Acoustic effectiveness of pulpit reflector in churches

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Since the 12th century, pulpits and pulpit reflectors (canopies) were widely used in churches. This paper studies the acoustic effectiveness of such devices based on in site measurements (*STI* and *D50*) in four (unoccupied) churches with pulpits with and without the canopy. The pulpit reflector can remove the late reflection resulting from a high ceiling and makes possible to improve the listening conditions at medium distance from the pulpit. The pulpit reflector effectiveness decreases and becomes even unfavourable when the height of the ceiling drops ($h < 10$ m) and when the distance to the speaker increases. The absolute variations of speech intelligibility ratings are generally rather weak (average *STI* variation from +0.01 to -0.03), but can increase in the presence of an assembly.

INTRODUCTION

Since the 12th century, the use of pulpits, generally provided with a pulpit reflector (canopy) spreads in churches. A recent study [1] showed that in Switzerland, about 76% of the churches still have pulpits and half of those are provided with a canopy. The use of the pulpits, which remains traditional for preaching in the Protestant churches, is now in disuse (about 32% of the Swiss pulpits are never used). This paper presents a study on the objective acoustic effectiveness of pulpits reflectors for the speech intelligibility ratings based on measurements in four standard churches.

METHOD

Two indices of objective evaluation of speech intelligibility (*STI* and *D50*) were calculated from the impulse response, established on the basis of two measuring devices (Symphony with dBBati32 of 01dB and MLSSA). The use of a MLS sequence makes it possible to reduce the duration of in site measurements and to provide instantaneously various evaluations of speech intelligibility ratings.
The measurements were carried out in unoccupied churches in two situations: initially, placing the sound source on the pulpit under its canopy at about 1.5 m (measurements named "with canopy"), then at the same height but on the side of the pulpit not to have the effect of its canopy (measurements named "without canopy"). Measurements were carried out in four churches in Lausanne (Switzerland) whose main room and pulpit characteristics are presented in tables 1 and 2. In each church four measuring points were studied (table 3).

Table 1. Main characteristics of the churches studied.

Church, symbol	Volume (m^3)	Nave high (m)	Area (m^2)	RT avr. (s)
Cathedral, C	35000	20.0	2400	6.5
Allemande, A	1680	11.5	-	3.0
Terreaux, T	3600	9.5	380	2.4
St. Laurent, SL	3150	10.5	300	2.5

Table 2. Pulpit and canopy main characteristics (m).

Ch.	Pulpit Position	Pulpit high	Canopy height	Canopy width	Canopy length
C	lateral nave	1.83	2.44	2.00	1.45
A	lateral choir	1.42	2.75	1.75	1.75
T	central choir	2.09	2.06	1.50	1.90
SL	central choir	2.15	2.00	1.00	1.00

Table 3. Measuring points - distance to sound source.

Church	1	2	3	4
C	4.0	8.2	10.1	15.5
A	3.2	8.6	7.8	12.5
T	4.5	10.0	15.0	18.0
SL	4.4	4.8	8.2	10.1

RESULTS

The results obtained with 01 dB for speech intelligibility parameters, expressed by the *STI* and *D50* with and without canopies, are presented in table 4. In the Cathedral (C) and in the church Allemande (A), that have a high ceiling, there is a beneficial effect of the canopy at medium distances (position 2). For the positions at long distance (positions 3 and 4) there is a slight deterioration. At short distances of the sound source (position 1) the speech intelligibility parameters are little influenced (C) or slightly underprivileged (A) by the presence of the canopy.

This last case can be explained by the displacement of the sound source for the measurement "without canopy" (increase in the distance source/receptor).
On contrary in the Terreaux and St. Laurent churches, that have a lower ceiling (h < 10 m), the presence of the canopy deteriorates the speech intelligibility parameters at short and medium distances of the sound source. In these cases, the sound reflection from the ceiling is useful for the speech intelligibility (delay with direct sound lower than 35 ms). The positions located at medium distances or apart from the pulpit axis, are those that present the most significant loss of speech intelligibility because they do not profit any more from a ceiling reflection neither benefiting from those from the canopy. Such churches do not benefit by the presence of a canopy.

Table 4: *STI* and *D50* values measured with and without canopy (%).

Situat.	Posit.	Cathed.		Allem.		Terr.		S. Laur.	
		STI	*D_{50}*	*STI*	*D_{50}*	*STI*	*D_{50}*	*STI*	*D_{50}*
with canopy	1	58	*54*	45	*29*	54	*42*	50	*39*
	2	55	*49*	49	*33*	51	*40*	48	*30*
	3	43	*26*	43	*22*	45	*24*	49	*32*
	4	38	*19*	46	*27*	47	*28*	48	*31*
	avg.	**49**	***37***	**46**	***28***	**49**	***34***	**49**	***33***
without canopy	1	59	*51*	46	*29*	61	*53*	53	*44*
	2	48	*38*	47	*32*	53	*36*	55	*46*
	3	43	*28*	45	*32*	49	*32*	52	*48*
	4	41	*24*	47	*31*	46	*26*	48	*30*
	avg.	**48**	***35***	**46**	***31***	**52**	***37***	**52**	***42***
"with canopy" - "without canopy"	1	-1	*3*	-1	*0*	-7	*-11*	-3	*-5*
	2	7	*11*	2	*1*	-2	*4*	-7	*-16*
	3	0	*-2*	-2	*-10*	-4	*-8*	-3	*-16*
	4	-3	*-5*	-1	*-4*	1	*2*	0	*1*
	avg.	**1**	***2***	**-1**	***-3***	**-3**	***-3***	**-3**	***-9***
	st.dev	4	*7*	2	*5*	3	*7*	3	*8*

DISCUSSION

The absolute variations of the speech intelligibility parameters are in general relatively modest (average *STI* variation from +0.01 to -0.03 according to church and standard deviation between measuring positions from 0.02 to 0.04) but can increase in the presence of an assembly. The variations of the *D50* values are coherent (slightly higher absolute values) with the *STI* values. These results are notably weaker than those obtained by Epstein [2] in the case of significant size canopies located in large Dutch churches, and slightly different from the predicted values obtained with a theoretical model and ray tracing simulations [3].
The detailed analysis of the *STI* modulation matrix highlights in certain cases (high ceiling without canopy) an increase, in certain bands of octaves, of the modulation coefficients between 6 and 8 Hz that corresponds to a late reflection. The correction of the *STI* predicted in these cases [3] would led to a reduction in the values from 0.8 to 1.4 and thus an additional increase in the effect of the canopy in the same proportions.
The measurement technique used does not seem well adapted for measurements at short distances. Indeed, the displacement of the sound source required for the measurements in the "without canopy" situation disadvantages these positions whatever the church.

CONCLUSION

Based on in site measurements in four churches, we can separate the churches according to their ceiling height (h ≥ 10 m as in the cathedral of Lausanne and the Allemande church or h < 10 m as in the Terreaux and St. Laurent churches). When the height of the ceiling and the size of the canopy are significant, a beneficial effect of this one is noted, mainly for the listeners located at medium distances from the pulpit. On the other hand, the effect of the canopy is almost non-existent at long distances. For short distances from the pulpit, a weak effect is noted that can be explained by a modification of the distance source-receiver. For churches with lower ceilings (< 10 m), an unfavourable effect of the canopy is noted at short and medium distances. In this case the presence of a canopy removes the early reflections from the ceiling church that are favourable for the listener. The presence of a canopy is thus not favourable in a low ceiling church, but it is interesting at medium distances in the higher ceiling churches. Whatever the ceiling height, the canopy does not have an effect at long distances.

REFERENCES

1. P. Buluschek and V. Desarnaulds, *Appréciation subjective de l'acoustique des églises en Suisse*, EPFL, Lausanne (1999).

2. D. Epstein, *Evaluation of the effectiveness of pulpit reflectors in three Dutch churches using Rasti measurements*. Inter-noise 1991, Sydney, pp. 823-826.

3. P. Chauvin and V. Desarnaulds, *Chaires et abat-voix. Mythe ou réalité acoustique?*, EPFL, Lausanne (2001).

4. IEC 60268-16 (1998). *Objective rating of speech intelligibility by speech transmission index*, International Electrotechnical Commission.