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# Synthèse de champ sonore diffuse

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Samuel Dupont  
Samu.dupont@laposte.net

# Table des matières

<b>1</b>	<b>Introduction</b>	<b>3</b>
1.1	Contexte. . . . .	3
1.2	Formulation du champ diffus . . . . .	3
1.3	Définition de l'absorption diffuse . . . . .	3
1.4	Analyse des termes diagonaux . . . . .	5
1.5	Optimisation des termes diagonaux pour un plan . . . . .	6
1.6	Conclusion . . . . .	7

# Chapitre 1

## Introduction

### 1.1 Contexte

### 1.2 Formulation du champ diffus

$$\hat{p}_{tot} = \sum_q \hat{p}_q e^{ik\mathbf{n}_q \cdot \mathbf{x}} \quad (1.1)$$

$$\rho c \hat{\mathbf{v}}_{tot} = \sum_q \mathbf{n}_q \hat{p}_q e^{ik\mathbf{n}_q \cdot \mathbf{x}} \quad (1.2)$$

A diffuse field can be taken as a superposition of many plane waves. It involves a double sum over indices  $q$  and  $q'$ , but the process of taking a local spatial average causes the cross terms ( $q \neq q'$ ) to average out. The spatial average of  $e^{ik(\mathbf{n}_q - \mathbf{n}_{q'}) \cdot \mathbf{x}}$  is nearly zero for a sufficiently large averaging volume.

$$\begin{aligned} 2 * \rho c I &= \sum_{q,r} \hat{p}_q \hat{p}_r^* e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \mathbf{n}_r \cdot \mathbf{n}_{out} \\ &= \sum_{q,r, q \neq r} \hat{p}_q \hat{p}_r^* e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \mathbf{n}_r \cdot \mathbf{n}_{out} + \sum_q \hat{p}_q \hat{p}_q^* \mathbf{n}_q \cdot \mathbf{n}_{out} \end{aligned} \quad (1.3)$$

### 1.3 Definition de l'absorption diffuse

If many plane waves are simultaneously incident on a wall, the individual waves reflect independently and the principle of superposition can be used in conjunction with the theory of plane-wave reflection. Such an analysis requires that the time average of the rate at which energy is absorbed (not reflected) by the surface per unit area be :

$$\frac{1}{2\rho c} \Re \{ p v^* \} \quad (1.4)$$

$$\frac{1}{2\rho c} \Re \left\{ \sum_{q,r} \hat{p}_q \hat{p}_r^* (1 + R_q)(1 - R_q^*) e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \mathbf{n}_r \cdot \mathbf{n}_{out} \right\} \quad (1.5)$$

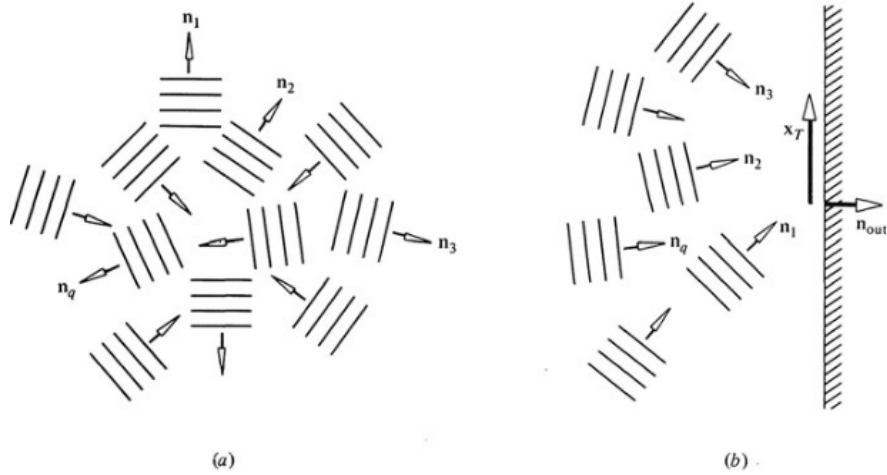


Figure 1.1 – (a) Reverberant field represented as a superposition of traveling plane waves. (b) Waves incident on a surface adjacent to a reverberant field, [1]

the sum is restricted to incident waves, such that  $\mathbf{n}_r$  points obliquely toward the wall. Inside the parenthesis we have :

$$\frac{1}{2\rho c} \Re \left\{ \sum_{q,r} \hat{p}_q \hat{p}_r^* (1 + R_q) (1 - R_q^*) e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \mathbf{n}_r \cdot \mathbf{n}_{out} \right\} \quad (1.6)$$

$$\begin{aligned} & \sum_{q,r} \hat{p}_q \hat{p}_r^* (1 + R_q) (1 - R_q^*) e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \mathbf{n}_r \cdot \mathbf{n}_{out} \\ &= \sum_{q,r,q \neq r} \hat{p}_q \hat{p}_r^* e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \\ &+ \sum_{q,r,q \neq r} R_q \hat{p}_q \hat{p}_r^* e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \\ &- \sum_{q,r,q \neq r} R_q^* \hat{p}_q \hat{p}_r^* e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \\ &+ \sum_{q,r,q \neq r} R_q^* R_q \hat{p}_q \hat{p}_r^* e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \\ &- \sum_{q,q} |p_q|^2 (1 + R_q - R_q^* - |R_q^2|) \end{aligned} \quad (1.7)$$

Considering that the spatial average of  $e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}}$  is nearly zero for a sufficiently large averaging volume.

$$\begin{aligned} & \sum_{q,r} \hat{p}_q \hat{p}_r^* (1 + R_q) (1 - R_q^*) e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \mathbf{n}_r \cdot \mathbf{n}_{out} \\ &= \sum_{q,q} |p_q|^2 (1 + R_q - R_q^* - |R_q^2|) \end{aligned} \quad (1.8)$$

Then by taking the real part :

$$\begin{aligned} & \frac{1}{2\rho c} \Re \left\{ \sum_{q,r} \hat{p}_q \hat{p}_r^* (1 + R_q) (1 - R_q^*) e^{ik(\mathbf{n}_q - \mathbf{n}_r) \cdot \mathbf{x}^T} \mathbf{n}_r \cdot \mathbf{n}_{out} \right\} \\ &= \frac{1}{2\rho c} \sum_{q,q} |p_q|^2 (1 - |R_q^2|) \mathbf{n}_r \cdot \mathbf{n}_{out} \end{aligned} \quad (1.9)$$

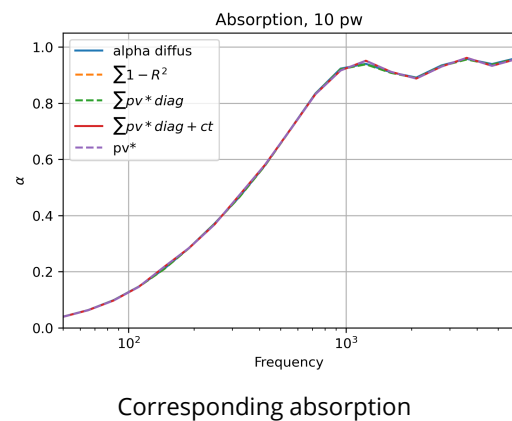
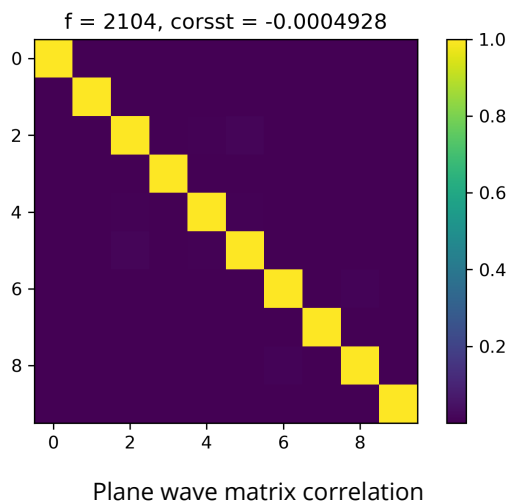
The diffuse field alpha can thus be obtain from : à revoir

$$\alpha_{\text{diff}} = \frac{\Re(\sum p v^*) z_0}{\sum |p_q|^2 2 \cos \phi} \quad (1.10)$$

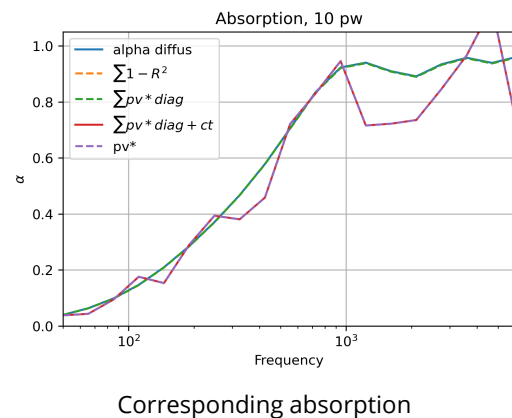
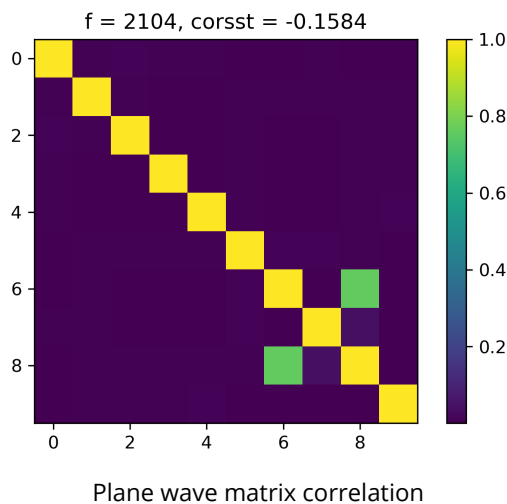
## 1.4 Analyse des termes diagonaux

Simulation en plane wave uniquement, sur un plan de microphones pour l'average spatial. La pression et la vitesse sont calculés dessus.

**Proof example :** 10 PW, 2000 Microphones réparties sur une large zone 10000 m ( spatial average)

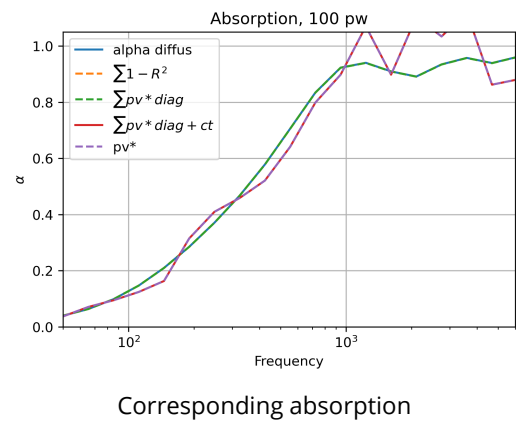
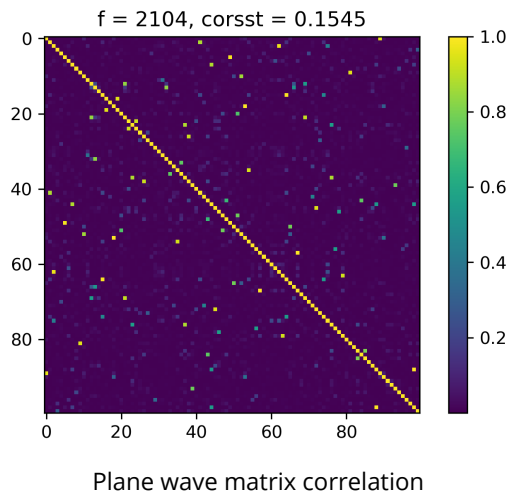


**Exemple :** 10 PW, 200 Microphones réparties sur une large zone 10000 m ( spatial average)



**Exemple :** 100 PW, 200 Microphones réparties sur une large zone 10000 m ( spatial average)

— Effet de la zone : petite zone = mauvais spatial averaging : lien avec la taille du sinus cardinal à faire



— Effet du nombre de PW à mieux définir

## 1.5 Optimisation des termes diagonaux pour un plan

Simulation en plane wave uniquement, sur un plan de microphones pour l'average spatial. La pression et la vitesse sont calculés dessus. Les positions des ondes planes sont optimisées pour réduire la matrice de cross-correlation.

**Proof exemple :** 10 PW, 200 Microphones réparties sur une large zone 10000 m ( spatial average)

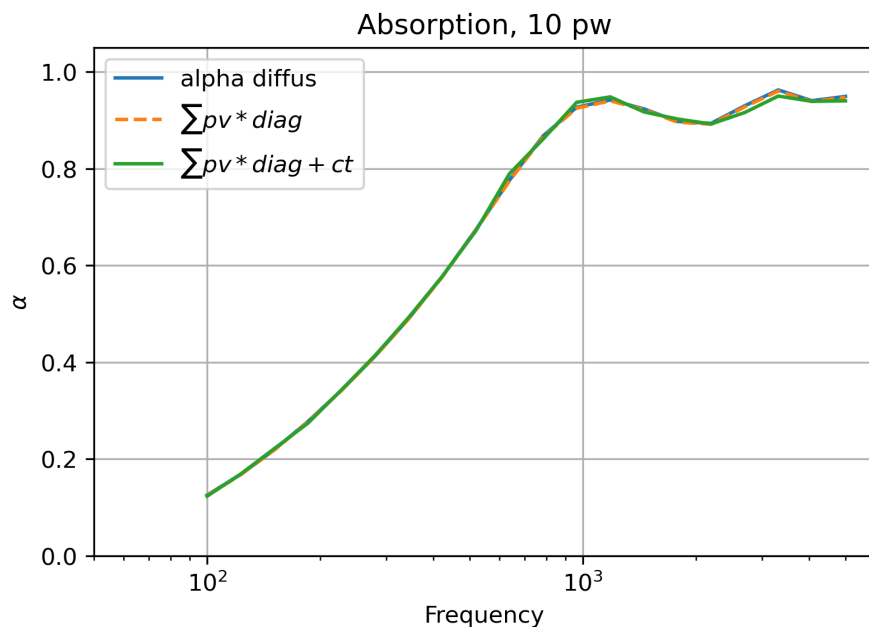


Figure 1.2 – Absorption avec les position des ondes planes diagonaux optimisés

— Effet du nombre de PW à mieux définir

- Mon catch c'est que le plan de microphone pourrait être réduit à un average sur la même position en faisant varier les positions spatiales de l'onde plane (une différente matrice de corrélation optimisée à chaque fois)

## 1.6 Conclusion

- Mettre au propre les codes
- Mettre au propre la partie rédaction ( Réf manquante? )
- Proof sur un doublet à faire.
- Effet des cross terme de réflexion à mieux définir

# Bibliographie

- [1] A. D. Pierce, *Acoustics : An Introduction to Its Physical Principles and Applications*. Cham : Springer International Publishing, 2019.