IEEE 802.4L

Through-the Air Physical Media, Radio

CHAPTER 3

NOISE STATISTICS

The noise source used in testing and theoretical work is gaussian. It can be described by its RMS voltage, and its bandwidth. It cannot be described by a peak voltage, however. Any observed peak voltage may eventually be exceeded. The probability that an observed value will be some factor, K, greater than the RMS value is plotted in figure 3-1 and figure 3-2. The odds that an observed value will be 10 times the RMS value is very small: at 1,000,000 observations per second, there is a good chance of seeing it once in the age of the universe.

The function plotted in figure 3-2 is defined as 2*Q(K). The probability that the magnitude of the peak observed value in N samples will be in the range K to K+d is:

P(K,d,N) = (1-2*Q(K+d))**N-(1-2*Q(K))**N

The likelihood that the peak voltage will be at value K is a probability density function, equal to P(K,d,N)/d as d approaches zero. This function is plotted in figure 3-3 and figure 3-4. It can be seen from figure 3-4 that in 1,000,000,000 samples the expected value of K in a peak hold measurement is 15.8 dB above the RMS value. (The maximum rate that a continuous system can provide independent samples is two times the bandwidth of the system.)

The ratio of signal RMS voltage to Noise RMS voltage is signal to noise ratio. Errors occur when the occasional peaks in noise obliterate the signal. If the noise has the same bandwidth as the signal, and the signal has an error rate of 1/1,000,000,000 at a signal to noise ratio of 20 dB, then the signal must be at least 20.0-15.8 dB or 4.2 dB above the peak noise to be detected without error.

Precise understanding of the effect that peak noise has on the network requires knowledge about the receiver used for the given signalling technique. The design of certain types of receivers is proprietary, and subject to patent application. Ultimate performance of one such design, developed at Inland, is shown in figures 3-5 and figure 3-6.

Actual measurements of noise on cable shows behavior that is not gaussian. The central limit theorem used in statistics would seem to indicate that all sources contributing to noise on the cable should combine to produce a gaussian normal curve. In fact, this does not happen, the theorem doesn't apply. In many real installations, some sources completely dominate the others. Measurement is made difficult, since many of these sources are off most of the time. For this reason, peak holding measurements over long periods of time are needed to obtain a valid estimate of the challange that noise will present to the network.

Assume that a 2 dimensional plane is covered with gaussian noise transmitters that have a high RMS output when they are on, but are usually off. The number of transmitters at a given distance from a receiver is proportional to the distance. The voltage, (not power), at the receiver is inversely proportional to that distance. A family of curves for equal power transmitters is plotted in figure 3-7. The envelope of the curves has a slope inversely proportional to voltage. For cases where this is a good model of the noise driving the cable, it is unlikely that the actual noise on the cable will have a gaussian distribution.

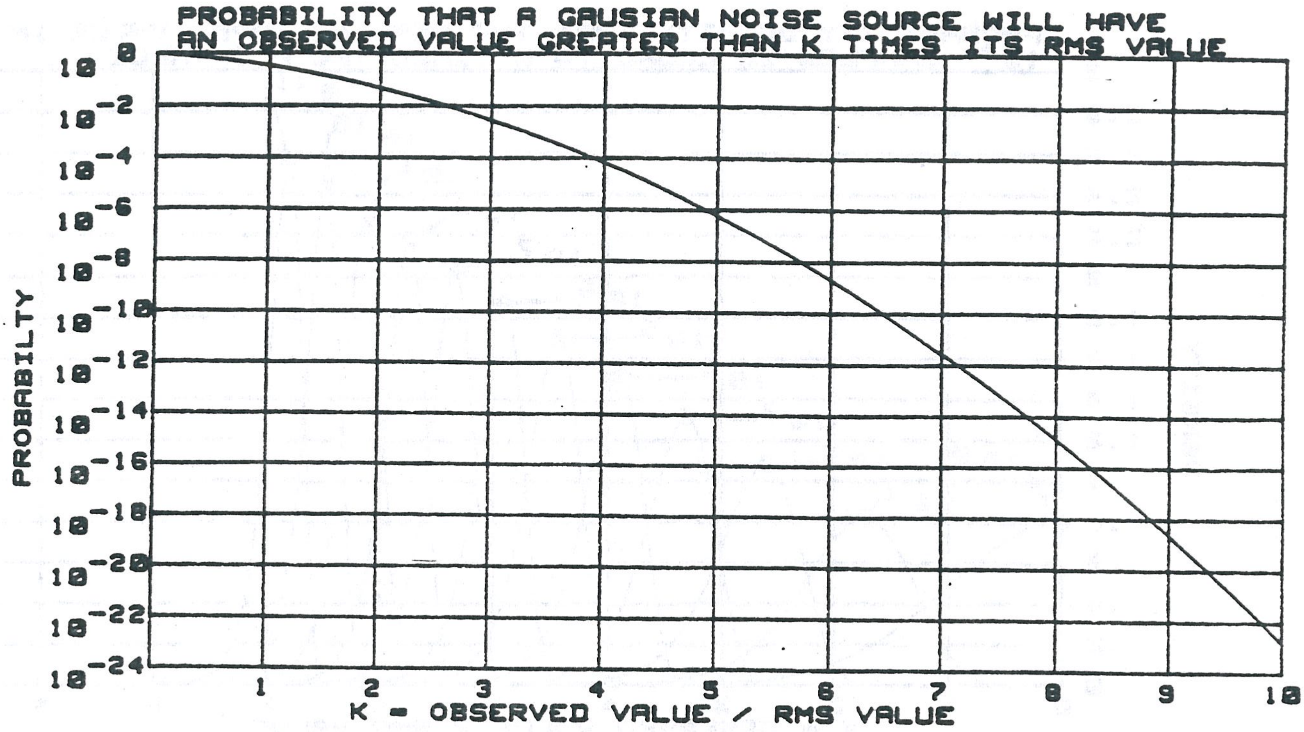


Figure 3-1

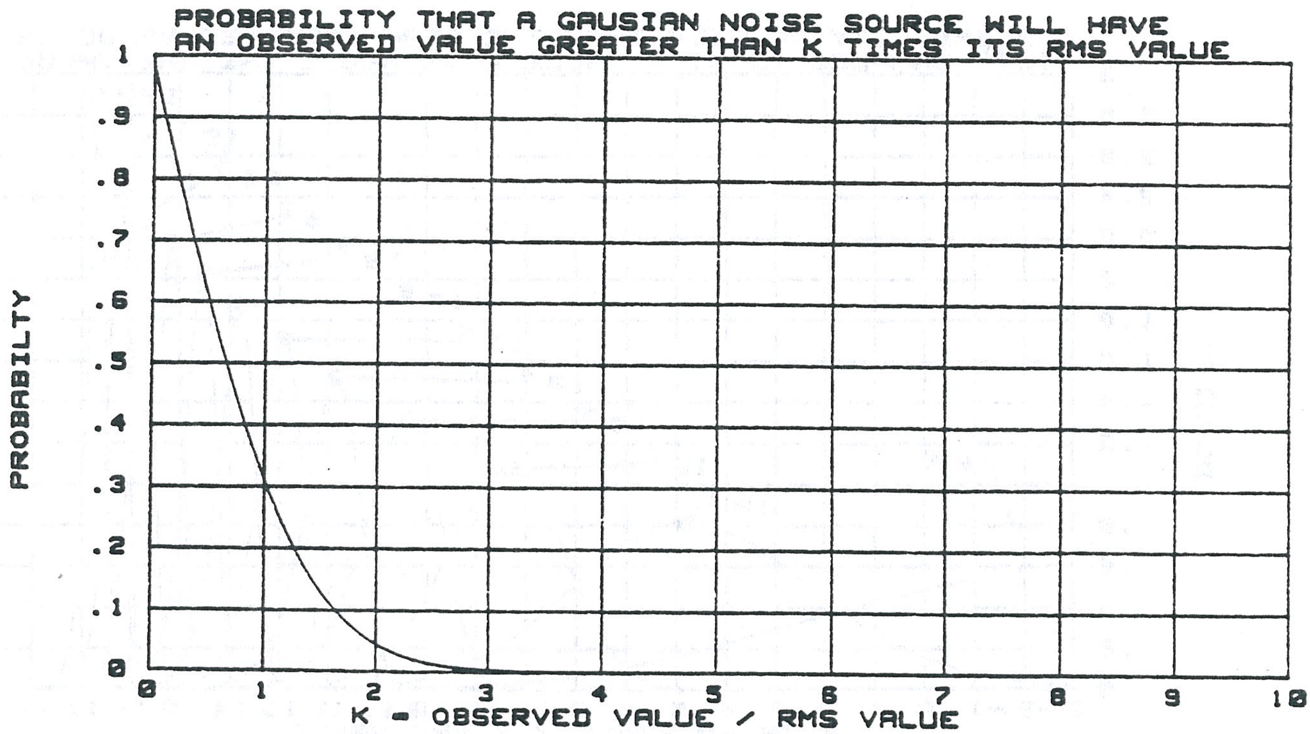


Figure 3-2

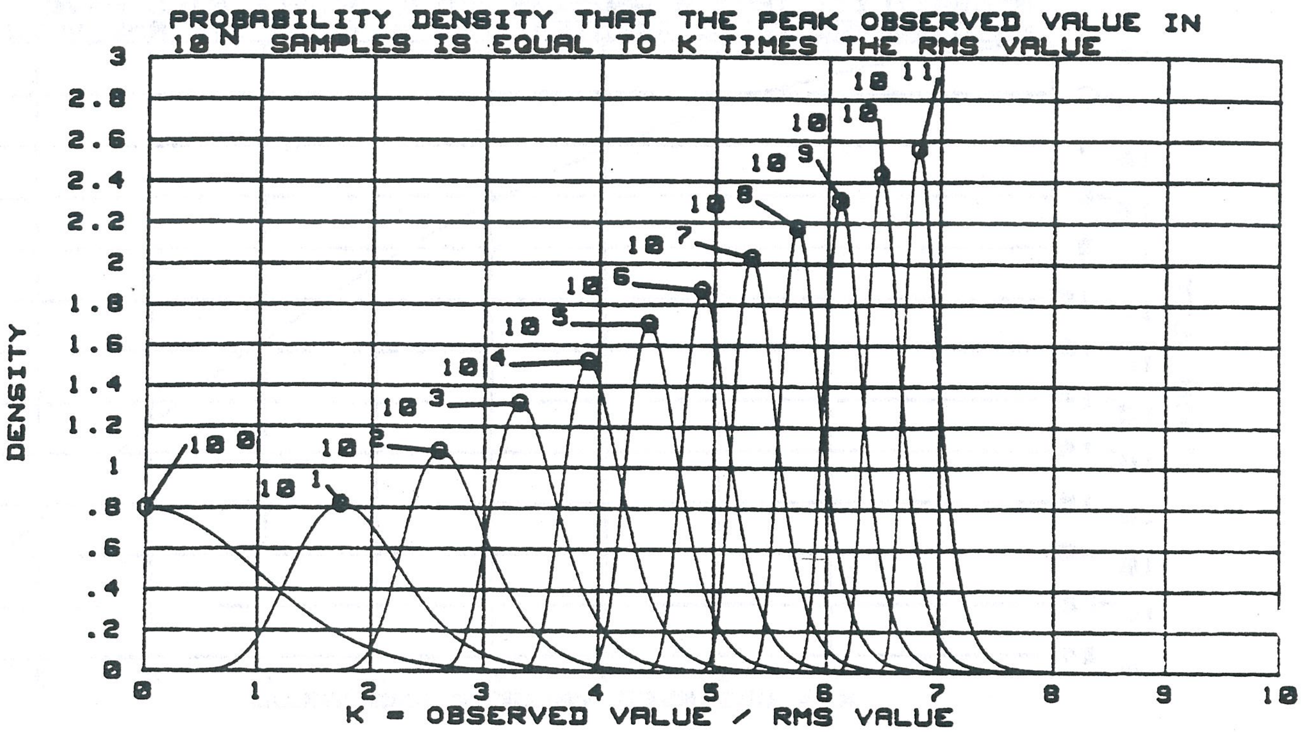


Figure 3-3

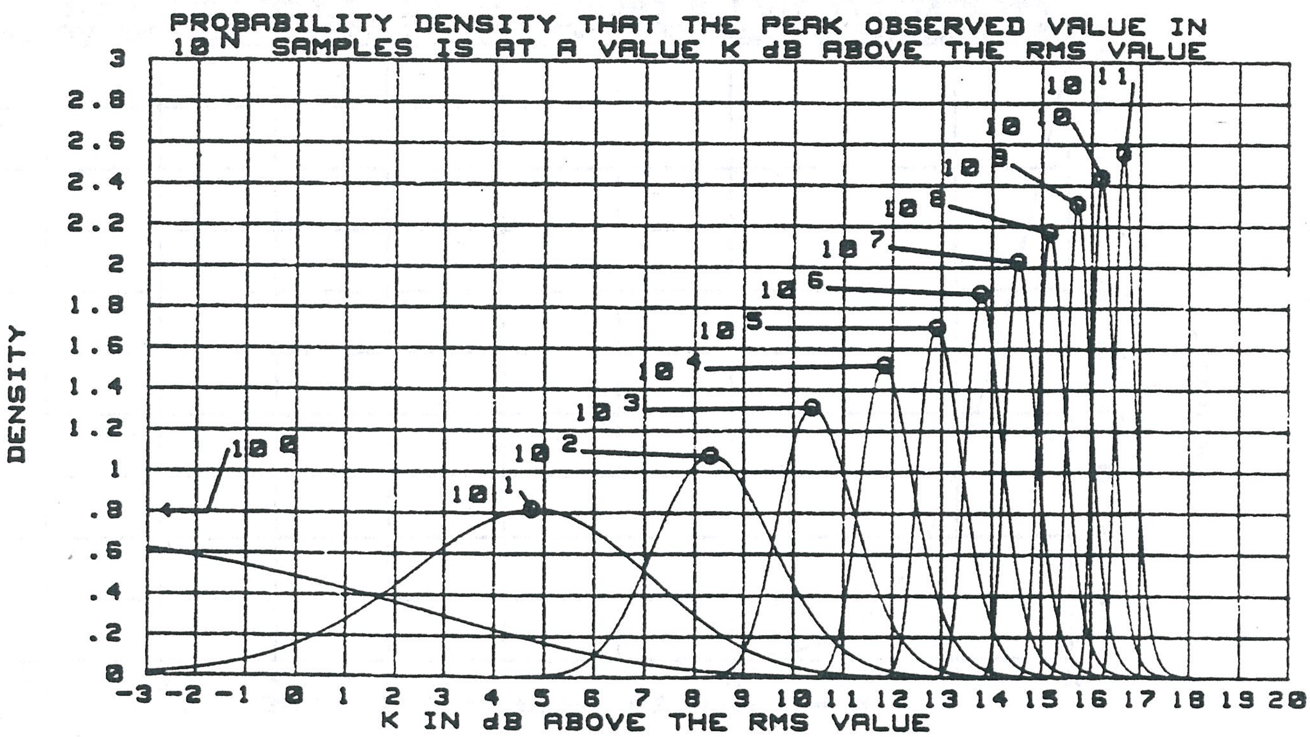


Figure 3-4

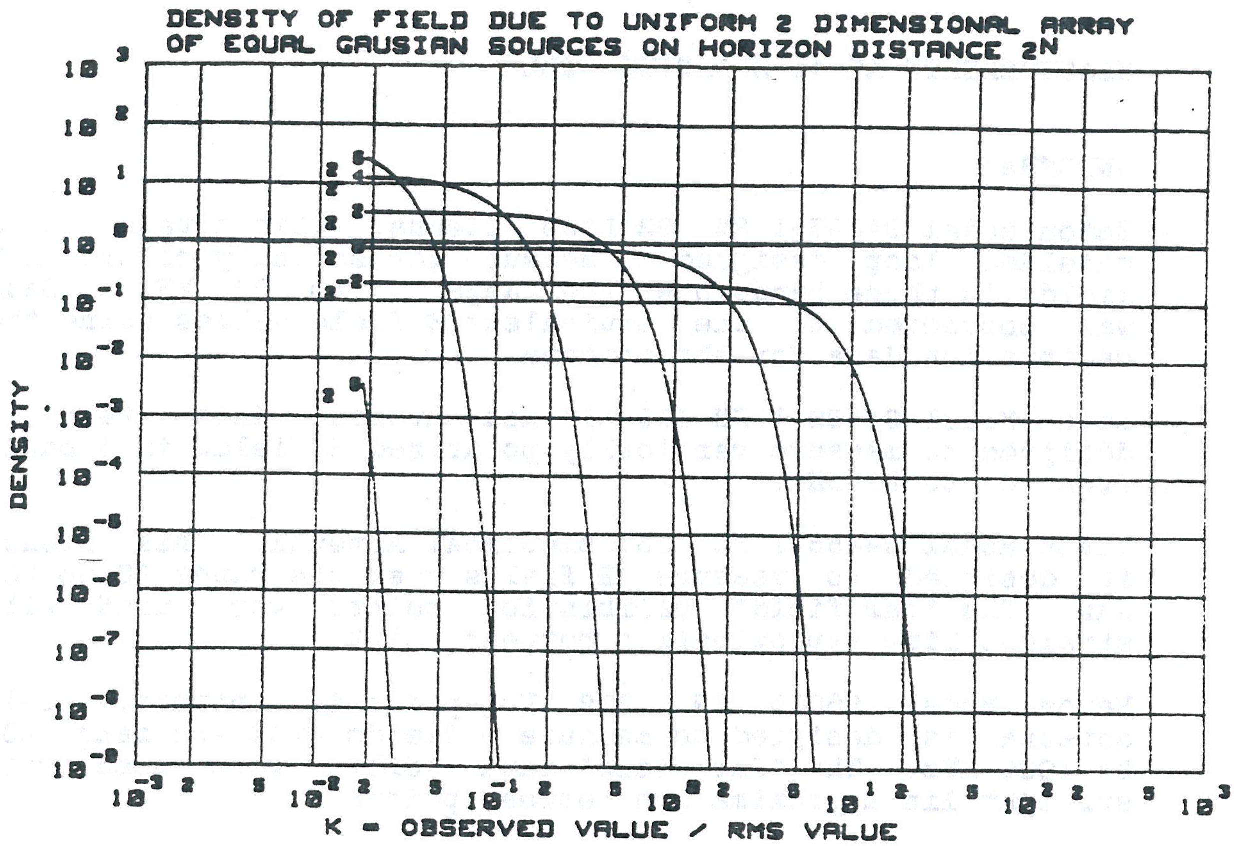


Figure 3-7

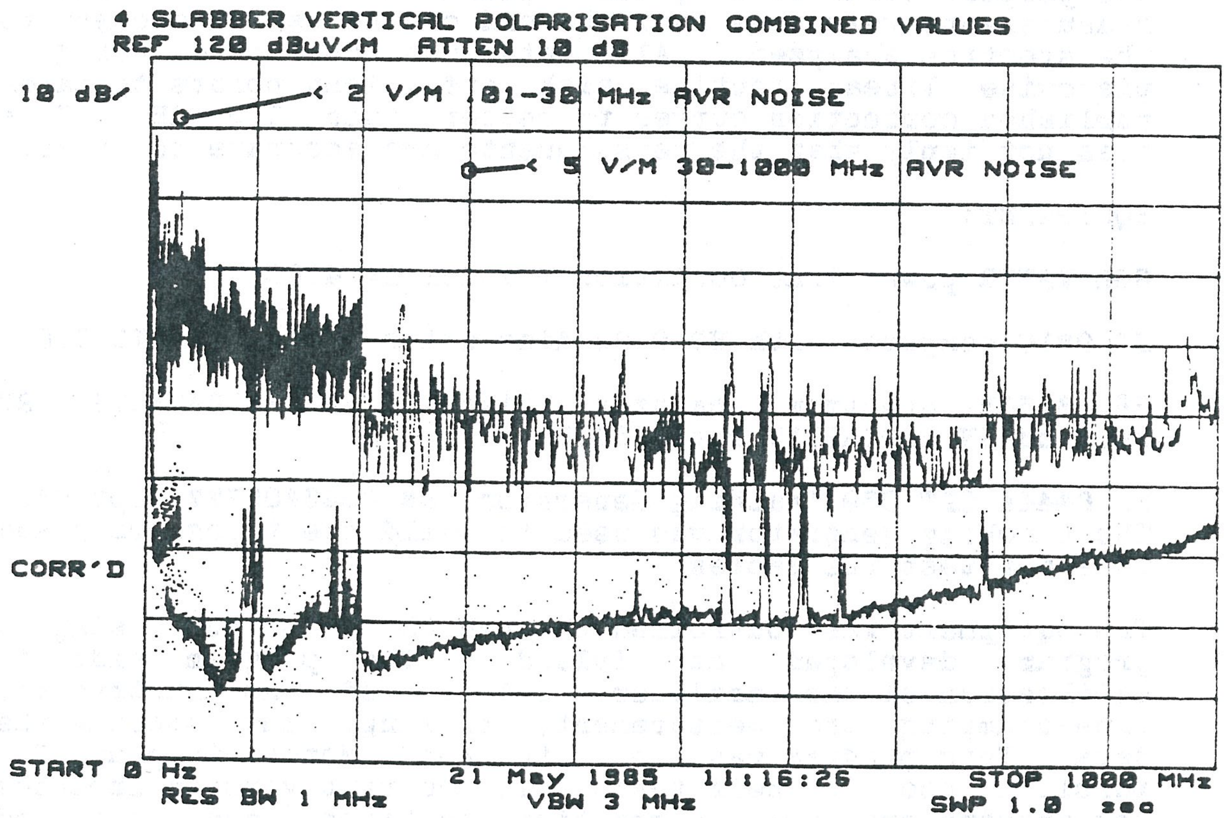


Figure 4-1

ANTENNA:

Eaton Model 94593-1 SN 392 Loop Antenna. This antenna is a shielded loop designed to measure horizontally polarized H fields in three bands over the range .01 to 32 MHz. Data was corrected to the equivalent E field values using the calibration data for the antenna.

Eaton Model 94592-1 SN 419 41" Rod Antenna. This antenna is designed to measure vertically polarized E fields in 5 bands from .01 to 32 MHz.

Eaton Model 94455-1 SN 1031 Biconical Antenna. This antenna is designed to measure E fields over the range 20 to 200 MHz. The "far field" calibration points were used with straight line approximation between points.

Eaton Model 96005 SN 1272 Log-periodic Antenna. This antenna is designed to measure E fields over the range 200 to 1000 MHz. The "far field" data points were used with straight lin approximation between points.

Antenna measurements were taken at a height of approximately 4 feet from the floor, except for the whip antenna, which was perpendicular to a ground plain laid on the floor. Measurements were made near the end of the cables closest to the spectrum analyzer. All data was corrected using a piecewise linear routine with sufficient points to match published correction curves to better than 0.5 dB. This does not imply that the measurements are accurate to .5 dB.

EQUIPMENT:

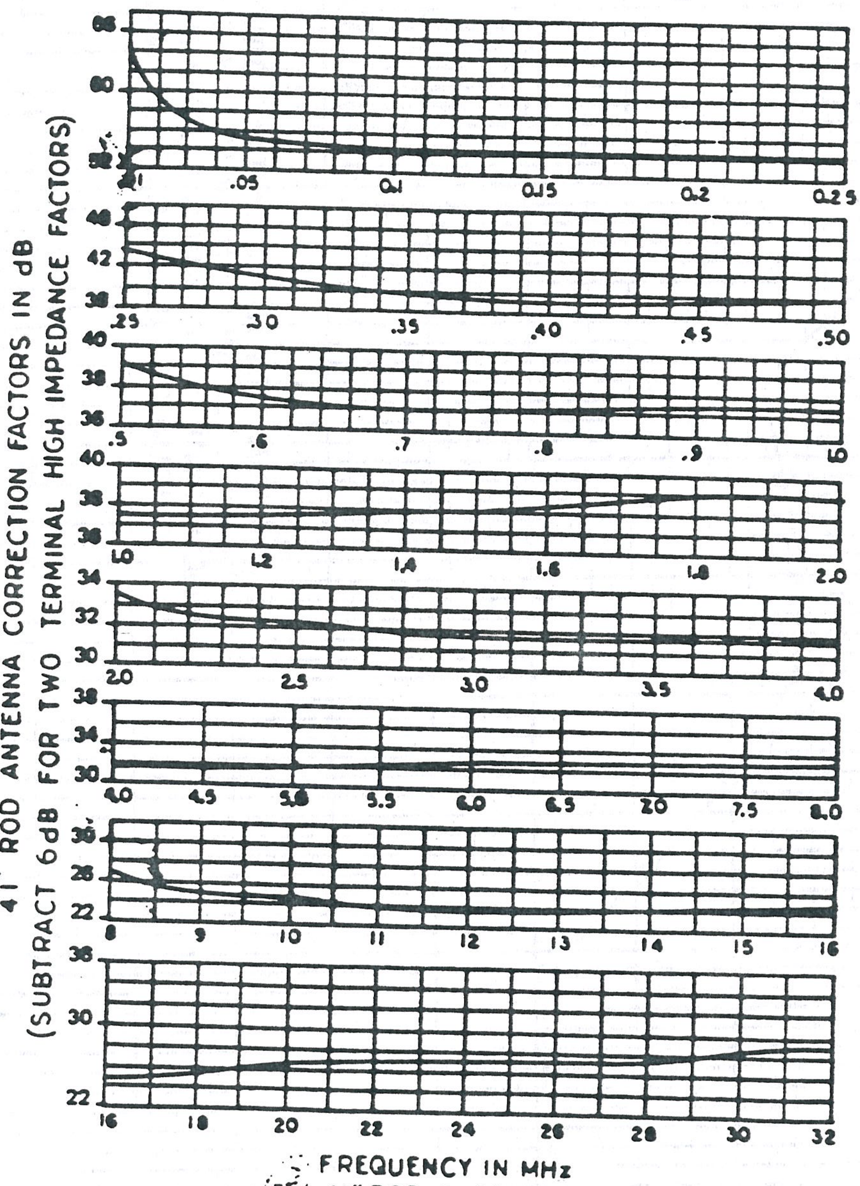
SGL WABER power line conditioner model LM 4100.

HP 9816 computer with HP 9122 disc drive running BASIC 3.0.

HP 8568B Spectrum Analyzer, Display SN 2403A08674, RF section SN 2503A0113 Opt 85680B.

HP 8444A OPT 059 Tracking Generator, SN 2325A05777, Opt 059. The tracking generator was used to build the transformer and to sweep test the cables.

The equipment was controlled through the HPIB bus using a program developed at Inland. The program aids in calibration of the analyzer, set up of the instrument, time-stamping the measurement, titling, and storing the data. This program was sent to Ford Motor Company for possible use in their tests. The current version includes the antenna and cable correction routines, and plot and annotation functions.



FREQUENCY IN MHz

41" ROD ANTENNA

CALIBRATED BY: MODEL 94592-1 ANTENNA COUPLER

DATE:

SERIAL NO. A19

CHART 1

1-403683-001

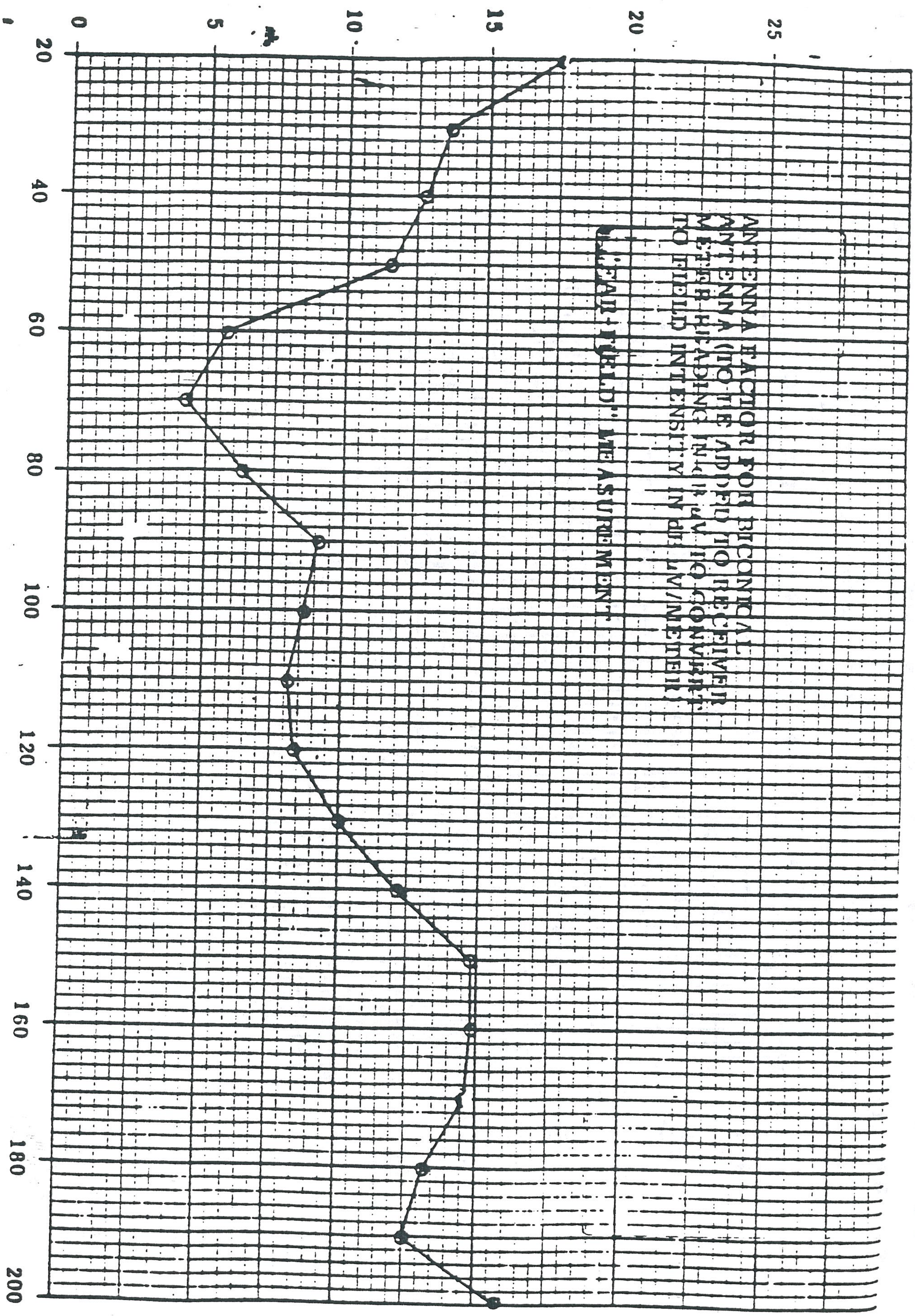
COUPLER

Meter)

5

d Above)

ANTENNA CORRECTION FACTOR IN dB

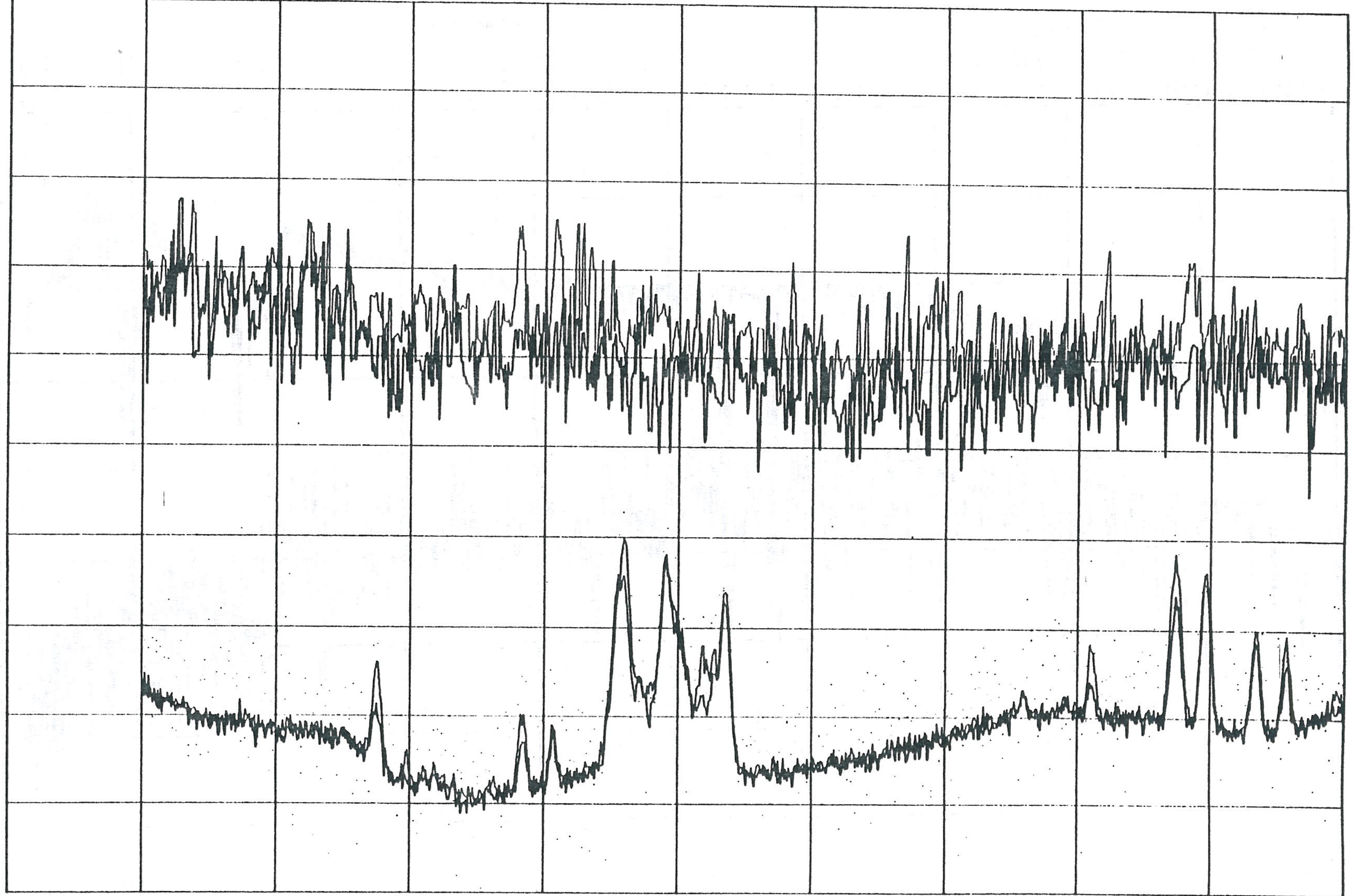


FREQUENCY IN MHz

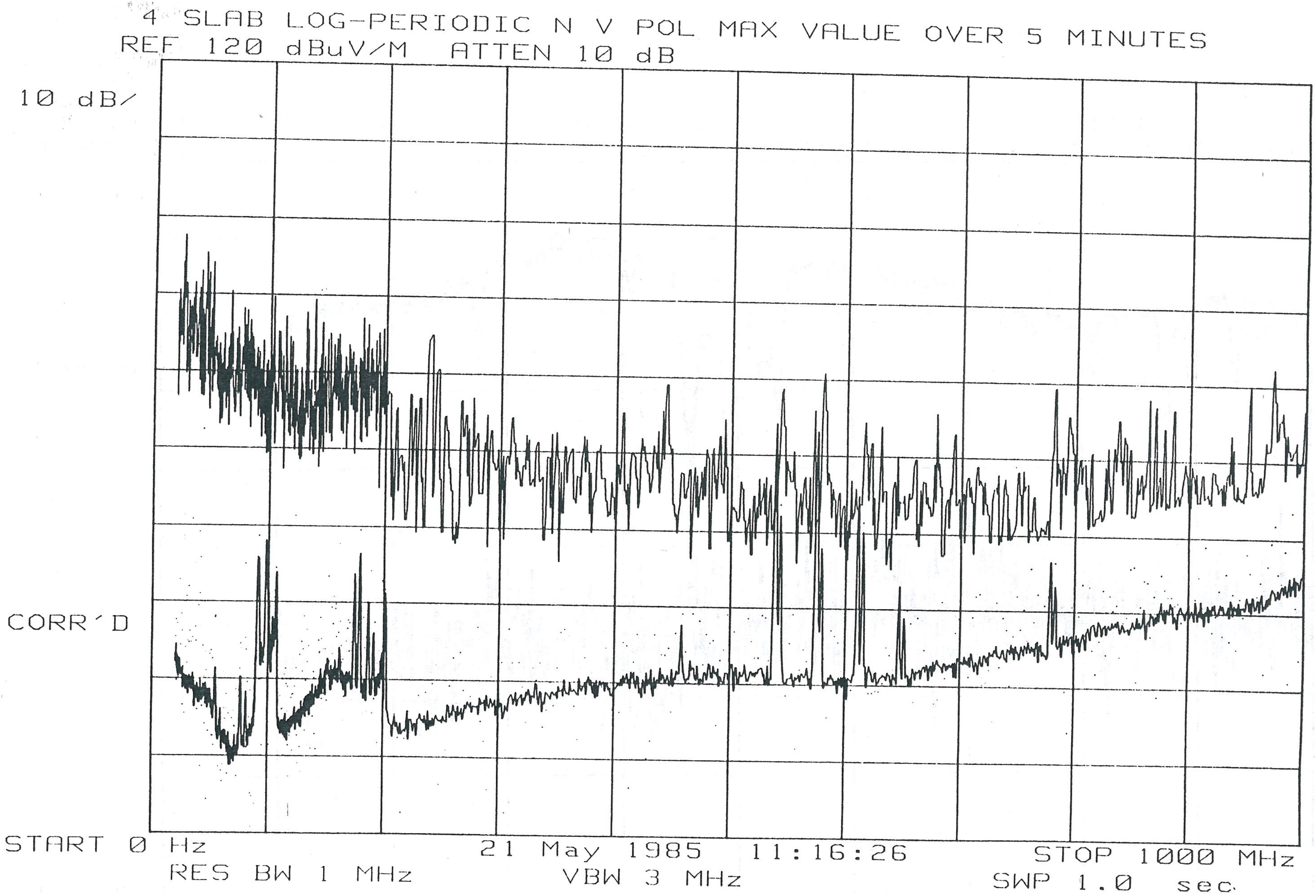
4 SLABBER BICONIC VERTICAL 5 AND 30 MINUTE MAXIMUMS
REF 120 dBuV/M ATTEN 10 dB

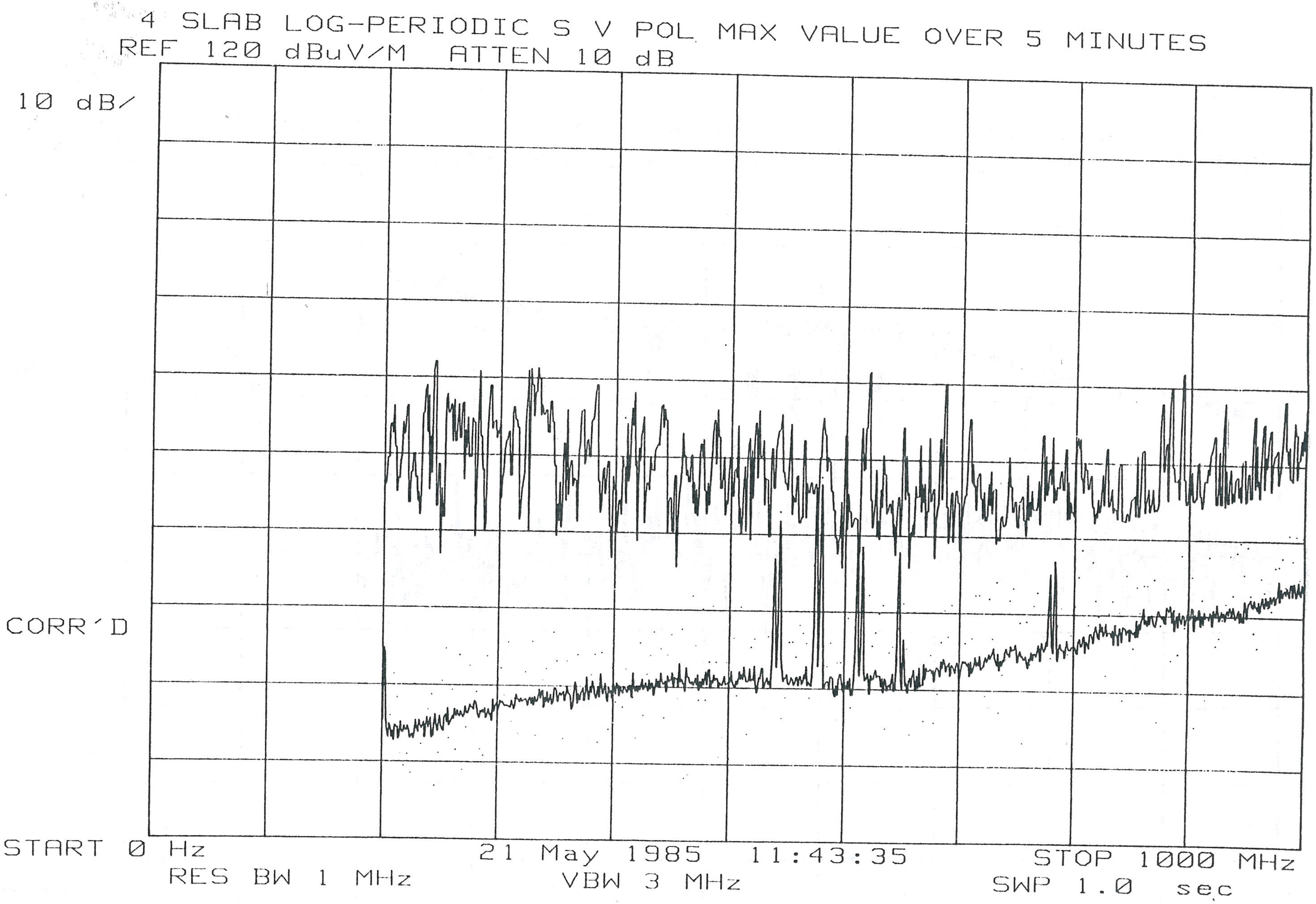
10 dB/

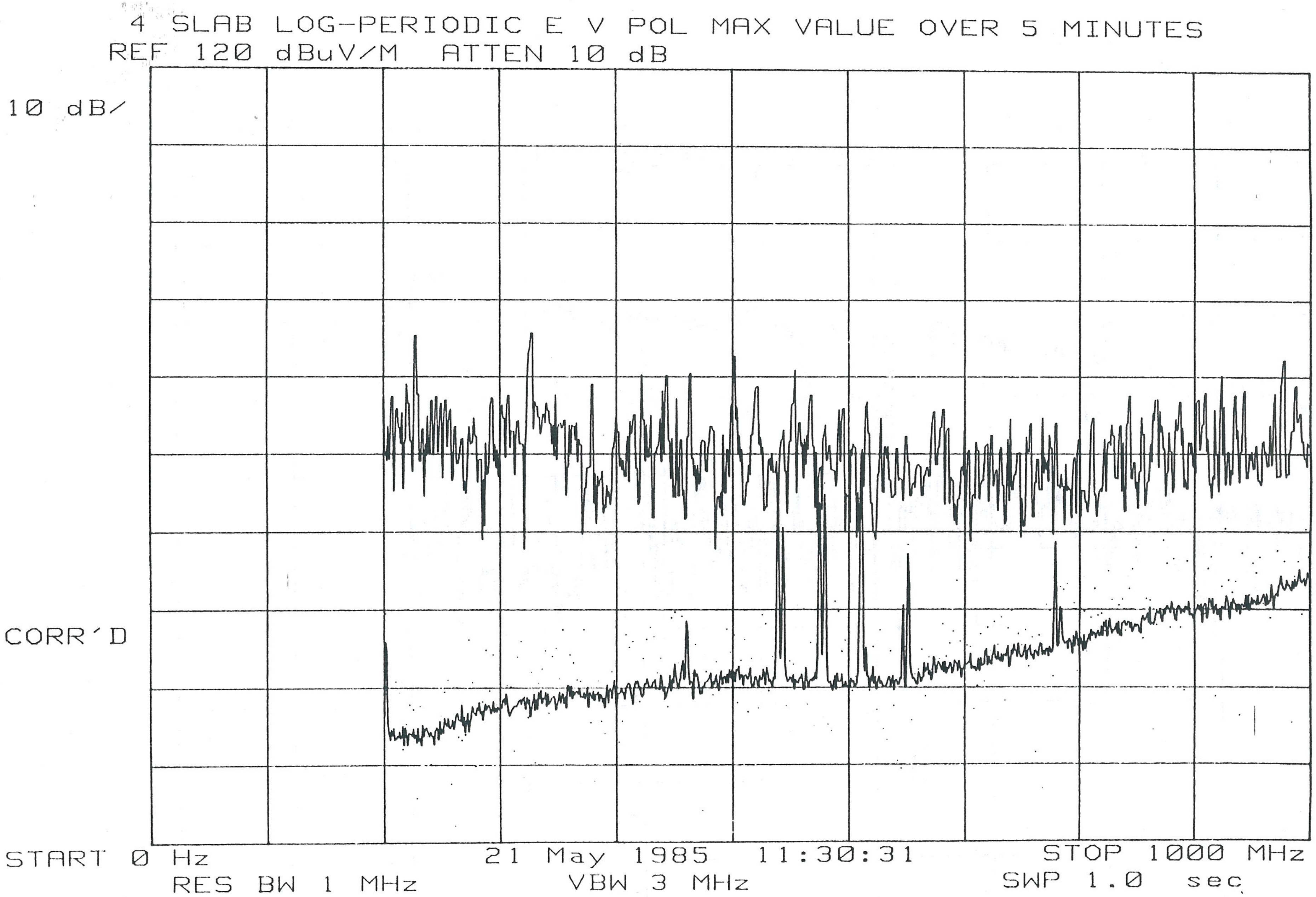
CORR'D

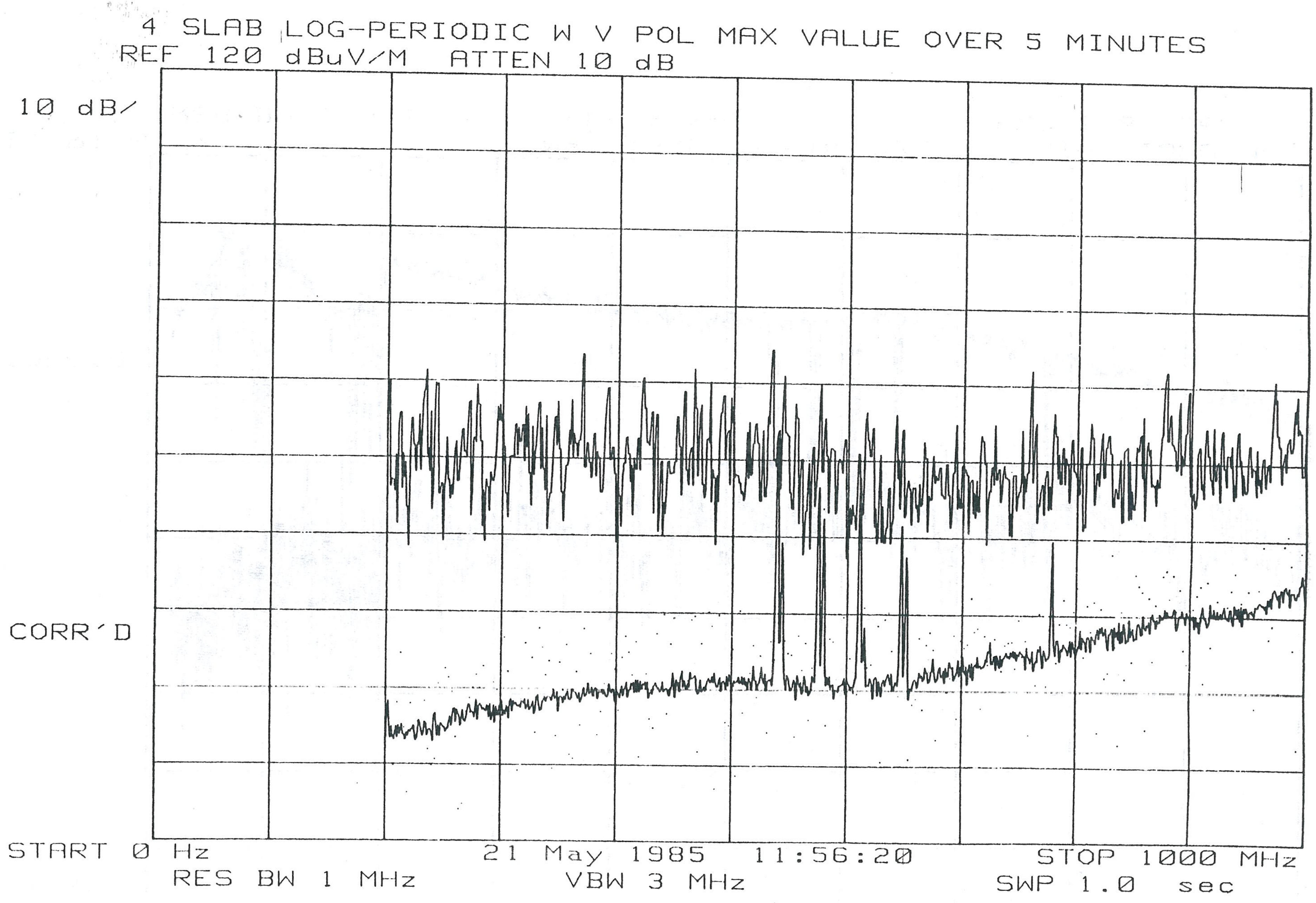


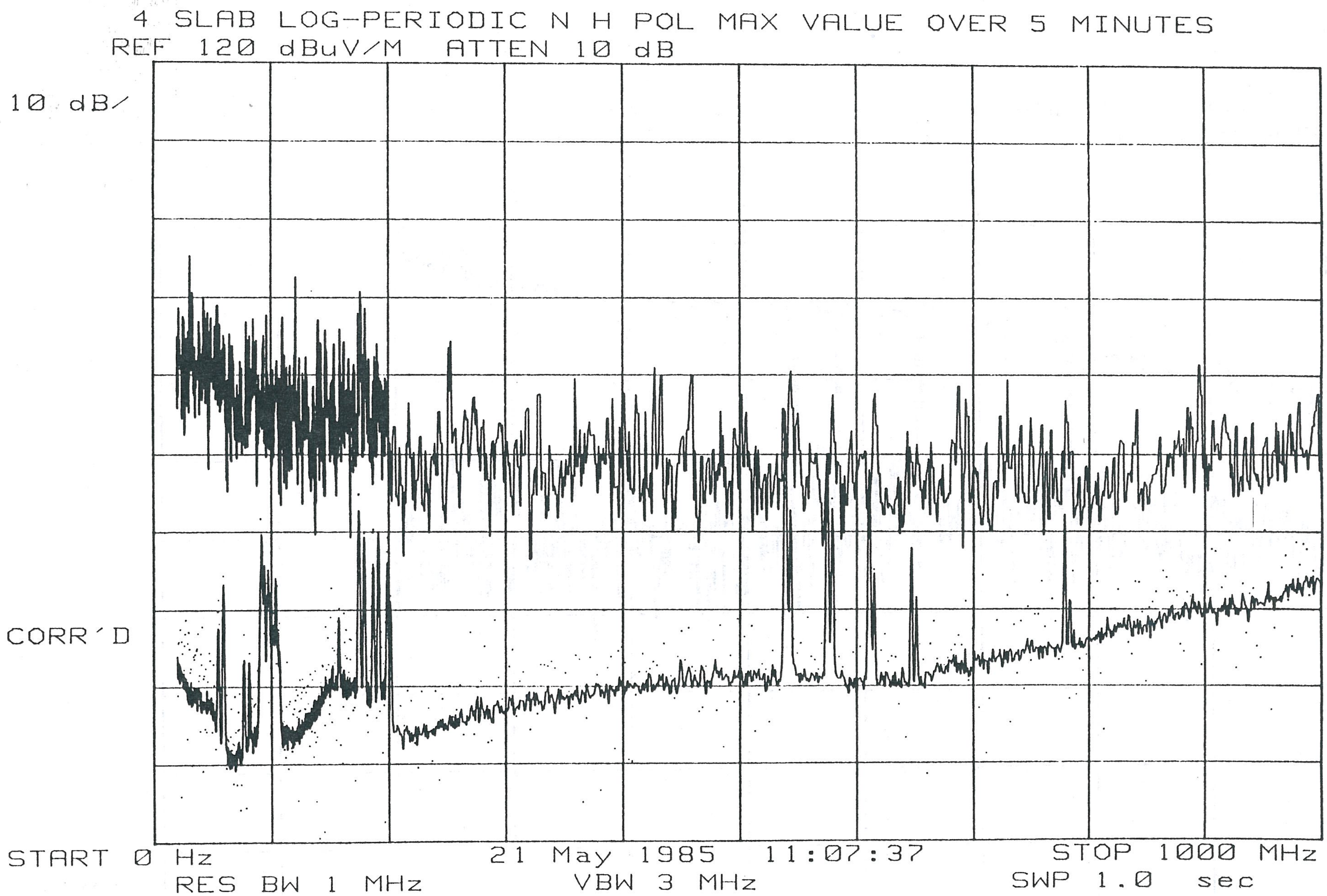
START 0 Hz 21 May 1985 12:06:21 STOP 200.0 MHz
RES BW 1 MHz VBW 3 MHz SWP 1.0 sec

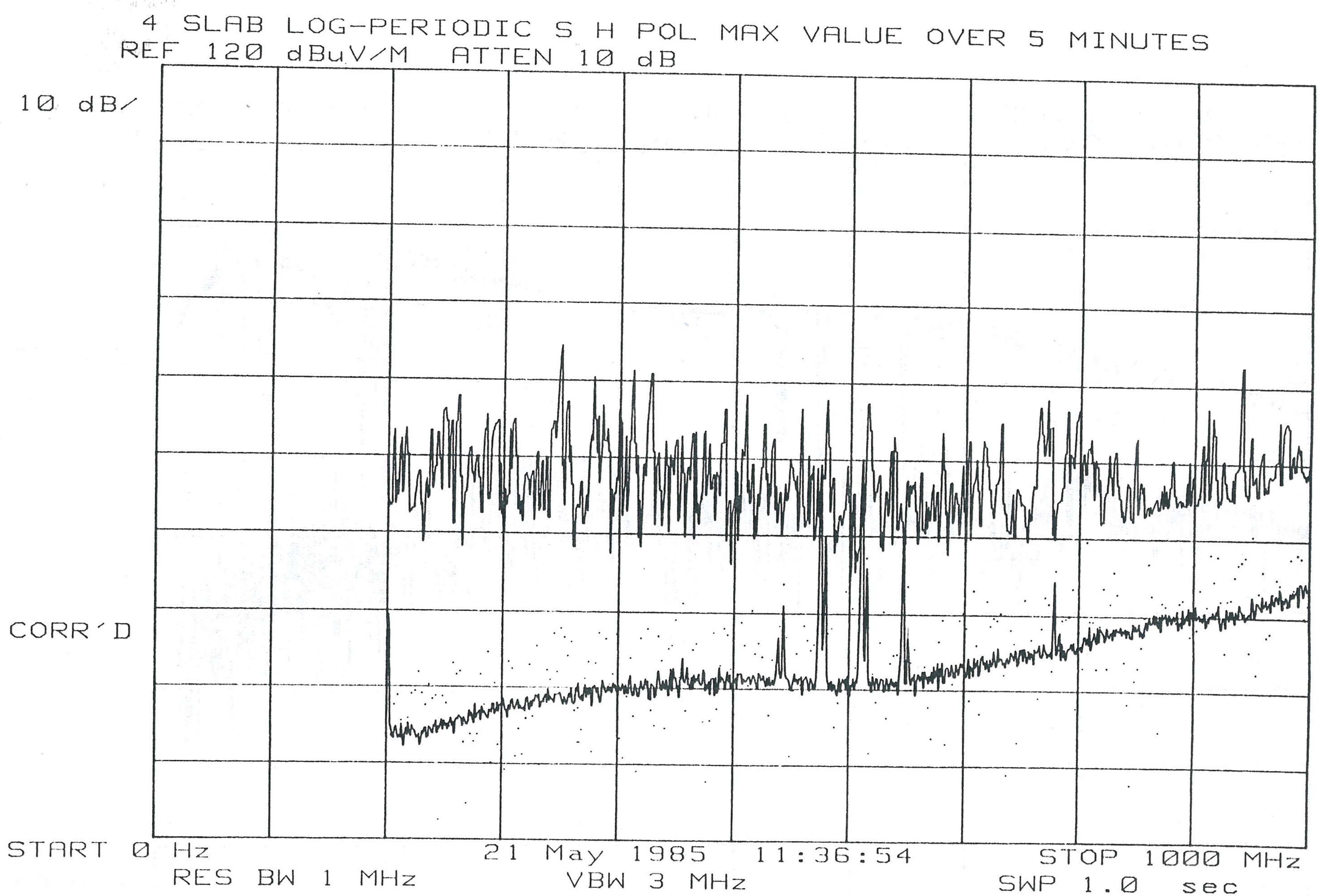

4 SLAB LOG-PERIODIC N V POL MAX VALUE OVER 5 MINUTES
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
21 May 1985 11:16:26
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec


4 SLAB LOG-PERIODIC S V POL MAX VALUE OVER 5 MINUTES
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
21 May 1985 11:43:35
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec

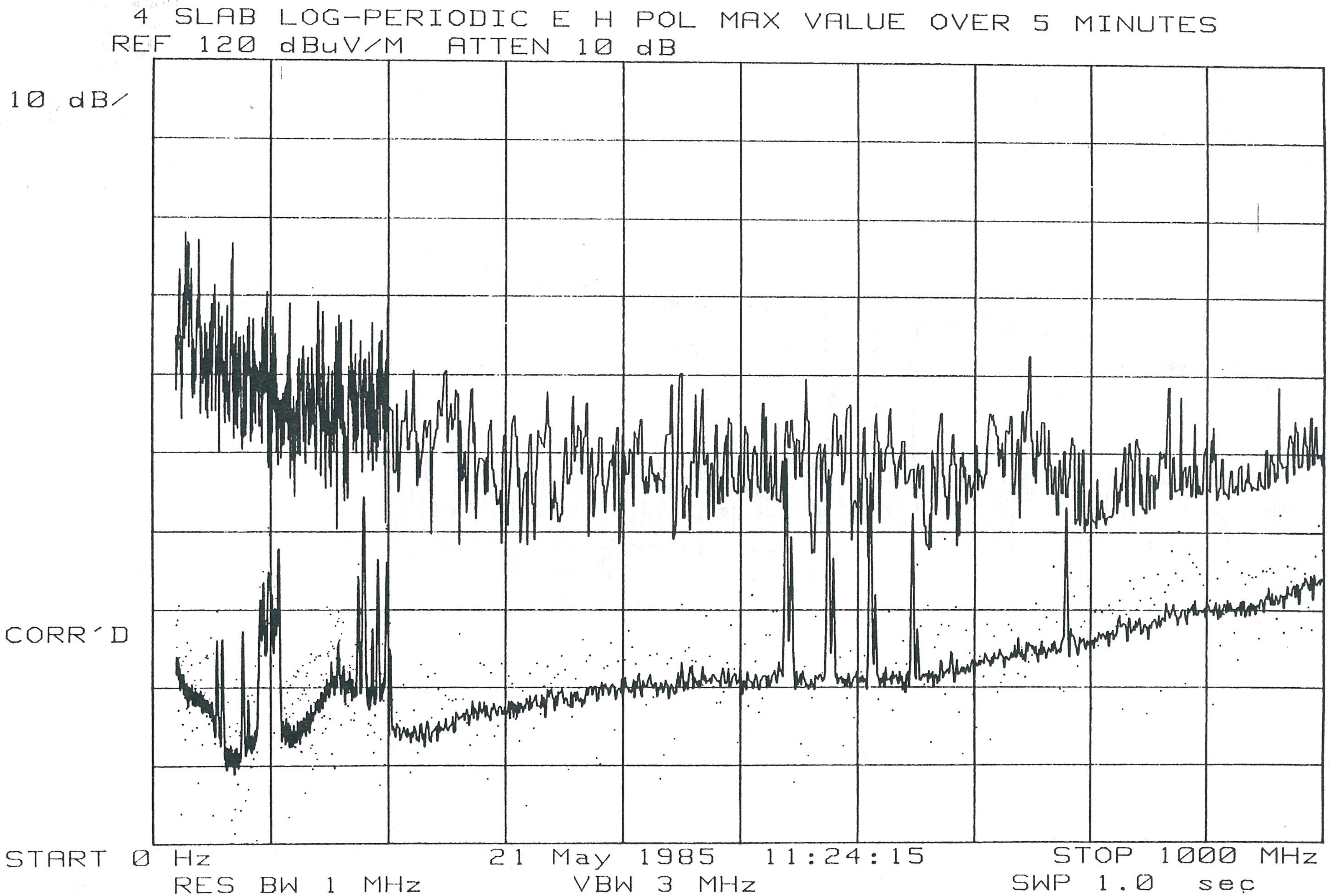

4 SLAB LOG-PERIODIC E V POL MAX VALUE OVER 5 MINUTES
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
21 May 1985 11:30:31
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec

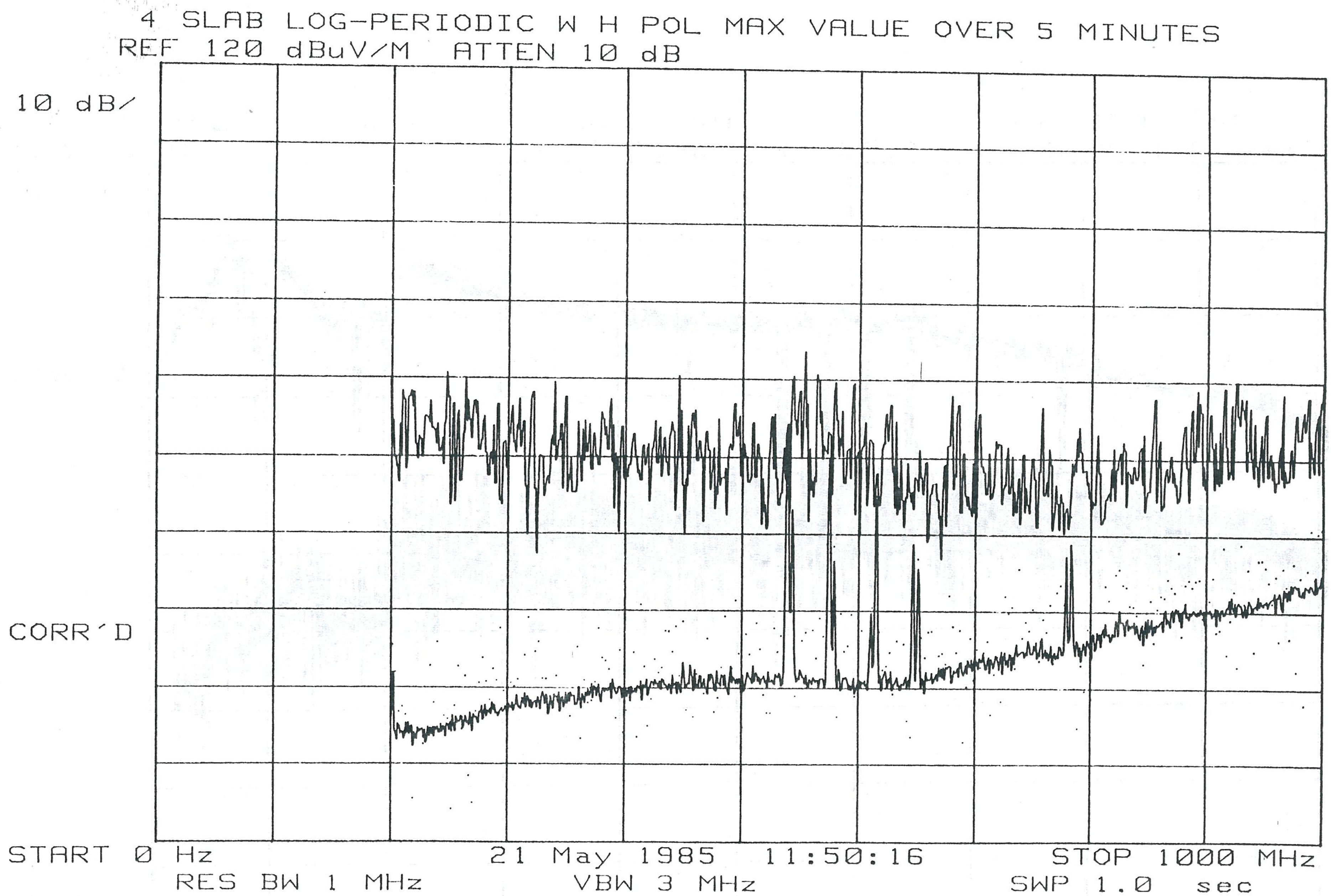

4 SLAB LOG-PERIODIC W V POL MAX VALUE OVER 5 MINUTES
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
21 May 1985 11:56:20
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec

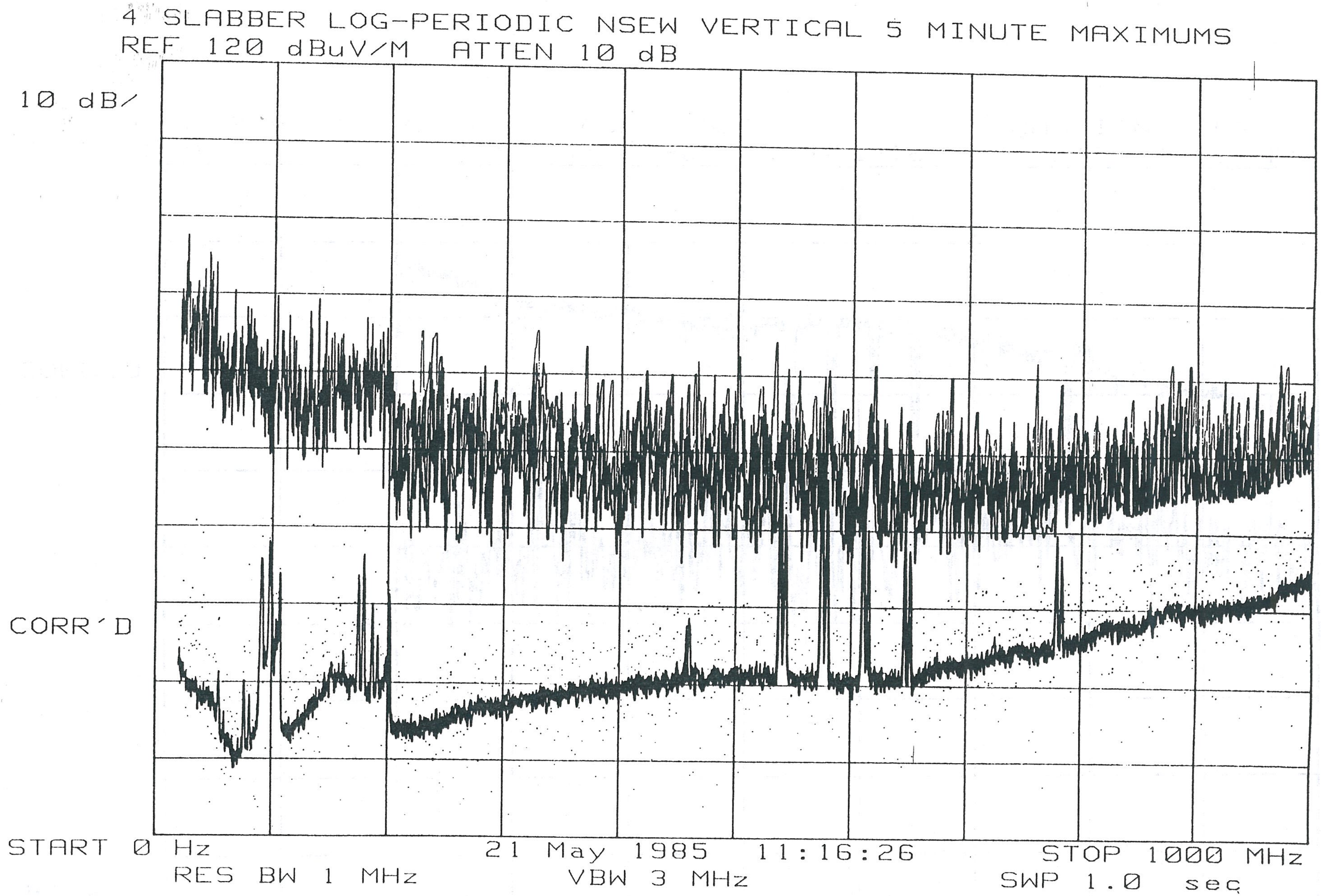

4 SLAB LOG-PERIODIC N H POL MAX VALUE OVER 5 MINUTES
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
21 May 1985 11:07:37
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec



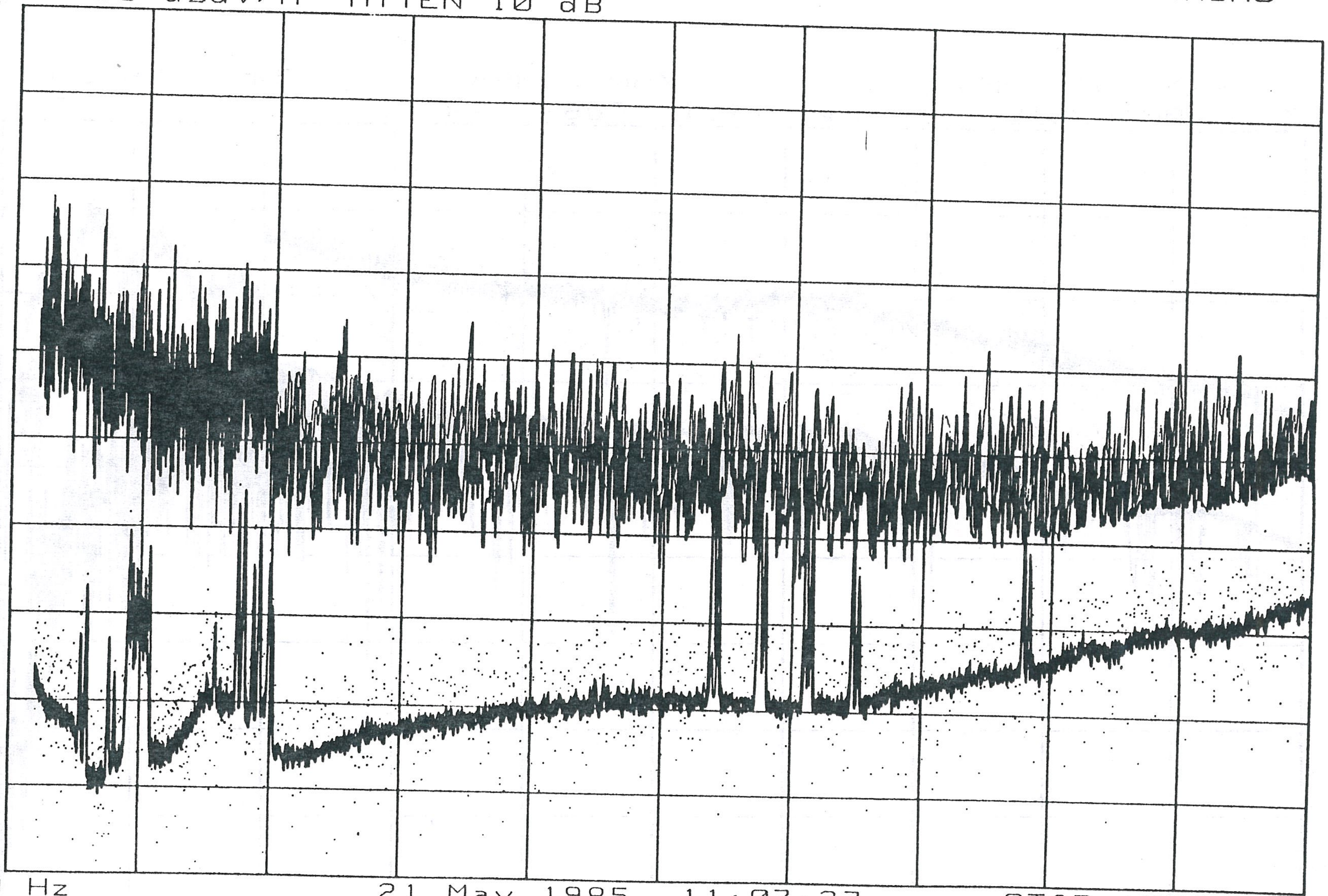
4 SLAB LOG-PERIODIC S H POL MAX VALUE OVER 5 MINUTES
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
21 May 1985 11:36:54
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec

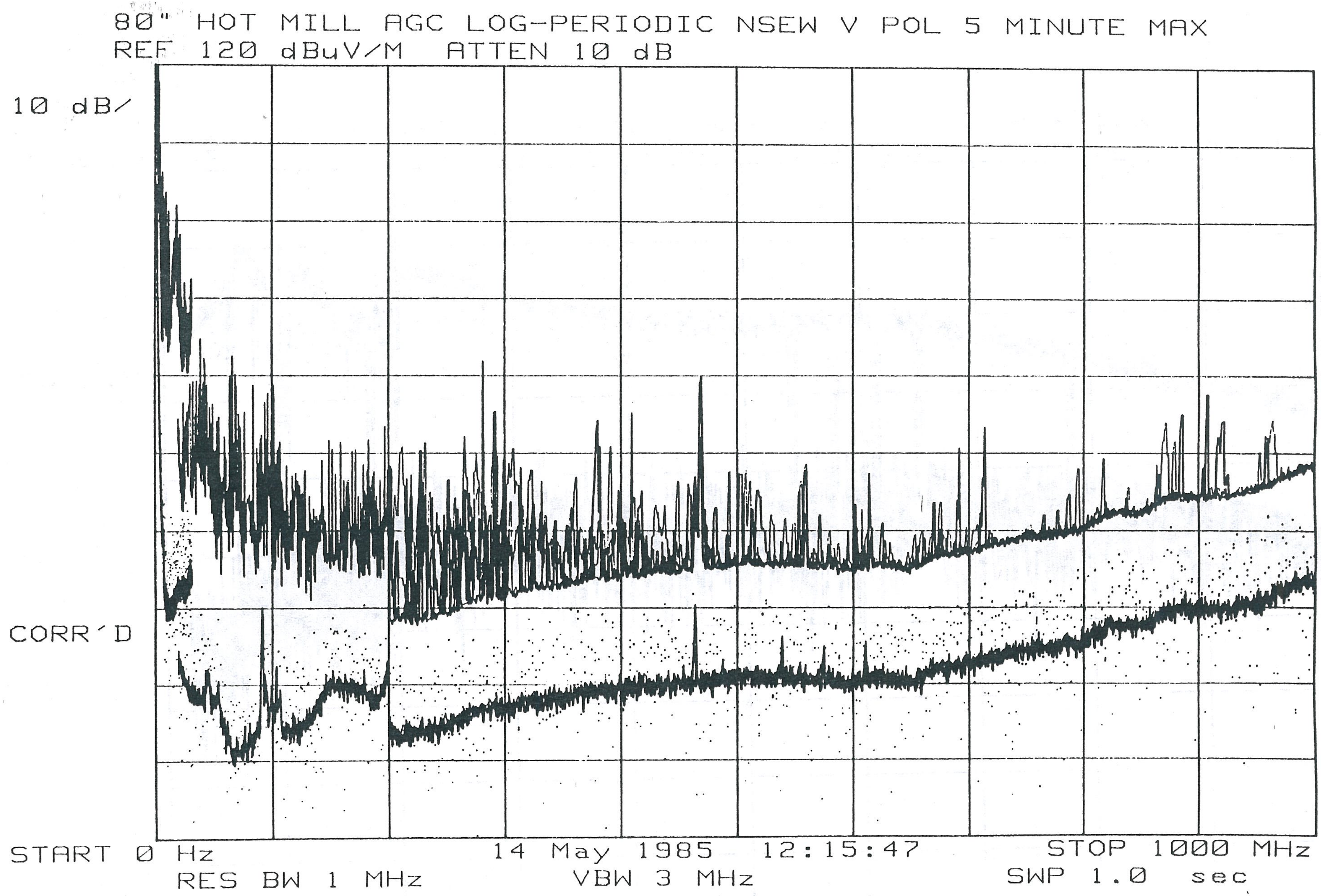

4 SLAB LOG-PERIODIC E H POL MAX VALUE OVER 5 MINUTES
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
21 May 1985 11:24:15
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec

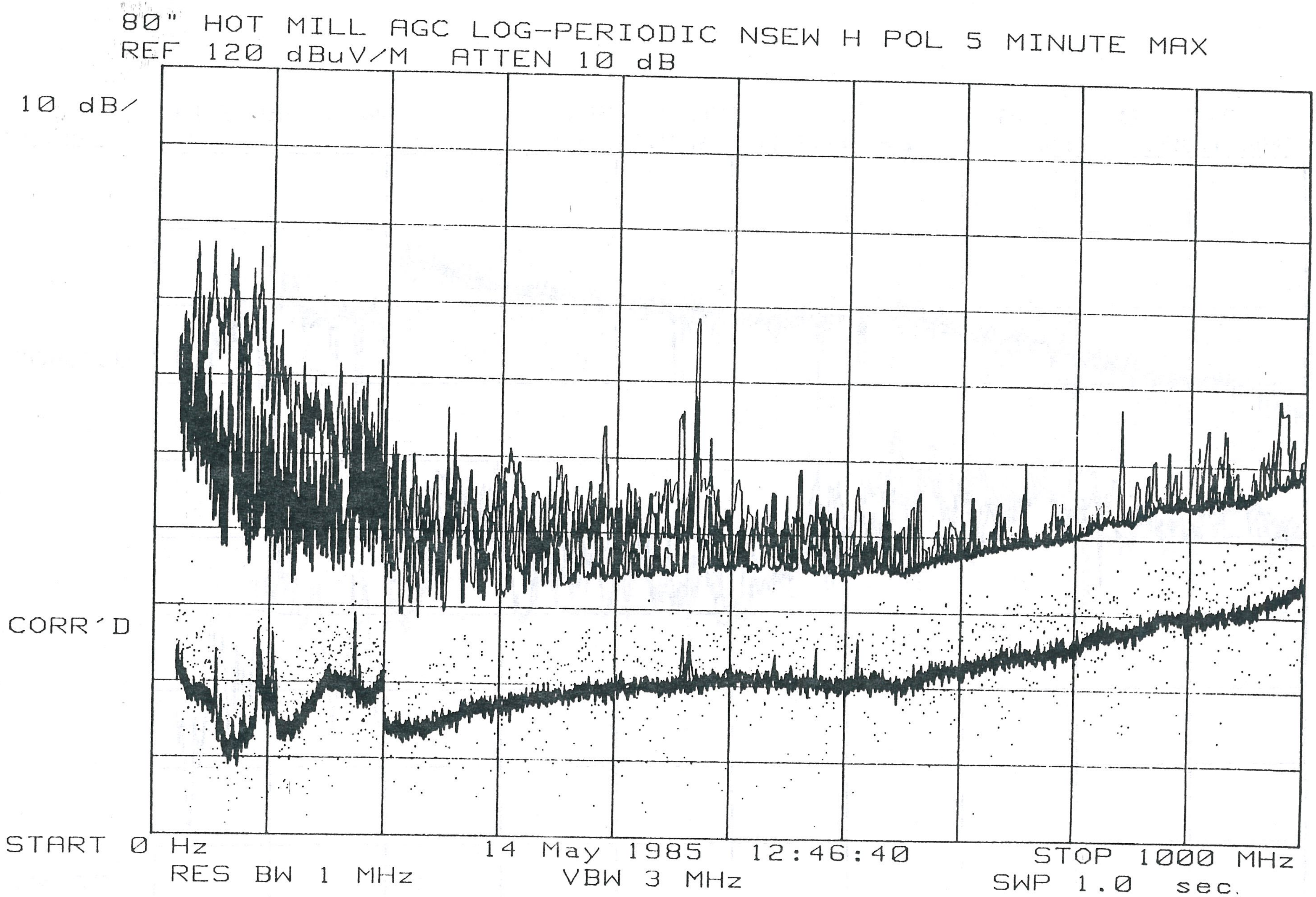

4 SLAB LOG-PERIODIC W H POL MAX VALUE OVER 5 MINUTES
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
21 May 1985 11:50:16
STOP 1000 MHz
RES BW 1 MHz
VBW 3 MHz
SWP 1.0 sec


4 SLABBER LOG-PERIODIC NSEW VERTICAL 5 MINUTE MAXIMUMS
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR´D
START 0 Hz
RES BW 1 MHz
21 May 1985 11:16:26
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec

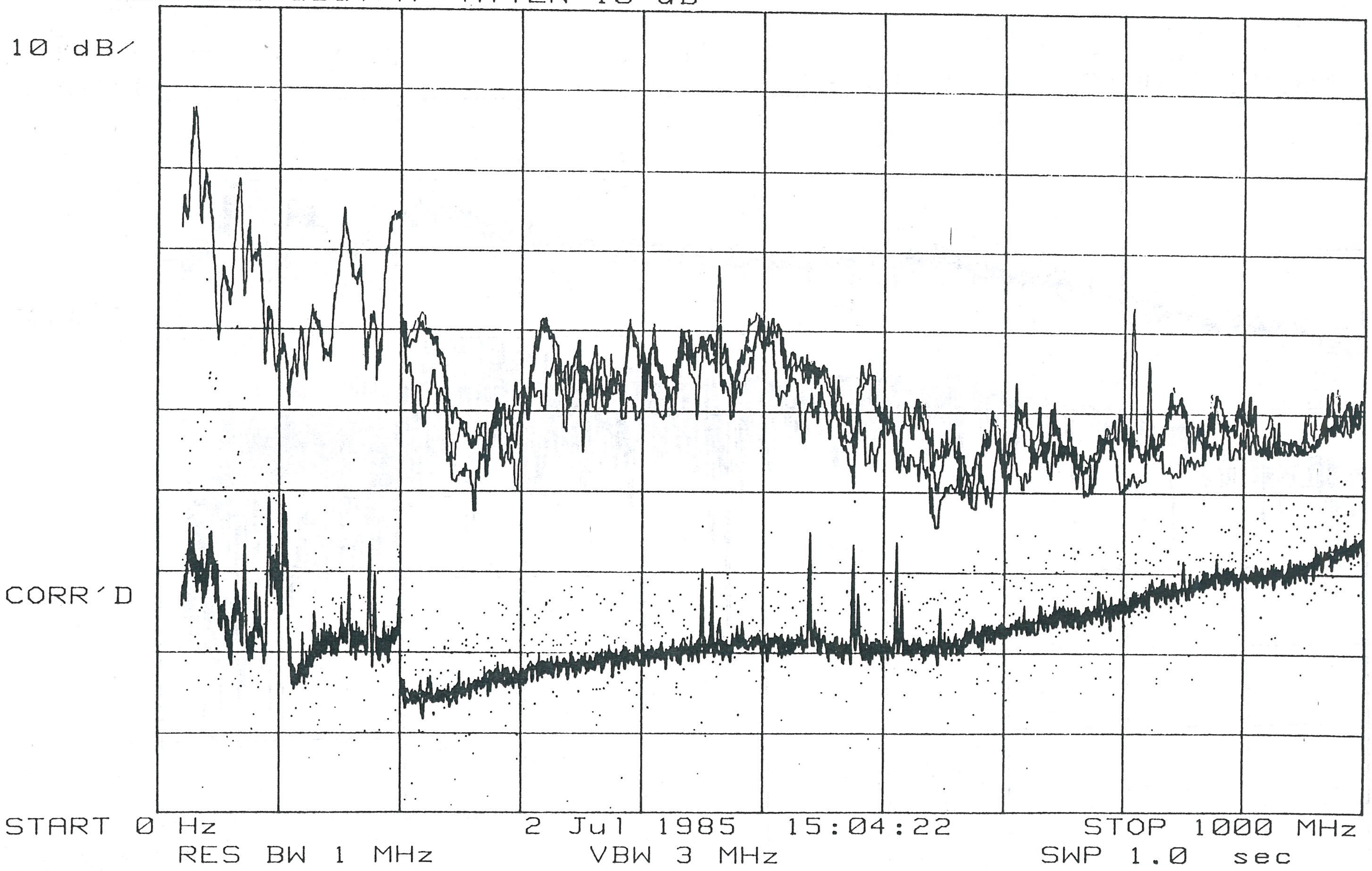
4 SLABBER LOG-PERIODIC NSEW HORIZONTAL 5 MINUTE MAXIMUMS
REF 120 dBuV/M ATTEN 10 dB

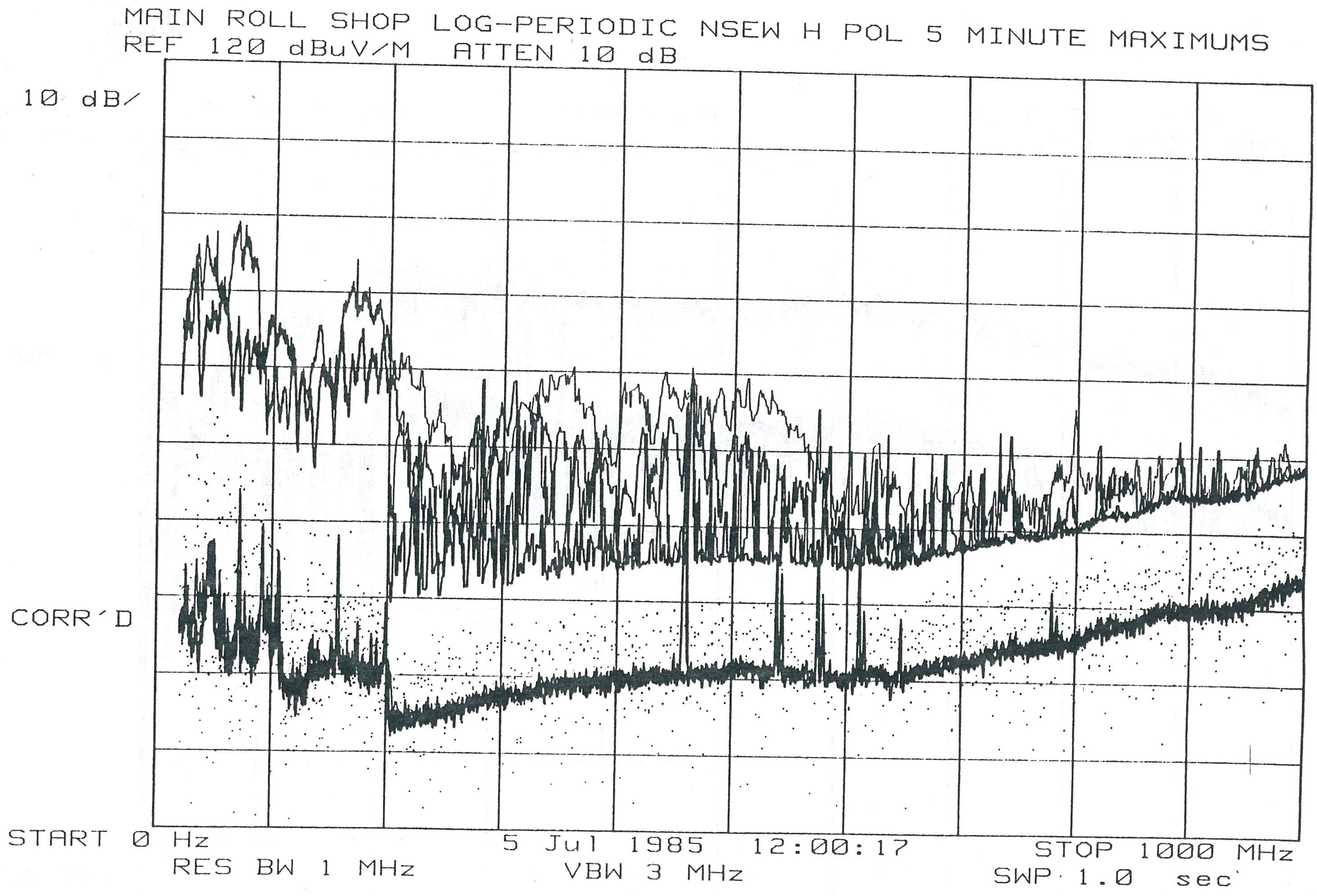



80" HOT MILL AGC LOG-PERIODIC NSEW V POL 5 MINUTE MAX
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
14 May 1985 12:15:47
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec

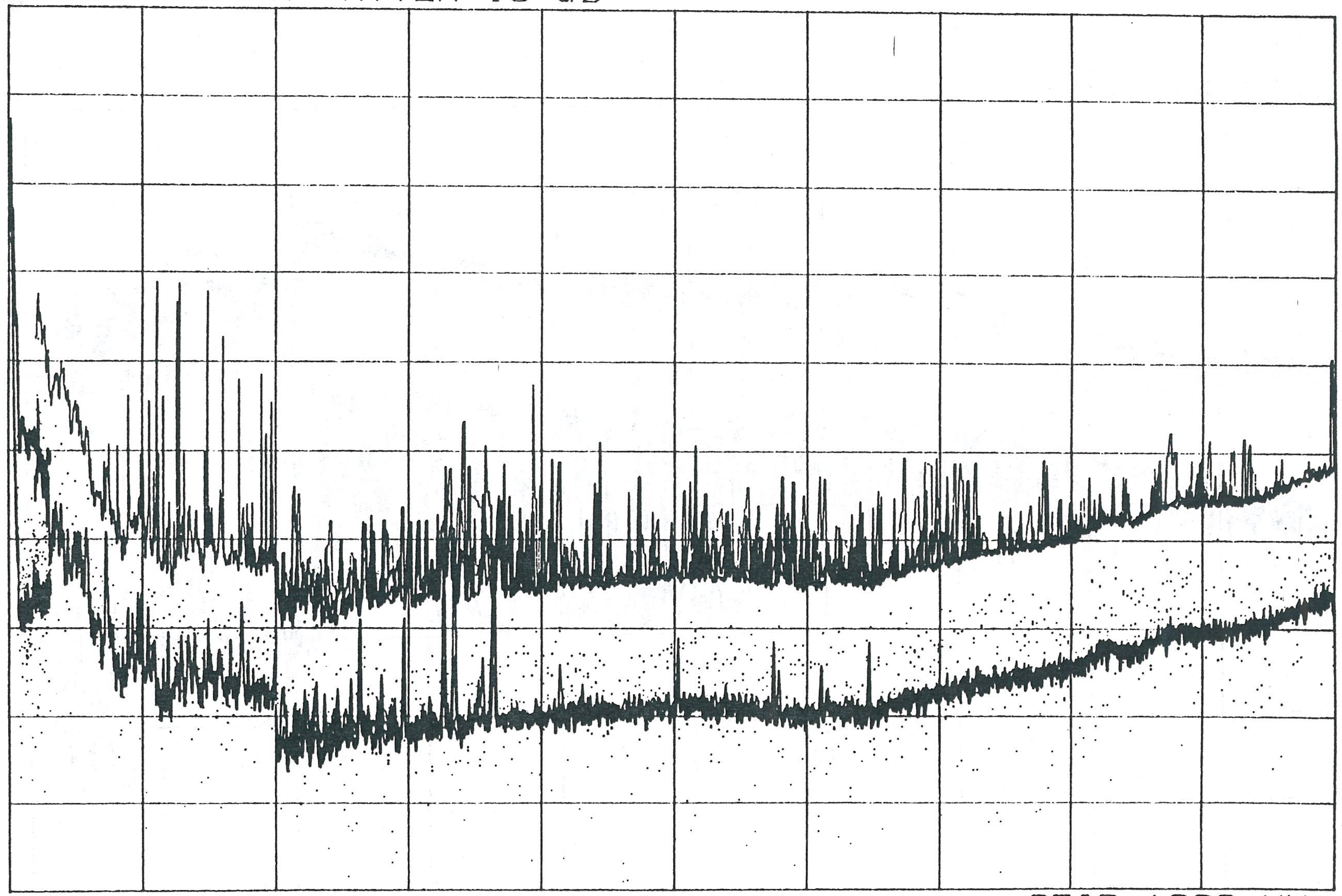

80" HOT MILL AGC LOG-PERIODIC NSEW H POL 5 MINUTE MAX
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
14 May 1985 12:46:40
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec.

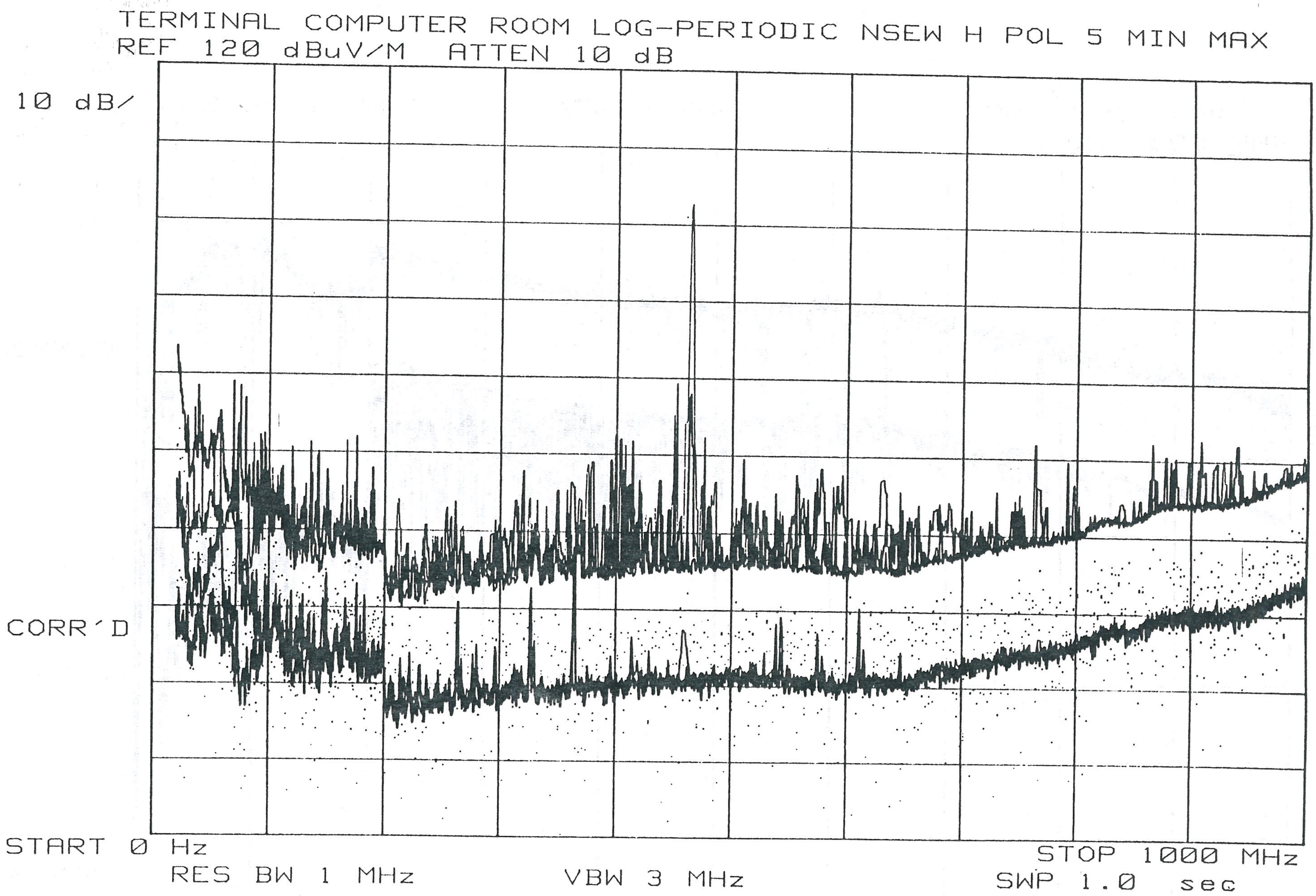
MAIN ROLL SHOP LOG-PERIODIC N EW V POL 5 MINUTE MAXIMUMS
REF 120 dBuV/M ATTEN 10 dB

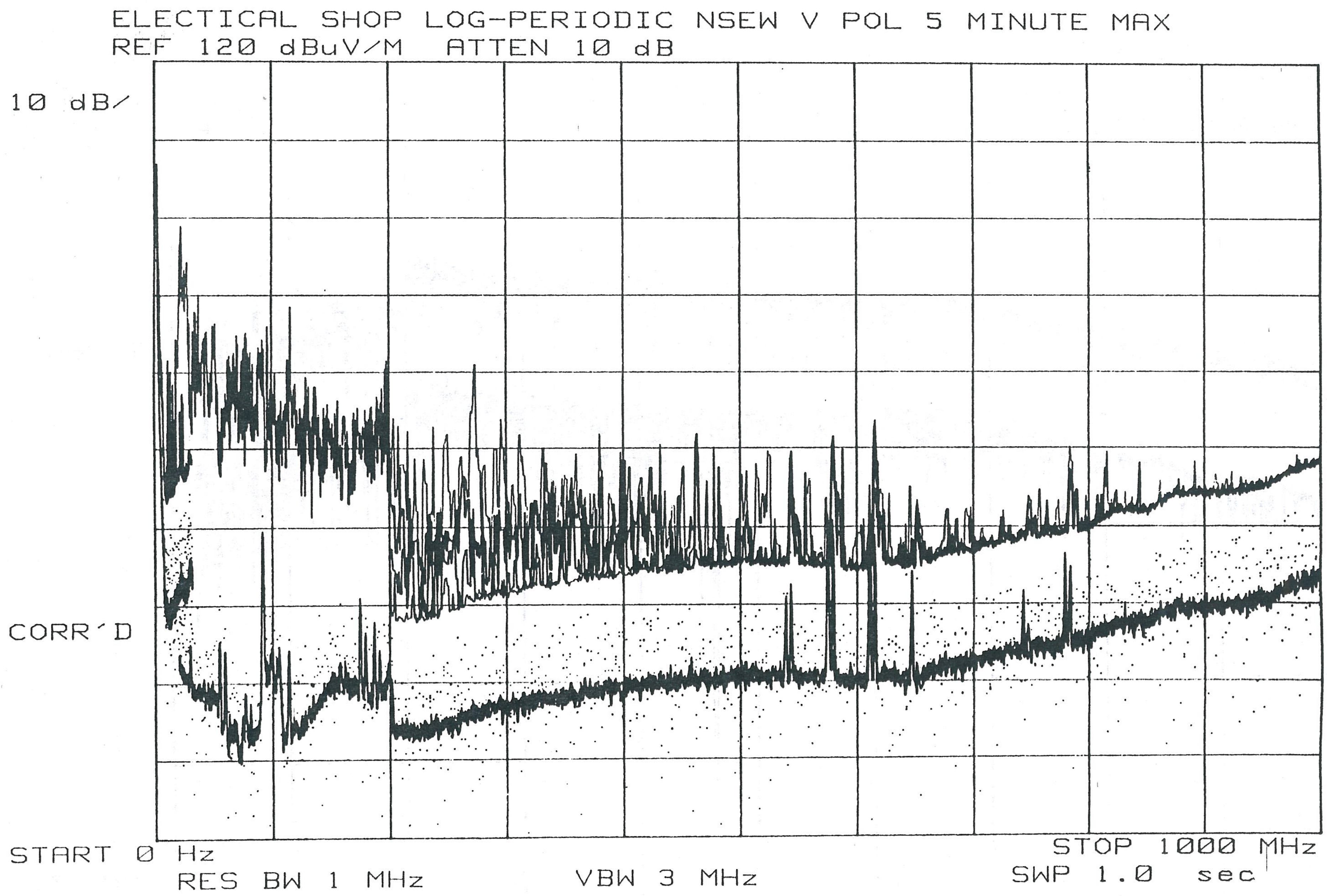


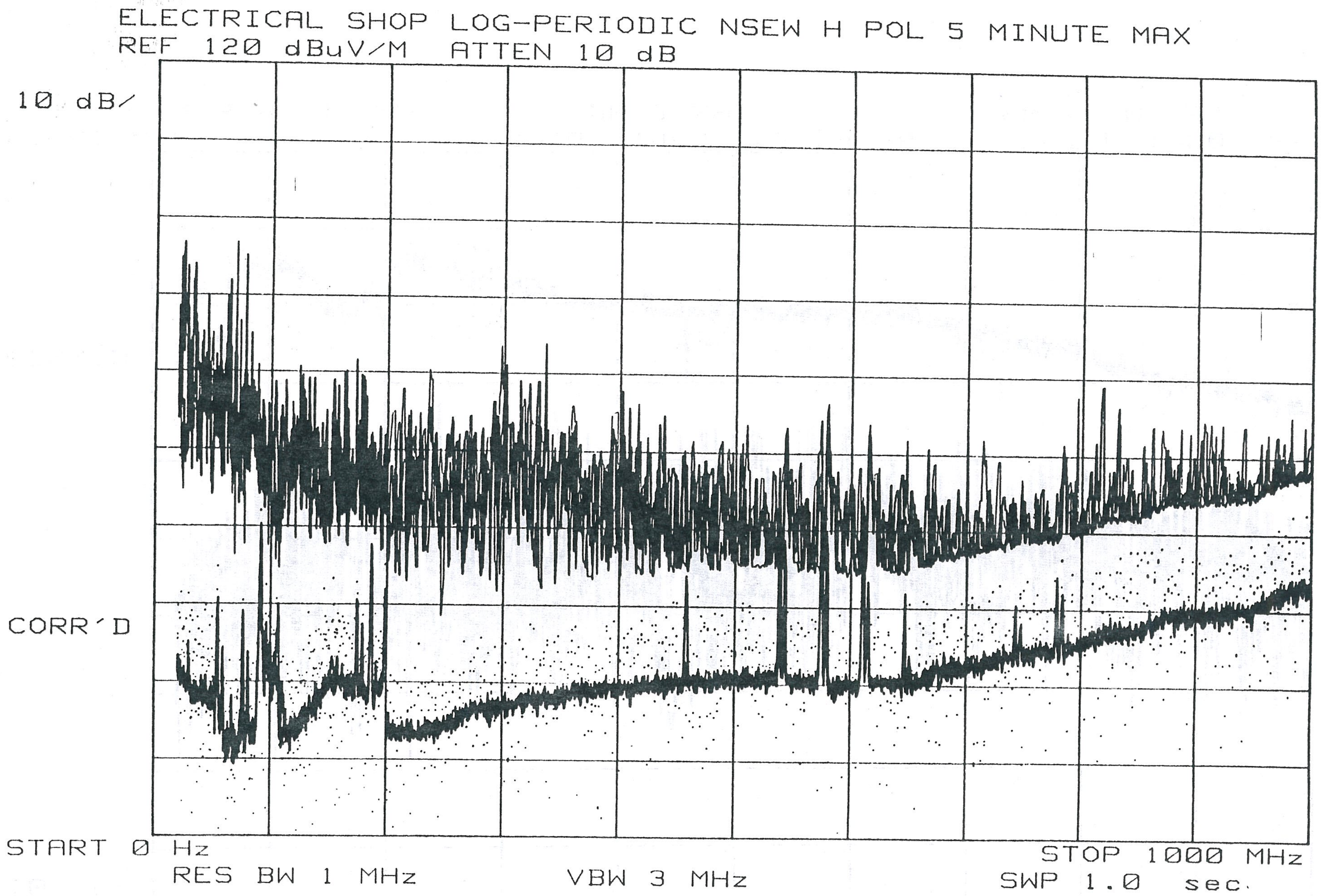

MAIN ROLL SHOP LOG-PERIODIC NSEW H POL 5 MINUTE MAXIMUMS
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
5 Jul 1985 12:00:17
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec

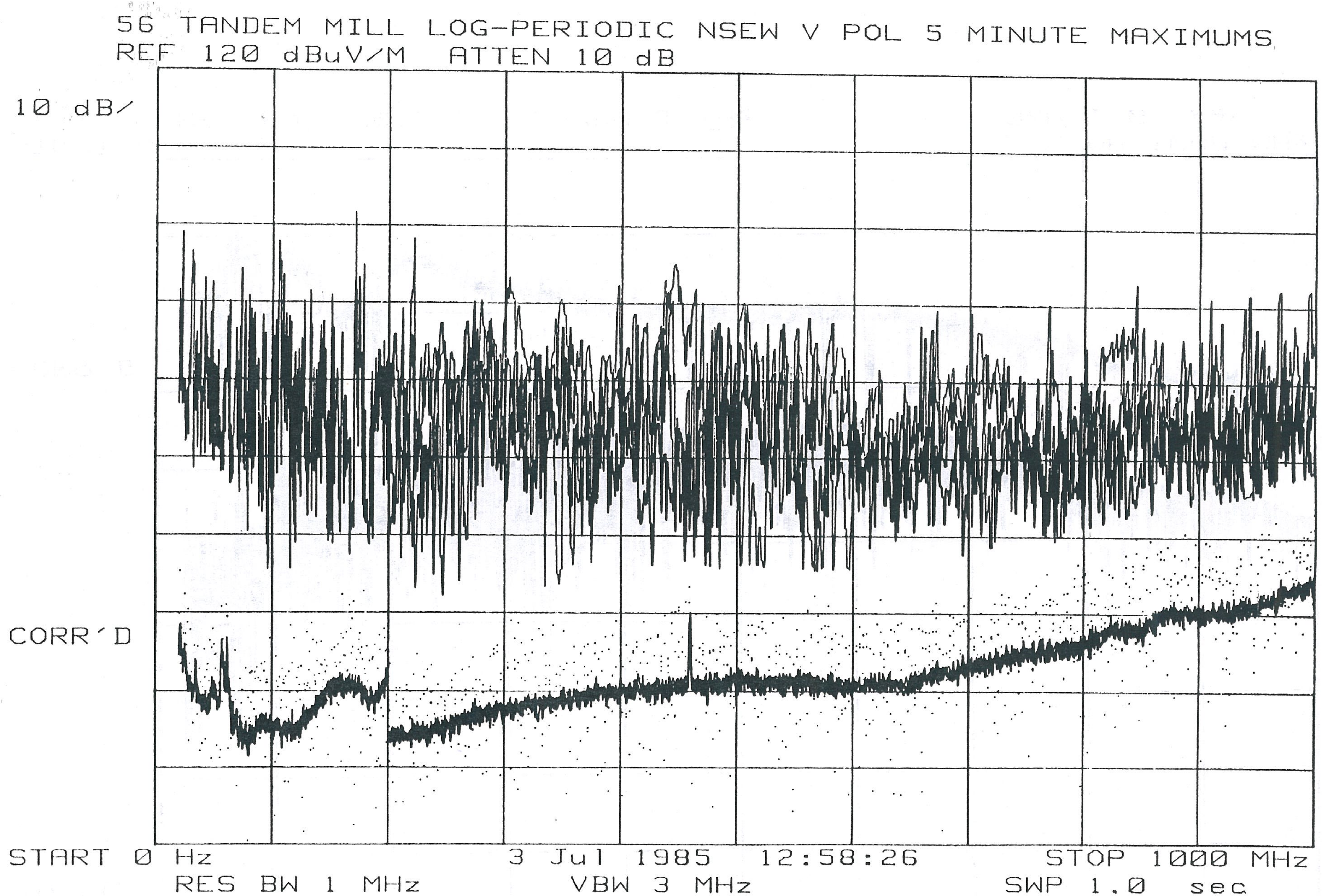
TERMINAL COMPUTER ROOM LOG-PERIODIC NSEW V POL 5 MIN MAX
REF 120 dBuV/M ATTEN 10 dB

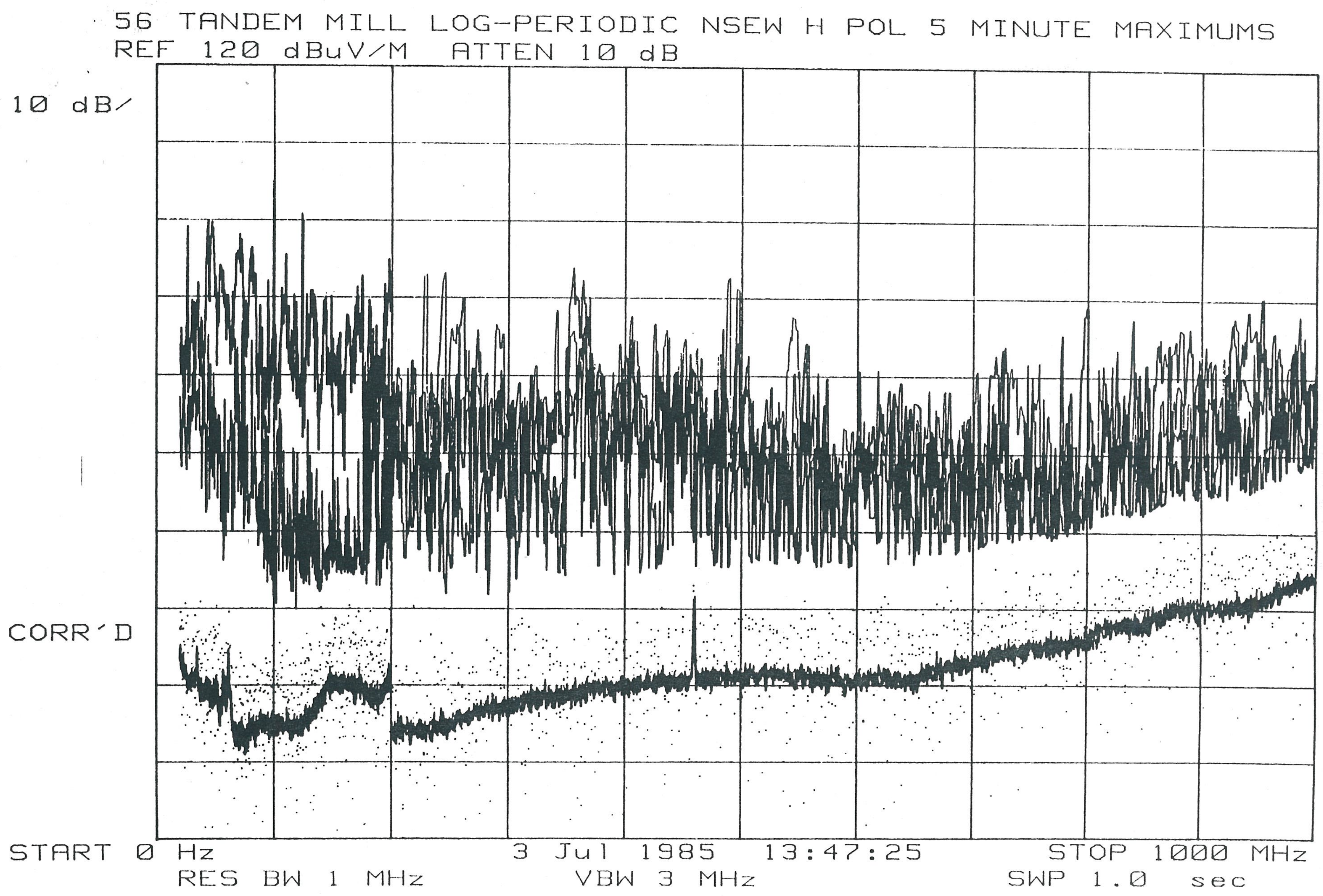



TERMINAL COMPUTER ROOM LOG-PERIODIC NSEW H POL 5 MIN MAX
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec


ELECTICAL SHOP LOG-PERIODIC NSEW V POL 5 MINUTE MAX
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec


ELECTRICAL SHOP LOG-PERIODIC NSEW H POL 5 MINUTE MAX
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
RES BW 1 MHz
VBW 3 MHz
STOP 1000 MHz
SWP 1.0 sec.


56 TANDEM MILL LOG-PERIODIC NSEW V POL 5 MINUTE MAXIMUMS
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
3 Jul 1985 12:58:26
STOP 1000 MHz
RES BW 1 MHz
VBW 3 MHz
SWP 1.0 sec


56 TANDEM MILL LOG-PERIODIC NSEW H POL 5 MINUTE MAXIMUMS
REF 120 dBuV/M ATTEN 10 dB
10 dB/
CORR'D
START 0 Hz
3 Jul 1985 13:47:25
STOP 1000 MHz
RES BW 1 MHz
VBW 3 MHz
SWP 1.0 sec