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A novel approach of multichannel and stereo control room acoustic treatment, second edition

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ABSTRACT

This paper describes additional development and improvement for all walls and ceiling diffusers, a new principle for multichannel or stereo control room setup/treatment, as was originally published at the 129th AES Convention (Paper Number 8295). The main effort focused on lowering the price of treatment, optimization of LF absorption, simplification of diffuser construction, solution for long diffusers without periodic repetition of diffusive sequence, and increasing room decay. All of these procedures and design principles will be described and attached to this paper, including theoretical analysis and room acoustical measurements from some of the first control rooms built following this new and improved principle.

1. INTRODUCTION

The main concerns of additional development of strong diffusive acoustical treatment of smaller room's design already described in [1] were:

- Avoiding periodical repetition of diffuser slats or modules, preventing aliasing.
- Increasing room liveliness
- Increasing LF absorption efficiency
- Decreasing air transparent diffuser construction/build complexity
- Decreasing relatively high price for initial design

This design was introduced 2007., to make room with floor surface smaller than 30m^2 more affordable for sound production, even if this means that all existing possibilities are very limited, so the only basic theoretical idea was not enough to become a full controllable design principle where people can reach desired characteristics, without disappointment.

2. A SECOND EDITION

2.1. Using Pseudo Random Noise Sequence for more than just binary diffusers

A big problem with the old design approach was Quadratic Residue Sequence diffuser, of the 7th and 13th order for diffuser modules. Some aliasing prevention was done with different orientation of same diffuser modules, following MLS (Maximum Length Sequence) sequence. To have non periodic diffuser construction, longer sequence is needed. Using longer Quadratic Residue Sequence is possible, but will introduce proportionally more different slat heights (similar as Primitive Root Sequence), what is rejected as non-acceptable, because higher costs. It is possible to do number rounding, for Primitive Root Sequence, and decrease the number of different slat height, but that will complicate design phase too much. Something other is needed for this purpose.

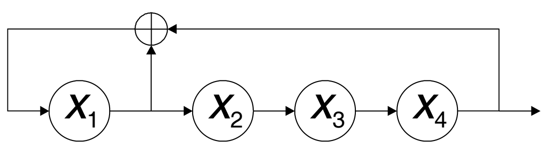

Figure 1 A PRN sequence generating system.

Pseudo Random Noise Sequence, one generator realization is shown in Figure 1, is binary sequence. Sequence basically can be long as we need. Diffuser built using this sequence can be amplitude grating only. But if we use more than just one element of long binary sequence to "program" slat height, we can introduce phase grating effect this way. So, using two, three or four adjacent numbers of the binary sequence, can define four, eight or sixteen different numbers, which can be used for slat height definition. This way we define quaternary, octal or hexadecimal diffuser, instead of just binary, by using the same PRN sequence. This construction will work as a phase grating diffuser.

So the binary sequence as 110101100111001010011, will be 6547123 in octal or 1ACE53 in hexadecimal sequence. Every single number means one slat height.

For physical realization, slat with height "0" is avoided, and to whole sequence is added an "offset" of one or two height steps, to provide physical stiffness to the thinnest slat. Principle of work wasn't affected this way, because differences of slat heights still follow the same sequence without exception, what is needed for phase grating functionality.

A question about quality of this type of phase grating diffuser realization need to be answered. Again software simulation was used. Software [3] cannot model absorptive function of gaps, but that is not important because we need answers to questions about basic diffusion performance, and absorption function is irrelevant now.

It is decided to simulate parameters of ~4m long diffuser built from QRD13, QRD101 and Pseudo Random Noise sequence, coded to 16 different slat heights.

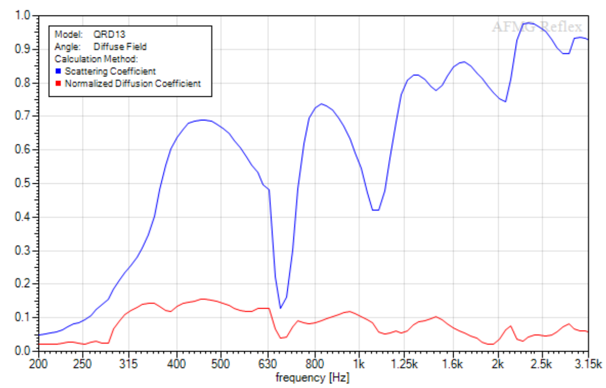

Figure 2 A 4m long diffuser built from QRD13 modules

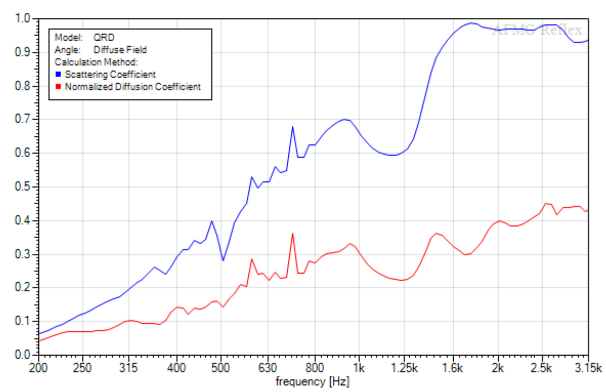

Figure 3 A 4m long diffuser built from one QRD101 diffuser

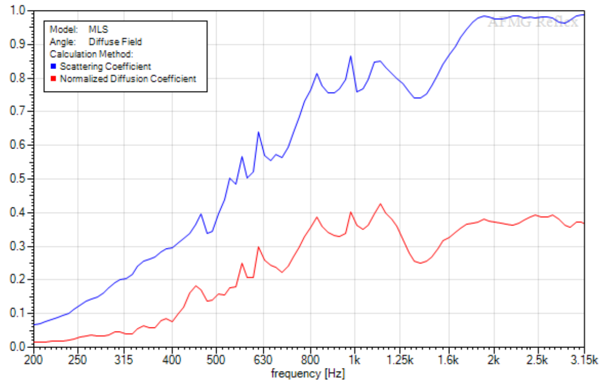

Figure 4 A 4m long diffuser built from aperiodic Pseudo Random Noise sequence with 16 possible heights

For all diffuser models 38mm slat width and 160mm maximum slat height, is common. For simulation, Diffuse Sound Field and 1/24 octave frequency resolution is chosen. From the simulation results, PRN diffuser with 16 possible slat height is not inferior to QRD solutions.

2.2. An "invisible" link between LF absorption efficiency and HF room liveliness

Even if old room from 2007., didn't sound psychoacoustically "dead", additional effort is made to design a room even more live than the first design, because more live control rooms decrease fatigue. The main reason for strong HF absorption of initial design, was a relatively wide gap between diffuser slats, and it is nearly same as slat width (50%). If we imagine classical Helmholtz slat absorber, decreasing the gap surface will lower the resonant frequency Helmholtz resonator, and in same time, decreasing the gap size will increase high frequency reflectivity of the overall surface, what is important here.

As can be seen in the Figure 5 air trapped in the gap can act as mass oscillating on spring formed by air enclosed behind air transparent diffuser [6]. Also, in Figure 5 can be seen that gap height is determined by the lower slat of adjacent pair. Mean value of gap height, which will be needed for software simulation, is determined by the equal probability of each slat height.

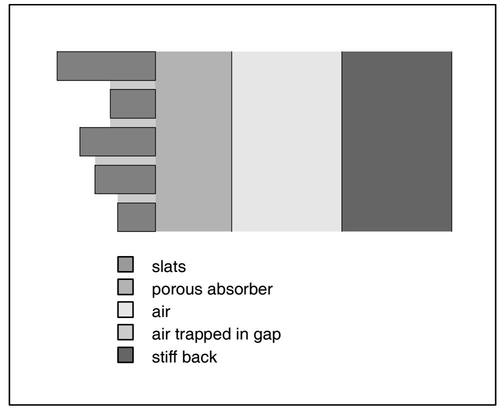

Figure 5 Air transparent diffuser and slat absorber, cross cut

Half of highest possible slat in sequence, plus offset height needed for physical realization, can be something as a first approximation of mean gap height value and that value was used in software simulation:

$$h = H_{\max}/2 + H_{offset} \quad (1)$$

where H_{max} is the maximum height of slat, and H_{offset} is the additional offset height used for physical stiffness.

Results of software simulation [2] of absorption coefficient of one practical construction is shown on Figure 6.

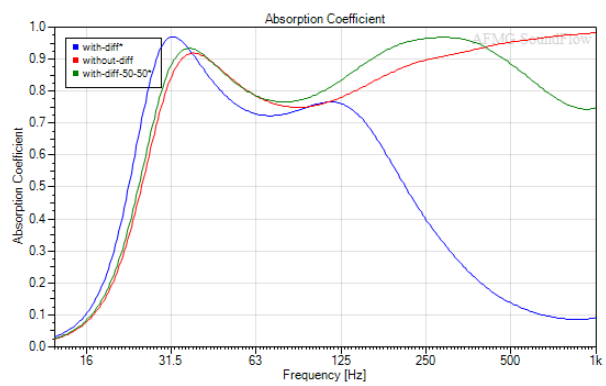

Figure 6 Absorption coefficient vs. frequency for three simulated situations

On picture red line is absorption characteristic of only porous absorber without any diffuser in front of it. Green line means the absorption coefficient of old diffuser construction since 2007., and there is visible strong absorption below 1kHz, while LF absorption is similar to the only porous absorber. The blue line is a new design with smaller gap and optimized slat-gap surface ratio, on the picture is visible both improvements, reflectivity increase above 250Hz, and more effective LF absorption.

Another way to control LF absorption is maximum slat height, which can be defined by lowest diffuse frequency, dependent on minimum listener distance from diffuser.

Increasing effectiveness of LF absorption can reduce the thickness of a needed porous absorber for roughly 10%.

The model used for simulation was Bies [4].

Actual parameters of simulation:

- Slat width of new air transparent diffuser: 45mm
- Gap width of new air transparent diffuser: 6mm
- Gap/ slat width of old air transparent diffuser: 25mm
- Mean slat gap height: 95mm
- Air gap behind porous absorber: None
- Absorbing material thickness: 600mm
- Absorbing material density: 20kg/m^3
- Absorbing material Gas Flow Resistance: 5kPa·s/m^2

2.3. Decreasing complexity

In a couple of studios already built following this new principle, all treatment realizations are adjusted to fairly skilled people without much experience in building studios. Even if there is a need for precise gap controlling, this need is minimized by including diffuser sides and only those pieces are done by CNC machine. Slat height has relaxed tolerance, and there can be used even construction wood. Using carpenter glue with dowel type joints to make things much easier to control, without needs of large tool kit or expensive machines.

2.4. Decreasing costs

Costs are minimized in many ways.

Decreasing labor costs by limiting the slat height to 4, 8 or 16 possible values, means that preparation of that material may be less expensive, because bigger quantities of slats with same height. Introducing porous absorber material instead of the Non - Environment “hanger” type of wide band LF absorbers, reduce costs and used space, without loss in absorber efficiency, on the contrary. Avoiding veneered particleboard/MDF material and introducing solid construction wood, which is usually less expensive. Introducing carpenter glue and dowels as non expensive, fast and quality joining principle of diffuser construction, where people don’t need special clamp tools to do it in other known ways.

3. MEASUREMENT RESULTS

Unfortunately, none of started building is fully finished... so this measurement results are without additional reflection surfaces, planned but not installed, as shown on Figure 9. The first result is for T30 value, shown in Figure 7.

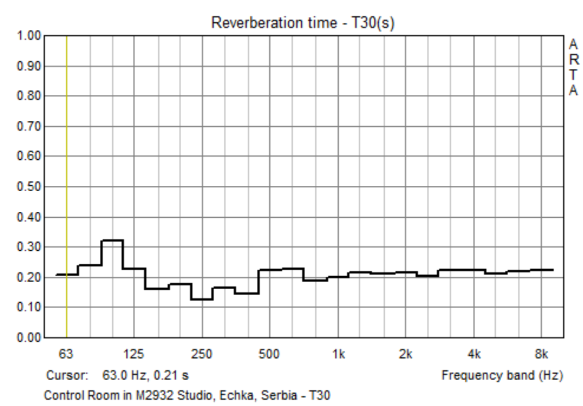

Figure 7 T30 results in first Control Room done by new principles

ETC result is shown in Figure 8.

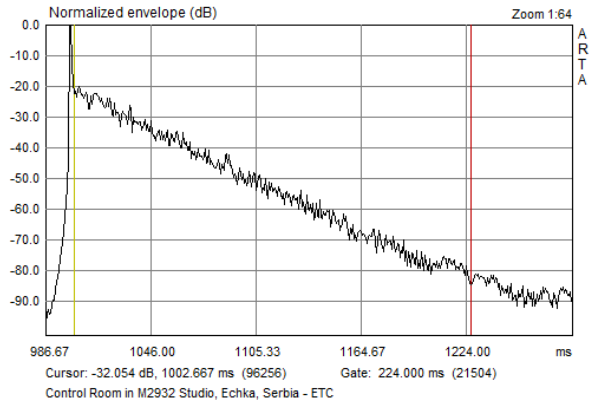

Figure 8 ETC results in first Control Room done by new principles

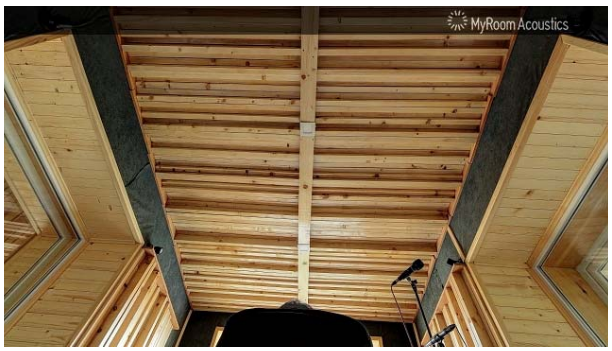

Figure 9 Celing treatment of first Control Room designed following new principle.

Control Room where measurements are done, have dimensions: W2.6m x H2.9m x L4.9m, which is 37m^3 of volume. So, from Equation 2 from [5]

$$Tm = \frac{1}{4}\sqrt[3]{\frac{V}{V_0}} \qquad (2)$$

we can calculate a nominal decay time, which is 0.18s. When we compare that value with measurement results, it is obvious that measured decay is higher than nominal for 30-40ms from 500Hz and above, what is a success, and method for increasing decay time is approved this way, even if not all reflective surfaces installed.

4. CONCLUSION

Additional effort is made to increase the quality of initial design since 2007., with success. But there will be more opportunity for additional improvements after another period of user observations and impressions.

5. REFERENCES

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