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REPEATED MEASUREMENTS ON HEARING PROTECTORS ON ACOUSTIC TEST FIXTURE

Eva Svensson

KAROLINSKA INSTITUTET
Teknisk Audiologi
Dept. of Technical Audiology

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Eva Svensson

ABSTRACT

Ten helmets with built-in hearing protectors, Model Telehelmet 5, were tested during slightly more than one year (April 1983 - June 1984). We wanted to verify changes that may occur in the hearing protector concerning the sound attenuation and the application force after regular use for various periods of time. For that purpose we used an Acoustic Test Fixture and made repeated measurements. Five of the helmets showed deteriorations of sound attenuation of 10 dB or more.

Mailing address:
Teknisk Audiologi/KI
c/o KTH
S-100 44 STOCKHOLM
Sweden

Visiting address:
Teknisk Audiologi
Lindstedtsvägen 1 & 7
Kungliga Tekniska Högskolan
Stockholm

Telephone:
Nat.: 08-11 66 60
Int.: +46 8 11 66 60

Fax:
Nat.: 08-791 71 30
Int.: +46 8 791 71 30

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INTRODUCTION

Ageing effects in hearing protectors is a matter which has not been considered much. Obviously the sealing rings get stiffer with time, but the effect on the attenuation values has not been evaluated. There is no doubt that the design of hearing protectors have improved during the years. That is true regarding both attenuation and comfort. The quality of the plastic foil for the sealing rings is much better nowadays and that is the case also for the sound absorbing foamed plastic material. However there is still reason to investigate the effect of ageing sealing rings on the attenuation.

The aim of the present investigation was to verify, by repeated measurements, changes that may occur in the hearing protector after regular use for various periods of time. The parameters checked were the sound attenuation and the application force. Presumably the ear-cushion is the part of the hearing protector that mainly contributes to worsened attenuation values as a result of long time use and/or of ageing of the plastic material. The hearing protectors are influenced also by the working environment; oil mist and especially perspiration can sometimes make the sealing rings so hard that they crack. Concerning ordinary muffs one can assume that a stretched headband - and as a consequence of that a decreasing application force - contributes to deteriorated attenuation values. Varying durations between the test occasions were chosen since we wanted to investigate for how long time a hearing protector would give a satisfactory protection. Accordingly we would be able to tell how often the ear-cushions should be changed to new ones, in order to obtain an adequate sound attenuation.

I. METHODS

A. Procedure

ISO Standard 4869 "Acoustics - Measurement of sound attenuation of hearing protectors - subjective method" and Swedish Standard SS 882151 "Hearing protectors - Test methods" describe a subjective method for measuring the sound attenuation of hearing protectors based on hearing thresholds. The other Scandinavian countries have corresponding standards of the same wording as the Swedish one.

For quality inspection purposes there is an objective method according to ISO/DIS 6290 "Acoustics - Simplified method for a measurement of insertion loss of hearing protectors of ear-muff type for quality inspection purposes". This document describes an "Acoustic Test Fixture", ATF, (Figure 1, page 10) on which the hearing protector's insertion attenuation is measured. The test fixture is intentionally not called artificial head. Therefore, the results from the measurements should not be used for determination of the attenuation on man since its impedance diverges strongly from the impedance of a human ear and it is not possible to simulate bone conduction transmission on a test fixture like this. It is also evident that resonances may arise which make measurements at higher frequencies unreliable. Because of that the judgment of the results has been restricted to the frequency range 63 - 1000 Hz in the Scandinavian documents.

Ten helmets, Model Telehelmet 5 (M7347-155010), were tested in April 1983 when they were brand new. They came back for retests in January, April and June 1984. When not tested in the laboratory, the helmets were used during certain types of military exercises. These helmets were made in the late seventies by Racal Safety Ltd, England.

Two of the helmets, No.s 2 and 3, were so delayed for the third test occasion that there was no time to return them to their army command to be used during the third period before the concluding measurement in June 1984. Consequently these helmets were tested only three times. Furthermore it was uncertain how many of the helmets that really had been actively used for the stipulated number of months between the test occasions. This applies particularly to the last period in spring 1984.

B. Measurements

The measurements were made according to the Swedish Standard SS 882151. The ATF was placed in a free field in an anechoic room, 7.35m x 4.35m x 2.6m (Figure 2, page 11). Using sine wave the frequency response from 63 Hz to 8000 Hz was measured with and without the hearing protector placed on the ATF. In the present report the term 'free field' shall be interpreted as using a 'plane progressive wave'. The field is achieved according to the standard. The frequency curve was recorded by the means of a Brüel & Kjaer measuring equipment (Figure 3, page 11) through the microphone in the acoustic test fixture. The acoustic isolation of the testing device was checked according to the standard (Figure 4, page 12). Then a frequency response was recorded, that is without any hearing protector fitted to the ATF. After that the helmet was placed on the testing device and adjusted to fit the ATF in the 'best' way. With 'best' fit means, in this investigation, that the earmuffs were thoroughly centered over the microphone and that the helmet rested upon the headband spacer on top of the test fixture. To equilibrate any static pressure difference that may occur a thin silicon tube was introduced under the ear-cushion of the hearing protector. The tube was pulled out when the earmuff had been adjusted into correct position. The attenuation curve was first recorded for the muff on one side, then the helmet was turned and an attenuation curve for the other muff was recorded. The measurements were repeated three times, alternately left - right, for helmets No.s 1 and 2 to get a measure of the accuracy. As the accuracy proved to be good, (Table 1, page 8, and, Figure 5, page 13), the rest of the helmets were measured only once on each side at each test occasion. To check that the system was properly calibrated reference curves were recorded for all helmets.

Measurements were also done with the acoustic test fixture placed inside a dummy skull made out of expanded polystyrene. The dummy worked as a support for the helmet.

The application force of a hearing protector against the ear was measured with a testing device similar to a spring balance (Figure 6, page 14). The device consists of two parallel metal plates. The distance between the outer sides of the plates shall be 145 mm according to the standards. Between the two plates a force indicator is placed. The hearing protector (the helmet) was placed on the measuring device. The measured force is expressed in newton. The results from this investigation are expressed as mean values of five measurements.

II. RESULTS

When analysing the results shown in Figures 7 - 46, page 15 - 54, it is evident, on one hand that uncertainty exists for 63 Hz, and on the other, as mentioned earlier, that higher frequencies show varying sound attenuation which can be explained by uncertainty in measurements at these frequencies. There are four helmets (No.s 1, 3, 4 and 5) that show no systematic deterioration in the frequency range 125 - 1000 Hz. The other helmets (No.s 2, 6, 7, 8 and 9) show systematic deteriorations of sound attenuation on the test fixture of 10 dB or more. For helmet No. 10 the value is 5 - 10 dB. Helmet No.s 6, 7 and 9 show deterioration after the second test occasion. The varying degrees of deterioration may be due to the fact that the hearing protectors were used for various periods of time.

To assess the reliability of the measurements the helmets No.s 1 and 2 were measured repeatedly three times on each side (both left and right side) at each test occasion. A common value of the standard deviation was obtained by calculating the square root of the mean of the variances for these two helmets. (Figure 47, page 55).

It is worth noting that in some cases impresses on the plastic foil were observed. They might have given rise to leakage and deteriorated attenuation at low frequencies.

However, it must be emphasized that the load of the earmuff was a plane metal surface and that the changes of the sound attenuation are relevant only when compared to earlier measurements by the same testing device. To get a good attenuation on man there are greater demands of the elasticity of the ear-cushions than when experimented with a measuring device, not to mention the individual variations. This means that it is most probable that the attenuation values on human ears are worse. The results achieved with the ATF can not be translated to be relevant to the human ear!

Changes in application force are small. However, a tendency to decreased application force is manifested for six of the ten helmets, (Table 2, page 9).

III. CONCLUSIONS

As can be seen from the results of the mean attenuation values the deterioration changed over time. The magnitude of the changes indicate that an exchange of the sealing rings would have been suitable at least once a year to ensure satisfactory protective effect. As mentioned earlier in this report, these hearing protectors were used during certain types of military exercises only, and not for every day use. Unfortunately we do not know for how long time they have been actively used.

Concerning the application force it has been difficult to draw any conclusions. As these are helmets with built-in hearing protectors and not ordinary hearing muffs one cannot be sure that it is the headband of the muff that has been extended. However, a tendency to decreased application force was manifested for a majority of the helmets.

IV. ACKNOWLEDGEMENTS

I would like to express my gratitude to the following colleagues of mine:

Sven-Eric Appelgren for very good collaboration with the physical measurements and the many calculations made;

Björn Hagerman for strongly supporting the work with this report;

Bertil Johansson for initiating the project;

Ann-Cathrine Lindblad for critical reading of earlier draft of the manuscript and for checking the English wording.

V. REFERENCES

ISO IS 4869 Acoustics - Measurement of sound attenuation of hearing protectors - subjective method.

Svensk Standard SS 882151 Hearing protectors - Test methods.

ISO/DIS 6290 Acoustics - Simplified method for a measurement of insertion loss of hearing protectors of ear-muff type for quality inspection purposes.

DATE: 840109

63	125	250	500	1000	2000	3150	4000	6300	8000	FREQUENCY, Hz
78	64	63	50	50	52	54	58	45	45	MEASUREM. 1
75	64	63	50	50	51	56	58	46	44	MEASUREM. 2
74	64	63	49	49	52	54	59	45	42	MEASUREM. 3
75.7	64	63	49.7	49.7	51.7	54.7	58.3	45.3	43.7	MEAN
2.1	< 0.6	< 0.6	0.6	0.6	0.6	1.2	0.6	0.6	1.5	STAND DEV

86	88	91	91	93	89	91	94	83	72	REF
75.7	64	63	49.7	49.7	51.7	54.7	58.3	45.3	43.7	MEAN
10.3	24	28	41.3	43.3	37.3	36.3	35.7	37.7	28.3	ATTENUATION, dB

Table 1 Attenuation values for helmet No. 1, right side, measured three times repeatedly

TEST OCCASION

	FEB 1983	JAN 1984	APRIL 1984	JUNE 1984
HELMET 1	$\bar{X}$ = 10,9 s = 0,2	$\bar{X}$ = 12,1 s = 0,5	$\bar{X}$ = 12,6 s = 0,4	$\bar{X}$ = 11,9 s = 0,2
HELMET 2	$\bar{X}$ = 11,7 s = 0,1	$\bar{X}$ = 12,3 s = 0,1	$\bar{X}$ = 9,7 s = 0,2	$\bar{X}$ = - s = -
HELMET 3	$\bar{X}$ = 12,0 s = 0,2	$\bar{X}$ = 11,8 s = 0,3	$\bar{X}$ = 12,5 s = 0,3	$\bar{X}$ = - s = -
HELMET 4	$\bar{X}$ = 11,7 s = 0,1	$\bar{X}$ = 12,2 s = 0,3	$\bar{X}$ = 10,4 s = 0,2	$\bar{X}$ = 9,4 s = 0,2
HELMET 5	$\bar{X}$ = 12,0 s = 0,2	$\bar{X}$ = 12,7 s = 0,2	$\bar{X}$ = 12,0 s = 0,2	$\bar{X}$ = 9,3 s = 0,4
HELMET 6	$\bar{X}$ = 11,3 s = 0,3	$\bar{X}$ = 12,4 s = 0,2	$\bar{X}$ = 13,1 s = 0,5	$\bar{X}$ = 11,5 s = 0,2
HELMET 7	$\bar{X}$ = 13,0 s = 0,2	$\bar{X}$ = 12,2 s = 0,3	$\bar{X}$ = 12,4 s = 0,2	$\bar{X}$ = 11,0 s = 0,1
HELMET 8	$\bar{X}$ = 11,4 s = 0,2	$\bar{X}$ = 10,7 s = 0,3	$\bar{X}$ = 12,5 s = 0,5	$\bar{X}$ = 8,9 s = 0,2
HELMET 9	$\bar{X}$ = 14,2 s = 0,2	$\bar{X}$ = 13,6 s = 0,4	$\bar{X}$ = 13,8 s = 0,5	$\bar{X}$ = 10,5 s = 0,3
HELMET 10	$\bar{X}$ = 11,9 s = 0,2	$\bar{X}$ = 11,6 s = 0,3	$\bar{X}$ = 12,6 s = 0,2	$\bar{X}$ = 10,2 s = 0,3
HELMET 1 & 4 - 10	$\bar{X}$ = 12,1 s = 1,0	$\bar{X}$ = 12,2 s = 0,8	$\bar{X}$ = 12,4 s = 1,0	$\bar{X}$ = 10,3 s = 1,1

Table 2 Application force, expressed in newton, for Telehelmet 5

Dimensions in mm

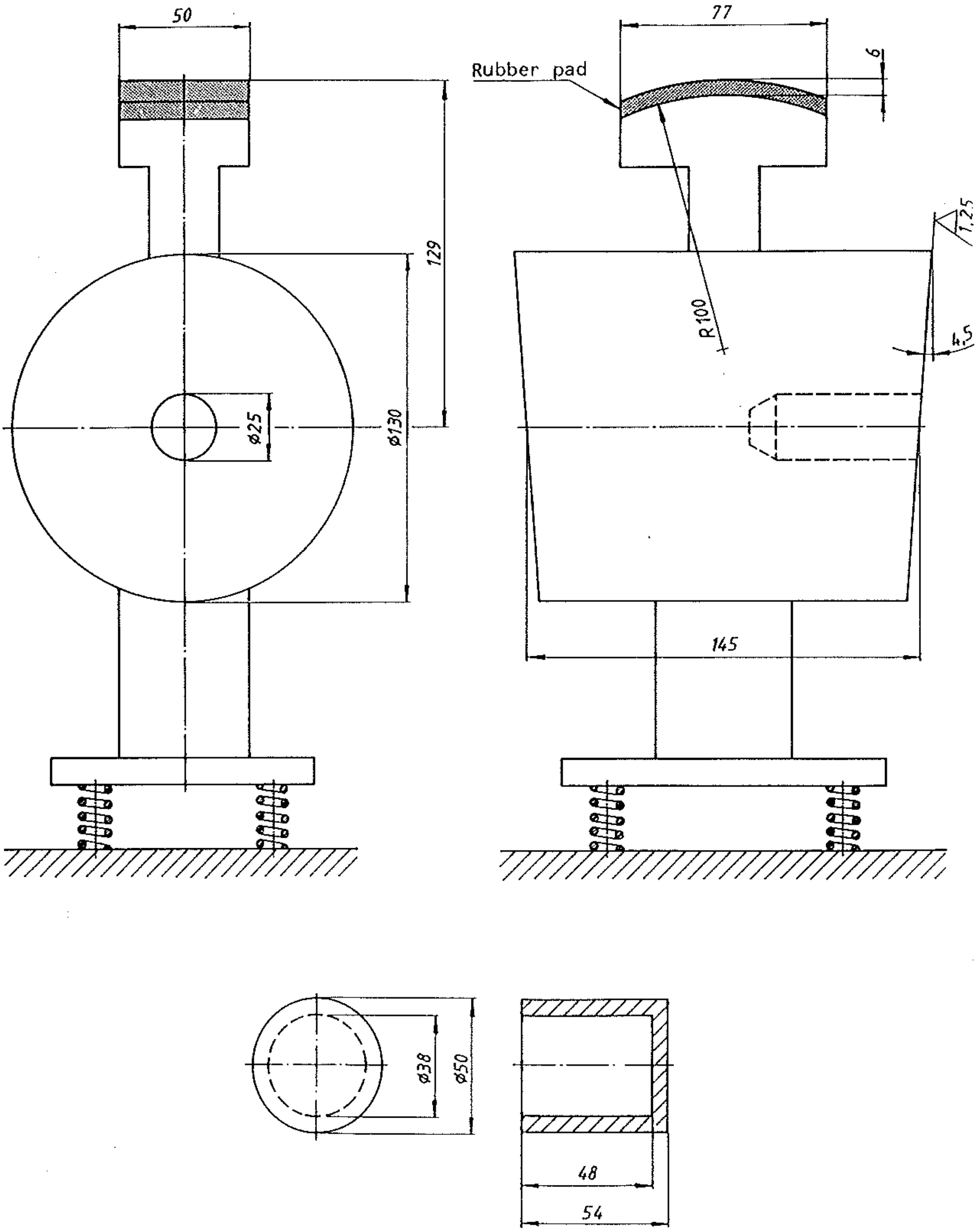

Figure 1 Test fixture for objective measurements (from SS 882151)

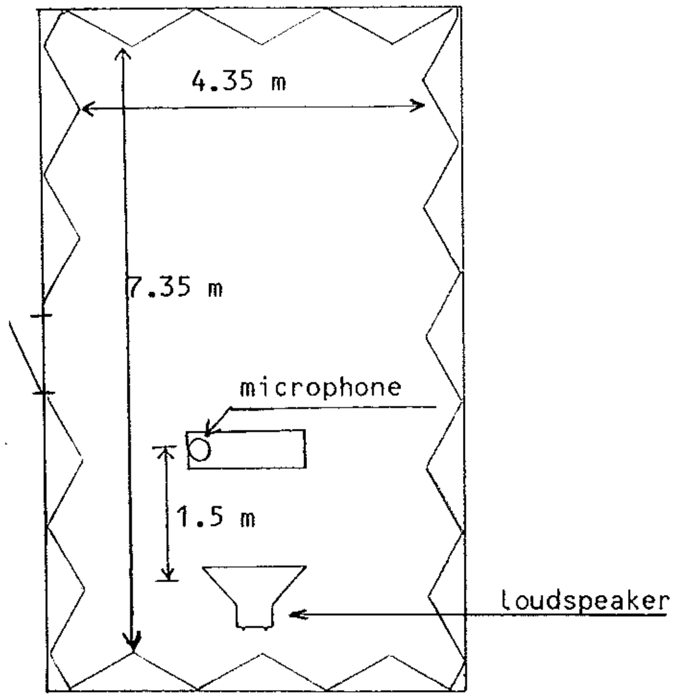

Figure 2 Position of the ATF in the anechoic room

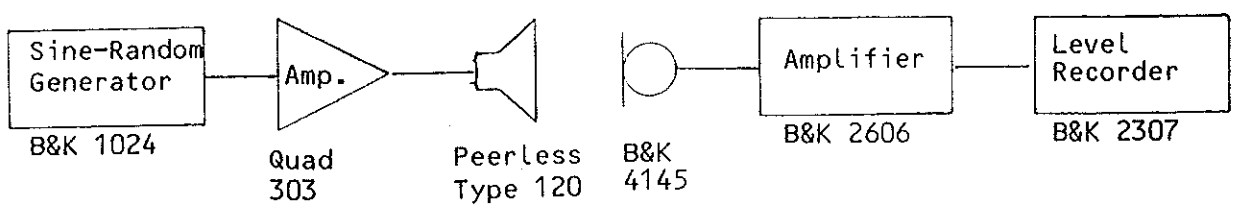

Figure 3 Measuring equipment

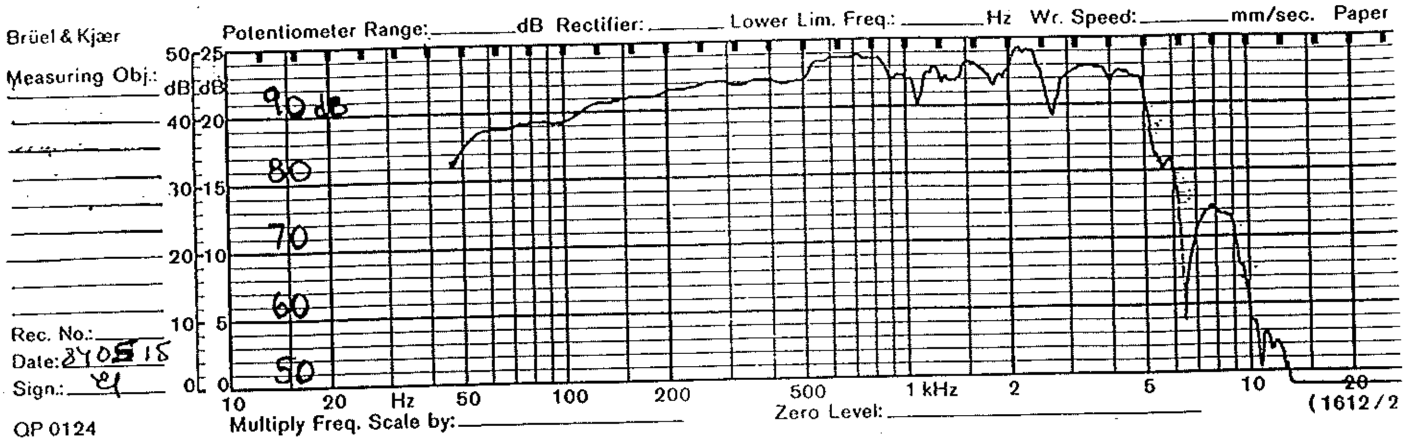

Figure 4 a

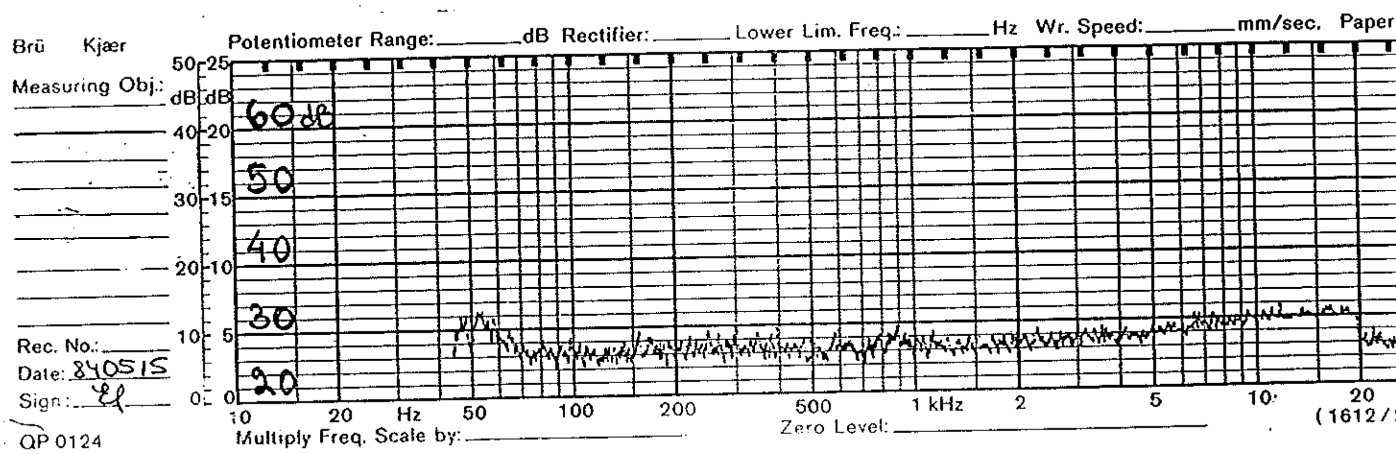

Figure 4 b

Figure 4 Frequency response for the acoustic test fixture
a) without the microphone covered
b) with the microphone covered

The acoustic isolation of the acoustic test fixture shall be at least 50 dB for the centre frequencies 63 - 125 Hz, 65 dB for 315 - 4000 Hz and 55 dB for higher centre frequencies.

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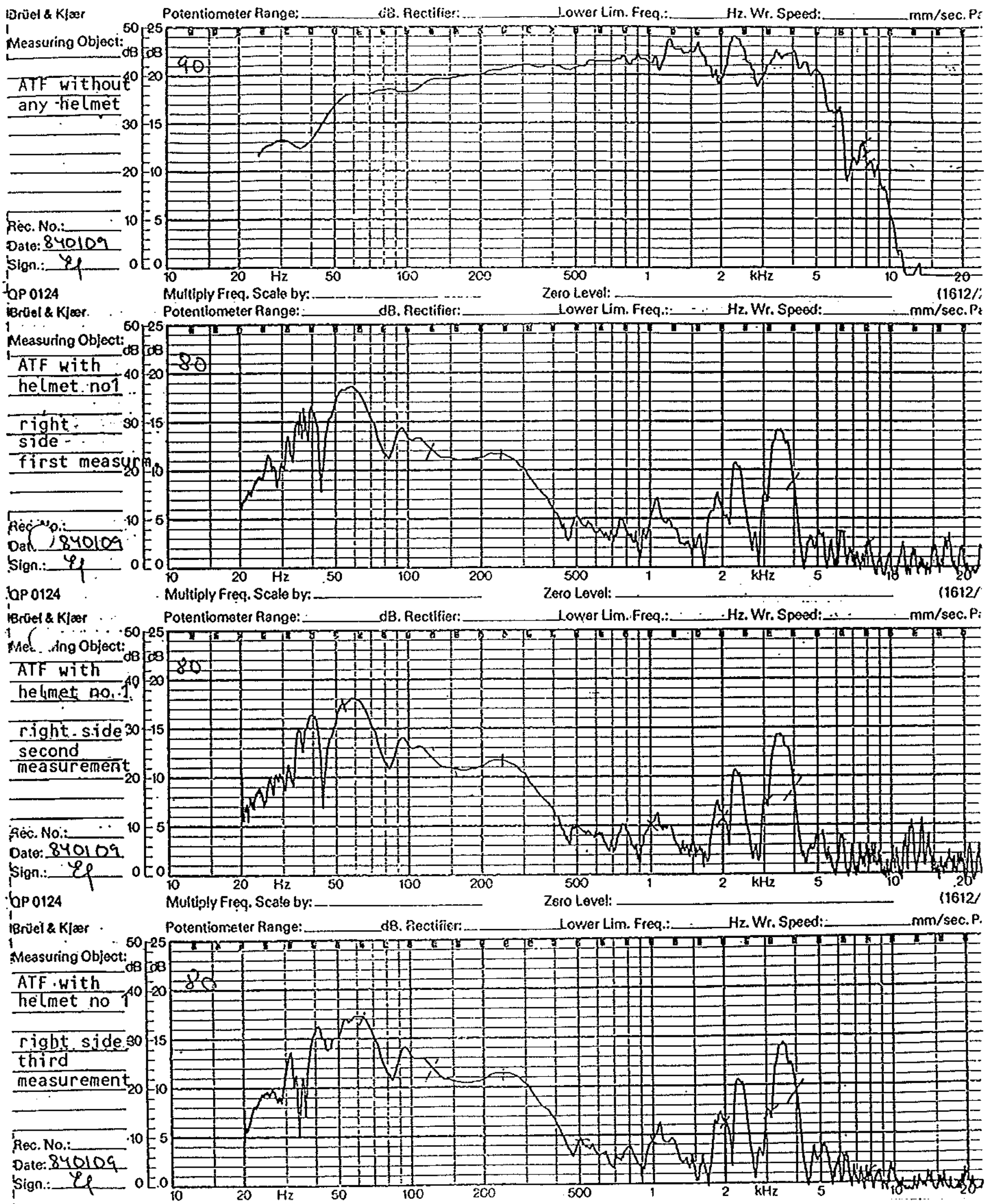

Figure 5 Attenuation curves recorded for helmet No. 1 measured three times repeatedly. Reference recording at the top.

Dimensions in mm

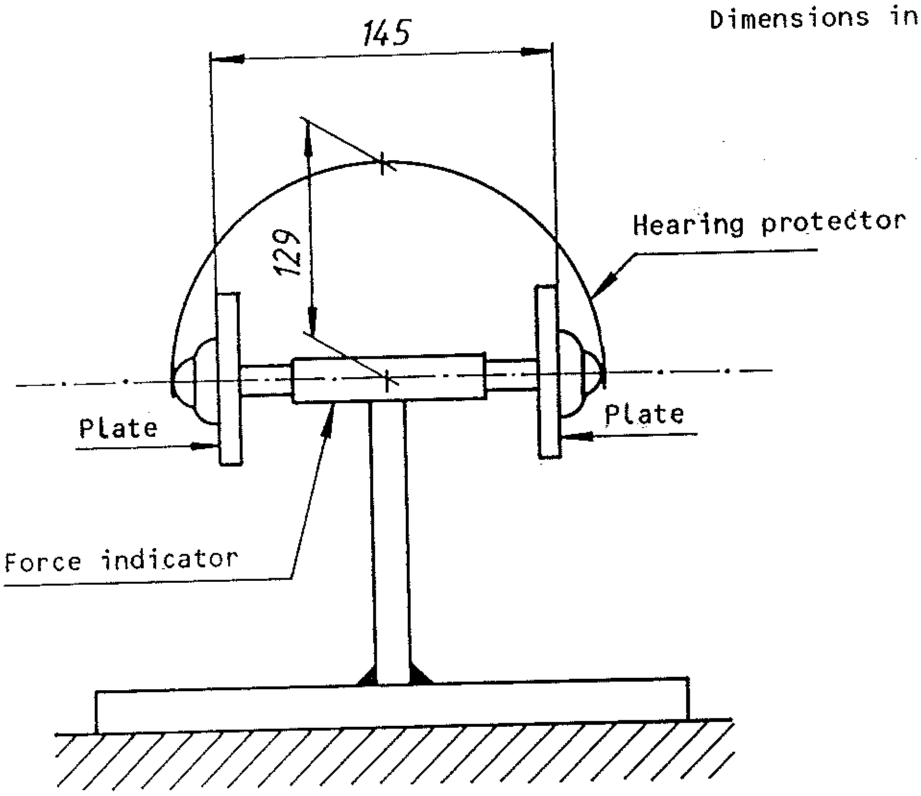

Figure 6 Testing device for application force (from SS 882151)

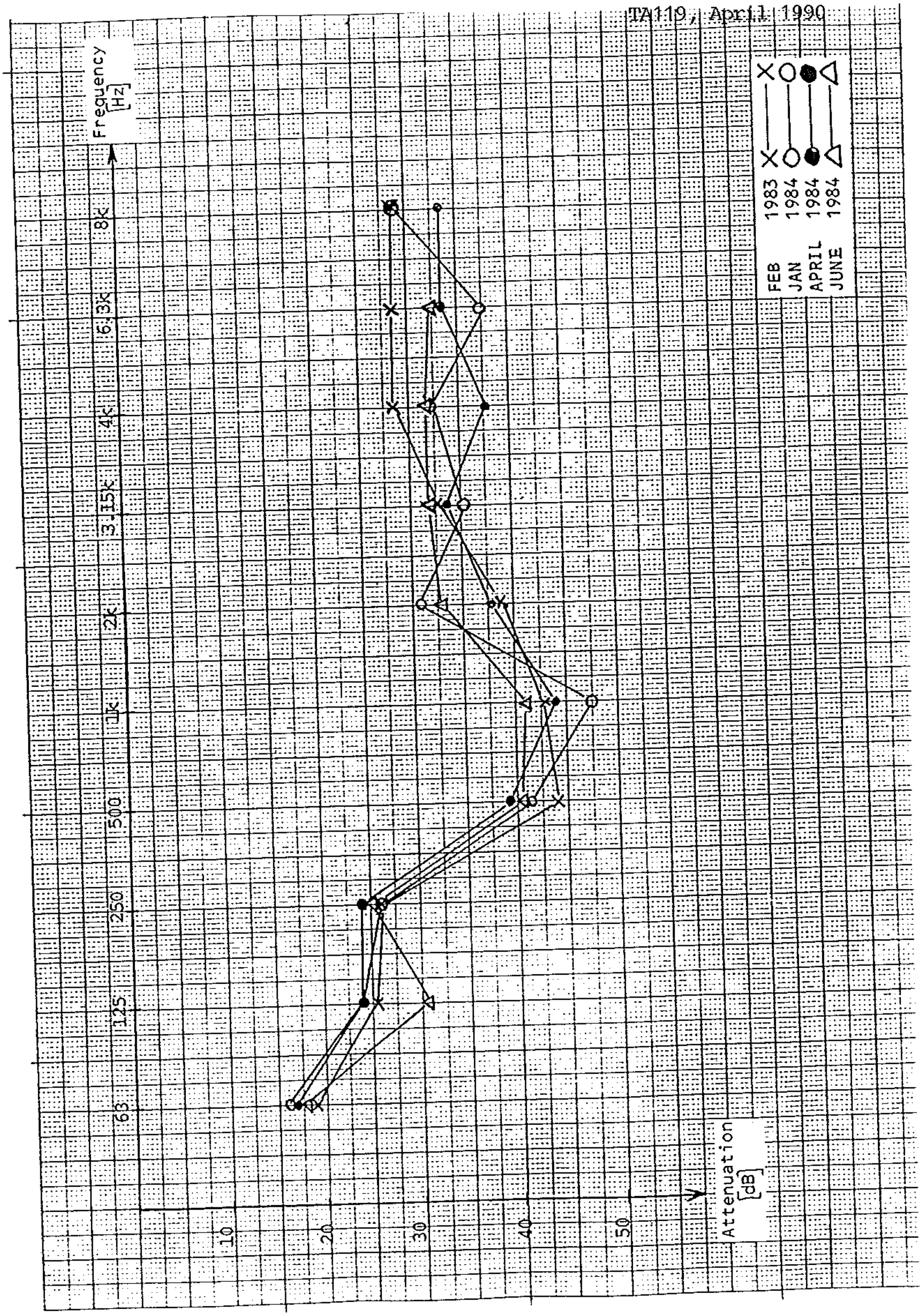

Figure 7 Mean sound attenuation for Telehelmet No. 1 without dummy skull, left side

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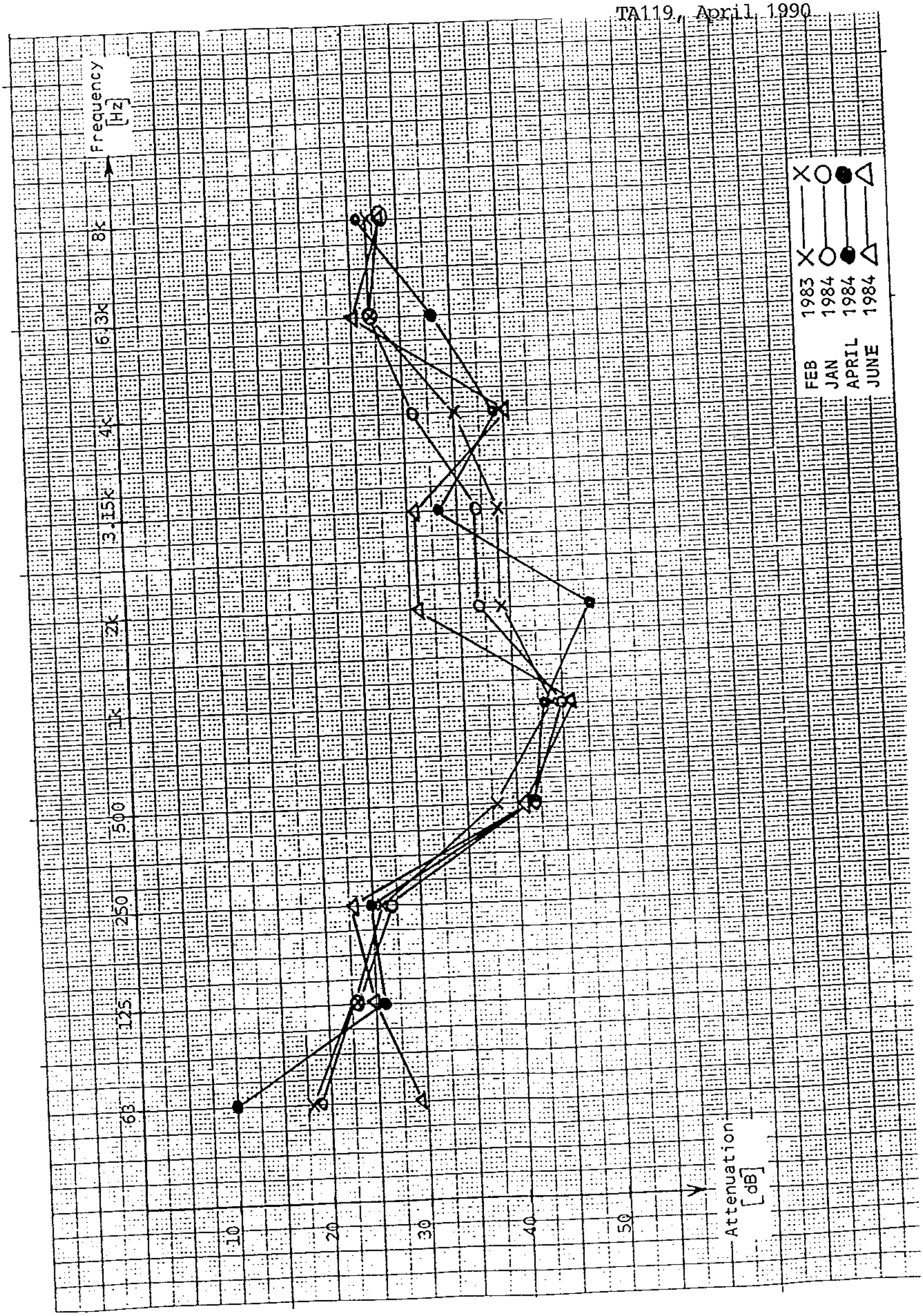

Figure 8 Mean sound attenuation for Telehelmet No. 1 with dummy skull, left side

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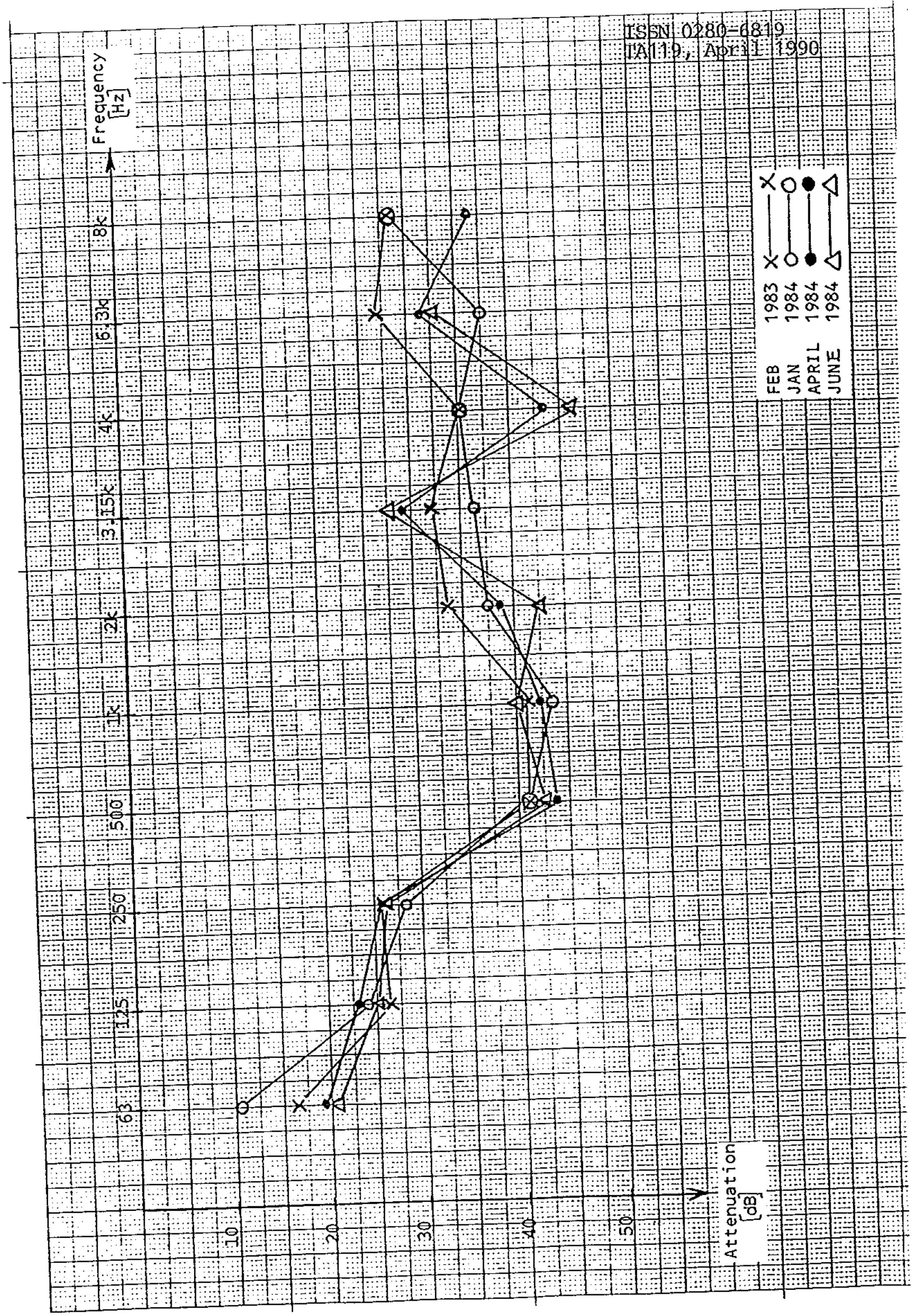

Figure 9 Mean sound attenuation for Telehelmet No. 1 without dummy skull, right side

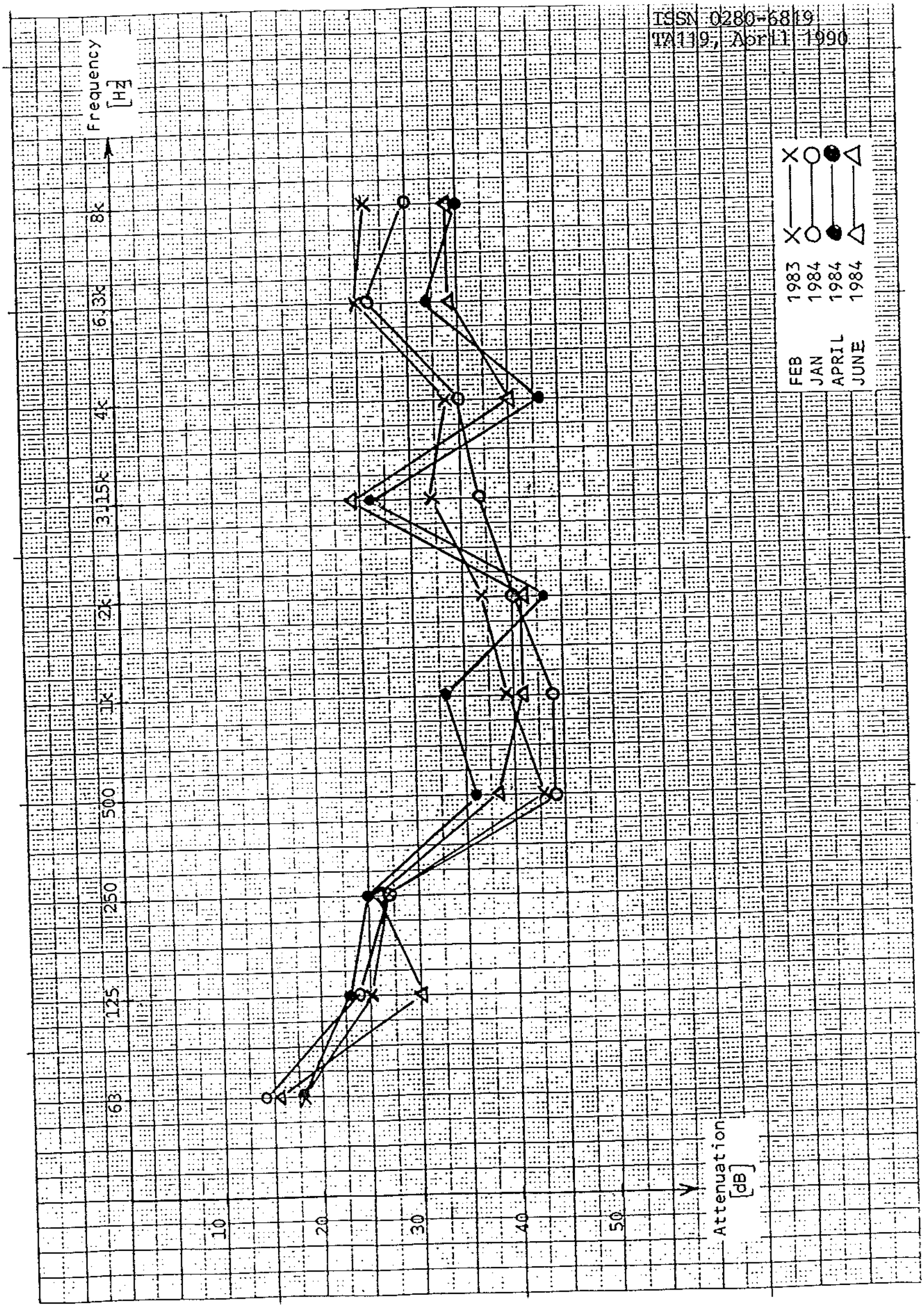

Figure 10 Mean sound attenuation for Telehelmet No. 1 with dummy skull, right side

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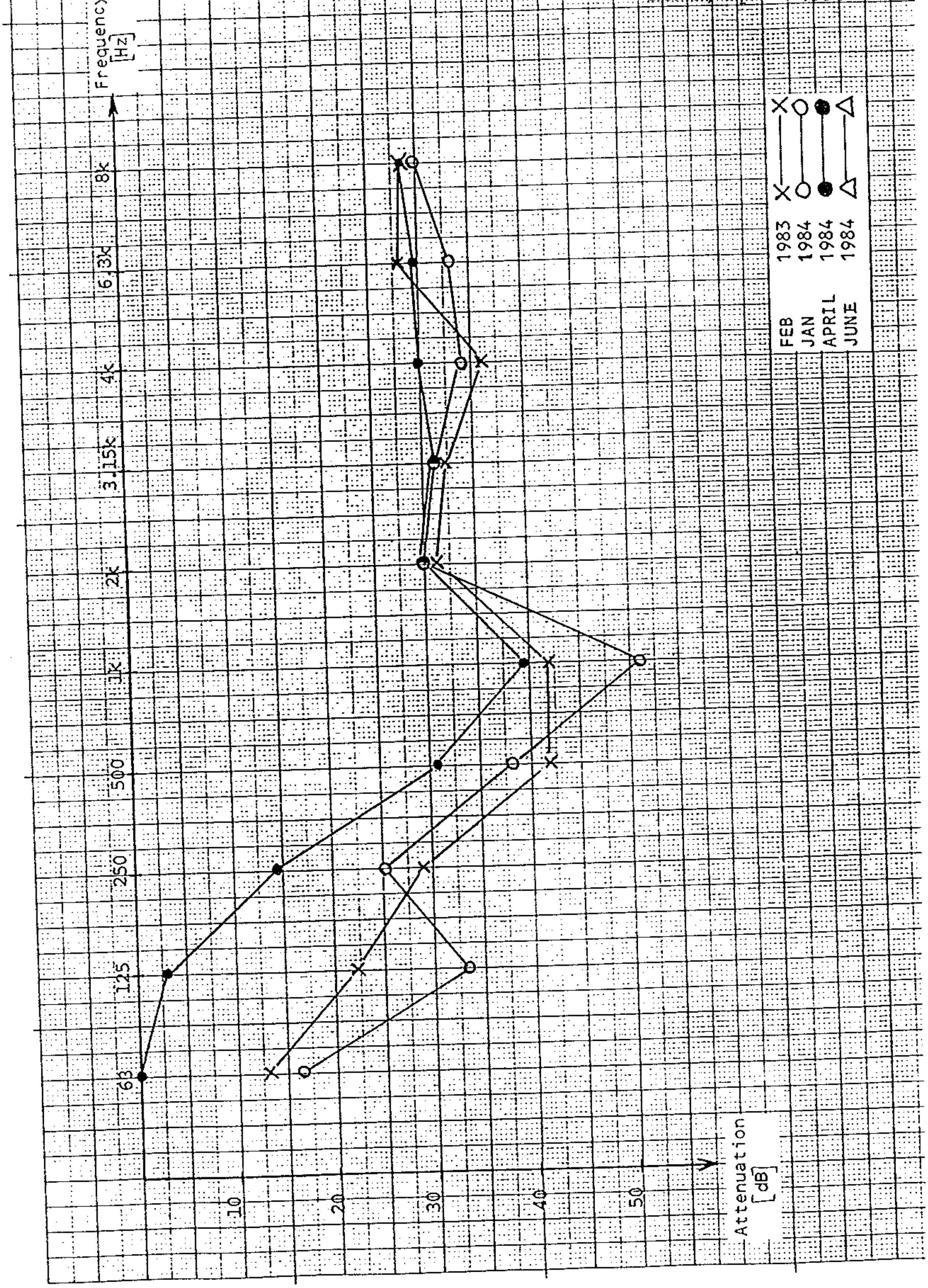

Figure 11 Mean sound attenuation for Telehelmet No. 2 without dummy skull, left side

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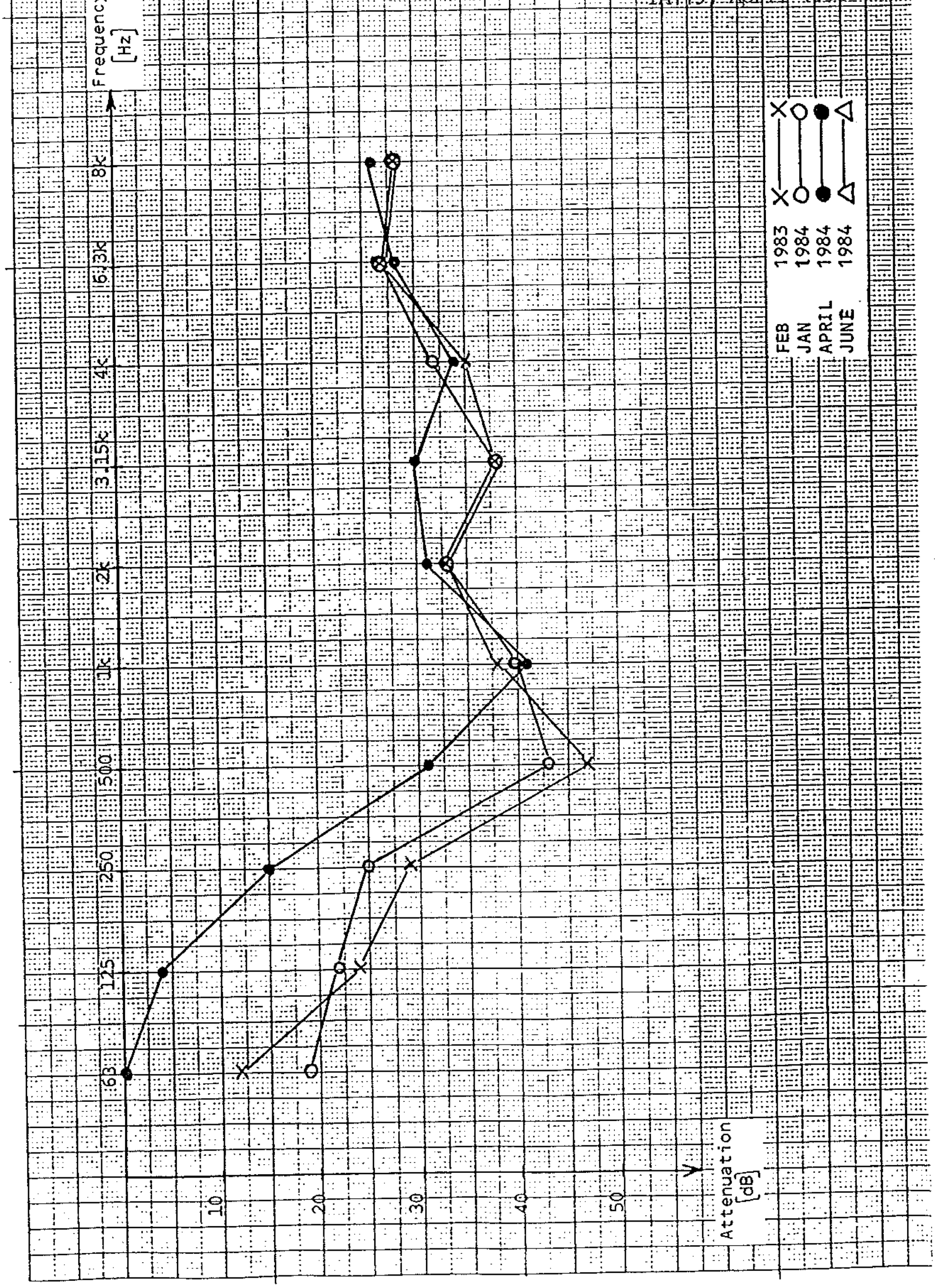

Figure 12 Mean sound attenuation for Telehelmet No. 2 with dummy skull, left side

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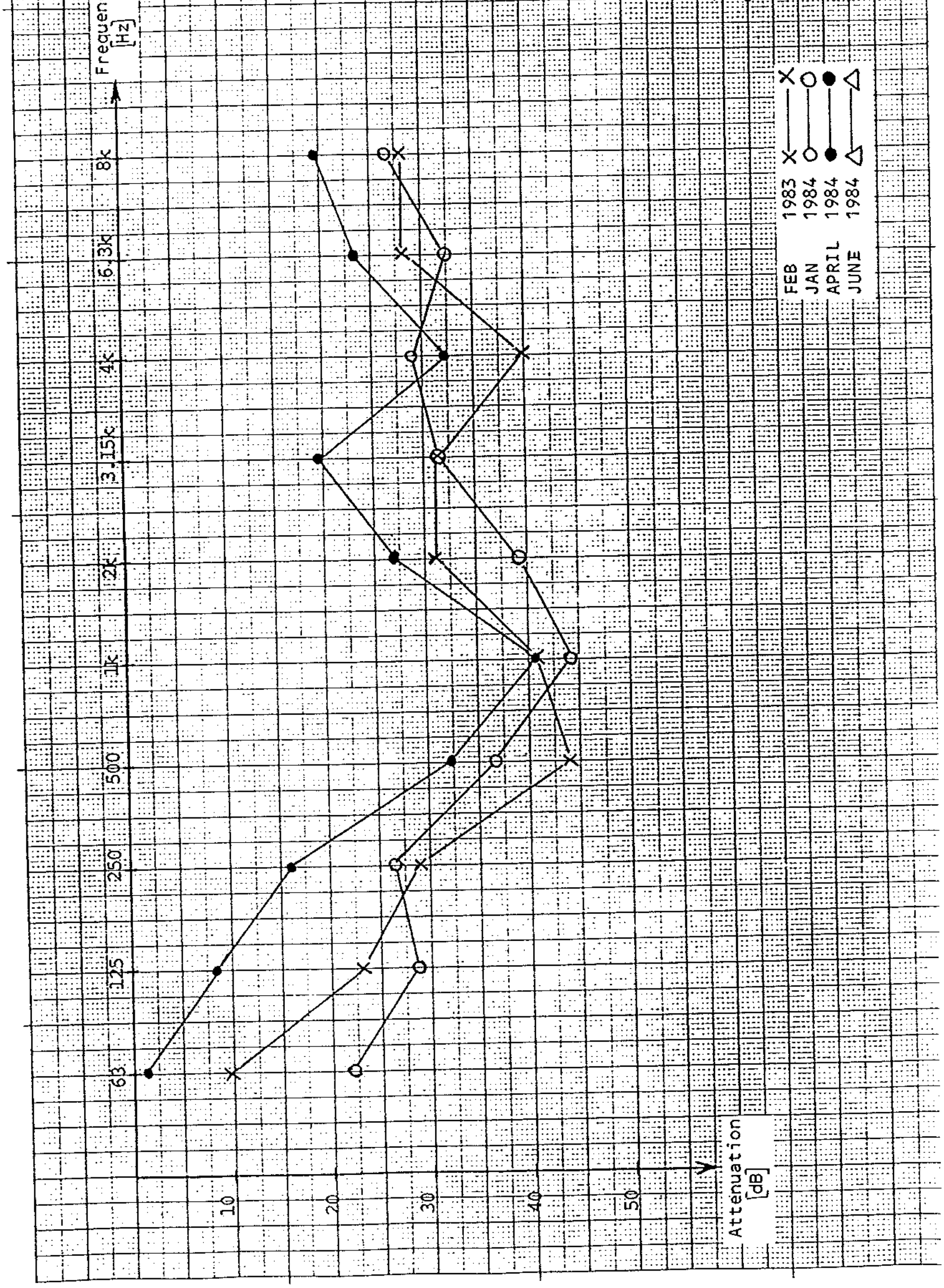

Figure 13 Mean sound attenuation for Telehelmet No. 2 without dummy skull, right side

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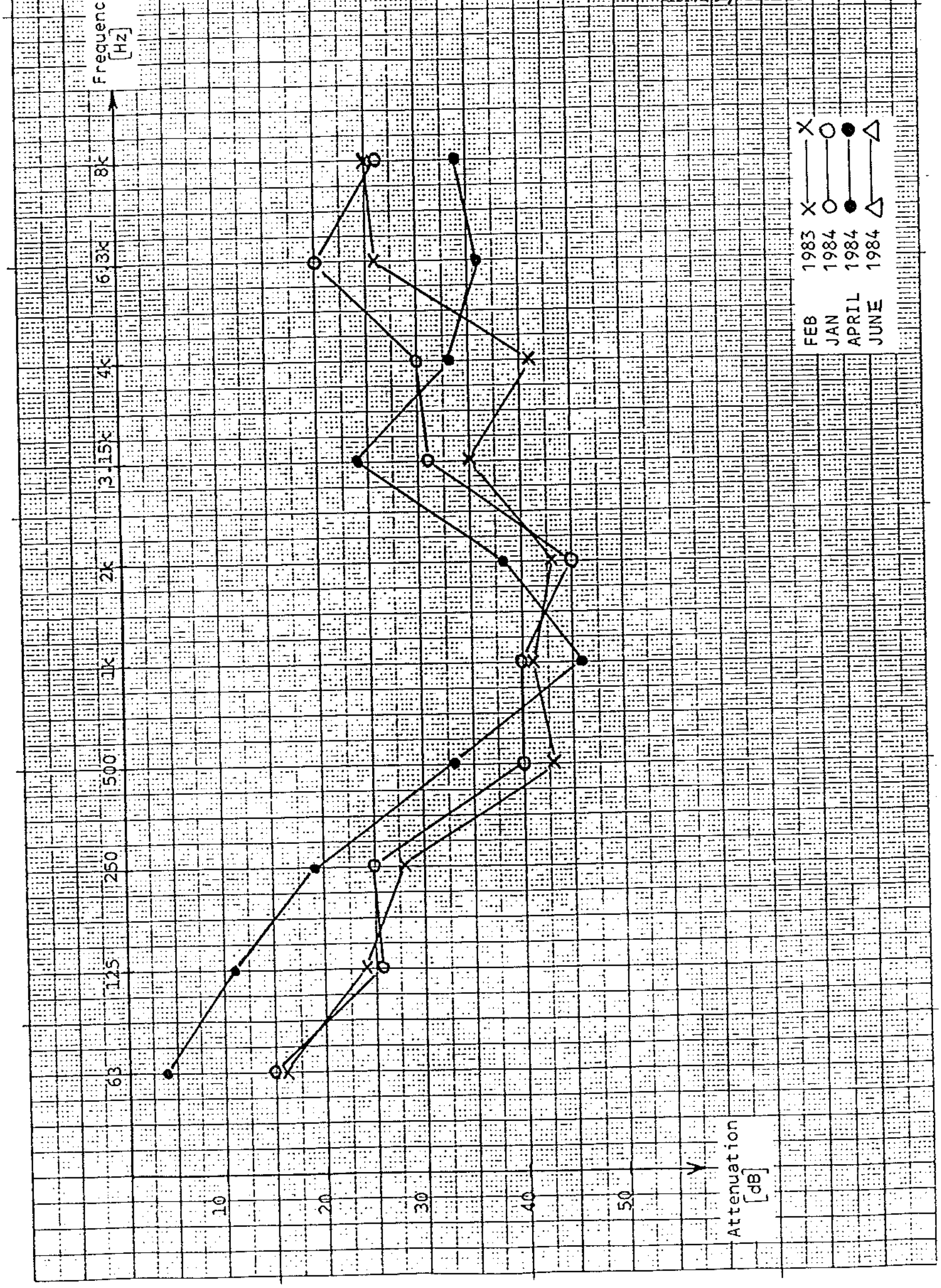

Figure 14 Mean sound attenuation for Telehelmet No. 2 with dummy skull, right side

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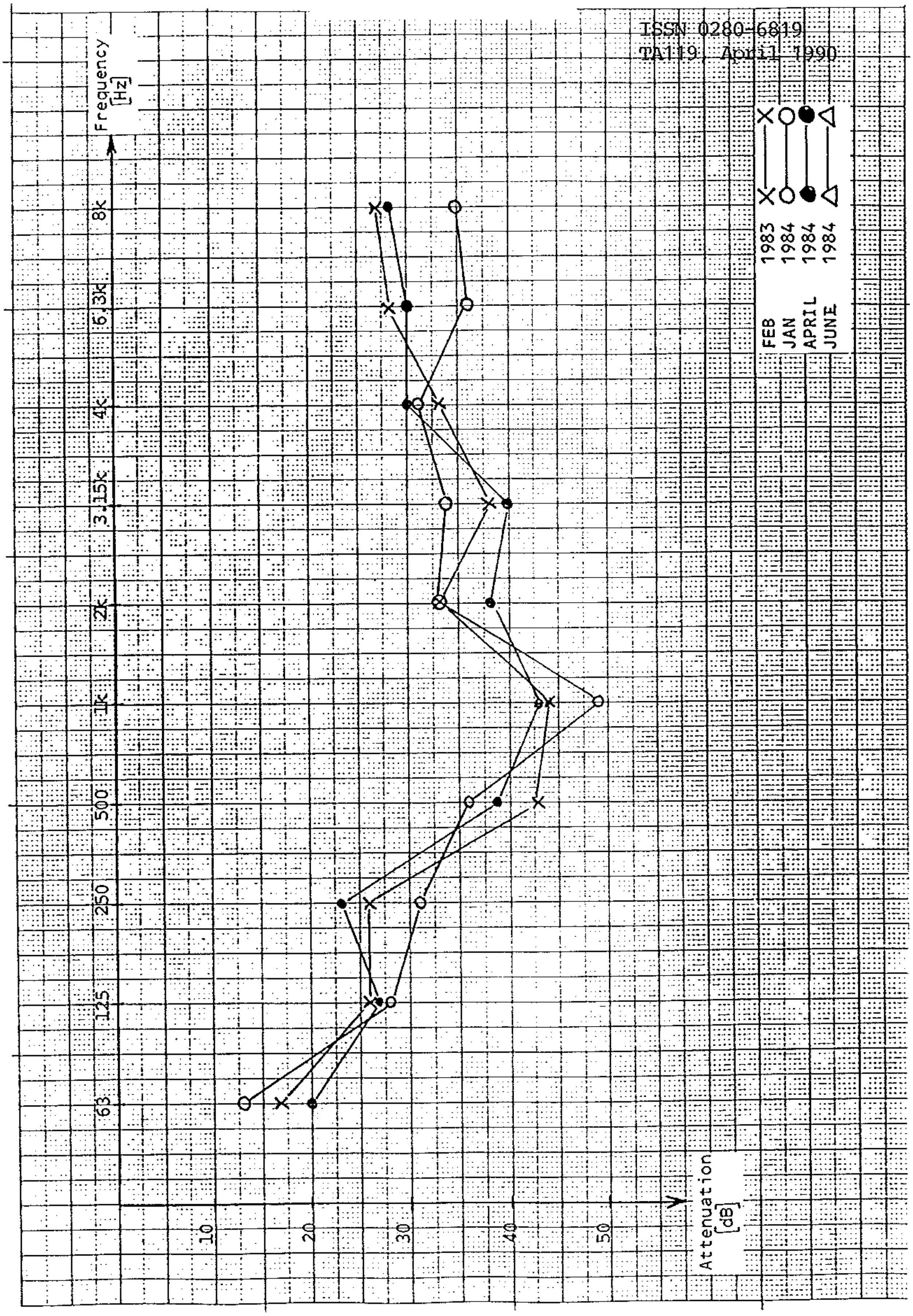

Figure 15 Mean sound attenuation for Telehelmet No. 3 without dummy skull, left side

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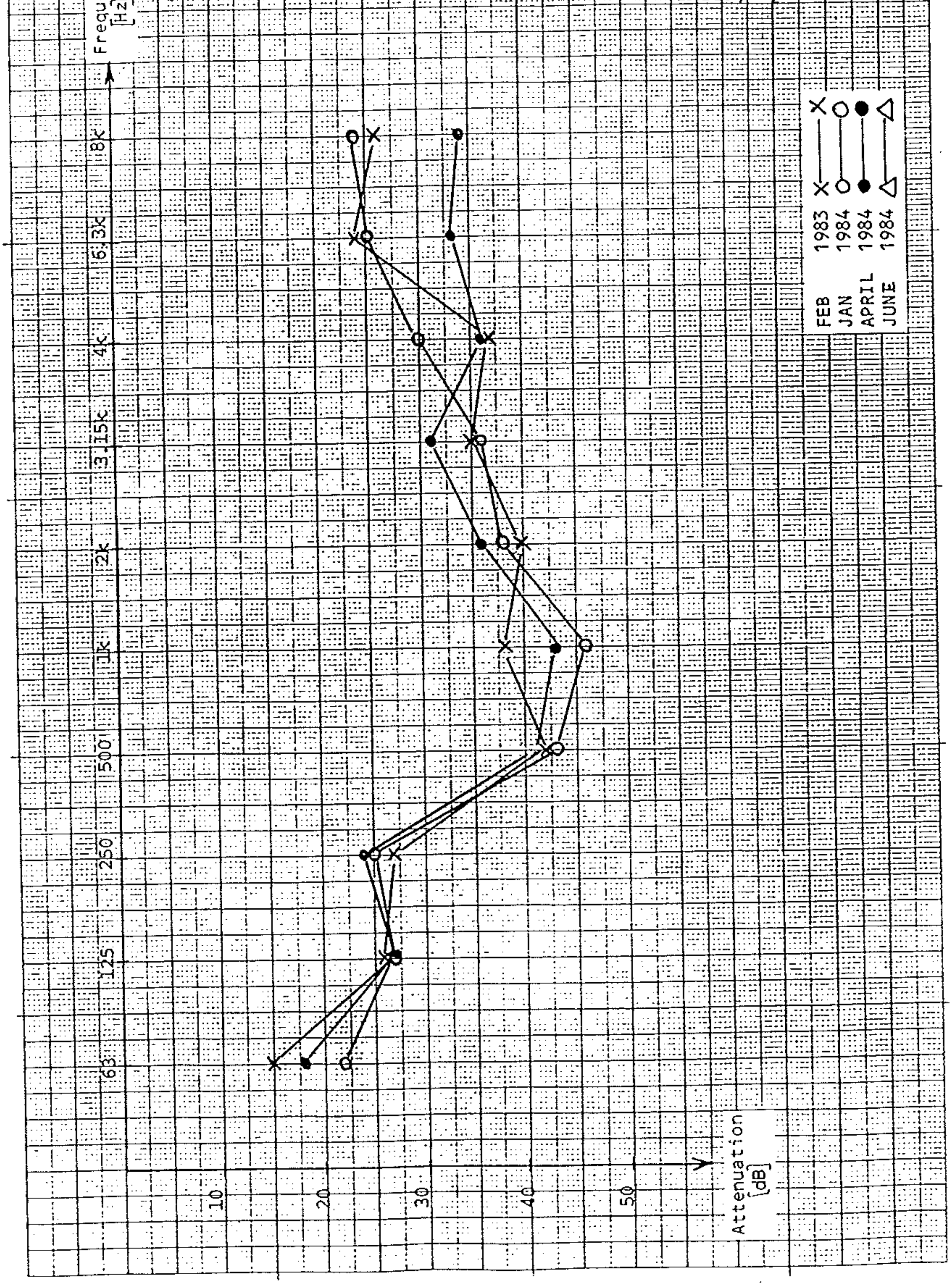

Figure 16 Mean sound attenuation for Telehelmet No. 3 with dummy skull, left side

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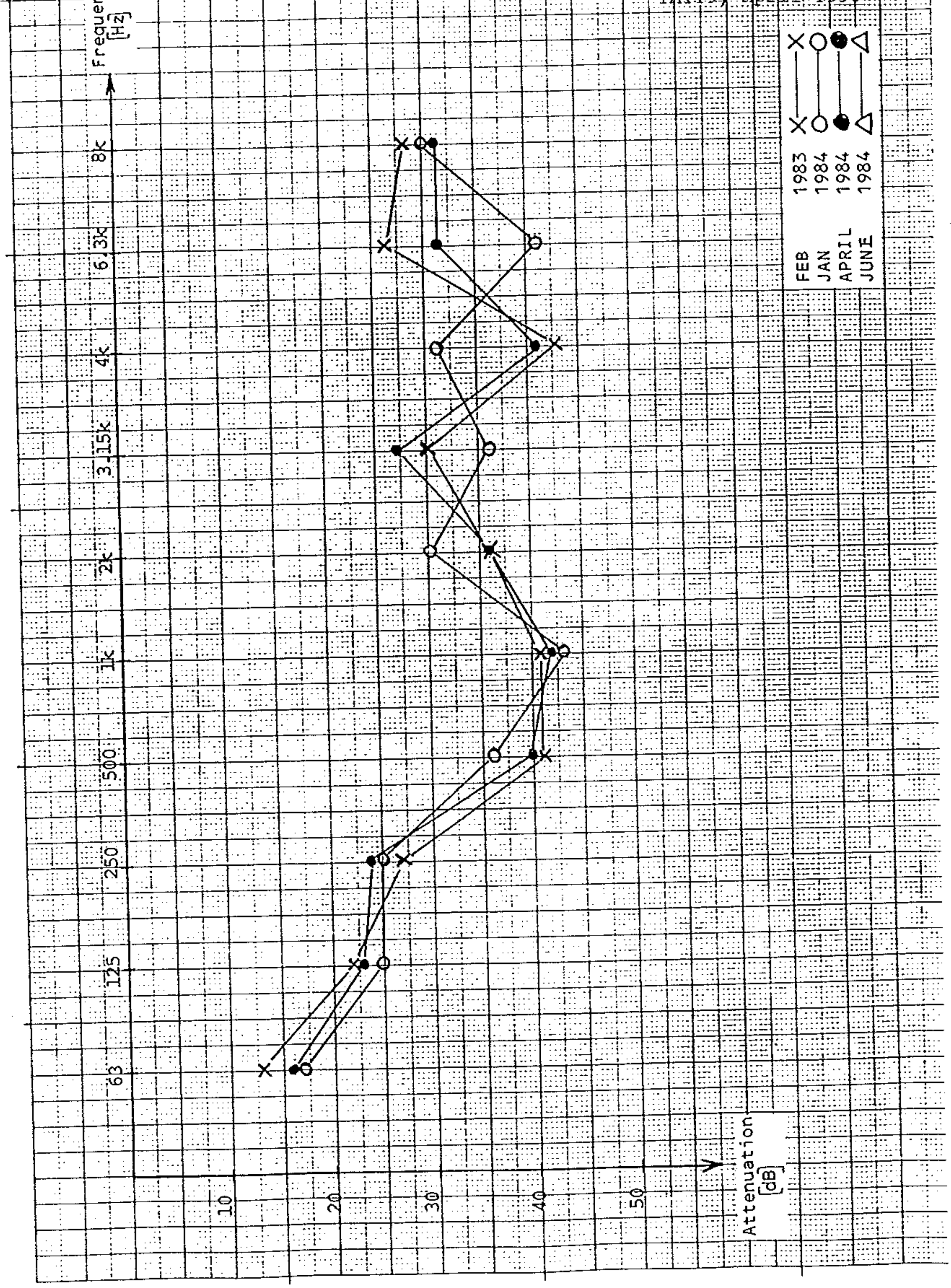

Figure 17 Mean sound attenuation for Telehelmet No. 3 without dummy skull, right side

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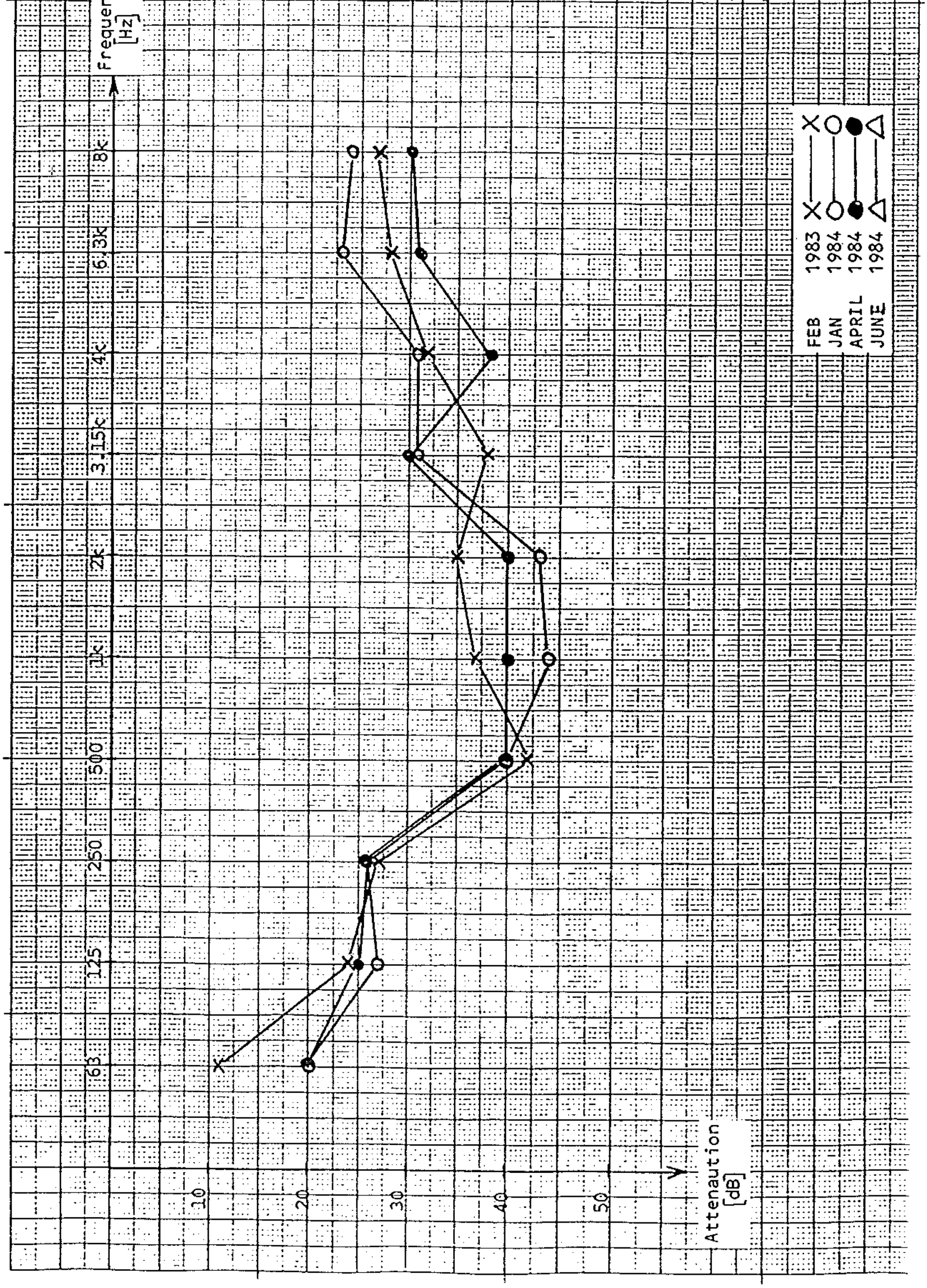

Figure 18 Mean sound attenuation for Telehelmet No. 3 with dummy skull, right side

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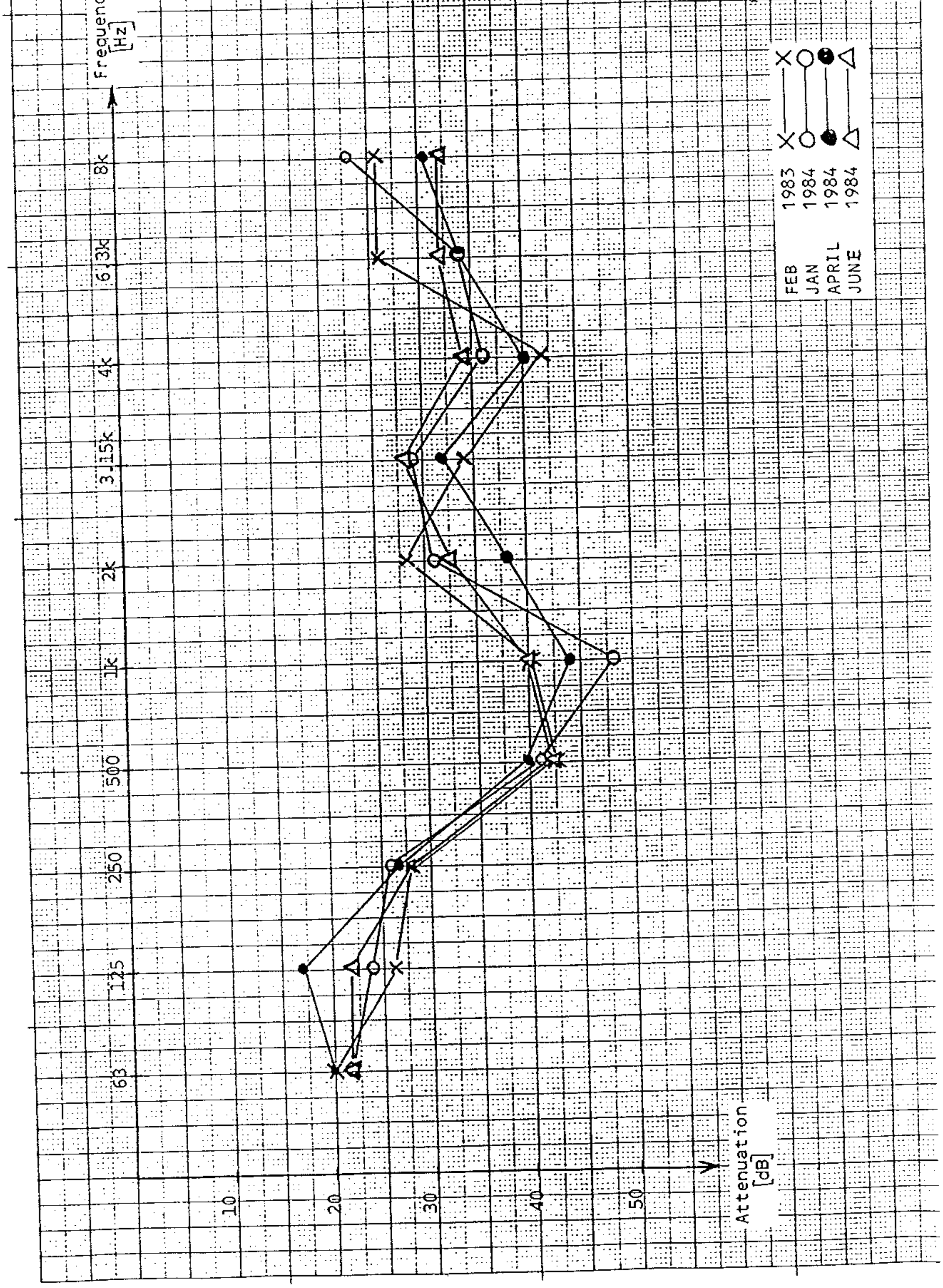

Figure 19 Mean sound attenuation for Telehelmet No. 4 without dummy skull, left side

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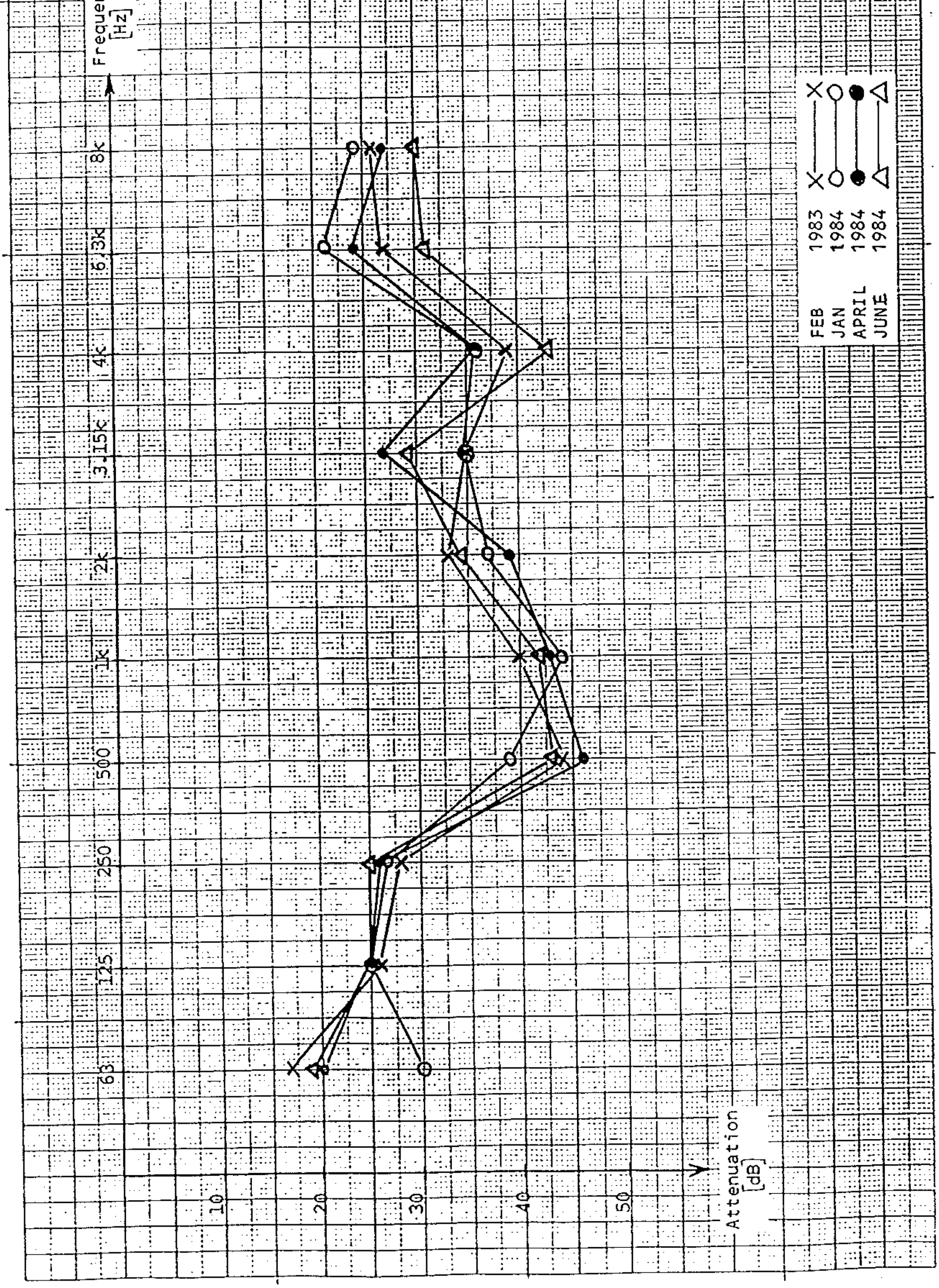

Figure 20 Mean sound attenuation for Telehelmet No. 4 with dummy skull, left side

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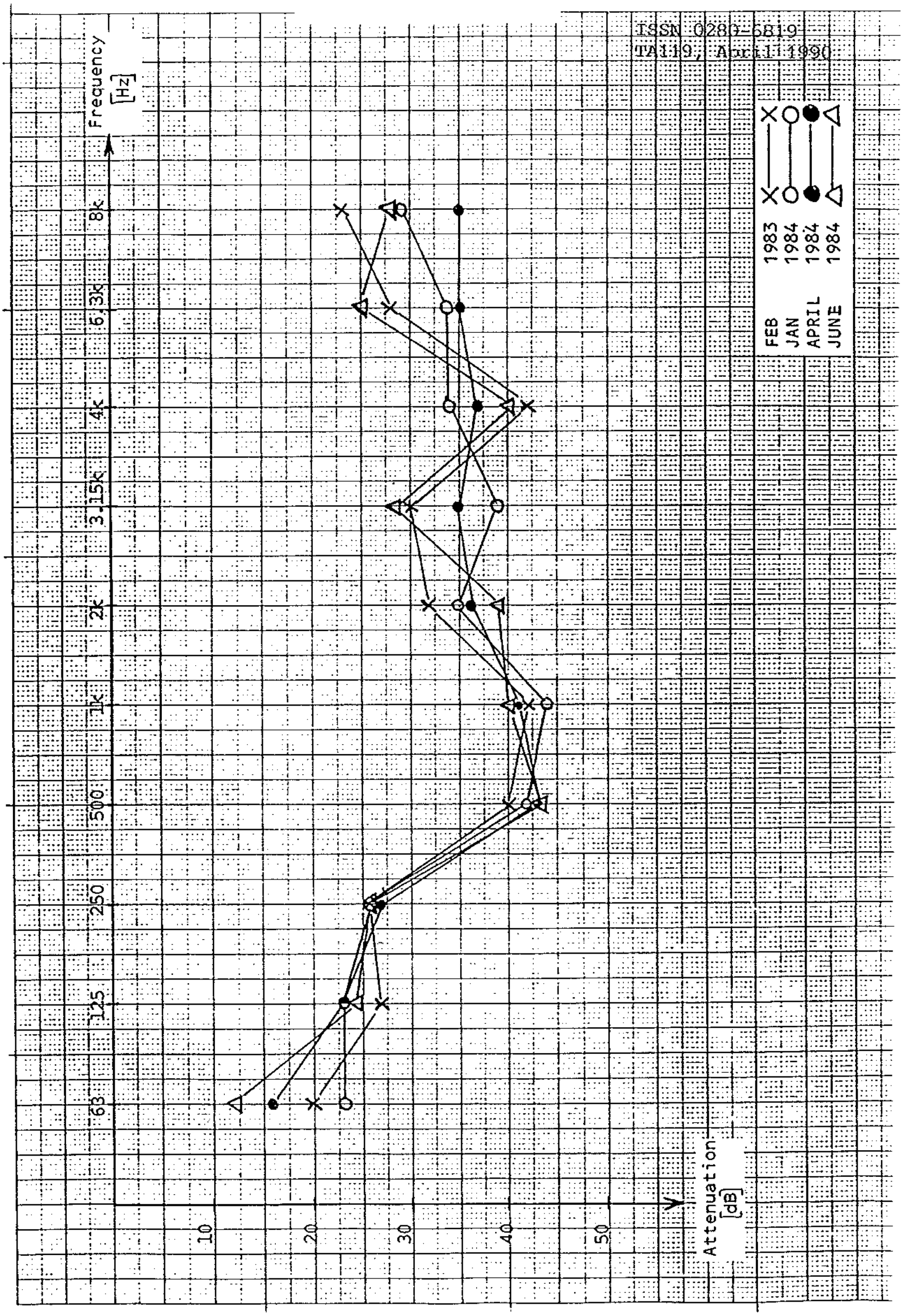

Figure 21 Mean sound attenuation for Telehelmet No. 4 without dummy skull, right side

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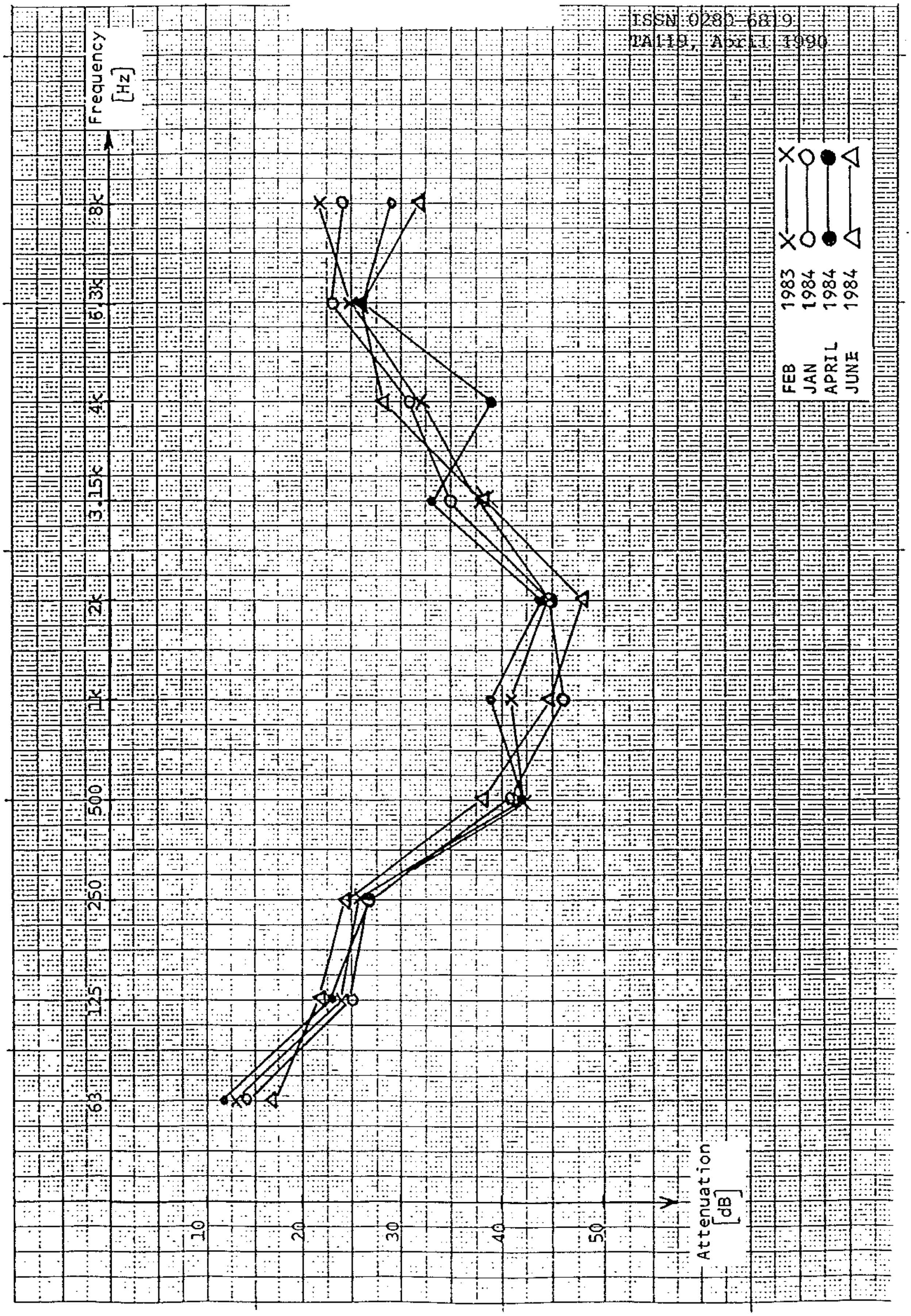

Figure 22 Mean sound attenuation for Telehelmet No. 4 with dummy skull, right side

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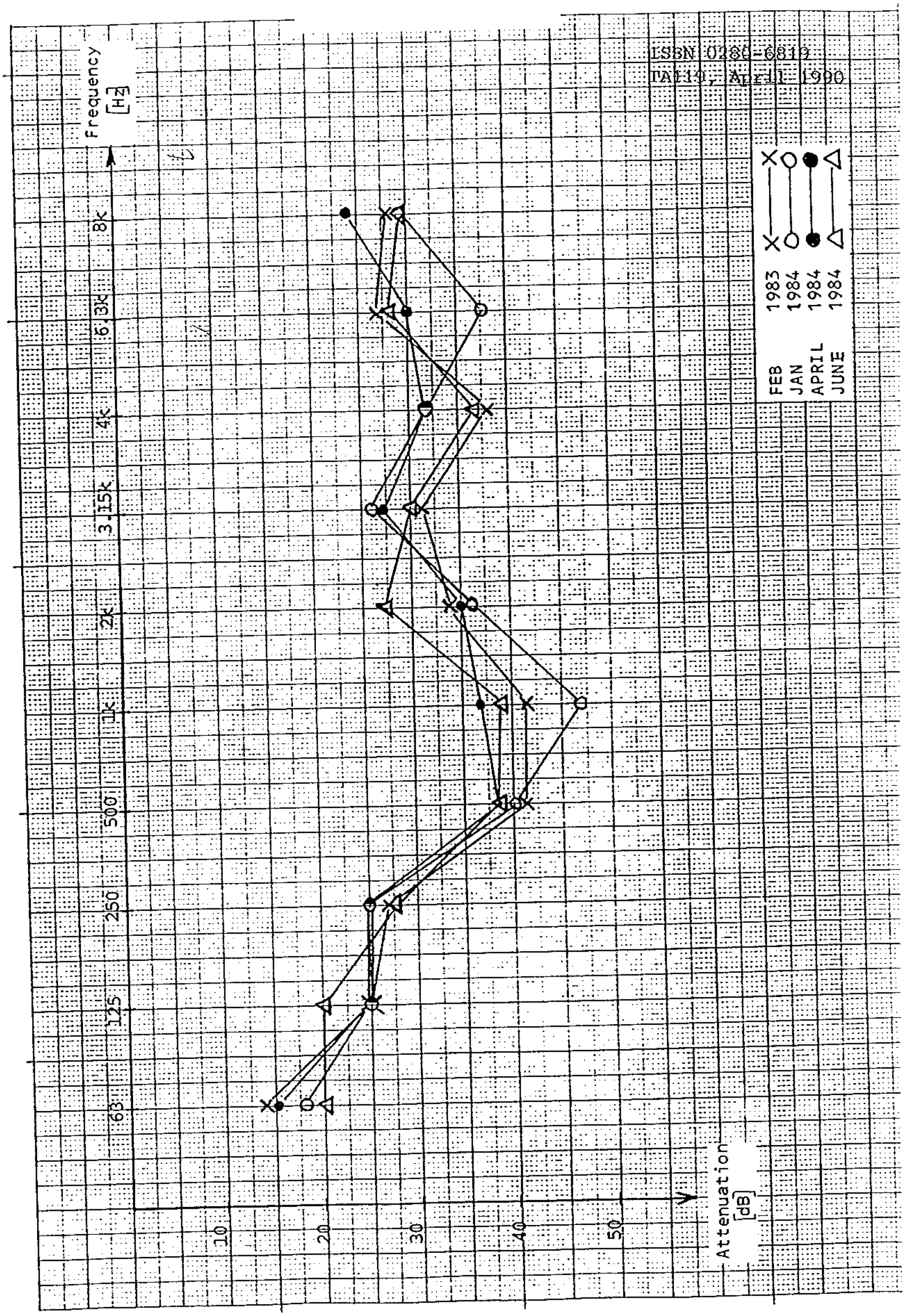

Figure 23 Mean sound attenuation for Telehelmet No. 5 without dummy skull, left side

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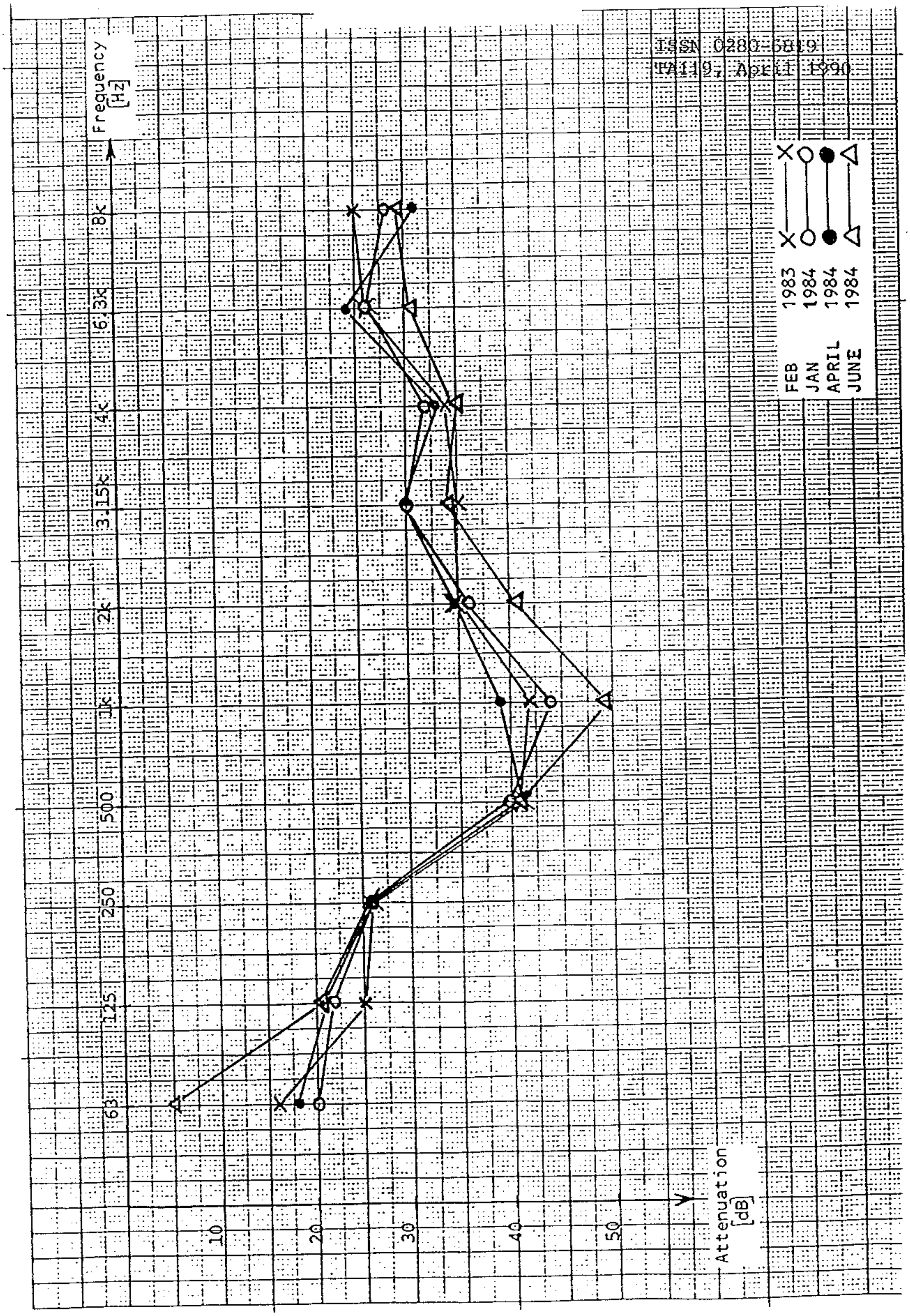

Figure 24 Mean sound attenuation for Telehelmet No. 5 with dummy skull, left side

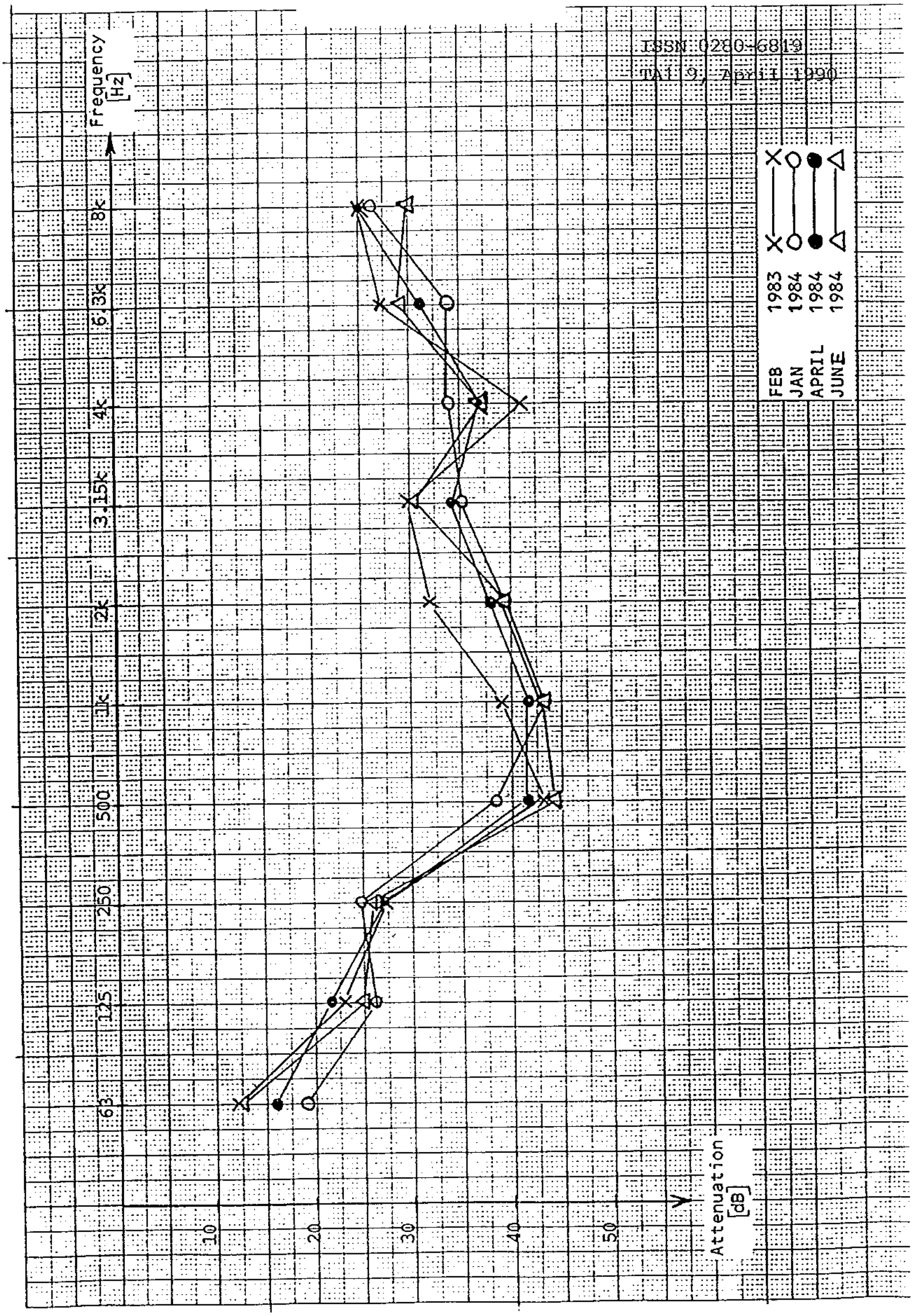

Figure 25 Mean sound attenuation for Telehelmet No. 5 without dummy skull, right side

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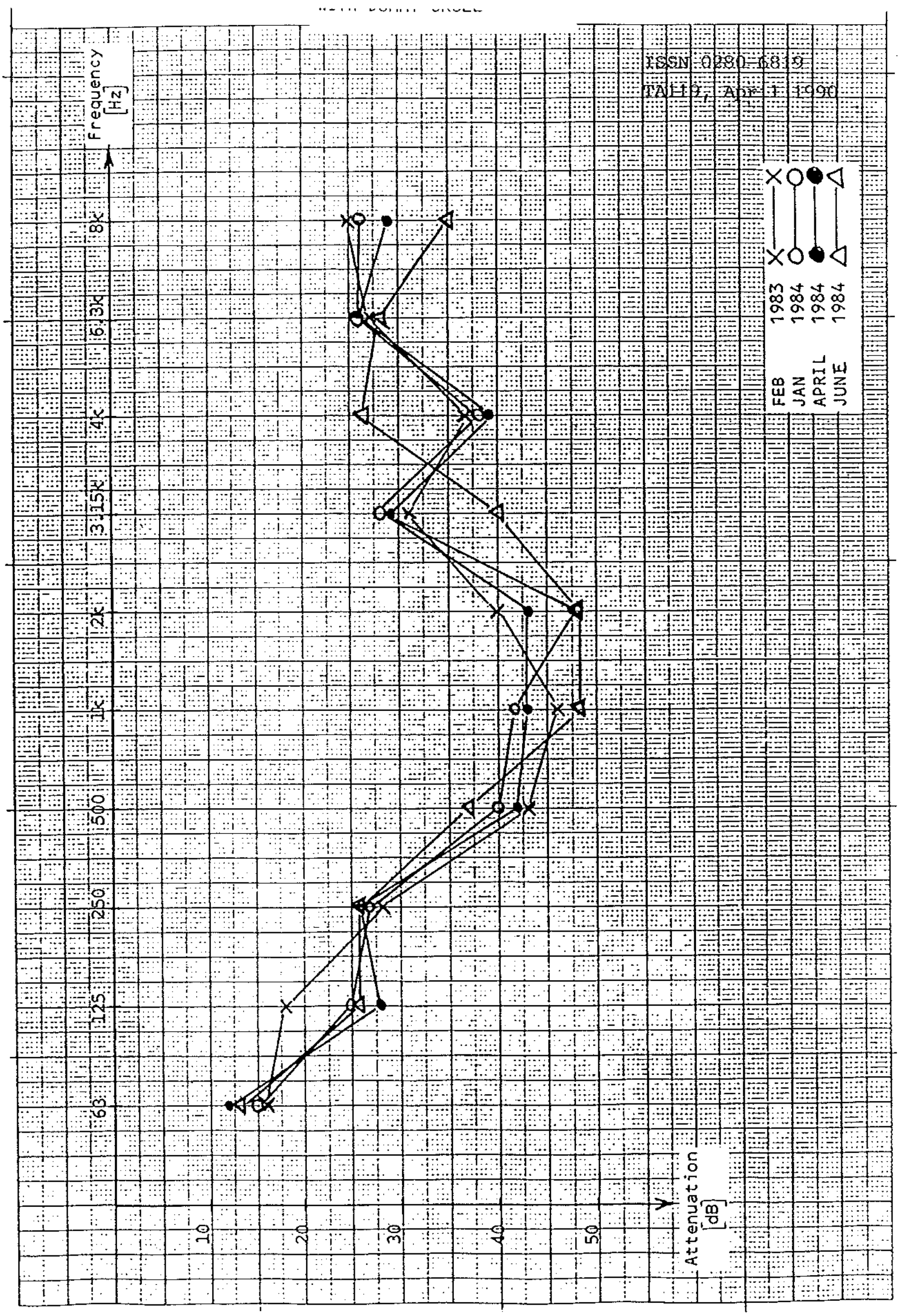

Figure 26 Mean sound attenuation for Telehelmet No. 5 with dummy skull, right side

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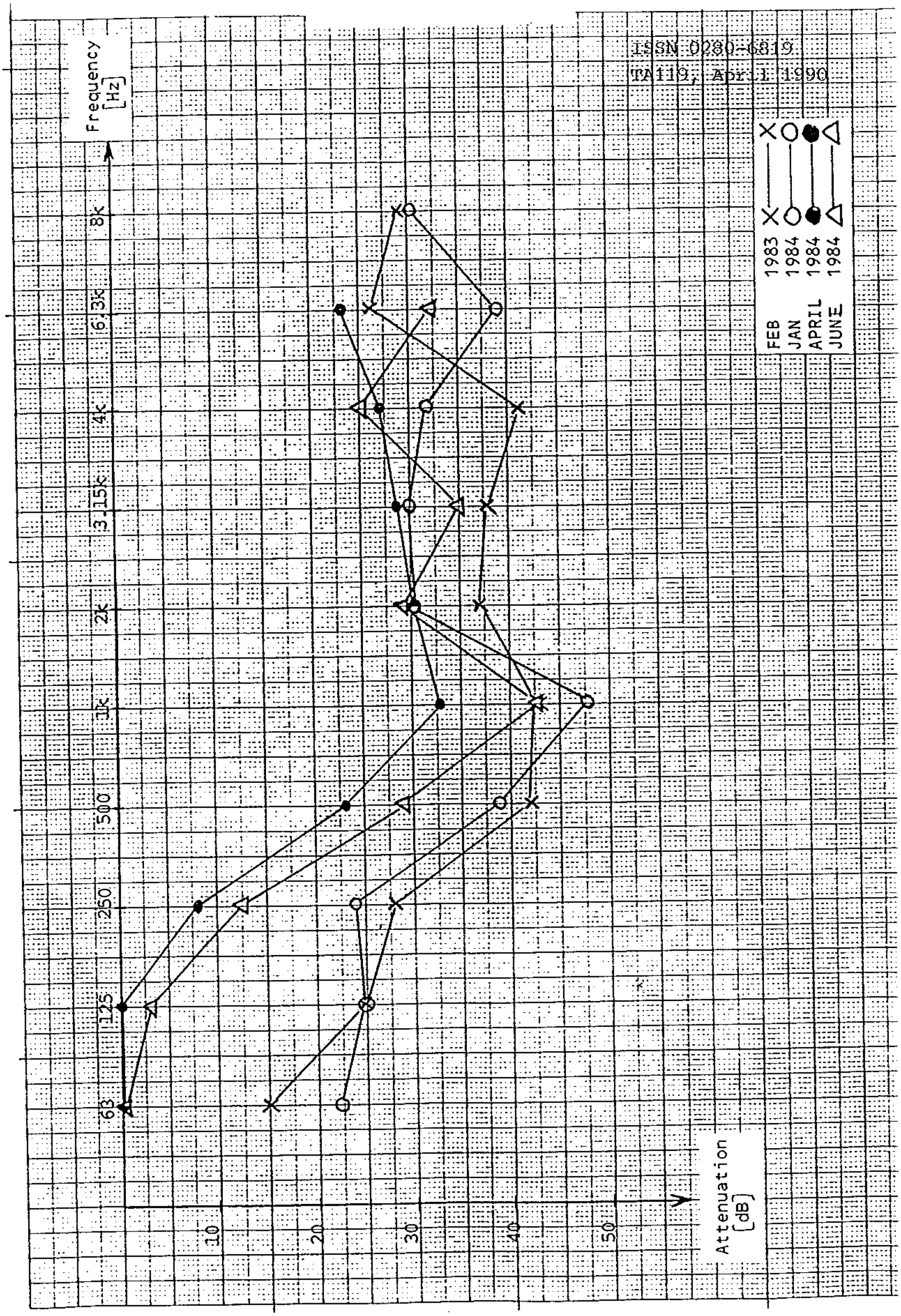

Figure 27 Mean sound attenuation for Telehelmet No. 6 without dummy skull, left side

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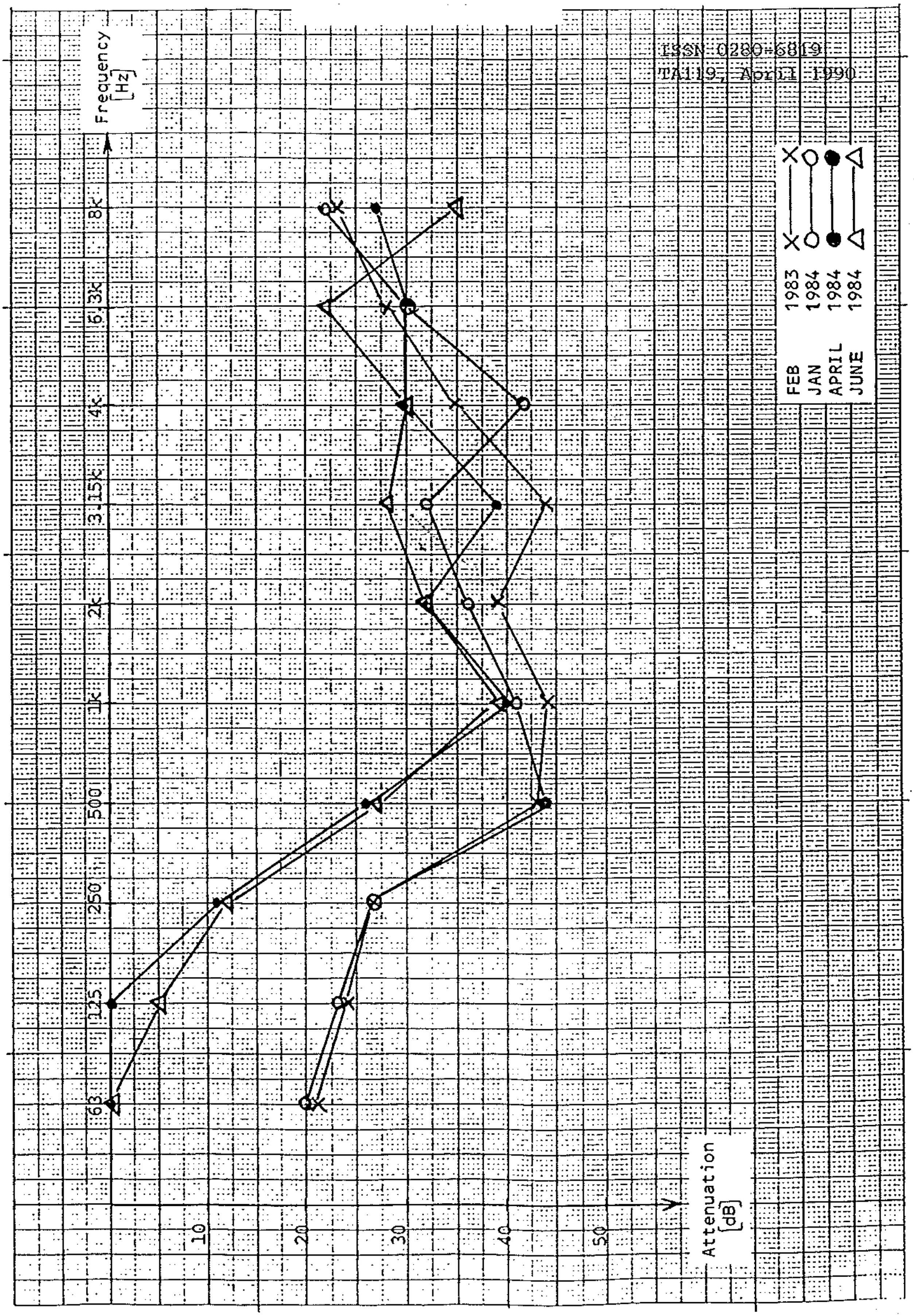

Figure 28 Mean sound attenuation for Telehelmet No. 6 with dummy skull, left side

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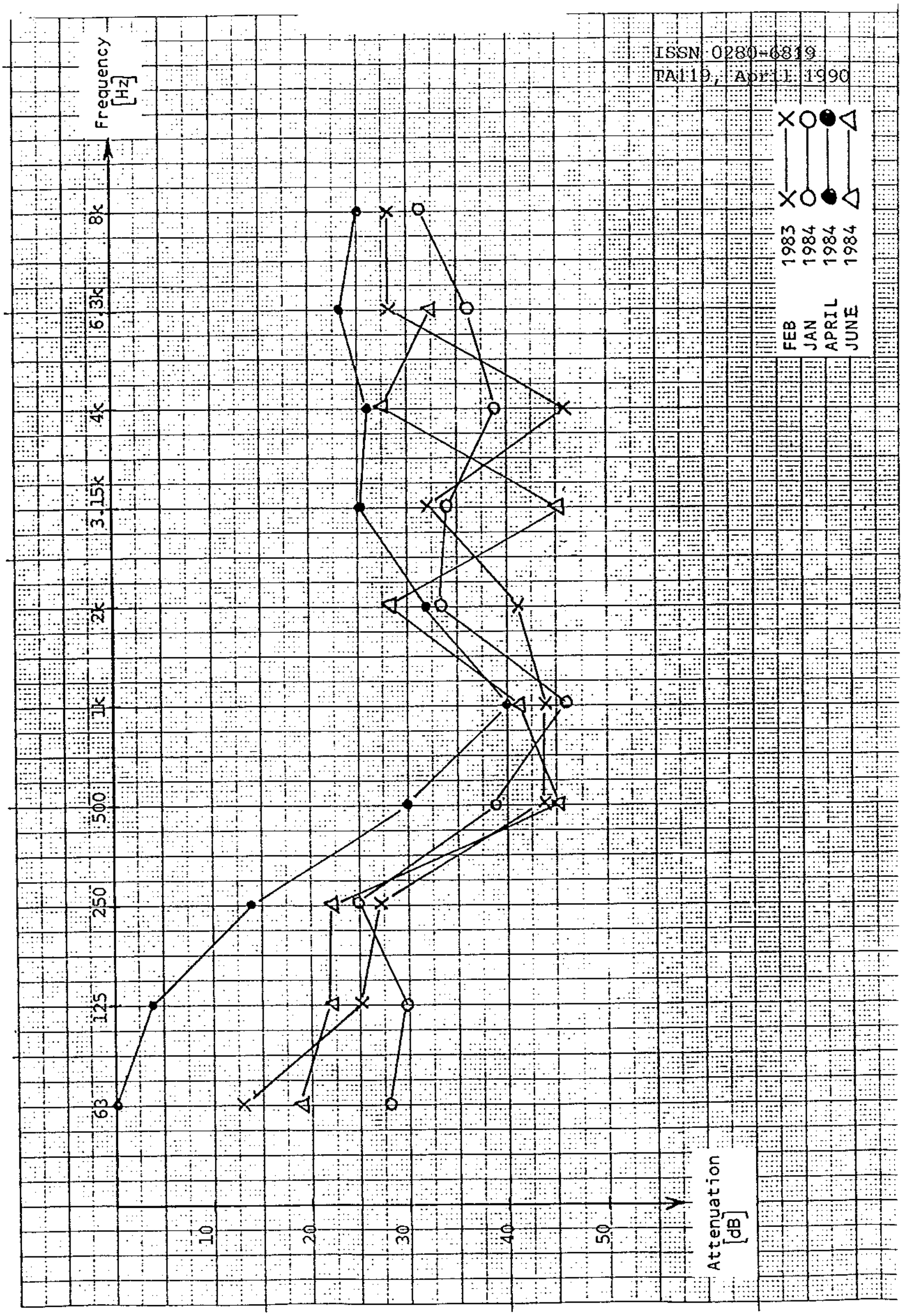

Figure 29 Mean sound attenuation for Telehelmet No. 6 without dummy skull, right side

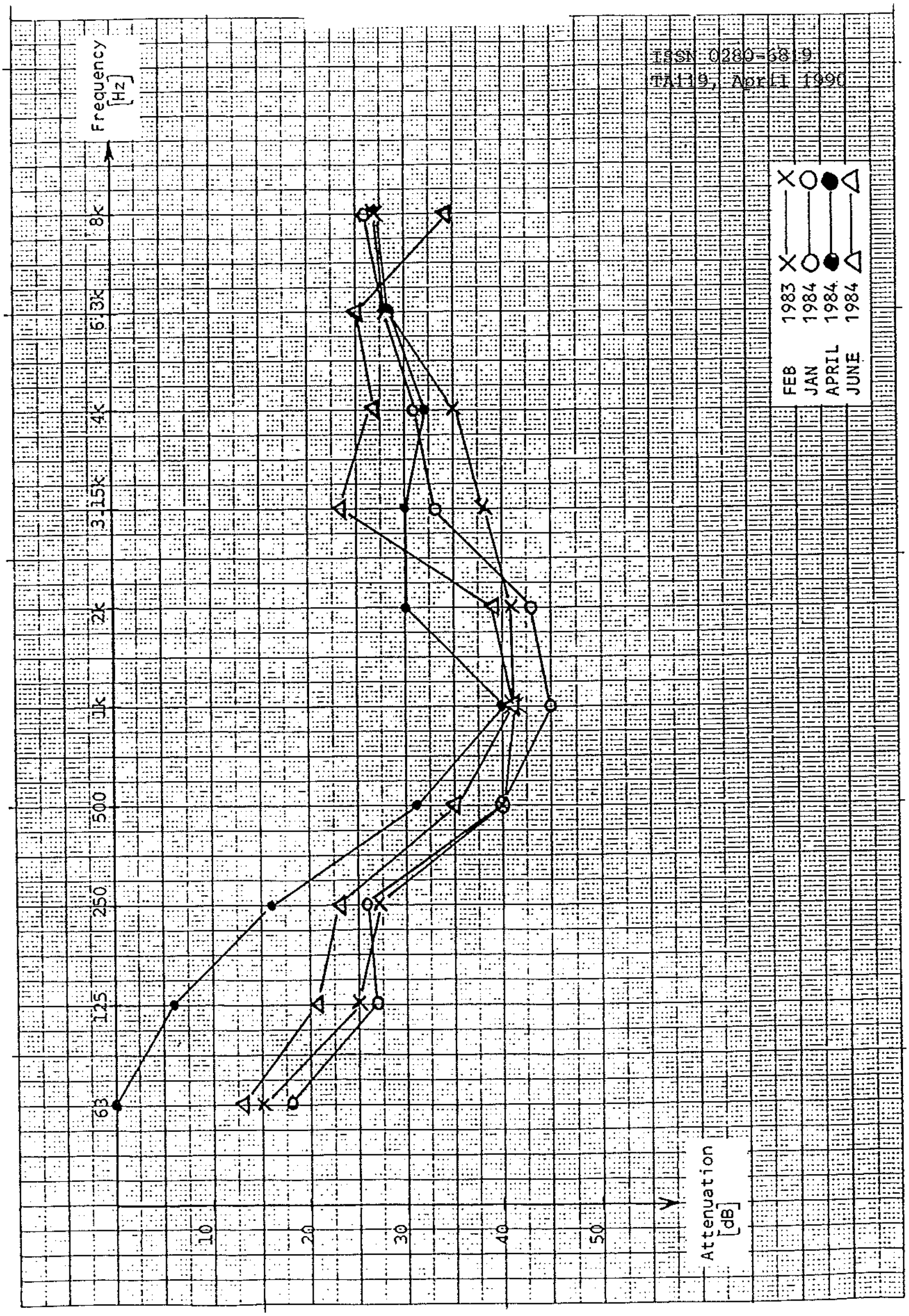

Figure 30 Mean sound attenuation for Telehelmet No. 6 with dummy skull, right side

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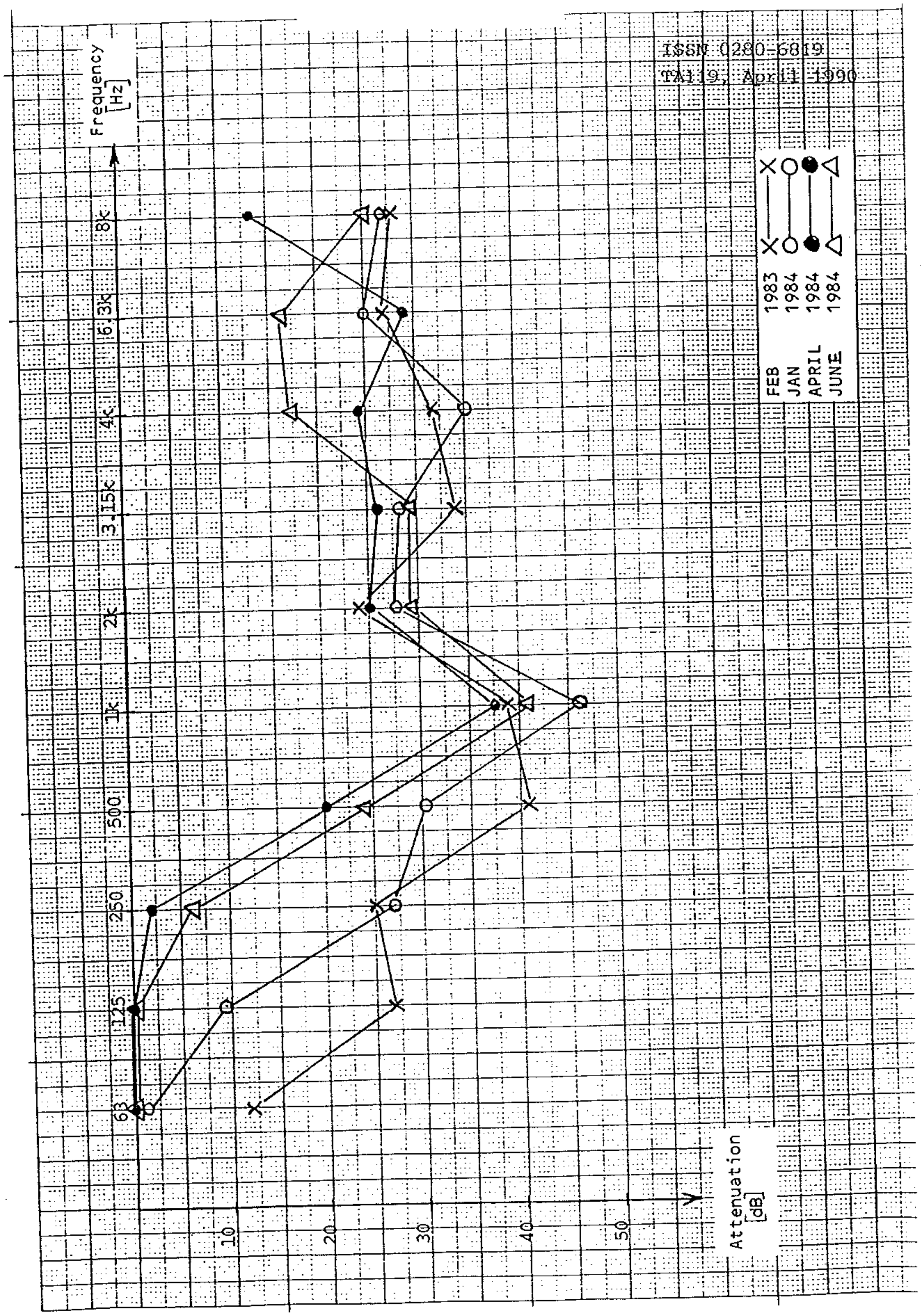

Figure 31 Mean sound attenuation for Telehelmet No. 7 without dummy skull, left side

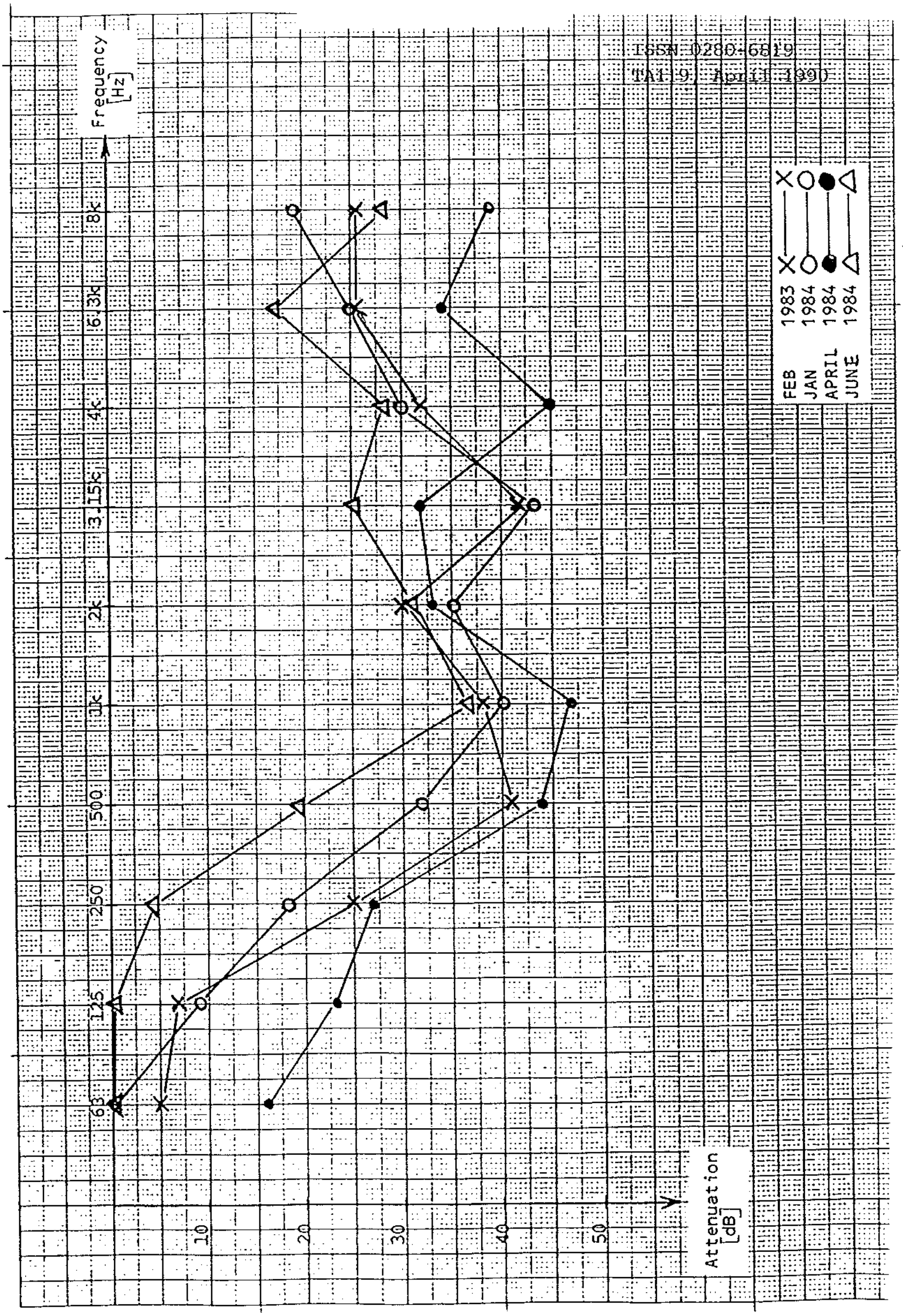

Figure 32 Mean sound attenuation for Telehelmet No. 7 with dummy skull, left side

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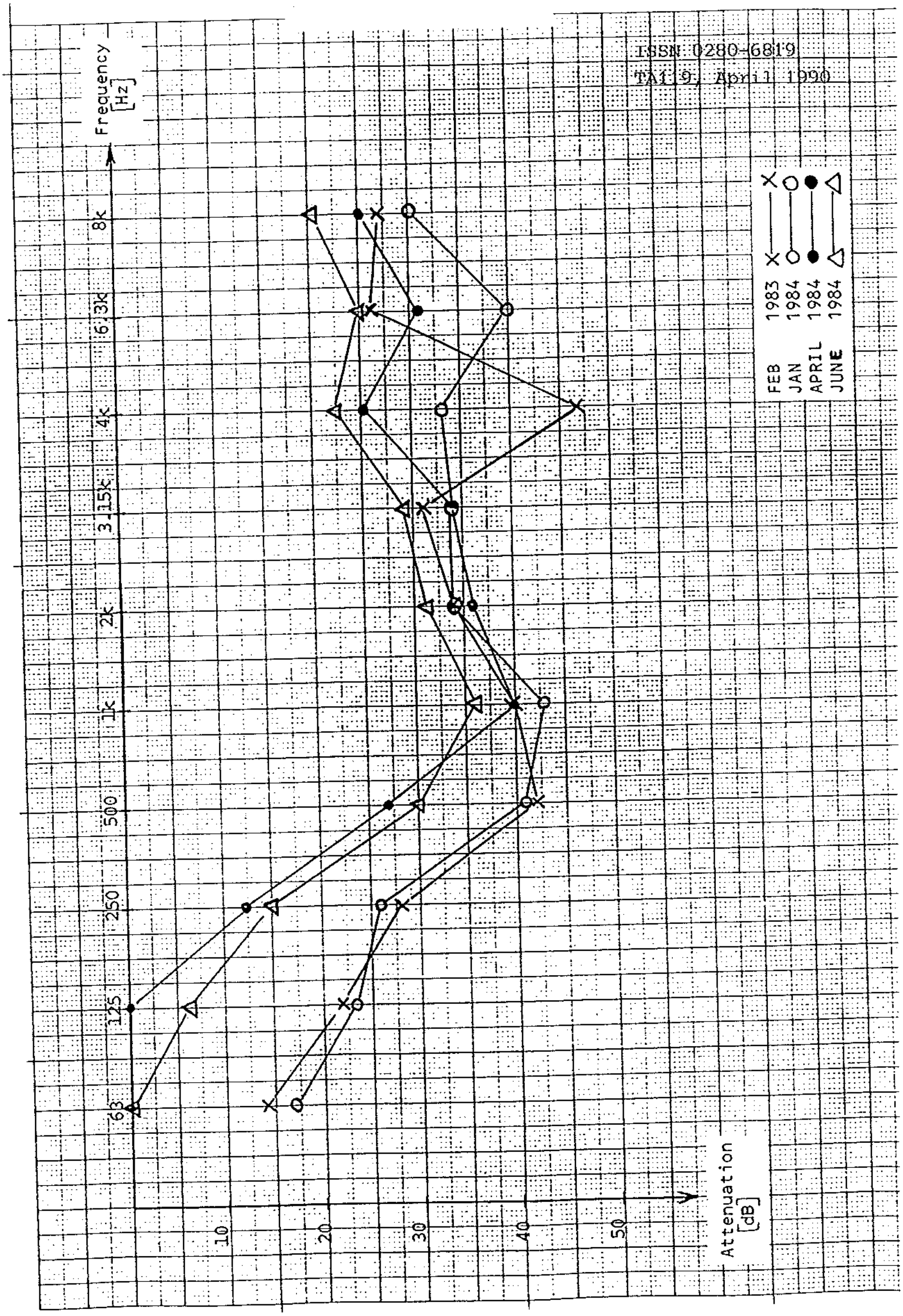

Figure 33 Mean sound attenuation for Telehelmet No. 7 without dummy skull, right side

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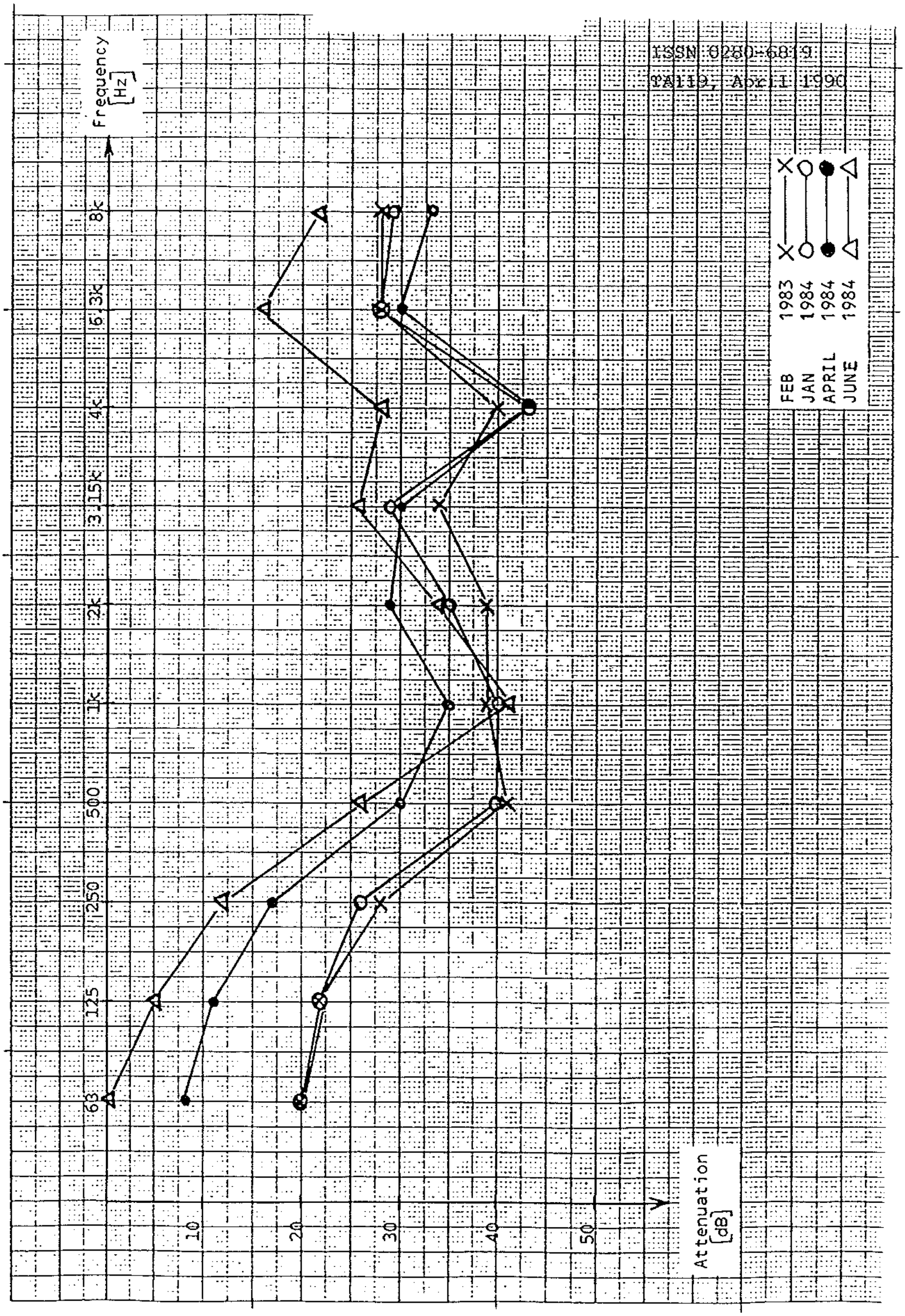

Figure 34 Mean sound attenuation for Telehelmet No. 7 with dummy skull, right side

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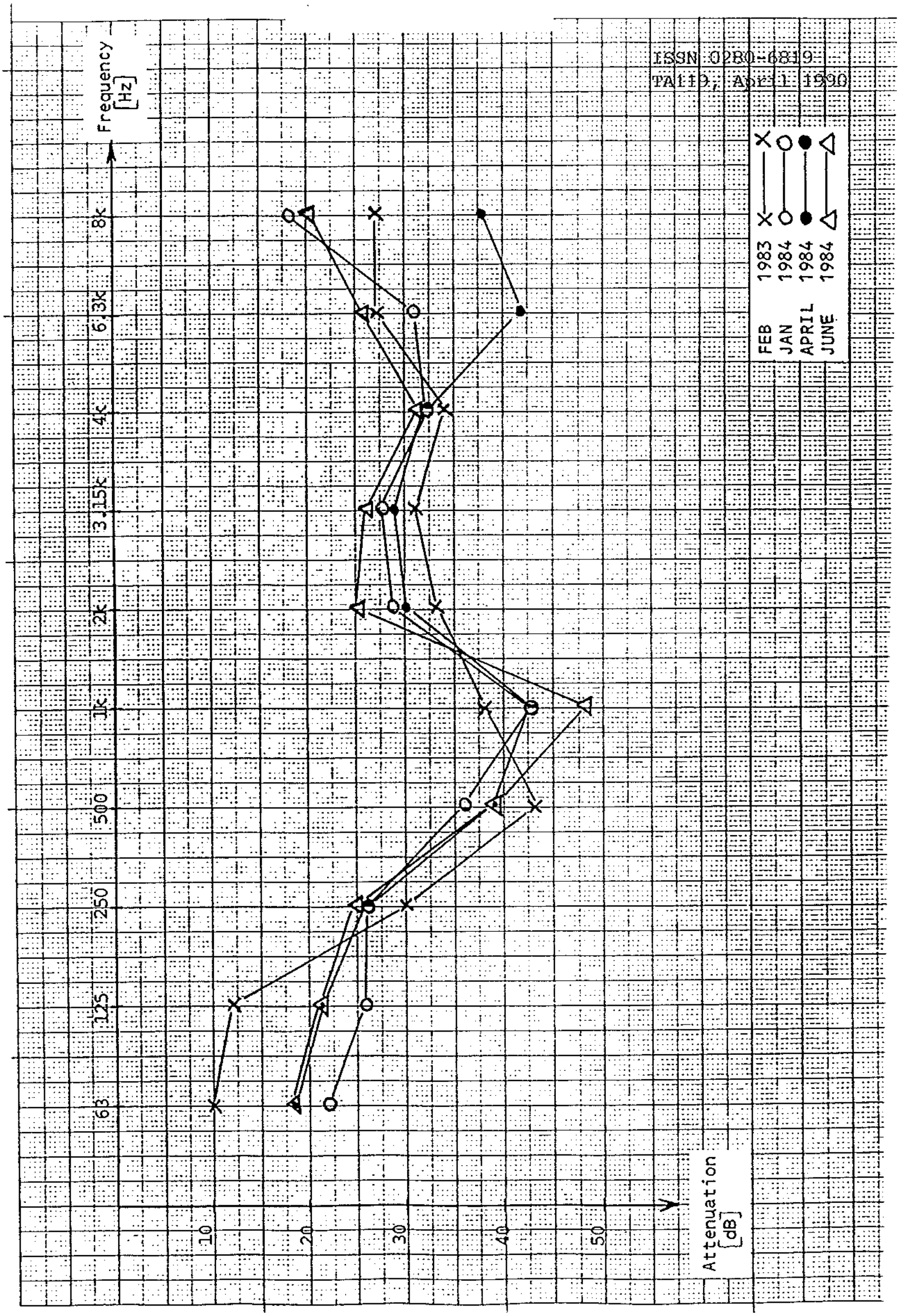

Figure 35 Mean sound attenuation for Telehelmet No. 8 without dummy skull, left side

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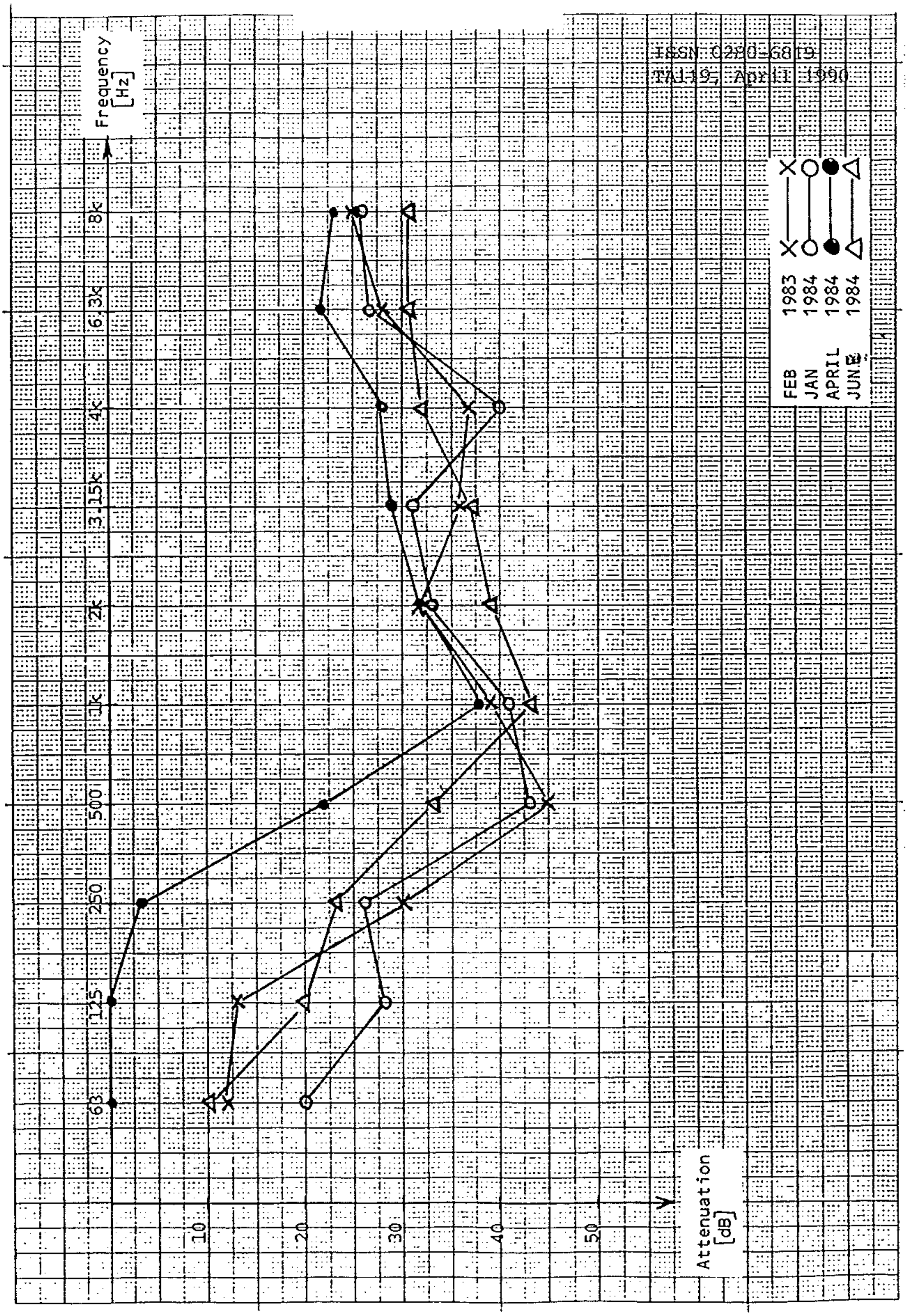

Figure 36 Mean sound attenuation for Telehelmet No. 8 with dummy skull, left side

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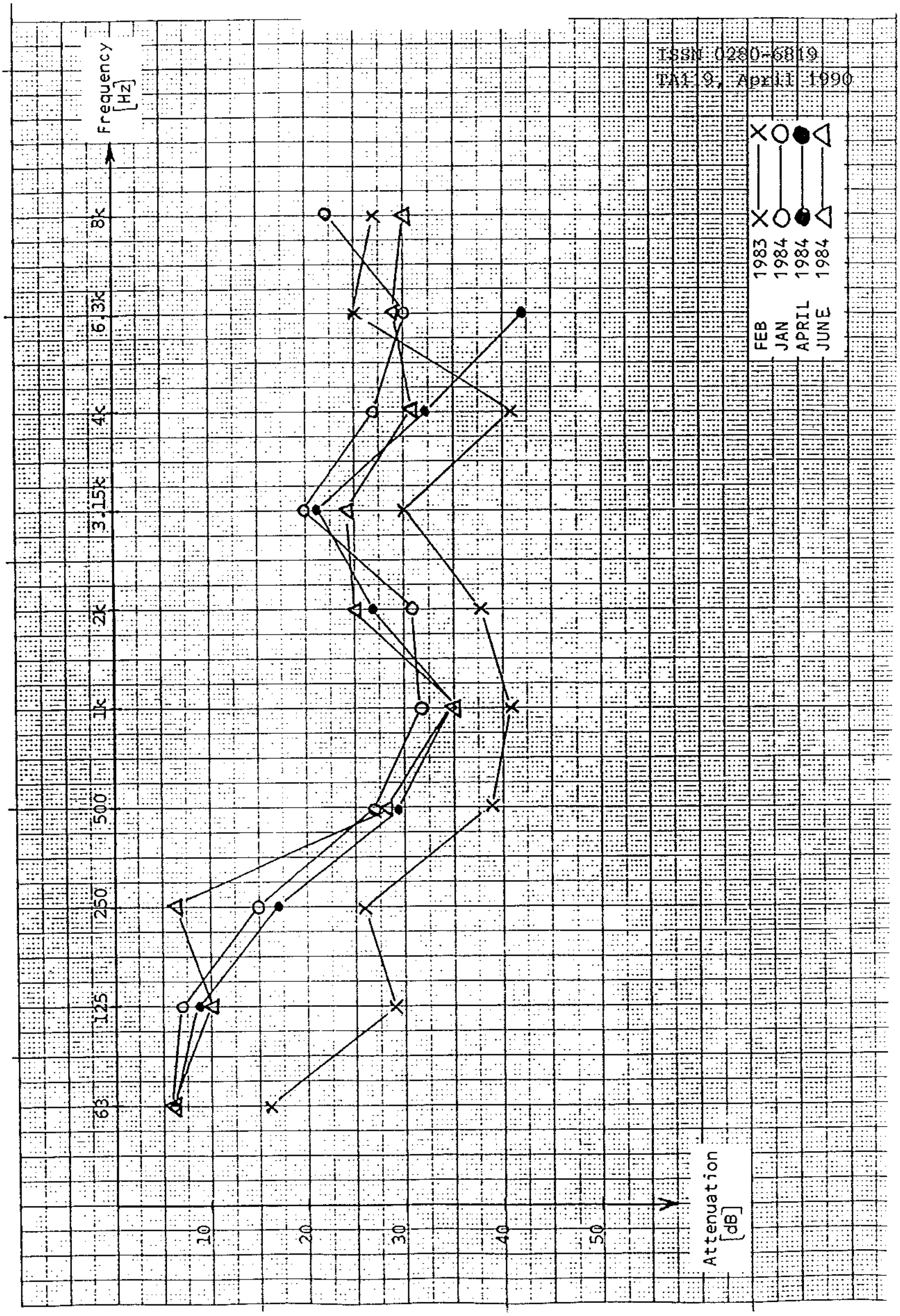

Figure 37 Mean sound attenuation for Telehelmet No. 8 without dummy skull, right side

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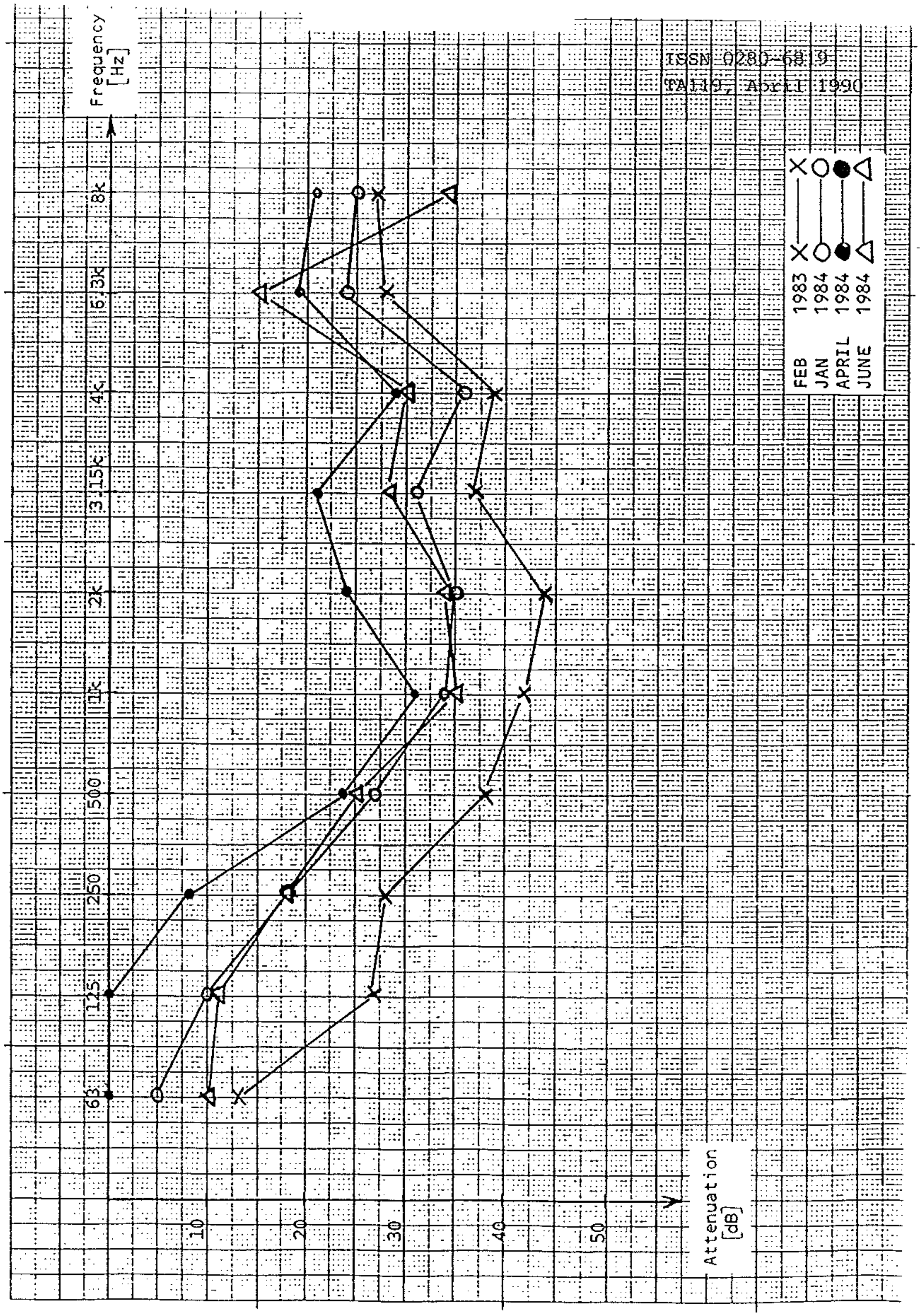

Figure 38 Mean sound attenuation for Telehelmet No. 8 with dummy skull, right side

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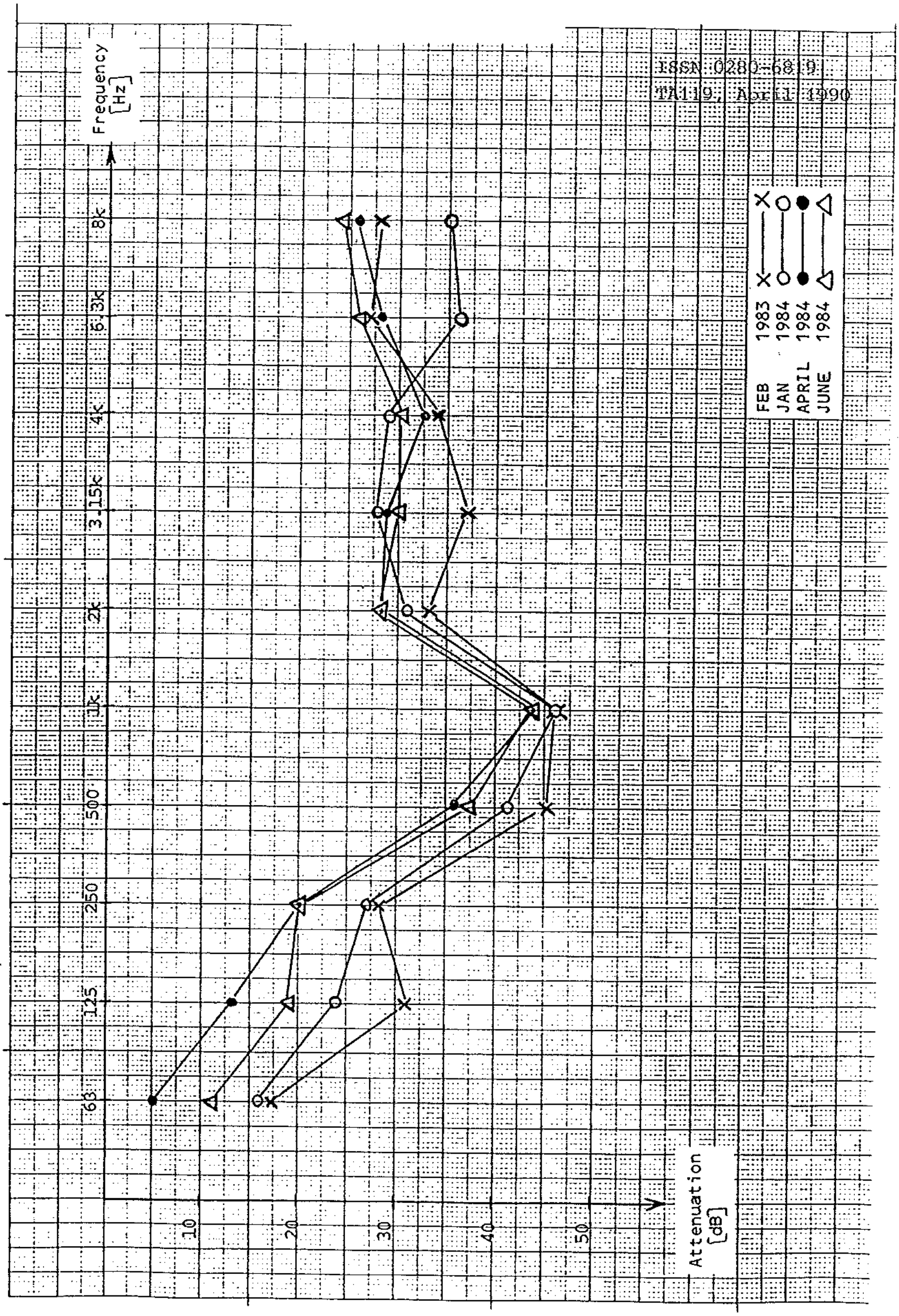

Figure 39 Mean sound attenuation for Telehelmet No. 9 without dummy skull, left side

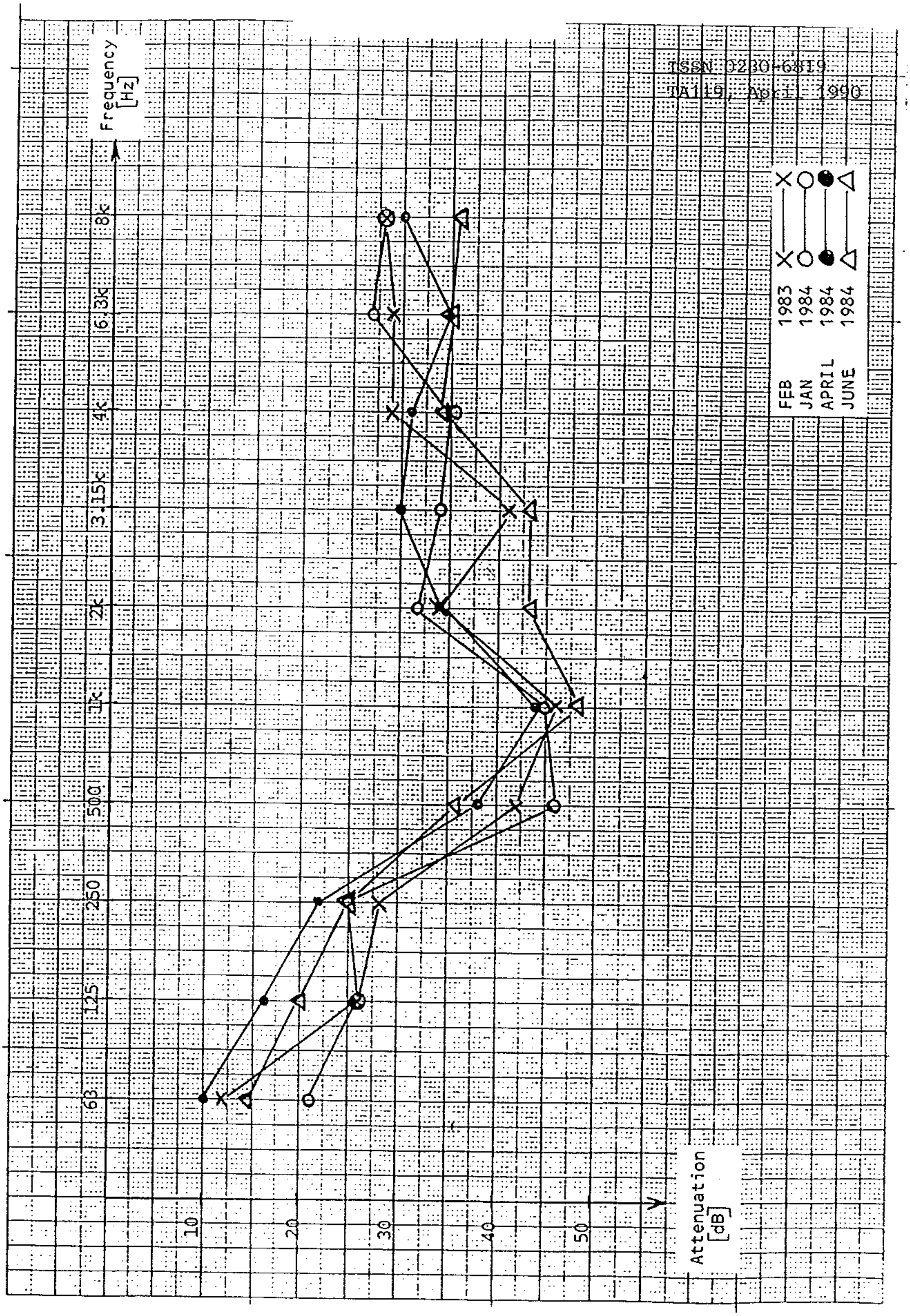

Figure 40 Mean sound attenuation for Telehelmet No. 9 with dummy skull, left side

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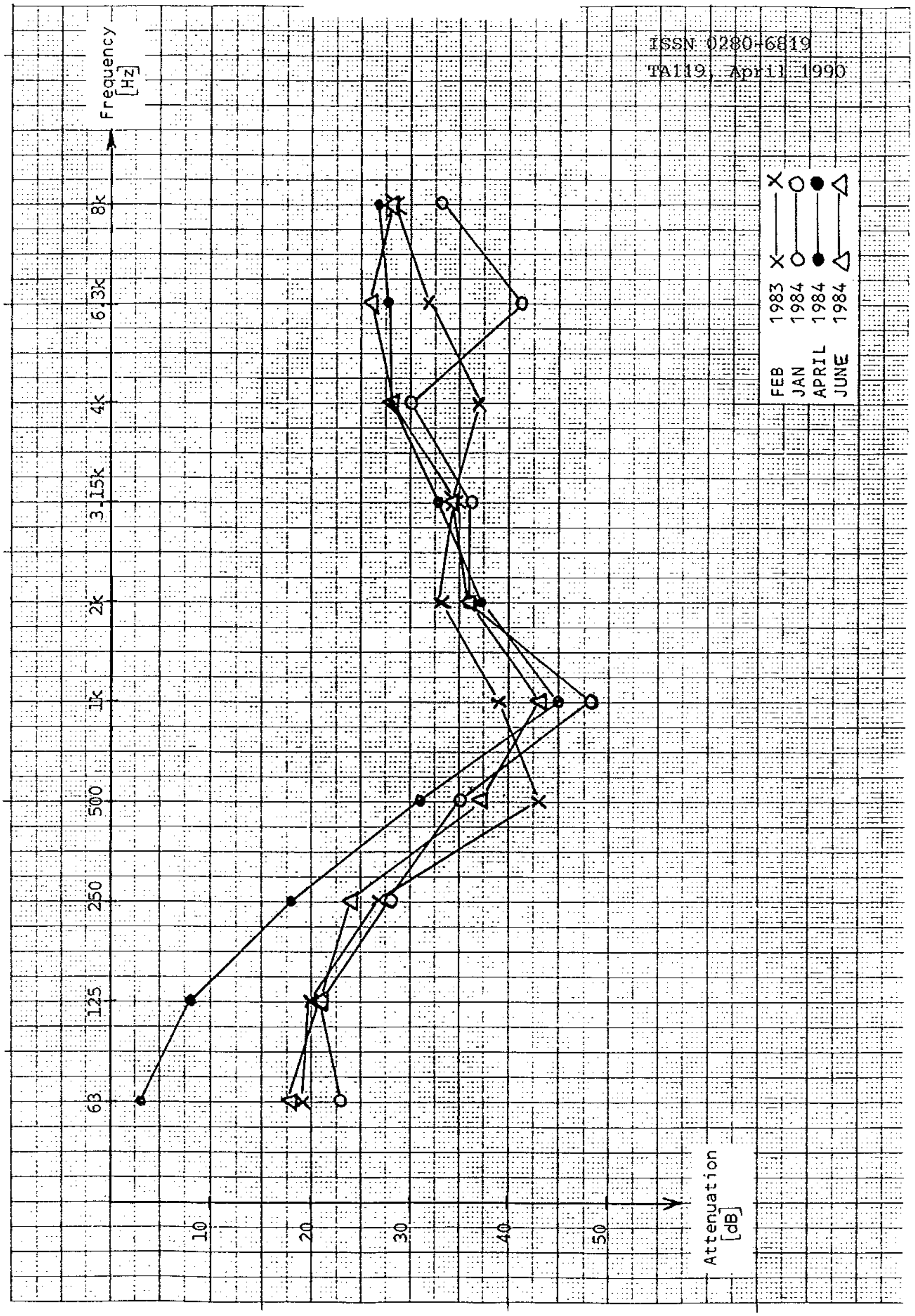

Figure 41 Mean sound attenuation for Telehelmet No. 9 without dummy skull, right side

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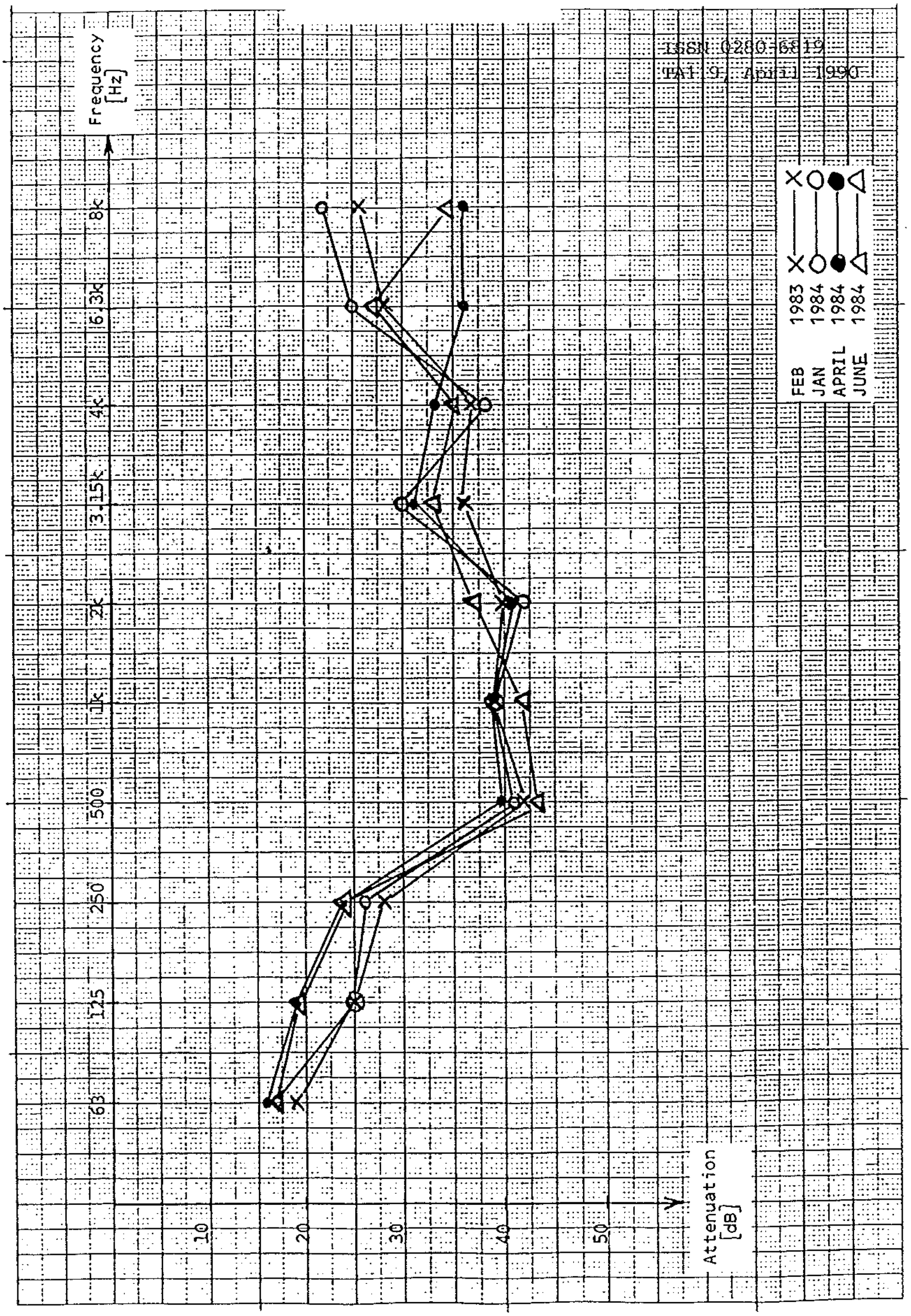

Figure 42 Mean sound attenuation for Telehelmet No. 9 with dummy skull, right side

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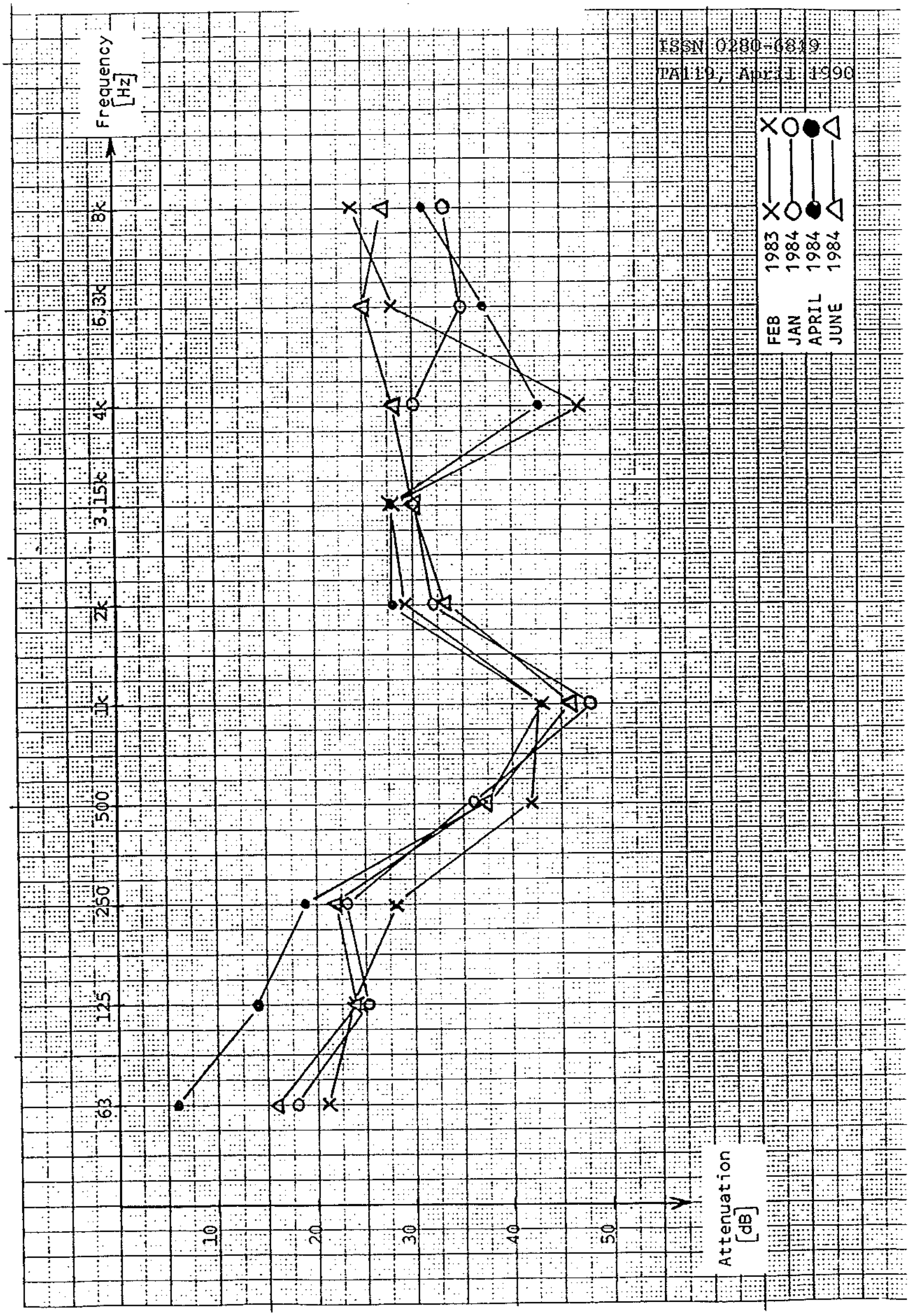

Figure 43 Mean sound attenuation for Telehelmet No. 10 without dummy skull, left side

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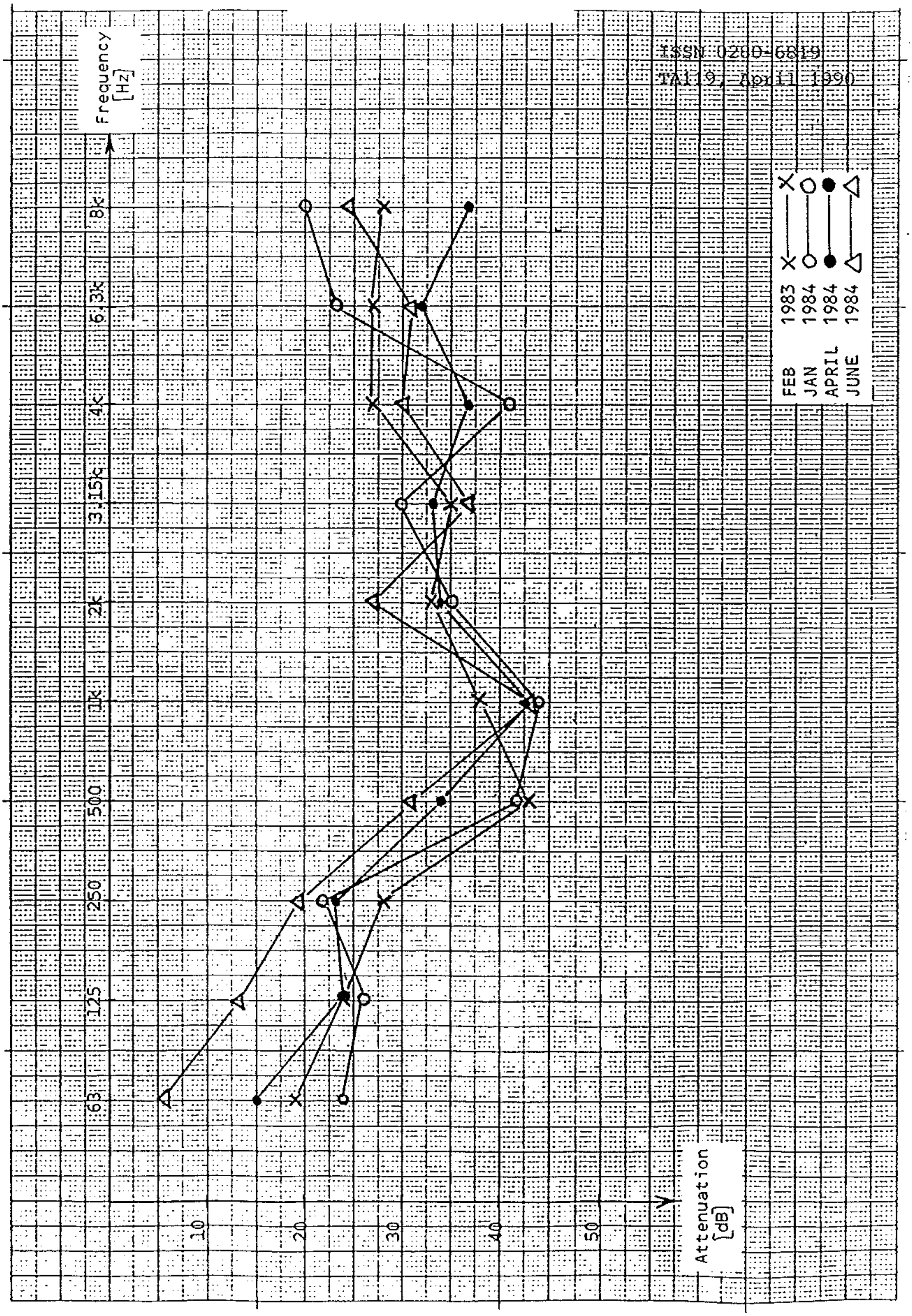

Figure 44 Mean sound attenuation for Telehelmet No. 10 with dummy skull, left side

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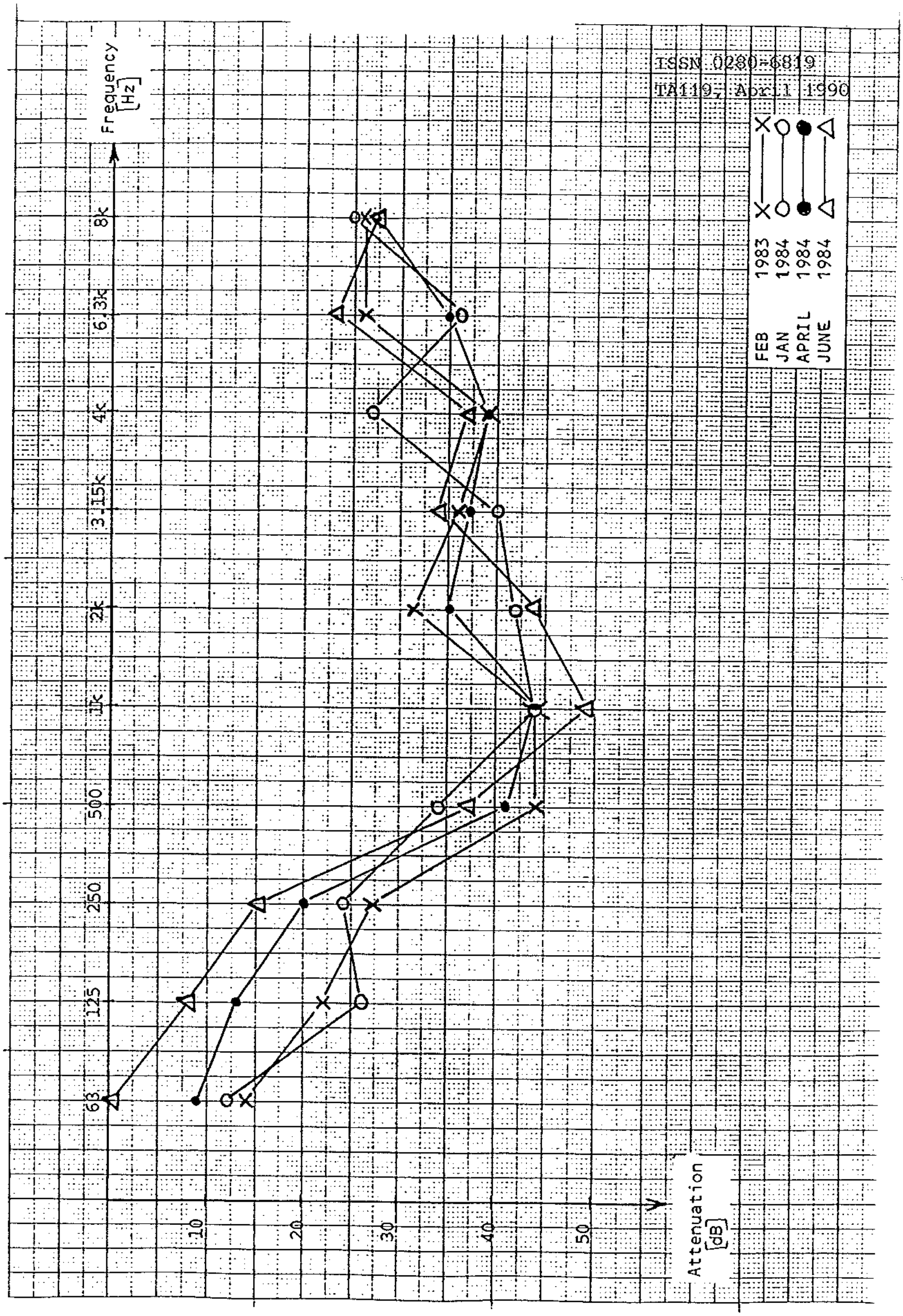

Figure 45 Mean sound attenuation for Telehelmet No. 10 without dummy skull, right side

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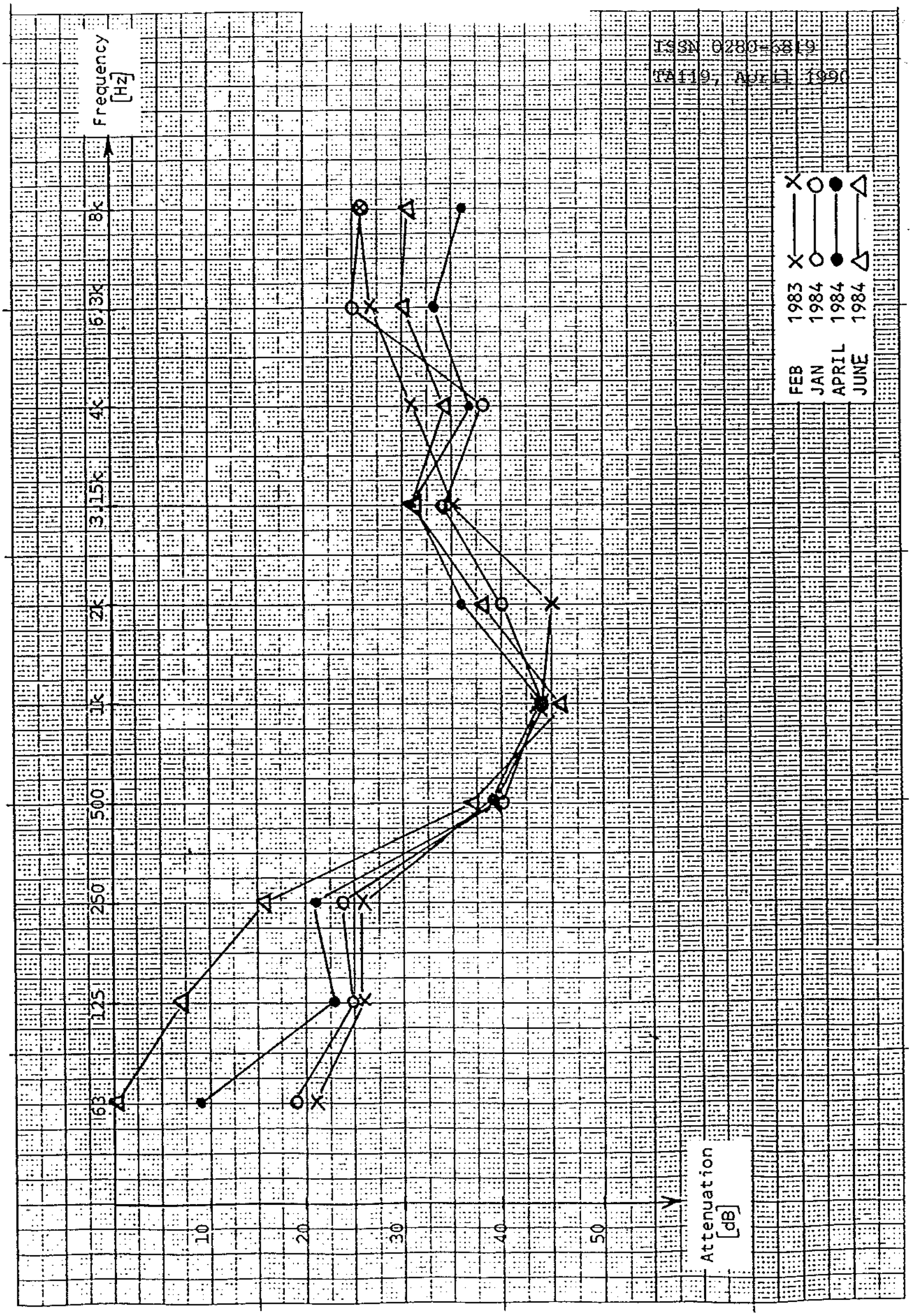

Figure 46 Mean sound attenuation for Telehelmet No. 10 with dummy skull, right side

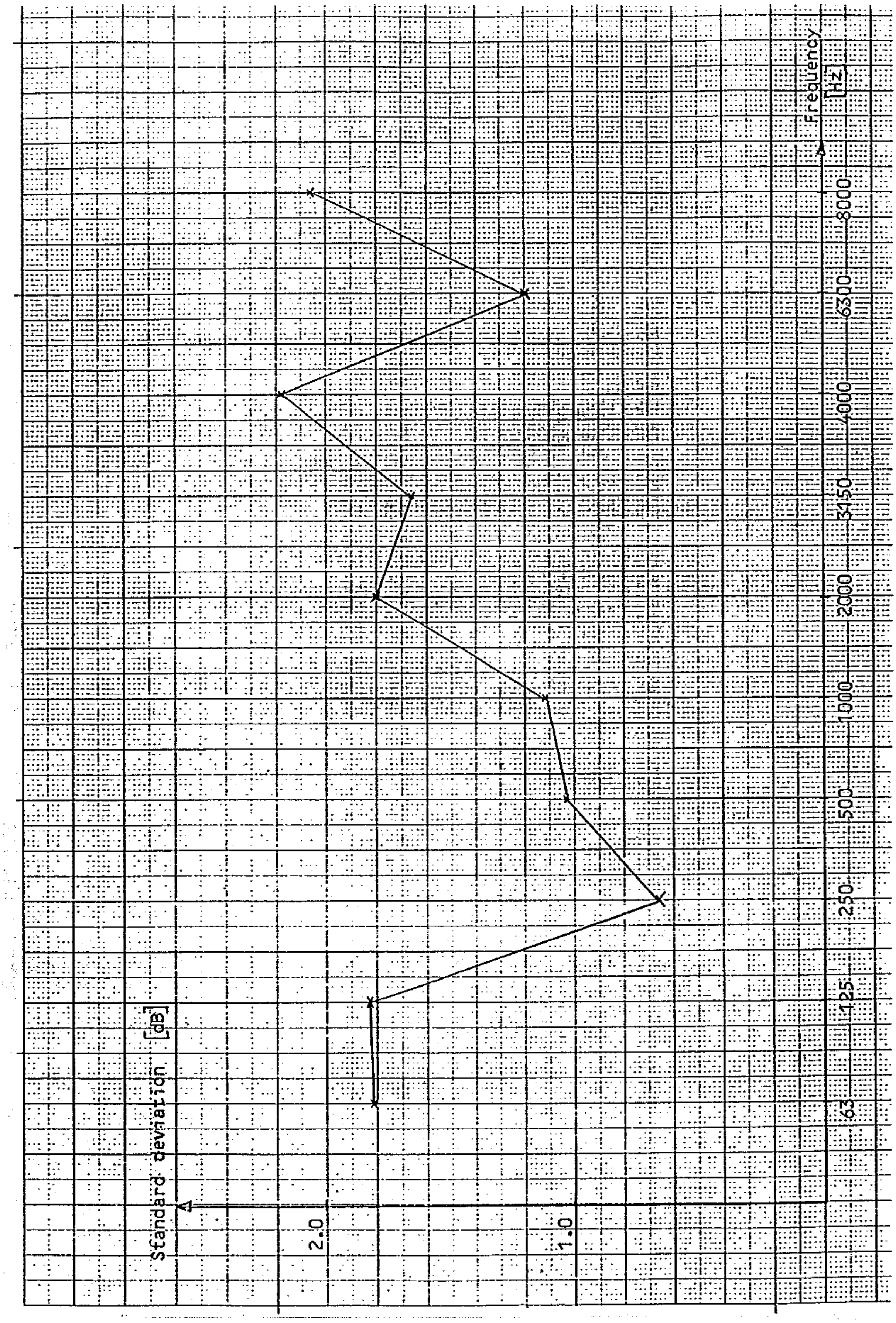

Figure 47 Standard deviation as a function of frequency for Telehelmets No. 1 and No. 2