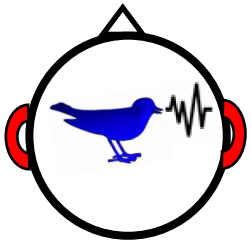
radiofrance

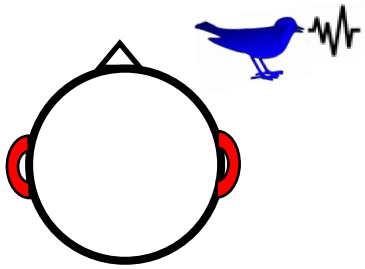
Département Production en Studios

AES Section Française

BINAURAL ET EXTERNALISATION



internalisation



externalisation

AES France

Bernard Lagnel
Ingénieur du son
Radio France

18 / 05 / 2018

AUDIOMÉTRIE

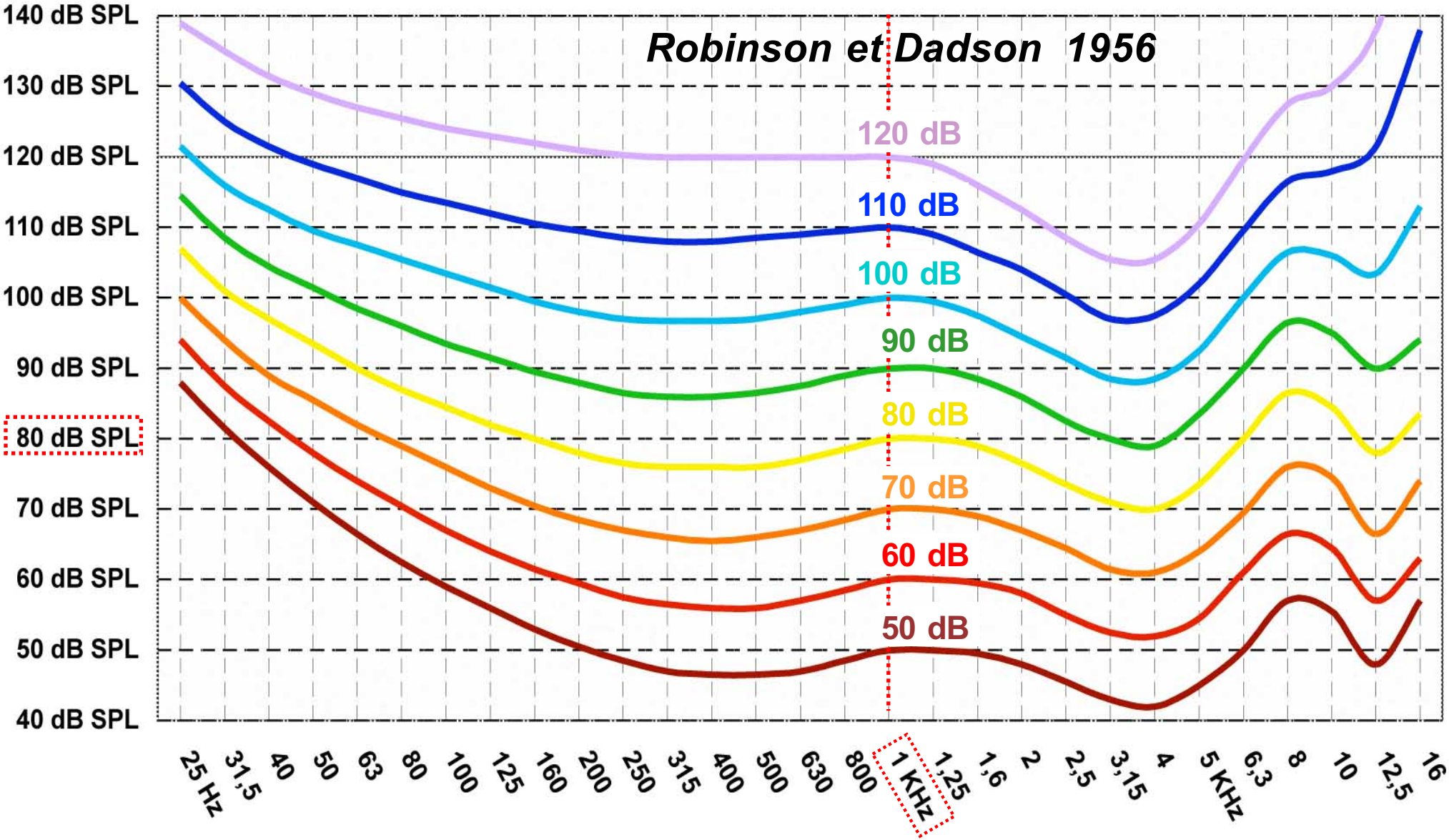
ÉCHELLE DU BRUIT

En dB SPL

Sound Pressure Level…

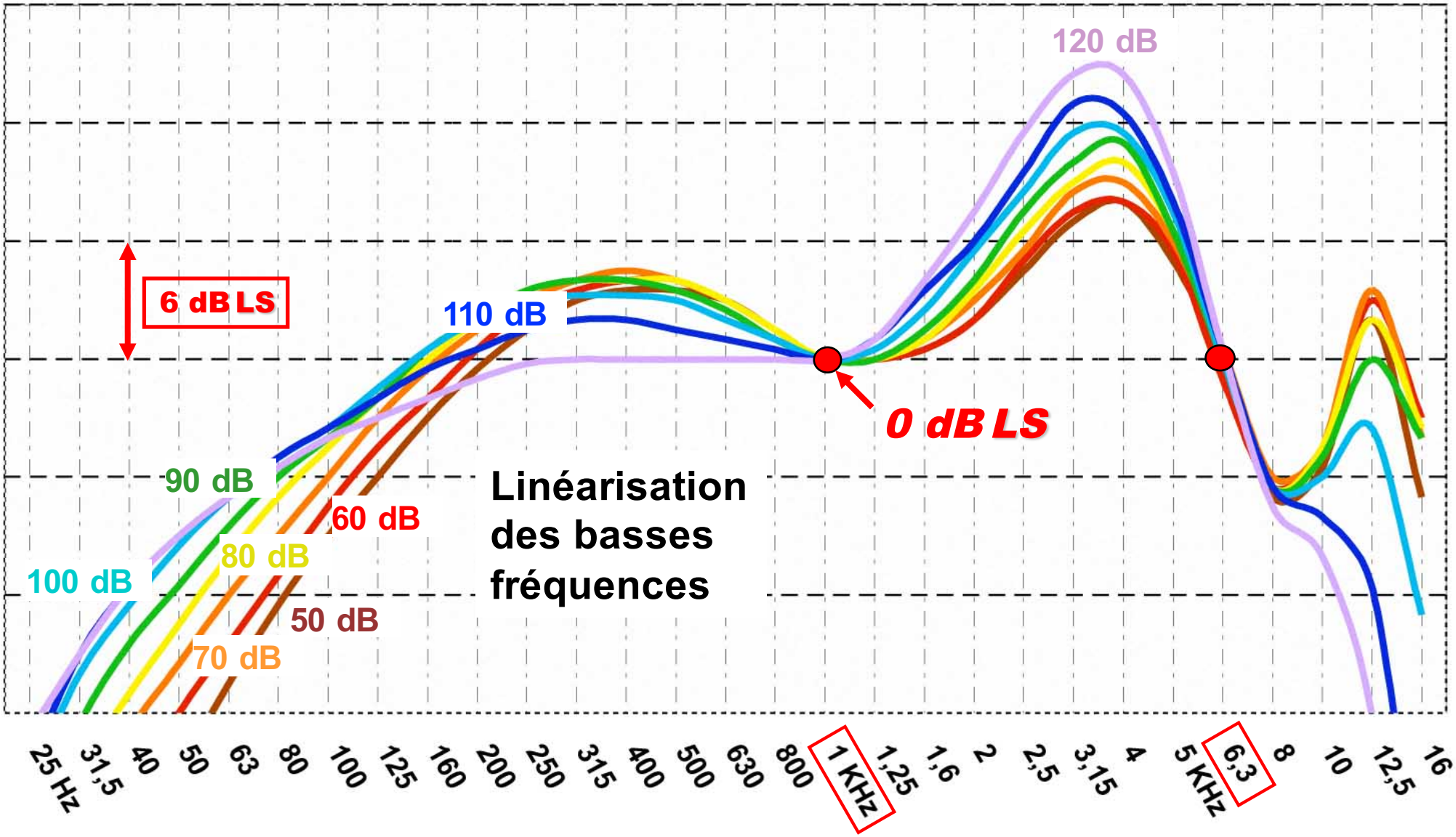
		PERÇUS :
130	Avion au décollage	DOULOUREUX
120	Marteau-piqueur	
110	Concert et discothèque	RISQUE DE SURDITÉ
100	Baladeur à puissance maximum	PÉNIBLE
90	Moto/Quad/Tracteur	
	Réflexe stapédien	
80	Automobile/Circulation	FATIGUANT
70	Aspirateur/Tondeuse	
60	Conversation courante	SUPPORTABLE
50	Machine à laver	
40	Bureau tranquille	AGRÉABLE
30	Chambre à coucher	
20	Conversation à voix basse	CALME
10	Vent dans les arbres	
0	Seuil d'audibilité	

Courbes isosoniques ISO 3746 pour une écoute binaurale en champ libre (utilisation d'une source frontale 0° *à 20 ans*)



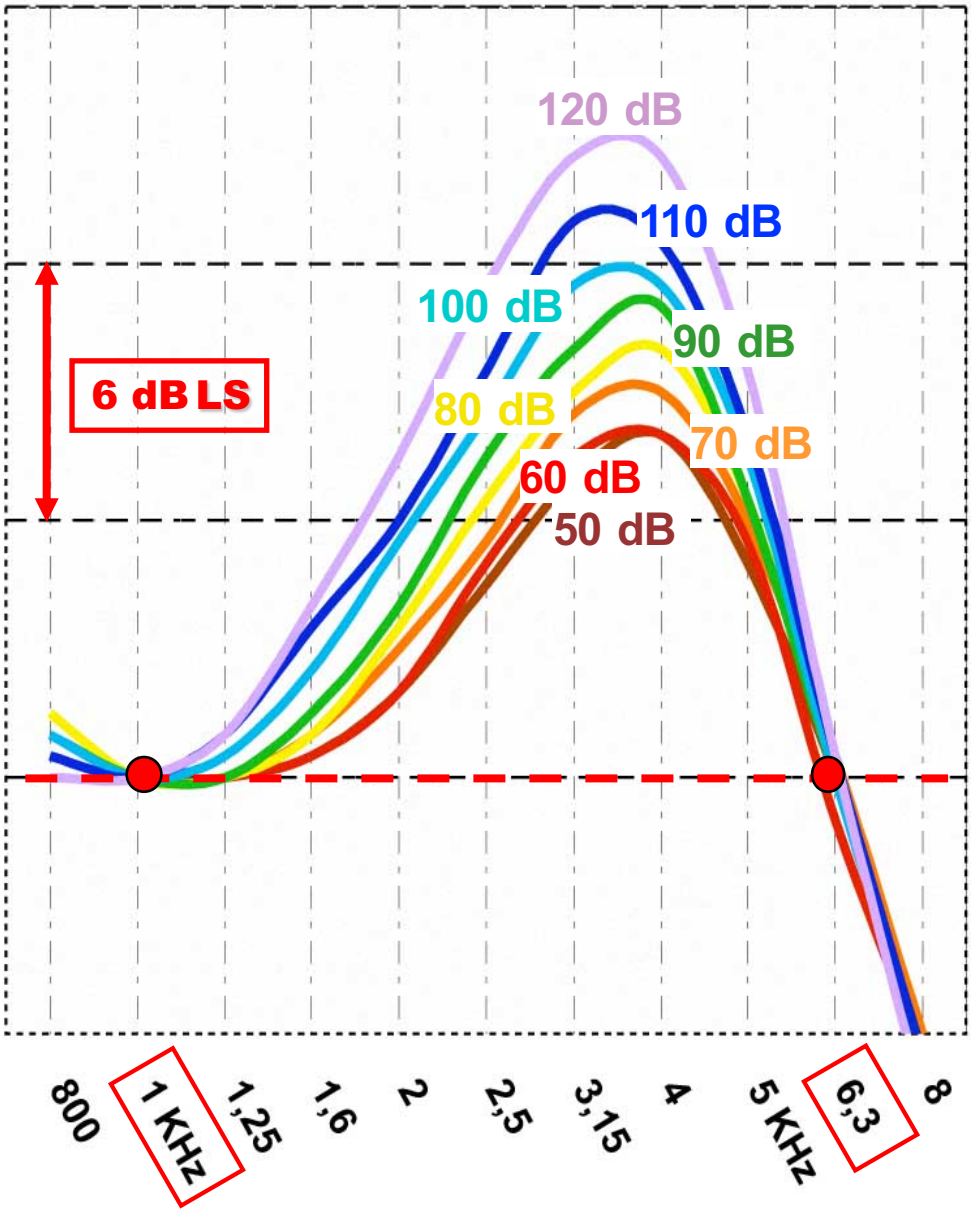
Les lignes isosoniques permettent de savoir quels niveaux physiques donnent une même sensation sonore quand on fait varier la fréquence

Sensation sonore en dB LS pour les différents seuils *à niveau constant* *Bruit Rose* sur tout le spectre…

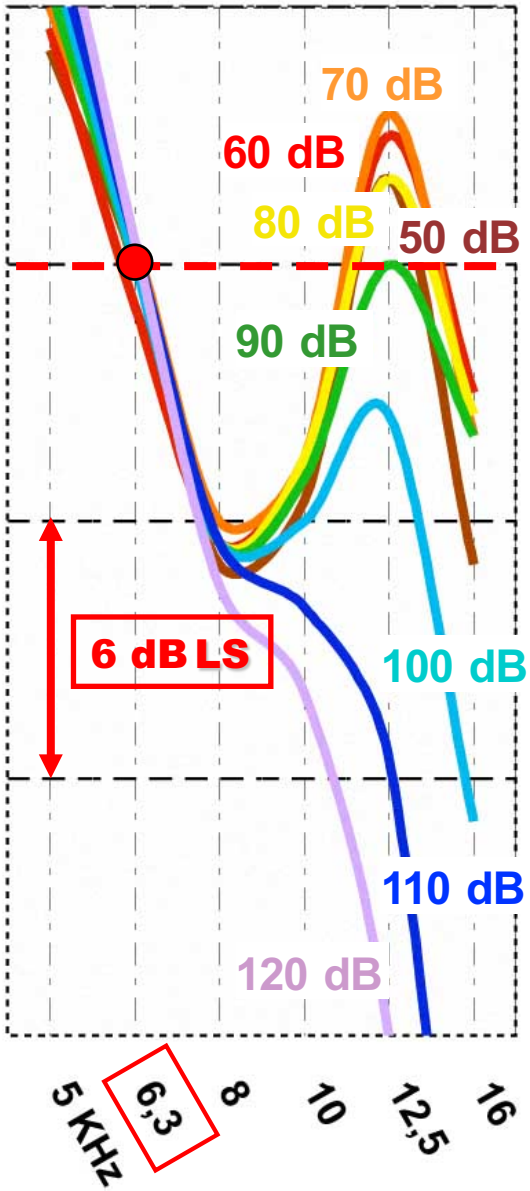


Ces seuils sont ramenés sur une **échelle relative** de ***0 dB LS*** …

De 1 KHz à 6,3 KHz



> à 6,3 KHz



À **3,5 KHz,** la sensibilité de l'oreille ne cesse d'augmenter avec le niveau…

Max pour **70 dB SPL**

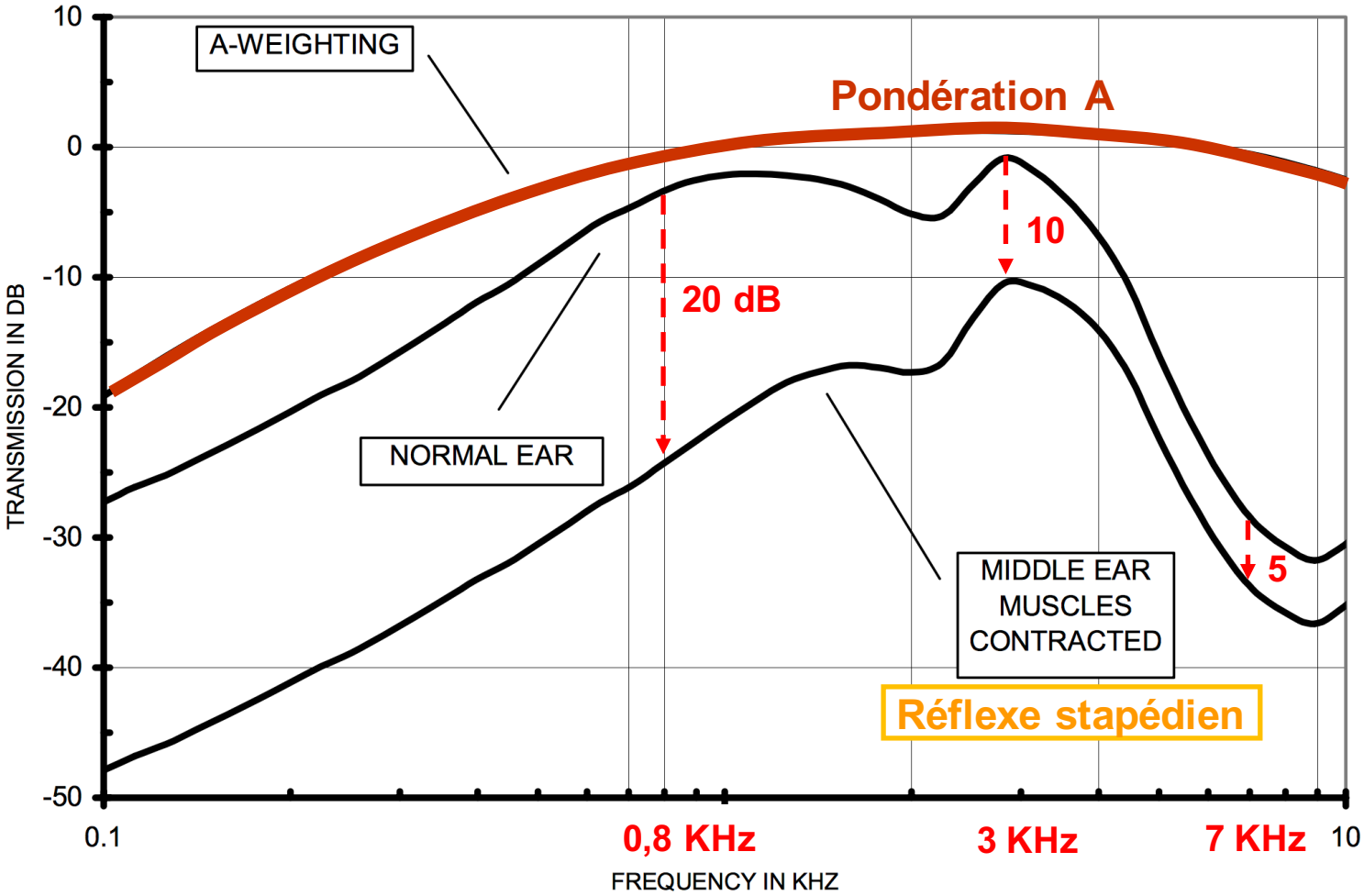
Réflexe stapédien ?

Études pour l'Armée Américaine

A New Method for Rating Hazard from Intense Sounds: Implications for Hearing Protection, Speech Intelligibility, and Situation Awareness

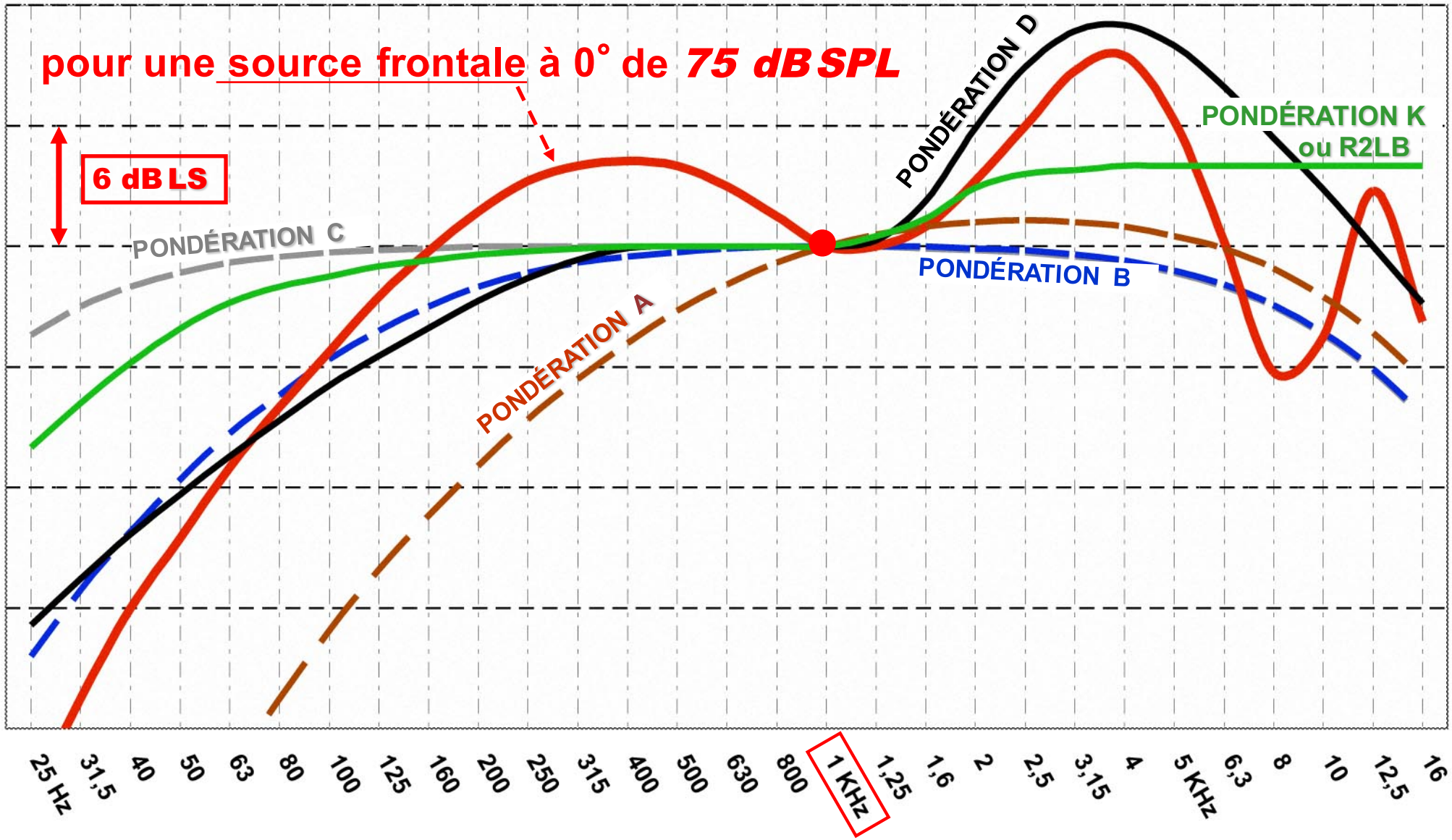
G. Richard Price
AHAnalysis
125 Conestoga Street, POB 368
Charlestown, MD 21914
USA

AHAnalysis@Comcast.net



Transmission of the human ear with no muscle contraction and with a middle ear muscle contraction compared with the A-weighting function

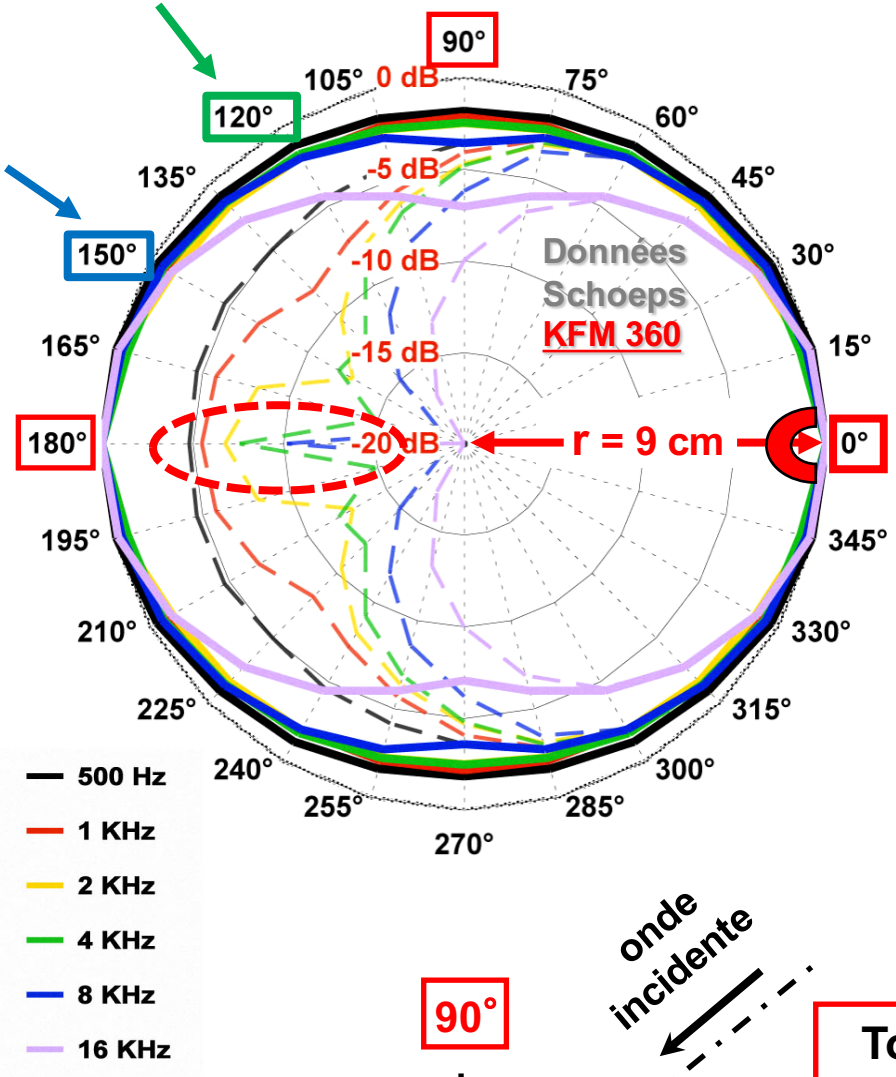
LES DIVERSES PONDÉRATIONS



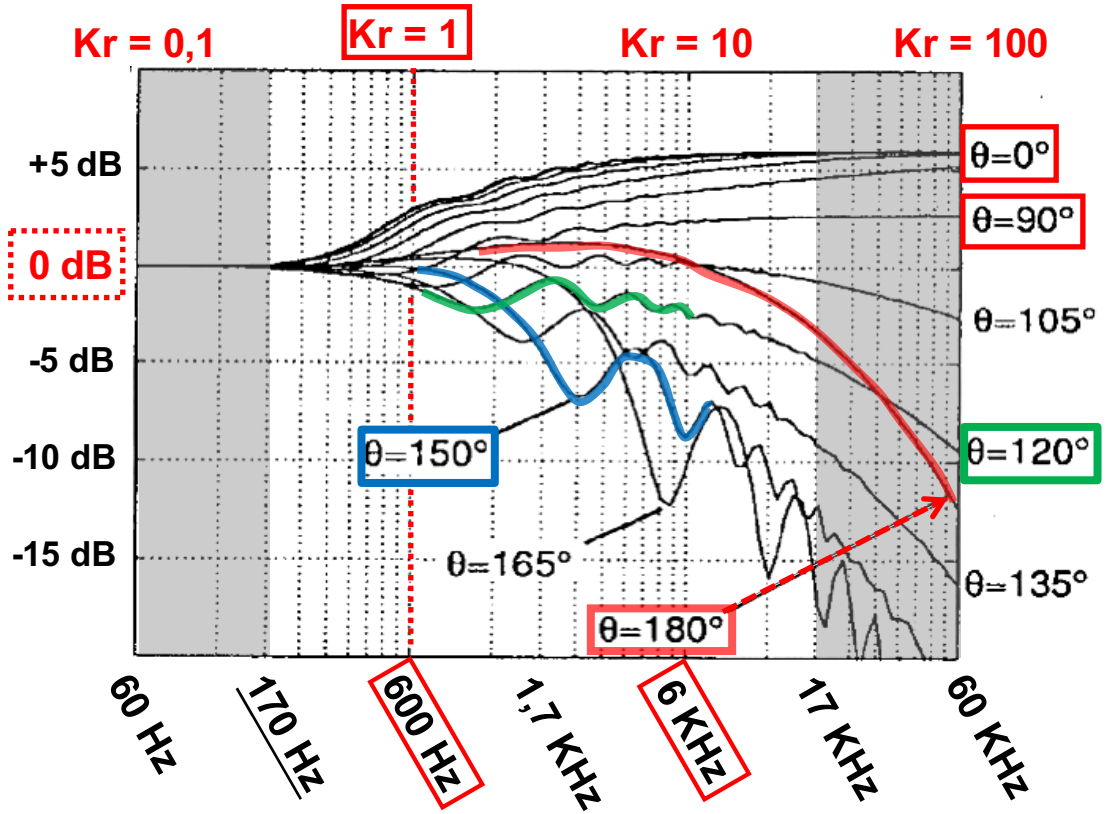
La pondération *K* ou *R2LB* est calquée sur la diffraction de la tête…

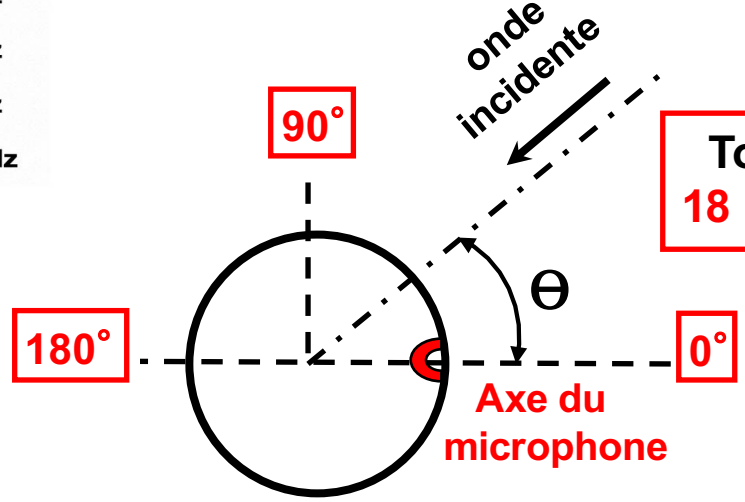
(Elle est le moteur de la norme *R128* pour évaluer le *LU*…)

DIFFRACTION DE LA TÊTE HUMAINE :



Modèle = Sphère de 18 cm de Ø





Tour de tête pour
18 cm de Ø = 56,5 cm

$$Kr = 2\pi r/\lambda$$

Pour Kr = 1 :

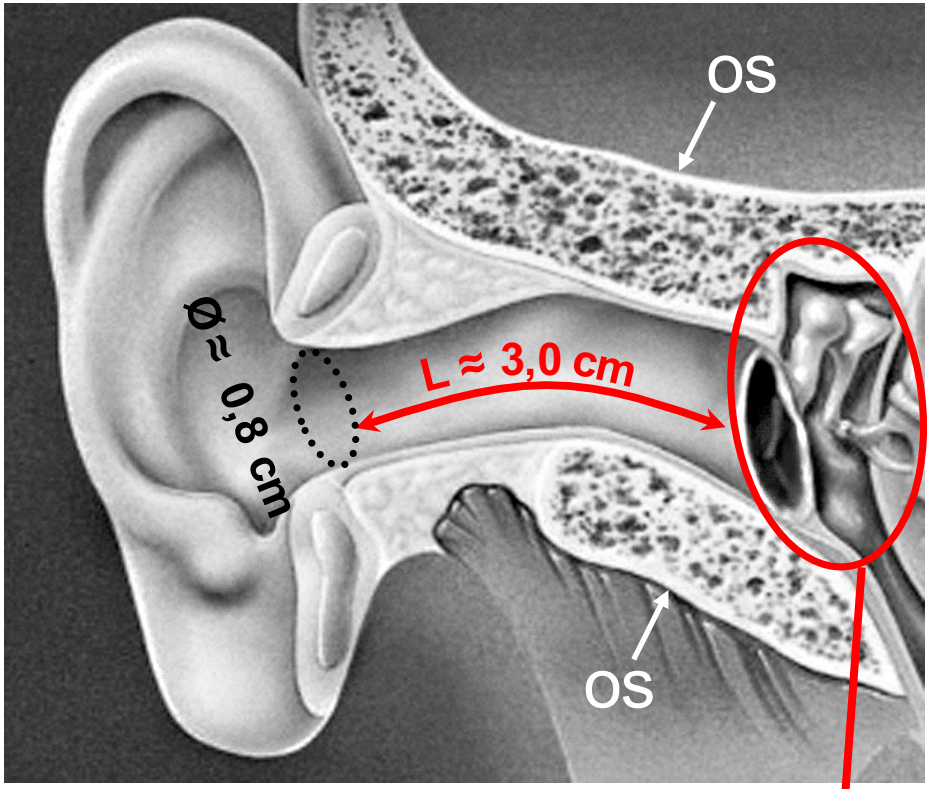
$$F = C/(2\pi r)$$

$$F \approx 600 \text{ Hz}$$

(C = Célérité du son)

RÉSONNANCES DU CONDUIT AUDITIF EN $\lambda/4$:

L'OREILLE EXTERNE

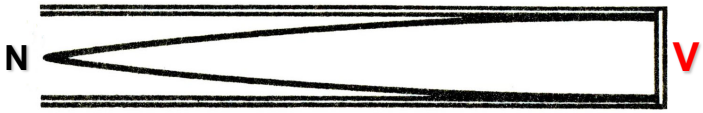


$$F = (2k+1)\frac{c}{4L+0{,}82\,r}$$

r = rayon du conduit auditif…

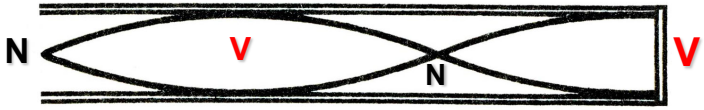
(0,82 r = corrections dues aux frottements)

Fondamental F = 2,7 KHz



k = 0

1ère Harmonique F = 8,3 KHz



k = 1

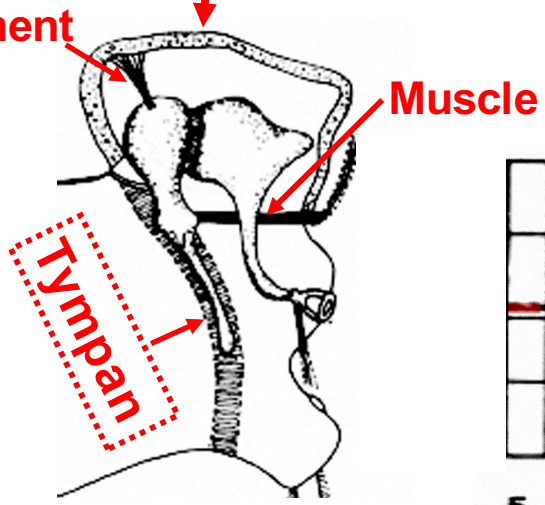
V = { VENTRE DE PRESSION / MAX DE PRESSION

Le reflex stapédien :

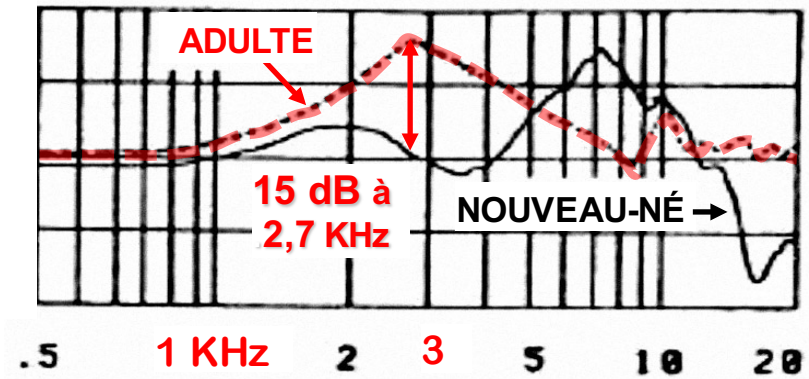
Limiteur Stéréo Organique !

pour un son > à 85 dB SPL

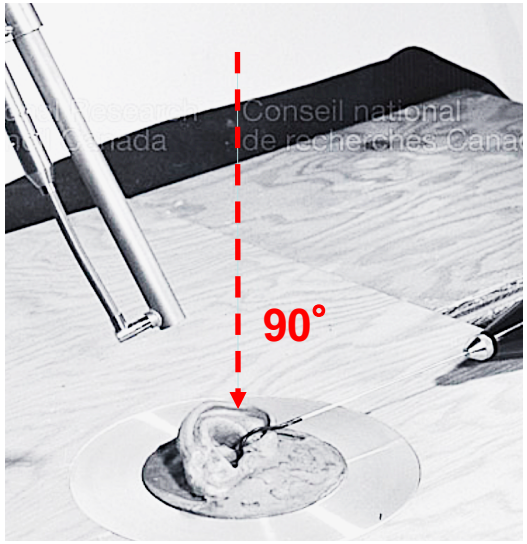
- Attack : 40 ms (mode Link)
- Bypass à 15 minutes…
(pour 100 dB SPL constant)

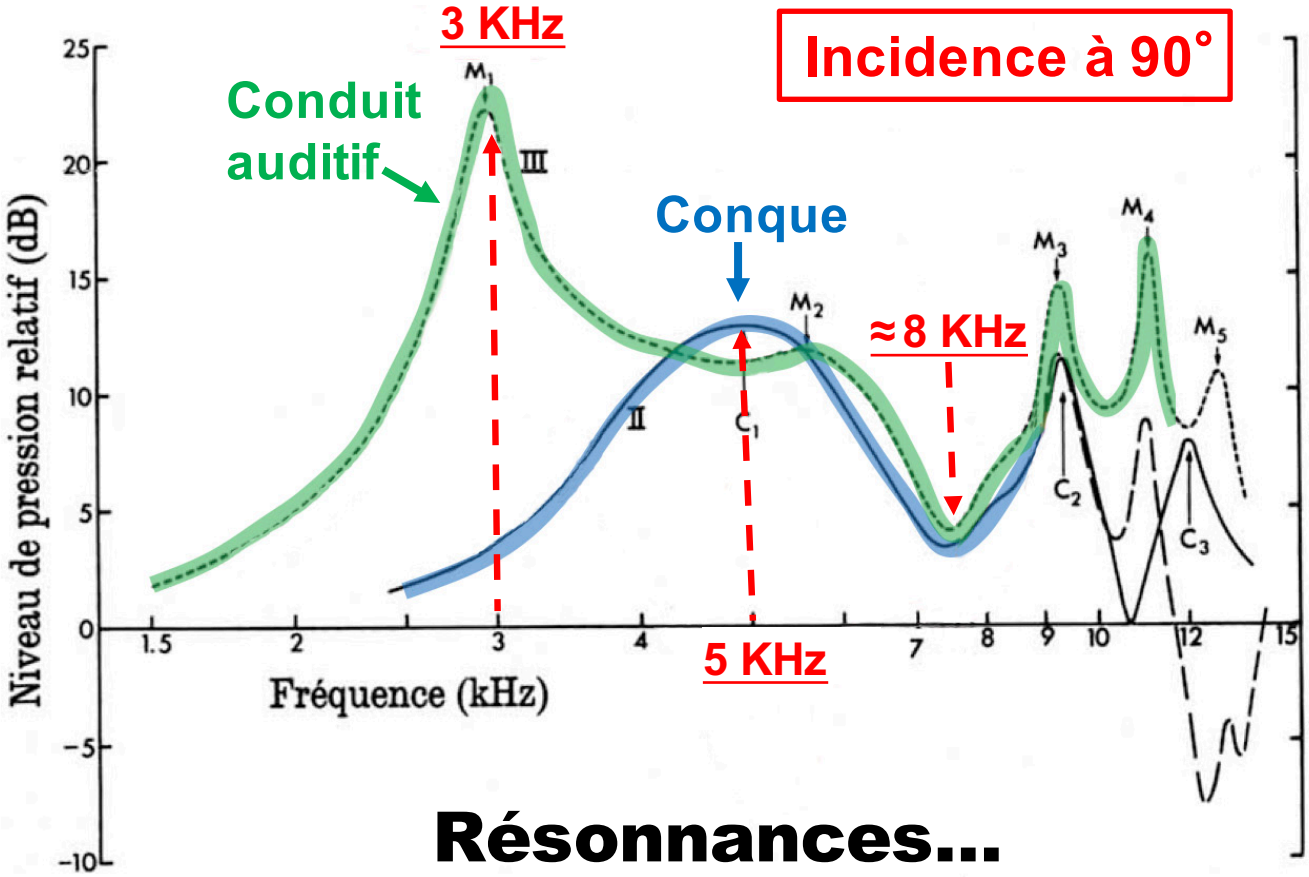


Les osselets de l'Oreille Moyenne

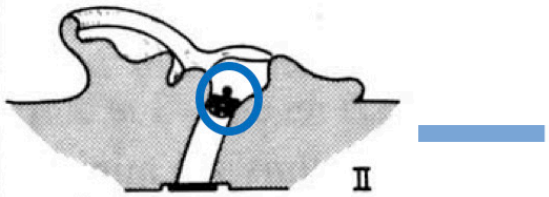


B. Kruger & R. Ruben, 1987

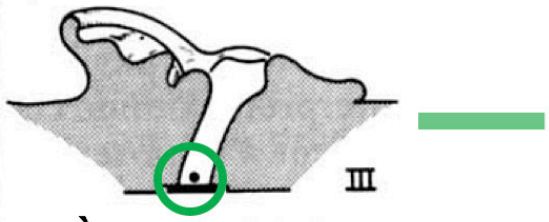




Shaw EAG, Teranishi R (1968). Sound pressure generated in an external-ear replica and real human ears by a nearby point source. J Acoust Soc Am 44:240-249



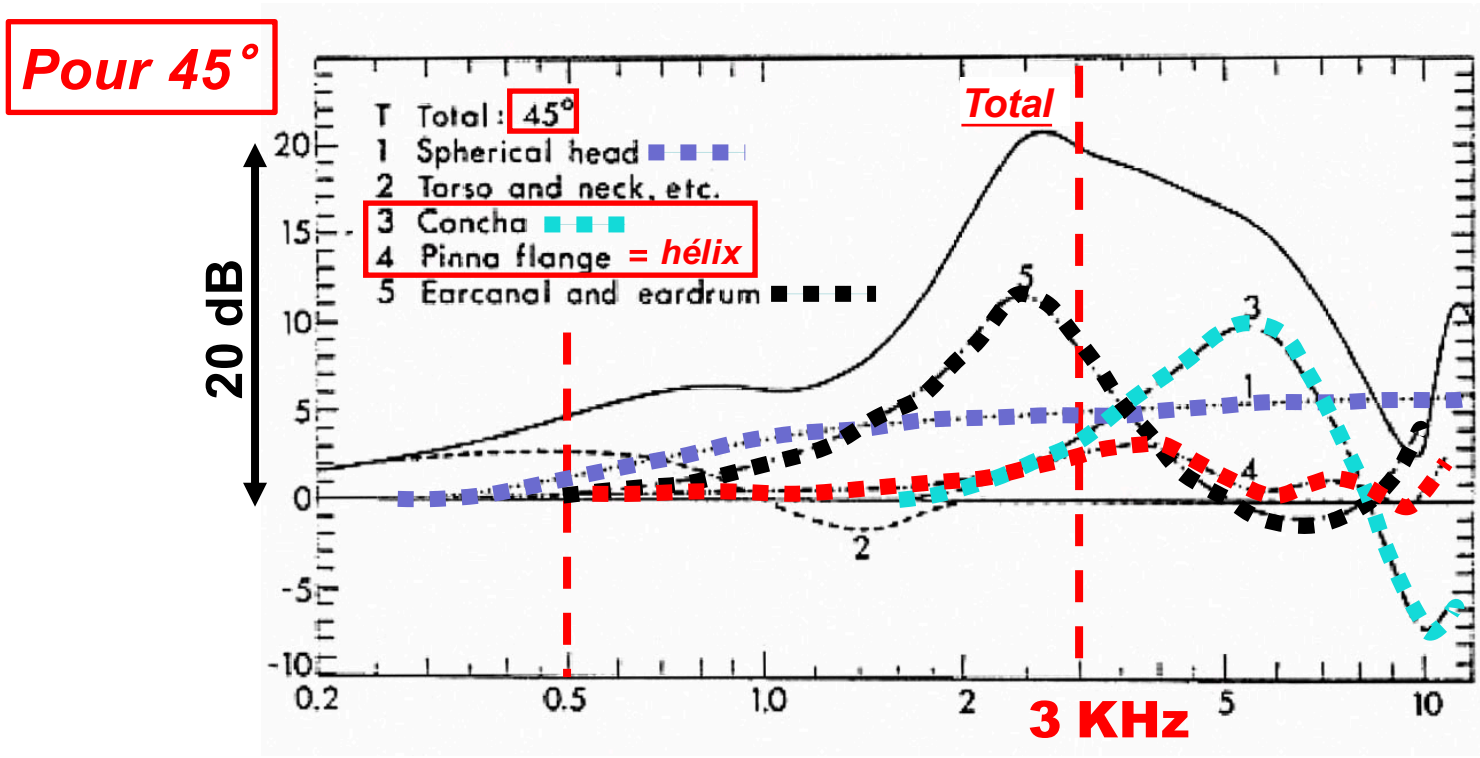
À l'entrée du conduit obturé

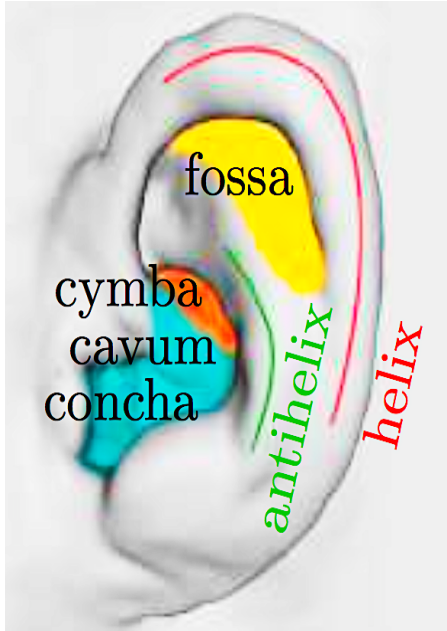


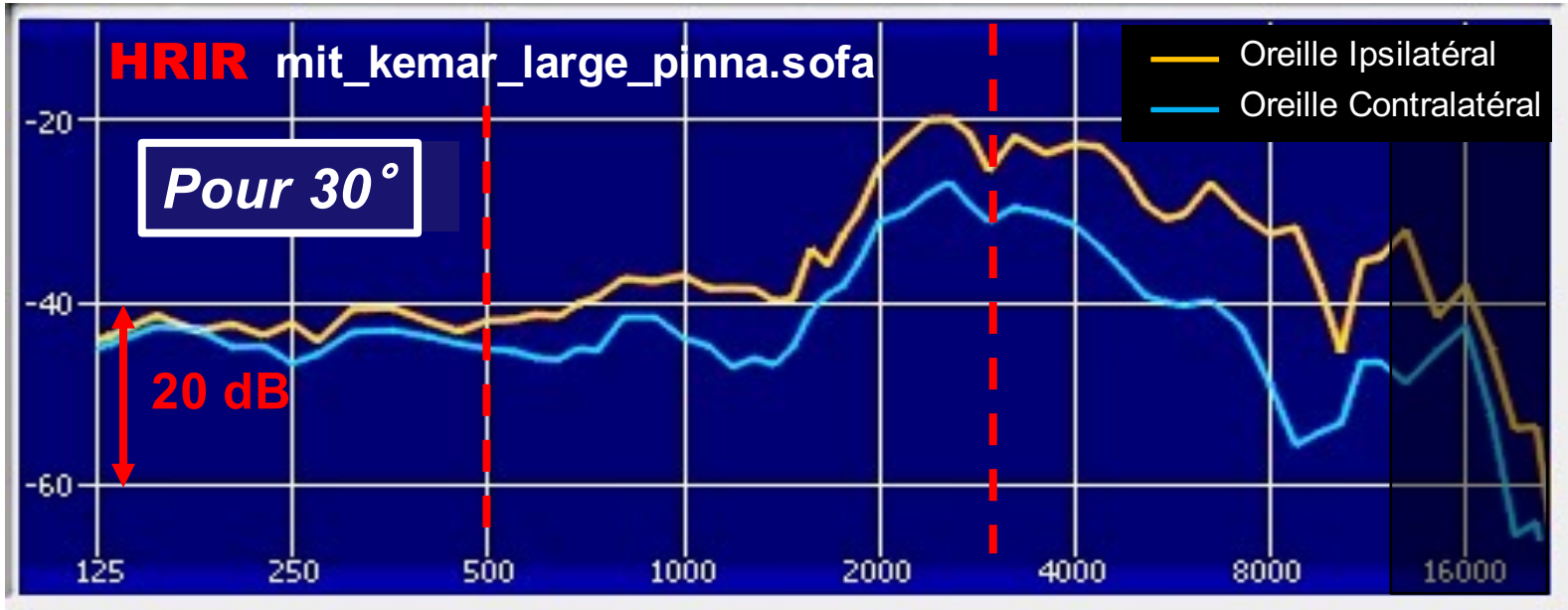
À proximité du tympan

Résonnances…

Gain acoustique, également appelé « gain étymotique » ou « Fonction de Transfert » *HRTF* de l'oreille externe



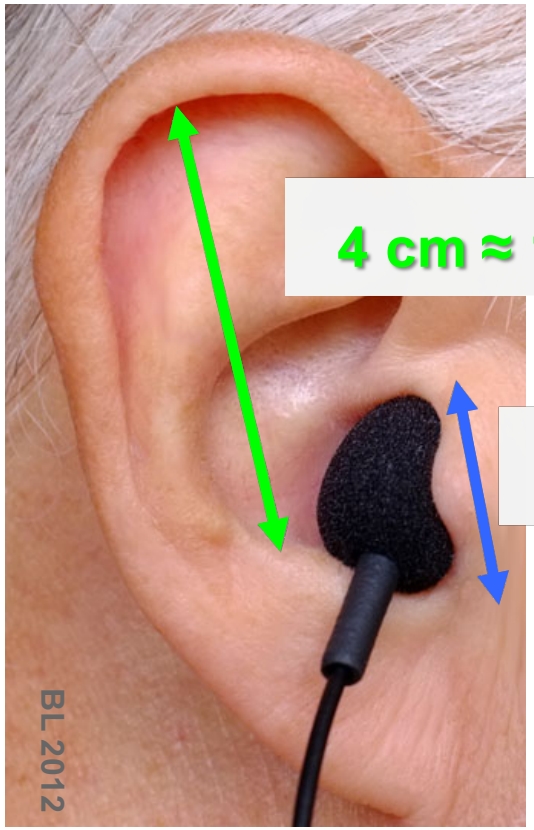




Kemar

L'oreille externe :

Réflexion (*et diffusion*) pour un objet de dimension ≥ 1/2 x λ

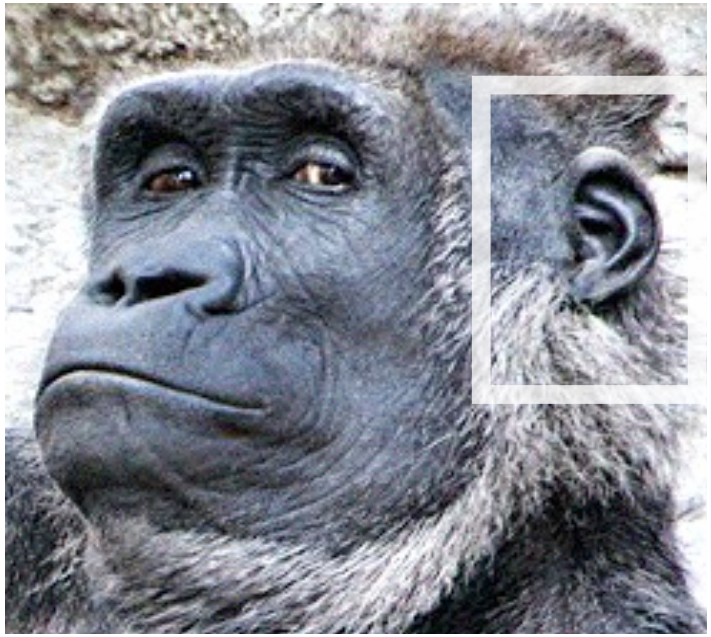


PAVILLON pour l'espace ***frontal***

4 cm ≈ 1/2 x λ à *4 kHz*

2 cm ≈ 1/2 x λ à *8 kHz*

TRAGUS pour l'espace ***dorsal***



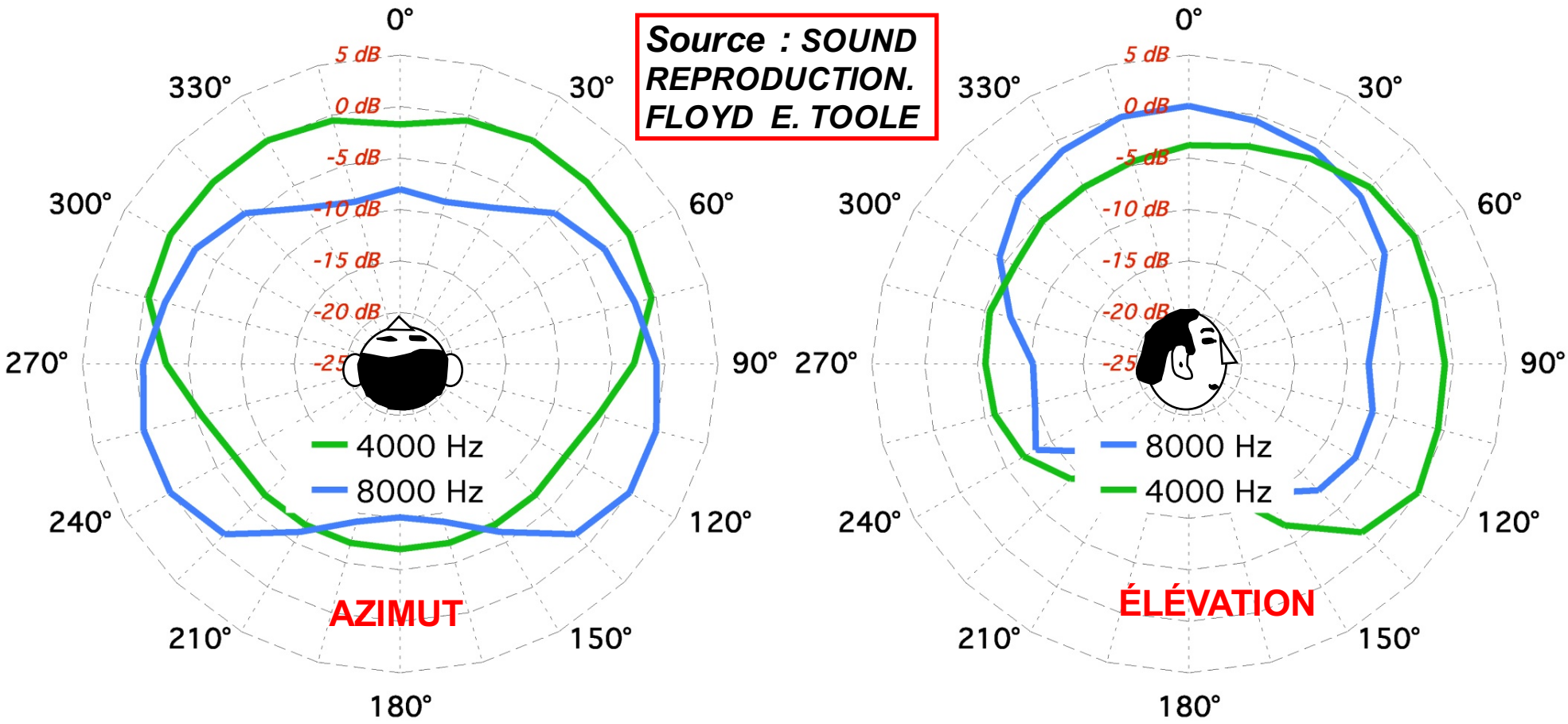
il y a + de 20 Ma !!

Indices Spectraux (IS) = 3D

Modifications des fréquences dues à l'Oreille externe… (de 4 KHz à 16 KHz)

Domaine **cognitif sensoriel** dans un environnement 3D

*Les **HRTF** de **Robinson & Whittle** 1960 :*

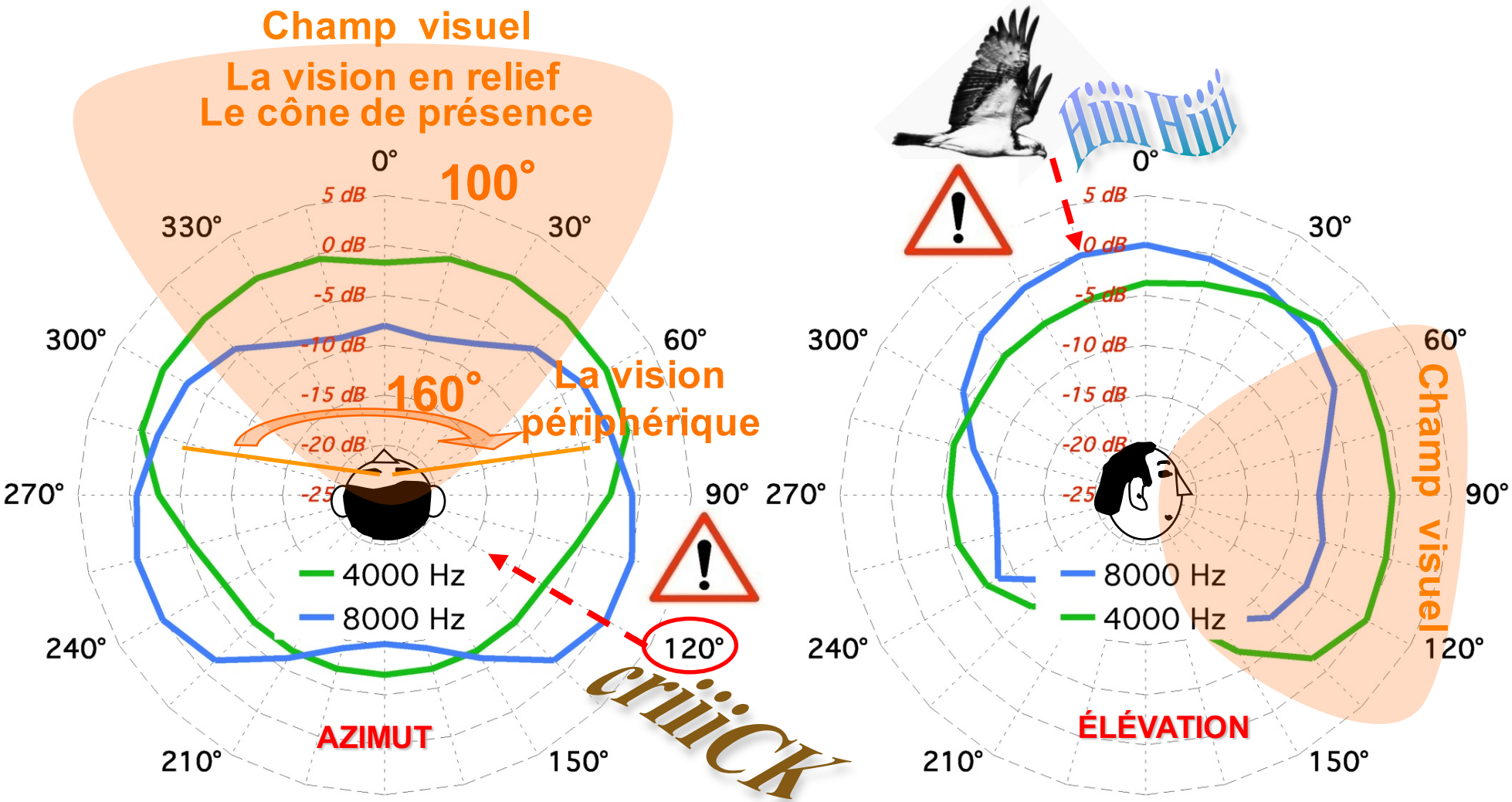


Directivité “ marquée ” de 2 fréquences : 4 kHz et 8 kHz

- **le 4 kHz = (présence / absence) ou la perception des distances**
- **le 8 kHz = (brillance / mat) et l’Espace sonore en 3D**

Domaine **cognitif sensoriel** dans un environnement 3D

*Les **HRTF** de **Robinson & Whittle** 1960 :*

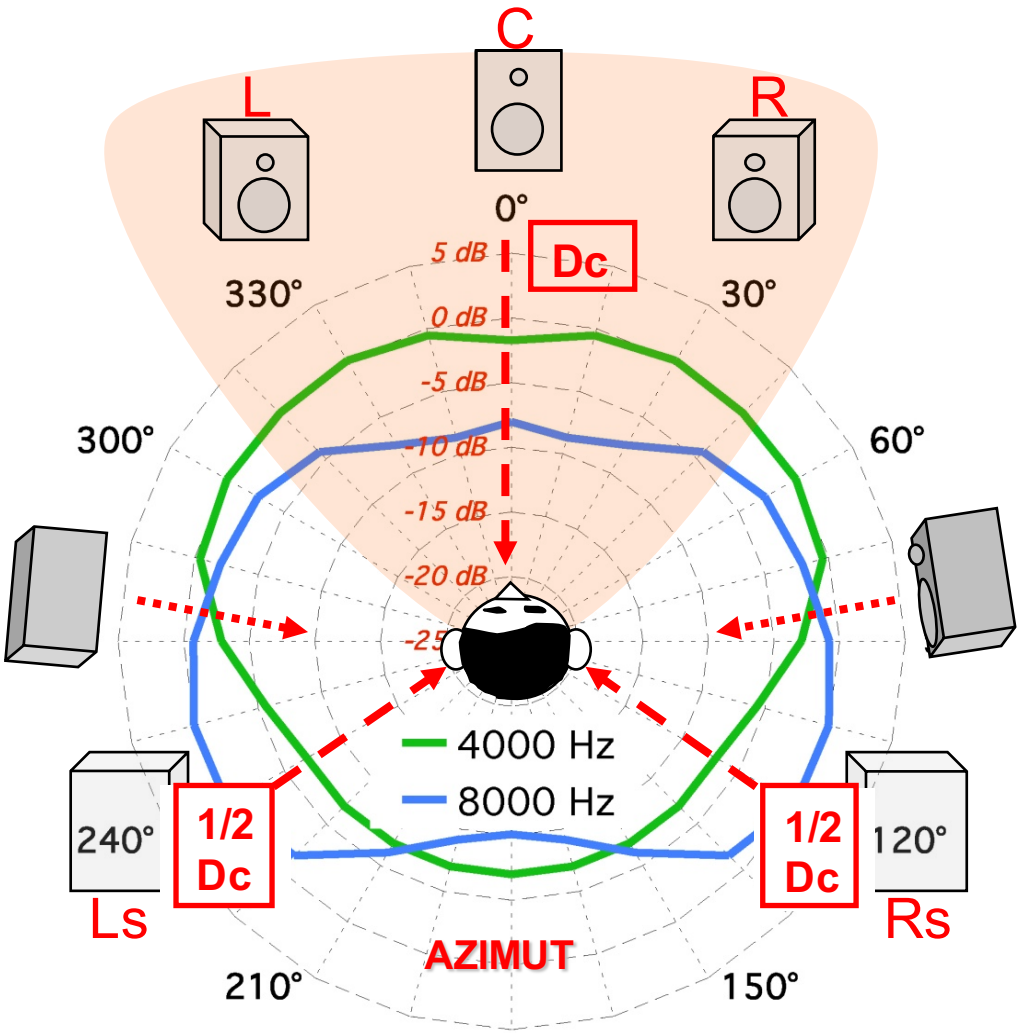


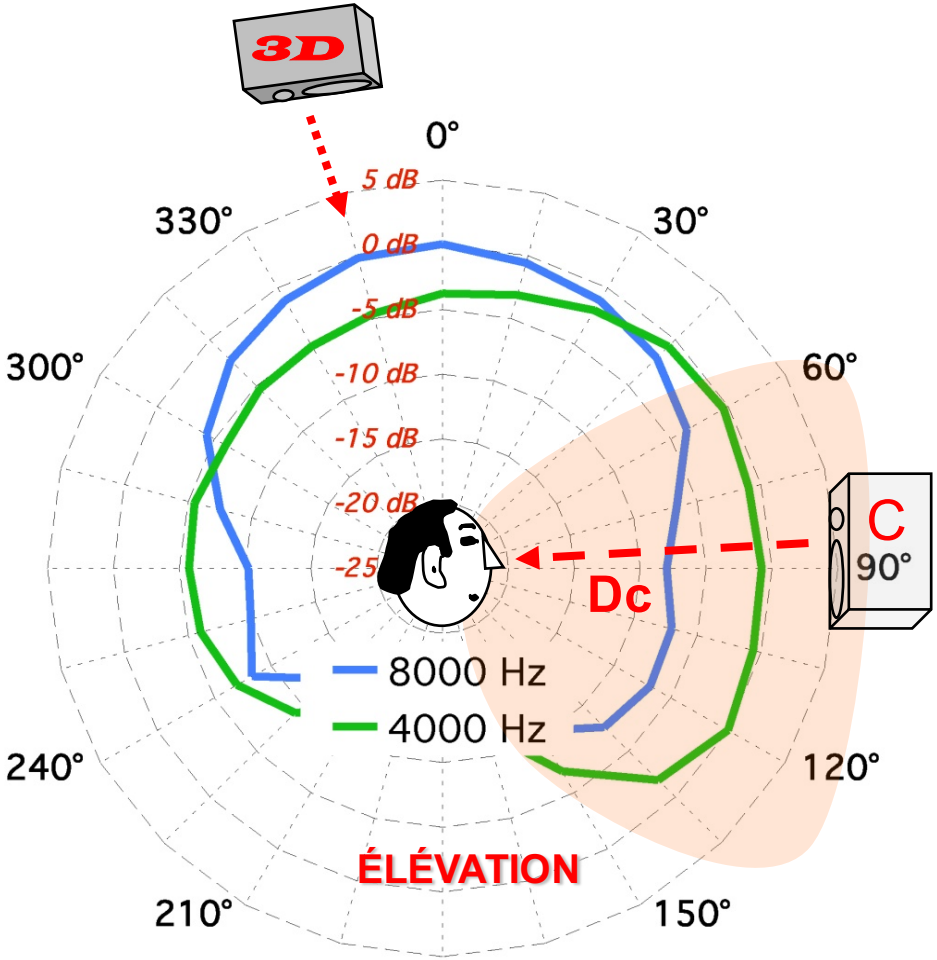
Oreille Primitive ⇔ Écoute de Vigilance en 3D

Pas d'homogénéité de l'espace sonore perçu

Domaine **cognitif sensoriel** dans un environnement 3D

*Les **HRTF** de **Robinson & Whittle** 1960 :*



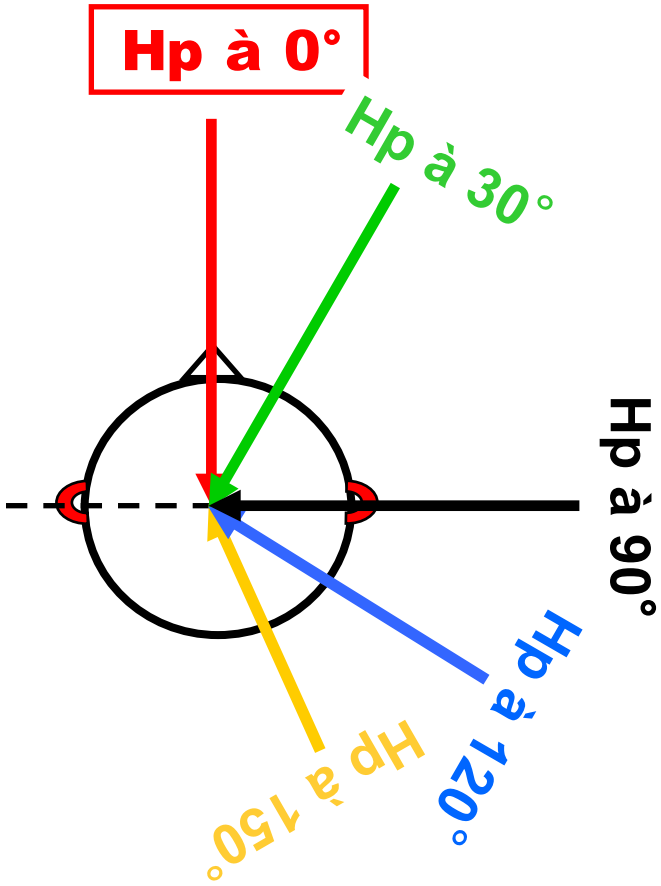


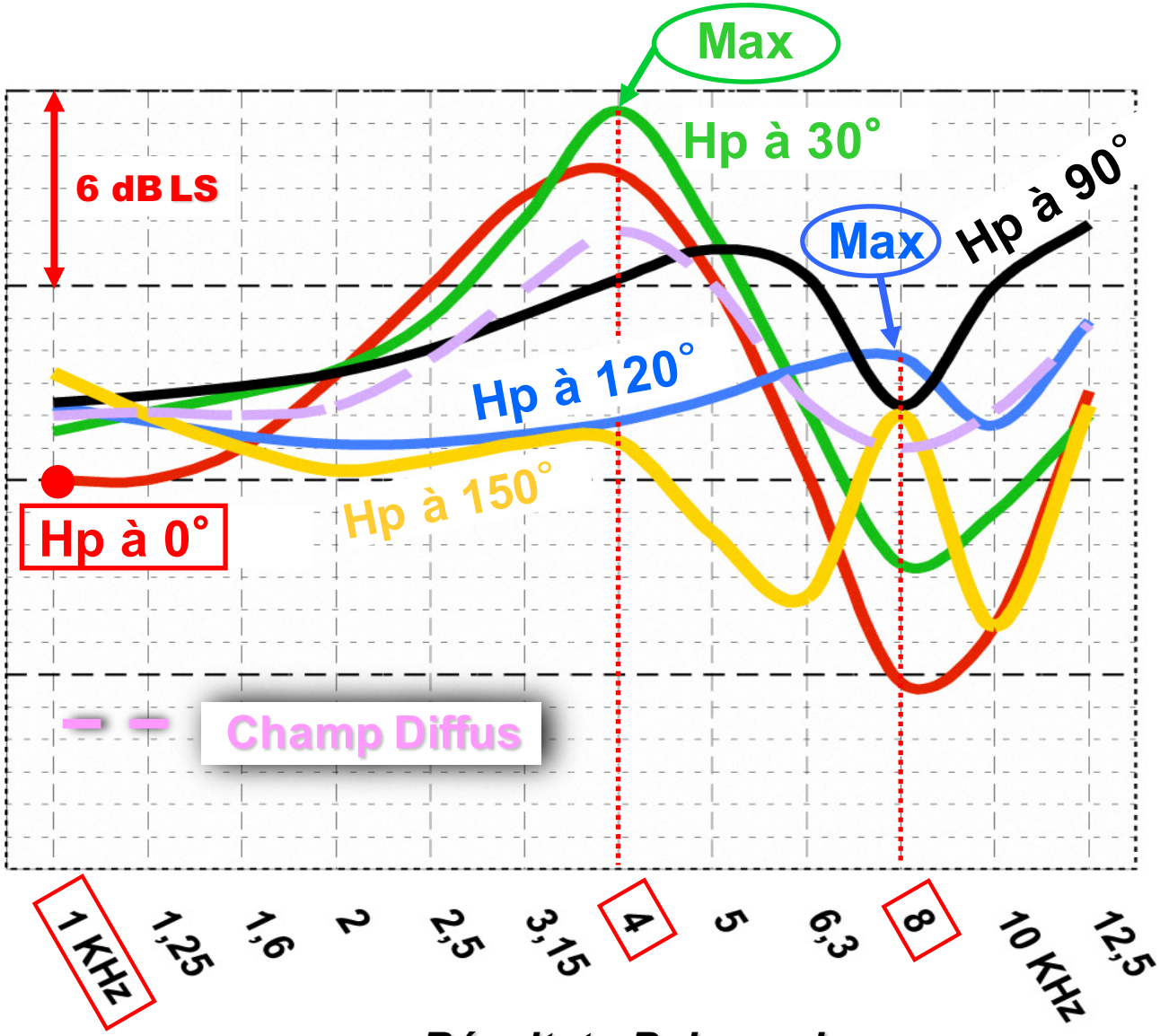
Localisation instable d'une source fantôme entre R et Rs ⇒ 7.0

Dc est mal perçue à l'arrière (Ls Rs) ⇒ délai pour conformité ITU.

Les Hauts parleurs en *7.0* dans le plan azimutal:

Sensation sonore pour 75 dB SPL sur du Bruit Rose :



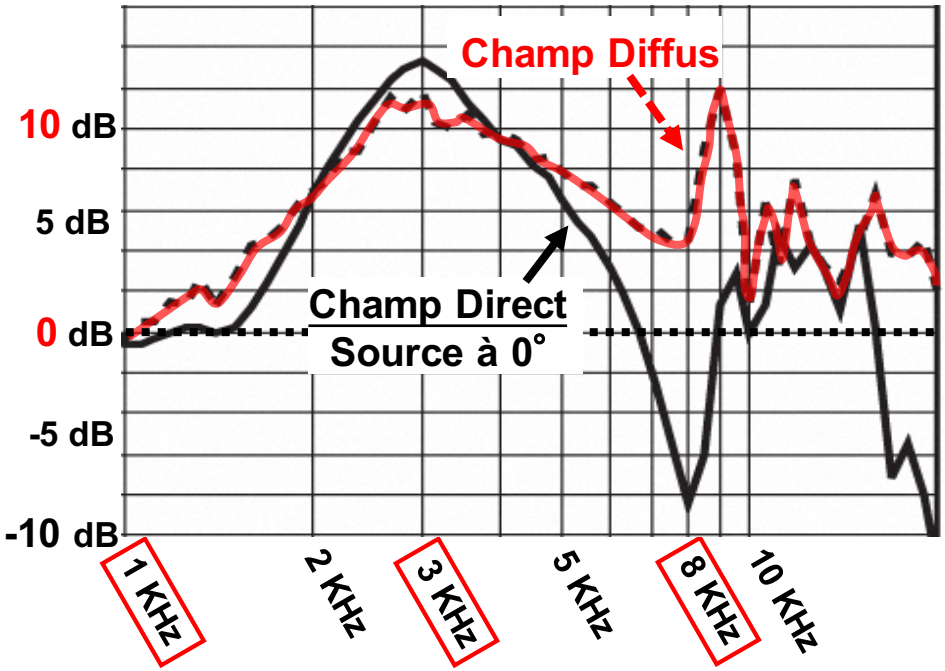


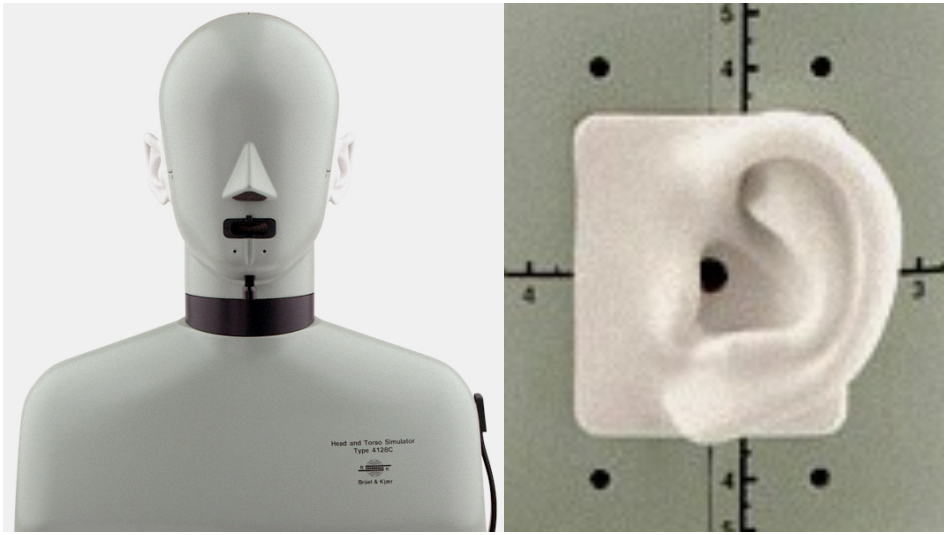
Résultats Polynomiaux

Mono
Stéréo
5.0
7.0

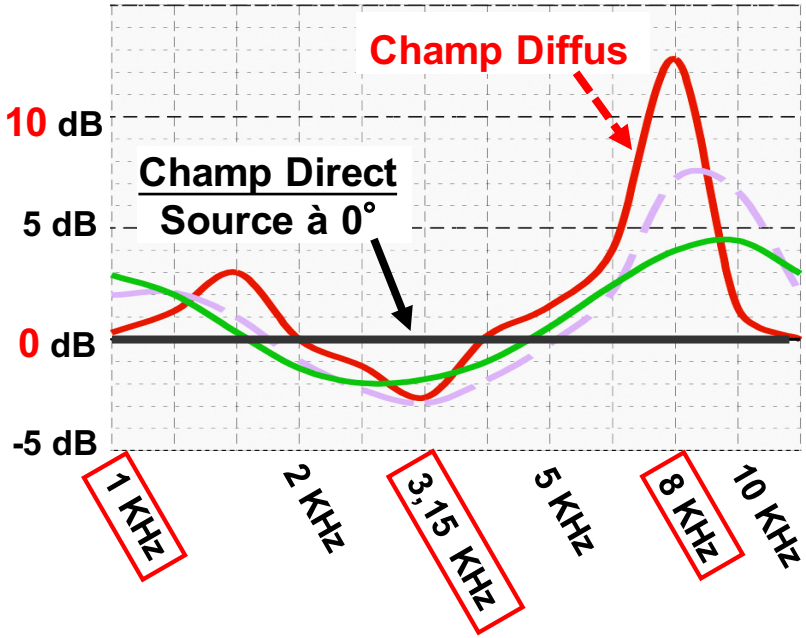
Brüel & Kjær

Tête et torse Type 4128 c





Documents et Photos **Brüel & Kjær**



Différence en niveau entre le champ diffus et le champ direct à incidence frontale, pour la tête et torse B&K type 4128 c…

Différence en niveau entre le champ diffus et le champ direct à incidence frontale, pour les résultats polynomiaux…

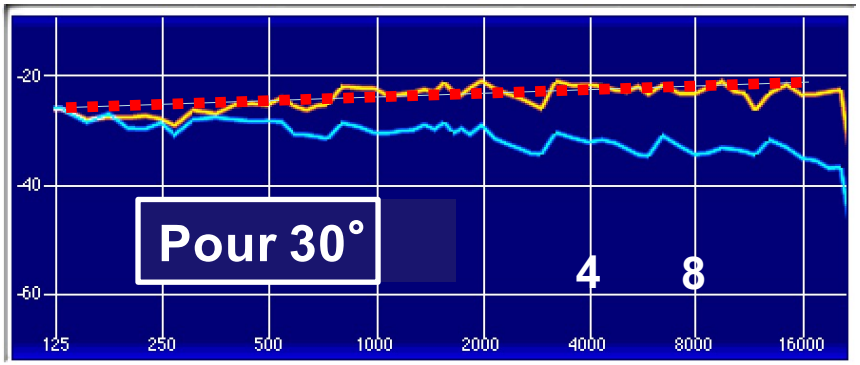
Norme *ISO 454* de 1975

« Relation entre les niveaux de pression acoustique de bandes étroites de bruit en champ diffus et en champ libre à incidence frontale pour des sonies égales. »

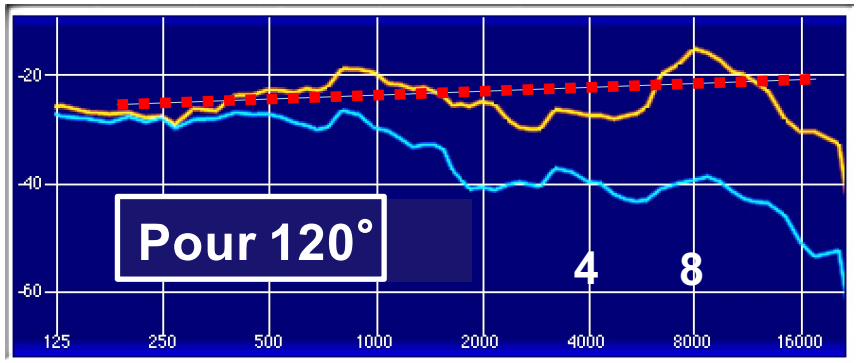
Corrections Champ Diffus (réponse linéaire) = Technique « EQ Matching »

Le Plug-in ***Nx*** de ***WAVES*** :

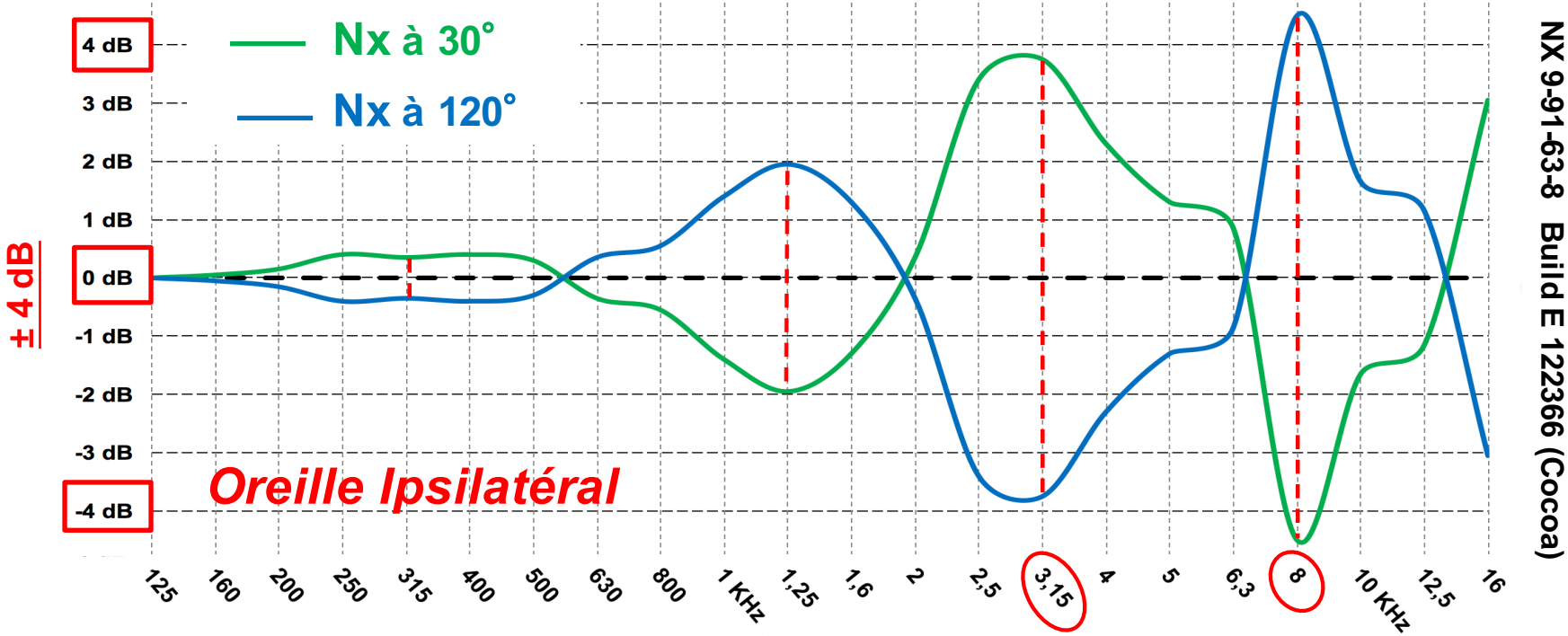
Oreille Ipsilatéral
Oreille Contralatéral



En 5.0



Corrections pour « ***binauraliser*** » en ***ILD*** du multicanal ***5.0*** :



*COMPARAISON ENTRE L'**AUDITION** ET LA **VISION** :*

⇔ 4 KHz

Rétine Centrale :

- **Présence de *cônes***
- **Faible sensibilité**
- **Forte acuité**
- **Traite les informations relatives à la *forme* et à la couleur**
- **Rôle : *Reconnaissance* de l'information…**

⇔ 8 KHz

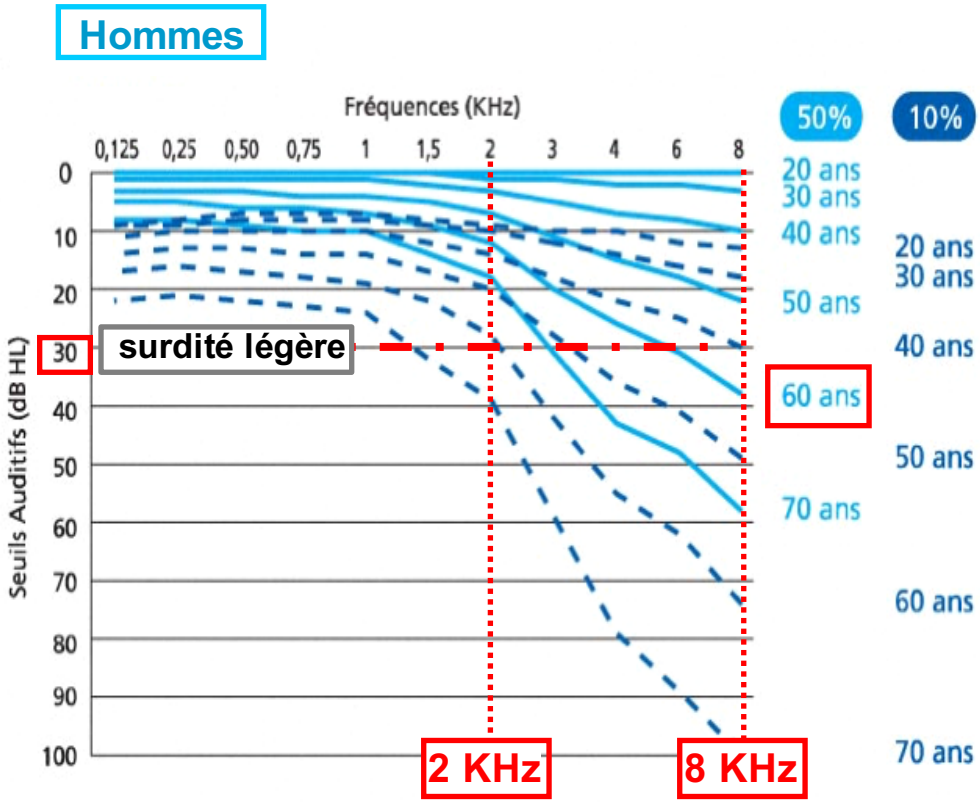
Rétine Périphérique :

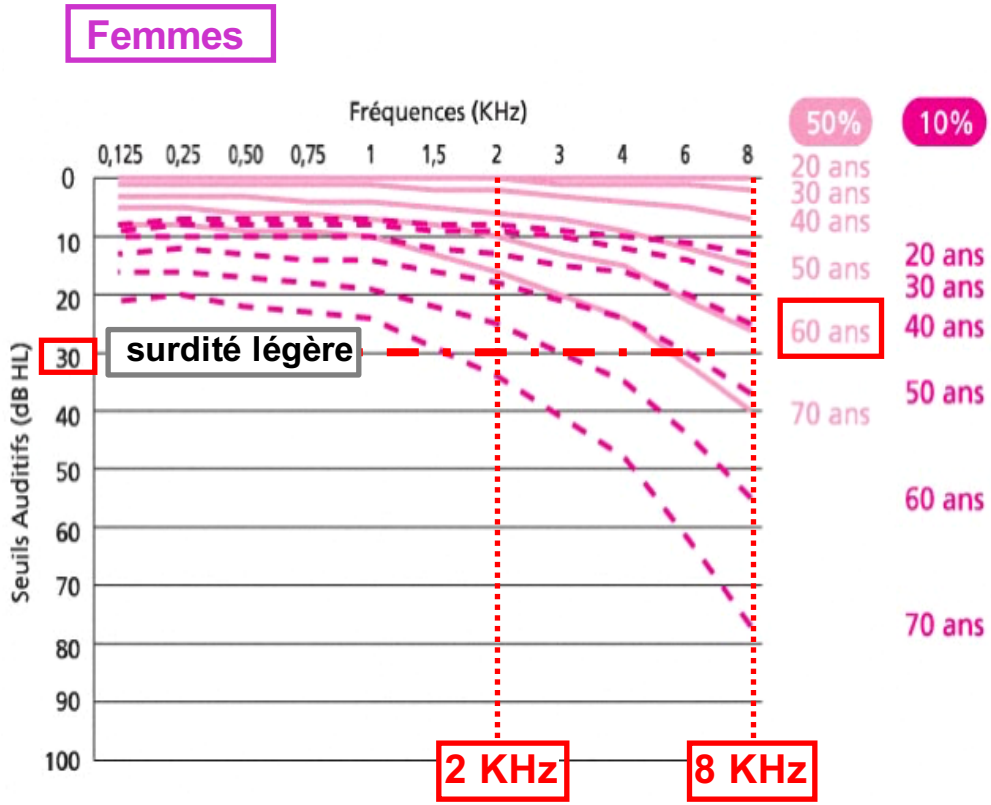
- **Présence de *bâtonnets***
- **Forte sensibilité**
- **Faible pouvoir de discrimination**
- **Traite les informations relatives au *mouvement***
- **Rôle : *Détection* de l'information et du** ⚠

wikipedia.org/Rétine

PRESBYACOUSIE norme ISO 7029

Audiogrammes :

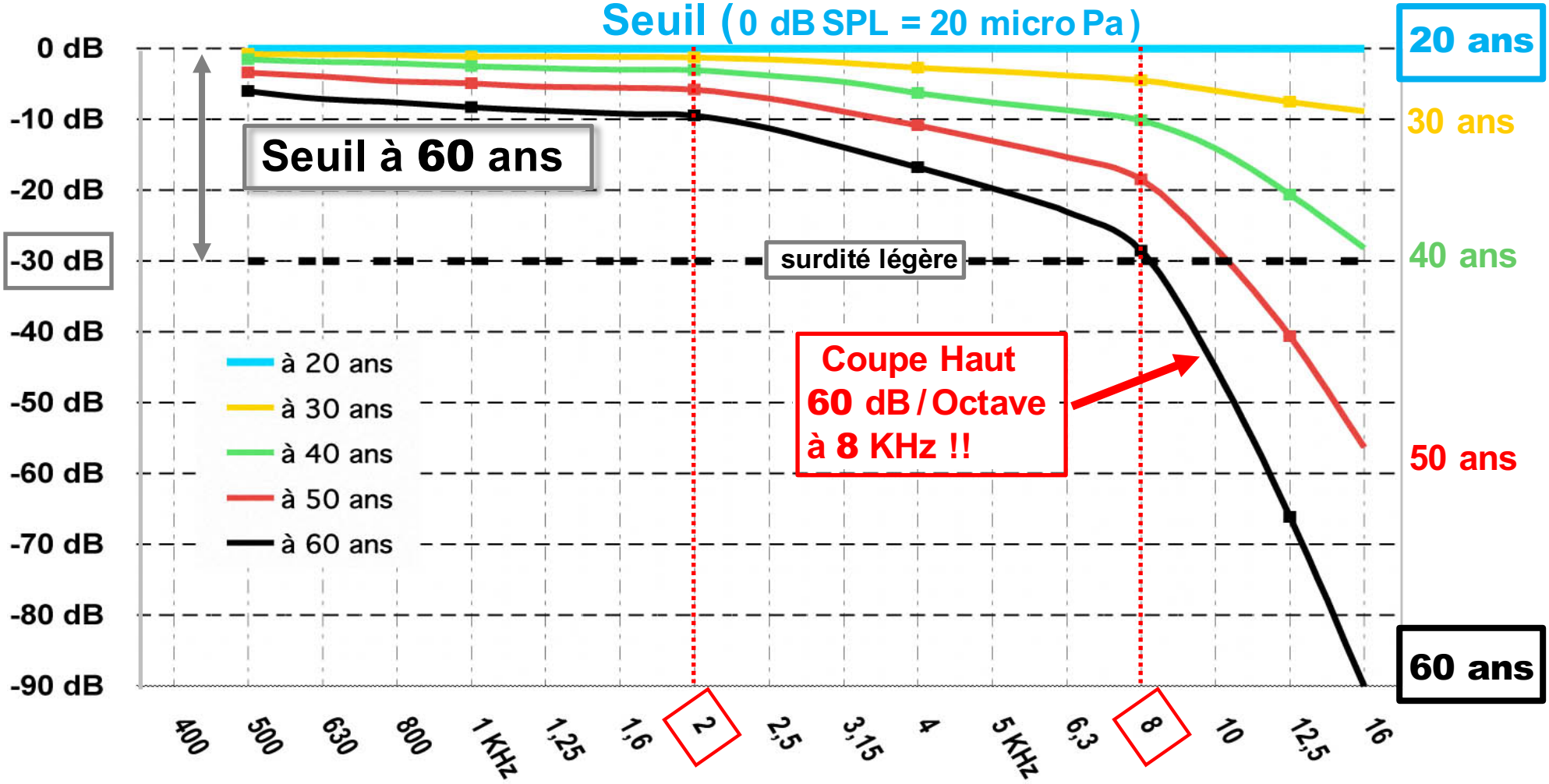




Ces données confirment les observations que chacun a pu faire ; l'effet de la presbyacousie est beaucoup plus marqué pour les fréquences supérieures à 2 KHz, avec une différence homme / femme notable.

KLARK TEKNIK The Audio System Designer

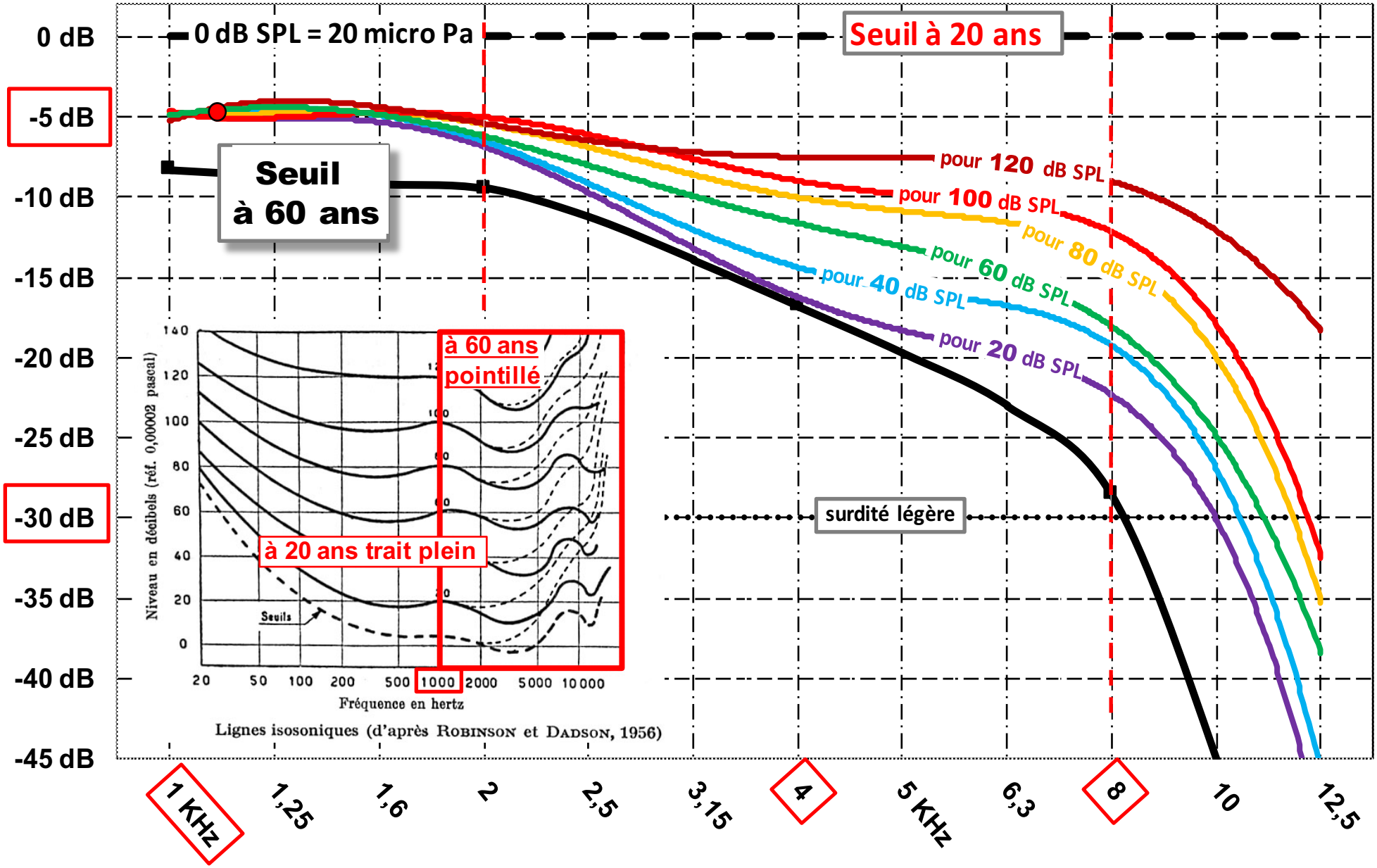
Technical Référence : *Presbyacousie* (Peter Mapp 1985)



Bandes directionnelles d'après Blauert 1969
*(dans le **plan médian**)*

Et le Son 3D ?

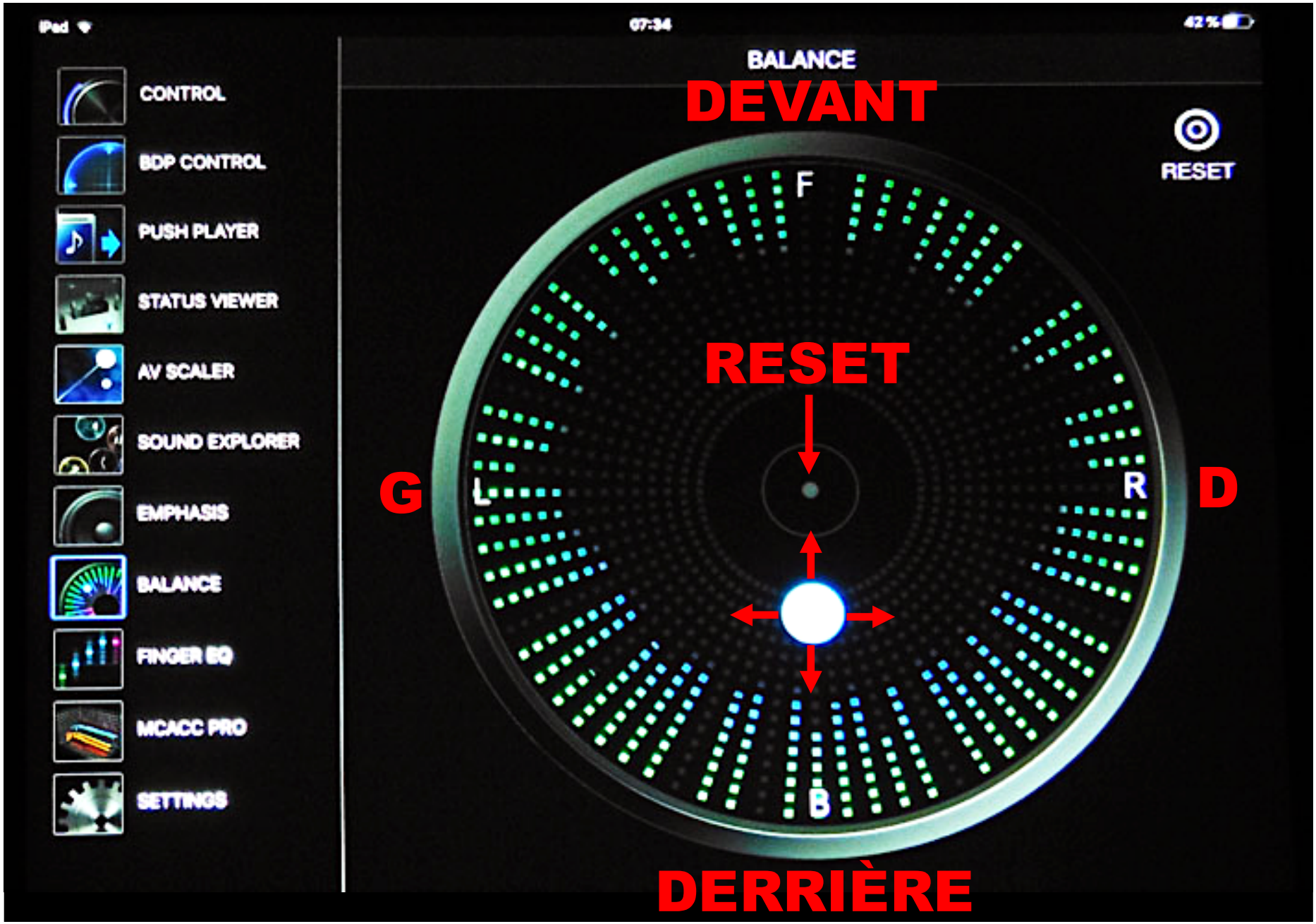
Presbyacousie à 60 ans en fonction du niveau acoustique



Robinson et Dadson 1956

Application pour IPAD: Pioneer iControlAV5

Down Mix du 5.1 au Binaural ?



CONCERT
A L'IMPROVISTE

Anne Montaron
France Musique

- **Duo IANA : Christine WODRASCKA,** piano
et Betty HOVETTE, piano 9 Avril 2018

- **Quartet HORNS** 12 octobre 2015

Saxophone ténor **Bertrand DENZLE**
Saxophone alto **Pierre-Antoine BADAROUX**
Trombone **Fidel FOURNEYRON**
Trompette **Louis LAURAIN**

DPA 4060 Miniature Omnidirectional Microphone, Hi-Sens

Binaural Natif

Specifications

Directional characteristics:
Omnidirectional

Frequency range, ± 2 dB:
Soft boost grid: 20 Hz – 20 kHz, 3 dB soft boost at 8 – 20 kHz.
High boost grid: 20 Hz – 20 kHz, 10 dB boost at 12 kHz.

Sensitivity, nominal, ±3 dB at 1 kHz:
20 mV/Pa; -34 dB re. 1 V/Pa **+5 dB comparé à Schoeps MK 4V**

Equivalent noise level, A-weighted:
Typ. 23 dB(A) re. 20 µPa (max. 26 dB(A))

S/N ratio, re. 1 kHz at 1 Pa (94 dB SPL):
71 dB(A)

Dynamic range:
Typ. 100 dB

Max. SPL, peak before clipping:
134 dB **Distorsion ?**

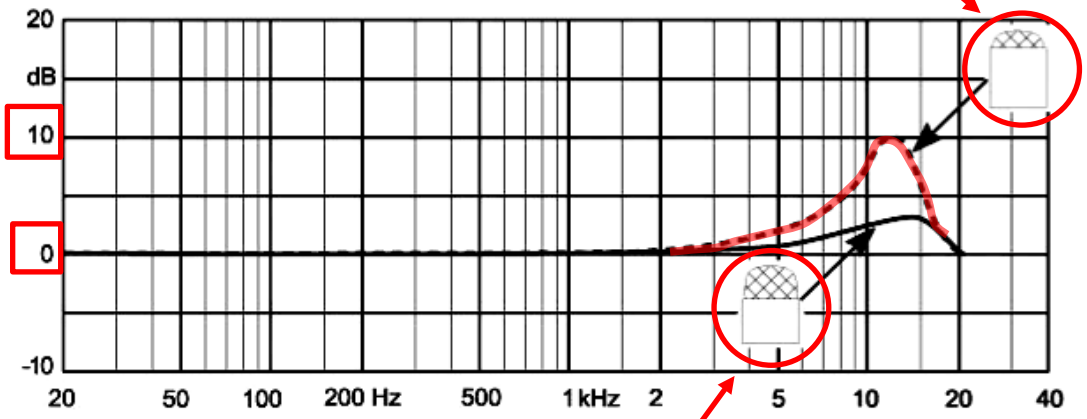
Power supply:
For wireless systems: Min. 5 V through DPA adapter. With DAD6001-BC/ DAD6024/DAD4099-BC: 48 V phantom power ±4 V for full performance.

Connector:
MicroDot

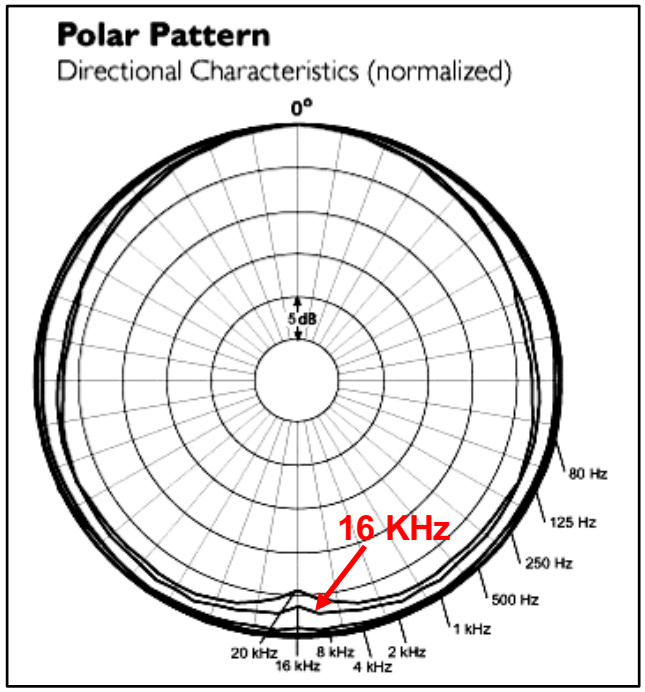
Cable length:
1.8 m (5.9 ft)

Les 2 grilles n'ont pas d'incidence sur la directivité : Omni à 10 kHz !!

À utiliser en extérieur DUA 6002



Miniature Grid Soft Boost DUA6001
dans la majorité des cas en intérieur…



Mise en place des DPA 4060

comme des bouchons d'oreille !

Ce n'est pas un coton tige !!

DPA DUA0560 Windscreen
(5 pièces)

23,90 €

Mousse qui permet de maintenir le micro au creux de l'oreille

Pour répondre à la question :

Pourquoi la capsule du *DPA 4060* est tournée vers le conduit auditif ?

Réponses :

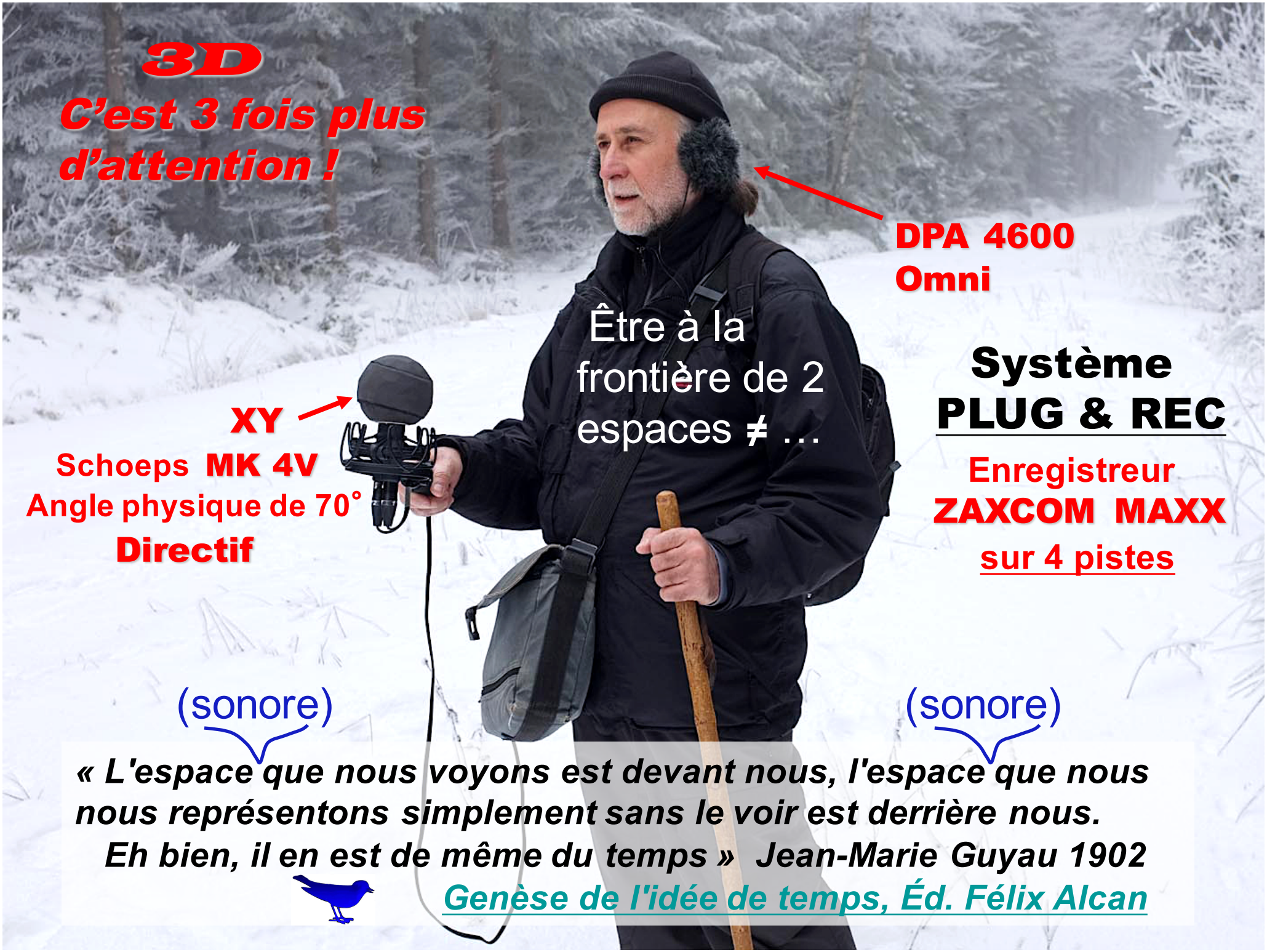
- Pour prendre toute l'**empreinte** de l'oreille externe (*indices spectraux* = ***IS***).
- Le **nœud de pression** à l'entrée du conduit ne produit aucune résonance.
- La **mousse** **DUA0560** permet de maintenir le micro au creux de l'oreille.
- La capsule est **Omni** quelque soit son orientation, jusqu'à 10 KHz.

Stéréo

Yann Paranthoën

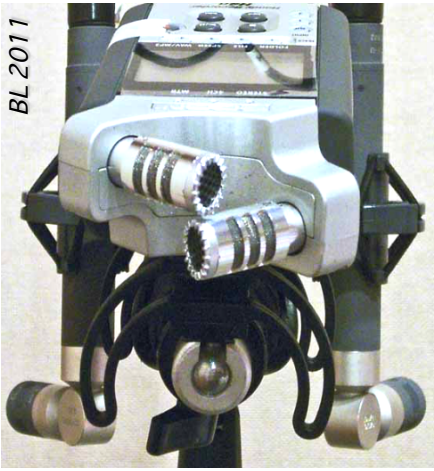
Pas de casque… ***est-ce parce qu'au casque, nous entendrions systématiquement au passé ? ….. ESPACE SPATIO-TEMPOREL***

Photo © Janneth Rodriguez / Arles, 1999


3D
C'est 3 fois plus d'attention !
DPA 4600
Omni
Être à la frontière de 2 espaces ≠ …
Système
PLUG & REC
Enregistreur
ZAXCOM MAXX
sur 4 pistes
XY
Schoeps MK 4V
Angle physique de 70°
Directif
(sonore)
(sonore)
« L'espace que nous voyons est devant nous, l'espace que nous nous représentons simplement sans le voir est derrière nous.
Eh bien, il en est de même du temps » Jean-Marie Guyau 1902
Genèse de l'idée de temps, Éd. Félix Alcan

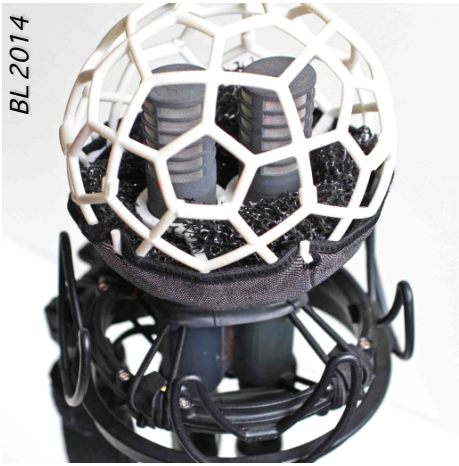
Les Micros Coïncidents ne fonctionnent qu'en ILD :

XY Zoom H4n



Suspension Rycote…

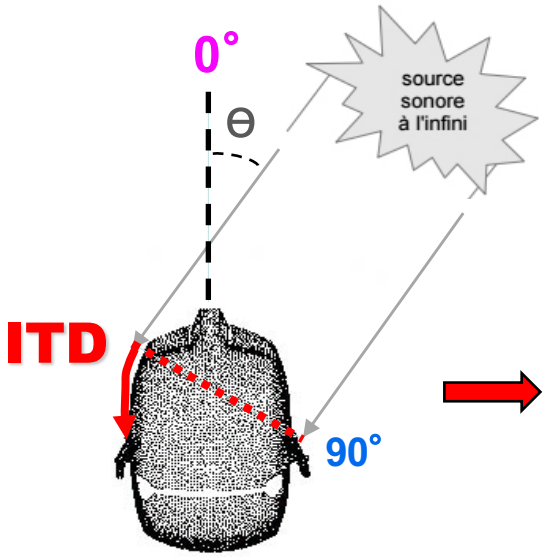
XY Schoeps MK 4v



Bonnette Cinela Léonard …
Suspension Rycote / Schoeps …

Double XY Ambisonic ©

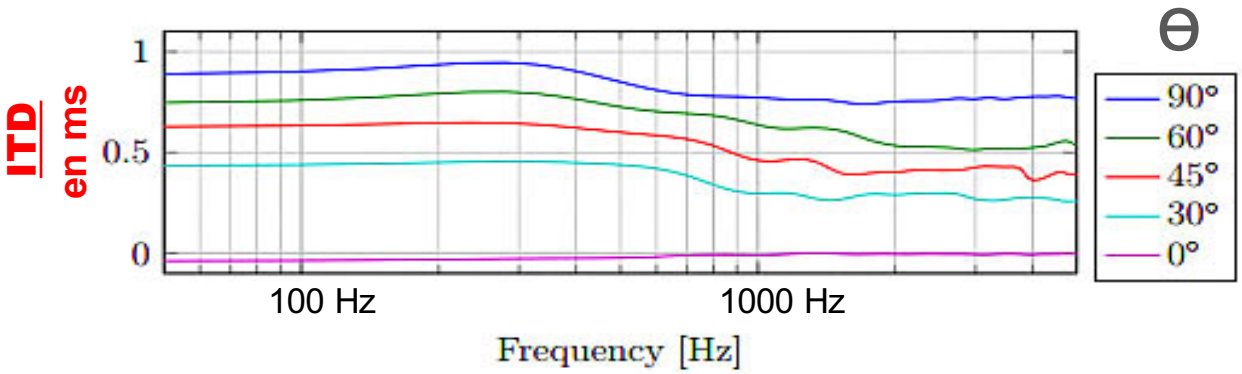
Suspension Shure A53M …



Tête Neumann KU 100

Attention :

L' ITD des PDA 4060 ne peuvent pas se mélanger à d'autres ITD …

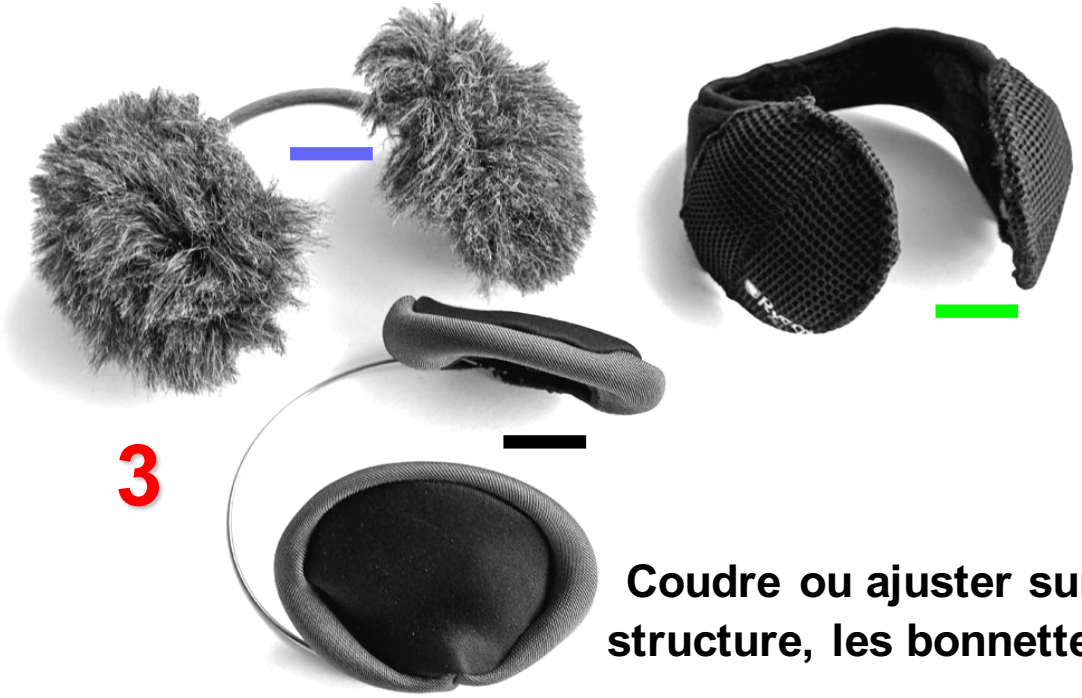


Jakob Vennerød
Trondheim, June 2014

Bonnettes *pour les* ***DPA 4060*** *dans ses oreilles :*

1

Protection des oreilles contre le froid ≈ 3 €



3

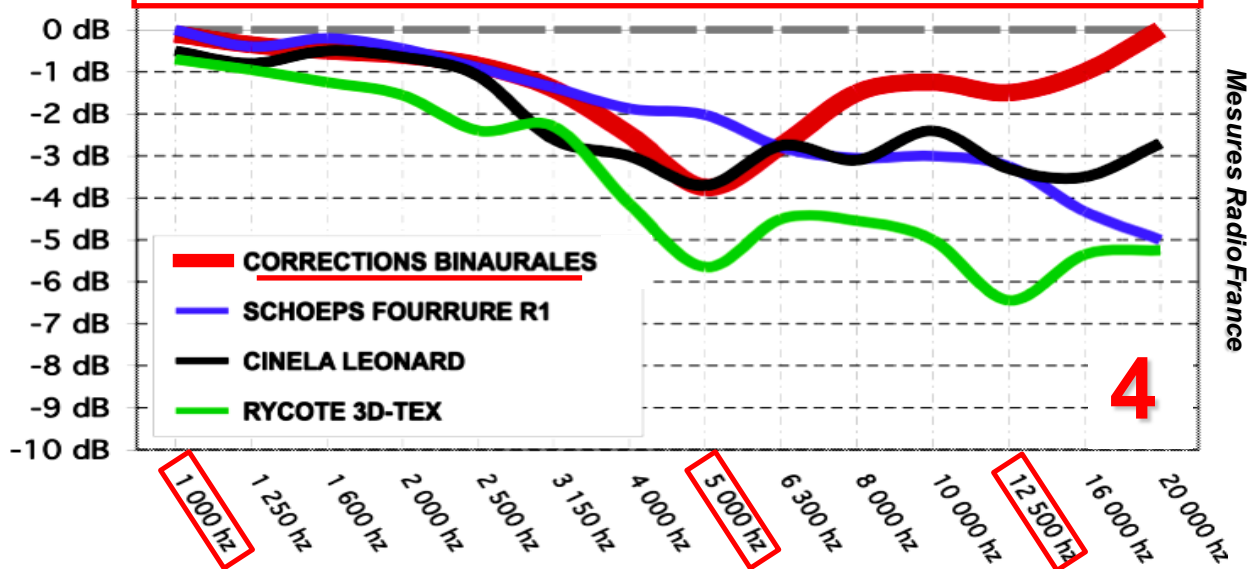
Coudre ou ajuster sur cette structure, les bonnettes…

Photos Bernard Lagnel

2

Ne garder que la structure métallique…

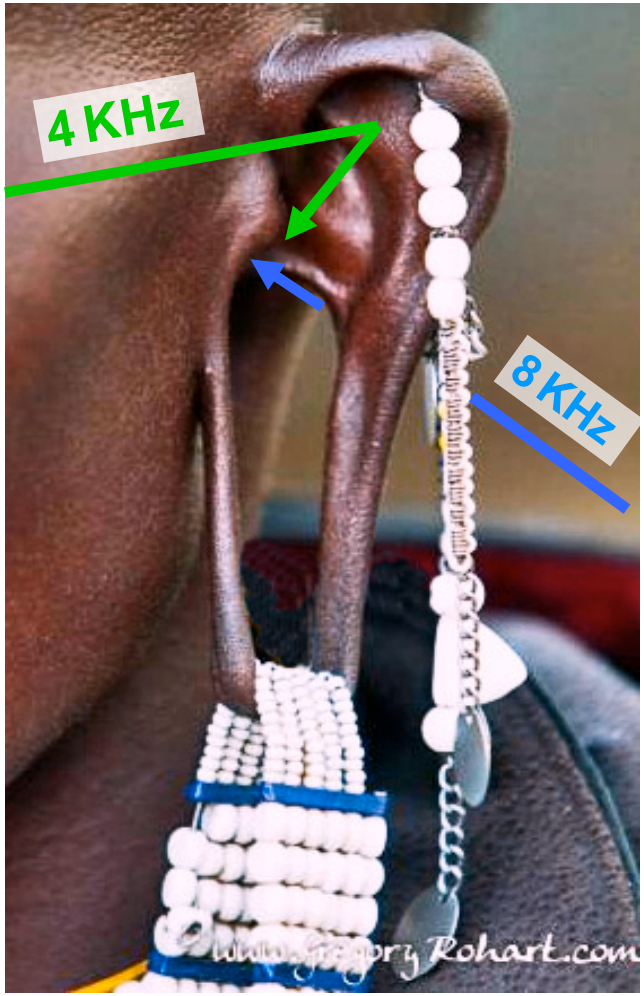
Perte d'aigus pour ces bonnettes :



4

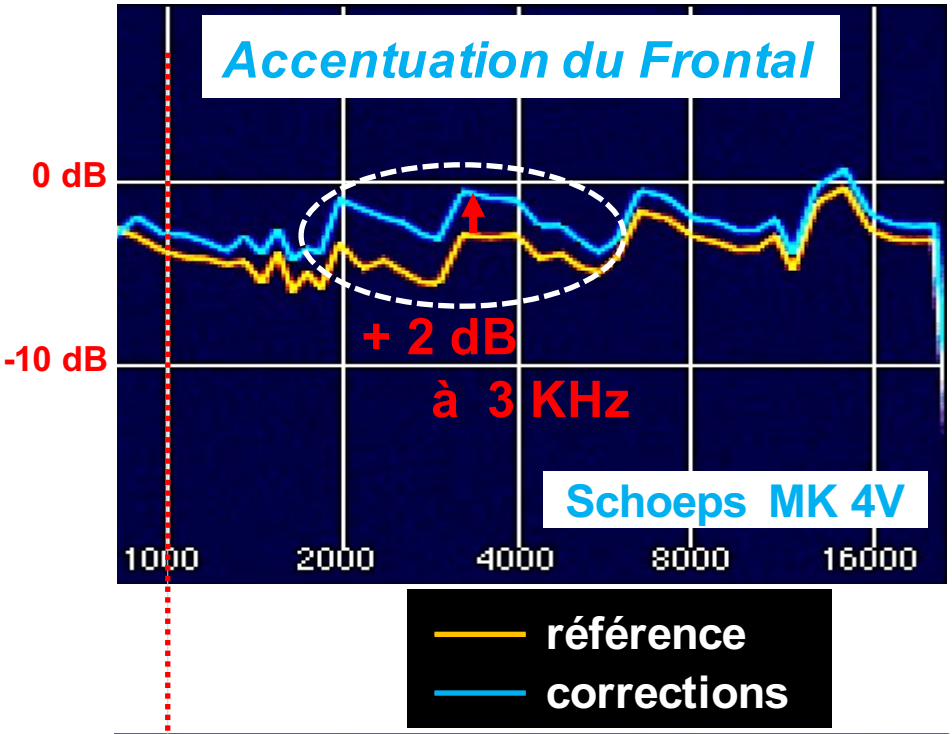
Mesures RadioFrance

Corrections apportées au *Système Plug&Rec :*



Oreille de guerrier Maasaï.

(Optimisée dans le plan horizontal pour la savane ??)

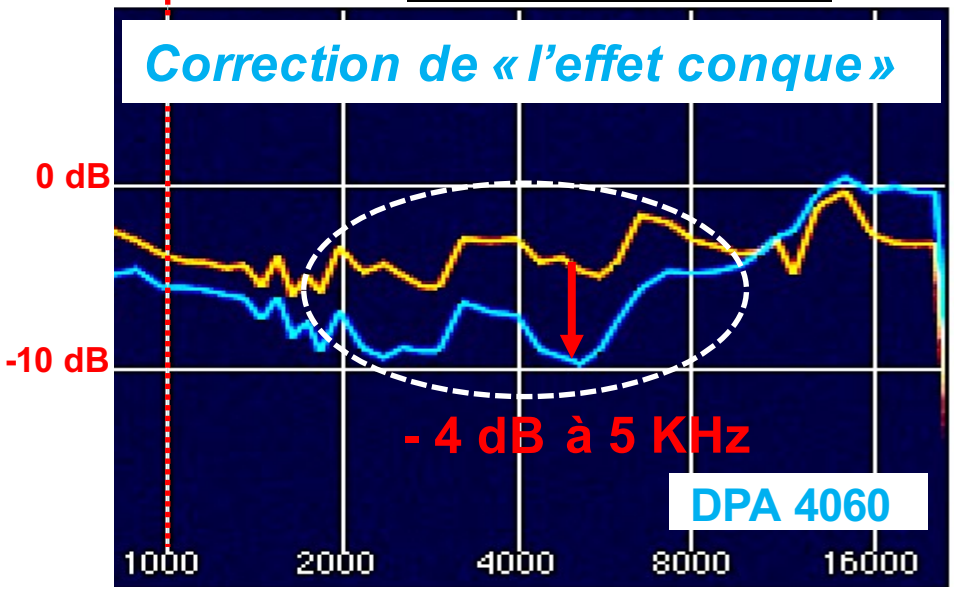


Espace

Frontal

Écoute :

- Anticipation
- Contour
- Matière
- Évaluation
- Désir, avidité…



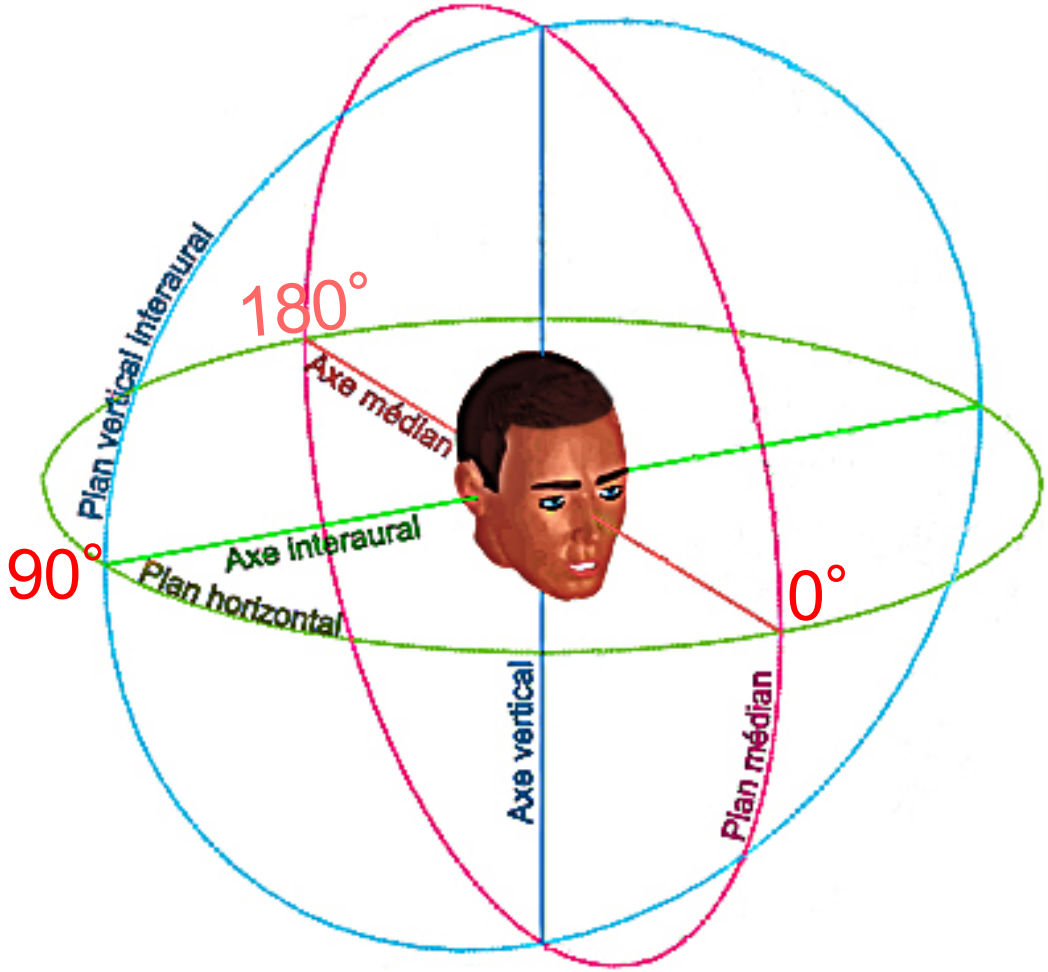
Espace

Dorsal

Écoute :

- Surveillance
- Déplacement
- Animale
- Discontinue
- Flottante…

L'écoute en 3D = 3 Plans



http://cyberdoc.univ-lemans.fr/theses/2009/2009LEMA1027.pdf

1. **Plan médian :**
   ILD ET ITD = 0
   IS L = IS R
   Internalisation

2. **Plan horizontal ou azimutal :**
   ILD ET ITD = MAX
   dans l'axe interaural à 90°
   IS L ≠ IS R
   Externalisation

3. **Plan vertical ou interaural :**
   ILD ET ITD = MAX
   dans l'axe interaural à 90°
   IS L ≠ IS R
   Externalisation

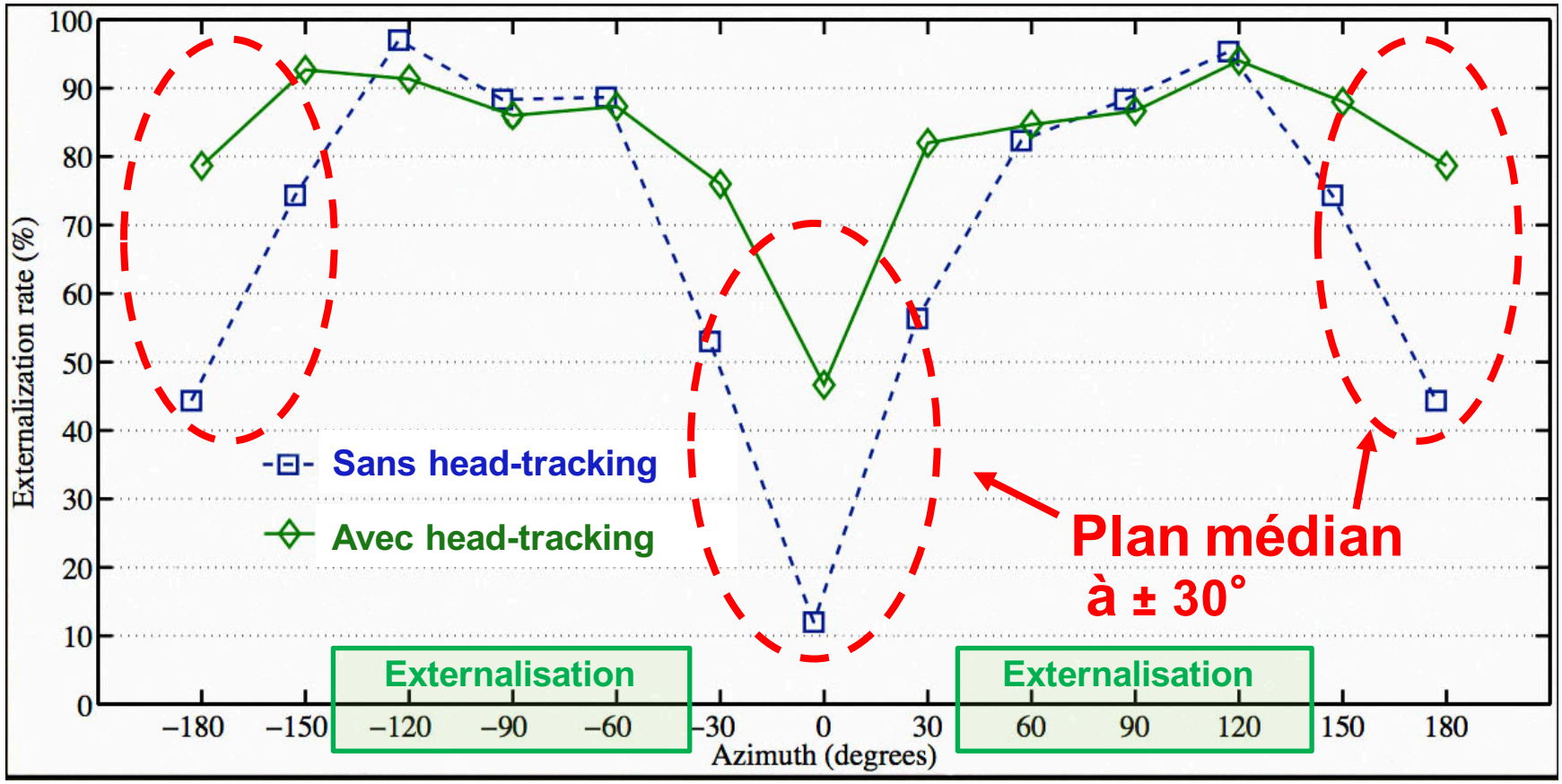
Σ

Internalisation ⇒ ***Corrélation*** ⇒ ***XY (Schoeps ou Zoom H4n)***

Externalisation ⇒ ***Dé corrélation*** ⇒ ***DPA 4060 + Oreilles, Elgar…***

QUELQUES REMARQUES SUR LE BINAURAL :

- **HRTF non-individualisées ⇒ appréciations différentes…**
- **La localisation binaurale au casque demande un certain apprentissage (meilleure externalisation avec head-tracking)**



Influence du « head-tracking » sur l'externalisation

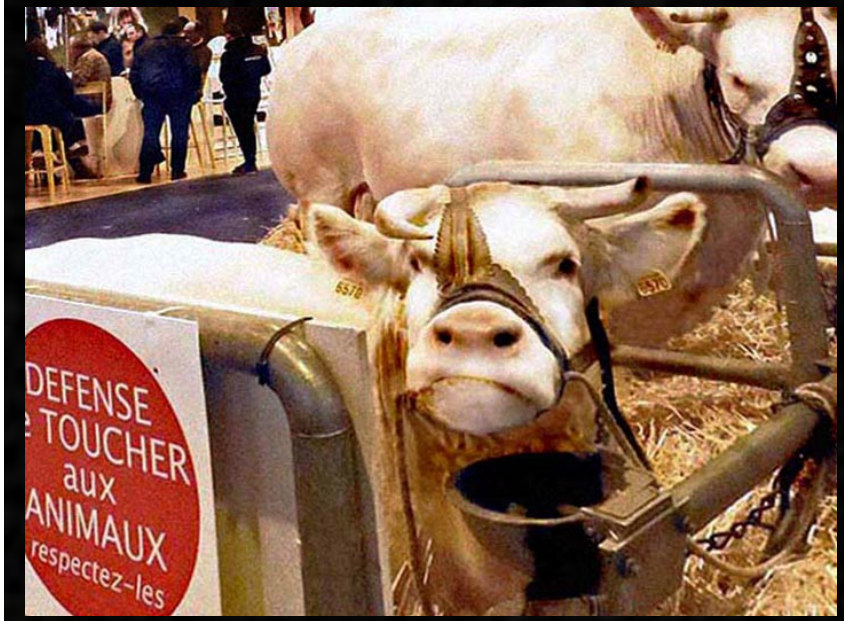
(en écoute binaurale non-individualisée)

Etienne Hendrickx, Peter Stitt, Jean-Christophe Messonnier, Jean-Marc Lyzwa, Brian F. G. Katz, Catherine De Boishéraud

Système PLUG & REC :
DPA 4060 dans mes oreilles + XY Schoeps

- Marché du Puy-en-Velay

Déambulation



- Salon de l'Agriculture 2018

Déambulation

Système PLUG & REC :
DPA 4060 dans mes oreilles + XY Schoeps

Photo Jean-Jacques Birgé

Les Essaims #1 Concerts

Extrait du concert, le 4 Mai 2018 :
- I pirati a Palermu, chant Elsa Birgé et le Spat'sonore.

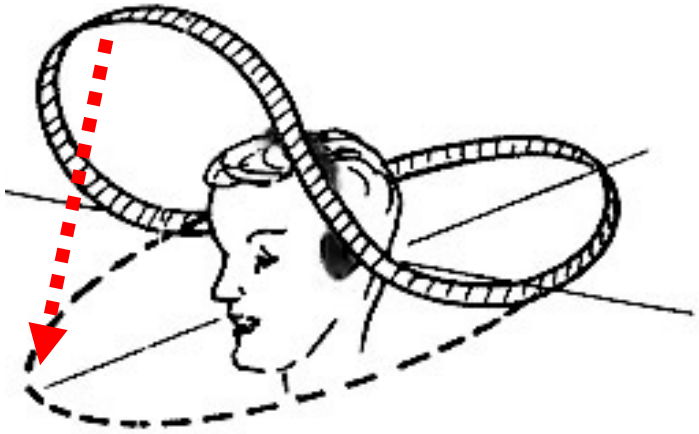
Église Saint-Merri, Paris 75004.

© Clodelle WWW.clodelle45autrement.fr

QUELQUES REMARQUES SUR LE BINAURAL :

- HRTF non-individualisées ⇒ appréciations différentes…
- La localisation binaurale au casque demande un certain apprentissage (meilleure externalisation avec **head-tracking**)
- **En stéréo sur Haut-parleurs, la sommation binaurale des 2 couples (XY + 4060) ajoute du relief, les Hp disparaissent… Le sweet spot s'agrandit et de l'extra largeur apparaît…**
- **Le XY seul du système *Plug & Rec,* traité à l'aide d'un plug-in 3D pour l'écoute en binaural (MyBino ou Orbit, les 2 gratuits) donne plus de poids à l'espace frontal.**

But : Faire descendre la source…



"… le cas le plus courant est d'avoir l'impression que la source monte en passant devant la tête…"

Jean Hiraga

NRDS n° 7 Avril 1977

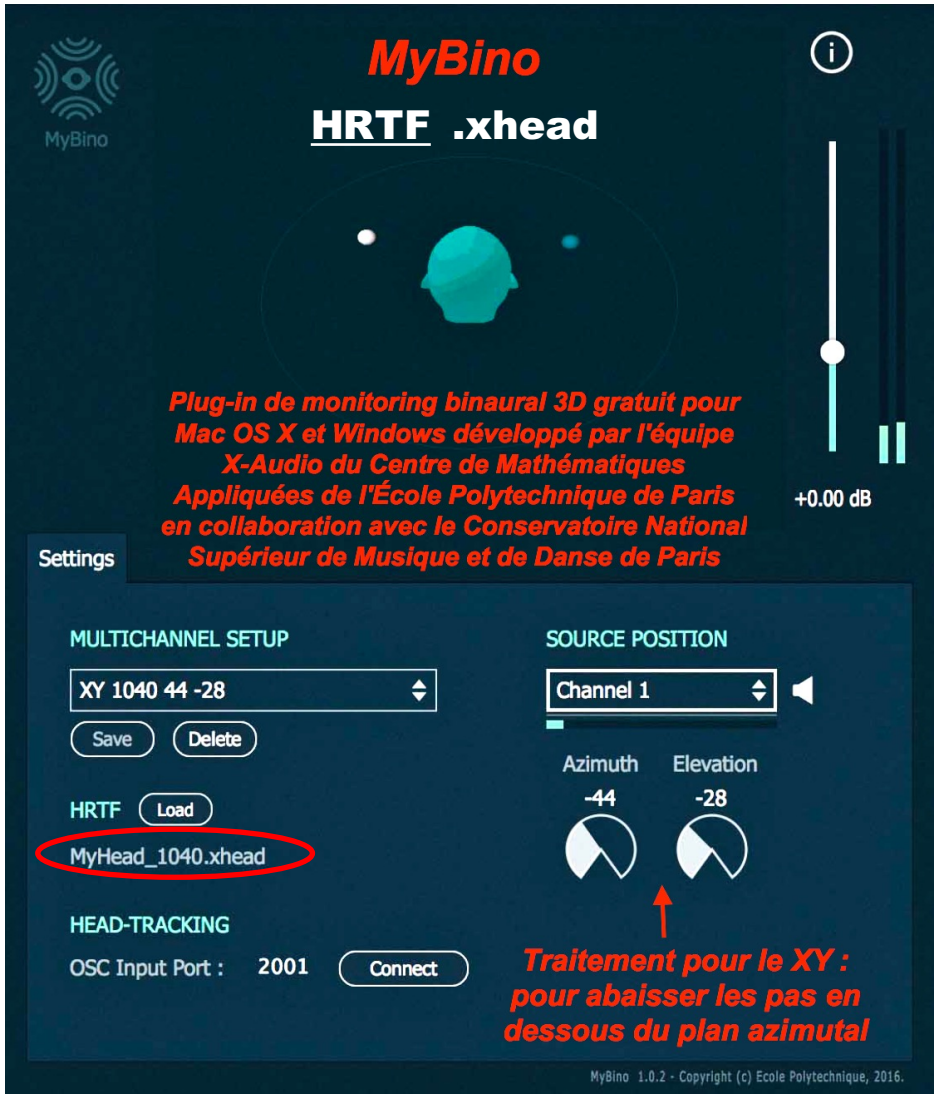
Binaural de synthèse

2 Plug-ins de Monitoring Binaural 3D ..... Gratuits

pour abaisser l'image sonore frontale en dessous de l'azimut :

https://fr-fr.sennheiser.com/ambeo-blueprints-downloads

http://www.cmap.polytechnique.fr/xaudio/mybino/



Bolet en Haute Loire

http://www.lesonbinaural.fr

OBJET SONORE

« Quand nous trouvons des champignons en parfait état, nous éprouvons un plaisir musical (non pas celui que l'on éprouve à être en mesure, juste, le plaisir de la coïncidence) »
John Cage - La flore de l'amateur de musique 1961.

Système PLUG & REC :
DPA 4060 dans mes oreilles + XY Schoeps.
Note : En post production, travail des plans en hauteur :
le XY dans le plug-in MyBino…

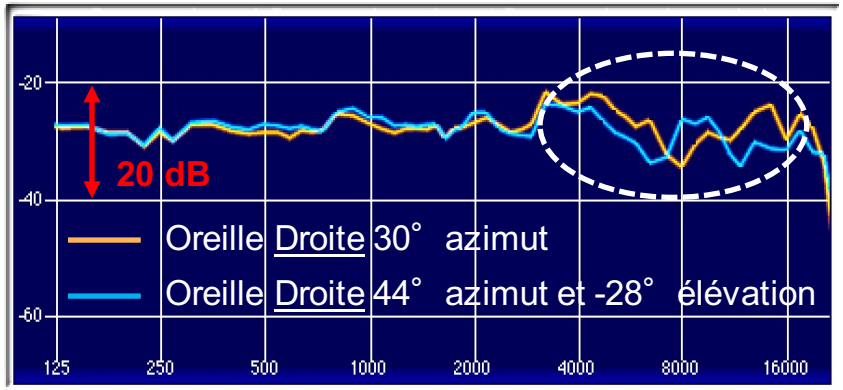
00:00 -00:00

Août 2016
6 min 32 sec

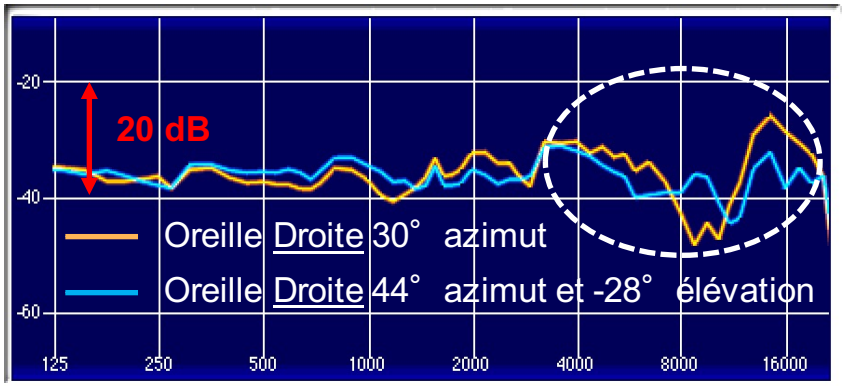
En **.WAV**
24 Bit / 48 KHz

Télécharger

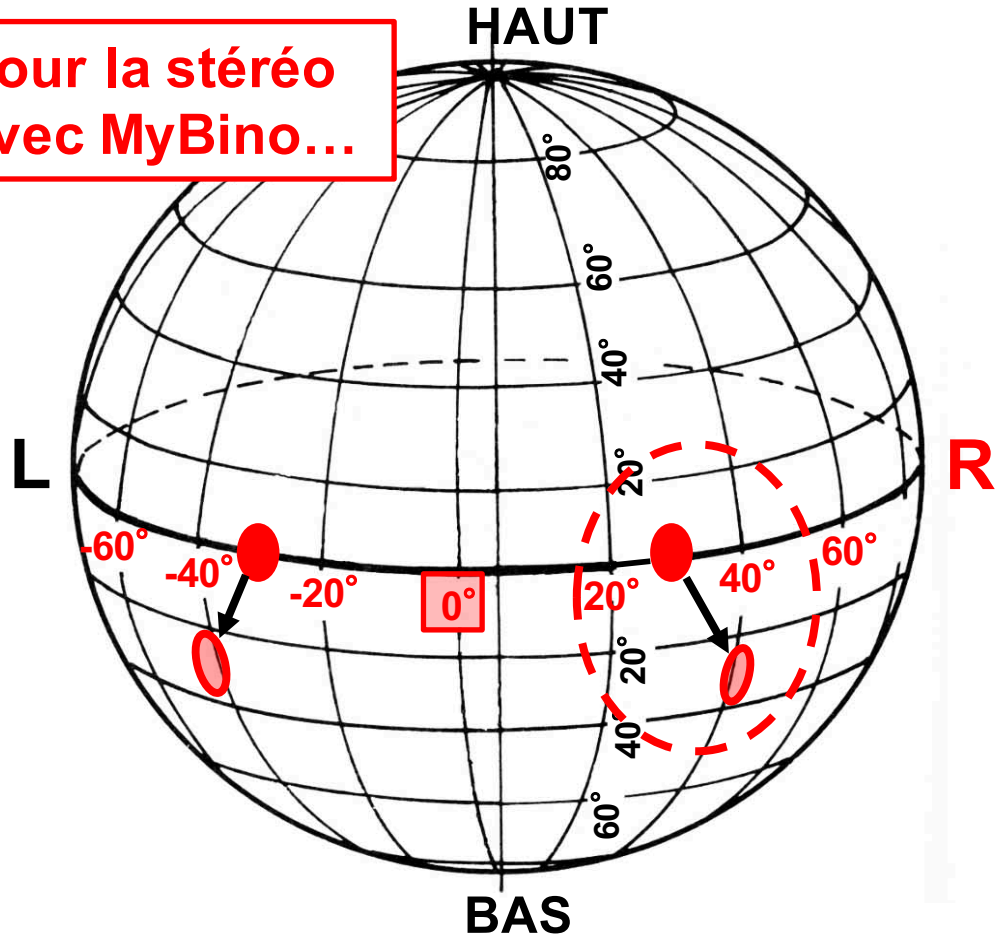
ORBIT



MyBino

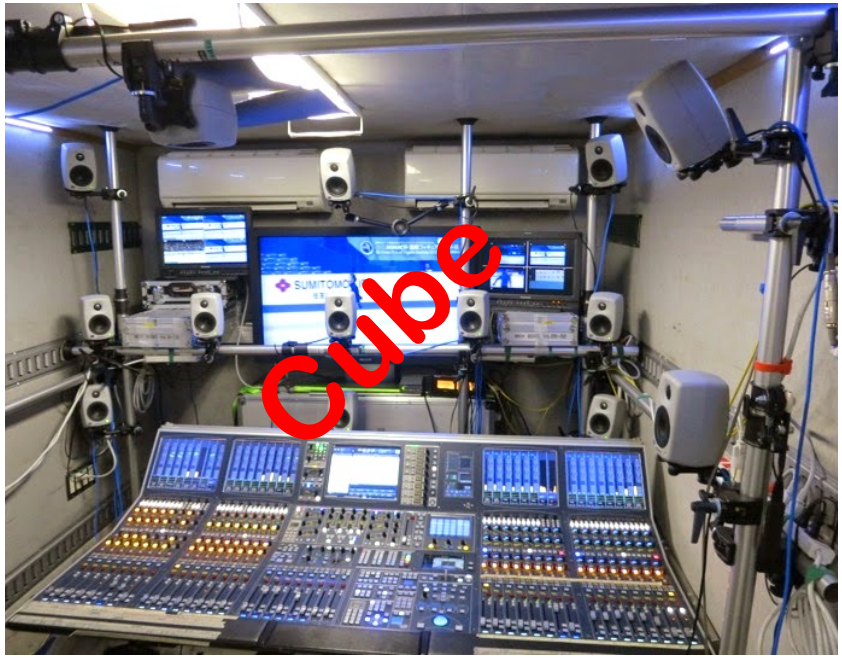


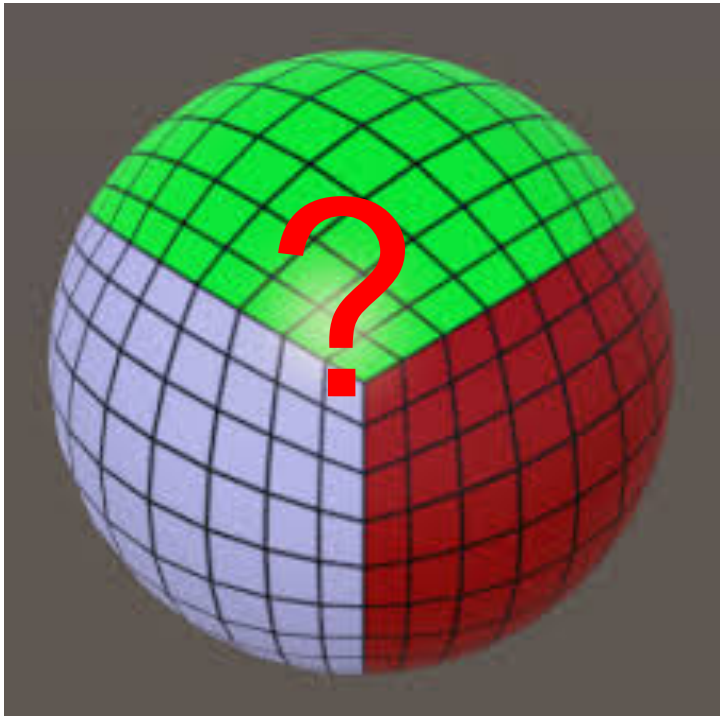
Pour la stéréo avec MyBino…

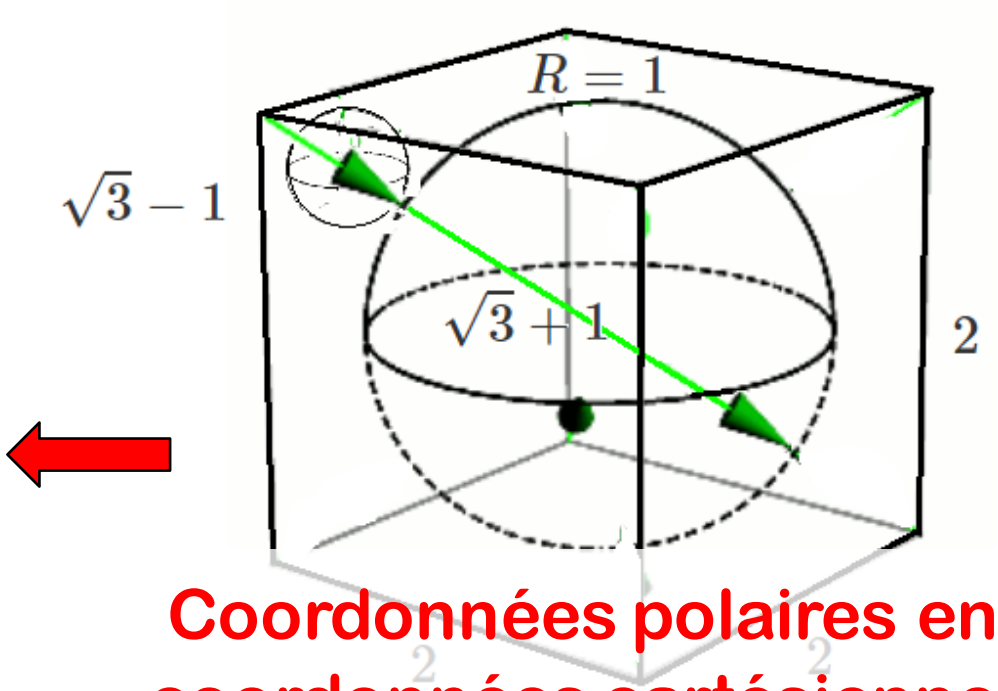


Mesure d' **HRTF** en conditions anéchoïques

Car régie NHK en **22.2**



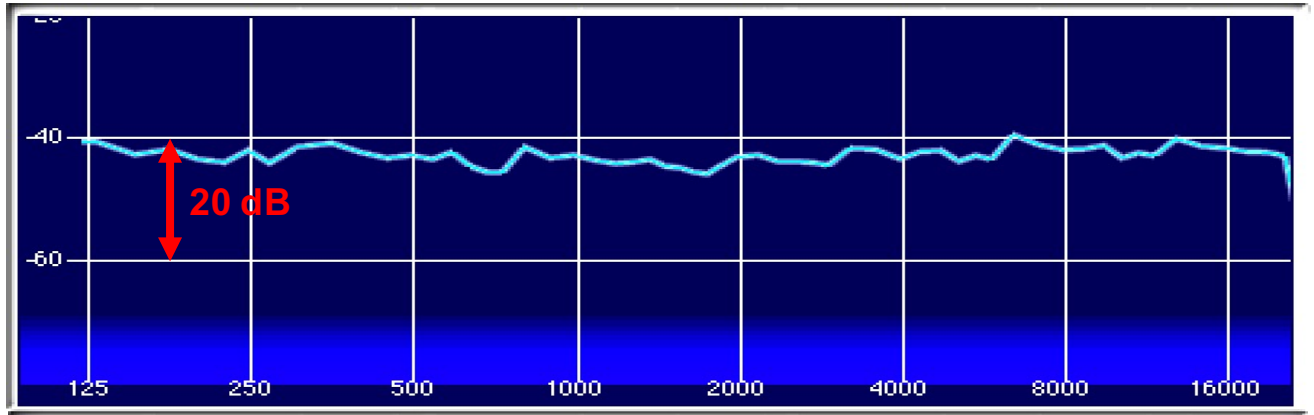




Coordonnées polaires en coordonnées cartésiennes

IN

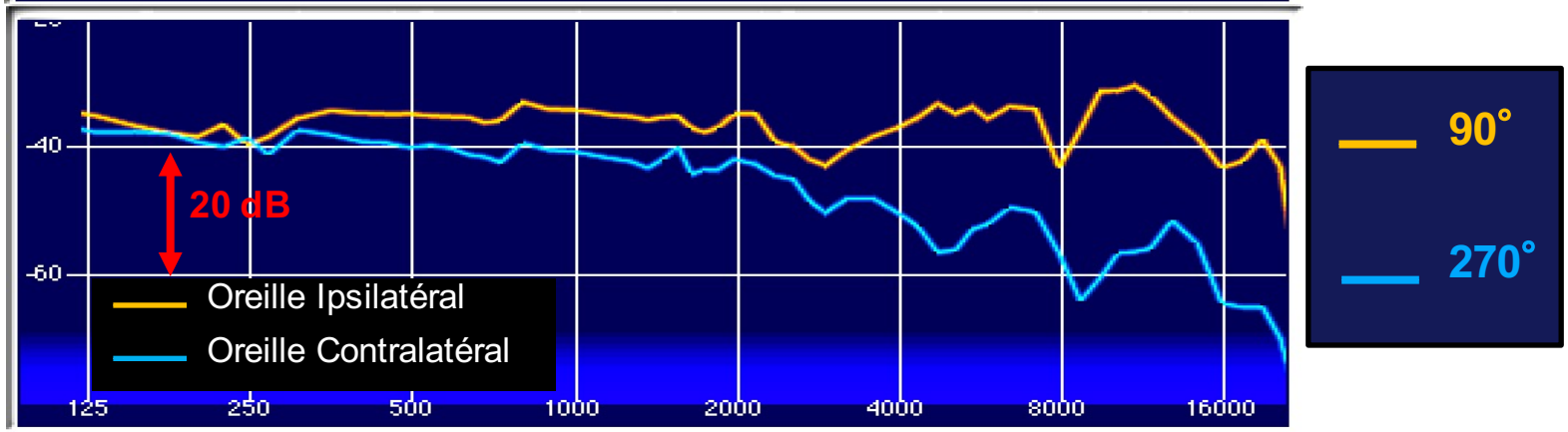
Bruit Rose



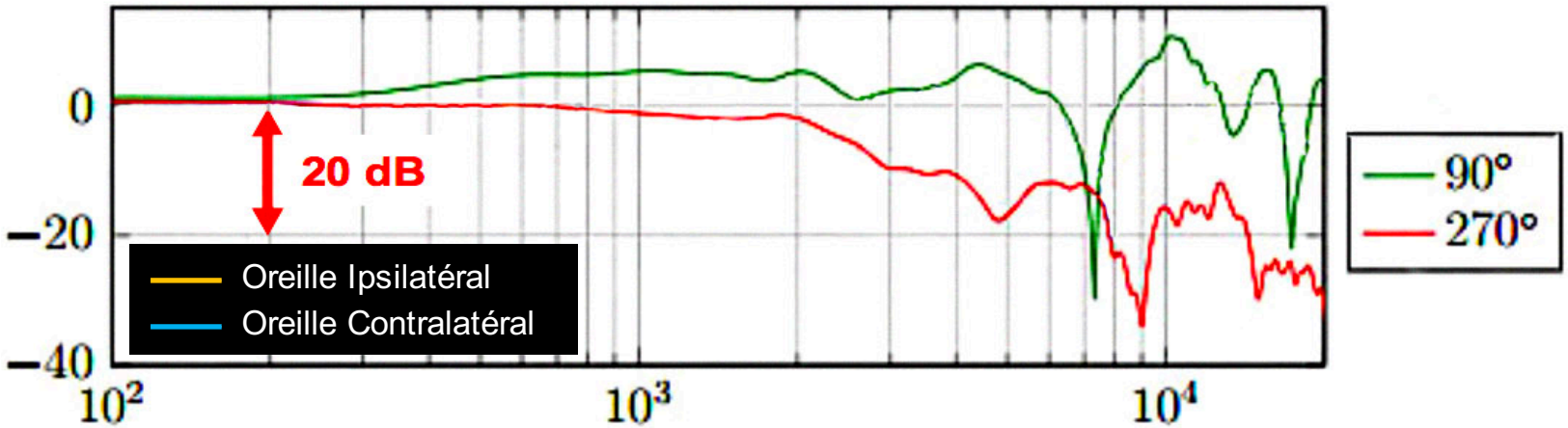
OUT

ORBIT

Clarity = 0%



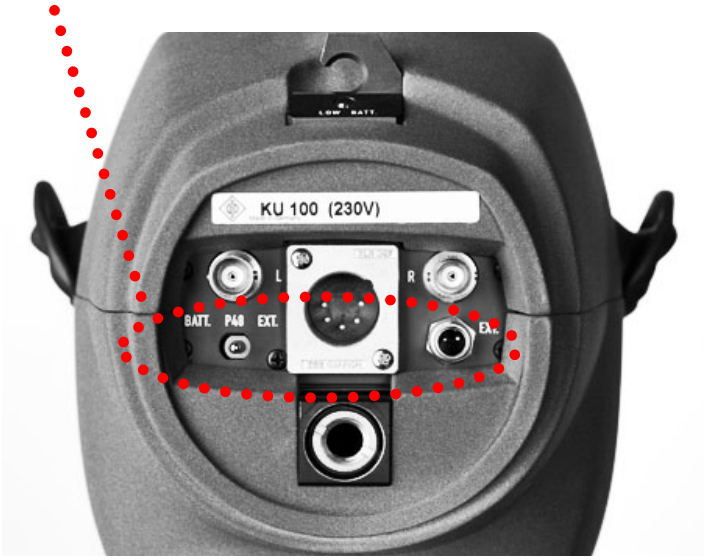
Jakob Vennerød
Trondheim, June 2014



https://www.researchgate.net/profile/Jakob_Vennerod/publication/278404811_Binaural_Reproduction_of_Higher_Order_Ambisonics_A_Real-Time_Implementation_and_Perceptual_Improvements/links/5580323408ae87edac4c9091/Binaural-Reproduction-of-Higher-Order-Ambisonics-A-Real-Time-Implementation-and-Perceptual-Improvements.pdf

En 1992 : NEUMANN KU 100 (≈ 7400 €)

BATT. pile 9v -- P48. fantôme 48v -- EXT. secteur 220v.



(Sorties : 1 XLR 5 + 2 BNC)

Les Oreilles sont anthropométriques (G et D identiques pour les mesures).

2 micros du système KM 100 (circuit de sortie sans transfo)

- **Tête égalisée pour une réponse linéaire en champ diffus.**

  Compatible avec haut-parleurs

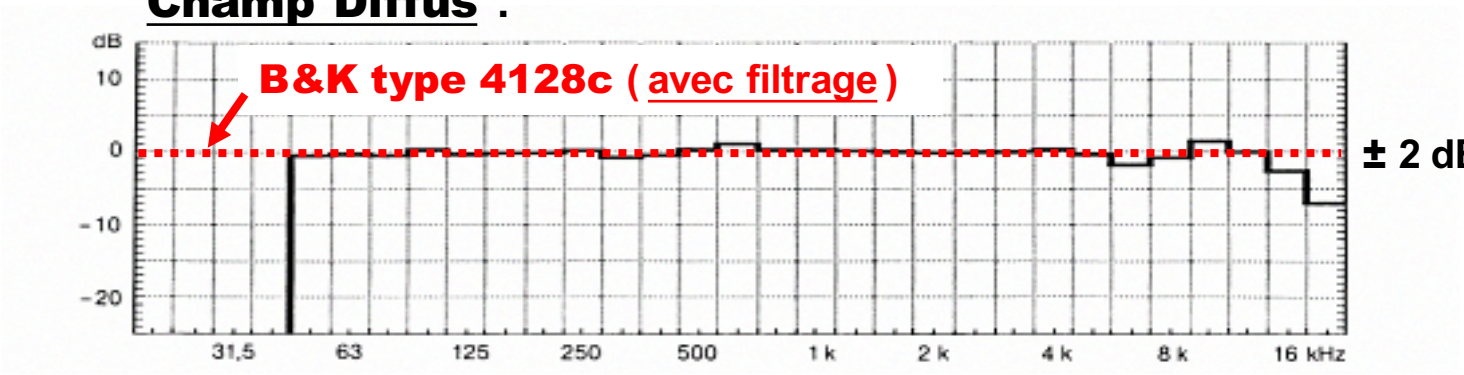
- **Filtre coupe bas à 40 Hz ou 150 Hz et atténuation de 10 dB.**

Photos : www.neumann.com et www.madooma.com

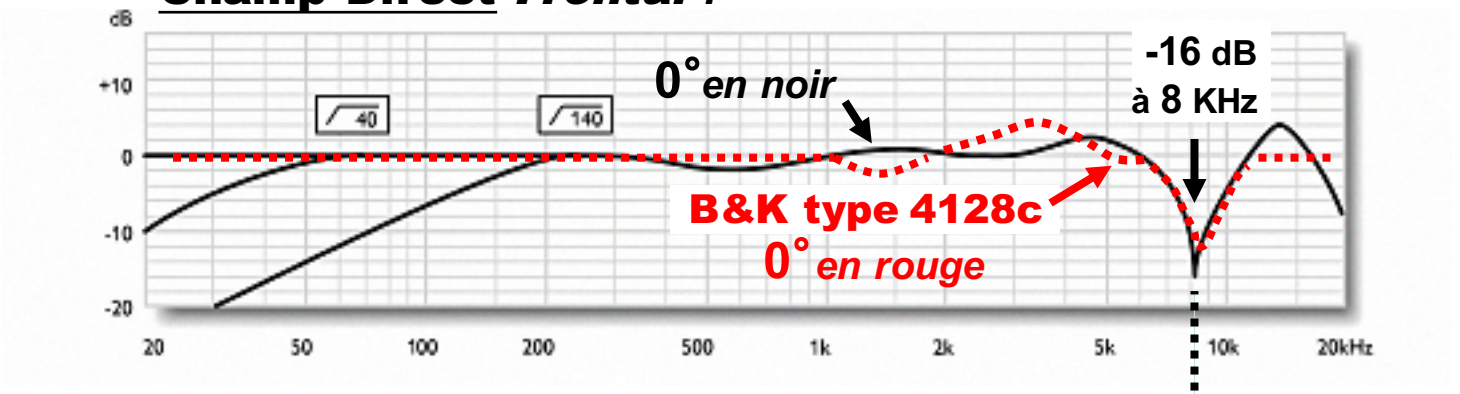
NEUMANN KU 100

Documents Neumann
Documents B&K

Champ Diffus :

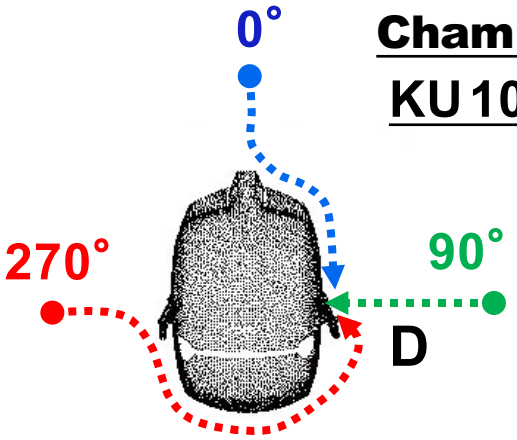


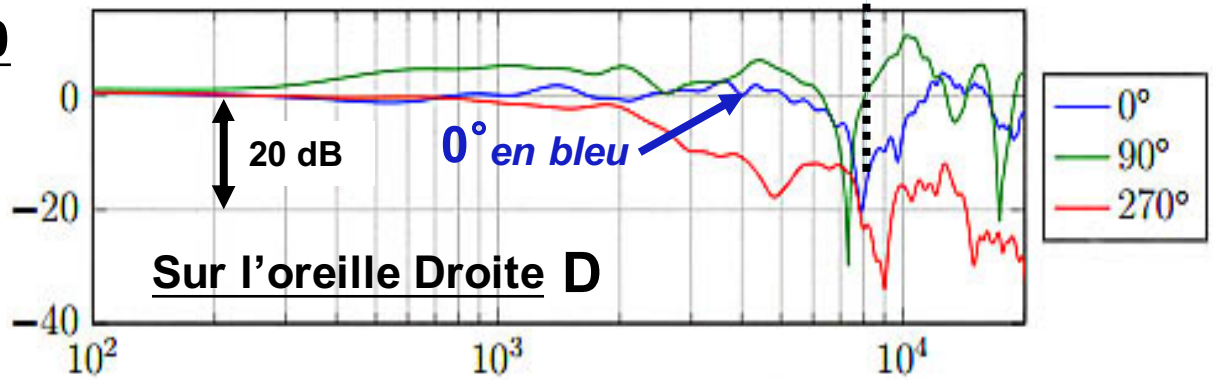
Champ Direct *Frontal* :



Champ Direct *Frontal* :

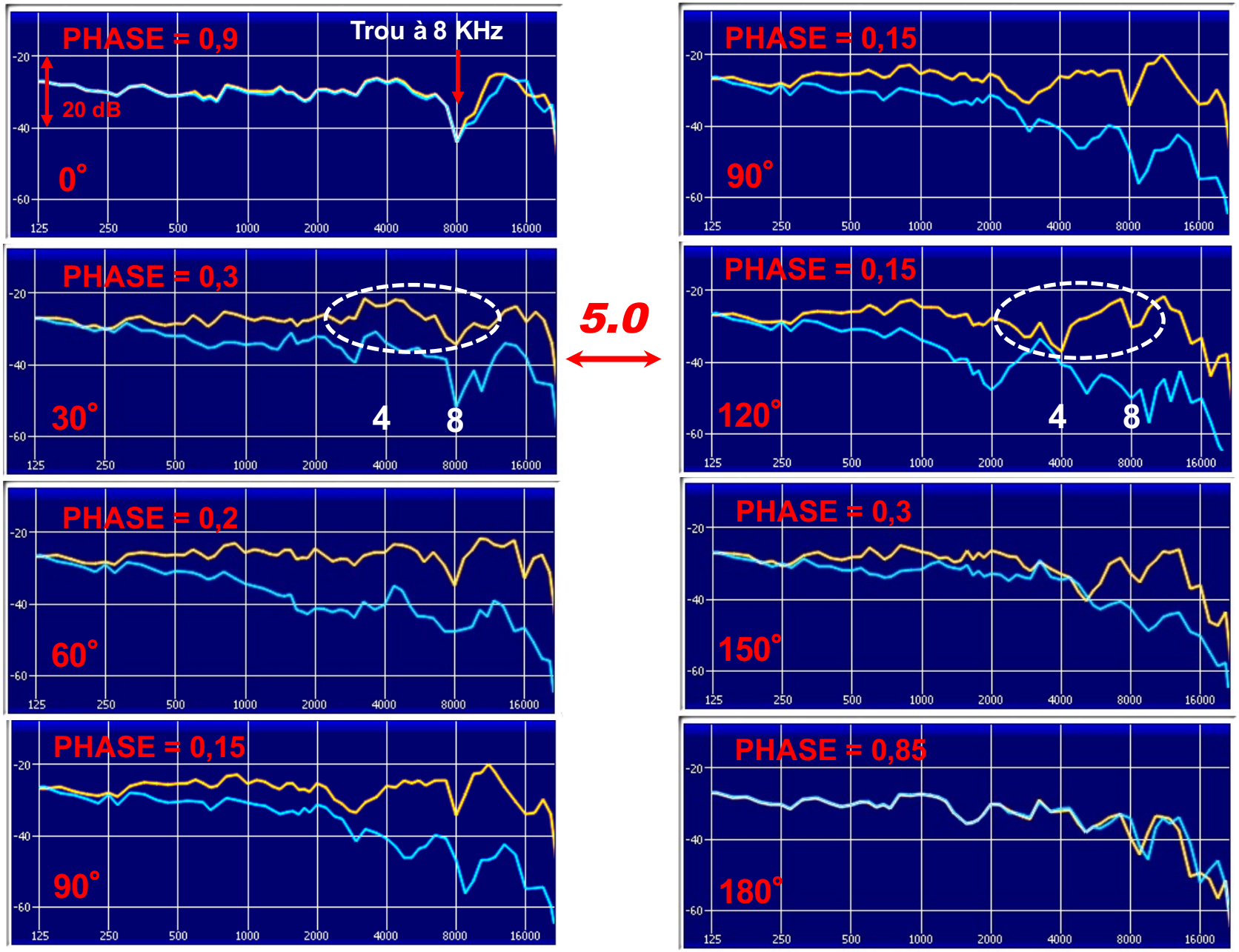
KU 100





Jakob Vennerød
Trondheim, June 2014

ORBIT : HRTF KU100 pour une source Mono…….. CLARITY 0 %



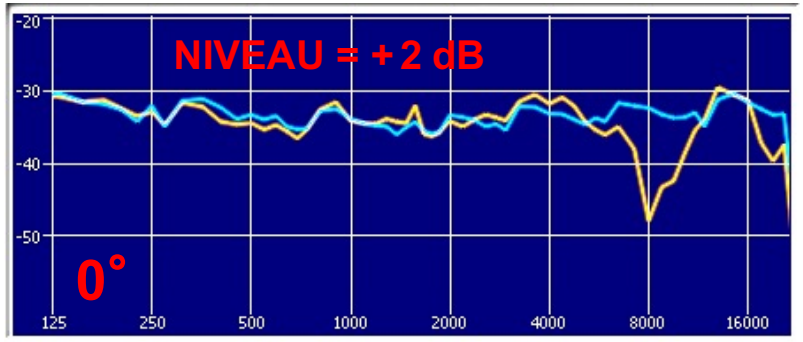
Oreille Ipsilatéral
Oreille Contralatéral

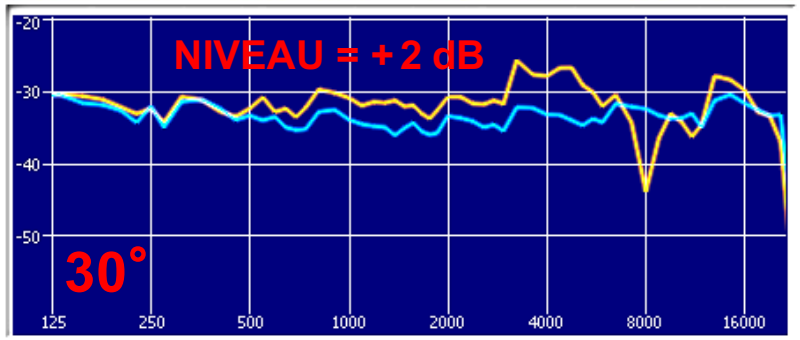
CLARITY 0 % = IS

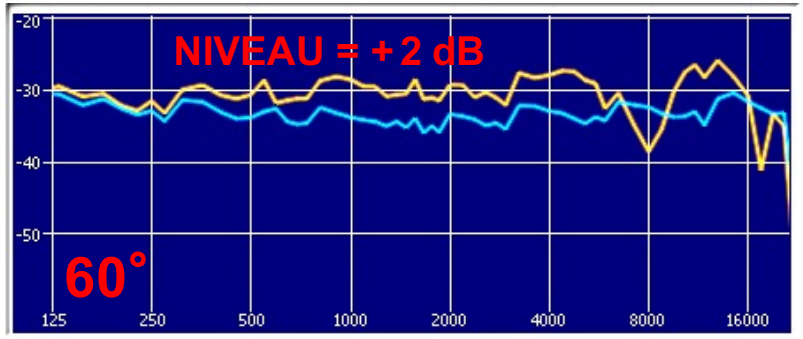
Oreille Ipsilatéral
Oreille Contralatéral

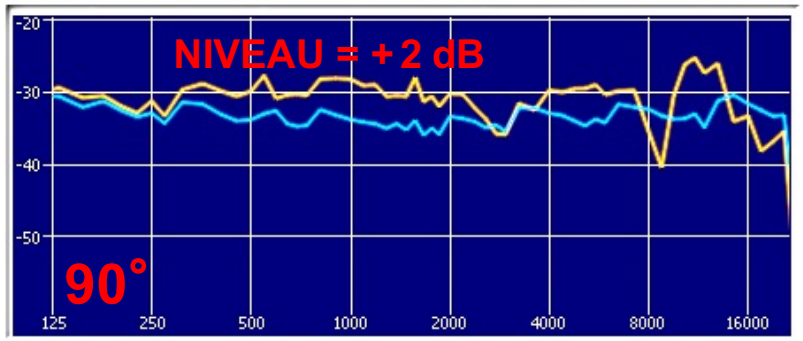
HRTF et Bruit Rose : ORBIT *KU 100*

Oreille Ipsilatéral L
BRUIT ROSE IN

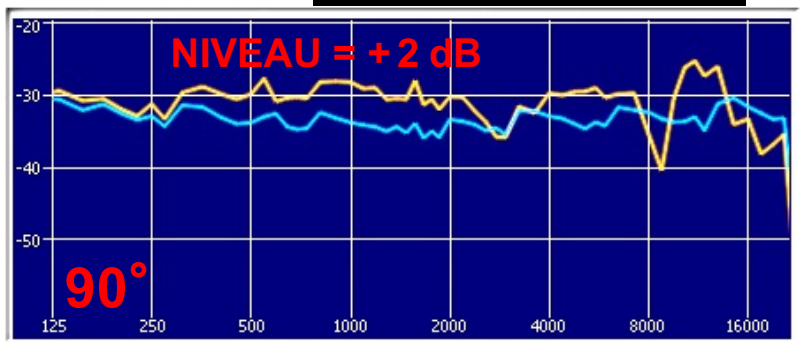


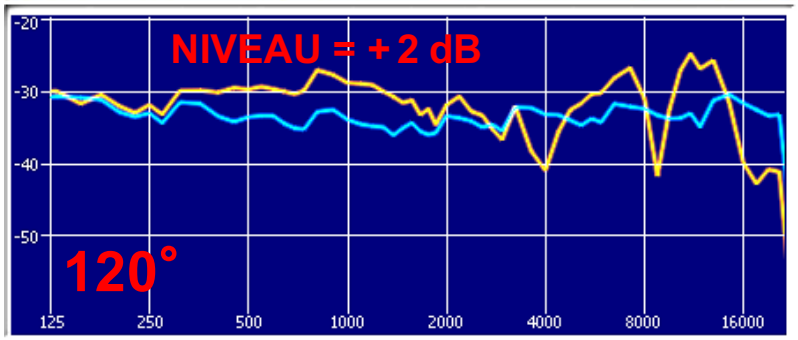


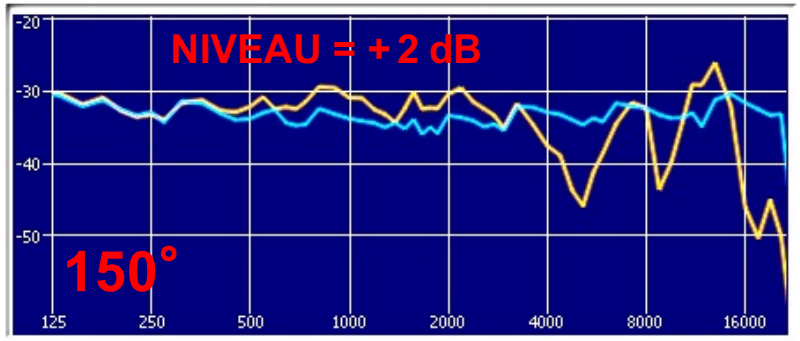


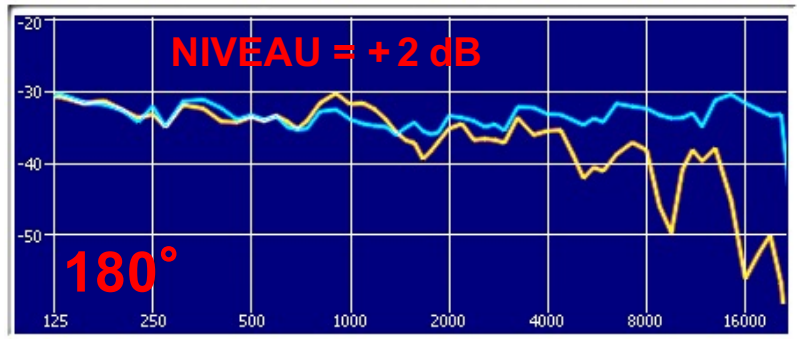


CLARITY 0 %

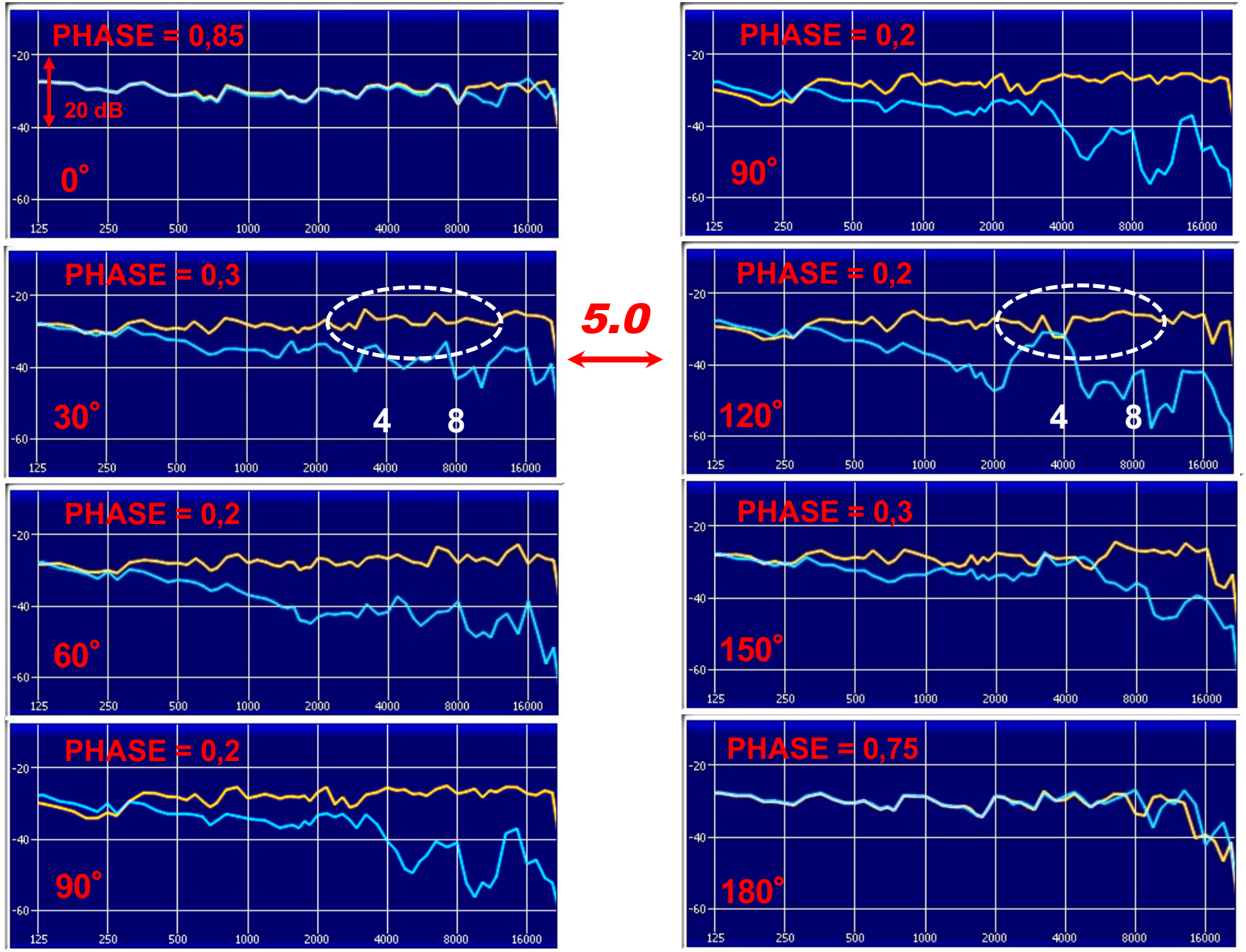








ORBIT : HRTF KU100 pour une source Mono…….. CLARITY 100 %



Oreille Ipsilatéral
Oreille Contralatéral

CLARITY 100 % = ~~IS~~

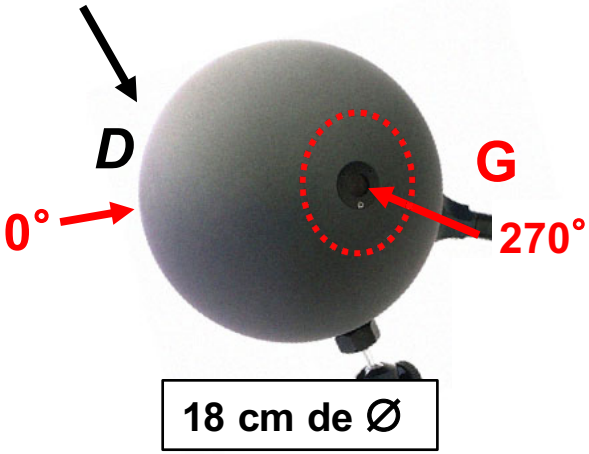
Oreille Ipsilatéral
Oreille Contralatéral

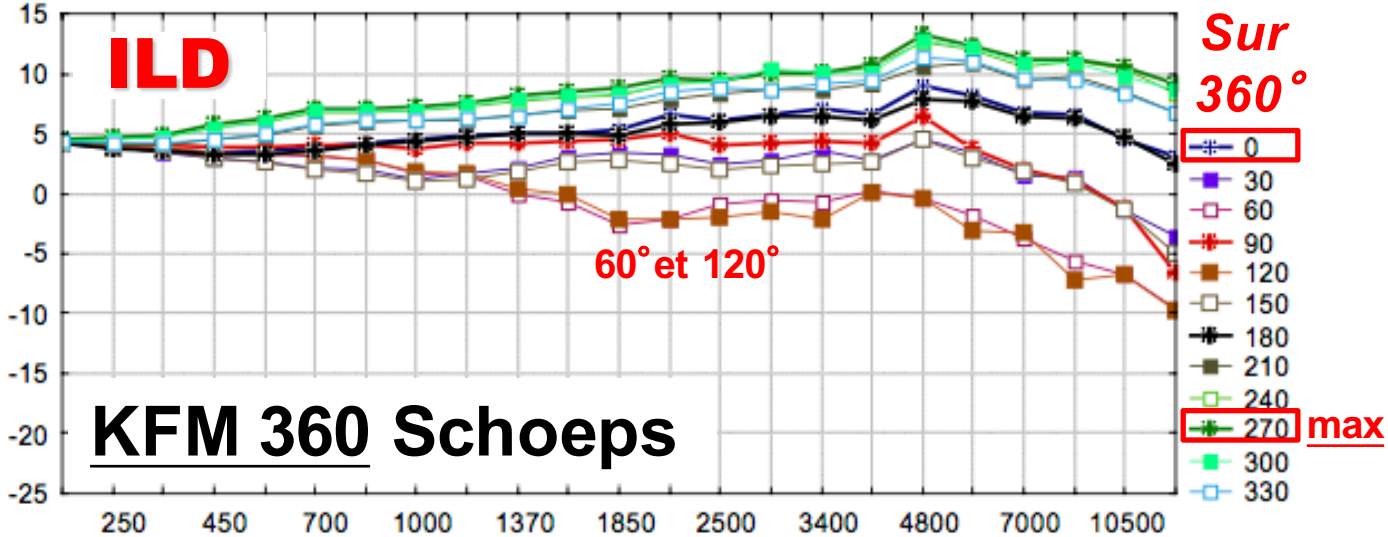
The microphone and artificial head sound pressure measurement

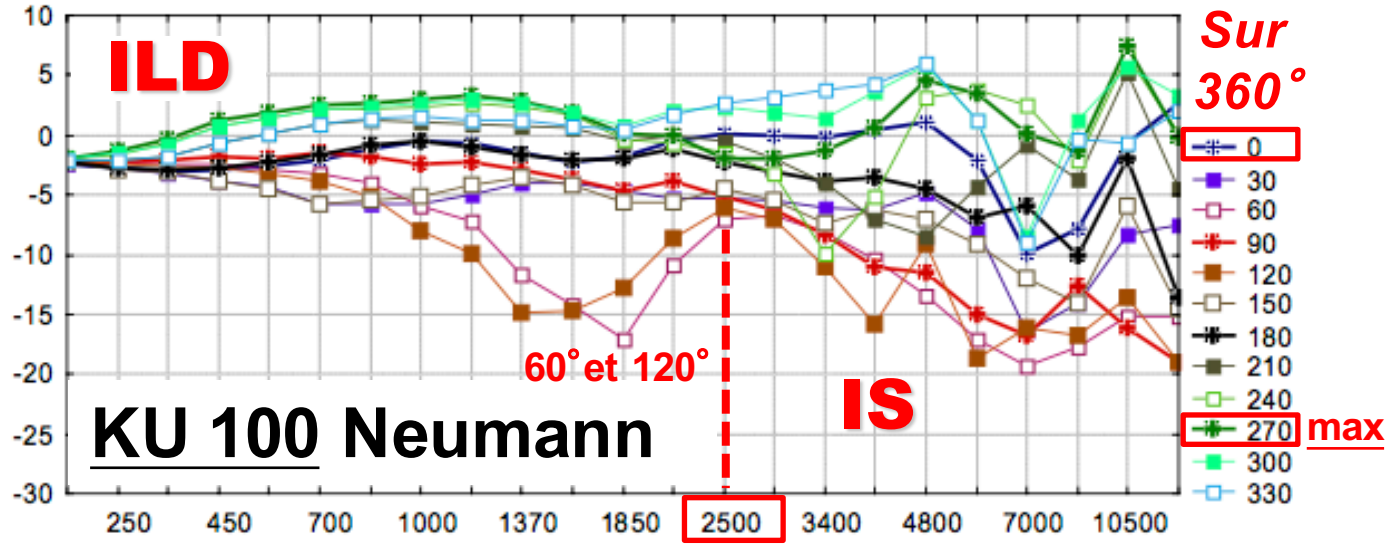
Zdenek Otcenasek **2004**

Sound Studio of the Faculty of Music, Academy of Performing Arts Prague,
Malostranske nam. 13, 118 00 Praha 1, Czech Republic, Email: otcenasek@hamu.cz

Canal Droit bouché



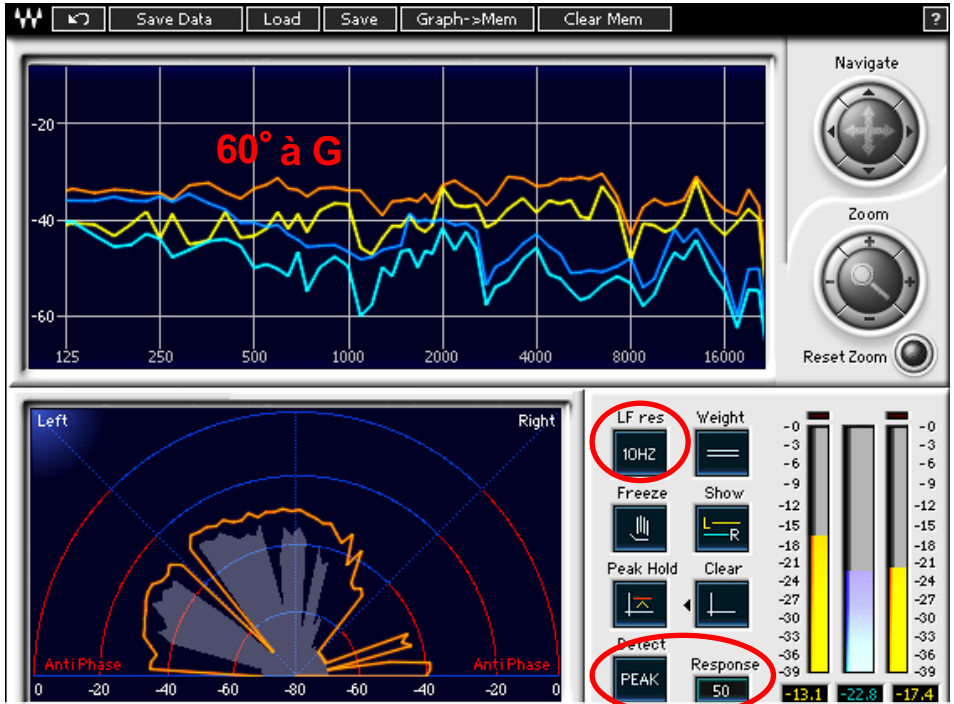




BINAURALIZER de NOISEMAKERS

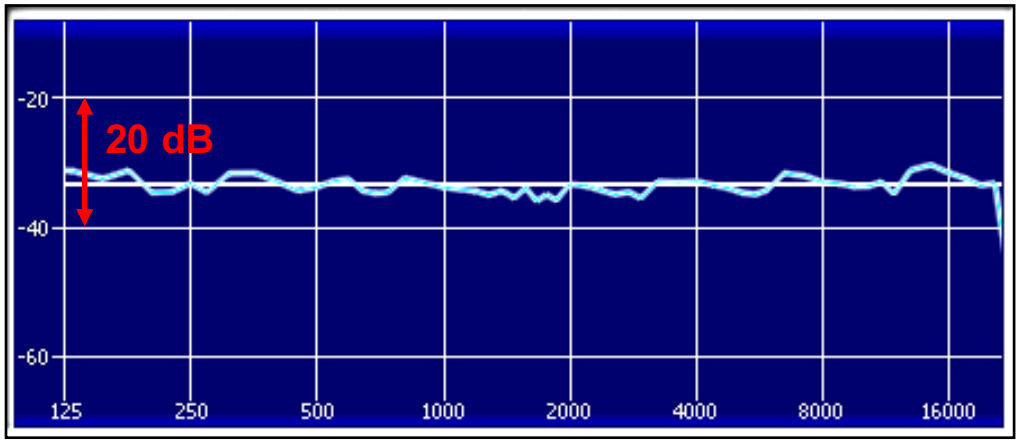
https://www.noisemakers.fr/product/binauralizer/

OUTPUT : *PAZ* de WAVES pour l'ILD

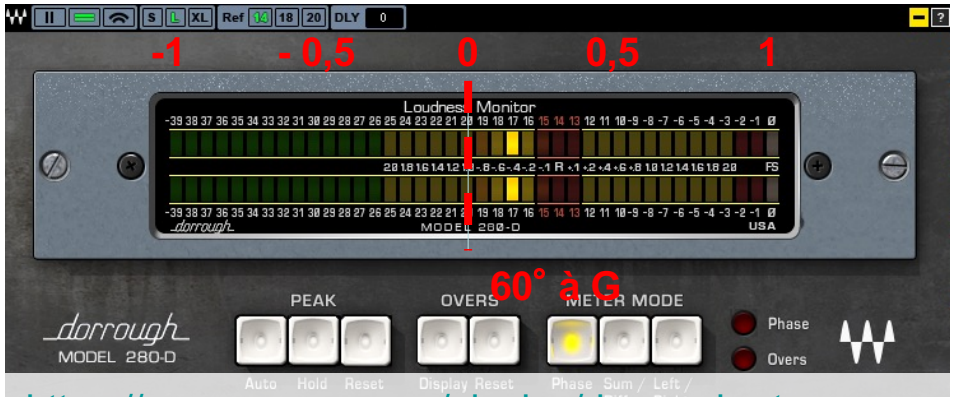


https://www.waves.com/plugins/paz-analyzer

INPUT : *BRUIT ROSE*



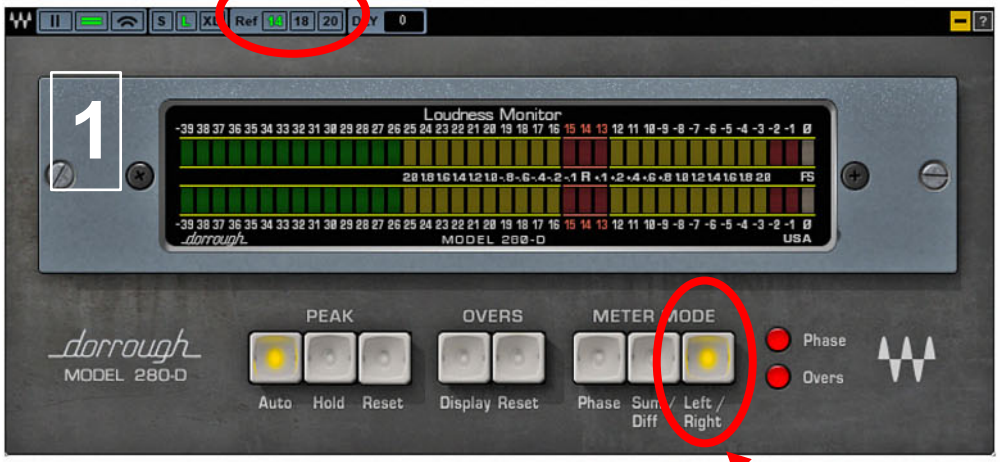
OUTPUT : *Dorrough* de WAVES pour la PHASE



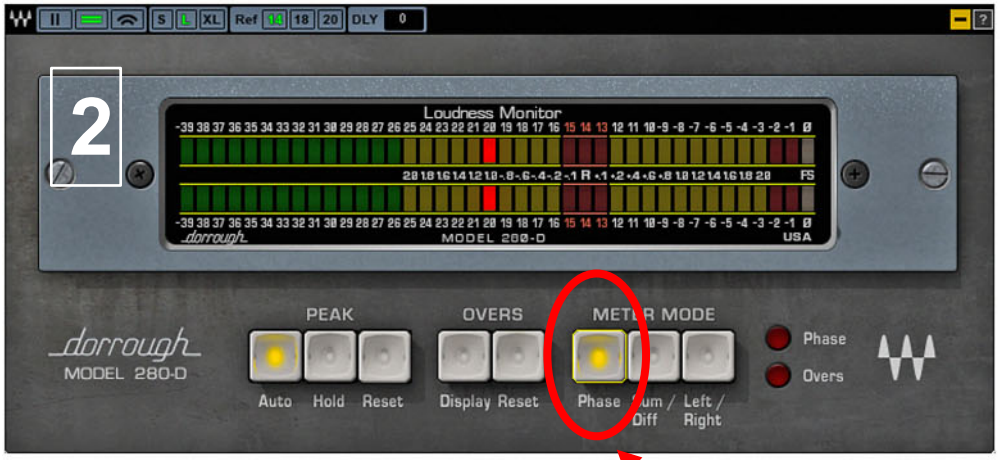
https://www.waves.com/plugins/dorrough-stereo

Le Plug-in Waves ***Dorrough*** *Stéréo*
utilisé comme **Phasemètre** :

Choisir Réf. 14



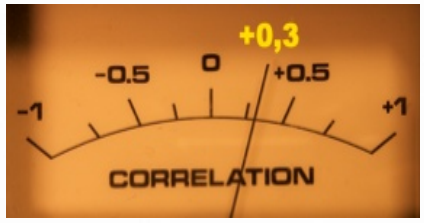
Mode Left / Right



Passer en Mode Phase

Caractéristiques Techniques :

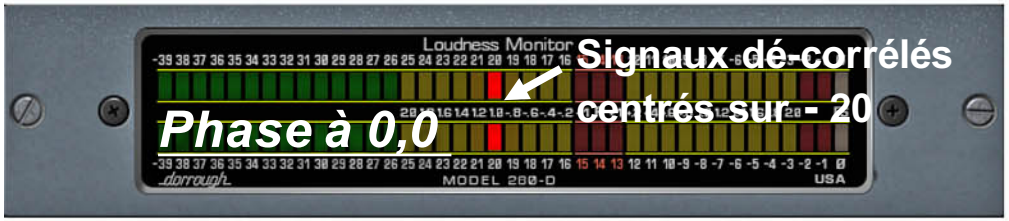
- Temps d'intégration ≈ 500 ms
- Seuil de sensibilité pour une réponse exacte ≈ - 32 dBFS (Affichage de la même valeur pour des écarts max de 32 dBFS d'IDL)
- Réponse linéaire de la phase et non logarithmique comme sur la plupart des *Phasemètres Plug-ins*…
- Phasemètre Plug-in comparable aux phasemètres analogiques du siècle dernier…

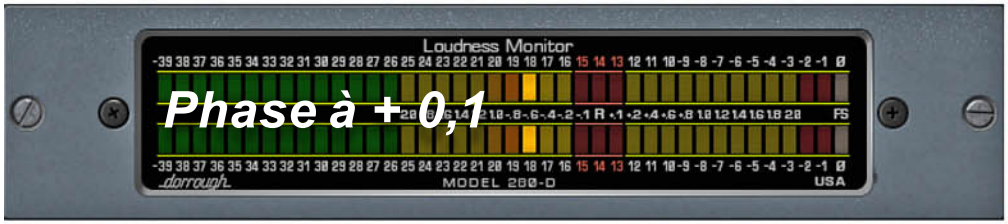


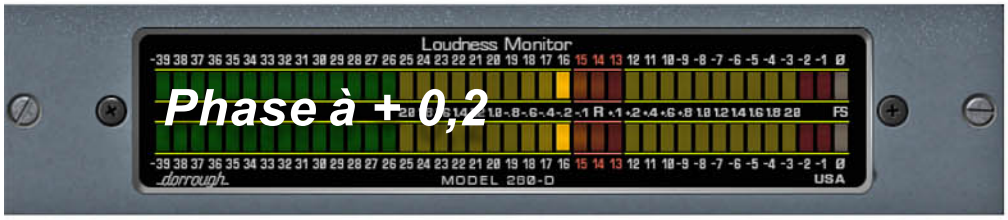
+ 0,3 = répartition Stéréo homogène

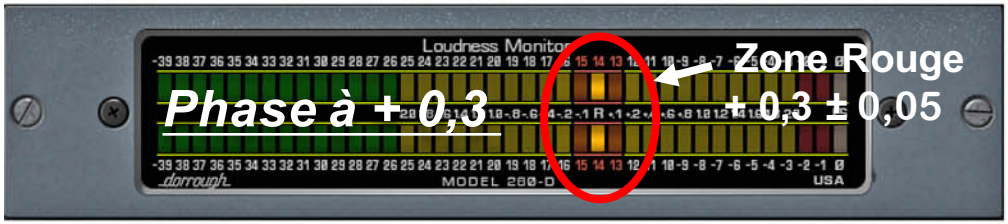
Étude psycho acoustique faite à Radio France sur du *bruit rose* : (valable pour la musique classique et les ambiances)

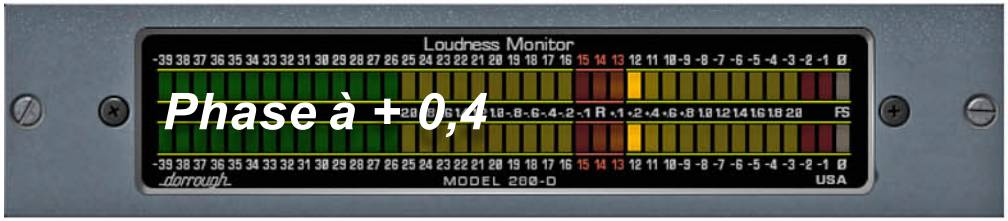
Indications **linéaires** de la phase sur le Plug-in *Waves* ***Dorrough*** *Stéréo :*

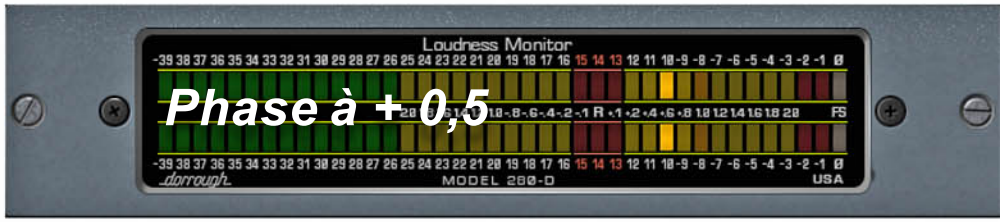


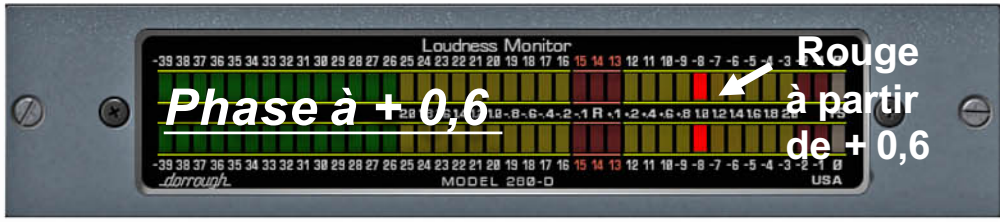


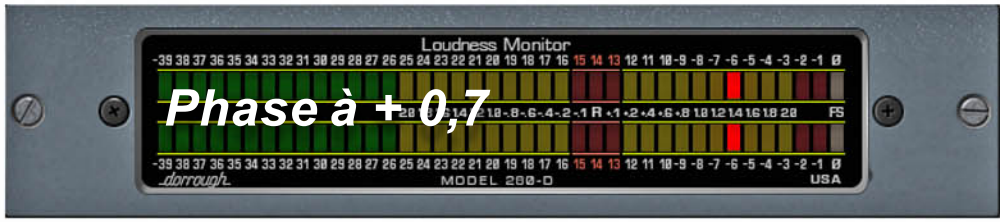


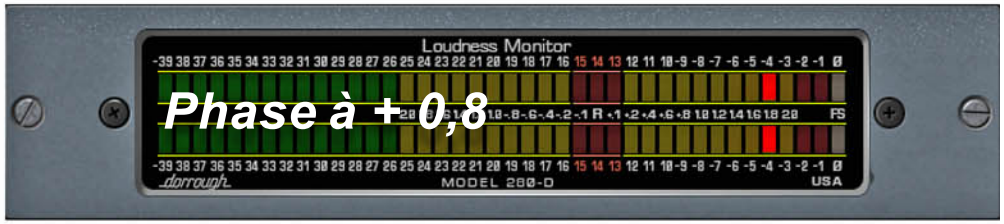


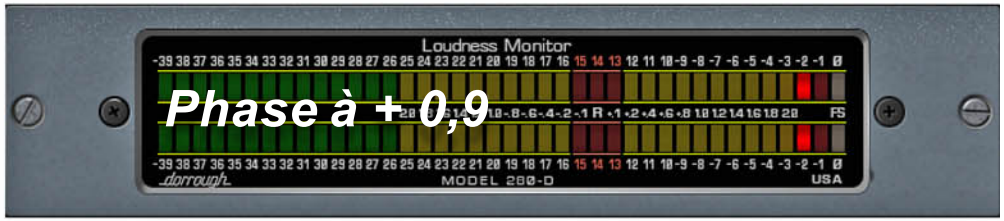


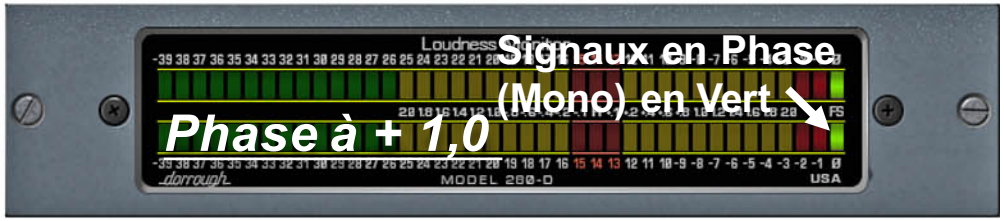












PLUG-IN KU 100 SADIE

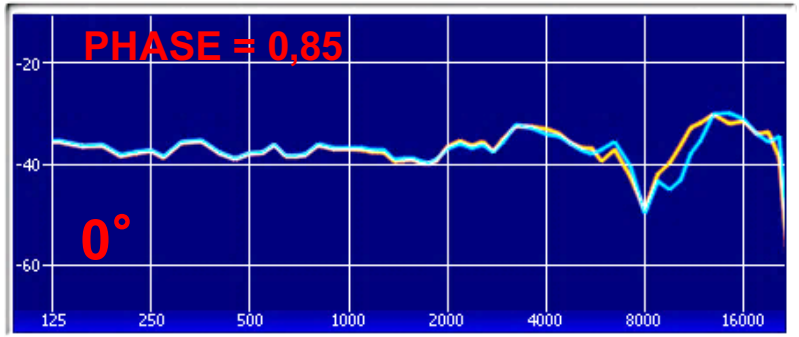
Adopté par :

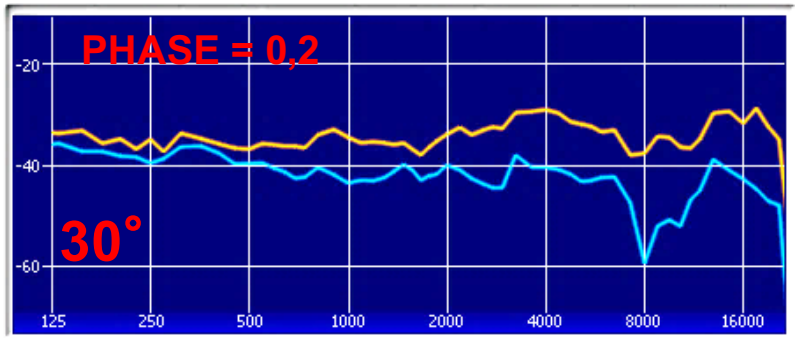
Youtube 360

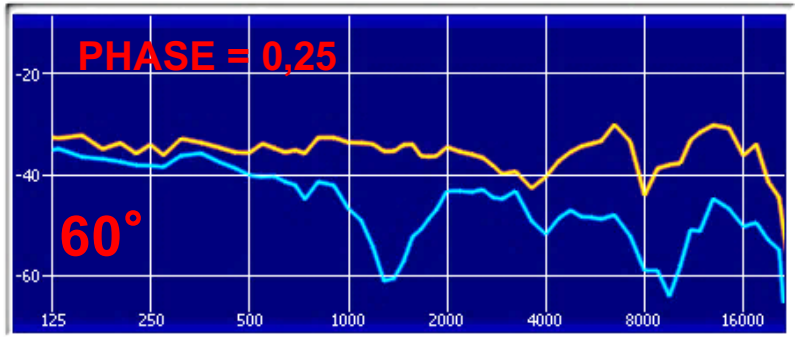
et Google VR

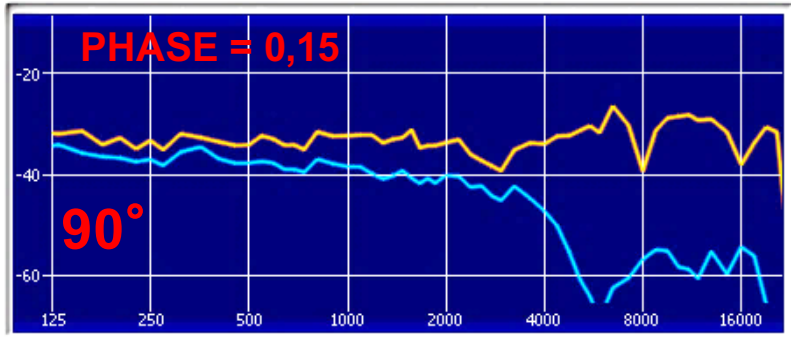
Oreille Ipsilatéral

Oreille Contralatéral





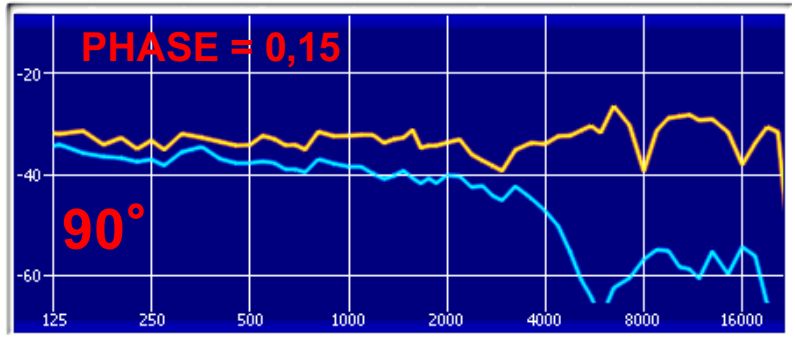


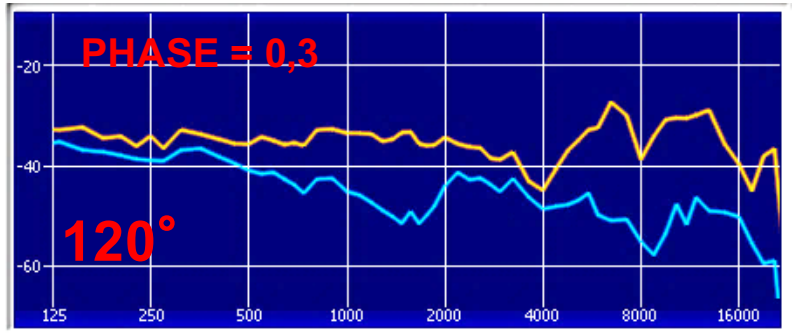


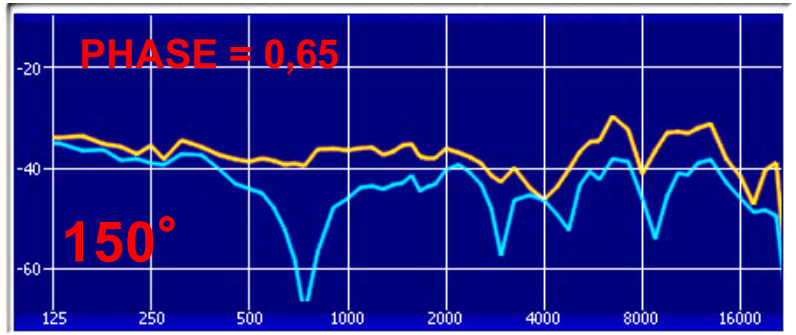
SADIE_KU100_DFC_256_order_fir_48000.sofa

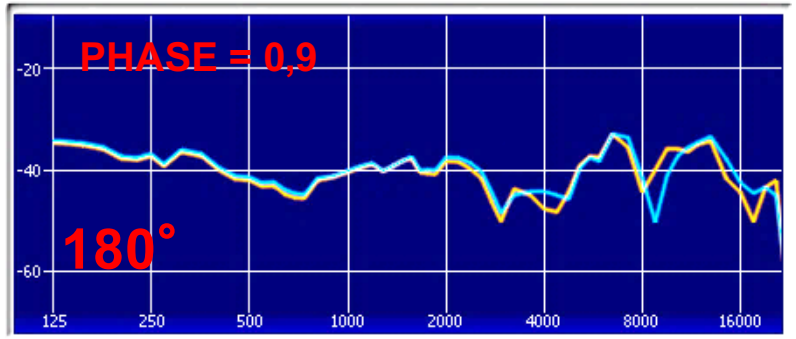
https://www.york.ac.uk/sadie-project/binaural.html

University of York



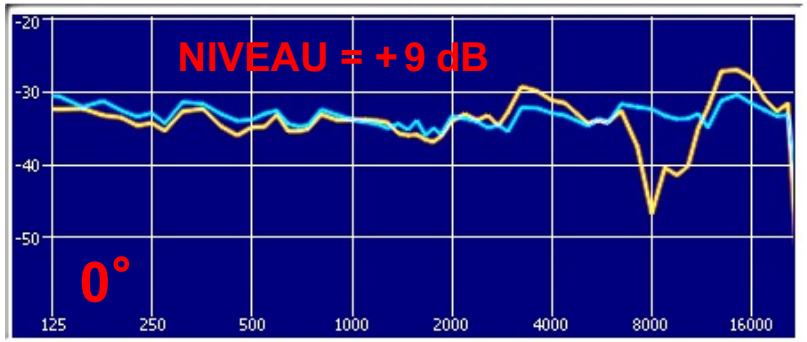


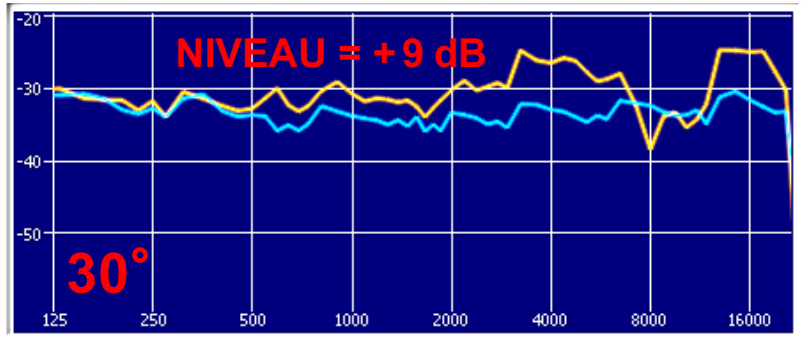


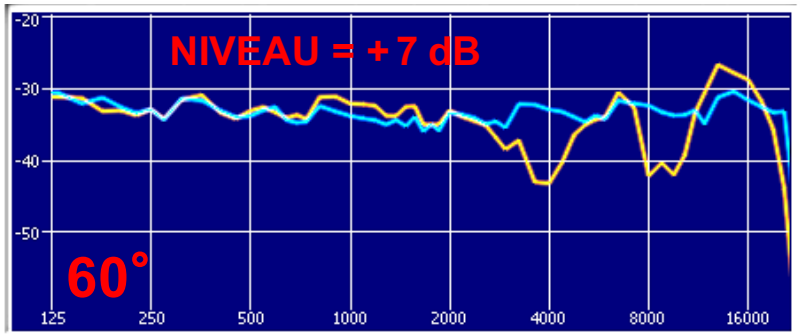


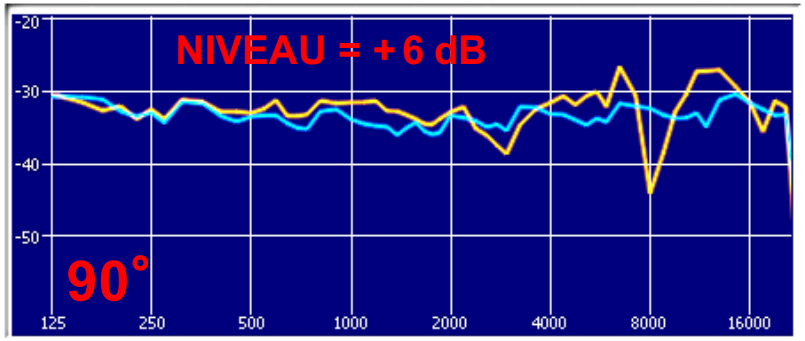
HRTF et Bruit Rose : SADIE *KU 100*

Oreille Ipsilatéral L
BRUIT ROSE IN



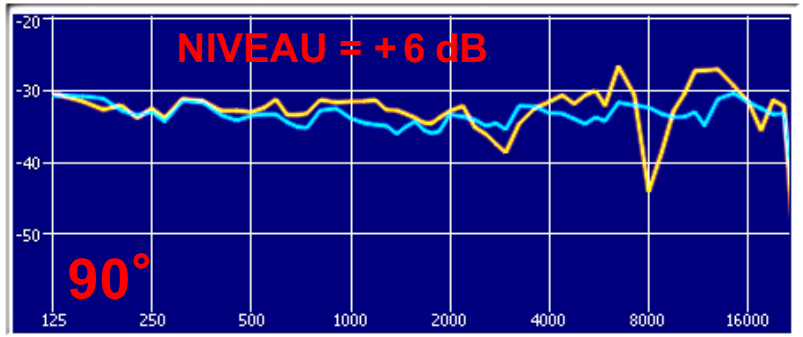


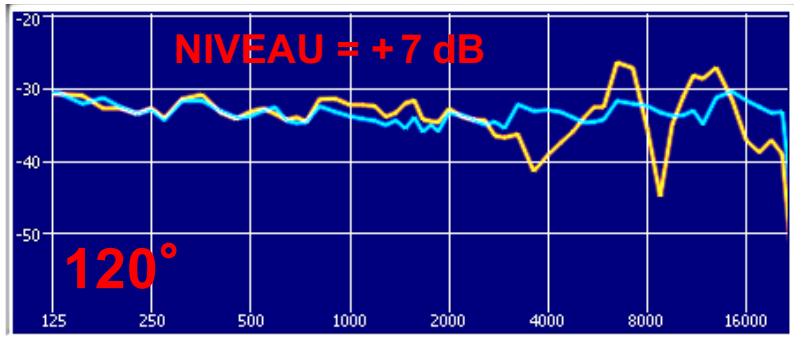


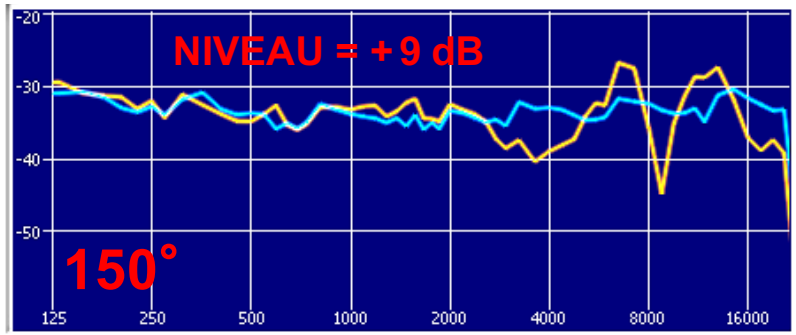


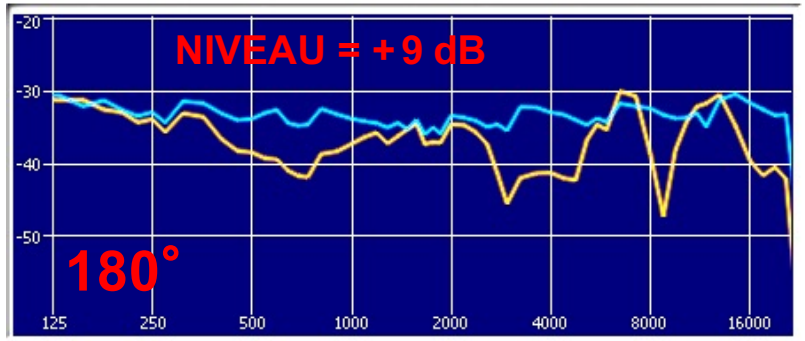
University of York

SADIE_KU100_DFC_256_order_fir_48000.sofa



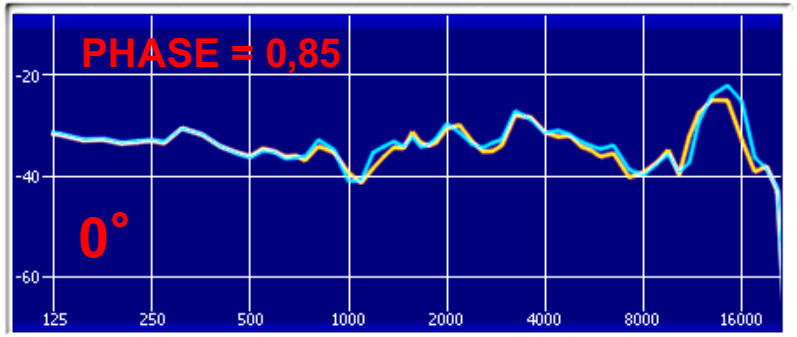


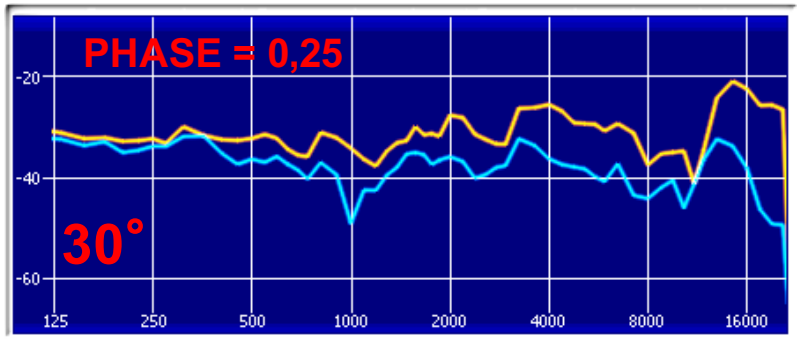


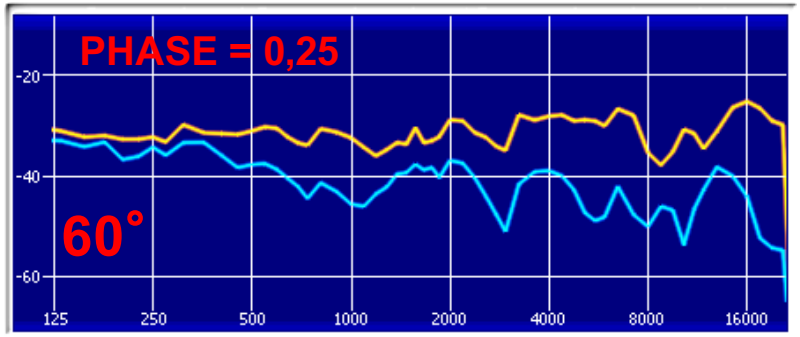


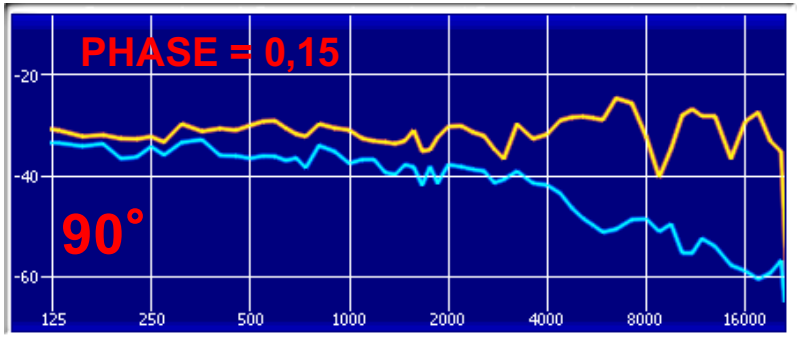
PLUG-IN HRTF 26 utilisé à Radio France

Oreille Ipsilatéral
Oreille Contralatéral









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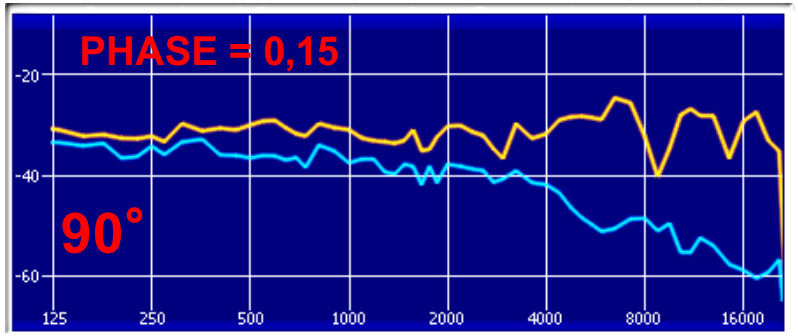
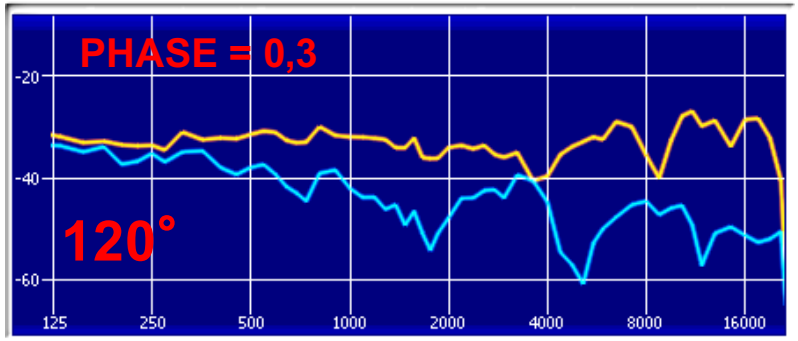
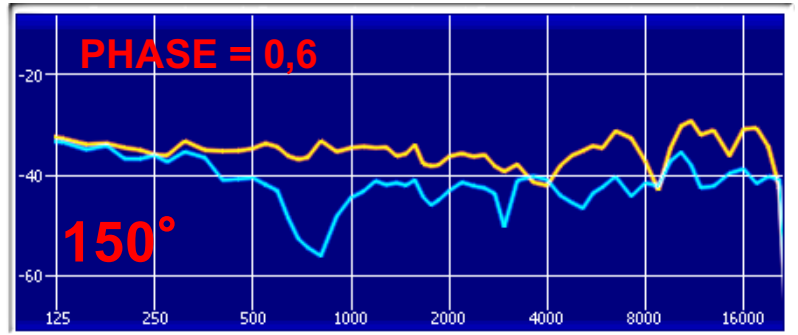
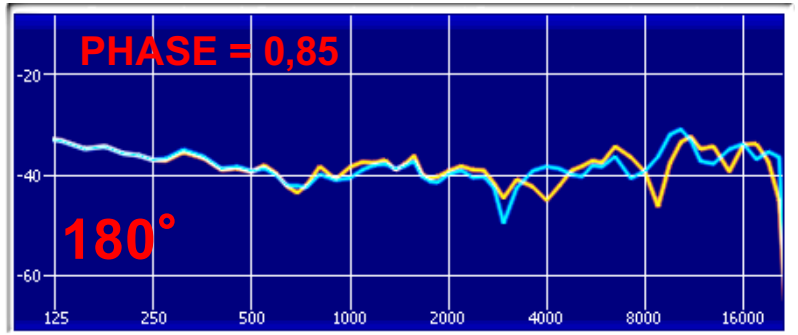


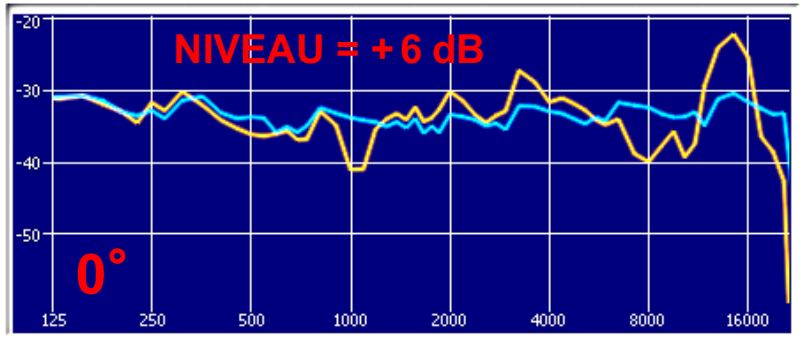


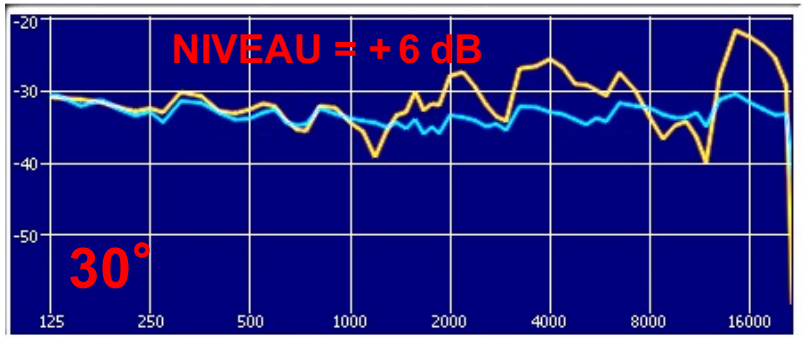


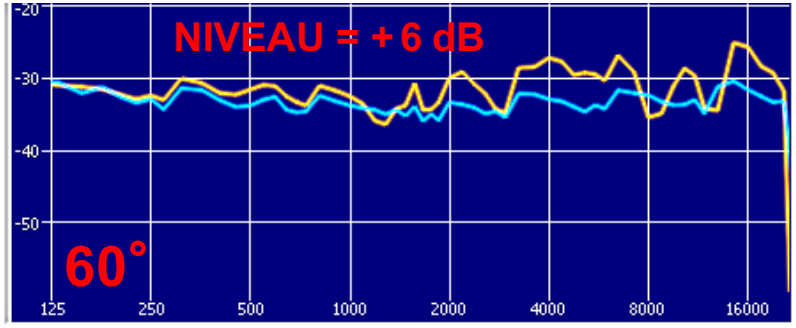


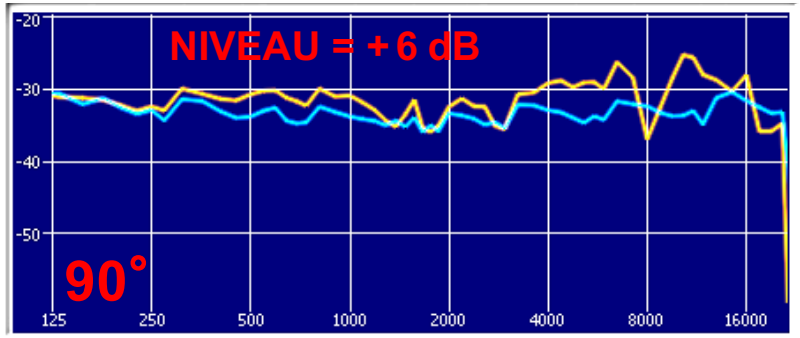
HRTF et Bruit Rose : RF 26 *Radio France*

Oreille Ipsilatéral L
BRUIT ROSE IN



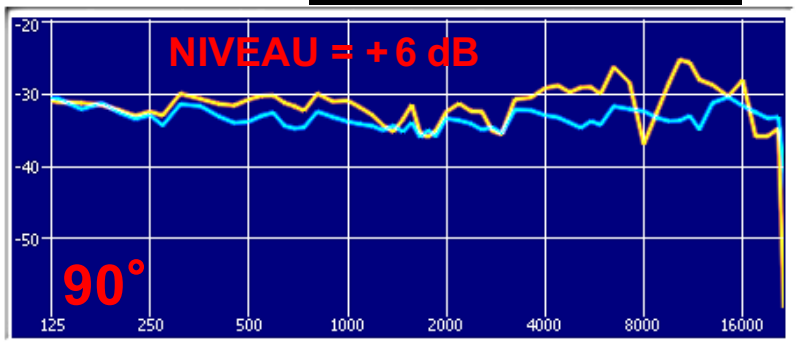


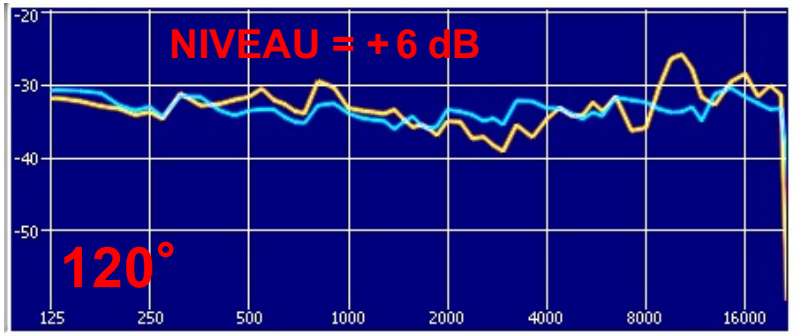


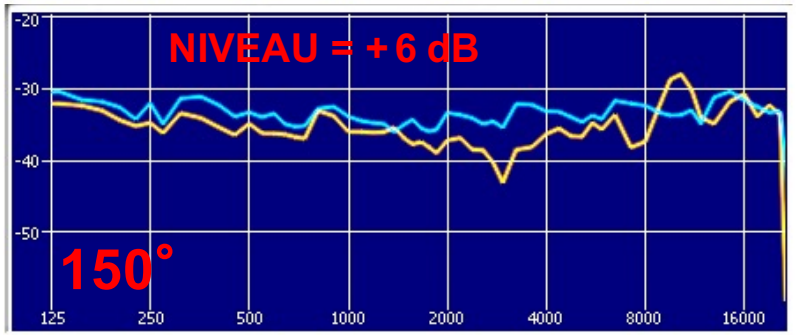


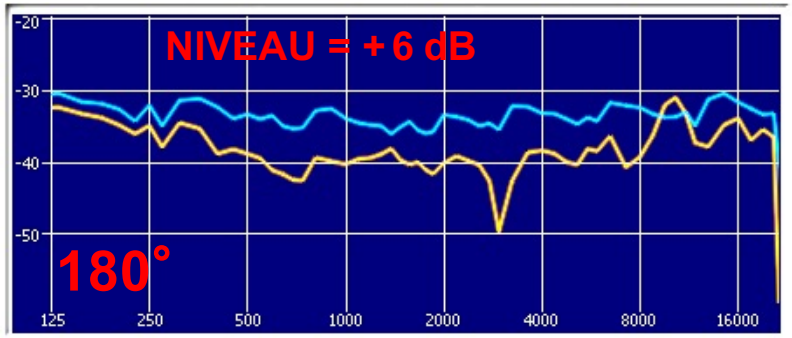
HYPER RADIO
SON 3D

IRC_512_Meth5_26_48000.sofa
Octobre 2015

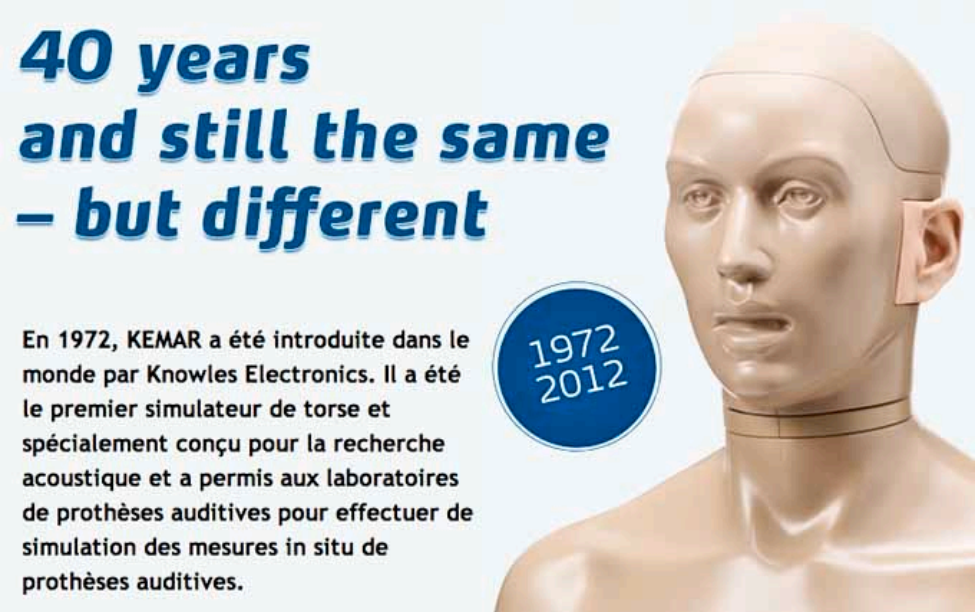








En 1972 : Kemar (*mannequin anthropométrique*)



http://kemar.us/KEMAR_Book.pdf

MANIKIN MEASUREMENTS - KEMAR by *GRAS*

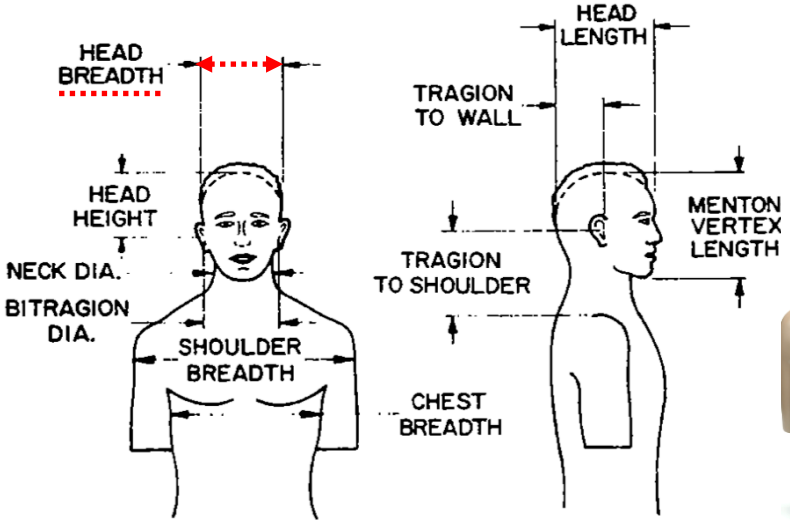
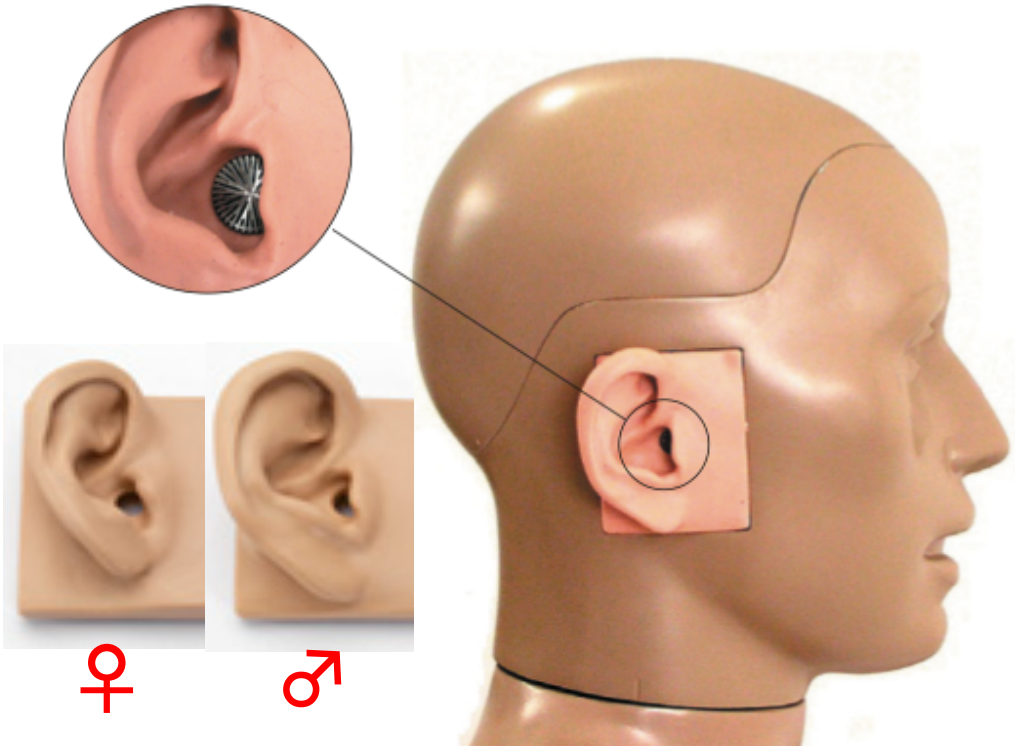


FIG. 1. Anthropometric measures used in design of KEMAR.

TABLE I. Dimensions for KEMAR and average human adults, in centimeters.

	Median male	Median female	Average human	KEMAR
Head breadth	15.5	14.7	15.1	15.2
Head length	19.6	18.0	18.8	19.1
Head height	13.0	13.0	13.0	12.5
Bitragion diameter	14.2	13.5	13.85	14.3
Tragion to wall	10.2	9.4	9.8	9.65
Tragion to shoulder	18.8	16.3	17.55	17.5[a]
Neck diameter	12.1	10.3	11.2	11.3
Shoulder breadth	45.5	39.9	42.7	44.0
Chest breadth	30.5	27.7	29.1	28.2
Menton vertex length	23.2	21.1	22.15	22.4

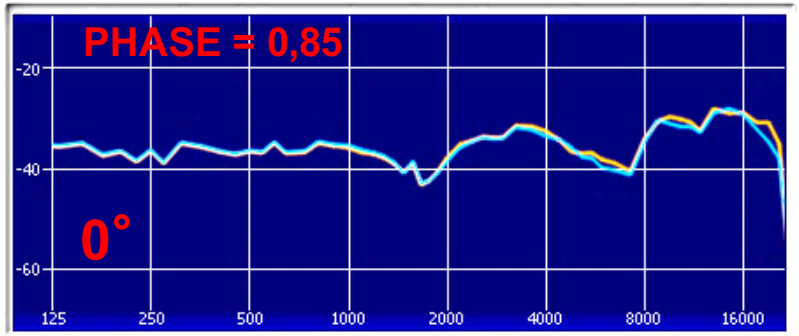
[a]Adjustable over ±1.27 cm.

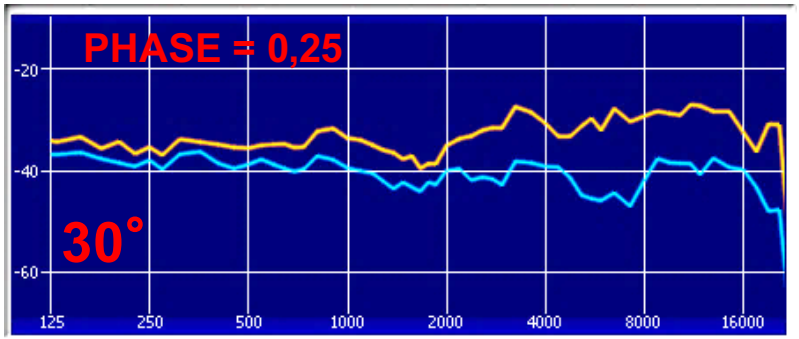


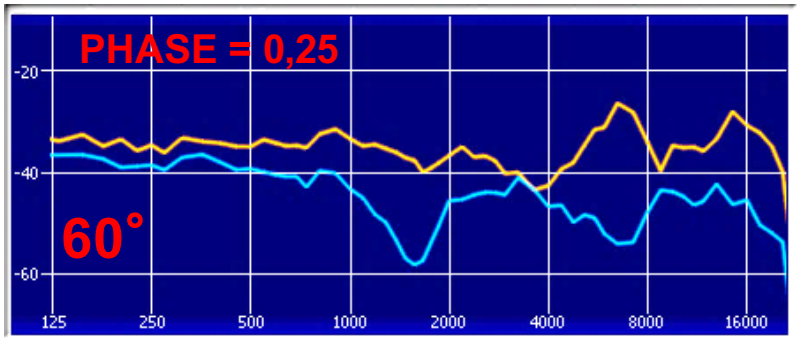
Photos : www.gras.dk

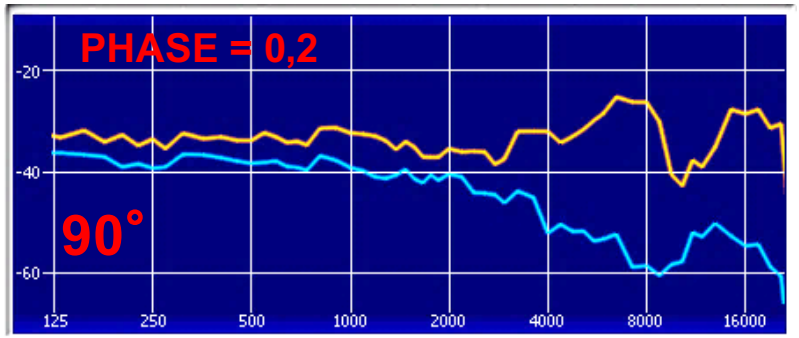
PLUG-IN KEMAR de SADIE

Oreille Ipsilatéral
Oreille Contralatéral





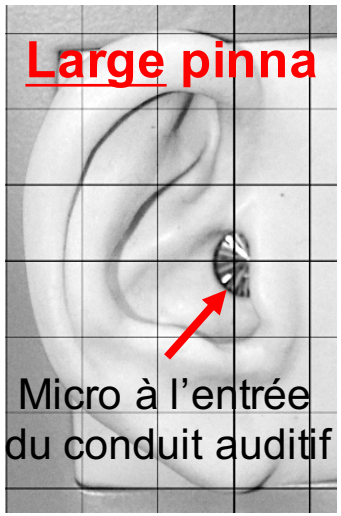


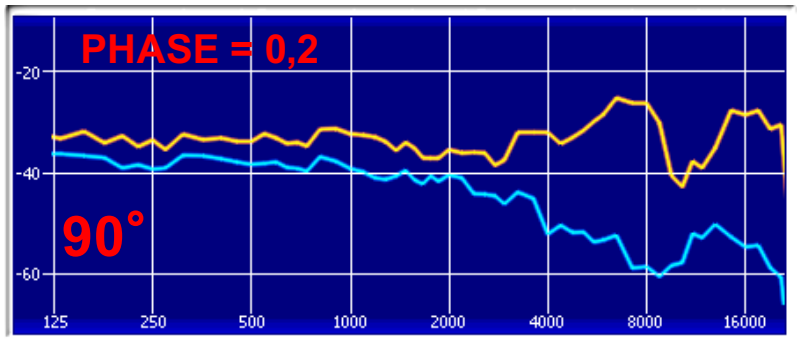


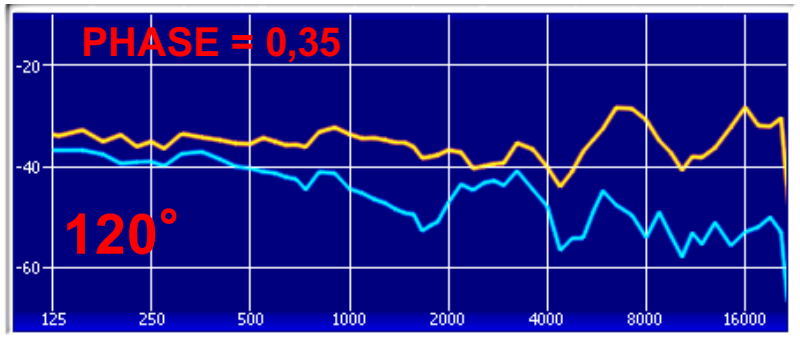
University of York

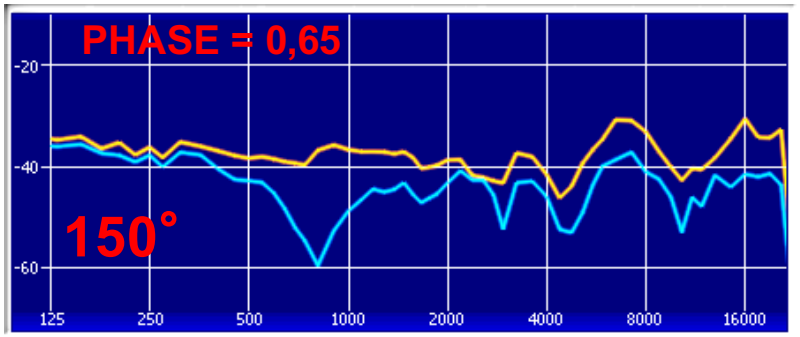
https://www.york.ac.uk/sadie-project/binaural.html

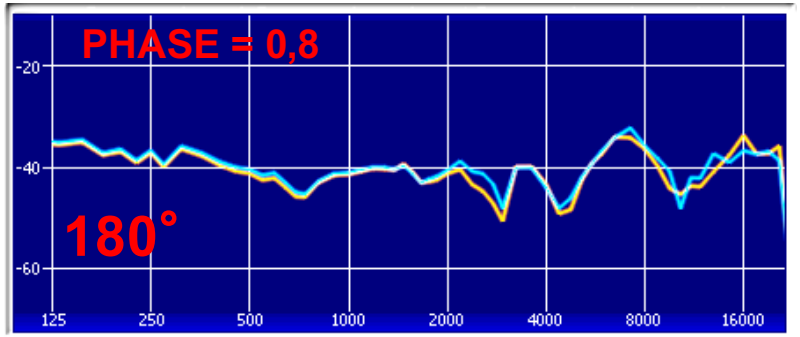
SADIE_KEMAR_DFC_256_order_fir_48000.sofa





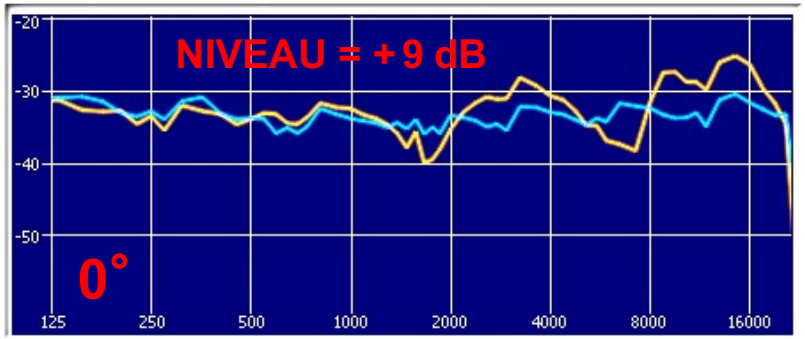


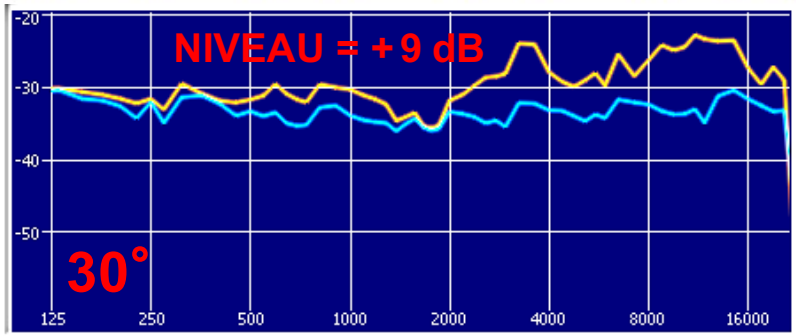


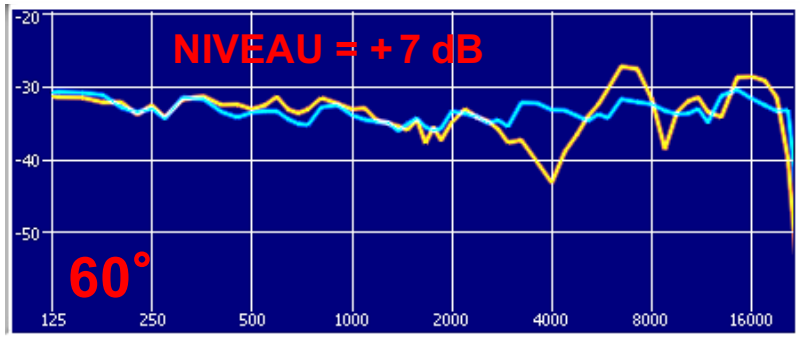


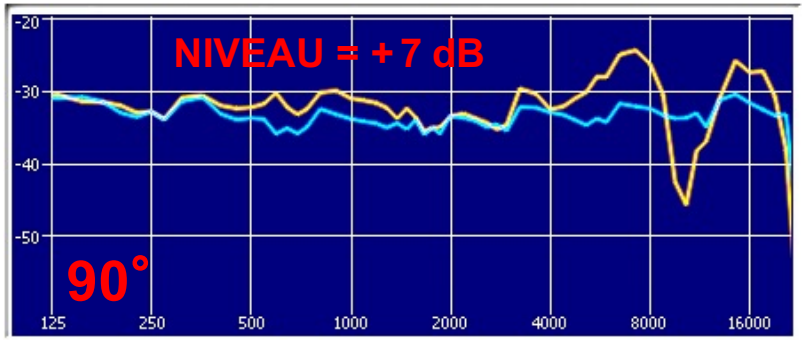
HRTF et Bruit Rose KEMAR de SADIE

Oreille Ipsilatéral L
BRUIT ROSE IN





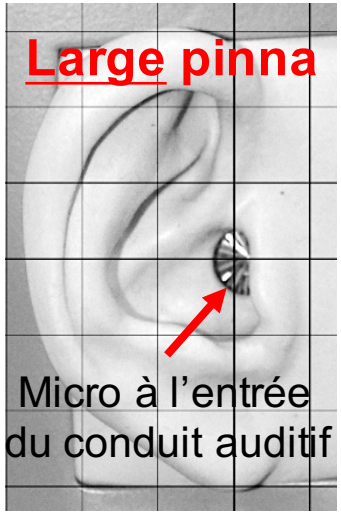


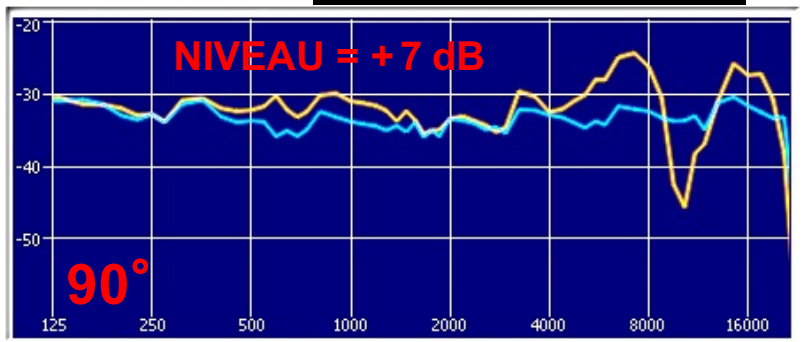


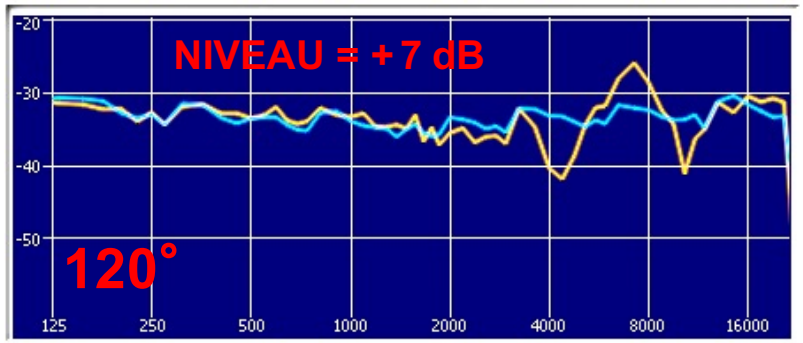
University of York

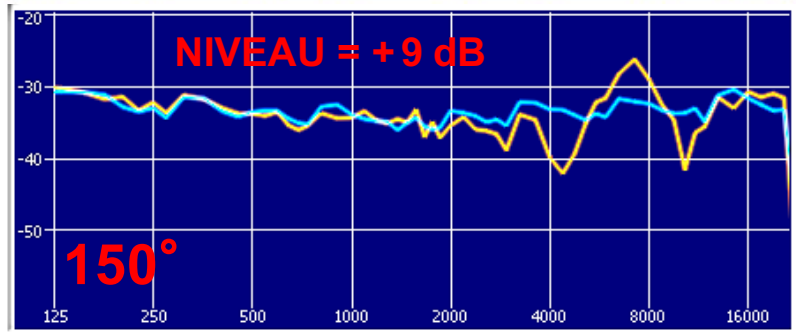
https://www.york.ac.uk/sadie-project/binaural.html

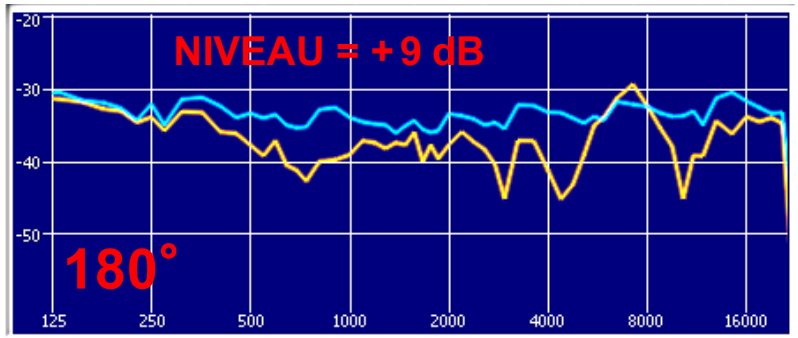
SADIE_KEMAR_DFC_256_order_fir_48000.sofa











Electroacoustic Measurements of Headphones

Christopher J. Struck

CJS Labs
San Francisco, CA – USA

2009

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IEC 60711 Ear Simulator

KEMAR

- Zwislocki *OR* IEC 60711 Ear Simulators
- Anatomical Pinnæ (soft or hard)
- Anthropomorphic Geometry
- Fulfills **ANSI S3.36** *(and IEC 60959 and ITU-T Rec. P.58*

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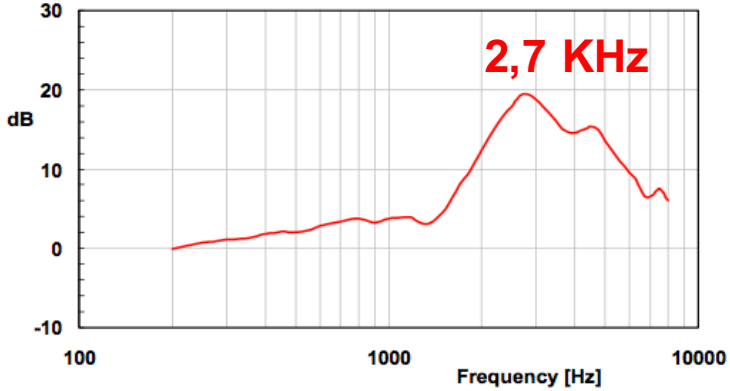
KEMAR Free Field Response

with Zwislocki Coupler



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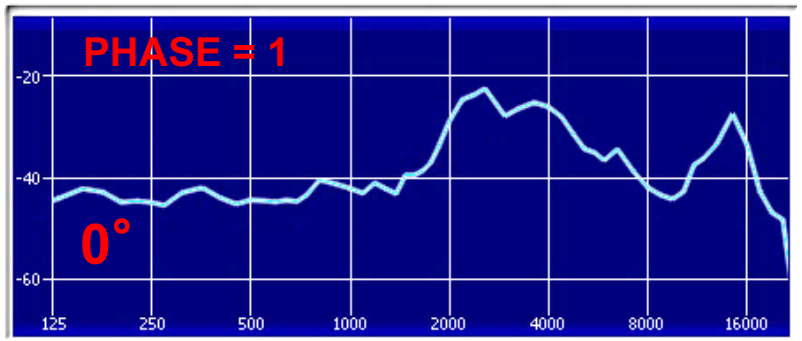
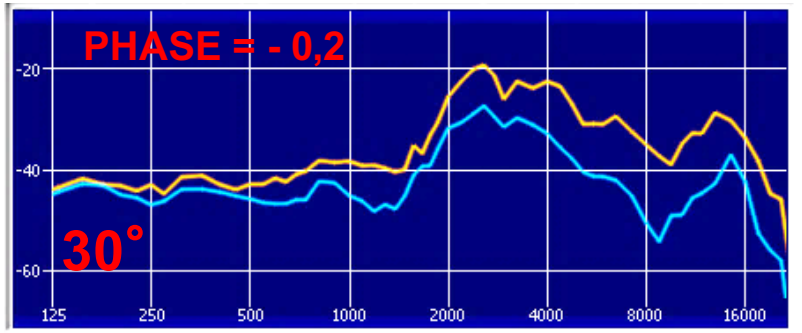
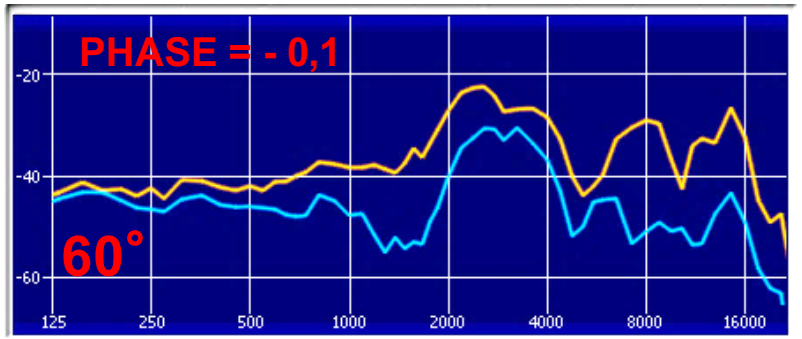
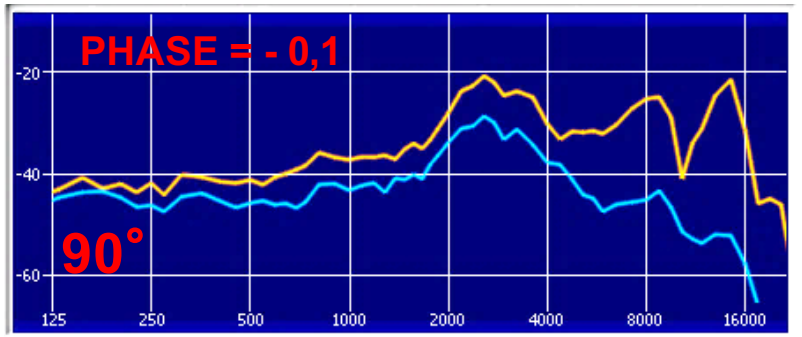
PLUG-IN KEMAR de MIT Oreilles Normales

Oreille Ipsilatéral
Oreille Contralatéral









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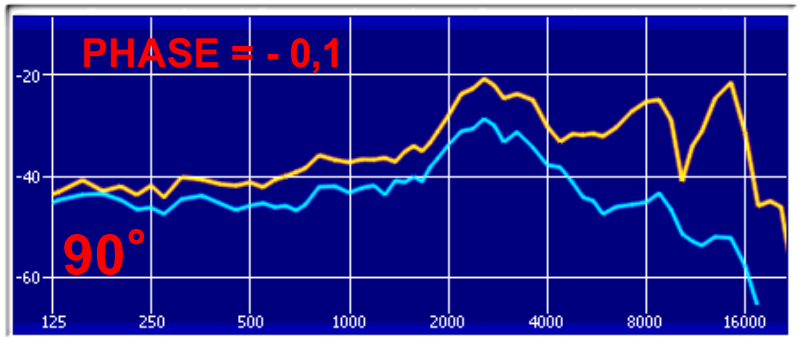
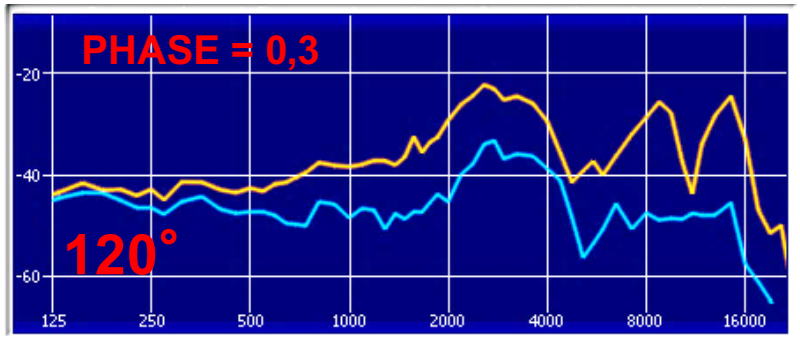
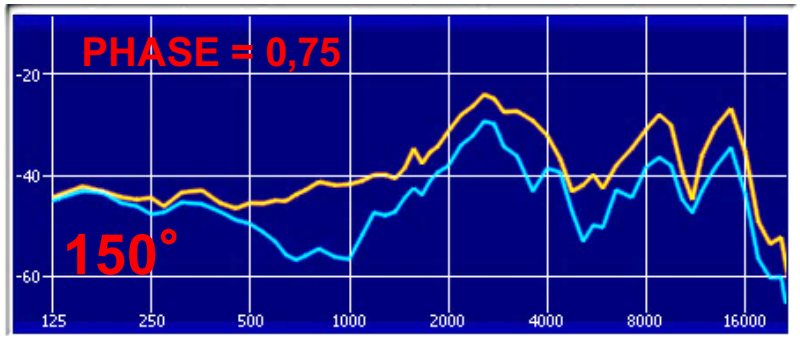
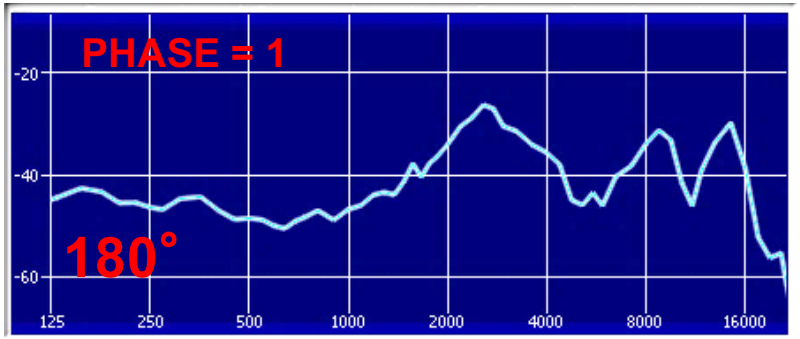


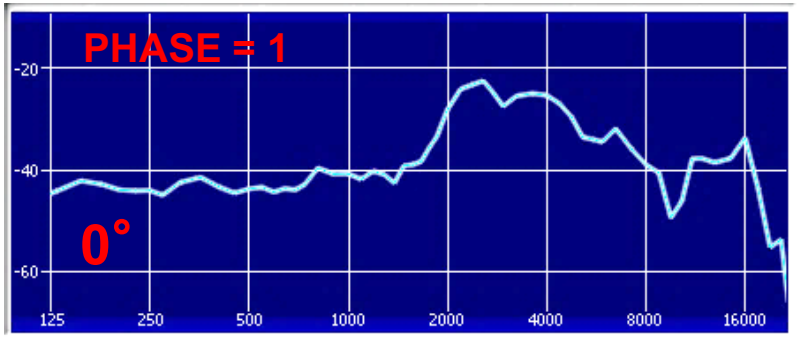


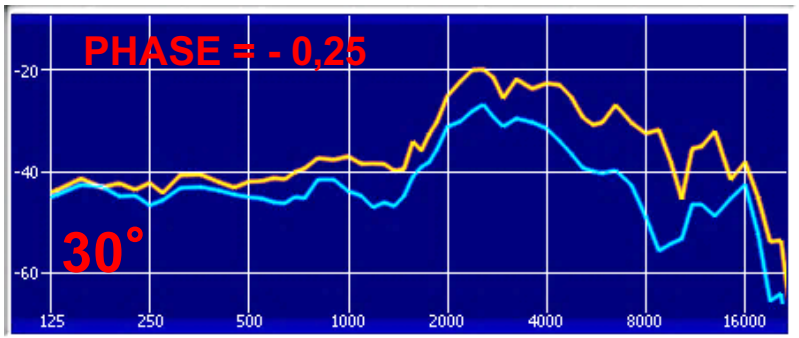


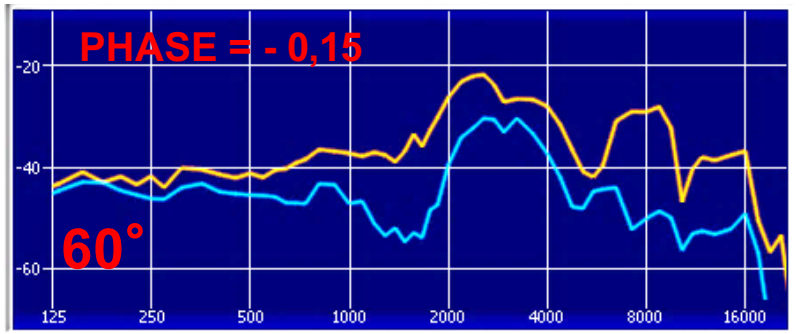


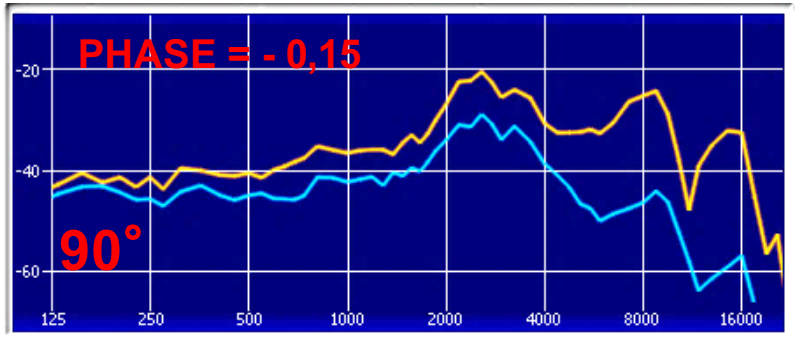
PLUG-IN KEMAR de MIT Oreilles Larges

Oreille Ipsilatéral
Oreille Contralatéral









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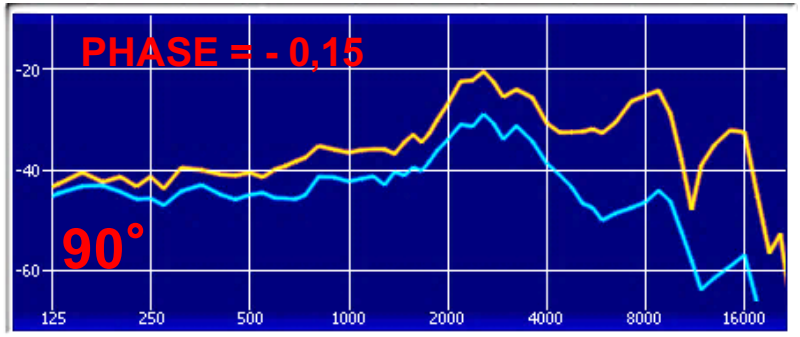
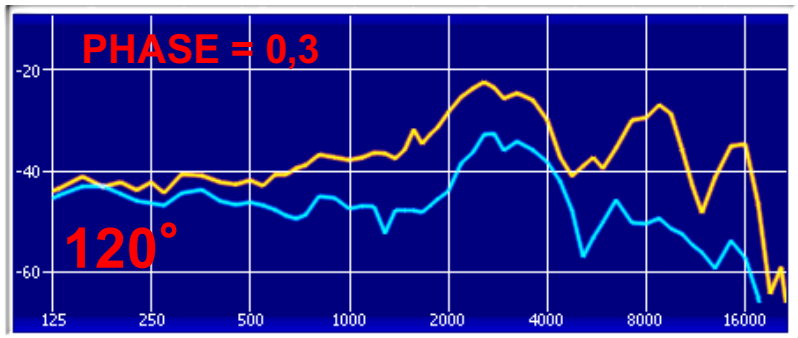
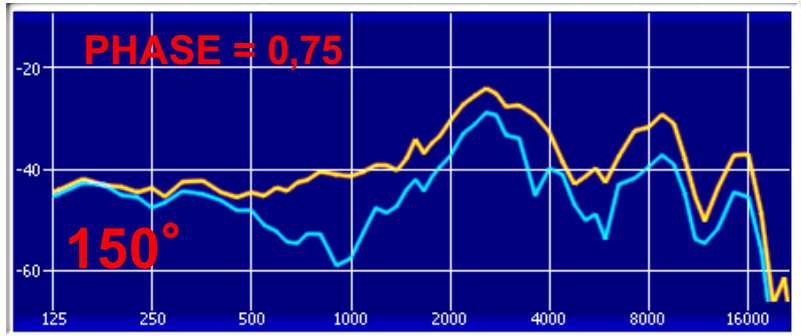
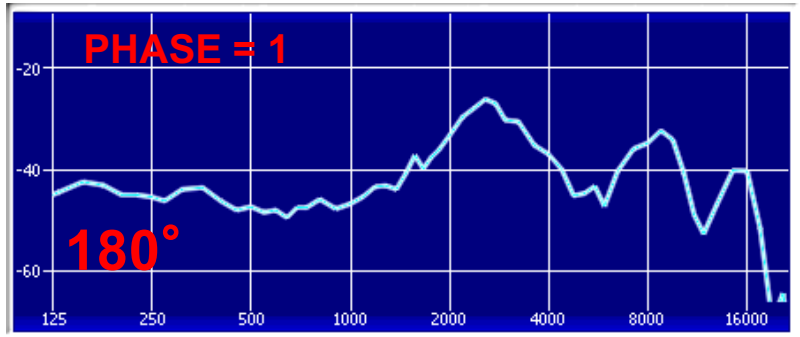




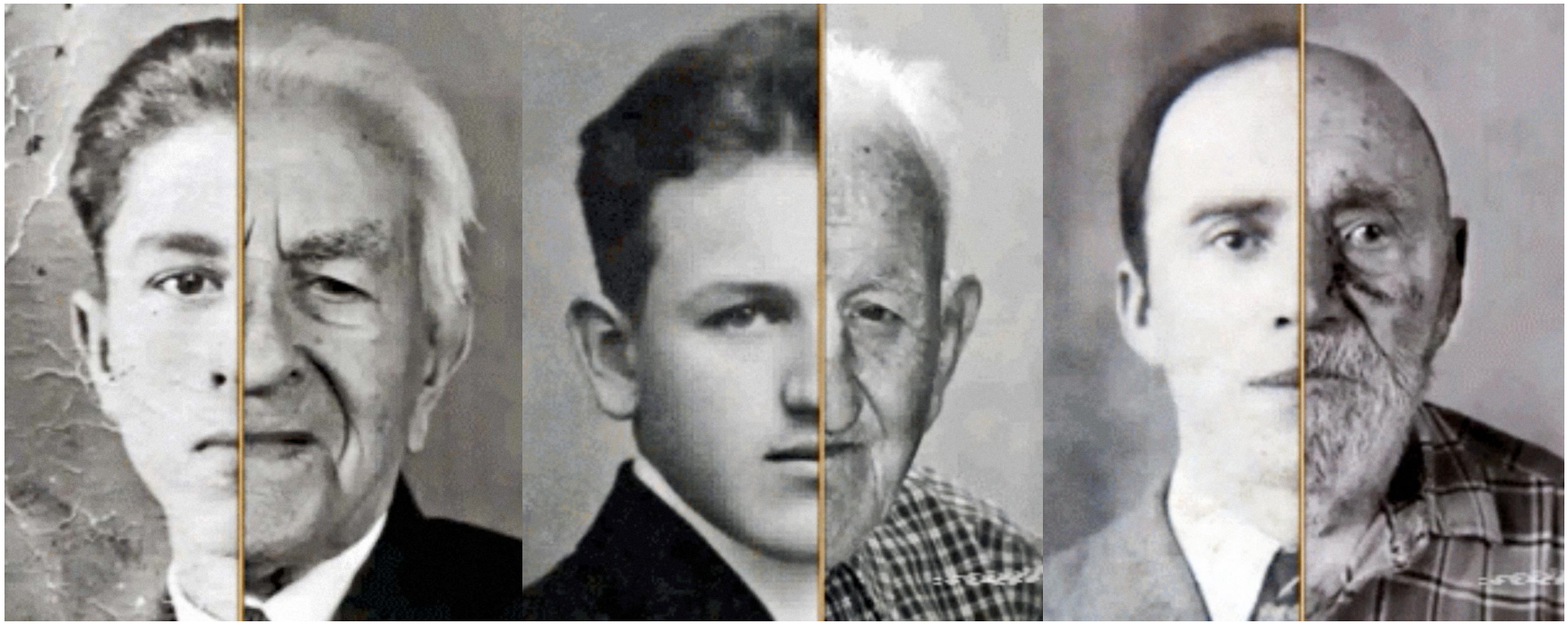


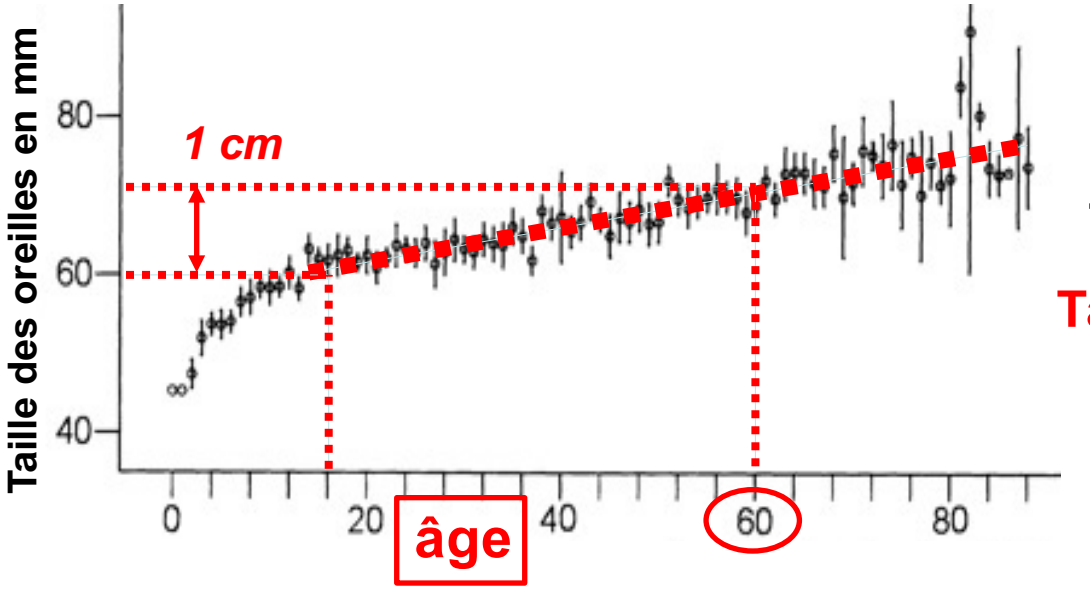


L'oreille ne cesse de grandir…

L'oreille grandit pour compenser la presbyacousie ?

bigbrowser.blog.lemonde.fr

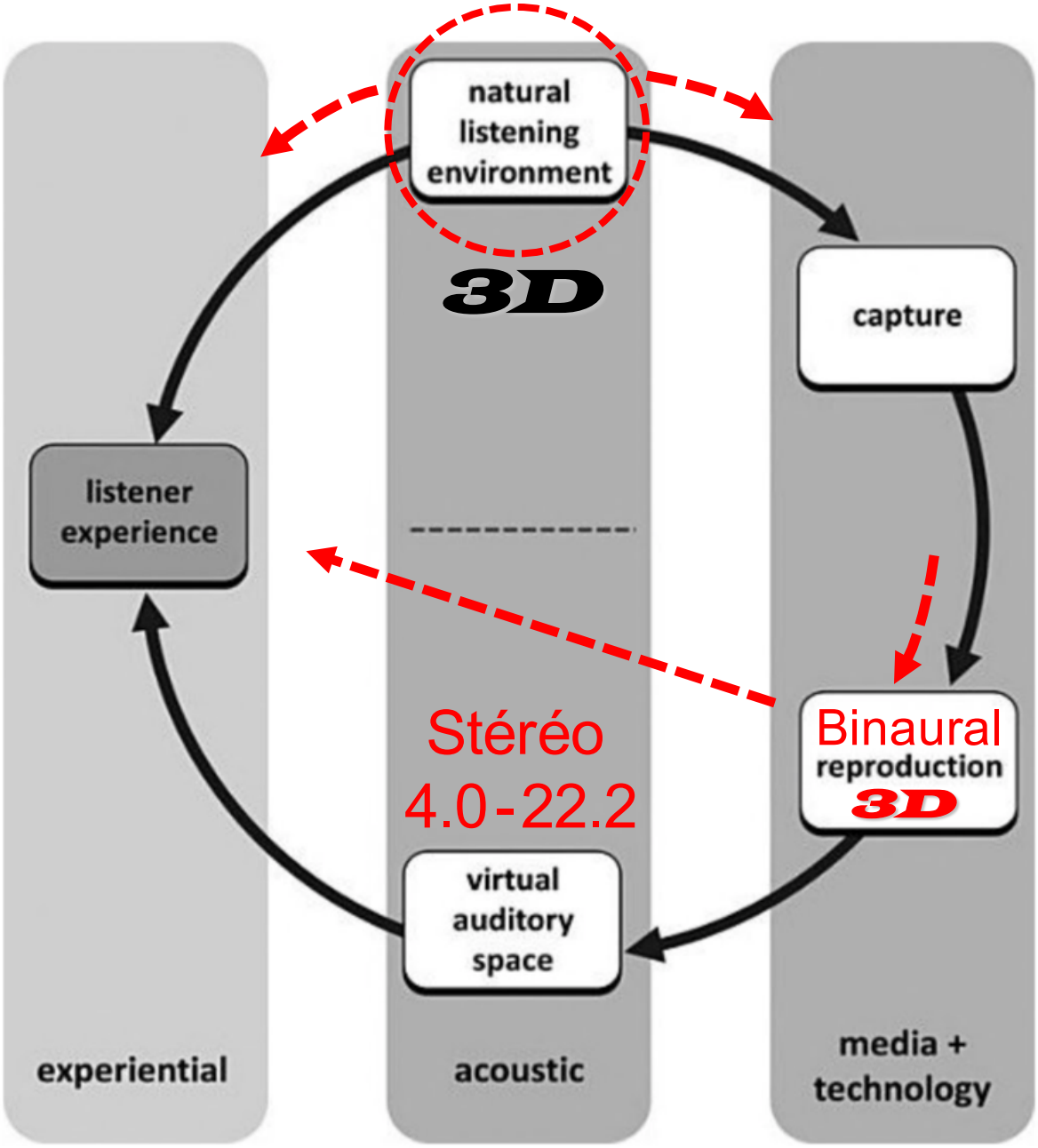




Une équation linéaire de régression fut tirée des données recueillies :

Taille des oreilles = 55.9 + (0.72 x âge)

Niemitz, C., et al. 2007



« La connaissance de l'homme ne peut aller au delà de son expérience » John Locke.

Merci de votre attention

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