Spanish Club of Magnetism Oviedo

Development of G^2 Motion Control Sensor Using MI Sensor in Mobile Phones

Dr. Yoshinobu Honkura

Director of Aichi Steel Corporation

October 28th, 2005.

AICHI STEEL

AICHI STEEL CORPORATION

A Toyota Group Company

Aichi Steel Corporation is one of the world's largest suppliers of specialty steel and forged parts and electromagnetic components in the automotive industry.

COMPANY PROFILE

Established: March 8, 1940

Consolidated Annual sales: 1.56 billion USD
(fiscal year ending March2004)

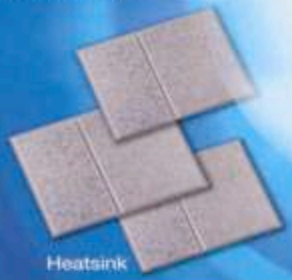
Employees: 2,400

One and Only Technology Products

Dental Magnetic Attachment
SA:80% (World No.1)

MAGFIT

G-Motion Sensor



Heatsink

MAGFINE Bonded Magnets

MAGFINE Motor

No.1 Share Products in the World

Forged Products
SA:14% (Domestic No.1)

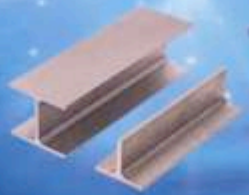
Forged Crankshafts

Driven Gears

CVT Pulley/Gears

Stainless Steel Products
SA:49%
(Domestic No.1)

Propeller Yokes



Angle bars of Stainless Steel

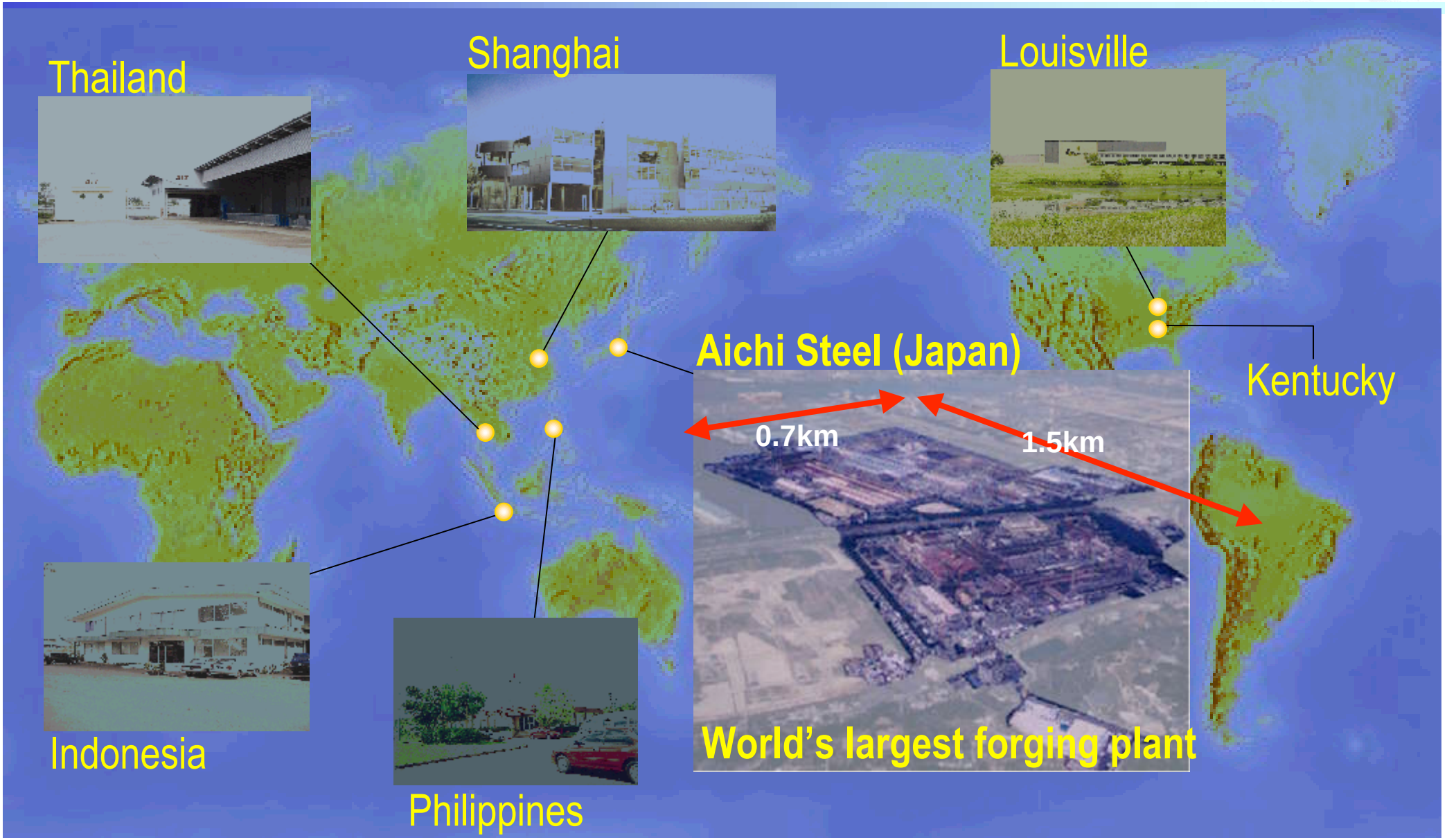
Recent News

Mr. Akiyoshi Morita
President of Aichi Steel Corporation

In the December 2005 issue of
Forbes Japan Magazine

Mr. Morita was ranked in the Top Ten
out of the100 Most Powerful CEOs
in Japan

Forging Plants of Aichi Steel Corporation



Magnet Division: MAGFINE and MAGFINE motor

MAGFINE is the World's Strongest Bonded Magnet developed by Aichi Steel Corporation.
MAGFINE motor is 50% lighter in weight than a conventional DC motor

From October 2005, Toyota adopted the MAGFINE motor
MAGFINE motor should contribute to a 20kg weight reduction in one car and will expand to global automobile market..

Conventional DC motor

MAGFINE motor

Ferrite sintered magnet（4MGOe）
Motor weight = 460g

MAGFINE motor (25MGOe)
Motor weight = 230g

Automobile Market Overview:

30 pieces / car
Total: 2 billion pieces / year

A typical luxury car has more than 100 pieces

Sensor Division:
Electronic compass and G^2 Motion sensor using GMI sensor

●LG Electronics

Electronic Compass

Mecca Indicator Phone

Launched in March 2004

Mecca Indicator Phone
Model: LG-F7100

AMI201
(2D sensor)
3.1×3.4×0.8mm

●Vodafone

G^2 Motion Sensor

Game Mobile Phone

Launched in February 2005

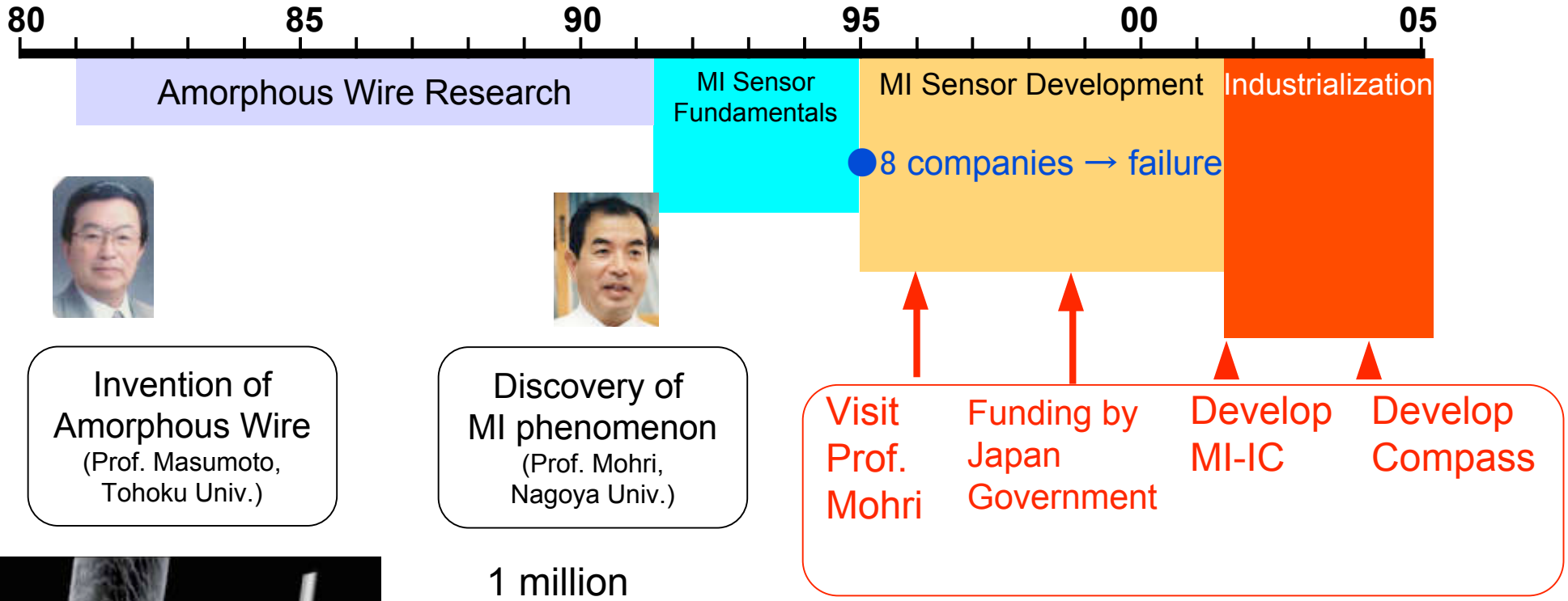
Model: V603SH
(Made by Sharp)
For Japan market

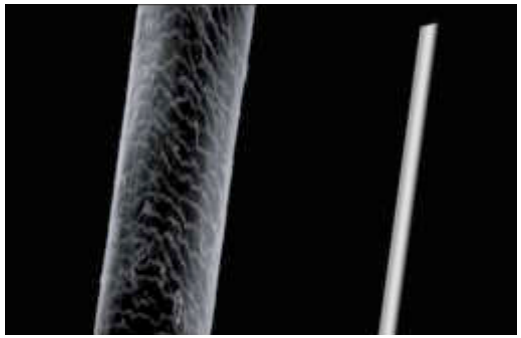
AMI501
(5D sensor)
5.5×5.5×1.5mm

Outline

1. **What is MI Sensor ?**
   - **Introduction of MI Sensor Base Technology**
2. **Electronic Compass using MI Sensor**
3. **G2 Motion Control Sensor using MI Sensor**
4. **Application of G2 motion sensor**
5. **Conclusion**

MI Sensor Development History





human hair 150μm

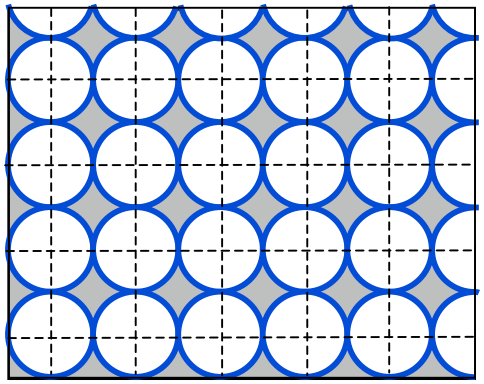
amorphous wire 20μm

1 million times sensitivity

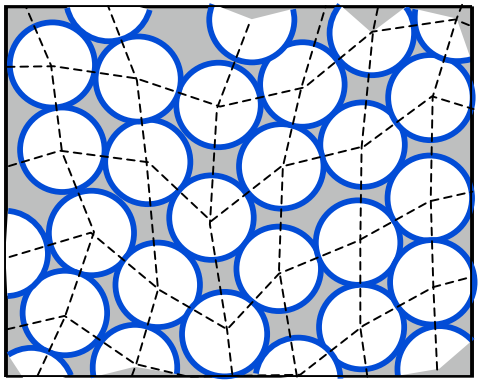
Aichi Steel Corporation

MI Sensor Principle

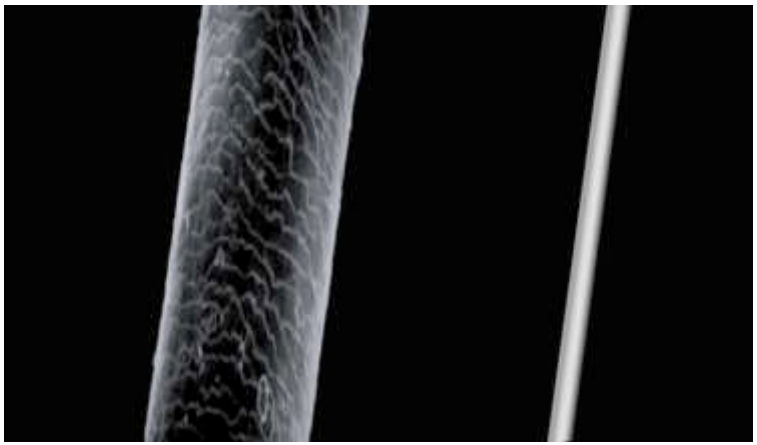
Key Material: Amorphous Metal Wire with ideal softmagnetic propreties



Crystal



Amorphous

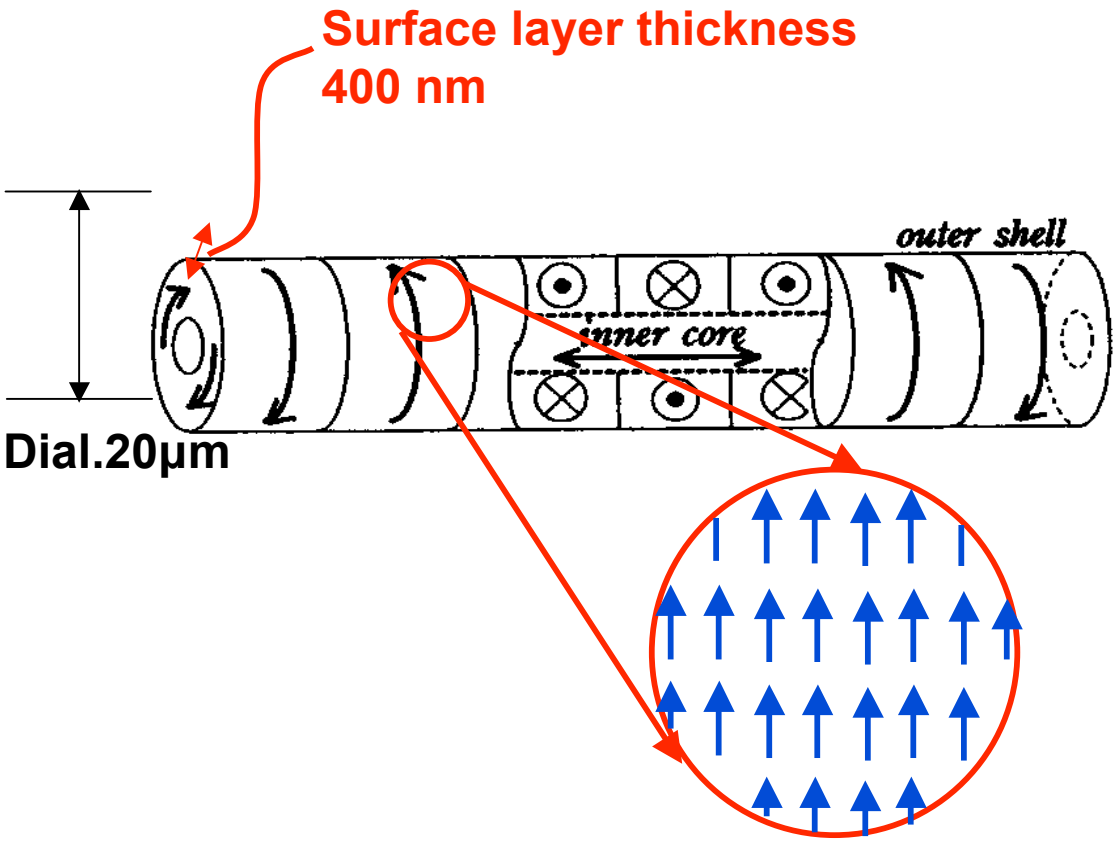


Human hair 150μm

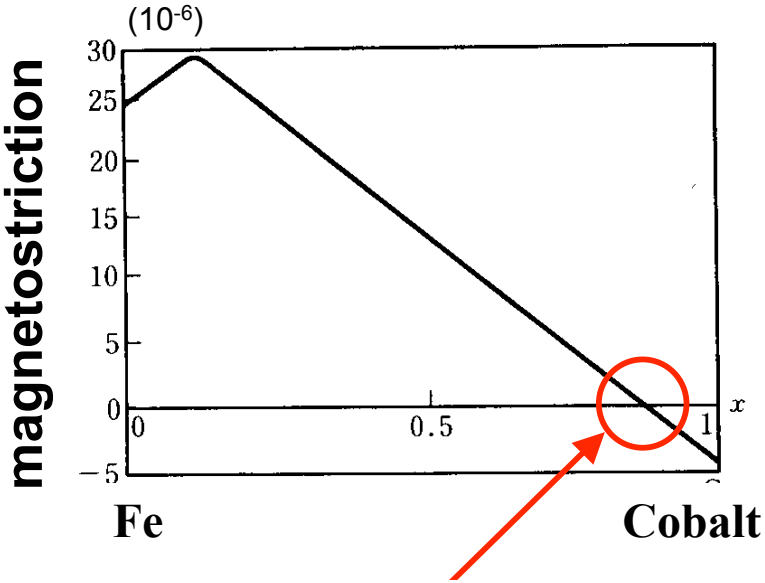
Amorphous wire 20μm

Amorphous is non-crystallized state in a solid substance

Magnetic Domain Structure of Amorphous Wire

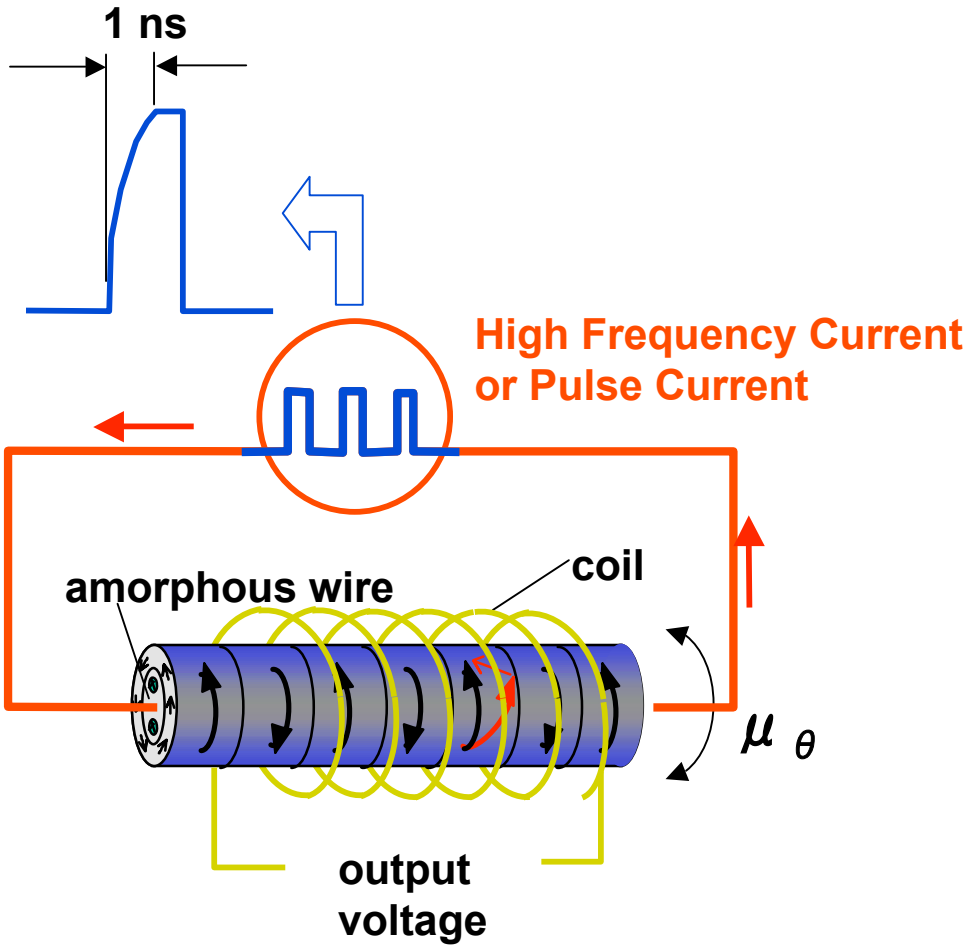


Electronic Spin Alignment

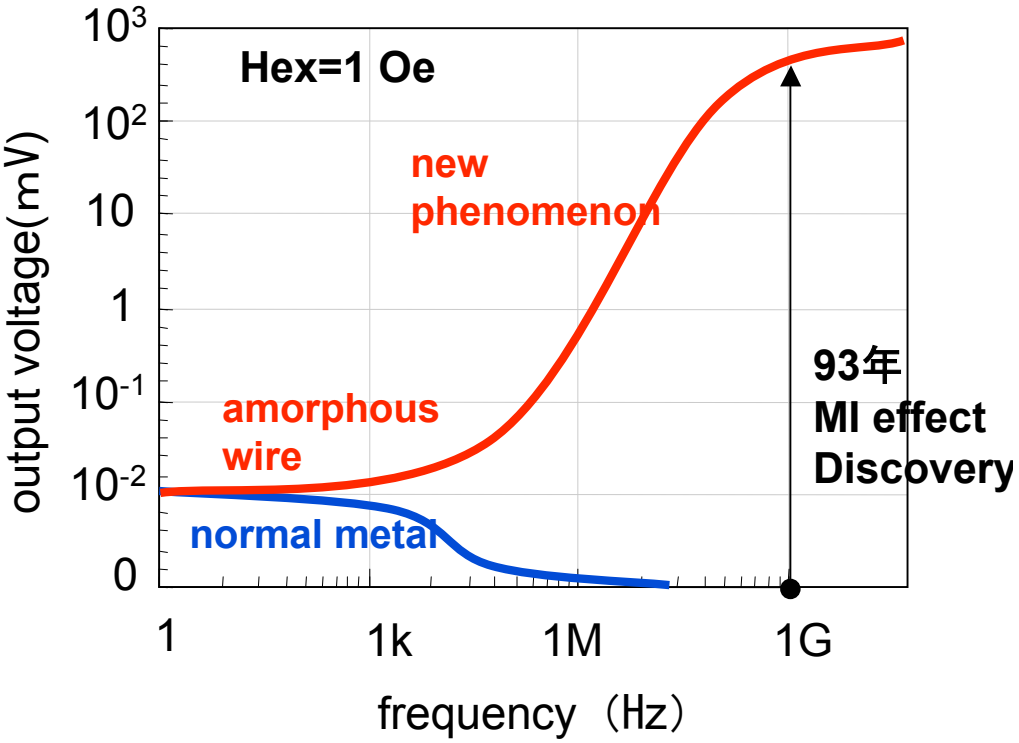


Magnetostrictive 0（95Co-5Fe）

Discovery of MI Principle in 1993

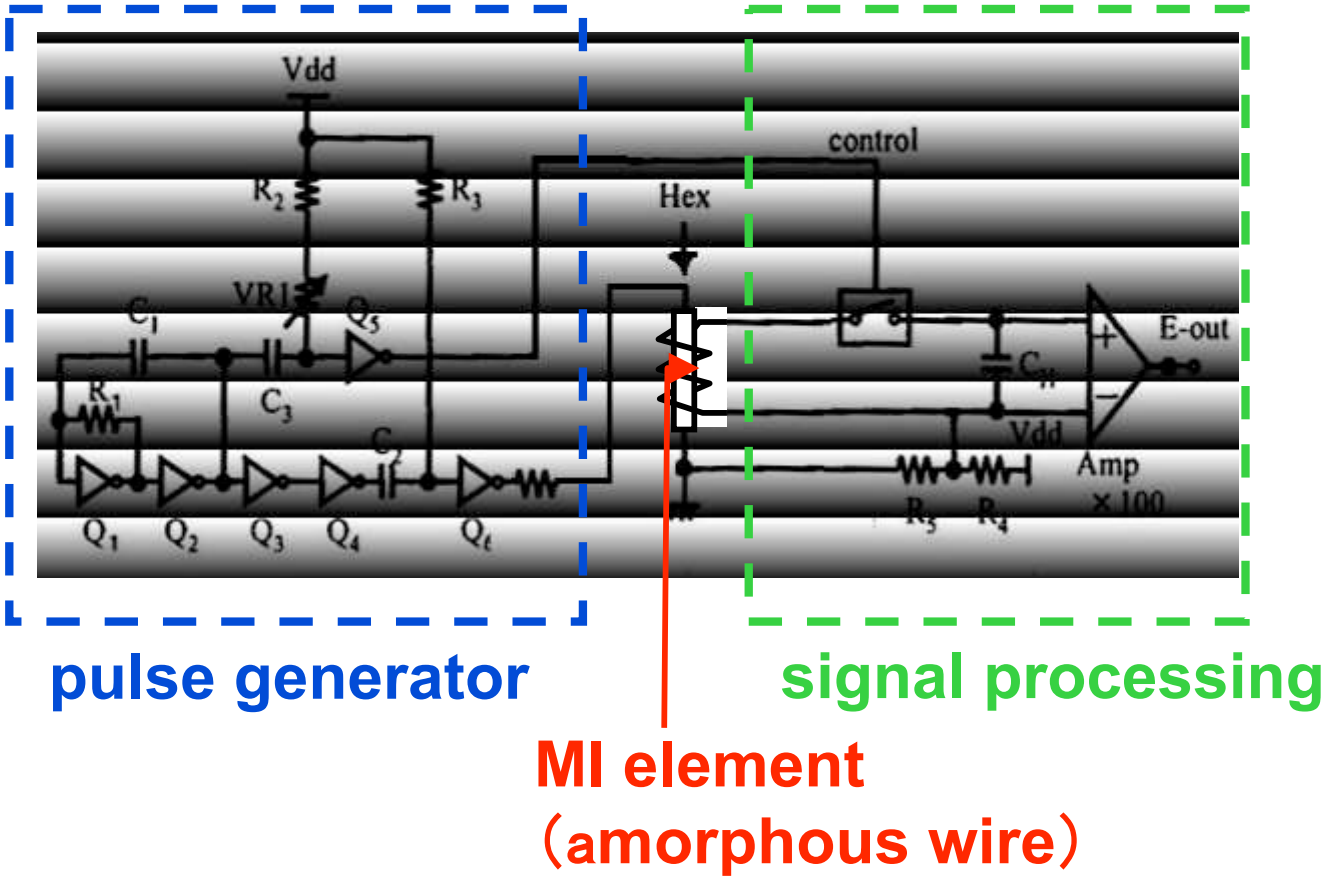


$$V = \frac{a}{2\sqrt{2\rho}} R_{dc} \sqrt{\omega \mu_\theta (H_{ex})}$$



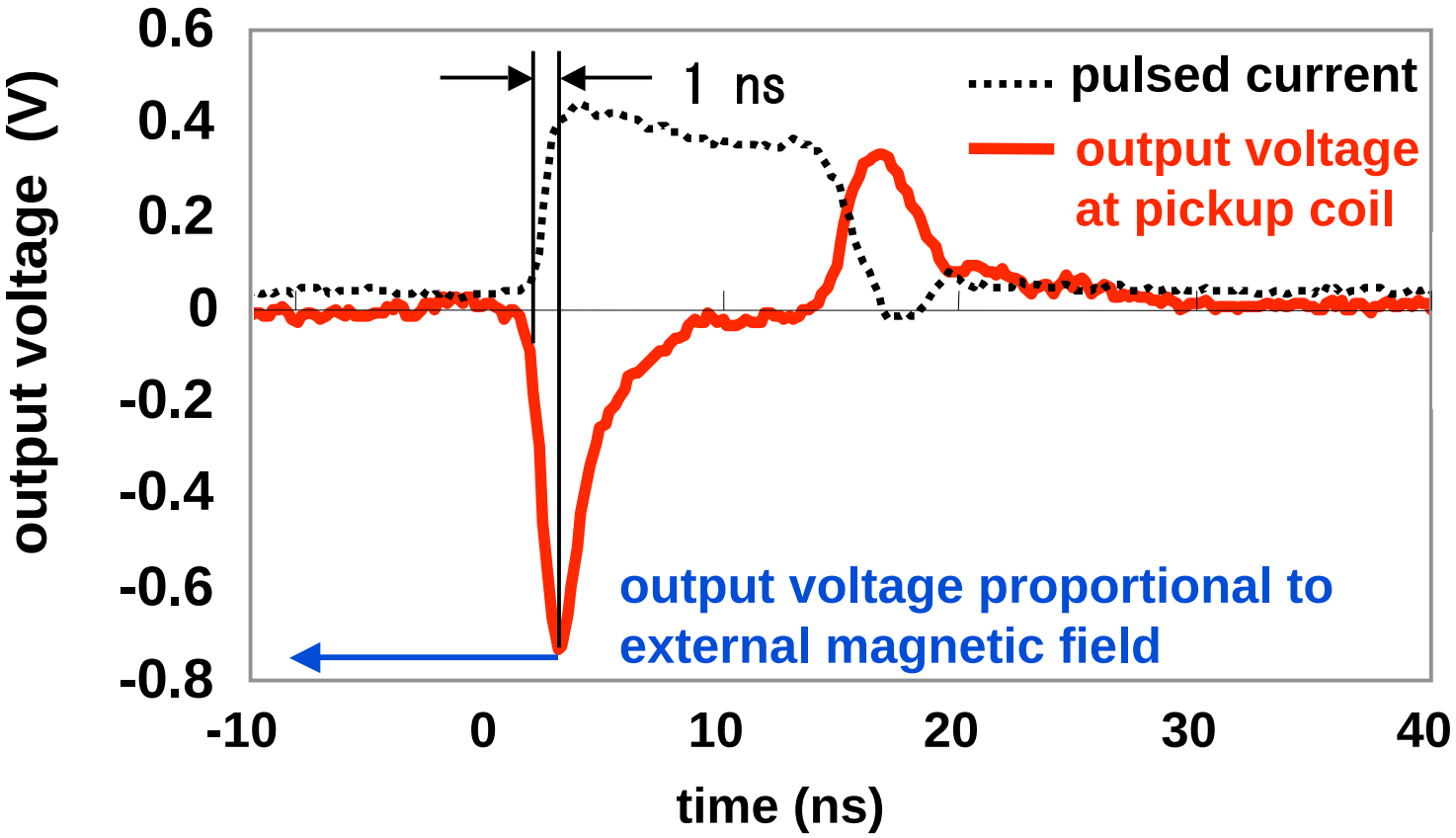
Pulse Current Drive Circuitry

- Simplified signal processing

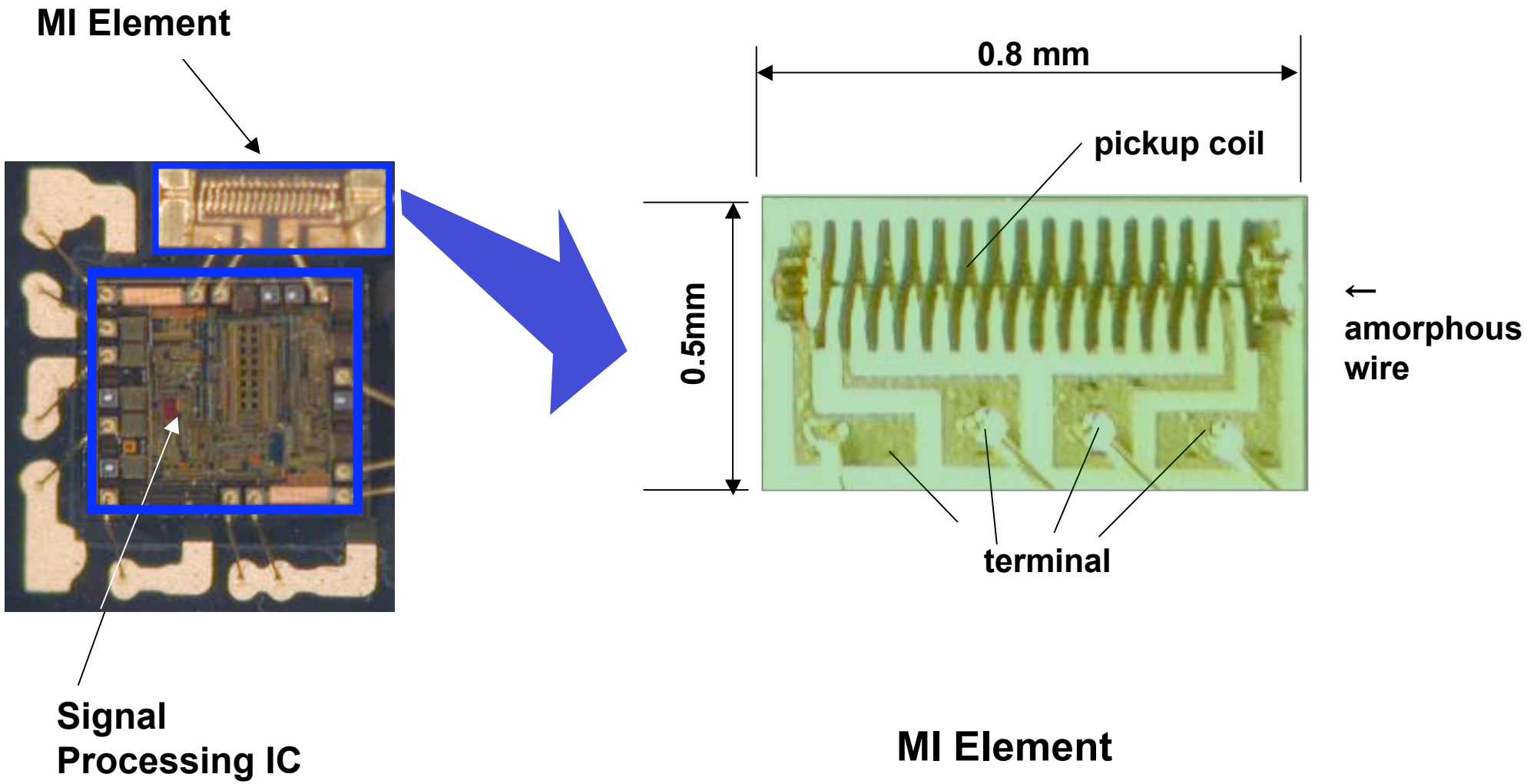


Output Signal Detected by Pickup Coil

1 ns after pulse input, the output voltage is measured in 0.2 ns

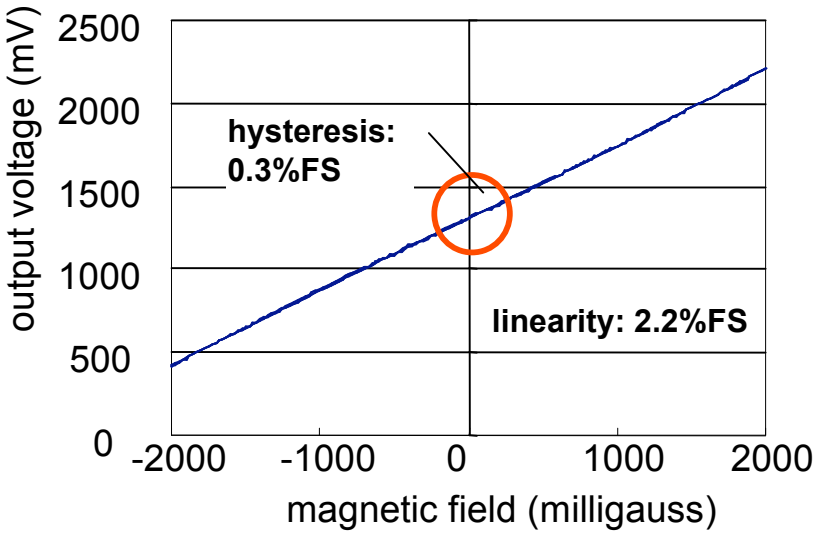


MI Element and Device Configuration

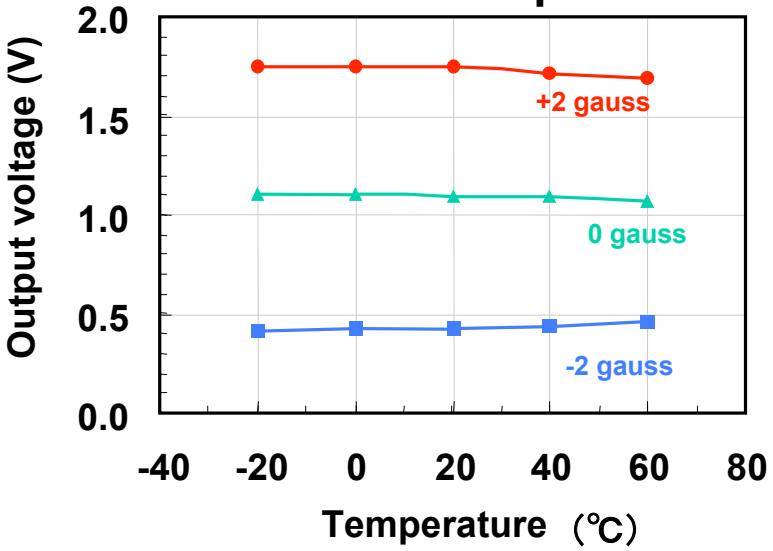


Performance

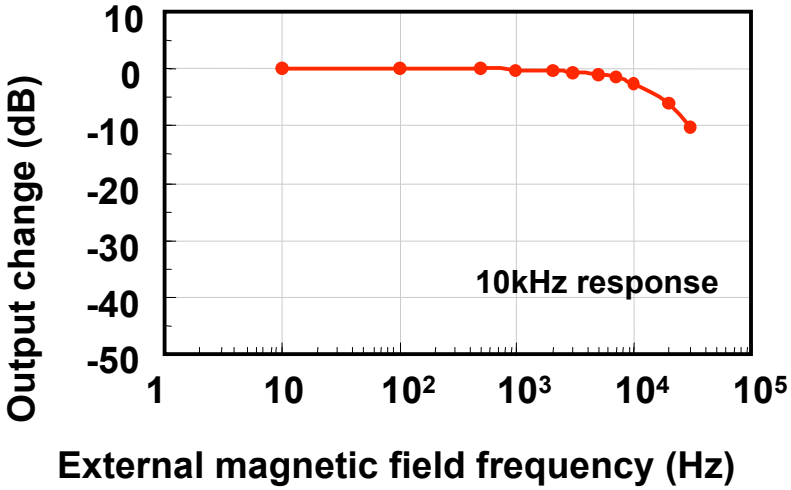
(1) Linearity



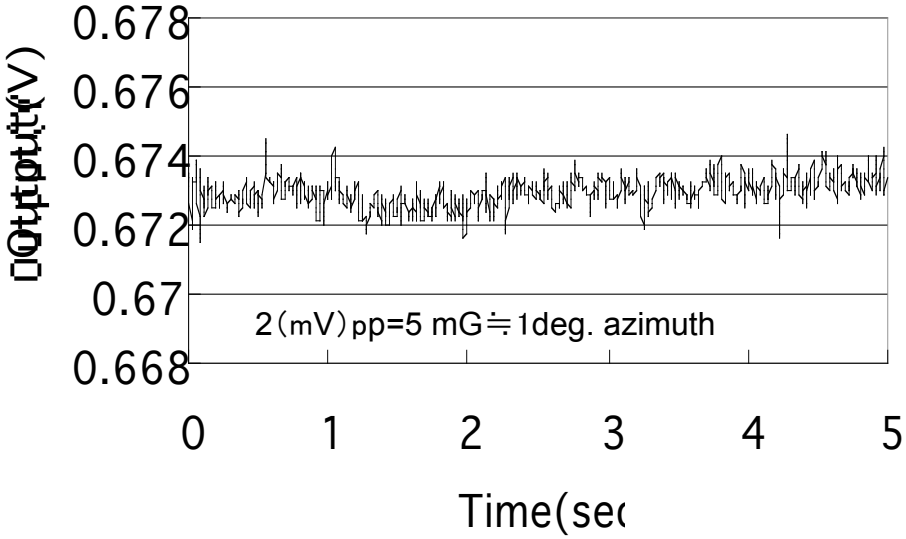
(2) MI Element inherent temperature stability



(3) Frequency Response



(4) Noise Level

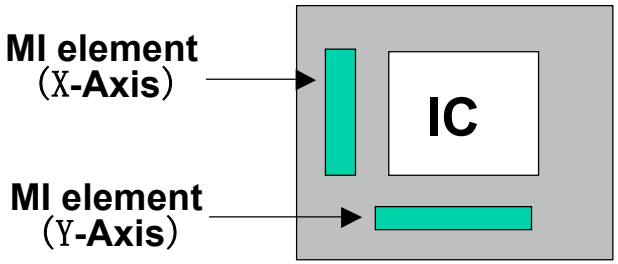


Outline

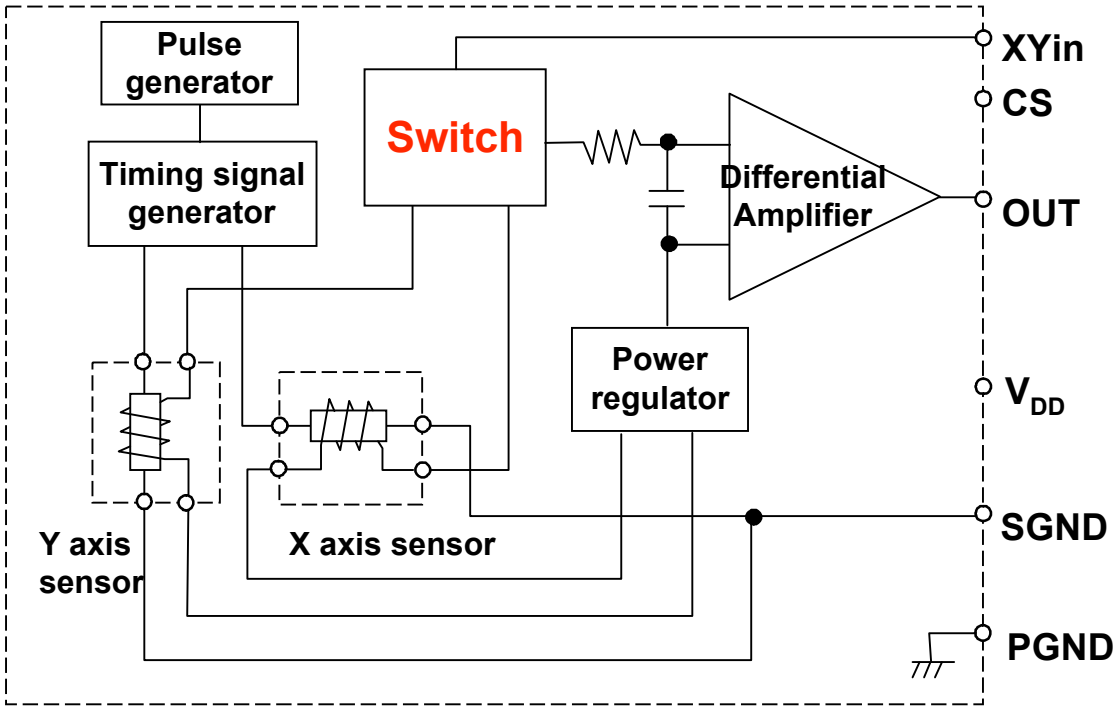
1. What is MI Sensor？
2. Electronic Compass using MI Sensor
3. G2 Motion Control Sensor using MI Sensor
4. Application
5. Conclusion

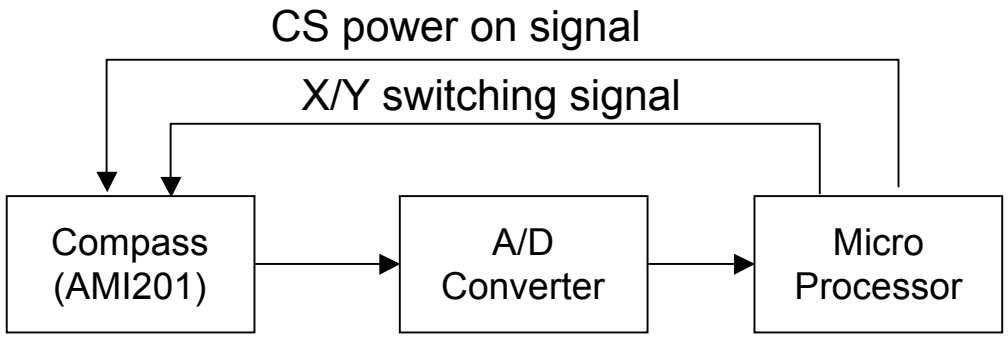
Electronic Compass and Block Diagram

Size：3.1×3.4×0.8mm

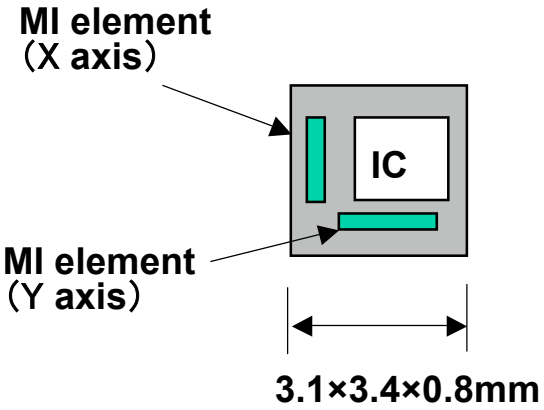


Structure



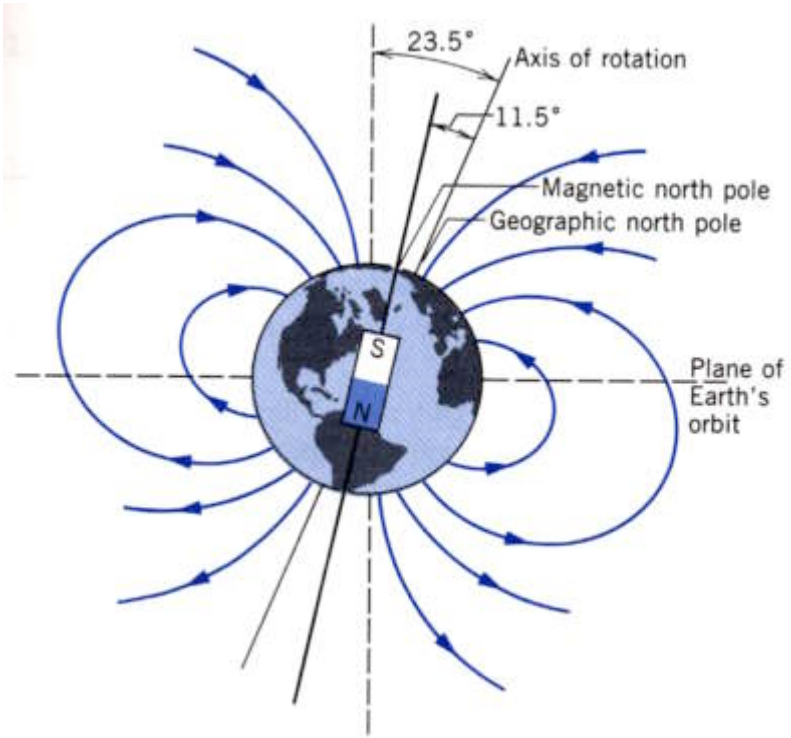


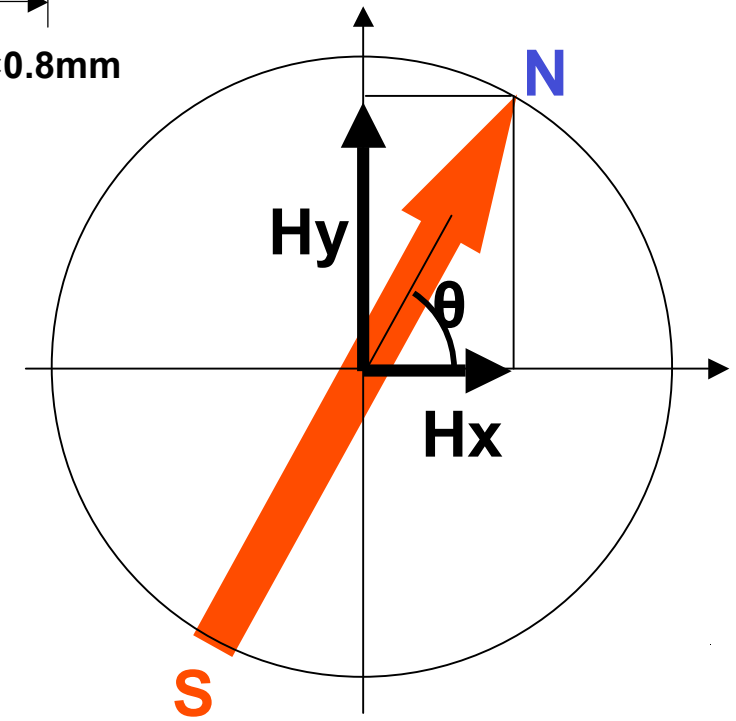
Azimuth Calculation



$$\tan\theta = \frac{Hy}{Hx}$$

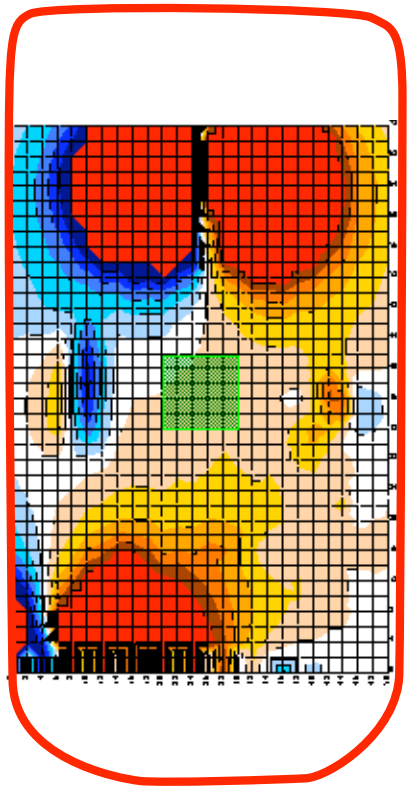
(θ= Azimuth)



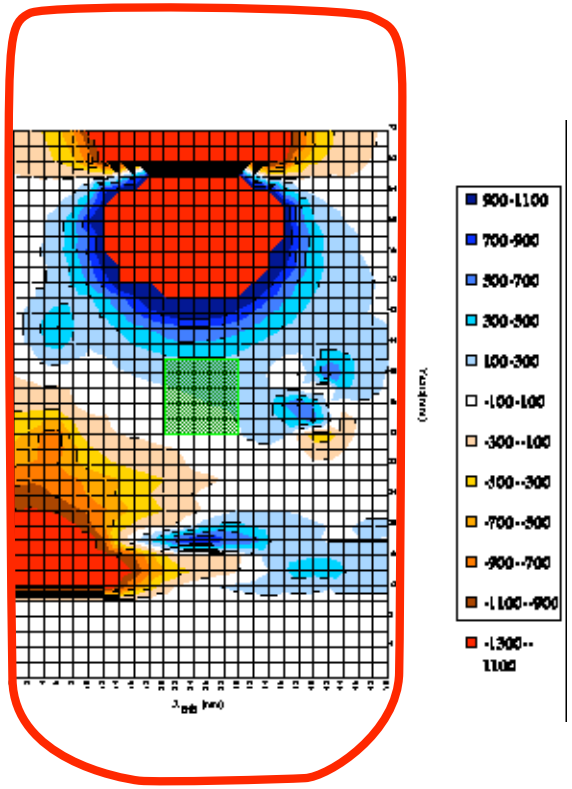


Internal magnetic field in the mobile phone

X-axis magnetic field

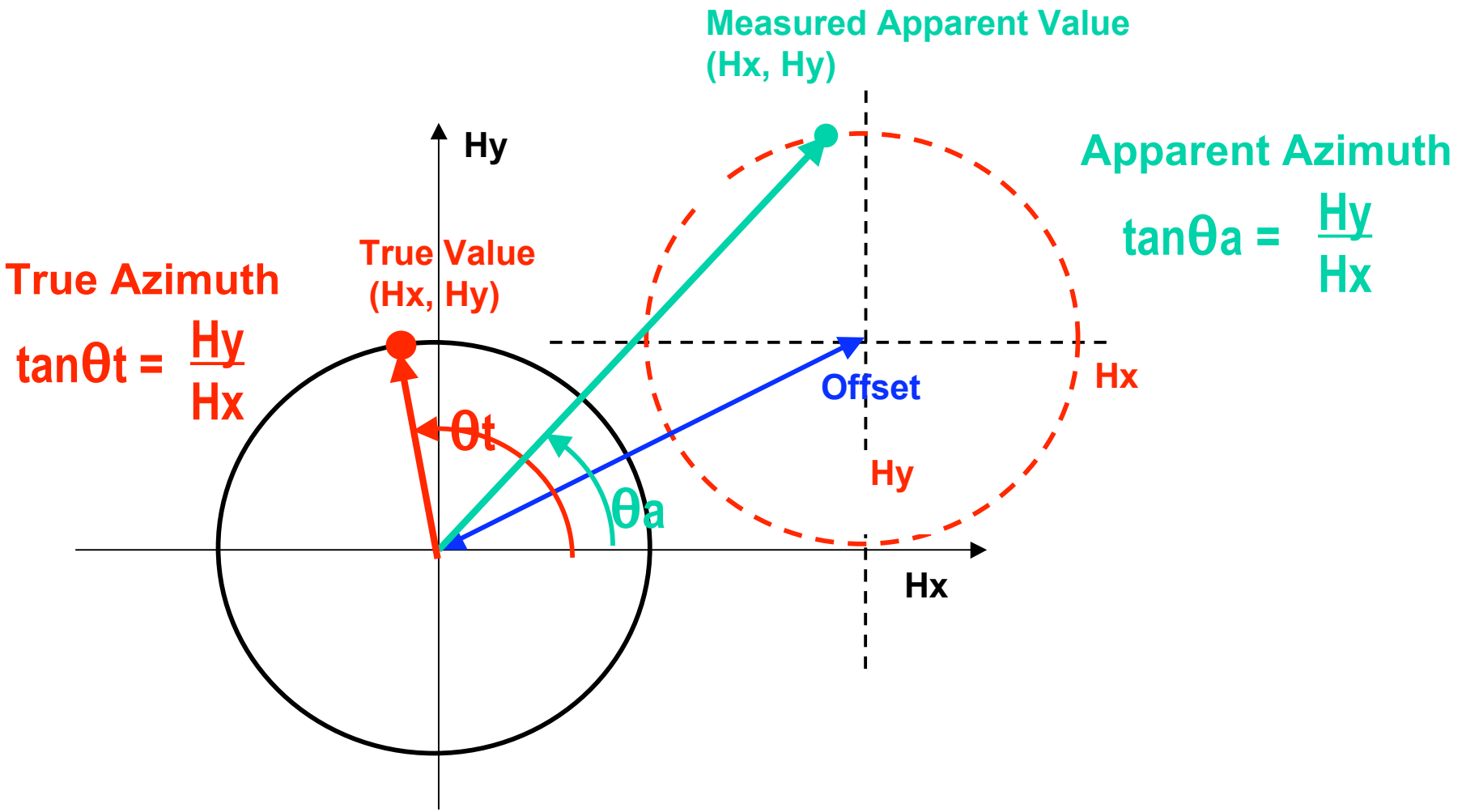


Y-axis magnetic field



Magnetic field sources: Speaker, Open/Close detection magnet, Vibration motor, etc

Compensation of offset error due to internal magnetic fields

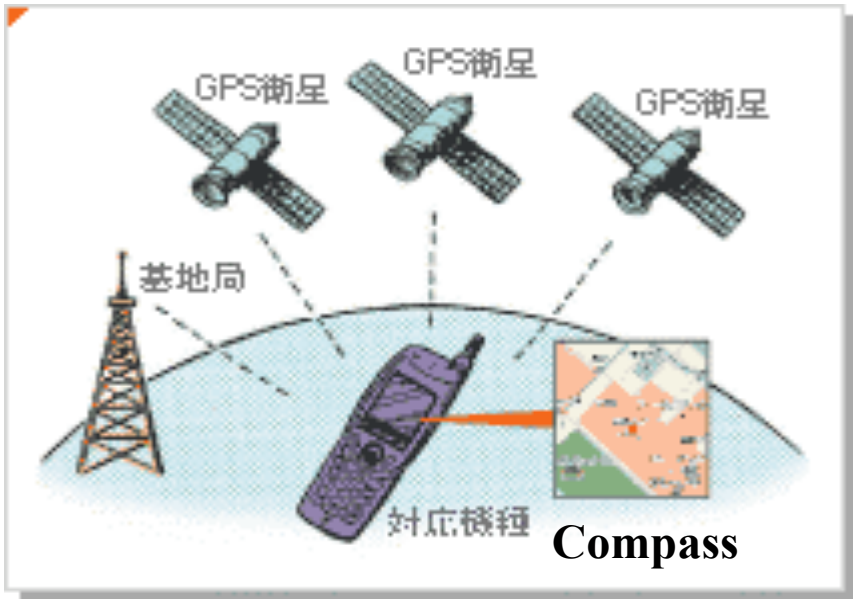


Field Test Results in downtown Nagoya

Mobile Phone-based Navigation Service

Navigation Service started from 2003 in Japan, China, and Korea

(1) Service Scheme

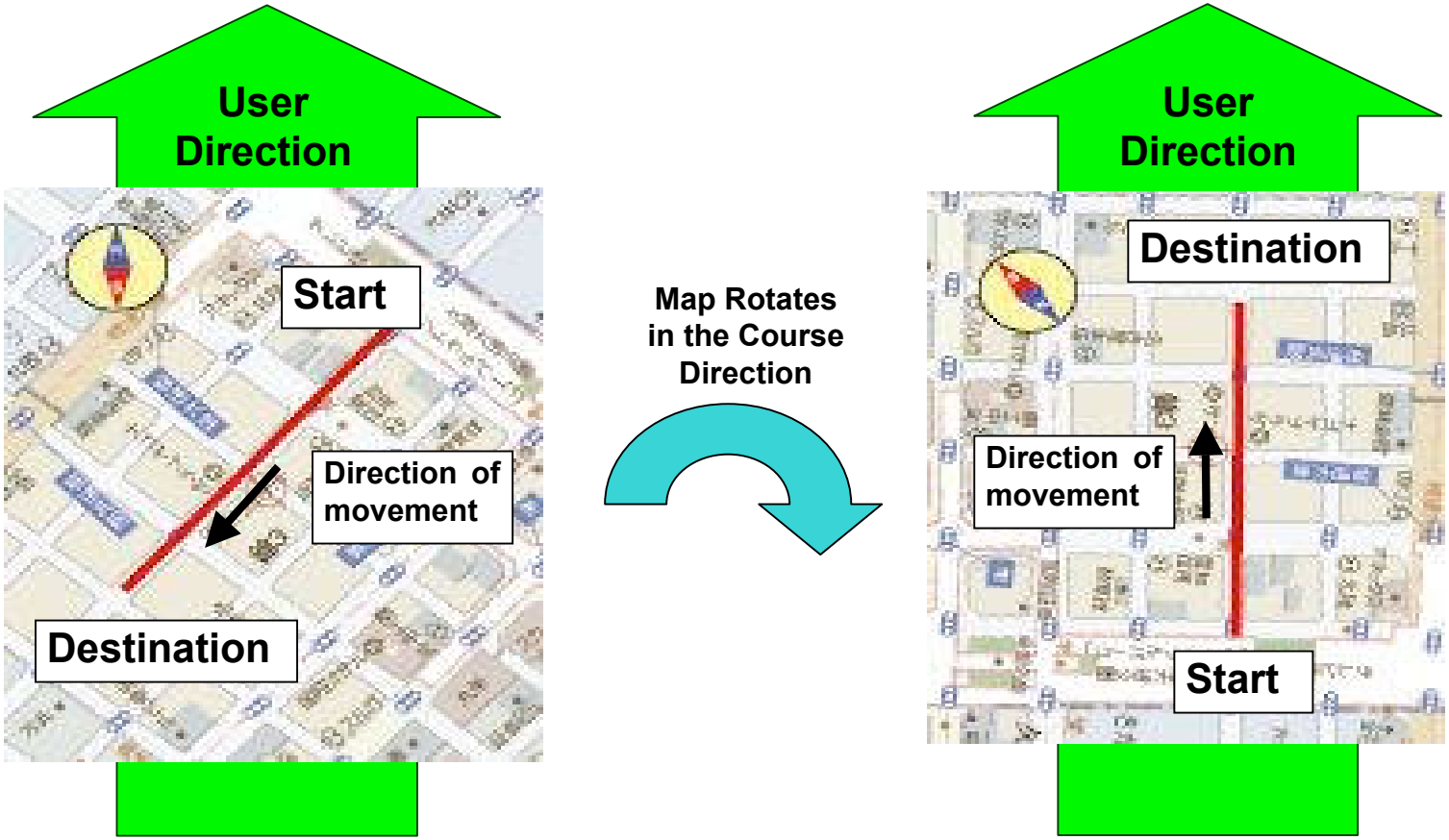


(2) Technologies

GPS
＋
Digital Map
＋
Compass

Map Heading Up Feature by Compass

Map rotates in real time, according to user direction



North Up

Heading Up

Electronic Compass Product Lineup

axis	Product	Photo	Output	Size (mm)
2-axis (2D)	AMI201		analog voltage output	3.1×3.4×0.8
3-axis (3D)	AMI302		analog voltage output	3.5×4.0×1.5
	AMI303	coming soon	serial azimuth output	5.5×4.5×1.5

Comparison with Other Products

Manufacturer	Aichi Steel AMI201	Company A	Company S
Detection Principle	Magneto Impedance	Hall Effect	Fluxgate
Sensitivity	◎290mV / gauss	× 0.8mV / gauss	○
Linearity	◎±2%FS	×	○
Package dimensions	◎ 3.1×3.4×0.8mm	× 6.3×5.9×1.0mm	× 6.5×6.5×1.2mm
Power supply voltage	○ 2.5 - 3.6V	○ 2.5 - 3.6V	○ 2.65 - 2.95
Power consumption	◎ less than 4mW	× 25mW	× 25mW
Compass resolution	◎±1°(360 segment)	× 16 segment	× 16 segment
Compass response	◎>0.01 sec		0.05 sec
Temp. stability	◎good	×	○
Price	◎Low	×High	×High
CONCLUSION	Suitable for mobile phones	Low sensitivity Low resolution Slow response	Low sensitivity Low resolution Slow response

Best of Sensors Expo Award in Boston

- High S/N ratio

WINNER

BEST OF SENSORS EXPO FALL 2002

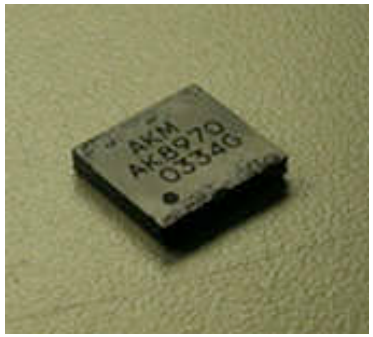
Silver Award: **2002/09/25**

AMI201 for electronic compasses, which uses amorphous ferromagnetic wire to detect two components of the Earth's magnetic field.

Outline

1. What is MI Sensor？
2. Electronic Compass using MI Sensor
3. G2 Motion Control Sensor using MI Sensor
4. Application
5. Conclusion

Chapter 3 G^2 Motion Control Sensor



3D Electronic Compass
(Asahi Kasei)

Size：6.5×6.0×1.2mm
Degree resolution：10°
Response：
0.01s/Dimesion

2D acceleration sensor
(MEMSIC)

Size ：5.0×5.0×2.0mm
Degree resolution ：1°
Response ：

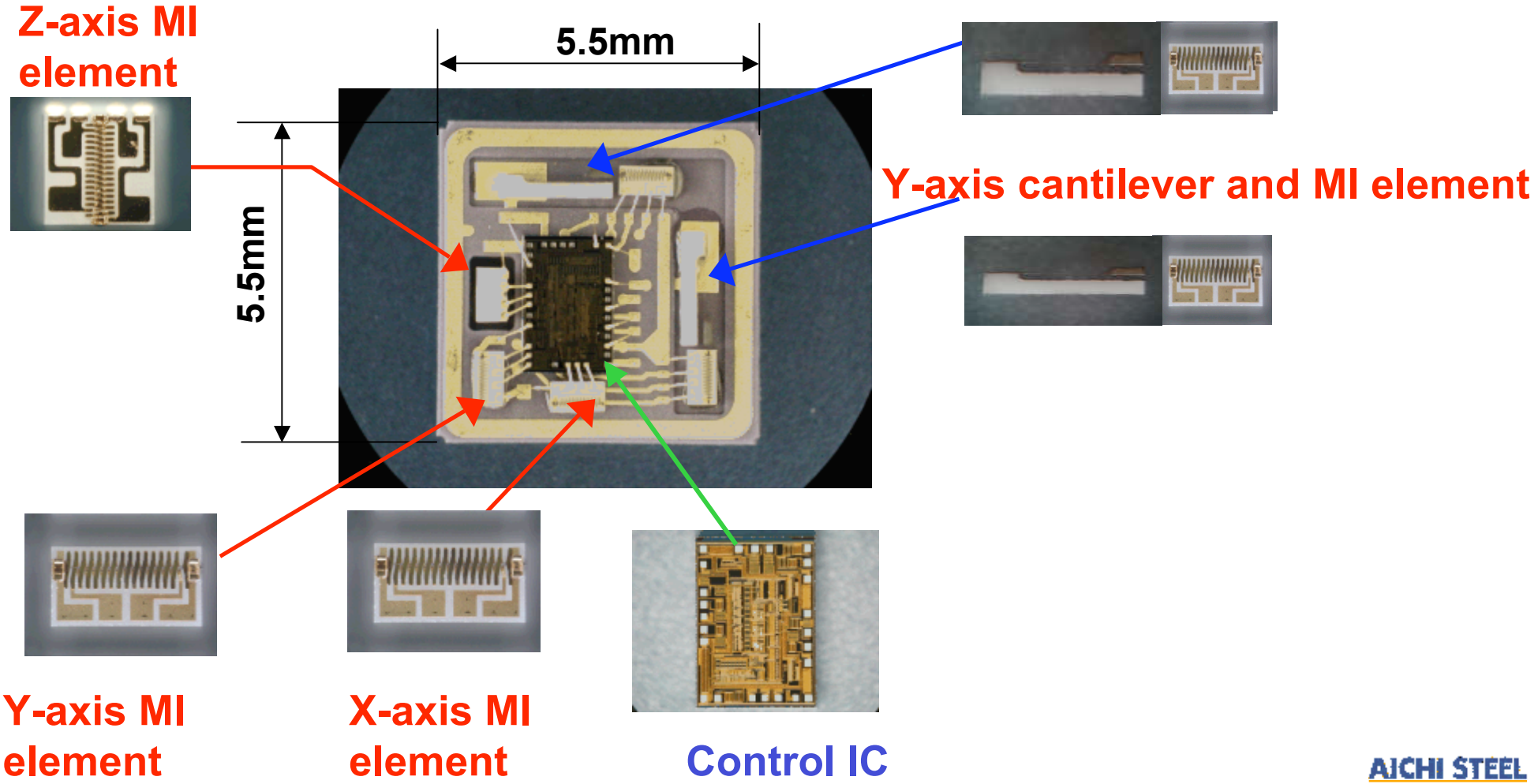
G2 Motion Control Sensor
An Innovative Integration
50% downsize

5.5×5.5×1.5mm

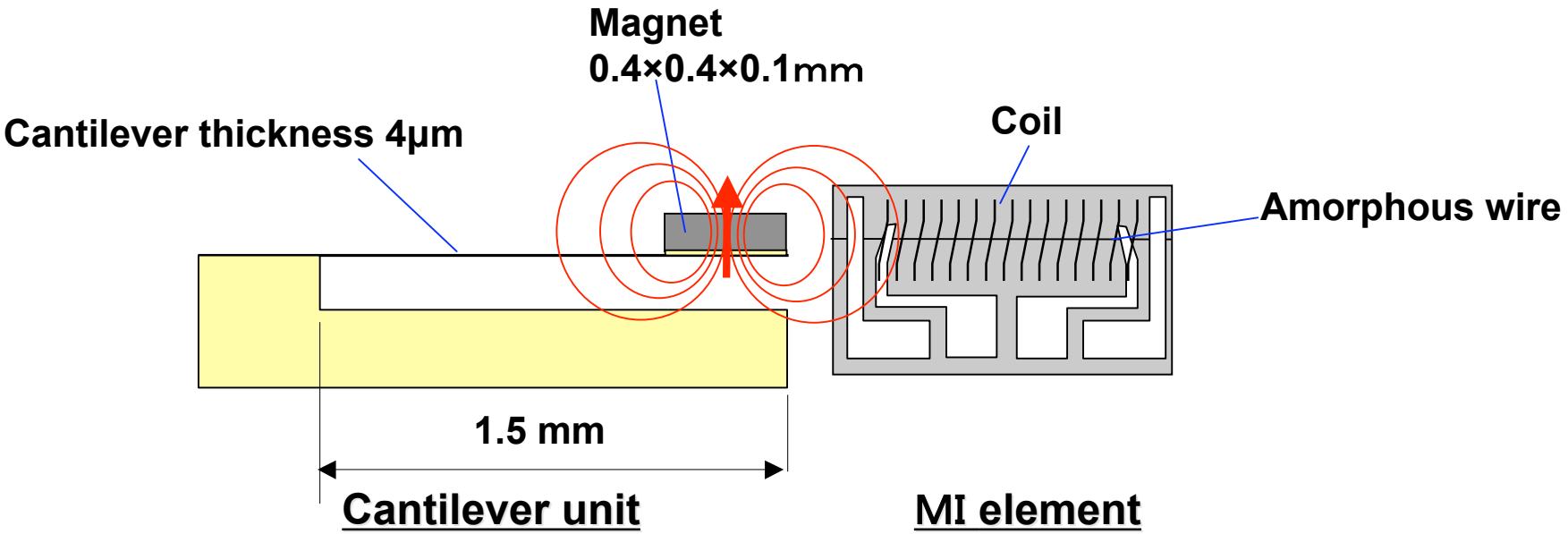
G2 Motion Sensor Internal Structure

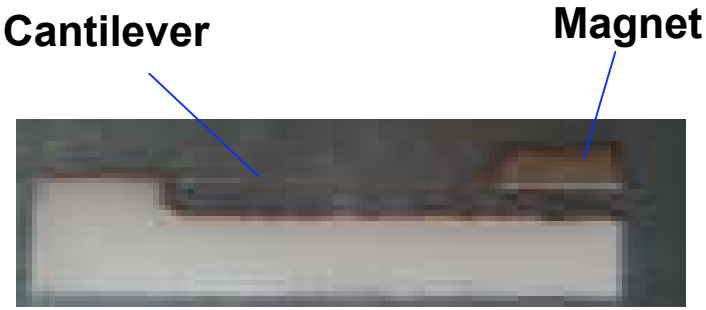
3D electronic compass part

2D acceleration sensor part



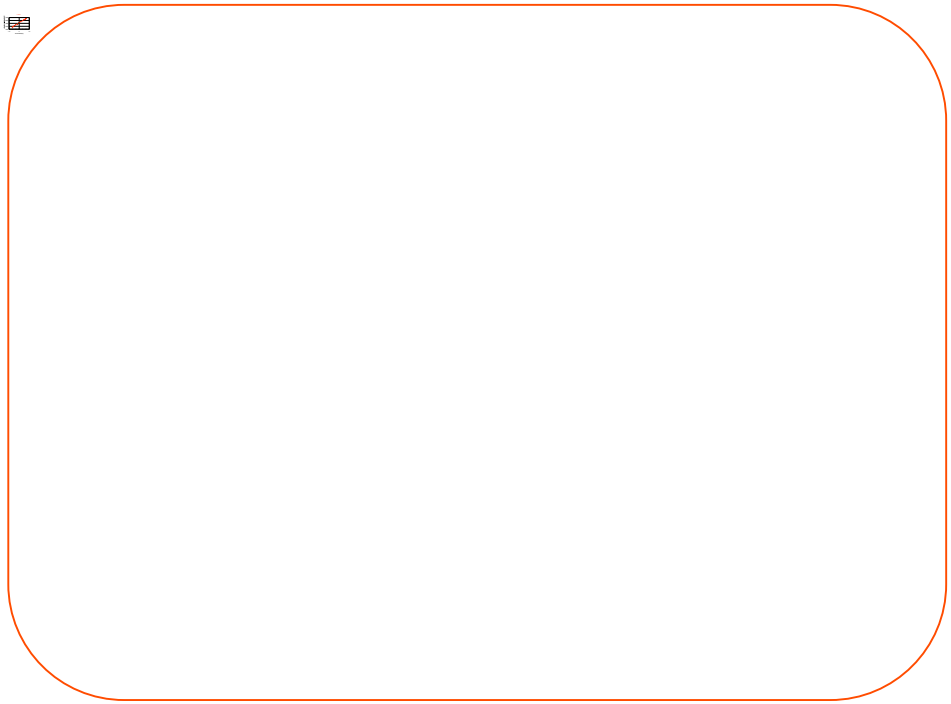
Development of Accelerometer using MI sensor



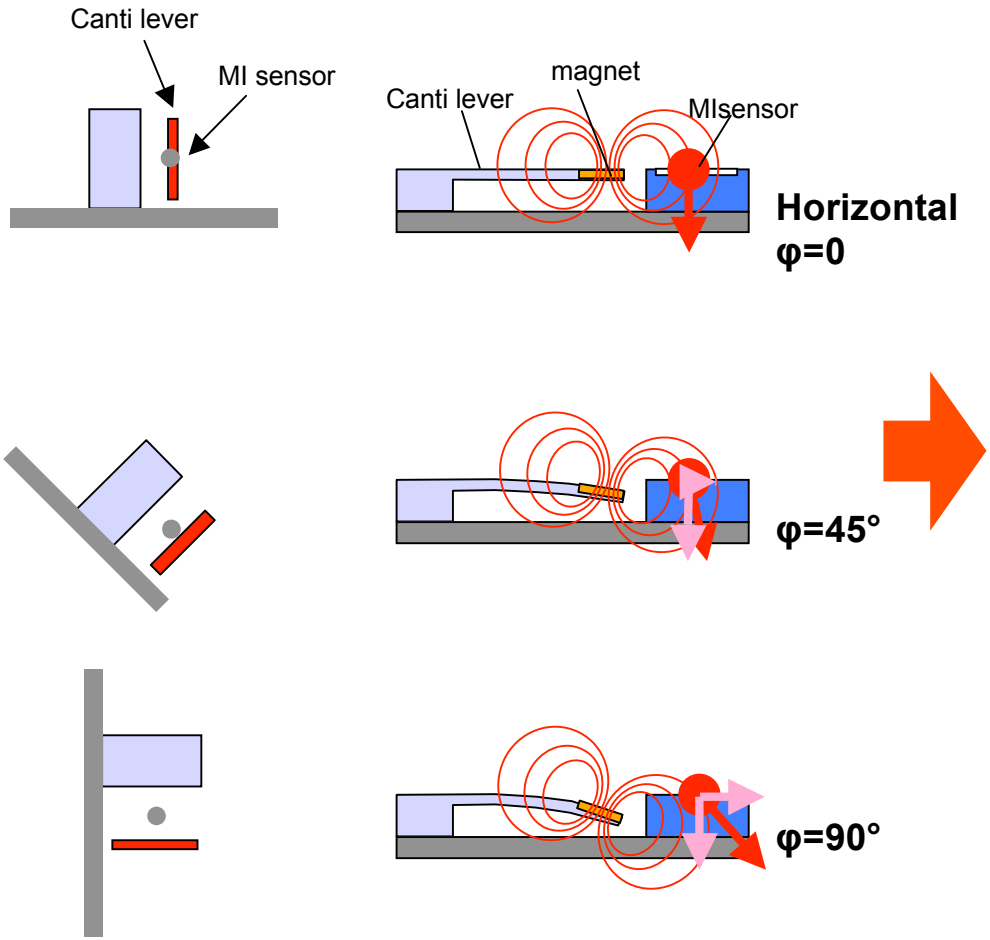


Conventional Accelerometers: Piezo resistor type、Capacitance type

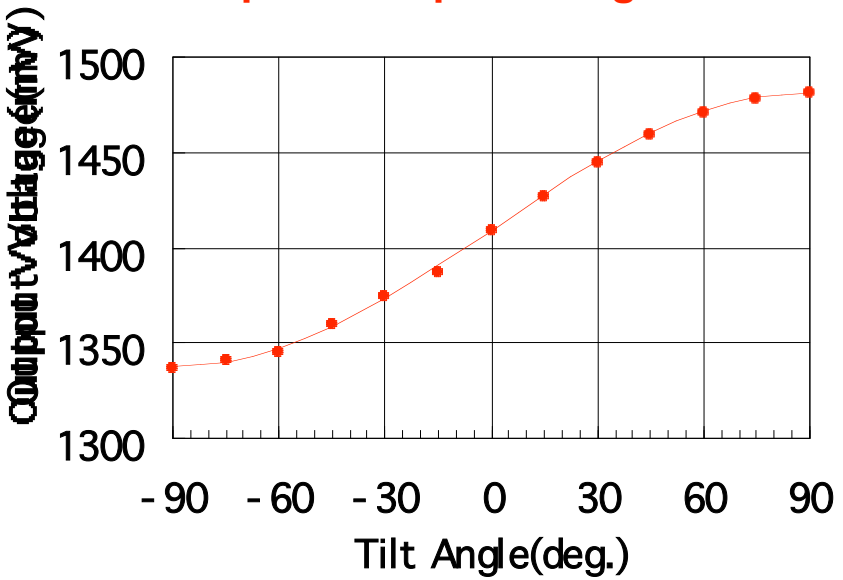
Output characteristics



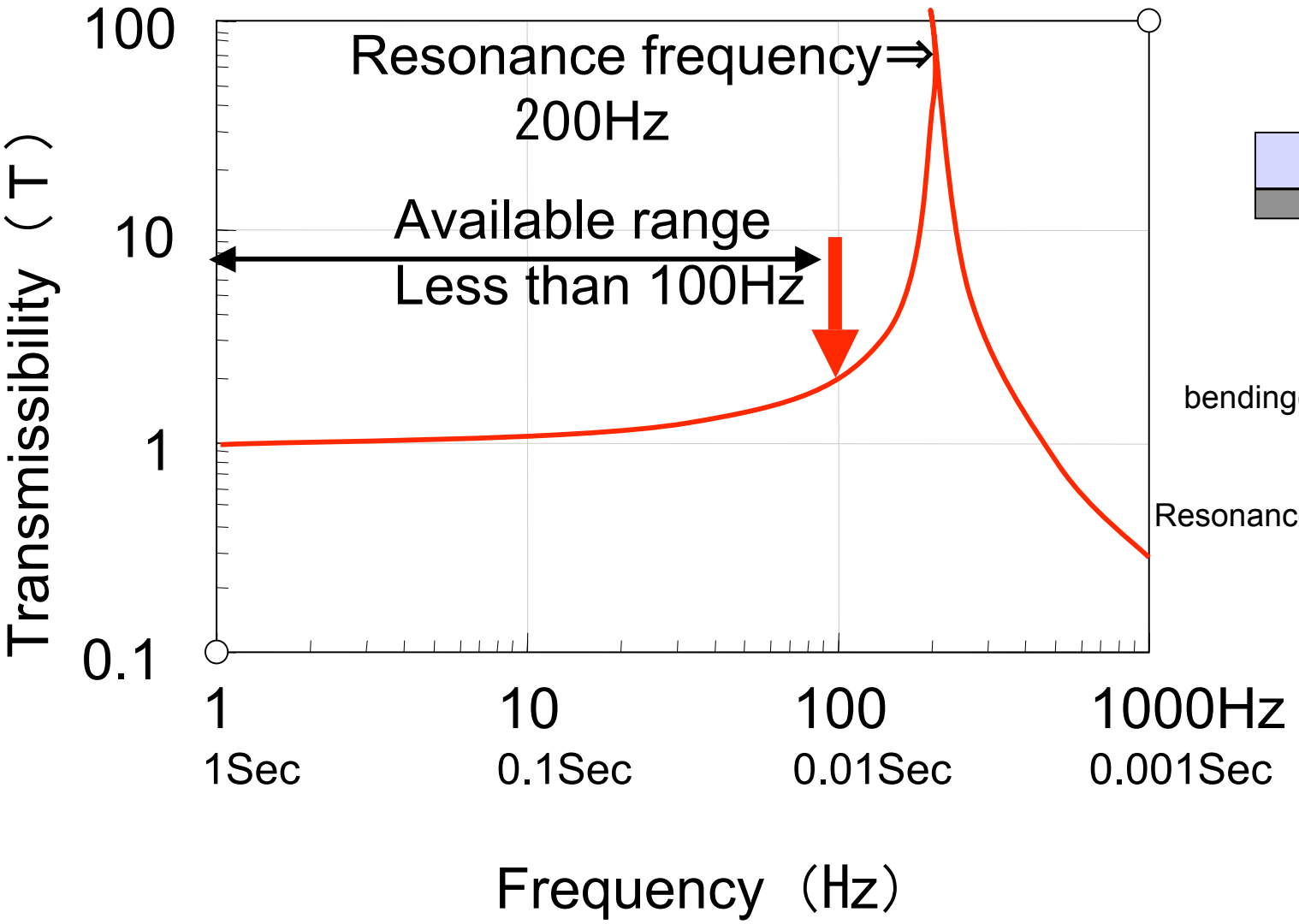
Principle of detecting tilt by accelerometer

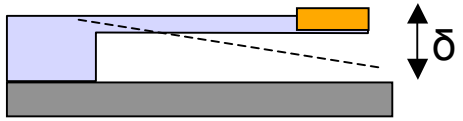


An example of output voltage versus tilt angle



Resonance frequency





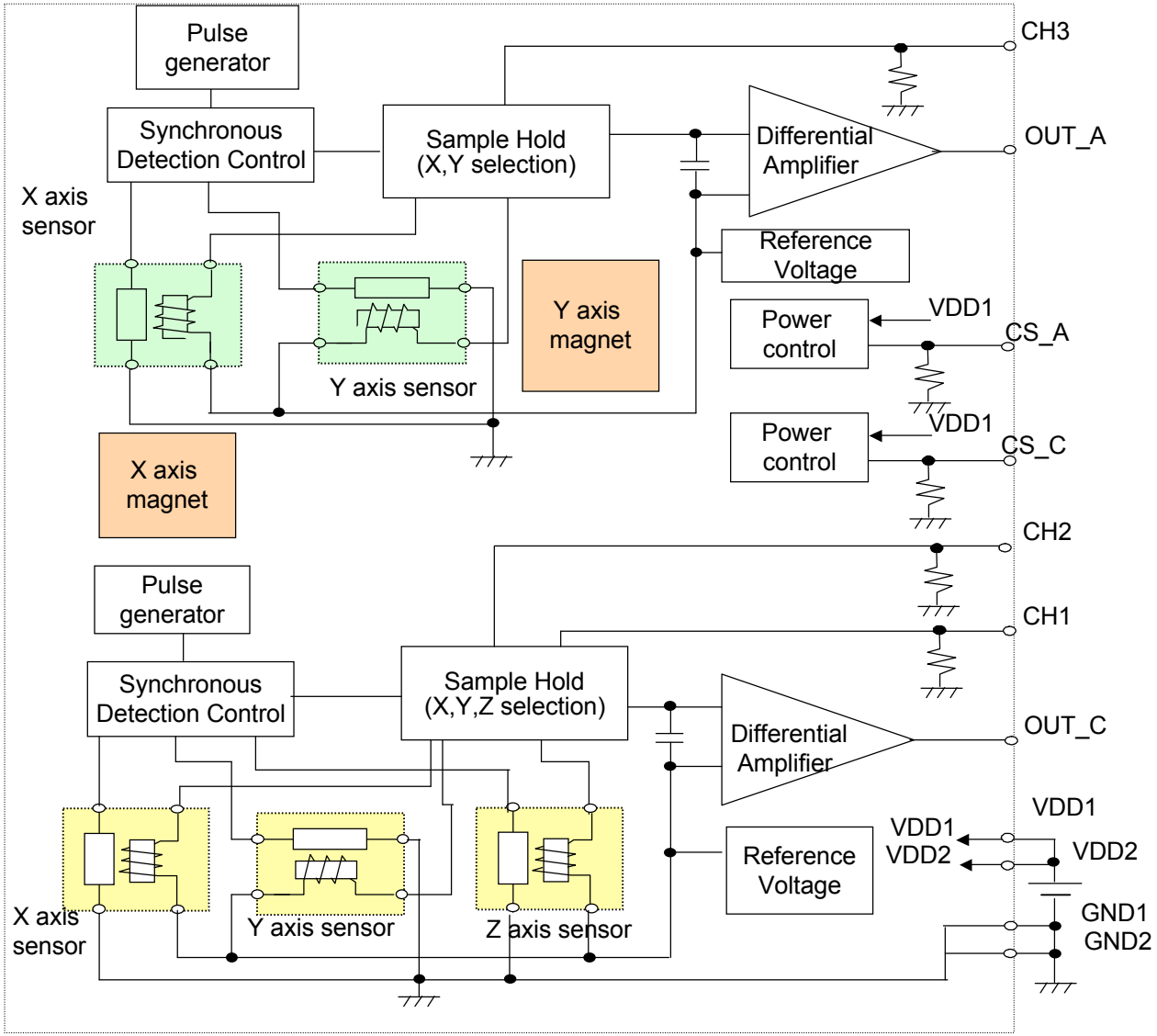
$$\text{bending}\delta = \frac{4 \times G \times L^3}{E \times b \times h^3}$$

Resonance $fr = (1/2\pi) \times \sqrt{(k/m)}$

k : Spring constant
m : weight

E : young ratio
b : width
h : height
L : length

Circuit Block Diagram



Specifications

Appearance

5.5×5.5×1.5mm

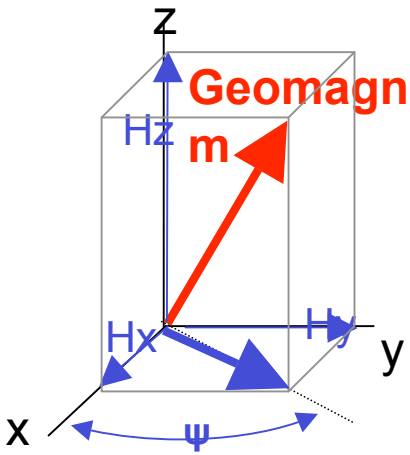
Major Characteristics

	Item	Condition	Min.	Typ.	Max.	Unit
	Power supply		2.6	3.0	3.6	V
	Operating temperature		-20		+85	℃
Magnetic sensor	Operating range	VDD=3.0V	±0.3			mT
	Output linearity			1.3	4	%FS
	Output voltage at zero magnetic field		800	1500	2200	mV
	Sensitivity		1.3	3.0	4.2	mV/ μT
	Frequency response				1	kHz
Accelerometer	Operating range		±2			g
	Output linearity			2	5	%FS
	Output voltage at zero g, zero magnetic field		800	1500	2200	mV
	Sensitivity		40	80	200	mV/g
	Frequency response				100	Hz

G^2 Motion Sensor can detect attitude

Geomagnetism is measured by MI sensor
Gravity is measured by accelerometer using MI sensor.

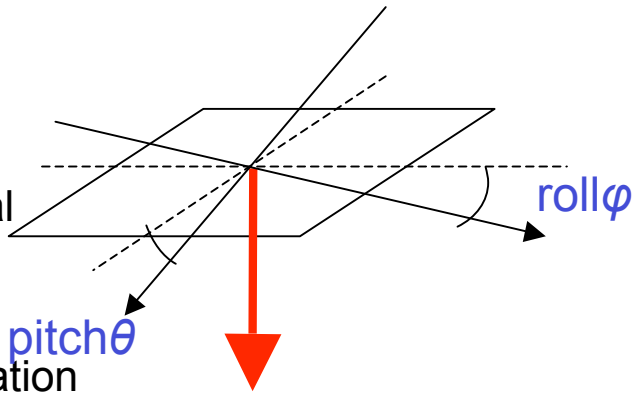
3D magnetic sensor



(Azimuth Angle)

$$\tan\psi = \frac{Hy}{Hx}$$

2D accelerometer sensor



Detecting the horizontal plane

Discriminating a translation or a rotation

Gravity

Geomagnetism ⟷ **Gravity**

Detecting ATTITUDE (G^2 Motion Sensor)

G2 Motion Control Sensor Demonstration

Outline

1. What is MI Sensor?
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Chapter 4 Recent Trend to offer new service using Sensors

Compass and accelerometer and their integration will create new applications such as Games, Navigation Service, Input Device and so on.

Maker	LG (Korea)		Pantech (Korea)	Samsung (Korea)	Sharp (Japan)	Nokia (Finland)	Siemens AG (Germany)
Model No	SV360	LP3000	PH-S6500	SCH-S310	V603SH	Nokia3230	CX70Emoty
Release			February 2005	May 2005		May 2005	May 2005
							
Sensor	Accelero meter	3-Axis Accelerometer 3-Axis Geomagnetic	3-Axis Accelerometer 3-Axis Geomagnetic	3-Axis Accelerometer Geomagnetic	2-Axis Accelerometer 3-Axis Geomagnetic	Accelerometer	Accelerometer
Application	Game	Navigation Electronic Compass	Pedometer Input Device Electronic Compass	Game Input Device Electronic Compass	Game Input Device Electronic Compass	Game	Input Device

Applications offered by Vodafone

1. Game

Shooting Game

Golf Game

Others: Baseball Game, Balance Game, etc.

2. TV view rotation

vodafone

V603SH by Sharp

2005 release

AMI501

3. Cursor Control

（Mouse Function：Analog input）

4. 3-Axis Electronic Compass

5. Input by Swing Motion

6. Shake Sounder

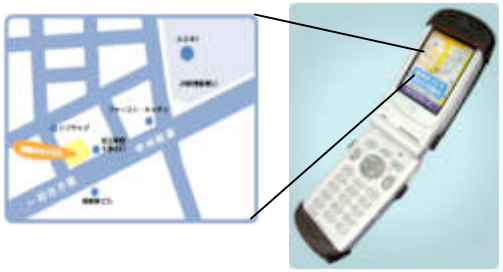
7. Shake Counter

Future Applications for Mobile Phone

Anti-Shake Correction

Pedometer

Drop Detection



Navigation system

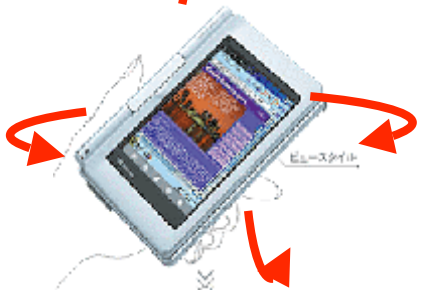
vodafone

Next year

AMI601

Diving simulation

Flight simulation



3D puzzle

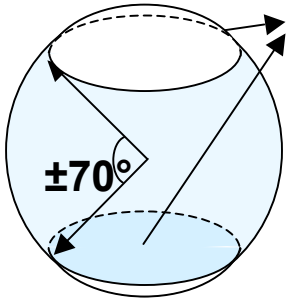
3D CG shopping

Future improvement of G2 Motion Sensor

① 6 Dimension

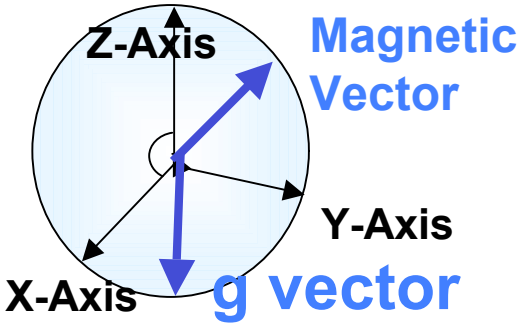
5 Dimension

Difficult over 70°



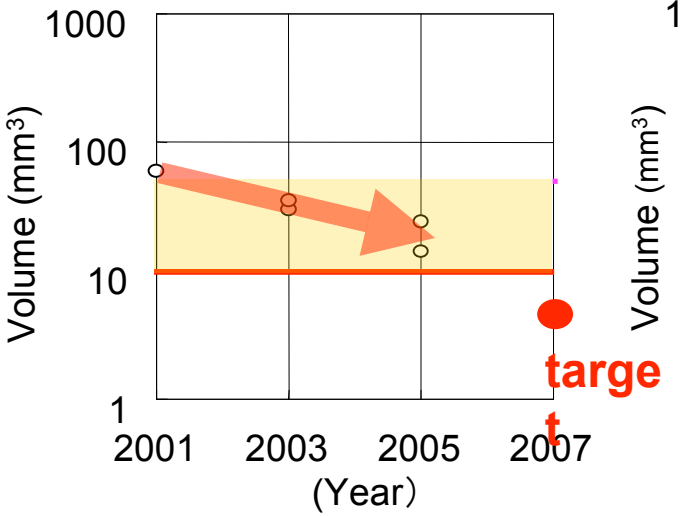
6 Dimension

Detect whole 360°Rotation

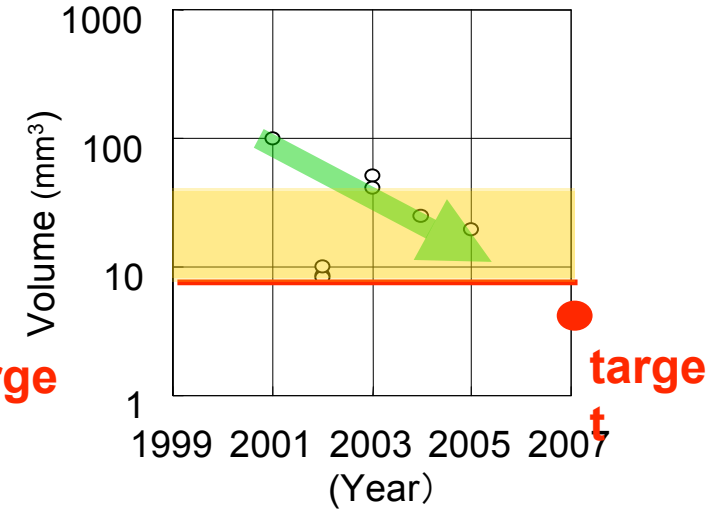


② Miniaturization

3-Axis Accelerometer

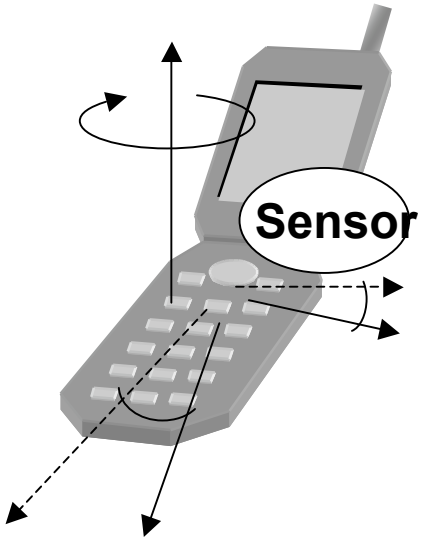


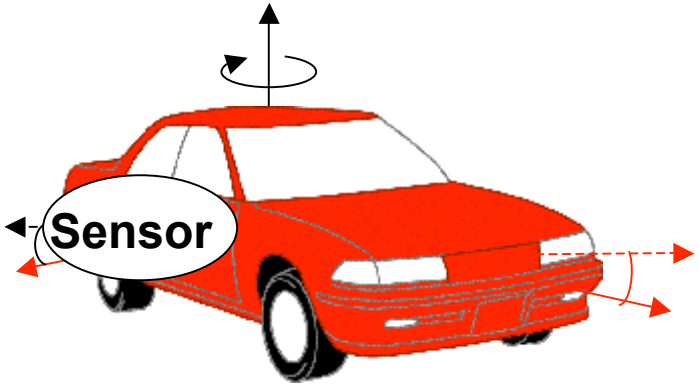
3-Axis Electronic Compass



Expansion of G2 Motion Sensor applications

G2 Motion sensor is similar to an electronic semicircular canal which is needed for digital mobile devices such as:

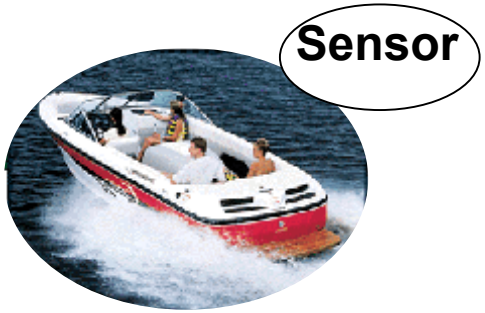




Traveling stability of car

Attitude stability of robot

Robot

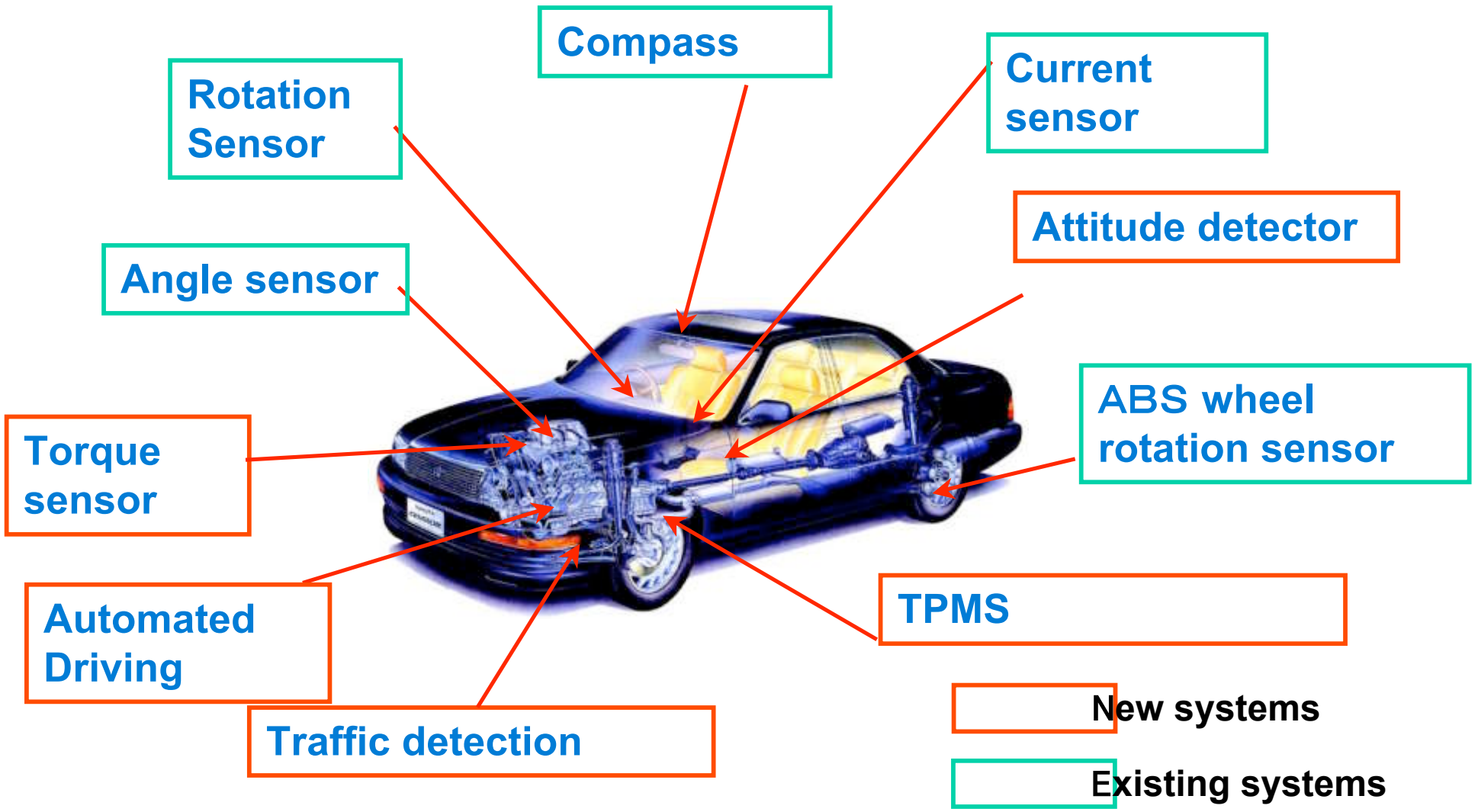


Ship

Bicycle

RC Helicopter

Many application possibilities for Automobiles



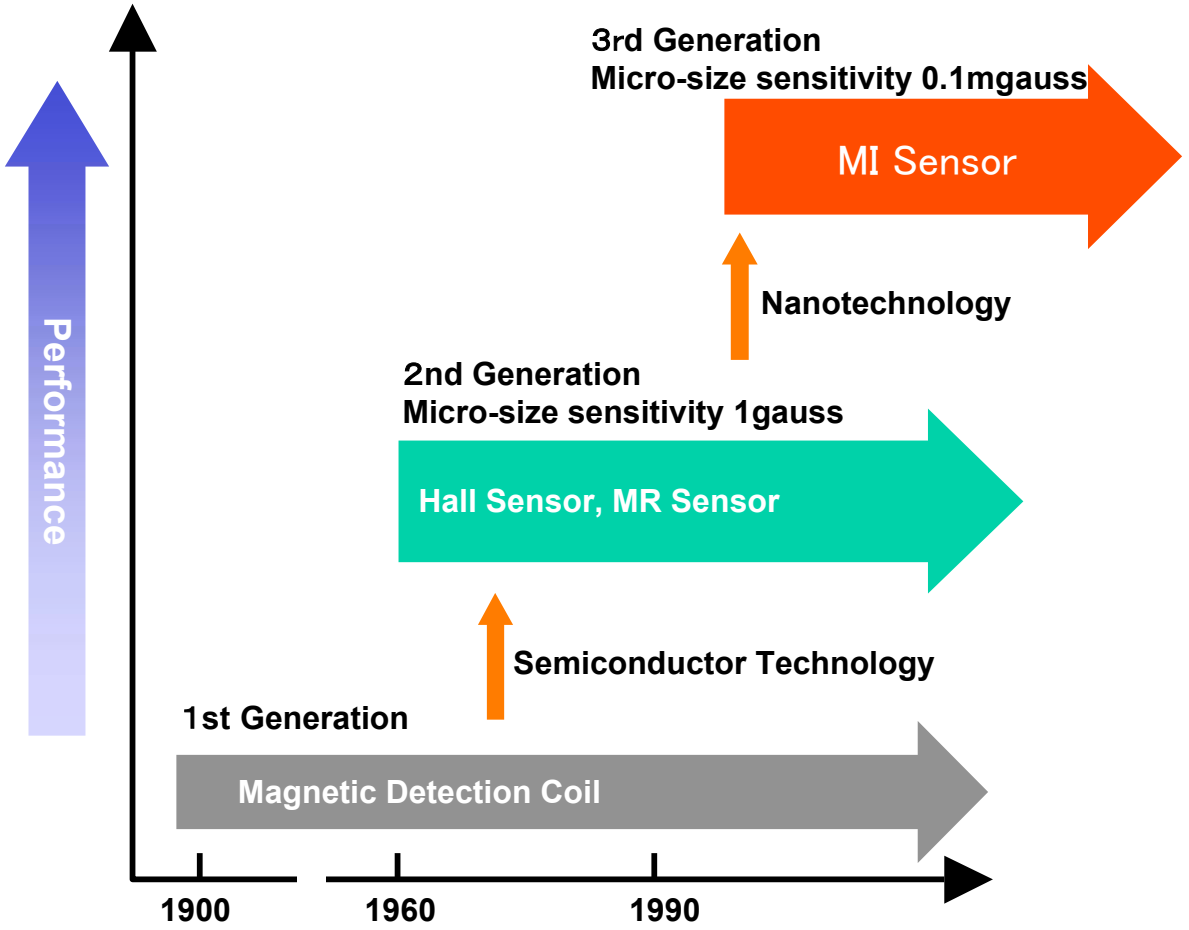
Outline

1. What is MI Sensor？
2. Electronic Compass using MI Sensor
3. G2 Motion Control Sensor using MI Sensor
4. Application
5. Conclusion

Chapter 5 Conclusion

What is GMI sensor?

GMI Sensor is the 3rd Generation Magnetic Sensor.



Thank you very much for your attention