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A Technical Evaluation of the Honeywell ELAC – Echograph LAZ 72 Sounder

N.A. Cochrane

Atlantic Oceanographic Laboratory
Ocean Science and Surveys, Atlantic
Department of Fisheries and Oceans

Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia B2Y 4A2

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A TECHNICAL EVALUATION OF THE HONEYWELL ELAC - ECHOGRAPH LAZ 72 SOUNDER

by

N.A. Cochrane

Atlantic Oceanographic Laboratory

and R. Burke

Canadian Hydrographic Service

Ocean Science and Surveys, Atlantic

Department of Fisheries and Oceans

Bedford Institute of Oceanography

P.O. Box 1006

Dartmouth, Nova Scotia

B2Y 4A2

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ABSTRACT

Cochrane, N.A. and Burke, R. 1980. A technical evaluation of the Honeywell ELAC - Echograph LAZ 72 sounder. Can. Tech. Rep. Fish. Aquat. Sci. 12.

A Honeywell ELAC - Echograph LAZ 72 echosounder is technically evaluated for hydrographic applications. System performance is discussed under the separate categories of transducer, transmitter, and receiver function. Performance is found to be in general agreement with published specifications and consistent with intended applications. Vital parameters for system interfacing to a digital data acquisition system such as transmit power under varying duty cycles and accuracy of receiver time variable gain are analysed in detail.

Key words: Technical Evaluation, Echosounder, Hydrographic

RÉSUMÉ

Cochrane, N.A. et Burke, R. 1980. A technical evaluation of the Honeywell ELAC - Echograph LAZ 72 sounder. Can. Tech. Rep. Fish. Aquat. Sci. 12

Un échosondeur Honeywell ELAC-échographe LAZ 72 est techniquement évalué pour des applications hydrographiques. Le rendement de l'appareil est étudié quant aux composantes suivantes: transducteur, transmetteur et récepteur. Le rendement est considéré comme généralement conforme aux spécifications publiées ainsi qu'aux applications prévues. Sont analysés à fond certains paramètres essentiels pour l'interfaçage de l'appareil avec un système de saisie de données numériques de manière à transmettre le courant avec des coefficients d'utilisation variables et la précision du gain, variable dans le temps, du récepteur.

Mot-clés: évaluation technique, échosondeur, hydrographique

INTRODUCTION

GENERAL

The Honeywell ELAC-ECHOGRAPH LAZ 72 sounder has been selected by the Atlantic Region, Canadian Hydrographic Service for bathymetric sounding aboard hydrographic survey launches replacing obsolete EDO 9040 units. This report contains a technical evaluation of a typical unit. Major performance parameters are evaluated, compared when possible to published specifications, then considered from the viewpoint of intended usage especially inclusion of the sounder in a future digital data acquisition system. A field evaluation has been reported by Berkeley & Burke (1980).

EQUIPMENT DESCRIPTION

The LAZ 72 sounders are the 30 kHz version[1] equipped with the PGN-26 transmitter and LSE 131 ZR transducer. Major specifications are as follows:

<u>Transmitter:</u>

Sounding frequency - 30 kHz
Power Output - Max 1 KW switchable to 1/10 power "basically dependent on sounding sequence in internal transmitter".
Transmit Pulse Length - 0.3, 1 and 3 ms
Output Impedance - 70 or 150 Ω selectable

<u>Receiver:</u>

Bandwidth - 2 or 7 kHz selectable
Gain Front end gain switchable in 11 increments of 6db.
TVG 20 log R to approx. 500 m
40 log R to approx. 300 m
User adjustable ramp.

1. Available in 12, 15, 18, 20, 24, 30, 37.5, 50, 150, and 200 kHz versions

Chart:

Type - dry electrosensitive

Width - 230 mm

Length - 25 m

Speed - switched with range, 125 mm/min. max.

Ranges - as below

Primary Range (m)	Shifted Ranges (m)	
0- 20	20- 40	40- 60
0- 50	50- 100	100- 150
0-100	100- 200	200- 300
0-200	200- 400	400- 600
0-500	500-1000	1000-1500

Power Consumption: 60-110 VA

Specific Unit Tested:

Type Sounder - LAZ 72 AT 22R 110 A.C.

- DHI-22-17-E-79

Serial No. - LAZ 72 980 1981

Type Transducer - ELAC LSE 131 ZR

Serial No. - 544141008 01 1027

SCOPE OF INVESTIGATION

Technical investigations are subdivided. (a). Transducer characteristics; (b) Transmitter characteristics; (c) Receiver characteristics. Transducer characteristics include beam pattern, transmit and receive sensitivities, and electrical impedance. Transmit characteristics include envelope character and power output for various pulse widths and repetition rates. Receive characteristics include overall gain, TVG range and accuracy, self noise, and bandwidth. Appendix 1 contains notes from an operational test aboard a hydrographic launch in Bedford Basin; Appendix 2 discusses constraints on overall receiver sensitivity.

Transducer and transmit characteristics were measured with the special floating acoustic calibration facilities of the Defence Research Establishment, Atlantic. Receiver performance was evaluated with the facilities of the Metrology Division, Atlantic Oceanographic Laboratory, Bedford Institute.

EVALUATION

TRANSDUCER

Procedure

The circular transducer was rigidly suspended at 7.7 m depth with axis horizontal. The appropriate calibrated acoustic projector or receiving hydrophone was suspended in the center of the main lobe at 10 m separation. To effect electrical connection to the transducer the supplied 10 m of transducer cable was lengthened by 8 m. Transducer characteristics were measured with dedicated calibration transmitters and receivers. To obtain beam pattern traces the transducer was rotated about the vertical axis while received levels were automatically plotted in polar coordinates. Transmit signals were pulsed and time gated on receive to eliminate spurious reflected signal paths. Beam patterns were assumed invariant about the transducer's own axis of circular symmetry.

Results

Transmit polar beam patterns for frequencies of 29,30, and 31 kHz appear in Figs. 1-3 respectively. The absolute transmit calibration of the main lobe over a wide range of frequencies is shown in Fig. 4. Corresponding receive beam patterns are displayed in Figs. 5, 6, and 7 respectively and the absolute receive sensitivity in Fig. 8. Transducer impedance magnitude and phase measured at the transmitter end of the transducer cable are shown as functions of frequency in Fig. 9.

TRANSMITTER

Procedure

Transmit characteristics were measured with the transducer load mounted as explained above. Voltages at the echosounder transmitter output terminals were monitored with an oscilloscope while transmitted pressure fields were monitored with a calibrated hydrophone. Nominal 3, 1, and

0.3 ms pulse widths were utilized at repetition rates determined by the 0-20, 0-100, and 0-500 m depth ranges. Observations were made at both maximum and 1/10 power settings.

Results

Carrier frequency was measured as (29.81 ± 0.1) kHz.

The output transmit pulse lengths were observed to be 2.6, 0.9, and 0.18 ms compared to nominal values of 3.0, 1.0, and 0.3 ms. The 0.18 ms pulse envelopes tended to assume a rounded as opposed to rectangular shape. The 3 ms pulses displayed noticeable amplitude sag during the transmit cycle. At maximum power, 3 ms pulse amplitudes were inversely correlated with repetition rate, while for shorter pulses at maximum power and all pulse lengths at 1/10 power little correlation with repetition rate was observed. Results were summarized in Table 1. Tabulated transmit voltages and receive hydrophone levels correspond to the leading edge, center, and trailing edge of the pulse.

A more meaningful parameter is instantaneous power output, $P = (V^2/Z) \cos \Phi$, where V is the rms transmit voltage output, Z the transducer impedance amplitude, and Φ its phase. The maximum instantaneous transmit voltage observed was about 800 v pp. For $Z = 74\ \Omega$ and $\Phi = 26.6°$ (measured) the delivered pulse power was 970 watts (rms). Reference to the transducer characteristics established a radiated pressure of + 119 db ref 1 μBar @ 1m. For the 3 ms pulse at the 0-500 m range repetition rate the power drooped from the above value at the leading edge of the transmit pulse to 620 watts at the end of the pulse. At the longer duty cycle imposed by the 0-20m range repetition rate, instantaneous transmit power varied from 80 to 40 watts (rms). At 1/10 power, droop still occurred particularly for 3 ms pulses. The 1/10 power maximum transmit voltage, 119 v pp, corresponded to an instantaneous power output of about 20 watts (rms).

RECEIVER

Procedure

The transmitter unit was disabled and an HP 208A-DB 600 Ω test oscillator and HP 5612A digital frequency monitor were coupled to the transceiver transducer terminals in parallel with a fixed resistance to simulate a nominal 70 Ω resistive transducer load. Receiver output was measured prior to signal detection at the point labelled "Basic Signal" (terminal L2 "Field Service Manual"). This was considered a convenient point for future electrical interfacing to a digital acquisition system. When used with the integral chart recorder the signal envelope is subject to post detection low pass filtering at 7 kHz for the 0.3 ms pulse or 2 kHz for the 1 and 3 ms pulses. Characteristics of the detection and greyline circuitry were not measured. The gain mode switch was first placed in the "AV" position with transmitter disabled resulting in a constant maximum gain characteristic. Front end receiver bandwidth was measured by varying the oscillator frequency. Overall voltage gains were measured for various settings of the master gain control. The TVG ramps for 20 log R and 40 log R gain modes were observed by operating the full sounder with a 70 Ω dummy load in place of the transducer while simultaneously injecting a very low level continuous 30 kHz carrier from the signal generator. Receiver self noise was in turn obtained by scaling the band limited random output at the "Basic Signal" point to an equivalent input voltage using the known gain function with only the 70 Ω dummy load connected to the transducer terminals.

Results

The receiver center frequency was measured as 30.1 kHz with upper and lower -6 db cutoffs at 33.1 and 27.1 kHz respectively. Signal gains at the "Basic Signal" point for various settings of the master gain control appear in Table 2.

Time variable gain was operative for 580 ms duration in 20 log R mode and for 360 ms in 40 log R mode corresponding to maximum reflection ranges of 435 m and 270 m respectively. Maximum obtainable dynamic range was 42 db for 20 log R and 35 db for 40 log R response. On the 0.3 ms transmit pulse, the TVG commenced its rise about 1 ms after initiation of the transmit pulse. Gains at TVG cutoff were equal to those of Table 2 for both ramp modes. Fig. 10 shows a log-log plot of measured signal amplitude vs. time. A perfect 20 log R characteristic would display a unity slope, a

40 log R characteristic a slope of 2. The 20 log R response was closely approximated only for water depths greater than 15 m (0.02s); the response deviating 2 db or less from the ideal over a dynamic range of about 27 db. At lesser depths an excessively shallow response slope led to a spreading loss undercompensation of about 5 db at 7.5 m (0.01s) increasing to over 10 db at depths of several meters. An approximate 40 log R response was approached only at the deep water end of the curve from 150 to 270 m ($\geq$0.2s).

Receiver self noise was estimated as 0.6 x 10^{-6} v rms equivalent at the transceiver input terminals corresponding to an on axis transducer pressure field of -50 db ref. 1 μ Bar.

POWER CONSUMPTION

Power consumption was calculated from mains voltage and measured current with no correction for power factor. Consumption varied between 44 VA at LO power and minimum duty cycle to 60 VA at HI power and maximum duty cycle. Adjusting the chart lamp from minimum to maximum illumination added 7 VA to the above totals. These values were near the lower end of the specified 60-110 VA range.

INTERPRETATION

One requirement for echosounder transducer beam patterns is sufficient beam width to eliminate excessive echo strength fluctuations arising from normal roll of the survey vessel. This is especially important if automated bottom tracking is contemplated. A second opposing requirement is a sufficiently narrow main lobe and sufficiently attenuated side lobes to efficiently utilize transmitted energy, reject non-axial ambient noise, and suppress intense diffraction patterns on surveys of U-shaped channels.

Measured transmit and receive beam patterns were essentially identical in accord with basic theory. The beam width measured between -3db points was about 14°, and between the -6 db points about 22°, beyond which rolloff was very steep. The first null occurred about 18° off axis, the first side lobe at 24° off axis, down 19 db, and the second lobe at

42°, down about 17 db. Reception via the rear of the transducer was attenuated about 16 db. In practical terms the leading edge of the bottom echo would vary by 6 db for a ship roll of 7° from equilibrium or 12 db for a roll of 11°.

The minimum required transducer bandwidth, Δf, is related to the transmitted pulse width by the approximate relation $\Delta f = 1/\Delta t$. For electro-acoustic conversion with minimal distortion, the bandwidth should be about twice this value. Therefore for the shortest nominal pulse width, 0.3 ms, the minimum bandwidth should be 3.3 kHz and preferably over 6 kHz. Figs. 4 & 8 show transmit and receive voltage responses flat to about 1 db over this frequency range. The shortest measured transmitter pulse width, 0.18 ms, would require bandwidths of the order of 11 KHz for high fidelity transmission. Fig. 4 indicates transmit response drops rapidly below about 27 kHz, consequently considerable envelope distortion might be expected for the radiated acoustic signal.

Transducer impedance varied irregularly in both amplitude and phase for several kHz either side of 30 kHz (Fig. 9). Rough calculations indicate efficient energy transfer for the range of frequencies arising from the nomimal pulse widths. For the abnormally short 0.18 ms pulse, (3 ms nominal) distortion probably arises from increasingly inefficient transmitter load coupling below 27 kHz. This conjecture was verified by replacing the transducer by a resistive dummy load whereupon the output pulse assumed a much more rectangular envelope. Losses from bandwidth considerations should at worst be less than 1 db, a minor consideration for the intended application.

The nominal transmit output of 1 KW was approached only under restricted operating conditions as suggested by the manufacturer's specifications. Rapid power sag under heavy duty cycle suggests the power supply is not conservatively designed. "1/10 power" was consistently about 20 watts, low, but again of minor significance from a practical point of view since the higher power range is always available. The transducer power factor of 0.89 corresponding to the resonant transducer impedance phase of 26.6° is acceptable. Calculations show the addition of 8 m of transducer cable during test is not sufficient to explain the non zero phase angle.

Receiver sensitivity was typical of state of the art sounders not utilizing sophisticated TR switching. An evaluation of overall system noise level is contained in Appendix 2. Receiver bandwidth characteristics were suitable for the nominal pulse widths employed and switchable gain increments were near nominal. TVG ranges were 10-13% less than the "approximate" ranges stated by the manufacturer. Inaccurate 20 log R TVG compensation in depths less than 15 m should not adversely effect digitizer bottom tracking because of the excellent attendant SNR possible at close range. Seawater acoustic absorption at 30 KHz is about 3 db/1000 m, resulting in an additional undercompensation at the maximum TVG range (2 x 500 m total path nominal, 20 log R). The combined effects of nonideality in the 20 log R response and lack of an absorption correction predict a 13 db or so uncompensated reduction in bottom signal on moving from water depths of a few meters to those approaching 500 m at the TVG depth limit (provided sounder duty cycle is not altered). One additional consideration is that the standard 20 log R compensation for the peak time domain intensity of incoherent bottom echoes assumes a transmit pulse of sufficient duration to simultaneously view all of the transducer beam footprint. For a 14° effective beam width the 0.3 ms pulse should not be used for ranges >30 m, the 1 ms pulse >100m, and the 3 ms pulse >300 m if near perfect compensation is desired. Insufficient pulse width would further exaggerate the ≈13 db reduction in signal strength predicted on moving to deep water. Higher signal amplitudes in shallow water are reported in Appendix 1 but no quantitative measurements were attempted.The more serious problems with the 40 log R response are of little consequence since this compensation mode is used primarily for isolated point targets, as in fish finding, rather than for hydrographic purposes.

CONCLUSIONS

Technical evaluation of an ELAC LAZ 72 sounder has revealed no design or operational flaws which would seriously compromise its utility as a conventional hydrographic sounder or as a component in a future digital system. Performance specifications appeared met with the relatively minor exceptions of the 0.3 ms transmit pulse being somewhat shorter than nominal, very low output under "1/10 power" operation, and considerable departure from ideal 40 log R TVG response. Significant power output sag from the manufacturer's optimum stated value was observed under heavy duty cycles. However power output appears sufficient for the intended application.

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Clay, C.S. and H. Medwin. 1979. Acoustical oceanography: Principles & applications. John Wiley & Sons, New York, N.Y. 544 p.

Urick, R.J. 1975. Principles of underwater sound. McGraw-Hill, New York, N.Y. 384 p.

APPENDIX 1: LAUNCH TEST OBSERVATIONS

On April 30, 1981 an ELAC LAZ 72 sounder installed aboard the 8 m launch "Cormorant" was taken to Bedford Basin for an observational test. The following comments are derived from notes pertaining to this cruise, the purpose of which was observational. Therefore these results do not constitute a carefully controlled quantitative experiment and at most should be regarded a crude impression of performance.

The transducer was mounted approximately amid ships 0.4 m below the waterline in a hydrodynamicaly streamlined transducer housing protruding slightly from the hull line on one side of the keel. An oscilloscope was used to observe the received echosounder signal before demodulation. With launch stationary starting the boat's diesel engine produced little change in background noise. No transients or noise spikes were observed with engine running. At cruising speed noise amplitudes rose by roughly a factor of 2 over ship stationary values. Signal background from within the water column remained constant on switching from 1/10 to full power suggesting an externally generated origin as opposed to water column backscatter. Sea conditions were calm throughout.

Most of the area profiled was characterized by rocky or gravel bottom. Bottom returns from these areas utilizing short transmit pulses were elongated 5-10 ms duration, indicative of incoherent bottom scatter as opposed to a specular reflection mechanism. Observed bottom impulses were highly irregular, general amplitudes varying by a factor of 2 between adjacent pings, often with sharp maxima suggesting discreet strong bottom scatterers (boulders?). On traversing a patch of soft silt, amplitudes dropped by a factor of 3 or 4, sharp peaks in bottom returns tended to disappear, and noticeable subbottom penetration was attained. Simultaneous chart recordings showed a clear grey scale differentiation between the two contrasting bottom types. Echo amplitudes increased slightly in shallow water in spite of the 20 log R compensatory gain characteristic.

To simulate a rougher sea state the launch was manoeuvred to cross through its own wake. Under these conditions signal attenuation was generally either total or non-existent often varying suddenly between adjacent pings with few intermediate values observed. It was not clear whether the aeration-generated extinction was due to folding under of the launch's bow wave in the rougher water with consequent under-hull entrapment of air or due to direct absorption by bubble clouds comprising the wake. Since relatively long continuous extinctions were observed while moving along the wake as opposed to moving perpendicularly across it the latter mechanism is considered more likely. These artificial conditions may be poorly representative of heavy breaking seas since the mode of air extrainment is different. They nonetheless suggest transducer placement is critical and that a special transducer housing such as an underhull retractable pod may be necessary to optimize system performance.

APPENDIX 2: EFFECTIVE RECEIVE SENSITIVITY

Ambient noise at 30 kHz is primarily wind generated (Urick, 1975). Therefore for any receiving system with known electrical characteristics, self generated noise character, and directivity, a parameter of performance may be defined consisting of the theoretical wind speed below which receiver performance is dominantly system noise limited and above which ambient noise limited. Receive sensitivity is about -74 db ref 1V/μ bar (Fig. 8); therefore a receiver self noise of 0.6×10^{-6} V rms translates to an on-axis pressure of 3.0×10^{-3} μ bars. Assuming the noise to be equally distributed across the 6 kHz reception band width the (isotropic) noise spectral density is $(3.0 \times 10^{-3}\ \mu\text{ bars})^2/6 \times 10^3\text{Hz} = 1.5 \times 10^{-9}\ \mu\text{bar}^2/\text{Hz}$. To convert from an isotropic to equivalent omnidirectional ambient noise one must multiply by the transducer directivity factor, which for a circular piston transducer, can be derived from the measured beam width (Clay & Medwin, 1977). For a -3 db point 7° off axis the directivity factor is about 1.7×10^2 yielding an omnidirectional ambient noise of $2.55 \times 10^{-7}\ \mu\text{bar}^2/\text{Hz}$ or -66 db ref 1 $\mu\text{bar}^2/\text{Hz}$ (34 db ref 1 $\mu\text{ Pa}^2/\text{Hz}$). Reference to standard tabulations of ambient nose vs. wind speed (Urick, 1975) yield an equivalent noise generating wind of about 7-10 knots. This means that with the launch stationary a wind of 7-10 knots would produce an ambient noise equal to the receiver self noise. On normal profiling operations from a moving launch, flow and propellor noise are important but difficult to estimate. One observation (Appendix 2) is that the noise background rises about 6 db while underway in a calm sea. This suggests a typical mobile operational noise level near -60 db ref. 1 $\mu\text{bar}^2/\text{Hz}$, equivalent to the ambient noise generated by average winds of about 17-21 knots. This noise level is consistent with the observation of Berkeley and Burke (1980) of "some noise on the graph" when operating the unit in 25 knot winds.

TABLE 1. Transmitter output voltages and relative hydrophone monitor levels for various sounder duty cycles. The three consecutive readings correpond to the initial rise, central portion, and rear edge of the transmit pulse envelope respectively.

FULL POWER

Pulse Width	Rep. Rate	XMIT-Voltage (p-p)	Hydrophone level (db)
3 ms	0- 20 m	225, 195, 170	2.2, 1.5, 0.6
"	0-100 m	580, 460, 370	9.2, 8.5, 7.0
"	0-500 m	>800, 770, 640	9.1 nearly constant
1 ms	0- 20 m	280 slight droop	6
"	0-100 m	760	9.4
"	0-500 m	790	9.3
0.3 ms	0- 20 m	620	9.0
"	0-100 m	700	9.0
"	0-500 m	700	9.1

1/10 POWER

Pulse Width	Rep. Rate	XMIT-Voltage (p-p)	Hydrophone level (db)
3 ms	All	110, 100, 90	-3.1, -3.7, -4.5
1 ms	"	115, 113, 110	-2.8 constant
0.3 ms	"	119 rounded	-2.8 rising

TABLE 2. Signal gains measured at "Basic Signal" point for various settings of Master Gain control.

Master Gain Setting	Gain (db)
1	29.5
2	35.9
3	41.9
4	47.8
5	54.1
6	60.7
7	66.9
8	72.8
9	78.1
10	83.7*
11	88.1*

*May be imprecise due to low signal values employed.

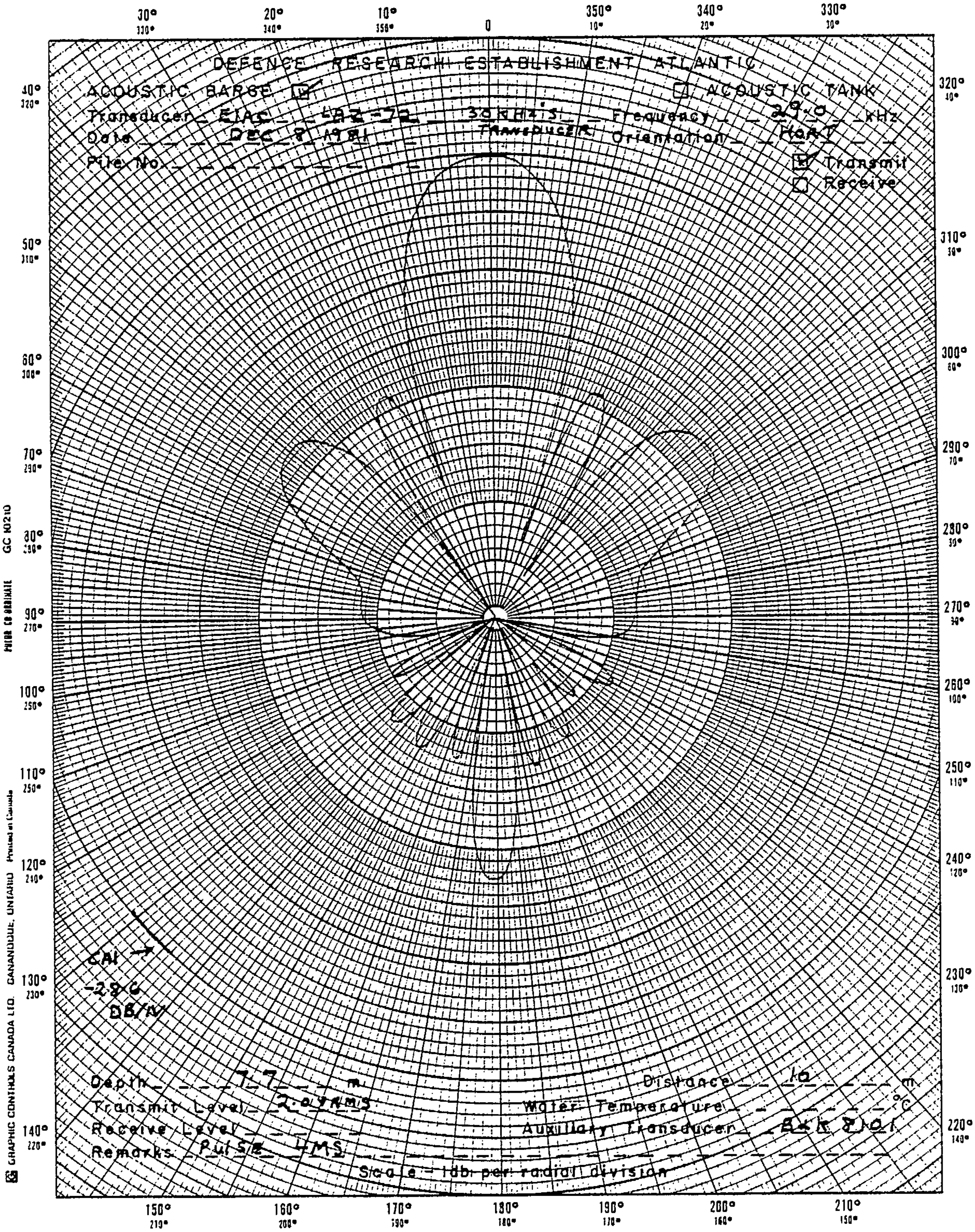

Fig. 1. Transmit pattern 29 kHz

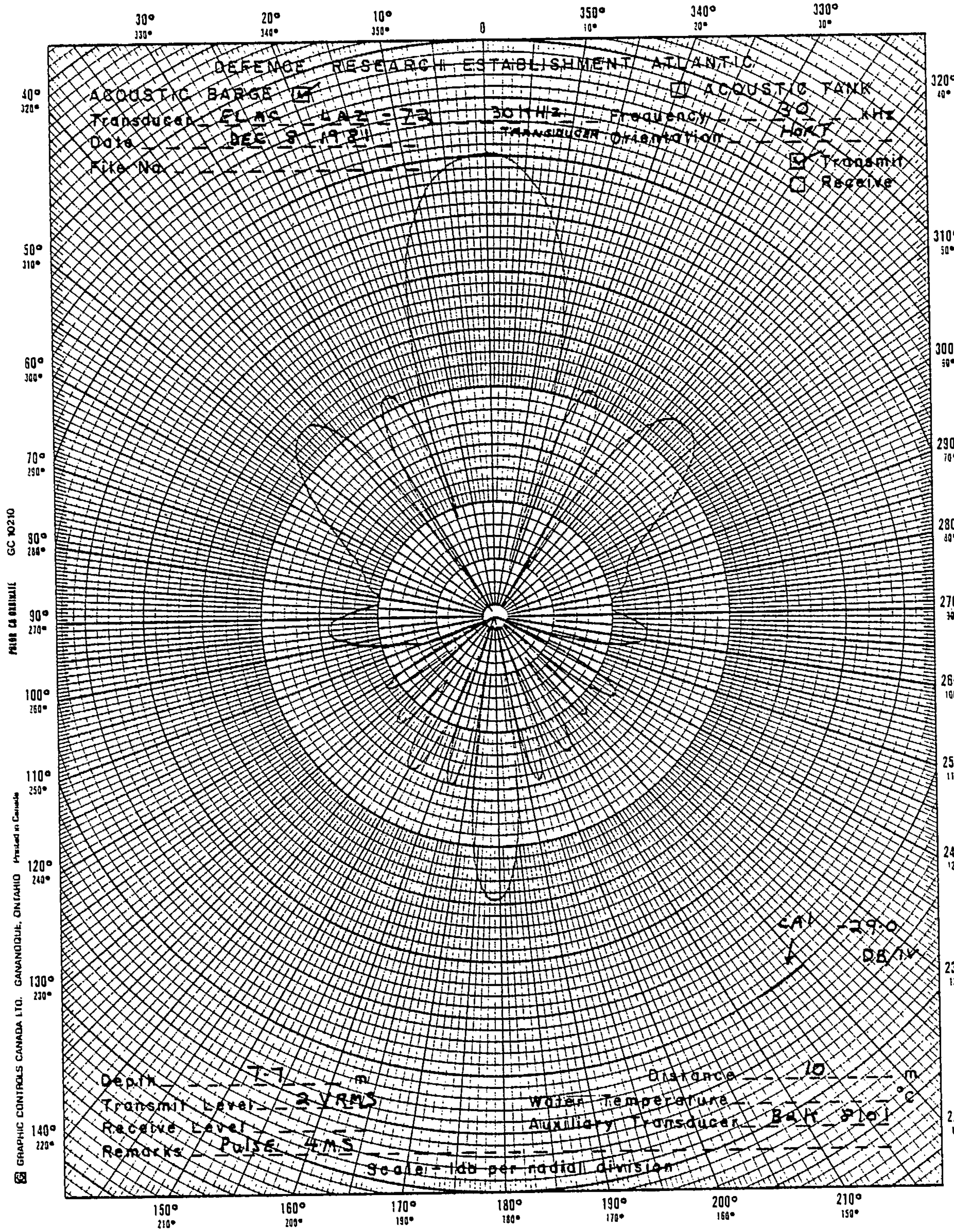

Fig. 2. Transmit pattern 30 kHz

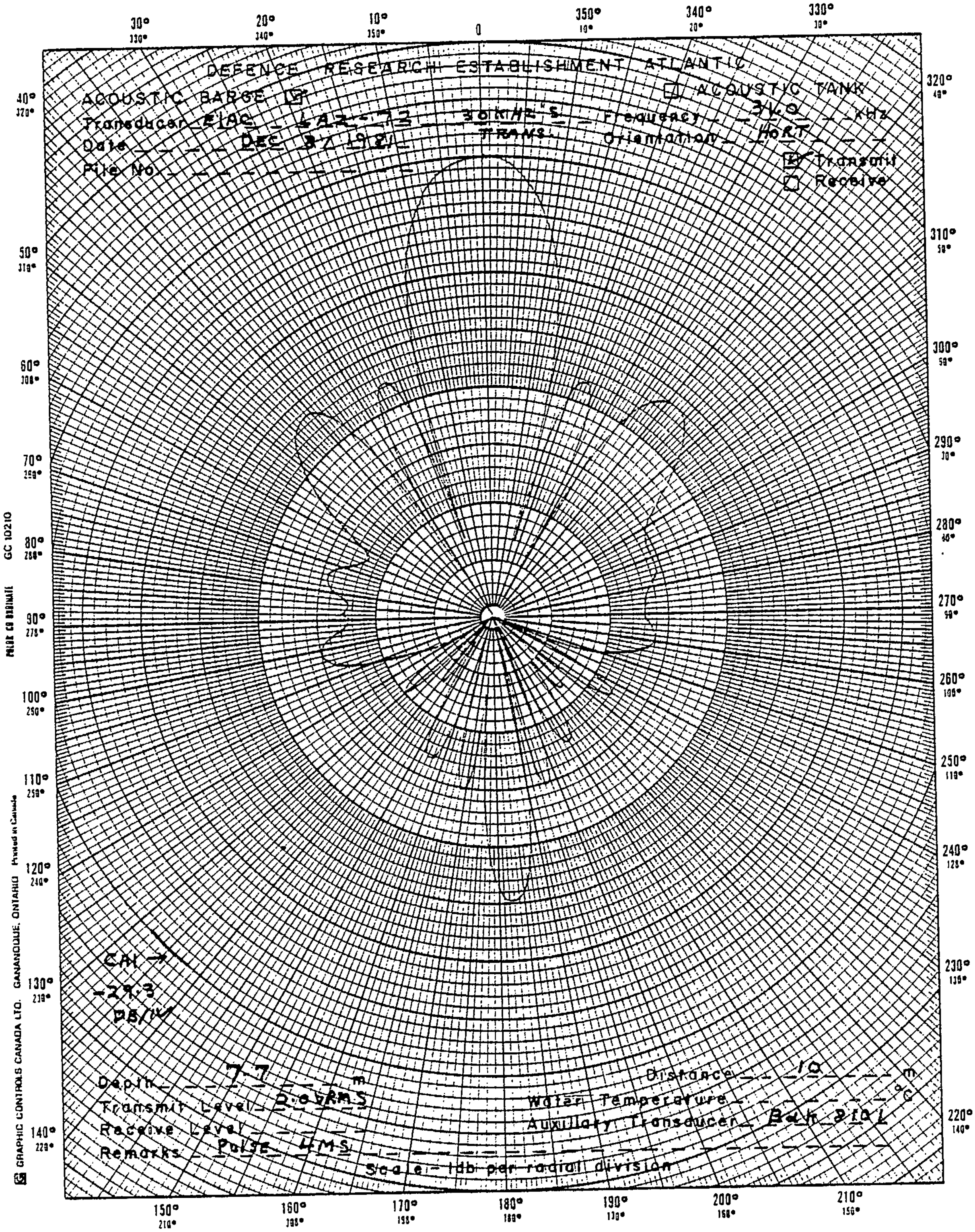

Fig. 3. Transmit pattern 31 kHz

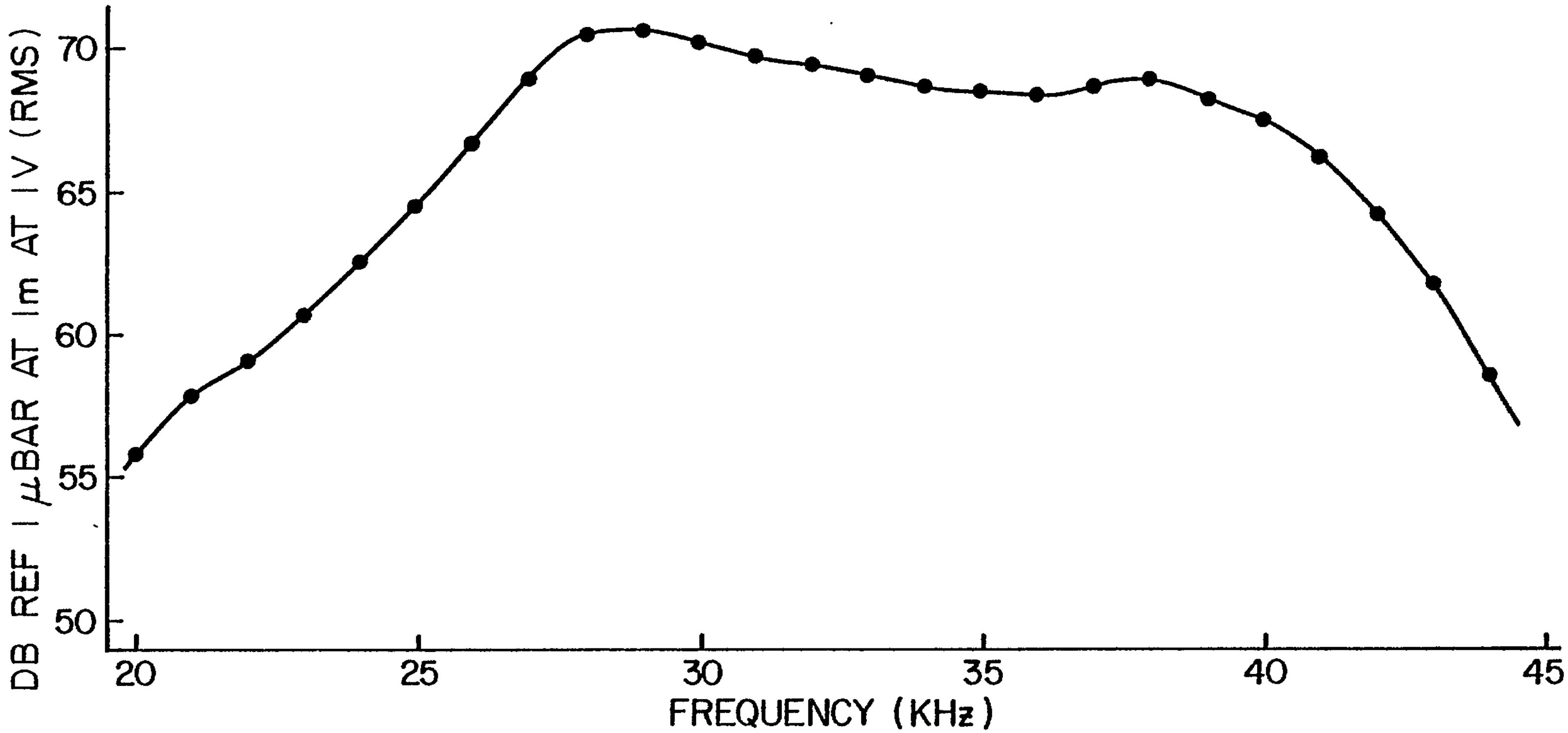

Fig. 4. Absolute transmit sensitivity of transducer vs. frequency

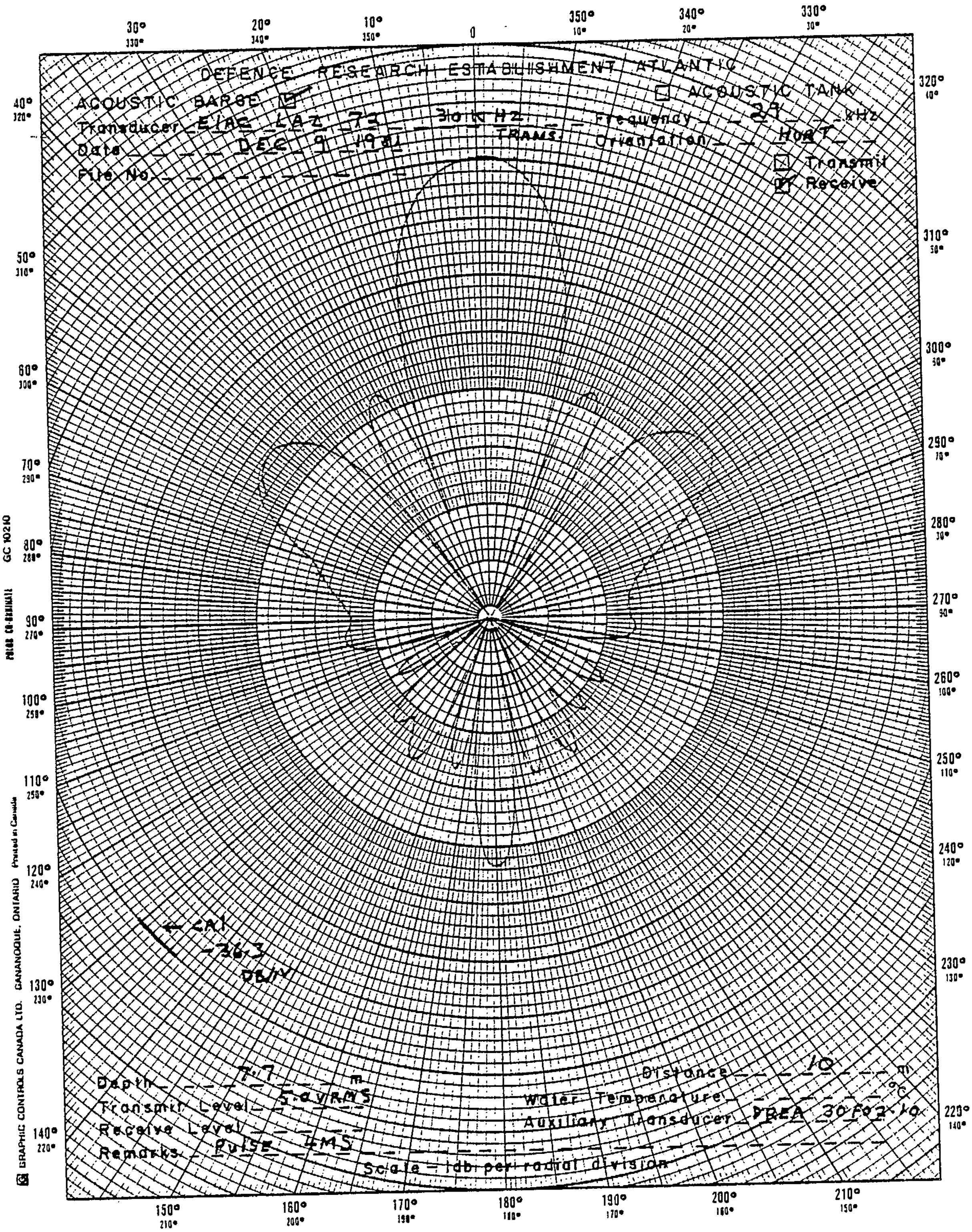

Fig. 5. Receive pattern 29 kHz

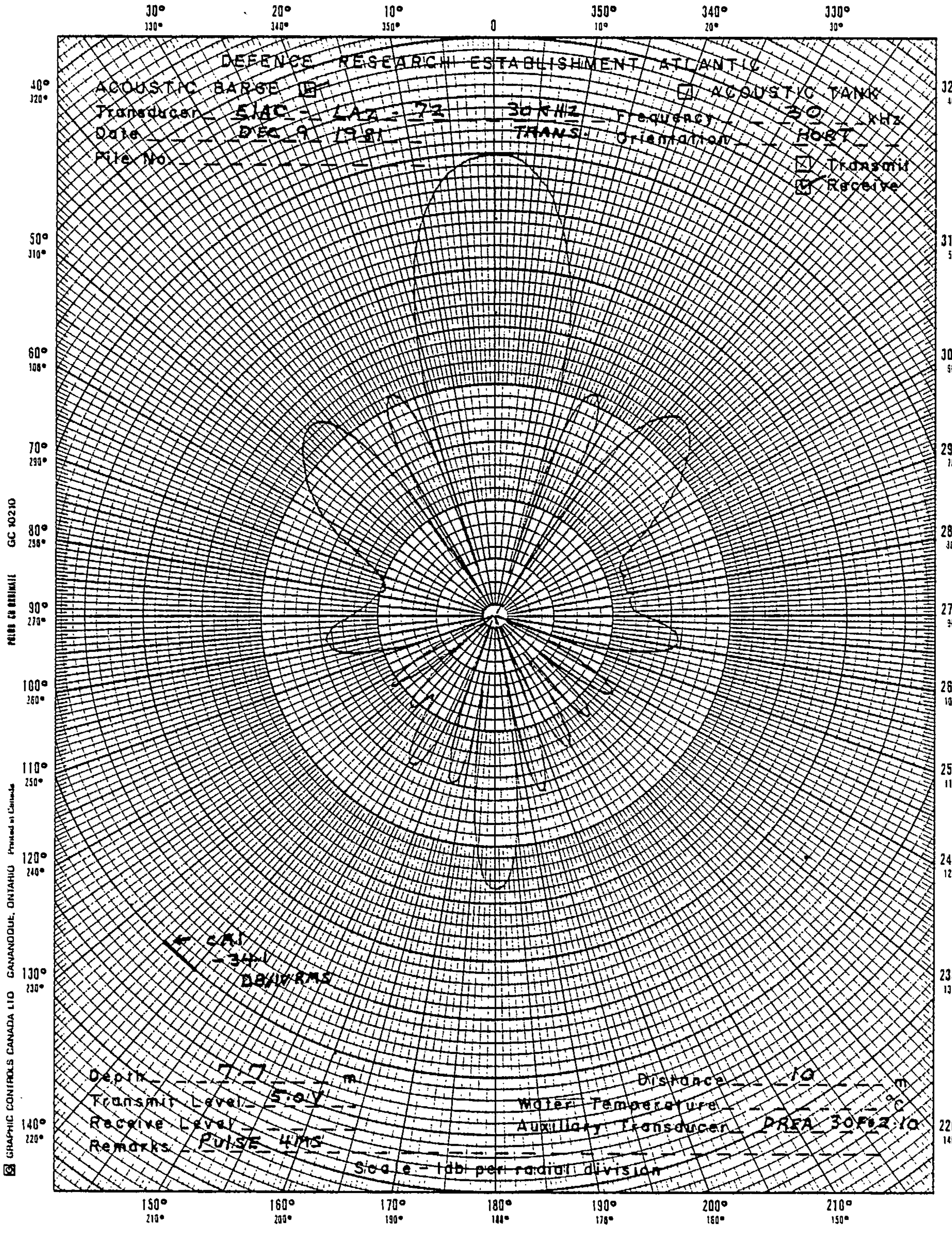

Fig. 6. Receive pattern 30 kHz

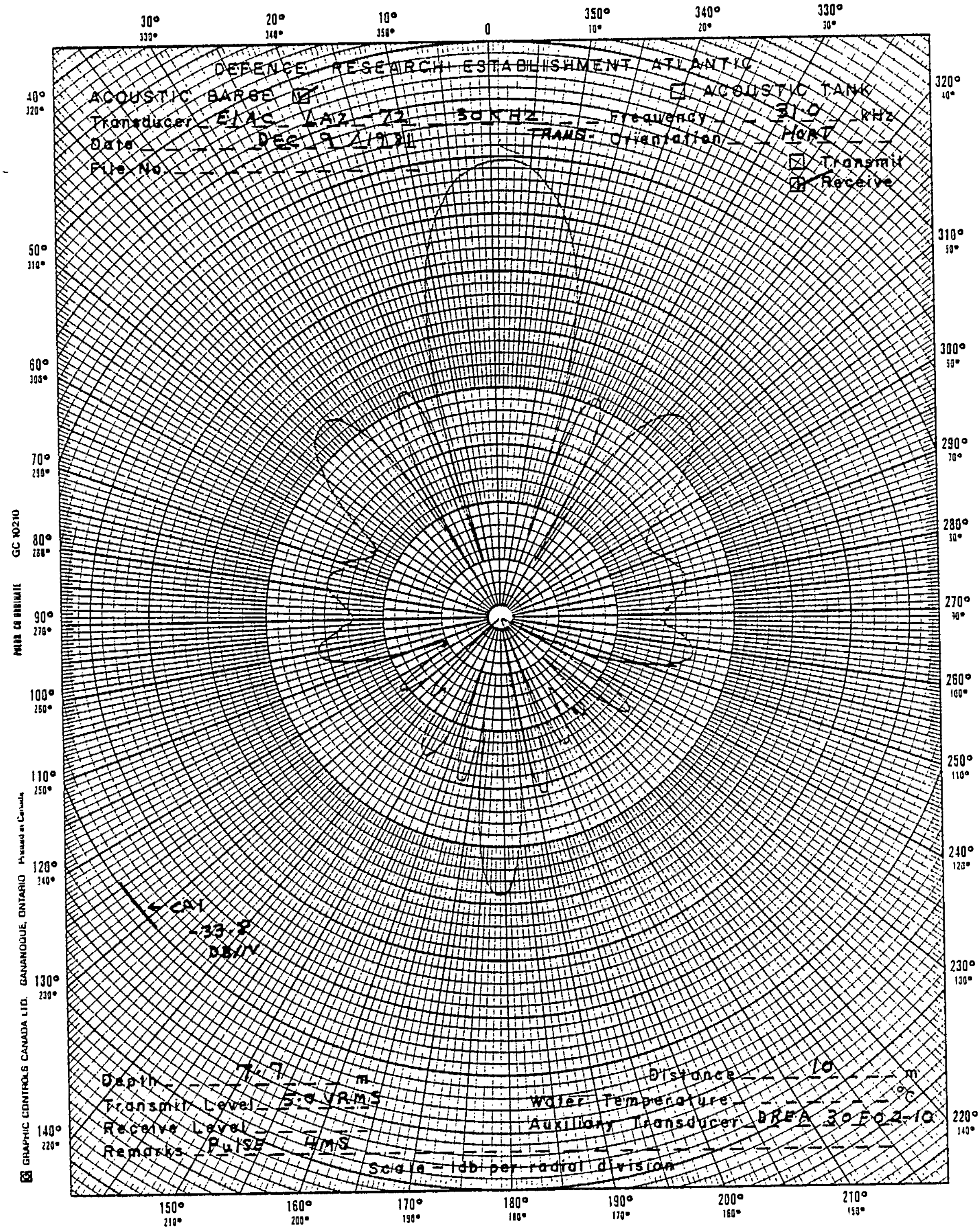

Fig. 7. Receive pattern 31 kHz

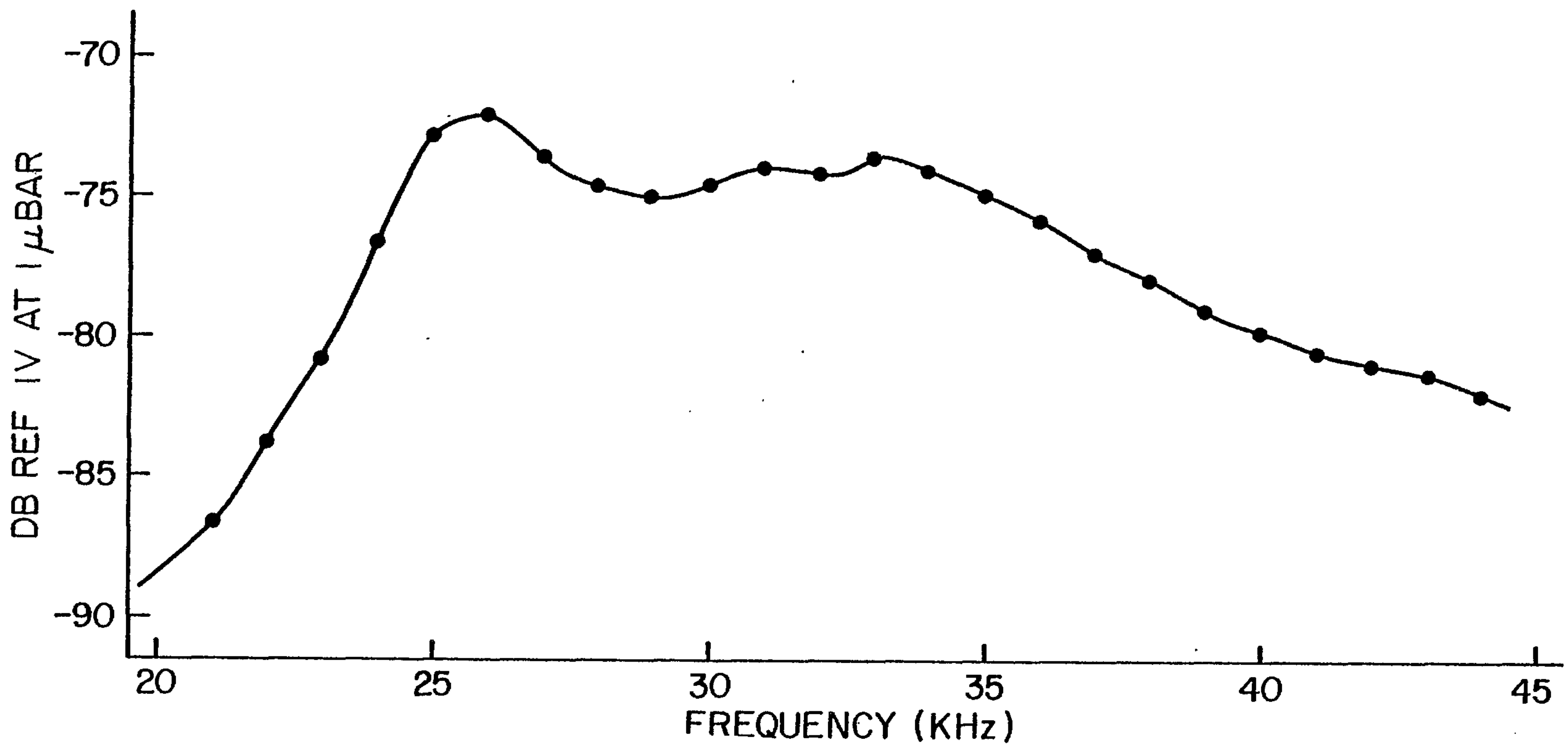

Fig. 8. Absolute receive sensitivity of transducer vs. frequency

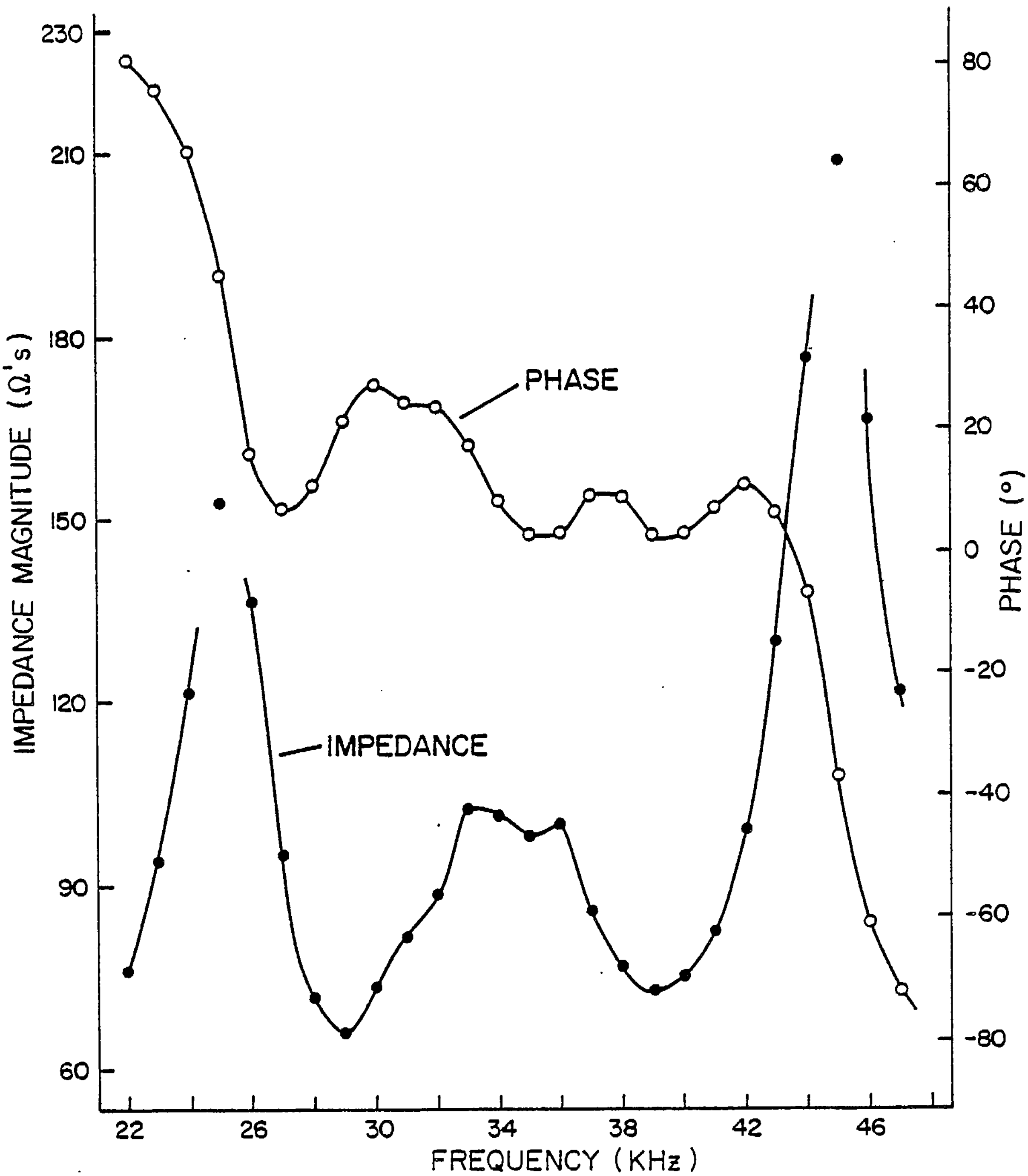

Fig. 9. Transducer impedance magnitude and phase vs. frequency

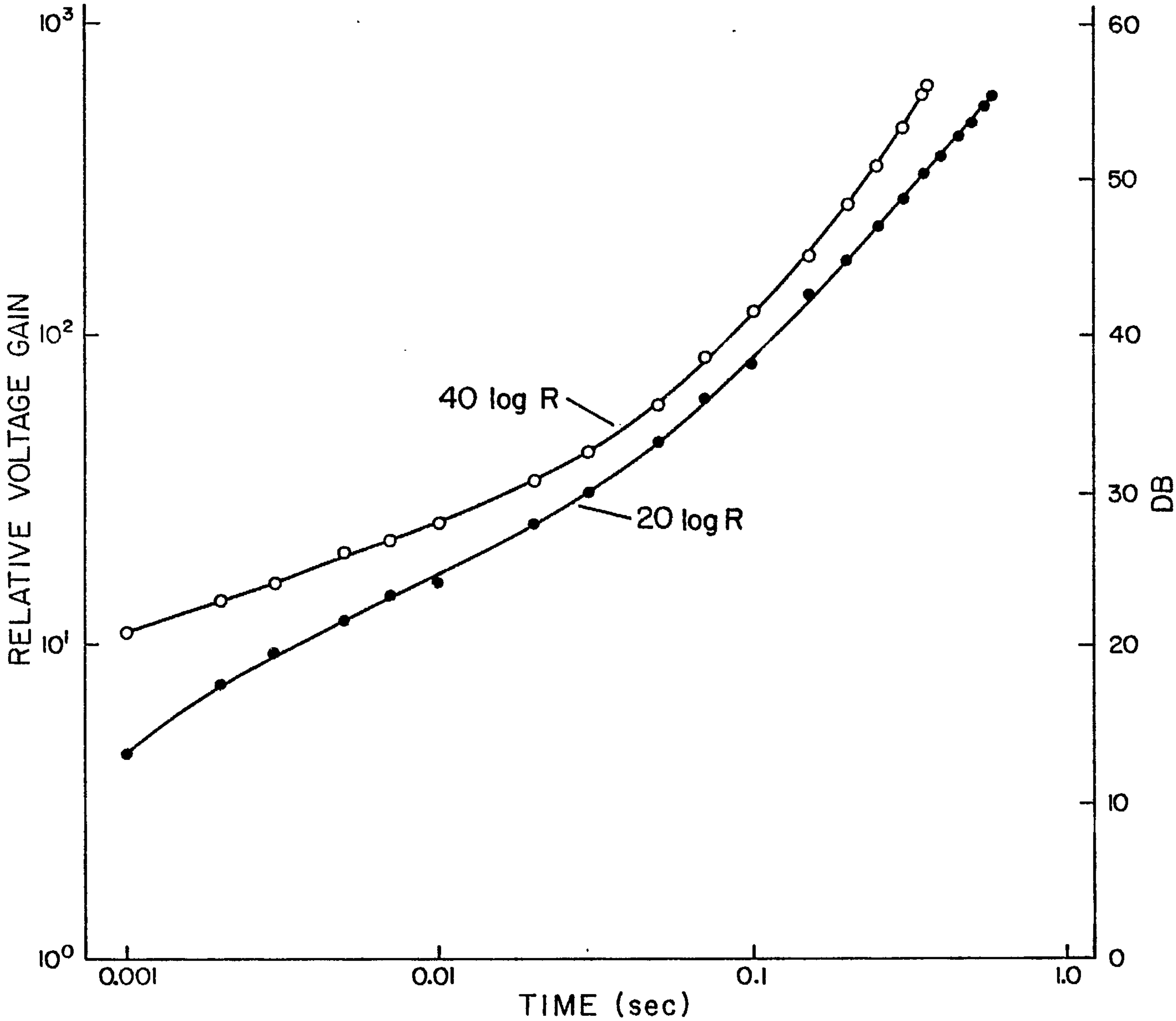

Fig. 10. Receiver TVG characteristic for 20 log R and 40 log R responses