ACOUSTIC DESIGN OF BROADCASTING STUDIOS IN YAMMAT FM RADIO STATION IN ZAGREB, CROATIA

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Abstract

Yammat FM, a Zagreb-based radio station, was recently relocated to a 100-year-old building in the city centre. In 2024, the new premises were fully restored and redesigned to create visually distinctive and acoustically accessible spaces. The paper presents two street-facing broadcasting studios. To ensure high-quality production of the radio programme, sound insulation and room acoustic conditions were given special attention, with target values defined primarily according to the Croatian national regulations, BBC WHP 021, and the HRN DIN 18041:2012 standard. Despite the proximity of a busy road and tram traffic route, the proposed glazed façade improved the insulation from approximately 30 dB to 37.0 dB in Studio 1, and 38.9 dB in Studio 3. Room acoustic conditions were designed and evaluated through simulations performed in ODEON 17.13. The proposed treatment combined high-quality acoustic plaster, perforated wooden and gypsum-board systems, carpeting, and carefully selected wall and ceiling assemblies. Simulated mid-frequency reverberation times of 0.36 s in Studio 1 and 0.22 s in Studio 3 were achieved. Studio 1 closely matched its target value of 0.35 s, while Studio 3 damped the target value of 0.30 s at mid- and high frequencies more strongly. Despite the architectural constraints, the integration of visual design and acoustically demanding spaces was achieved successfully into a transparent, street-visible architectural concept.

Keywords: *radio station, broadcasting studio, acoustic treatment, architectural acoustics, sound insulation*

1. Introduction and Case study

Broadcasting studios are special-purpose rooms with unique architectural and acoustic requirements that need to be integrated and dealt with simultaneously [1]. Acoustics of radio production rooms features short and controlled reverberation, low background noise, and adequate sound insulation from adjacent spaces and services, as well as from outdoor space [2].

Yammat FM has been based in Zagreb since 2015. In 2024 it was relocated to a 100-year-old building in the city centre. The new location was designed by a renowned Croatian architectural practice Studio 180. The aim was to visually connect its broadcasting studios and the street they face using large glass façade openings. This allows the passers-by to visually observe daily operation and reinforces the station's broader commitment to transparency and openness toward the public. The location right next to road and tram traffic routes, as shown in Figure 1, presents a challenge that adds to already strict standards for broadcast-quality acoustics.

Figure 1. Location of the broadcasting studios in the city centre, next to road and tram traffic routes, facing the street with large glass façade openings

The century-old building fabric and the large, glazed openings present additional challenges to achieving the required levels of sound insulation and acoustic comfort. The reconstruction envisaged a conversion from business premises (offices) into seven distinct technological and supporting spaces used for production of radio programme. All these spaces required an improvement in sound insulation and room acoustics, compared to their pre-existing state.

This study presents Studio 1 and Studio 3 of the Yammat FM radio station, being the most sensitive and the most demanding spaces at the same time. Located on the ground floor level facing the street, these spaces were designed as visually appealing and are the ones that are exposed to outdoor noise the most. Studio 1 is the largest space, with a volume of 206 m^3 and the floor area of 56 m^2. It is used primarily intended for radio programme production and is large enough to host occasional live music performance. Studio 3 is smaller, with a volume of 52 m^3 and floor area of 13.1 m^2 and is used for radio programme production. Short reverberation time is required in both studios. Large, glazed façade openings in both studios represent the biggest challenge in achieving adequate sound insulation from outdoor noise. In addition, they are highly reflective and cannot be used for placement of sound absorbing materials.

2. Methodology

The leading parameters for assessing acoustic quality were the façade sound insulation, the reverberation time, and background noise level within the studios.

2.1 Sound insulation

2.1.1 Façade sound insulation

As the initial input, the Strategic Noise Map from 2023 [3] indicated daytime road-traffic noise levels (L_{day}) below 65 dB(A) at the location site. However, due to the amid congested urban road and tram traffic, a value of 70 dB(A) was measured about 1 m from the façade and was adopted as the final input for subsequent calculations of façade sound insulation.

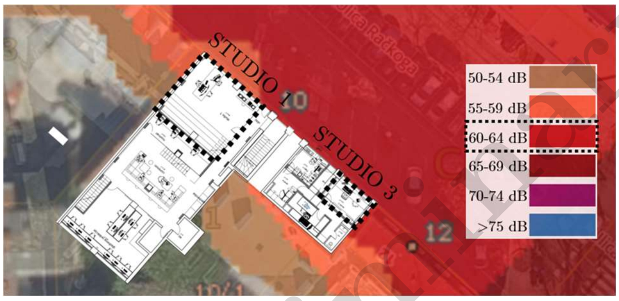

Figure 2. Strategic Noise Map from 2023 on the site; L_{day} road traffic noise (Source: adapted from [3])

The required sound insulation of each complete façade was calculated in accordance with DIN 4109 from the adopted external and internal layers, façade area, room absorption area, and the relevant correction. Both existing and proposed façades were evaluated as combinations of a massive wall and glazing. As nearby road and tram traffic noise has a substantial low-frequency content, the C_{tr} spectrum was applied to the glazing rating. The initial target NR25 noise rating corresponds to an overall A-weighted level of approximately 36.9 dB(A) [4]. This upper limit was further reduced to 35 dB(A) as the maximum permitted noise level in cinemas, reading rooms, exhibition rooms, lecture halls, and similar premises, according to Croatian national regulation [5]. For Studio 1, the construction of an additional entrance vestibule was recommended to reduce the risk of external noise entering the studio when external and internal doors are opened. Possible structure-borne noise caused by vibrations from passing trams that propagate through the ground and foundations were recognized as a relevant issue.

2.1.2 Sound insulation within the building

The existing 100-year-old wall partitions and inter-floor assemblies towards adjacent spaces were upgraded using independent lightweight partition walls and additional claddings adjoining neighbouring units, resiliently suspended ceilings and a raised floor with textile finish to provide adequate sound insulation for the intended use of the building. The new lightweight partitions were designed for R'_w = 66 dB, existing loadbearing structures, both walls and inter-floor construction slabs, towards the neighbouring units got the lightweight lining, with overhangs on beams. The glazed wall between Studio 1 and the entrance hall was treated similarly as the façade glazing, to meet the set noise level requirements of 35 dB(A), assuming the noise level in the entrance hall and the common room does not exceed 65 dB(A). The existing floor is designed as a double floor (floor slabs on pads with an elastic pad to dampen impact sound) with a final textile covering to improve both the acoustic quality of the space and reduce the transmission of impact sound.

2.2 Acoustic treatment

2.2.1 Room acoustics

All room acoustic simulations were made using ODEON 17.13 Auditorium Room Acoustics Software [6]. The drawings for the three-dimensional room models were prepared by the architectural studio that oversaw the entire project and adapted for ODEON by the authors. Appropriate absorption and scattering coefficients were assigned to the surfaces in the modelled rooms. The target values of reverberation times were determined according to the size (volume) and intended use of each studio, primarily following BBC WHP 021, *Acoustic Criteria and Specification* [7]. Additional consultation was performed using the HRN DIN 18041:2012 standard [8], even though special-purpose spaces are out of its scope.

As stated before, large, glazed surfaces were preserved to maintain visual connection with the street and adjacent interior areas, as shown in Figure 3. Acoustically, these surfaces are challenging as they contribute very little mid- and high-frequency absorption and reduce the amount of available wall area for conventional acoustic treatment. The acoustic treatment therefore combined several systems with the emphasis on integration into the overall architectural expression. With the wall-to-wall carpet contributing to overall sound absorption to a lesser extent, the greatest potential for reducing reverberation time was

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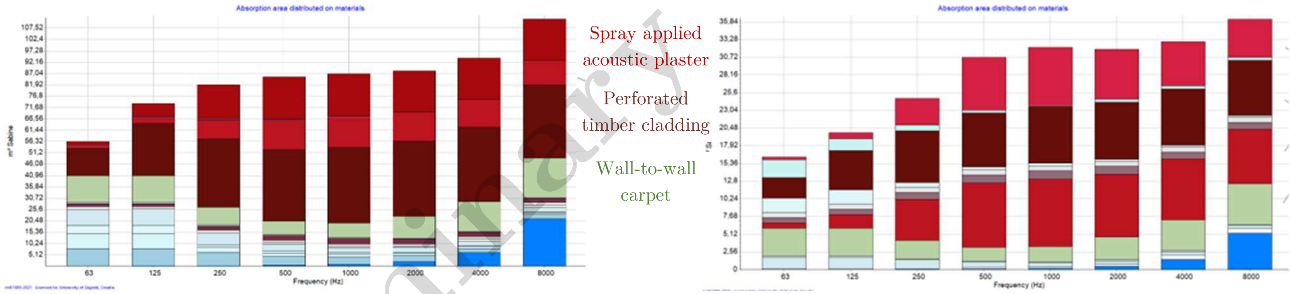
identified in the remaining surfaces that needed to be finished with highly absorbing materials. As shown in Figure 3, the main contribution to the total sound absorption was provided by perforated panels with an open area of 31% applied to the ceilings and partially on the walls, and the high-quality spray-applied acoustic plaster system (Ecophon Fade, 25 mm and 40 mm) applied to the remaining available wall surfaces. The sound absorption coefficients of the materials used in acoustic simulations are shown in Table 1.

a) b)

Figure 3. Three-dimensional acoustic models developed in ODEON (top) and the corresponding finished spaces (bottom): (a) Studio 1; (b) Studio 3.



a) b)

Figure 4. Contribution of individual materials to total absorption in: (a) Studio 1; (b) Studio 3.

Table 1. Surface materials and their associated sound absorption coefficients (measured according to HRN EN ISO 354, sound absorption performance evaluated according to HRN EN ISO 11654)

Studio	Surface materials	Frequency [Hz]					
		125	250	500	1000	2000	4000
1	Floor – 5 mm carpet on a raised floor	0.30	0.20	0.15	0.17	0.25	0.34
1	Street glazing	0.15	0.05	0.03	0.03	0.02	0.02
1	Hallway indoor glazing	0.18	0.06	0.04	0.03	0.02	0.02
1	Spray-applied high-quality acoustic plastering system, 43 mm mounting depth (Ecophon Fade 40 mm)	0.30	0.80	0.99	0.99	0.95	0.95
3	Spray-applied high-quality acoustic plastering system, 28 mm mounting depth (Ecophon Fade 25 mm)	0.10	0.45	0.90	0.99	0.85	0.75
1	Timber-clad seating platforms and stairs - horizontal surfaces	0.40	0.30	0.20	0.17	0.15	0.10
1, 3	Perforated timber, 31% perforation; 56 mm depth, backed by 30 mm mineral wool, Vertical surfaces of the seating platforms in Studio 1; Partition wall in Studio 3	0.20	0.61	0.95	0.99	0.93	0.90
1, 3	Perforated timber, 31% perforation; 216 mm depth, backed by 30 mm mineral wool, Acoustic suspended ceiling	0.67	0.88	0.92	0.97	0.97	0.96

2.2.2. HVAC noise modelling

HVAC noise modelling was conducted in ODEON 17.13 using the three-dimensional models of the two studios and the sound power spectra of the active air terminals, as specified in the service equipment design documentation. The criterion of the upper indoor noise limit of 35 dB(A) was maintained.

3. Results and Discussion

3.1 Façade sound insulation

The calculated sound insulation performance of the existing and proposed façades is summarized in Table 2. The assessment shows that the original façades of both studios are inadequate in terms of sound insulation, primarily because of the large proportion of shopfront glazing exposed directly to road and tram traffic.

For Studio 1, the calculated weighted apparent sound reduction index of the existing complete façade is approximately R'_w = 30.0 dB, while the minimum required value is $R'_{w,min}$ = 36.5 dB. The original shopfront glazing is acoustically the weakest element of the façade. Its surface area of approximately 24.4 m² is considerably larger than that of the massive external wall and therefore has a dominant influence on the resulting performance of the complete façade. Improved laminated glazing was proposed to address this deficit. The selected glazing has a laboratory airborne sound-insulation rating of R_w (C; C_{tr}) = 52 (-1, -5) dB. Beside the C_{tr}, a further reduction of approximately 2–3 dB was allowed for the large dimensions of the glazing panels, leading to the effective design value of the selected glazing $R_{,effective\_esign}$ = 52 – 5 – 3 = 44 dB. The sound insulation of the entire façade with built-in improved glazing yielded the resulting value of R'_w for Studio 1 of 37.0 dB and was assessed as satisfactory.

For Studio 3, the existing complete façade provides a calculated value of approximately 29.9 dB, while the minimum required value is 38.2 dB. The resulting deficit is approximately 8.3 dB. The higher requirement in comparison with Studio 1 is associated with the smaller room volume and absorption area of Studio 3, together with the larger fraction of glazing in its total surface area. With the proposed improved glazing, the sound insulation of the complete façade of Studio 3 was calculated in the same manner as for Studio 1 and was deemed satisfactory, as the R'_w increases to 38.9 dB.

The difference between the glazing rating and the calculated values of the complete façades should be noted. The value of approximately 44 dB refers to the effective sound insulation of the selected glazing after corrections for the traffic-noise spectrum and the dimensions of the panels. The values of 37.0 and 38.9 dB refer to the calculated performance of the complete façades, including both the glazed and massive sections of the façade walls and considering their respective surface areas.

The requirements on sound insulation and the calculated performance, as shown in Table 2, reveal that the proposed façade solutions satisfy the adopted requirements. Nevertheless, the final performance will depend strongly on the quality of construction and workmanship. Airtight perimeter sealing, acoustically appropriate frames, and careful treatment of the junctions between the glazing and the surrounding construction are essential, as leakage through frames or joints could substantially reduce the sound insulation of the completed façade.

An entrance vestibule was additionally recommended for Studio 1. Without such a vestibule, the simultaneous opening of the external entrance door and the studio door could temporarily form a direct sound transmission path between the street and the studio, thus bypassing the sound-insulating façade.

Table 2. Design criteria and principal calculated or simulated results.

Studio	Volume / Area	Façade sound insulation R'_{w} Existing / Required / Proposed	Reverberation time $T_{30,\mathrm{mid}}$ Target / Calculated	HVAC noise $L_{\mathrm{R,Aeq}}$
1	206 m³ / 56 m²	30.0 / 36.5 / 37.0 dB	0.35 s / 0.36 s	14.6 (13.5-15.6) dB(A)
3	52 m³ / 13.1 m²	29.9 / 38.2 / 38.9 dB	0.30 s / 0.22 s	22.6 (21.7-23.5) dB(A)

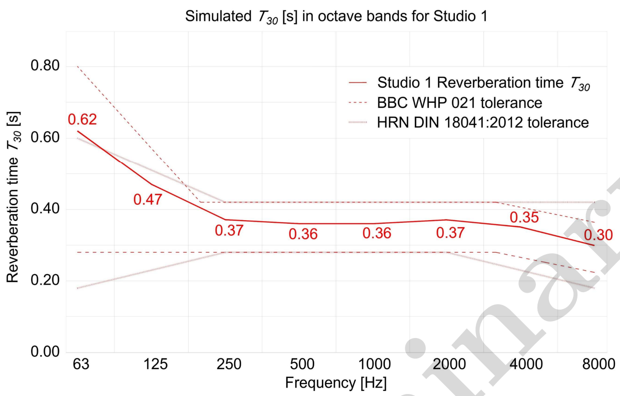
3.2 Acoustic treatment

The reverberation time T_{30} was adopted as the principal parameter for evaluating the room-acoustic conditions. In accordance with the volumes, floor areas and intended functions of the rooms, the design values were set to 0.35 s for Studio 1 and 0.30 s for Studio 3. The frequency-dependent values of reverberation time T_{30} and its average, single-number values are presented in Table 2 and Figure 5. For Studio 1, the calculated mid-frequency reverberation time $T_{30,\mathrm{mid}}$ is 0.36 s. This value agrees very well with the design value of 0.35 s. The reverberation-time characteristic is reasonably balanced throughout the principal frequency range and remains within the tolerance limits defined by BBC WHP 021, as presented in Figure 5a. According to HRN DIN 18041, the values are also satisfactory, with only a minor exceedance at the lowest investigated frequencies, particularly in the 63-Hz octave band.

The favourable result in Studio 1 is associated with its larger volume and with the possibility of distributing sound-absorbing treatment across several surface types. High quality spray-applied acoustic plaster system was used to form visually continuous absorptive surfaces, while perforated wooden elements contributed both to sound absorption and to the architectural character of the interior. Additional absorption was provided by the wall-to-wall carpet and by the treated ceiling and tribune surfaces. The resulting room is therefore expected to provide short and controlled reverberation suitable not only for speech production, but also for live amplified music performance.

Studio 3 presented a more demanding room-acoustic problem because of its considerably smaller volume and the large, glazed surface that had to remain visually exposed. The calculated mid-frequency reverberation time $T_{30,\mathrm{mid}}$ is 0.22 s, which is lower than the nominal design value of 0.30 s. As shown in Figure 5b, in the middle- and high-frequency range, the calculated reverberation time also falls below the lower tolerance limits defined by both BBC WHP 021 and HRN DIN 18041. The room can therefore be described as acoustically dry in this part of the frequency range. At low frequencies, however, the reverberation time increases to approximately 0.54 s at 63 Hz and 0.45 s at 125 Hz. These values are considerably higher than the ones obtained at middle and high frequencies. The result represents a more pronounced imbalance of reverberance than that obtained for Studio 1 and is a direct consequence of the small room volume, the large untreated glazed surface and the restrictions imposed on the dimensions and locations of low-frequency absorbers by the architectural design. The distribution of treatment in Studio 3 was deliberately limited to avoid making the room excessively dead. The northwest wall serves the room acoustic design through an absorptive 25-mm-thick Ecophon Fade system. The southeast wall, on the other hand, is designed as a lightweight independent lining whose principal purpose is to improve sound insulation towards the neighbouring space and to compensate for the shortcomings of the existing construction. Providing strong absorption on both walls would further reduce the already short middle- and high-frequency reverberation and would therefore be acoustically unfavourable.

Despite the increased low-frequency decay, no significant difficulties are expected during the planned use of Studio 3 for speech-based radio production and close-microphone recording. The overall level of reverberant sound is very low, and the room is expected to be acoustically adequate for normal broadcasting activities. Additional low-frequency control would, however, be advisable if the studio were to be used for more critical music recordings.



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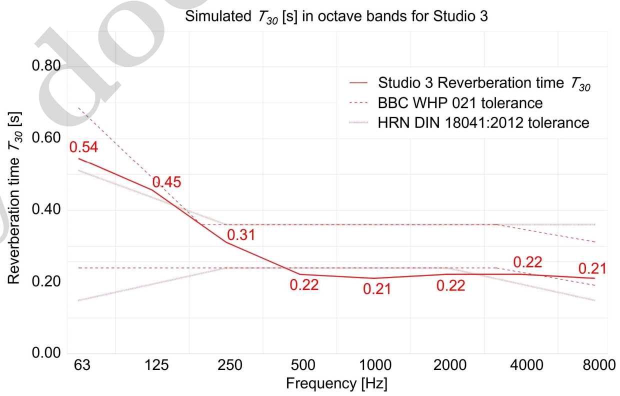

b)

Figure 5. Frequency-dependent reverberation times with tolerance limits according to BBC WHP 021 and HRN DIN 18041 tolerance, shown for target values of (a) 0.35 s in Studio 1, and (b) 0.30 s in Studio 3

3.3 HVAC-generated background noise

The simulated A-weighted sound-pressure level generated by the HVAC system averages at 14.6 dB(A) in Studio 1, with individual receiver values ranging from 13.5 to 15.6 dB(A). In Studio 3, the corresponding average value is 22.6 dB(A), with a range from 21.7 to 23.5 dB(A). The calculated HVAC contribution is therefore below the adopted limit of 35 dB(A) in both studios. Under the simulated normal operating conditions, noise generated by the ventilation system is not expected to interfere with speech production or close-microphone recording.

4. Conclusion

The acoustic design of the two street-facing broadcasting studios at Yammat FM in Zagreb demonstrates the possibility of combining demanding acoustic requirements with a transparent architectural concept. Both analysed studios are located directly along a busy urban street and are visually connected with the public sidewalk through large, glazed surfaces. This arrangement introduced two principal acoustic challenges: protection from road and tram traffic noise, and the achievement of suitable room-acoustic conditions despite the limited surface area available for acoustic treatment.

The calculations show that the sound insulation of existing façades would be insufficient for the intended use. Their calculated weighted apparent sound reduction indices R'_w are approximately 30.0 dB for Studio 1 and 29.9 dB for Studio 3, compared with minimum required values of 36.5 and 38.2 dB, respectively. Improved laminated insulating glazing was therefore proposed for both studios. With this glazing, the calculated R'_w of the complete façades increases to 37.0 dB in Studio 1 and 38.9 dB in Studio 3. The proposed solutions, therefore, satisfy the adopted requirements.

The room acoustic treatment was integrated into the architectural language of the studios rather than introduced as a visually independent technical layer. Acoustic plaster was used to create continuous surfaces, while perforated wooden elements contributed to both sound absorption and a recognisable interior identity.

The room acoustic properties of Studio 1 agree with the design requirements, as its calculated mid-frequency reverberation time of 0.36 s agrees closely with the target value of 0.35 s. A moderate increase remains at low frequencies, but the resulting characteristic is suitable for radio production and occasional live performance. In Studio 3, the calculated mid-frequency reverberation time of 0.22 s is lower than the design value of 0.30 s. The room is therefore very dry at middle and high frequencies, while maintaining longer decay at 63 and 125 Hz. This imbalance is primarily associated with small room volume, the area of the glazed façade and the limited options of installing low-frequency absorbers. Nevertheless, the calculated conditions are expected to be suitable for speech-based broadcasting and close-microphone sound capturing. The use of highly absorbing material on only one principal wall prevents further reduction of the middle- and high-frequency reverberation time.

The predicted HVAC-generated levels are also satisfactory. Average values of 14.6 dB(A) in Studio 1 and 22.6 dB(A) in Studio 3 remain well below the adopted limit of 35 dB(A).

The case study confirms that acoustic performance and architectural openness do not necessarily represent opposing design objectives. Their successful integration, however, requires early coordination between architects, acousticians, mechanical-services designers, contractors and future users. Post-completion measurements of reverberation time, background noise and façade sound insulation should be carried out to verify the calculated performance. The measurement programme should also include an assessment of possible structure-borne noise generated by tram traffic, as this transmission mechanism is not fully represented by the façade airborne-sound-insulation calculations.

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