AD-A160 547 SEI (SHIPPING ENVIRONMENT INSTRUMENTATION) ELECTROMAGNETIC INTERFERENCE T..(U) ARMY MISSILE COMMAND REDSTONE ARSENAL AL TEST AND EVALUATION D.. 1/1

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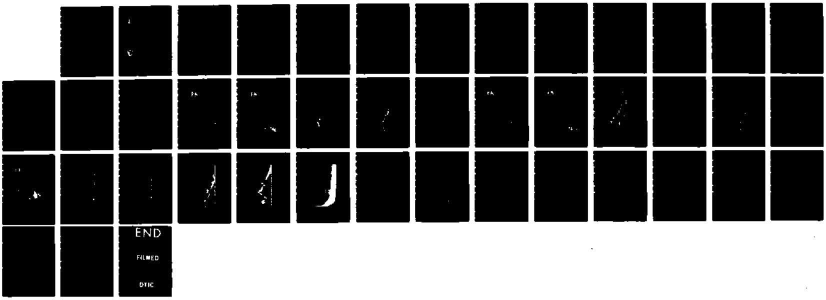

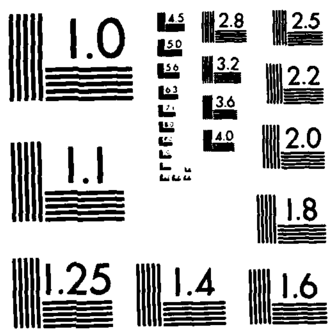

MICROCOPY RESOLUTION TEST CHART
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TECHNICAL REPORT RT-85-11

SEI ELECTROMAGNETIC INTERFERENCE TEST

Birtha L. Hooks
Robert A. Snead
Test and Evaluation Directorate
US Army Missile Laboratory

AUGUST 1984

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35898-5000

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Electromagnetic Interference
MIL-STD-461
Space Shuttle
Solid Rocket Boosters

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Teledyne Brown SEI Electronics Unit (Part of the space shuttle SRB shipping instrumentation) was tested per the requirements of MIL-STD-461B. Test results and recommendations are included.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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ILLUSTRATIONS

ILLUSTRATIONS (Concluded)

I. BACKGROUND

The SEI Electronics unit is part of the equipment required to monitor environmental conditions during shipment and handling of the Space Shuttle Solid Rocket Boosters (SRB's). The specific unit tested (serial no. 3) is designed to fly inside the cargo bay of a C-5 aircraft during the flight from United Space Booster's Kennedy Spacecraft Center operations to Vandenburg Air Force Base, CA. The unit consists of a data acquisition and recording system containing a tape recorder to record the various data channels, a multiplex unit to select the correct channel signal, an uninterruptable power source (UPS), and other components, and cabling. The entire system is self supporting and will operate in the aircraft cargo bay using the 400 Hz power available in the cargo bay. System integration tasks are being performed by Teledyne Brown Engineering in Huntsville, AL.

II. TEST PROCEDURES

A. General Information

The tests were performed to the requirements of MIL-STD-461B using the test procedures of MIL-STD-462. The test facilities were those of the Electromagnetic and Nuclear Effects Group of the US Army Missile Command, Test and Evaluation Directorate at Redstone Arsenal, AL.

The tests were conducted in a 13 ft by 10 ft by 8 ft shielded enclosure with walls, roof and floor consisting of two layers of copper mesh. In the center of the enclosure there is a double layer copper mesh partition separating the test area from the instrumentation room.

Commercial (60 cycle) power is fed to the recepticles in both areas through a set of Filtron FSR709E commercial power line filters in both legs and the neutral of the 220 volt single phase service to the shielded enclosure.

Power (400 Hz) was fed directly to the test item from the Generator 30-029 60 to 400 Hz inverter through a set of Acme S-1035-1 power line filters mounted outside the instrumentation room. The 400 Hz line run through the instrumentation area was shielded with metal foil and foil tape to prevent reradiation of digital noise from the measurement area into the test area. The foil was grounded to the wall of the enclosure at both ends.

Proper grounding of the SEI system in the shielded enclosure was difficult. The isolated nature of the interior screens combined with the different power supply paths produced a ground loop which made isolation of the 400 Hz supply and 60 cycle power necessary. Therefore, the EUT was not grounded to the ground plane when the 400 Hz power was used. The EUT was grounded to the 400 Hz return line at the plug on the inside of the instrumentation area. Also, the 10 microfarad feed-through capacitors were eliminated since the EUT was being powered by an entirely separate supply.

B. Conducted Emissions

The EUT was placed in the shielded enclosure on a wooden shipping pallet. A Solar 6741-1 Current probe was placed around each power lead, in turn, and the emissions present on each lead were measured. The measurement data was processed and plotted on the appropriate graph using custom software developed by the US Army Missile Command. Also, there was a ground plane under the shipping pallet. Measured resistance to the chamber walls from the ground plane was 0.2 milliohms. For all data recorded after run 17, the EUT was connected to the ground plane by a piece of 3/4 inch ground strap approximately 18 inches long and power was supplied by the commercial power system of the test facility. Emissions were recorded using a Hewlett-Packard 8566 Spectrum Analyzer. Data analysis was performed on a Hewlett-Packard 9825 calculator.

C. Radiated Emissions

The EUT was placed in the shielded enclosure as in paragraph A and power was applied. The radiated emissions were recorded over the applicable frequncy band by placing the appropriate antenna for each band one meter from the cable connector panel on the left side of the EUT. As before, the emissions were recorded using the Hewlett-Packard 8566 Spectrum Analyzer.

III. TEST RESULTS

A. General Comments

The test results for radiated and conducted emissions will be presented separately. The reader may best understand the test results if the numbered figures containing the appropriate data are referenced as each is discussed in the text of this report.

B. Conducted Emissions

Figures 1 and 2 show the conducted emissions data recorded on the 120 volt 400 cycle power lines when the SEI unit was active and recording data. Broadband emissions do not meet the criteria at most frequencies below 10 MHz as shown in Figure 1. The recorded levels indicate failure margins from 1 to nearly 20 dB. Maximum deviation from the specification occurred at 100 kHz (15dB), 1 MHz (11 dB), and in the 3 to 4 MHz (33dB) bands. Broadband emissions of this type are typically due to switching power supplies or regulators.

Figure 2 is a plot of the narrowband data appearing on the 120 volt 400 Hz power line. All recorded deviations above the criteria in frequency bands below 10 MHz are manifestations of the broadband noise recorded in Figure 1 except for emissions recorded at 9.57 MHz, 9.05 MHz, and 7.83 MHz. These emissions are confined to those frequencies, and even though they have some pulse characteristics, the emissions bandwidth is very narrow.

Figure 3 is a plot of the raw emissions data appearing on the power line. The two traces represent the data obtained using the spectrum analyzer peak hold mode (upper), and the video averaging mode (lower). The amount of noise reduction due to averaging is an indication of the duty cycle. The reduction in this case amounted to about 40 dB which corresponds to a duty cycle of 0.0001.

Figure 4 is a plot of the conducted emissions appearing on the 120 volt 400 Hz line in the 1 to 15 MHz band. The major emissions recorded in this band consisted of narrowband peaks at 7.83 MHz, 9.05 MHz, and 9.57 MHz. The data for this plot was taken using the spectrum analyzer peak hold mode.

Figure 5 is a plot of conducted emissions over the same band as Figure 4, but using the analyzer signal averaging mode. It is interesting to note that the narrowband emissions drop drastically, even though their spectrum is very narrow. This is an indication of pulse type noise.

Figures 6 and 7 are plots of the conducted emissions recorded on the power return line. Figure 6 shows the broadband emissions. Note that deviations from the specification as large as 20 dB are present at some points in the under 1 MHz band. Also, broadband emissions were present in the 1 to 10 MHz band, peaking at around 2.5 MHz. As would be expected, this noise is again typcial of a switching power supply or regulator.

Figure 7 shows the narrowband noise recorded on the power return lead. As on the power leads, the data shown below 5 MHz is a manifestation of the high broadband levels present. The emissions shown in the 5 to 10 MHz region are again noise having pulse characteristics but narrow bandwidth.

Figure 8 is a plot of the noise envelope taken using the analyzer peak hold mode versus the noise recorded using signal averaging techniques. The bandwidth of interest was 15 kHz to 1 MHz and the conducted emissions on the power return were measured. The large difference (typically 10 to 20 dB) is indicative of the pulse type spectral content of the noise.

Figure 9 is a recording of the average level of the conducted emissions over the 1 to 15 MHz band. Figure 10 is a record of the envelope of peak emissions recorded over the same band. As before, the large difference in the levels recorded is an indication of the pulse type characteristics of the noise. Even narrowband noise shows a drastic reduction using signal averaging. This again is characteristic of noise generated by switching power supplies or regulators.

Figures 11 through 14 detail results of radiated emissions tests which will be discussed in later sections of this report.

Figures 15 and 16 are plots of the conducted emissions in the 15 kHz to 10 MHz band with the tape recorder on and recording data with the power being supplied by the 400 Hz supply (upper trace) and the battery backup (lower trace). The only difference in the two plots is that the spectrum analyzer resolution bandwidth was changed.

Figure 17 is a plot of the conducted emissions recorded on the power line over the 15 kHz to 10 MHz band with the tape unit in record mode and the spectrum analyzer in clear-write mode. The spectral components of the broadband noise pulses are clearly visible, and would form the previously recorded envelope if the analyzer was switched to peak hold mode. Note that the two large spikes to the right of the seventh horizontal scale division exhibit narrowband characteristics.

Figures 18 through 22 detail radiated emissions test results which will be presented in later sections of this report.

Figure 23 is a plot of the narrowband conducted emissions on the power lead when the tape recorder was replaced with a TEMPEST certified tape recorder. Emissions levels dropped drastically. The only out of tolerance conditions appearing in the narrowband conducted emissions data were those occurring at four frequencies above 5 MHz.

Figure 24 is a plot of the broadband data using the same procedures used to record Figure 23. Again, the use of the TEMPEST certified recorder reduced the emissions levels. Maximum deviation of the broadband data from the specification limit again occurred at 1 MHz. However, this time the out of tolerance condition was only about 5 dB. Therefore the out of tolerance condition would be marginal, assuming the other equipment on the power bus met the susceptability requirements of MIL-STD-461.

The ambient data obtained can be seen in Figures 25 and 26.

C. Radiated Emissions

Figures 11 and 12 contain the results of the radiated emissions measurements taken one meter from the cable termination panel on the left hand side of the unit per the requirements of MIL-STD-461B. As shown on Figure 11, broadband emissions were out of tolerance by as much as 50 dB in the frequency band below 2 MHz. The narrowband radiated emissions were out of tolerance by as much as 40 dB in the 20 to 200 MHz band. Out of tolerance measurements recorded on the narrowband plot below 5 MHz are manifestations of the broadband emissions present, and should not be considered failures from a narrowband standpoint.

Figure 13 is a plot of the raw data in the 20 to 200 MHz band. The numerous spectral components were apparently produced by the tape recorder since they decreased significantly when the tape was switched from record mode to halt. In this plot the 400 Hz supply was used.

Figure 14 is a plot taken in the same manner as Figure 13, except the 400 Hz power was disabled and the power to the unit was supplied by the battery backup. The insignificant increase in emissions indicates that the emissions are radiating predominently from the EUT, and not from the power cables.

Figures 19 through 22 are plots of the radiated emissions measured in the 20 to 200 MHz band when the EUT is operating off the 60 cycle power and grounded to the ground plane. Figure 19 is a plot of the emissions measured when the EUT is powered through the UPS.

Figure 20 is a plot of the emissions measured when the EUT is powered directly using the UPS bypass. Again, the insignificant change in emissions indicates that there is little contribution to the measured emissions from the power lines.

Figure 21 is measurement of the radiated emissions recorded in the 20 to 200 MHz band when the SEI system contains a TEMPEST qualified recorder and is running off 60 cycle power. Note the large decrease in emissions, indicating that the recorder is indeed a source of many emissions.

Figure 22 is a plot of the same data with the SEI enclosure doors open. No significant increase in emissions was recorded.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The conducted and radiated emissions recorded in the measurments taken during this test were predominently produced by the recorder. Replacement or modification of this recorder could significantly decrease both radiated and conducted emissions.

The narrowband radiated emissions in the 5 to 10 MHz band are not coming from the recorder. The multiplexer and UPS should be investigated to determine if they are the source of these emissions.

Grounding or isolating the EUT from the ground plane appears to have little effect on the noise.

B. Recommendations

Use the TEMPEST qualified tape recorder in the final version of the SEI for improved emissions control.

Investigate the UPS and multiplexer to determine the source of the emissions recorded in the 5 to 10 MHz band. Particular attention should be paid to the electrical continuity of the equipment cases and adequate filtering and routing of external power leads.

Internal cable routing should be modified in order to separate digital signal leads as much as possible from power leads between the UPS and system power supply.

EQUIPMENT LIST

Description	Model No.	Manufacturer	Cal/Service
Spectrum Analyzer	8566B	Hewlett-Packard	
Calculator	9825T	Hewlett-Packard	11/83
Plotter	9872A	Hewlett-Packard	CNR
Antenna	3301	Emco	CNR
Antenna	3104	Emco	CNR
Antenna	3108	Emco	CNR
Antenna	3106	Emco	CNR
Current Probe	6741-1	Solar	CNR
10 uuf Feedthru	6512-106R	Solar	CNR
60 to 400 Hz Inverter	30-029	Georator	CNR
Bonding Meter	670A	Shalltronix	11/83

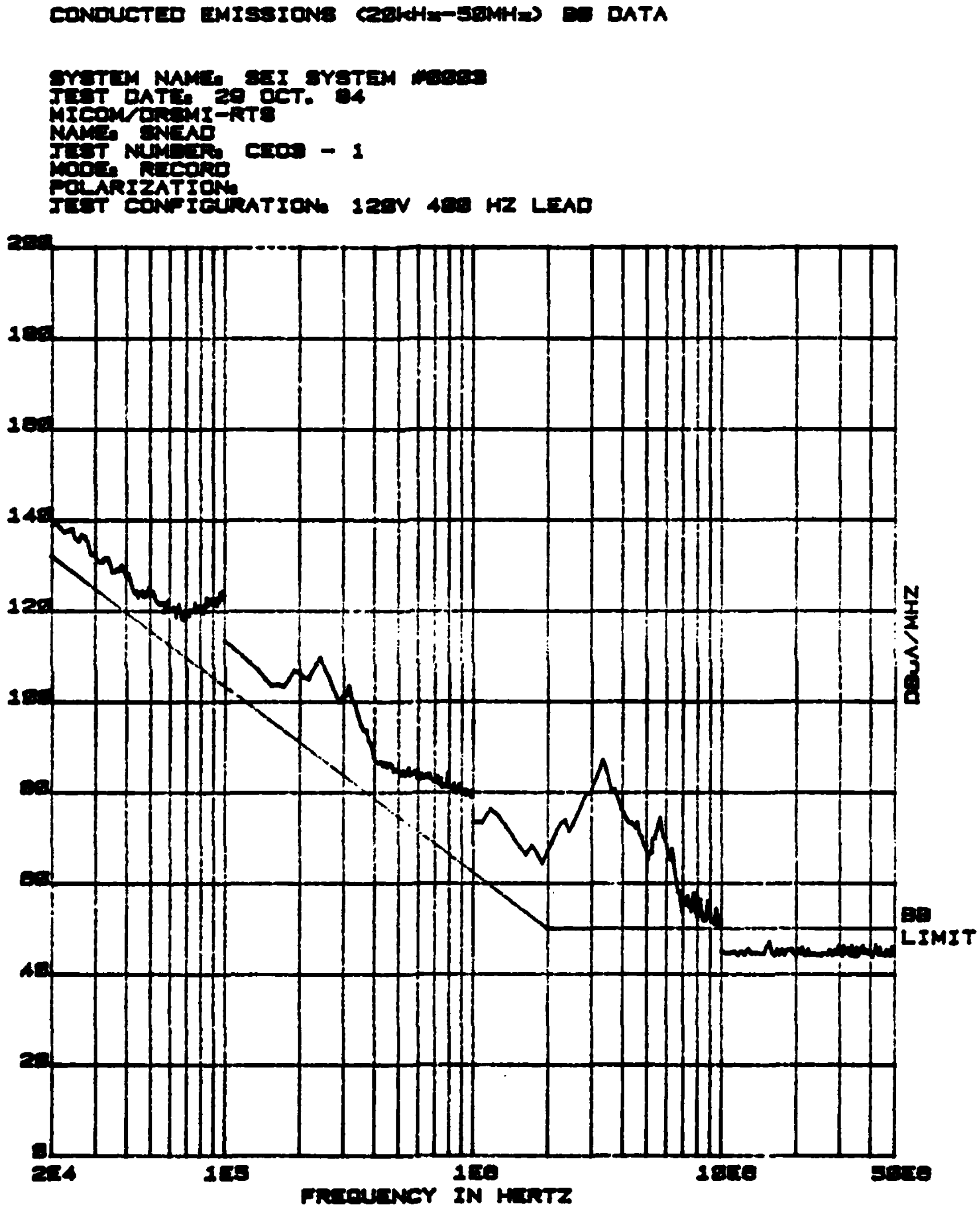

Figure 1. <u>Broadband conducted emissions measured on the 400 Hz power line using procedure CE03</u>.

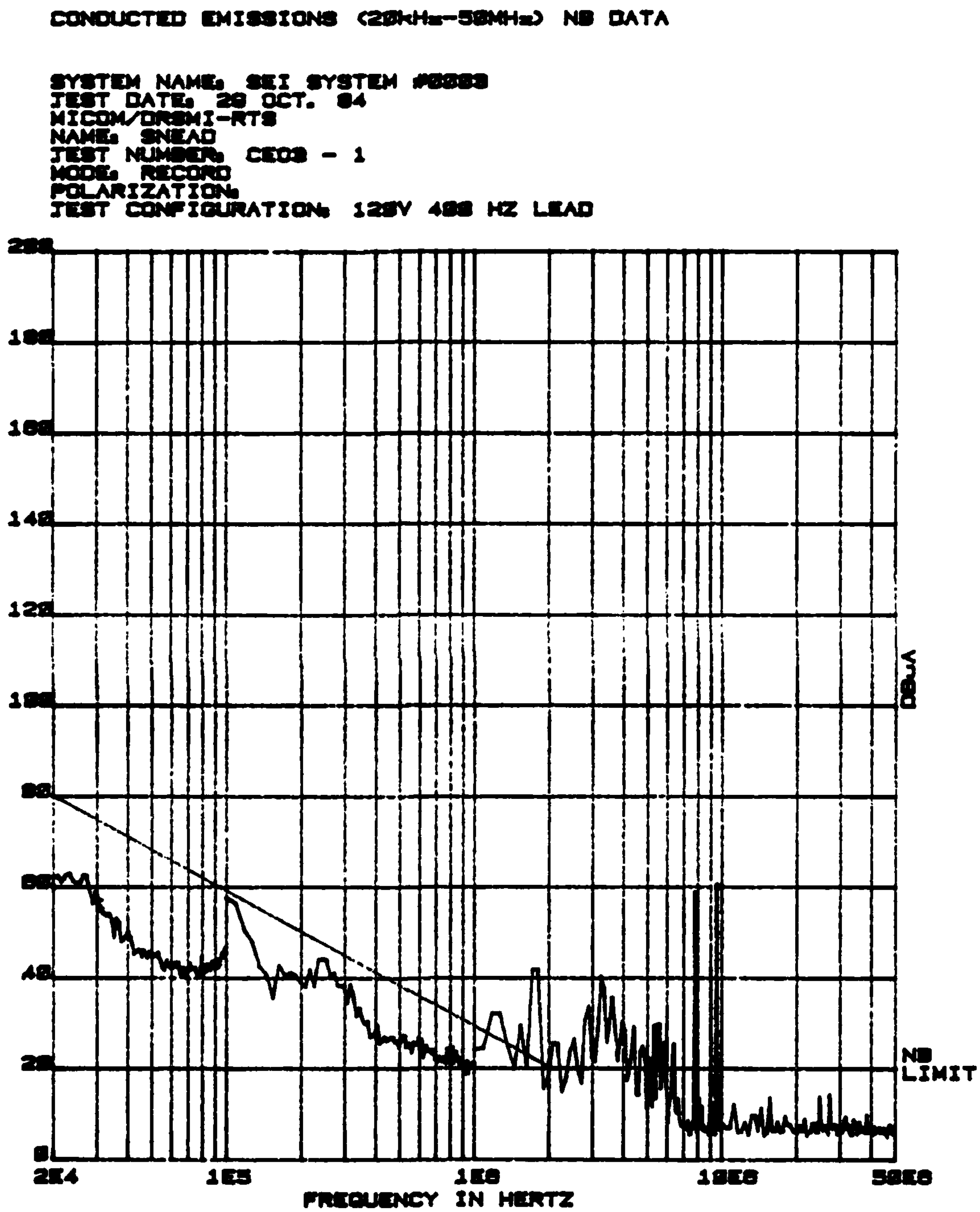

Figure 2. Narrowband conducted emissions measured on the 400 Hz power line using procedure CE03.

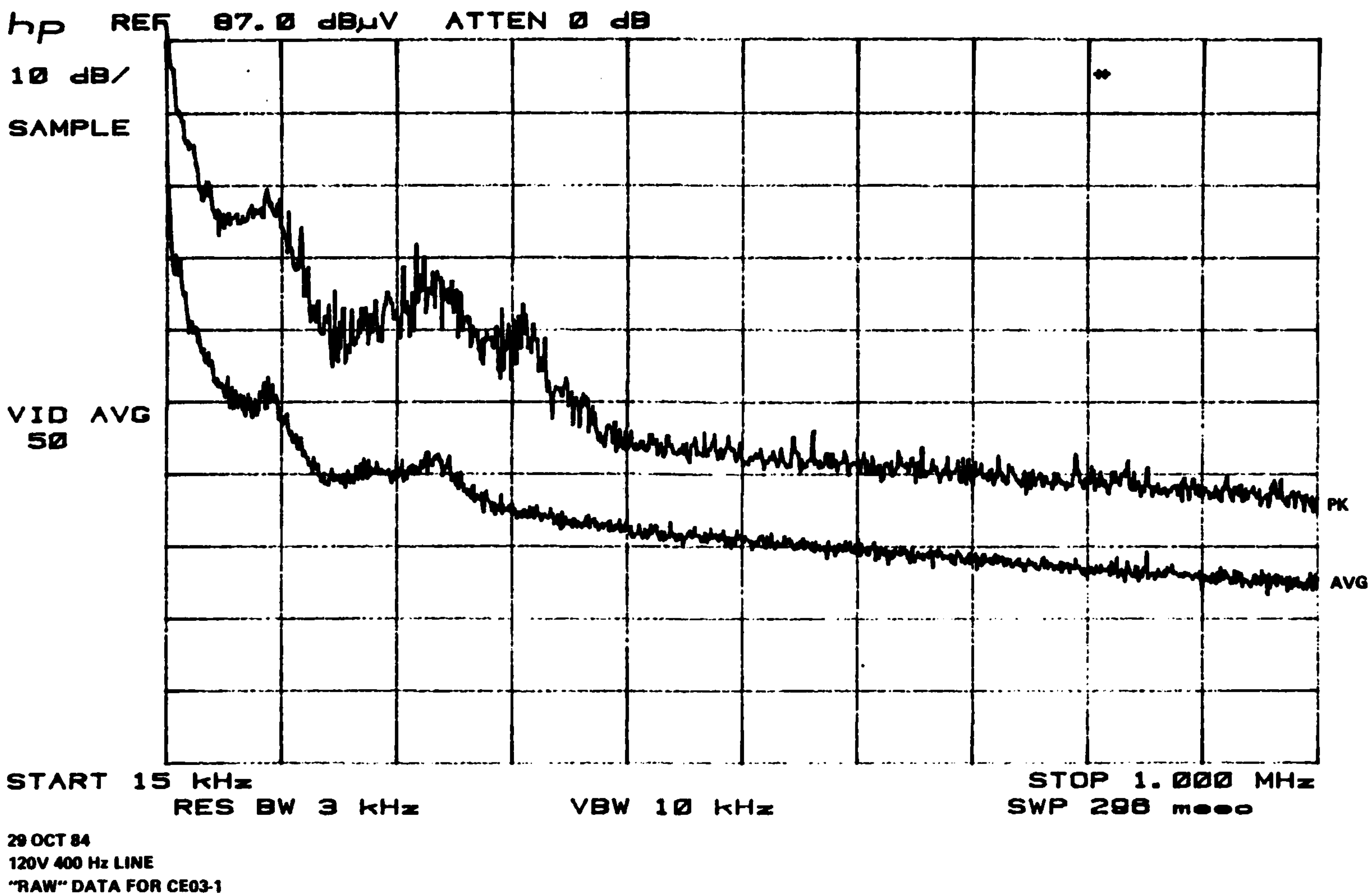

Figure 3. Raw data for conducted emissions measured on the 400 Hz power line (15 kHz to MHz band).

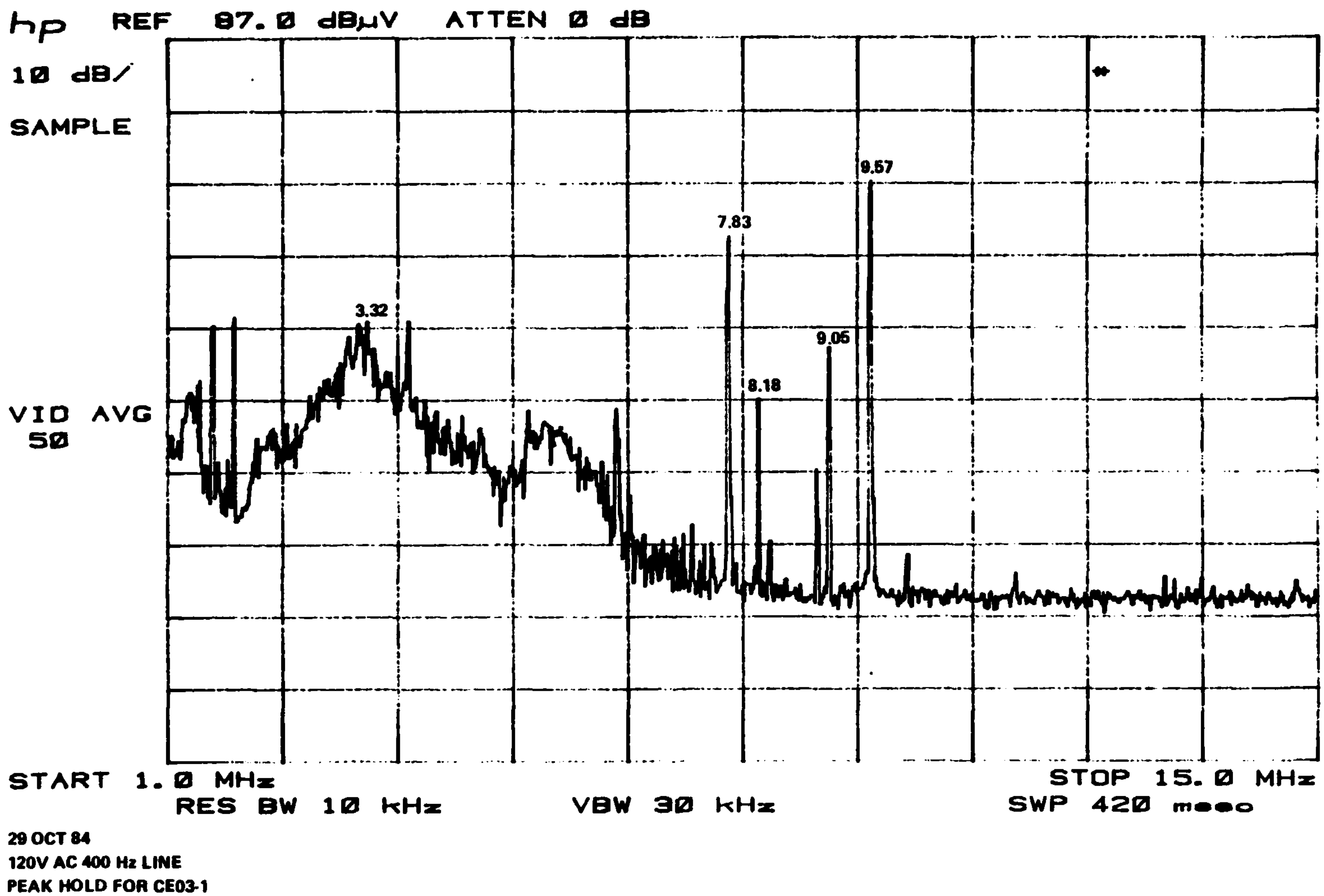

Figure 4. Raw data for conducted emissions (1 to 15 MHz band) measured on the 400 Hz power line using peak hold mode.

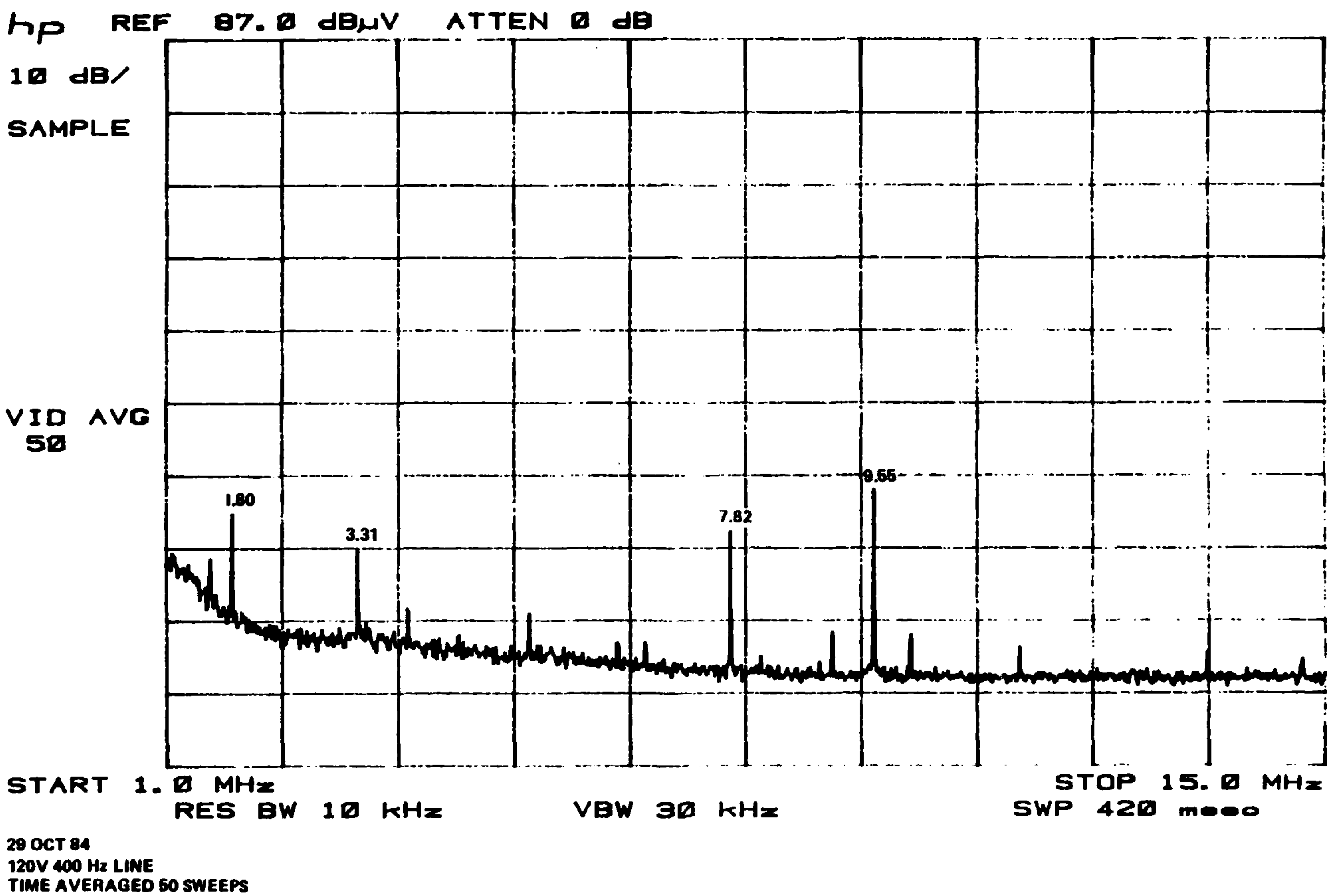

Figure 5. Raw data for conducted emissions (1 to 15 MHz band) measured on the 400 Hz power line using signal averaging mode.

CONDUCTED EMISSIONS (20kHz-50MHz) BB DATA

SYSTEM NAME: SEI ELECTRONICS #[illegible]
TEST DATE: 29 OCT 84
MICOM/DRSMI-RTS
NAME: SNEAD
TEST NUMBER: CE03 - 2
MODE: RECORD
POLARIZATION:
TEST CONFIGURATION: 120V 400HZ RETURN

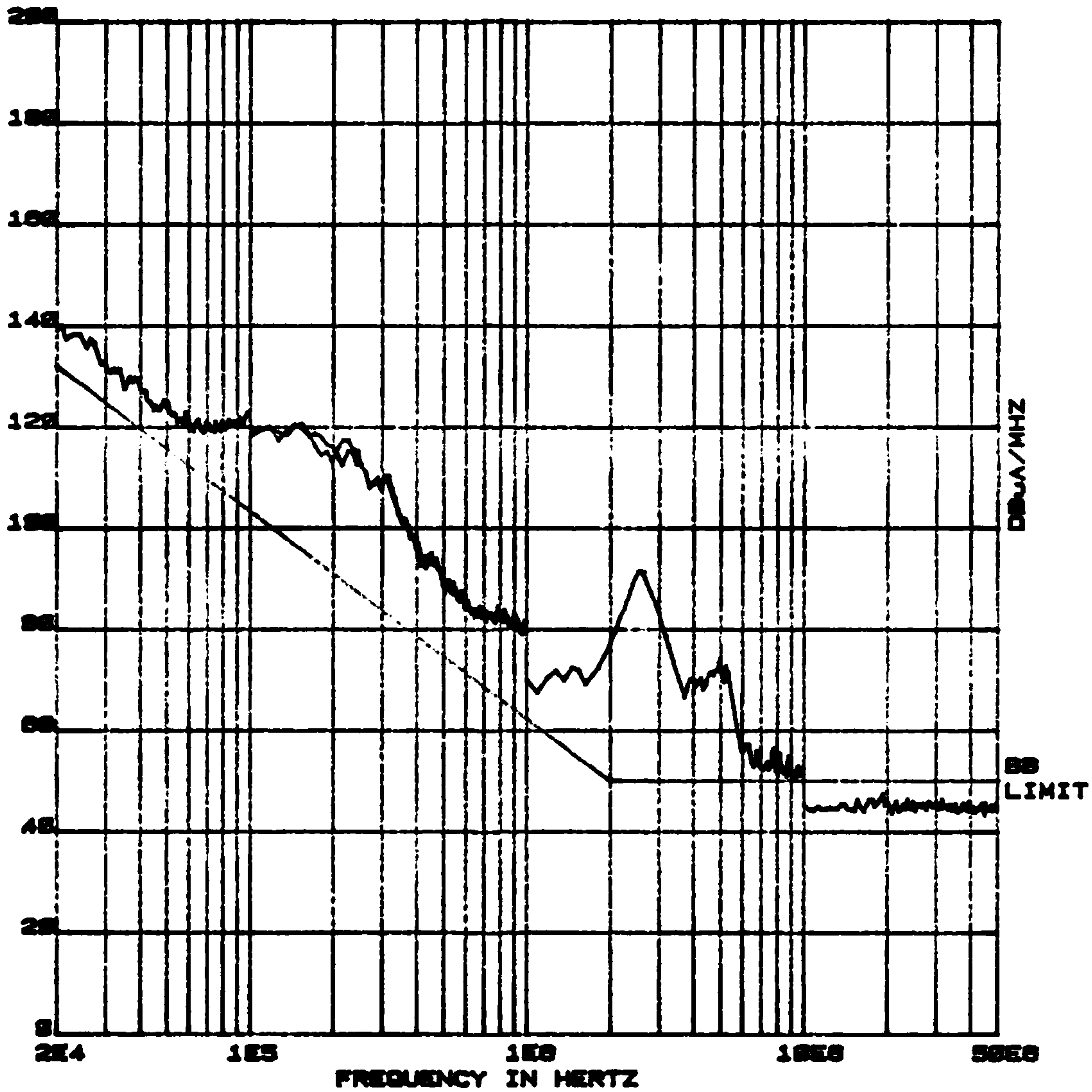

Figure 6. Broadband conducted emissions measured on the 400 Hz power return using procedure CE03.

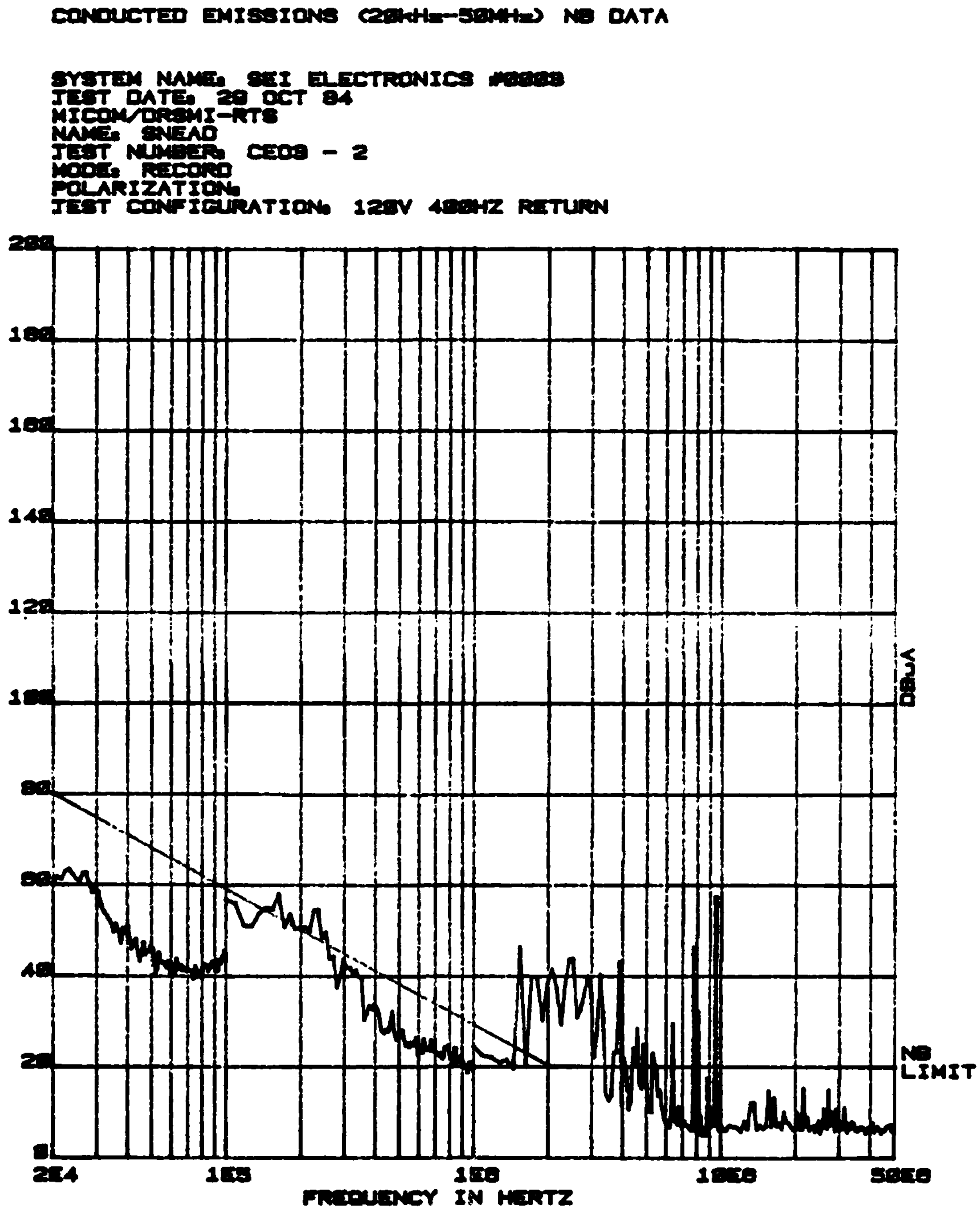

Figure 7. Narrowband conducted emissions recorded on the 400 Hz power return using procedure CE03.

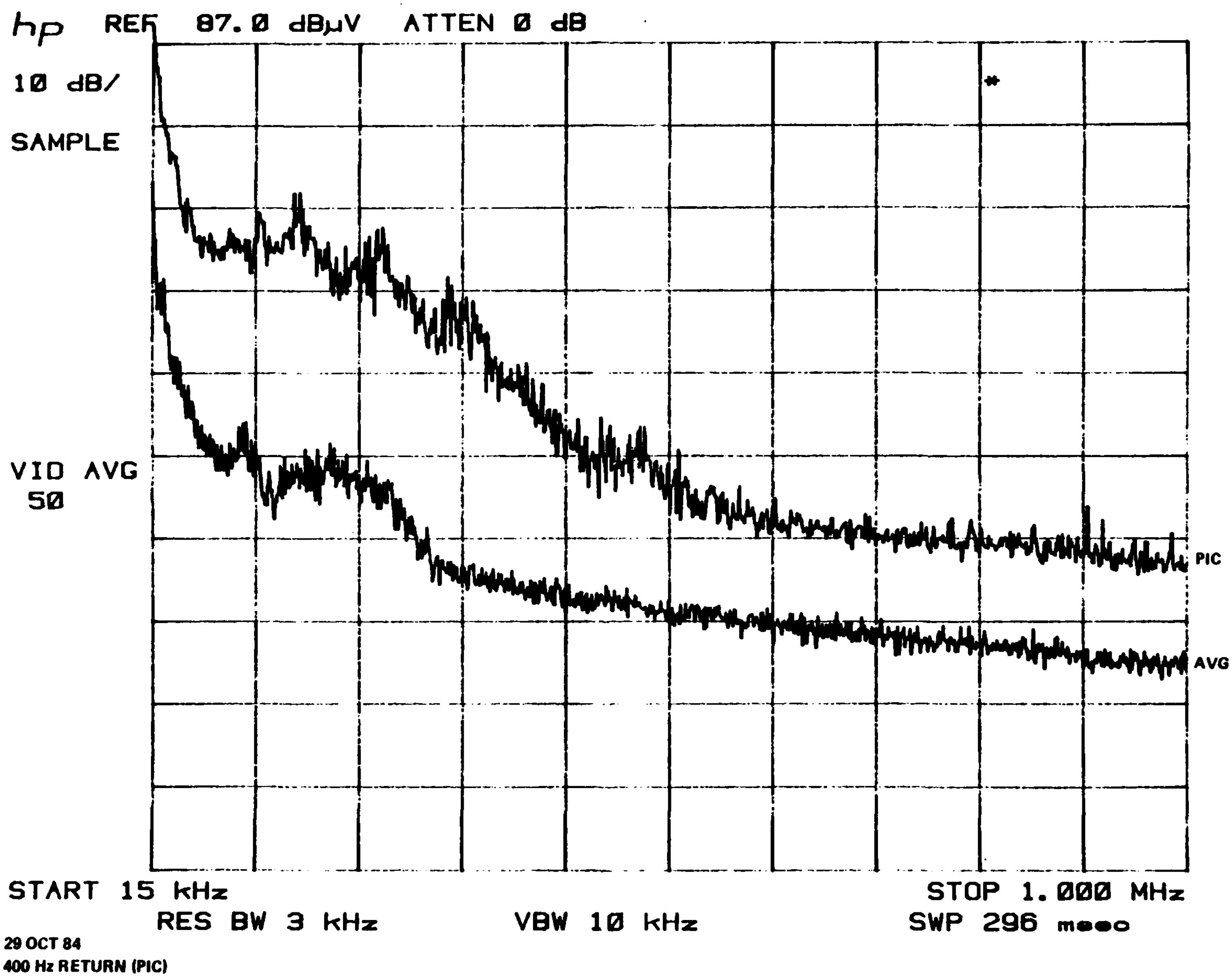

Figure 8. Raw data for conducted emissions measurements on the 400 Hz power return line (15 kHz to 1 MHz band).

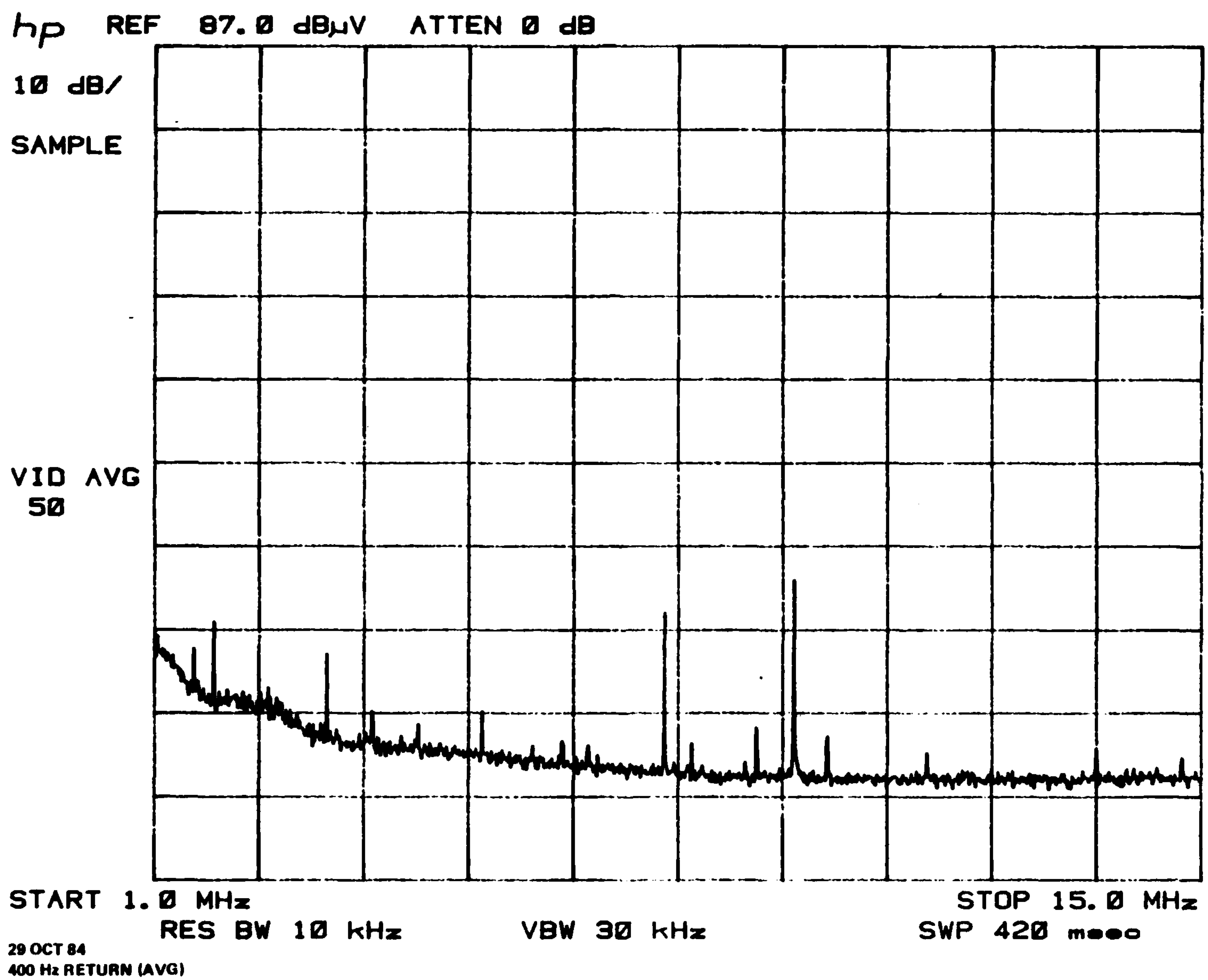

Figure 9. Raw data for conducted emissions measurements on the 400 Hz power return line (1 to 15 MHz band) using peak hold mode.

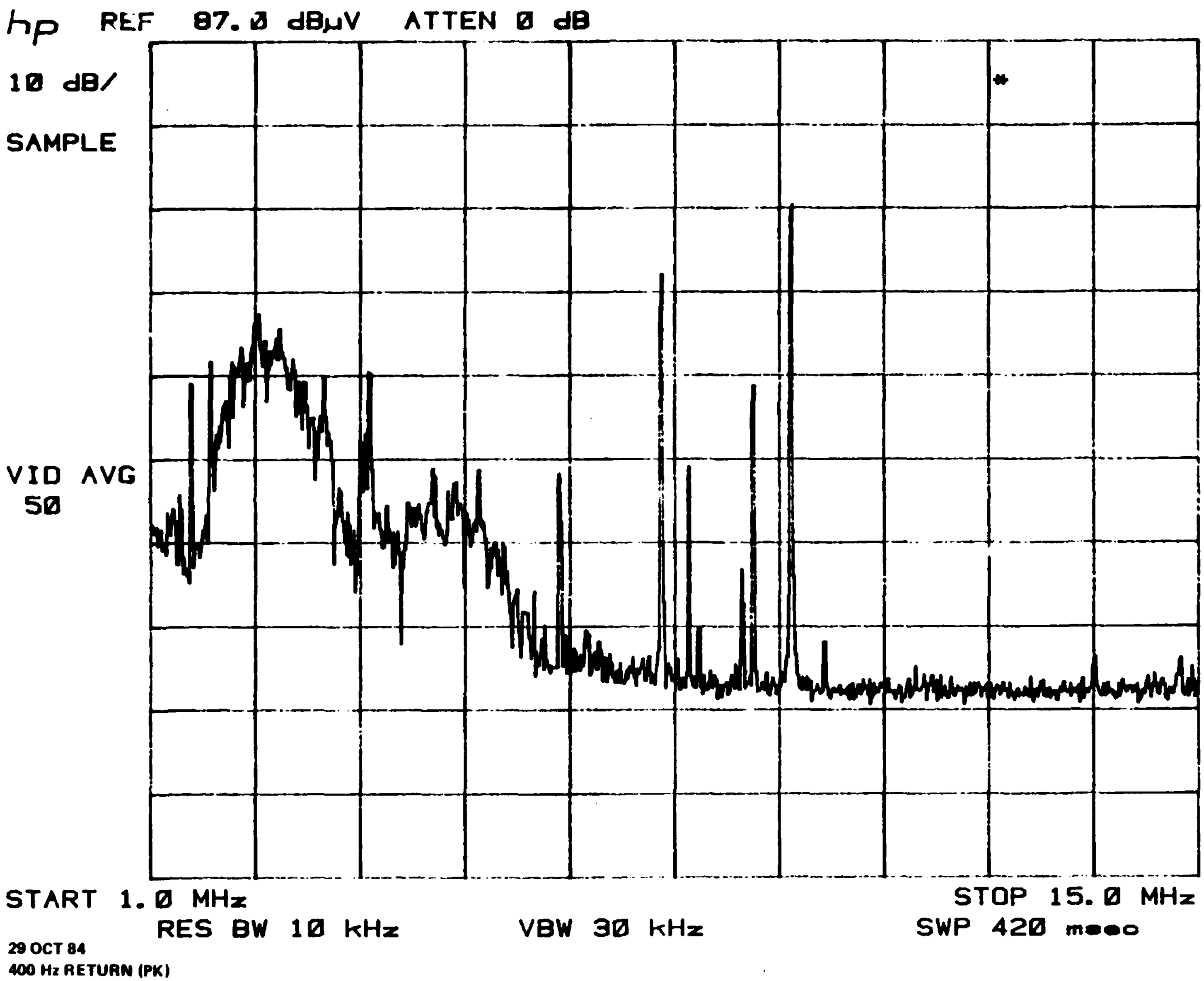

Figure 10. Raw data for conducted omissions measurements on the 400 Hz power return line (1 to 15 MHz band) using signal averaging mode.

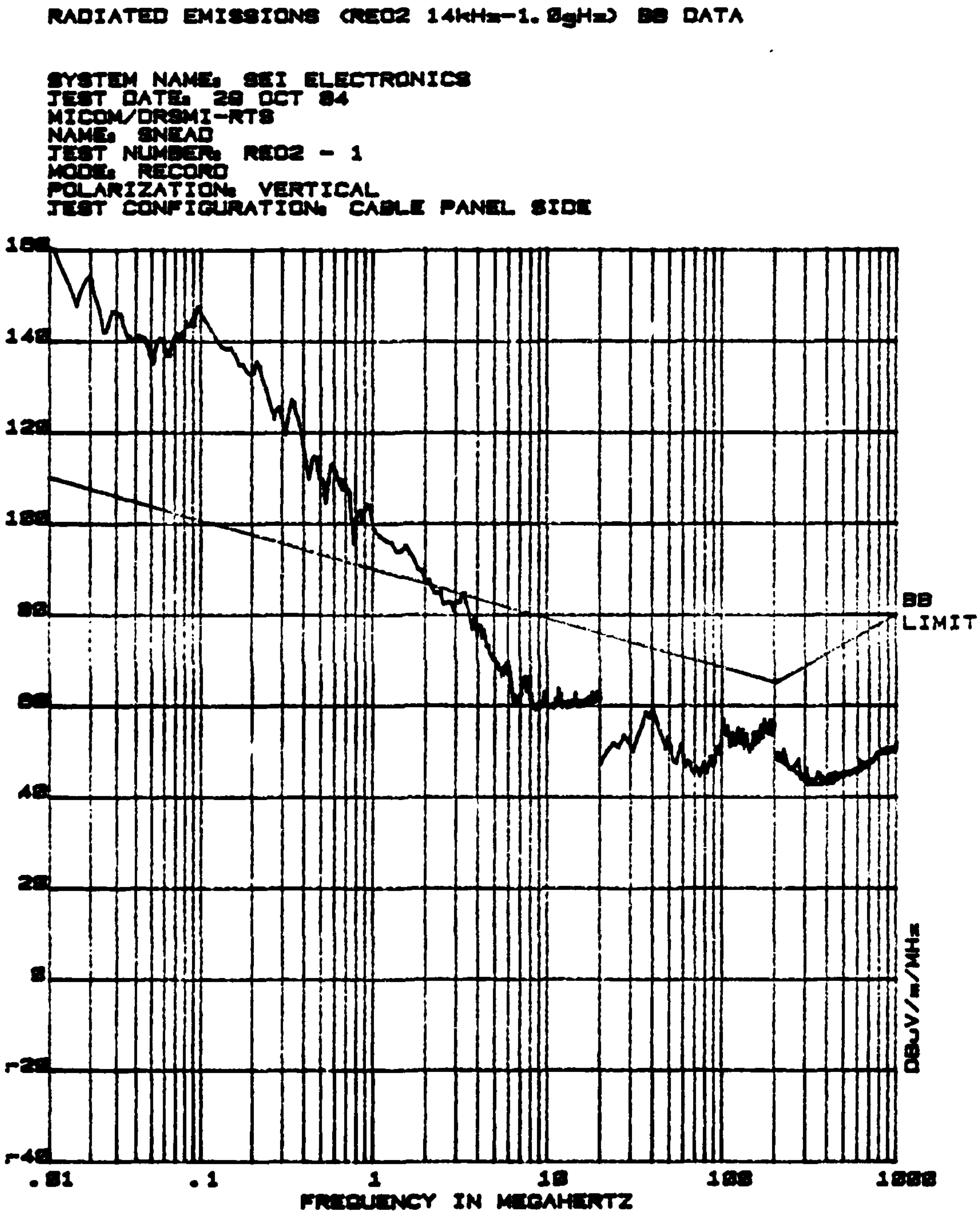

Figure 11. Broadband radiated emissions measured at a point one meter from the cable interface panel to the SEI using procedure RE02.

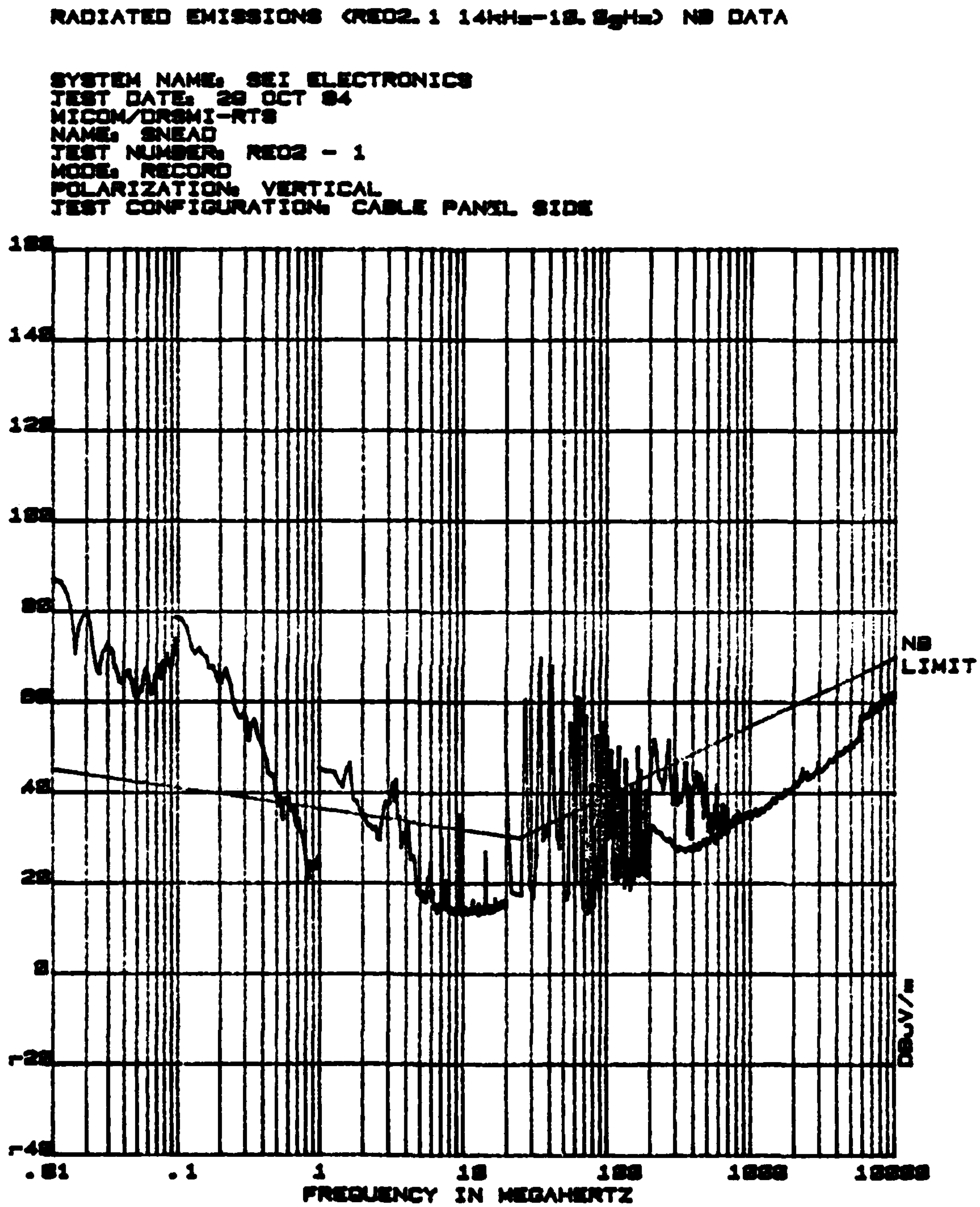

Figure 12. Narrowband radiated emissions measured at a point one meter from the cable interface panel to the SEI using procedure RE02.

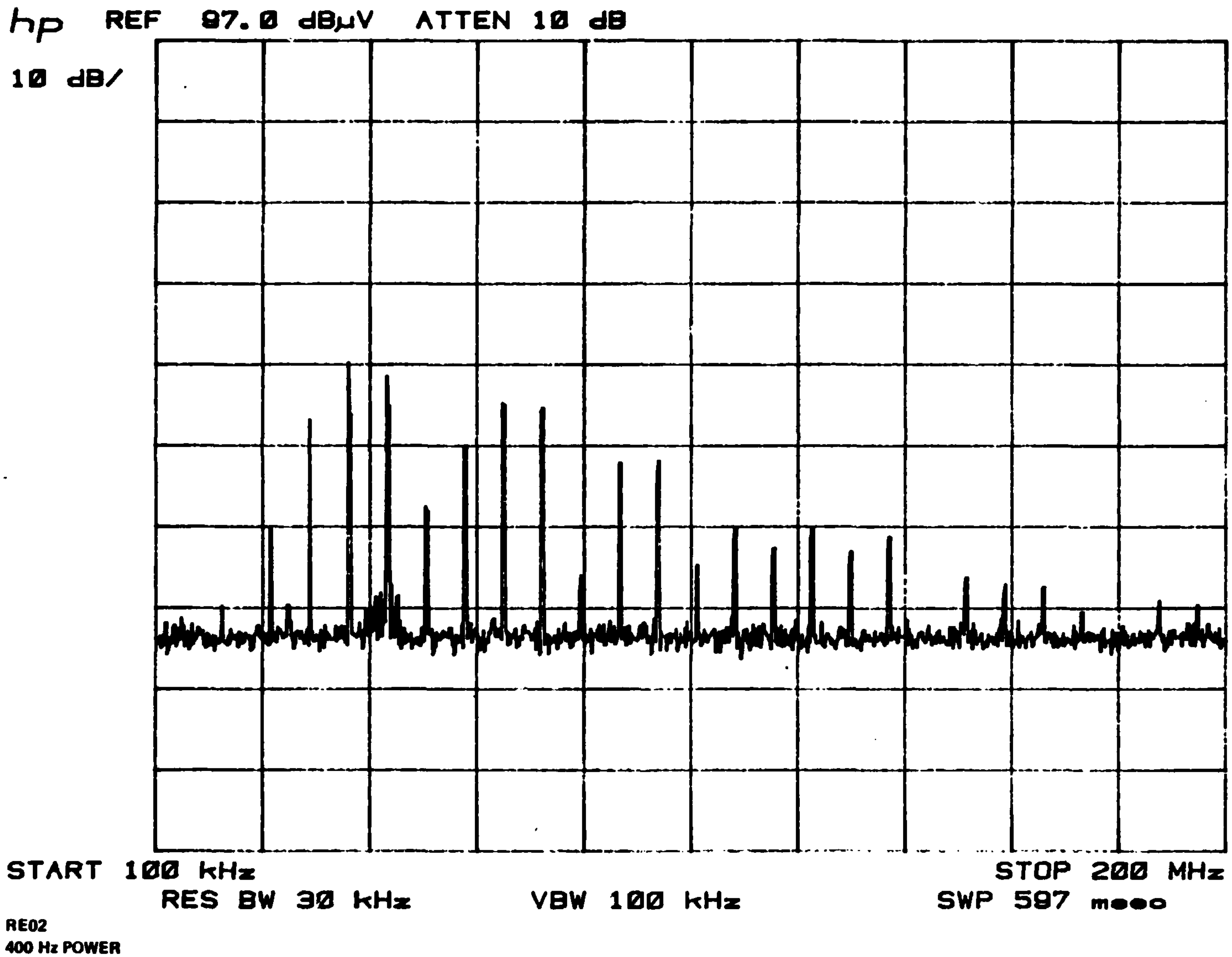

Figure 13. Raw radiated emissions data measured in the 100 kHz to 200 MHz band using peak hold mode. System power supplied by 400 Hz power generation system.

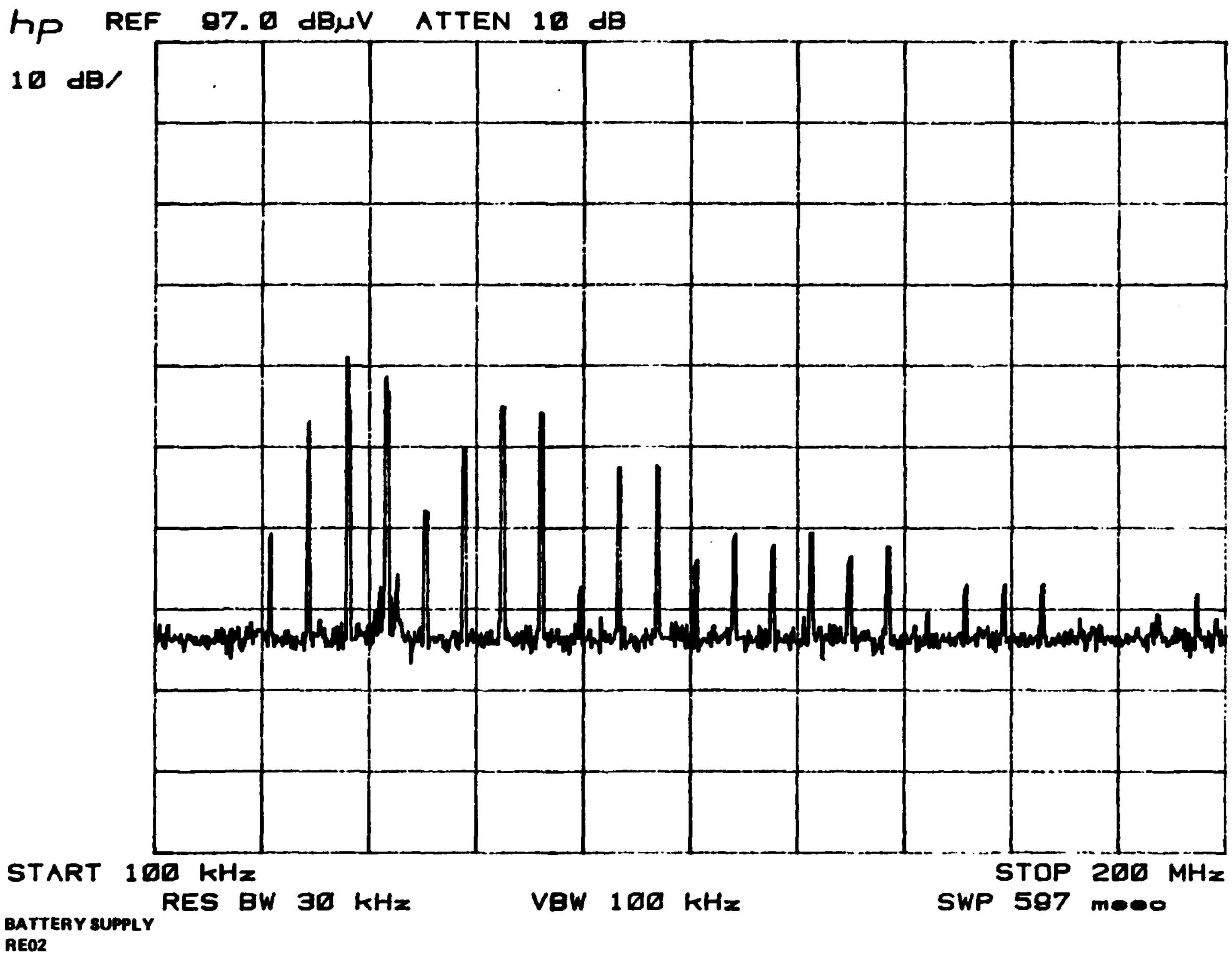

Figure 14. Raw radiated emissions data measured in the 100 Khz to 200 MHz band using peak hold mode. System power supplied by battery backup, 400 Hz supply system deenergized.

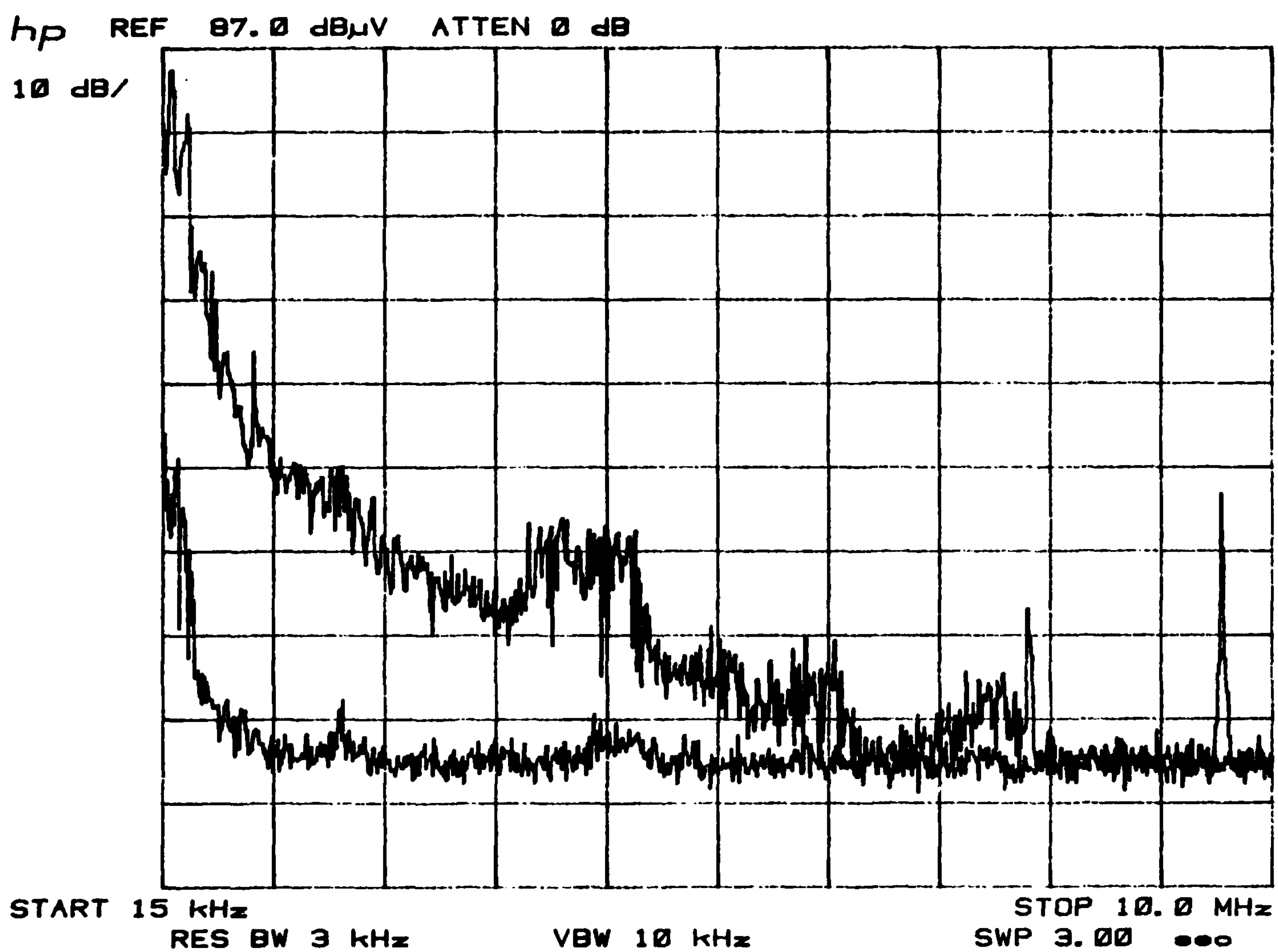

Figure 15. Raw conducted emissions data measured on the 400 Hz power line in the 15 kHz to 10 MHz band with tape on but not recording.

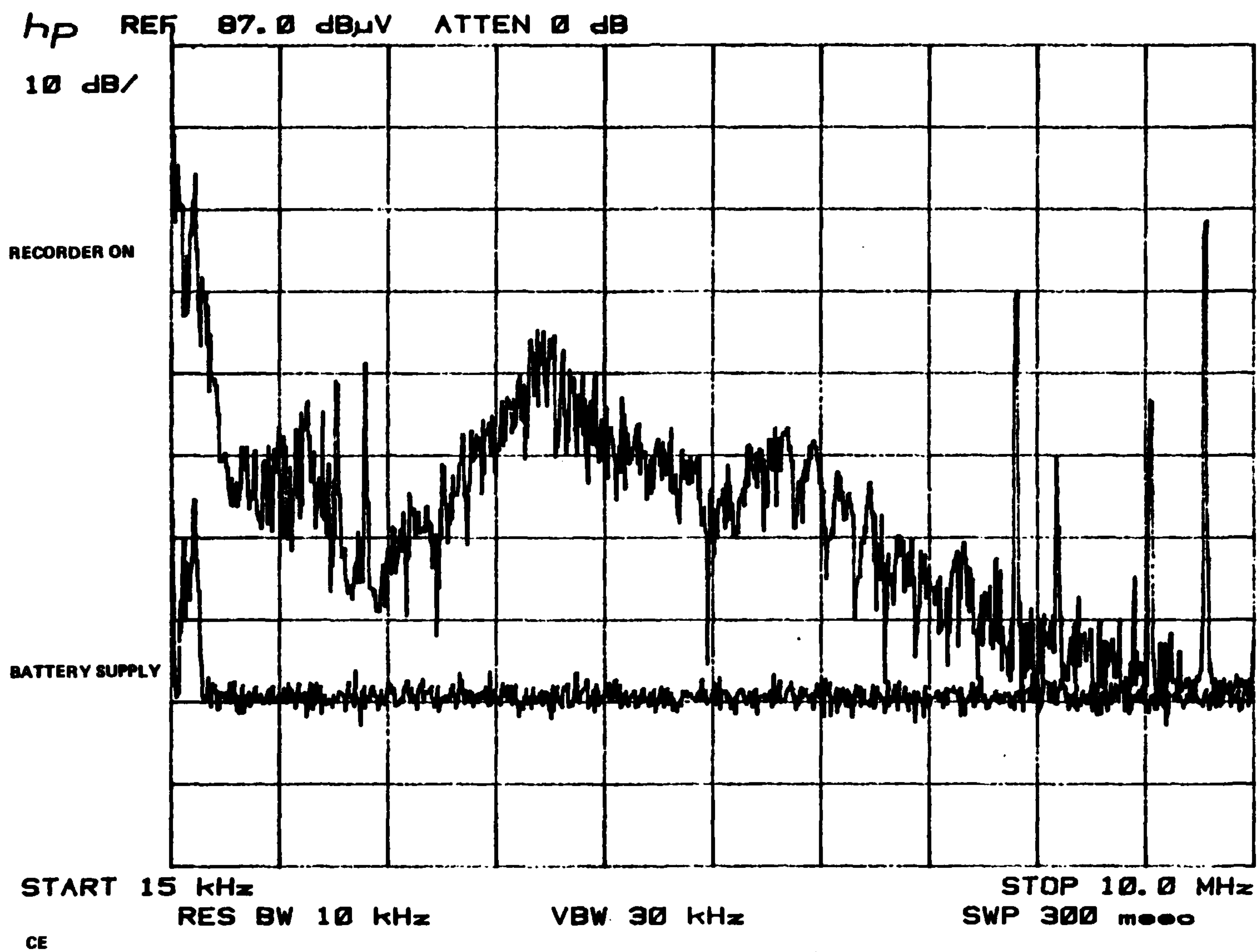

Figure 16. Raw conducted emissions data measured on the 400 Hz power line in the 15 kHz to 10 MHz band with tape drive in record mode.

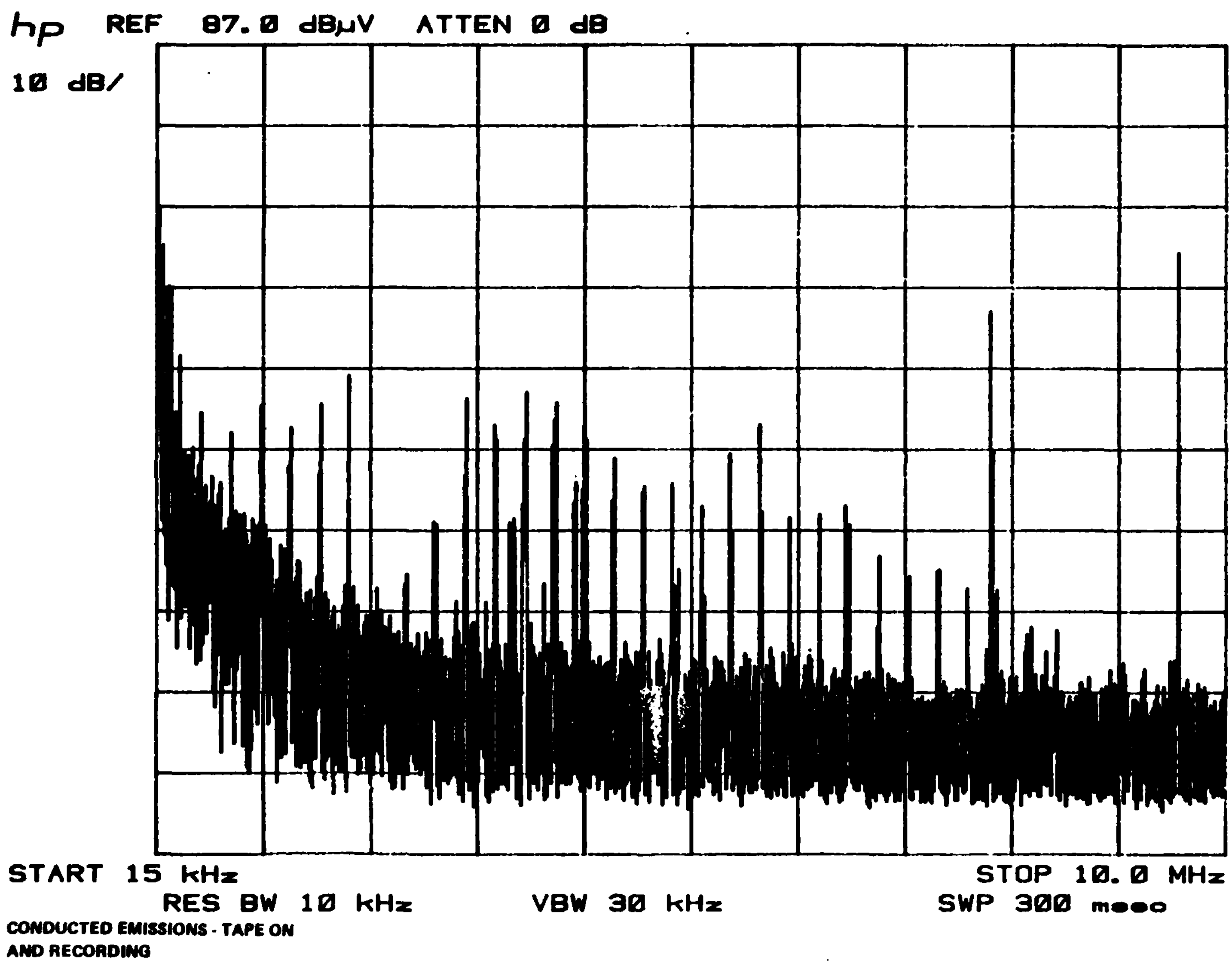

Figure 17. Typical conducted emissions raw data taken using clear-write mode.

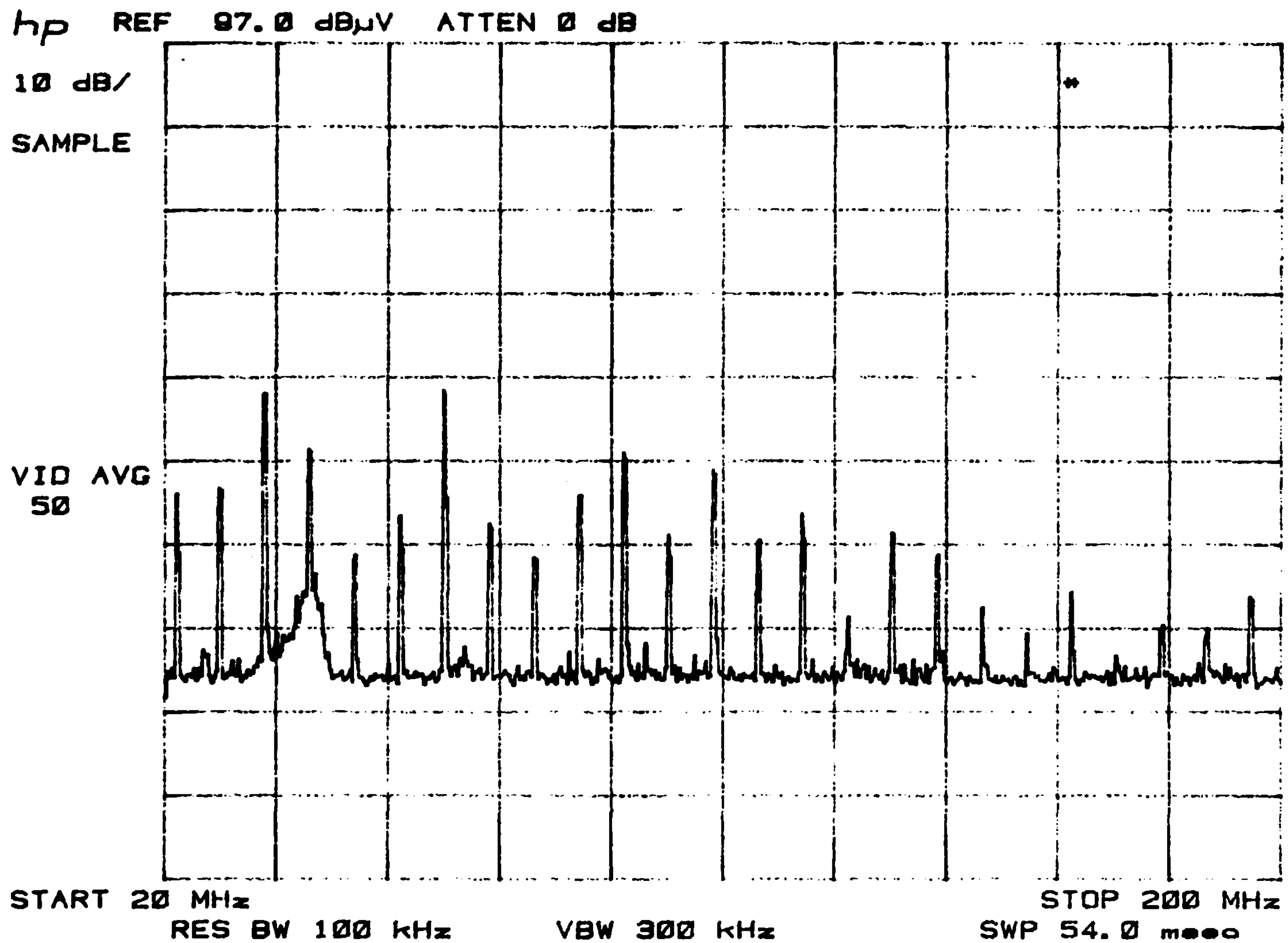

Figure 18. Raw radiated emissions data (20 to 200 MHz band) with the SEI unit grounded to the ground plane and running on the battery backup.

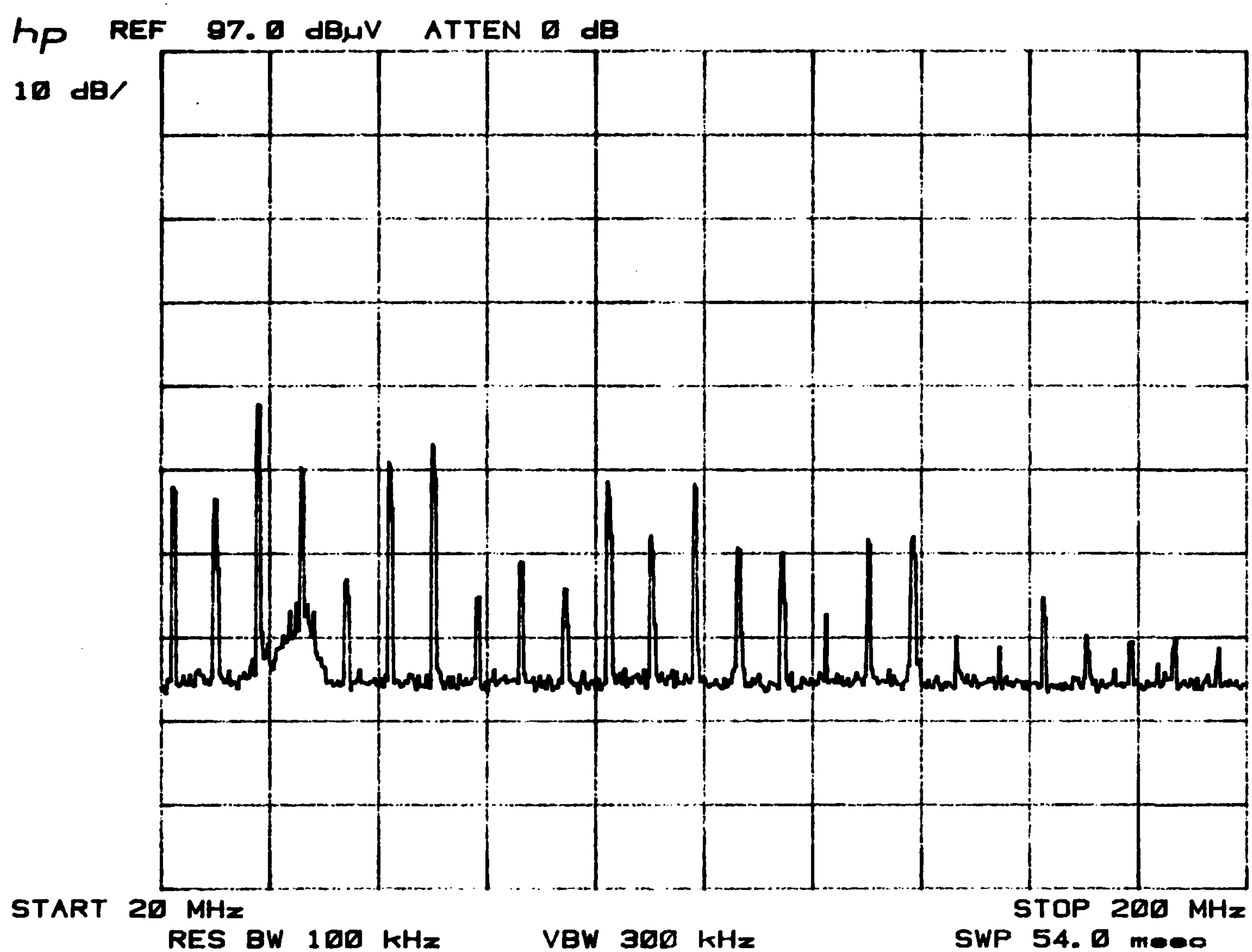

Figure 19. Raw radiated emissions data (20 to 200 MHz band) with the SEI unit grounded to the ground plane and running on 60 cycle power.

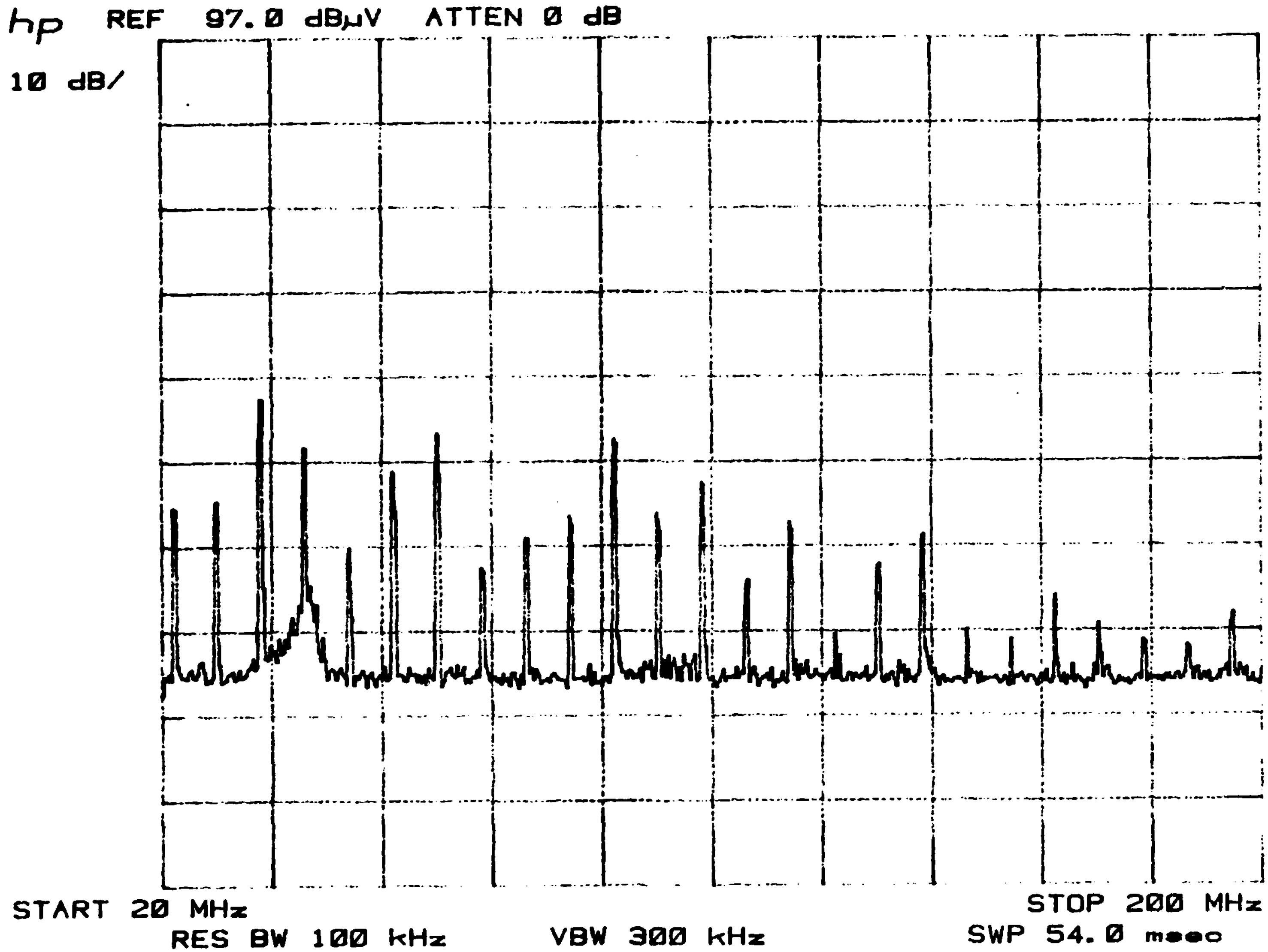

Figure 20. Raw radiated emissions data (20 to 200 MHZ band) with the SEI unit grounded to the ground plane and running on the 60 cycle power through the UPS bypass.

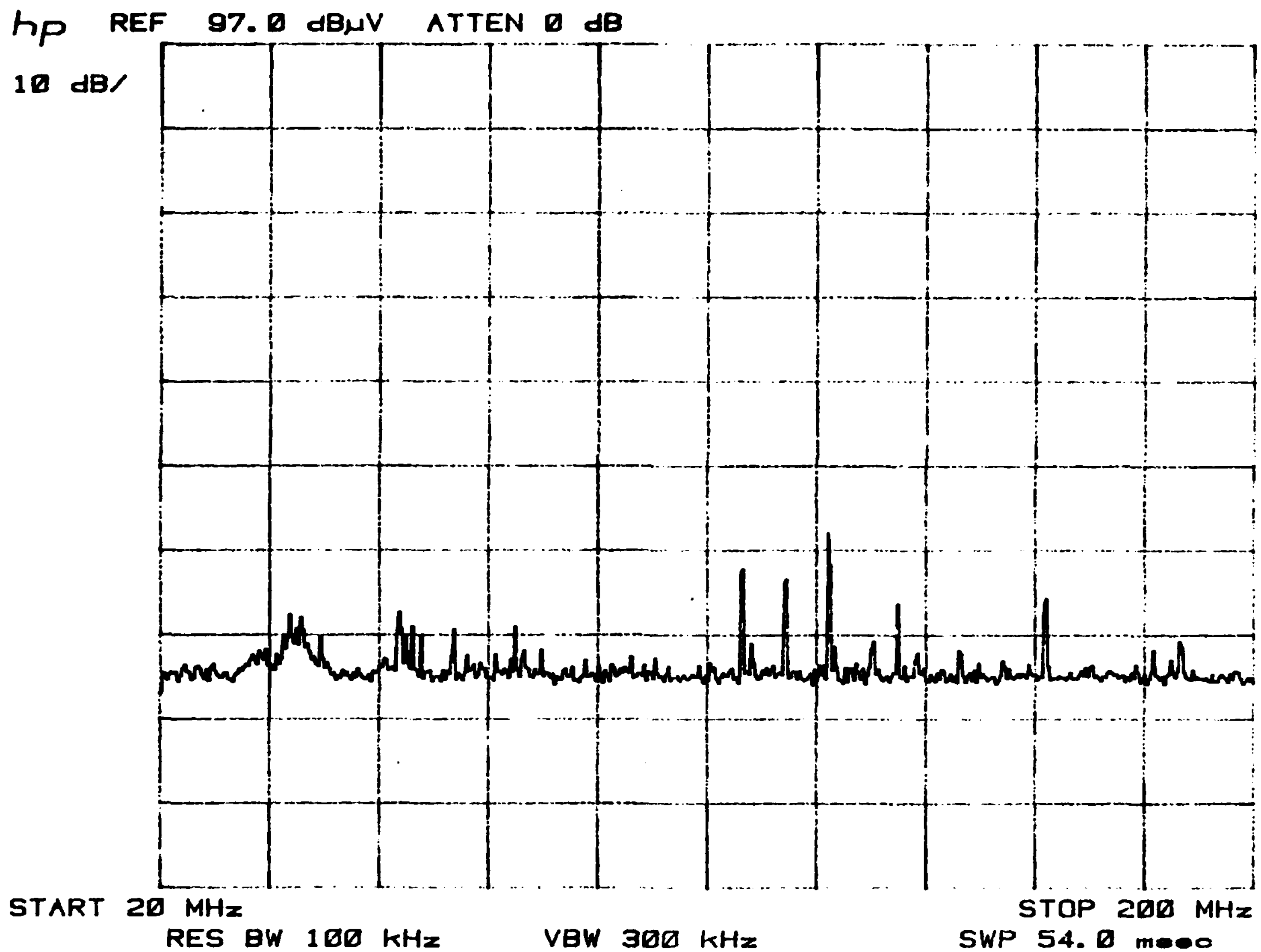

Figure 21. Raw radiated emissions data (20 to 200 MHz band) with the SEI unit grounded to the ground plane and running on 60 cycle power with the TEMPEST qualified tap recorder in the record mode with tape drive doors closed.

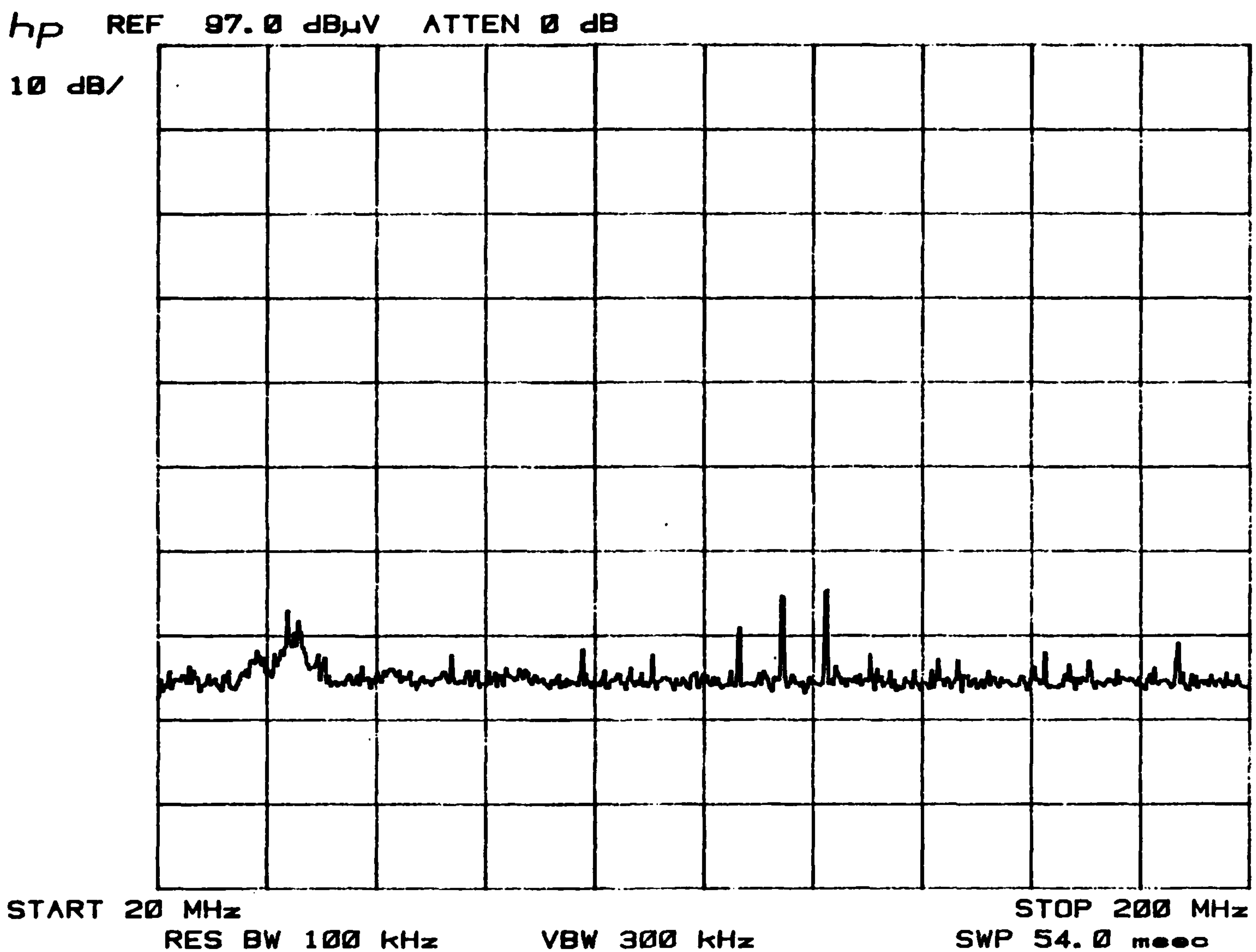

Figure 22. Raw radiated emissions data (20 to 200 MHz band) with the SEI unit grounded to the ground plane and running on 60 cycle power with the TEMPEST qualified recorder in the record mode and the tape drive doors open.

CONDUCTED EMISSIONS (20kHz-50MHz) NB DATA

SYSTEM NAME: SEI ELECTRONICS #0003
TEST DATE: 30 OCT 84
MICOM/DRSMI-RTS
NAME: B. HOOKS
TEST NUMBER: CE03--1
MODE: RECORD
POLARIZATION:
TEST CONFIGURATION: TEMPEST RECORDER--DOOR OFF -60hz-grounded

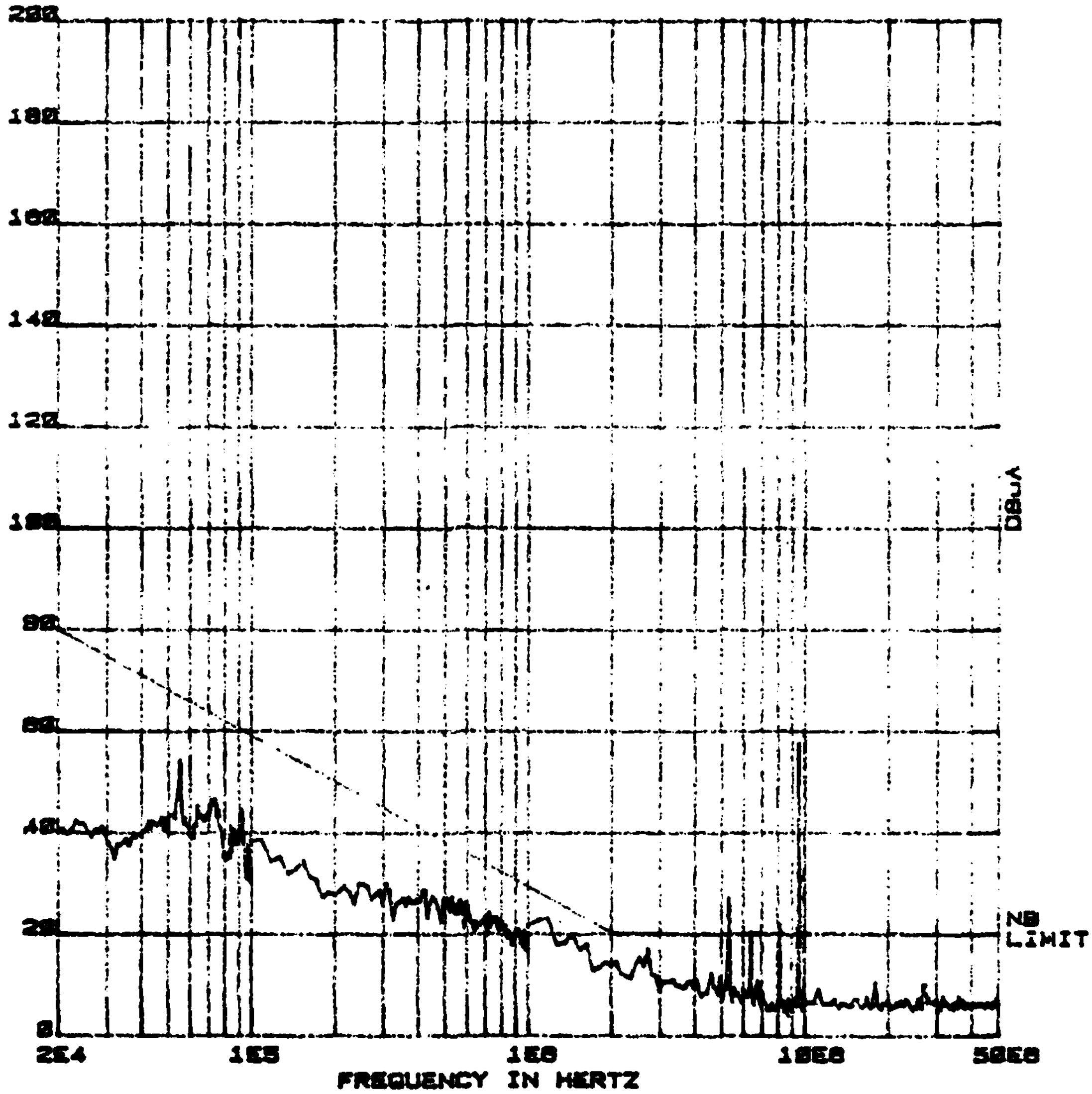

Figure 23. Conducted emissions narrowband data per procedure CE03 measured on the 110 V 60 cycle line with the TEMPEST certified recorder in record mode.

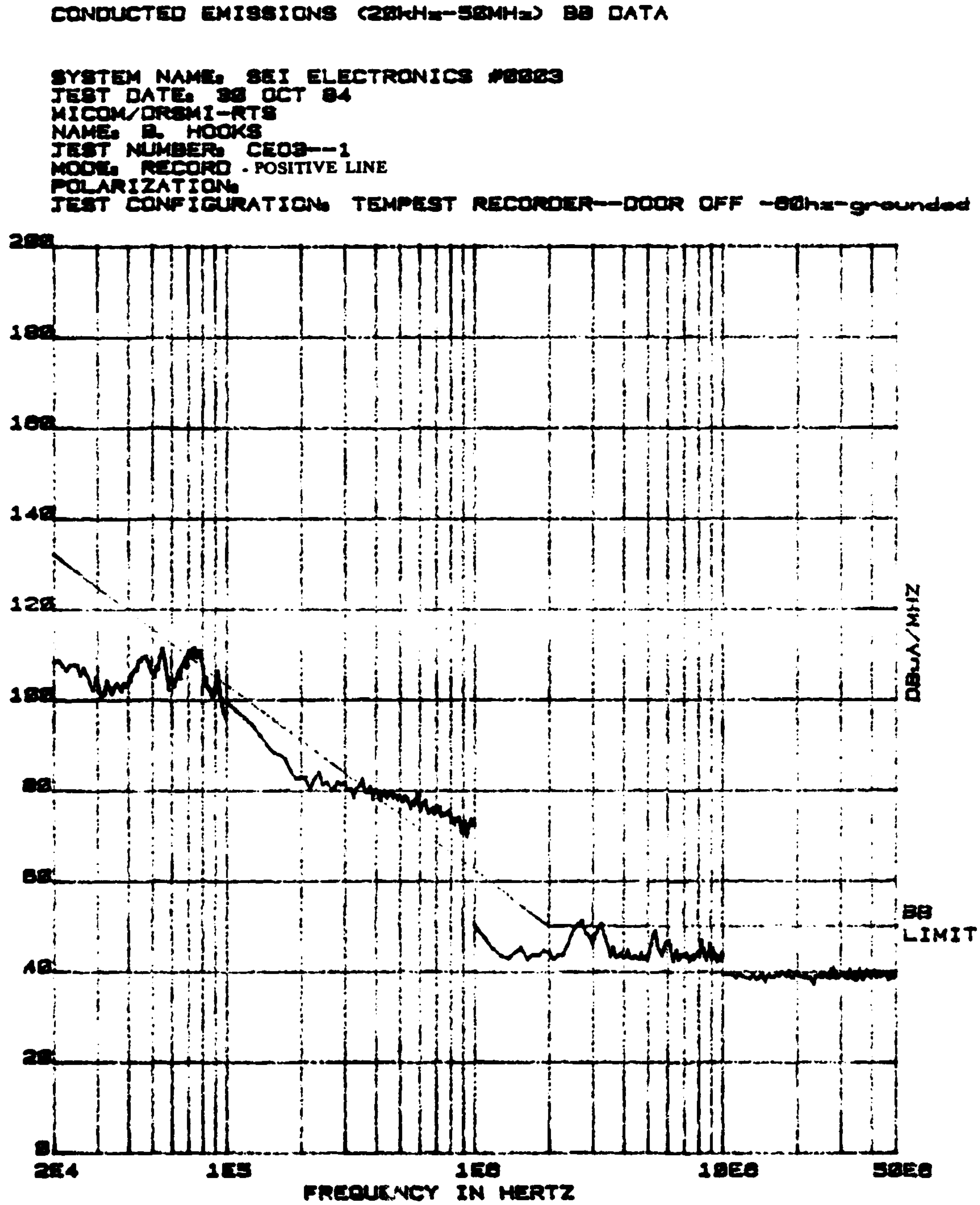

Figure 24. Conducted emissions broadband data per procedure CE03 measured on the 120 V 60 cycle line with the TEMPEST certified recorder in record mode.

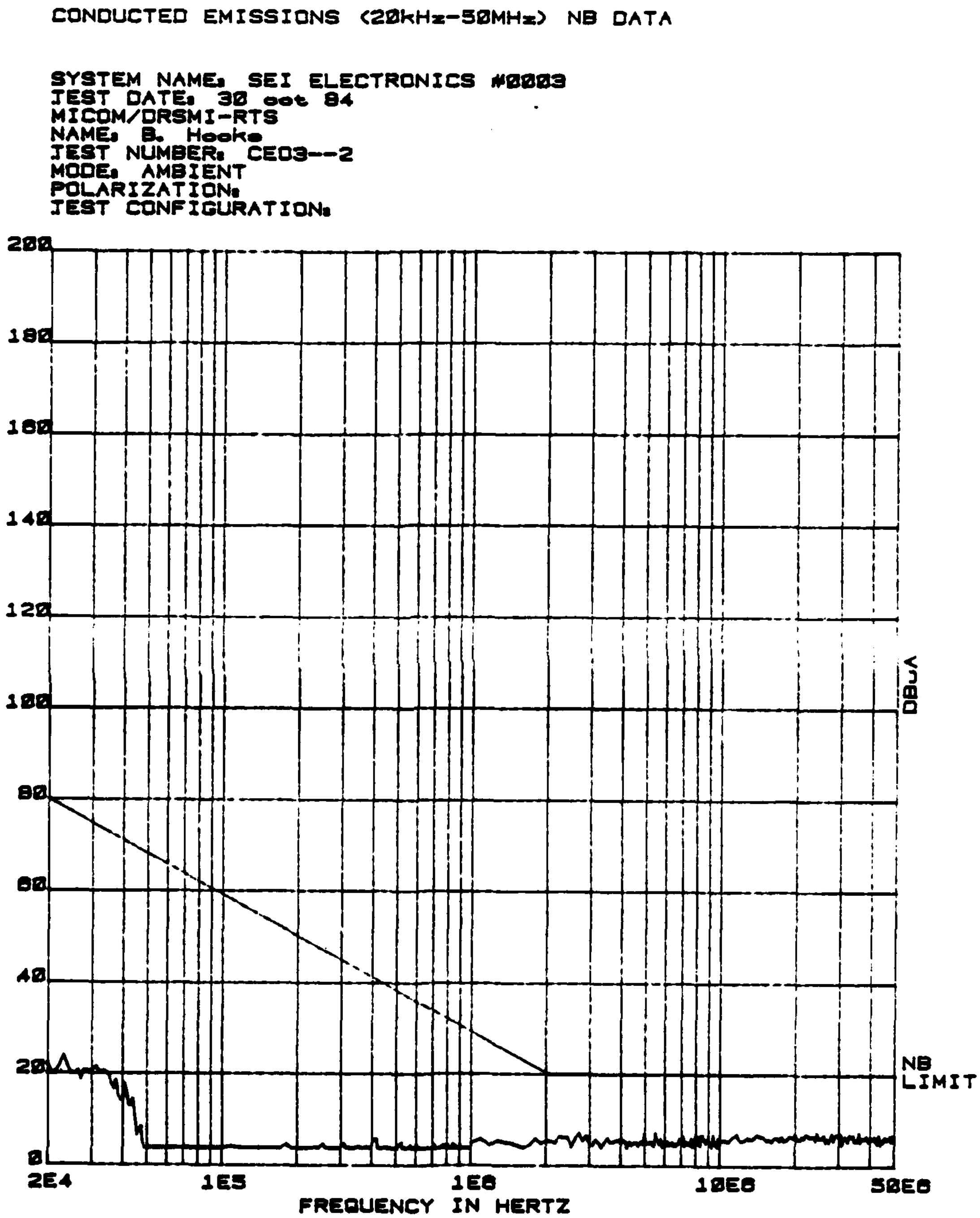

Figure 25. Narrowband conducted emissions ambient.

CONDUCTED EMISSIONS (20kHz-50MHz) BB DATA

SYSTEM NAME: SEI ELECTRONICS #0003
TEST DATE: 30 oct 84
MICOM/DRSMI-RTS
NAME: B. Hooke
TEST NUMBER: CE03--2
MODE: AMBIENT
POLARIZATION:
TEST CONFIGURATION:

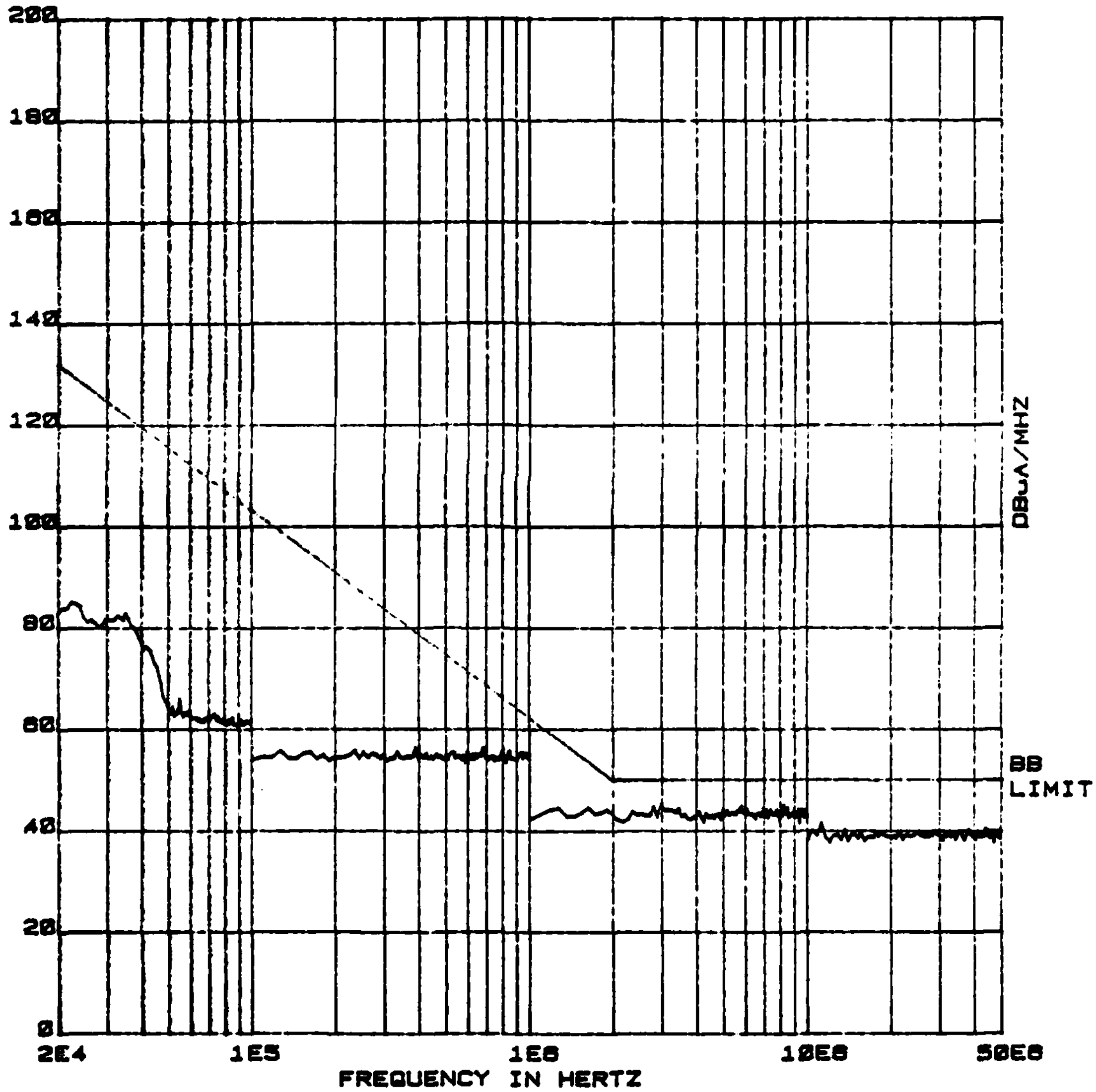

Figure 26. Broadband conducted emissions ambient.

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