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**Users' Manual for a Computer Program
To Calculate Discrete Frequency Noise
of Conventional and Advanced Propellers**

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SUMMARY

This report serves as a users' manual for a computer program for calculation of discrete frequency noise of conventional and advanced propellers. The computer program was developed at the Langley Research Center by F. Farassat and Paul A. Nystrom. The structure of the program and the subroutines describing the input functions are discussed in this manual. A detailed definition of input variables and their default values and the variables in the output data sheet are included here.

Two versions of the program are available. These differ only in the graphic output capability. One version has only printed output capability. A second version with extensive graphic output capability is available for the computer system at Langley.

This manual includes four detailed examples of both the printed and graphic outputs. These examples may be reproduced by users to check their code on their computer system.

INTRODUCTION

During the last 30 years, the application of the propeller as a propulsion system for large commercial and military aircraft has been neglected. Flight speed limitations, excessive noise, and high operating costs are a few of the reasons for this neglect. Over the past decade, however, the energy crisis has created a new incentive for the aircraft industry to reconsider propellers for future aircraft designs. It is well-known that the efficiency of propellers is generally higher than that of jet-driven propulsors, but the problem of the high noise levels generated by conventional high-speed propellers is a major obstacle to their increased utilization.

An attempt has been made in recent years to develop an advanced blade geometry to decrease propeller operating noise and to optimize performance. These new high-speed blades are designed with substantial out-of-plane sweep and blade twist. Model tests have demonstrated the effectiveness of these new designs in reducing noise and maintaining high efficiency.

Since model and full-scale tests of propellers are very expensive and time consuming, considerable effort has been made to predict the noise theoretically to complement the aerodynamic design calculations. A computer program called PROPFAN was developed at the Langley Research Center. This program has the capability of predicting the noise generated by a propeller with advanced blade geometry operating at both subsonic and supersonic tip speeds. Special effort was made during the development of PROPFAN to describe the blade shape as accurately as possible and to minimize mathematical approximations. The program input format also allows the user a great deal of flexibility and convenience when applying the code to different engineering problems.

The first section of this paper describes briefly the theoretical formulation of this noise prediction method. The method is basically a numerical finite-difference approach using two forms of the solution of the Ffowcs Williams-Hawkings wave equation. The computing algorithm and a discussion of the details of some of the methodology are also included in this section.

The computer program PROPFAN itself is discussed in the second section. The program operating environment, structure, and organization are explained. The final section of this paper discusses the operating instructions for executing PROPFAN. The input parameters and functions are defined, and the output data are explained.

Appendix A contains an explanation of the two methods used for calculating the emission time. Appendix B contains an example of control cards for a multiple-case job as used at the Langley Research Center. Several examples of the input functions and printed output are given in appendix C. Examples of the graphics output of the version of the program currently operational at Langley are presented in appendix D.

SYMBOLS AND ABBREVIATIONS

BPF	blade passage frequency
c	speed of sound in undisturbed medium
d	distance of observer from x_3 -axis (see fig. A1)
E2	radial distance along η_2 -axis
ER	= E2/R
$f(\vec{x}, t) = 0$	equation of blade surface
$g = \tau - t + \frac{r}{c} = 0$	equation of collapsing sphere centered at observer position \vec{x}
i, j	indices of summation, i and j = 1, 2, or 3
K(τ)	function defined by equation (A5)
LE	leading edge of blade
l_i	local force (per unit area) on fluid in direction i
M	helical Mach number
M_r	Mach number in radiation direction
OASPL	overall sound pressure level, dB (re 20 μ Pa)

PCA	pitch change axis
$p'(\vec{x}, t)$	acoustic pressure
Q	nondimensional distance from leading edge in chordwise direction based on local chord
R	blade outer radius
r	length of radiation vector, $ \vec{x} - \vec{y} $
\vec{r}	radiation vector, $\vec{x} - \vec{y}$
$\hat{\vec{r}}$	unit radiation vector
S	surface area of blade
SPL	sound pressure level, dB (re 20 μ Pa)
TE	trailing edge of blade
t	observer time
v_n	local normal velocity of blade surface
\vec{v}	local velocity of blade surface
\vec{x}	observer position in frame fixed with respect to undisturbed medium or in moving frame fixed to aircraft
\vec{x}_f	observer position in fixed frame
\vec{x}_m	observer position in moving frame
\vec{y}	source position
β	azimuthal coordinate of observer
Γ	curve of intersection of blade surface and collapsing sphere
$\delta(f)$	Dirac delta function
$\vec{\eta}$	rotating frame coordinates; η is distance from origin in polar coordinates (see fig. A1)
θ	angle between blade surface normal and radiation vector
ρ_0	density of undisturbed medium

τ	source time
τ^*	emission time
ϕ	azimuthal coordinate of source at time $\tau > 0$
ψ	azimuthal coordinate of source at $\tau = 0$
ω	rotational speed of blades

Subscripts:

f	frame fixed with respect to undisturbed medium
m	moving frame fixed to aircraft
r	radiation direction
ret	evaluated at $\tau = \tau^*$
1,2,3	coordinate directions

THEORY AND EQUATIONS

Theoretical Formulation

The problem of noise prediction can be reduced to the solution of the wave equation with a given distribution of sources on a moving boundary (the propeller blade surface). There are basically two steps in the prediction process as follows:

- (1) The determination of the source distribution on the moving boundary
- (2) Solving the three-dimensional wave equation with specified source distributions on the blade surface

Previously formulated noise prediction theories (refs. 1 to 4) have been somewhat successful with conventional propeller designs, but all these methods have certain limitations which make them unsuitable for applications to propellers with advanced geometry. Some of these limitations are the assumption of compactness of the acoustic sources and the far-field positioning of the observer. Three new requirements were considered in the development of the present prediction technique as follows:

- (1) Sources on the blade surface could not be approximated by sources in a plane because the blades have considerable twist and out-of-plane sweep
- (2) The propeller helical tip speed may be supersonic
- (3) Near-field noise calculations should be included

These requirements led to the selection of a purely numerical approach for noise calculations. The formulations used are two forms of the solution of the Ffowcs Williams-Hawkings (FW-H) wave equation (ref. 5) where the quadrupole term has been dropped. Thus, only the surface source terms have been retained. These solutions are derived in reference 6.

The governing equation for the determination of the acoustic pressure $p'(\vec{x}, t)$, the Ffowcs Williams-Hawkings equation, is

$$\frac{1}{c^2} \frac{\partial^2 p'}{\partial t^2} - \nabla^2 p' = \frac{\partial}{\partial t} \left[\rho_0 v_n |\nabla f| \delta(f) \right] - \frac{\partial}{\partial x_i} \left[l_i |\nabla f| \delta(f) \right] \quad (1)$$

where c and ρ_0 are the speed of sound and the density in the undisturbed medium, respectively. The variable v_n is the local normal velocity on the blade surface described by the equation $f(\vec{x}, t) = 0$. The local force per unit area exerted by the blade surface on the fluid is denoted by l_i , and $\delta(f)$ is the Dirac delta function.

The two forms of solution for equation (1) which are used to calculate propeller noise are

$$4\pi p'(\vec{x}, t) = \frac{1}{c} \frac{\partial}{\partial t} \int_{f=0} \left[\frac{\rho_0 c v_n + l_r}{r |1 - M_r|} \right]_{\text{ret}} dS + \int_{f=0} \left[\frac{l_r}{r^2 |1 - M_r|} \right]_{\text{ret}} dS \quad (2)$$

$$4\pi p'(\vec{x}, t) = \frac{\partial}{\partial t} \int_{f=0} \int_{g=0} \frac{\rho_0 c v_n + l_r}{r \sin \theta} d\Gamma d\tau + \int_{f=0} \int_{g=0} \frac{c l_r}{r^2 \sin \theta} d\Gamma d\tau \quad (3)$$

In equations (2) and (3), dS is an element of surface area on the blade $f = 0$, and $d\Gamma$ is an element of length of the curve of intersection of the surfaces $f = 0$ and $g = \tau - t + (r/c) = 0$. The symbol θ represents the angle between the normal to the surface $f = 0$ and the radiation vector $\vec{r} = \vec{x} - \vec{y}$. In equation (2), $M_r = \vec{v} \cdot \hat{r}/c$, where \vec{v} is the local velocity on the blade surface, $\hat{r} = \vec{r}/r$ is the unit vector in the radiation direction, and $l_r = l_i \hat{r}_i$ is the force per unit area on the fluid in the radiation direction. The collapsing sphere method discussed in this paper refers to the application of equation (3). (See ref. 6.)

The computer program discussed in this paper can handle cases in which the observer has the same forward speed as the propeller. This capability is achieved by letting \vec{x}_m be the position of the observer in the moving frame; therefore, the observer position in the frame fixed to the undisturbed medium is

$$\vec{x}_f = \vec{x}_m + \int_0^t \vec{v}(t') dt'$$

where $\vec{v}(t')$ is the forward velocity of the propeller. Therefore, in the moving frame, the numerical value of $p'(\vec{x}_m, t)$ is the same as $p'(\vec{x}_f, t)$. In this instance, $\vec{x}_f = \vec{x}_f(\vec{x}_m, t)$, and the value can be determined if the motion of the propeller is specified.

Numerical Approach

Figure 1 shows the flow chart for program PROPFAN. To commence the noise calculation, each blade is divided into panels. Since the blades of advanced propellers can have substantial amounts of twist and sweep, the noise sources may not be assumed to be in a plane. For this reason, a coordinate frame as shown in figure 2 is used to account for the three-dimensional character of the blades. This frame, called the rotating η -frame, is fixed to each blade. The center of this frame is on the propeller axis, and the η_2 -axis coincides with the pitch change axis (PCA) of each blade.

In order to describe the blade, the leading-edge curve of the blade is given as a function of distance along the pitch change axis η_2 . Then the chord, airfoil section, twist, and thickness ratio of the blade are specified as functions of η_2 . The specification of these parameters is sufficient to describe the blade completely.

To subdivide the blades into panels, each blade is cut in the radial direction by planes perpendicular to the pitch change axis. In the chordwise direction, a new nondimensional variable Q is introduced. This variable is the distance from the leading edge along the chord divided by the local chord CH . The upper and lower surfaces of the blade are now mathematically described as a function of the variables η_2 and Q . From these values the surface position vector, unit normal vector, and surface area for each panel can be calculated. Figure 3 gives the definition of some of the parameters and symbols for the blade description.

For the thickness noise calculations, both the upper and lower blade surfaces are divided into panels. For loading noise calculations, the same blade division method is used if the upper and lower surface pressures are specified. However, if the pressure differential is specified, the mean surface (comprised of local chord lines) is divided into panels. This option between describing the input pressure function as either surface pressure or differential pressure is available to the program user because details of blade surface pressure distribution are not generally available.

After each blade has been divided into panels, the value of the helical Mach number of each panel is calculated to determine whether the panel is in subsonic or transonic/supersonic operation. Two different methods are used to determine the emission time. These two methods are explained in appendix A. If the element has subsonic motion, method 1 is used. If the panel moves at

transonic or supersonic tip speed, the possibility of multiple emission times exists and the more complicated method 2 must be used.

The contributions of the i th panel to the acoustic pressure, denoted by p_i' , from equations (2) and (3), may be written in finite-difference form as

$$4\pi p_i'(\vec{x}, t) = \frac{1}{c} \frac{\Delta}{\Delta t} \left[\left(\frac{\rho_0 c v_n + z_r}{r|1 - M_r|} \right)_i \right]_{\text{ret}} \Delta S_i + \left[\left(\frac{z_r}{r^2|1 - M_r|} \right)_i \right]_{\text{ret}} \Delta S_i \quad (4)$$

$$4\pi p_i'(\vec{x}, t) = \frac{\Delta}{\Delta t} \sum_j \left(\frac{\rho_0 c v_n + z_r}{r \sin \theta} \right)_i \Delta \Gamma(\tau_j) \Delta \tau + \sum_j \left(\frac{c z_r}{r^2 \sin \theta} \right)_i \Delta \Gamma(\tau_j) \Delta \tau \quad (5)$$

Once the emission time (or times) of a panel has been calculated, the value of the radiation Mach number in the observer direction at the panel center is calculated. If this Mach number, M_r , is less than a prescribed input value (usually taken as 0.98), equation (4) is used for that panel. For larger values of M_r , equation (5) is used. The combined use of these two formulas improves the accuracy and efficiency of program execution. Although the application of equation (4) is simpler and faster than equation (5), it cannot be used as the value of M_r approaches unity.

Finally, the contributions of all the panels are summed to obtain the acoustic pressure signature $p'(\vec{x}, t)$. The numerical differentiations in equations (4) and (5) are performed after the summation is completed.

PROGRAM DESCRIPTION

Program PROPFAN consists of a main program element and 19 additional sub-routines (including 3 input subroutines). The program was written for batch execution but can be converted to interactive format if desired. The program input includes three subroutines and a FORTRAN namelist of input parameters.

The program is written in FORTRAN IV and has been implemented at the Langley Research Center under the Network Operating System (NOS) on Control Data CYBER 170 series computer systems. The program as used at Langley has a maximum central memory requirement of approximately 43535 (octal) 60-bit words. A typical single-case run for a propeller operating at subsonic tip speed requires 300 CPU seconds. For propellers with supersonic tip speeds, depending on the number of blade passage harmonics required, a typical case may take several thousand CPU seconds.

There are two versions of the program currently in use. The version called PROPFAN developed for use by industry has only printed output capability. In view of the great diversity in computing and graphics hardware, it was felt that

this basic version of the program will be more valuable for easy implementation on users' computing systems. Users may add their own routines to program PROPFAN for plotting, data storage, and editing options according to their own needs.

The version presently used at Langley is called NPROPFN and has elaborate graphics capability. An example of a control card deck used to execute this version at Langley is given in appendix B. Examples of the printed output of PROPFAN are presented in appendix C. The graphic output of NPROPFN for the examples given in appendix C are presented in appendix D. The two versions of the program are mathematically identical in the main part of the code where the acoustic calculations are performed.

The following sections describe each program element and its function for PROPFAN. Note that for identification purposes only, the name of each subroutine in NPROPFN is kept the same as that in PROPFAN except for the letter N preceding the first letter. For example, the subroutine KRUD in PROPFAN is called NKRUD in NPROPFN.

Main Program - PROPFAN

PROPFAN, the main program, is the driving element which calls each main subroutine in the proper order. Calls INTLZ, GMTRY, DBYDT, and DOPRINT.

Main Subroutines

INTLZ initializes the input parameter default values and reads in namelist input changes. Some constants are calculated and storage arrays are zeroed. Called by PROPFAN.

GMTRY divides each blade into panels using spanwise and chordwise divisions according to the input values of NPCA, NPCAF, NLE, NCHF, and THKMAXL. The geometry and coordinates of each panel are calculated after calling the input subroutines FUNE2 and FUNE2Q. The blade pressure functions are obtained from input subroutine FUNPRES. Each panel's contribution to the acoustic pressure at each observer time is found by calling PROP. The torque, thrust, and power are also calculated in GMTRY. Called by PROPFAN; calls FUNE2, FUNE2Q, FUNPRES, and PROP.

PROP steps each panel through observer time and adds each contribution to the total acoustic pressure. Three pressure arrays are generated: thickness, loading, and drag (skin friction). The near- and far-field terms are calculated for loading and drag noise. Subroutines QINTLZ and QULOCK are first called for an initial estimate of the time step. Called by GMTRY; calls QINTLZ, QULOCK, QURUD, KRUD, and KLOCK.

DBYDT evaluates the integrals in the acoustic equations and performs differentiation with respect to the observer time if required (refer to eqs. (4) and (5)). This routine produces the final output consisting of the component pressure signatures and spectra. It also contains code which rotates the

acoustic pressure signature (if periodic) to center the pressure peak. This is useful if graphics output is used. The acoustic pressure spectra are calculated in this subroutine. Called by PROPFAN.

DOPRINT generates the printed output. The basic output consists of a Data Sheet listing the input parameters and output values of torque, thrust, power, and sound pressure level. A more detailed output is optionally available (controlled by logical variable PRINT) which includes the pressure signatures and spectra of the thickness, loading, and drag noise components. Called by PROPFAN.

ADDIN adds separately the positive and negative contributions of the integrals in equations (4) and (5) to improve the accuracy of the integrations. Called by CORRECT, KRUD, and QURUD.

Subsonic Logic

KRUD calculates the pressure integrands and sums them for blade panels which move at subsonic speed. Called by PROP; calls KLOCK and ADDIN.

KLOCK calculates the retarded time for any observer time for blade panels which move at subsonic speed. Called by KRUD.

Supersonic Logic

QINTLZ initializes the parameters for the first call to QULOCK. Called by PROP.

QURUD calculates the pressure integrands and sums them for blade panels which move at transonic/supersonic speed. Called by PROP; calls QULOCK and ADDIN.

QULOCK calculates the retarded time or times for a fixed observer time for blade panels moving at transonic/supersonic speed. Called by QURUD.

CORRECT calculates the pressure integrands and sums them for blade panels which move at transonic/supersonic speed. This part of the code corrects for the $1/|1-M_r|$ singularity (eq. (4)) as M_r approaches unity by replacing it with an equivalent expression using the collapsing sphere technique. Called by QURUD; calls QINTLZ, QULOCK, GETSET, CROSSED, and ADDIN.

CROSSED determines if the collapsing sphere centered at the observer crosses the blade panel for supersonic regions of the blade; if so, the width of the crossing is calculated. Called by CORRECT.

GETSET calculates the coordinates of the corners of each blade panel for use in subsequent calls to CROSSED. Called by CORRECT; calls FUNE2.

Interpolation Routines

PCS performs curve interpolation from a data array using the piecewise cubic spline method. Called by FUNE2, FUNE2Q, or FUNPRES if input functions are in tabular data form; calls ORTHO.

ORTHO calculates the coefficients of an Nth order polynomial which provides the best least-squares fit for a set of points. Called by PCS.

OPERATING INSTRUCTIONS

The program PROPFAN requires certain input functions and a namelist input. In the following sections these requirements are described.

Input Functions

Three input subroutines, FUNE2, FUNE2Q, and FUNPRES, are required by program PROPFAN. These subroutines are used to describe the physical and aerodynamic characteristics of the propeller blade.

Subroutine FUNE2 defines the blade angle of attack, leading-edge curve, chord width, and thickness ratio as functions of the location along the blade span only. Routine FUNE2Q defines the camber and thickness functions of the blade as each varies with location along the span and/or chord. The third, FUNPRES, describes the blade pressure distribution functions which may also depend on span and/or chord coordinates. The pressure function may be described as surface or differential pressure as is convenient to the user.

These three routines allow great flexibility in the definition of blade geometry and loading. The input variables may be described by using analytic functions or they may be input in tabular data form. If the input is in array form, a mathematical interpolation routine (such as routine PCS) must be used to calculate the required set of points.

Subroutine FUNE2: The variables in this subroutine are all functions of radial distance E2 along the pitch change axis. Note that R is the propeller radius. Calling sequence: (E2, R, AA, AAP, CH, CHP, LED, LEDP, THKRAT, THKRATP, CAMRAT, CAMRATP). Refer to figures 2 and 3.

<u>Variable</u>	<u>Definition</u>
AA	Real. Angle of attack (degrees). Angle between mean chord line and η_1 -axis.
CH	Real. Local chord (meters). Distance along mean chord line from leading edge to trailing edge.

LED Real. Leading-edge displacement (meters). Distance from leading edge to pitch change axis, measured along line parallel to mean chord line. Positive direction of measurement is from leading edge to trailing edge. LED is typically negative. For conventional straight blades, use LED = -0.25*CH.

THKRAT Real. Airfoil thickness ratio. Ratio of maximum airfoil thickness at each radial location to local chord.

CAMRAT Real. Airfoil camber ratio. Ratio of maximum camber at each radial location to local chord.

AAP, CHP, LEDP, THKRATP, CAMRATP Real. Derivatives of the above variables with respect to E2. Note that $\frac{\partial}{\partial E2} = \frac{1}{R} \frac{\partial}{\partial ER}$ where ER = E2/R (nondimensional radial distance).

Subroutine FUNE2Q: The variables in this subroutine are generally functions of nondimensional chordwise variable Q. The variable E2 (radial distance, meters) is carried into this subroutine to allow for any change of airfoil section at different radial stations. Variables in this subroutine can also be functions of E2 if required. Calling sequence: (E2, R, Q, CMBR, CMBRP, THK, THKP). Refer to figure 3.

<u>Variable</u>	<u>Definition</u>
CMBR	Real. Nondimensional camber. Distance from chord surface to camber surface, divided by camber ratio times chord. Generally function of Q, where Q = X/CH. For symmetric airfoil, CMBR equals zero.
THK	Real. Nondimensional thickness. Distance from camber surface to blade surface, divided by thickness ratio times chord. Generally a function of Q.
CMBRP, THKP	Real. Derivatives of above variables with respect to Q.

Subroutine FUNPRES: This routine describes the pressure and viscous shear stress distribution on the blade surfaces. These distributions can be a function of the radial distance E2 and/or the nondimensional chord location Q.

The input may be expressed as pressure on the upper and lower surfaces (absolute pressure minus atmospheric pressure) or as a differential pressure. If the surface pressure approach is used, the user can include a description of the viscous shear stress (skin friction) for use in the noise calculations. If the input is in differential pressure form, the program does not include drag terms in the calculations and these variables must be set equal to zero. Calling sequence: (E2, R, Q, SURFP, DP, SPU, SPL, SIGMAU, SIGMAL).

<u>Variable</u>	<u>Definition</u>
SURFP	Logical. If true, the variables being returned to the program are upper and lower surface pressures (SPU and SPL) and skin friction stress (SIGMAU and SIGMAL) may be defined or set equal to zero. If false, the variable returned is pressure differential (DP) and skin friction stress values must be set equal to zero.
DP	Real. Differential pressure (pascals) acting on camber surface. This variable may be defined as $DP = SPL - SPU$.
SPU, SPL	Real. Absolute pressure minus ambient pressure acting on upper and lower blade surfaces, respectively (pascals).
SIGMAU, SIGMAL	Real. Skin friction (viscous shear) stress acting on upper and lower blade surface (pascals). Set equal to zero if SURFP is false.

Namelist Parameters

A namelist called \$INPUT is used to read in the basic parameters such as blade dimensions, rotational speed, and forward propeller speed. The namelist also includes several parameters which control the speed and accuracy of program execution. For example, the number of spanwise and chordwise divisions, number of harmonics, the allowable time step error, and similar variables are defined through the namelist. In addition, there are four logical flags which control the specific amount and type of printed output.

For each namelist variable, there is a default value defined within the program which applies to the case of a three-blade propeller in subsonic operation. If any of these variables are not redefined by the namelist input during a particular single-case run, the default values are automatically used. Multiple-case runs which vary the namelist parameters while holding the input subroutines constant can be executed within the same job. This may be done by submitting sequential namelists and identifiers for each case. However, once a variable is defined within a job, that value will be retained for all the following cases within that job until it is subsequently redefined.

A complete list of the namelist parameters, their definitions, and default values is given in the following list. An example of the control cards and input format for a multiple-case run of program NPROPFN (including graphics package) may be found in appendix B.

<u>Variable</u>	<u>Definition</u>	<u>Default</u>
C	Real. Speed of sound.	345.0 m/sec
CHECK	Logical. When true, the following intermediate values from subroutine GMTRY are included as output: iteration indices for spanwise and chordwise stepping; geometry of each blade element; η -frame coordinates of each element on the mean, upper, and lower surfaces; unit normal vector components on each surface. The output is particularly useful for debugging.	False
CORCALL	Logical. When true, the number of calls to CORRECT for each observer time is included in printed output.	False
EPSILON	Real. Maximum allowable error in iterative calculation of retarded time, defined as a percent of observer time step used. The iteration process for finding retarded time will stop when two successive approximations of retarded time differ by less than $0.01 \times \text{EPSILON} \times \Delta t$ where Δt is observer time step in the program. Reducing EPSILON will increase execution time.	0.5 percent
FRACDT	Real. Fraction of time step to use in observer time differentiation. For subsonic cases, use $0.5 \leq \text{FRACDT} \leq 1.0$; for supersonic blades, use $1.0 \leq \text{FRACDT} \leq 3.0$.	0.50
MOTION	Logical. When true, observer moves forward with propeller. When false, observer is stationary with respect to undisturbed medium.	True
MTRANS	Real. If helical Mach number of blade panel becomes greater than or equal to MTRANS, control is switched from subsonic to transonic/supersonic logic. For efficient program execution, use a range of 0.95 to 0.99.	0.95
NBLADES	Integer. Number of propeller blades.	3

NCHF	Integer. Factor to multiply chordwise divisions (NLE and NTE) for transonic/supersonic regions of blades in order to create a larger number of smaller panels. $2 \leq NCHF \leq 4$ is recommended.	2
NLE	Integer. Number of chordwise divisions from leading edge to THKMAXL. These divisions are unequally spaced by code to force a greater number of divisions close to leading edge. For sharp leading edge, set NLE = 0. For blunt leading edge, $5 \leq NLE \leq 10$ is recommended.	5
NPCA	Integer. Number of spanwise divisions for subsonic regions of blade. Optimum range is $15 \leq NPCA \leq 25$.	15
NPCAF	Integer. Factor to multiply number of spanwise divisions (NPCA) for transonic/supersonic regions of blades in order to create larger number of smaller panels. $2 \leq NPCAF \leq 4$ is recommended.	3
NPTS	Integer. Number of points in time per blade passage period. For subsonic blades, $100 \leq NPTS \leq 200$ is adequate. For supersonic tip speeds, use rule $NBLADES * NPTS < 650$. The value of NPTS must always be even and less than 400.	150
NSPEC	Integer. Number of harmonics used to calculate acoustic spectrum. NSPEC must be less than one-half of NPTS.	30
NTAU	Integer. Number of source time subdivisions to use in collapsing sphere routine for panels moving at transonic/supersonic speed. Increasing NTAU increases accuracy of acoustic calculations but also increases program execution time.	10
NTE	Integer. Number of chordwise divisions from THKMAXL to trailing edge. These divisions are equally spaced by the code. A good range for this variable is $10 \leq NTE \leq 20$.	10
PLOTS	Logical. Used only in NPROPFN version. When true, plots of output data are generated.	False

PRINT	Logical. When false, only Data Sheet is printed. When true, component pressure signatures and spectra are also printed.	True
R	Real. Blade radius.	1.3 m
REV	Real. Propeller rotational speed.	2145.0 rpm
RHO	Real. Density of air.	1.2029 kg/m ³
RINNER	Real. Inner blade radius.	0.3 m
THKMAXL	Real. Location of transition point between NLE and NTE type chord divisions, defined as fraction of chord from leading edge. For a sharp leading edge, set THKMAXL = 0 and NLE = 0. For other cases, use $0.05 \leq \text{THKMAXL} \leq 0.10$.	0.05
TRANS	Real. If radiation Mach number (M_r) from an element to observer becomes greater than TRANS, noise calculations are done using collapsing sphere technique (eq. (5)).	0.98
TWICE	Logical. When true, output is printed twice.	False
V3	Real. Propeller forward speed, perpendicular to plane of rotation (x_1x_2 -plane).	40.0 m/sec
X0	Real, three dimensional. For moving observer, this is initial position with respect to frame fixed to propeller center. Propeller plane is in x_1x_2 -plane and axis of propeller is along x_3 -axis. For stationary observer, observer must be specified in frame which has origin at center of propeller, with same orientation, at observer time $t = 0$. This frame will remain stationary for later observer times.	(7.28,0.,0.) m

Output Identification

A card with a 10-character identifier (Format A10) in the first 10 columns is used following the namelist \$INPUT in order to label each case run. Failure to use this identifier will produce an error message. The output Data Sheet, pressure signature, and spectrum tables will all be labeled with this identifier.

Output Data

The output data initially consists of a Data Sheet listing each of the namelist input parameters and the calculated output values of torque, thrust, power, and component sound pressure levels. The Data Sheet also lists the value of the observer time step (DT) for the calculation of acoustic pressure and the number of calls (INDEXSL) to the supersonic code (subroutine CORRECT). Two tables listing the pressure signature (in pascals) and the pressure spectrum (in decibels) are optionally available through the use of the logical input variable PRINT.

The pressure signature output is the time history of the thickness, loading, drag, and overall noise levels calculated for the specified number of observer times (input variable NPTS). When the acoustic pressure is periodic, the program rotates the signature to center the pressure peak within the data array. This rotation is useful in producing well laid-out plots of the output. At the bottom of the signature table, one point number is labeled with the letter C. This indicates that this point number (with the corresponding pressure values) was actually the initial zero observer time used to start the noise calculations before rotation of the data array. Thus, relative phase information can be obtained by comparing the starting points of different case runs. If the observer is stationary and the propeller is in forward motion, the pressure signatures are not periodic.

The pressure spectrum output lists a table of the component and overall noise levels calculated for the specified number of harmonic frequencies (input variable NSPEC).

CONCLUDING REMARKS

The computer program discussed in this report is based on two of many theoretical formulations available for prediction of the noise of rotating blades. These formulations were selected for their simplicity and ease of programming. The blade description in the program is such that complicated designs for advanced propellers can be specified easily. All geometric parameters of the blade such as the twist and spanwise variation of blade thickness can be prescribed precisely and utilized in the acoustic calculations. Comparisons of the output of this program with measured acoustic data have been very encouraging. It is hoped that this program will be beneficial to the users as a tool in propeller design and noise study.

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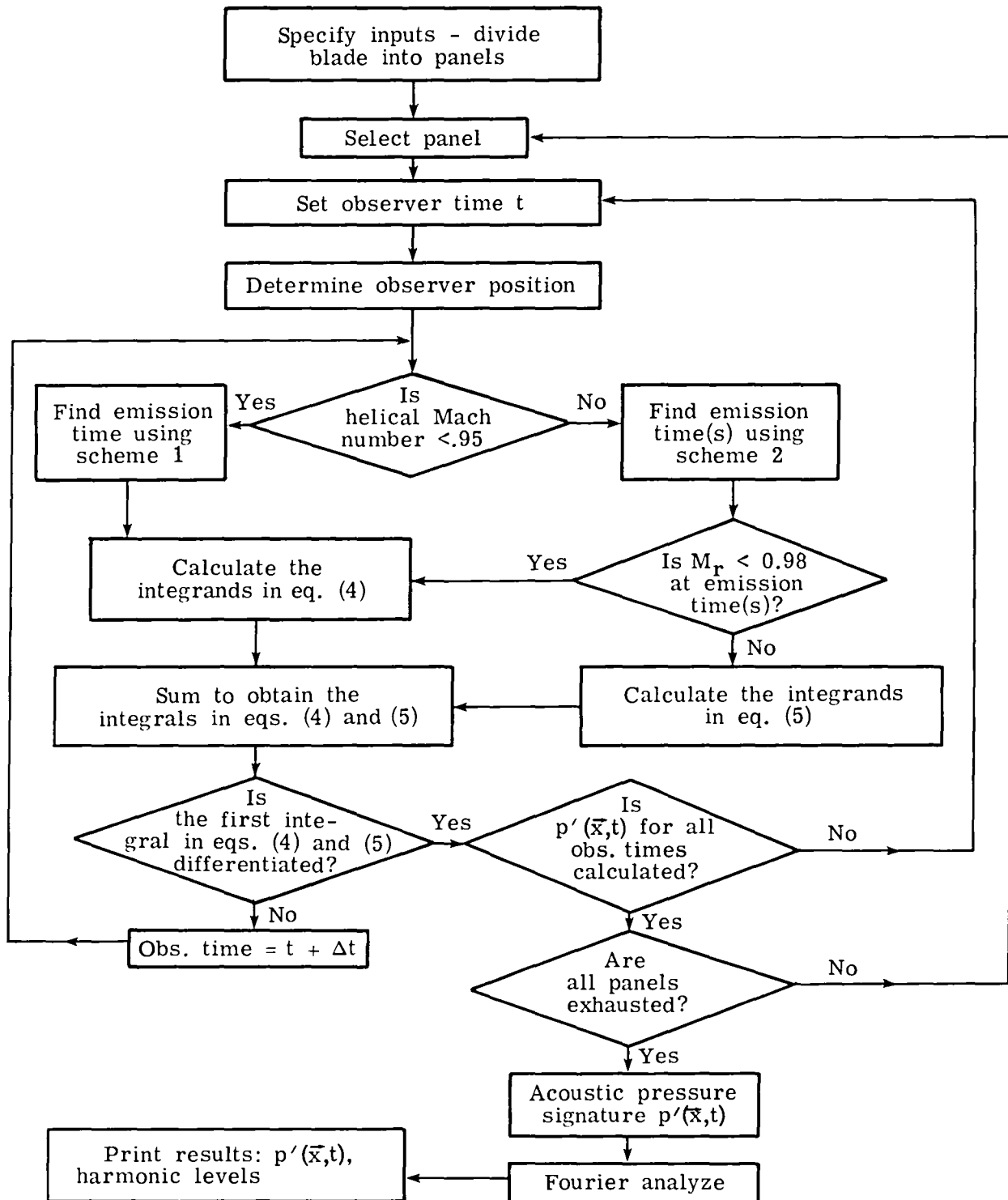
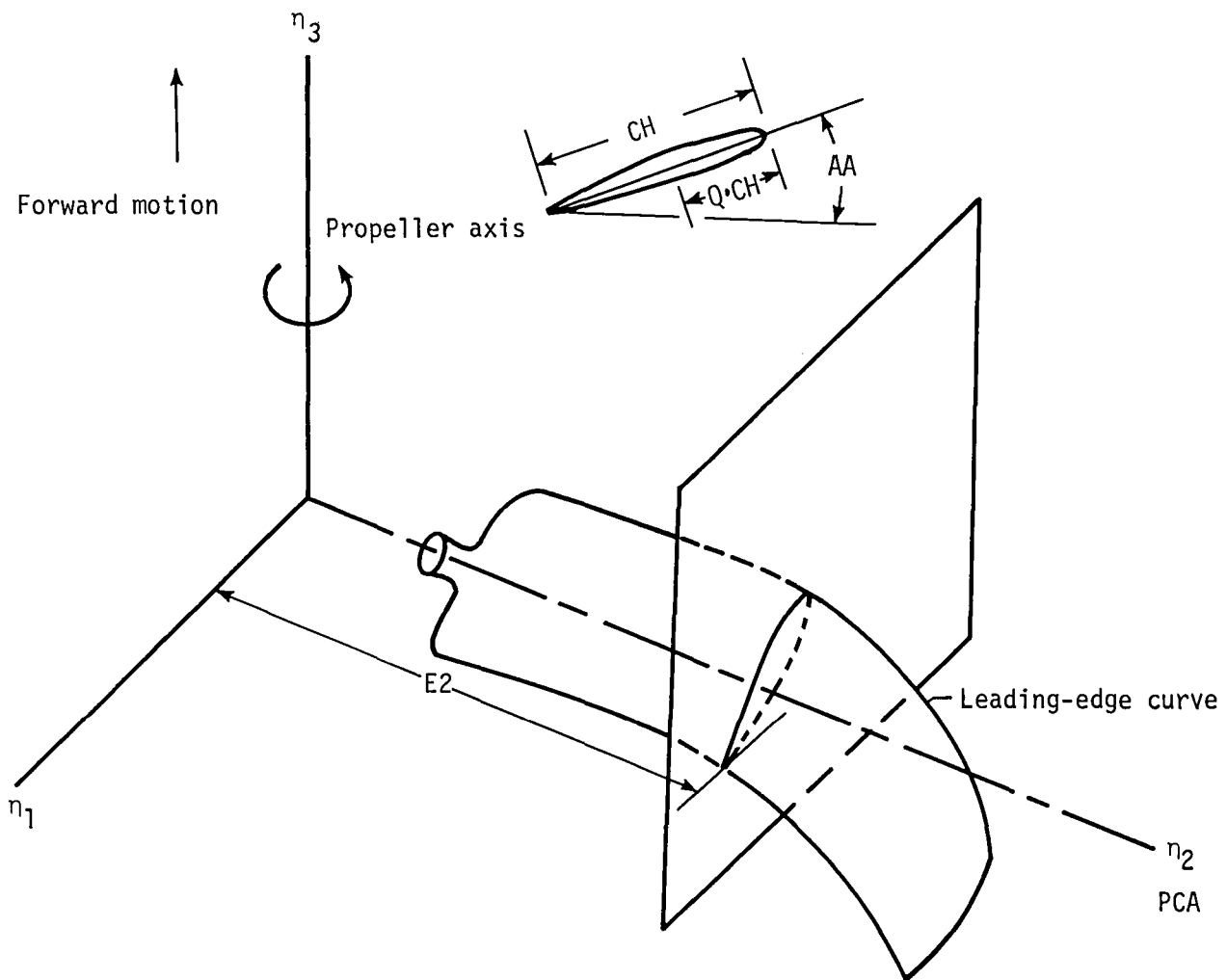
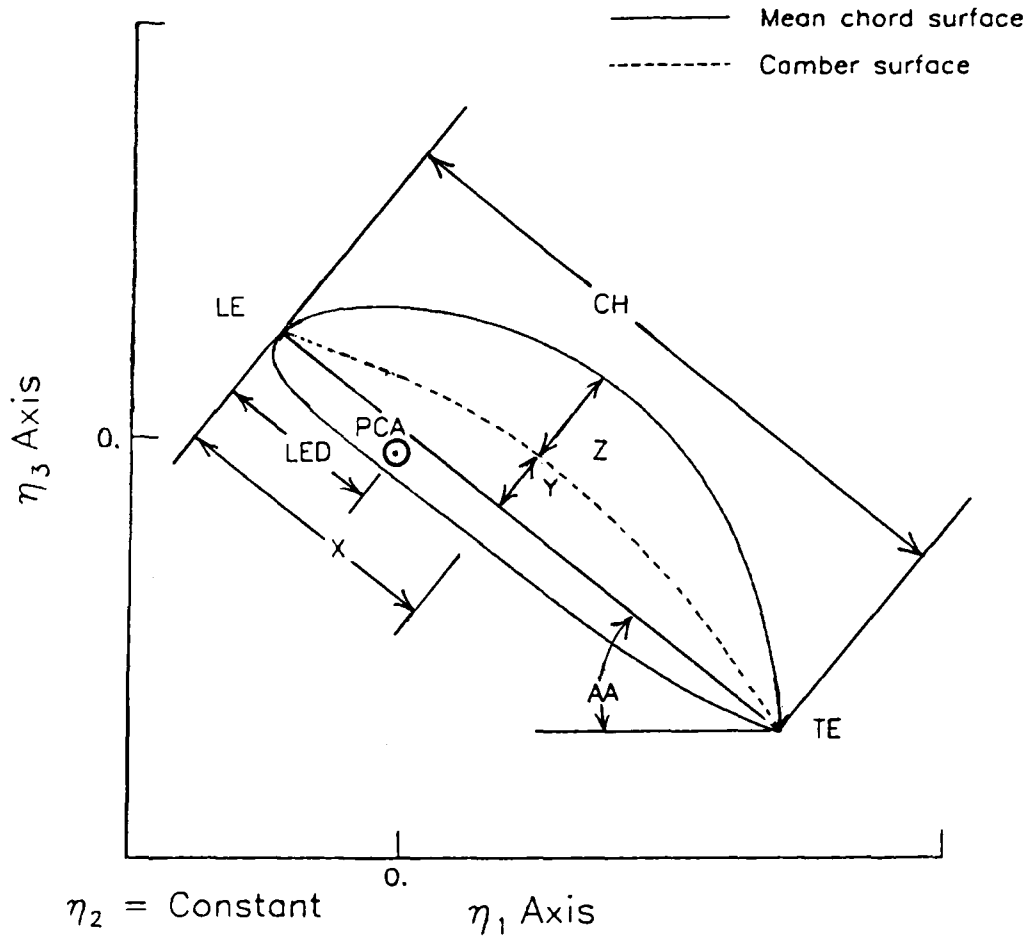


Figure 1.- Flow chart of propeller noise prediction program PROPFAN.



- E2 radial location on η_2 -axis
- AA geometric angle of attack (function of η_2)
- PCA pitch change axis
- CH local chord (function of η_2)
- Q distance from LE divided by local chord (CH)

Figure 2.- Curvilinear coordinate system (Q, η_2) used to describe blade geometry of advanced propellers. Blade mean surface is not in plane.



$$Q = \frac{X}{CH}$$

$$CMBR = \frac{Y}{CAMRAT * CH}$$

$$THK = \frac{Z}{THKRAT * CH}$$

Figure 3.- Blade section geometry in $\eta_1\eta_3$ -plane. See section "Namelist Parameters" for definition of symbols.

APPENDIX A

CALCULATION OF EMISSION TIME

If the source and the observer times are τ and t , respectively, and the distance between the observer and the source is r , the emission time $\tau = \tau^*$ is calculated from the relation

$$c(\tau^* - t) + r = 0 \quad (A1)$$

The emission time is the time when the sources on the panel emit sound which arrives at the observer at time t . The source position \vec{y} is a function of τ , so that r itself is a function of τ . Because of the trigonometric terms in r (eq. (A4)), equation (A1) cannot be solved for τ^* in closed form. A numerical method must be used. Two schemes are used depending on the speed of the source.

Method 1: Subsonic Helical Tip Speeds

When the observer time and position are fixed, one can show for a given source in motion that

$$\frac{\partial g}{\partial \tau} = 1 - M_r \quad (A2)$$

where $g = \tau - t + (r/c)$. Equation (A1) indicates that, viewed as a function of a single variable τ , the emission times of a source in motion are the zeros of function g . For sources in subsonic motion, one has $M_r < 1$ and $\partial g / \partial \tau > 0$. This means that the function g is a strictly increasing function of τ and thus can have only one zero.

Newton's method was used to develop a fast iterative scheme to find the emission time of each panel on the blade. To speed up the convergence of iteration, the known emission time of a nearby panel is used as the initial guess for the emission time of the next panel. This method has resulted in shortened computation time for general aviation propellers operating at subsonic tip speeds.

Method 2: Transonic/Supersonic Helical Tip Speeds

For panels moving at supersonic speeds, the range of search for each root of equation (A1) must be narrowed to find the appropriate nontrivial solutions.

Assume that the source lies in the x_1x_2 -plane at source time $\tau = 0$. The source position at this time is described by (η, ψ) in polar coordinates as

APPENDIX A

shown in figure A1. The source rotates around the x_3 -axis (propeller axis) at an angular velocity of ω and moves forward in the positive direction of the axis at velocity v_3 . The \vec{x} -frame is fixed to the undisturbed medium and is not in motion. The observer position and time are \vec{x} and t , respectively. Viewed by the observer in this frame, the source path is a helix. From equation (A1), the following equation may be obtained:

$$c^2(\tau^* - t)^2 - r^2 = 0 \quad (A3)$$

with only the solutions $\tau^* \leq t$ being physically acceptable. The square of the distance between the source and the observer can be written as follows:

$$r^2 = x_3^2 + d^2 + \eta^2 - 2 d\eta \cos (\phi - \beta) + v_3^2 \tau^2 - 2x_3 v_3 \tau \quad (A4)$$

where $\phi = \psi + \omega\tau$, and d is the distance of the observer from the x_3 -axis. (Refer to fig. A1.) Assuming $v_3/c = M < 1$ and $\tau_0 = x_3/c$, equation (A3) can now be written as

$$\begin{aligned} K(\tau) &\equiv c^2(1 - M^2)\tau^2 - 2c^2(t - M\tau_0)\tau + c^2(t^2 - \tau_0^2) \\ &= d^2 + \eta^2 - 2 d\eta \cos (\phi - \beta) \end{aligned} \quad (A5)$$

The graphs of

$$\begin{aligned} K(\tau) &= c^2(1 - M^2)\tau^2 - 2c^2(t - M\tau_0)\tau + c^2(t^2 - \tau_0^2) \\ K(\tau) &= d^2 + \eta^2 - 2 d\eta \cos (\phi - \beta) \end{aligned}$$

are a parabola and a sinusoidal curve in the τK -plane, respectively. Thus, to find the roots of equation (A5), the points of intersection of a parabola and a sinusoidal curve must be determined. These roots must lie between the points of intersection of the lines $K = (d \pm \eta)^2$ parallel to the τ -axis in the τK -plane. These lines are obtained by setting $\cos (\phi - \beta)$ in equation (A5) equal to -1 and 1, respectively.

Not all the roots of equation (A5) are emission times because the requirement $\tau^* \leq t$ is not satisfied for all the roots. Only the roots obtained by the intersection of the parabola and the sinusoidal curve which are to the left of the axis of the parabola are the emission times. One can graphically demonstrate that only an odd number of emission times are obtained if multiple roots are counted by their multiplicity (e.g., two equal roots are counted as two roots). The method of modified regula falsi discussed in reference 7 is used to

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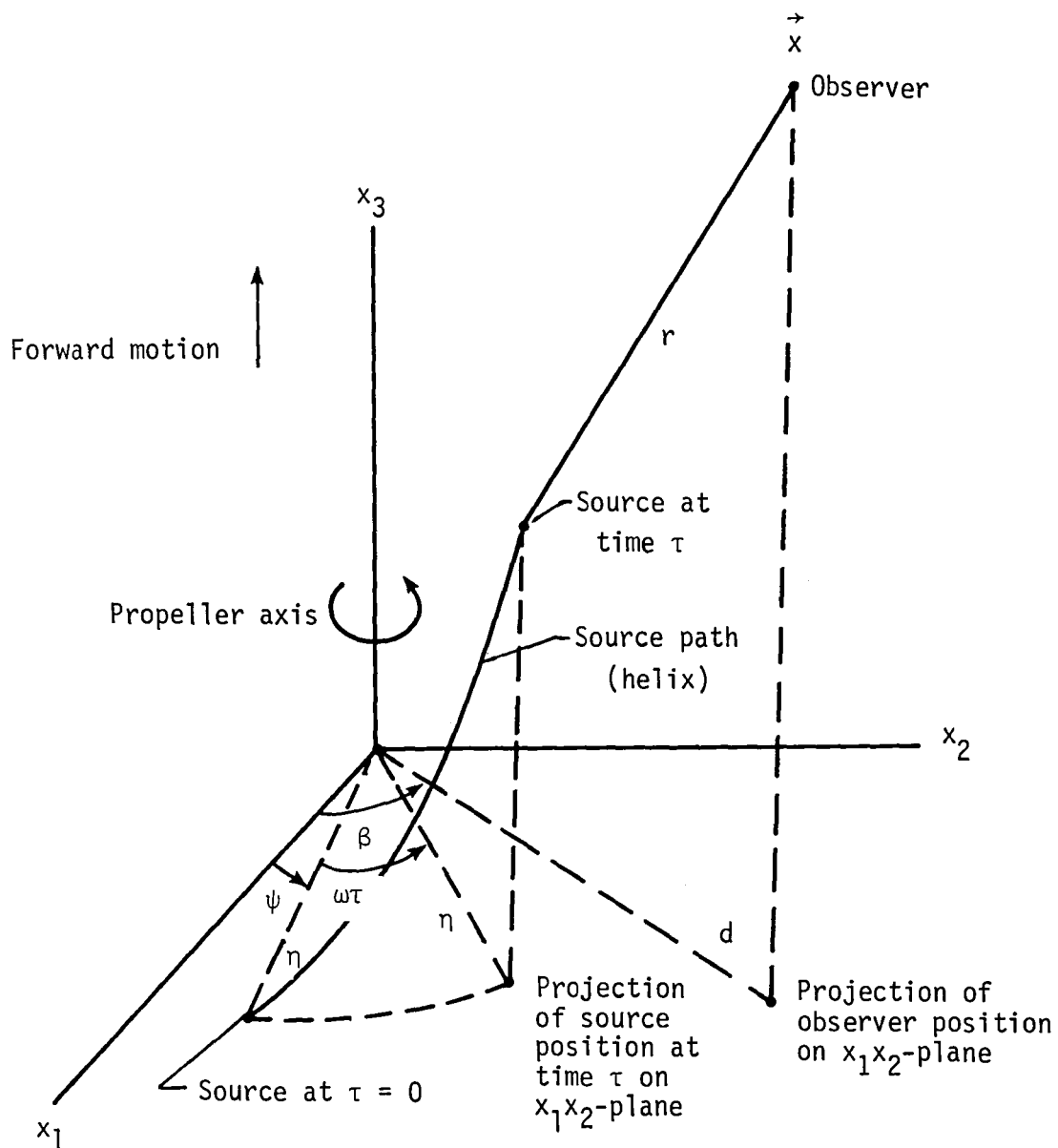


Figure A1.- Geometry of source and observer position used for calculation of emission time in scheme 2.

$$\phi = \omega\tau + \psi.$$

APPENDIX A

find the roots of equation (A5). In the implementation of this method, the intervals in which each root of the equation lie are found first. An iterative method is then used in each interval to find the roots. This method is more time consuming to implement on the computer than that of method 1. However, of the several methods for finding emission time tried in the course of the development of the computer program, the scheme based on modified regula falsi was the most satisfactory, both in precision and speed and in guaranteeing that all the roots would be found.

APPENDIX B

EXAMPLE CONTROL CARD DECK

This appendix presents an example of a control card deck used at Langley Research Center to execute a multiple-case run of program NPROPFN including the graphics package.

```

*
* JOBNAME, ACCOUNT AND CHARGE CARDS
*
JOBNAME,T50000.
ACCOUNT,123456N.
CHARGE,987654,LRC.
*
* COPY INPUT SUBROUTINES TO APPROPRIATE FILES,
* COPY NAMELIST INPUT TO TAPE1.
*
COPYBR,INPUT,FUNE2.
COPYBR,INPUT,FUNE2Q.
COPYBR,INPUT,FUNPRES.
REWIND,FUNE2,FUNE2Q,FUNPRES.
GET,NDOPROP/ST=CPF,UN=564526N.
CALL,NDOPROP.
*
* END OF RECORD, READ IN FUNE2.
*
7-8-9
SUBROUTINE FUNE2
$ (E2,R,AA,AAP,CH,CHP,LED,LEDP,THKRAT,THKRATP,CAMRAT,CAMRATP)
| |
| |
| |
RETURN
END
*
* END OF RECORD, READ IN FUNE2Q.
*
7-8-9
SUBROUTINE FUNE2Q
$ (E2,R,Q,CMBR,CMBRP,THK,THKP)
| |
| |
| |
RETURN
END
*
* END OF RECORD, READ IN FUNPRES.
*

```

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7-8-9

```
SUBROUTINE FUNPRES  
$ (E2,R,Q,SURFP,DP,SPU,SPL,SIGMAU,SIGMAL)
```

```
  |   |  
  |   |  
  |   |
```

```
RETURN  
END
```

*

* END OF RECORD, READ IN NAMELIST INPUT.

*

7-8-9

```
$INPUT
```

```
C = 344.7,
```

```
NLE = 8,
```

```
NPTS = 200,
```

```
NTE = 12,
```

```
RHO = 1.206,
```

```
V3 = 63.79,
```

```
XO = 7.28, 0., 0. $
```

```
EXAMPLE 1
```

```
$INPUT
```

```
XO = 7.28, 0., -3.05 $
```

```
EXAMPLE 2
```

*

* END OF INFORMATION.

*

6-7-8-9

NDOPROP PROCEDURE LISTING

```

* START OF NDOPROP
*   (INPUT ON TAPE1, OUTPUT ON TAPE2)
*
* GET MAIN PROGRAM AND READ INPUT SUBROUTINES.
*
GET,NPROPFN/ST=CPF,UN=564526N.
COPYBR,NPROPFN,LIST.
COPYBR,FUNE2,LIST.
COPYBR,FUNE2Q,LIST.
COPYBR,FUNPRES,LIST.
PACK,LIST.
*
* COMPILE MAIN PROGRAM AND INPUT SUBROUTINES
*
FTN,I=LIST,L=MYLIST,B=BINARY,A,P.
GOTO,200.
EXIT.
REWIND,MYLIST.
COPY,MYLIST,OUTPUT.
EXIT.
*
* EXTRACT INPUT FUNCTIONS FROM FUNE2,FUNE2Q,FUNPRES
*
200,REWIND,FUNE2,FUNE2Q,FUNPRES.
COPYBR,FUNPRES,TAPE4.
COPYBR,FUNE2Q,TAPE4.
COPYBR,FUNE2,TAPE4.
PACK,TAPE4.
GET,FUNEX/ST=CPF,UN=564526N.
EDIT,TAPE4,N,FUNEX,0.
RETURN,NPROPFN,FUNE2,FUNE2Q,FUNPRES,LIST.
*
* ATTACH LIBRARIES, LOAD AND EXECUTE
*
GET,NPROLIB/ST=CPF,UN=564526N.
GET,MYLIB4/ST=CPF,UN=564526N.
ATTACH,FINMLIB,LRCGOSF/UN=LIBRARY,NA.
LDSET,LIB=NPROLIB/MYLIB4/FTNMLIB/LRCGOSF.
LDSET,MAP=SB/PROPMAP,PRESETA=DEBUG.
LOAD,BINARY.
NOGO,FILE.
RETURN,BINARY,NPROLIB,MYLIB4,FTNMLIB,LRCGOSF.
FILE.
GOTO,300.
EXIT.
REWIND,PROPMAP.
COPY,PROPMAP,OUTPUT.
EXIT.
*

```

APPENDIX B

```
* RETURN FILES
*
300,RETURN,TAPE6,TAPE7,FILE.
*
* PLOTTING INSTRUCTIONS.
*
PLOT.CALPOST,FB (FRAMCNT=120)
CONT. // SHEET PAPER - 8-1/2 x 11 INCHES
CONT. BLACK INK. LEROY .3 MM
CONT.
CONT. X=8.5 AND Y=11 //
GOTO,400.
EXIT.
*
* END OF NDOPROP
```

APPENDIX C

EXAMPLES OF PRINTED OUTPUT

In this appendix, four examples of the output of PROPFAN are presented. Examples 1 and 2 are for a conventional propeller in subsonic operation. Examples 3 and 4 are for an advanced design propeller in supersonic operation. A list of the input functions and parameters (Data Sheet) is always printed in the output listing. The noise component pressure signature and pressure spectra output which are optionally available are also included here. These examples were chosen to demonstrate the versatility of PROPFAN with regard to the input and output data. The graphic output (generated by NPROPFN) for these examples is presented in appendix D. Several other examples for advanced design propellers and comparisons with measured noise data are given in reference 8.

Examples 1 and 2

Examples 1 and 2 illustrate the use of analytic functions to describe a conventional propeller. In subroutine FUNE2, the variables AA, CH, LED, and THKRAT are all given as functions of E2, while the camber ratio (CAMRAT) is defined as a constant. In subroutine FUNE2Q, the camber (CMBR) is defined as a function of the nondimensional distance along the chord line (Q). In addition, two different thickness functions (THK) are specified which vary with Q and with radial location E2.

In example 1, because logical variable SURFP is set false, subroutine FUNPRES supplies pressure as the differential pressure (DP), and the skin friction values (SIGMAU and SIGMAL) are necessarily set equal to zero (refer to section "Input Functions," Subroutine FUNPRES). In example 2, logical variable SURFP is set true, and the subroutine returns the surface pressures (SPU and SPL). In this case, SIGMAU and SIGMAL are defined as functions of radial distance E2. The observer locations (X0) are also different in these two examples.

Examples 3 and 4

Examples 3 and 4 illustrate the use of arrays of input data to describe the geometry and loading of an advanced design propeller operating with supersonic helical tip Mach number. In subroutine FUNE2, the data arrays and associated variables are labeled as follows:

AA1	angle of attack (degrees), data array corresponding to ERL
ERL	radial location divided by propeller radius (nondimensionalized radial position)
OFFSET	offset (degrees) for angle of attack to obtain desired pitch angle at operating condition

APPENDIX C

CH2	chord divided by propeller diameter, data array corresponding to ER2
THKRT2	thickness radio, data array corresponding to ER2
LED2	leading-edge displacement divided by chord, data array corresponding to ER2
ER2	radial location divided by propeller radius (nondimensionalized radial position)
WORK1, WORK2, WORK3, WORK4	storage arrays for interpolation subroutine PCS
I1, I2, I3, I4	initialization indices for interpolation subroutine PCS

The specific arrays needed for program execution are interpolated from these data arrays using subroutine PCS. Note that the array of LED2 values has the opposite sign as LED, because this is how the blade is specified for manufacture. The derivatives AAP, CHP, and THKRATP are taken with respect to radial distance (ER1 for AAP and ER2 for the remaining derivatives). The variable CAMRAT is defined analytically as a function of radial distance E2 and the derivative CAMRATP is taken with respect to E2.

In subroutine FUNE2Q, the airfoil thickness (THK) and camber (CMBR) functions are described analytically. Variable CMBR is defined as a function of Q and of E2 because the inner section of the blade ($ER \leq 0.45$) uses a series 65 airfoil and the outer section ($ER > 0.45$) uses a series 16 airfoil section.

In subroutine FUNPRES, the differential pressure (DP) across the mean surface of the blades is used for both examples. Thus, variable SURFP must be defined as false, and the skin friction stresses (SIGMAU and SIGMAL) must be set equal to zero. The pressure distribution (DP) is derived from a data array of lift coefficients. The additional variables are defined as follows:

CP2	lift coefficient, data array corresponding to ER2
ER2	radial location divided by propeller radius (nondimensionalized radial position)
INTRVL	initialization value for interpretation subroutine PCS
FACTOR	scaling factor to adjust lift coefficient to obtain desired power absorbed by the blades
OMEGA	propeller speed (radians/sec)
RHO	density of air (kg/m^3)
VINFS	relative wind velocity at blade tip, squared (m^2/sec^2)

APPENDIX C

The lift coefficients at each radial location are interpolated from the CP2 data array using subroutine PCS. Then the differential pressure (DP) values are calculated by using the lift coefficients and nondimensional chord location Q . Thus, in this case the pressure varies with both radial and chordwise location.

The only difference between examples 3 and 4 is the position of the observer (X0). In example 3, the observer is located almost in the plane of the propeller and in motion with the propeller. Note that the supersonic section of the program is used many times during execution. This can be seen from the value of INDEXSL printed on the Data Sheet which indicates the number of calls to the supersonic code. In example 4, the observer is located behind the propeller and the blades do not move at supersonic speeds toward the observer at any time. In this case, the program executes very quickly since only the subsonic code is used. This efficiency is achieved mainly by using only coarse panel sizes (input variables NCHF and NPCAF are set equal to one).

APPENDIX C

EXAMPLE 1

```

SUBROUTINE FUNE2
$ (E2,R,AA,AAP,CH,CHP,LED,LEDP,THKRAT,THKRATP,CAMRAT,CAMRATP)
C
  REAL LED, LEDP
  ER = E2/R
C
C - TWIN OTTER INPUT FUNCTIONS, EXAMPLE 1.
C
  AAEXP = EXP(-3.491*ER)
  AA = 12.622 + 78.037*AAEXP
  AAP = -209.529*AAEXP
C
  ROOT = SQRT( 1.-ER )
  POLY = 1.474 + ER*( 2.544 + ER )
  CH = 0.069*ROOT*POLY
  CHP = 0.069/R*(-0.5/ROOT*POLY + ROOT*(2.*ER+2.544))
C
  LED = -0.25*CH
  LEDP = -0.25*CHP
C
  THKEXP = EXP(-11.200*ER)
  THKRAT = 0.069 + 3.2244*THKEXP
  THKRATP = -27.778*THKEXP
C
  CAMRAT = 0.03
  CAMRATP = 0.
C
  RETURN
  END

```

```

SUBROUTINE FUNE2Q
$ ( E2, R, Q, CMBR, CMBRP, THK, THKP )
C
C - TWIN OTTER INPUT FUNCTIONS, EXAMPLE 1.
C
  CMBR = 4.*(Q-Q**2)
  CMBRP = 4.-8.*Q
C
  IF (Q.GT.0.5) GO TO 100
  THK = 0.989665*SQRT(Q) + Q*(-0.23925 + Q*(-0.041 - Q*0.5594))
  THKP = 0.4948325/SQRT(Q) - .23925 + Q*(-0.082 - Q*1.6782)
  GO TO 200
C
100  QM = 1. - Q
     QMP = -1.
     THK = 0.01 + QM*(2.325 + QM*(-3.42 + QM*1.46))
     THKP = (2.325 + QM*(-6.84 + QM*4.38))*QMP
C
200  RETURN
     END

```

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EXAMPLE 1

```

SUBROUTINE FUNPRES
$ (E2, R, Q, SURFP, DP, SPU, SPL, SIGMAU, SIGMAL)
C
  LOGICAL SURFP
C
C - TWIN OTTER INPUT FUNCTIONS, EXAMPLE 1.
C - DIFFERENTIAL PRESSURE.
C
  SURFP = .FALSE.
  A = .719618*10.**6.
C
  ER = E2/R
  IF (Q-.05) 10,20,20
10  SPQU = EXP(800.*Q*(Q-.1)) - 0.5
  SPQL = 0.9*EXP(500.*Q*(Q-.1)) - 0.4
  GO TO 100
C
20  IF ((Q-.05)*(Q-.5)) 30,30,40
30  SPQL = -0.1421
  SPQU = -0.3647
  GO TO 100
C
40  SPQL = .2842*(Q-1.0)
  SPQU = .7293*(Q-1.0)
C
100 SPU = SPQU*ER**2.833*SQRT(1.-ER)*A
  SPL = SPQL*ER**2.833*SQRT(1.-ER)*A
C
  DP = SPL - SPU
C
  SIGMAU = 0.
  SIGMAL = 0.
C
  RETURN
  END

```

APPENDIX C

DATA SHEET

EXAMPLE 1

C = 344.7 M/SEC
 RHO = 1.2060 KG/M**3

 XO = (7.28, 0.00, 0.00) M OBSERVER IS IN MOTION

 V3 = 63.8 M/SEC
 = 142.7 MPH

 R = 1.300 M
 RINNER = .300 M

 REV = 2145.0 RPM
 NBLADES = 3

 NPCA = 15
 NLE = 8
 NTE = 12

 THKMAXL = .05

 NPTS = 200
 NSPEC = 30

 EPSILON = .50 %

 TORQUE = 581.43 N-M/BLADE
 THRUST = 1947.37 N/BLADE
 POWER = 130.60 KW/BLADE
 = 175.07 HP/BLADE

 OASPL = 113.52 DB RE 20.E-6 PA
 = 108.74 DB RE 20.E-6 PA (THICKNESS)
 = 111.69 DB RE 20.E-6 PA (LOADING)
 = -158.57 DB RE 20.E-6 PA (DRAG)

HELICAL M-TIP = .867

 PER = 9.3240E-03 SEC
 BPF = 107.3 HZ

 NPCAF = 3
 NCHF = 2

 NTAU = 10

 DT = 4.6620E-05 SEC
 FRACDT = .500
 MTRANS = .950
 TRANS = .980
 INDEXSL = 0

PRESSURE SIGNATURES OF NOISE COMPONENTS

EXAMPLE 1

POINT NUMBER	OBSERVER TIME (MSEC)	THICKNESS NOISE (PA)	LOADING NOISE			DRAG NOISE			OVERALL NOISE (PA)	POINT NUMBER
			FAR FIELD (PA)	NEAR FIELD (PA)	COMBINED (PA)	FAR FIELD (PA)	NEAR FIELD (PA)	COMBINED (PA)		
1	0.00	.9814	1.7755	-2.1219	-.3464	0.0000	0.0000	0.0000	.6350	1
2	.05	.9812	1.8787	-2.1214	-.2427	0.0000	0.0000	0.0000	.7386	2
3	.09	.9813	1.9819	-2.1206	-.1387	0.0000	0.0000	0.0000	.8426	3
4	.14	.9818	2.0850	-2.1196	-.0346	0.0000	0.0000	0.0000	.9472	4
5	.19	.9826	2.1882	-2.1183	.0698	0.0000	0.0000	0.0000	1.0524	5
6	.23	.9837	2.2914	-2.1168	.1745	0.0000	0.0000	0.0000	1.1583	6
7	.28	.9853	2.3947	-2.1151	.2796	0.0000	0.0000	0.0000	1.2648	7
8	.33	.9871	2.4982	-2.1132	.3850	0.0000	0.0000	0.0000	1.3721	8
9	.37	.9894	2.6019	-2.1110	.4909	0.0000	0.0000	0.0000	1.4802	9
10	.42	.9920	2.7059	-2.1087	.5972	0.0000	0.0000	0.0000	1.5892	10
11	.47	.9950	2.8101	-2.1061	.7040	0.0000	0.0000	0.0000	1.6990	11
12	.51	.9983	2.9147	-2.1032	.8114	0.0000	0.0000	0.0000	1.8098	12
13	.56	1.0021	3.0196	-2.1002	.9195	0.0000	0.0000	0.0000	1.9216	13
14	.61	1.0063	3.1250	-2.0969	1.0281	0.0000	0.0000	0.0000	2.0344	14
15	.65	1.0108	3.2309	-2.0933	1.1375	0.0000	0.0000	0.0000	2.1484	15
16	.70	1.0158	3.3373	-2.0896	1.2477	0.0000	0.0000	0.0000	2.2635	16
17	.75	1.0212	3.4443	-2.0856	1.3586	0.0000	0.0000	0.0000	2.3799	17
18	.79	1.0271	3.5519	-2.0814	1.4705	0.0000	0.0000	0.0000	2.4976	18
19	.84	1.0334	3.6602	-2.0770	1.5832	0.0000	0.0000	0.0000	2.6166	19
20	.89	1.0402	3.7692	-2.0723	1.6969	0.0000	0.0000	0.0000	2.7370	20
180	8.34	1.0632	-.4841	-2.0782	-2.5622	0.0000	0.0000	0.0000	-1.4990	180
181	8.39	1.0559	-.3694	-2.0828	-2.4522	0.0000	0.0000	0.0000	-1.3963	181
182	8.44	1.0490	-.2557	-2.0871	-2.3428	0.0000	0.0000	0.0000	-1.2939	182
183	8.48	1.0424	-.1430	-2.0912	-2.2342	0.0000	0.0000	0.0000	-1.1918	183
184	8.53	1.0361	-.0312	-2.0950	-2.1262	0.0000	0.0000	0.0000	-1.0901	184
185	8.58	1.0302	.0798	-2.0986	-2.0188	0.0000	0.0000	0.0000	-.9885	185
186	8.62	1.0247	.1900	-2.1019	-1.9119	0.0000	0.0000	0.0000	-.8872	186
187	8.67	1.0195	.2994	-2.1049	-1.8056	0.0000	0.0000	0.0000	-.7861	187
188	8.72	1.0146	.4080	-2.1077	-1.6997	0.0000	0.0000	0.0000	-.6851	188
189	8.76	1.0101	.5161	-2.1103	-1.5942	0.0000	0.0000	0.0000	-.5842	189
190	8.81	1.0059	.6234	-2.1126	-1.4891	0.0000	0.0000	0.0000	-.4833	190
191	8.86	1.0020	.7302	-2.1146	-1.3844	0.0000	0.0000	0.0000	-.3824	191
192	8.90	.9984	.8365	-2.1164	-1.2800	0.0000	0.0000	0.0000	-.2815	192
193	8.95	.9952	.9422	-2.1180	-1.1758	0.0000	0.0000	0.0000	-.1805	193
194	9.00	.9924	1.0475	-2.1193	-1.0718	0.0000	0.0000	0.0000	-.0794	194
195	9.04	.9898	1.1524	-2.1204	-.9680	0.0000	0.0000	0.0000	.0218	195
196	9.09	.9876	1.2569	-2.1212	-.8643	0.0000	0.0000	0.0000	.1233	196
197	9.14	.9857	1.3611	-2.1218	-.7607	0.0000	0.0000	0.0000	.2250	197
198	9.18	.9841	1.4650	-2.1222	-.6572	0.0000	0.0000	0.0000	.3269	198
199	9.23	.9829	1.5687	-2.1223	-.5537	0.0000	0.0000	0.0000	.4292	199
200	9.28	.9820	1.6722	-2.1222	-.4501	0.0000	0.0000	0.0000	.5319	200
201	9.32	.9814	1.7755	-2.1219	-.3464	0.0000	0.0000	0.0000	.6350	201
127C	15.20	2.0874	-9.3223	-1.3504	-10.6727	0.0000	0.0000	0.0000	-8.5853	127C

APPENDIX C

EXAMPLE 1

APPENDIX C

PRESSURE SPECTRA OF NOISE COMPONENTS

EXAMPLE 1

----- HARMONIC ----- NUMBER	FREQUENCY (HZ)	THICKNESS NOISE (DB)	LOADING NOISE (DB)	DRAG NOISE (DB)	OVERALL NOISE (DB)
1	107.25	99.01	109.51	-158.57	109.88
2	214.50	100.96	105.20	-158.57	106.69
3	321.75	100.96	101.26	-158.57	104.24
4	429.00	100.28	97.71	-158.57	102.30
5	536.25	99.26	94.45	-158.57	100.58
6	643.50	98.05	91.42	-158.57	98.96
7	750.75	96.73	88.56	-158.57	97.38
8	858.00	95.33	85.84	-158.57	95.81
9	965.25	93.89	83.23	-158.57	94.25
10	1072.50	92.42	80.72	-158.57	92.68
11	1179.75	90.91	78.28	-158.57	91.11
12	1287.00	89.37	75.89	-158.57	89.52
13	1394.25	87.83	73.57	-158.57	87.94
14	1501.50	86.29	71.32	-158.57	86.37
15	1608.75	84.77	69.14	-158.57	84.82
16	1716.00	83.23	66.99	-158.57	83.26
17	1823.25	81.66	64.85	-158.57	81.67
18	1930.50	80.06	62.71	-158.57	80.06
19	2037.75	78.48	60.62	-158.57	78.47
20	2145.00	76.95	58.60	-158.57	76.92
21	2252.25	75.43	56.64	-158.57	75.40
22	2359.50	73.88	54.68	-158.57	73.84
23	2466.75	72.27	52.69	-158.57	72.23
24	2574.00	70.66	50.70	-158.57	70.60
25	2681.25	69.10	48.78	-158.57	69.04
26	2788.50	67.62	46.95	-158.57	67.55
27	2895.75	66.13	45.13	-158.57	66.06
28	3003.00	64.57	43.28	-158.57	64.50
29	3110.25	62.95	41.41	-158.57	62.88
30	3217.50	61.35	39.63	-158.57	61.28

```

SUBROUTINE FUNE2
$ (E2,R,AA,AAP,CH,CHP,LED,LEDP,THKRAT,THKRATP,CAMRAT,CAMRATP)
C
  REAL LED, LEDP
  ER = E2/R
C
C - TWIN OTTER INPUT FUNCTIONS, EXAMPLE 2.
C
  AAEXP = EXP(-3.491*ER)
  AA = 12.622 + 78.037*AAEXP
  AAP = -209.529*AAEXP
C
  ROOT = SQRT( 1.-ER )
  POLY = 1.474 + ER*( 2.544 + ER )
  CH = 0.069*ROOT*POLY
  CHP = 0.069/R*(-0.5/ROOT*POLY + ROOT*(2.*ER+2.544))
C
  LED = -0.25*CH
  LEDP = -0.25*CHP
C
  THKEXP = EXP(-11.200*ER)
  THKRAT = 0.069 + 3.2244*THKEXP
  THKRATP = -27.778*THKEXP
C
  CAMRAT = 0.03
  CAMRATP = 0.
C
  RETURN
  END

```

```

SUBROUTINE FUNE2Q
$ ( E2, R, Q, CMBR, CMBRP, THK, THKP )
C
C - TWIN OTTER INPUT FUNCTIONS, EXAMPLE 2.
C
  CMBR = 4.*(Q-Q**2)
  CMBRP = 4.-8.*Q
C
  IF (Q.GT.0.5) GO TO 100
  THK = 0.989665*SQRT(Q) + Q*(-0.23925 + Q*(-0.041 - Q*0.5594))
  THKP = 0.4948325/SQRT(Q) - .23925 + Q*(-0.082 - Q*1.6782)
  GO TO 200
C
100  QM = 1. - Q
     QMP = -1.
     THK = 0.01 + QM*(2.325 + QM*(-3.42 + QM*1.46))
     THKP = (2.325 + QM*(-6.84 + QM*4.38))*QMP
C
200  RETURN
     END

```

```

SUBROUTINE FUNPRES
$ (E2, R, Q, SURFP, DP, SPU, SPL, SIGMAU, SIGMAL)
C
  LOGICAL SURFP
C
C - TWIN OTTER INPUT FUNCTIONS, EXAMPLE 2.
C - SURFACE PRESSURE.
C
  SURFP = .TRUE.
  A = .702244*10.**6.
C
  ER = E2/R
  IF (Q-0.05) 10,20,20
10  SPQU = EXP(800.*Q*(Q-.1)) - 0.5
  SPQL = 0.9*EXP(500.*Q*(Q-.1)) - 0.4
  GO TO 100
C
20  IF ((Q-.05)*(Q-.5)) 30,30,40
30  SPQL = -0.1421
  SPQU = -0.3647
  GO TO 100
C
40  SPQL = .2842*(Q-1.0)
  SPQU = .7293*(Q-1.0)
C
100  SPU = SPQU*ER**2.833*SQRT(1.-ER)*A
  SPL = SPQL*ER**2.833*SQRT(1.-ER)*A
C
  DP = SPL - SPU
C
  PI = 3.14159
  REV = 2145.0
  OMEGA = REV*PI/30.
  V3 = 63.79
  SIGMAU = 0.0018*((E2*OMEGA)**2 + V3*V3)
  SIGMAL = SIGMAU
C
  RETURN
  END

```

DATA SHEET

EXAMPLE 2

C = 344.7 M/SEC
RHO = 1.2060 KG/M**3

XO = (7.28, 0.00, -3.05) M OBSERVER IS IN MOTION

V3 = 63.8 M/SEC
= 142.7 MPH

R = 1.300 M
RINNER = .300 M
HELICAL M-TIP = .867

REV = 2145.0 RPM
NBLADES = 3
PER = 9.3240E-03 SEC
BPF = 107.3 HZ

NPCA = 15
NLE = 8
NTE = 12
NPCAF = 3
NCHF = 2

THKMAXL = .05
NTAU = 10

NPTS = 200
NSPEC = 30
DT = 4.6620E-05 SEC
FRACDT = .500
MTRANS = .950
TRANS = .980
EPSILON = .50 %
INDEXSL = 0

TORQUE = 582.04 N-M/BLADE
THRUST = 1894.25 N/BLADE
POWER = 130.74 KW/BLADE
= 175.26 HP/BLADE

OASPL = 115.83 DB RE 20.E-6 PA
= 100.91 DB RE 20.E-6 PA (THICKNESS)
= 115.69 DB RE 20.E-6 PA (LOADING)
= 81.64 DB RE 20.E-6 PA (DRAG)

PRESSURE SIGNATURES OF NOISE COMPONENTS

EXAMPLE 2

POINT NUMBER	OBSERVER TIME (MSEC)	THICKNESS NOISE (PA)	LOADING NOISE			DRAG NOISE			OVERALL NOISE (PA)	POINT NUMBER
			FAR FIELD (PA)	NEAR FIELD (PA)	COMBINED (PA)	FAR FIELD (PA)	NEAR FIELD (PA)	COMBINED (PA)		
1	0.00	.7506	-2.1545	1.1437	-1.0108	-.0402	-.0195	-.0596	-.3199	1
2	.05	.7472	-1.9772	1.1337	-.8435	-.0370	-.0196	-.0566	-.1530	2
3	.09	.7439	-1.8010	1.1241	-.6769	-.0339	-.0197	-.0536	.0134	3
4	.14	.7408	-1.6258	1.1149	-.5109	-.0308	-.0198	-.0506	.1793	4
5	.19	.7379	-1.4515	1.1061	-.3454	-.0277	-.0199	-.0476	.3449	5
6	.23	.7352	-1.2781	1.0977	-.1804	-.0246	-.0200	-.0446	.5102	6
7	.28	.7326	-1.1054	1.0897	-.0157	-.0216	-.0201	-.0416	.6753	7
8	.33	.7303	-.9335	1.0821	.1486	-.0185	-.0201	-.0387	.8402	8
9	.37	.7281	-.7622	1.0749	.3128	-.0155	-.0202	-.0358	1.0051	9
10	.42	.7261	-.5914	1.0681	.4767	-.0125	-.0203	-.0328	1.1700	10
11	.47	.7243	-.4211	1.0617	.6406	-.0096	-.0203	-.0299	1.3350	11
12	.51	.7226	-.2512	1.0557	.8045	-.0066	-.0204	-.0270	1.5001	12
13	.56	.7211	-.0816	1.0501	.9685	-.0037	-.0204	-.0241	1.6656	13
14	.61	.7199	.0878	1.0449	1.1326	-.0007	-.0205	-.0212	1.8313	14
15	.65	.7188	.2570	1.0400	1.2970	.0022	-.0205	-.0183	1.9974	15
16	.70	.7179	.4261	1.0356	1.4616	.0051	-.0205	-.0154	2.1641	16
17	.75	.7171	.5951	1.0315	1.6267	.0080	-.0205	-.0125	2.3313	17
18	.79	.7166	.7643	1.0279	1.7922	.0109	-.0205	-.0096	2.4991	18
19	.84	.7163	.9336	1.0246	1.9582	.0138	-.0205	-.0067	2.6677	19
20	.89	.7161	1.1031	1.0217	2.1248	.0167	-.0205	-.0038	2.8371	20
180	8.34	.8633	-6.2696	1.4537	-4.8159	-.1169	-.0150	-.1320	-4.0846	180
181	8.39	.8562	-6.0509	1.4344	-4.6165	-.1127	-.0153	-.1280	-3.8883	181
182	8.44	.8493	-5.8350	1.4155	-4.4195	-.1085	-.0156	-.1241	-3.6943	182
183	8.48	.8426	-5.6218	1.3971	-4.2247	-.1044	-.0159	-.1203	-3.5024	183
184	8.53	.8360	-5.4113	1.3792	-4.0321	-.1004	-.0162	-.1166	-3.3126	184
185	8.58	.8296	-5.2033	1.3618	-3.8415	-.0964	-.0164	-.1129	-3.1248	185
186	8.62	.8233	-4.9978	1.3448	-3.6530	-.0925	-.0167	-.1092	-2.9389	186
187	8.67	.8173	-4.7947	1.3283	-3.4664	-.0887	-.0169	-.1056	-2.7547	187
188	8.72	.8114	-4.5939	1.3123	-3.2816	-.0849	-.0172	-.1021	-2.5723	188
189	8.76	.8056	-4.3953	1.2967	-3.0986	-.0812	-.0174	-.0986	-2.3915	189
190	8.81	.8001	-4.1988	1.2816	-2.9172	-.0775	-.0176	-.0951	-2.2123	190
191	8.86	.7947	-4.0044	1.2669	-2.7375	-.0739	-.0178	-.0917	-2.0345	191
192	8.90	.7895	-3.8119	1.2526	-2.5593	-.0703	-.0180	-.0884	-1.8582	192
193	8.95	.7845	-3.6213	1.2388	-2.3825	-.0668	-.0182	-.0850	-1.6831	193
194	9.00	.7796	-3.4325	1.2254	-2.2071	-.0634	-.0184	-.0818	-1.5092	194
195	9.04	.7749	-3.2454	1.2125	-2.0330	-.0599	-.0186	-.0785	-1.3365	195
196	9.09	.7704	-3.0600	1.2000	-1.8600	-.0565	-.0187	-.0753	-1.1649	196
197	9.14	.7661	-2.8761	1.1879	-1.6882	-.0532	-.0189	-.0721	-.9942	197
198	9.18	.7620	-2.6937	1.1762	-1.5175	-.0499	-.0191	-.0689	-.8245	198
199	9.23	.7580	-2.5127	1.1650	-1.3477	-.0466	-.0192	-.0658	-.6556	199
200	9.28	.7542	-2.3330	1.1541	-1.1789	-.0434	-.0193	-.0627	-.4874	200
201	9.32	.7506	-2.1545	1.1437	-1.0108	-.0402	-.0195	-.0596	-.3199	201
139C	15.76	.6535	-17.6574	2.7168	-14.9406	-.3920	.0082	-.3837	-14.6708	139C

APPENDIX C

EXAMPLE 2

APPENDIX C

PRESSURE SPECTRA OF NOISE COMPONENTS

EXAMPLE 2

----- HARMONIC ----- NUMBER	FREQUENCY (HZ)	THICKNESS NOISE (DB)	LOADING NOISE (DB)	DRAG NOISE (DB)	OVERALL NOISE (DB)
1	107.25	95.00	113.77	79.24	113.83
2	214.50	95.34	109.27	75.58	109.44
3	321.75	93.83	104.73	71.70	105.06
4	429.00	91.70	100.38	67.91	100.93
5	536.25	89.28	96.21	64.23	97.02
6	643.50	86.72	92.20	60.64	93.30
7	750.75	84.07	88.33	57.14	89.74
8	858.00	81.37	84.54	53.69	86.29
9	965.25	78.59	80.82	50.28	82.92
10	1072.50	75.79	77.16	46.91	79.62
11	1179.75	73.01	73.60	43.63	76.42
12	1287.00	70.29	70.16	40.42	73.35
13	1394.25	67.54	66.76	37.20	70.30
14	1501.50	64.69	63.30	33.92	67.20
15	1608.75	61.78	59.82	30.66	64.08
16	1716.00	59.02	56.51	27.55	61.12
17	1823.25	56.49	53.44	24.60	58.41
18	1930.50	53.95	50.36	21.57	55.71
19	2037.75	51.06	47.00	18.29	52.68
20	2145.00	47.82	43.44	14.88	49.36
21	2252.25	44.75	40.20	11.76	46.26
22	2359.50	42.30	37.59	9.15	43.78
23	2466.75	40.33	35.26	6.72	41.68
24	2574.00	38.20	32.55	4.01	39.27
25	2681.25	35.63	29.14	.83	36.36
26	2788.50	32.73	25.33	-2.62	33.39
27	2895.75	29.53	21.88	-5.71	30.76
28	3003.00	26.72	20.44	-7.36	29.05
29	3110.25	25.97	21.19	-7.60	28.81
30	3217.50	26.57	21.13	-8.63	28.85

APPENDIX C

EXAMPLE 3

```

SUBROUTINE FUNE2
$ (E2,R,AA,AAP,CH,CHP,LED,LEDP,THKRAT,THKRATP,CAMRAT,CAMRATP)
C
REAL LED, LEDP, LED2
DIMENSION ER1(12),AA1(12),ER2(20),CH2(20),LED2(20),THKRAT2(20),
$ WORK1(60),WORK2(60),WORK3(60),WORK4(60)
C
C - HIGH SPEED PROPELLER INPUT FUNCTIONS, EXAMPLE 3.
C
C - DATA ARRAYS DEFINING BLADE GEOMETRY
C AA1 = BLADE ELEMENT ANGLE (DEG.)
C CH2 = LOCAL CHORD DIVIDED BY PROPELLER DIAMETER
C LED2 = LEADING EDGE DISPLACEMENT DIVIDED BY LOCAL CHORD
C THKRAT2 = LOCAL THICKNESS RATIO
C
DATA ER1 /.239,.286,.367,.449,.531,.612,.694,.776,.857,
$ .939,.980,1.000/
DATA AA1 /82.83,80.65,76.99,73.61,70.21,66.89,63.75,60.80,
$ 58.05,55.59,54.58,54.09/
DATA ER2/.30,.40,.50,.55,.60,.65,.70,.75,.80,.825,.85,.875,.90,
$ .925,.95,.96,.97,.98,.99,1.00/
DATA CH2 /.170,.187,.200,.202,.200,.195,.188,.178,.166,.160,.152,
$ .141,.129,.116,.102,.096,.090,.084,.077,.071 /
DATA LED2 /.527,.597,.621,.598,.558,.503,.429,.332,.206,.132,.041,
$ -.075,-.218,-.399,-.637,-.760,-.896,-1.057,-1.260,-1.479/
DATA THKRAT2 /.102,.060,.044,.039,.034,.029,.026,.024,.022,.022,
$ .021,.021,.021,.020,.020,.020,.020,.020,.020,.020/
DATA I1,I2,I3,I4/-1,-1,-1,-1/
C
ER = E2/R
C
OFFSET = -.435
CALL PCS (ER1,AA1,12,ER,AA,AAP,I1,WORK1)
AA = AA + OFFSET
AAP = AAP/R
C
IF (ER.LT.0.30) ER = 0.30
CALL PCS (ER2,CH2,20,ER,CH,CHP,I2,WORK2)
CH = 2.*R*CH
CHP = 2.*CHP
C
CALL PCS (ER2,LED2,20,ER,LED,LEDP,I3,WORK3)
LED = -CH*LED
LEDP = -CHP*LED - CH*LEDP/R
C
CALL PCS (ER2,THKRAT2,20,ER,THKRAT,THKRATP,I4,WORK4)
THKRATP = THKRATP/R
C
CAMRAT = 0.03 - 0.0913*(E2 - 0.093)
CAMRATP = -0.0913
C
RETURN
END

```

APPENDIX C

EXAMPLE 3

```

SUBROUTINE FUNE2Q
$ ( E2, R, Q, CMBR, CMBRP, THK, THKP )
C
C - HIGH SPEED PROPELLER INPUT FUNCTIONS, EXAMPLE 3.
C
ER = E2/R
C
CMBR = 4.*(Q-Q**2)
CMBRP = 4.-8.*Q
C
IF (ER.GT.0.45) GO TO 50
C
C - SERIES 65 AIRFOIL.
C
IF (Q.GT.0.4) GO TO 25
THK = 1.1722*SQRT(Q) + Q*(0.078 + Q*(-12.3902 +
$ Q*(56.9872 - Q*75.6761)))
THKP = 0.5861/SQRT(Q) + 0.078 + Q*(-24.7804 +
$ Q*(170.9616 - Q*302.7044))
GO TO 200
C
25 QM = Q - 0.4
THK = 0.5 + QM*QM*(-2.8333 + QM*2.4074)
THKP = QM*(-5.6666 + QM*7.2222)
GO TO 200
C
C - SERIES 16 AIRFOIL.
C
50 IF (Q.GT.0.5) GO TO 100
THK = 0.989665*SQRT(Q) + Q*(-0.23925 + Q*(-0.041 - Q*0.5594))
THKP = 0.4948325/SQRT(Q) - .23925 + Q*(-0.082 - Q*1.6782)
GO TO 200
C
100 QM = 1. - Q
QMP = -1.
THK = 0.01 + QM*(2.325 + QM*(-3.42 + QM*1.46))
THKP = (2.325 + QM*(-6.84 + QM*4.38))*QMP
C
200 RETURN
C
END

```

APPENDIX C

EXAMPLE 3

```

SUBROUTINE FUNPRES
$ (E2,R,Q,SURFP,DP,SPU,SPL,SIGMAU,SIGMAL)
LOGICAL SURFP
DIMENSION ER2(20), CP2(20), WORK(60)
C
C - HIGH SPEED PROPELLER INPUT FUNCTIONS, EXAMPLE 3.
C - DIFFERENTIAL PRESSURE INPUT.
C
DATA ER2/.30,.40,.50,.55,.60,.65,.70,.75,.80,.825,.85,.875,.90,
$ .925,.95,.96,.97,.98,.99,1.00/
DATA CP2 /.214,.259,.307,.315,.318,.319,.320,.327,.339,.340,
$ .336,.329,.320,.312,.297,.285,.278,.258,.248,0./
DATA INTRVL/-1/
C
ER = E2/R
IF (ER.LT.0.30) ER = 0.30
SURFP = .FALSE.
C
C - DEFINE POWER FACTOR (FACTOR), ROTATIONAL SPEED (OMEGA),
C FORWARD SPEED (V3), DENSITY (RHO).
C
FACTOR = 0.7861
PI = 3.14159
OMEGA = 7878.4/30.*PI
V3 = 241.2
RHO = .4570
CALL PCS (ER2,CP2,20,ER,CP,CPP,INTRVL,WORK)
CP = FACTOR*CP
C
C - DEFINE LOCAL VELOCITY, SQUARED (VINFS), AND
C DIFFERENTIAL PRESSURE (DP).
C
VINFS = (E2*OMEGA)**2. + V3*V3
DP = 3.*RHO*VINFS*CP*(Q-Q*Q)
C
SPU = 0.
SPL = 0.
SIGMAU = 0.
SIGMAL = 0.
C
RETURN
END

```

APPENDIX C

DATA SHEET

EXAMPLE 3

C = 301.5 M/SEC
 RHO = .4570 KG/M**3

 XO = (.81, 0.00, -.01) M OBSERVER IS IN MOTION

 V3 = 241.2 M/SEC
 = 539.5 MPH

 R = .312 M
 RINNER = .093 M

 REV = 7878.4 RPM
 NBLADES = 4

 NPCA = 20
 NLE = 5
 NTE = 10

 THKMAXL = .05

 NPTS = 150
 NSPEC = 30

 EPSILON = .50 %

 TORQUE = 20.22 N-M/BLADE
 THRUST = 46.51 N/BLADE
 POWER = 16.69 KW/BLADE
 = 22.37 HP/BLADE

 OASPL = 142.38 DB RE 20.E-6 PA
 = 139.78 DB RE 20.E-6 PA (THICKNESS)
 = 133.45 DB RE 20.E-6 PA (LOADING)
 = -156.07 DB RE 20.E-6 PA (DRAG)

HELICAL M-TIP = 1.170

 PER = 1.9039E-03 SEC
 BPF = 525.2 HZ

 NPCAF = 3
 NCHF = 2

 NTAU = 10

 DT = 1.2693E-05 SEC
 FRACDT = 2.000
 MTRANS = .950
 TRANS = .980
 INDEXSL = 38794

PRESSURE SIGNATURES OF NOISE COMPONENTS

EXAMPLE 3

POINT NUMBER	OBSERVER TIME (MSEC)	THICKNESS NOISE (PA)	LOADING NOISE			DRAG NOISE			OVERALL NOISE (PA)	POINT NUMBER
			FAR FIELD (PA)	NEAR FIELD (PA)	COMBINED (PA)	FAR FIELD (PA)	NEAR FIELD (PA)	COMBINED (PA)		
1	0.00	-68.6105	95.7354	-15.7404	79.9950	0.0000	0.0000	0.0000	11.3845	1
2	.01	-56.0640	91.1677	-15.5995	75.5681	0.0000	0.0000	0.0000	19.5041	2
3	.03	-115.4197	81.9249	-15.5212	66.4037	0.0000	0.0000	0.0000	-49.0160	3
4	.04	-104.9222	82.5168	-15.4019	67.1149	0.0000	0.0000	0.0000	-37.8073	4
5	.05	-74.7874	79.5310	-15.3685	64.1625	0.0000	0.0000	0.0000	-10.6249	5
6	.06	-103.5242	75.1177	-15.2701	59.8476	0.0000	0.0000	0.0000	-43.6766	6
7	.08	-110.7724	65.4773	-15.2323	50.2450	0.0000	0.0000	0.0000	-60.5274	7
8	.09	-129.4907	59.7124	-15.1169	44.5956	0.0000	0.0000	0.0000	-84.8951	8
9	.10	-133.2506	51.7046	-15.1019	36.6026	0.0000	0.0000	0.0000	-96.6479	9
10	.11	-137.1576	55.2064	-15.0537	40.1527	0.0000	0.0000	0.0000	-97.0048	10
11	.13	-150.5800	29.7830	-15.0287	14.7543	0.0000	0.0000	0.0000	-135.8257	11
12	.14	-168.6043	29.0084	-15.0054	14.0029	0.0000	0.0000	0.0000	-154.6014	12
13	.15	-161.5778	23.7662	-14.9731	8.7931	0.0000	0.0000	0.0000	-152.7847	13
14	.17	-143.3184	20.6980	-14.9797	5.7183	0.0000	0.0000	0.0000	-137.6001	14
15	.18	-160.5617	20.3922	-14.9839	5.4083	0.0000	0.0000	0.0000	-155.1534	15
16	.19	-161.6439	10.1030	-15.0199	-4.9169	0.0000	0.0000	0.0000	-166.5608	16
17	.20	-168.6064	-11.8672	-14.9720	-26.8392	0.0000	0.0000	0.0000	-195.4456	17
18	.22	-179.0823	-22.0207	-15.0324	-37.0531	0.0000	0.0000	0.0000	-216.1354	18
19	.23	-156.1153	-24.6496	-15.0364	-39.6860	0.0000	0.0000	0.0000	-195.8013	19
20	.24	-169.9904	-14.1905	-15.2049	-29.3954	0.0000	0.0000	0.0000	-199.3858	20
140	1.76	-46.9409	129.7920	-17.2485	112.5435	0.0000	0.0000	0.0000	65.6025	140
141	1.78	-24.3012	134.1412	-17.0903	117.0509	0.0000	0.0000	0.0000	92.7497	141
142	1.79	-40.0762	127.8688	-16.9421	110.9267	0.0000	0.0000	0.0000	70.8504	142
143	1.80	-41.5873	127.3471	-16.7731	110.5740	0.0000	0.0000	0.0000	68.9867	143
144	1.82	-65.2115	118.5694	-16.6325	101.9369	0.0000	0.0000	0.0000	36.7254	144
145	1.83	-61.3185	120.5018	-16.4795	104.0223	0.0000	0.0000	0.0000	42.7038	145
146	1.84	-67.9980	113.1377	-16.3405	96.7972	0.0000	0.0000	0.0000	28.7992	146
147	1.85	-69.5087	115.5055	-16.2138	99.2917	0.0000	0.0000	0.0000	29.7830	147
148	1.87	-61.9047	103.0294	-16.0586	86.9709	0.0000	0.0000	0.0000	25.0661	148
149	1.88	-55.9023	107.9377	-15.9703	91.9674	0.0000	0.0000	0.0000	36.0651	149
150	1.89	-58.6788	102.5642	-15.8180	86.7462	0.0000	0.0000	0.0000	28.0674	150
151	1.90	-68.6105	95.7354	-15.7404	79.9950	0.0000	0.0000	0.0000	11.3845	151
109C	3.27	183.7243	75.7185	-21.5544	54.1641	0.0000	0.0000	0.0000	237.8883	109C

APPENDIX C

EXAMPLE 3

APPENDIX C

EXAMPLE 3

PRESSURE SPECTRA OF NOISE COMPONENTS

----- HARMONIC ----- NUMBER	FREQUENCY (HZ)	THICKNESS NOISE (DB)	LOADING NOISE (DB)	DRAG NOISE (DB)	OVERALL NOISE (DB)
1	525.23	138.48	132.83	-156.07	141.34
2	1050.45	128.37	124.31	-156.07	132.30
3	1575.68	127.98	112.38	-156.07	129.24
4	2100.91	124.73	105.41	-156.07	124.46
5	2626.13	119.54	101.35	-156.07	119.99
6	3151.36	123.16	97.07	-156.07	123.54
7	3676.59	119.60	96.02	-156.07	119.85
8	4201.81	121.17	88.56	-156.07	121.25
9	4727.04	119.50	95.93	-156.07	119.42
10	5252.27	117.58	96.89	-156.07	116.96
11	5777.49	118.10	90.79	-156.07	117.93
12	6302.72	115.86	93.44	-156.07	115.86
13	6827.95	115.04	88.17	-156.07	114.95
14	7353.17	111.45	90.78	-156.07	111.27
15	7878.40	108.66	88.41	-156.07	108.23
16	8403.63	110.01	89.78	-156.07	109.36
17	8928.85	95.37	91.75	-156.07	86.72
18	9454.08	101.08	77.83	-156.07	100.86
19	9979.31	95.67	90.49	-156.07	99.12
20	10504.53	93.05	74.55	-156.07	93.23
21	11029.76	90.89	89.30	-156.07	89.44
22	11554.99	96.16	84.46	-156.07	98.12
23	12080.21	84.11	88.56	-156.07	91.98
24	12605.44	101.14	90.26	-156.07	101.53
25	13130.67	70.00	85.25	-156.07	83.67
26	13655.89	91.63	88.00	-156.07	89.16
27	14181.12	98.15	89.59	-156.07	100.70
28	14706.35	84.62	84.44	-156.07	87.66
29	15231.57	103.21	90.36	-156.07	104.92
30	15756.80	102.52	89.51	-156.07	102.03

APPENDIX C

EXAMPLE 4

```

SUBROUTINE FUNE2
$ (E2,R,AA,AAP,CH,CHP,LED,LEDP,THKRAT,THKRATP,CAMRAT,CAMRATP)
C
REAL LED, LEDP, LED2
DIMENSION ER1(12),AA1(12),ER2(20),CH2(20),LED2(20),THKRAT2(20),
$ WORK1(60),WORK2(60),WORK3(60),WORK4(60)
C
C - HIGH SPEED PROPELLER INPUT FUNCTIONS, EXAMPLE 4.
C
C - DATA ARRAYS DEFINING BLADE GEOMETRY
C AA1 = BLADE ELEMENT ANGLE (DEG.)
C CH2 = LOCAL CHORD DIVIDED BY PROPELLER DIAMETER
C LED2 = LEADING EDGE DISPLACEMENT DIVIDED BY LOCAL CHORD
C THKRAT2 = LOCAL THICKNESS RATIO
C
DATA ER1 /.239,.286,.367,.449,.531,.612,.694,.776,.857,
$ .939,.980,1.000/
DATA AA1 /82.83,80.65,76.99,73.61,70.21,66.89,63.75,60.80,
$ 58.05,55.59,54.58,54.09/
DATA ER2/.30,.40,.50,.55,.60,.65,.70,.75,.80,.825,.85,.875,.90,
$ .925,.95,.96,.97,.98,.99,1.00/
DATA CH2 /.170,.187,.200,.202,.200,.195,.188,.178,.166,.160,.152,
$ .141,.129,.116,.102,.096,.090,.084,.077,.071 /
DATA LED2 /.527,.597,.621,.598,.558,.503,.429,.332,.206,.132,.041,
$ -.075,-.218,-.399,-.637,-.760,-.896,-1.057,-1.260,-1.479/
DATA THKRAT2 /.102,.060,.044,.039,.034,.029,.026,.024,.022,.022,
$ .021,.021,.021,.020,.020,.020,.020,.020,.020,
DATA I1,I2,I3,I4/-1,-1,-1,-1/
C
ER = E2/R
C
OFFSET = -.435
CALL PCS (ER1,AA1,I2,ER,AA,AAP,I1,WORK1)
AA = AA + OFFSET
AAP = AAP/R
C
IF (ER.LT.0.30) ER = 0.30
CALL PCS (ER2,CH2,20,ER,CH,CHP,I2,WORK2)
CH = 2.*R*CH
CHP = 2.*CHP
C
CALL PCS (ER2,LED2,20,ER,LED,LEDP,I3,WORK3)
LED = -CH*LED
LEDP = -CHP*LED - CH*LEDP/R
C
CALL PCS (ER2,THKRAT2,20,ER,THKRAT,THKRATP,I4,WORK4)
THKRATP = THKRATP/R
C
CAMRAT = 0.03 - 0.0913*(E2 - 0.093)
CAMRATP = -0.0913
C
RETURN
END

```

APPENDIX C

EXAMPLE 4

```

SUBROUTINE FUNE2Q
$ ( E2, R, Q, CMBR, CMBRP, THK, THKP )
C
C - HIGH SPEED PROPELLER INPUT FUNCTIONS, EXAMPLE 4.
C
ER = E2/R
C
CMBR = 4.*(Q-Q**2)
CMBRP = 4.-8.*Q
C
IF (ER.GT.0.45) GO TO 50
C
C - SERIES 65 AIRFOIL.
C
IF (Q.GT.0.4) GO TO 25
THK = 1.1722*SQRT(Q) + Q*(0.078 + Q*(-12.3902 +
$ Q*(56.9872 - Q*75.6761)))
THKP = 0.5861/SQRT(Q) + 0.078 + Q*(-24.7804 +
$ Q*(170.9616 - Q*302.7044))
GO TO 200
C
25 QM = Q - 0.4
THK = 0.5 + QM*QM*(-2.8333 + QM*2.4074)
THKP = QM*(-5.6666 + QM*7.2222)
GO TO 200
C
C - SERIES 16 AIRFOIL.
C
50 IF (Q.GT.0.5) GO TO 100
THK = 0.989665*SQRT(Q) + Q*(-0.23925 + Q*(-0.041 - Q*0.5594))
THKP = 0.4948325/SQRT(Q) - .23925 + Q*(-0.082 - Q*1.6782)
GO TO 200
C
100 QM = 1. - Q
QMP = -1.
THK = 0.01 + QM*(2.325 + QM*(-3.42 + QM*1.46))
THKP = (2.325 + QM*(-6.84 + QM*4.38))*QMP
C
200 RETURN
C
END

```

APPENDIX C

EXAMPLE 4

```

SUBROUTINE FUNPRES
$ (E2,R,Q,SURFP,DP,SPU,SPL,SIGMAU,SIGMAL)
LOGICAL SURFP
DIMENSION ER2(20), CP2(20), WORK(60)
C
C - HIGH SPEED PROPELLER INPUT FUNCTIONS, EXAMPLE 4.
C - DIFFERENTIAL PRESSURE INPUT.
C
DATA ER2/.30,.40,.50,.55,.60,.65,.70,.75,.80,.825,.85,.875,.90,
$ .925,.95,.96,.97,.98,.99,1.00/
DATA CP2 /.214,.259,.307,.315,.318,.319,.320,.327,.339,.340,
$ .336,.329,.320,.312,.297,.285,.278,.258,.248,0./
DATA INTRVL/-1/
C
ER = E2/R
IF (ER.LT.0.30) ER = 0.30
SURFP = .FALSE.
C
C - DEFINE POWER FACTOR (FACTOR), ROTATIONAL SPEED (OMEGA),
C FORWARD SPEED (V3), DENSITY (RHO).
C
FACTOR = 0.7861
PI = 3.14159
OMEGA = 7878.4/30.*PI
V3 = 241.2
RHO = .4570
CALL PCS (ER2,CP2,20,ER,CP,CP,INTRVL,WORK)
CP = FACTOR*CP
C
C - DEFINE LOCAL VELOCITY, SQUARED (VINFS), AND
C DIFFERENTIAL PRESSURE (DP).
C
VINFS = (E2*OMEGA)**2. + V3*V3
DP = 3.*RHO*VINFS*CP*(Q-Q*Q)
C
SPU = 0.
SPL = 0.
SIGMAU = 0.
SIGMAL = 0.
C
RETURN
END

```

APPENDIX C

DATA SHEET

EXAMPLE 4

C = 301.5 M/SEC
 RHO = .4570 KG/M**3

 XO = (.81, 0.00, -.81) M OBSERVER IS IN MOTION

 V3 = 241.2 M/SEC
 = 539.5 MPH

 R = .312 M
 RINNER = .093 M

 REV = 7878.4 RPM
 NBLADES = 4

 NPCA = 20
 NLE = 5
 NTE = 10

 THKMAXL = .05

 NPTS = 150
 NSPEC = 30

 EPSILON = .50 %

 TORQUE = 20.36 N-M/BLADE
 THRUST = 46.82 N/BLADE
 POWER = 16.79 KW/BLADE
 = 22.51 HP/BLADE

 OASPL = 124.48 DB RE 20.E-6 PA
 = 104.57 DB RE 20.E-6 PA (THICKNESS)
 = 125.17 DB RE 20.E-6 PA (LOADING)
 = -156.07 DB RE 20.E-6 PA (DRAG)

HELICAL M-TIP = 1.170

 PER = 1.9039E-03 SEC
 BPF = 525.2 HZ

 NPCAF = 1
 NCHF = 1

 NTAU = 10

 DT = 1.2693E-05 SEC
 FRACDT = 1.000
 MTRANS = .950
 TRANS = .980
 INDEXSL = 0

PRESSURE SIGNATURES OF NOISE COMPONENTS

EXAMPLE 4

POINT NUMBER	OBSERVER TIME (MSEC)	THICKNESS NOISE (PA)	LOADING NOISE			DRAG NOISE			OVERALL NOISE (PA)	POINT NUMBER
			FAR FIELD (PA)	NEAR FIELD (PA)	COMBINED (PA)	FAR FIELD (PA)	NEAR FIELD (PA)	COMBINED (PA)		
1	0.00	4.1082	-4.4962	1.1994	-3.2967	0.0000	0.0000	0.0000	.8115	1
2	.01	4.0377	-3.2728	1.0313	-2.2415	0.0000	0.0000	0.0000	1.7963	2
3	.03	3.9685	-2.0617	.8685	-1.1932	0.0000	0.0000	0.0000	2.7754	3
4	.04	3.9013	-.8638	.7111	-.1527	0.0000	0.0000	0.0000	3.7486	4
5	.05	3.8345	.3234	.5590	.8825	0.0000	0.0000	0.0000	4.7170	5
6	.06	3.7695	1.4988	.4125	1.9112	0.0000	0.0000	0.0000	5.6807	6
7	.08	3.7054	2.6664	.2713	2.9377	0.0000	0.0000	0.0000	6.6431	7
8	.09	3.6422	3.8225	.1356	3.9581	0.0000	0.0000	0.0000	7.6003	8
9	.10	3.5804	4.9686	.0055	4.9740	0.0000	0.0000	0.0000	8.5544	9
10	.11	3.5191	6.1049	-.1191	5.9858	0.0000	0.0000	0.0000	9.5048	10
11	.13	3.4590	7.2328	-.2382	6.9947	0.0000	0.0000	0.0000	10.4537	11
12	.14	3.3996	8.3510	-.3517	7.9994	0.0000	0.0000	0.0000	11.3990	12
13	.15	3.3410	9.4610	-.4595	9.0015	0.0000	0.0000	0.0000	12.3425	13
14	.17	3.2832	10.5636	-.5618	10.0018	0.0000	0.0000	0.0000	13.2850	14
15	.18	3.2259	11.6572	-.6583	10.9988	0.0000	0.0000	0.0000	14.2247	15
16	.19	3.1693	12.7447	-.7493	11.9954	0.0000	0.0000	0.0000	15.1648	16
17	.20	3.1132	13.8240	-.8345	12.9895	0.0000	0.0000	0.0000	16.1027	17
18	.22	3.0581	14.8964	-.9139	13.9824	0.0000	0.0000	0.0000	17.0405	18
19	.23	3.0028	15.9630	-.9877	14.9753	0.0000	0.0000	0.0000	17.9780	19
20	.24	2.9484	17.0218	-1.0557	15.9662	0.0000	0.0000	0.0000	18.9146	20
140	1.76	5.0039	-18.8979	3.3900	-15.5079	0.0000	0.0000	0.0000	-10.5040	140
141	1.78	4.9111	-17.5075	3.1659	-14.3415	0.0000	0.0000	0.0000	-9.4304	141
142	1.79	4.8208	-16.1370	2.9467	-13.1903	0.0000	0.0000	0.0000	-8.3696	142
143	1.80	4.7332	-14.7802	2.7323	-12.0480	0.0000	0.0000	0.0000	-7.3148	143
144	1.82	4.6490	-13.4435	2.5228	-10.9206	0.0000	0.0000	0.0000	-6.2716	144
145	1.83	4.5658	-12.1196	2.3184	-9.8012	0.0000	0.0000	0.0000	-5.2355	145
146	1.84	4.4851	-10.8140	2.1190	-8.6951	0.0000	0.0000	0.0000	-4.2100	146
147	1.85	4.4060	-9.5209	1.9247	-7.5962	0.0000	0.0000	0.0000	-3.1902	147
148	1.87	4.3289	-8.2447	1.7356	-6.5092	0.0000	0.0000	0.0000	-2.1803	148
149	1.88	4.2535	-6.9806	1.5516	-5.4290	0.0000	0.0000	0.0000	-1.1755	149
150	1.89	4.1800	-5.7325	1.3729	-4.3596	0.0000	0.0000	0.0000	-.1796	150
151	1.90	4.1082	-4.4962	1.1994	-3.2967	0.0000	0.0000	0.0000	.8115	151
6C	1.97	3.7695	1.5012	.4124	1.9136	0.0000	0.0000	0.0000	5.6832	6C

APPENDIX C

EXAMPLE 4

APPENDIX C

PRESSURE SPECTRA OF NOISE COMPONENTS

EXAMPLE 4

---- HARMONIC -----		THICKNESS	LOADING	DRAG	OVERALL
NUMBER	FREQUENCY	NOISE	NOISE	NOISE	NOISE
	(HZ)	(DB)	(DB)	(DB)	(DB)
1	525.23	102.13	124.28	-156.07	123.64
2	1050.45	98.55	116.73	-156.07	115.83
3	1575.68	94.74	110.19	-156.07	109.05
4	2100.91	90.98	104.29	-156.07	102.92
5	2626.13	87.24	98.79	-156.07	97.20
6	3151.36	83.48	93.55	-156.07	91.76
7	3676.59	79.70	88.48	-156.07	86.50
8	4201.81	75.87	83.52	-156.07	81.38
9	4727.04	71.99	78.64	-156.07	76.36
10	5252.27	68.06	73.80	-156.07	71.42
11	5777.49	64.09	69.00	-156.07	66.57
12	6302.72	60.06	64.24	-156.07	61.81
13	6827.95	55.98	59.47	-156.07	57.07
14	7353.17	51.86	54.78	-156.07	52.52
15	7878.40	47.81	50.12	-156.07	47.85
16	8403.63	43.69	45.40	-156.07	43.40
17	8928.85	39.55	40.88	-156.07	39.10
18	9454.08	35.50	36.22	-156.07	34.24
19	9979.31	31.41	30.40	-156.07	30.42
20	10504.53	27.25	26.33	-156.07	26.35
21	11029.76	23.30	20.95	-156.07	22.35
22	11554.99	20.82	15.54	-156.07	19.98
23	12080.21	16.24	18.56	-156.07	20.62
24	12605.44	13.46	14.94	-156.07	8.78
25	13130.67	9.04	3.50	-156.07	11.89
26	13655.89	10.99	-.02	-156.07	9.47
27	14181.12	8.08	8.62	-156.07	13.23
28	14706.35	8.96	-2.83	-156.07	9.55
29	15231.57	4.35	14.08	-156.07	11.84
30	15756.80	9.71	16.95	-156.07	12.33

APPENDIX D

EXAMPLES OF LANGLEY GRAPHICS OUTPUT

The following graphs were selected from the graphics output generated by program NPROPFN for the four examples given in appendix C. Each graph is clearly labeled with an example number at the top right corner. The graphs which have been included for each example are:

Overall Pressure

Overall Spectrum

Thickness Noise

Thickness Spectrum

Loading Noise Components

Loading Noise

Loading Spectrum

For example 2, three additional graphs have been included:

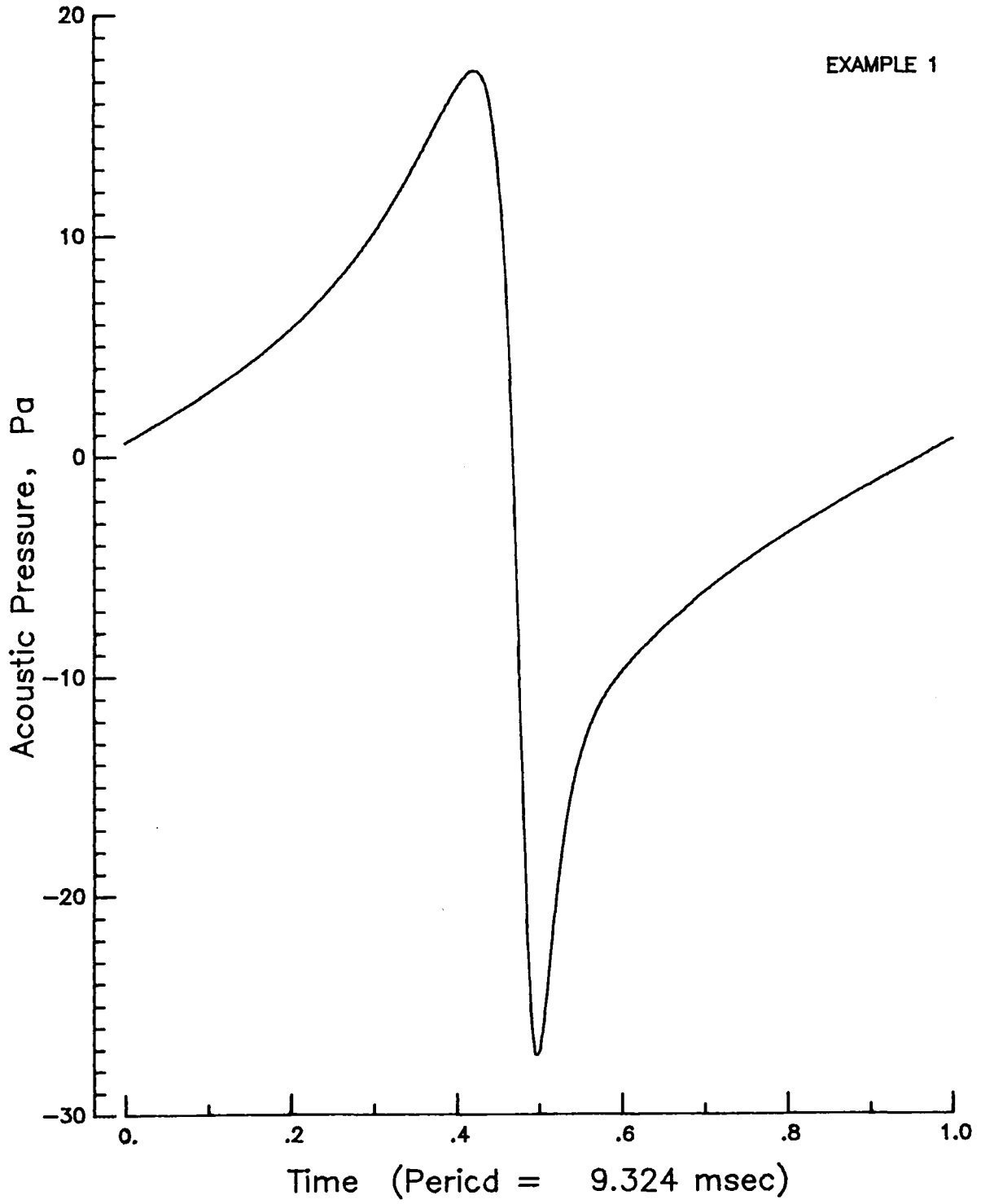
Drag Noise Components

Drag Noise

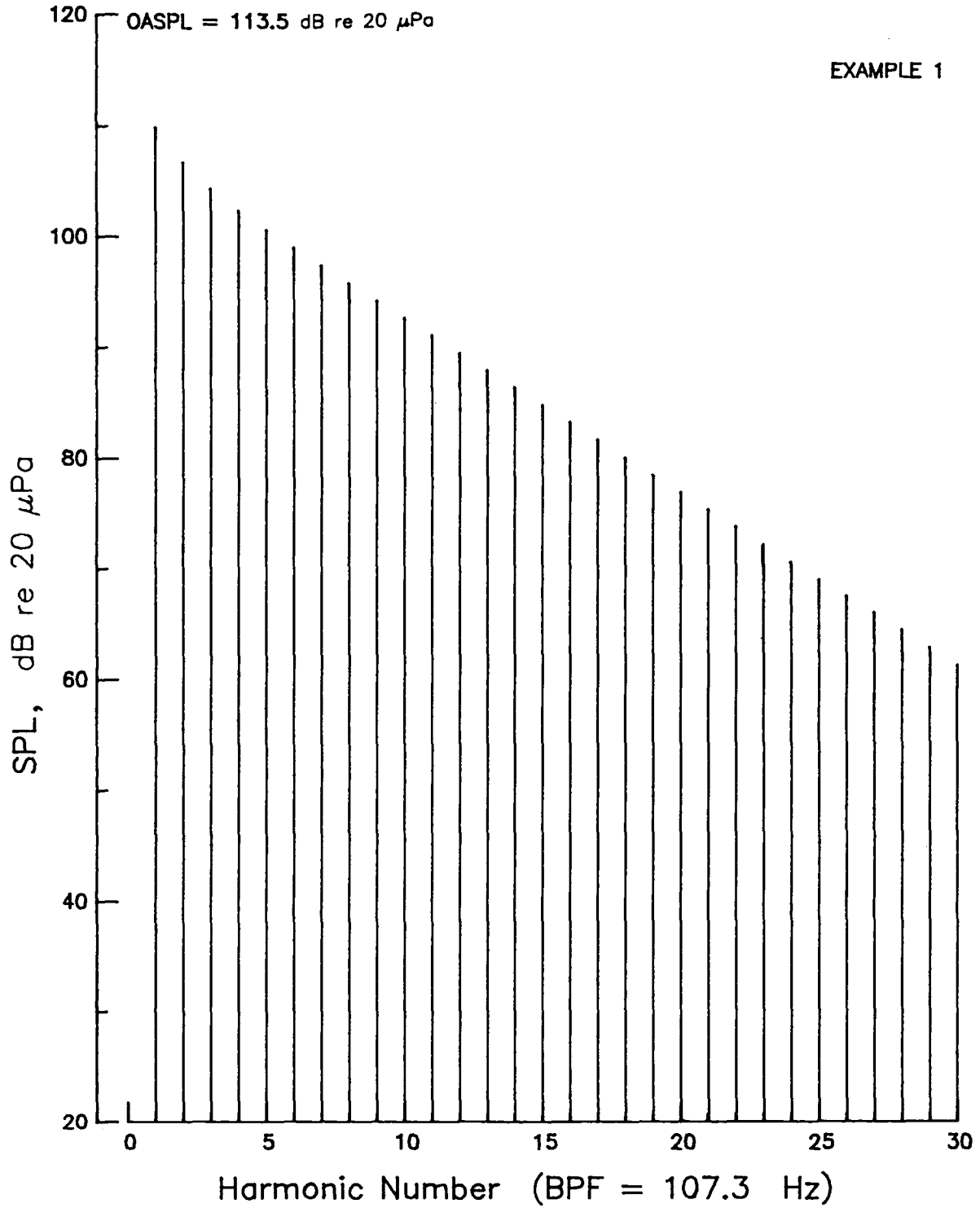
Drag Spectrum

The Langley version of this program also has the capability to plot the η_1 and η_3 blade coordinates, angle of attack, chord, and thickness ratio functions as each varies with the blade radius η_2 .

EXAMPLE 1

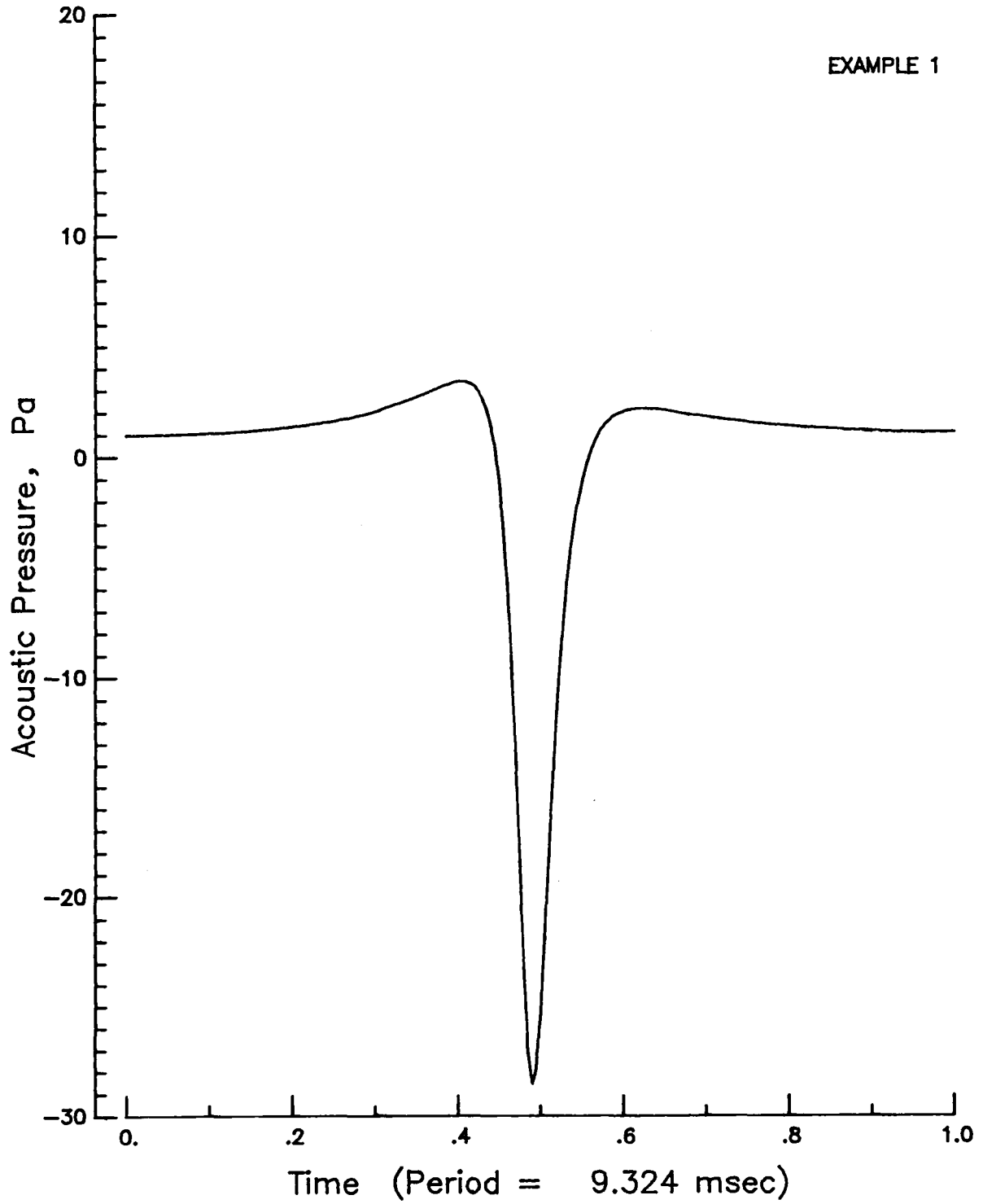


OVERALL PRESSURE

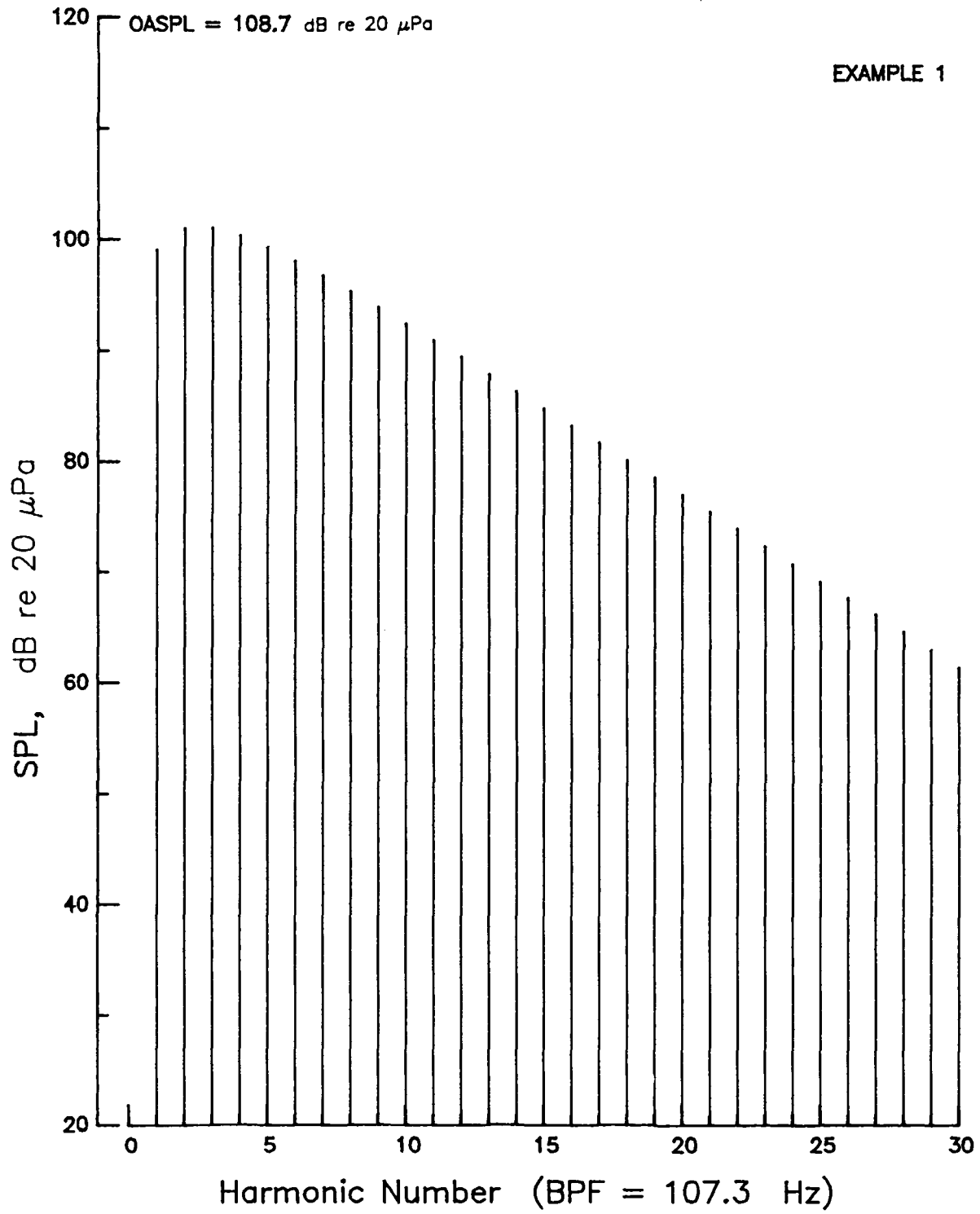


OVERALL SPECTRUM

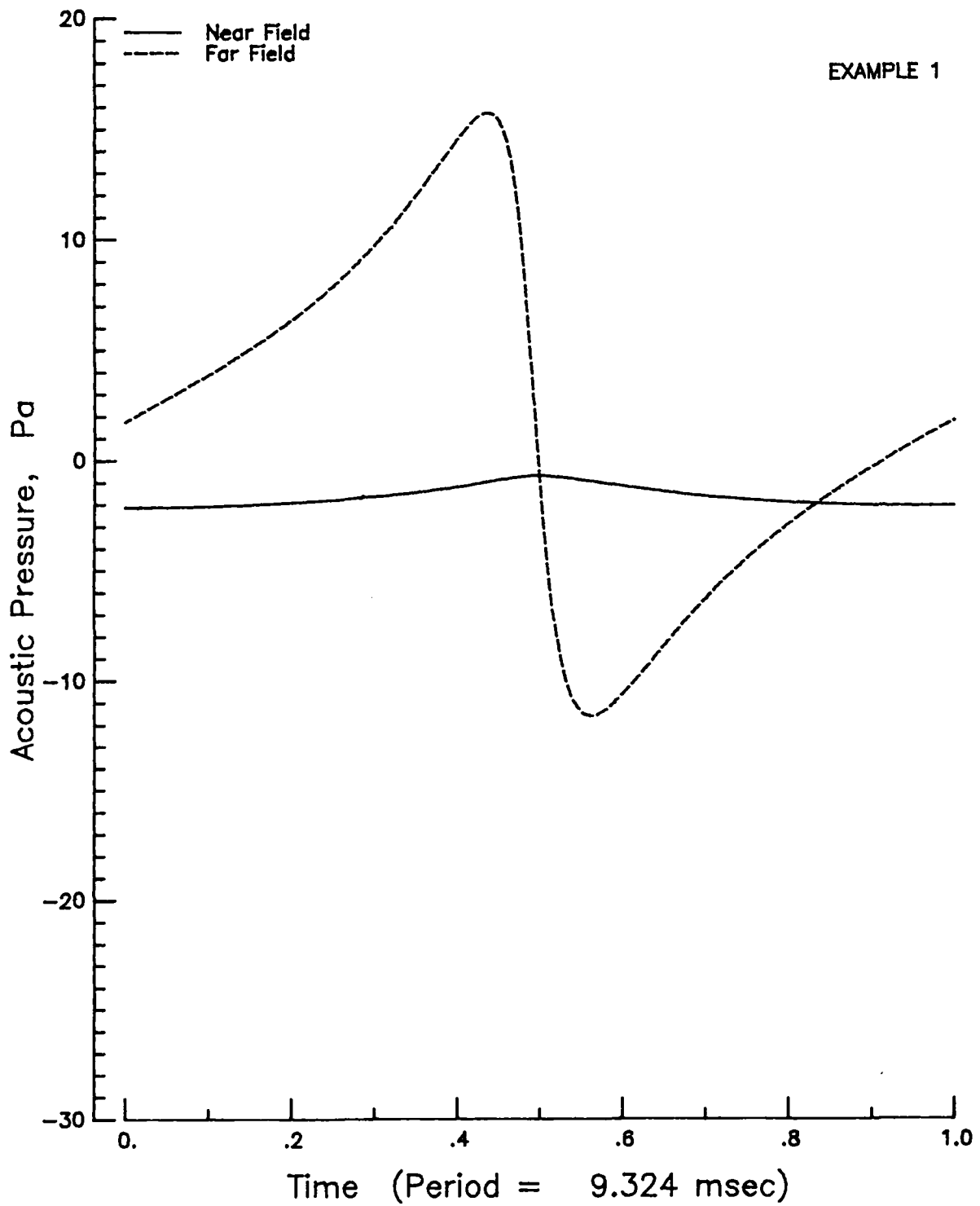
EXAMPLE 1



THICKNESS NOISE

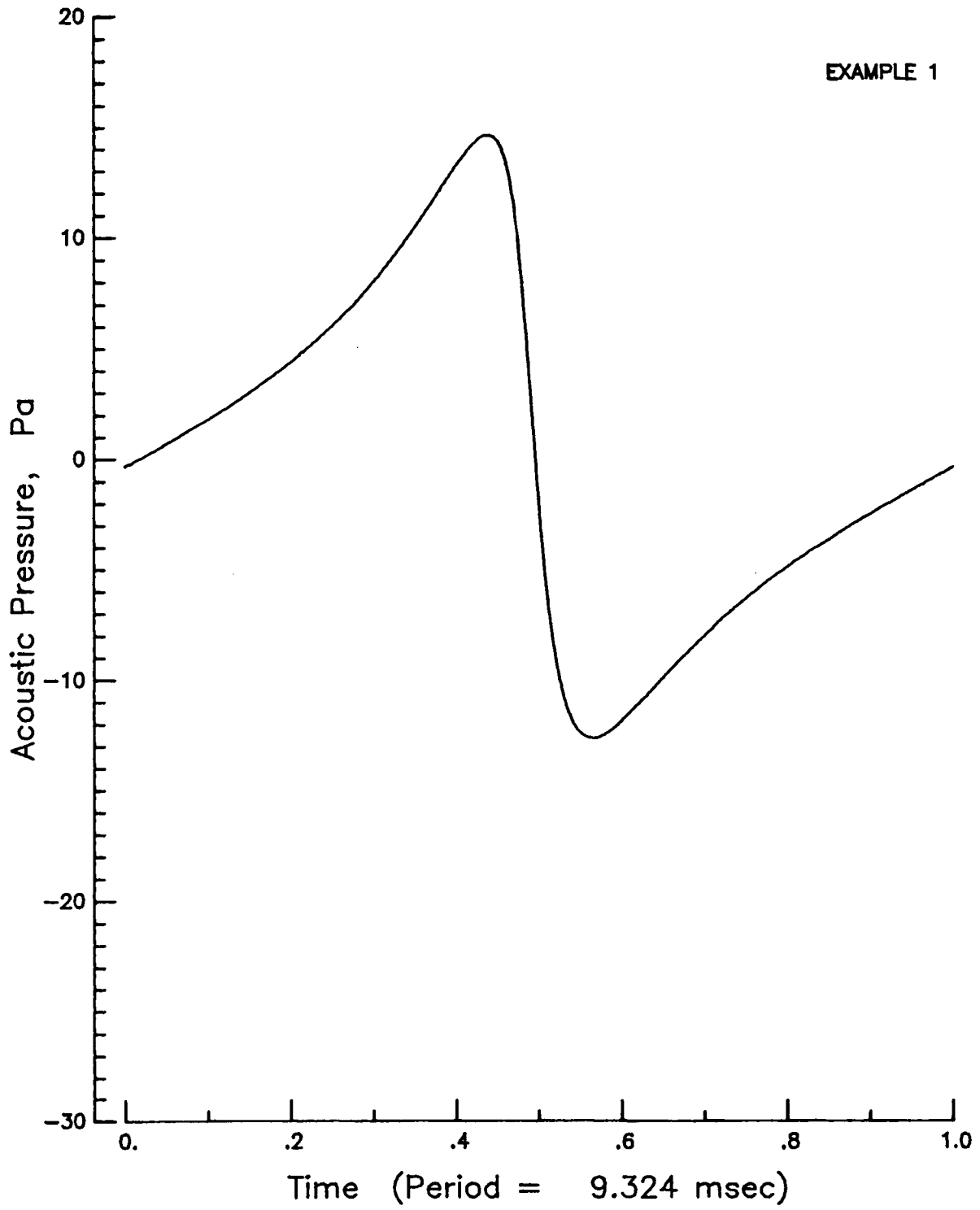


THICKNESS SPECTRUM

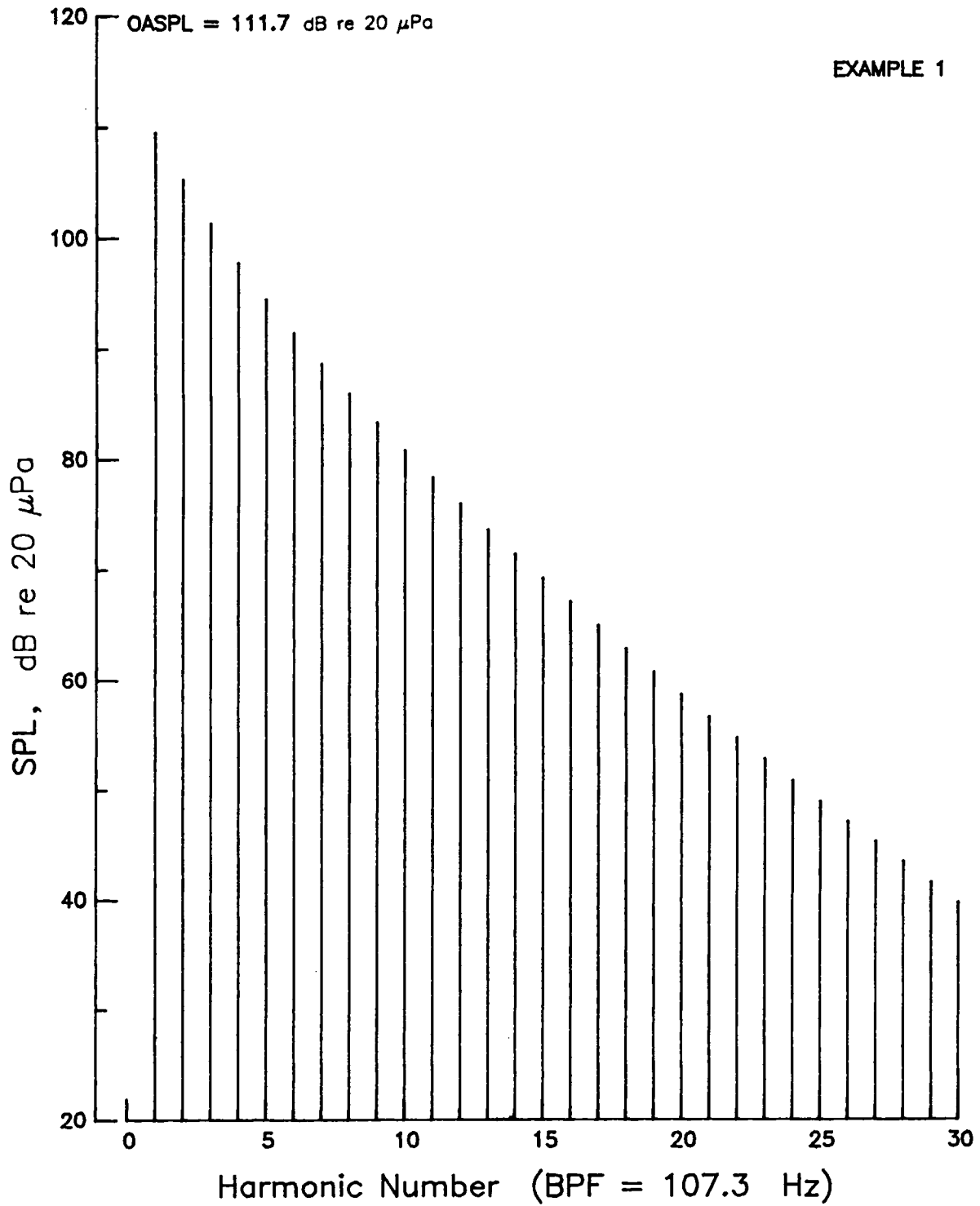


LOADING NOISE COMPONENTS

EXAMPLE 1

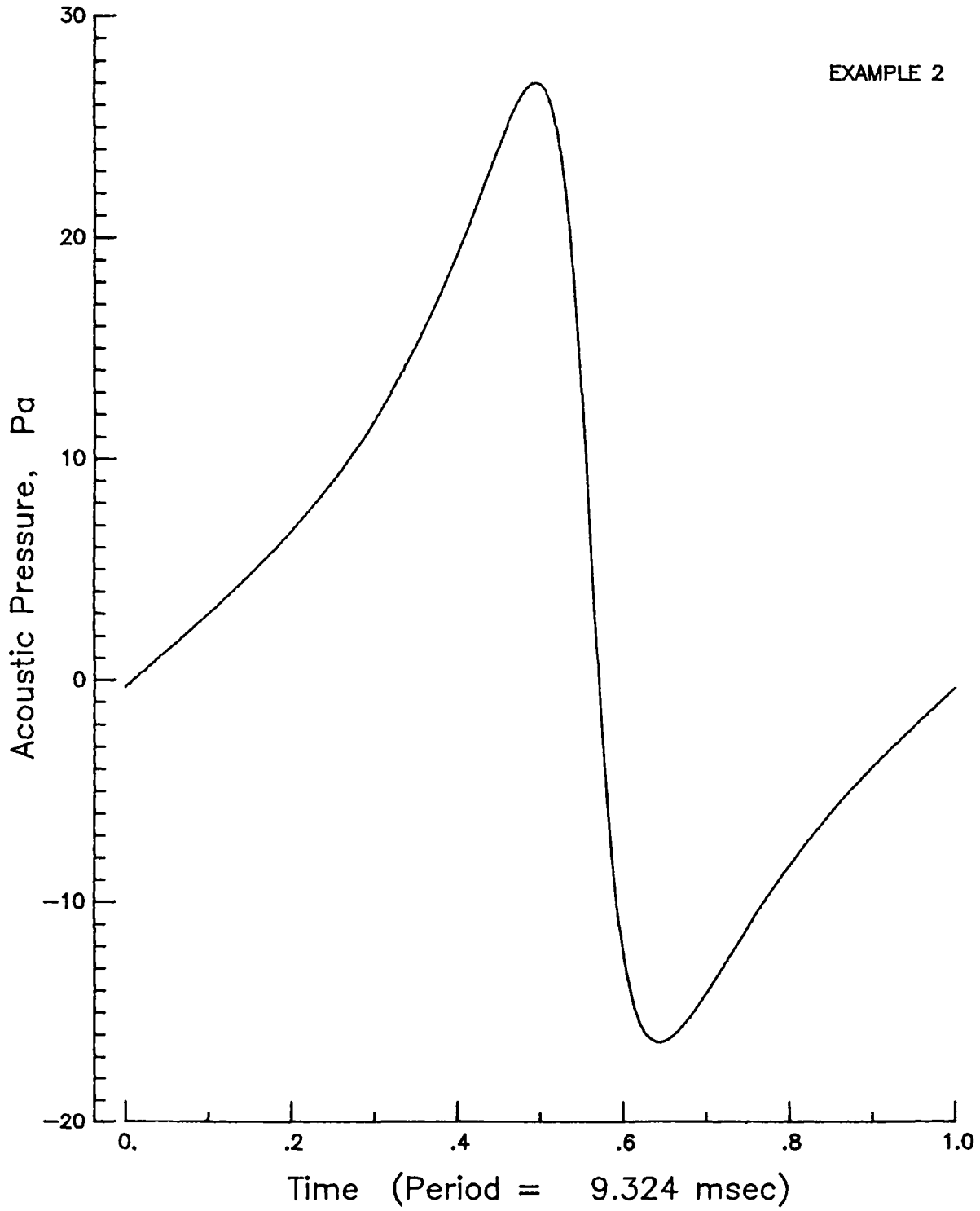


LOADING NOISE

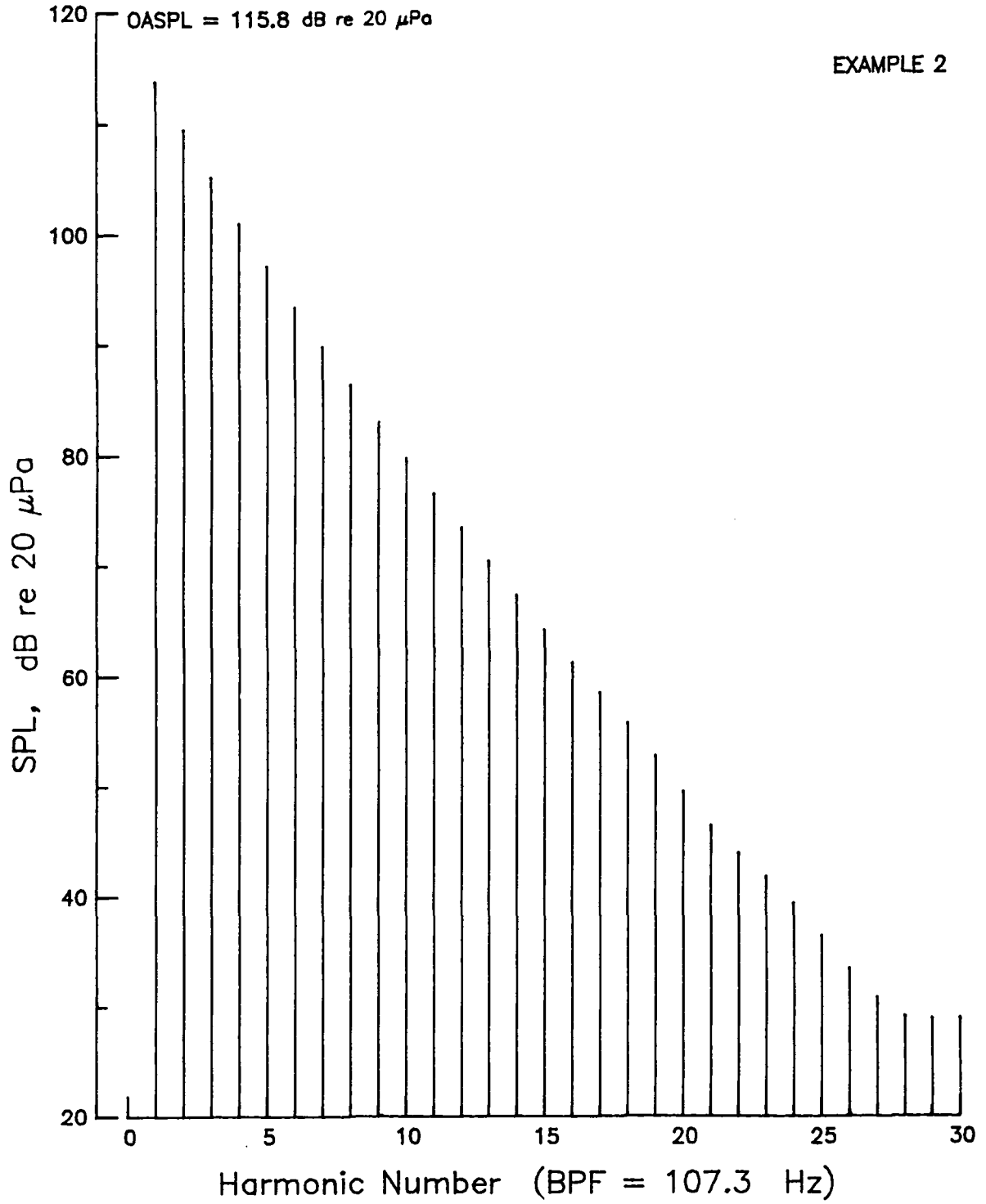


LOADING SPECTRUM

EXAMPLE 2

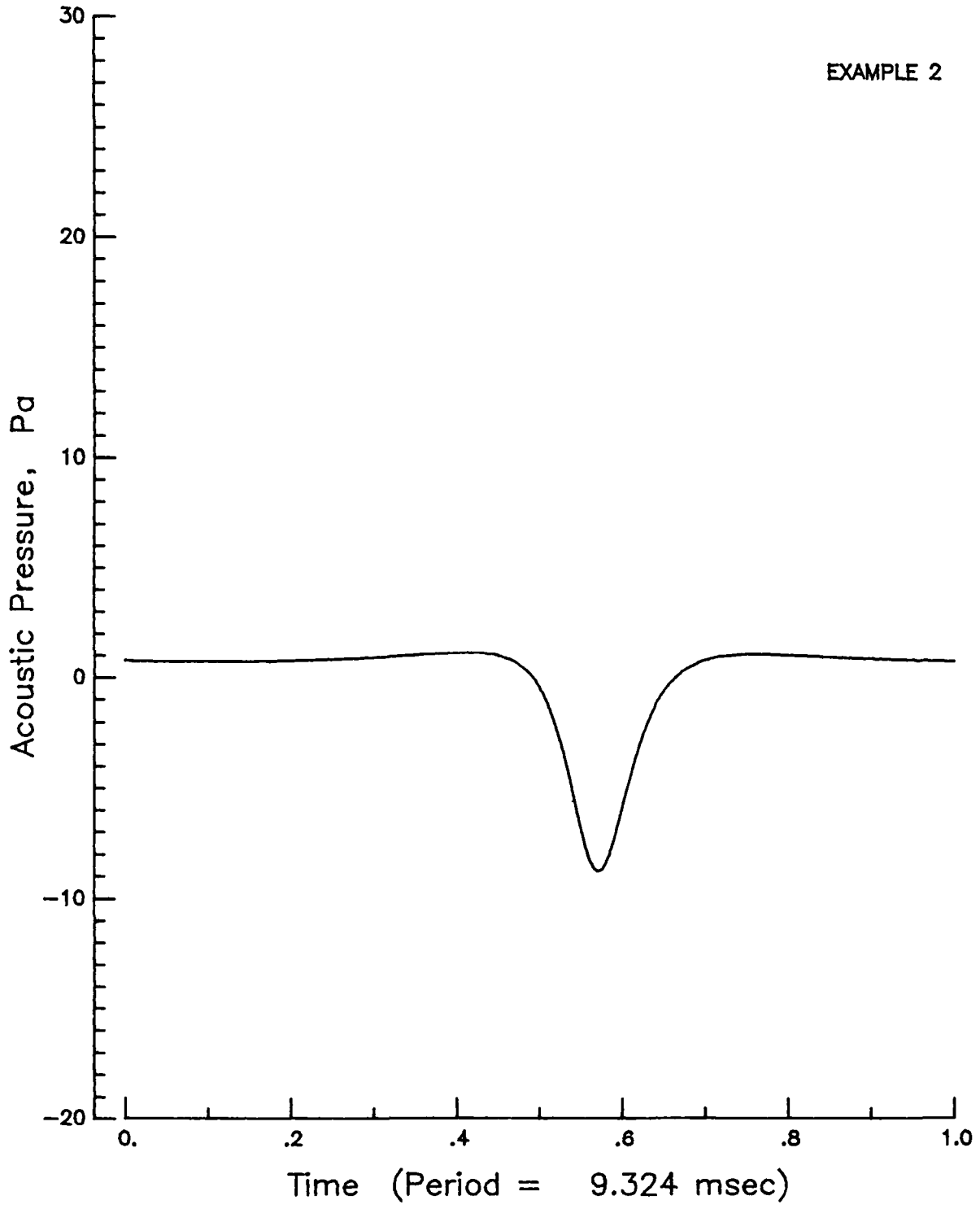


OVERALL PRESSURE

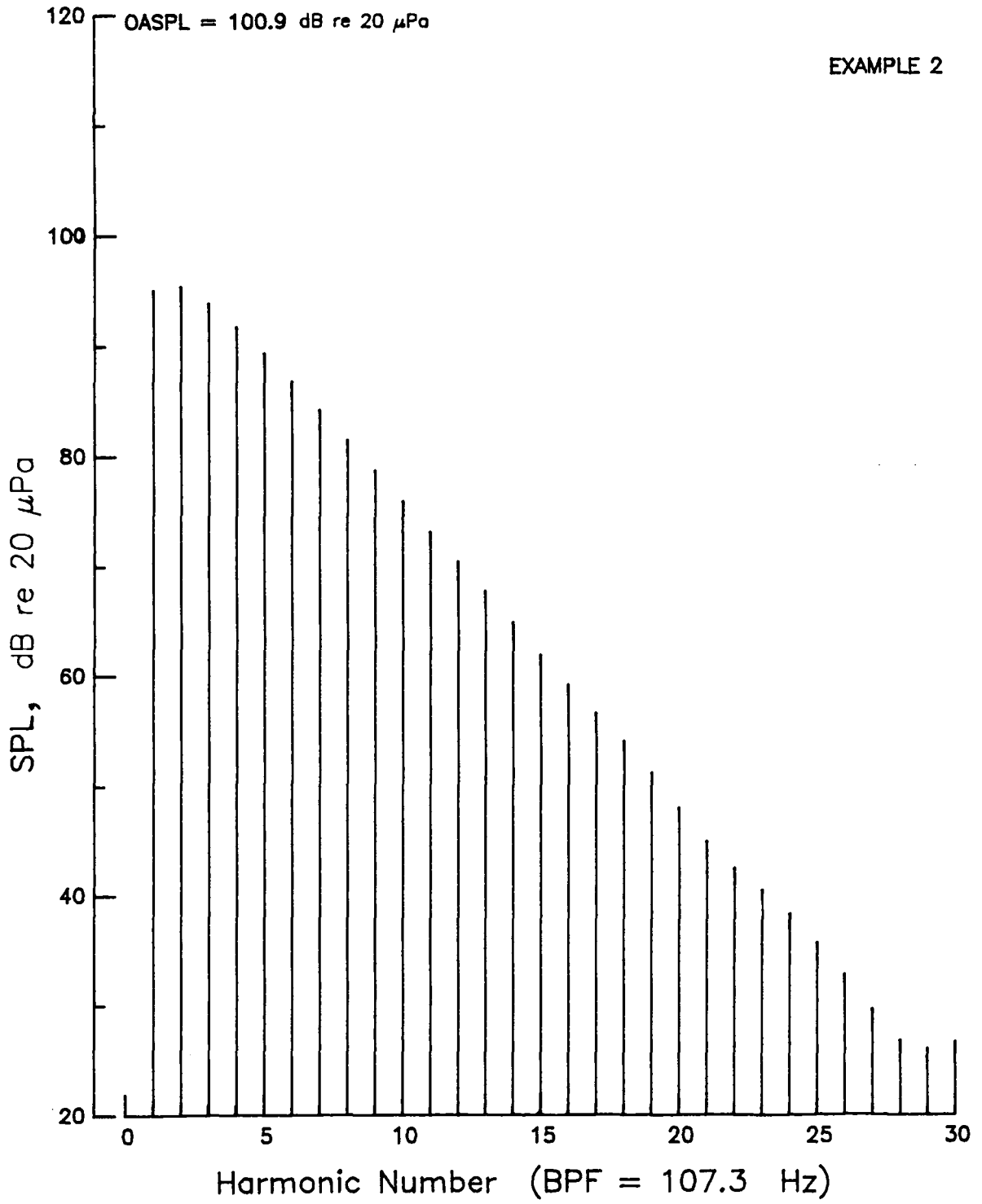


OVERALL SPECTRUM

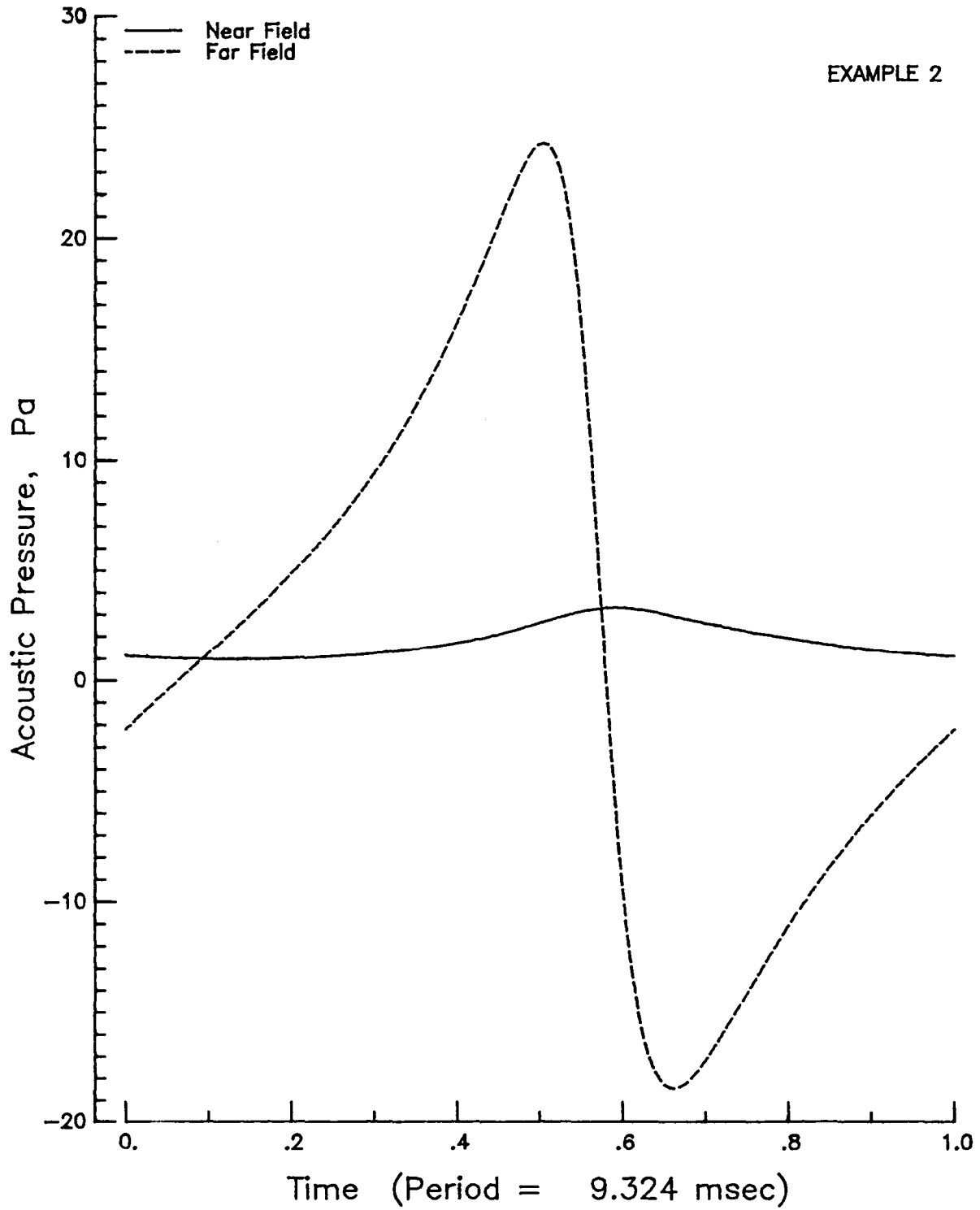
EXAMPLE 2



THICKNESS NOISE

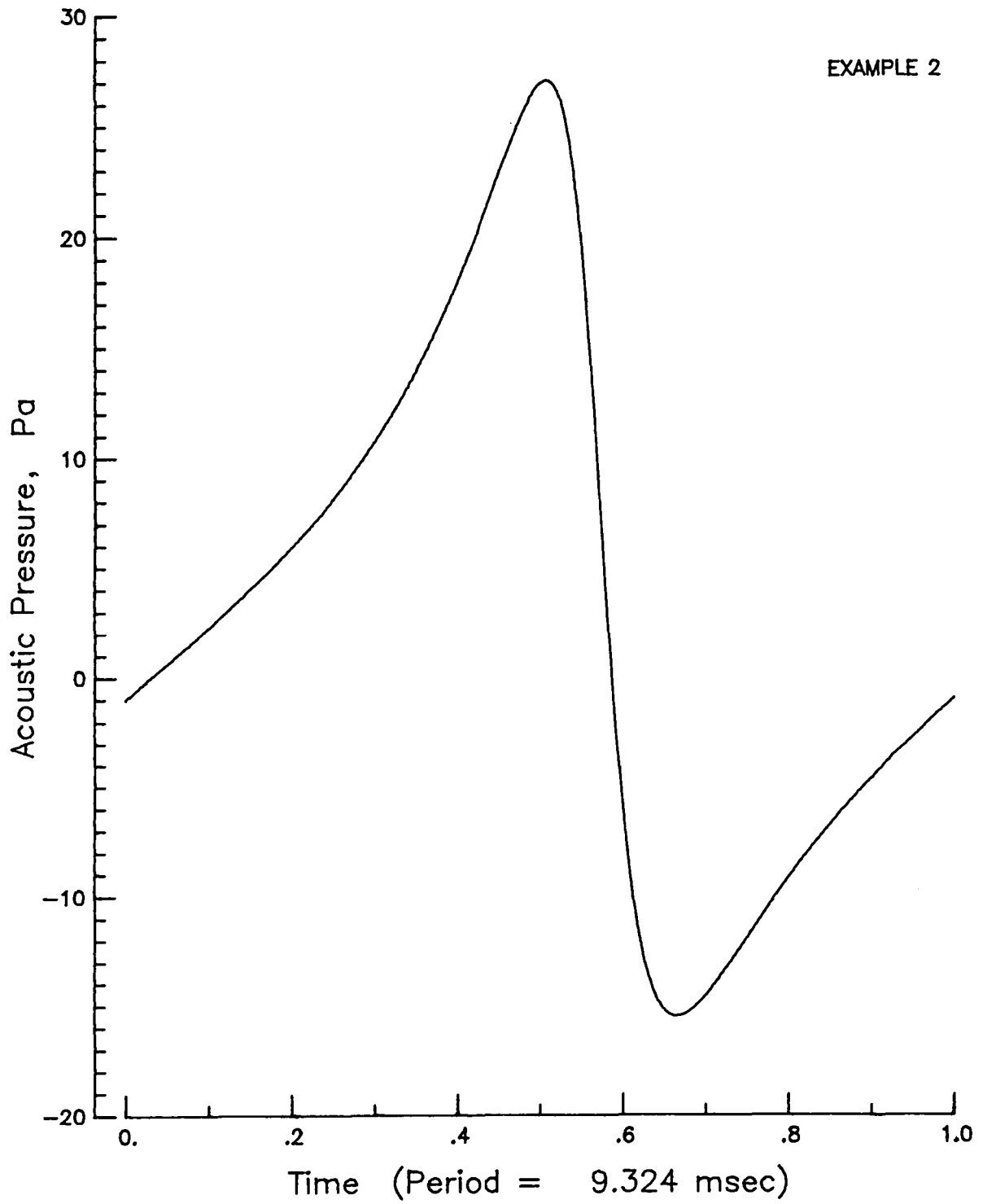


THICKNESS SPECTRUM

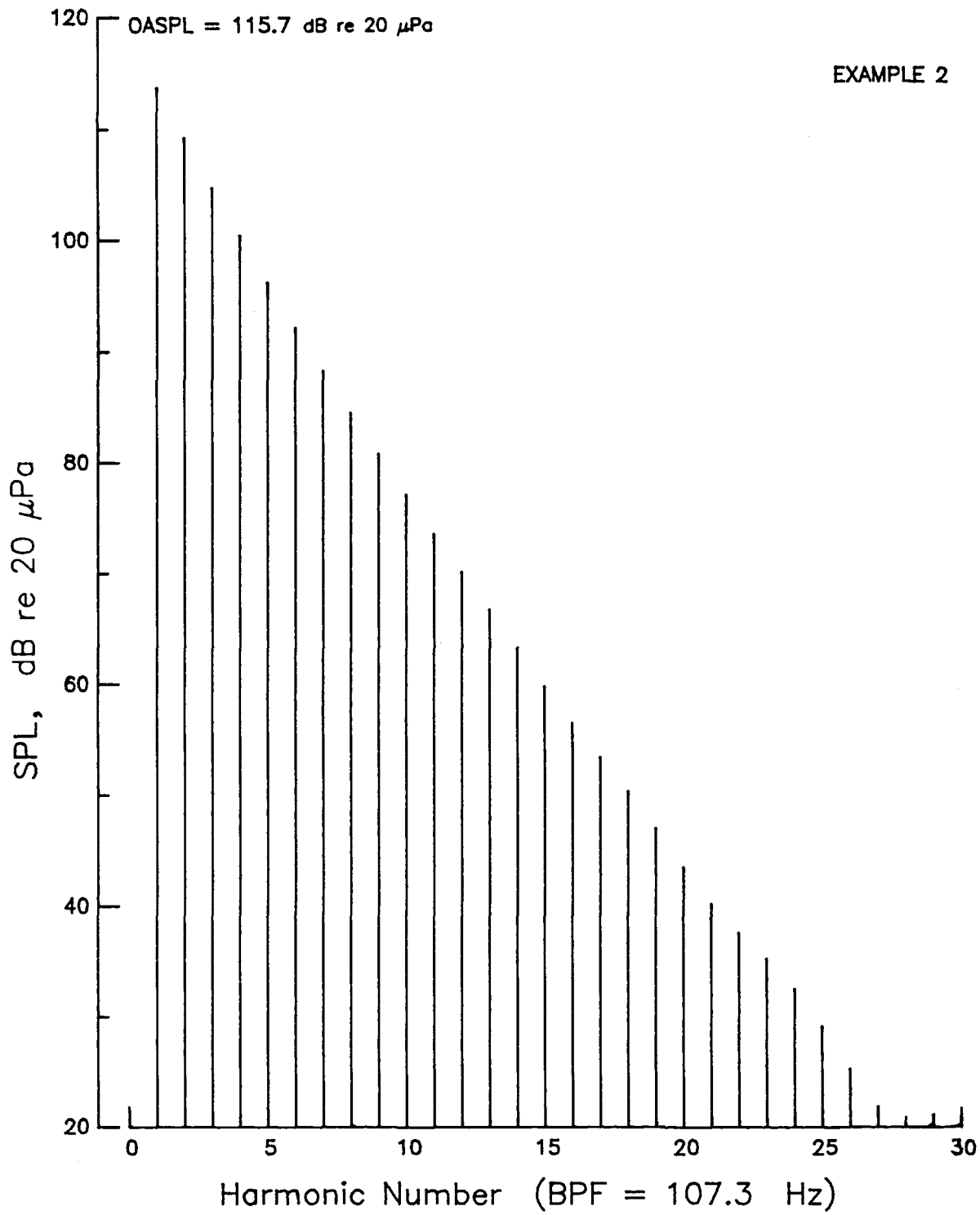


LOADING NOISE COMPONENTS

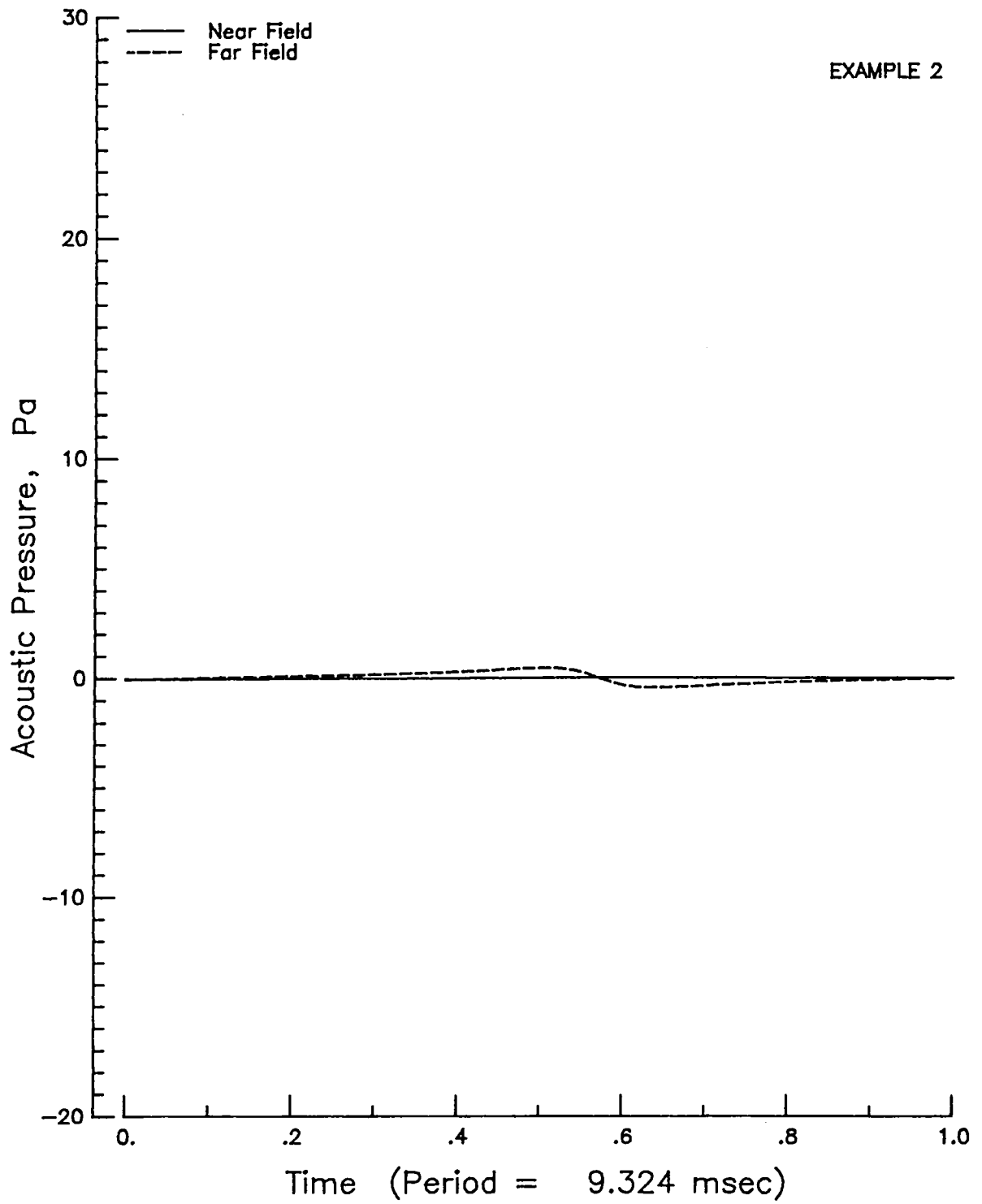
EXAMPLE 2



LOADING NOISE

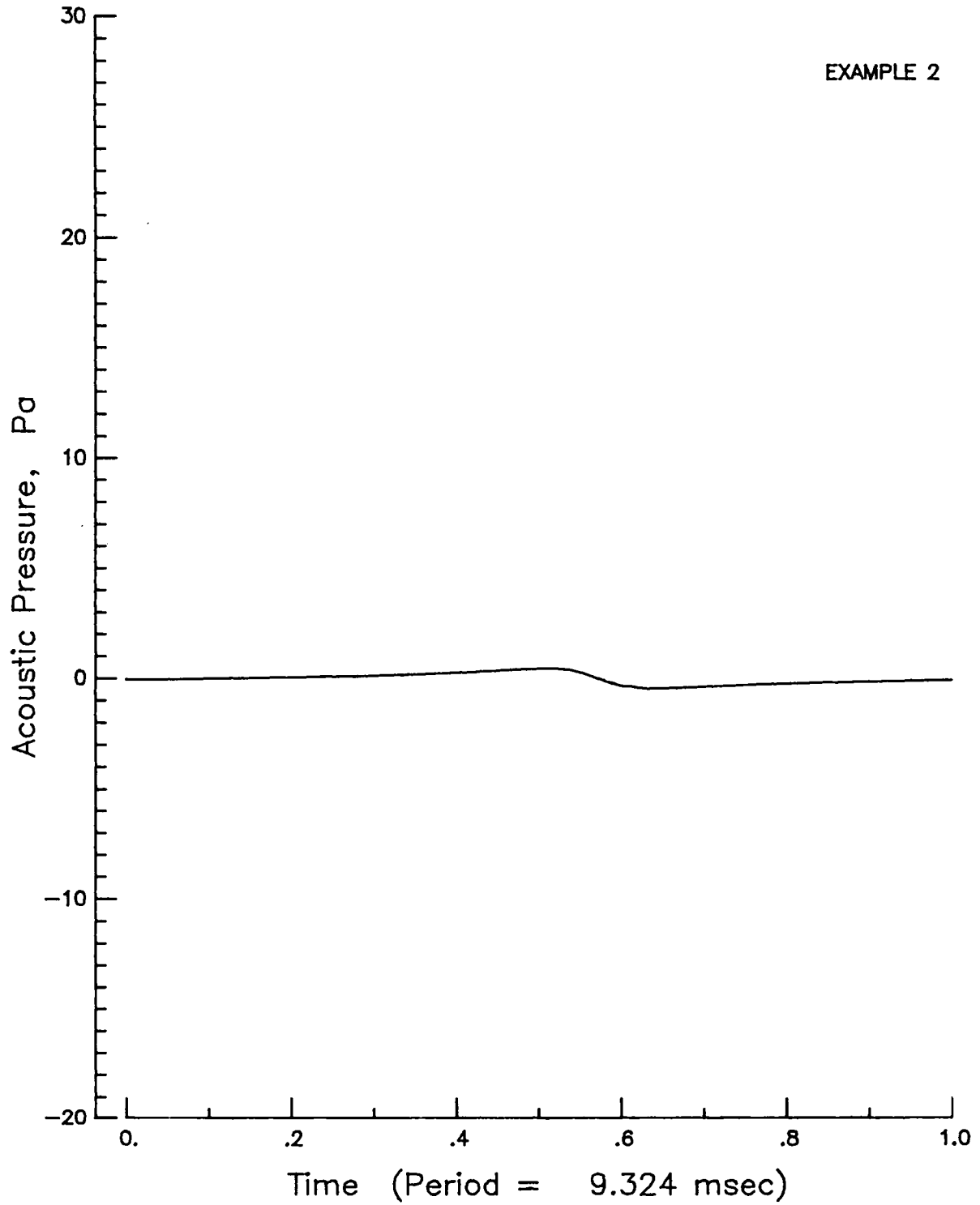


LOADING SPECTRUM



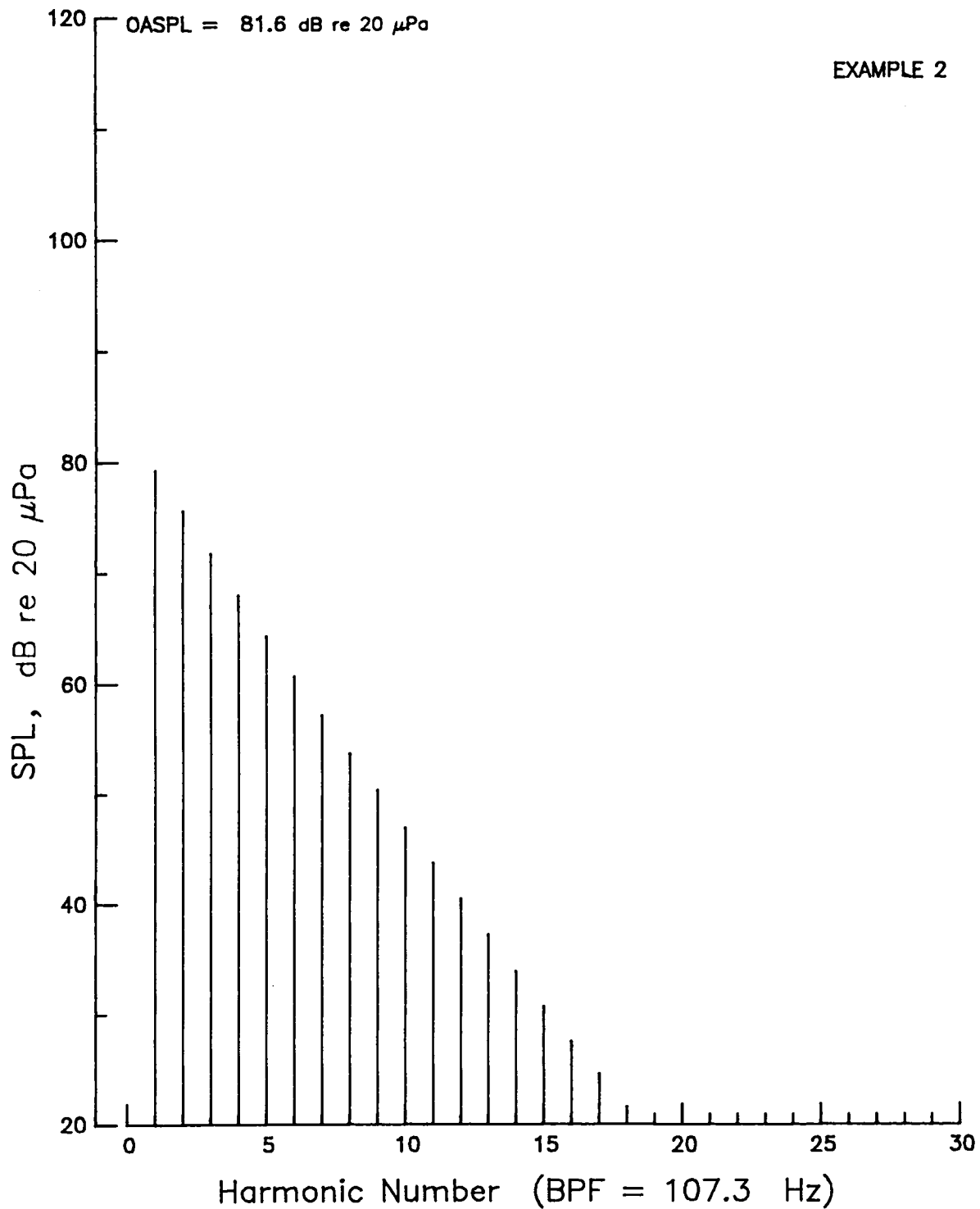
DRAG NOISE COMPONENTS

EXAMPLE 2



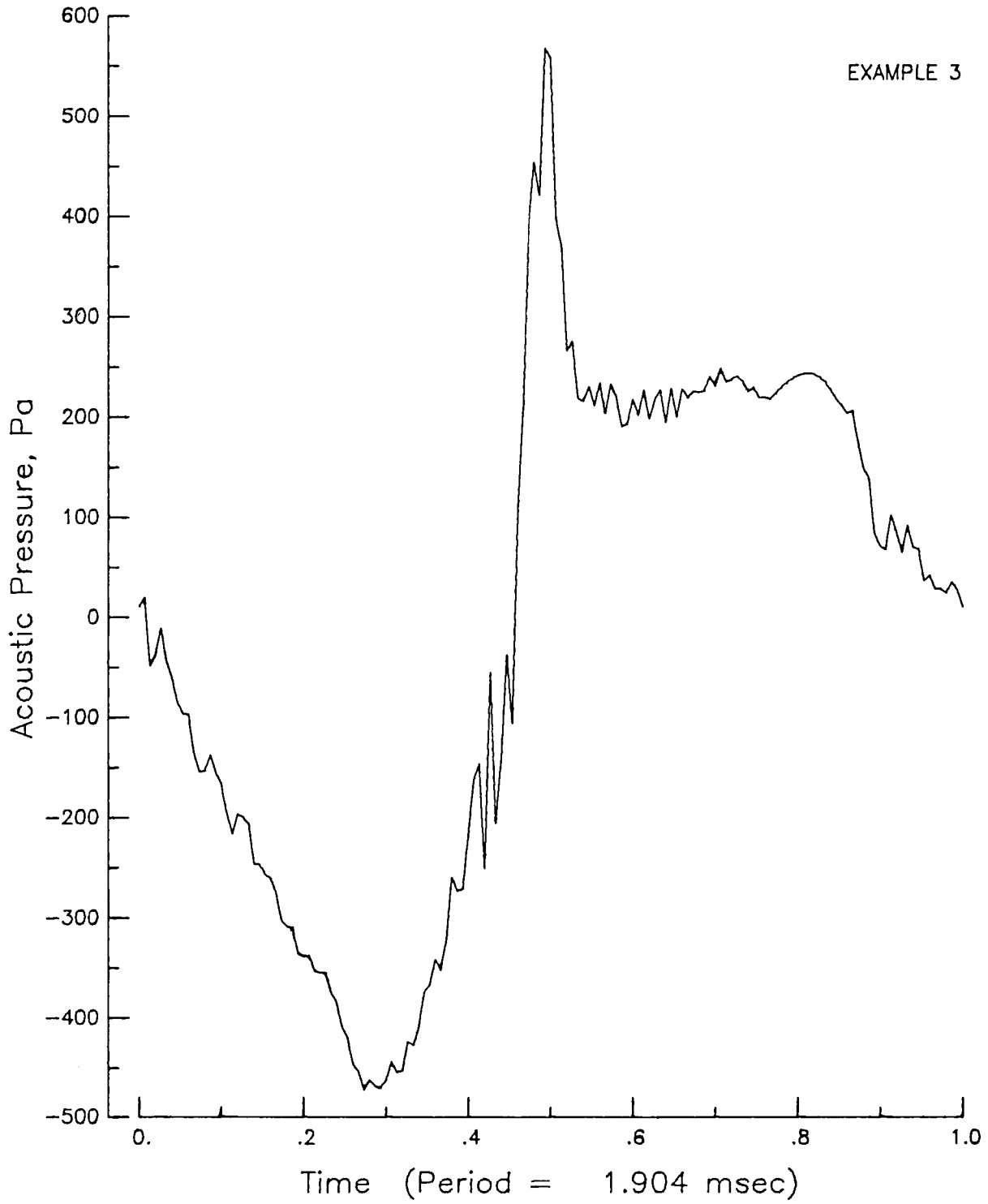
DRAG NOISE

EXAMPLE 2



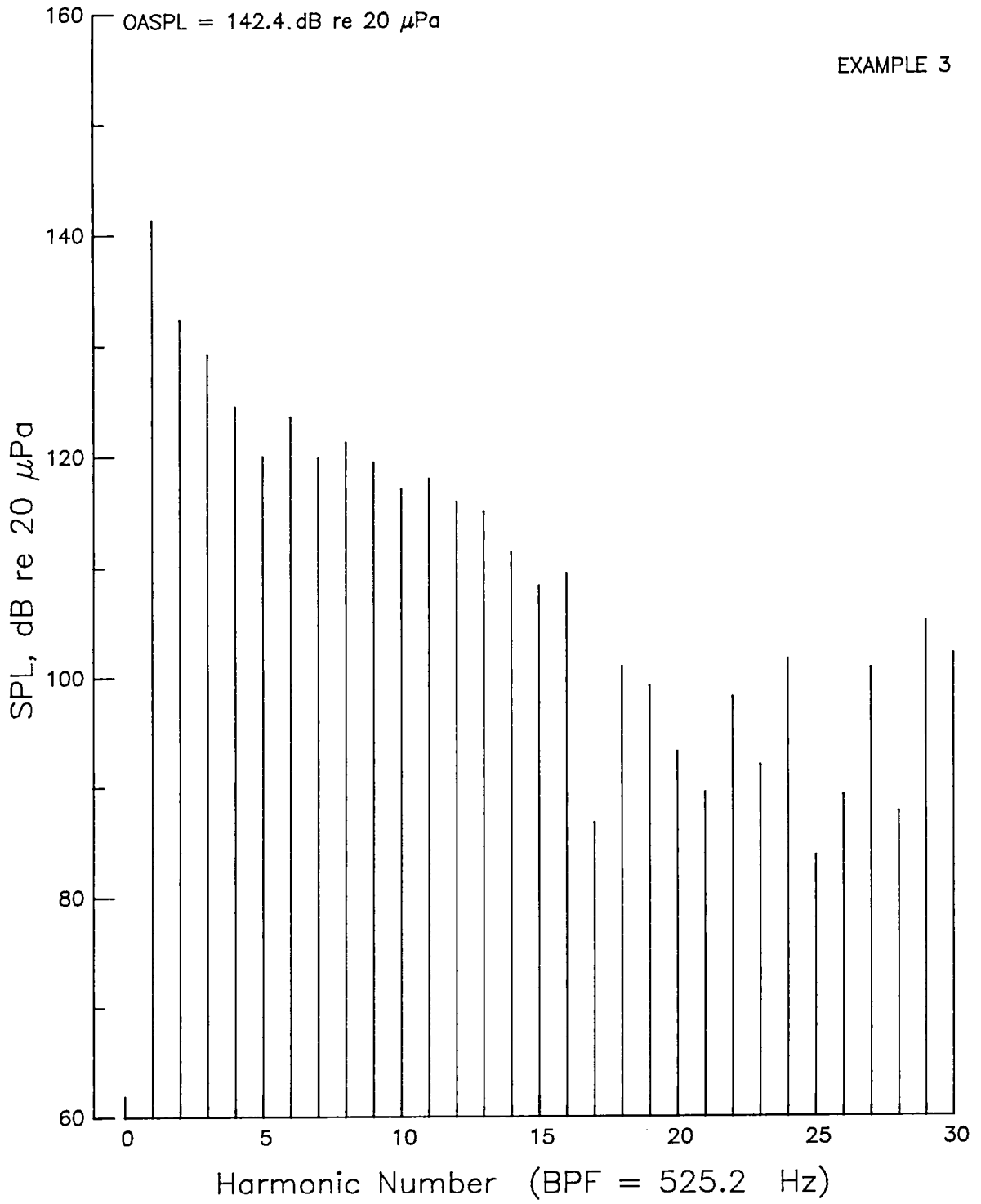
DRAG SPECTRUM

EXAMPLE 3

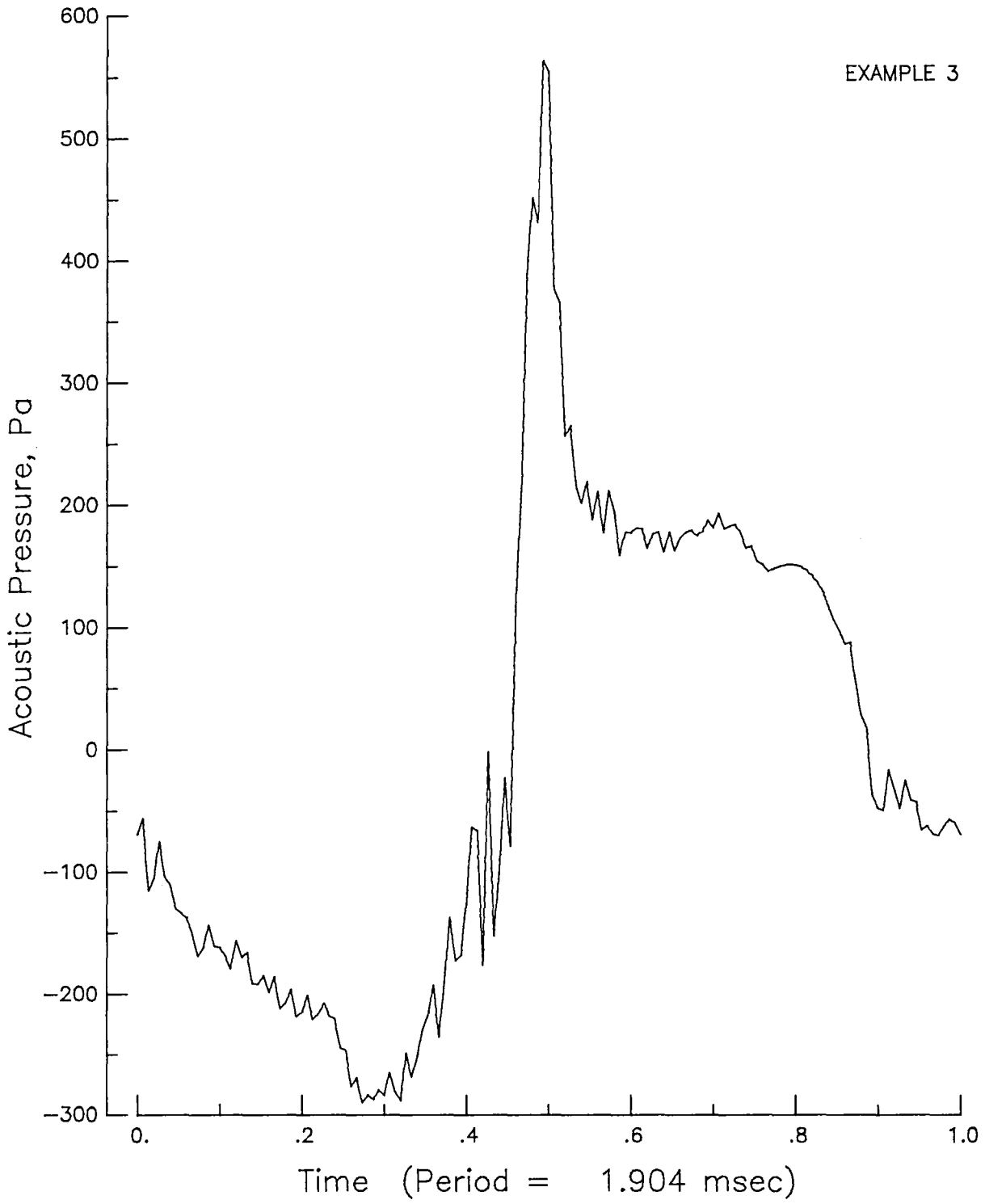


OVERALL PRESSURE

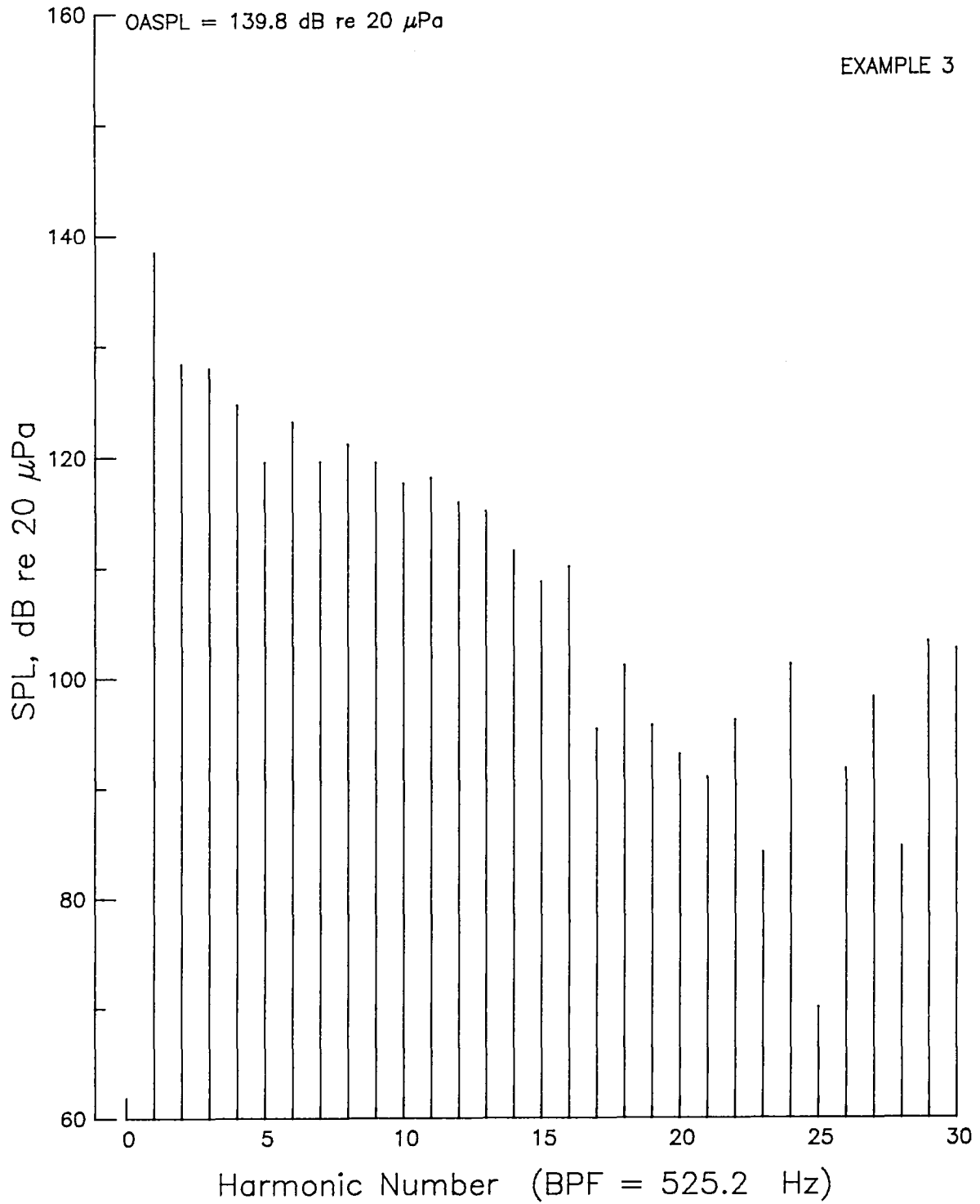
EXAMPLE 3



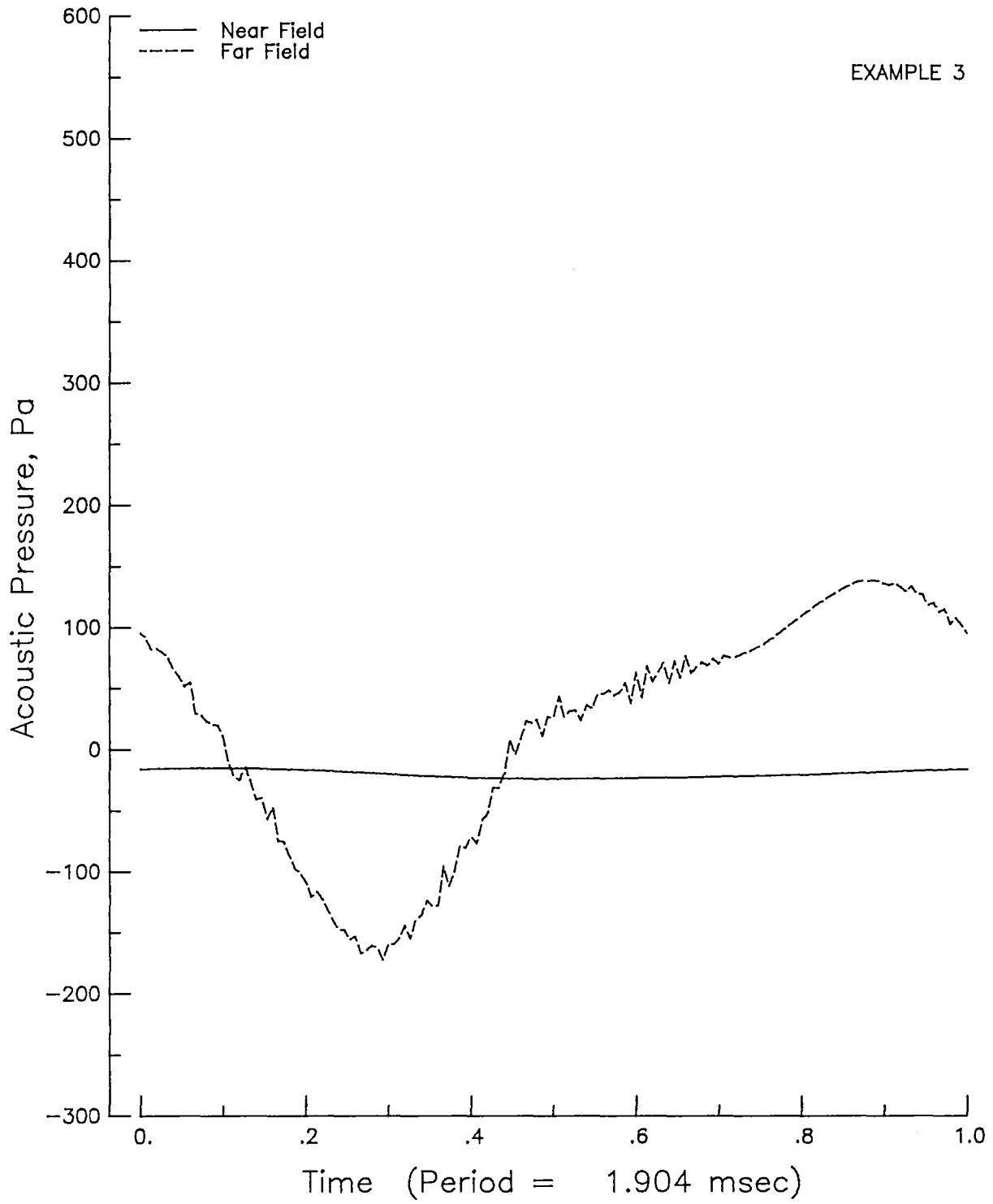
OVERALL SPECTRUM



THICKNESS NOISE

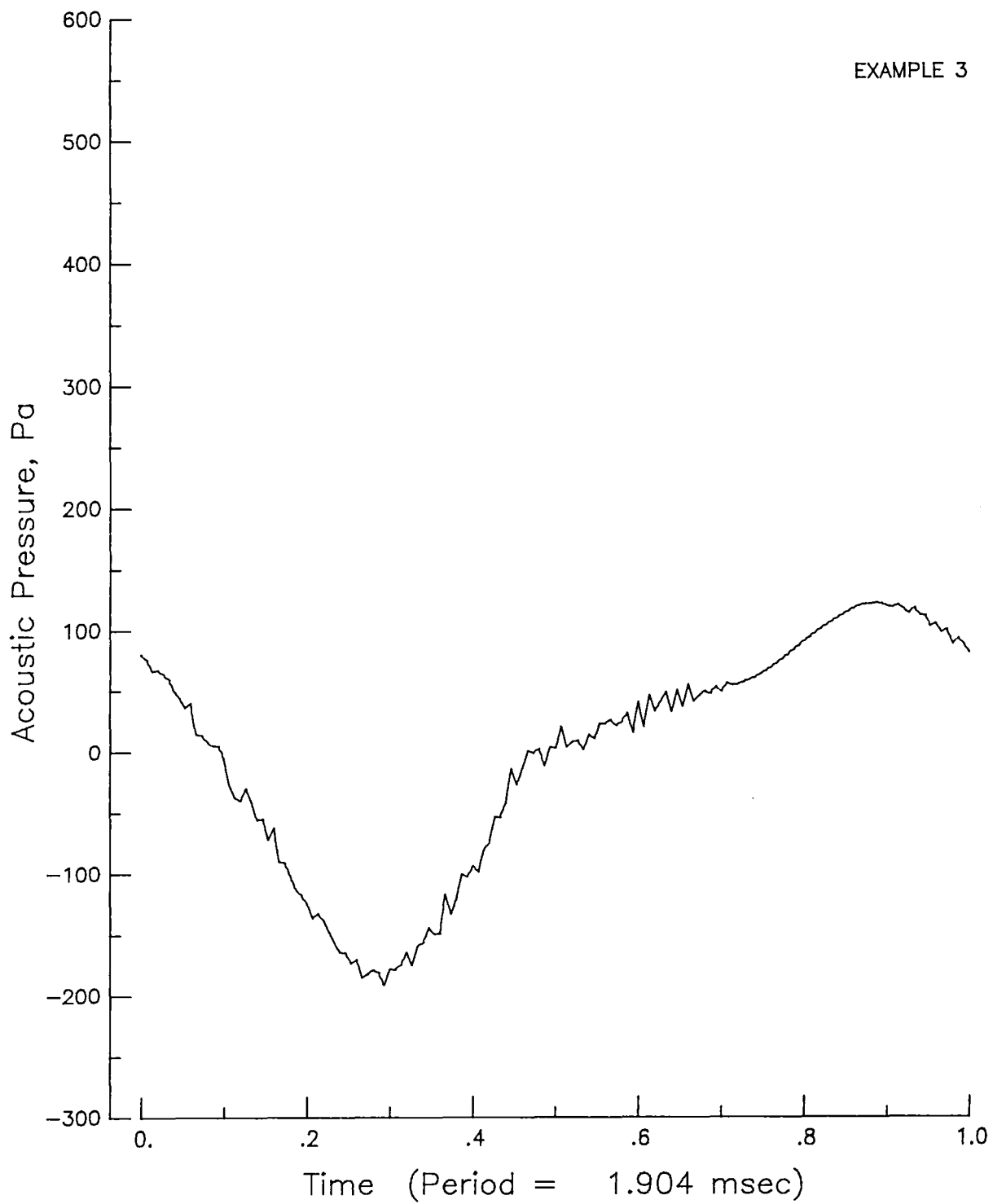


THICKNESS SPECTRUM

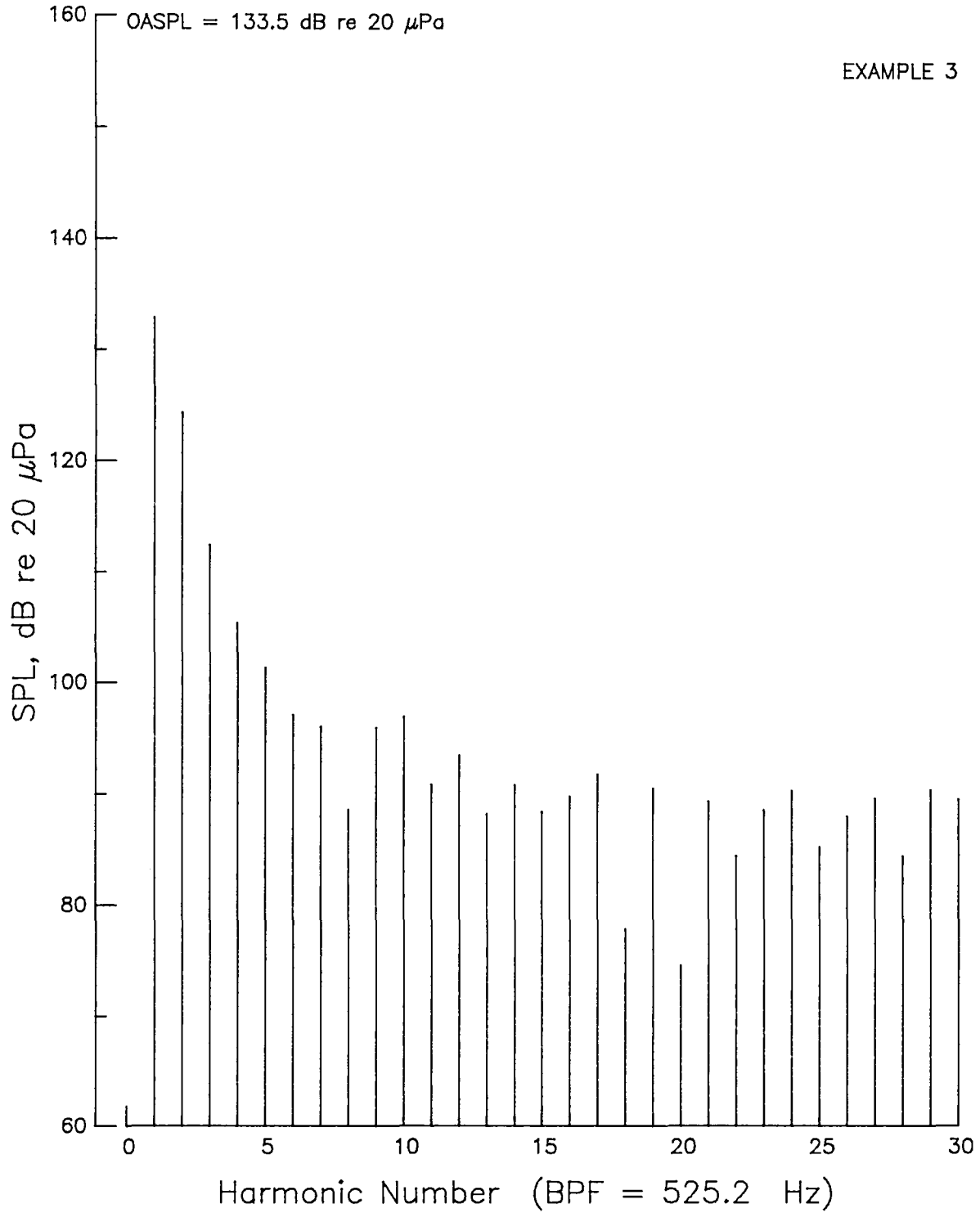


LOADING NOISE COMPONENTS

EXAMPLE 3

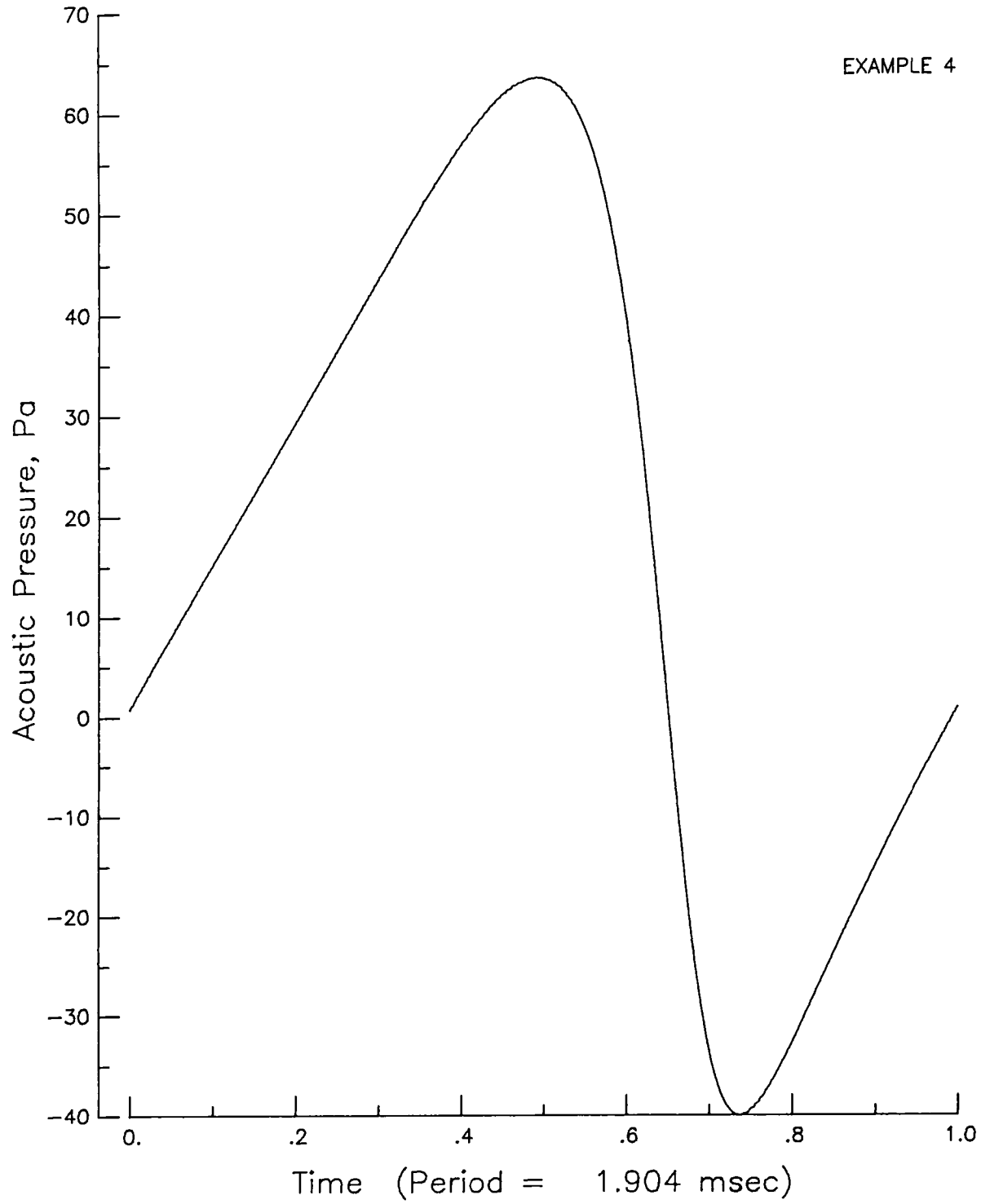


LOADING NOISE

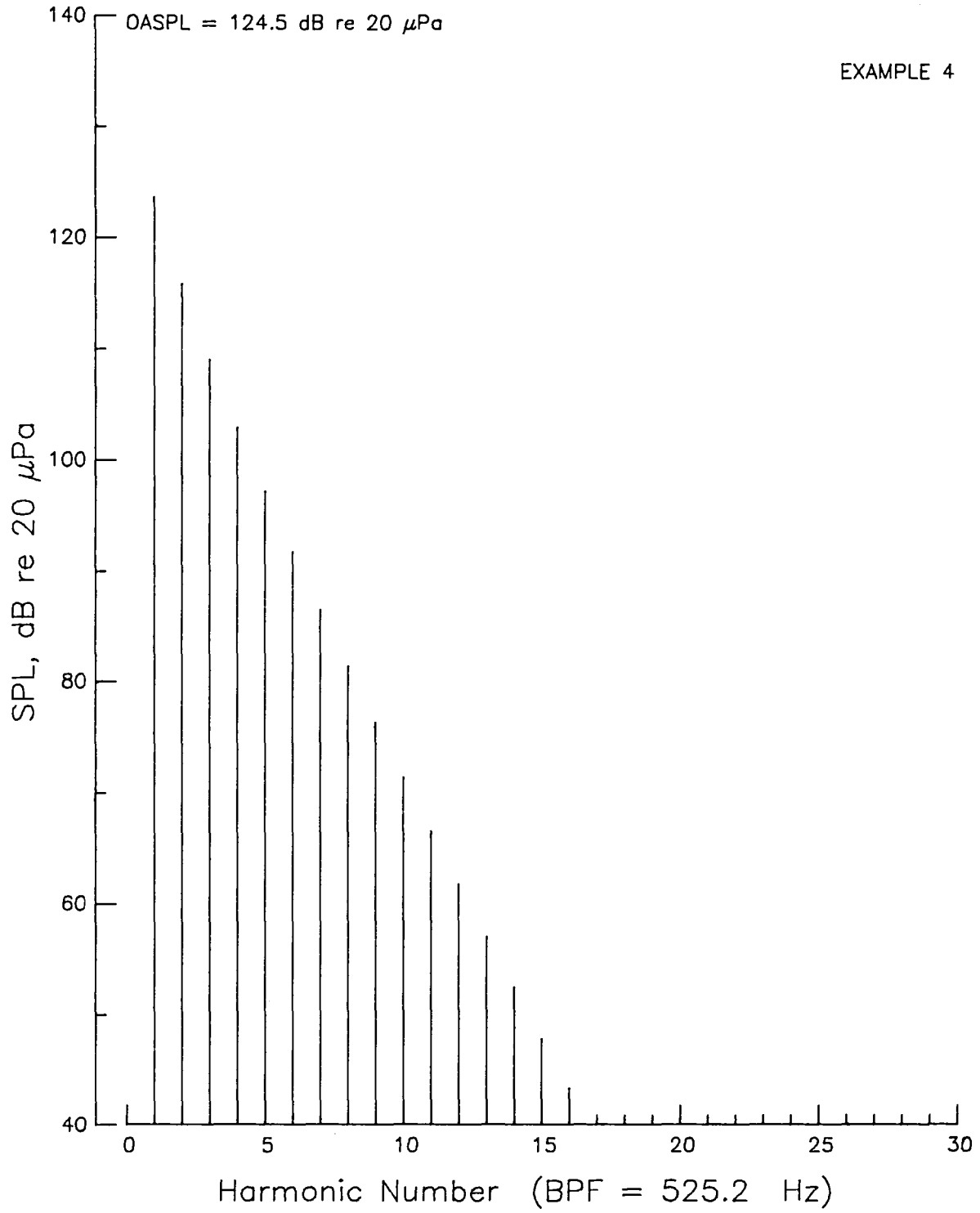


LOADING SPECTRUM

EXAMPLE 4

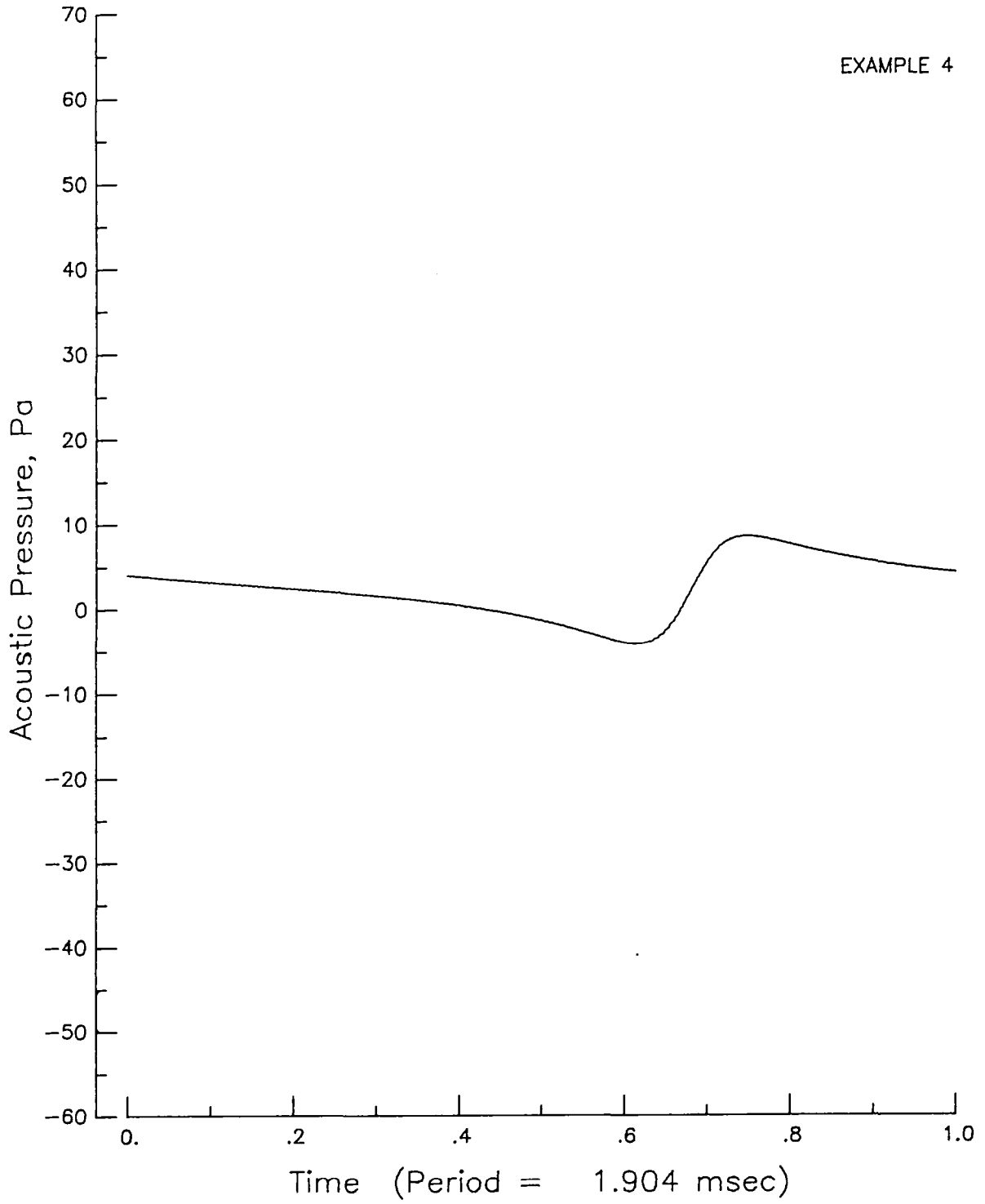


OVERALL PRESSURE



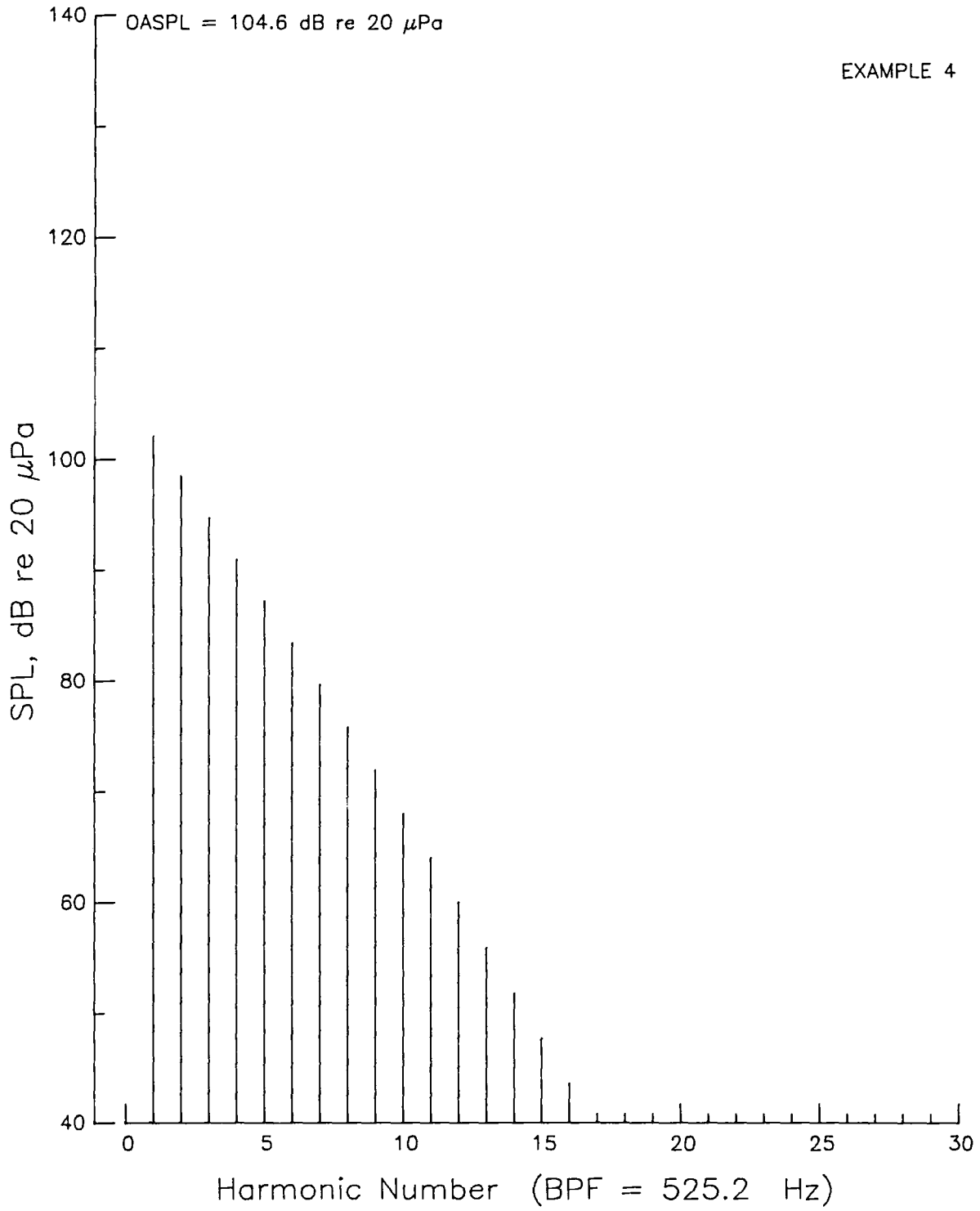
OVERALL SPECTRUM

EXAMPLE 4



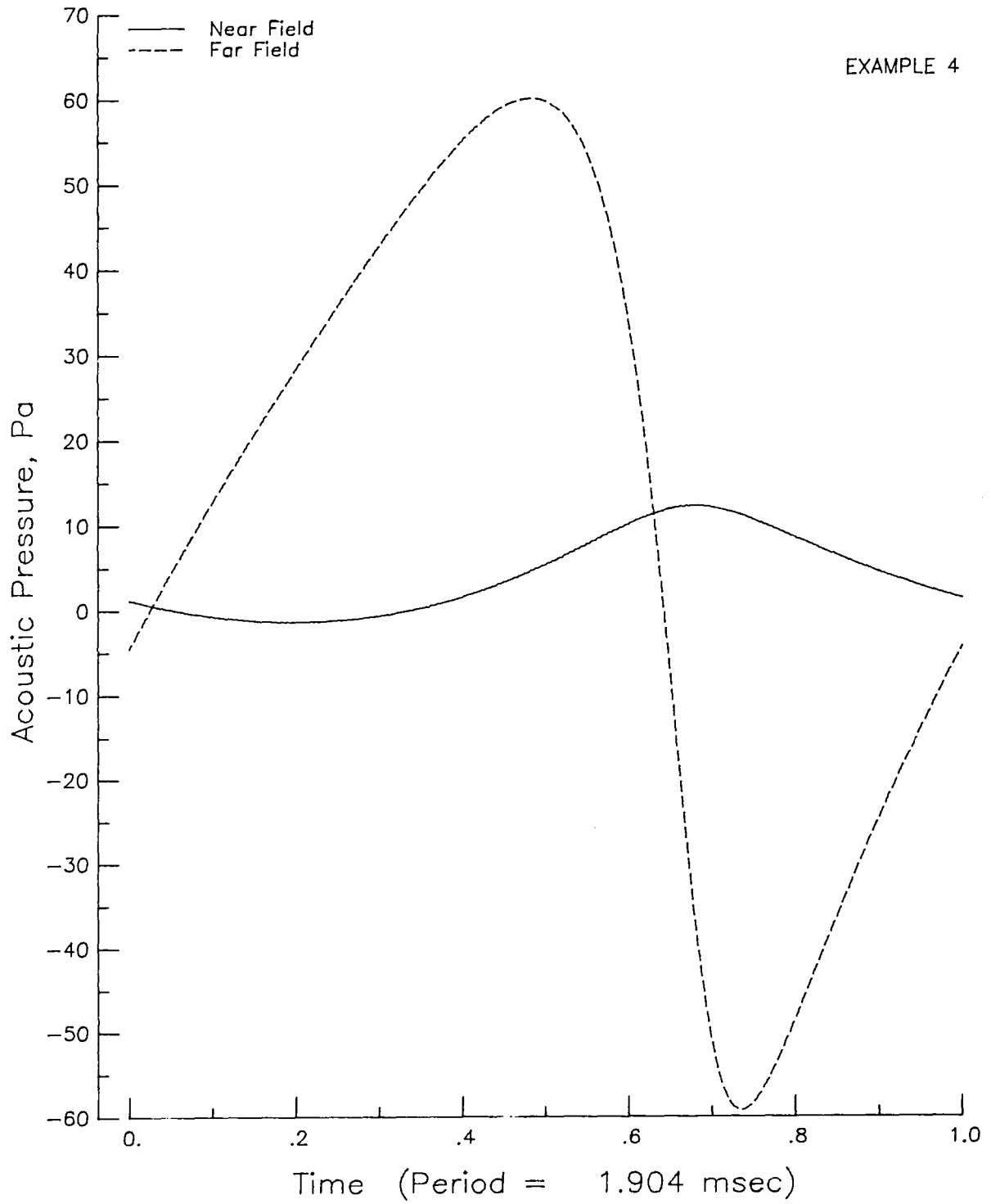
THICKNESS NOISE

EXAMPLE 4



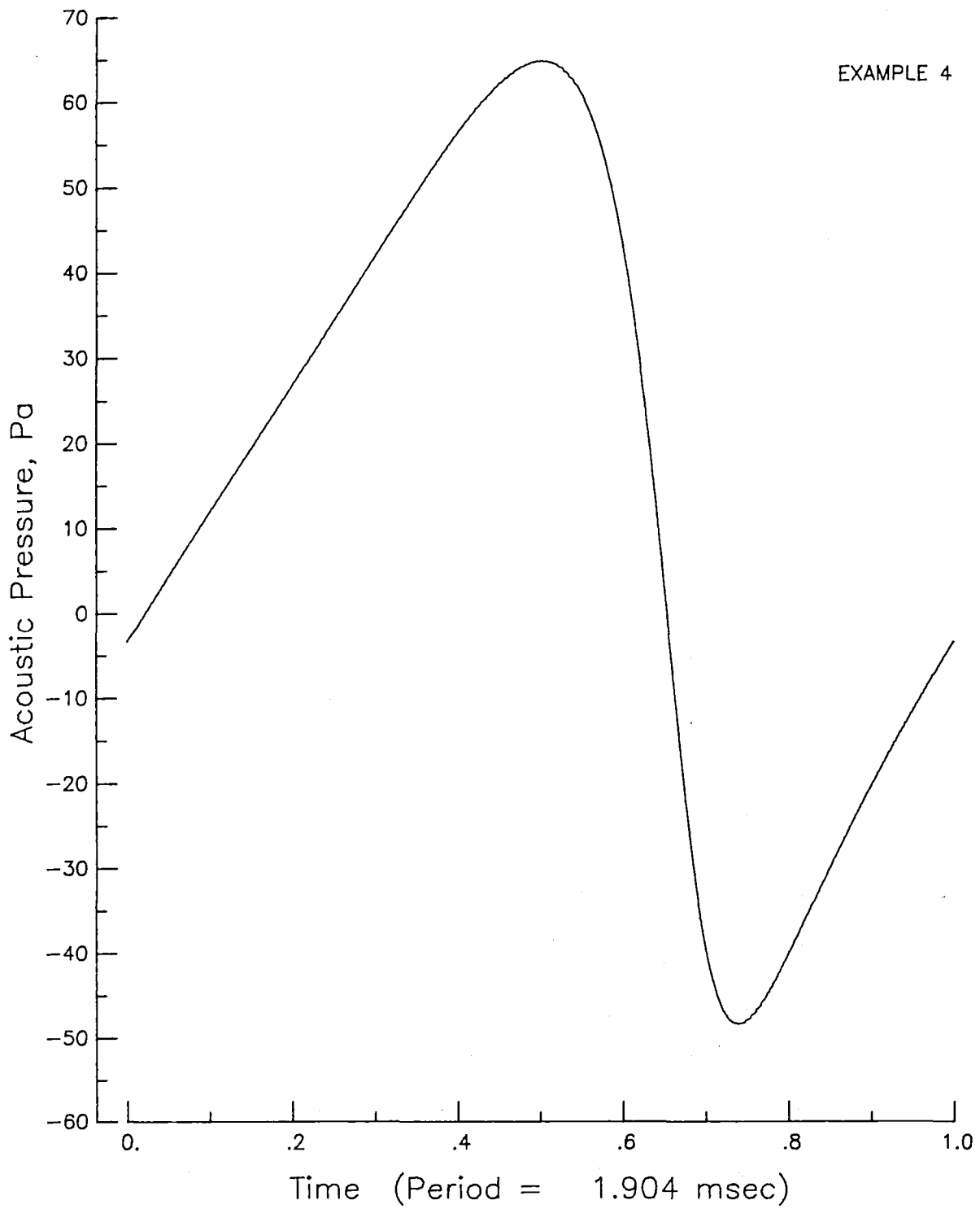
THICKNESS SPECTRUM

EXAMPLE 4

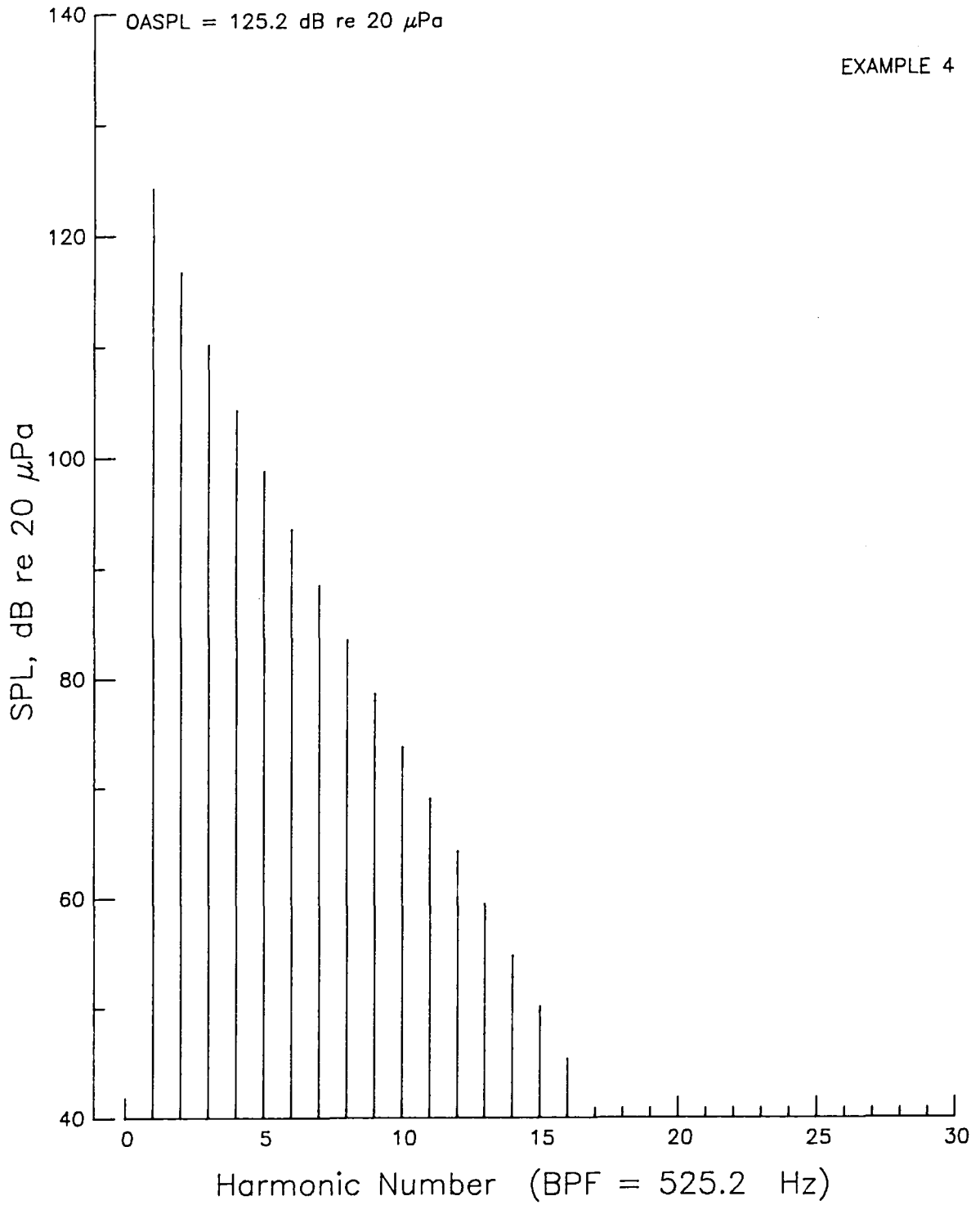


LOADING NOISE COMPONENTS

EXAMPLE 4



LOADING NOISE



LOADING SPECTRUM

1. Report No. NASA TM-83135		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle USERS' MANUAL FOR A COMPUTER PROGRAM TO CALCULATE DISCRETE FREQUENCY NOISE OF CONVENTIONAL AND ADVANCED PROPELLERS				5. Report Date August 1981	
				6. Performing Organization Code 505-41-43-01	
7. Author(s) R. M. Martin and F. Farassat				8. Performing Organization Report No. L-14374	
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665				10. Work Unit No.	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546				13. Type of Report and Period Covered Technical Memorandum	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract This report serves as a users' manual for a computer program for calculation of discrete frequency noise of conventional and advanced propellers. The computer program was developed at the Langley Research Center by F. Farassat and Paul A. Nystrom. The structure of the program and the subroutines describing the input functions are discussed in this manual. A detailed definition of input variables and their default values and the variables in the output data sheet are included. Two versions of the program are available. These differ only in the graphic output capability. One version has only printed output capability. A second version with extensive graphic output capability is available for the computer system at Langley. This manual includes four detailed examples of both the printed and graphic outputs. These examples may be reproduced by users to check their code on their computer system.					
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