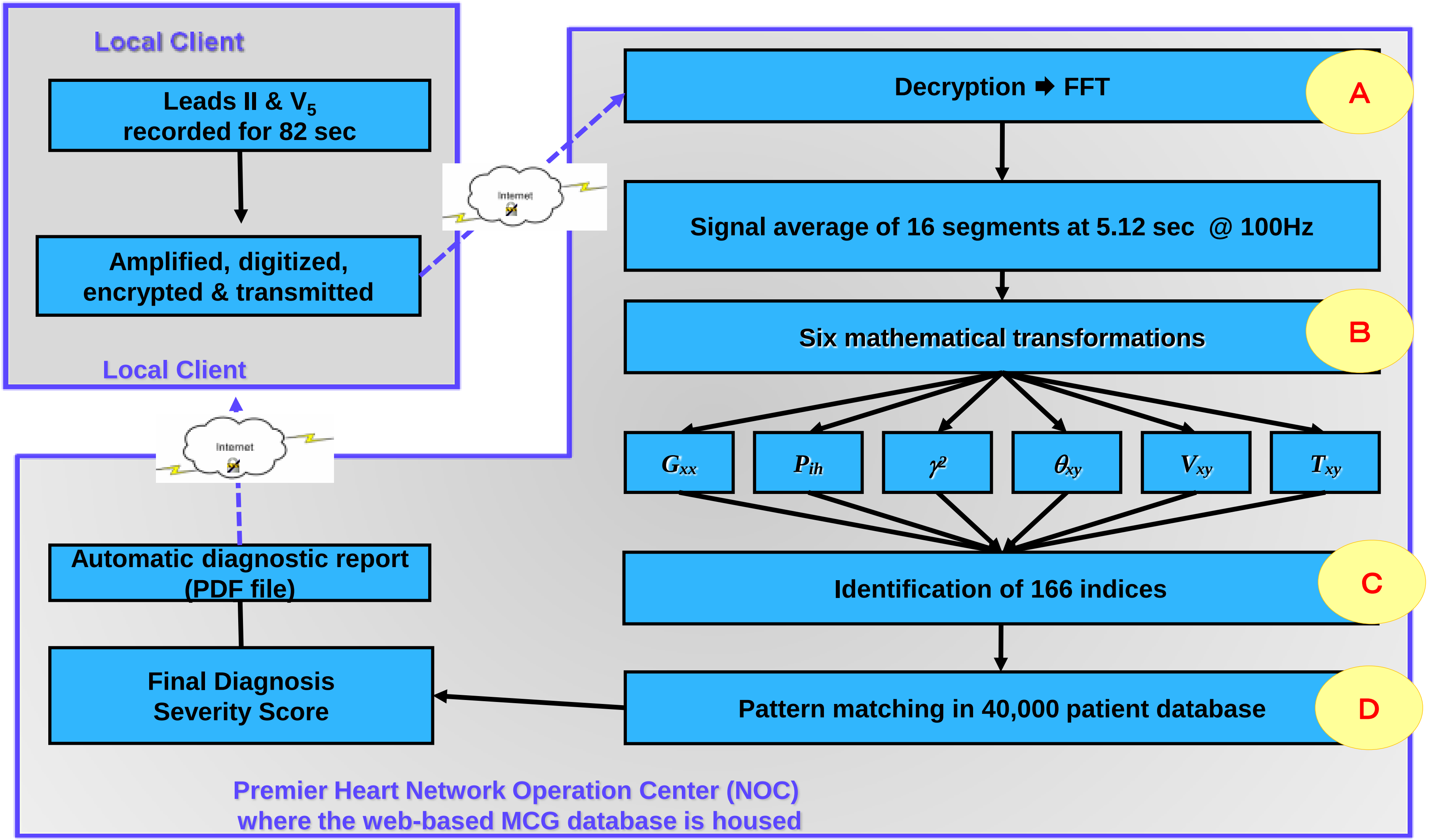
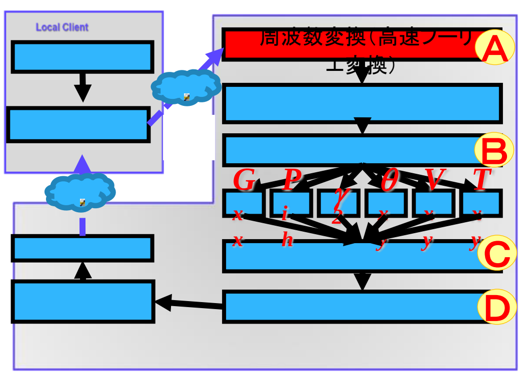
Behind MCG Analysis

MCG Analysis Flow over view



A

Frequency Analysis



Frequency Analysis Example 1 :

PREMIER HEART

A

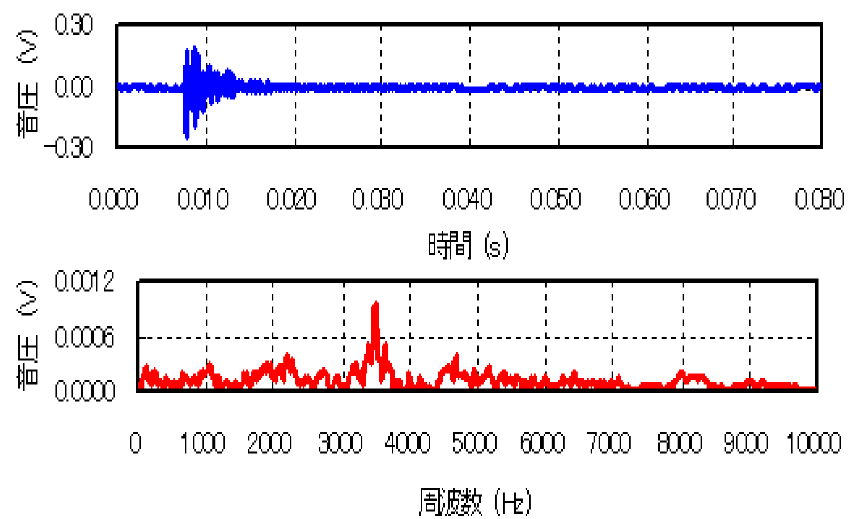
Hammering Test

An inspection method using generated sound. By striking an abject and analyzing generated sound system can recognize the difference in thickness , the quality of material , or the existence of defects.

Data Collection

FFT Analysis

Sound Wave

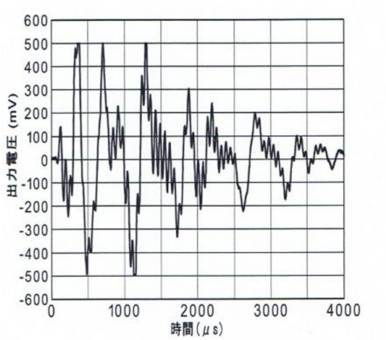


FFT analyzer

Frequency Distribution

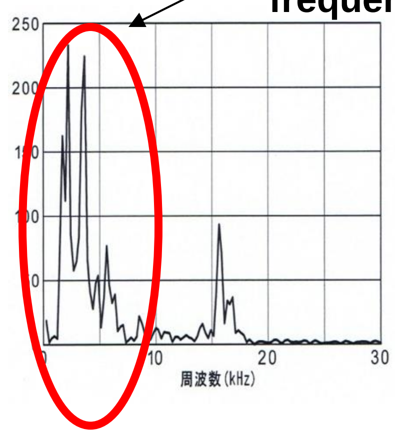
Sound Wave → **Frequency Distribution**

Hammering sound wave

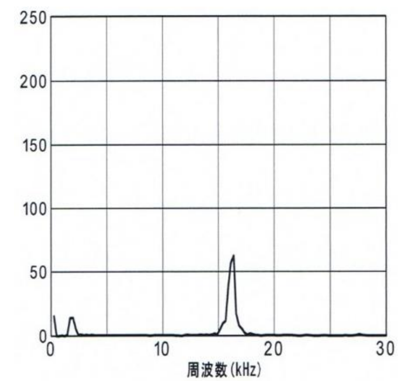


FFT Analysis

Index for abnormal frequency distribution



Abnormal empty space section

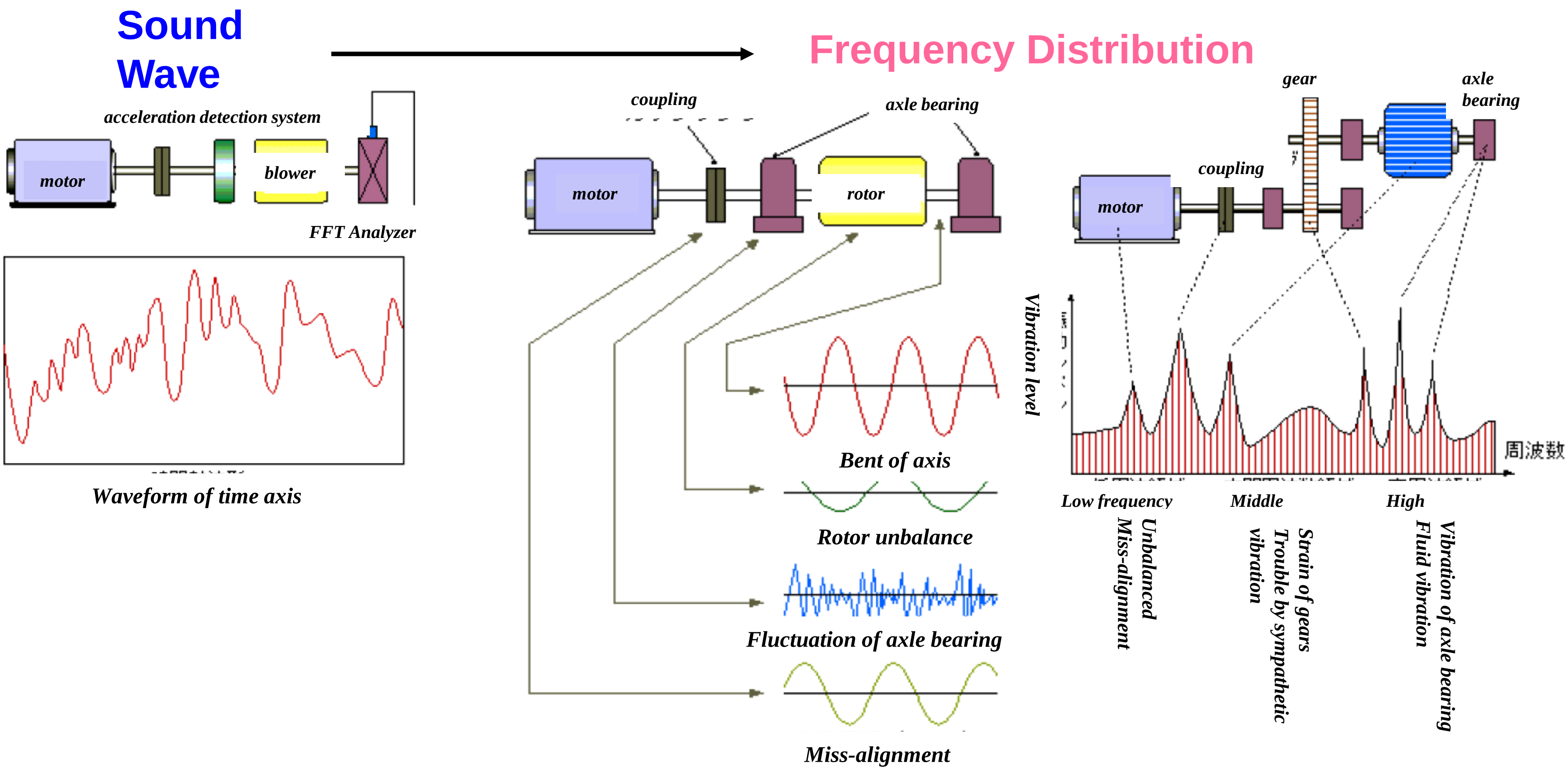


Normal section

Frequency Analysis Example 2： Engine Drive

A

By analyzing generated sound the system can recognize the difference in the quality of material , or the existence of defects of each system component parts



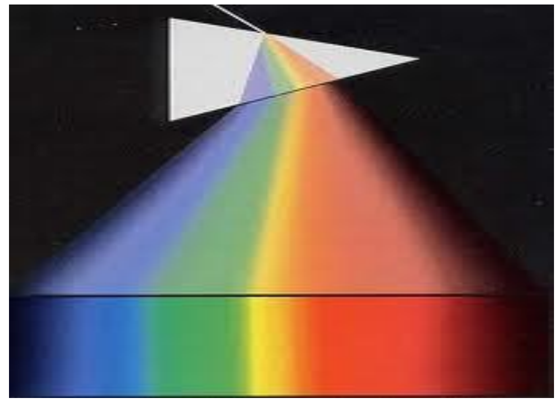
Frequency Analysis Example 3： A Prism

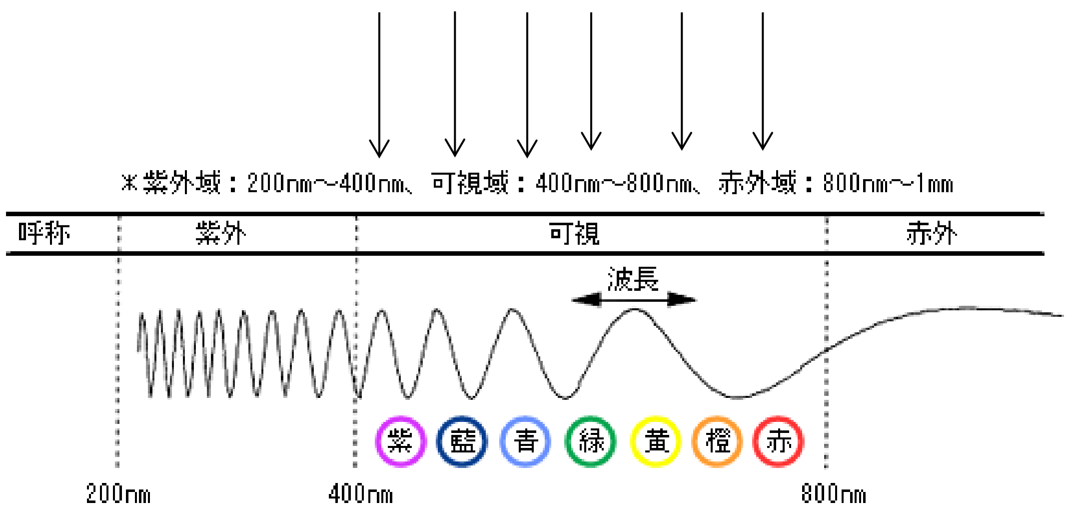
A

Break light up into its constituent spectral colors (Wave length)

White Light Wave

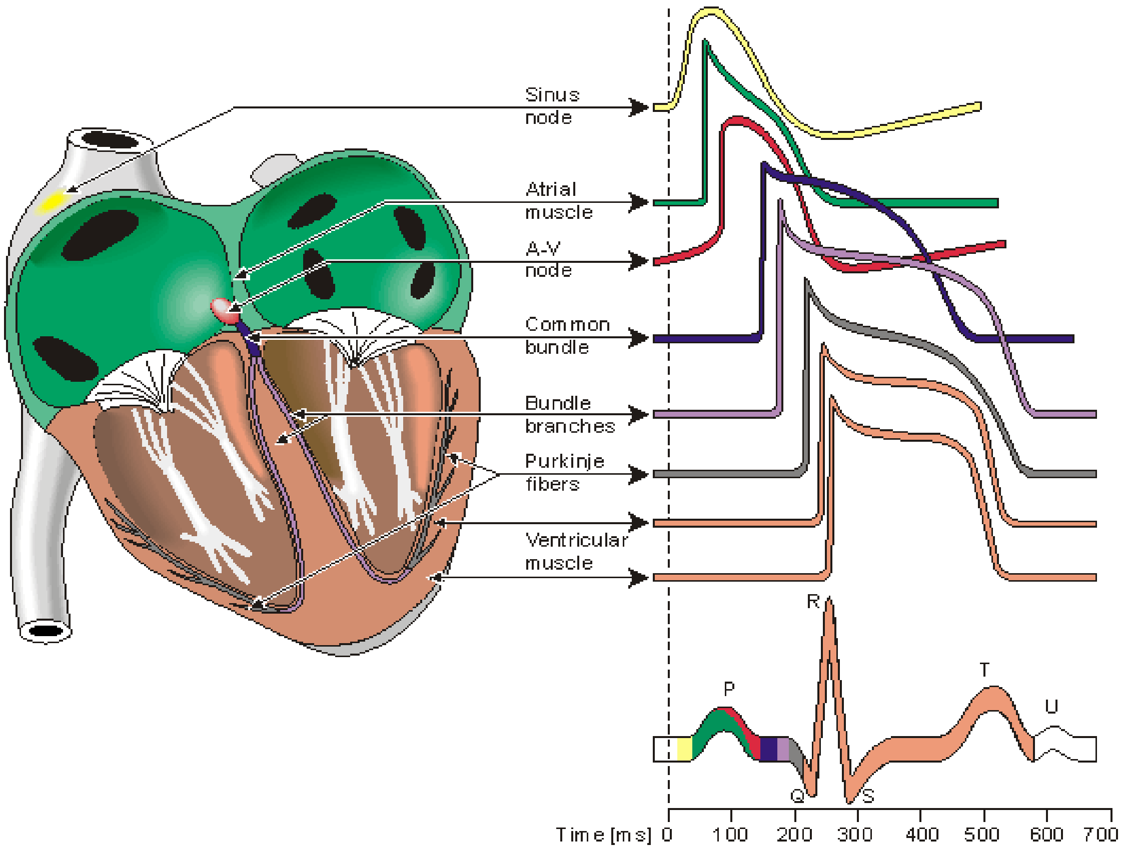
Wave length distribution





Apply FFT Analysis into ECG Wave

A



Apply FFT Analysis into Action Potential

A

Table 6.1. Electric events in the heart

Location in the heart	Event	Time [ms]	ECG-terminology	Conduction velocity [m/s]	Intrinsic frequency [1/min]
SA node	impulse generated	0		0.05	70-80
atrium, Right	depolarization *)	5	P	0.8-1.0	
Left	depolarization	85	P	0.8-1.0	
AV node	arrival of impulse	50	P-Q interval	0.02-0.05	
	departure of impulse	125			
bundle of His	activated	130		1.0-1.5	20-40
bundle branches	activated	145		1.0-1.5	
Purkinje fibers	activated	150		3.0-3.5	
endocardium					
Septum	depolarization	175	QRS	0.3 (axial) - 0.8 (transverse)	
Left ventricle	depolarization	190			
epicardium	depolarization	225			
Left ventricle	depolarization	250			
Right ventricle					
epicardium					
Left ventricle	repolarization	400	T	0.5	
Right ventricle	repolarization				
endocardium					
Left ventricle	repolarization	600			

*) Atrial repolarization occurs during the ventricular depolarization; therefore, it is not normally seen in the electrocardiogram.

Apply FFT Analysis into ECG Wave

A

ECG Wave form = sum of heart muscles electric out put (intrinsic frequency)

Electrical Potential Wave

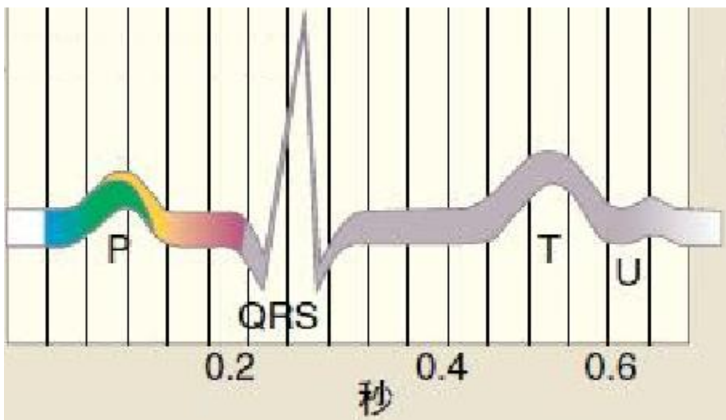
ECG

FFT

Frequency Distribution

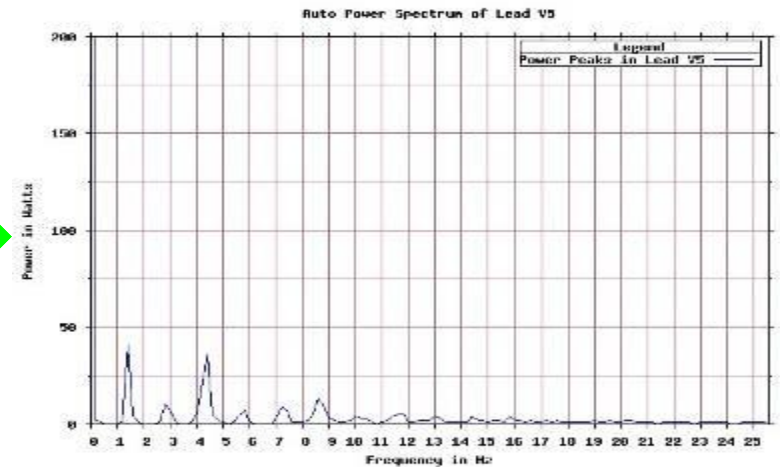
MCG

Y：mV



X：Time

Y：Power

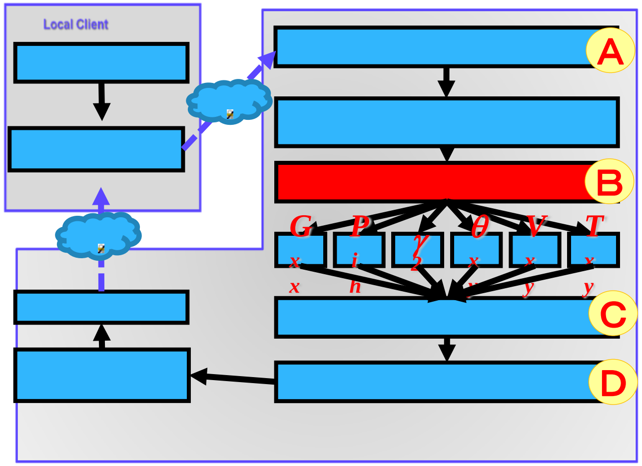


X：Frequency Hz

B

Six mathematical transformations

(Control Systems Engineering)



Confidential

MCG解析特徴 ① ***数式変換　周波数解析***

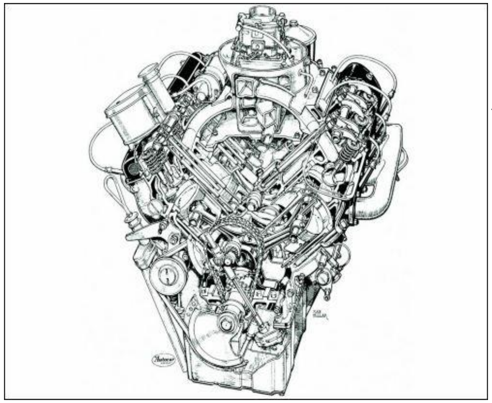
PREMIER HEART

B

1) Auto Power Spectrum	$Gxx = Sx(f) \times Sx(f)i$
2) Phase Angle Shift	$qxy = \tan^{-1} \frac{Txy(I)}{Txy(R)} = \tan^{-1} \frac{Gxy / Gxx(I)}{Gxy / Gxx(R)}$
3) Impulse Response	$Pih = F^{-1} Txy$
4) Cross Correlation	$Vxy = F^{-1} Gxy$
5) Coherence Function	$g^2 = \frac{Gxy^2}{(Gxx)(Gyy)}$
6) Transfer Function	$Txy = \frac{Gxy}{Gxx} \quad Txy = A, f$

Control Engineering

Control engineering is a type of engineering that applies control theory to various design systems. Control engineers work with numerous types of technology from household appliances to rockets in order to create control systems. Control engineering is based upon specific mathematical theories that allow engineers to effectively gather control feedback.



Apply Control Engineering to Human Heart

Confidential

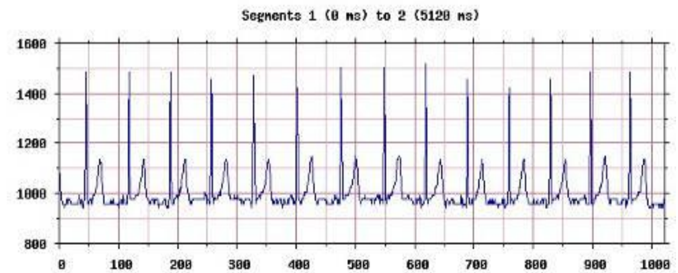
Mathematical Transformation

PREMIER HEART

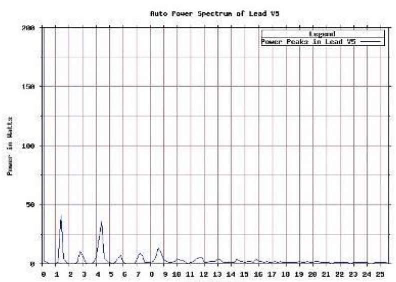
B

You can see a different world through mathematical transformations

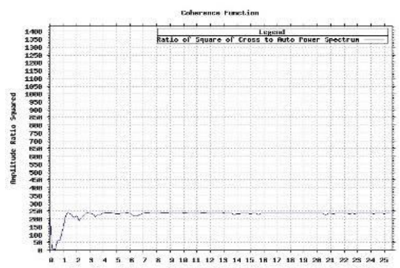
ECG Wave



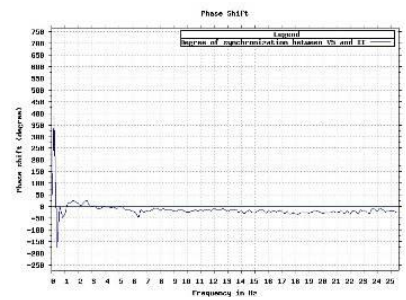
Mathematical Transformations



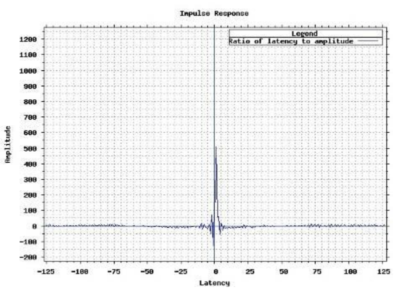
Auto Power Spectrum



Coherence Function



Phase Shift



Impulse Response

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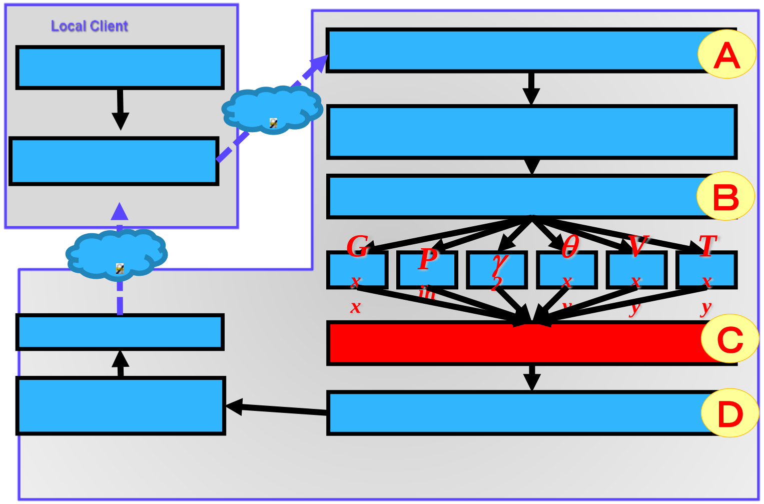
C

Identification of indices



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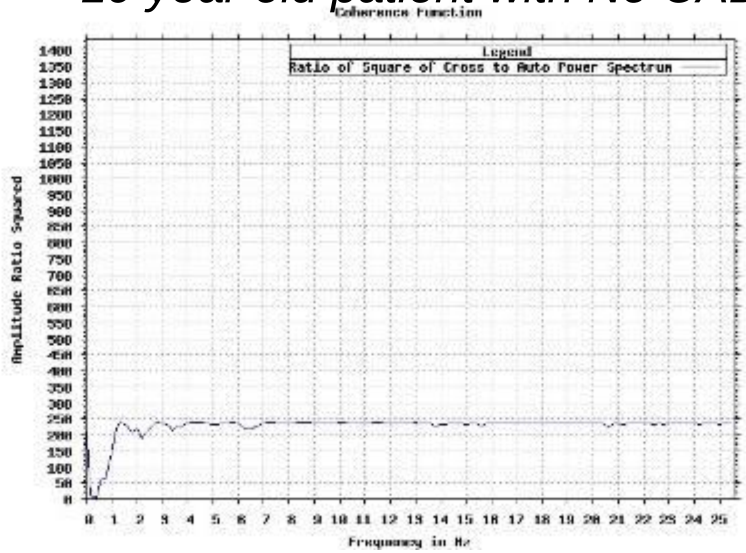
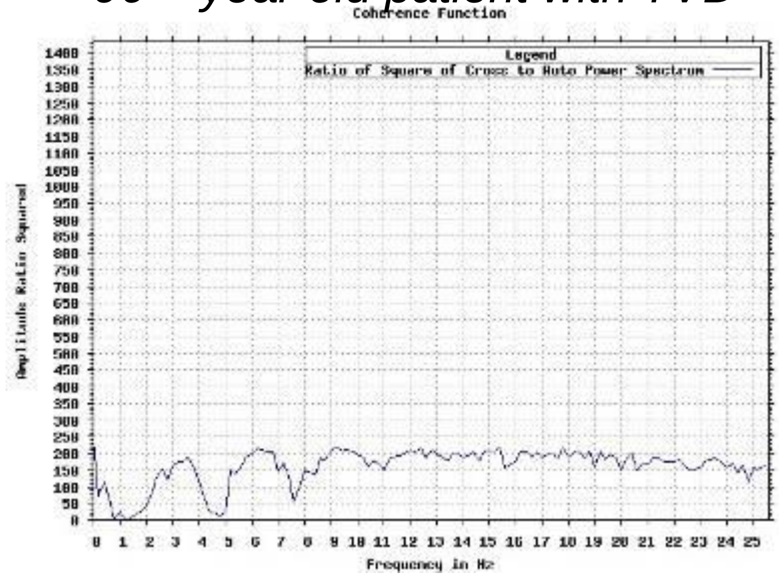
Identification of indices （**Normal vs Abnormal**）

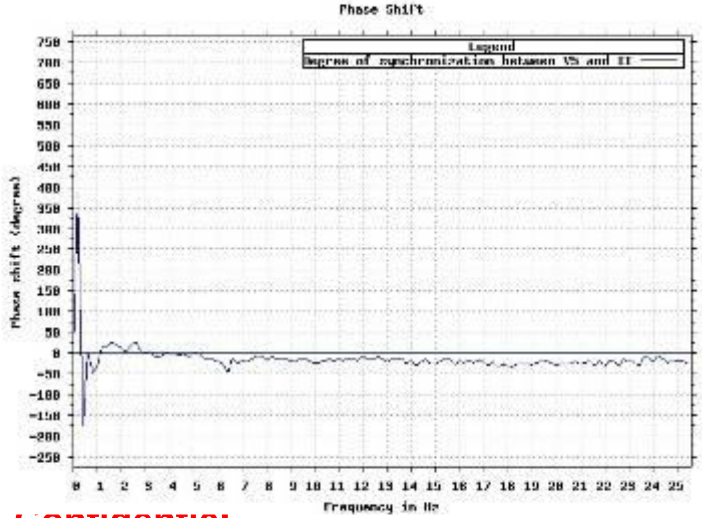
PREMIER HEART

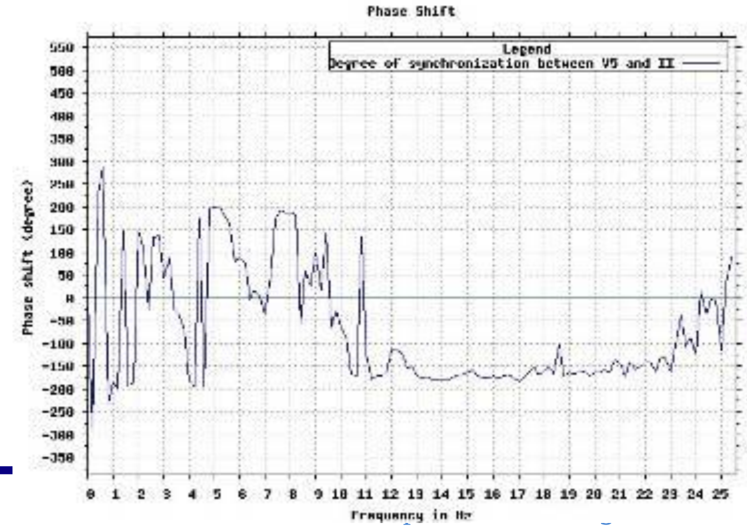
19 year old patient with No CAD



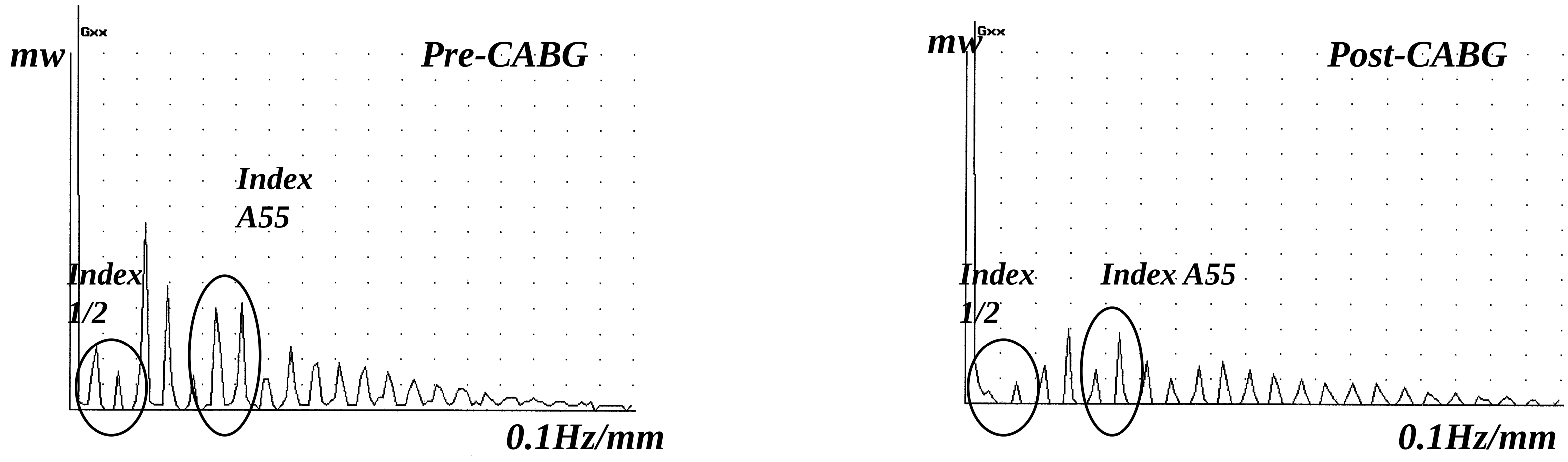
90 + year old patient with TVD







Power Spectrum of V5 lead



A55, indicated above, pre-surgically indicates chronic compensation for more than 12 months;

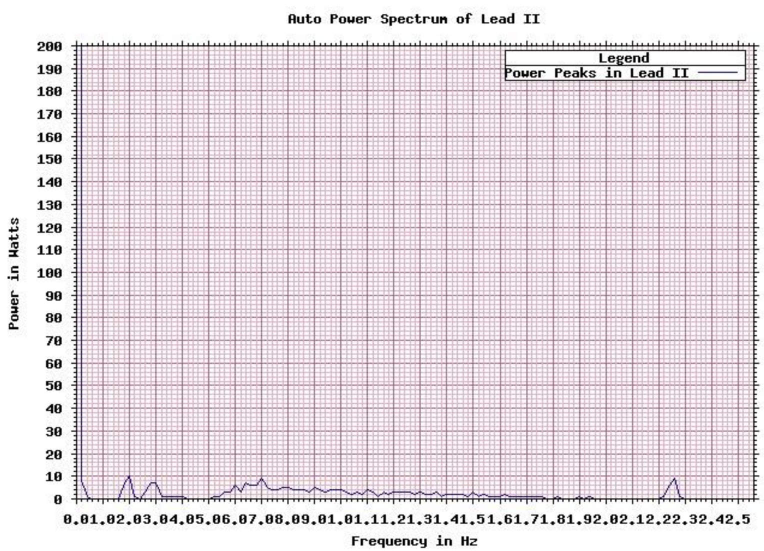
A55, shown here, post-surgically indicates the reduced amplitudes of the frequency peak;

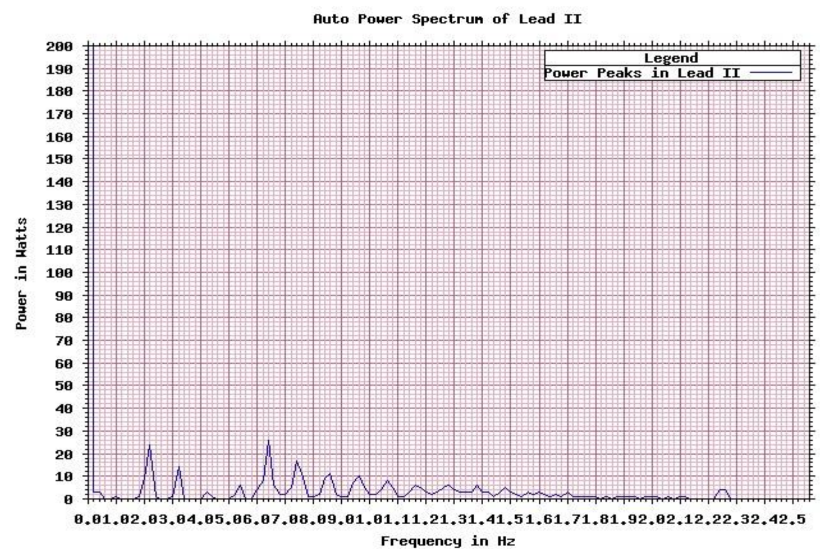
1/2, also highlighted, demonstrates the temporary reduction in power of the left ventricle as result of general anesthesia.

Pre and Post PCI/Stenting Example #1

PREMIER HEART

- **A Male Patient with Bi-Vessel Disease**
  - **This pair of power spectra belong to a male patient who was diagnosed with severe two vessel disease and Type II DM. He received PTCA/Double Stenting for two critical RCA stenosis with remaining RCX having a 40-50% lesion. Pre-intervention he had a MCG disease severity score of 8 with global ischemia. Following his intervention his MCG severity score decreased to 2.5 with mild global ischemia.**

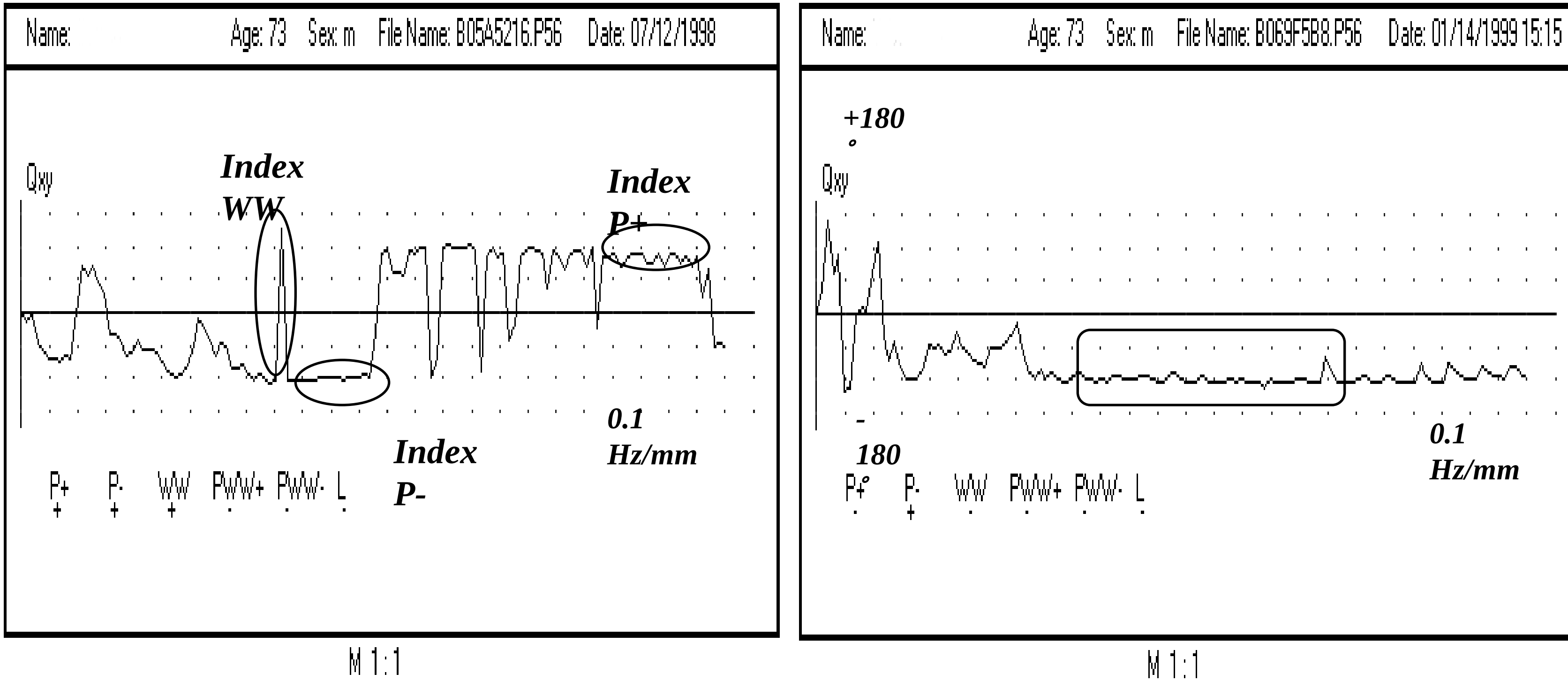




1/2	O	U1	U2	U3	U3xy	U4	N1	N3	S	SS	F	FF	A1	A2	A3	A4	A5	A55
+	-	+	+	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-

1/2	O	U1	U2	U3	U3xy	U4	N1	N3	S	SS	F	FF	A1	A2	A3	A4	A5	A55
+	-	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	+

Phase Angle Shift



P+: left-sided global asynchrony P- : right-sided global asynchrony;
ww: non-synchronization at a particular frequency.

These three indices may be caused by hibernation due to ischemia and/or infarct.

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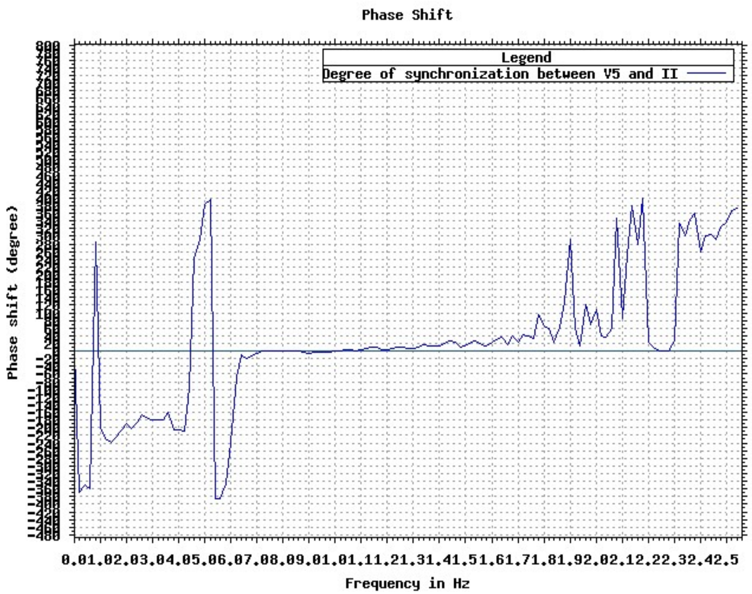
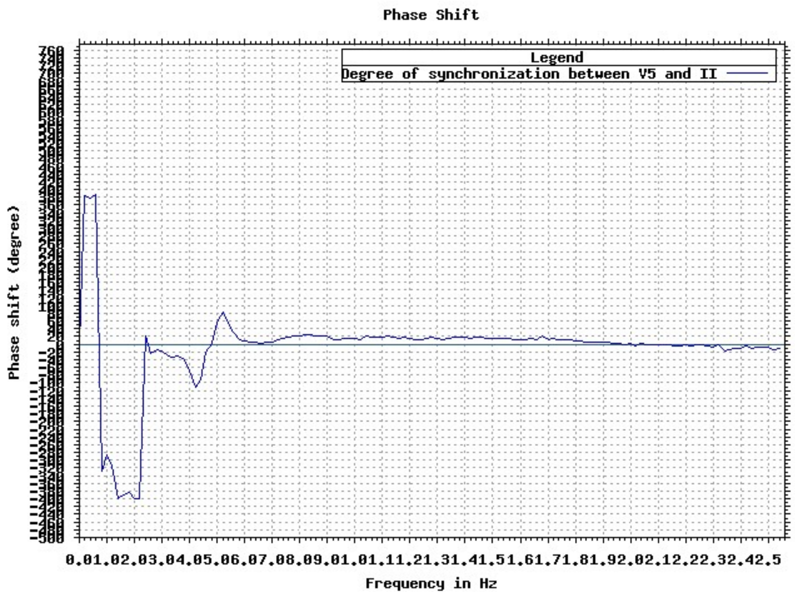
Pre and Post PCI/Stenting Example #1

- A Male Patient with Bi-Vessel Disease (continued)
  - This pair of phase shift functions belong to the same male patient who was diagnosed with two vessel disease. The differences in both the power spectra (previous page) and phase shift functions pre- and post-intervention are discernable and calculable by MCG.



P+	P-	WW	PWW+	PWW-	L
-	-	+	+	-	-



P+	P-	WW	PWW+	PWW-	L
-	-	-	-	-	-

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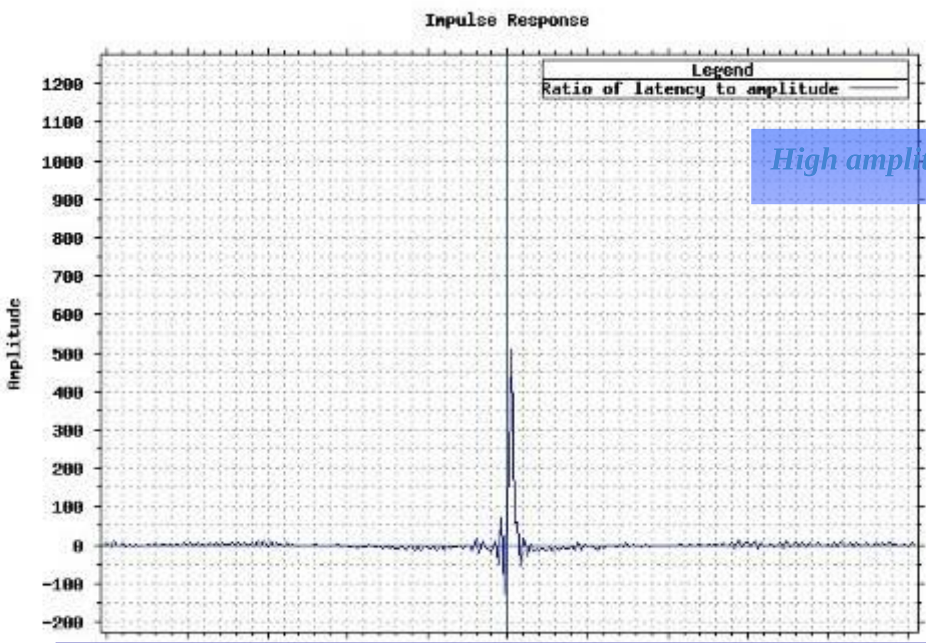
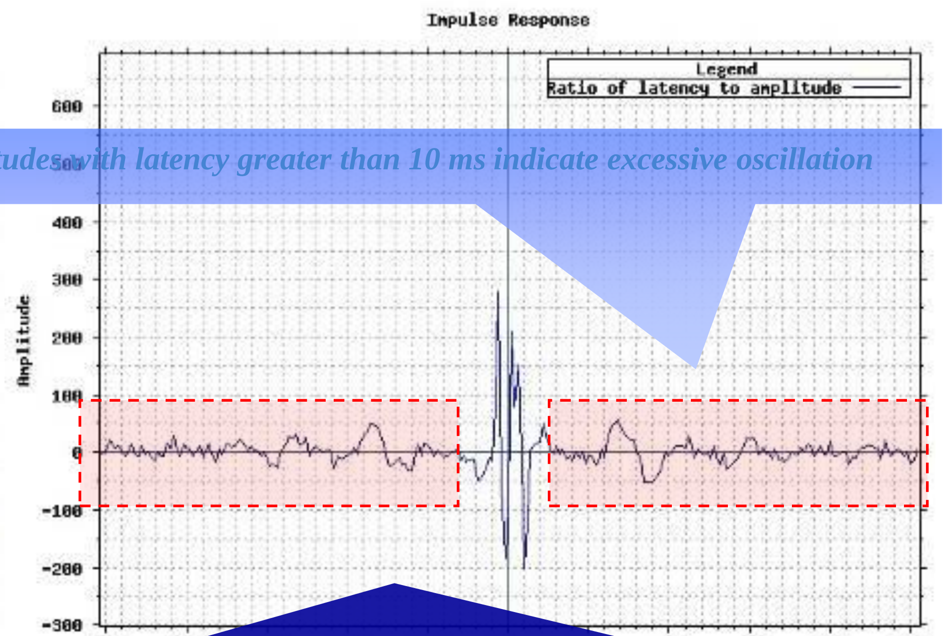
Impulse Response

19 y.o. (Female) with No CAD



97 y.o.(Male) patient with TVD

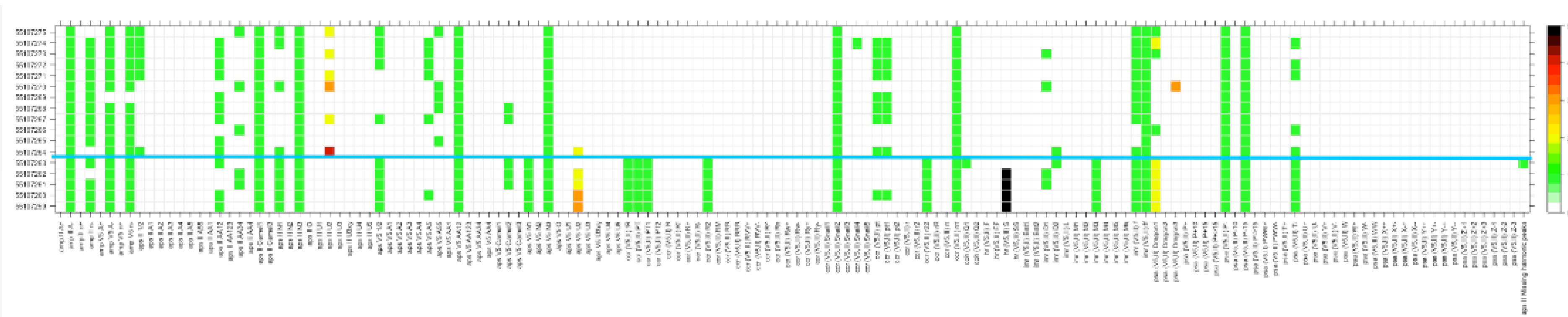


- *The impulse response function is used to measure the quality of the system.*
- *Impulse response data can be used to detect changes in the cardiac muscle and in blood flow, including ventricular remodeling, increases or decreases in myocardial compliance, conduction blockage or delays and potential arrhythmia.*
- *Distortion in the impulse response can indicate part of the cardiac cycle not visible in the conventional ECG signal including hidden arrhythmias*

166 MCG Indices

PREMIER HEART

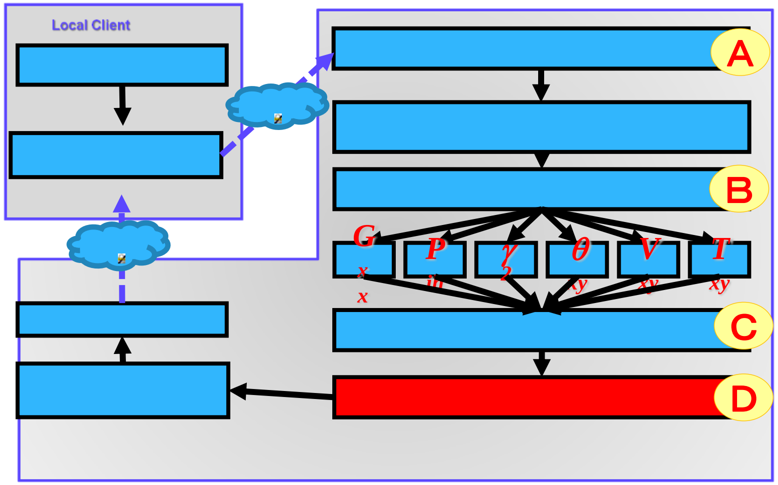
C



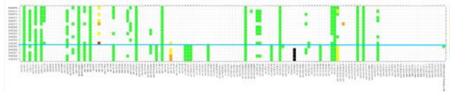
166

D

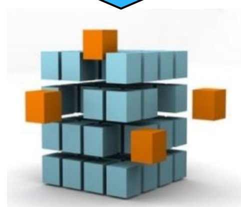
Pattern matching
(in 42,000 patient database)



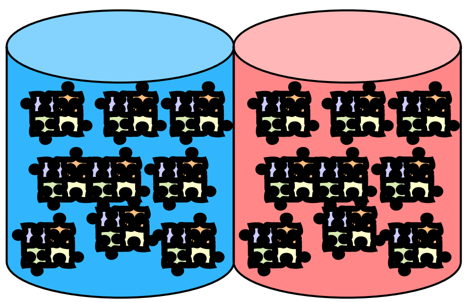
D



Identification of Patients 166 indices



Create Patient unique index pattern



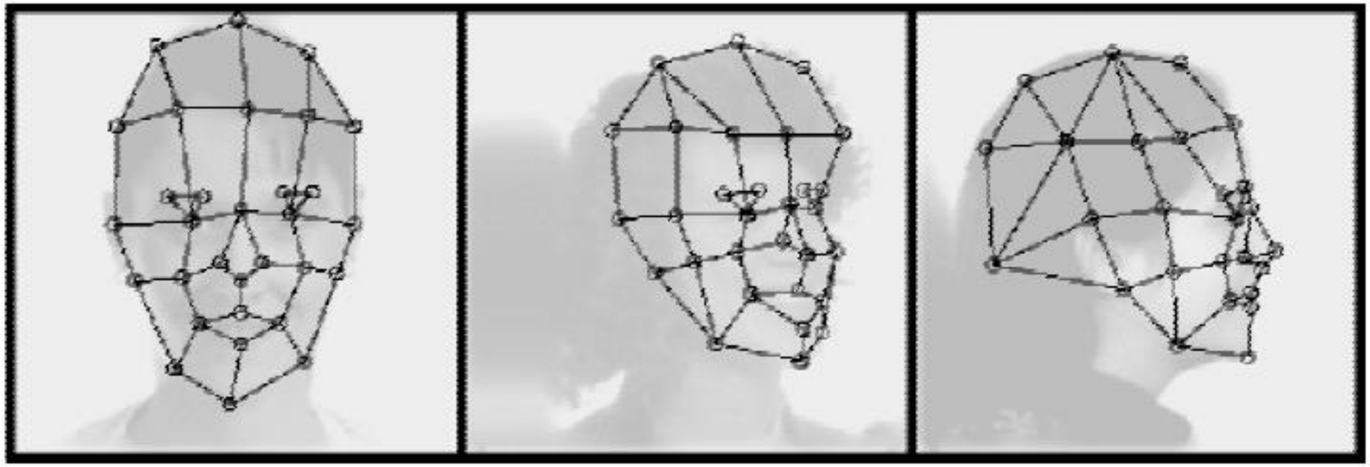
Database pattern matching

Normal Index Pattern ***Abnormal Index Pattern***

Pattern matching

D

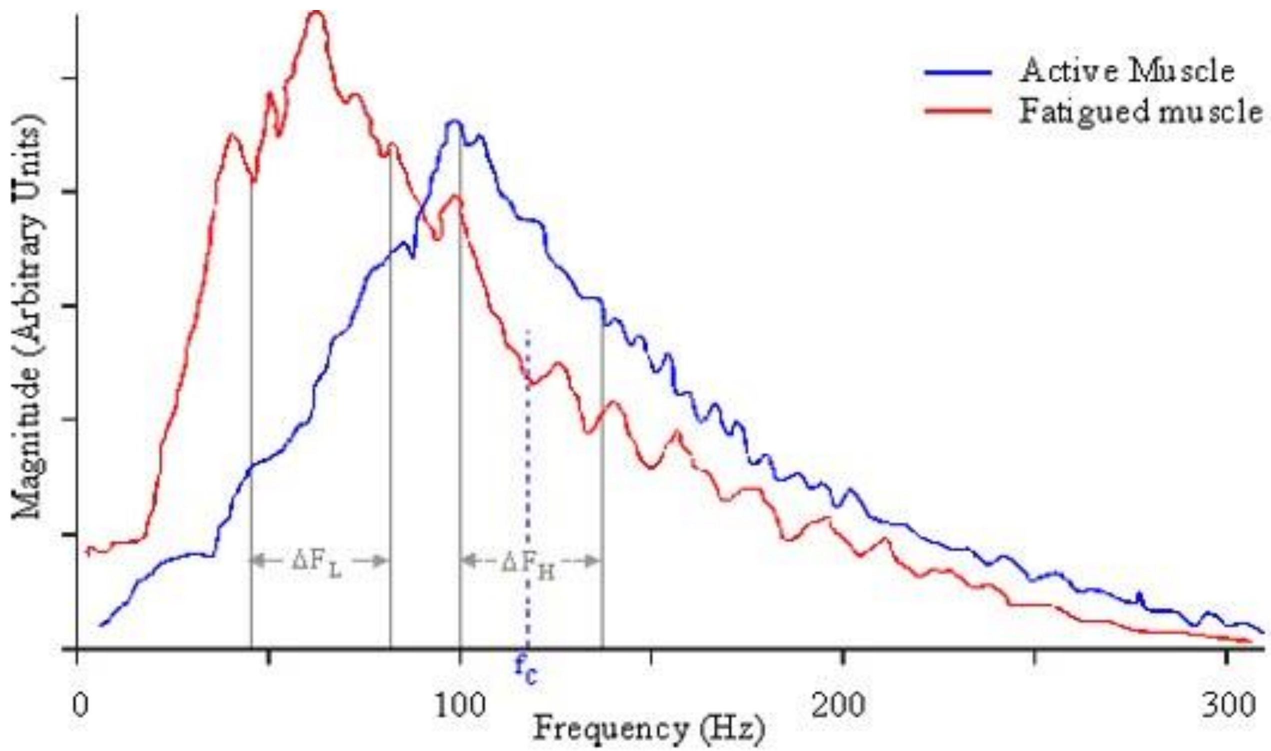
（Ex：Face recognition system）



（Appendix）

(Example) Electromyogram EMG

Difference in frequency of Active muscle and fatigued muscle.



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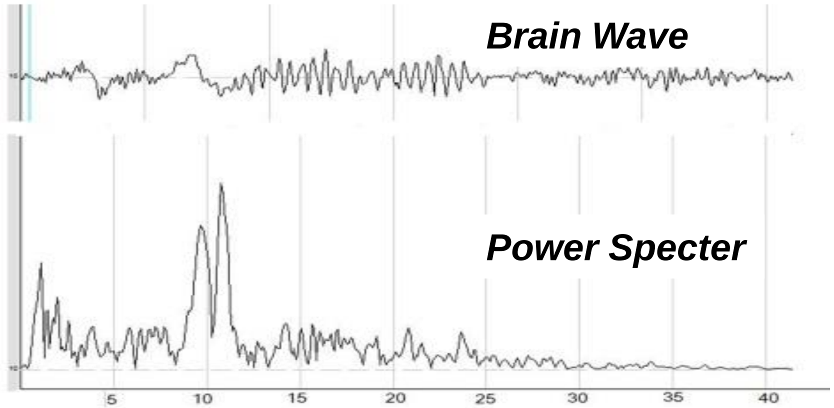
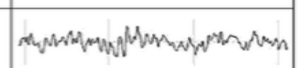
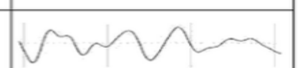
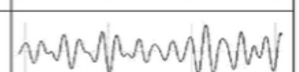
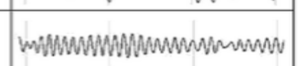
(Example) EEG　Power specter



Frequency Band Name	Frequency Bandwidth	State Associated with Bandwidth	Example of Filtered Bandwidth
Raw EEG	0–45 Hz	Awake	
Delta	0.5–3.5 Hz	Deep Sleep	
Theta	4–7.5 Hz	Drowsy	
Alpha	8–12 Hz	Relaxed	
Beta	13–35 Hz	Engaged