

### Measurement of Reverberation Time with the Single/Dual Channel Real-time Analyzer 2123/33

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#### Introduction

The determination of reverberation time is of interest for several acoustic applications. Examples of these are sound power measurements in reverberation rooms, building acoustic measurements and sound absorption.

A suitable measurement procedure for a given purpose depends on the frequency range of interest, the length of the reverberation time and the required precision.

#### Measurement Methods

Choosing a measurement method and procedure means that a lot of detailed decisions are made – consciously or unconsciously.

- These decisions concern:
- Main measurement parameters
    - Frequency range
    - Filter bandwidth
  - Excitation method
    - Interrupted noise or impulse
  - Measurement technique (sampling)
    - Exponential or linear averaging
    - Averaging time
    - Time interval between samples
    - Total “recording” time
  - Evaluation
    - Range
    - Principle (e.g. linear regression)

- Spatial averaging
  - Source positions
  - Microphone (or accelerometer) positions
  - Type of averaging (decays or reverberation times)
- Amount and precision of measurement results
  - Storage of decays or only reverberation times
  - Check of precision, only occasionally or more systematic

If standardized measurements are required, such as ISO 354, many deci-

sions are made beforehand, but there are still a lot of choices to make.

Measuring a reverberation decay implies the measurement of a multispectrum. During a decay “instantaneous” spectra are measured with a user-defined time interval between two consecutive spectra down to nominal 5 ms. The multispectrum concept is illustrated in Fig. 1. It is possible to inspect the decays by “cutting” the multispectrum and showing the level as function of time in a display type called Slice, see Fig. 1.

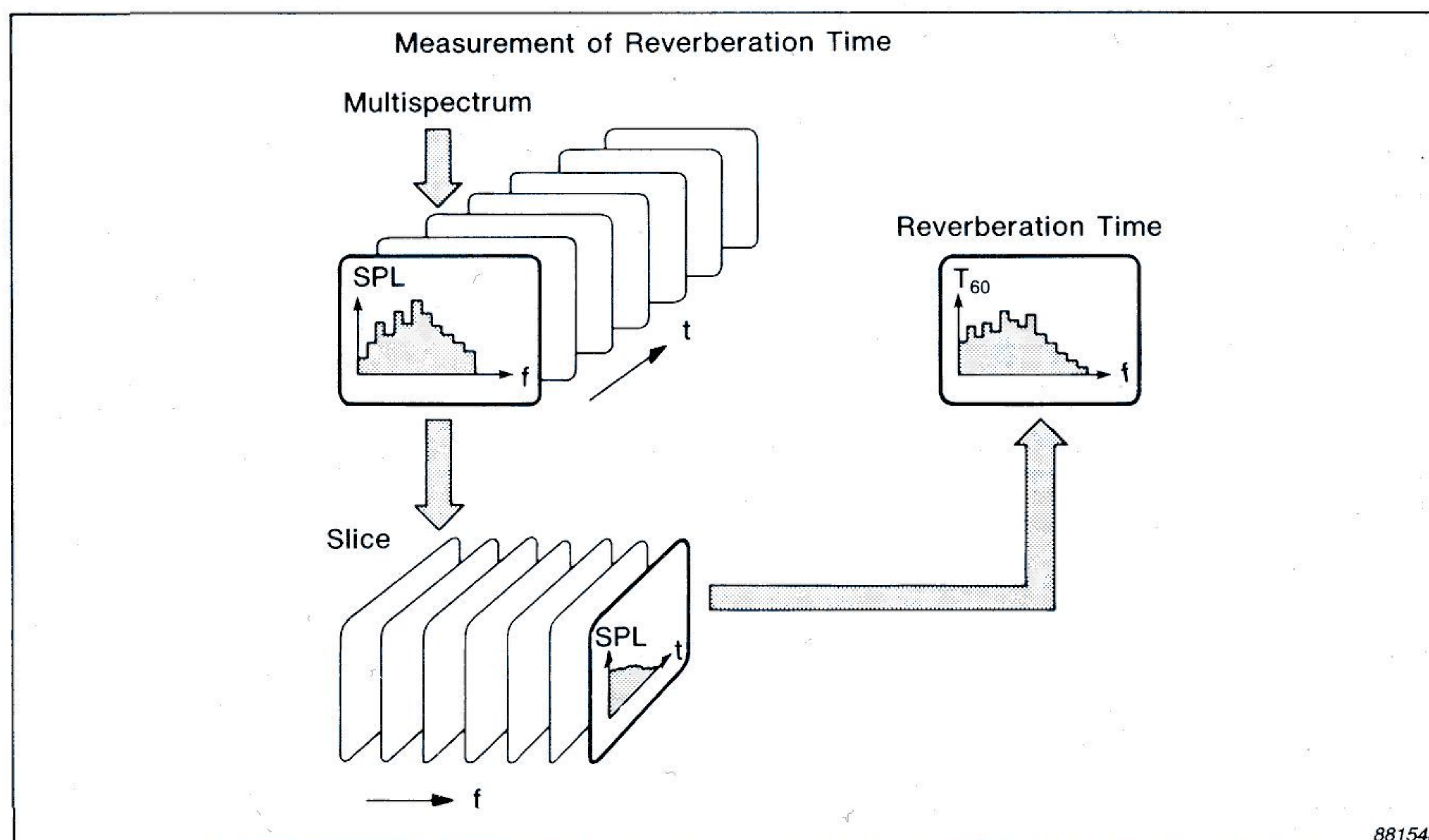


Fig. 1. Illustration of the multispectrum concept

When measuring reverberation time in practice (field or laboratory), spatial averaging is necessary. This can be an averaging of reverberation times or of the directly measured data, i.e. averaging a number of multispectra. The latter is illustrated in Fig. 2. The analyzer has an input memory and a buffer memory, and averaging of multispectra can take place in the buffer memory. "Multi 50 Rate: 20 ms" specified in the input memory means that 50 spectra are recorded with a time interval of 20 ms between spectra. "Avg. Multi 5" in the buffer memory line means that a measurement is made 5 times and that the averaged multispectrum, which is the average of the five measurements, is stored in the buffer memory.

## Measurements with interrupted noise

Fig. 3 shows a typical measurement set-up for a reverberation time measurement using interrupted noise; typical instrumentation is shown in Fig. 4. For spatial averaging the analyzer can automatically control either a Rotating Microphone Boom Type 3923 or a Multiplexer Type 2811. The multiplexer can, of course, also be controlled manually.

It should be noted that when noise-burst signals are used both the ON

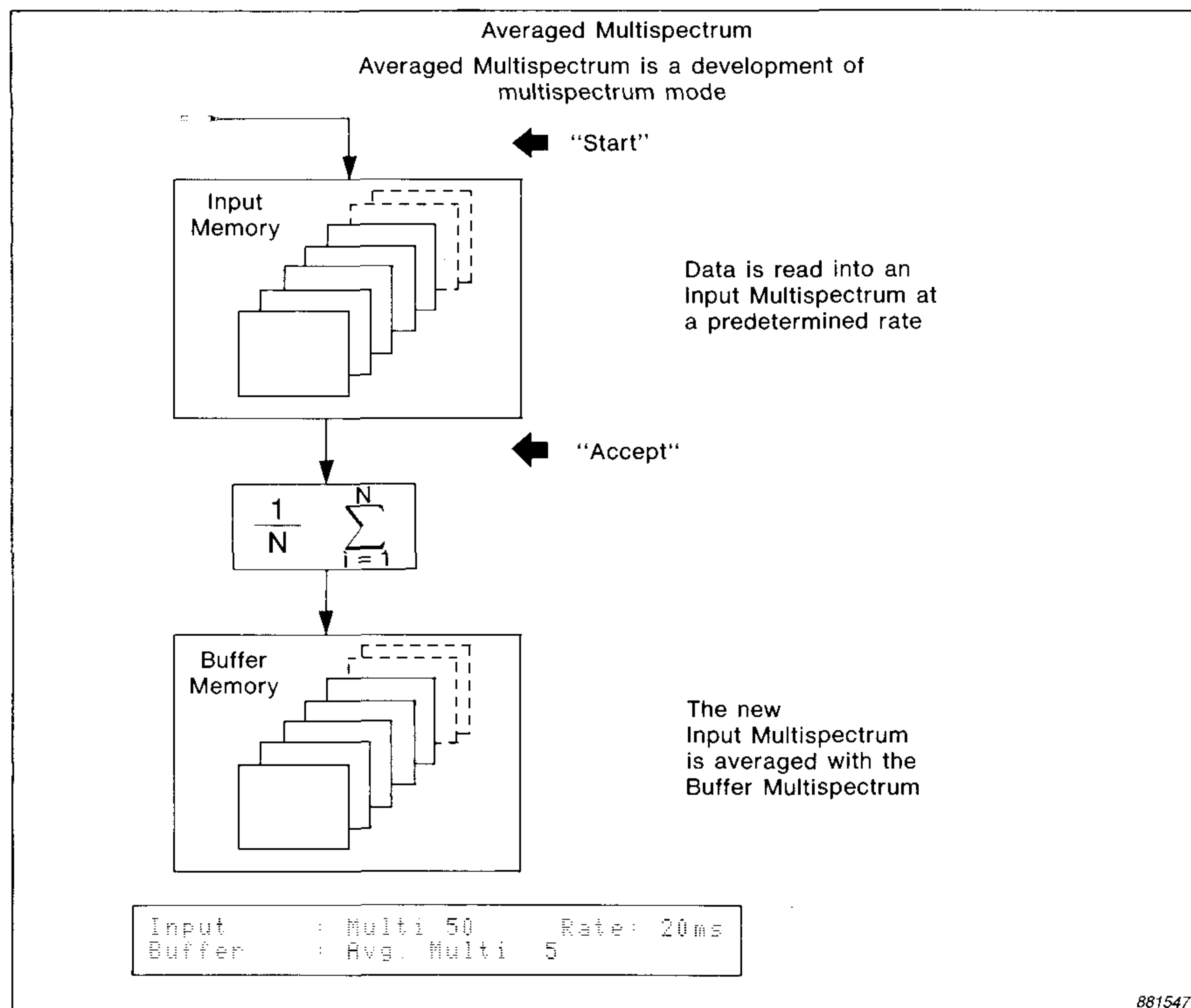


Fig. 2. Illustration of averaged multispectrum

time and the OFF time must be longer than the reverberation time.

Calculation of reverberation time from the measured multispectrum is done by recalling the function no. 50:Reverb. The details of how the

reverberation time is to be evaluated need not be specified before the measurements. The multispectrum is a database, which can be used for calculation of a variety of reverberation times, for example, corresponding to different evaluation ranges, see Fig. 5.

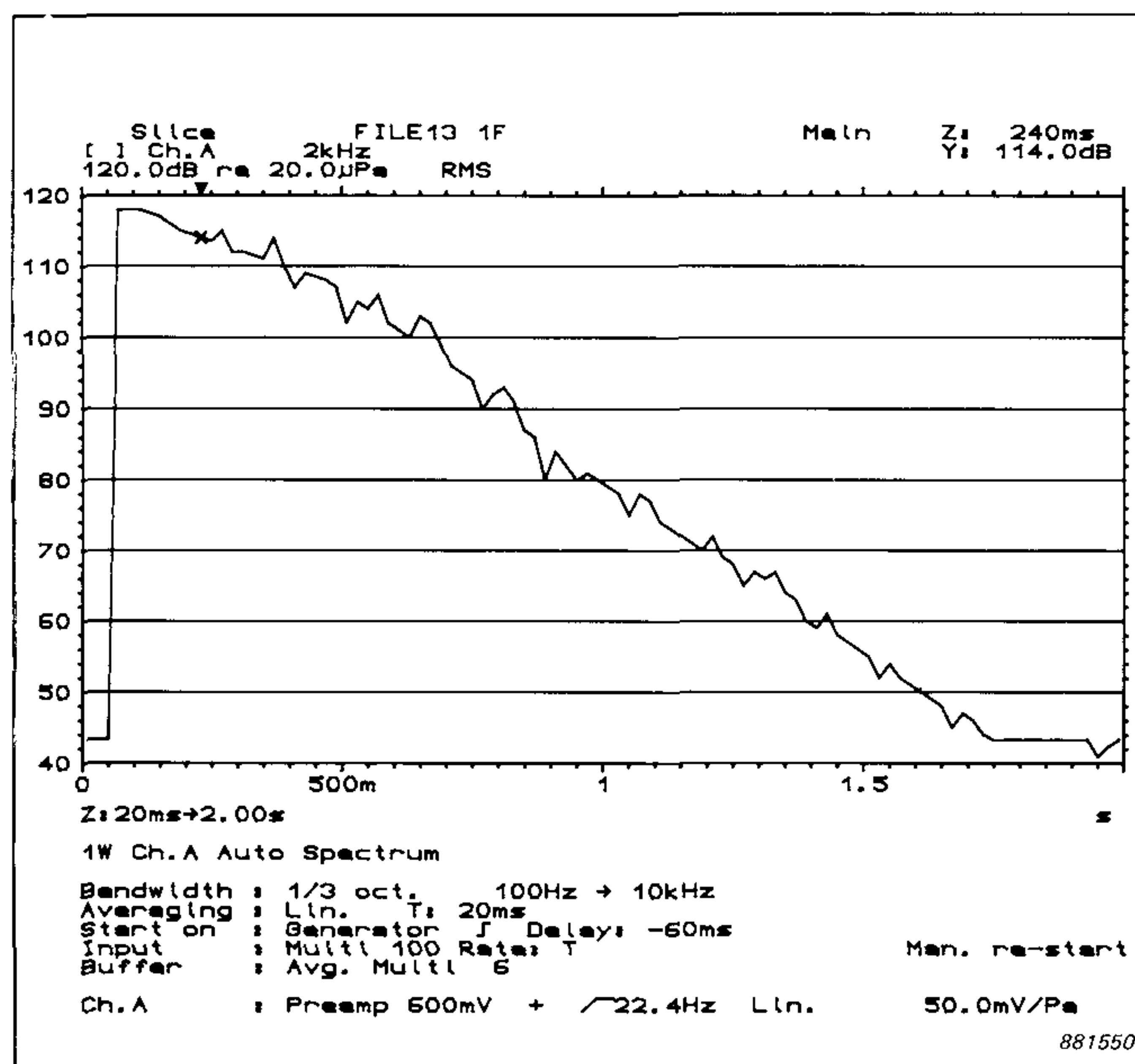


Fig. 3. Typical measurement set-up for a reverberation time measurement using interrupted noise

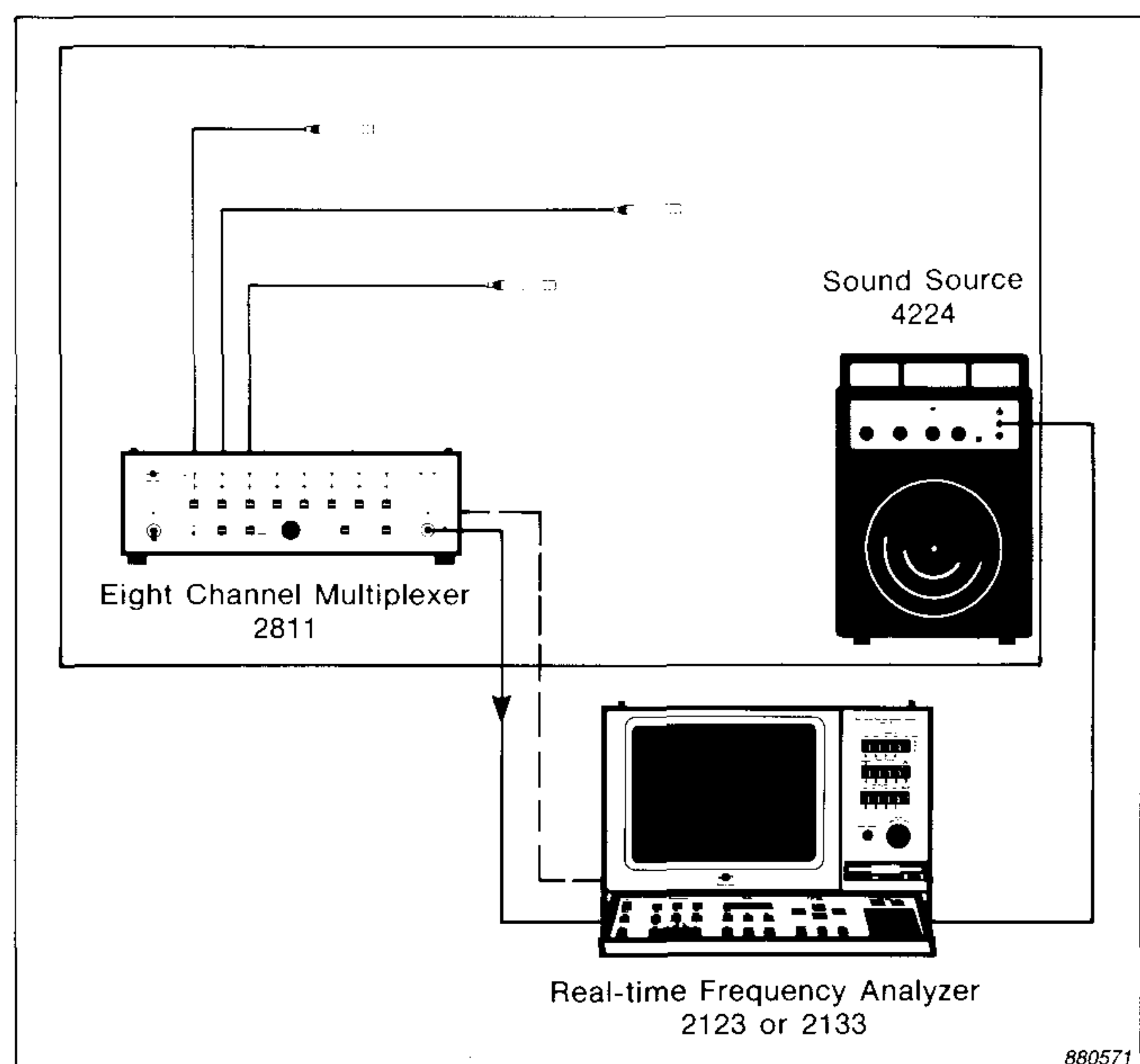


Fig. 4. Instrumentation for reverberation time measurements according to the interrupted noise method

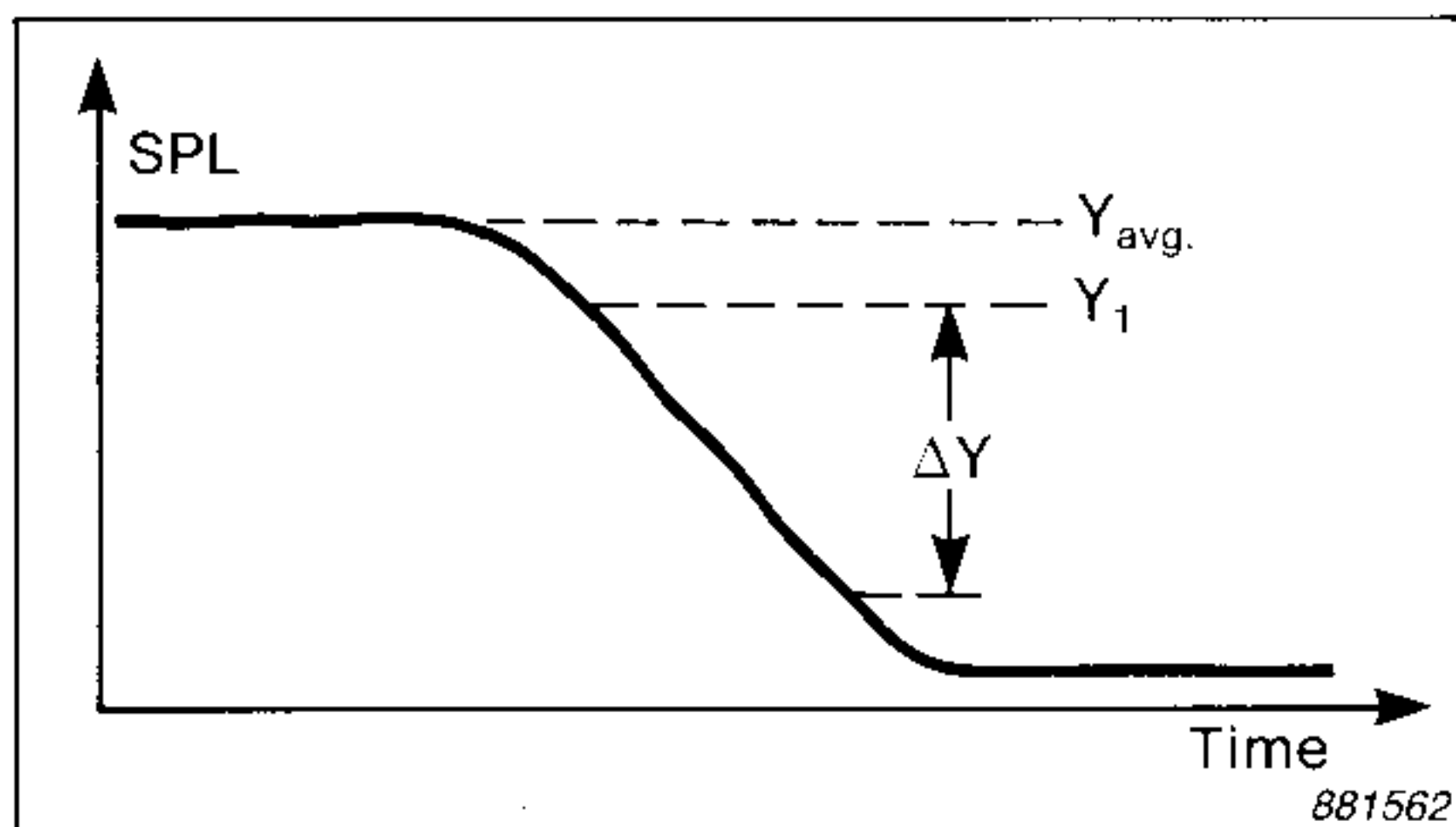


Fig. 5. Reverberation decay with evaluation range used in calculations of reverberation time

Reverberation times corresponding to evaluation ranges 5 to 15 dB, 5 to 25 dB and 5 to 35 dB below steady-state level, can simply be typed in as user-defined functions:

$$T_{10} = \text{REVERB}(\$ , 5, 10)$$

$$T_{20} = \text{REVERB}(\$ , 5, 20)$$

$$T_{30} = \text{REVERB}(\$ , 5, 30)$$

Further, it is possible to define the evaluation individually for each filter band. This is made by omitting the constants in the formula implying that  $Y_{\text{avg}} - Y_1$  and  $\Delta Y$  are specified in a table connected to the function set-up.

Beside the evaluation range, it is possible to specify the minimum number of samples within the evaluation range. The reverberation time for a given frequency band is calculated, if the conditions are fulfilled. If not, a change of conditions may be considered.

Calculation of reverberation time is made by a linear regression on curve points within the defined evaluation range. The reverberation time as a function of frequency can be shown on the screen. A warning line below a result means that the correlation coefficient is below a user-specified value (default 0,95). A warning line at a frequency without result means, that the other above-mentioned conditions are not fulfilled, see Fig. 6.

## Measurement with impulse excitation

Fig. 7 shows a typical measurement set-up for measurements of reverberation time using impulse excitation, and Fig. 8 shows an instrumentation example.

When the recording has been made, the result can be inspected directly, but it is also possible to use backwards

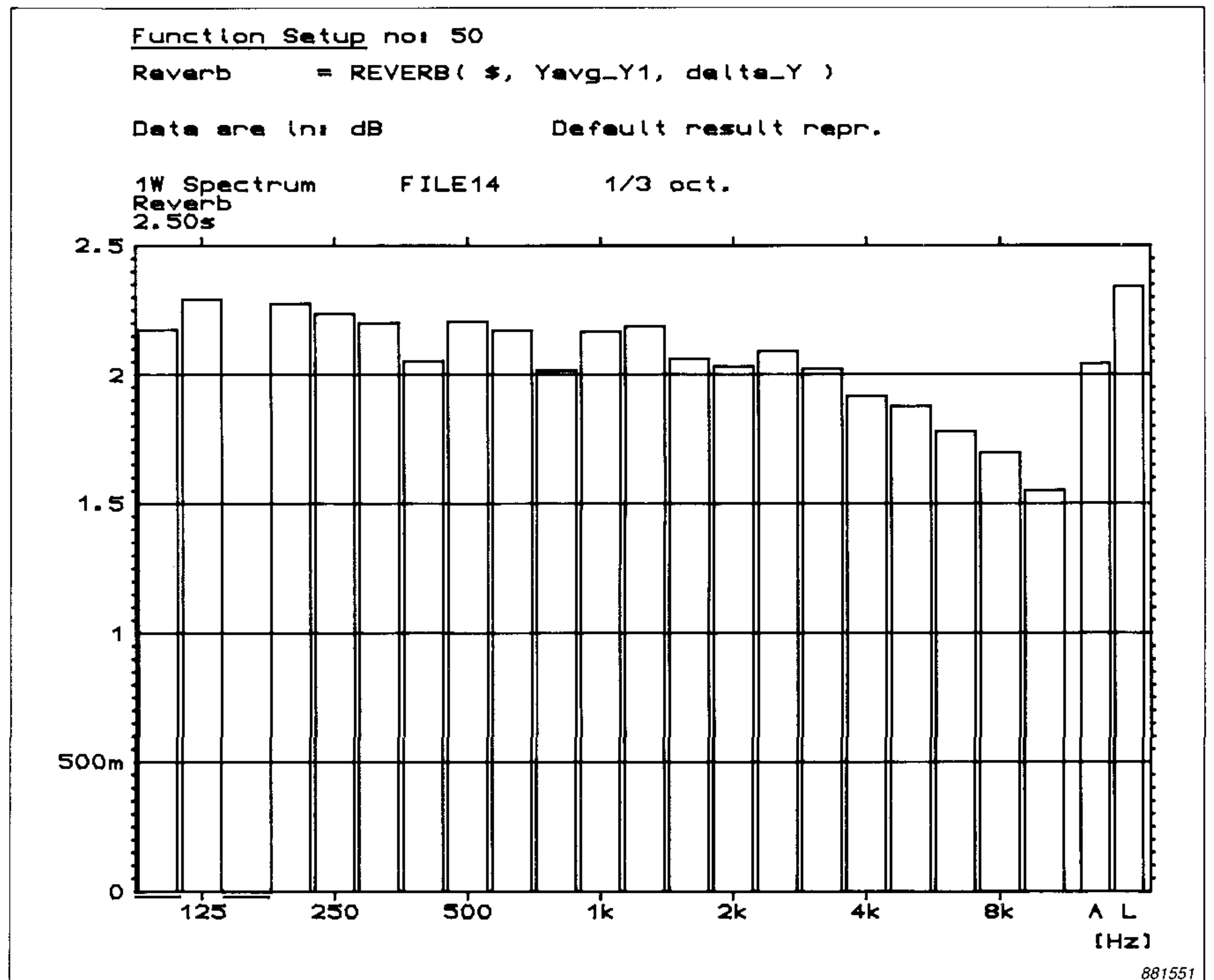


Fig. 6. Reverberation time calculation using the function Reverb.

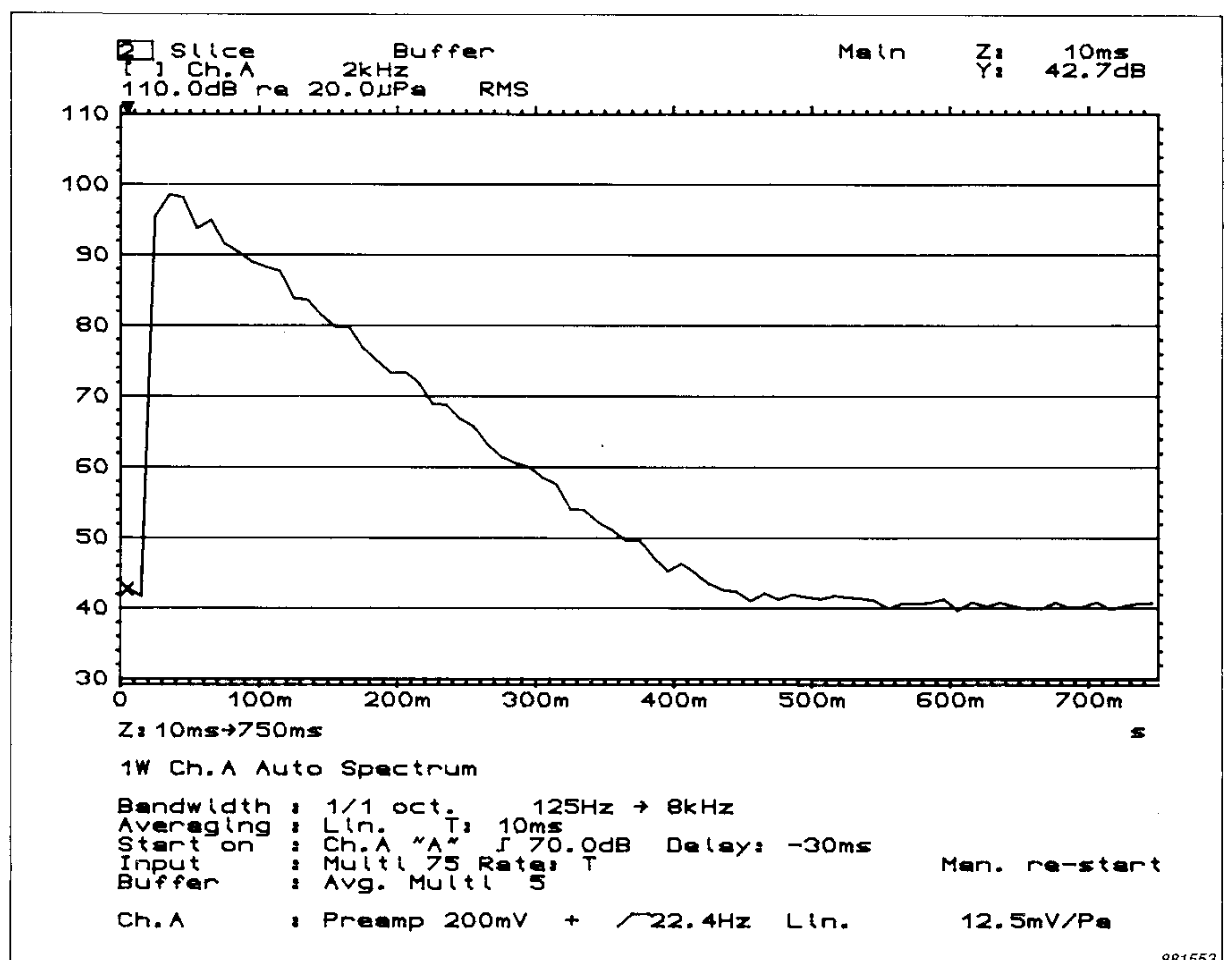


Fig. 7. Typical measurement set-up for a reverberation time measurement using impulse excitation

integration according to Schroeders method, by using the function no. 52: Back\_Int. A detailed study of decays can be made on the screen using the delta cursor and the corresponding reverberation time can be read in the

upper right corner of the screen, Fig. 9. However, the calculation of reverberation time can be made directly on the sampled impulse response using the function no. 51: Reverb Back.

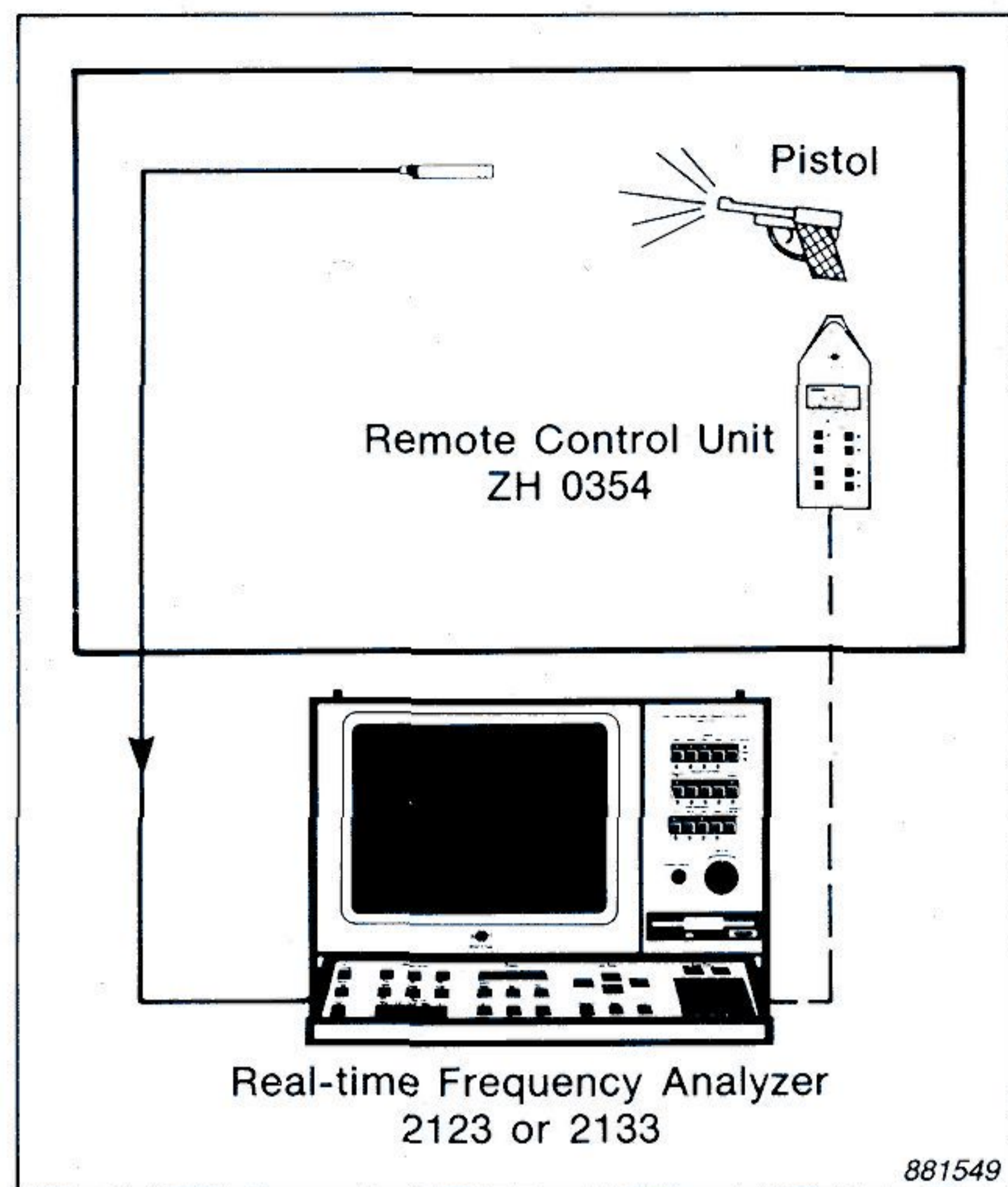


Fig. 8. Instrumentation for reverberation time measurements according to Schroeder's method of integrated impulse response

## Averaging of reverberation times

In some situations with several microphone/sound source positions where the initial sound pressure levels are not the same, averaging on samples will create curvature on the decays, which will cause misinterpretation of the result.

Therefore, it can be an advantage to average the reverberation times. An example could be to average three reverberation times, each determined from three decays and each identified by a suitable name, such as T1, T2 and T3. Each reverberation time is stored on disk, identified by its file name. When the measurement procedure is finished the final reverberation time is

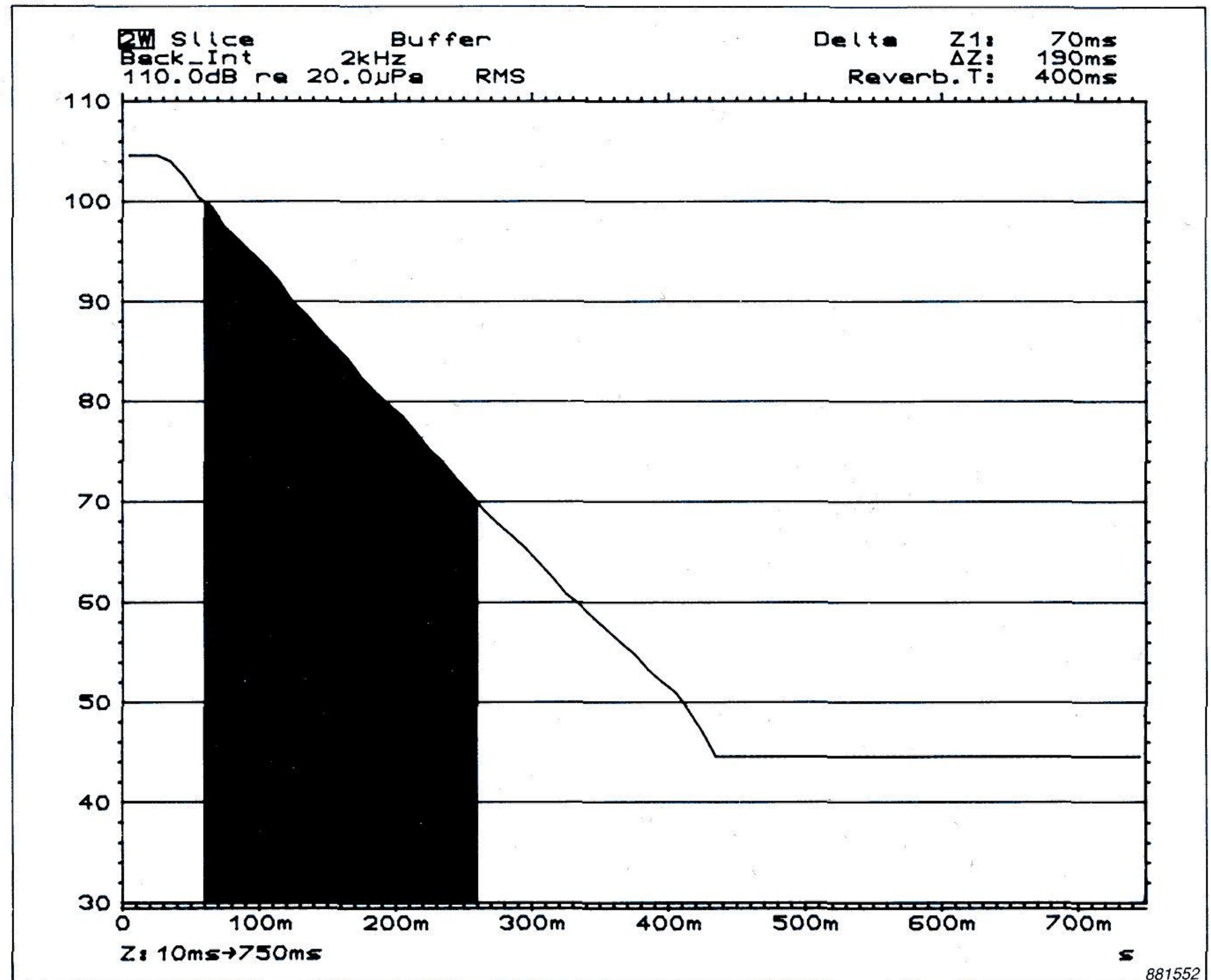


Fig. 9. Backwards integration of the same decay as Fig. 7 and using the delta cursor for calculation of the reverberation time

calculated by use of the user-defined function:

$$RT = (T1 + T2 + T3)/3$$

## Conclusion

This application note has described how reverberation time can be measured and calculated by use of the single/dual channel Real-time Analyzer Type 2123/33. Different averaging techniques have also been described. Documentation of the results is available via the 2123/33 screen dump and digital plotter outputs.

## References:

- [1] ISO 3382 "Acoustics – Measurement of reverberation time in auditoria"
- [2] ISO 354 "Acoustics – Measurement of sound absorption in a reverberation room"
- [3] Schroeder, M.R.: "New Method of Measuring Reverberation Time" *Journal of the Acoustical Society of America*, 1965

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