Preprint 2336 (E6)

Free-field pressure stepfunction tests acoustic transformation chain

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Presented at the 80th Convention 1986 March 4-7 Montreux, Switzerland

AUDIO ES ®

AES

AN AUDIO ENGINEERING SOCIETY PREPRINT

FREE-FIELD PRESSURE STEPFUNCTION TESTS
ACOUSTIC TRANSFORMATION CHAIN

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INTRODUCTION

Because of its physical nature, a condenser microphone is undoubtedly the best device to choose for the receiving side of an acoustical transmission chain /1/. When two high-quality condenser microphones are used with the same frequency response curve, polar and level response nevertheless will sound differently to the user. Discussion very often comes to transient response capability /2/.

In electric circuitry description, transient response of a system is a common parameter. But in acoustics it appears impossible to gain this dynamic single measurment information in time domain response in order to compare input shape to output shape.

Additional information on describing a system under test is what we want. For example: damping of resonance phenomena on a microphone. In frequency domain as a steady-state measurement this would be a tedious task and as a dynamic measurement an obvious description. Another reward could be faster and easier measurement.

DYNAMIC MEASUREMENT IN ACOUSTICS

In a two-port dynamic measurement chain an unsurmountable obstacle is the acoustic transmitter, counterpart to the receiver microphone. Computer aided FFT makes use of a "reference" microphone and delivers an indirect result, at the expense of a huge equipment adding e.g. time averaging rules to the result /3/.

To achieve wide based practical results in dynamic direct measurements, we asked European manufacturers of condenser type studio- or recording microphones, to support the survey. We supplied preliminary information by sending stepfunction pictures (see Fig. 5) taken from B & K measurement condenser microphones. 26 different studio- plus 3 different measurement microphones finally provided about 500 pictures taken from the oscilloscope. This paper reports on 21 different condenser microphones with 139 transient response pictures on 6 pages.

On page 7 36 pictures show the result when the same testsignal, see Fig. 4, is applied to conventional loudspeakers, see Fig. 6, radiating into the measurement microphone previously tested, see Fig. 5. This extends the survey by changing the transmitter side of the two-port acoustical chain while holding the receiver side constant.

RECEIVER CONVERTER

In order to make any acoustic event a quantitatively measurable event an electroacoustic converter must be used. Widely independent of frequency is a condenser microphone response, below its cut-off frequency, fc; (-3 dB bandwidth). The natural cut-off frequency is often extended by mechanical resonance towards higher limits. This range of the first 200 µs in time is the most critical interval range, representing the "character" of the individual condenser microphone construction. Selecting of a higher resonance frequency normally means decrease in diaphragm size. Whereby diaphragm mass is decreased and stiffness is increased at the expense of a reduced sensitivity.

With cut-off values available from 15 kHz up to 100 kHz with different microphone samples, satisfactory bandwidth is achieved with respect to the audio range. Against this background only condenser type microphones were used as receivers in the two-port measurement chain. During survey we studied omnidirectional, cardioid and unidirectional microphone constructions.

IMPULSIVE SOUND SOURCE

Electric arc, pistol shot, see Fig. 2, spark discharge, see Fig. 3, balloon puncture, - they all are examples of impulsive sound sources. Certain limits appear, if applied to the study of microphones' high-end roll off behaviour in time domain.

Experimenters learnt how to live with unreliable amplitude changes, they report /4/. But the usefulness of any "explosive" sound source is limited by the fact that it produces a train of pressure pulses with positive and negative excursions. And this within the time range where the system under test, the microphone, is supposed to have a delicate deviation to be observed. Excitation pressure is a doublet shaped impulse that is a positive and a negative unit impulse. The disadventage is explained on the next chapter.

Electrostatic actuators limited to metal diaphragms, are the most reliable measurement devices. But the interference and diffraction effects by the microphone body are not taken into account during the measurement. In frequency domain, this measurement difference is known as pressure to free-field correction /5/. In time domain very few results are known /6/. But with the newly developed M-transducer a pressure stepfunction, for instance as test signal, is feasible under free-field conditions for time domain measurements. Whereby the total time limit to the new bending wave mode M-transducer is a N-shaped pressure wave. Under survey conditions the time window appears as a stepfunction in pressure.

STEPFUNCTION OR UNIT IMPULSE

By a system under test, a stepfunction impulse is delayed in rise time according to the system's upper cut-off frequency (fc) /7/. For example, approximately 20 µs rise time delay until reaching 90 % of the final output value at 25 kHz (fc)

When applying an unit impulse to the system under test both the impulse rise time and the impulse decay time, are delayed according to the system's upper cut-off frequency (fc). In this case the output pulse width is extended to approximately 40 µs at a cut-off frequency of 25 kHz.

Doublet impulse compared to stepfunction exhibits four times the numerical pulse width extension, i. e. 80 µs at a cut-off frequency of 25 kHz. This results in an enormous "time smear". The time range most inportant to the test object, around resonance frequency from 20 µs to 200 µs becomes a smear. On doublet excitation the diffuse field correction for instance, displayed on film No. 2 as an overshoot on 0 degree incidence angle, disappears widely by superposition.

Preliminary tests were arranged with stepfunction, unit impulse and doublet impulse excitation with the intention to clarify how to get best additional detailed information about system's time capability with regard to rise time, overshoot, overshoot ratio, ringing and damping coefficient.

M-TRANSDUCER

Fortunately the M-transducer due its wide-band nature does not cause any signal differentiation, neither to the stepfunction, nor to the unit impulse within the time window displayed on the oscilloscope /8/. All preliminary test details emphasised what theory predicts: Stepfunction test signal is superior to unit - or doublet - impulse when compared with each other in a measurement set up as shown on Fig. 1. Each photographic picture gives a clear physical description for each microphone system under test in time domain with stepfunction test signal excitation.

Test set up Fig. 1 is an acoustical series connection; a combined two-port acoustical measurement chain, which means that transmitter behaviour is superimposed on to the time behaviour of the receiver. Any electric input function will be slightly distorted and delayed according to the cut-off frequency of the M-transducer resulting in 16 µs rise time, as can be seen from the photos taken on the B & K 1/4" 4135 measurement microphone, see F3/3. What means, electric input signal shape is preserved within the test range when impinging the microphone under "working condition", as demonstrated by photos taken on B & K 1/2" 4133 measurement microphone with a cut-off frequency of 25 kHz, representing about 20 µs combined rise time, see F1/3.

TEST SET UP

See Fig. 1: Throughout the survey only a stepfunction, see Fig. 4, is used for transmitter excitation. Delivered from a 30 Hz squarewave generator, burstgate ratio 1 to 30 on/off; the amplifier has 1,5 µs rise time, class A, dc-coupled. M-transducer - MSW - flush wall mounted, see Fig. 7 and 8. Microphone diaphragm under test is always on axis with the transducer. Microphone supply is standard 48 Volt balanced, except for measurement microphones, connected directly to the oscilloscope in an asymmetric way. No additional transformer is used. Soundpressure level was about 80 dB rel. on peak value measurement in 1 m distance.

ROOM INFLUENCE

Room reflections, see Fig. 7 and 8, are without influence during measurement survey. Because at a scale of 100 µs per major division 10 divisions open a time window on the oscilloscope of 1 ms. Earliest room reflection arrives 3.55 ms later at the microphone.

GENERAL NOTES

Abbrevations used to identify films and pictures e.g.: F3/5 - Filmstrip 3, Picture 5 = 20 µs per major division on 180 degree rotated according to Fig. 7 with respect to the perpendicular axis of MSW = M-transducer. Rotations of the microphone are described on Fig. 7 and Fig. 8 in horizontally and upright mounted position.

For each microphone the consecutive number and the diameter are indicated on film. Picture sequence on each film is 100 µs, 50 µs, 3 times 20 µs and 100 µs per major division on time axis. Starting at 0 degree incidence angle. Followed by 2 pictures for incisive comparison in 20 µs with incidence angles 90 degree and then 180 degree. Construction alignments for free-field and diffuse field in time domain can easily be compared in 100 µs scale on the far left and the far right photograph, e.g. F1/1 to F2/6.

All the films displayed are contact copies of the original filmstrips taken. Each photographic trace was exposed for 2 seconds.

MEASUREMENT MICROPHONES WITH PROTECTION GRID

F1 B & K 4133 microphone 1/2",according to calibration chart: Free-field characteristic to give on perpendicular (0 degree) sound waves an extremely flat frequency response; +1 dB/12 kHz, fc = 25 kHz (overdamped).

F2 B & K 4134 microphone 1/2",according to calibration chart: Diffuse sound field alignment to give a flat frequency response, +3 dB/15 kHz, fc = 25 kHz (critically damped).

F3 B & K 4135 microphone 1/4", according to the calibration chart: Free-field characteristic to give on perpendicular (0 degree) sound waves an extremely flat frequency response ± 1 dB, fc approx. 100 kHz.

DISCUSSION OF F1 - F3

F3 measurement microphone 1/4" assignes a rise time of about 16 µs to the M-transducer, see F3/3. Theoretic value should be close to 5 µs rise time at fc 100 kHz /7/. F1 and F2 microphones 1/2" are already slower, 25 kHz fc stands for approximately 20 µs rise time. Combined transmitter and receiver rise time approaches the 20 µs very nicely, see F1/3 and F2/3. Eye catching the difference in transient behaviour on F1 and F2. But looking at the trace of F1/1 and F2/6 pictures display nearly equal stepfunction response. F1 B & K 4133 is a free-field and F2 B & K 4134 is a diffuse field microphone construction.

For practical applications it's good to keep in mind what a diffuse field alignment really means? It stands for an overshoot on 0 incident sound pressure impinging the diaphragm. Under unknown circumstances of sound direction a difference of up to 8 dB so far is possible. Smooth control of the resonance range by damping is the most dramatic display in high resolution within the range of interest to the microphone construction.

STUDIO MICROPHONE OMNIDIRECTIONAL TYPES: F4 - F13

No matter what the rotation angle is, see Fig. 7, the stepfunction ramp off, is hardly involved with an omnidirectional microphone, in contrast to all directional-type microphones, (next group). Sensitivity increases in general with diameter as well as length of overshoot in time, see F4 - 13/3. All other studio microphones except F4 have a pronounced overshoot amplitude within the boundaries from a strict 0 degree free-field (like F1/3) to a strict 180 degree diffuse (like F2/3) alignment.

A fresh livelike transparent sound sensation is apperantly not quite satisfying to the sound recording engineer with 0 degree flat free-field response /9/. On the other hand a high end overshoot tending to diffuse field alignment stands for ringing on unsufficient damping. Although there is not much knowledge in psychoacoustics in short periodic perception, it's nice to see what's physical behaviour under "working condition" on a microphone. A fine alignment to my opinion is the F11 microphone, although it is of 20 mm diameter. Representing fast rise times in free-field as well as in diffuse field with unimportant ringing after overshoot in a flat ramp with very few ripples.

STUDIO MICROPHONE CARDIOID TYPES F15 - F20

More complex in construction, it gives more freedom in making different alignments. F15 with the smallest 18.4 mm diameter microphone represents surprisingly the slowest rise time in this group of about 40 µs at approximately 12.5 kHz (fc). F15 has a comparatively long throw oscillation. F18/1 exhibits high-end ringing lasting for 400 µs. F17 and F20 appear to be in good alignment. For F17/6 the 180 degree damping shows even on the high end good values compared to all other microphones in this group.

STUDIO MICROPHONE UNIDIRECTIONAL TYPE F21 - F25

F21 and F22 are on Fig. 8 rotation, picture sequence is in the previous manner. Three build-in switches provide the following alterations: Five directional patterns F25/1-5; high pass filter F23 and attenuation F24. Microphone is in upright position, see Fig. 8 for F25 measurements with 6 times 30 degree steps. F25 contains on each picture 6 plus 1 traces including 0° incidence angle. Directional patterns in time domain describe changes in rise time, ringing and polarity in response to equal incidence stepfunction excitation under "working condition".

LOUDSPEAKER 2 AND 3 WAY CONSTRUCTION

Measurement microphone F1 B & K 4133 microphone 1/2" as previously measured is receiver. Distance to the loudspeaker is 1 m perpendicular to the identified tweeter (TW), midrange (MI) or to the woofer (WO). F26 - F28 is a 2 way construction; F29 - F31 is a 3 way construction; F32 - F37 is a 3 way construction (another brand).

Summary to page 6 is not easy, unless the listener keeps in mind, that every pressure change in direction changes the listener's eardrum excursion direction. Each picture shows the variations in response for different microphone positions and different constructions for one single step input excitation to the loudspeaker sample under test.

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/8/ M. Heckl, Math. Description: Abstrahlung von einer ringförmig angeregten sehr biegeweichen, großen Platte, Privat Info, not published.

/9/ J. Wuttke, Herkömmliches und Neues zum Thema "Kondensator Mikrofon mit Kugelcharakteristik", 13. Tonmeistertagung München 1984, S 75 ff, Berichtsband VDT Berlin Bildungswerk

/10/ P.V. Brüel, Do we meassure damaging Noice correctly, Noise control Engineering 3/4 1977.

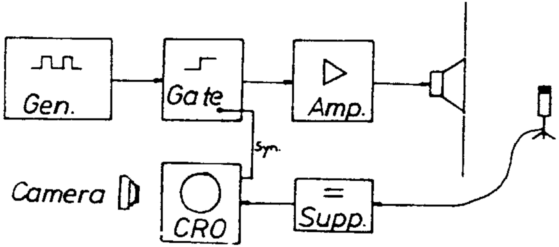


FIG. 1 STEPFUNCTION TEST SET UP

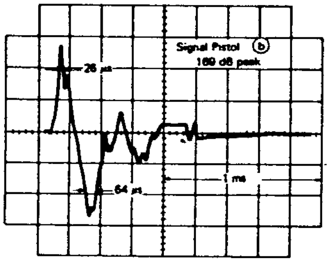


FIG. 2 PISTOL SHOT (from P.V. Brüel) /10/

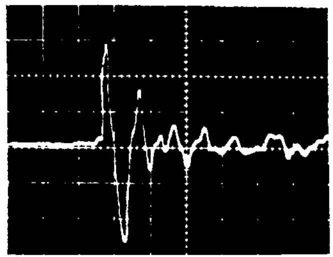


FIG. 3 SPARK DISCHARGE (from Lininger) /2/

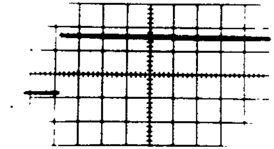


FIG. 4 ELECTRICAL SIGNAL INTO THE ACOUSTIC TRANSMITTER

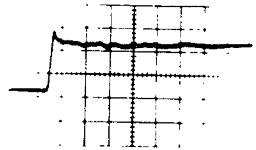


FIG. 5 M-TRANSDUCER RESPONSE WITH B+K 4133 MEASUREMENT MICROPHONE ½" (= F1/1)

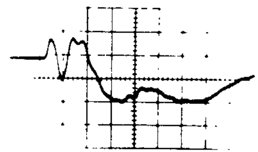


FIG. 6 CONVENTIONAL LOUDSPEAKER RESPONSE WITH B+K 4133 MEASUREMENT MICROPHONE ½" (= F 32/1)

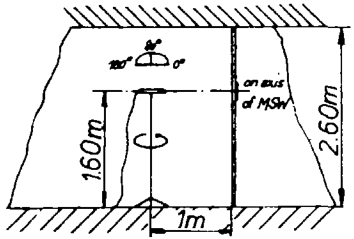


FIG. 7 MIC. HORIZONTAL POSITION AND ROTATION ANGLE

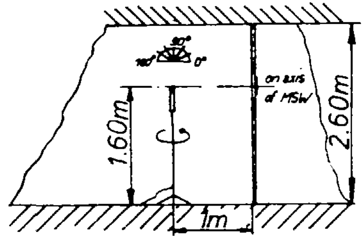
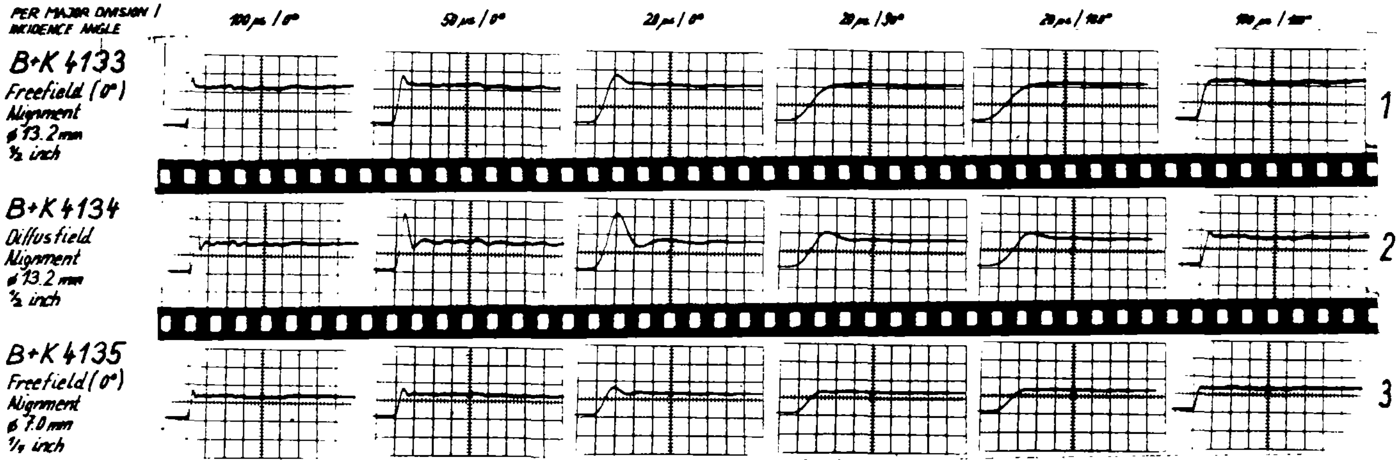
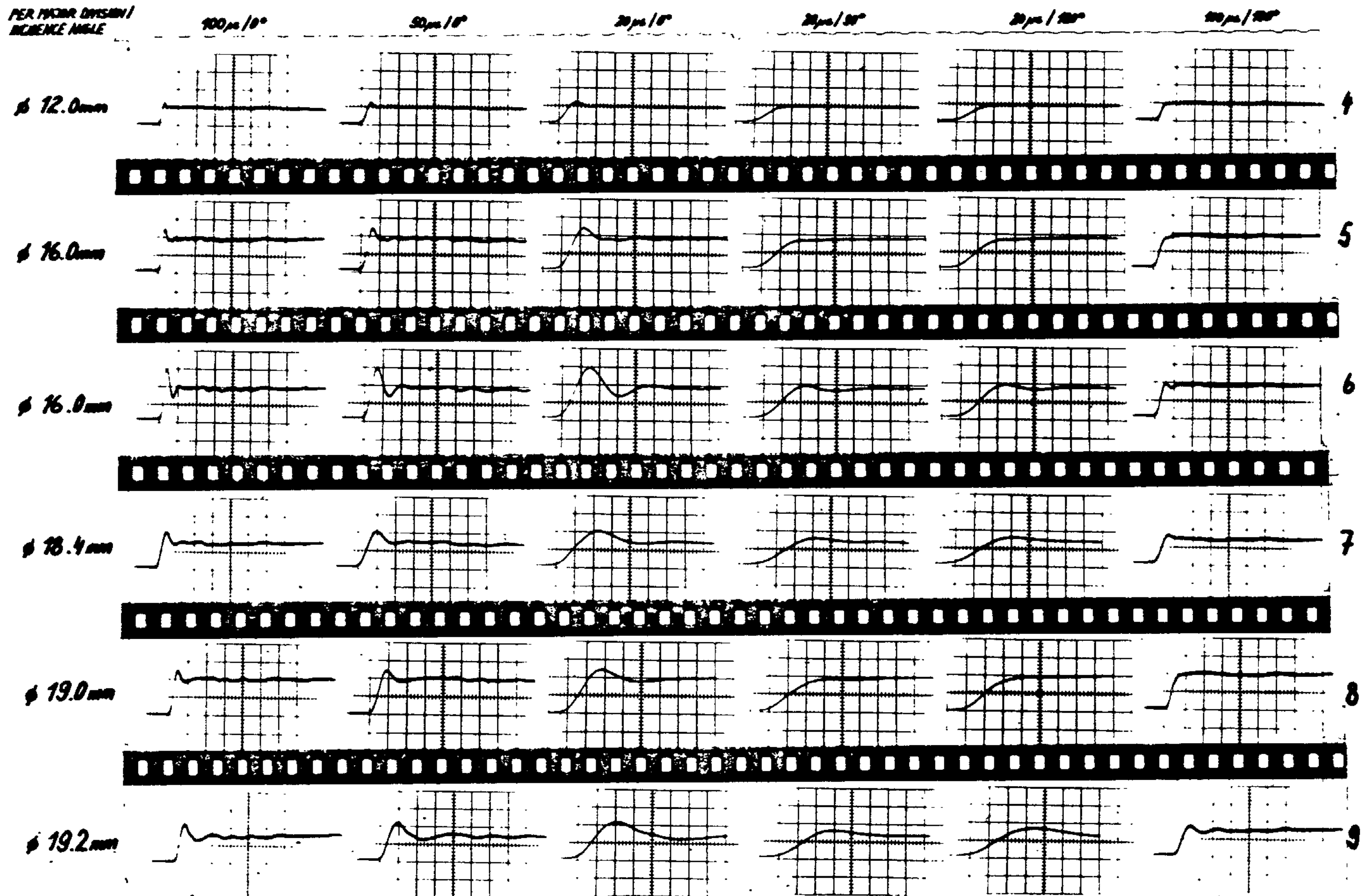


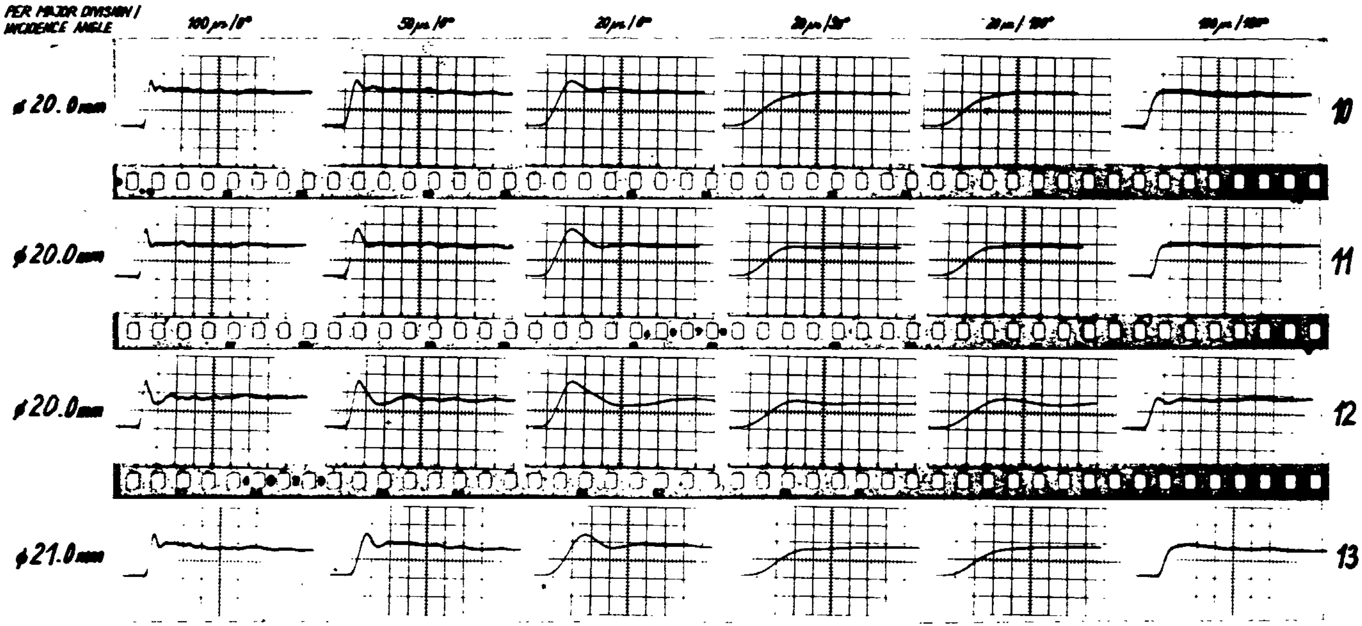
FIG. 8 MIC. UPRIGHT POSITION AND ROTATION ANGLE



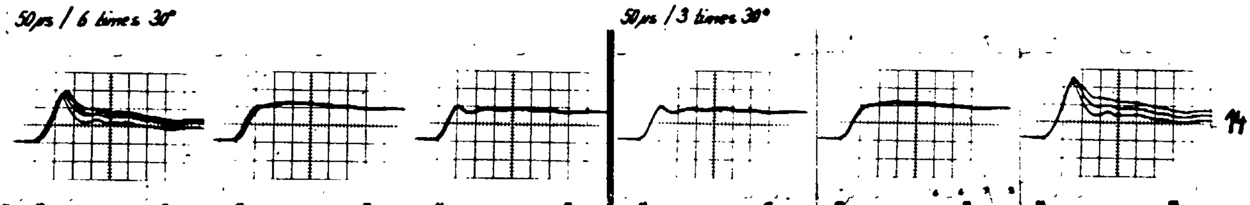
Film 1 - 3: OMNIDIRECTIONAL MEASUREMENT CONDENSER MICROPHONES - ON FIG. 7 ROTATION



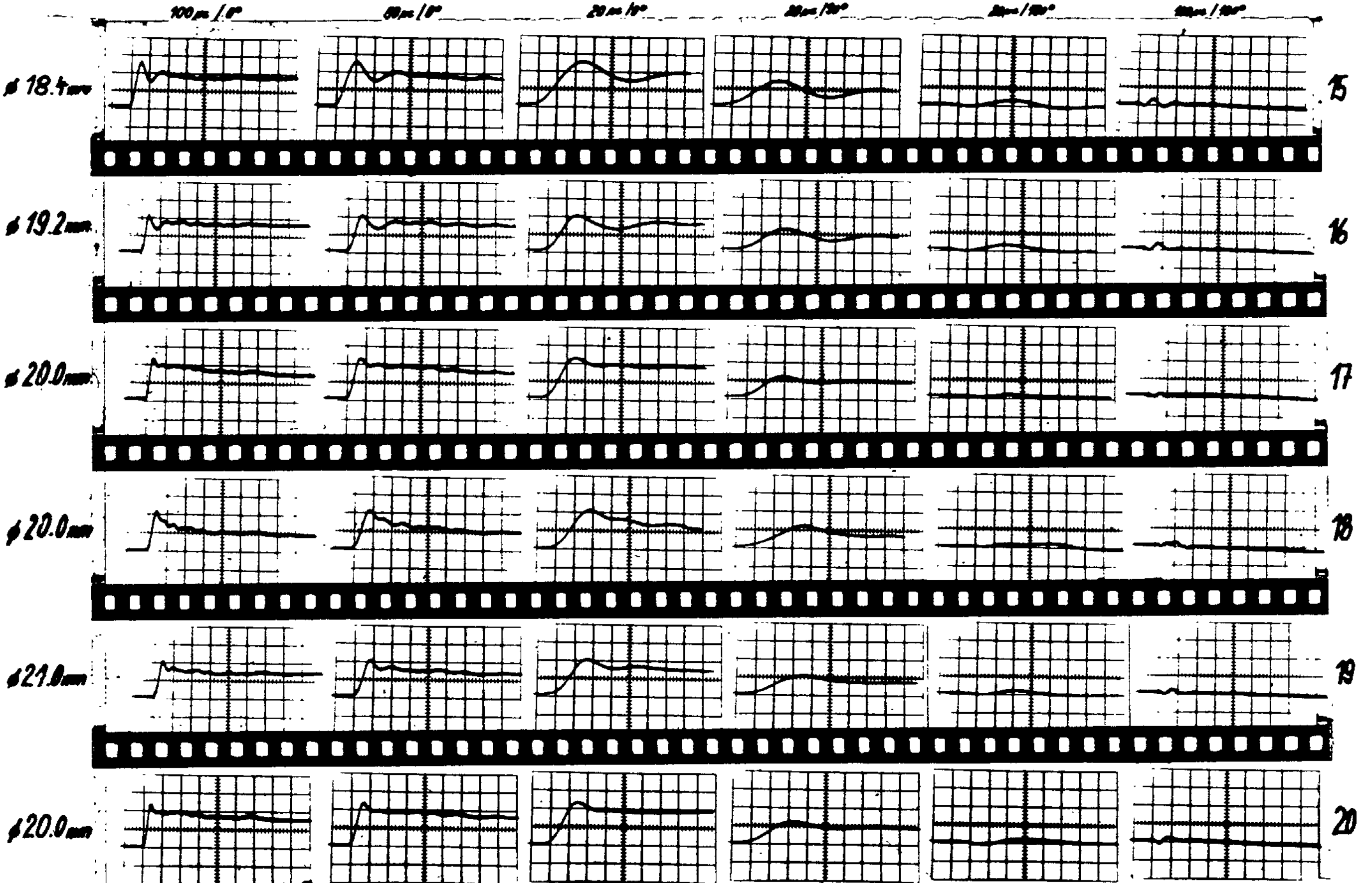
Film 4 - 9: OMNIDIRECTIONAL STUDIO CONDENSER MICROPHONES - ON FIG. 7 ROTATION



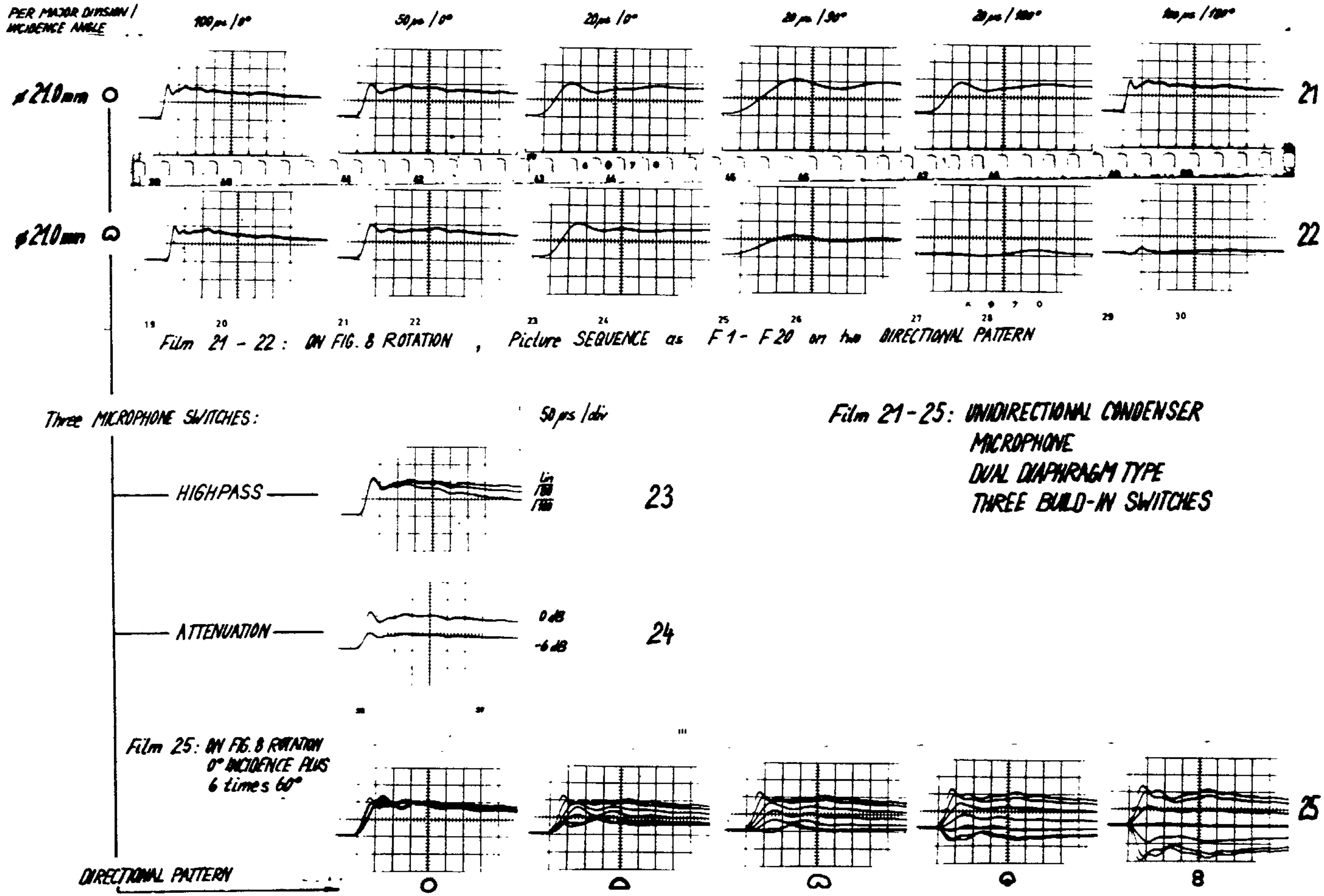
Film 10 - 13 : OMNIDIRECTIONAL STUDIO CONDENSER MICROPHONES - ON FIG. 7 ROTATION

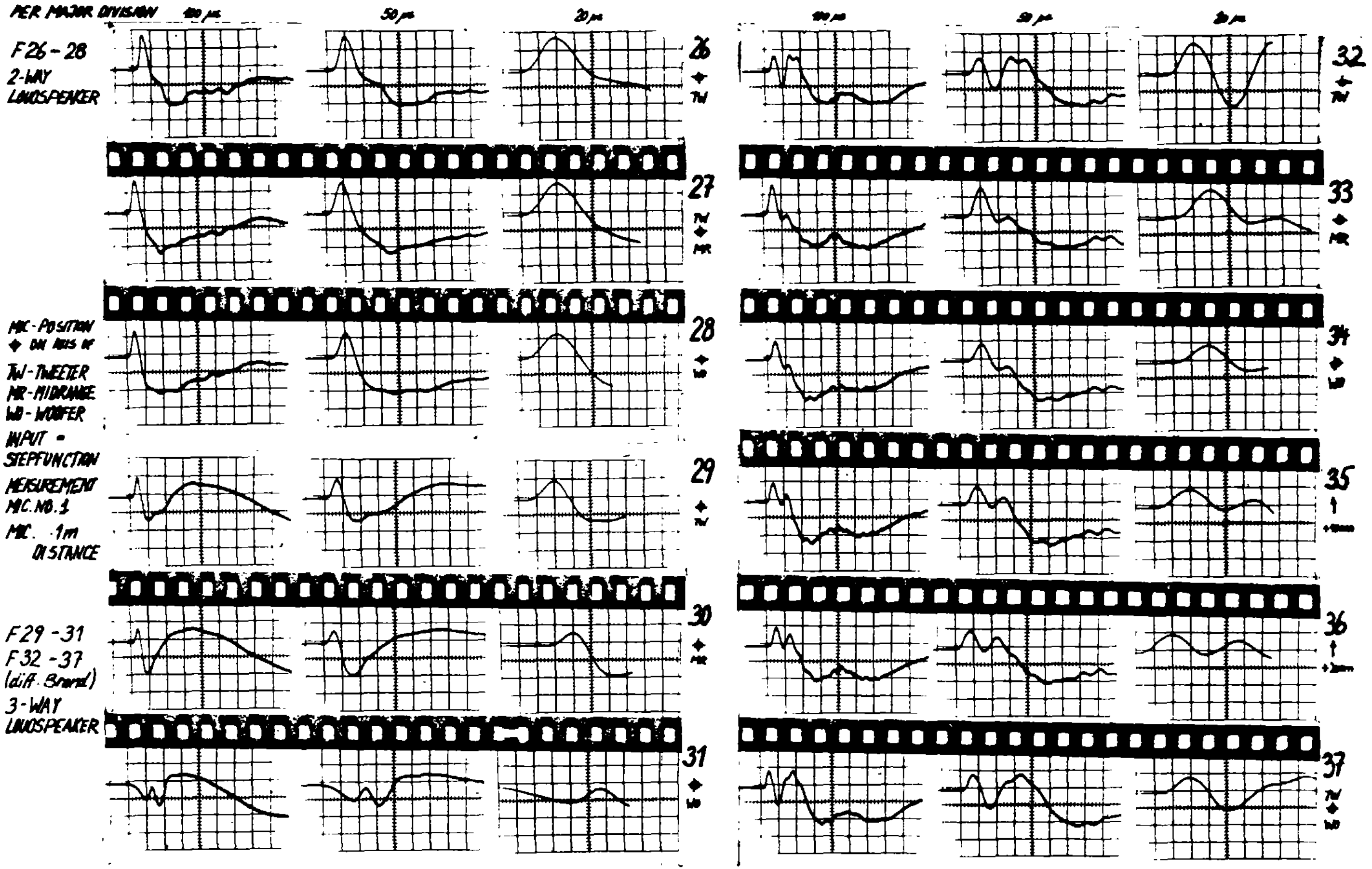


Film 14 : THREE DIFFERENT MICROPHONES F 18 + 5 + 12 - ON FIG. 8 ROTATION (left : ± 1mm EXCENTRIC ; right : ≈ ± 0 mm)



Film 15 - 20 : CARDIOIDE STUDIO MICROPHONES - IN FIG. 7 ROTATION


PER MAJOR DIVISION / INCIDENCE ANGLE
100 μs / 0°
50 μs / 0°
20 μs / 0°
ø 21.0 mm
ø 21.0 mm
21
22
Film 21 - 22 : ON FIG. 8 ROTATION , Picture SEQUENCE as F 1 - F 20 on the DIRECTIONAL PATTERN
Three MICROPHONE SWITCHES :
50 μs / div
Film 21 - 25 : UNIDIRECTIONAL CONDENSER MICROPHONE
DUAL DIAPHRAGM TYPE
THREE BUILD-IN SWITCHES
HIGHPASS
23
ATTENUATION
0 dB
-6 dB
24
Film 25 : ON FIG. 8 ROTATION
0° INCIDENCE PLUS
6 times 60°
25
DIRECTIONAL PATTERN
8


PER MAJOR DIVISION
100 µs
50 µs
20 µs
F26 - 28
2-WAY
LOUDSPEAKER
MIC-POSITION
◆ ON AXIS OF
TW-TWEETER
MR-MIDRANGE
WO-WOOFER
INPUT =
STEPFUNCTION
MEASUREMENT
MIC. NO. 1
MIC. 1m
DISTANCE
F29 -31
F32 -37
(diff. Brand)
3-WAY
LOUDSPEAKER
26
TW
27
TW
MR
28
WO
29
TW
30
MR
31
WO
32
TW
33
MR
34
WO
35
36
37
TW
WO