



SPATIAL COMPRESSION OF MULTI-CHANNEL AUDIO SIGNALS USING INVERSE FILTERS Toshiyuki KIMURA, Kazuhiko KAKEHI (Graduate School of Human Informatics, Nagoya University/CIAIR), Kazuya TAKEDA and Fumitada ITAKURA (Graduate School of Engineering, Nagoya University/CIAIR) **2. COMPRESSION ALGORITHM <u>Compression (Extraction of the Sound Source Signals)</u>** • Convolve the inverse transfer function matrix to the *M* channel signals $S_i(\omega)$: *i*th source signal Inverse $X_i(\omega)$: *j*th channel signal Transfer Transfer 、 - Function -Function $S'_{i}(\omega)$: *i*th extracted source signal Matrix $[H_{ji}(\omega)]$ $G_{ii}(\omega)$: Room impulse response $[S_i(\omega) \rightarrow X_i(\omega)]$ $H_{ii}(\omega)$: Inverse transfer function $[X_i(\omega) \rightarrow S'_i(\omega)]$ **COMPRESSION** $\mathbf{G}(=[G_{ii}(\omega)])$: Room impulse response matrix (*N*×*M*) $\mathbf{GH} = \mathbf{D}$ $\mathbf{H}(=[H_{ii}(\omega)])$: Inverse transfer function matrix ($M \times N$) **D**: Unit matrix $(N \times N)$ Diagonal component : $D_i(\omega) (=S'_i(\omega)/S_i(\omega))$ $\mathbf{H} = \mathbf{G}^+ \mathbf{D}$ **G**⁺: Moore-Penrose pseudo inverse matrix of **G** Reconstruction • Convolve the room transfer function matrix to the *N* extracted source signals $S_1(\omega)$ Room Transfer $S'_{i}(\omega)$: *i*th extracted source signal Function Matrix $X'_{i}(\omega)$: *j*th reconstructed channel signal $[G_{ij}(\omega)]$ $\left| \mathbf{Z} \right| S_{N}^{'}(\omega) \right|$ RECONSTRUCTION **5. SUBJECTIVE ASSESSMENT Experimental Environment** <u>Se</u> **Experimental Conditions** 3 males (The person who pass the pre-test) Subjects BBBA. About 70dB(A) Sound 15° 🕅 pressure level (at a center of circle) Method Pair test(Stimulus 1 vs Stimulus 2) o° 🗊 ---- ^{4m}---- 0° 🚺 Interval: 0.5sec -15° 🔽 🛛 "Different" or "Same" Answer Note A head is fixed -30° Height of Loudspeakers : 1.2m **Result** 0.8 **6. CONCLUSION** 0.6 A new spatial compres This method performs 0.4 ute The Extraction of the Ř 02 \Rightarrow The source signal 320ms 160ms SI(Piano) SQ SD SI(Speech)



essurement of Ro						
<u>asui cin</u> ciit ui Ku	om Impulse Respon	nse				
				Measuremen	t Conditions	
	Room Height : 2.7m	Re	verber	ation time	150ms	300ms
E		Ro	om ter	mperature	19.5°C	19.2°C
$\frac{52}{10}$ 0.5m			Noise	e level	20.0dB(A)	19.4dB(A)
1.7m		Sour	nd pres	sure level ^{*1}	90.0dB(A)	91.6dB(A)
		Sar	npling	frequency	48]	kHz
E E		R	eferen	ce signal	TSP(655	36 points)
1.52	Height of Loudspeakers and Microphones : 0.835m	The nu	umber	of repetitions	1	16
5.725m		F	FIR filter order		7200 14400	
		*1 One	meter fi	rom loudspeaker		
<u>ithesis of Channe</u>	el Signals					
Sound Source	Speech	Piano	R	everberatio	n time of c	hannel sig
e number of sources	1 (Azimuth angle = -1	$15^{\circ}, 0^{\circ}, 15$	^o)	1 5 0		
Duration	About 5sec	2		150ms	<u>~~4</u>	0.6sec
ampling Frequency	12kHz			300ms		1.2sec
Bandwidth	50Hz-5kHz	Z				
<u>mputation of Inv</u>	erse Filter					
Time domain	Frequency doma	ain		Conditions	of Computat	ion
FIR Room	NET Room Transfe	er	Reve	rberation	0.6sec	1.2sec
npulse Response $\begin{bmatrix} 1 \\ -1 \end{bmatrix}$	Function Matrix	x G		time		
$\{g_{ij}(n)\}$	(5×24)		DF	Г points	16384	32768
			Dela	y of BPF	10ms, 20ms	, 40ms,
ID Inverse Filter I	DET Function Matrix	ter			80ms, 160ms	s, 320ms
$\{h_{n}(n)\}$	$\frac{DTT}{(24\times5)}$		Filte	er length	7200	14400
Sampling frequency:	12kHz, Bandwidth: 50H	Iz-5kHz)	the c	coding dela	y	
Sampling frequency:	12kHz, Bandwidth: 50H	Iz-5kHz)	the c	coding dela	y	
Sampling frequency:	12kHz, Bandwidth: 50H	Iz-5kHz)	the c	coding dela	y	
Sampling frequency:	12kHz, Bandwidth: 50H	Iz-5kHz) <u>Soi</u>	the c	oding dela	y	
ampling frequency: ions und Quality(SQ) ource : Piano, RT=1.2	12kHz, Bandwidth: 50H 2sec, Azimuth angle=0°	Iz-5kHz) <u>Sot</u>	the c und Di ource :	Speech , RT=	y 0.6sec	
Sampling frequency: Ions und Quality(SQ) ource : Piano, RT=1.2 ondition Stimulus 1 ontrol Original	12kHz, Bandwidth: 50H 2sec, Azimuth angle=0° Stimulus 2 Tr Original	Iz-5kHz)	the c ind Di ource : ondition	Example 1 Contraction (SD) Speech, RT= Stimulus 1	y 0.6sec Stimulus 2	Tı
Sampling frequency: Image: Sa	12kHz, Bandwidth: 50H 2sec, Azimuth angle=0° Stimulus 2 Tr Original Tr Coding (Delay=10ms) Tr	Iz-5kHz) Sol	the c ind Di ource : ondition ontrol	coding dela rection(SD) Speech, RT= Stimulus 1 Original (-15°) Original (0°)	y 0.6sec Stimulus 2 Original (-15°) Original (0°)	Tı
Sampling frequency: Ions Ind Quality(SQ) ource : Piano, RT=1.2 ondition Stimulus 1 ontrol Original valuation Original	12kHz, Bandwidth: 50H 2sec, Azimuth angle=0° Stimulus 2 Tr Original Image: Coding (Delay=10ms)	Iz-5kHz) Sor	the condition	Example 2 Contraction (SD) Speech, RT= Stimulus 1 Original (-15°) Original (0°) Original (15°)	y 0.6sec Stimulus 2 Original (-15°) Original (0°) Original (15°)	
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Sampling frequency: ions und Quality(SQ) ource : Piano, RT=1.2 ondition Stimulus 1 ontrol Original valuation Original atial Impression(SI) ource : Speech & Piazo	12kHz, Bandwidth: 50H 2sec, Azimuth angle=0° Stimulus 2 Tr Original Tr Coding (Delay=10ms) Tr no, Azimuth Angle=0° Tr	Iz-5kHz) Sor	the control	coding dela coding dela coding dela rection(SD) Speech, RT= Stimulus 1 Original (-15°) Original (0°) Original (-15°) Original (-15°) Original (-15°) Original (15°) Original (0°) Original (15°)	y 0.6sec Stimulus 2 Original (-15°) Original (0°) Original (15°) Coding(-15°, D Coding(0°, Dela Coding(15°, Dela	$\begin{array}{c c} & Ti \\ \hline \\ $
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Room Height : 2.7m	<u>115</u> C					
Room Height : 2.7m	<u> </u>		Measureme	nt Conditions		
		Revert	eration time	150ms	300ms	
E		Room	temperature	19.5°C	19.2°C	
5. − 0.5m		No	ise level	20.0dB(A)) 19.4dB(A)	
1.7m	S	Sound p	ressure level ^{*1}	90.0dB(A)) 91.6dB(A)	
		Sampli	ng frequency	48	kHz	
		Refer	ence signal	TSP(655	36 points)	
Height of Loudspeakers	Th	ne numb	er of repetition	ns	16	
5.725m		FIR filter order		7200	7200 14400	
	*1	One mete	r from loudspeak	er		
nthesis of Channel Signals						
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ne number of sources 1 (Azimuth angle = -1	$15^{\circ}, 0^{\circ}$	^o , 15 ^o)			C	
Duration About 5sec	c		150m	s $\times 4$	0.6sec	
ampling Frequency 12kHz			300m	S	1.2sec	
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mputation of Inverse Filter						
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mpulse Response $ DFT \rightarrow $ Function Matri	$\mathbf{x} \mathbf{G}$		time	0.0500	1.2500	
$\{g_{ij}(n)\} \tag{5\times24}$			PFT points	16384	32768	
$\mathbf{H} = \mathbf{G}^+\mathbf{J}$	D	De	elav of BPF	10ms. 20ms	s. 40ms.	
Inverse Trans	fer			80ms, 160m	s, 320ms	
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IR Inverse Filter $\{h_{ji}(n)\}$ IDFT Function Matri (24×5) iagonal element of D : DFT of FIR band-pass iagonal element of D : DFT of FIR band-pass iampling frequency: 12kHz, Bandwidth: 50F ions ions ions ionition stimulus 1 Stimulus 2 ontrol Original valuation Original Coding (Delay=10ms) atial Impression(SI) purce : Speech & Piano, Azimuth Angle=0° 2ondition Stimulus 1 Stimulus 2 Tri control Original (0.6sec) Original (1.2sec) Original (1.2sec) original (1.2sec) Coding(0.6sec, Delay=10ms)	ials 3 3 3	r Hz) De the the	lter length lay of BPF : e coding del coding del coding del birection(SD e : Speech, RT on Stimulus 1 0riginal (-15°) 0riginal (0°) 0riginal (15°) on Original (15°) on Original (15°)	7200 Correspor ay =0.6sec Stimulus 2 Original (-15°) Original (0°) Original (0°) Original (15°) Coding(-15°, Del Coding(0°, Del Coding(15°, Del	14400 nd to nd to Tri 2 2 2 2 2 2 2 2 2 2 2 2 2	
IR Inverse Filter $\{h_{ji}(n)\}$ IDFT Function Matri (24×5) iagonal element of D : DFT of FIR band-pas Sampling frequency: 12kHz, Bandwidth: 50F ions und Quality(SQ) ource : Piano, RT=1.2sec, Azimuth angle=0° ondition Stimulus 1 Stimulus 1 Stimulus 2 ontrol Original valuation Original coding (Delay=10ms) atial Impression(SI) ource : Speech & Piano, Azimuth Angle=0° Condition Stimulus 1 Stimulus 2 Tri Original (0.6sec) Original (0.6sec) Original (1.2sec) Original (1.2sec) Svaluation Original (0.6sec) Original (1.2sec) Coding(0.5sec, Delay=10ms)	ials 3 3 3	r Hz) De the the	Iter length	7200 Correspor ay =0.6sec Stimulus 2 Original (-15°) Original (0°) Original (0°) Original (15°) Coding(0°, Del Coding(0°, Del	14400 nd to Tri Tri Delay=10ms)	
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easurement of Roo	om Impulse Respo	onse				
	1 1			Measureme	ent Conditions	5
/ t	Room Height : 2.7n	n	Revert	peration time	150ms	300ms
u u		$ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	Room	temperature	19.5°C	19.2°C
$\frac{5}{-1}$ 0.5m			Nc	oise level	20.0dB(A) 19.4dB(A)
1.7m			Sound p	ressure level ^{*1}	90.0dB(A) 91.6dB(A)
			Sampli	ng frequency	48	3kHz
E			Refer	ence signal	TSP(655	536 points)
1.52	Height of Loudspeakers and Microphones · 0.835m	Tł	he numb	er of repetition	ns	16
5.725	m	→	FIR	filter order	7200	14400
		*1	One mete	er from loudspeak	ker	
thesis of Channe	<u>l Signals</u>					
Sound Source	Speech	Piano	0	Reverberati	ion time of o	channel sig
e number of sources	1 (Azimuth angle =	$-15^{\circ}, 0^{\circ}$	°, 15°)	1 = 0		
Duration	About 5se	ec		150m	$1S \rightarrow 4$	U.6sec
ampling Frequency	12kHz			300m	IS	1.2sec
Bandwidth	50Hz-5kH	Ηz				
<u>mputation of Inve</u>	erse Filter					
Time domain	Frequency dor	nain	1	Condition	s of Computa	tion
FIR Room	Room Trans	sfer	Re	verberation	0.6sec	1.2sec
	$\xrightarrow{\mathbf{n}}$ Function Mat	riv C		time		
npulse Response $\begin{bmatrix} D \\ -D \end{bmatrix}$	(5×24)			tille		
npulse Response $\{g_{ij}(n)\}$	(5×24)			OFT points	16384	32768
npulse Response $[g_{ij}(n)]$	(5×24) $H = G^{-1}$	+D		OFT points elay of BPF	16384 10ms, 20m	32768 s, 40ms,
npulse Response $[g_{ij}(n)]$	$\mathbf{H} = \mathbf{G}^{-1}$ $\mathbf{H} = \mathbf{G}^{-1}$ Inverse Tran Eurotion Mat	⁺ D sfer		OFT points elay of BPF	16384 10ms, 20m 80ms, 160m	32768 s, 40ms, is, 320ms
inpulse Response $\{g_{ij}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ iagonal element of D Sampling frequency: 1	$\begin{array}{c} (5 \times 24) \\ \downarrow \mathbf{H} = \mathbf{G}^{-} \\ \hline \mathbf{H} =$	⁺ D sfer rix H ass filte Hz-5kI	r Hz)	OFT points elay of BPF ilter length elay of BPF e coding del	16384 10ms, 20m 80ms, 160m 7200 : Correspon ay	32768 s, 40ms, as, 320ms 14400 nd to
Impulse Response Impulse $\{g_{ij}(n)\}$ Impulse Response Impulse $\{g_{ij}(n)\}$ Impulse Response Impulse $\{h_{ji}(n)\}$	(5×24) $H = G$ Inverse Tran Function Mati (24×5) $DFT \text{ of FIR band-pa}$ 2kHz, Bandwidth: 50	⁺ D sfer rix H ass filte Hz-5k	r Hz)	OFT points elay of BPF ilter length elay of BPF e coding del	16384 10ms, 20m 80ms, 160m 7200 : Correspon lay	32768 s, 40ms, as, 320ms 14400 nd to
npulse Response $\{g_{ij}(n)\}$ TR Inverse Filter $\{h_{ji}(n)\}$ iagonal element of D Sampling frequency: 1	f = G = G = G = G = G = G = G = G = G =	⁺ D sfer rix H ass filte Hz-5k	r Hz)	PFT points elay of BPF ilter length elay of BPF e coding del	16384 10ms, 20m 80ms, 160m 7200 : Correspon lay	32768 s, 40ms, as, 320ms 14400 nd to
inpulse Response $\{g_{ij}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ iagonal element of D ampling frequency: 1 Cons Ind Quality(SO)	$f = (5 \times 24)$ $f = G$ Inverse Tran Function Mati (24 \times 5) $f = (24 \times 5)$ $f = (24 \times 5)$ $f = (24 \times 5)$	⁺ D sfer rix H ass filte Hz-5kH	r Hz) Sound	Direction(SD	16384 10ms, 20m 80ms, 160m 7200 : Correspon ay	32768 s, 40ms, as, 320ms 14400 nd to
npulse Response $\{g_{ij}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ iagonal element of D ampling frequency: 1 Ons ons ons ource : Piano, RT=1.2	(5×24) $H = G$ Inverse Tran Function Mati (24 \times 5) : DFT of FIR band-pa 2kHz, Bandwidth: 50	⁺ D sfer rix H ass filte Hz-5kH	Image: Constraint of the second s	DFT points PFT points elay of BPF ilter length elay of BPF e coding del Direction(SD e : Speech, RT	16384 10ms, 20m 80ms, 160m 7200 : Correspon lay	32768 s, 40ms, as, 320ms 14400 nd to
npulse Response D $\{g_{ij}(n)\}$ II IR Inverse Filter II $\{h_{ji}(n)\}$ II iagonal element of D ampling frequency: 1 Ind Quality(SQ) III ondition Stimulus 1	(5×24) $H = G$ Inverse Tran Function Mati (24 \times 5) : DFT of FIR band-pa 2kHz, Bandwidth: 50	⁺ D sfer rix H ass filte Hz-5kH	Image: Condition Image: Condition Image: Condition	DFT points PFT points PFT points Pay of BPF PFT points PFT po	16384 10ms, 20m 80ms, 160m 7200 : Correspon ay :=0.6sec	32768 s, 40ms, as, 320ms 14400 nd to
Inpulse Response $\{g_{ij}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ Iagonal element of D ampling frequency: 1 Iagonal element of D ampling frequency: 1 ONS ONS Ind Quality(SQ) purce : Piano, RT=1.2 ondition Stimulus 1 ontrol Original	f unction function (5×24) H = G Inverse Tran Function Matrix (24×5) : DFT of FIR band-pa 2kHz, Bandwidth: 50 Stimulus 2 Original Coding (Delay=10mc)	⁺ D sfer rix H ass filte Hz-5kI Hz-5kI	Image: Condition of the ser of th	DFT points PFT points elay of BPF ilter length elay of BPF e coding del Direction(SD e : Speech, RT on Stimulus 1 Original (-15°)	16384 10ms, 20m 80ms, 160m 7200 Correspon ay Stimulus 2 Original (-15°)	32768 s, 40ms, as, 320ms 14400 nd to
Inpulse Response $\{g_{ij}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ Iagonal element of D ampling frequency: 1 Image: Ima	(5×24) $H = G$ Inverse Tran Function Mata (24×5) : DFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) (24×5)	$\frac{1}{1} \mathbf{C}$ $\frac{1}{1} \mathbf{D}$ $\frac{1}{1} \mathbf{D}$ $\frac{1}{1} \mathbf{S}$ $\frac{1}{1} \mathbf{C}$ $\frac{1}$	Image: Condition of the second se	DFT points PFT points PFT points Pay of BPF ilter length Prection (SD e : Speech, RT on Stimulus 1 Original (-15°) Original (0°) Original (15°)	16384 10ms, 20m 80ms, 160m 7200 Correspon ay S=0.6sec Stimulus 2 Original (-15°) Original (0°) Original (15°)	32768 s, 40ms, as, 320ms 14400 nd to
npulse Response Image: Conservation of the second structure is a second structure is	f = G = G = G = G = G = G = G = G = G =	⁺ D sfer rix H ass filte Hz-5k Hz-5k	Image: Condition of the second se	DFT points PFT points PFT points Pay of BPF ilter length Prection(SD e coding del Direction(SD e : Speech, RT on Stimulus 1 Original (-15°) Original (0°) Original (15°) ion Original (-15°)	16384 10ms, 20m 80ms, 160m 7200 Correspon ay Stimulus 2 Original (-15°) Original (0°) Original (15°) Coding(-15°, 1	32768 s, 40ms, as, 320ms 14400 nd to
npulse Response $\{g_{ij}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ Iagonal element of D ampling frequency: 1 iagonal element of D ampling frequency: 1 Ons ons ons ons ons ons ons ontrol Original ontrol Original valuation Original ource : Speech & Piar	$f unction tviation (5 \times 24)$ $H = G^{-1}$ Inverse Tran Function Mata (24 \times 5) $f = 0^{-1}$	$\frac{1}{1} \mathbf{C}$ $\frac{1}{1} \mathbf{D}$ $\frac{1}{1} \mathbf{D}$ $\frac{1}{1} \mathbf{S}$ $\frac{1}{1} \mathbf{C}$ $\frac{1}$	Image: Condition of the second se	DFT points PFT points Pay of BPF ilter length PFE coding del Direction(SD coding del Direction(SD e : Speech, RT on Stimulus 1 Original (-15°) Original (0°) Original (0°)	16384 10ms, 20m 80ms, 160m 7200 Correspon Stimulus 2 0riginal (-15°) 0riginal (0°) 0riginal (15°) Coding(0°, De	32768 s, 40ms, as, 320ms 14400 nd to nd to Delay=10ms) elay=10ms)
npulse Response $\{g_{ij}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ iagonal element of D ampling frequency: 1 iagonal element of D ampling frequency: 1 ONS onts ind Quality(SQ) purce : Piano, RT=1.2 ondition Stimulus 1 ontrol Original atial Impression(SI) ource : Speech & Pian ondition Stimulus 1 ource : Speech & Pian	$f unction fvide (5×24) H = G^{-1} Inverse TranFunction Mata(24×5): DFT of FIR band-pa2kHz, Bandwidth: 50Stimulus 2OriginalCoding (Delay=10ms)no, Azimuth Angle=0cStimulus 21$	Trials fix G fix H fix H fix H fix H	Image: Condition of the second se	DFT points PFT points elay of BPF ilter length elay of BPF e coding del Direction(SD e : Speech, RT on Stimulus 1 0riginal (-15°) 0riginal (0°) 0riginal (15°) ion Original (15°)	16384 10ms, 20m 80ms, 160m 7200 Correspon Stimulus 2 0riginal (-15°) Original (-15°) 0riginal (0°) 0riginal (15°) Coding(0°, De Coding(0°, De	32768 s, 40ms, as, 320ms 14400 nd to nd to Delay=10ms) Delay=10ms) Delay=10ms)
npulse Response $\{g_{ij}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ iagonal element of D ampling frequency: 1 Ons ons ons ond Quality(SQ) ource : Piano, RT=1.2 ondition Stimulus 1 ontrol Original attial Impression(SI) ource : Speech & Piant ondition Stimulus 1 ondition Stimulus 1 ource : Speech & Piant ondition Stimulus 1 ource : Speech & Piant	$f unction tviation (5 \times 24)$ $f unction Mathematical (5 \times 24)$ $f uncerse Tran Function Mathematical (24 \times 5)$ $f unction Mathematical (24 \times$	$\frac{1}{1} \mathbf{C}$ $\frac{1}{1} \mathbf{D}$ $\frac{1}$	Image: Condition of the second se	DFT points PFT points Play of BPF ilter length Play of BPF e coding del Direction(SD e coding del Direction(SD e coding del Stimulus 1 0 riginal (-15°) Original (0°) Original (15°) ion Original (15°)	16384 10ms, 20m 80ms, 160m 7200 Correspon Stimulus 2 0riginal (-15°) 0riginal (-15°) 0riginal (0°) 0riginal (0°) 0riginal (15°) Coding(-15°, 1 Coding(0°, De	32768 s, 40ms, as, 320ms 14400 nd to nd to Delay=10ms) elay=10ms) elay=10ms)
npulse Response $\{g_{ij}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ iagonal element of D ampling frequency: 1 Ons ons ons ont variation Stimulus 1 ontrol Original ontial Impression(SI) ource : Speech & Pian ondition Stimulus 1 ondition Stimulus 1 ondition Stimulus 1 ondition Stimulus 1 ontrol Original (0.6sec) Original (1.2sec)	Prediction function (5×24) $H = G^{-1}$ Inverse Tran Function Matrix (24×5) : DFT of FIR band-particular 2kHz, Bandwidth: 50 Stimulus 2 Original Coding (Delay=10ms) no, Azimuth Angle=0 ^c Stimulus 2 Toriginal (0.6sec) Original (0.6sec) Original (0.6sec) Original (0.6sec) Coding (0 (case Delay = 10))	Trials $\frac{1}{1}$ C $\frac{1}{1}$	Image: Condition of the second se	DFT points PFT points elay of BPF ilter length elay of BPF e coding del Direction(SD e : Speech, RT on Stimulus 1 0riginal (-15°) 0riginal (0°) 0riginal (15°) ion Original (15°) ion Original (15°)	16384 10ms, 20m 80ms, 160m 7200 Correspones Correspones Stimulus 2 Original (-15°) Original (15°) Original (15°) Coding(0°, Determines) Coding(15°, Determines)	32768 s, 40ms, as, 320ms 14400 nd to nd to Delay=10ms) elay=10ms) elay=10ms)
npulse Response $\{g_{ij}(n)\}$ Image: Conservent of the servent o	f unction interval (5×24) H = G Inverse Tran Function Mata (24×5) : DFT of FIR band-pa 2kHz, Bandwidth: 50 Stimulus 2 Original Coding (Delay=10ms) no, Azimuth Angle=0c Stimulus 2 Toriginal (0.6sec) Original (1.2sec) Coding(0.6sec, Delay=10ms) Coding(1.2sec, Delay=10ms)	Trials $\frac{1}{1}$ $\frac{1}{1}$ $\frac{1}{1$	Image: Condition of the second se	DFT points elay of BPF ilter length e coding del birection(SD e : Speech, RT on Stimulus 1 0riginal (-15°) 0riginal (0°) 0riginal (15°) ion Original (15°) ion Original (15°)	16384 10ms, 20m 80ms, 160m 7200 Correspon ay Correspon 5 6 5 5 5 5 5 5 5 5 10 10 10 10 10 10 10 10 10 10	32768 s, 40ms, as, 320ms 14400 nd to nd to Delay=10ms) Delay=10ms) Delay=10ms)
npulse Response $\{g_{ij}(n)\}$ IR Inverse Filter $\{h_{ji}(n)\}$ Iagonal element of D ampling frequency: 1 Ons ons ond Quality(SQ) purce : Piano, RT=1.2 purce : Piano, RT=1.2 purce : Piano, RT=1.2 purce : Piano, RT=1.2 purce : Speech & Pian ondition Stimulus 1 purce : Speech & Pian ontrol Original (0.6sec) Original (1.2sec) O	(5×24) $H = G$ Inverse Tran Function Mata (24×5) : DFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : DFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : OFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : OFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : OFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : OFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : OFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : OFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : OFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : OFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : OFT of FIR band-pa 2kHz, Bandwidth: 50 (24×5) : OFT of FIR band-pa (24×5) : OFT of	Trials $\frac{1}{1}$ $\frac{1}{1}$ $\frac{1}{1$	Image: Condition of the sector of	DFT points PFT points PFT points Pay of BPF a coding def PFT Prection(SD a Stimulus 1 Original (-15°) Original (0°) Original (15°) ion Original (15°) Original (0°) Original (15°)	16384 10ms, 20m 80ms, 160m 7200 Correspon Stimulus 2 5=0.6sec Stimulus 2 Original (-15°) Original (0°) Original (15°) Coding(-15°, 1 Coding(0°, Det Coding(15°, D	32768 s, 40ms, as, 320ms 14400 nd to nd to
mpulse Response $\{g_{ij}(n)\}$ FIR Inverse Filter $\{h_{ji}(n)\}$ Piagonal element of D Sampling frequency: 1 ions und Quality(SQ) ource : Piano, RT=1.2 condition Stimulus 1 condition ontrol Original valuation Original atial Impression(SI) ource : Speech & Pian Condition Stimulus 1 Condition Stimulus 1 ource : Speech & Pian Condition Original (0.6sec) Original (1.2sec) Original (1.2sec)	(5×24) $H = G$ Inverse Tran Function Matrix (24×5) $DFT ext{ of FIR band-pa} 2kHz, Bandwidth: 50 Stimulus 2 ext{ original} Coding (Delay=10ms) no, Azimuth Angle=0c Stimulus 2 ext{ original (0.6sec)} Original (1.2sec) Coding (0.6sec, Delay=10ms) Coding (1.2sec, Delay=10ms)$	$\frac{1}{1} \mathbf{C}$ $\frac{1}{1} \mathbf{D}$ $\frac{1}$	Image: Condition of the sector of	DFT points PFT points PFT points Pay of BPF autor length Pay of BPF autor description Prection(SD autor description Direction(SD autor description Autor description Priginal (-15°) Original (0°) Original (0°) Original (15°) Original (15°)	16384 10ms, 20m 80ms, 160m 7200 Corresponents Corresponents Stimulus 2 Original (-15°) Original (0°) Original (15°) Coding(-15°, 1 Coding(0°, De Coding(15°, D	32768 s, 40ms, as, 320ms 14400 nd to nd to



Control Evaluation

The influence of the so \Rightarrow The sound field perception is affected by the coding in the condition of coding delay 10ms \Rightarrow It needs to evaluate in the condition of the longer coding delay