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application notes

Microphone Intermodulation Distortion Measurements using the High Pressure Microphone Calibrator Type 4221

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Introduction

In applications where microphones are used to measure very high sound pressure levels, special calibration may be needed to check linearity, distortion and other characteristics of the measuring system. For measuring intermodulation distortion, both excitation frequencies should be regulated. A system allowing this type of measurement at sound pressure levels up to 164 dB is described in the following and typical results are given.

Measuring System

In order to obtain very high sound pressure levels, the B & K High Pressure Microphone Calibrator Type 4221 should be used. This instrument, shown in Fig.1, allows measurements at sound pressure levels up to 164 dB with continuous excitation (levels up to 172 dB SPL may be obtained with tone-burst excitation using the Gating System Type 4440).

The Calibrator is delivered with two couplers, a Low Frequency Coupler allowing measurements down to below 0,01 Hz, and a High Pressure Coupler giving a frequency range of 3 Hz to 1000 Hz (using compression to compensate for the coupler resonance). The high sound pressure is produced by a piston moved by an electrodynamic exciter. Such a force-controlled system has definite advantages over constant volume displacement systems (such as the pistonphone) for very high sound pressure level excitation since, with the 4221, sound pressure is independent of coupler volume variation, atmospheric pressure variation, change from adiabatic to isothermic conditions at low frequencies, non linearity in load impedance at high dynamic pressures. Further, harmonic distortion of Type 4221 is approx. 6 dB lower than the theoretical limit obtainable with a constant volume displacement system at 164 dB. Full details on Type 4221 are given in References [1] and [2].

For intermodulation distortion measurements, two excitation tones are necessary. Both tones should be regulated independently due to the resonance of the coupler (Fig.2). Using traditional compression techniques, such a dual frequency compressor loop would result in a relatively complex system (Reference [3]). However, a rather simple measurement system can be obtained using the Audio Test Station Type 2116 (Fig.3).

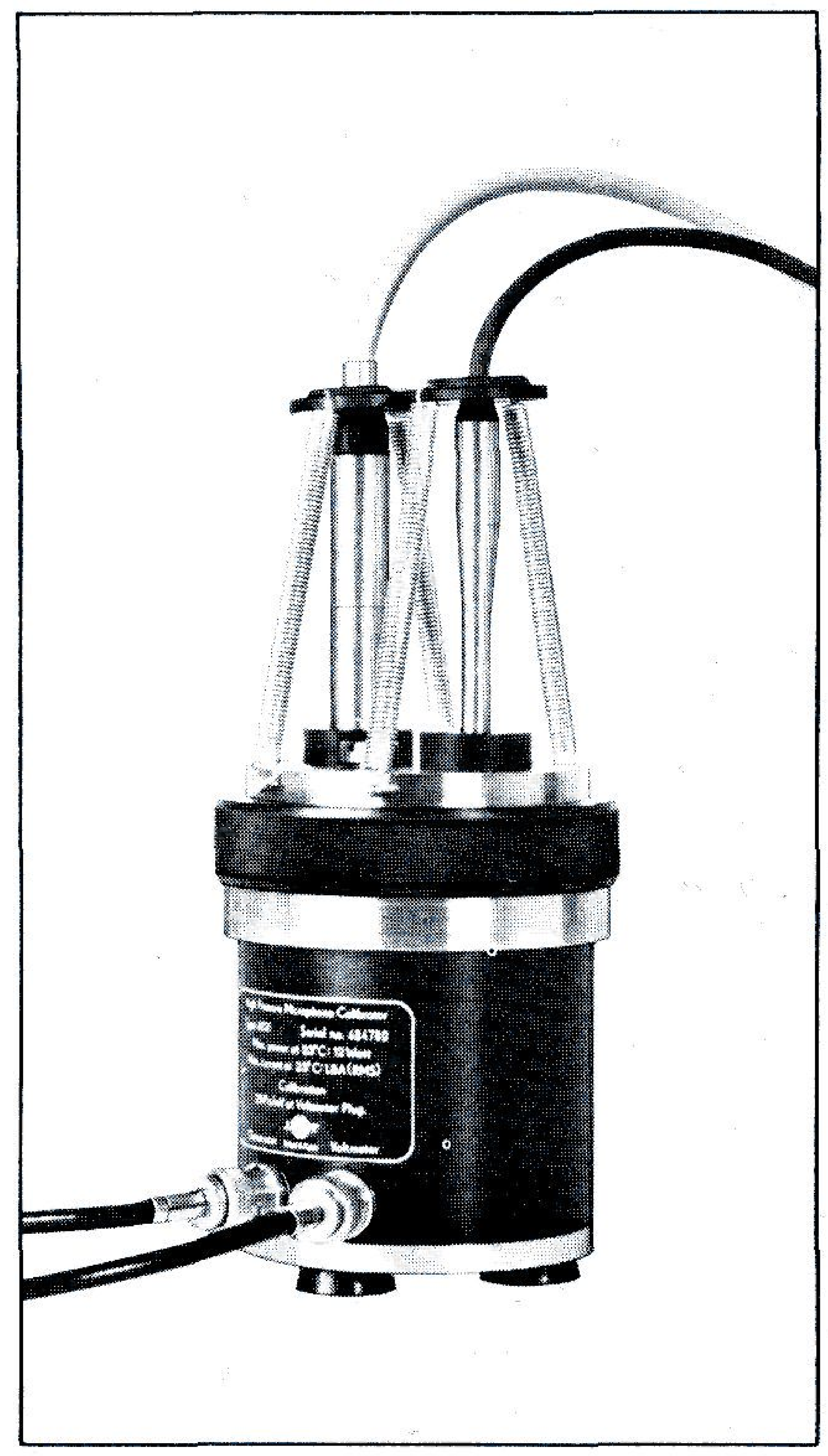

Fig.1. The High Pressure Microphone Calibrator Type 4221

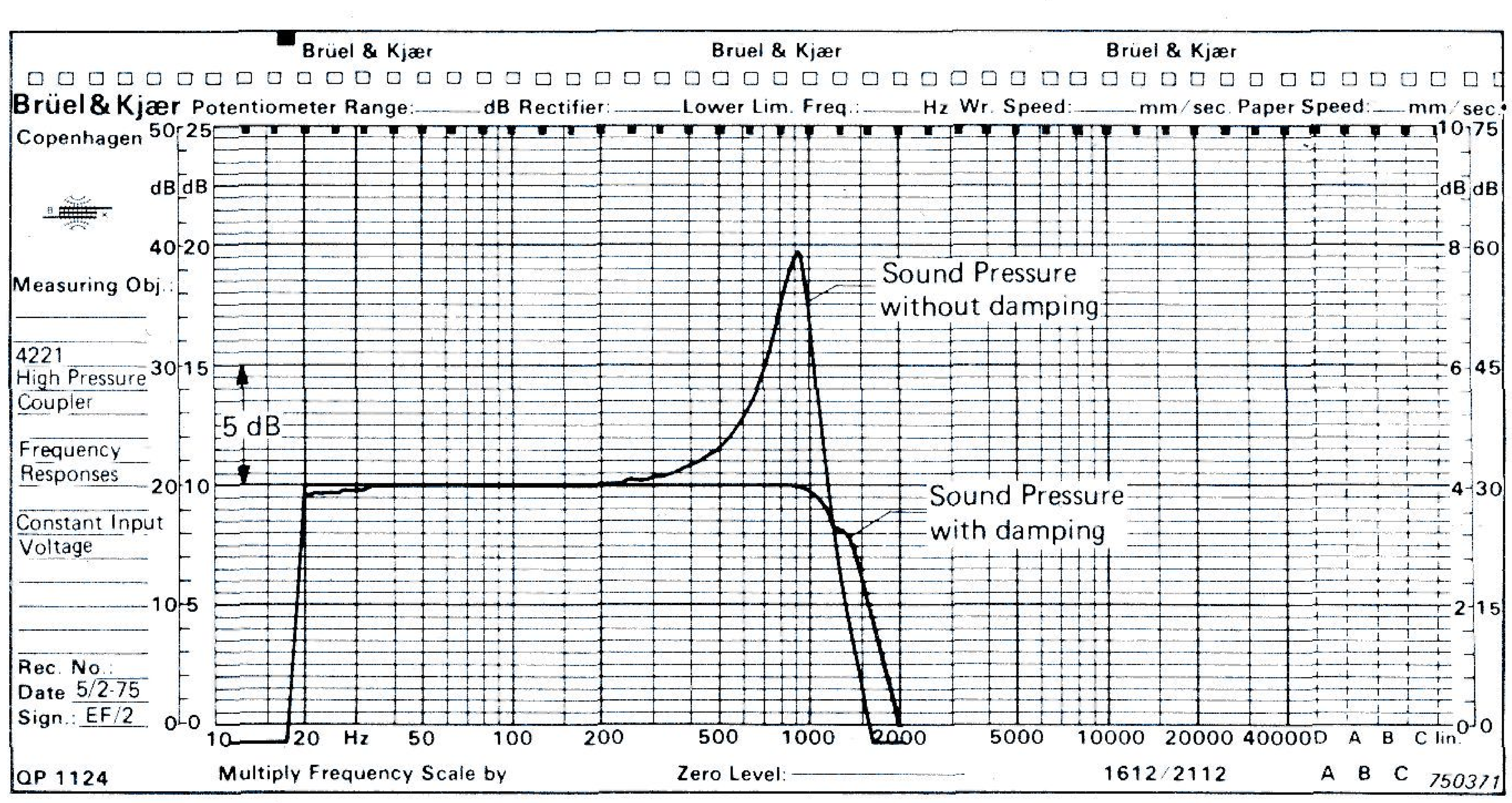

Fig.2. Frequency Response of Type 4221 fitted with the High Pressure Coupler

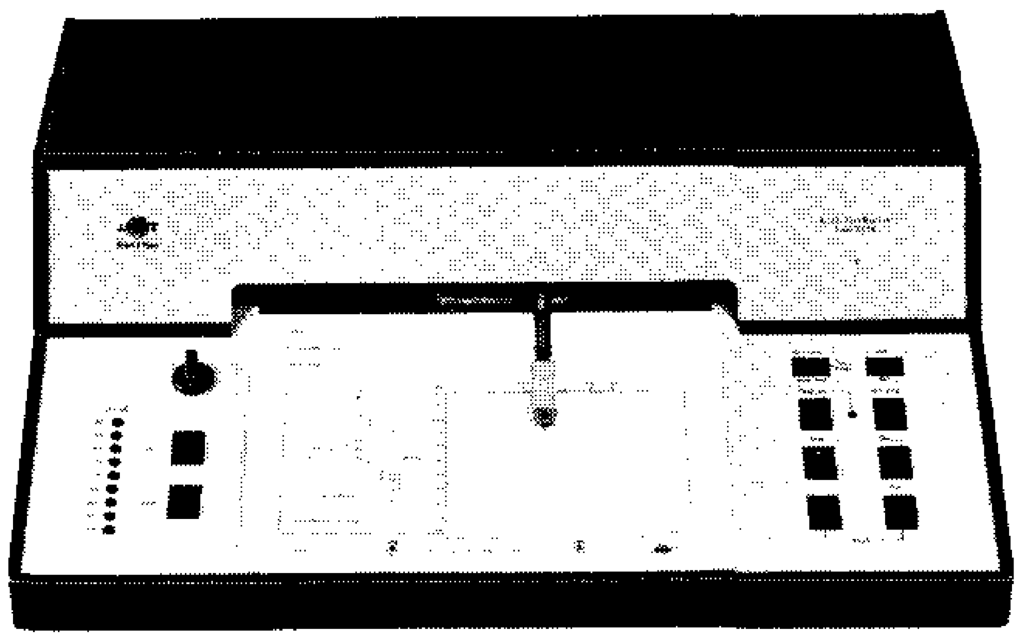

Fig.3. The Audio Test Station Type 2116

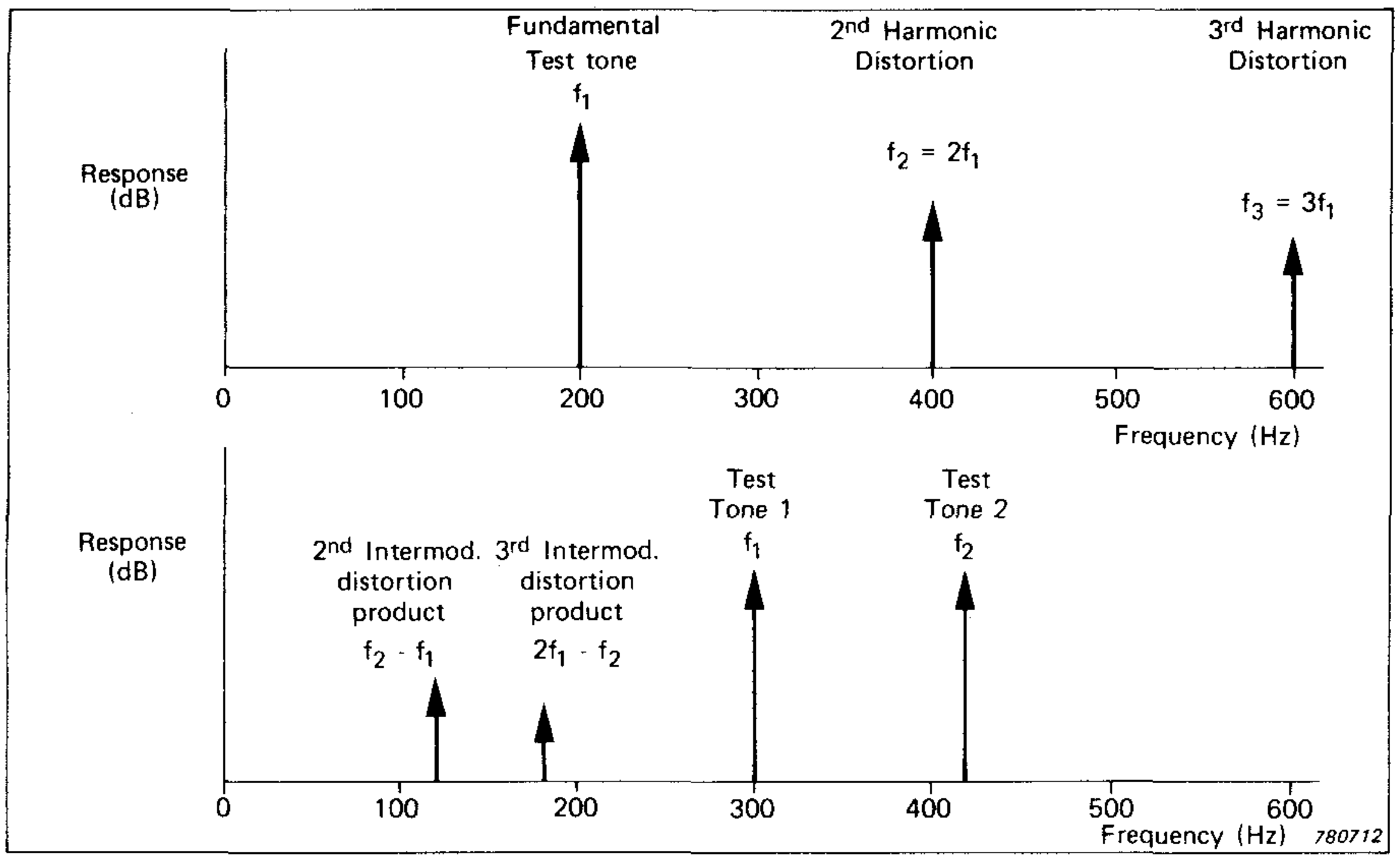

Fig.4. Harmonic distortion (upper) and intermodulation distortion (lower) as measured by Type 2116

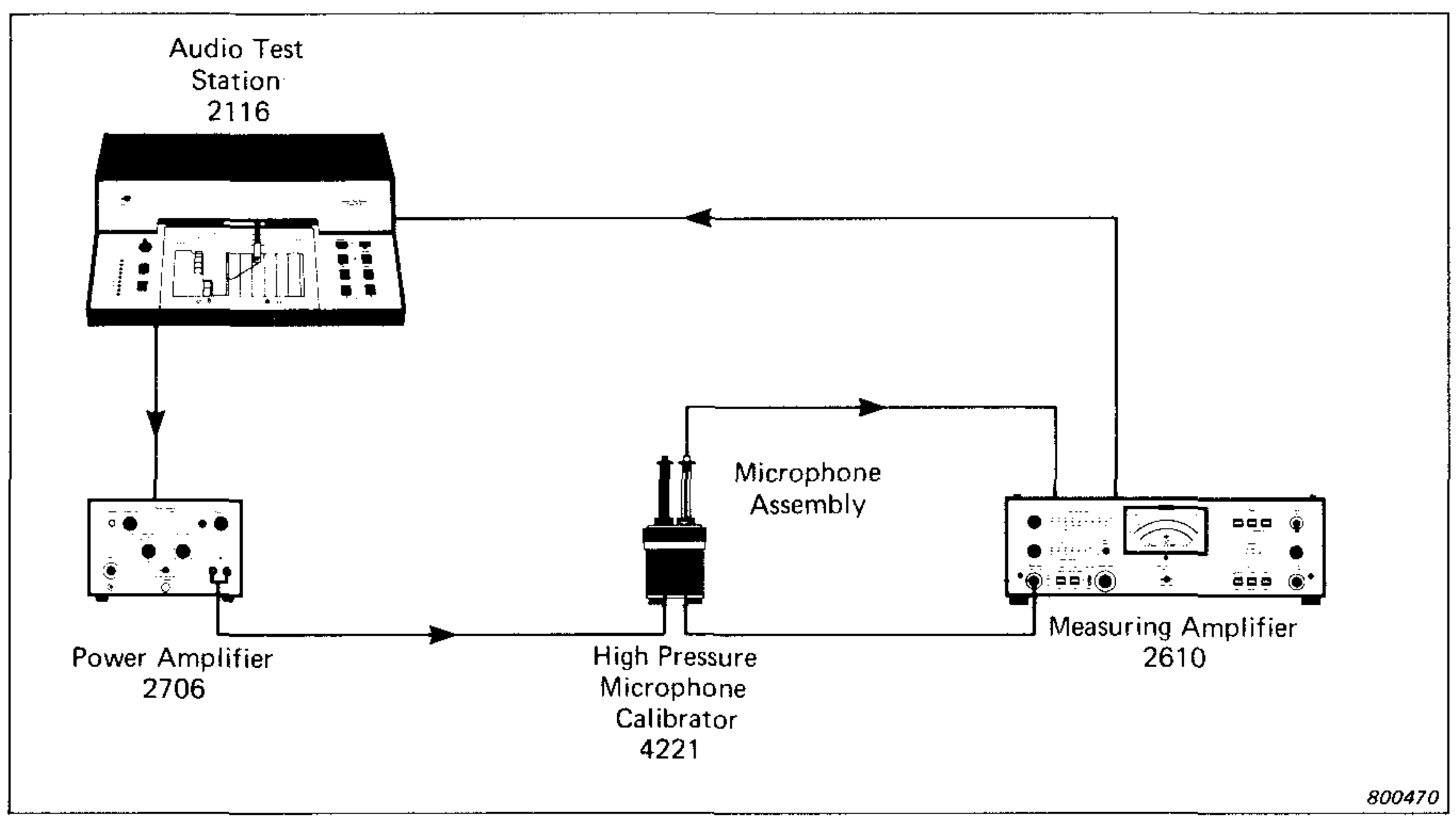

Fig.5. Set-up for measuring harmonic and intermodulation distortion of microphones at high sound pressure levels

The instrument includes a generator (100 Hz to 10 kHz), an analyzer/recorder section and a memory which can store the frequency response of a test object and automatically compensate possible irregularities during later frequency sweeps.

In the Intermodulation Distortion mode of Type 2116, two tones with a constant frequency ratio of 1,4 are produced, each being individually regulated using the proper attenuation factors stored in the memory so that they both have the same amplitude over the frequency range of interest. Both second and third intermodulation distortion product can be measured by the 2116 ($f_2 - f_1$ and $2f_1 - f_2$ respectively, where f_1 and f_2 are both excitation frequencies, related by $f_2 = 1,4 f_1$). Second and third harmonic distortion products can also be measured (see Fig.4).

The complete measuring system is shown in Fig.5. The output of the 2116 is not sufficient to drive the 4221 at full rating. The excitation signal is therefore fed to the Power Amplifier Type 2706. The sound pressure level in the coupler can be read on the Measuring Amplifier Type 2610 connected to the VOLTMETER output of the 4221. At 95 Hz, a 1 mV output corresponds to 20 Pa sound pressure (120 dB SPL). The Measuring Amplifier is also used to condition the microphone output so that it corresponds to the measuring range of the Audio Test Station.

Measurements

The first step is to measure the distortion characteristics of the measuring set-up. For that purpose, a special acoustical attenuator was used so that the sound pressure level acting on the 1/4" Condenser Microphone Type 4135 was approximately 30 dB below the sound pressure level in the coupler. It can therefore be expected that any distortion measured is produced by the excitation part of the system.

With the acoustical attenuator in place, the 2116 was set to "Frequency Response" with the COMPRESSION switch set to "Out". The SPL selector was set to 90 dB. The 2116 was started. The sweep was stopped at 100 Hz and the gain of the Power Amplifier Type 2706 was adjusted until the reading on the Measuring Preamplifier Type 2610 was corresponding to a sound pressure level of 164 dB in the coupler. The 2610 was then switched to the "Preamp." INPUT and the gain was adjusted so that the pen of the 2116 was lying on the "90 dB" line, which is the reference level used when reading-in the correction curve.

The COMPRESSION switch was then set to "In" and the correction curve was recorded. The sweep was stopped around 1 kHz. In this way, all further sweeps using the recorded correction curve stop automatically at the last recorded frequency.

To check that the correction curve was read-in correctly, the frequency response of the system was recorded as well as second and third harmonic distortion components (Fig.6). Intermodulation distortion was then recorded and was found at least 50 dB below the excitation level (Fig.7). At such low levels, the distortion products can be of the same order of magnitude as hum

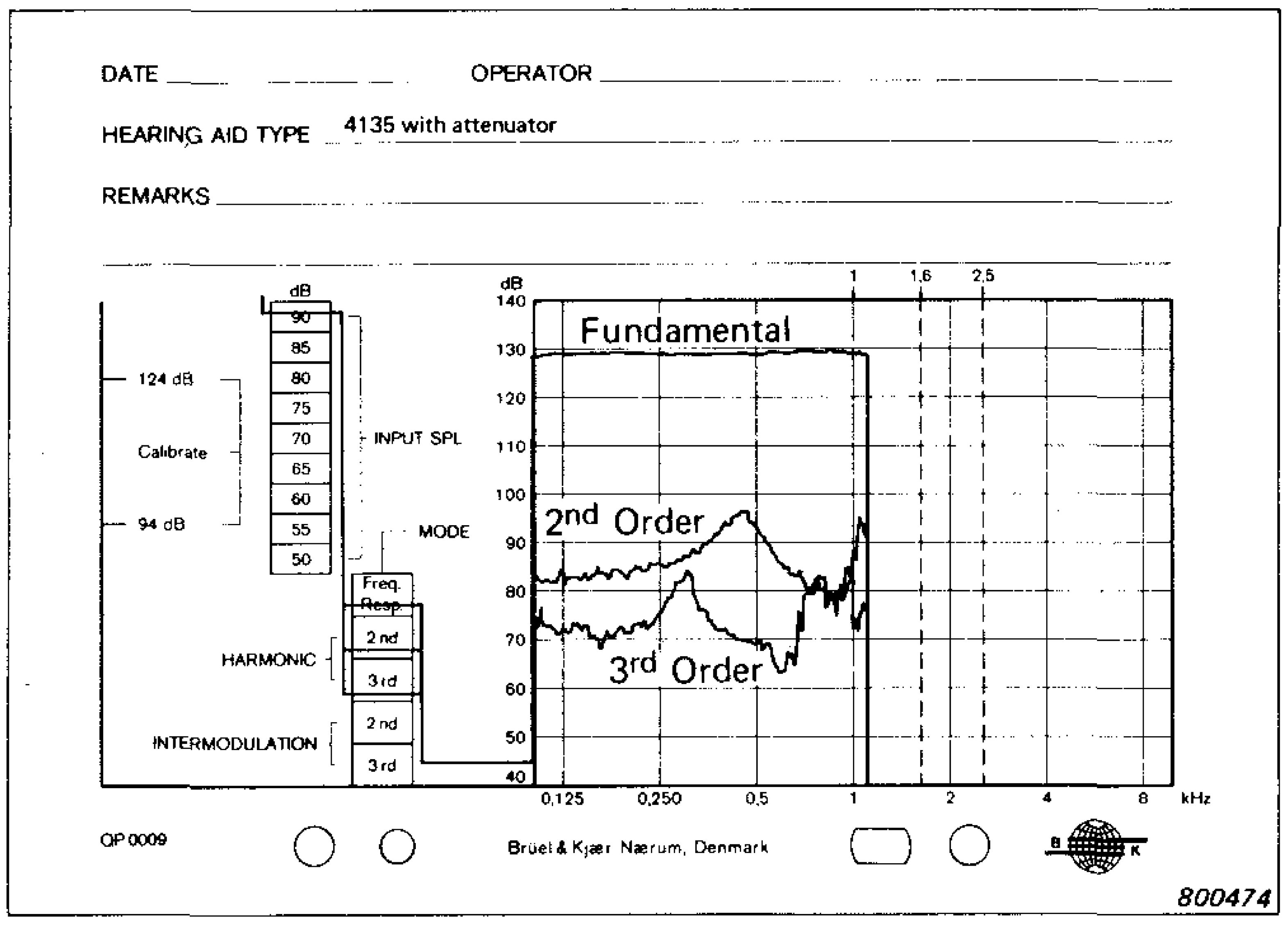

Fig.6. **Harmonic distortion of the measuring set-up at 164 dB SPL (measured with 4135 and acoustical attenuator)**

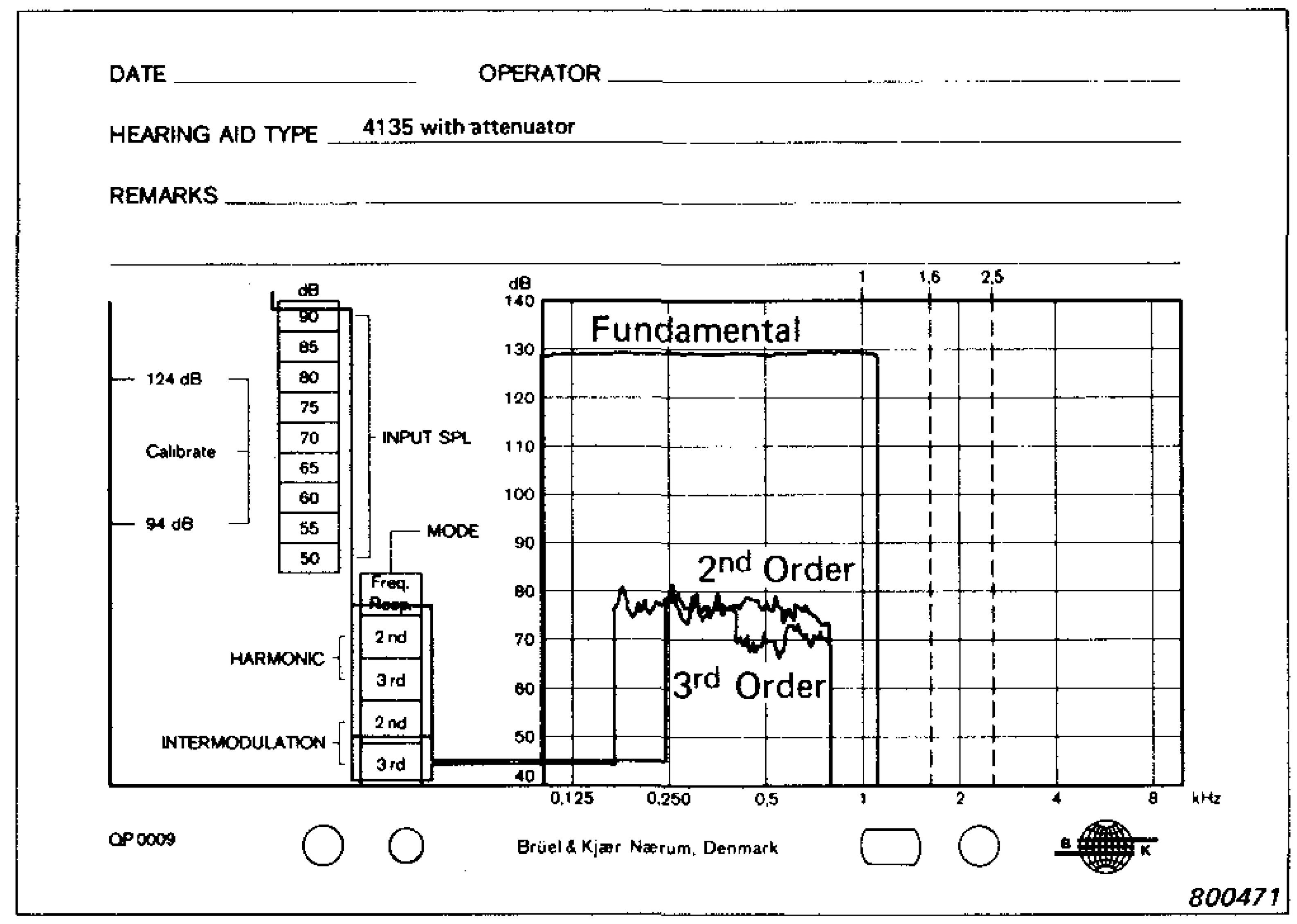

Fig.7. **Intermodulation distortion of the measuring set-up at 164 dB SPL**

components. To eliminate this effect and check the measured intermodulation products, the signal from the microphone was fed to a Narrow Band Spectrum Analyzer Type 2031. The noise and hum spectrum was first measured (averaging 128 spectra) and stored in the memory of the Analyzer. A sweep was then started on the 2116. The sweep was stopped at one frequency and 128 spectra were averaged. The "I - M" display mode of the 2031 was used, thus eliminating hum components from the display. The result, recorded on a X-Y Recorder Type 2308, is shown in Fig.8, where the two lower intermodulation component appear lower than second and third harmonic distortion components. Another intermodulation component is seen at $f_1 + f_2$, but it is still more than 35 dB below excitation level.

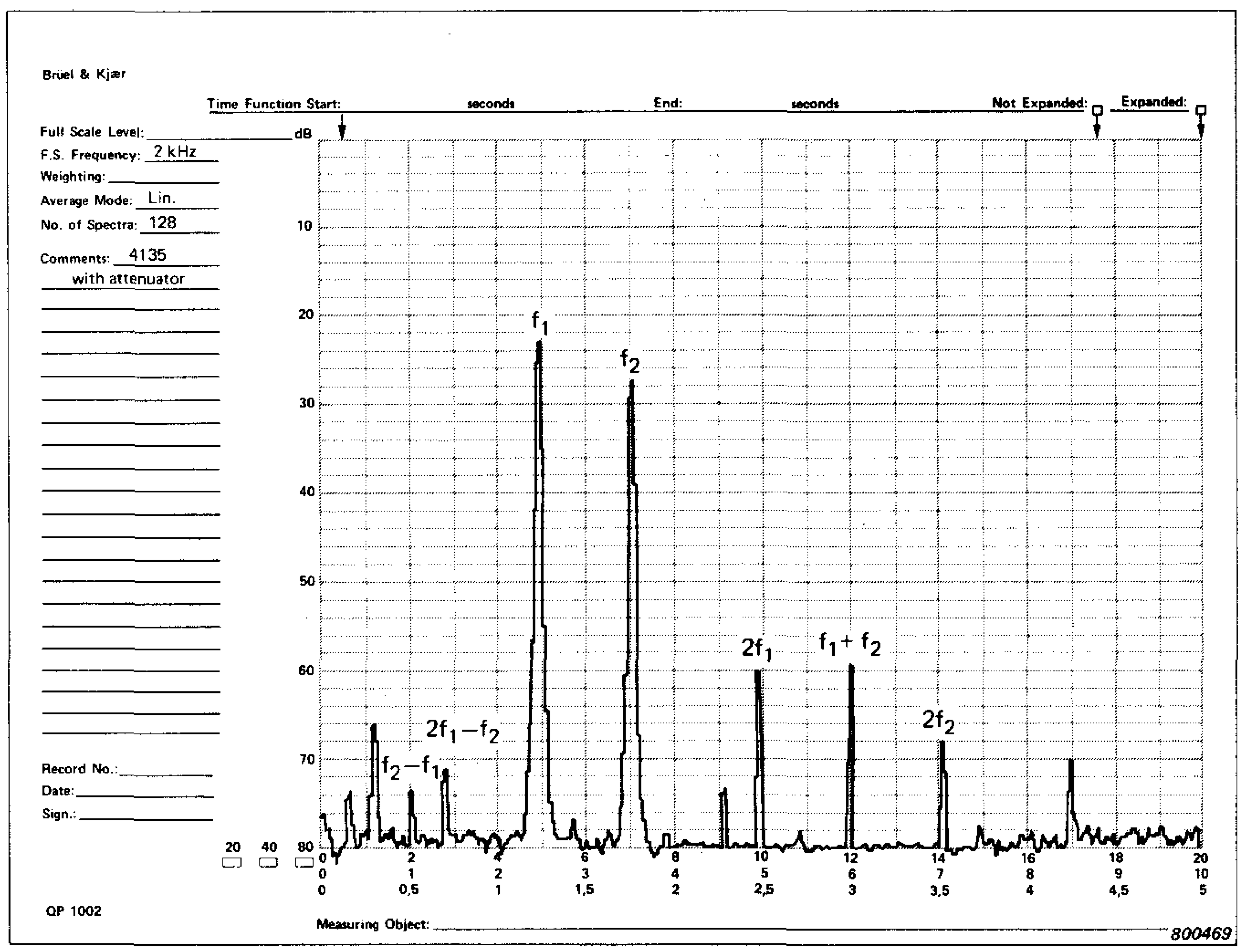

Fig.8. **Frequency spectrum showing excitation frequencies as well as harmonic and intermodulation distortion components of the measuring set-up at 164 dB SPL**

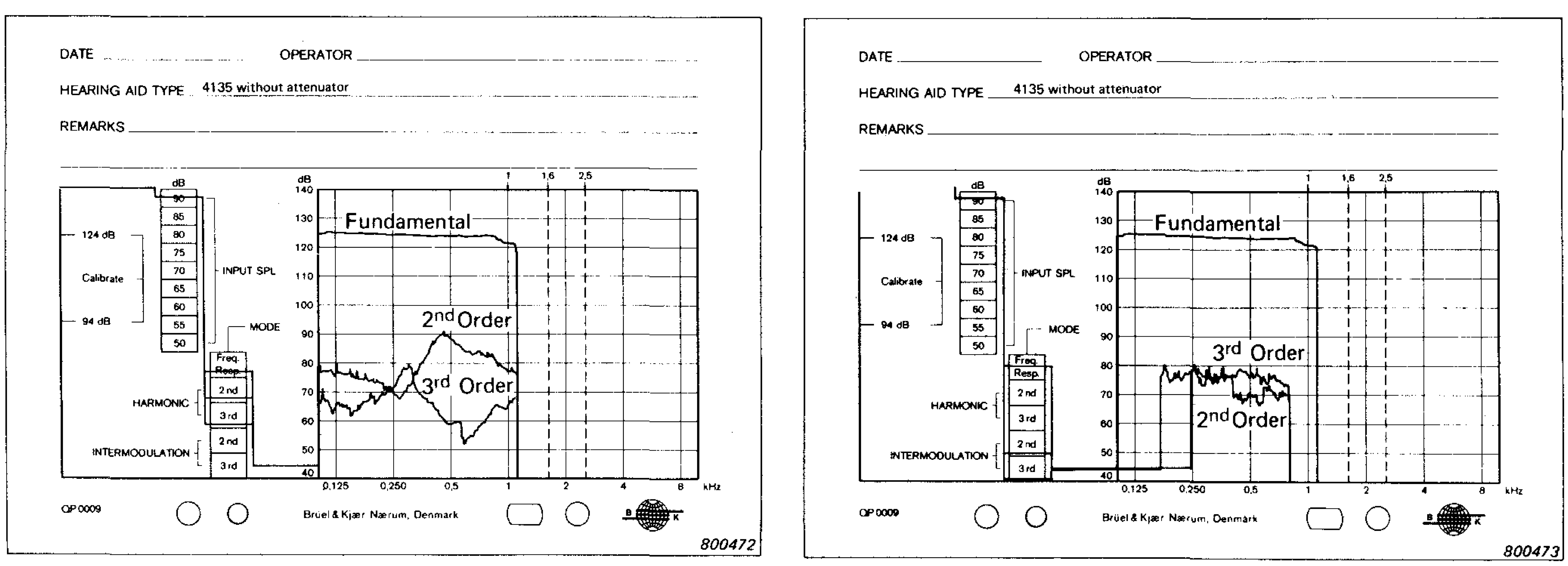

Fig.9. **a) Harmonic distortion and b) Intermodulation distortion at 164 dB SPL for the 4135 without acoustical attenuator**

The acoustical attenuator was removed and the measurements were repeated with the 4135 now excited at 164 dB. The results are shown in Fig.9 as recorded on the 2116 while Fig.10 shows the spectrum obtained at one frequency, again using the "I - M" mode of the 2031. Harmonic distortion of the 4135 for 250 Hz fundamental frequency (see Fig.10) is approx. 2,2%, which corresponds to already published data (Reference [4]). The first intermodulation distortion product has gone up by approx. 10 dB compared to Fig.8, but is still more than 40 dB below excitation level. The second intermodulation product does not show a significant increase. This is also the case for the product at $f_1 + f_2$.

Finally, a similar spectrum was measured using the 1/2 inch Condenser Microphone Type 4134 at 160 dB SPL, which is the specified 3% harmonic distortion limit for this microphone. This spectrum (Fig.11) shows that harmonic distortion is approx. 3% and so is the component at $f_1 + f_2$. The second intermodulation distortion component is approx. 1%, while the second one is virtually unchanged compared to that obtained for the system itself.

Conclusion

Based on the Audio Test Station Type 2116 and the High Pressure Microphone Calibrator Type 4221, a simple system can be set-up to measure harmonic and intermodulation distortion of microphones at high sound pressure levels. Amplitude linearity at one frequency can also be checked simply by stepping the SPL selector of the 2116 in 5 dB steps. Measurements made on B & K Condenser Microphones have shown that their intermodulation distortion is small and does not exceed harmonic distortion.

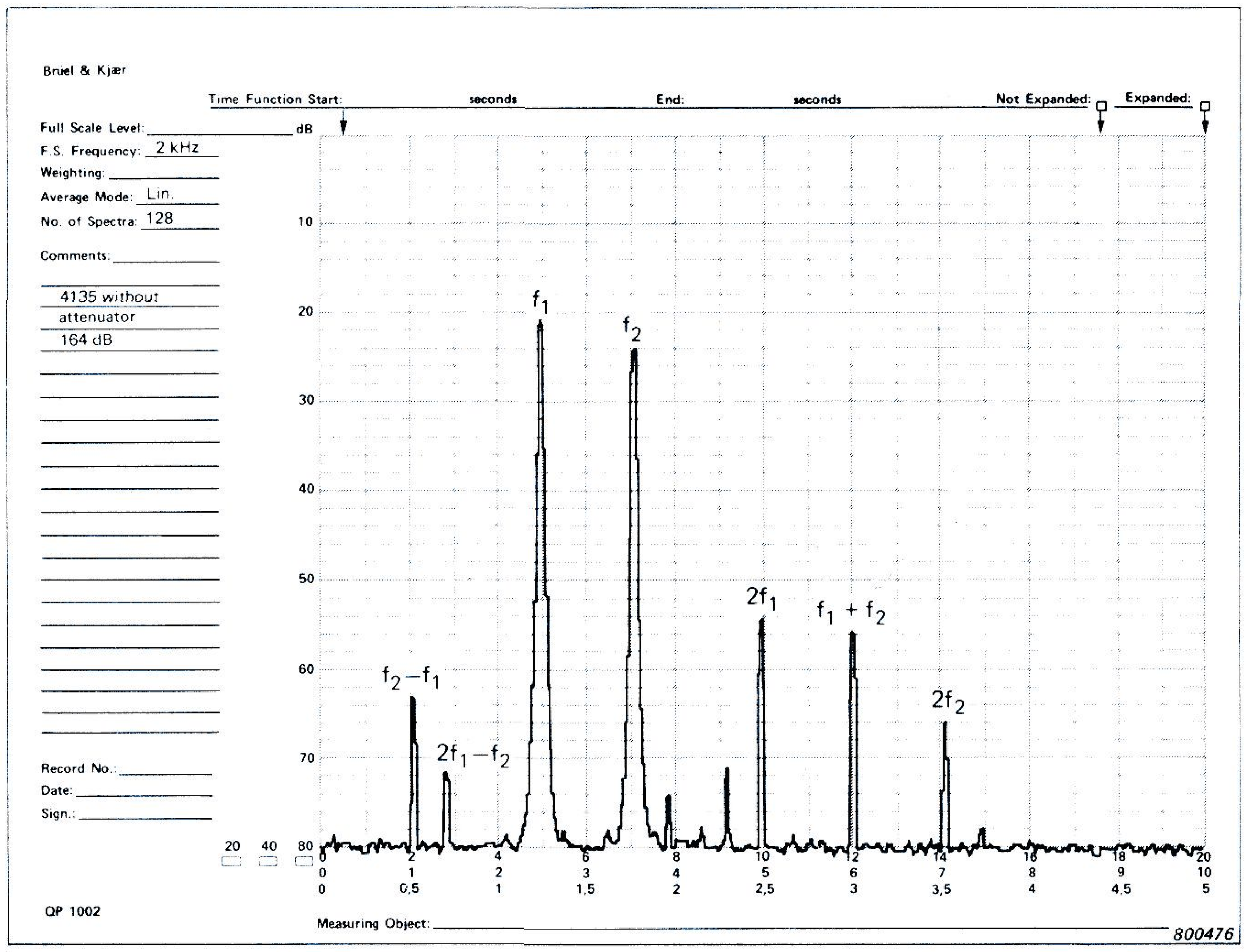

Fig.10. Frequency spectrum for dual frequency excitation at 164 dB SPL of the 4135 without acoustical attenuator

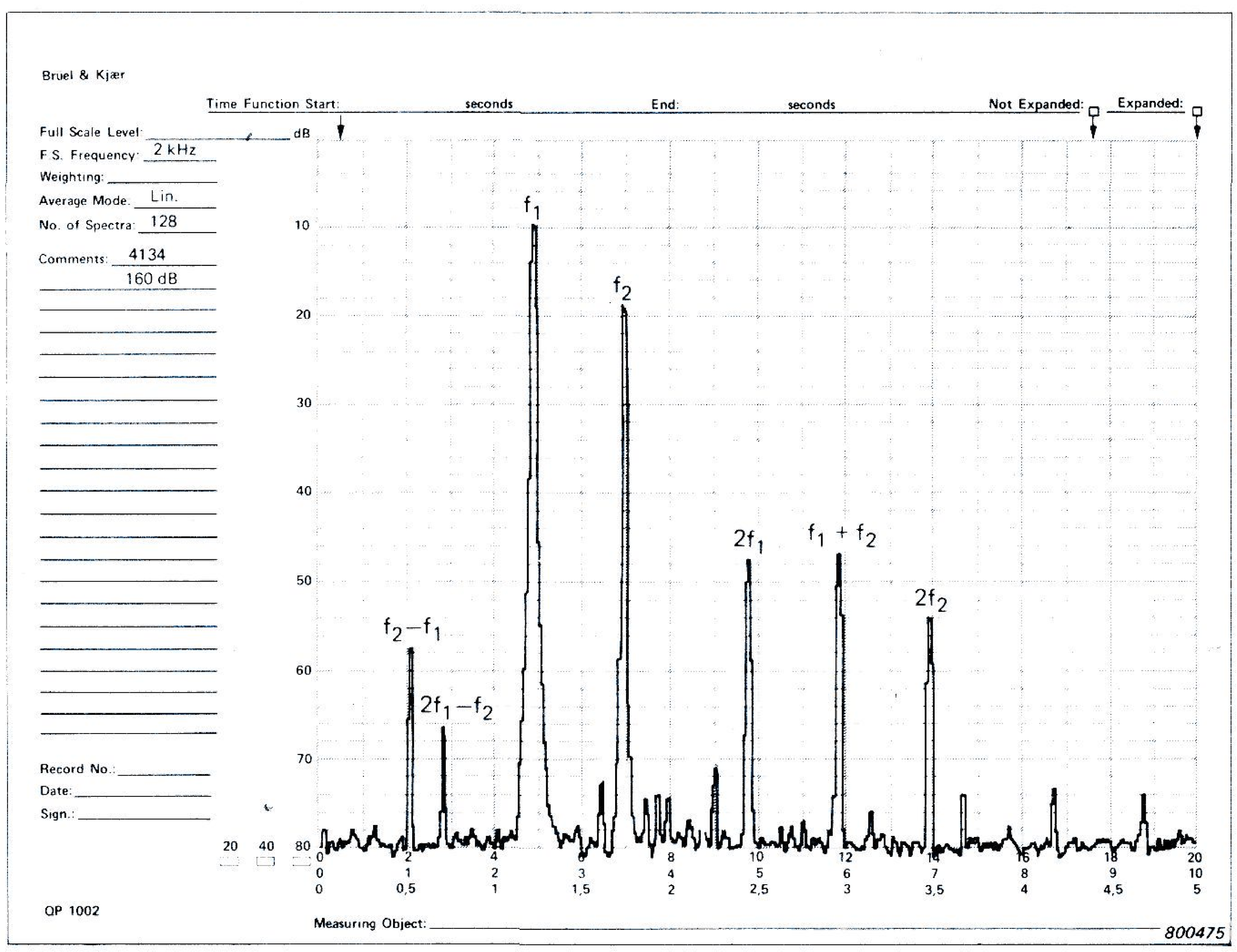

Fig.11. Frequency spectrum for dual frequency excitation of the 4134 at 160 dB SPL

References

[1] "Low Impedance Microphone Calibrator and its Advantages" by Erling Frederiksen, B & K Technical Review No.4-1977.

[2] "High Pressure Measurements with the High Pressure Microphone Calibrator 4221" Pierre Bernard and Erling Frederiksen, B & K Application Notes 17—231.

[3] "Swept Measurements of Difference Frequency, Intermodulation and Harmonic Distortion of Hearing Aids" by Philip S. White, B & K Application Notes 16—017.

[4] "Condenser Microphones and Microphone Preamplifiers — Theory and Application Handbook", Brüel & Kjær Publication, May 1977.

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