ARIA - A COMPREHENSIVE ACOUSTIC MEASUREMENT SYSTEM FOR PERSONAL COMPUTERS.

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1. INTRODUCTION.

Modern digital signal processing techniques enable a suite of sophisticated measurement programs to eliminate bulky, dedicated analysers. The ARIA system is based on a laptop computer and has been developed as a precision, yet practical measurement tool. Its range of applications include sound intensity, spectral analysis, building and architectural acoustics, and environmental noise investigations.

2. THE ARIA SYSTEM'S METHODOLOGY, COMPUTER REQUIREMENTS, AND PHILOSPHY.

2.1 System Methodology.

The ARIA system uses digital sampling techniques based on Nyquist's theorem to truly represent an acoustic input. The actual ARIA acoustic measurement system, as shown below, consists of a combination of a high performance digital signal processor card housed in a host computer which receives electrical inputs via transducers such as microphones or intensity probes. Application software modules treat the received signal to provide requisite outputs such as periodic values and generate measurement reports.

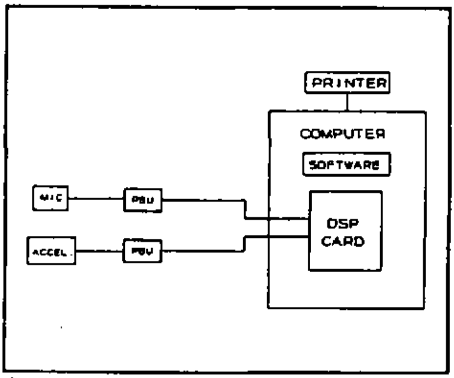

Figure 1 : Block Diagram of A Twin Channel ARIA System.

2.2 Computer Requirements.

Since ARIA is intended to be a highly transportable system then it's computer requirements are relatively easy to fulfill. The software is designed to operate from hard disk under the globally acceptable MS-DOS operating system and uses a 80286 or better processor with basic memory requirements of 512K of useable RAM. The digital processor card provides the main computer constraints, these being a full size 16 bit expansion card capability and a hard disk access speed of less than 28 milliseconds. These requirements are easily satisfied by modern laptop computers such as the Toshiba T3200 and T5200 units and include the latest colour laptop variants.

2.3 System Philosphy.

The ARIA system was not conceived to be another acoustic instrument but to be a totally new type of measurement acoustics. The system's philopsphy is not to focus on the measurement, but to consider the complete measurement and reporting process. With this in mind the ARIA system uses the host computer's calculating power and attendant peripherals to completely revise the measurement process : wherever possible raw data is stored and analytical decisions can be made after the raw data has been collected. Data can be reanalysised at will allowing multiple scenarios to be investigated from a single datafile, thus saving the acoustic practitioner valuable time and post measurement dissonance. The use of a report generator and standard output devices such as laser-jet printers all combine into an integrated measurement, analysis and reporting system.

3. APPLICATIONS

The concept of a modular computer based measurement system was proposed by Luquet and Rozwadowski (1) and resulted from discoveries made during earlier investigations to produce a data storing sound level meter (2). These modules are reviewed in approximate chronological order of development.

3.1 Environmental Noise Investigation.

The first implementation of a computer based acoustic instrument was as an L_{eq} meter. This used the concept of short Leq first proposed by Komorn and Luquet in 1979 (3). This allows virtually any acoustic index to be calculated after a measurement has been made using the "Outbox Processing" methodology. Initially, this represented an alternative to the conventional L_{eq} meter, however, this power was considerably enhanced by the addition of a threshold triggered event recording option. Such events are digitally recorded by the system and are stored on the computer's disk for later replay using the processor card's digital to analogue converter linked to a replay loudspeaker. Thus, the L_{eq} time history can be correlated with such audio events records thus easing the problem of actual noise nuisance definition. Since the discrete noise events are stored the signal files may be passed into the system's FFT analysis option to allow narrow band spectral data to be produced.

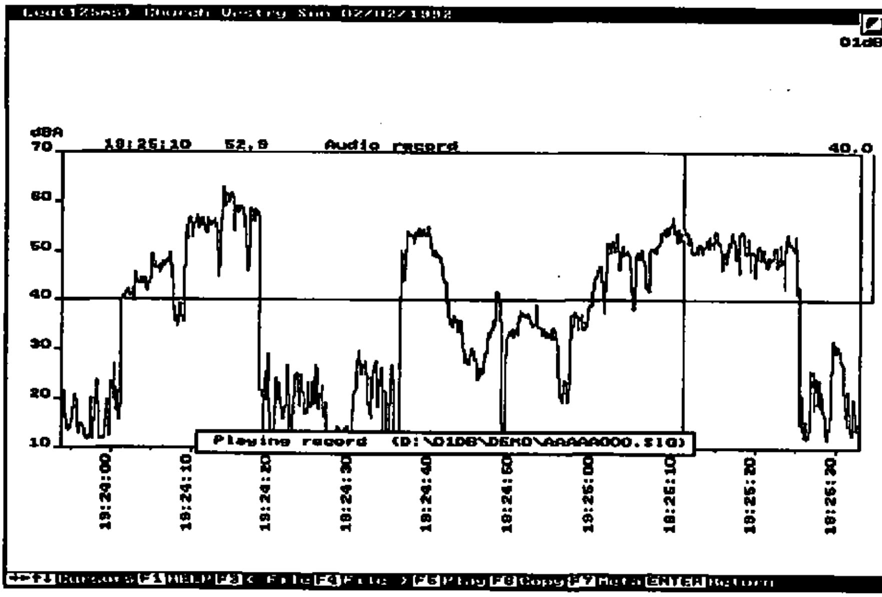

Figure 2 : A Typical Short L_{eq} Time History With Audio Event Replay In Progress.

3.2 Spectral Analysis.

The digital signal processor card contains fast fourier transform routines that allow the received input to be analysed in the frequency domain. The spectral analysis module allows the user to reanalyse digitally stored signal files into octave, one third octave, or narrow band spectrum. Recognising that such a system would have to fulfil conventional analysis requirements the FFT analysis allows normal features such as zooming and averaging to be incorporated, but with the extra power of storing results data on a screen or directly printing graphics or results tables on a standard printer. Alternatively, using an on-board co-processor the frequency analysis may be performed in pseudo-real-time. A typical analysis is shown in Figure 4.

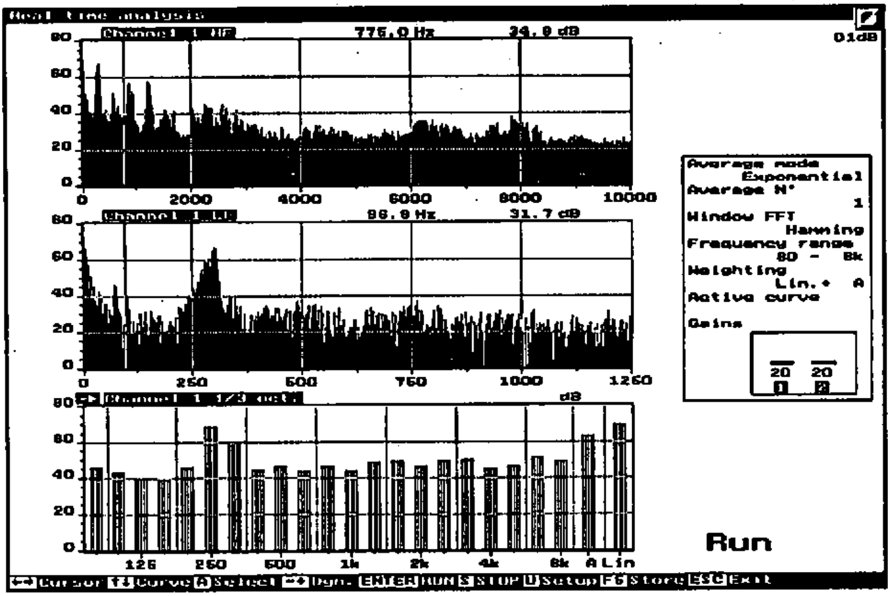

Figure 3: A Typical Real Time F.F.T. Spectral Analysis Performed On A Single Input Signal.

3.3 Acoustic Intensity and Sound Power Determination.

The European Machinery Directive (4) requires acoustic power determination for machines with an L_{eq} in excess of 85 dB(A). Such measurements may be obtained using either pressure methods or by use of sound intensity techniques, the advantages of the latter technique has been expounded by Fahey (5) and are primarily that a measurement may be made with the sound power source in-situ and that intensity techniques exclude the influence of other sound fields. Hence, it was desirable to develop an acoustic power determination module and this was achieved in a joint collaboration with Centre Tecnique des Industries Mecaniques (C.E.T.I.M.) (6). The computational power was novelly harnessed using an unmatched intensity probe with continuous narrow band phase error correction to attain accuracy previously possible only with costly phase matched intensity prbes. This produced a system not only satisfying the requirements of ISO 9614, but also suggested the measurement surface, allowed access to field indicators during the measurement, and provided ease of reporting field measurements.

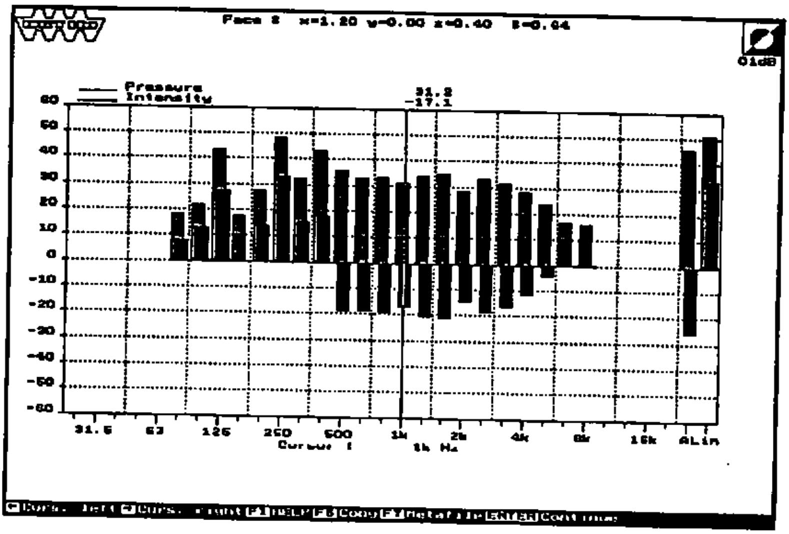

Figure 4: Intensity and Pressure in One-Third Octaves At A Particular Face During An Acoustic Power Determination.

3.4 Building and Architectural Acoustics.

Outbox processing techniques used in the early spectral analysis and Leq modules is ideally suited to many building and architectural acoustics measurements. This was first evidenced as a reverberation time add-on module which allowed measurement of octave and one-third octave R_{T60}'s and determination of isolation levels. With the advent of the latest international standards such as ISO 140 and ISO 717 then the reverberation time module has been enhanced to allow determination of additional parameters such as L_{nW} and R'_{W}.

A more recent addition to ARIA's building acoustics capabilities has resulted from joint developments with another French centre of excellence, the Centre Scientifique et Technique du Batiment (C.S.T.B.) in Grenoble. The newer module determines a building's impulsive response to an internally generated pseudo-random white noise burst. By using a wideband noise signal the limitations of traditional sources such as gunshots namely non-linearity and poor dynamic range are avoided. By performing an FFT analysis on the received signal then architectural indices such as RASTI, STI, and the Lochner-Burger signal to noise ratio may be calculated. A typical echogram and decay curve is given in figure 6.

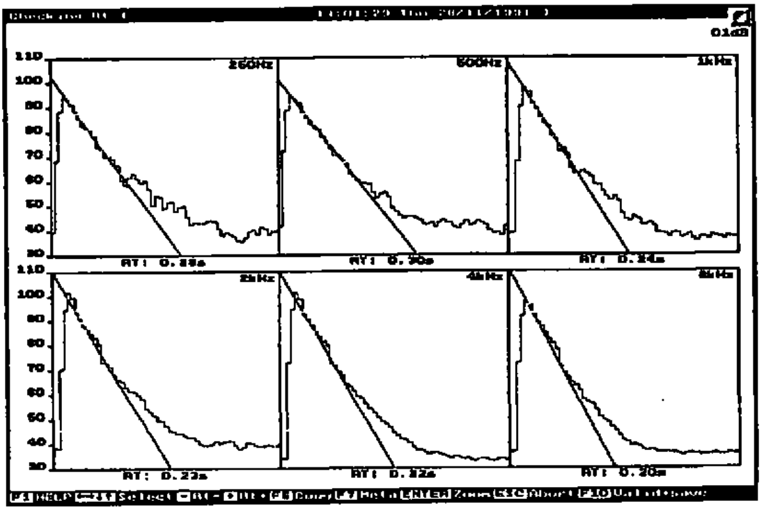

Figure 5 : Octave Band Reverberation Time Curves.

3.5 Time Delay Spectrometry.

A final application module has been the implementation of a time delay spectrometry analyser. The user programmed t.d.s. signal is generated by the d.s.p. board's analogue output and the returning signal is digitally stored for subsequent analysis. The analytical procedure can then be repeated using differing filter specifications to generate energy time curves, phase difference, and group delay curves. Again, the "number crunching" skills of the host computer have been skillfully utilised to allow powerful post-processing analysis to be repeatedly undertaken.

4. MEASUREMENT ACCURACY.

While it is relatively easy to develop an indicative system, all ARIA system modules are designed to provide precision solutions to known measurement problems. This has resulted in the component specifications far in excess of those normally associated with computer based instrumentation and a resultant associated cost. This philosophy was vindicated when the ARIA system became the world's first computer based acoustic measurement system to be verified as a type 1 sound level meter (7). Additionally, the FFT module has shown excellent agreement with classical analysers in independent comparative tests (8).

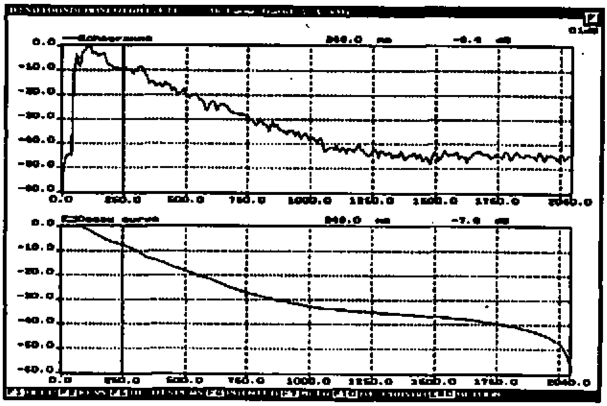

Figure 6: Echogram and Decay Curve Produced By Analysing A Room's Impulsive Response.

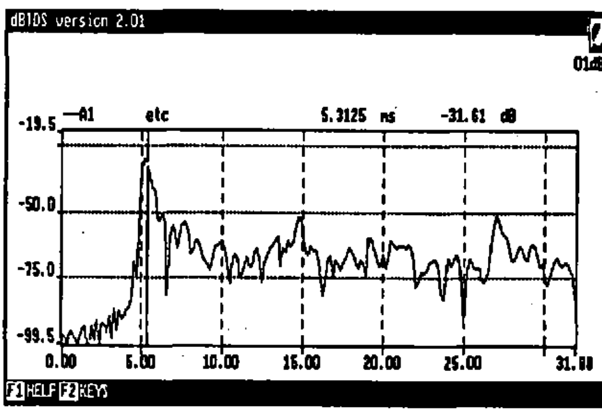

Figure 7 : Energy Time Curve from dBTDS.

5. FUTURE DEVELOPMENTS.

Since the ARIA system is essentially computer based, its future developments is limited only by the need to provide solutions to measurement problems. Therefore, future development may take four forms :

New modules geared to known problems such as vibration.
Customised modules for research or investigative use.
Upgraded modules to reflect changing international standards.
Alternative computer operating systems such as WINDOWS to increase ARIA's implementation possibilities.

6. CONCLUSION.

A precision acoustic measurement system has been successfully implemented on a laptop computer system. This provides a lightweight solution with all the presentation possibilities offered by today's generation of computer software.

All of the above supports the claim that the ARIA system truly represents a comprehensive, versatile, yet flexible and evolutive acoustic measurement system - a new kind of acoustics.

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