Application Notes

Applications of the Real-time Frequency Analyzer Type 2143

by *Roger Upton*

1. Introduction

The Real-time Frequency Analyzer Type 2143 brings laboratory-standard analysis to the field. It is a fully portable, battery-operated analyzer weighing less than 9,5 kg (21 lb) including batteries, and comes in a robust, weather resistant, easy-to-use package. At the same time it offers real-time 1/1-, 1/3-, *1/12-*, and 1/24-octave digital filtering with the precision and dynamic range of current laboratory systems, to bring the advantages of all-digital operation to the field user. Alternatively, the 2143 is equally at home in the laboratory, where it can be powered from a mains power supply.

The 2143 can be described as the next logical step up from a sound level or vibration meter, while also providing a link to sophisticated laboratory systems, and in particular allows on-line laboratory-standard analysis in the field where otherwise tape recorders would be used to bring the data back to the laboratory. It has many applications in the analysis of sound, vibration, and other signals. The purpose of this application note is to describe how the features of the 2143 can be used in some of these applications.

2. Using the Real-time Frequency Analyzer Type 2143

The Real-time Frequency Analyzer Type 2143 is shown in Fig.1. How its features can be used in different applications is described in Section 3, but since some features are general to all applications, they are described here. In addition to those features already described in section 1, they include:

Microphone, charge, and direct inputs — allow input of a broad range of signal types.
Non-volatile memory for 512 1/3-octave spectra with optional expansion — means that when the 2143 is switched off, the stored data will be preserved.
Read-in rates to memory down to 1 ms/spectrum — allows the 2143 to document fast moving signals.
PC/MS-DOS compatible disk-drive formats — allows easy transfer of data from the 2143 disk to, for exam-

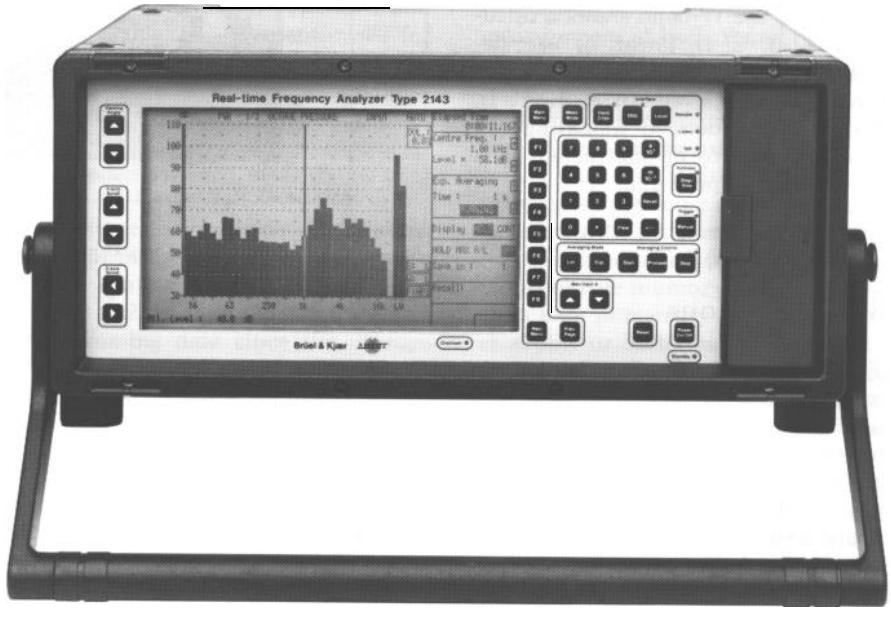

Fig. 1. The Real-time Frequency Analyzer *Type 2143*

ple, a spreadsheet or database on a PC (via software pack WT9342).
IEEE 488 **and RS-232 interfaces — so** that the 2143 can connect to a wide range of computers and be controlled through a modem.
IBM, HP, **and Epson print formats —** allows inexpensive printers to be used as hard copy devices for the 2143.
LCD **with selectable back-lighting —** means that 2143 display data can be seen under almost any lighting conditions.
Disk-data compatible with 2123/33 — allows 2143 disk-data to be processed by the Brüel & Kjær laboratory analyzers 2123 and 2133.

Control of the 2143 is through a system of interactive menus. A typical menu is shown in Fig.2. This particular menu controls the internal trigger for triggered data collection using the 2143. Note the use of a diagram to show the analyzed signal level in the trigger channel in relation to the trigger level. Such diagrams are frequently used in the 2143 as an aid in setting up the analyzer. Help pages are available as a further aid. A typical help page is shown in Fig.3. Every menu page has its associated help page, and additional help pages are available describing the measurement modes of the analyzer. The help pages essentially mean that the 2143 has a built-in instruction manual.

Fig.4 shows the 2143 display screen in one of the measurement modes of the analyzer. Note, in addition to the displayed spectrum, the A/L- and W-bands. The A/L-band shows a measured A-weighted or linear broadband level while the W-band shows a calculated A, B, C, D, linear, or user-defined weighted broadband level or inverse weighted level. An A, B, C, D, linear, or user-defined weighting can also be added to or subtracted from the measured spectrum.

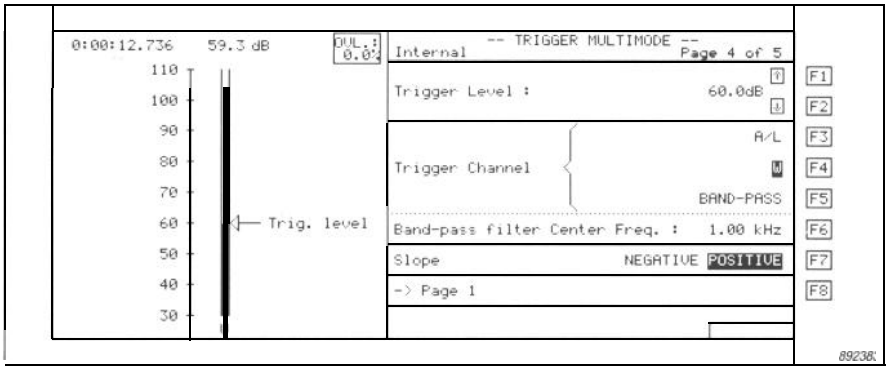

Fig. 2. A typical 2143 menu page (for controlling the internal trigger)

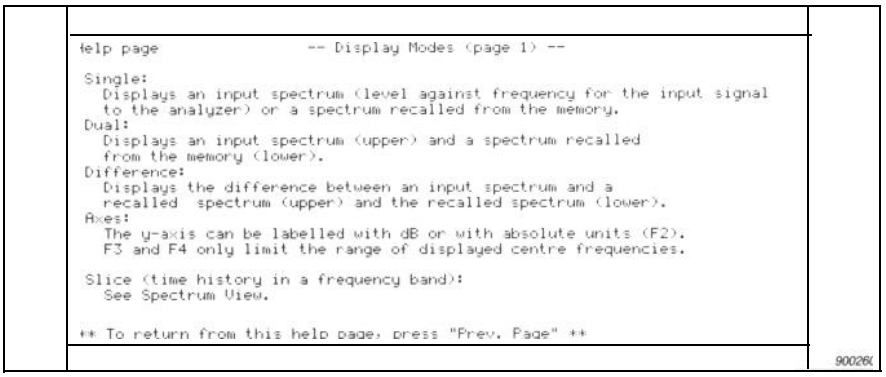

Fig. 3. A typical help page from the 2143

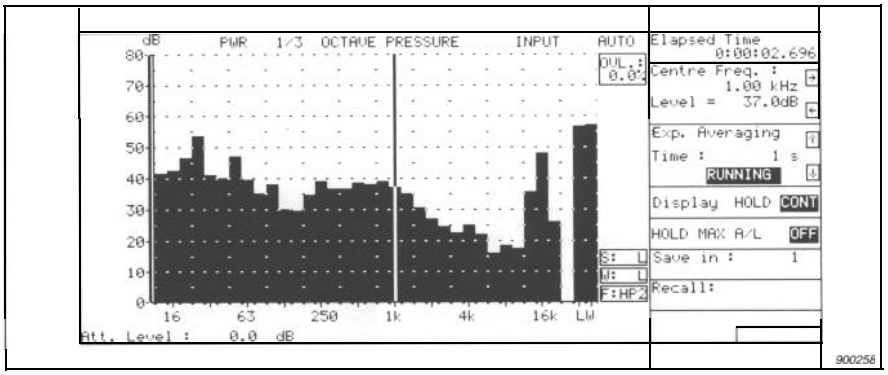

Fig. 4. The 2143 display in measurement mode

3. Applications

The following applications are by no means meant to be a comprehensive list for the 2143. They are more meant to serve as examples of how the various features of the 2143 can be used in practice. Further, some of the features introduced under a specific application might have more general uses. For instance, the data exclude mode described under environmental noise measurements has the more general use of allowing the removal of overloads, bad data, etc., from any type of ongoing measurement, and then continuing the measurement.

The first two applications dealt with are of a general nature. Thereafter, the applications become more specific.

3.1. General Noise Analysis

The term "general noise analysis" is here used to describe situations where a sound level meter, a measuring amplifier with a filter set, or a real-time analyzer might be used. The features of the 2143 related to this application are as follows:

Microphone input — allows direct connection of a preamplifiers microphone without the need for external power supplies.

1/1-, **%-octave analysis** — allows measurements in accordance with international standards.
Selectable pre-A-weighting — means the 2143 can be used as a type 1 sound level meter.
Selectable post-A/B/C/D/user-defined-weighting — allows other weightings to be added to or subtracted from a measurement.
Easy calibration in dB — an auto-calibrate mode allows easy and precise calibration using an external reference (see Fig. 5).
Can store data as a function of position — multispectrum maps can store data from an array of microphone positions.
Can store data as a function of time — read-in rates to memory down to 1 ms/spectrum can be used to store the evolution of signals in non-stationary signal analysis.
Maximum/minimum hold — allow maximum and minimum excursions of data to be measured.
Addition, subtraction of data on a dB or absolute power basis — allow calculation of attenuation, background noise subtraction, etc.

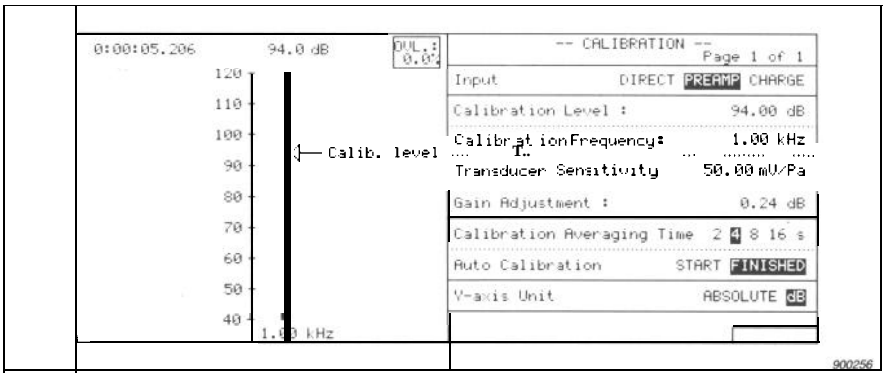

Fig. 5. Auto-calibration menu on the 2143

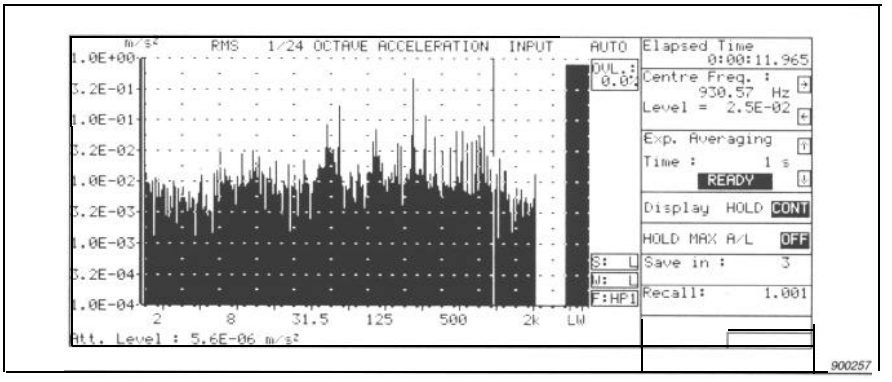

Fig. 6. 3% (1/24 octave) analysis on *the 2143, with absolute units calibration*

3.2. General Vibration Analysis
Vibration meters operating with a filter set usually present their data with a constant percentage bandwidth format. The 2143 presents its data in a similar format. Its main advantage for such measurements are, however, its real-time operation, which allows measurements to be made in a shorter space of time, and its memory, which allows results to be plotted at the convenience of the user after the measurements have been completed. Other features for general vibration analysis include:

Charge input — allows direct connection of accelerometers without the need for external amplifiers.
l/12-, 1/24-octave analysis — give 6% and 3% analysis respectively (see Fig. 6).
Absolute units read-out — the 2143 can read in absolute units as well as dB, for example, ms^{-2}.
Easy calibration in absolute units -the 2143 can be calibrated either by keying in the transducer sensitivity or by using an external reference and the auto-calibrate routines.
Integration and differentiation of results — allow, for instance, integration from acceleration to velocity to displacement.
Built-in high- and low-pass filters — allow the filtering out of high-frequency resonances, low-frequency noise, etc.

3.3. Environmental Noise Measurements
The 2143, being battery operated and fully portable, has been optimised for field measurements. This makes it extremely useful for environmental noise measurements. In addition, the 2143 has some features which arc specifically intended for such measurements:

1/1-, **1/3-octave analysis** — for standardised measurements.
True L_{eq} averaging — in linear averaging, the 2143 always shows the L_{eq} of the incoming data since the average was started.
Selectable pre-A-weighting — allows 2143 to be used as a type 1 sound level meter.
Selectable post-A/B/C/D/user-defined-weighting — allows other weightings to be added to or subtracted from the measured data.
Automatic standby/wake-up mode and repetition of measurements — allows unattended use of the 2143 for repetitive measurements.
Data exclude mode — deletes up to 20s of the last-analyzed data from an ongoing measurement. This allows the removal of unwanted data, overloads, etc., from such a measurement.
Minimum hold function — allows measurement of background noise levels in the presence of intermittent higher noise levels.
Can monitor random events — using internal triggering, the 2143 can collect spectra or multispectra describing events happening at random intervals and with documentation of when the events occurred (see Fig.7).
Non-volatile memory -the 2143 retains data in memory even if the power supply or batteries fail.
Can be powered from a DC-source — allows the 2143 to be powered for long-term monitoring at remote sites (required source voltage 11-16V).
Easy transfer of data to a spreadsheet for further processing — 2143 data can easily be transferred via software pack WT9342 to a spreadsheet for calculation of environmental noise indices such as L_N.

3.4. Architectural Acoustics

The features of the 2143 which can be used in architectural acoustics are similar to those listed under general noise analysis (see Section 3.1) with the following additions:

Software pack WT9342 can be used to calculate reverberation time — the software pack WT9342 can be used in a PC to calculate and average reverberation times from 2143 supplied data.

Silent operation — since the 2143 requires no ventilation fan, it creates no background noise to disturb measurements in quiet environments.

Read-in to memory at down to l ms/spectrum — allows the 2143 to collect reverberation decays with a resolution as small as 1 ms (see Fig. 8).

Complete arrays of data can be stored — allows 2143 to collect data as a function of position, for example, for noise mapping.

Data transferable to the 2123133 — 2143 disk data can be read by the Brüel & Kjær laboratory Real-time analyzers 2123 and 2133. This allows data collected using the 2143 to be processed on the 2123/33, for example, to calculate reverberation time (requires software packs BZ5027 and BZ5028 on the 2123 and 2133, respectively).

Fully **portable unit weighing <9,5kg — means** that it can be easily transported into unfinished buildings and other measuring sites (fits under an aircraft seat).

3.5. Whole-body/Hand-arm Vibration Measurements

Whole-body and hand-arm measurements often take place at sites where it is inconvenient or difficult to use a laboratory %-octave analyzer. The 2143 lends itself to these types of measurements through the following features:

Charge input — allows direct connection of accelerometers. The x, y, and z directions can be measured sequentially and stored in a single file.

l/l-, **1/3-octave analysis — as required by current whole-body/hand-arm vibration analysis practice.**

Analysis down to 0,4Hz — the 2143 covers the entire whole-body and hand-arm frequency ranges.

Can read-in the whole-body/hand-arm weighting as user-defined weightings — allows the measurement of weighted spectra and broadband levels (see Fig.9.)

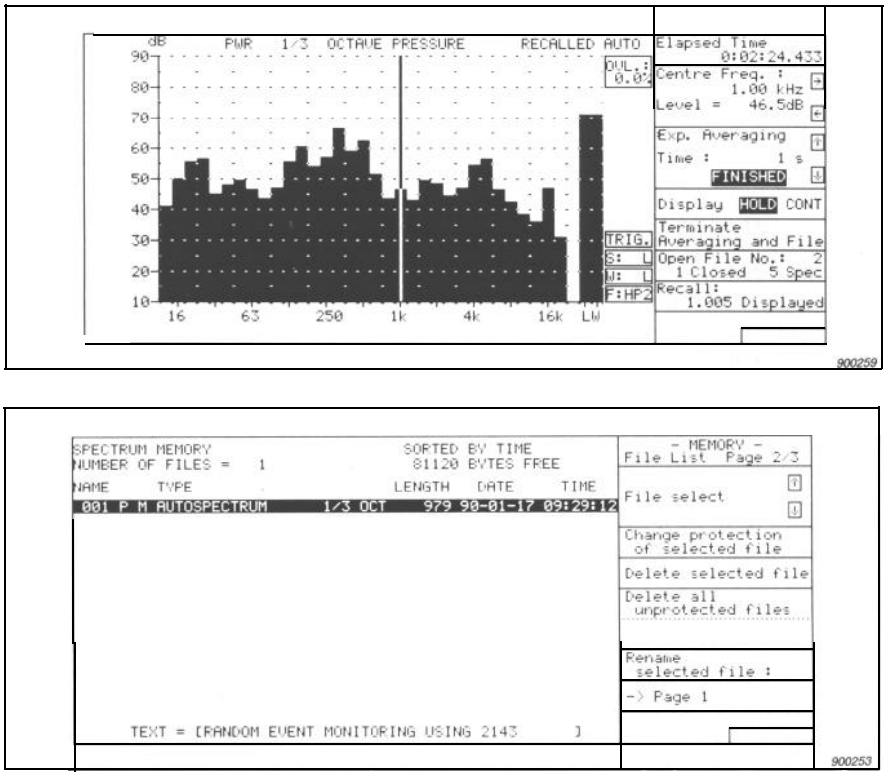

Fig. 7. Use of the 2143 for random event monitoring: (a) spectral display shows the setting of the elapsed time counter when the spectrum was captured. (b) The file list shows when the measurement was started. Note the use of additional text identifying the file. This text is stored with the file

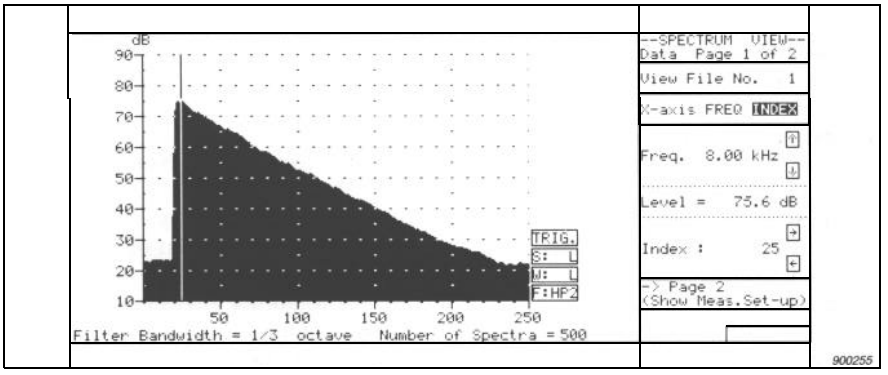

Fig. 8. An example of a reverberation decay collected using the 2143 with 1 ms resolution on the decay

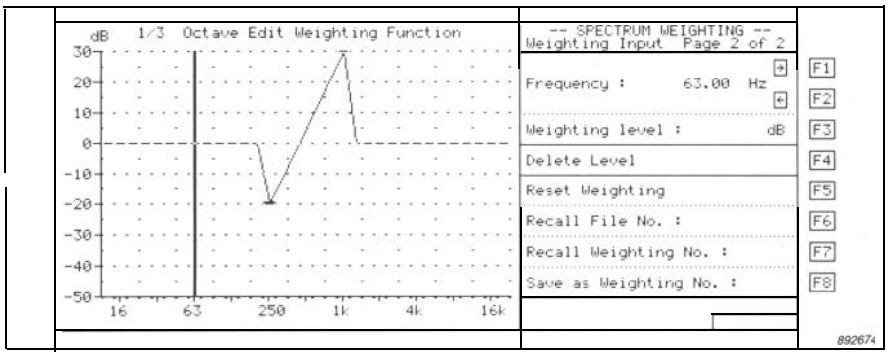

Fig. 9. Menu for entering user-defined spectrum weightings

Can combine x, y, and z directions through internal post-processing functions — allows calculation of overall levels.
Fully **portable unit weighing <9,5kg** — the 2143 can easily be taken to remote measuring sites (fits under an aircraft seat).

3.6. Measurements of Machine Cycles and other Repetitive Signals

The 2143 contains advanced facilities for measurements of repetitive signals, such as machine cycles. It allows the evolution of such signals to be measured as a function of time, position in a cycle, etc. In addition to those described under general noise analysis and general vibration analysis, the 2143 has these features for such measurements:
Advanced triggering facilities — with internal, external, manual, time, and free-running triggers, the 2143 offers advanced triggering facilities. In this type of measurement, external triggering is most frequently selected, an adjustable trigger delay being used to offset data collection with respect to the trigger (see Fig.10).
Read-in to memory at down to 1 ms/spectrum — allows data to be examined with a high time-domain resolution, within the limits of filter response time and the BT product.
Possibility of gated averaging — allows measurements to be made as a function of position in a repetitive cycle and averaged over many cycles to average out random variations.

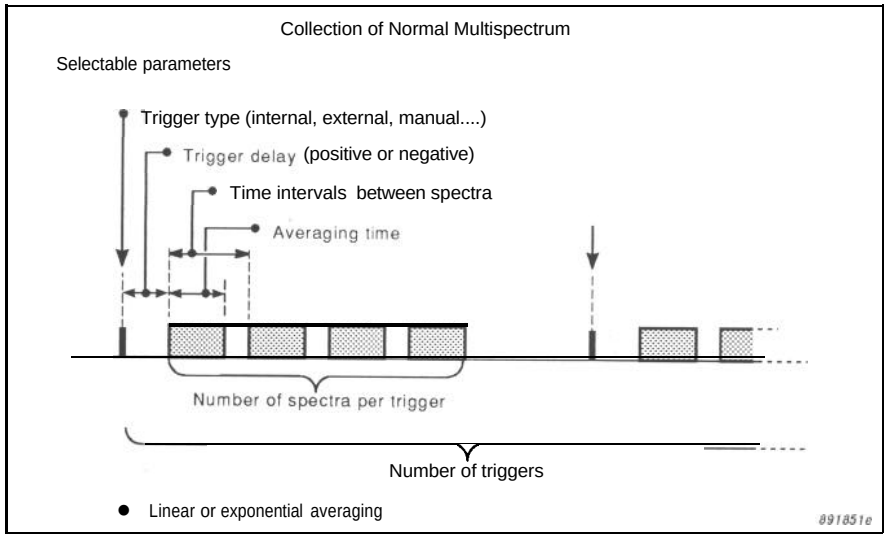

Fig. 10. Triggering facilities available for collection of multispectra on 2143

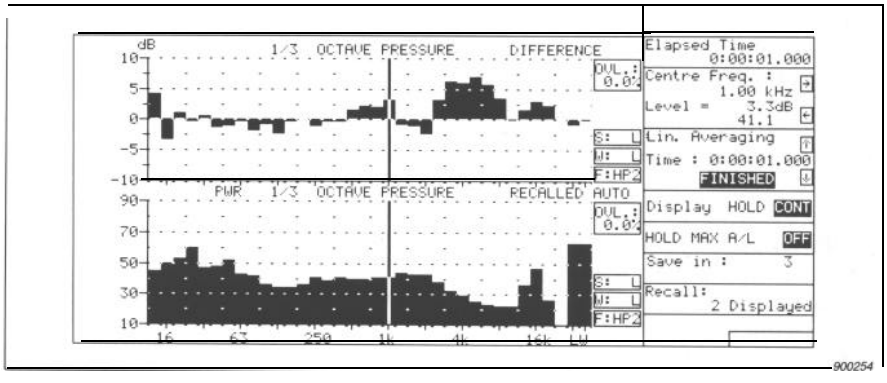

Fig. 11. Example of a difference spectrum display on the 2143

3.7. Vibration Monitoring

In vibration monitoring, the 2143 finds applications in fault detection and simpler fault diagnosis. In addition to those features described under general vibration analysis, the following features of the 2143 can be used in vibration monitoring.
Constant percentage bandwidth analysis — means that results measured using the 2143 are less sensitive to small machine speed variations than constant bandwidth measurements. Note that since the 2143 measures directly with constant percentage bandwidth in real-time, it will usually be considerably faster than an FFT analyzer in obtaining such results.
Can download references over the IEEE 488 or RS-232 interfaces — **so** that comparisons with reference data can be made in the field.
Can subtract out reference spectra — for easy comparison of current running condition with the reference.
Can use pre-stored set-ups — for easy set-up in the field.
The 2143 can be autosequenced — allows more complex measurement procedures to be automated, for example, where they are to be carried out by non-qualified personnel.
384-line **"narrow band" 3%** (1/24-octave) **analysis for diagnosis of simpler faults** — will often be sufficient in the diagnosis, for example, of faults associated with rotating shafts.
Fully **portable** — the 2143 can be taken to remote measuring sites (fits under an aircraft seat).
Water-resistant front panel with protection for the disk-drive — means the 2143 can be taken into difficult environments, for instance, with dripping water, dust, etc.

3.8. Quality Control

A primary consideration in quality control applications is the duration of the test, especially when frequency analysis is used instead of simple measurements of level. In addition to those mentioned under general noise analysis and general vibration analysis, the 2143 exhibits the following features for quality control:
Real-time operation — means that the analysis is obtained in the shortest time allowed by the laws of frequency analysis.
1/1-, 1/3-, 1/12-, 1/24-octave operation — allow the user to select the degree of detail needed.
IEEE 488 and RS-232 interfaces — allow the results to be quickly transmitted to a computer for further analysis and to make the pass/fail decision.
Can subtract out reference spectra — allows the 2143 to be used directly in simpler quality control applications such as field audits and tolerance level verification (see Fig. 11).

Easy-to-operate data-gathering tool — makes it easy to operate for production-line personnel. The PC/MS-DOS compatible disk allows easy transfer of test data to a PC for further processing, for example, statistical analysis.
Can use pre-stored set-ups, can be autosequenced — allows the analyzer to be used by non-qualified personnel.
Unattended use through wake-up mode — allows periodic sampling of production processes without the need for attendant control.
Minimum hold function — allows measurements to be made in the presence of higher intermittant background noise.
Robust unit — with its sealed front panel and dust-proof lid to protect the disk-drive, the 2143 is built to survive a typical factory environment. Further, the lack of any ventilation fans means that the 2143 will not suck in any dust in dusty environments.
Lower cost/channel — the 2143 often represents a more economical solution to production-line testing and quality control than laboratory analyzers.

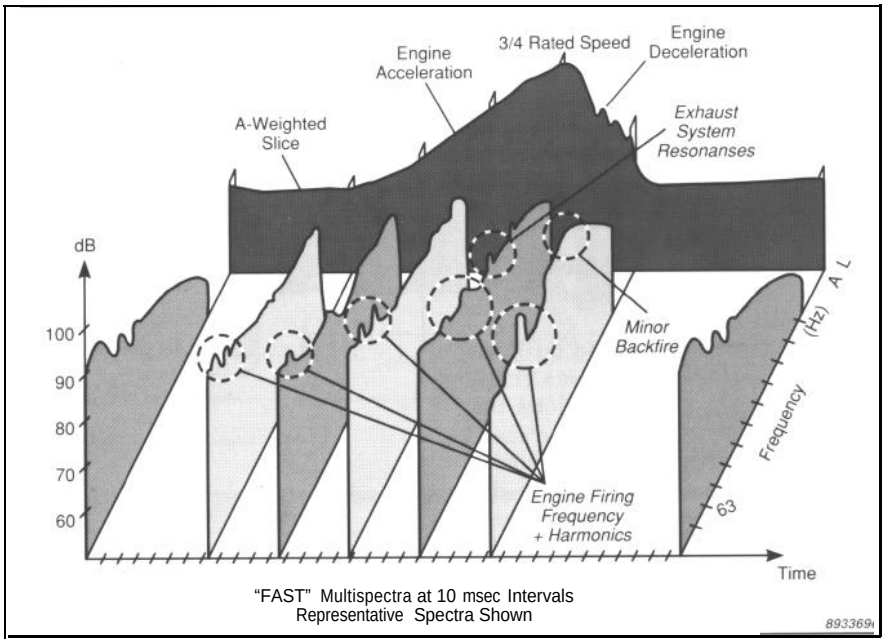

Fig. 12. Example of pass-by noise ***testing using 2143***

3.9. Product Noise Measurements
General product noise measurements fall under general noise analysis. Where, however, sound power measurements are required, the 2143 exhibits some additional features.
Can gather data for sound power determination — the 2143 can gather and store sound pressure data for sound power determination.
IEEE 488 and RS-232 interfaces — mean that the data can be easily transferred to a computer for further analysis.
Data transferable to 2123133 — 2143 disk data can be read by the Brüel & Kjær laboratory real-time analyzers 2123 and 2133. This allows data collected using the 2143 to be processed using the 2123/33 to, for example, calculate sound power (requires software packs BZ 5027 and BZ5028 on the 2123 or 2133 respectively).
In repetitive measurements, can calculate sound power directly — in repetitive measurements, the 2143 can be autosequenced to calculate sound power directly, provided the free field or reverberation room comparison methods are followed.

3.10. Automotive Measurements
The portability of the 2143, its small size, and its silent operation mean that it can be used to make measurements in moving vehicles and in the restricted spaces usually associated with passenger vehicles. The major features of the 2143 related to automotive measurements are as follows:
Advanced triggering facilities — allow collection of data as a function of time or some other parameter, such as distance, RPM, speed, load.
Read-in to memory at down to 1 ms/spectrum — allows collection of non-stationary data, for example, pass-by noise tests, or impulsive signals such as door slams or in-place switch operation with down to lms resolution (see Fig. 12).
Maximum hold facility — allows, for example, automatic capture of the spectrum at the maximum A-weighted level.
Optional memory expansion available — allows the memory to be expanded to allow multispectrum analysis of longer time signals with high time-domain resolution.
Possibility of gated measurements — allows signal variations through a repetitive cycle, for example engine vibration, air-conditioner noise, to be examined.
Sampling can be controlled externally — allows order tracking analysis of engines, gearboxes, etc., in conjunction with the Order Tracking Multiplier Type 5050.
RPM interval trigger available through WB 1116 or 5050/WH 2346 — allows the 2143 to collect data as a function of RPM.
Can track engine orders in real-time to 22 kHz — when used in single pass, l/12- or l/24-octave mode with the Order Tracking Multiplier Type 5050, by lining up an order with one of the l/12- or l/24-octaves, it becomes possible to track that order in real-time to 22kHz, which is a distinct advantage over FFT analyzers when performing acceleration/deceleration tests.

3.11. Measurements related to Aerospace
The small size and portability of the 2143 makes it highly suitable for in-flight measurements as found in the aerospace industry. Its high-precision laboratory-standard analysis makes it equally suitable for measurements on the ground. Many of the features of the 2143 for aerospace-related measurements have already been described under general noise analysis. Other major features not described there include:
Battery powering — means the 2143 can be used for "at-the-pole" measurements at remote sites and for verifying tape-recorded data in, for example, aircraft noise certification exercises, before the data is taken back to the laboratory for analysis.
Can be powered from a 400Hz mains supply — means that the 2143 can be battery or mains powered when used for in-flight measurements.

Small size — allows the 2143 to be used for measurements in confined spaces, for example, around aircraft seats.

Can collect data at exact 500ms time intervals — which coupled with laboratory-standard 1/3 octave analysis means the 2143 can be used for data analysis in aircraft noise certification.

Sophisticated IEEE 488 and RS-232 interfaces — makes the 2143 an excellent front-end for a computer.

Can be triggered over the IEEE 488 interface — means that a computer can trigger the 2143 to, for example, synchronise data collection on the 2143 with an IRIG time code.

4. Conclusion

This application note has illustrated just a few of the wealth of applications which exist for the analyzer. Many other applications exist which have not been described here. Further, with the Upgrading Kit Type UA 1111 (available later) the 2143 can be upgraded to dual-channel analysis and the possibility of intensity and cross spectral analysis, to open up an additional vast area of applications.

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