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- Catholic Churches, Sound-Reinforcement Systems and RASTI
- The Effect of Structural Coincidences on the Acoustic Fields Radiated from a Ribbed Plate under Light Fluid-Loading
- Piezoelectric Accelerometer Modification Based on the Finite Element Method
- Active Noise Control with a Simplified Multichannel Genetic Algorithm
- Weather Effects on Outdoor Sound Propagation
- A Literature Review of Diesel Engine Noise with Emphasis on Piston Slap

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EDITORIAL

ARTICLES

INFORMATION

Catholic Churches, Sound-Reinforcement Systems and RASTI

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This paper concentrates on the Rapid Speech Transmission Index (RASTI) values within churches and on their differences with the sound-reinforcement systems (SRS) off and on. The RASTI was measured in 31 unoccupied Portuguese Catholic churches built in the last 11 centuries. Four receiver locations were used in each church, with and without the use of the SRS from the altar area. The vast majority of churches tested with the SRS off have RASTI values not greater than 0.45 giving a poor rating in the quality of speech intelligibility. It was determined that only for distances greater than about 11 m from the altar area is the SRS useful in increasing the RASTI values. In general, the standard SRS systems used in Portuguese churches provide an average increase of 7 per cent in the RASTI values when all receiver positions are considered. Excluding the closest position to the sound source, the average increase of the RASTI is about 19 per cent from the RASTI values measured with the SRS off.

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1. INTRODUCTION

This study is part of a research program initiated in 1991 at the University of Porto (Portugal) and the University of Florida (USA). The aim of the program is to explore methods to evaluate, and compare the acoustical qualities of churches. The program involves field measurements in a very large number of Portuguese Catholic churches and has included two major components to date:

- *Objective studies* — Measurements of nine objective acoustical parameters at multiple locations in each church.[1-3]
- *Subjective studies* — Evaluations of live musical performances and speech intelligibility using a large sample of listeners and several locations in each church.[2,4,5]

This article presents a report regarding the first item and concerning the Rapid Speech Transmission Index (RASTI) measurements.

2. METHODOLOGY

2.1. Method Summary

The main research hypothesis is that the differences in the RASTI values among churches, with and without the use of their Sound-Reinforcement Systems (SRS), can be measured.

The study consisted of two parts both regarding RASTI analyses in unoccupied churches (apart from the two experimenters). The first part was to gather objective evaluations of the acoustical qualities of the churches, from the use of the RASTI, using only their own sound source at the altar area (the parameter named RASTI_SRS.off). The second part was to gather the same type of evaluations of the same sample of churches but with the use of the churches' SRS (parameter named RASTI_SRS.on). The loudspeaker arrangement commonly present in the churches tested was the distributed line source system (but with no signal-delayed), which is the standard in Portugal especially in older churches (see Fig. 1). In all the churches the pew area was hard-surfaced and sound reflecting.

The limitations using this type of methodology for evaluations were fully realised and understood. The acoustical response of a church changes when it is fully occupied (especially due to the increase of absorption in the seating area). Nevertheless this methodology gives a normalised sound environment that can be easily compared among churches.

The relative on/off performance of the acoustical environment can be compared among churches even if the SRS performance is so design-dependent as it is. This holds true in many situations because:

i) the distributed loudspeakers are usually placed vertically on a wall (or column) facing the opposite reflecting wall and not directed down to the pew area (that can be increasingly absorptive when the number of occupants increases);

ii) the majority of religious services in churches are now held with only a few persons, who do not cover most of the reflecting pew area (Sunday services are the exceptions).

Therefore, as the percentage of the seating area occupied by a congregation increases, the less useful the results of this study become. For these reasons, the data of this study should not be extrapolated to a fully occupied church or when it has a non-reflecting pew area.

For the RASTI measurement in each church, the transmitter location was in front of the main altar at about 1.65 m above the floor to represent a standardised speech situation during services. The sound level of the source was set to +10 dB compared with the RASTI standard level due to the large volume of some of the churches.[6] Four positions in each church were used for the receiver location (named *A*, *B*, *C* and *D* as seen in Fig. 2). In each receiver position three or four RASTI measurements were taken and then averaged to give the RASTI value at that location. All the statistical analyses were done using the *SYSTAT*® software.

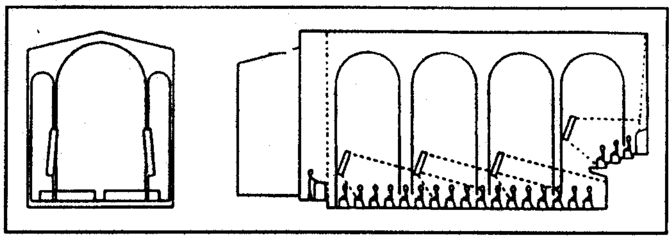

Figure 1. The loudspeaker arrangement commonly present in the churches tested was the distributed line source system (but with no signal-delayed) which is the standard in Portugal. [Adapted from D. Klepper and L. King.[6]]

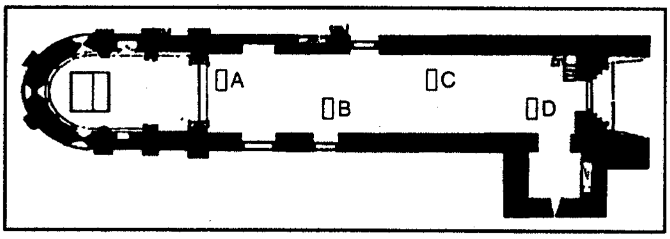

Figure 2. The four standard receiver positions from left (altar area) to right: *A*, *B*, *C* and *D*.

2.2. Sample of Churches Used

This study reports on acoustical field measurements made in 1998 in a survey of 31 Roman Catholic churches in Portugal (Table 1). Portugal is one of the oldest European countries and it has played a prominent role in some of the most significant events in world history. Portuguese churches can be considered as a representative example of Catholic churches found throughout the world.

The churches are a sample that represents 11 centuries of church building in Portugal. The oldest church tested was no. 13 (São Martinho de Cedofeita - Old, Porto) which was built around the 10th century. The most recent was church no. 20 (the new church of architect Siza Vieira in the town of Marco de Canaveses). It was completed in 1997.

The churches were selected to represent the main architectural styles found throughout Portugal and also to represent the evolution of church construction in Portugal: six Romanesque churches (10th-13th centuries), five gothic churches (13th-15th centuries), eight baroque churches (16th-18th centuries), six neo-classic (18th-19th centuries) churches and six contemporary churches (20th century). For more uniformity of the sample, only churches with a room volume of less than 17500 m^3 were selected for the study. The statistics of the main architectural features of these churches are displayed in Table 2.

2.3. The Parameter RASTI

The RASTI method involved measurement (with a Brüel & Kjær type 3361 set) of the reduction of a transmitted test signal that has certain characteristics representative of the human voice. This method, a simplified version of the Speech Transmission Index (STI), was developed in 1984 and has been related to subjective intelligibility (see Table 3).[7-9]

The advantage of RASTI compared with other methods is that it can be quickly evaluated without speakers or listeners. It involves the measurement of the reduction of a transmitted test signal that has certain characteristics such as intensity, modulations or directional proprieties, representative of the human voice. A transmitter generates pink noise at levels of 59 and 50 dB, or +10 dB (situation used in this survey), for the 500 Hz and 2000 Hz octave bands, respectively, to mimic the long-term speech spectrum and with similar directional proprieties that would be measured with a human speaker (at 1 m). The low frequency modulations that exist in speech are simulated by nine discrete modulation frequencies. A microphone receives the signal that is analysed by the receiver unit to calculate the RASTI from the modulation reduction factors.

Table 1. List of the 31 churches tested.

No.	Church name (Town)	Volume (m^3)	Avg. 1 kHz Rev. Time* (s)
1	Lapa (Porto)	11423	5.7
2	Clérigos (Porto)	5130	3.3
3	Santo Ildefonso (Porto)	3813	3.5 c
4	Santíssimo Sacramento (Porto)	6816	5.0
5	Gondarém (Porto)	3904	3.0 c
6	São Francisco (Porto)	12045	1.8
7	Grilos (Porto)	14497	5.5 c
8	São Bento da Vitória (Porto)	17460	5.5 c
9	Nevogilde (Porto)	1137	1.7 c
10	Sé Catedral (Porto)	15260	3.4
11	Santa Clara (Porto)	2491	1.3
12	São Martinho de Cedofeita - New (Porto)	8470	3.0
13	São Martinho de Cedofeita - Old (Porto)	1117	3.4
14	Nª Senhora da Boavista (Porto)	3740	3.6
15	Serra do Pilar (V.N. Gaia)	11566	7.7
16	Mosteiro de Grijó (V.N. Gaia)	13818	7.0 c
17	Mosteiro de Tibães (Braga)	8608	2.8
18	Sé Catedral (Braga)	13662	7.5 c
19	Mosteiro de Pombeiro (Felgueiras)	11380	7.5 c
20	Santa Maria (Marco de Canaveses)	8994	9.0 c
21	Bustelo (Penafiel)	6476	4.0
22	Cete (Paredes)	1515	2.4
23	Paço de Sousa (Penafiel)	6028	2.9
24	Cabeça Santa (Penafiel)	751	1.8
25	São Pedro (Paços de Ferreira)	2912	3.3
26	São João Baptista (Porto)	6048	4.0 c
27	Nª S.ra da Conceição (Porto)	12532	8.5 c
28	Santa Maria (Azurara)	7212	6.0 c
29	Matriz (Vila do Conde)	8408	6.0 c
30	São Pedro (Rates)	3918	3.1
31	Santa Clara (Vila do Conde)	5394	5.5 c

* measured values with a sound source at the altar area or calculated (c) values

The RASTI has a value between 0 and 1 and is derived from the measured reduction in signal modulation between the transmitter and receiver positions. It automatically includes the effect of reverberation and background noise because it is derived from the measured signal degradation.

Perfect transmission of speech requires that the received temporal speech envelope replicates the one emitted. This can be quantified in terms of alterations brought in the modulation of the speech envelope as the result of the acoustical characteristics of the room.

Very few data are available in the literature regarding RASTI in churches or in other religious buildings.[10-14]

Table 2. Simple architectural statistics for all churches tested.

Architectural Feature	Minimum	Median	Mean	Maximum
Volume (m^3)	751	6816	7630	17460
Area (m^2)	108	549	586	1300
Maximum Height (m)	5.9	16.1	15.7	35.1
Maximum Length (m)	17.9	37.2	39.3	63.0
Width Nave (m)	5.4	13.0	13.7	26.1

Table 3. Definition of the RASTI transfer function (see Ref. 9).

RASTI	Subjective Intelligibility Scale
0.00 - 0.30	Bad
0.30 - 0.45	Poor
0.45 - 0.60	Fair
0.60 - 0.75	Good
0.75 - 1.00	Excellent

3. RESULTS

3.1. Overall Results

Table 4 displays the 248 averaged RASTI data measured in each of the four receiver positions in the churches, for both situations (SRS off and on) and with their relative distances also shown.

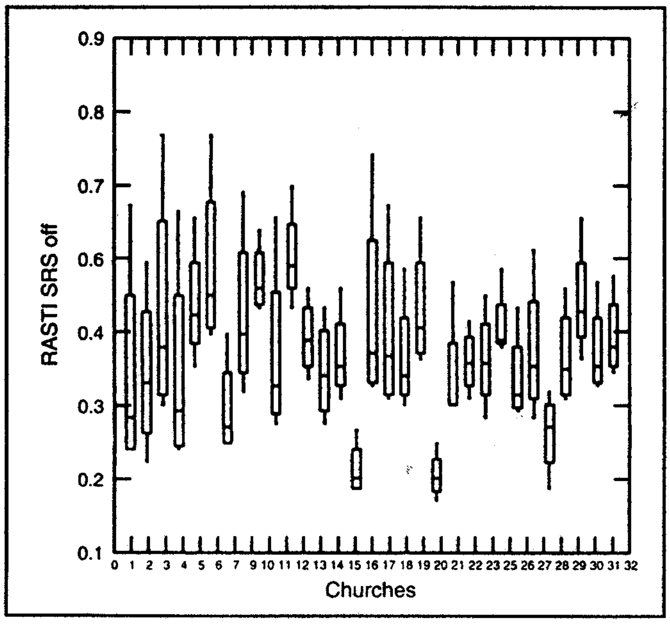

Figure 3. Within church variation of the RASTI values (SRS off) (the x-axis shows the 31 churches numbered 1 to 31 from left to right).

As a brief overview, Table 5 presents a simple general statistical analysis concerning all data collected (all four receiver positions, 124 measurement points). The Figures 3 and 4 present general analyses of the RASTI data collected for each one of the 31 churches in the survey. These figures show the within church RASTI variation (for each tested church) using boxplots. In them, each line and bar represents the within church variation where the centre horizontal line marks the median of the sample. The length of each box shows the range within which the central 50 per cent of the values fall, with the box edges (called *hinges*) at the first and third quartiles. The *whiskers* show the range of observed values that fall within the 1.5*Interquartile Range (the difference between the values of the two hinges). Values outside the *whiskers* (the outliers) are plotted with asterisks.

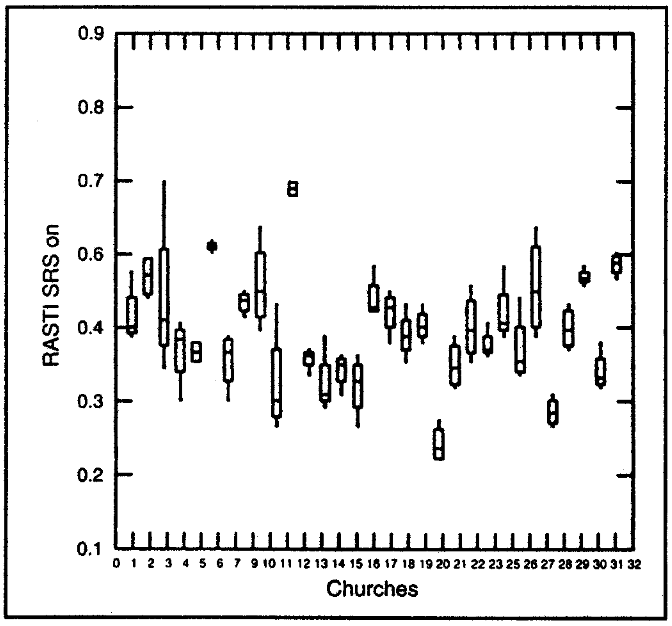

Figure 4. Within church variation of the RASTI values (SRS on) (the x-axis shows the 31 churches numbered 1 to 31 from left to right).

Table 5. Simple general statistics regarding all RASTI data collected (all four receiver positions: 124 RASTI values = 31 × 4).

Parameter	RASTI SRS.off	RASTI SRS.on
Minimum	0.18	0.24
Maximum	0.75	0.67
Range	0.57	0.43
Mean	0.42	0.44
Median	0.40	0.43
Standard deviation	0.12	0.09
Skewness (a)	0.54	0.33
Kurtosis (a)	0.08	0.14

(a) Skewness >> 0 indicates a long right tail, < 0, a long left tail; Kurtosis >> 0 indicates longer tails than a normal distribution, < 0 that it is flatter than a normal distribution.

The church mean RASTI values range from 0.18 to 0.66. Only one church has its mean RASTI value above 0.60. The vast majority of churches have RASTI values below 0.45 giving a poor rating in the quality of speech intelligibility. This value is below the minimum performance of 0.50 required in many spaces, for instance when using voice systems.[15]

Table 6 and Figs. 5 and 6 display the RASTI behaviour controlling for each of the four receiver locations (*A*, *B*, *C* and *D*). The Figs. 3 to 6 show that the SRS.on contributes for a sound field homogenisation within the churches. In a historic perspective, it is interesting to note that the SRS is the

Table 4. Data for all four positions (*A*, *B*, *C* and *D*) in each church regarding the RASTI with the SRS *off* and *on*.

Church No.	Distance to Sound Source (Altar) (m)				RASTI SRS.off (%)				RASTI SRS.on (%)			
	A	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*
1	4.5	18.9	29.7	41.5	64	36	26	26	53	45	43	44
2	3.8	7.4	13.2	20.4	55	40	33	24	50	55	55	49
3	3.2	8.7	13.1	19.6	75	48	36	33	67	46	38	45
4	4.3	11.9	19	27.9	63	37	27	26	33	43	45	42
5	5.4	11	15.5	23.2	62	48	46	39	42	42	39	39
6	4.6	12	19.7	26.5	75	54	46	44	56	57	58	57
7	8	14	19.4	23.6	44	32	27	27	33	42	39	43
8	5.5	11.5	16.3	22.5	66	47	41	35	49	50	48	46
9	6.5	9.5	13.8	16.6	60	53	48	49	60	52	48	44
10	6.5	13.8	24.2	31.5	62	39	33	30	48	34	32	29
11	8.4	12.3	17.5	22.7	67	54	48	55	65	65	67	67
12	5	10.5	15.3	20.4	51	45	41	37	40	37	40	41
13	3.2	6.1	8.5	13	48	41	34	30	43	34	32	34
14	4.4	7.7	12.5	17.2	51	40	38	34	38	34	40	39
15	14.8	20.4	22.8	27.4	29	23	20	20	40	37	29	35
16	4.6	10.6	17.4	25.2	72	45	37	36	54	47	47	48
17	6.7	15.8	25.8	33.6	64	46	35	34	42	50	47	48
18	9.8	20.7	31.1	41.4	54	39	33	36	48	43	43	39
19	5.7	11.3	17.3	23.8	62	48	42	40	48	45	44	42
20	7.3	11.5	16.8	22.3	27	18	22	21	30	27	24	24
21	5.8	12.3	19.8	29.2	52	33	33	33	43	40	35	36
22	5.2	11.1	17	23.2	46	41	34	38	39	42	51	46
23	6.8	12.8	17.5	23	50	41	38	31	45	41	41	40
24	5.6	9.1	12.4	15	54	43	42	43	54	45	45	43
25	6.3	11.8	16.4	20.9	48	36	33	32	49	38	40	37
26	7.3	16.3	23.4	29.8	57	41	37	31	43	60	54	46
27	9.4	15	22	28.6	35	31	28	20	29	34	32	30
28	7.9	13.6	19.1	24.7	51	42	34	35	41	42	48	46
29	6.5	13.3	19.7	26.3	62	48	40	47	51	54	52	52
30	5.2	9.3	13	15.4	52	41	37	36	42	35	36	37
31	7.6	12.1	15.5	20.1	53	44	40	38	54	55	56	52
V - volume (m³); A - Total Absorption (m²)												

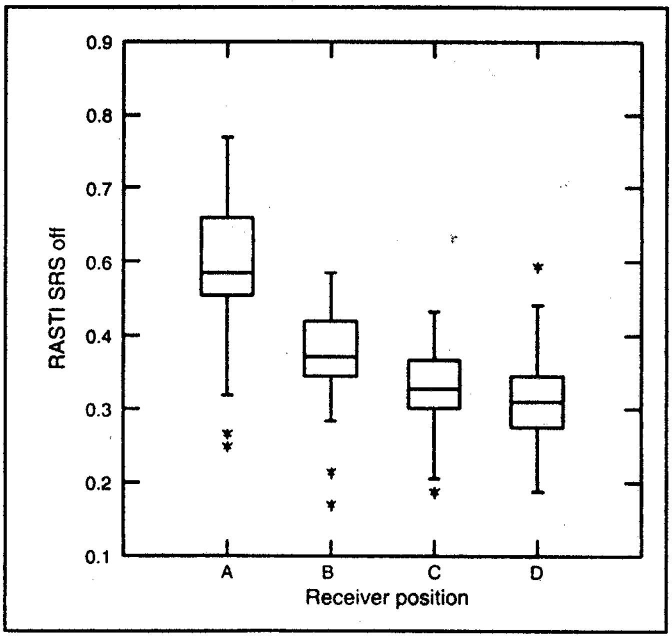

Figure 5. RASTI values (SRS off) controlling for the receiver position within the churches (*A* is the closest to the altar).

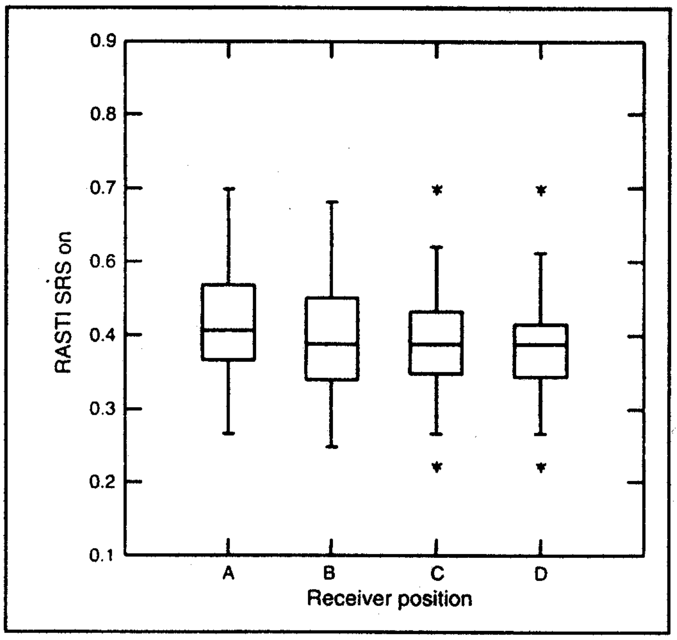

Figure 6. RASTI values (SRS on) controlling for the receiver position within the churches (*A* is the closest to the altar).

Table 6. Simple general statistics regarding the RASTI data collected, controlling for the receiver position (31 RASTI values = 31 churches).

Parameter	Receiver Position *A*		Receiver Position *B*		Receiver Position *C*		Receiver Position *D*	
	RASTI SRS.off	RASTI SRS.on	RASTI SRS.off	RASTI SRS.on	RASTI SRS.off	RASTI SRS.on	RASTI SRS.off	RASTI SRS.on
Minimum	0.27	0.29	0.18	0.27	0.20	0.24	0.20	0.24
Maximum	0.75	0.67	0.54	0.65	0.48	0.67	0.55	0.67
Range	0.48	0.38	0.36	0.38	0.28	0.43	0.35	0.43
Mean	0.55	0.46	0.41	0.44	0.34	0.44	0.34	0.43
Median	0.54	0.45	0.41	0.43	0.36	0.43	0.34	0.43
Standard deviation	0.12	0.09	0.08	0.09	0.07	0.09	0.08	0.08
Skewness (a)	-0.55	0.26	-0.84	0.40	-0.26	0.03	0.35	0.42
Kurtosis (a)	0.28	-0.19	1.06	-0.30	-0.27	-0.30	0.14	1.24

(a) Skewness >> 0 indicates a long right tail, < 0, a long left tail;
Kurtosis >> 0 indicates longer tails than a normal distribution, < 0 that it is flatter than a normal distribution.

twentieth century way of doing what the pulpits did during the previous five or six centuries. The pulpits were then a way to make the sound field more homogeneous by putting the sound source (the priest) in a more central and elevated area of the church.[16]

The Figs. 7 and 8 plot the variation of the RASTI values (SRS off and on) with the distance to the sound source (altar) with a logarithmic smoothing. These two figures show that there is a steep decrease in RASTI with increasing distance for the positions closer to the sound source (altar) where positions are located in the "direct field" and a reduced slope at larger distances where receiver positions are located in the "reverberant field". The best-fit equation (with a log smooth) found for the SRS.off as a function of distance is given in Eq. (1) with a $R^2 = 0.52$.

$$\text{RASTI\_SRS.off} = 0.797 - 0.148\,\lg(\text{Distance}). \quad (1)$$

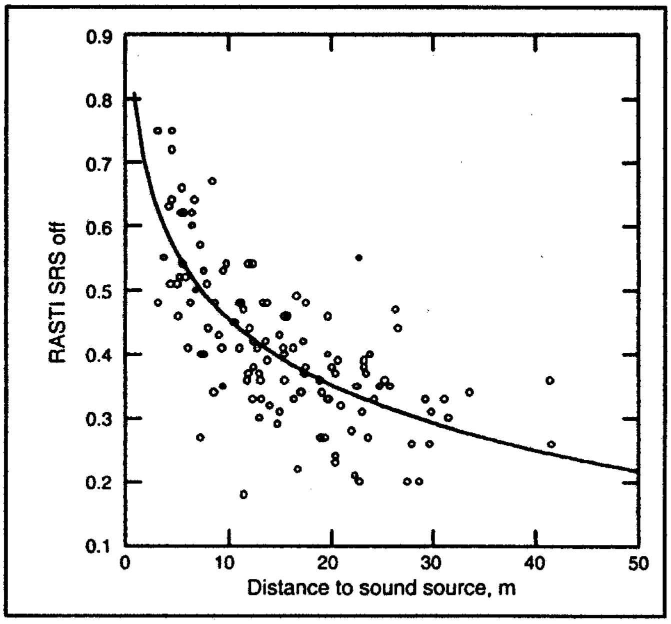

Figure 7. RASTI values (SRS off) against distance to the sound source (the test loudspeaker at the altar).

The best-fit line drawn on Fig. 8 is almost horizontal and indicates that no reasonable fit was found between so much scattered data (the regression curve presented has a $R^2 = 0.02$ and is of no value). A homogenisation of the sound field is the justification for those data.

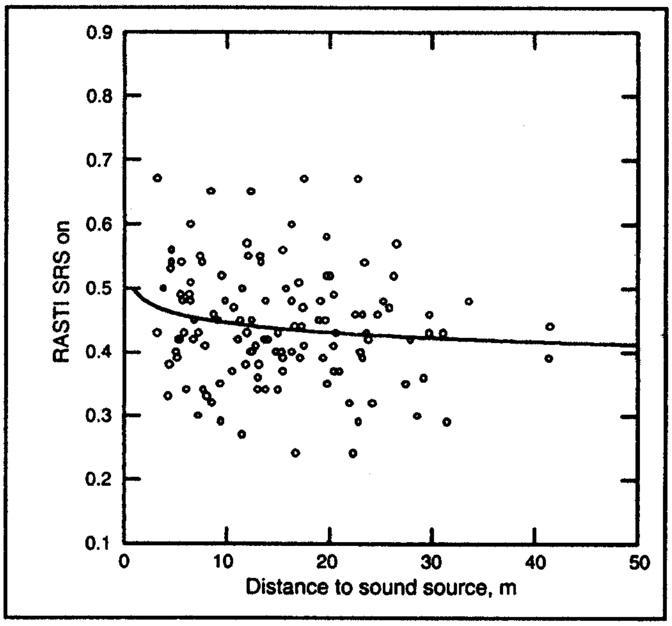

Figure 8. RASTI values (SRS on) against distance to the sound source (the test loudspeaker at the altar).

3.2. Comparison between RASTI with the SRS on and off

Figure 9 presents the RASTI values (data for all four receiver positions simultaneously: *A*, *B*, *C* and *D*) measured for both situations: SRS on and off with a logarithmic best-fit smoothing curve given by Eq. (2) with a $R^2 = 0.34$.

$$\text{RASTI\_SRS.on} = 0.602 + 0.402\,\lg(\text{RASTI\_SRS.off}). \quad (2)$$

To check the effect of the SRS in the RASTI values in the churches a new parameter was defined, the RASTI_Gain, which represents the difference between the RASTI values measured, in the same position, with the SRS on and off as given by Eq. (3).

$$\text{RASTI\_Gain} = (\text{RASTI\_SRS.on}) - (\text{RASTI\_SRS.off}). \quad (3)$$

If the value of the RASTI_Gain parameter is positive it indicates that the SRS.on improves the RASTI values in that church position; if it is negative it gives the decrease in the RASTI values at that receiver position by the use of the SRS. Figure 10 displays the RASTI_Gain with the distance to the sound source (altar). For distances up to about 11 m it is shown that the value for the RASTI_SRS.on is usually smaller than the value for the RASTI_SRS.off. Its best-fit (quadratic) equation is given in Eq. (4) with a $R^2 = 0.55$.

$$\text{RASTI\_Gain} = -0.00040(\text{Distance})^2 + 0.0226(\text{Distance}) - 0.202. \quad (4)$$

For measurement positions very distant from the sound source (more than about 30 m), the best-fit equation shows a decrease in the RASTI_Gain. However, due to the lack of sufficient measured data in that range of distances, this decrease should not be taken as definite and it is reasonable to expect a more horizontal behavior for the trend.

Figure 11 presents the RASTI_Gain data controlling for each receiver position (A, B, C and D). It is shown that for position A (the closest to the altar) the use of the SRS generally decreases the RASTI values. In fact, 87 per cent of the churches did not experience an improvement in their RASTI value at the receiver position *A*, when their SRS were used. Almost the opposite happens for receiver positions *B*, *C* and *D* where the SRS.on usually increases the RASTI values (up to +0.25). It can be concluded that the use of the SRS is not beneficial in increasing the RASTI values for the seats closest to the altar.

To understand better the effect of the SRS on the RASTI values within the churches an *Improvement Factor* (*IF*) was defined in Eq. (5).

$$IF = \frac{(\text{RASTI\_SRS.on})_{church.average}}{(\text{RASTI\_SRS.off})_{church.average}}. \quad (5)$$

Table 7 shows the *IF*s calculated for all 31 churches listed in order of increasing values of *IF*. The use of the SRS, con-

Table 7. Improvement Factors (*IF*) calculated for all 31 churches, listed by increasing *IF* values.

Church No.	RASTI SRS.off (church avg.)	RASTI SRS.on (church avg.)	IF (=On/Off)	RASTI SRS.on - RASTI SRS.off	IF' (without receiver position *A*)
5	0.49	0.41	0.83	-0.08	0.90
10	0.41	0.36	0.87	-0.05	0.93
30	0.42	0.38	0.90	-0.04	0.95
12	0.44	0.40	0.91	-0.04	0.96
14	0.41	0.38	0.93	-0.03	1.01
19	0.48	0.45	0.93	-0.03	1.01
13	0.38	0.36	0.93	-0.03	0.95
9	0.53	0.51	0.97	-0.02	0.96
21	0.38	0.39	1.02	0.01	1.12
3	0.48	0.49	1.02	0.01	1.10
8	0.47	0.48	1.02	0.01	1.17
24	0.46	0.47	1.03	0.01	1.04
16	0.48	0.49	1.03	0.02	1.20
6	0.55	0.57	1.04	0.02	1.19
23	0.40	0.42	1.04	0.02	1.11
17	0.45	0.47	1.04	0.02	1.26
29	0.49	0.52	1.06	0.03	1.17
4	0.38	0.41	1.07	0.03	1.44
18	0.41	0.43	1.07	0.03	1.16
28	0.41	0.44	1.09	0.04	1.23
27	0.29	0.31	1.10	0.03	1.22
25	0.37	0.41	1.10	0.04	1.14
22	0.40	0.45	1.12	0.05	1.23
11	0.56	0.66	1.18	0.10	1.27
20	0.22	0.26	1.19	0.04	1.23
7	0.33	0.39	1.21	0.07	1.44
1	0.38	0.46	1.22	0.08	1.50
26	0.42	0.51	1.22	0.09	1.47
31	0.44	0.54	1.24	0.11	1.34
2	0.38	0.52	1.38	0.14	1.64
15	0.23	0.35	1.53	0.12	1.60
		Average	1.07	0.03	1.19

sidering all four receiver positions within the churches, increases on average, 7 per cent the RASTI values or 0.03 their RASTI absolute values. However, only 30 per cent of the churches tested show a noticeable average improvement of more than 10 per cent of their RASTI values by the use of the SRS. While fully 26 per cent of the churches even experience a decrease in their RASTI values. In fact, only in seven churches (23 per cent of the sample) the RASTI values achieved the minimum performance of 0.50 required in many spaces when using voice systems.[15] The highest *IF* values found were for churches no. 15 and no. 2 that have a circular (or almost circular) plan shape. Due to their plan shape there is no largely delayed signal arriving, at the majority of the receiver positions, from the surrounding loudspeakers, as normally happens in longer churches.

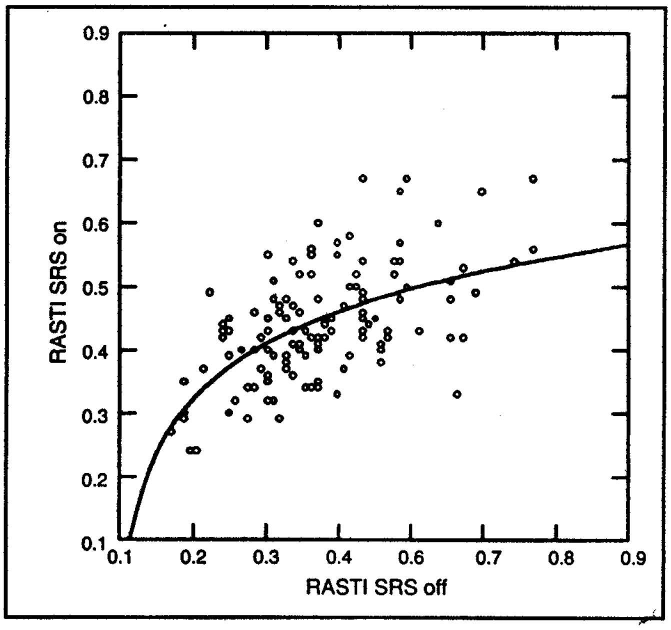

Figure 9. Comparison among RASTI values (SRS off and on) with logarithmic smoothing.

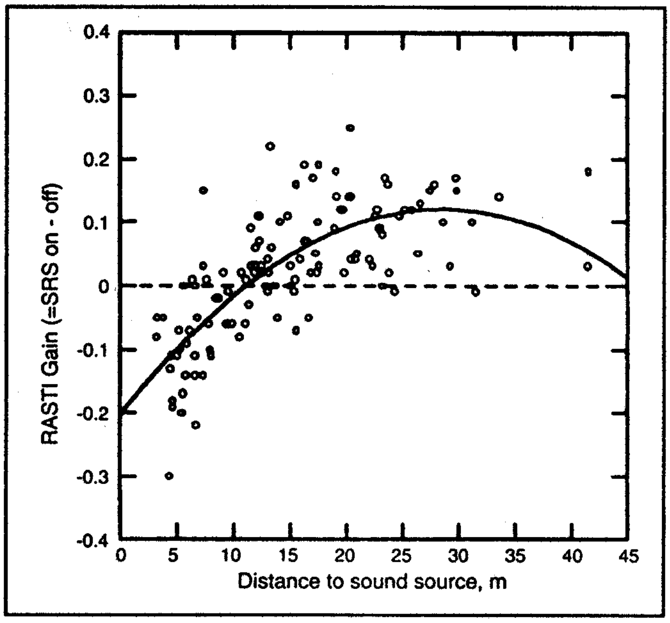

Figure 10. Gain in the RASTI values with the SRS on against distance to sound source (altar).

Table 7 also shows the RASTI *IF*s, which were calculated without the data measured at receiver position *A* (in the direct field). In this situation the RASTI values, with the SRS on, increase an average of 19 per cent in each church.

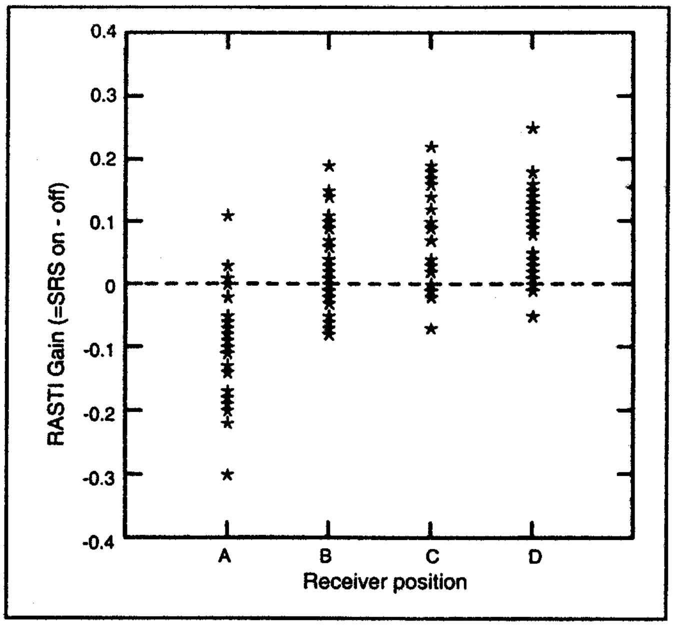

Figure 11. Relationship between the RASTI Gain (SRS on and off) and the receiver positions (*A*: the closest to the altar).

4. SUMMARY AND CONCLUSIONS

The RASTI was measured in 31 hard-surfaced unoccupied Roman Catholic churches built in the last 11 centuries in Portugal. Four receiver locations were used in each church, with and without the use of sound-reinforcement systems (SRS) from the altar area. The loudspeaker arrangement commonly present in the churches tested was the distributed line source system (but with no signal-delayed) which is the standard in Portugal.

This paper concentrates on the RASTI values within churches and on their differences with the SRS off and on. The vast majority of churches tested (70 per cent) have RASTI values, with the SRS off, not greater than 0.45 (0.40 was the calculated median) giving a poor rating in the inferred quality of speech intelligibility. The mean RASTI values without the SRS on varied from 0.22 to 0.56 while the ones measured with the SRS on changed from 0.26 to 0.66.

Regarding the RASTI_Gain by the use of SRS, a best-fit equation with a R^2 of 0.55 was found for its relationship with the distance to the sound source (altar). It was determine that only for distances greater than about 11 m from the altar area, is the SRS useful in increasing the RASTI values. The use of the SRS is not beneficial in increasing the RASTI values for the seats closest to the altar.

In general, the standard SRS systems used in Portuguese churches produce an average increase of 7 per cent in the mean RASTI values in each church or about 0.03 in their mean RASTI absolute values when all receiver positions are considered. Excluding the closest position to the sound source, the average increase of the RASTI is about 19 per cent from the RASTI values measured with the SRS off.

These results are representative of the acoustical performances of churches where the congregation area is nonabsorptive. Therefore, extrapolations from these results to the SRS performance of fully occupied churches should be done with caution.

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