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OBJECTIVE MEASUREMENTS OF SPEECH INTELLIGIBILITY UNDER HIGHLY REVERBERANT CONDITIONS

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INTRODUCTION

Interest in measuring speech intelligibility started in the beginning of this century. Investigations tried to find methods which were able to evaluate speech intelligibility. This is rather difficult because many factors influences, so until now only a few objective methods and subjective methods have been used. The subjective methods are very time consuming and uses a lot of subjects listening and are therefore quite expensive.

Objective methods ought to produce the same results as subjective methods, but they should be very much faster. The RASTI (Rapid Speech Transmission Index) method is described in an IEC draft standard (1). It is the first time ever that it has been possible to measure speech intelligibility in rooms in 8 seconds and both the background noise and the reverberation time are taken into account.

THE RASTI METHOD

RASTI is a method of rating the intelligibility of transmitted speech and is based upon the Speech Transmission Index method (2,3,4,). Perfect transmission of speech implies that the envelope function of the speech signal at the listeners position corresponds to the signal at the speakers mouth. The speech intelligibility, can be quantified from a measure of the change in modulation of the speech envelope as a result of reverberation and background noise, Fig.1.

The reduction of the modulation can be expressed by a modulation reduction factor. The modulation reduction expressed as a function of the modulation frequency is called the MTF (Modulation Transfer Function). The modulation transfer function provides an objective measure for speech intelligibility, and from it, the STI value is derived, Fig.2.

The test signal used in the RASTI method consists of two octave bands of noise as shown in Fig.3. The levels for these two bands are chosen to be equivalent to the average levels found in normal speech (L_{eqA} = 60 dB), equivalent to 59 dB in the 500 Hz octave and 50 dB in the 2 kHz octave, all levels given at 1 m from the speaker.

A RASTI measurement is made by transmitting the special test signal from the speaker's position (in the room considered or, in connection with public address system, in the control room) and analysing it at the listener's position. The reduction in modulation index for each of the nine modulation frequencies is calculated. The nine modulation reduction indices obtained are interpreted as though they were about by background noise alone, as indicated in Fig.4. A qualitative interpretation of the RASTI-values is shown in Fig.5.

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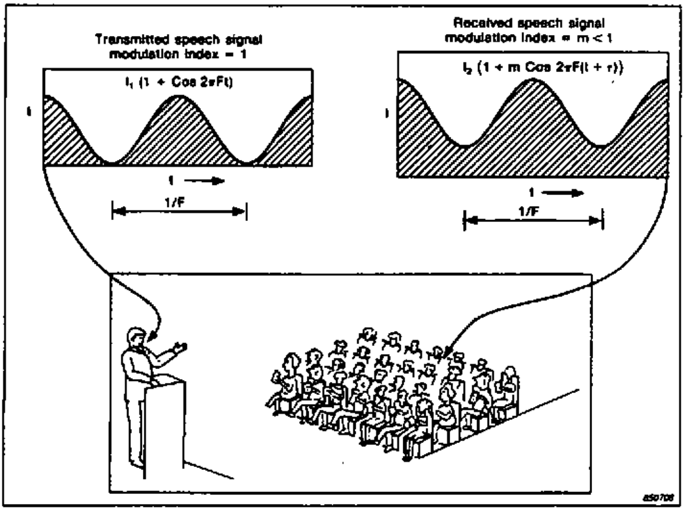

Fig. 1. Illustrates the reduction in modulation of the speech signal caused by noise and reverberation.

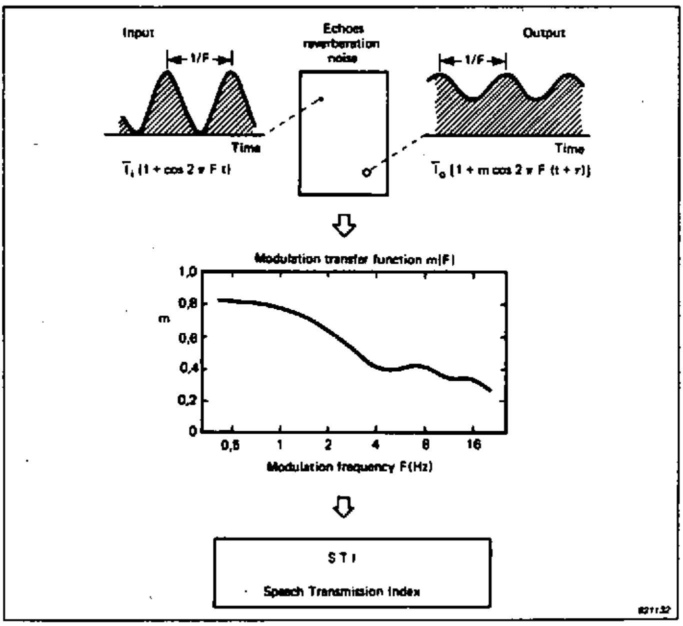

Fig. 2. Shows how Speech Transmission Index is derived from the modulation transfer function.

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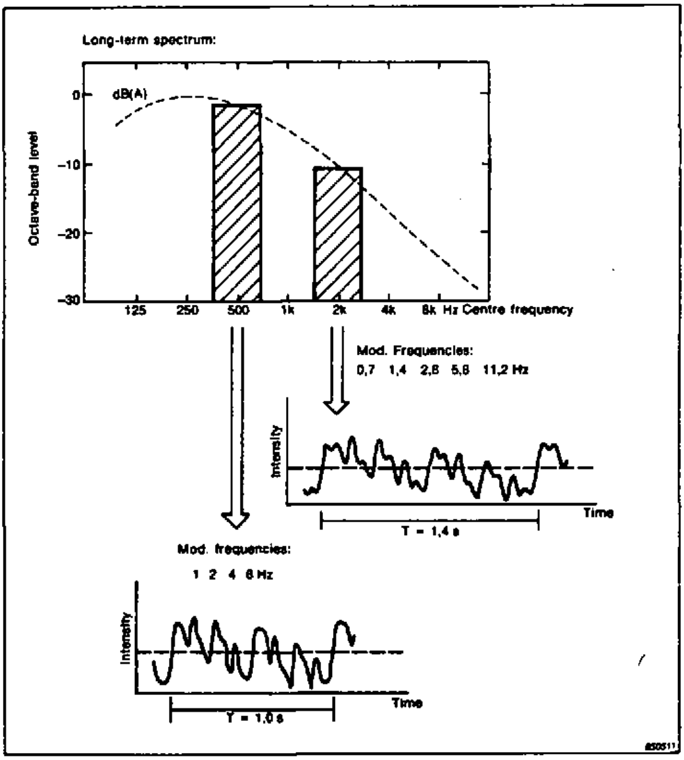

Fig. 3. Illustration of the RASTI test signal. Two octave bands of pink noise are presented at the same time, with an intensity envelope comprising four or five simultaneous modulation frequencies, and with a modulation index of 0.4 and 0.32 respectively.

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CALCULATION OF THE RASTI VALUE

Nine apparent signal to noise ratios, one for each modulation frequency, are calculated as follows:

$$X_i = 10 \, \text{Log} \, [m_i/(1-m_i)]$$

where X_i is the apparent signal to noise ratio corresponding to the measured modulation reduction factor, m_i.

The X_i values are truncated at X_i = 15 dB such that:

If $X_i >$ 15 dB, then let X_i = 15 dB
If $X_i <$ −15 dB, then let X_i = −15 dB

The arithmetic mean of these 9 X_i values is obtained and normalized to yield an index which ranges from 0 to 1.

RASTI value = $(\bar{X}_i + 15)/30$

Fig. 4. Calculation of the RASTI-value

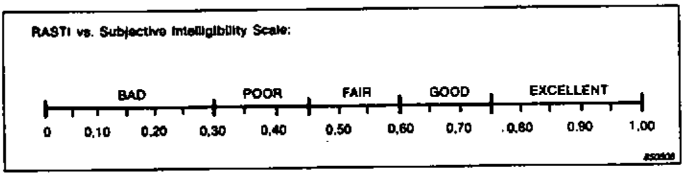

Fig. 5. Qualitative interpretation of RASTI

MEASUREMENTS

There excists many different applications for the RASTI method. By means of Brüel & Kjær Speech Transmission Meter. Transmitter Type 4225 and Receiver Type 4419 many different measurements have already been performed. One of the measurement performed was in The "Grundtvigs Kirke".

The "Grundtvigs Kirke" is a large church in Copenhagen consisting of a main nave and two side naves. The naves have a length of 56 m, the width is 10 m and 5,5 m, respectively, for which reason the total width sums to 21 m. The total volume is 25,000 m^3.

The reverberation time is very long in the church because of the large volume and the complete lack of sound absorption materials. At 80 Hz about 14 seconds down to about 1.3 seconds at 6.4 kHz due to absorption in the air.

In 1959 O.J. Pedersen performed some subjective measurements in order to evaluate speech intelligibility in the church, these measurement are compared with RASTI measurements in fig.6. There is as can be seen a very good correlation between the subjective measurements and the RASTI measurements. The discrepancy is position 4 can be explained from very high sensitivity to fit the exact position. This is made clear in the contour plot shown in fig.7.

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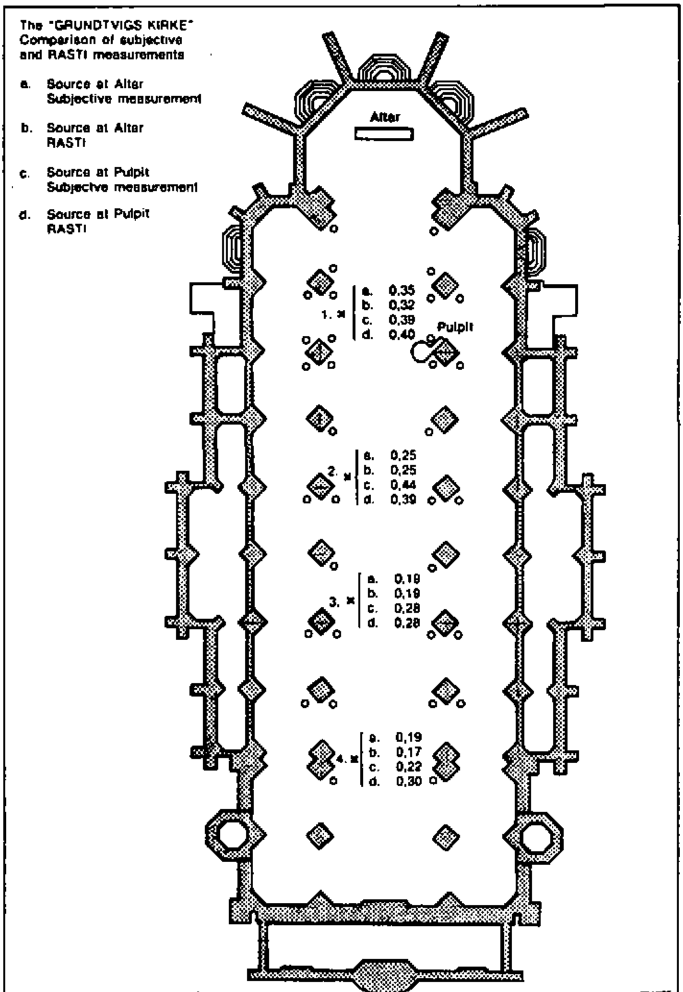

Fig. 6. Comparison of results from subjective and RASTI measurements. Transmitter placed on pulpit.

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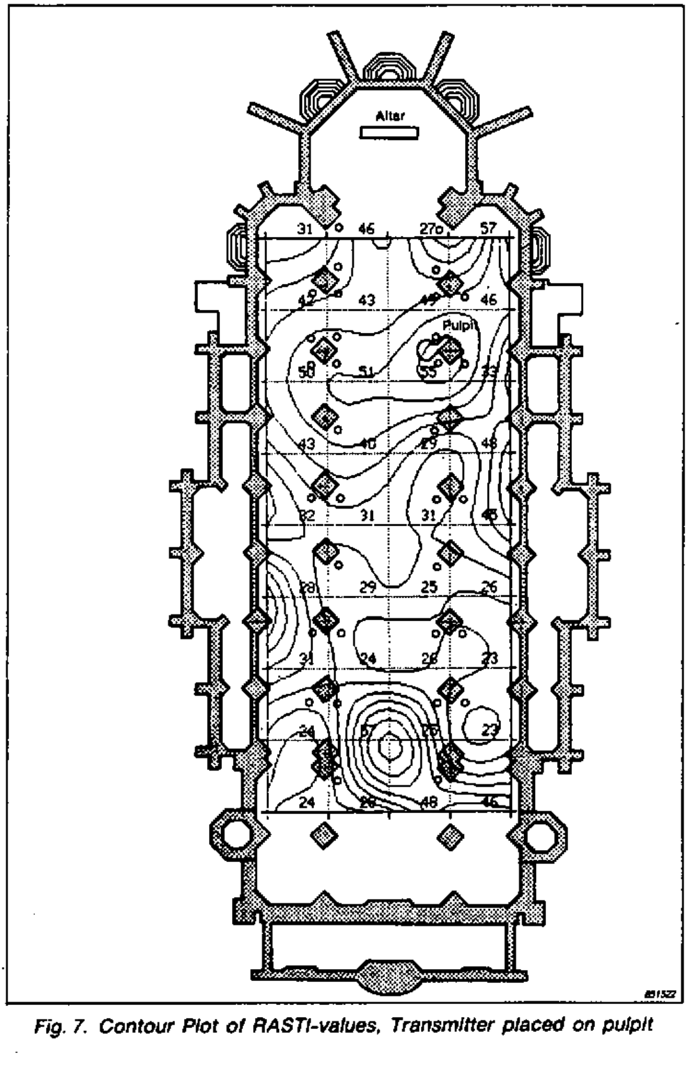

Fig. 7. Contour Plot of RASTI-values, Transmitter placed on pulpit

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In the summer of 1985 a new sound system was installed. The sound system consists of 33 loudspeakers equaly spaced in the church and interconnected via three different time delays, there is a fixed microphone on the pulpit and an portable michrophone for the alter. The measuring results shows that there has been an obvious increase in Speech Intelligibility in most part of the church, fig.8. But the RASTI measurements also makes clear that it is very difficuult to design a soud system, which is good when the listener is in the near-field of the speaker, in the "Grundtvigs Kirke" speech intelligibility has decreased in the near-field of the speaker with the new sound system on.

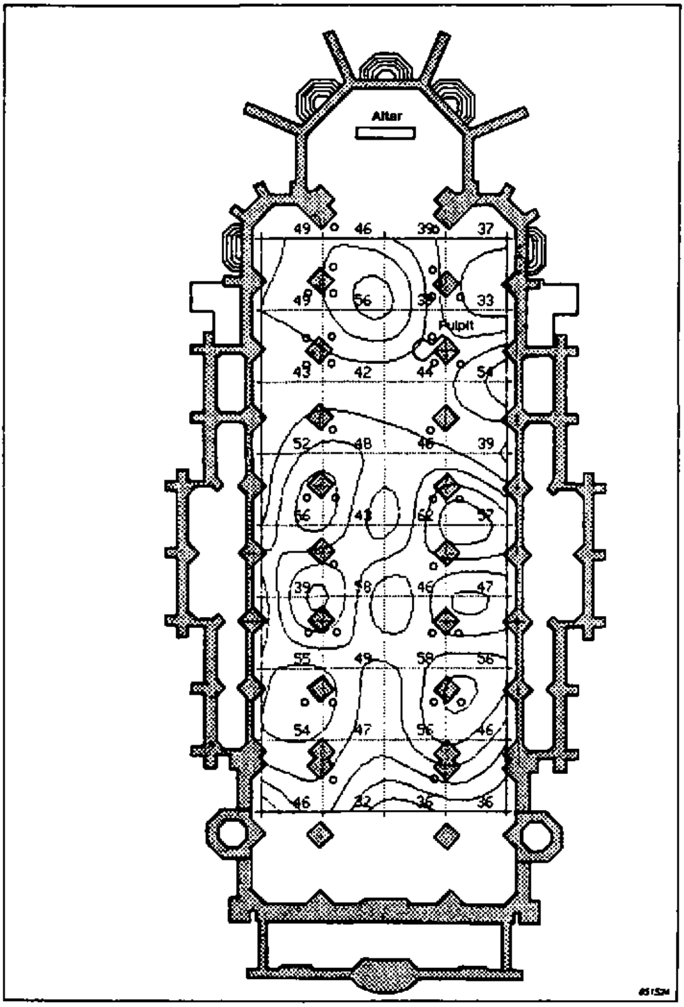

Fig. 8. Contour Plot of RASTI-values with new sound system installed, Transmitter placed on pulpit, compare also with Fig.7.

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CONCLUSION

The new RASTI method has been shown to be a very practical and fast method for the assessment of speech intelligibility. Measurements performed with the Brüel & Kjær Speech Transmission Meter have shown good correlation between subjective assessment and the RASTI-value.

REFERENCE

[1] Draft-IEC publication 268: Sound System Equipment – Part 16. "*Report on the RASTI method for the objective rating of speech intelligibility in auditoria*".

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[3] STEENEKEN, H.J.M. & HOUTGAST, T.: "*A Physical Method for Measuring Speech-Transmission Quality*", *J. Acoust. Soc. Amer. 67*, 318–326 (1980).

[4] HOUTGAST, T. & STEENEKEN, H.J.M. : "*A review of the MTF concept in Room Acoustics and its use for estimating speech intelligibility in auditoria*", *J. Acoust. Soc. Amer., 77(3)*, 1069–1077 (1985).