Product Data

Spatial Transformation of Sound Fields (STSF) Software

Type 7688, WT 9260 and WT 9263

USES:

- ❍ High resolution source localization using active and reactive intensity, particle velocity, sound power and sound pressure
- ❍ 3 D visualisation of sound radiation
- ❍ Calculation of sound pressure level spectrum at specified points in space from near-field measurements
- ❍ Source contribution analysis
- ❍ Engine and gearbox testing
- ❍ Tyre/road noise analysis
- ❍ Complete vehicle noise analysis
- ❍ Wind noise measurements

FEATURES:

- ❍ Inclusion and exclusion of partial fields
- ❍ Contour, vector and 3 D graphics for enhanced visualization of source location and sound radiation
- ❍ Complete measurement, data storage and analysis system
- ❍ Validation of measurement data
- ❍ Simulation of source modifications
- ❍ Support of flexible array size
- ❍ Multiple hardware interface: for use with 3561, 3551 and 3550 data acquisition and analysis systems
- ❍ Fully annotated printer/plotter output
- ❍ Optional automatic traverse mechanism

Spatial Transformation of Sound Fields (STSF) Software is applications software for assessing the 3-dimensional sound-field of a test object, including functions for source modification simulation.

A reference and scan microphone array system is used to obtain a complete description of the sound field (both near-field and far-field) within a given solid angle from measurements over a planar surface close to a stationary sound source.

Enhanced colour graphics include:

- ❍ High resolution source localization and ranking
- ❍ 3 D field assessment
- ❍ Simulation of source modification

STSF software has been designed to run with one of three hardware platforms:

- ❍ Intelligent Data Acquisition System Type 3561 (Type 7688)
- ❍ Multichannel Data Acquisition System Type 3551 (WT 9263)
- ❍ Multichannel Analysis System Type 3550 (WT 9260)

STSF software runs on a HP 9000 series 700 UNIX workstation. The system can be enhanced by the addition of robot system Type 9665, a traverse system for automatic positioning of the scan array.

General

STSF software applies the Helmholtz Integral Equation and Near-field Acoustic Holography to cross-spectra of the sound pressure over a plane close to the sound source, and then calculates the descriptors of the sound field at other points.

The Helmholtz Integral Equation is used to calculate the sound pressure level at larger distances, while Near-field Acoustic Holography is used to calculate pressure, particle velocity, and active and reactive acoustic intensity in the near-field region.

Sound is recorded using three sets of transducers:

- ❍ Scan microphones or hydrophones
- ❍ Reference transducers
- ❍ Exclude reference transducers

and measurements are made using one of Brüel & Kjær's three multichannel systems:

- ❍ Intelligent Data Acquisition System Type 3561
- ❍ Multichannel Data Acquisition System Type 3551
- ❍ Multichannel Analysis System Type 3550

The corresponding STSF software packages provide a menu-driven front-end for each of these systems including facilities for calibration, measurement and processing.

In addition, STSF software executes a number of data inspection functions including:

- ❍ Data validation
- ❍ Stationarity analysis
- ❍ Coherence and virtual coherence
- ❍ Principal component analysis

Theory

The Helmholtz Integral Equation states that from a knowledge of the sound pressure and particle velocity distributions over a closed surface surrounding a sound source, the sound pressure can be calculated at any point outside the closed surface.

The closed surface, which can be of any shape, is, in the STSF method, a hemisphere of infinite radius bounded by an infinite plane. By a suitable choice of Green's function in the Helmholtz Integral Equation, the external sound field can be calculated from either the sound pressure distribution or particle velocity (normal component) distribution. In the STSF system, the sound pressure is measured over a finite part of the plane, providing a sufficiently good approximation.

The same measured data are used to perform near-field acoustical holography and simulation of source attenuation.

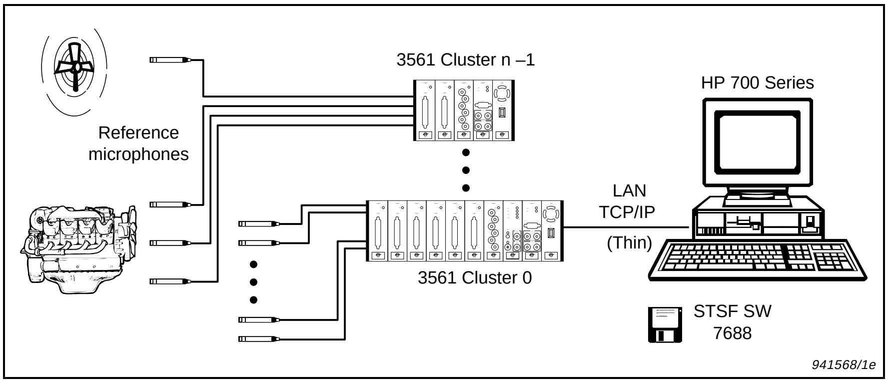

Fig.1 STSF set-up based on Intelligent Data Acquisition System Type 3561 and STSF Software Type 7688

Measurement Description

A practical STSF measurement is based on a two-dimensional scan over a plane surface close to the test object, during which the cross-spectra are measured from each scan point to each of a set of reference points (scan measurement). The cross-spectra must also be measured between every pair of references (reference measurement). Further, the pressure is recorded at each measurement point in order to validate the data.

The system allows all power descriptors of the radiated sound field to be calculated from the sound pressure distribution, which is measured during the scanning of an array of single microphones over a measurement window. The source must be stationary during the scan.

During the collection of scan spectra, the use of traverse equipment (a robot with controller) for moving the array microphones to various scan locations, can reduce the total measurement time significantly. STSF software includes drivers for control of the Brüel&Kjær Microphone Positioning System Type 9665. Auto-positioning equipment from other manufacturers can also be used*.

* Contact Brüel & Kjær's Customer Project Unit in the Industrial Measurement Division for further information

Reference Transducers

Reference transducers supply phase, amplitude and coherence references. The absolute values of the signals are not important although they must remain constant throughout the measurement. Thus, the reference signals can be provided by microphones, hydrophones, accelerometers, laser velocity transducers, etc.

The reference transducers are used to distinguish between the different mutually uncorrelated partial fields in a sound field and to achieve a complete model of the sound field in the measurement region.

An STSF measurement provides a complete model of a sound field, if the set of references can distinguish all significant, independent sources through a number of sufficiently different views. Thus, the number of references must be at least equal to the number of significant, independent sound sources.

Exclude References

Exclude references are typically used to remove strong background noise in cases where this background noise cannot be avoided by the normal (include) reference signals. In order to be applied properly, the background noise must be the only noise picked up by the exclude references.

Scan Transducers

The scan transducers must be free-field or pressure microphones, or hydrophones, with mutual phase deviations not exceeding ±3° within the frequency range of interest. In addition, their amplitude linearity must be good they must have a high stability.

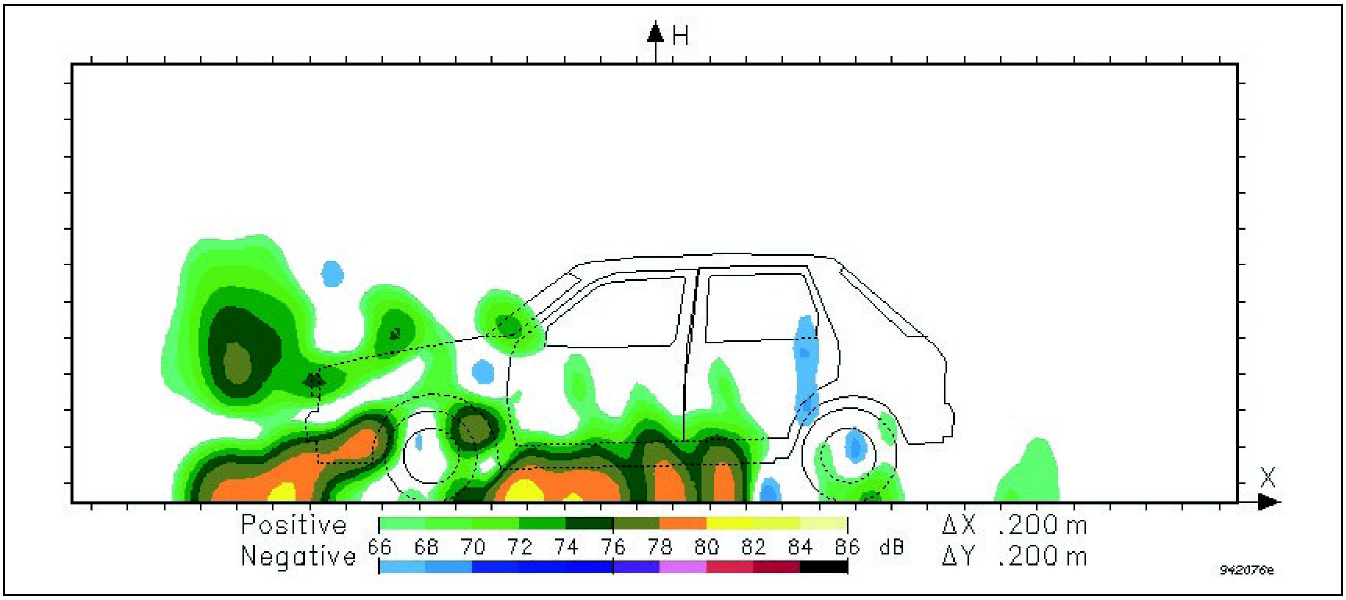

Fig.2 Active sound intensity from a car on a dynamometer. Frequency range: 610 to 630 Hz with Z component of intensity at Z = – 0.2 m which is at the surface of the car

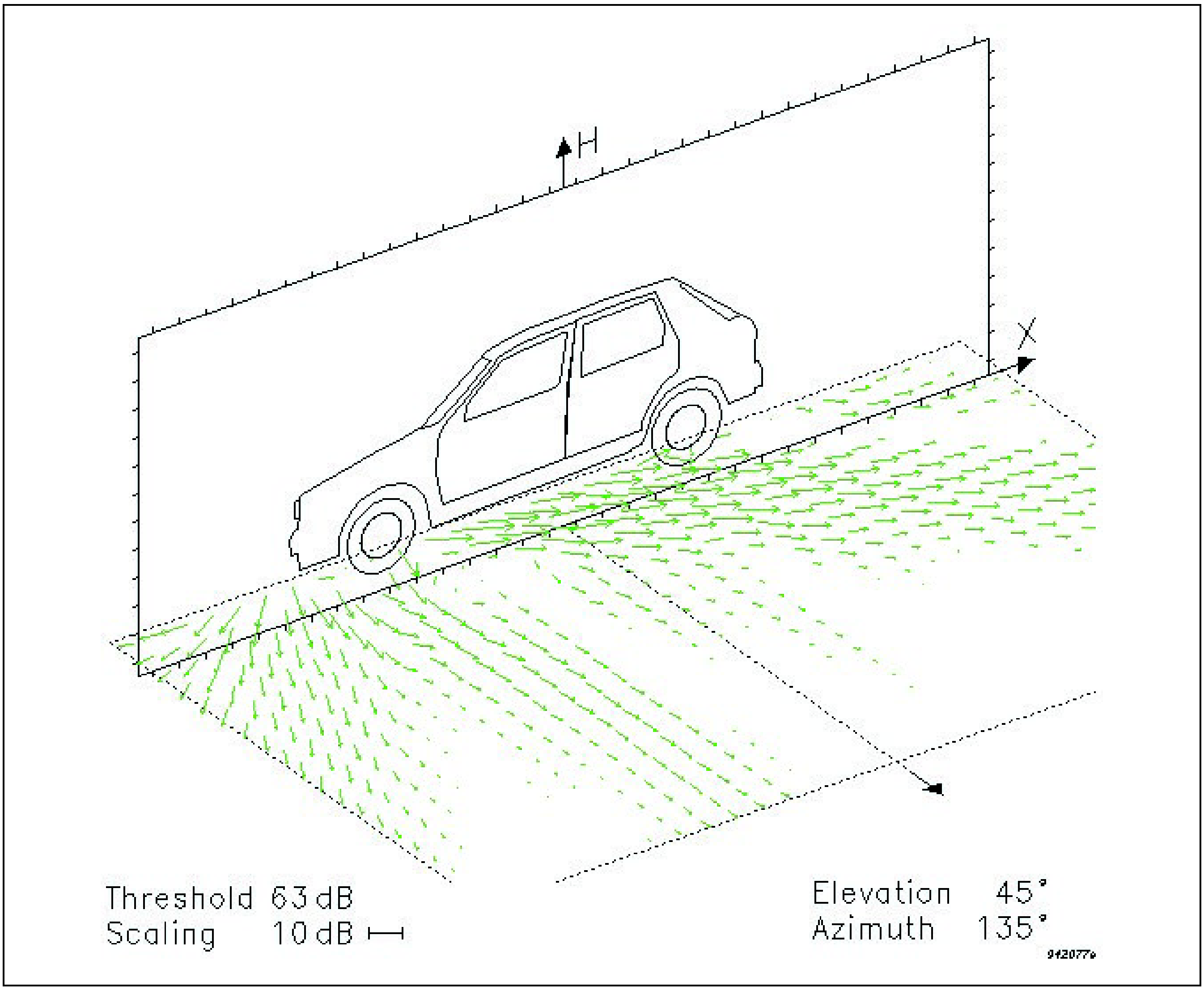

Fig.3 Active sound intensity from a car on a dynamometer. Frequency range 610 to 630 Hz with intensity vectors in the plane H = 0.1 m which is 0.1 m above the reflective ground plane

Preparing the Noise Source

Before a measurement can begin, the noise source and its surroundings must be checked and, if necessary, modified so that either free-field or mirror ground conditions exist over the entire measurement region and frequency range of interest.

In addition, the noise radiated by the source must be kept stationary throughout the measurement. The narrower the bandwidth used, the steadier the sound source must be.

Stationarity Monitoring

During a measurement, the STSF software monitors deviations from stationarity of the reference signals. For each reference this is done by comparing the current autospectrum with the autospectrum that was measured during the reference measurement, which is done first.

Two measures of deviation are monitored during the scan: changes in the overall A-weighted level of the autospectrum, and the overall A-weighted level of the absolute difference spectrum.

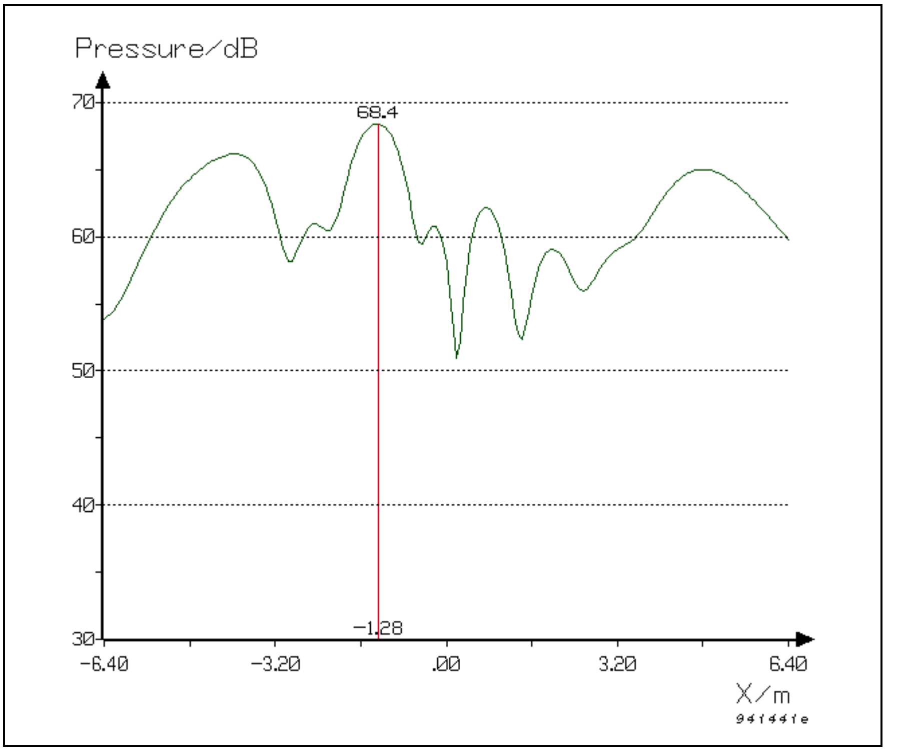

Fig.4 Sound Pressure Level from the same car and for the same frequency range as in Figs. 2 and 3: SPL along a line 0.1 m above the floor at Z = 3.6 m, the outer limit of the 3D vector plot in Fig.3

Inspecting the Sound Field Model

The sound field model applied in all STSF calculations contains the part of the total sound field which is coherent with at least one of the reference signals. Principal component decomposition of the reference signals avoids multiple inclusion of components which are coherent with more than one reference. The principal components are linear combinations of the true independent sound fields and are mutually uncorrelated.

Principal Component Analysis

The autospectra of the principal components of the reference signals can be obtained as the *eigenvalues* of the reference cross spectrum matrix. The number of significant principal components (eigenvalues) at a particular frequency is the number of independent sources detected by the references at that frequency.

Overlap Analysis and Validation

Overlap Analysis techniques are used to determine whether a reference microphone is redundant, while Validation can be used to verify whether the number of reference transducers and their locations have been properly chosen to obtain a complete sound field model.

Coherence and Virtual Coherence

Virtual coherence analysis shows to what degree a principal component represents a measured reference or scan signal in the STSF sound field model.

Data Post-processing

Once a measurement has been completed, various types of calculation can be performed using Near-field Acoustic Holography (NAH) or Helmholtz Integral Equation (HIE), or both.

To calculate the radiation pattern or Sound Pressure Level (SPL) along a line, NAH can be applied to perform a spatial windowing and filtering of the measured data before HIE is applied to obtain the desired output.

Calculate

The Calculate function extracts a principal component representation of the sound field from the measured cross-spectra. Based on this sound field representation, the following types of calculation can be performed:

- Holography: calculation of pressure, and the normal component of particle velocity, active and reactive intensity in any plane parallel with the measurement plane using NAH (Fig.2).
- Vector intensity: calculation of 3-dimensional active and reactive intensity vectors in a set of planes parallel with the measurement plane using NAH. From these calculations, plots of the intensity vectors can be made in planes orthogonal to the measurement plane, as illustrated in Fig.3.
- SPL along a line: calculation of SPL spectra at a set of points along a horizontal line parallel with the scan plane (Fig.4).
- Radiation pattern: calculation of the far-field SPL radiation pattern (Fig.5).

Simulation of Source Attenuation

The Calculate function also applies for the following simulation: how is the radiated sound field modified if the normal component of particle velocity is attenuated over selected areas in a plane close to the surface of the sound source? The four types of calculation listed above can be performed on the modified sound field.

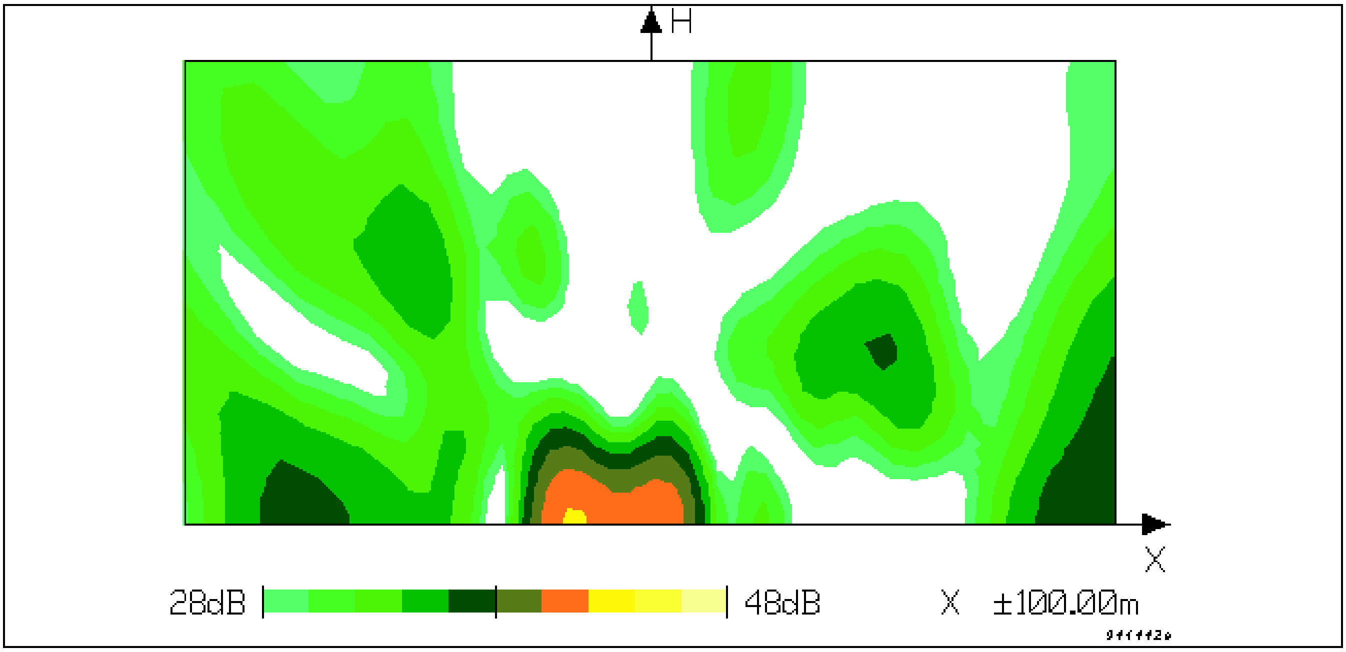

Fig.5 Sound Pressure Level in the plane Z=100 m from the same car and for the same frequency range as in Figs. 2 to 4

Fig. 6 shows a source modification function and Fig. 7 shows the same intensity vector plot as Fig. 3, but after application of the modification function.

Graphical Results

Sophisticated graphics drivers included with STSF software provide a platform for viewing a number of measurement results both two and three-dimensionally.

Two main graphics tools are used to present the data:

- ❍ Draw
- ❍ Plot

Draw

This function allows you to introduce your own source drawing. You can use a digitizer or mouse to provide the basis for viewing measurement results as they are displayed overlaid on the source drawing. Draw allows you to align the source drawing with respect to the measurement scan area, to define areas for source ranking and to define a source attenuation function for simulation of source modification.

Plot

This function provides a range of graphical representations of post-processed (calculated) data, for example spectra, function graphs, 3D plots, line and contour plots, and vector plots in 2 and 3 dimensions.

A radiation pattern calculation enables the SPL over a (projected) hemisphere or a plane to be plotted (Fig. 5). An SPL calculation along a line allows plots of frequency-weighted SPL along that line (Fig. 4) or SPL spectra at points on the line to be obtained.

A holography calculation provides pressure, particle velocity, active and reactive intensity over an output plane parallel with the measurement plane. Any one of the four different parameters can be plotted. In addition, the sound power for various parts of the scan area can be obtained.

From a vector intensity calculation, all vectors in any principal plane (xy, yz or xz) can be plotted in a 3-dimensional view.

Computer Platform

STSF runs on an HP 9000 series 700 workstation with very fast Floating Point calculations.

For Types 3550 and 3551 an IEEE–488 interface is required. For Type 3561 systems an ethernet connection is used. See the ordering information for further details.

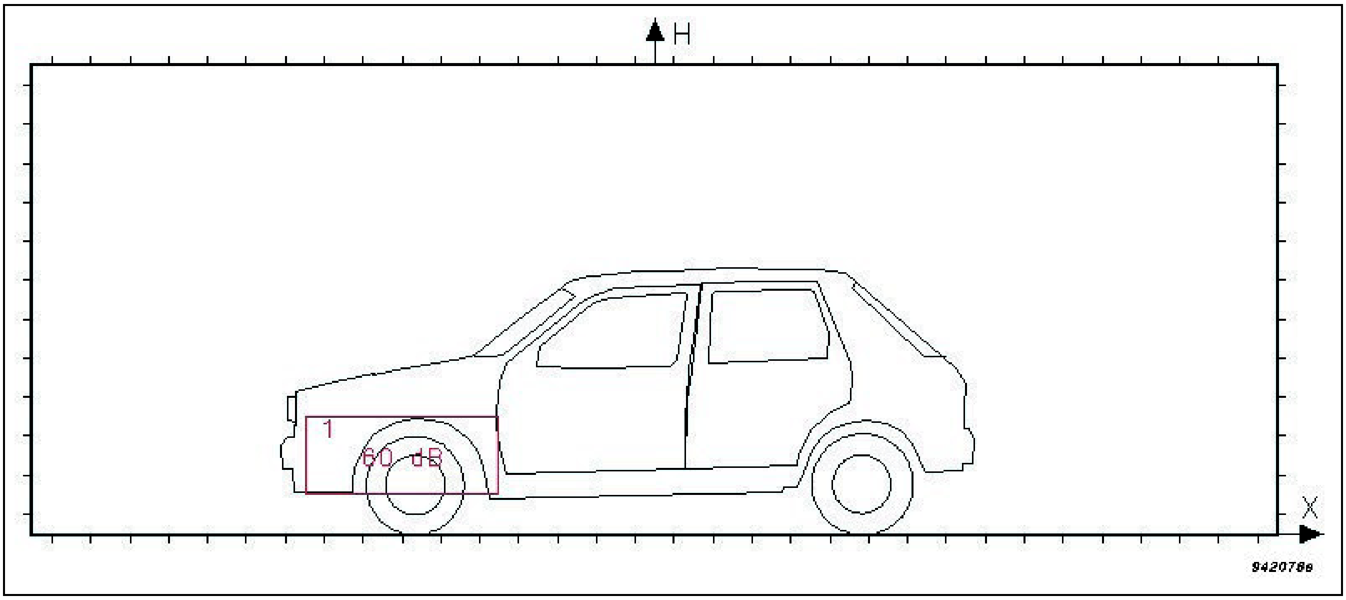

Fig.6 Source modification function for the situation shown in Fig.2

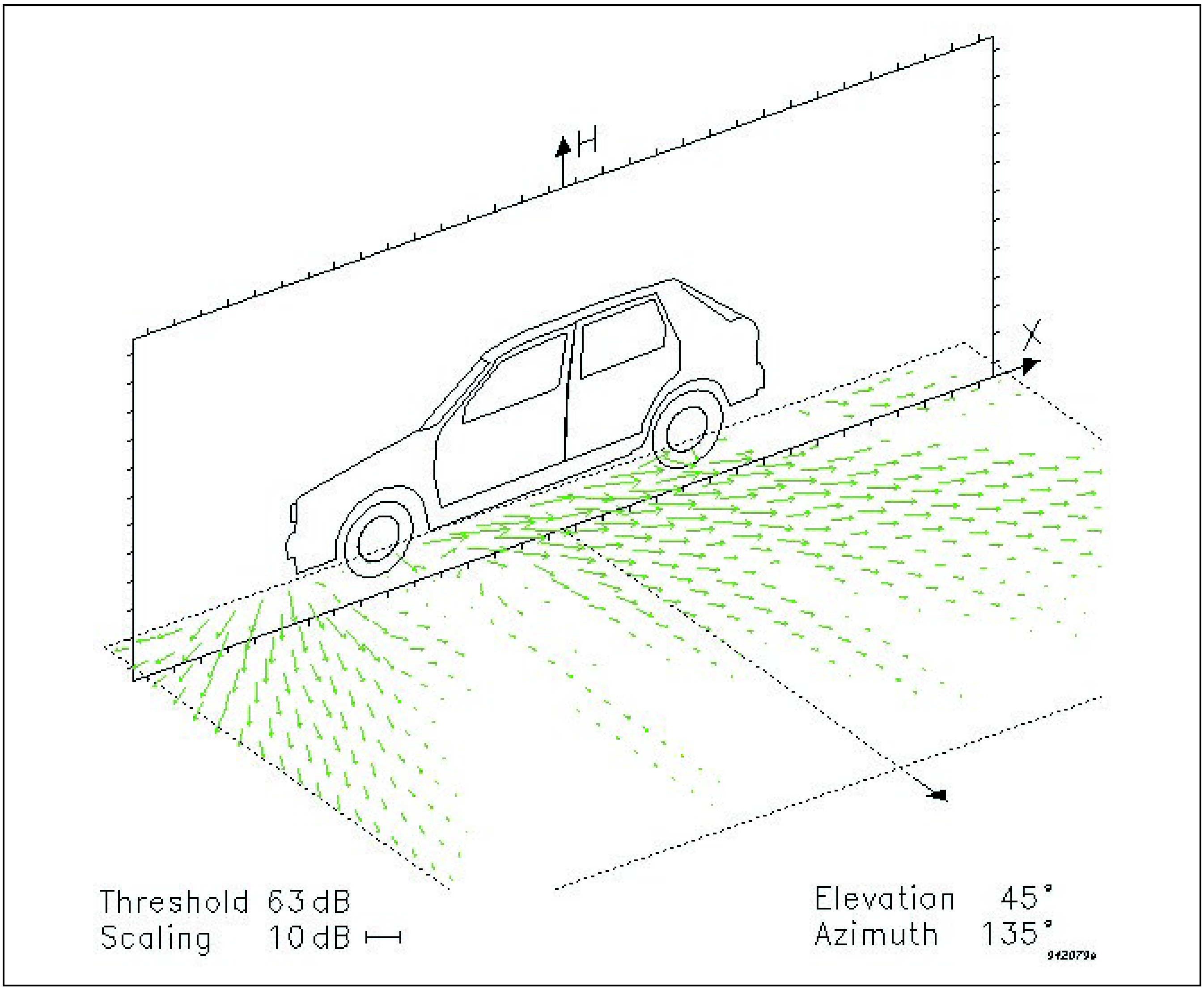

Fig.7 The intensity vector plot of Fig.3 after the application of the source modification function in Fig.6

Specifications 7688, WT 9260, WT 9263

MEASUREMENT CONDITIONS:
Free-field or reflecting ground-plane

METHOD OF CALCULATION:
Helmholtz Integral Equation
Near-field holography
Simulation of source attenuation
All calculations formulated for application with partially incoherent fields

ACCURACY:
With optimally chosen measurement parameters the obtainable accuracy is typically:
From scan plane and outwards: ±0.5 dB(A)
Inwards from scan plane: Resolution limitation

	Type 3561 Array-based STSF system	Type 3551 Front-end-based STSF system	Type 3550 Analyzer-based STSF system
STSF Software:	**Type 7688**	**WT 9263**	**WT 9260**
Help	✔	✔	✔
Measure	✔	✔	✔
Automated channel configuration	✔		
Time data storage	✔		
Multiple use of time data	✔		
Acoustical array check	✔		
Inspect (validation, stationarity check, coherence analysis)	✔	✔	✔
Save/Recall	✔	✔	✔
Draw	✔	✔	✔
Calculate	✔	✔	✔
Plot (3D, contour, vector)	✔	✔	✔
Attenuation calculation	✔	✔	✔
Frequency range	30 Hz – 6.4 kHz	1 Hz – 12.8 kHz	
Transducer Support:			
Max. no. of scan transducers	200	15	
Max. no. of references	18	10	
Array dimensions	1 D, 2 D	1 D	
Scan microphones/preamplifiers Reference microphones/preamplifiers	Type 4196 Type 4188/2669 L Type 4189/2669 L	Type 4190/2669 B	
Scan hydrophones (/preamplifiers)	Type 8105 (/5674)	Type 8105	
Optional reference transducers	Accelerometers, hydrophones, laser velocity meters, etc.		
Microphone Positioning System Support:	Type 9665		
Computer Configuration Requirements:			
Computer	HP 9000 series 700		
Interface to front-end	LAN TCP/IP	IEEE–488.2	
Interface to microphone positioning system	RS–232		

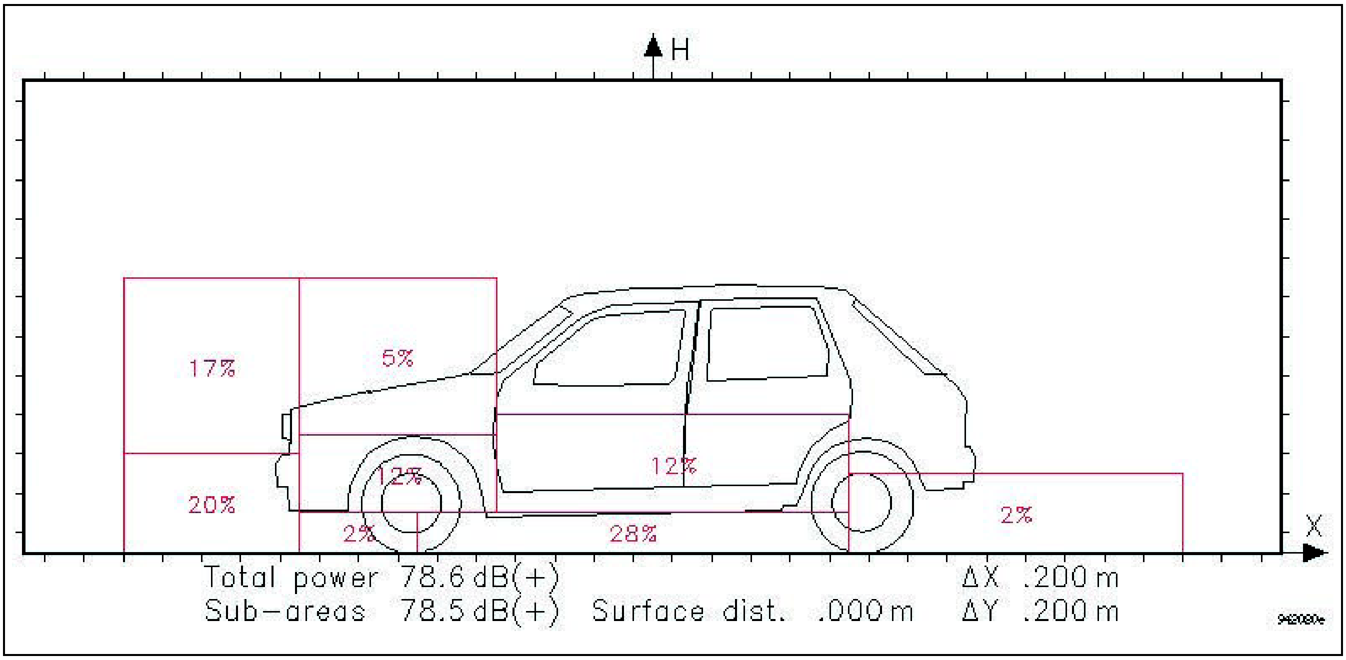

Fig.8 Source ranking for the situation shown in Fig.2

Ordering Information

Spatial Transformation of Sound Fields Software packages Type 7688, WT 9260 and WT 9263 are single products which require the following accessories:

Accessories Required

Unix Workstation:
HP 9000 series 700 workstation configured as described below.

COMPUTER CONFIGURATION:
The recommended computer is HP9000 series 700 workstation with:

- UNIX (ver. 9.0)
- GRAFPAK–GKS run-time
- minimum 32 Mbyte RAM Memory
- minimum 1 Gbyte Hard disk
- Display: minimum resolution 1024 × 768 with 6 colour planes
- DAT recorder for installation of the software and for backup of measurements
- digitizer (e.g. 46087C)

Data Acquisition Front-ends:

Software	Front-end
Type 7688	Type 3561: Intelligent Data Acquisition System
WT 9263	Type 3551: Multichannel Data Acquisition System
WT 9260	Type 3550: Multichannel Analysis System

SCAN TRANSDUCERS:
Microphones or hydrophones (free-field or pressure transducers) with ±3° phase match

REFERENCE TRANSDUCERS:
Microphones, hydrophones, accelerometers, laser velocity-transducers, etc.

PRINTER:
General colour PostScript printer
Screen dump to, e.g., a PaintJet XL

Optional Accessories

Type 9665: Microphone Positioning System and accessories

Training

A training course is recommended in connection with the installation of the system. Order:
WW 5750: Installation and training on site

Brüel & Kjær

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