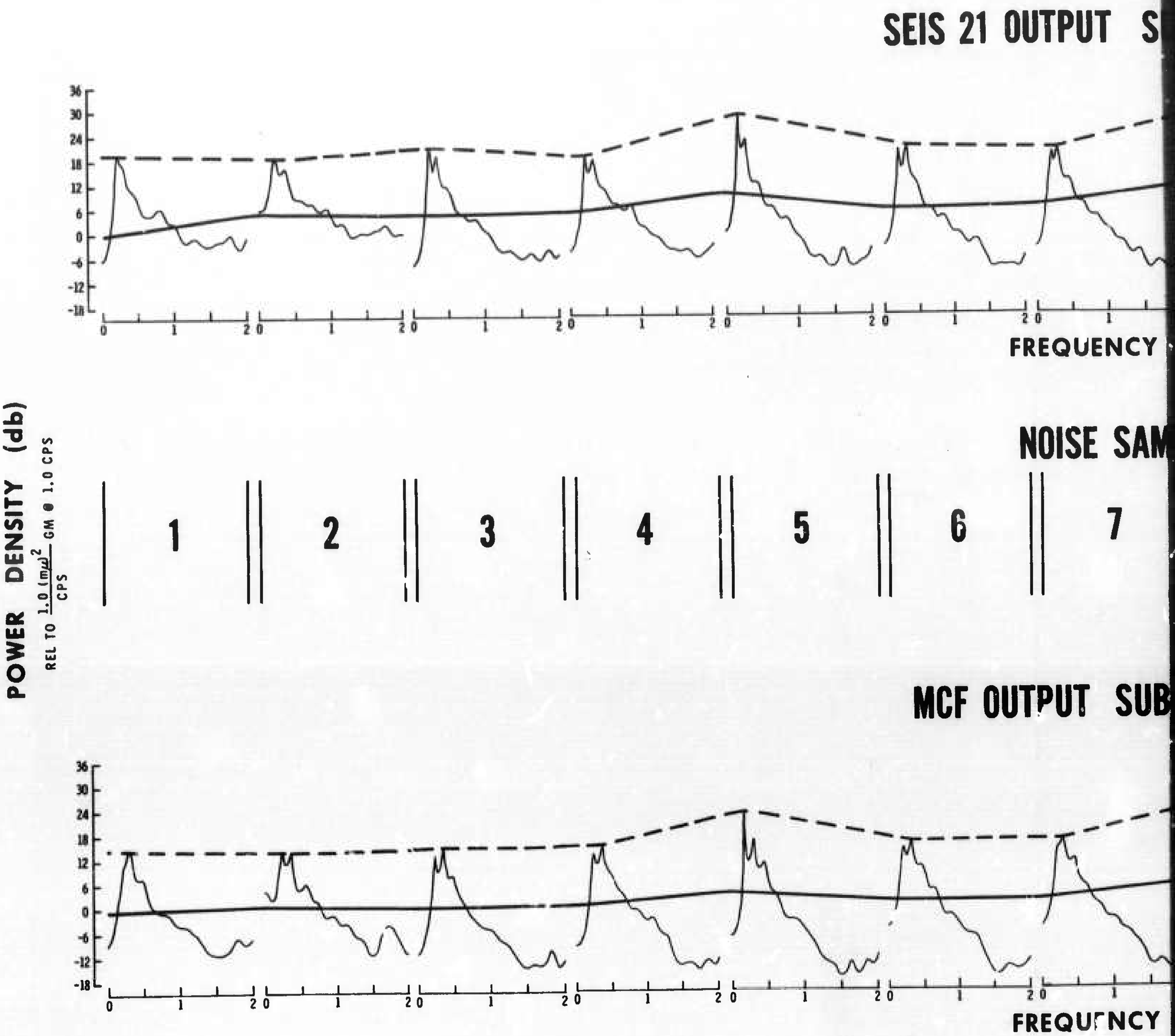


Figure IV-3. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray B2


SEIS 21 OUTPUT S
FREQUENCY
POWER DENSITY (db)
REL TO 1.0 (mμ)² / CPS GM @ 1.0 CPS
NOISE SAM
1
2
3
4
5
6
7
MCF OUTPUT SUB
FREQUENCY

A

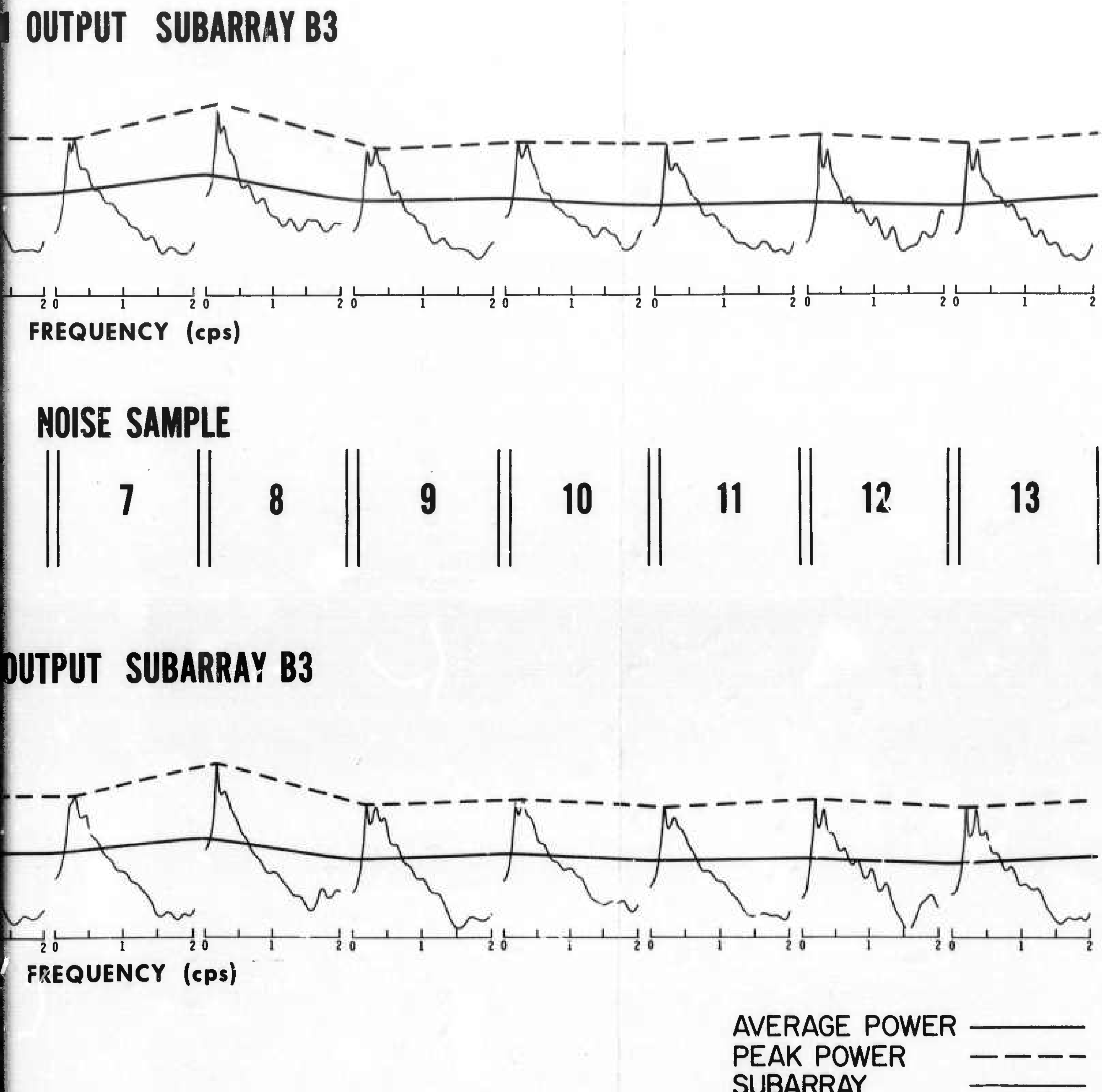
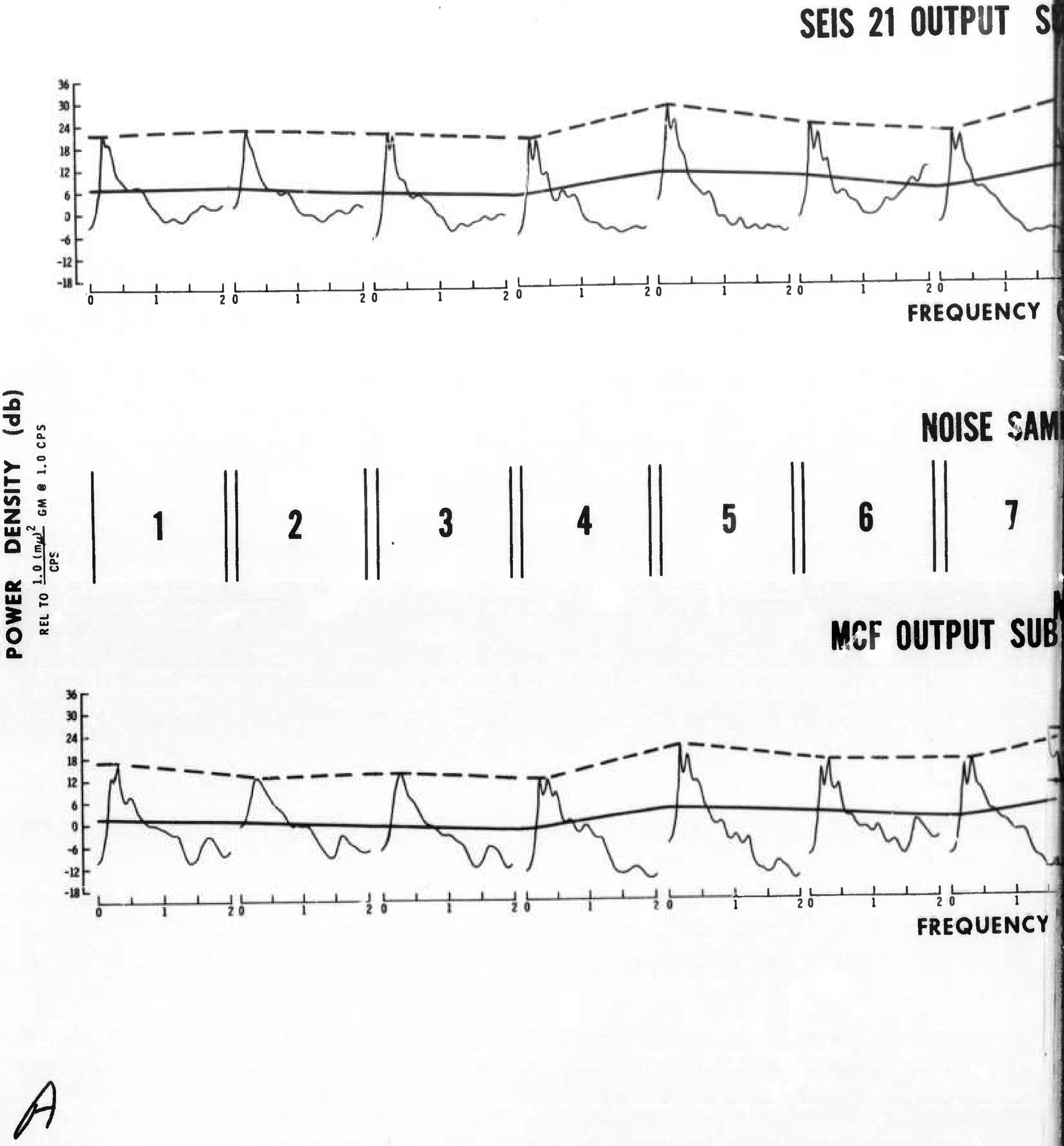


Figure IV-4. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray B3


SEIS 21 OUTPUT
NOISE
MCF OUTPUT
POWER DENSITY (db)
REL TO $\frac{1.0\ (m\mu)^2}{CPS}$ GM @ 1.0 CPS
FREQUENCY
1
2
3
4
5
6
7
36
30
24
18
12
6
0
-6
-12
-18
0
1
2

A

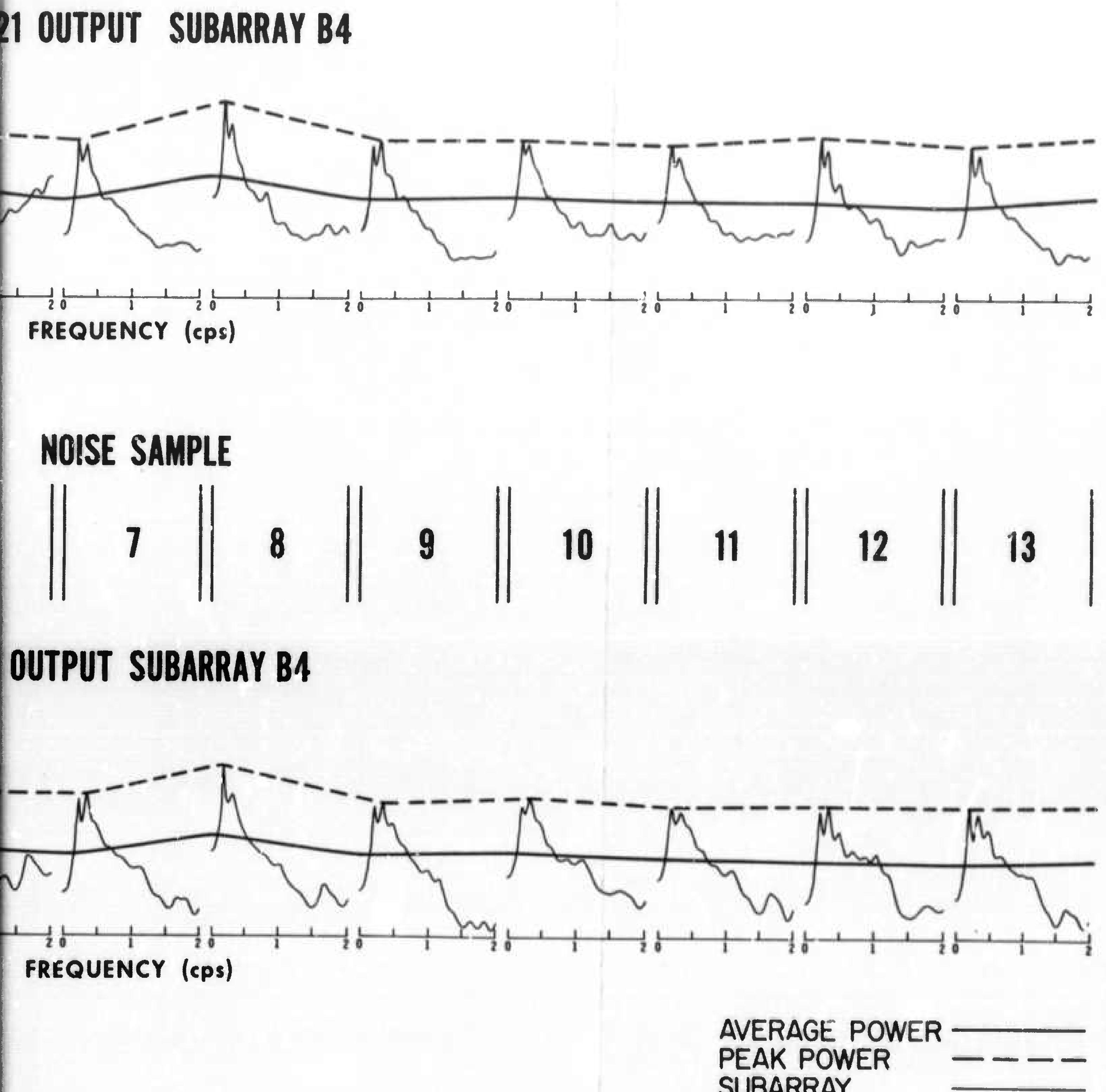
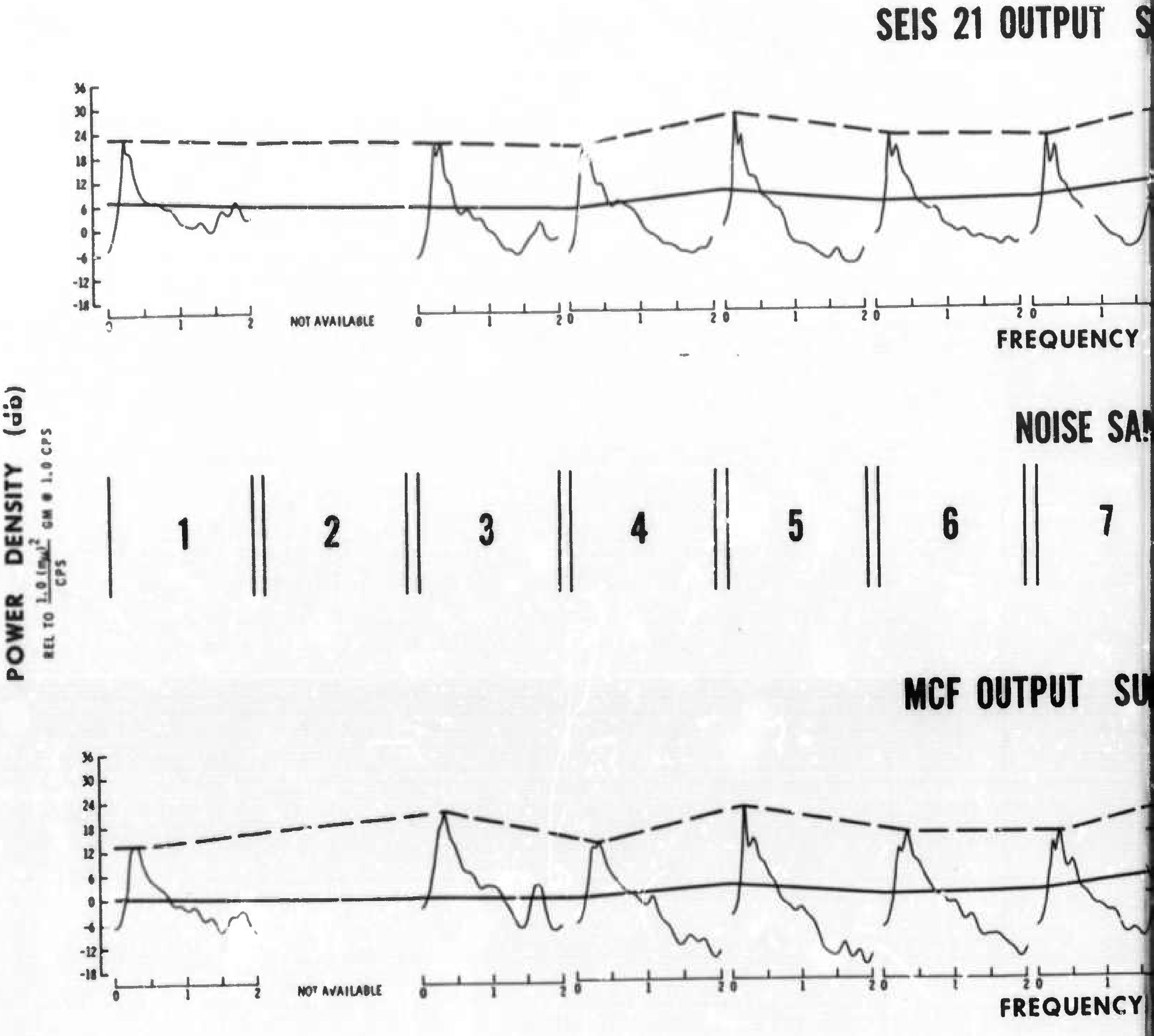


Figure IV-5. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray B4

B


SEIS 21 OUTPUT
NOISE
MCF OUTPUT
POWER DENSITY (db)
REL TO 1.0 (mμ)² GM @ 1.0 CPS / CPS
36
30
24
18
12
6
0
-6
-12
-18
NOT AVAILABLE
FREQUENCY
1
2
3
4
5
6
7

A

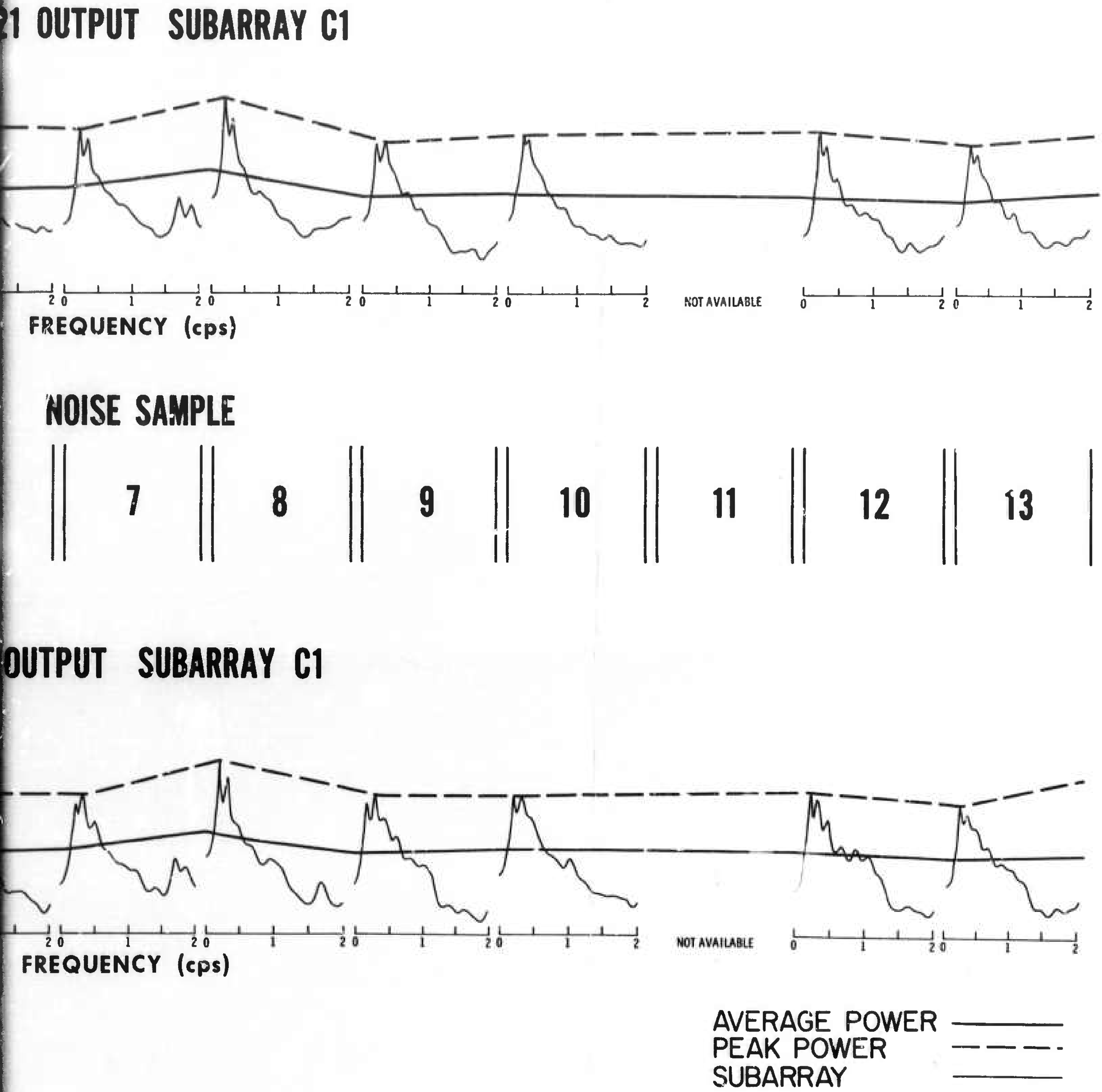
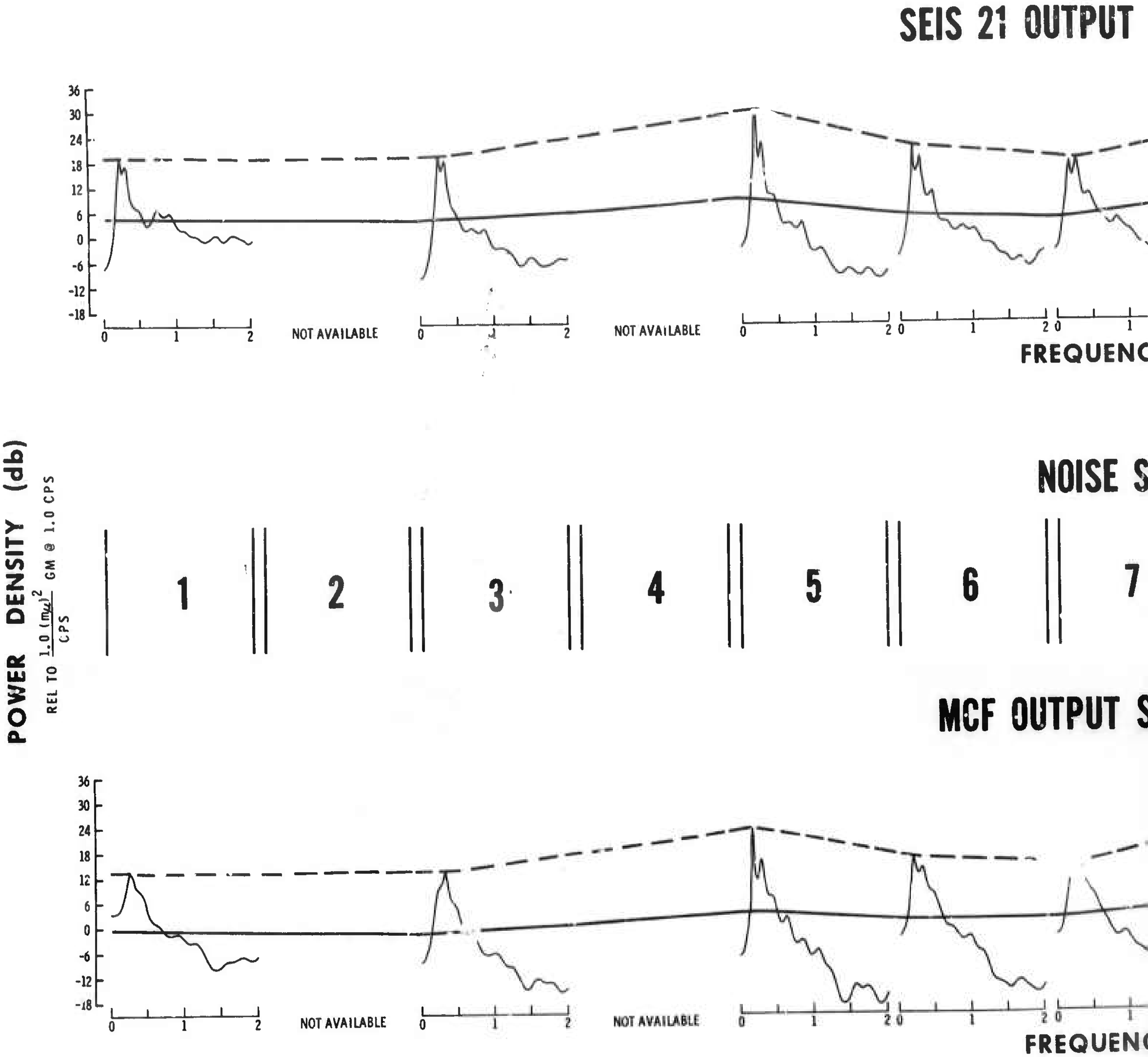


Figure IV-6. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray C1

B


SEIS 21 OUTPUT
NOISE S
MCF OUTPUT S
POWER DENSITY (db)
REL TO $\frac{1.0\,(m\mu)^2}{CPS}$ GM @ 1.0 CPS
1
2
3
4
5
6
7
NOT AVAILABLE
NOT AVAILABLE
NOT AVAILABLE
NOT AVAILABLE
FREQUENC
FREQUENC

A

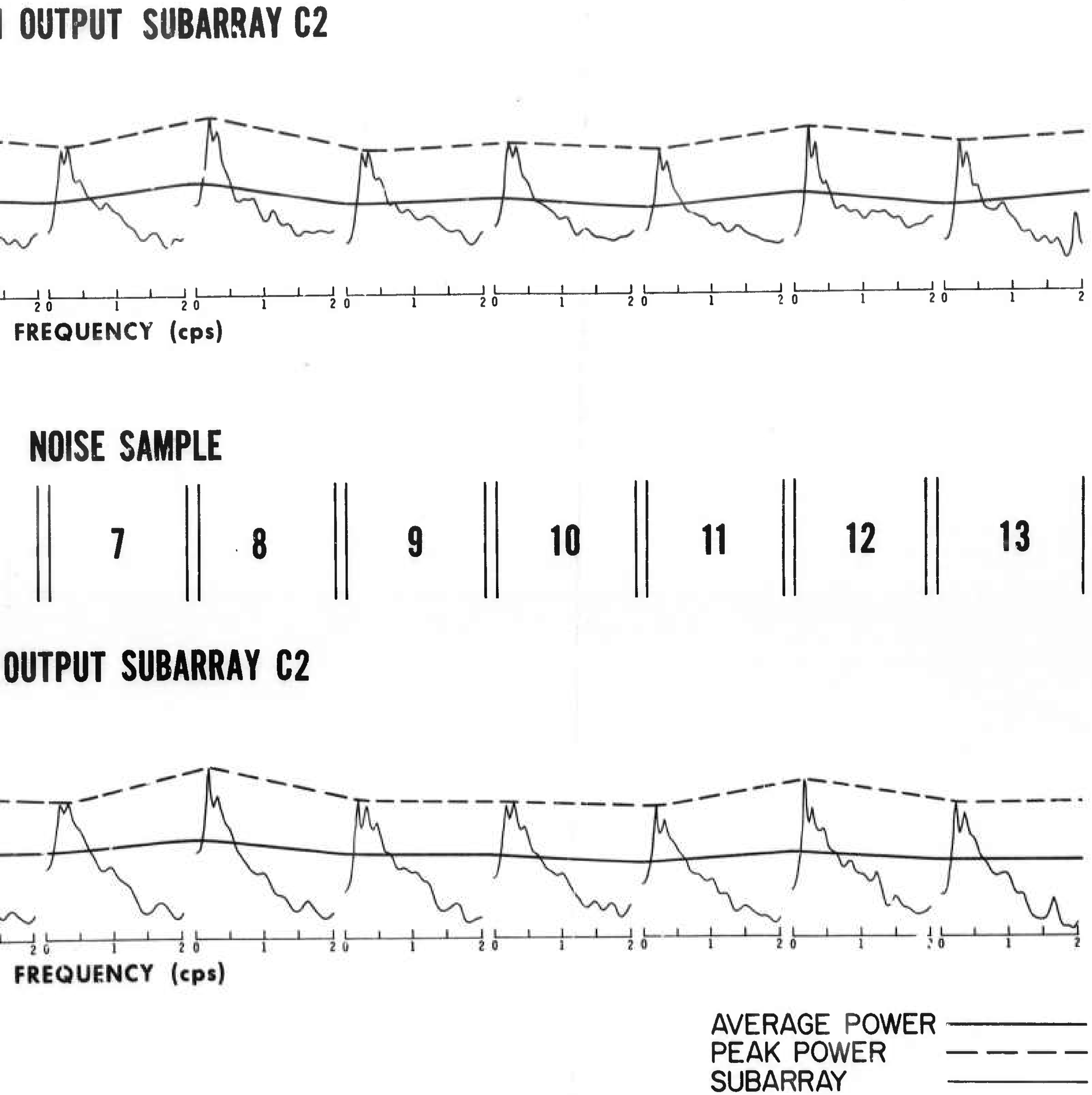
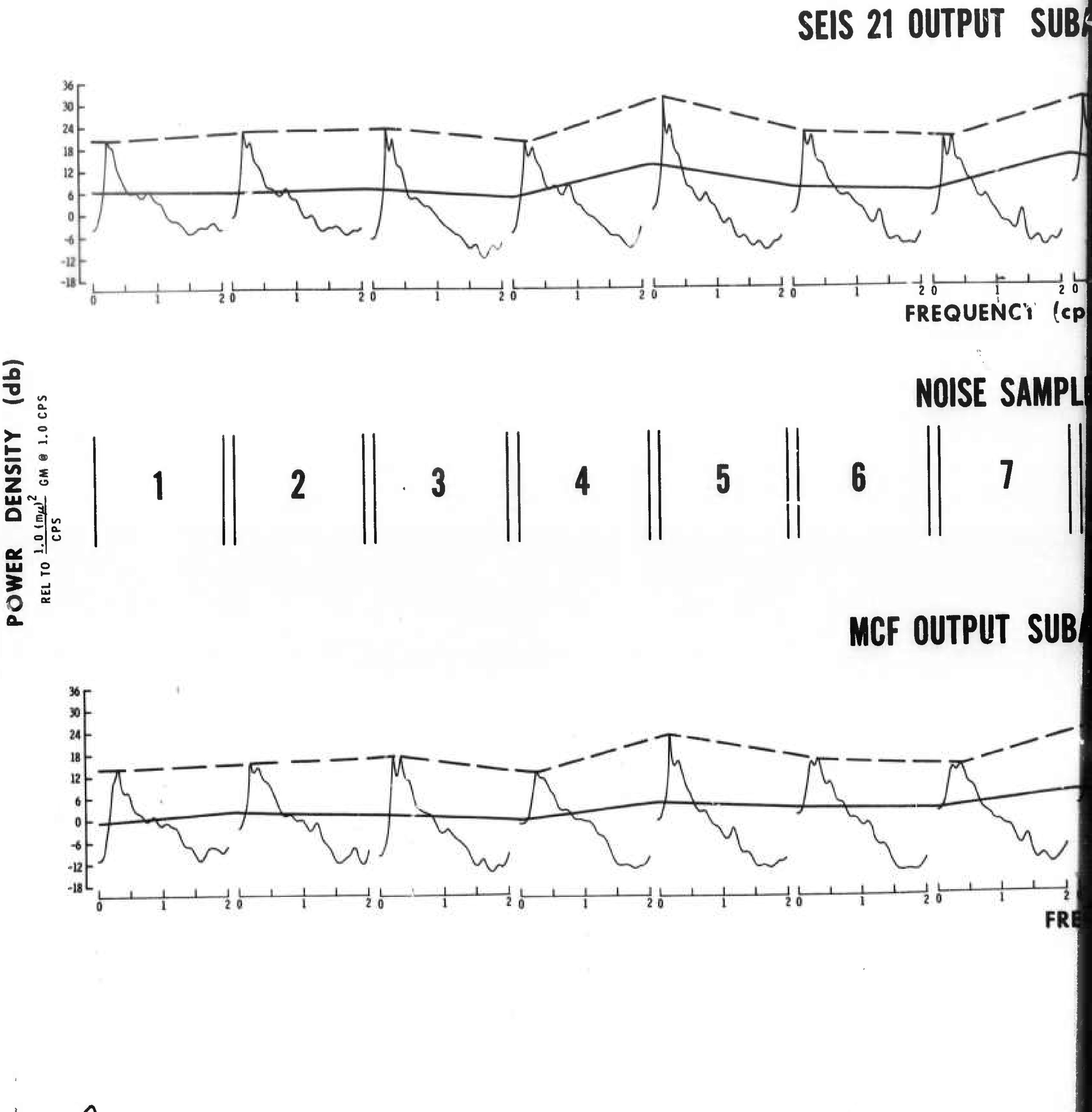


Figure IV-7. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray C2

B



SEIS 21 OUTPUT SUBA
NOISE SAMPL
MCF OUTPUT SUBA
POWER DENSITY (db)
REL TO $\frac{1.0\ (m\mu)^2}{CPS}$ GM @ 1.0 CPS
1
2
3
4
5
6
7
FREQUENCY (cp
FRE

A

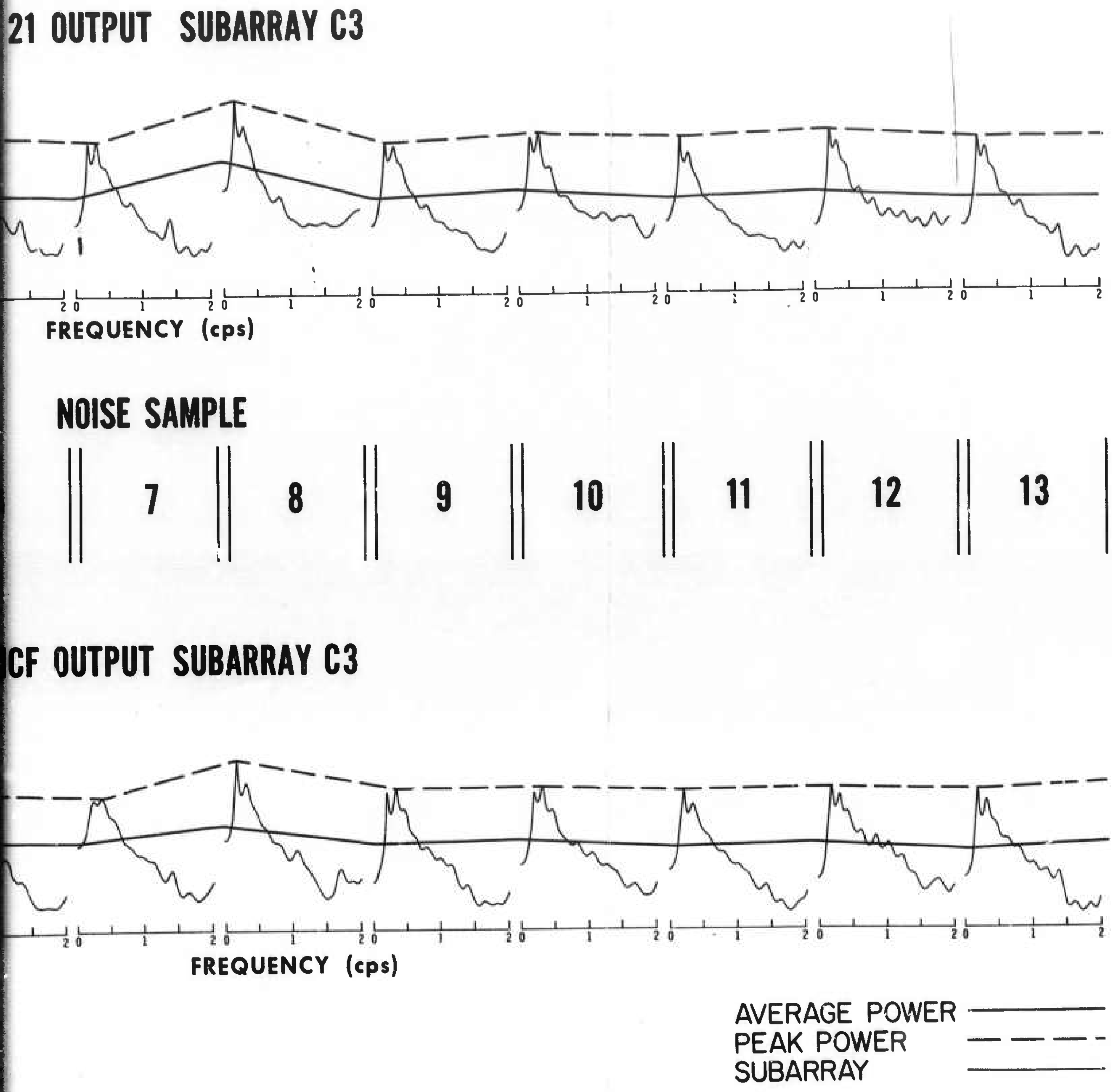
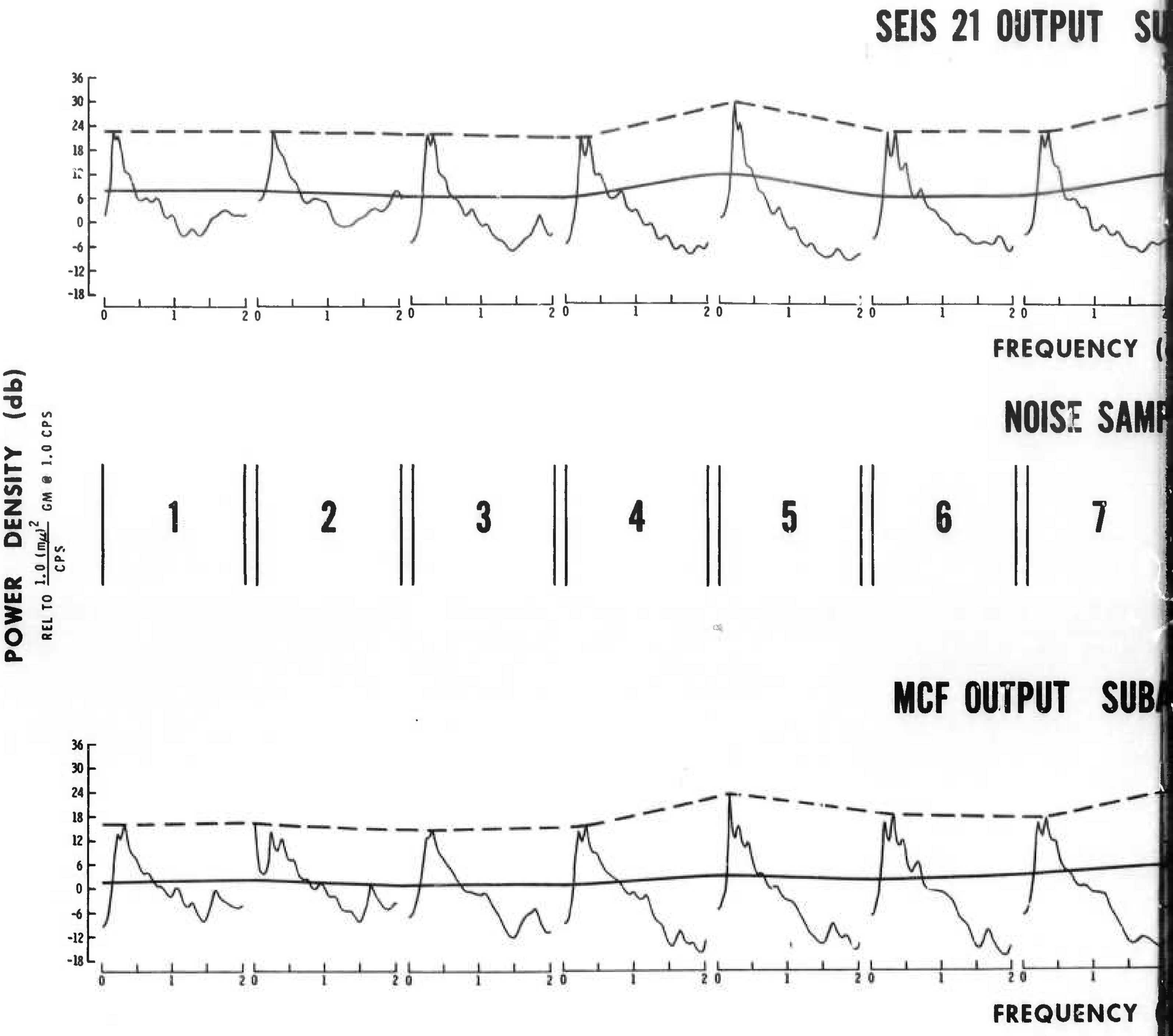


Figure IV-8. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray C3


SEIS 21 OUTPUT SU
POWER DENSITY (db)
REL TO $\frac{1.0\ (m\mu)^2}{CPS}$ GM @ 1.0 CPS
36
30
24
18
6
0
-6
-12
-18
0 1 2
FREQUENCY (
NOISE SAMP
1
2
3
4
5
6
7
MCF OUTPUT SUBA
36
30
24
18
12
6
0
-6
-12
-18
FREQUENCY

A

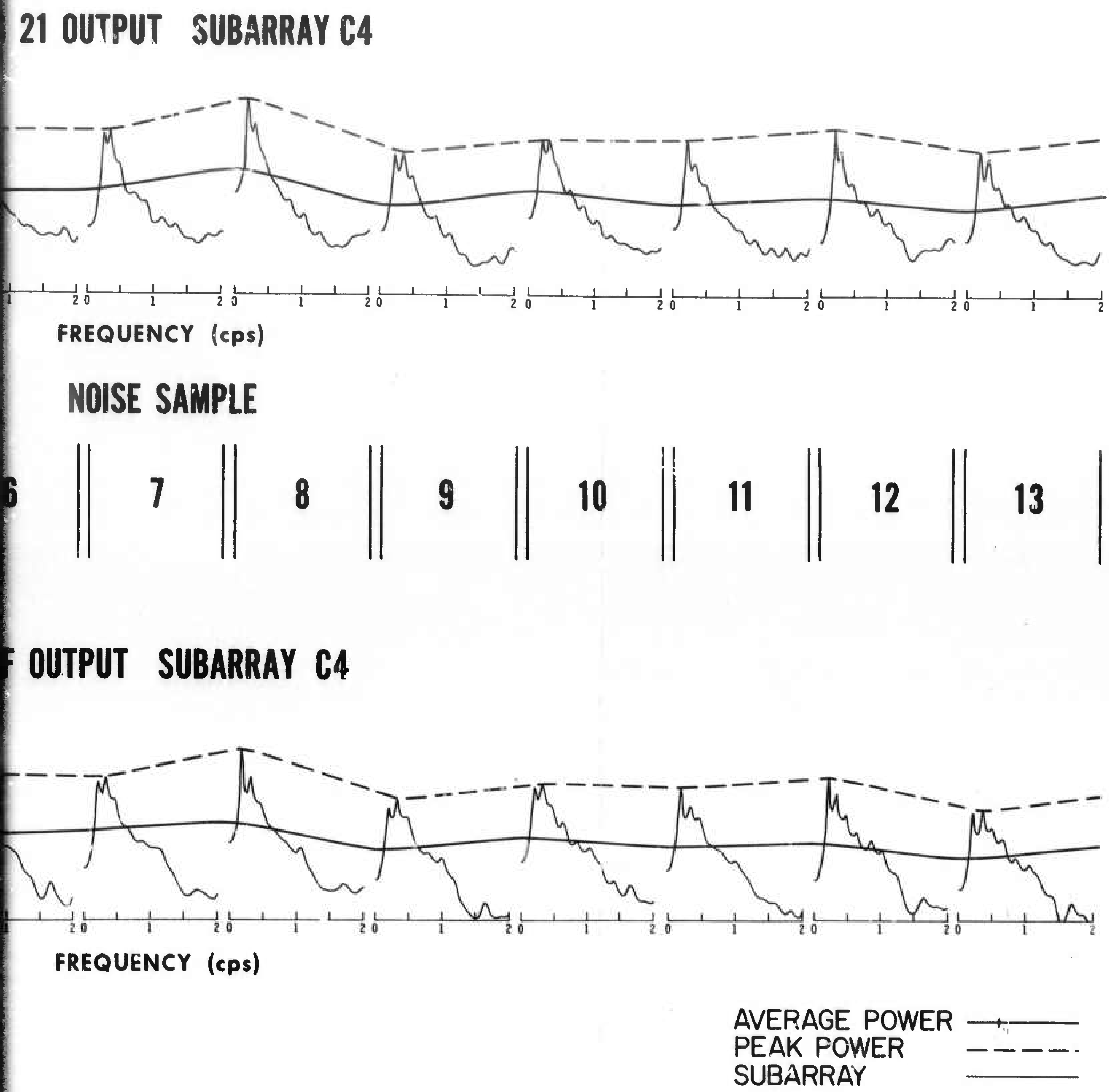
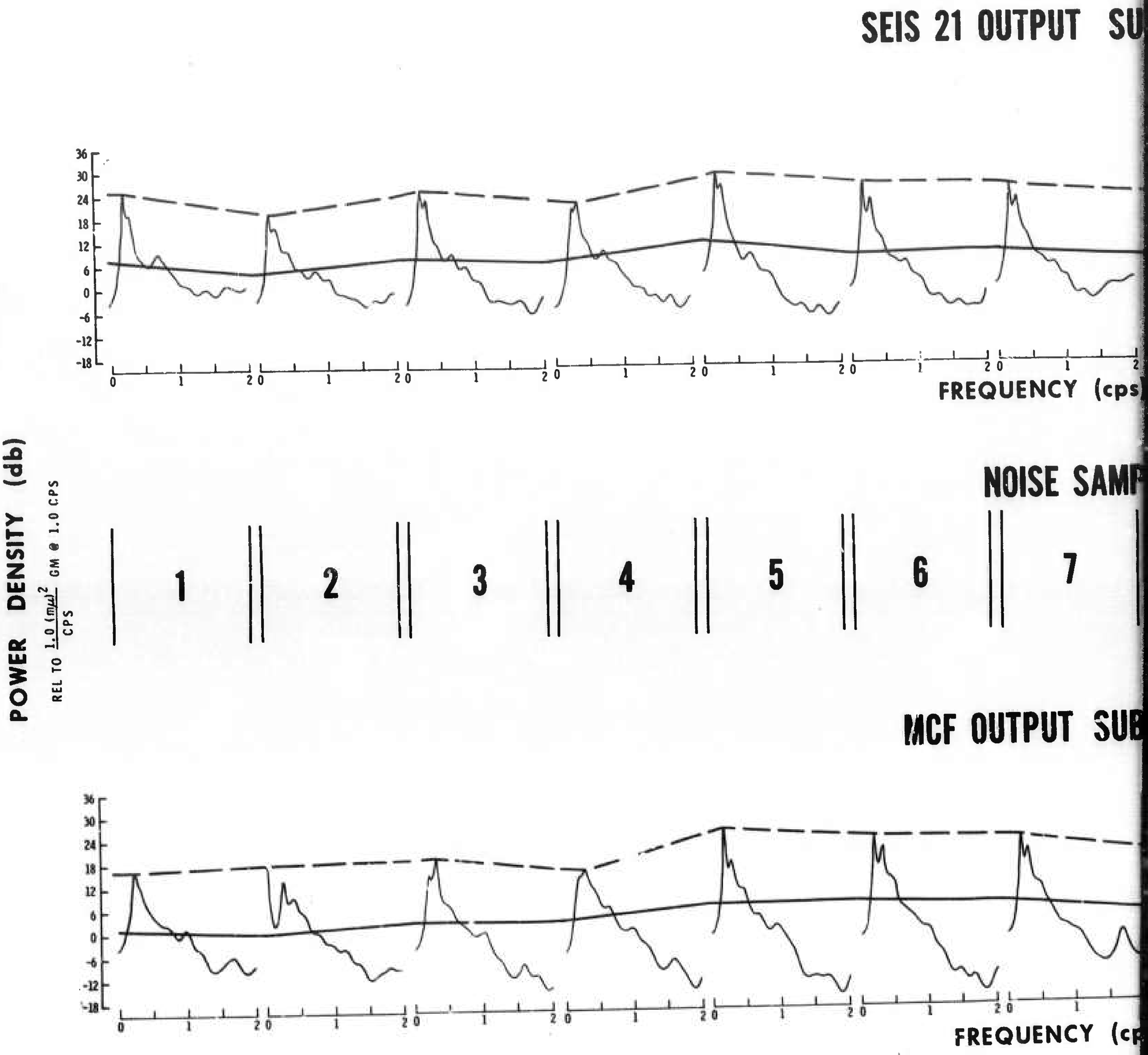


Figure IV-9. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray C4


SEIS 21 OUTPUT SU
FREQUENCY (cps)
NOISE SAMP
1
2
3
4
5
6
7
MCF OUTPUT SUB
FREQUENCY (cp
POWER DENSITY (db)
REL TO 1.0 (mμ)² / CPS GM @ 1.0 CPS

A

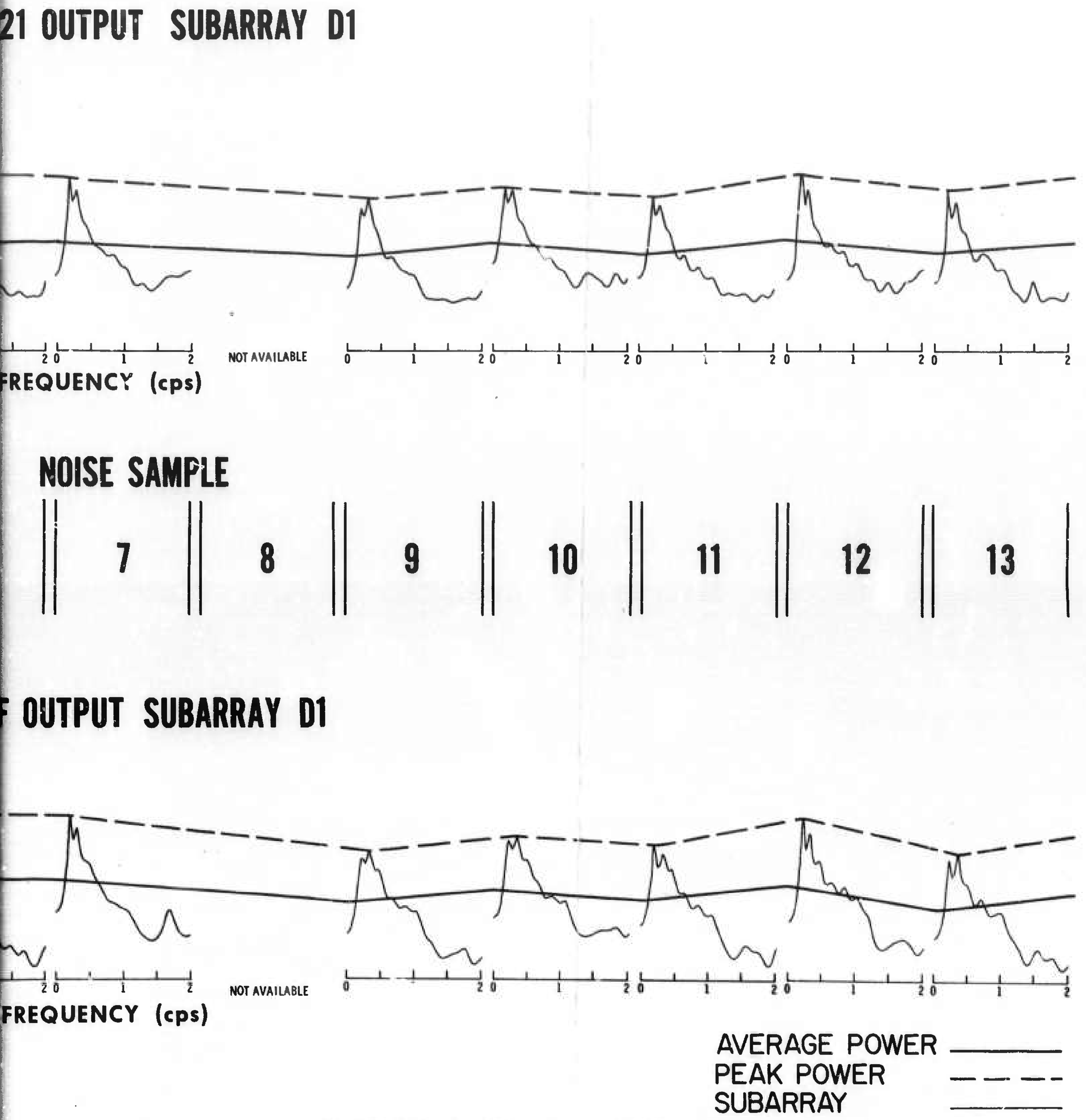
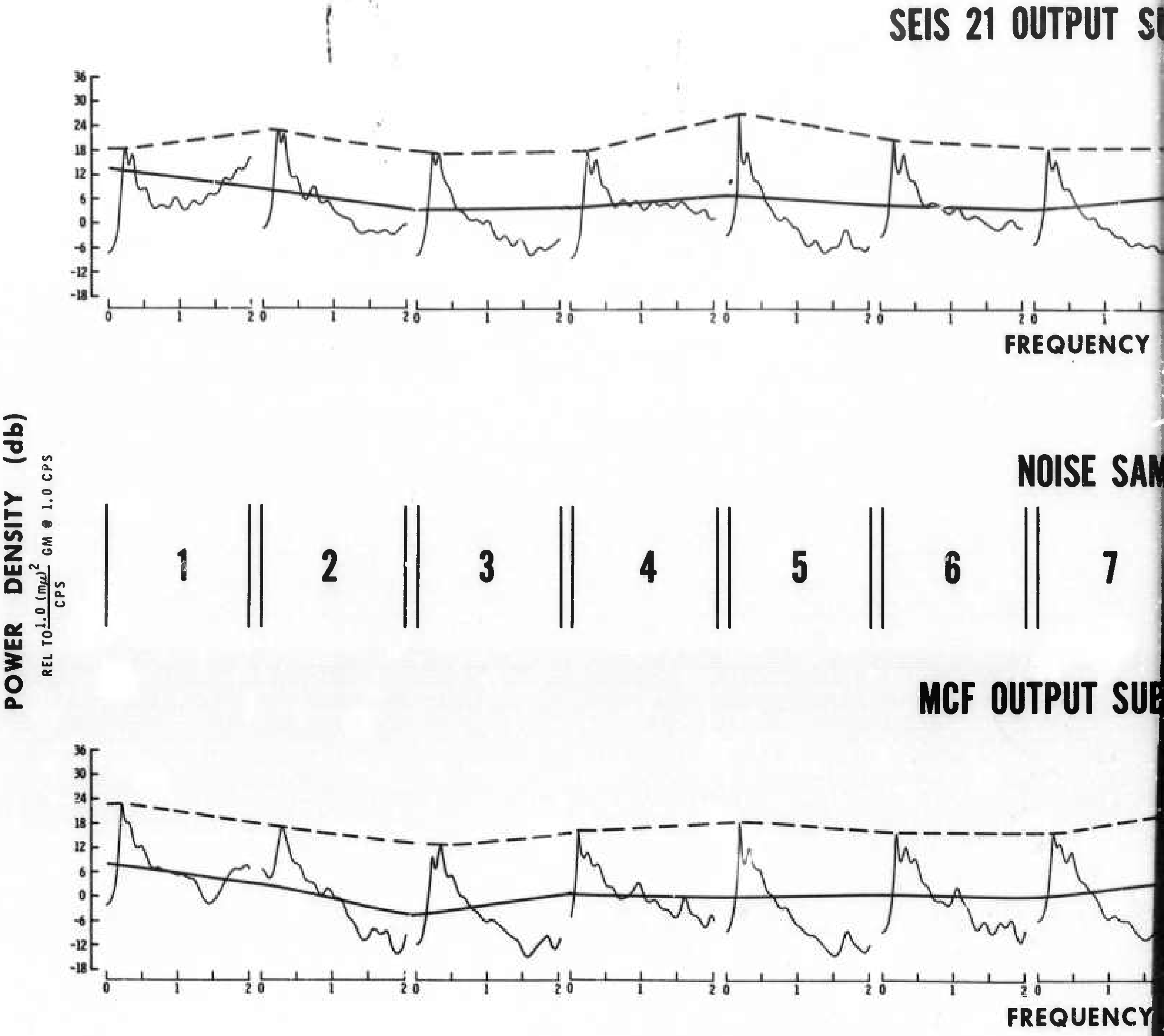


Figure IV-10. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray D1

B


SEIS 21 OUTPUT SU
36
30
24
18
12
6
0
-6
-12
-18
0
1
2 0
FREQUENCY
POWER DENSITY (db)
REL TO $\frac{1.0\ (m\mu)^2}{CPS}$ GM @ 1.0 CPS
NOISE SAM
1
2
3
4
5
6
7
MCF OUTPUT SUB
FREQUENCY

A

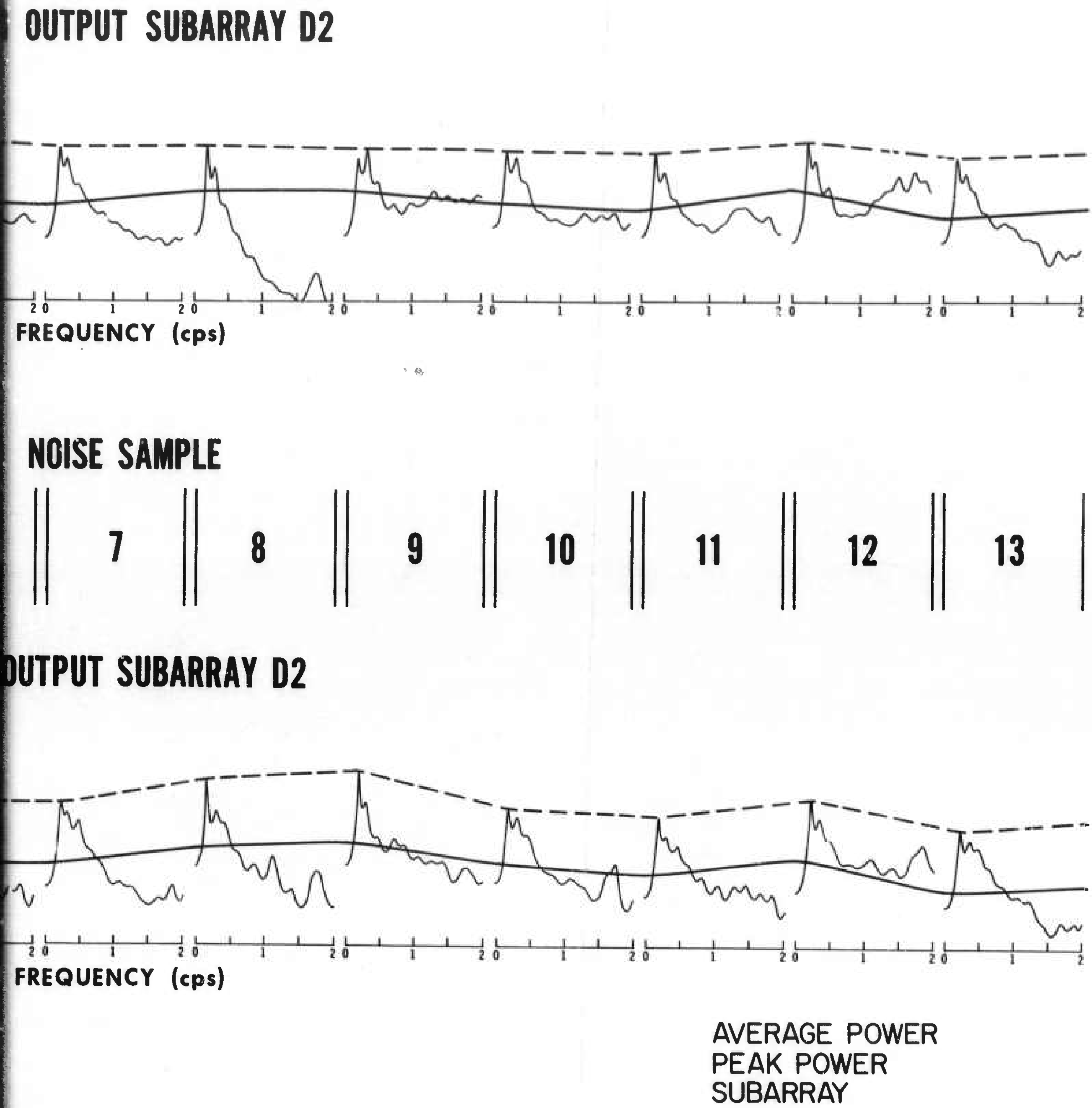
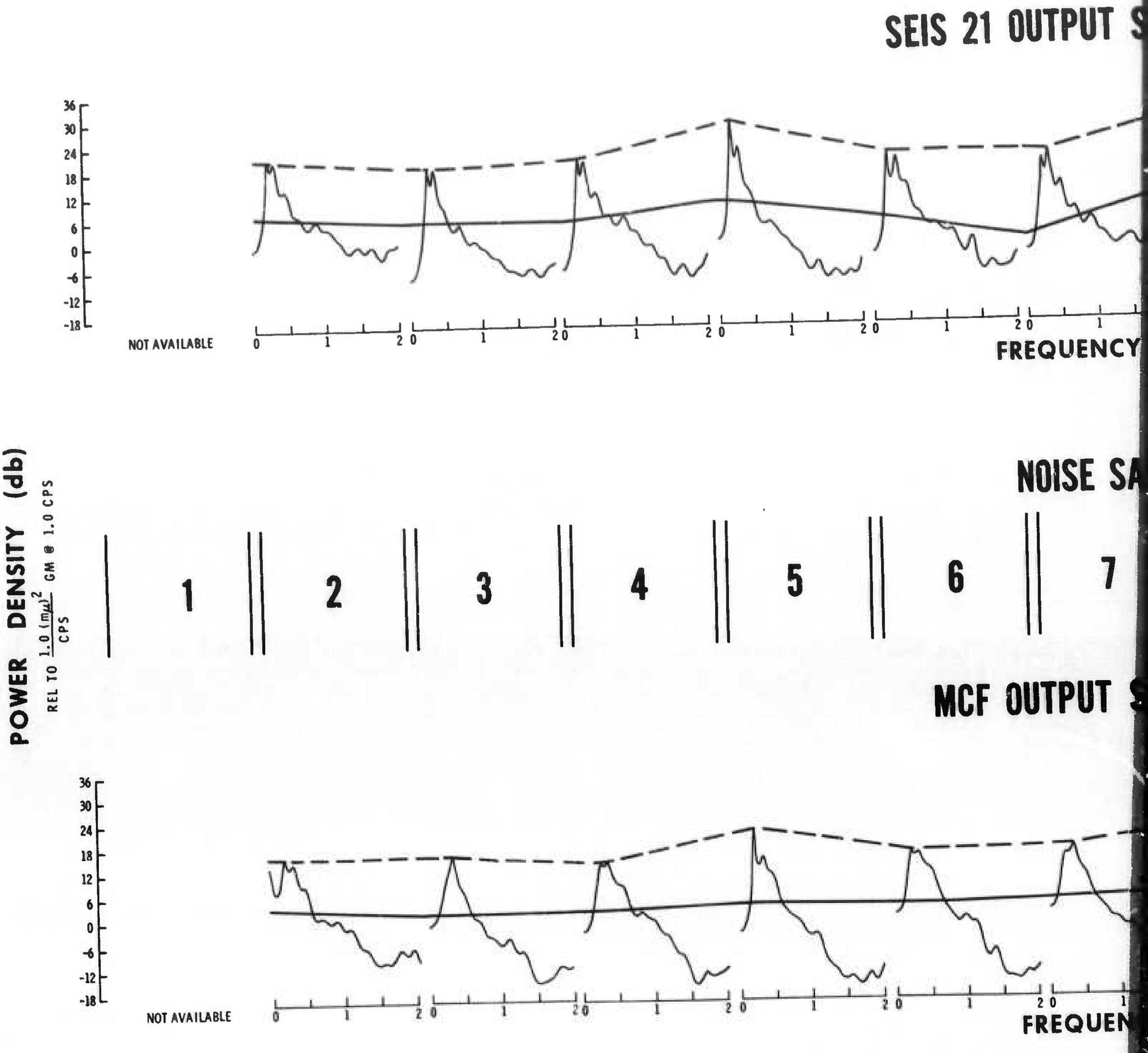


Figure IV-11. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray D2

B


SEIS 21 OUTPUT S
36
30
24
18
12
6
0
-6
-12
-18
NOT AVAILABLE
0 1 2
FREQUENCY
NOISE SA
1
2
3
4
5
6
7
POWER DENSITY (db)
REL TO 1.0 (mμ)² / CPS GM @ 1.0 CPS
MCF OUTPUT S
FREQUEN

A

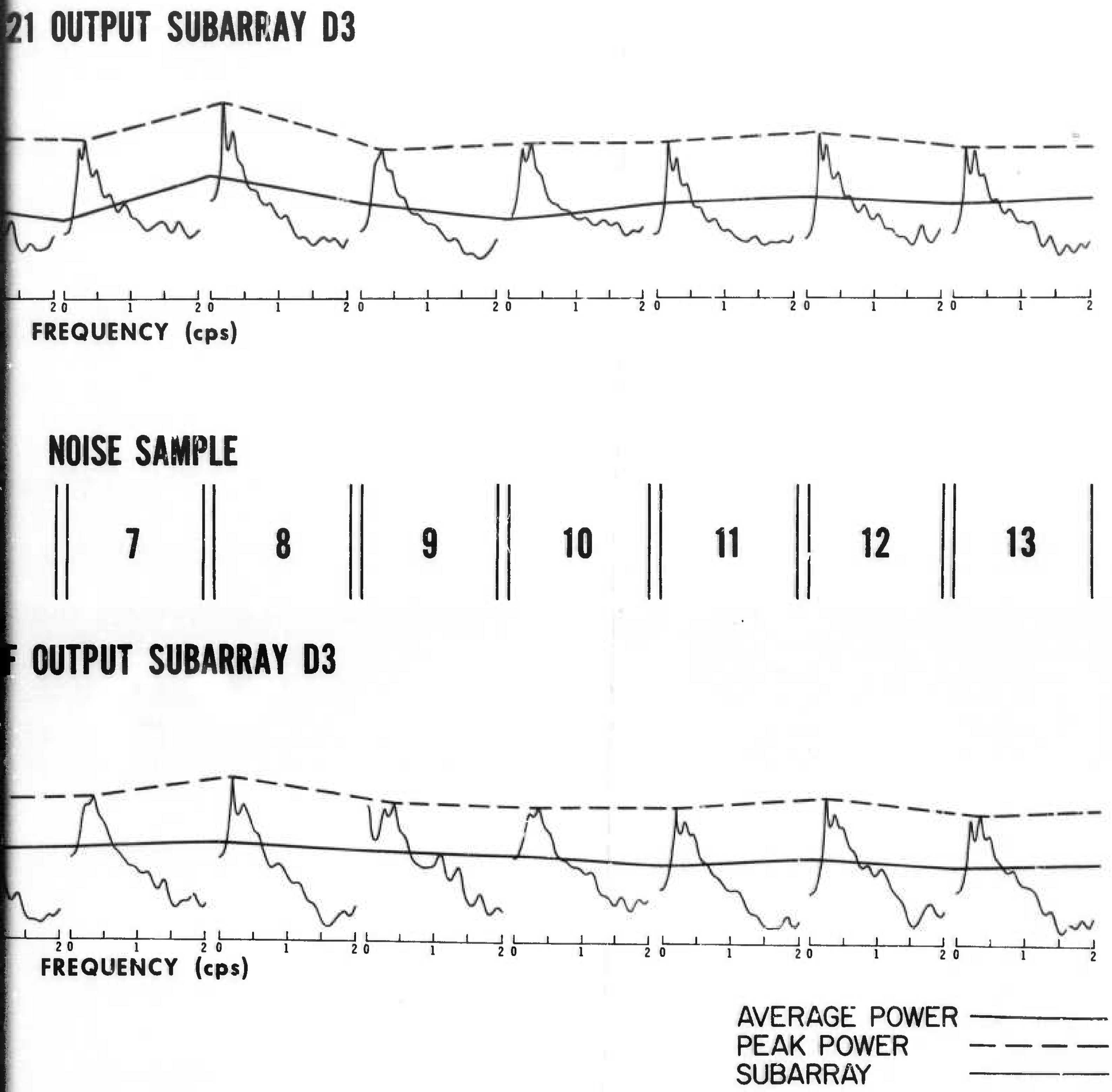
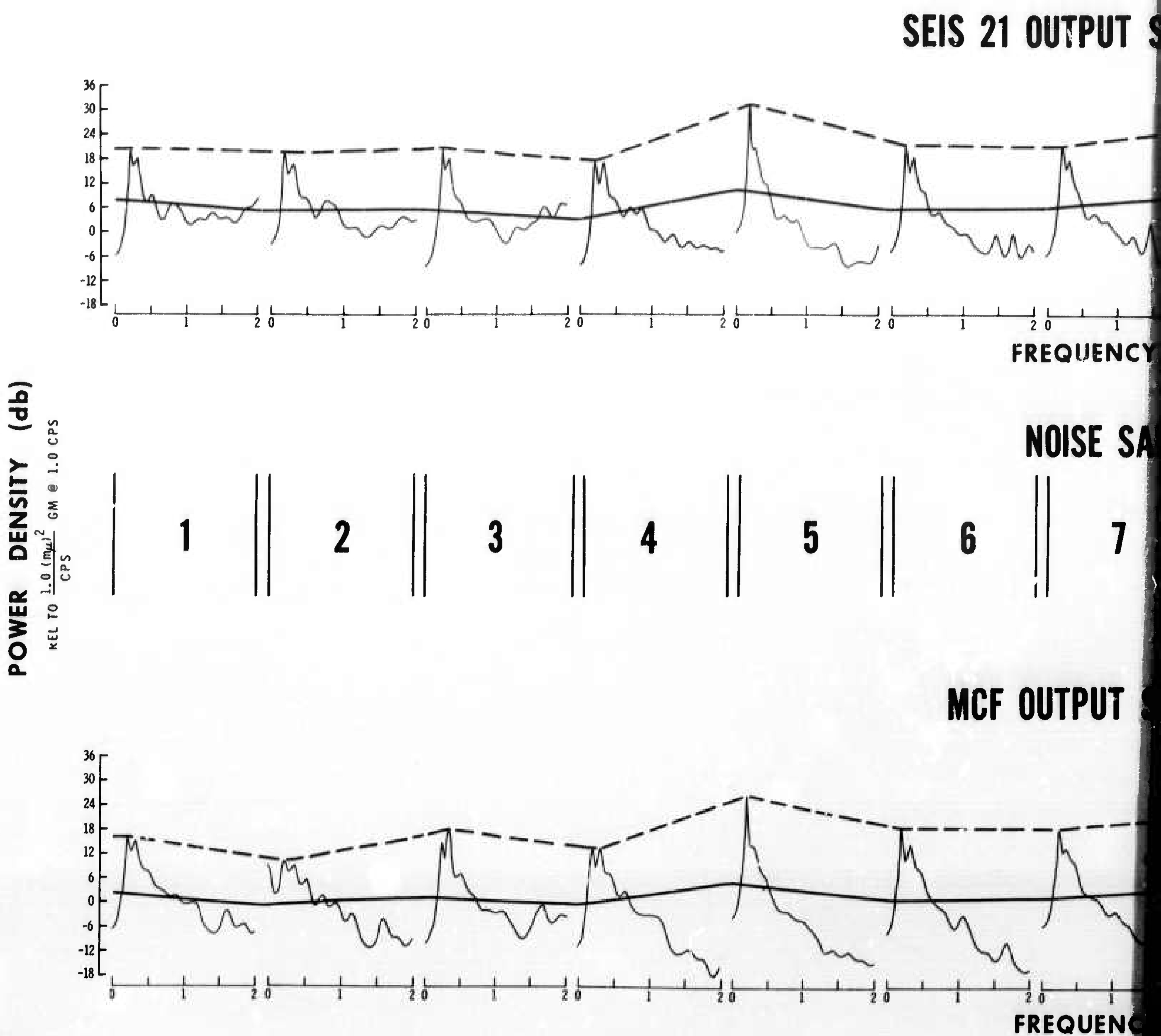


Figure IV-12. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray D3

B


SEIS 21 OUTPUT S
36
30
24
18
12
6
0
-6
-12
-18
0 1 2 0 1 2 0 1 2 0 1 2 0 1 2 0 1 2 0 1
FREQUENCY
POWER DENSITY (db)
REL TO 1.0 (mμ)² / CPS GM @ 1.0 CPS
NOISE SA
1
2
3
4
5
6
7
MCF OUTPUT S
FREQUENC

A

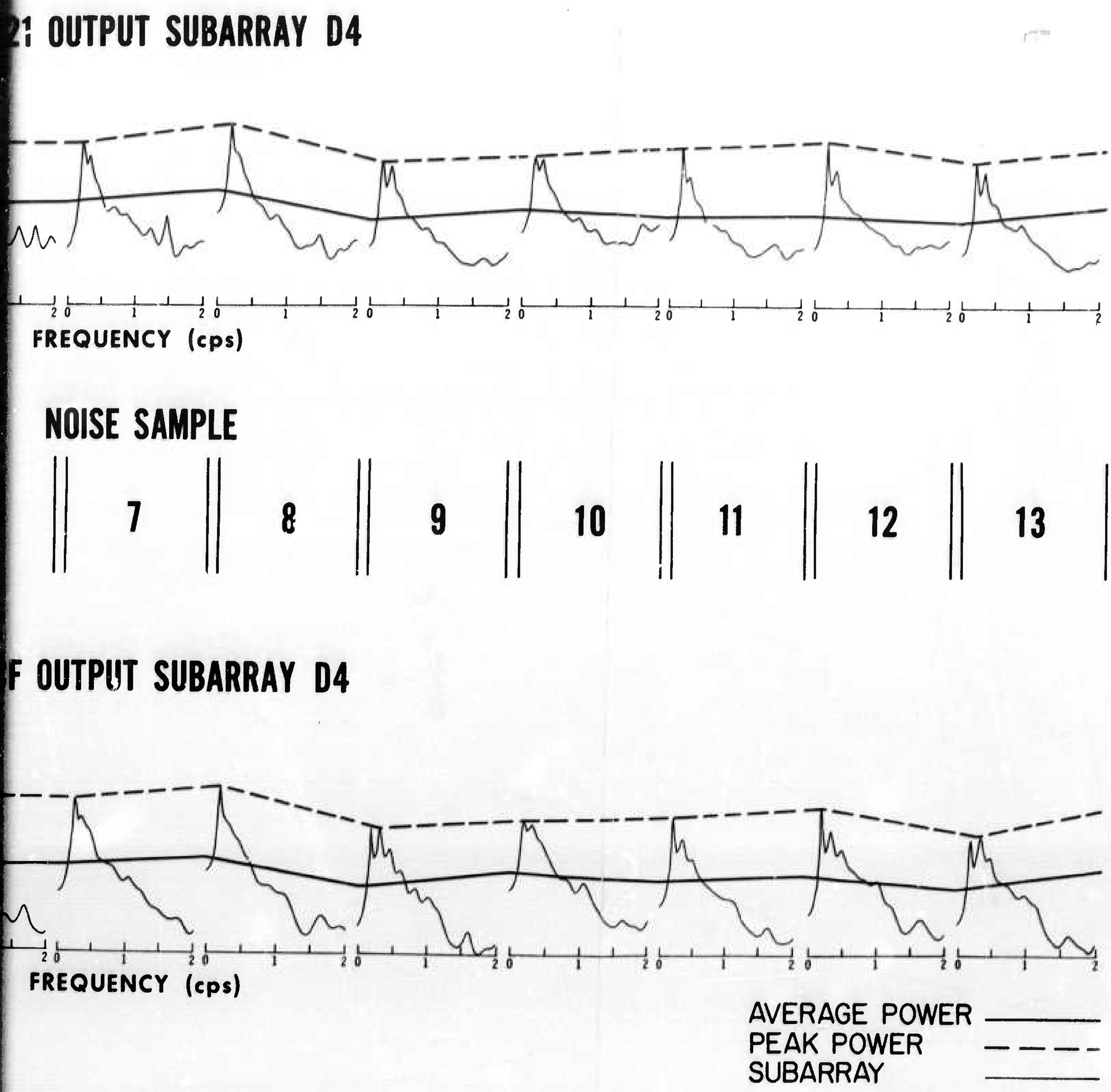
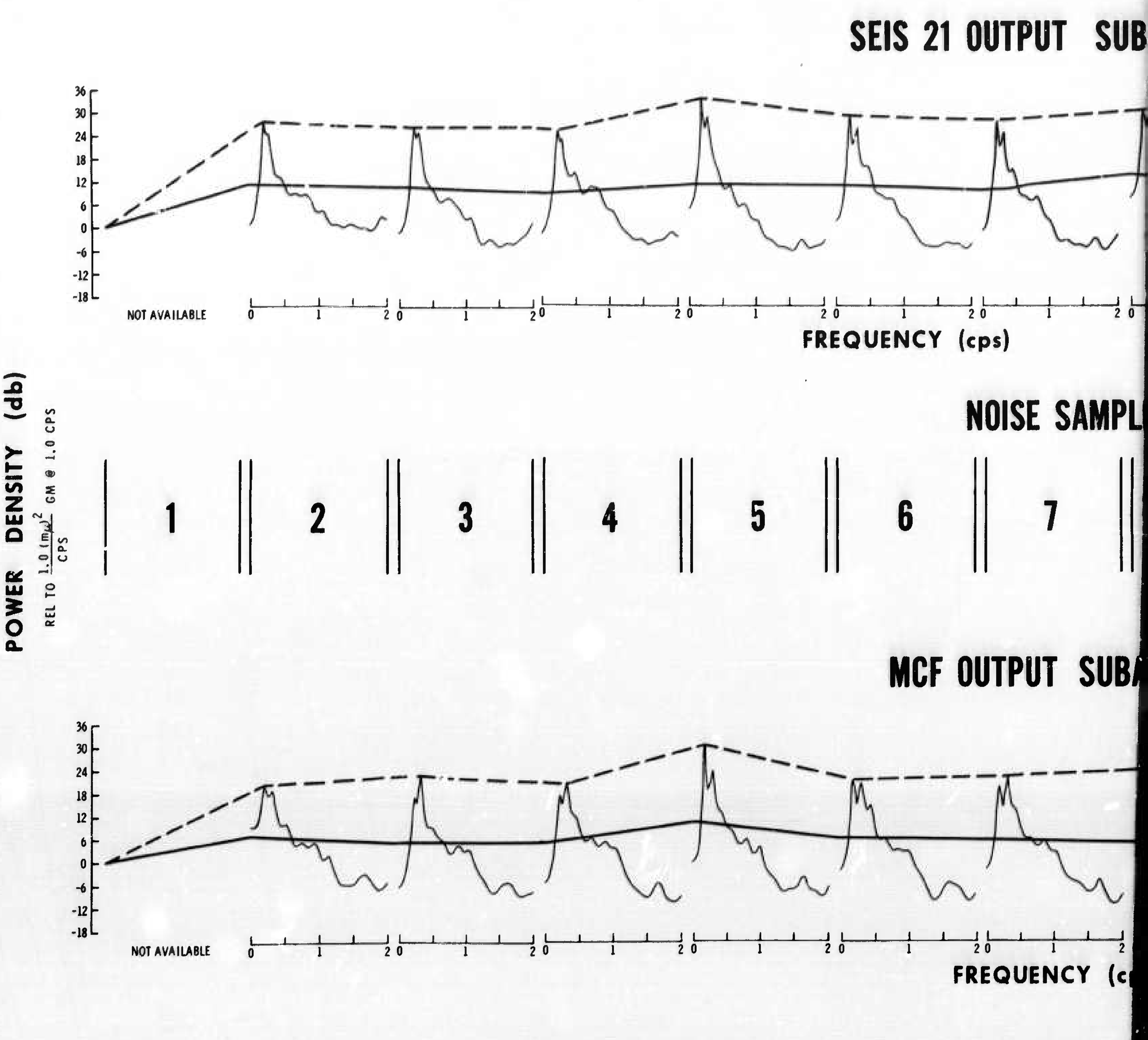


Figure IV-13. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray D4


SEIS 21 OUTPUT SUB
NOISE SAMPL
MCF OUTPUT SUBA
POWER DENSITY (db)
REL TO $\frac{1.0\,(m\mu)^2}{CPS}$ GM @ 1.0 CPS
36
30
24
18
12
6
0
-6
-12
-18
NOT AVAILABLE
0
1
2
FREQUENCY (cps)
1
2
3
4
5
6
7
FREQUENCY (c

A

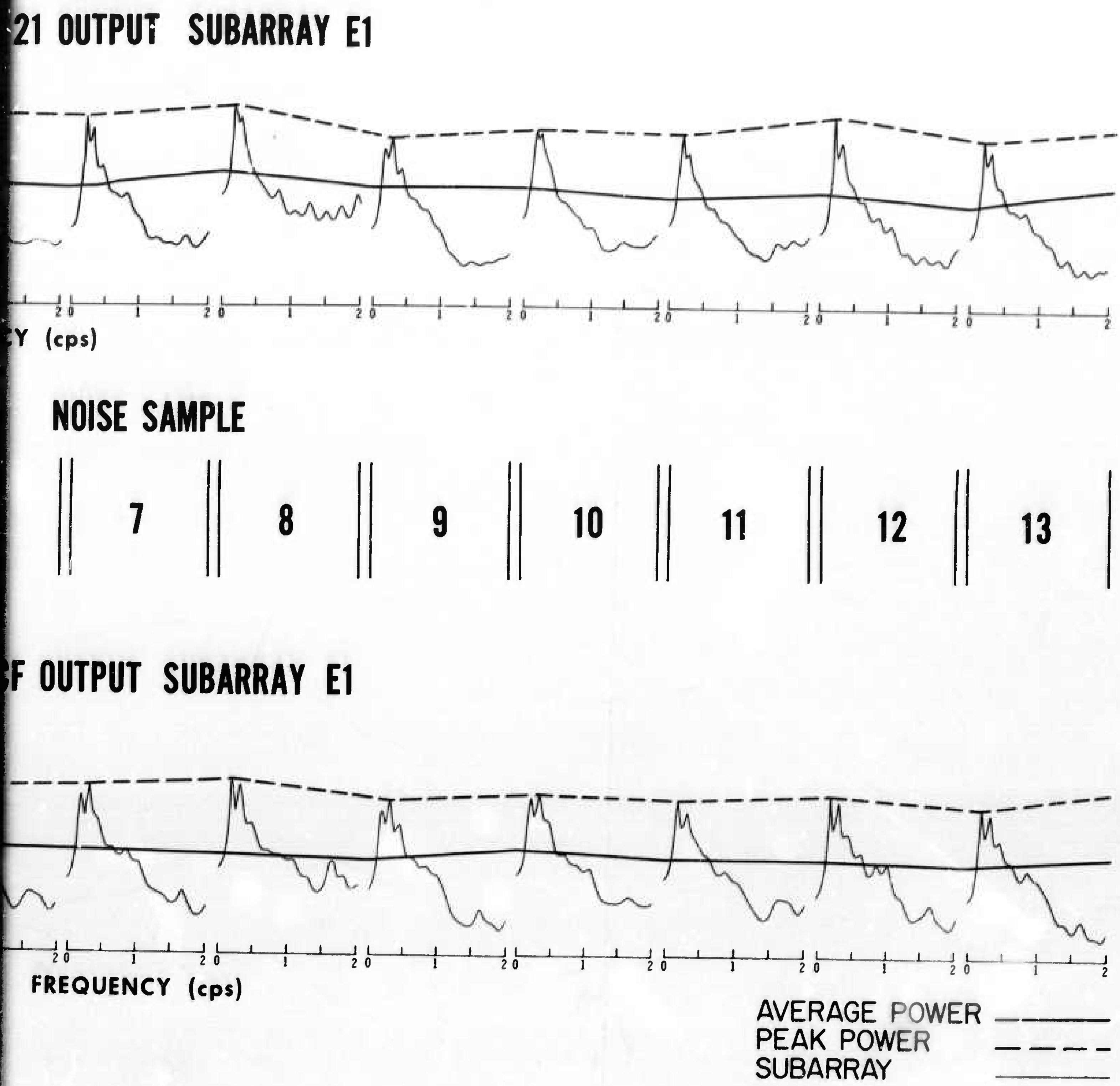
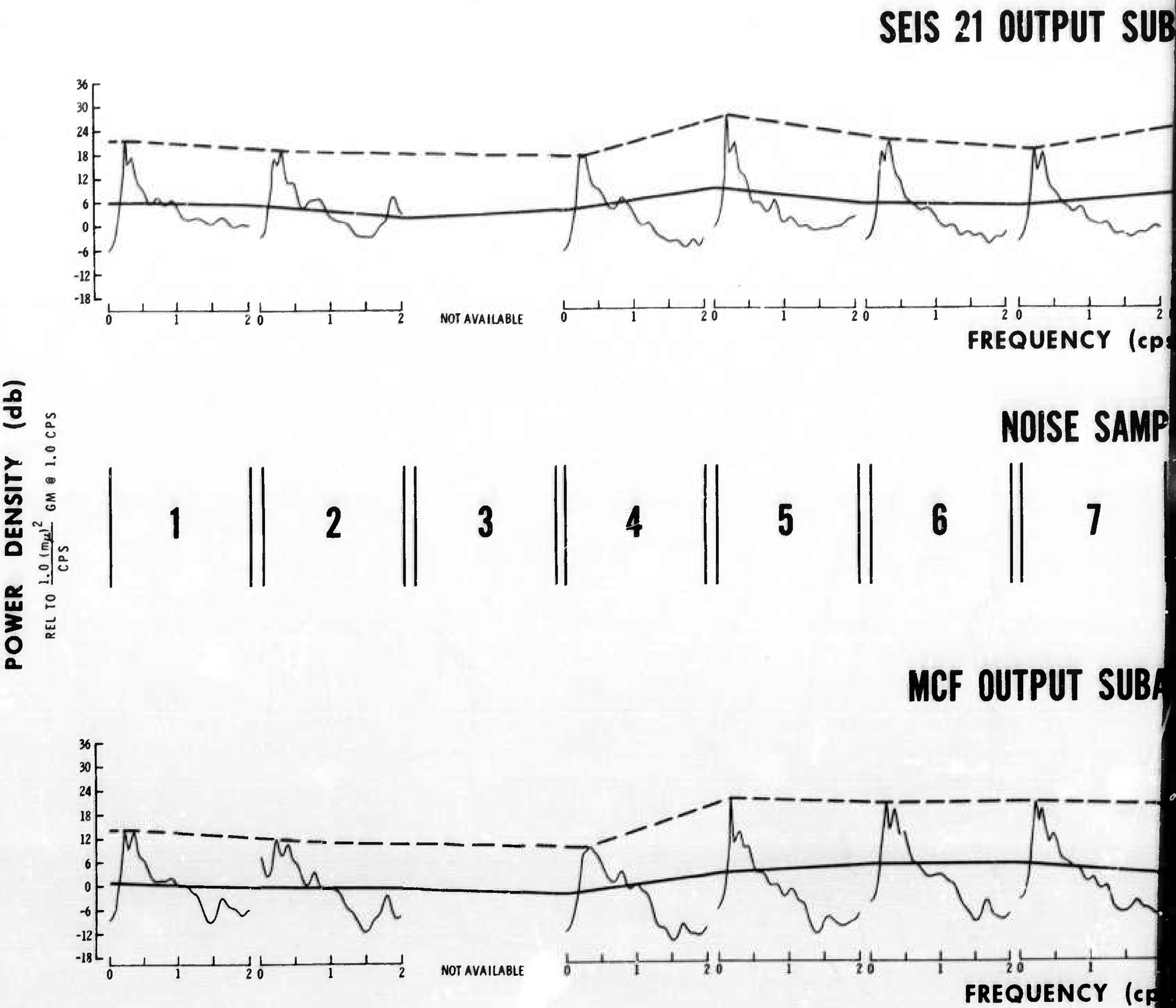


Figure IV-14. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray E1

B


SEIS 21 OUTPUT SUB
36
30
24
18
12
6
0
-6
-12
-18
0 1 2
NOT AVAILABLE
FREQUENCY (cps
POWER DENSITY (db)
REL TO $\frac{1.0\,(m\mu)^2}{CPS}$ GM @ 1.0 CPS
NOISE SAMP
1
2
3
4
5
6
7
MCF OUTPUT SUBA
NOT AVAILABLE
FREQUENCY (cp
A

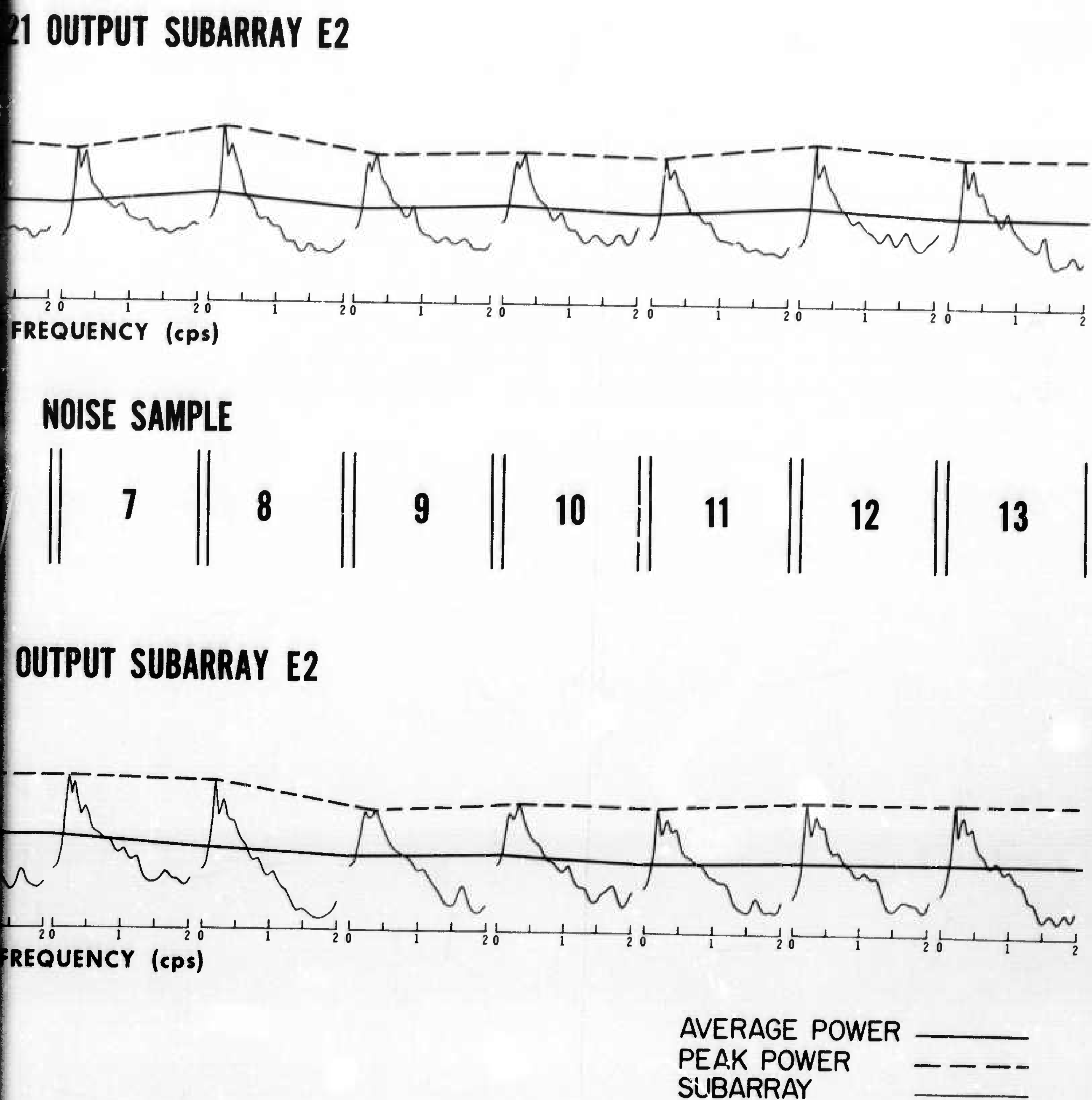
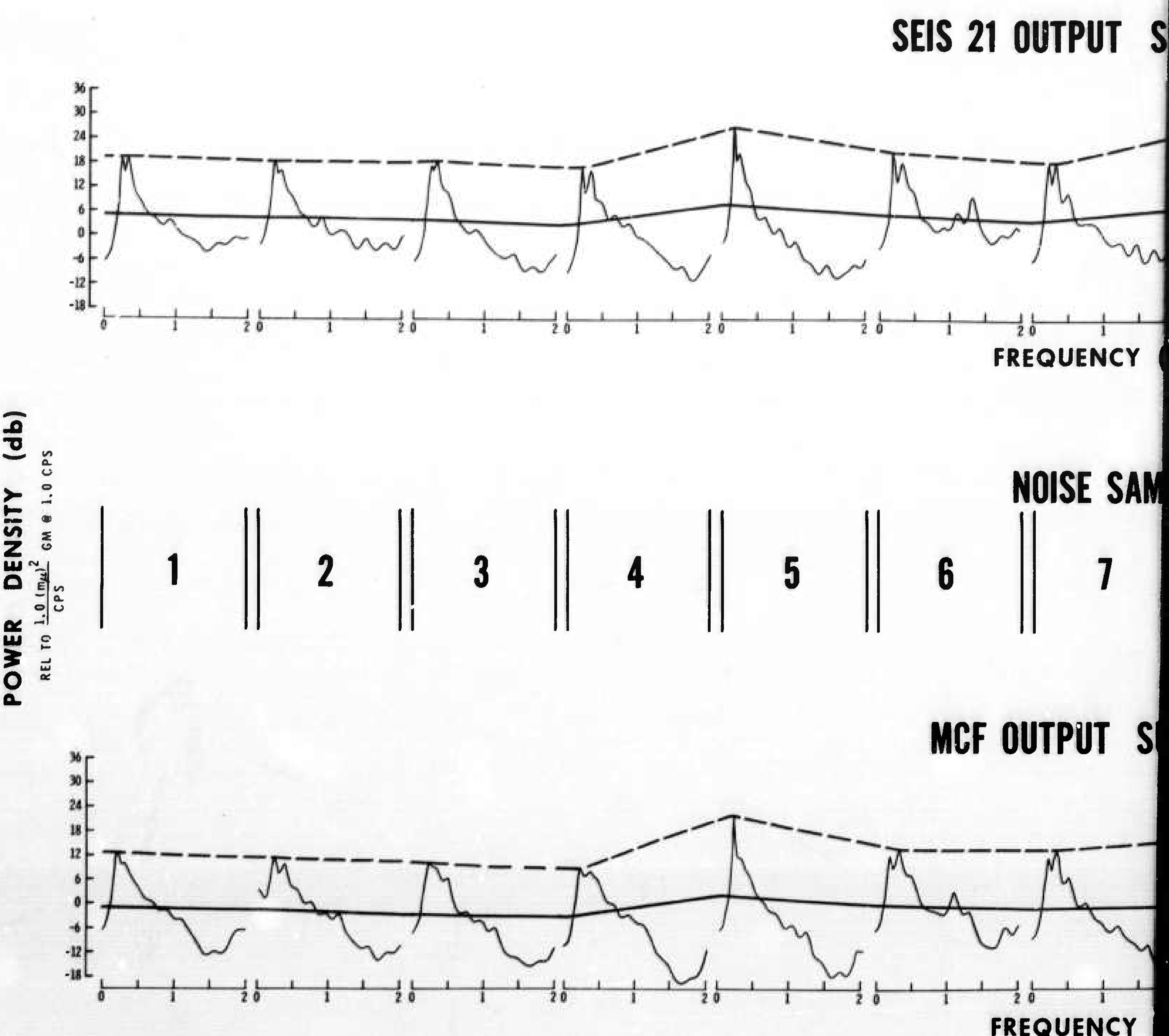


Figure IV-15. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray E2

B



SEIS 21 OUTPUT S
FREQUENCY
NOISE SAM
1
2
3
4
5
6
7
MCF OUTPUT S
FREQUENCY
POWER DENSITY (db)
REL TO $\frac{1.0\ (m\mu)^2}{CPS}$ GM @ 1.0 CPS

A

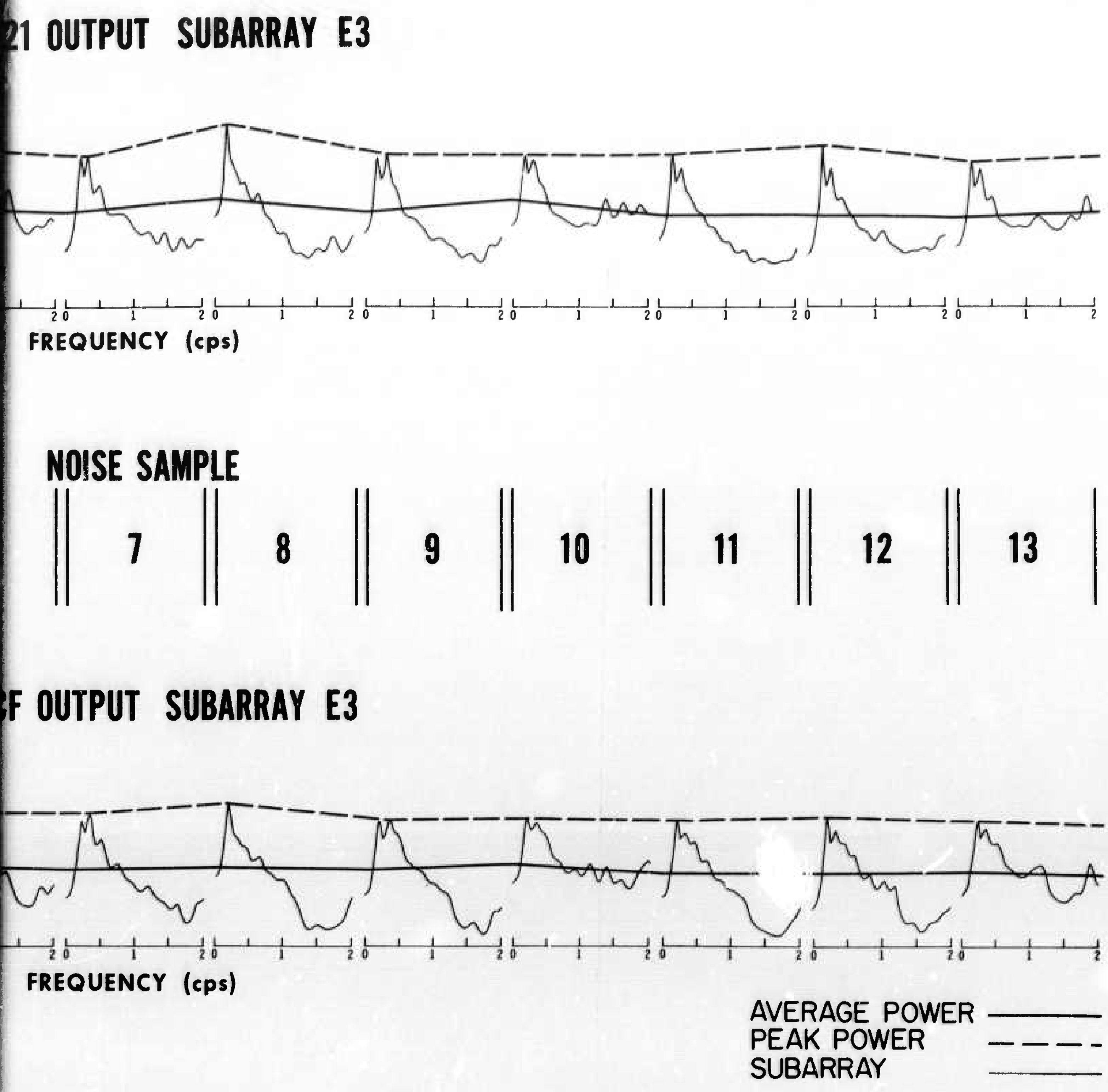
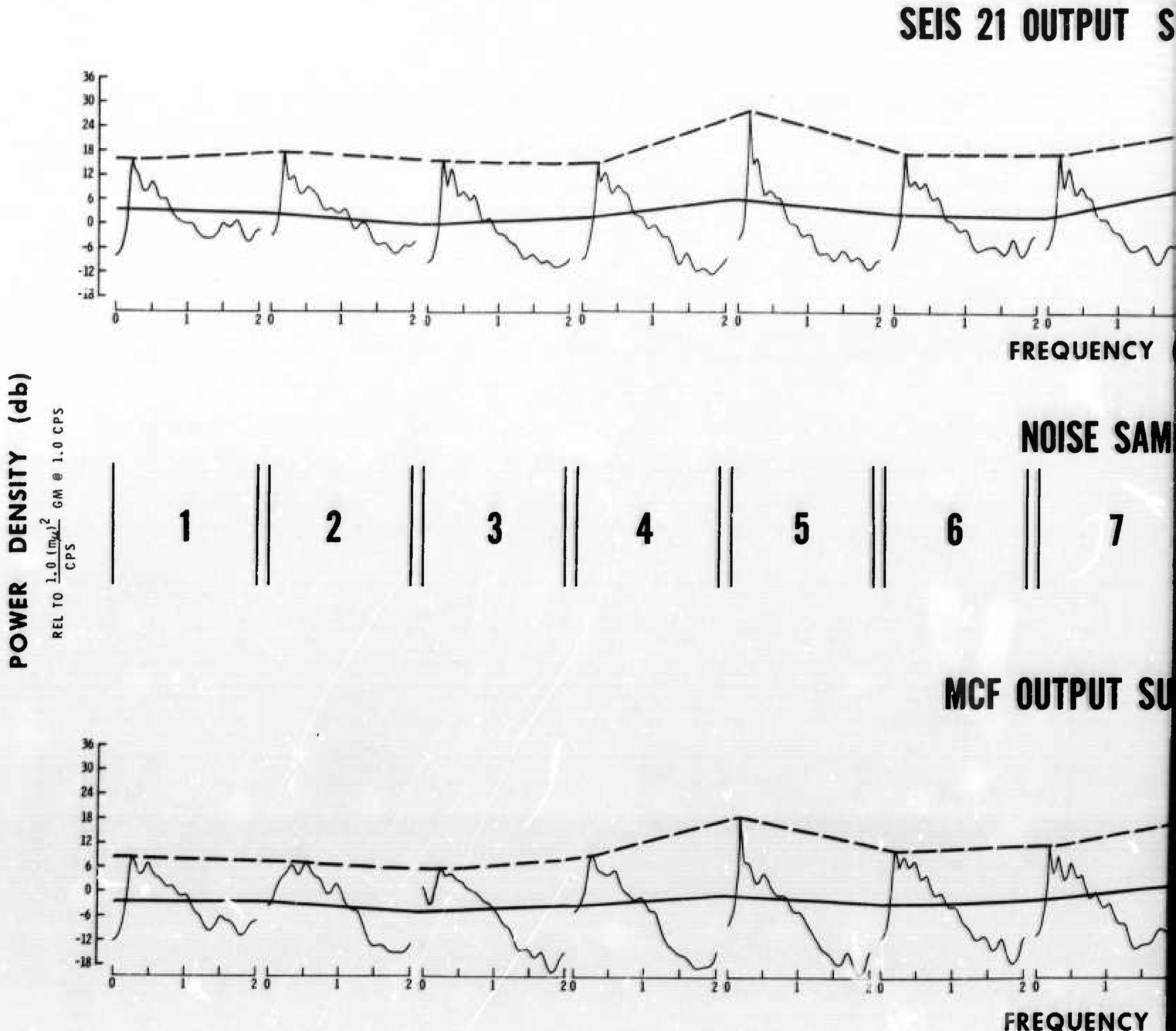


Figure IV-16. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray E3


SEIS 21 OUTPUT S
FREQUENCY
NOISE SAM
MCF OUTPUT SU
FREQUENCY
POWER DENSITY (db)
REL TO $\frac{1.0\,(m\mu)^2}{CPS}$ GM @ 1.0 CPS
1
2
3
4
5
6
7
36
30
24
18
12
6
0
-6
-12
-18
0
1
2

A

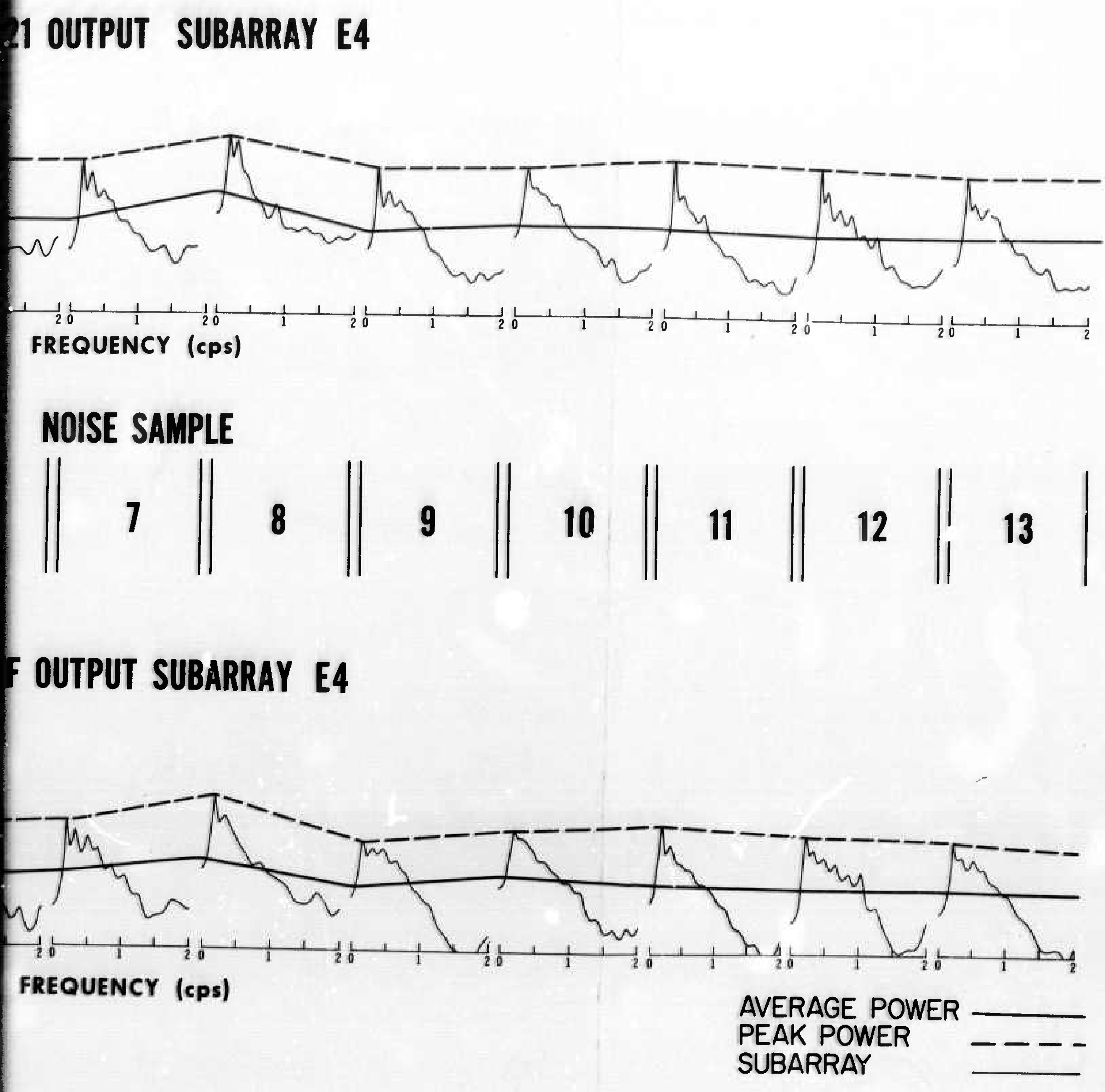
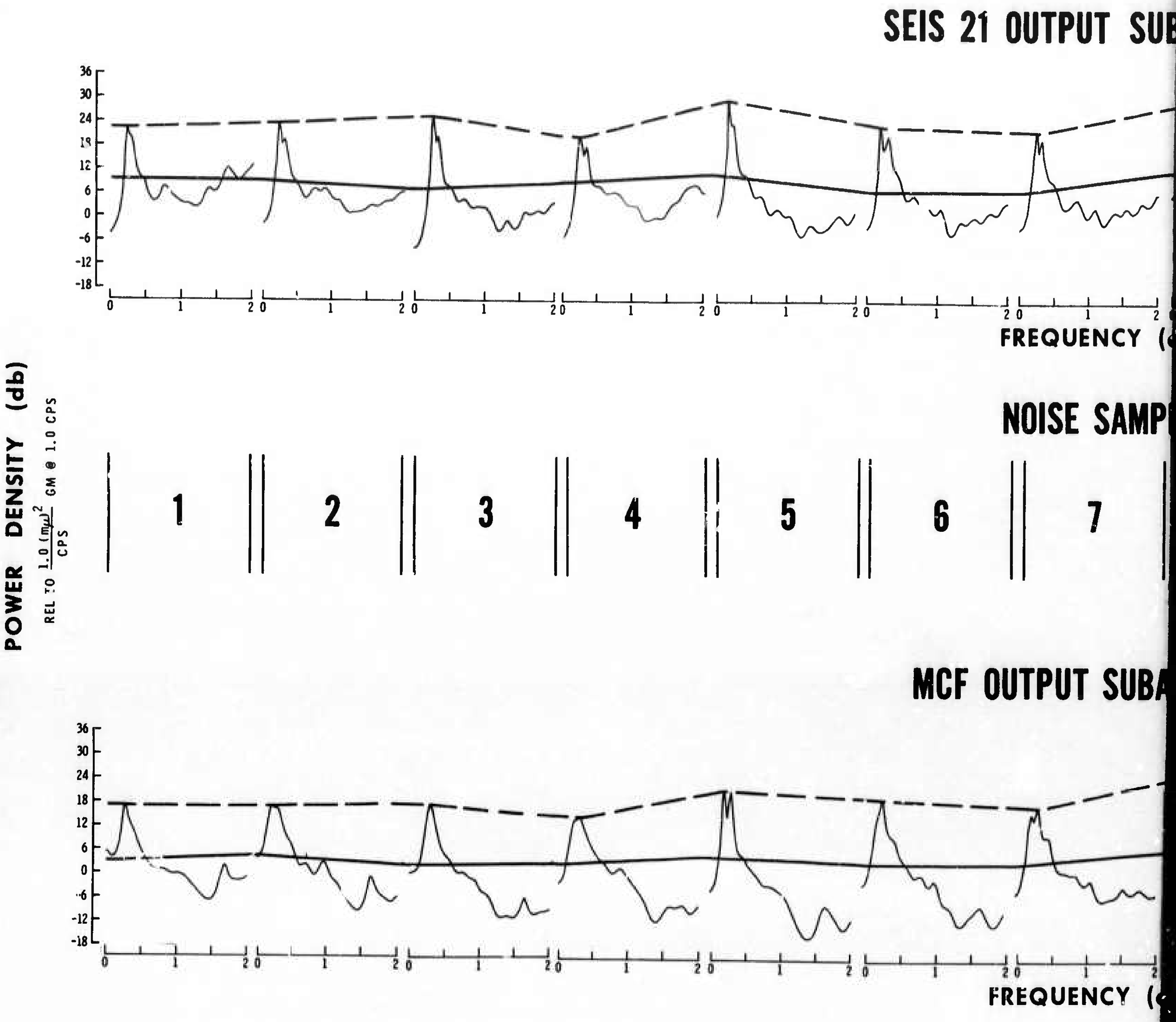


Figure IV-17. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray E4


SEIS 21 OUTPUT SUB
36
30
24
18
12
6
0
-6
-12
-18
FREQUENCY (
POWER DENSITY (db)
REL TO 1.0 (mμ)² / CPS GM @ 1.0 CPS
NOISE SAMP
1
2
3
4
5
6
7
MCF OUTPUT SUBA
FREQUENCY (

A

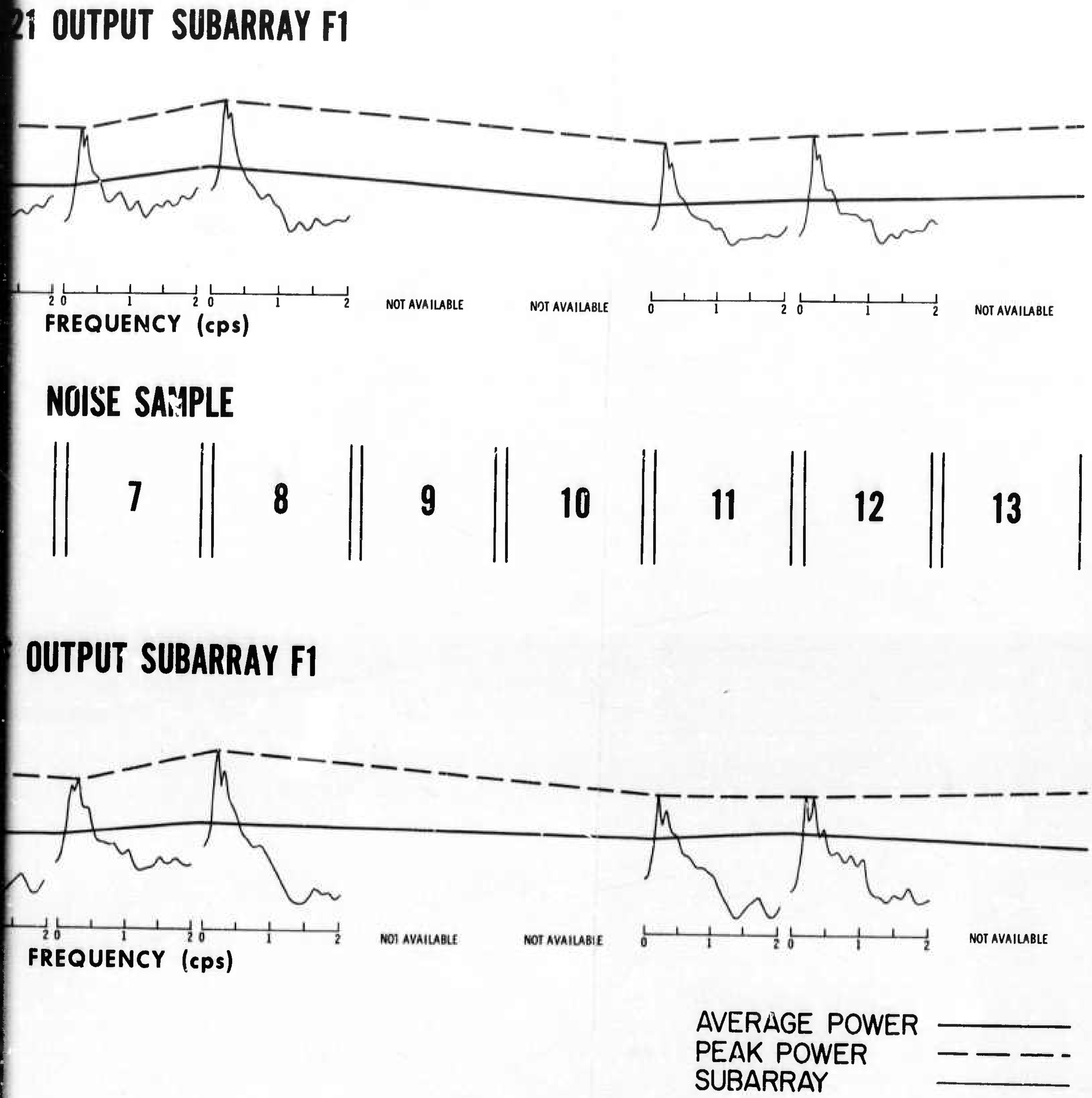
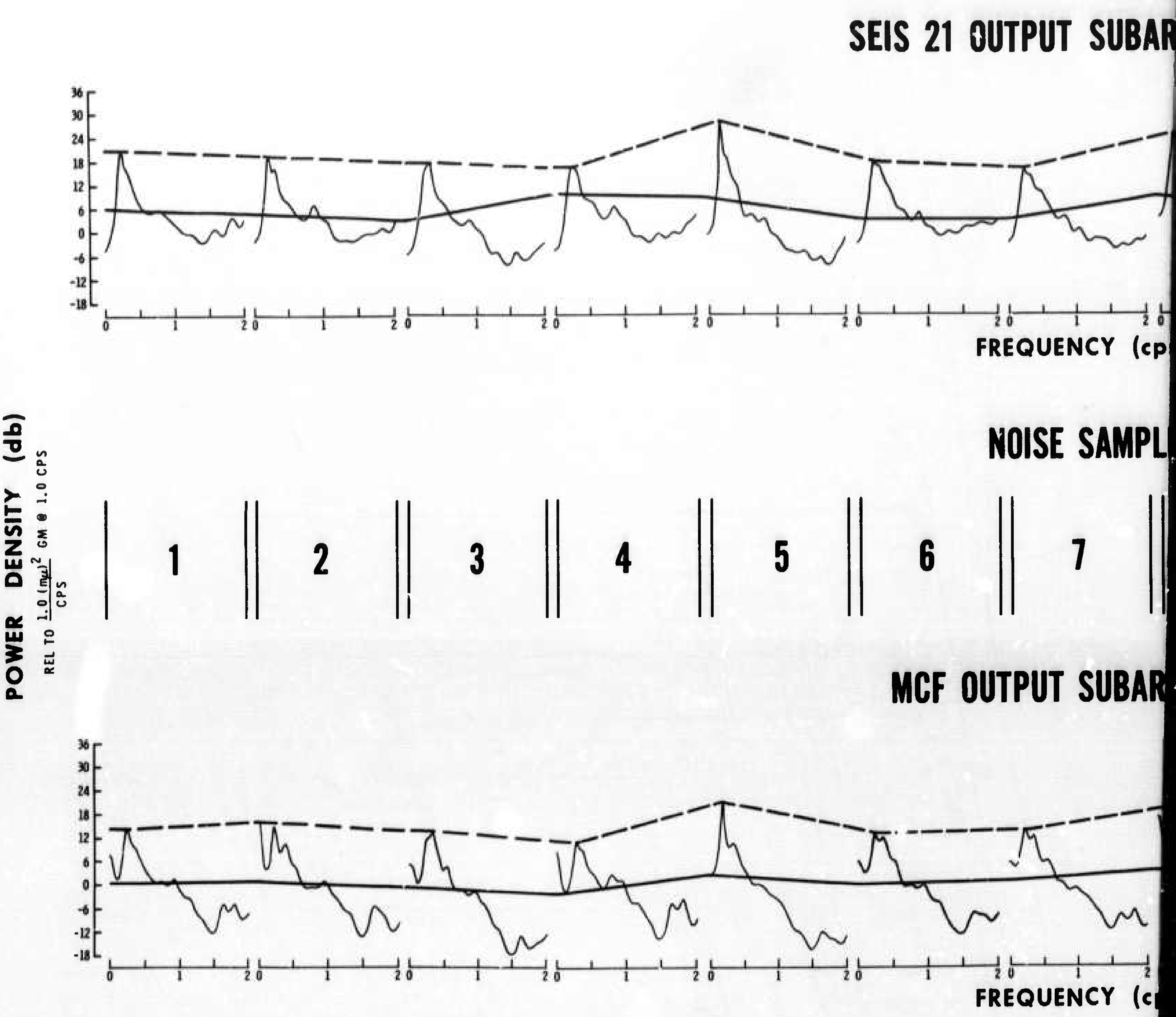


Figure IV-18. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray F1

B



SEIS 21 OUTPUT SUBAR
FREQUENCY (cp
NOISE SAMPL
1
2
3
4
5
6
7
MCF OUTPUT SUBAR
FREQUENCY (c
POWER DENSITY (db)
REL TO 1.0 (mμ)² GM @ 1.0 CPS / CPS

A

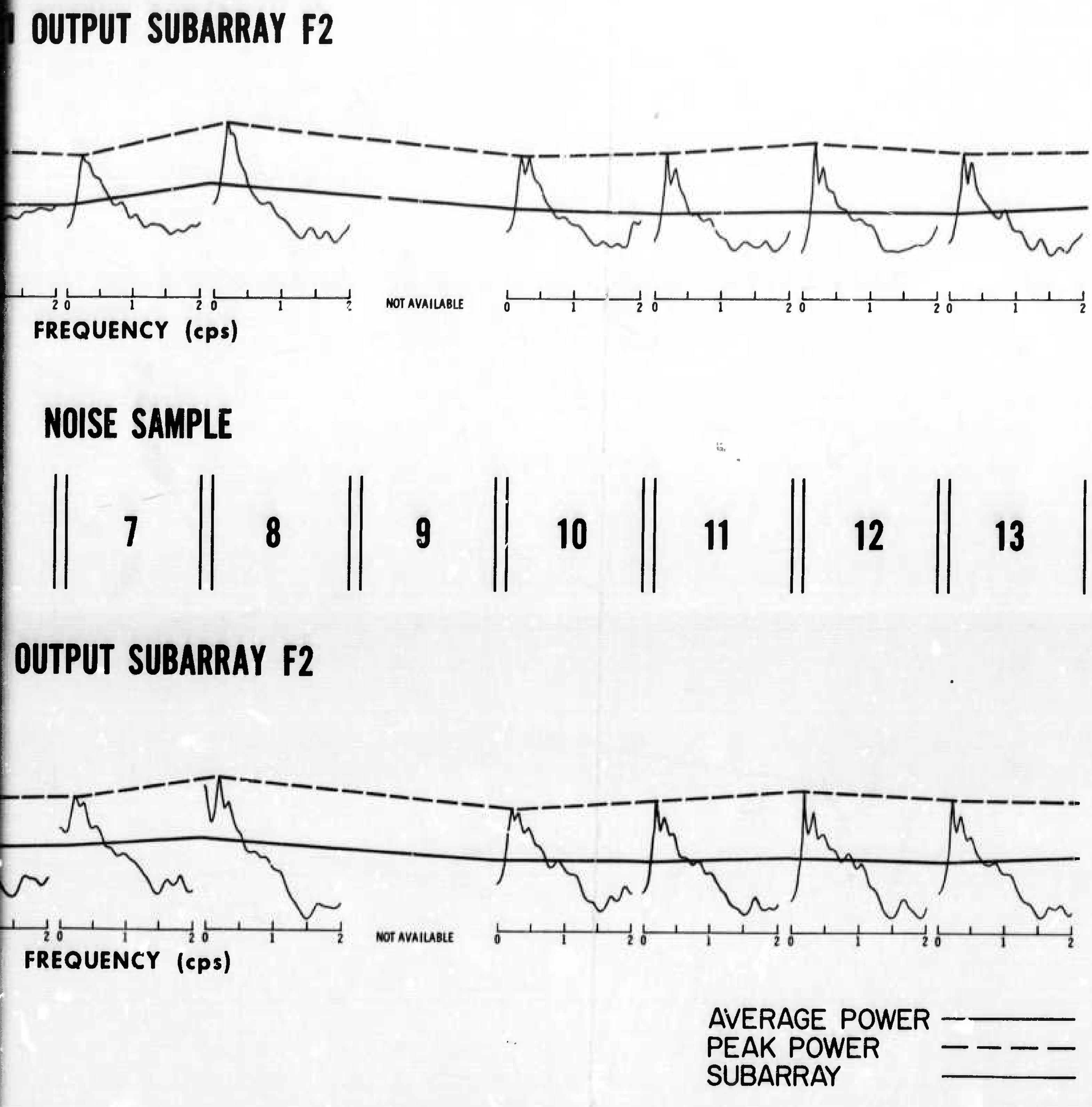
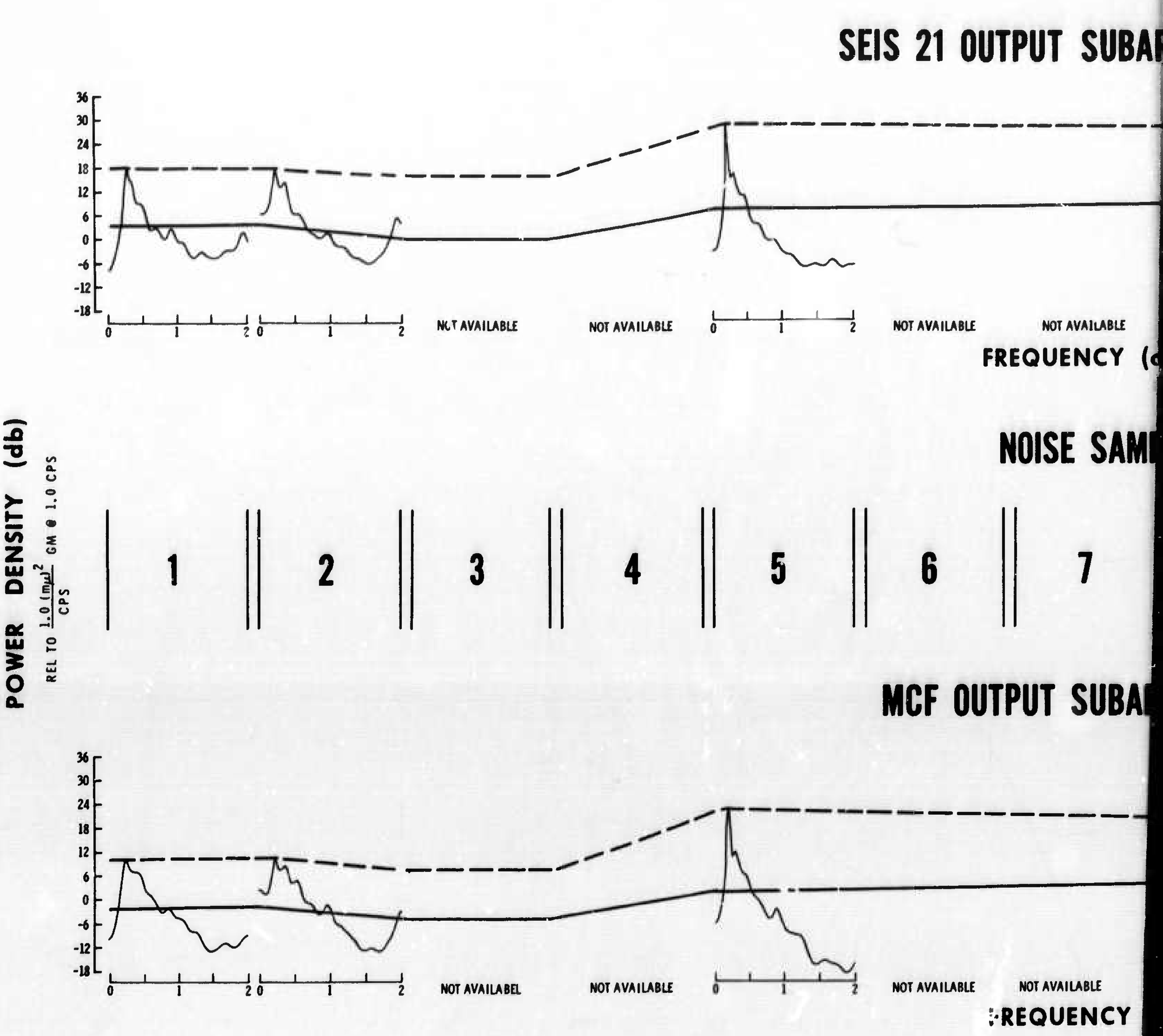


Figure IV-19. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray F2


SEIS 21 OUTPUT SUBA
36
30
24
18
12
6
0
-6
-12
-18
0
1
2
NOT AVAILABLE
NOT AVAILABLE
NOT AVAILABLE
NOT AVAILABLE
FREQUENCY
POWER DENSITY (db)
REL TO $\frac{1.0\ (m\mu)^2}{CPS}$ GM @ 1.0 CPS
NOISE SAM
1
2
3
4
5
6
7
MCF OUTPUT SUBA
NOT AVAILABEL
NOT AVAILABLE
NOT AVAILABLE
NOT AVAILABLE
FREQUENCY

A

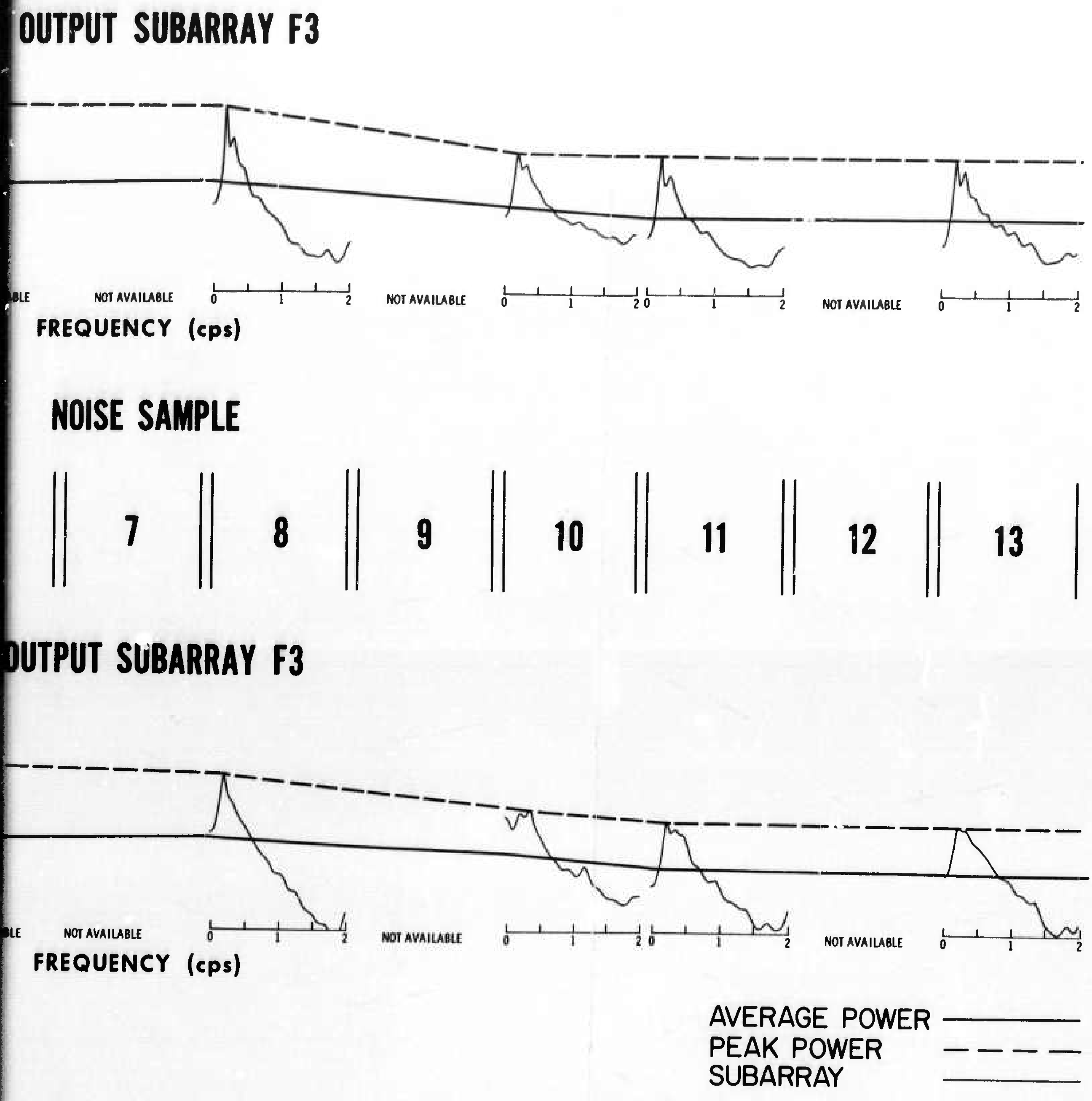
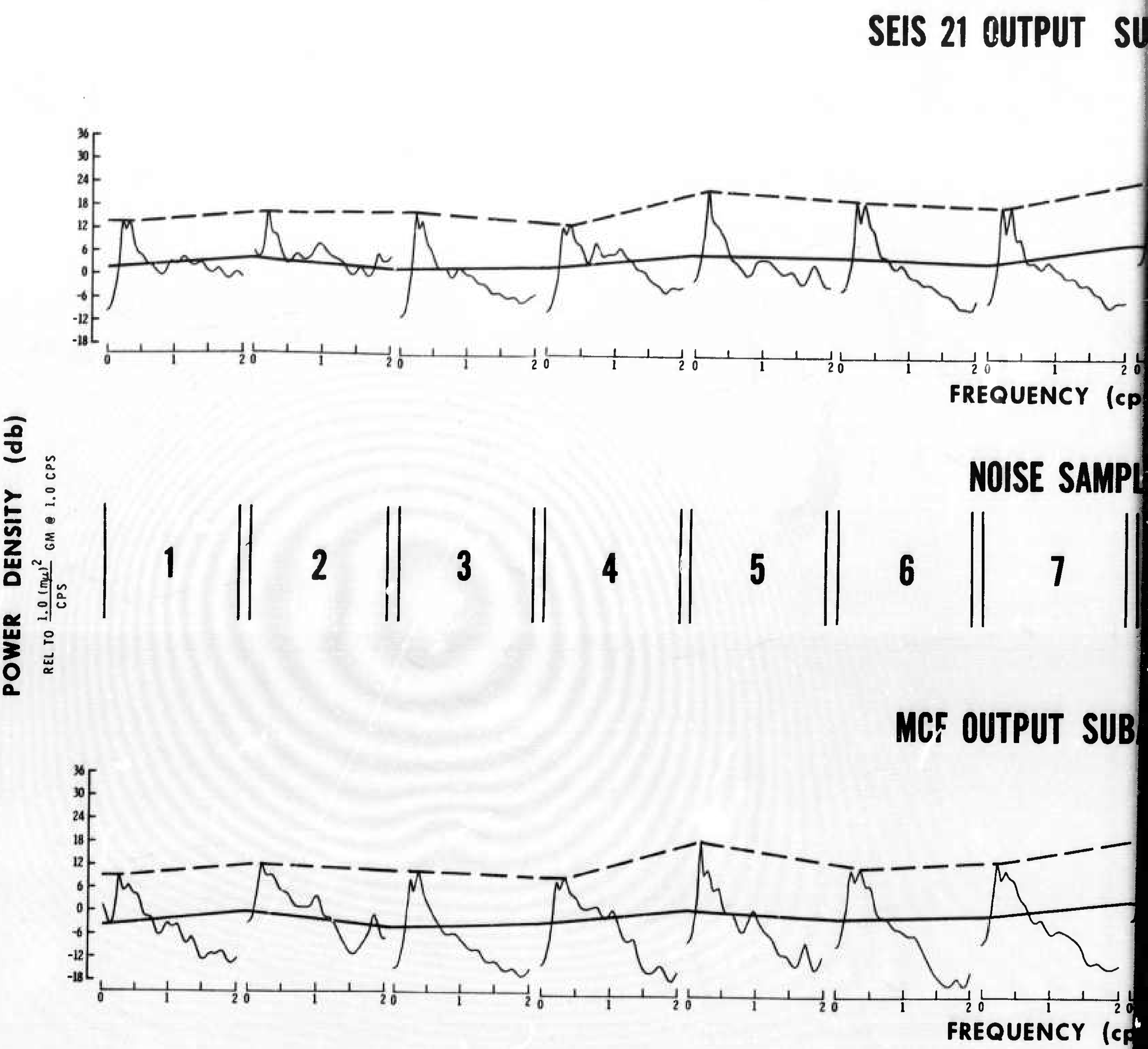


Figure IV-20. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray F3


SEIS 21 OUTPUT SU
FREQUENCY (cp
NOISE SAMPL
1
2
3
4
5
6
7
MCF OUTPUT SUB
FREQUENCY (cp
POWER DENSITY (db)
REL TO $\frac{1.0\ (m\mu)^2}{CPS}$ GM @ 1.0 CPS

A

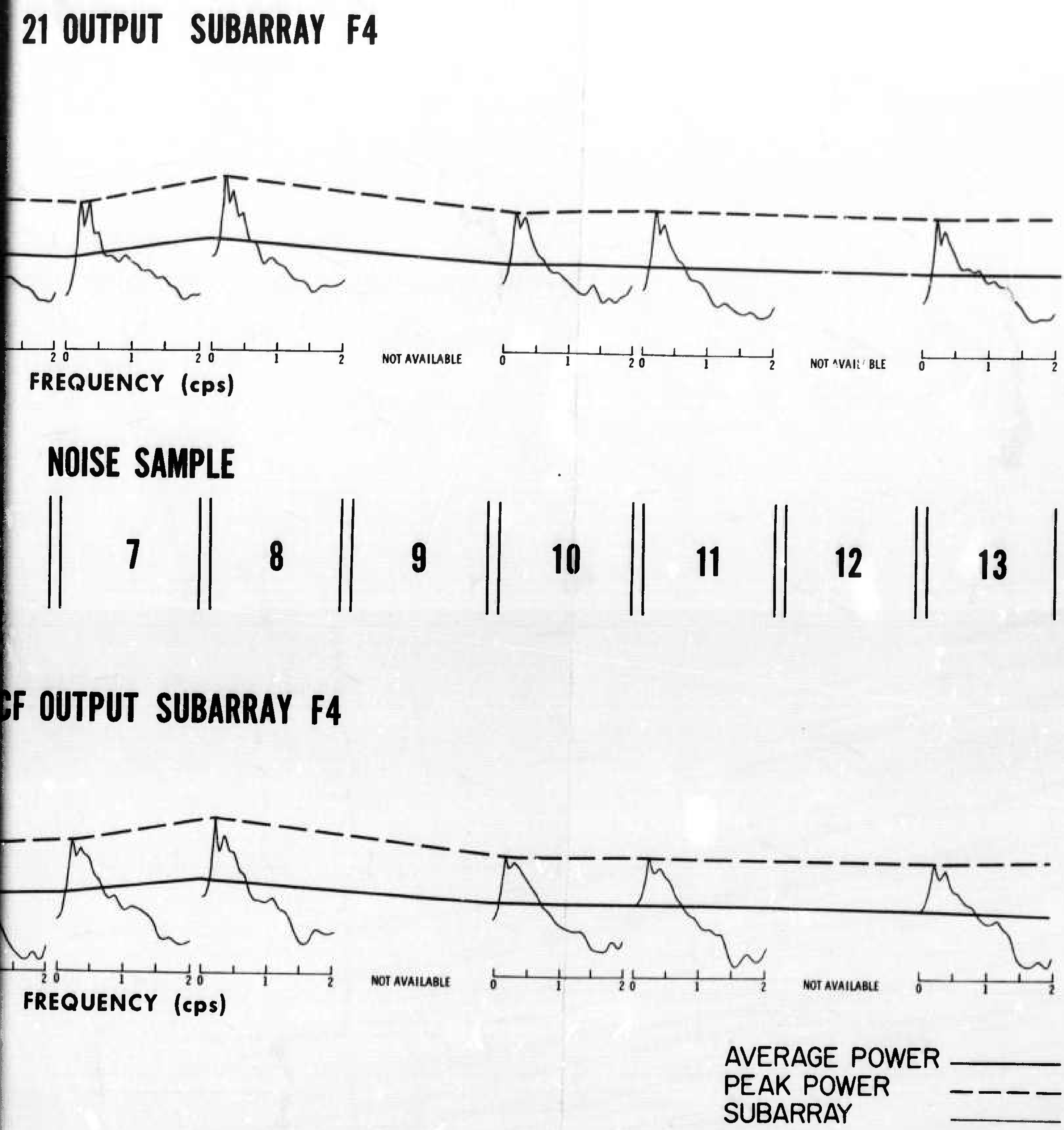


Figure IV-21. Time Variability of Seismometer 21 and MCF Power Spectra, Subarray F4

B

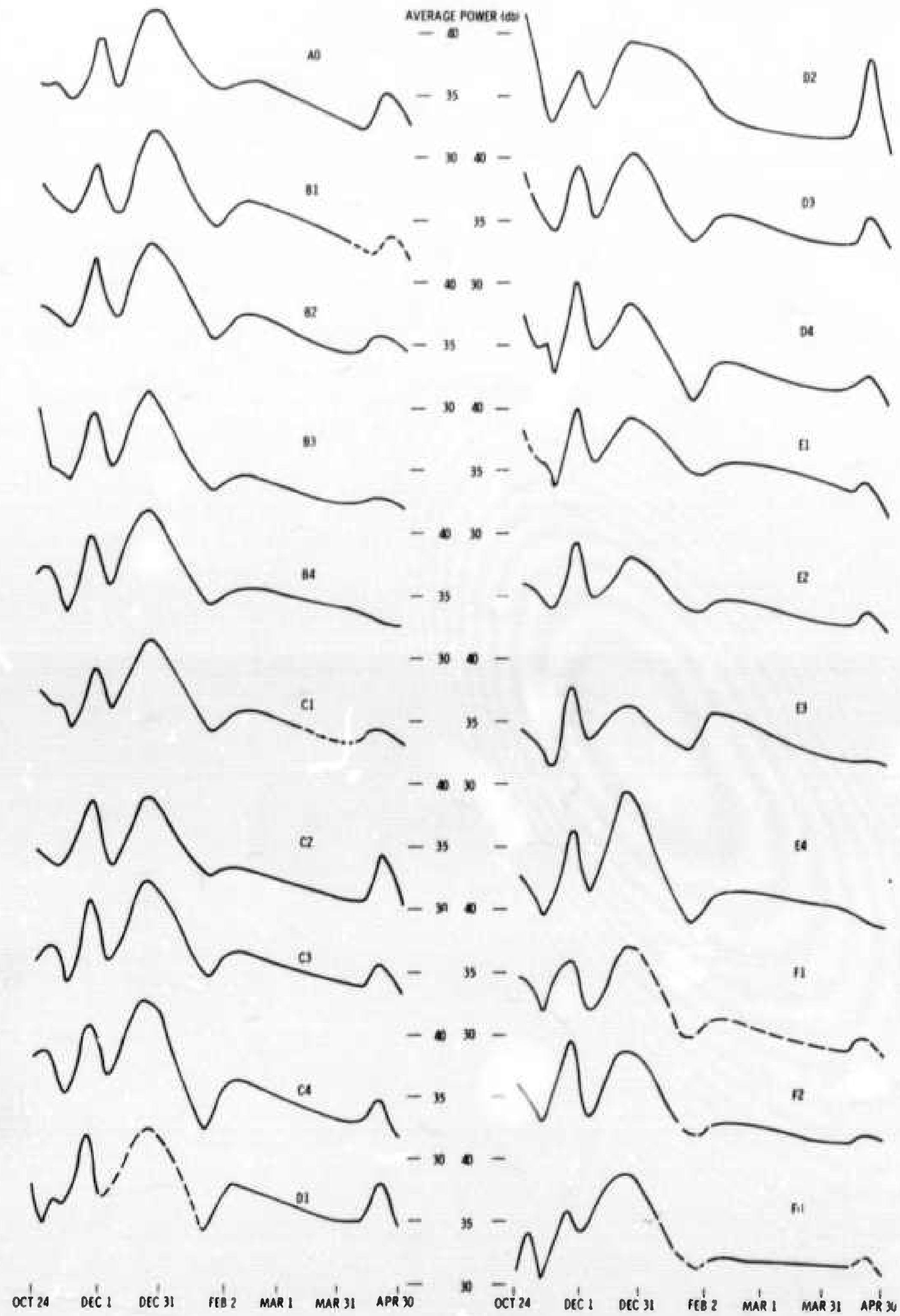


Figure IV-22. Variation of Noise Average Power Levels with Time

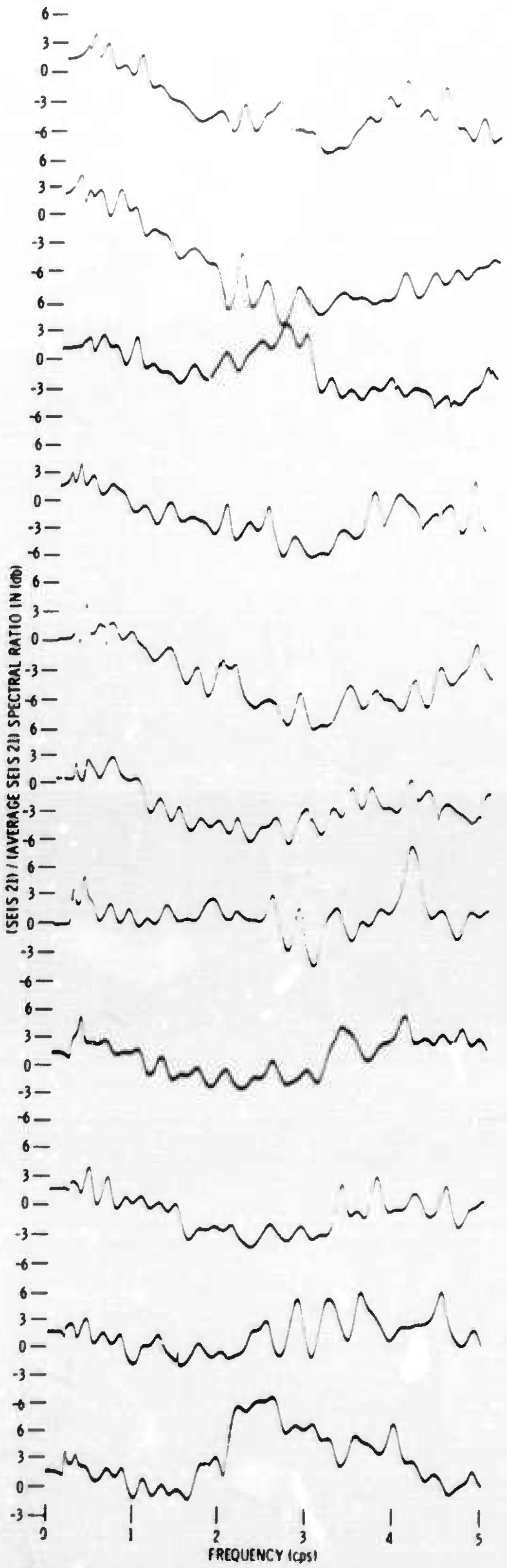


Figure IV-23. Seismometer 21/Average Seismometer 21 Spectral Ratios for All Noise Samples, Subarray B2

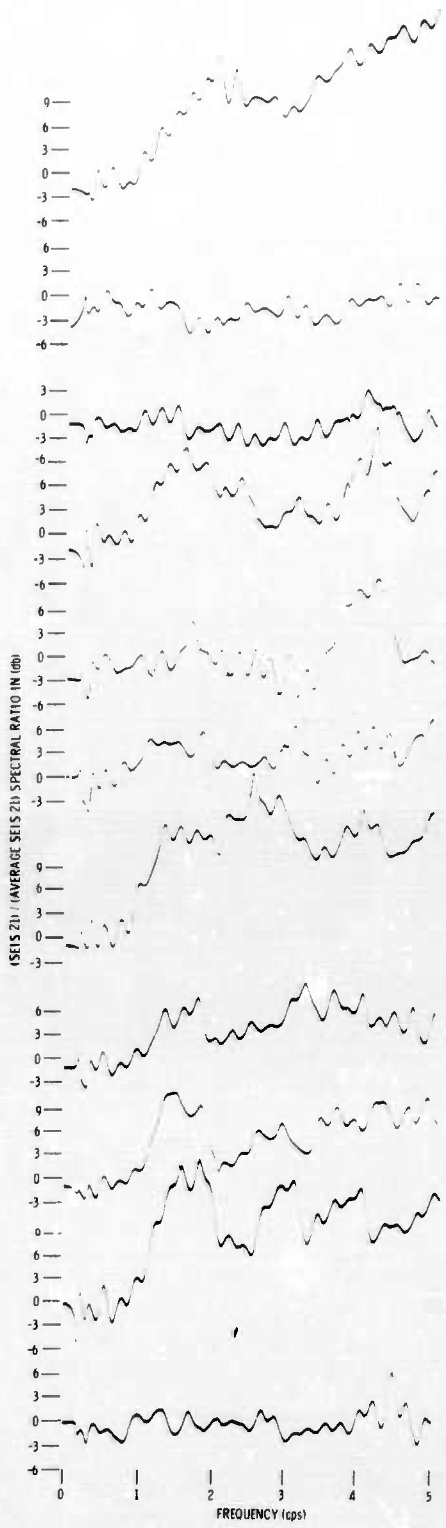


Figure IV-24. Seismometer 21/Average Seismometer 21 Spectral Ratios for All Noise Samples, Subarray D2

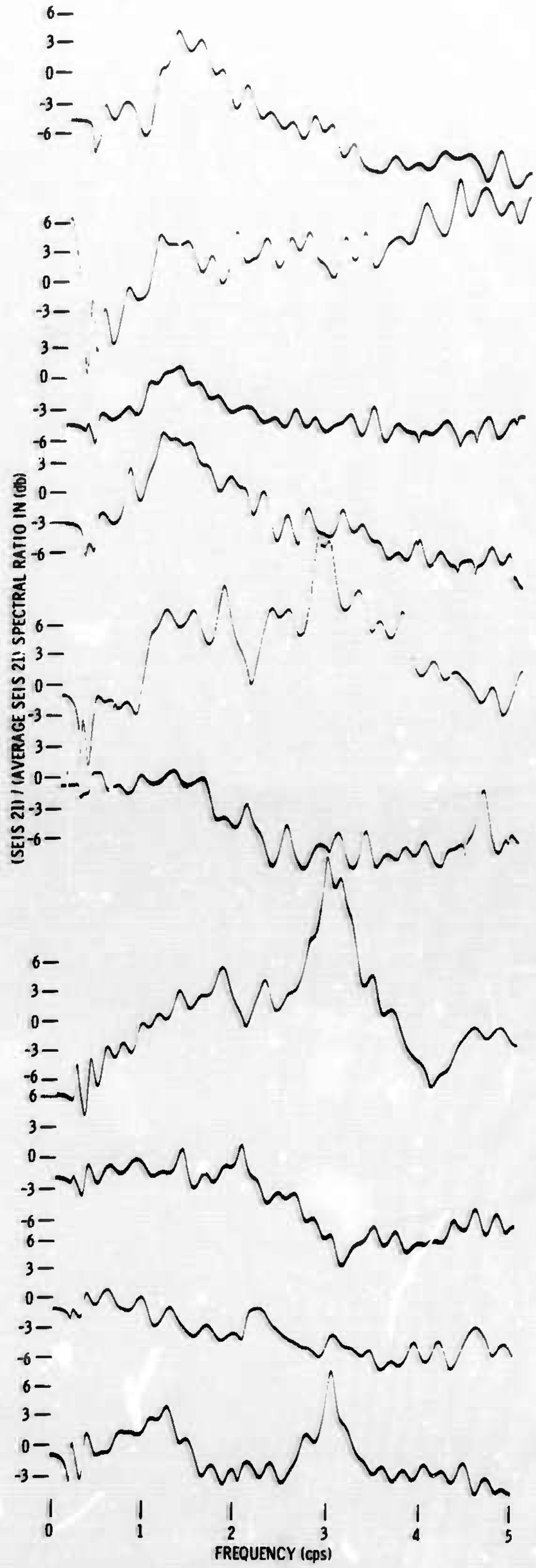


Figure IV-25. Seismometer 21/Average Seismometer 21 Spectral Ratios for All Noise Samples, Subarray F4

SECTION V

REFERENCES

1. Texas Instruments Incorporated, 1967: Subarray Processing, Large-Array Signal and Noise Analysis, Spec. Scientific Rpt. No. 3, Contract AF 33(657)-16678, 16 Oct.

2. Texas Instruments Incorporated, 1967: Analysis of Subarray Wavenumber Spectra, Large-Array Signal and Noise Analysis, Spec. Scientific Rpt. No. 6, Contract AF 33(657)-16678 30 Sep.

3. Texas Instruments Incorporated, 1967: Short-Period Signal Waveform Similarity at LASA, Large-Array Signal and Noise Analysis, Spec. Scientific Rpt. No. 8, Contract AF 33(657)-16678, 1 Aug.

4. Texas Instruments Incorporated, 1967: Array Research Final Rpt., Sect. II, Contract AF 33(657)-12747, 20 Jan.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Texas Instruments Incorporated Science Services Division P.O. Box 5621, Dallas, Texas, 75222	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE
LARGE-ARRAY SIGNAL AND NOISE ANALYSIS – SPECIAL SCIENTIFIC REPORT NO. 4 – SPACE AND TIME VARIABILITY OF THE SHORT-PERIOD LASA NOISE FIELD

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Special Scientific

5. AUTHOR(S) (Last name, first name, initial)
Harley, Terence W.

6. REPORT DATE 30 October 1967	7a. TOTAL NO. OF PAGES 58	7b. NO. OF REFS 4
8a. CONTRACT OR GRANT NO. Contract No. AF 33(657)-16678 b. PROJECT NO. AFTAC Project No. VT/6707 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) __________ 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) __________	

10. AVAILABILITY/LIMITATION NOTICES
This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Chief, AFTAC.

11. SUPPLEMENTARY NOTES ARPA Order No. 599	12. SPONSORING MILITARY ACTIVITY Air Force Technical Applications Center VELA Seismological Center Headquarters, USAF, Washington, D.C.

13. ABSTRACT

To study the time and space variability of the LASA noise field, 13 noise samples were used. For every noise sample, power spectra were computed for both the output of seismometer 21 and the output of the multichannel filter system at each subarray. Finally, ratios of the individual spectra to the average spectrum were obtained for each noise sample. At the 0.2- to 0.3-cps microseismic peak, results were consistent for the 13 samples. Subarrays E4, F3, and F4 were significantly quieter sites than the average. It appears that the Porcupine Dome and its associated complex geology significantly attenuated the low-frequency microseismic energy. Subarrays D1, E1, and F1, which are in the northeast sector of LASA, were significantly noiser sites than the average. No explanation for their higher noise levels is known. Variations in the peak power levels were highly correlated over all of the LASA, which implies a common source for most of the energy at 0.2 to 0.3 cps. This observation is consistent with the theory that large storms at sea are the major source of low-frequency microseismic evergy. Above approximately 1.5 cps, power levels varied considerably from subarray to subarray as well as from noise sample to noise sample. Thus, most of the energy above 1.5 cps appeared to be nontime stationary and generated in the vicinity of a subarray. ( )

DD FORM 1 JAN 64 1473

UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Large-Array Signal and Noise Analysis Space Variability Time Variability Short Period LASA Noise Field						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.