

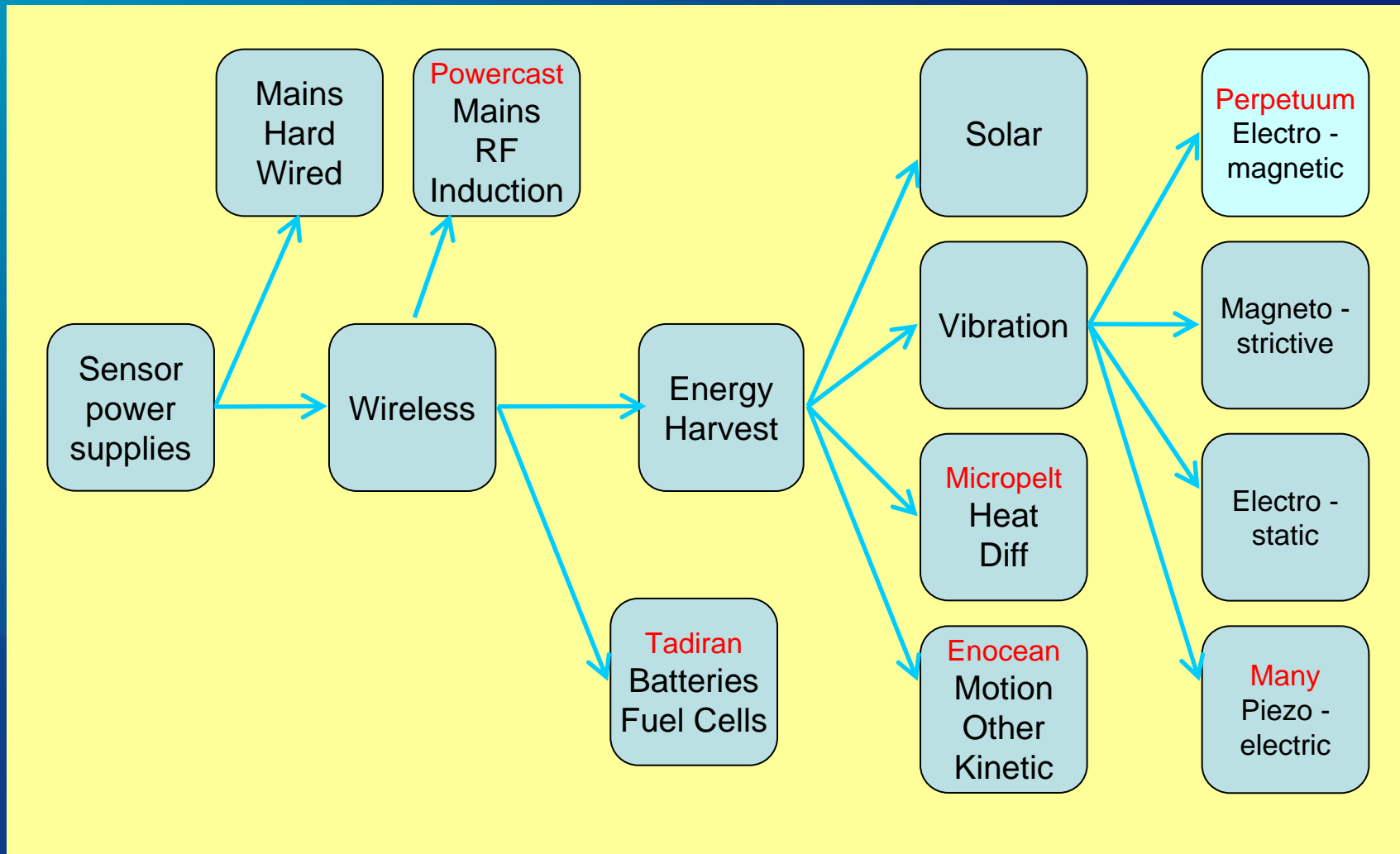
Practical Alternatives for Successful Energy Harvesting



Roy Freeland, C.E.O.
Perpetuum Ltd
Vibration Energy Harvesters



Alternative Methods of Powering Sensors



Energy Harvesting Source Options

- Solar
 - Widely used for power generation
 - Can be used for sensors e.g. EnOcean in buildings
- Thermal
 - Requires temperature difference. Peltier effect devices can be used. Limited efficiency - Carnot
- Wind/Wave/Tidal
 - Not normally practical as reliable source for sensors
- Machine vibration/motion
 - When present is ideal source of energy

Vibration/motion energy harvesting

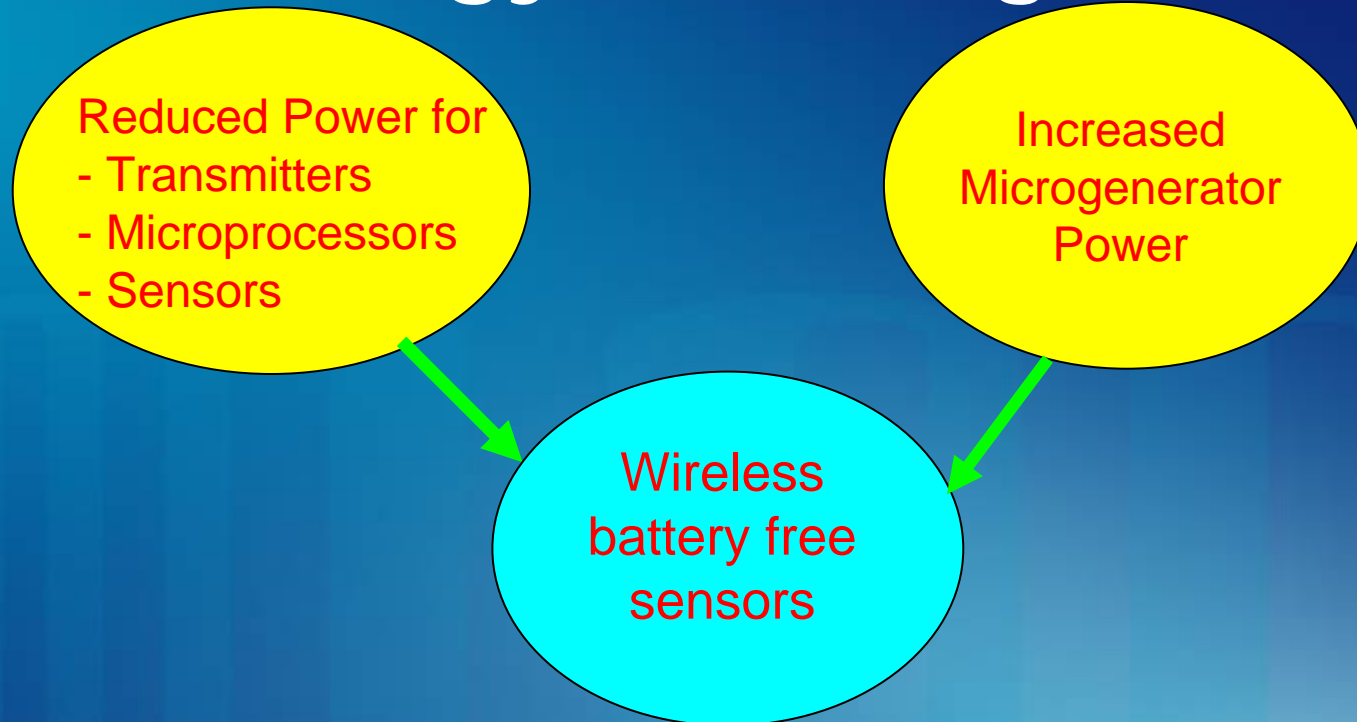
- Converts movement of mechanical resonator into electrical power:
 - Seismic mass should be as large as possible.
 - Resonator should stay tuned near vibration frequency.
- Power transduction mechanism should be:
 - Efficient
 - Reliable
 - Low cost
 - Compact



Power transduction mechanisms

- Piezoelectric
 - Ceramic Material
 - Simple
 - Low-cost
 - Compact
 - Long term reliability?
 - High internal resistance
- Electromagnetic
 - Copper/steel/NdFeB
 - Simple
 - Low-cost
 - Compact
 - Reliable
 - Accurate Models
- Magnetostrictive
 - New materials
 - Two-stage conversion
 - Efficiency?
 - Immature technology
 - Reliability?
- Electrostatic
 - Requires initial charge

Technology Convergence



Sensor/wireless systems designed for battery power.....
.....but many customers will not accept batteries

What to use and Where

- Natural Sources (Wind/Solar/Hydro)
 - Most are impractical for wireless sensors
 - Solar possible in some locations – (not Alaska)
- Batteries
 - Reliability issues
 - Add to maintenance burden
 - Use in non critical, easy to access e.g. domestic
- Assessing Energy Harvesting
 - What energy is available
 - Is it reliable
 - Is there enough
 - Select transduction method

Early Adopter Applications for Energy Harvesting Wireless Sensors

- Boeing, EnOcean, Powercast, Advanced Cerametrics and others presenting here
- Successful applications using Vibration Energy Harvesting
- Some details still commercially confidential as users wish to exploit competitive advantage

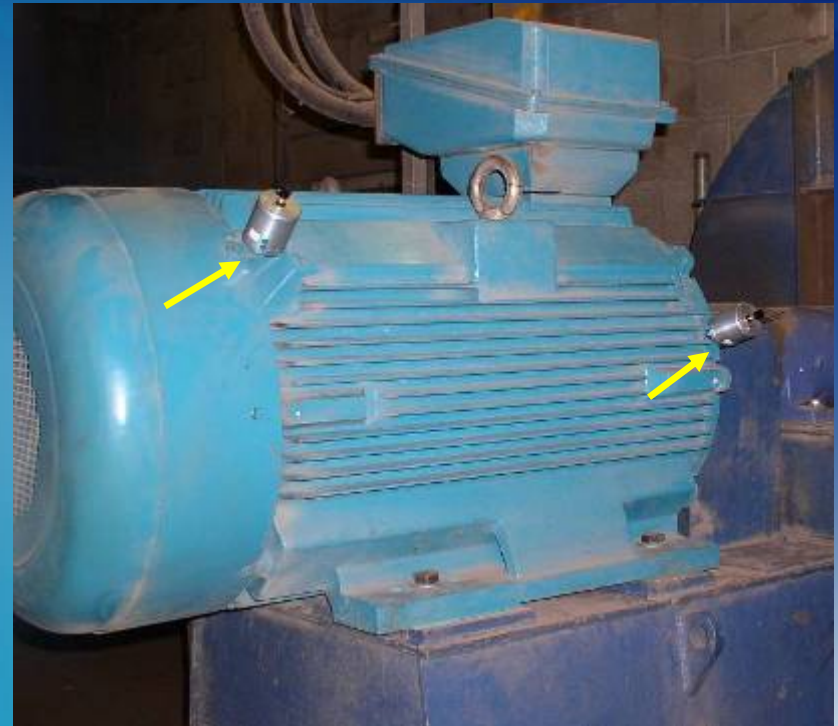
Condition Monitoring – Petrochemical

- Condition Monitoring System for major International Oil Co.
- Integrated with standard system from leading C.M Company
- Dust Networks radio
- ATEX Zone 1
- Transmits full vibration spectra
- Conventional Hard wiring too expensive



Condition Monitoring – Water Utility

- Yorkshire Water need to increase C.M. to reduce maintenance costs and improve service levels
- RLW Inc. developed W.S.N.
 - Moteiv radio
 - TI Chipcon2420 -802.15.4
- 6 kBytes vibration spectrum every 10 minutes
- Pruftechnik Software

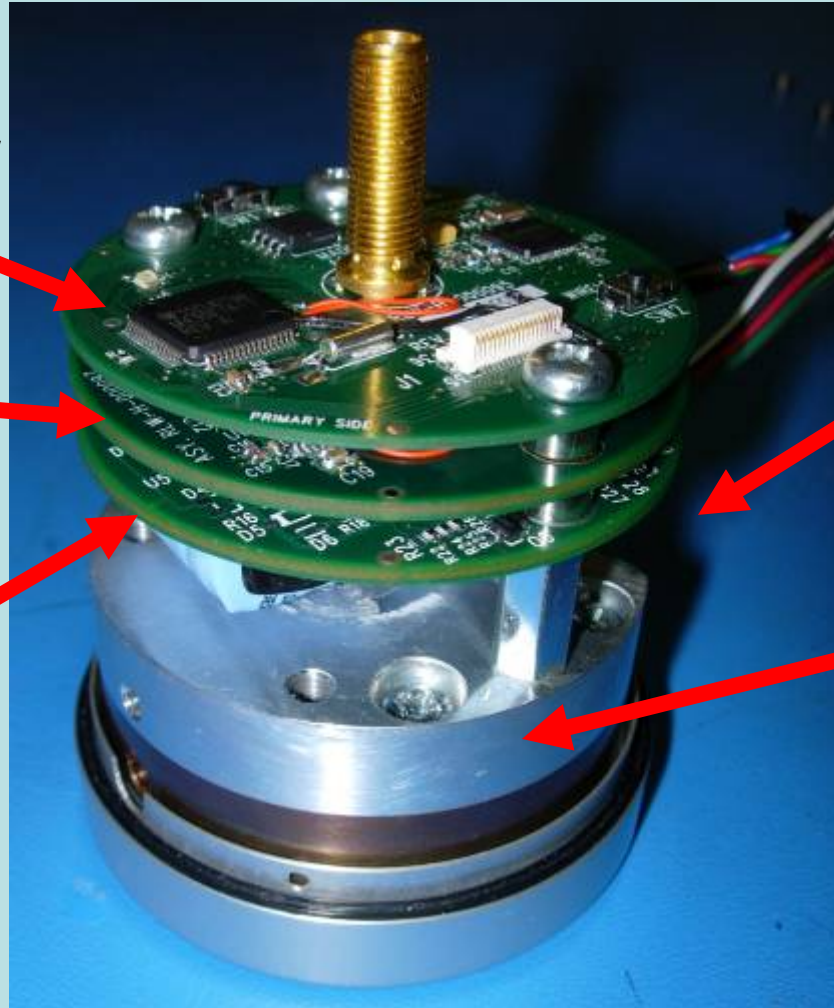


S5NAP Assembly

Wireless Microcontroller Module

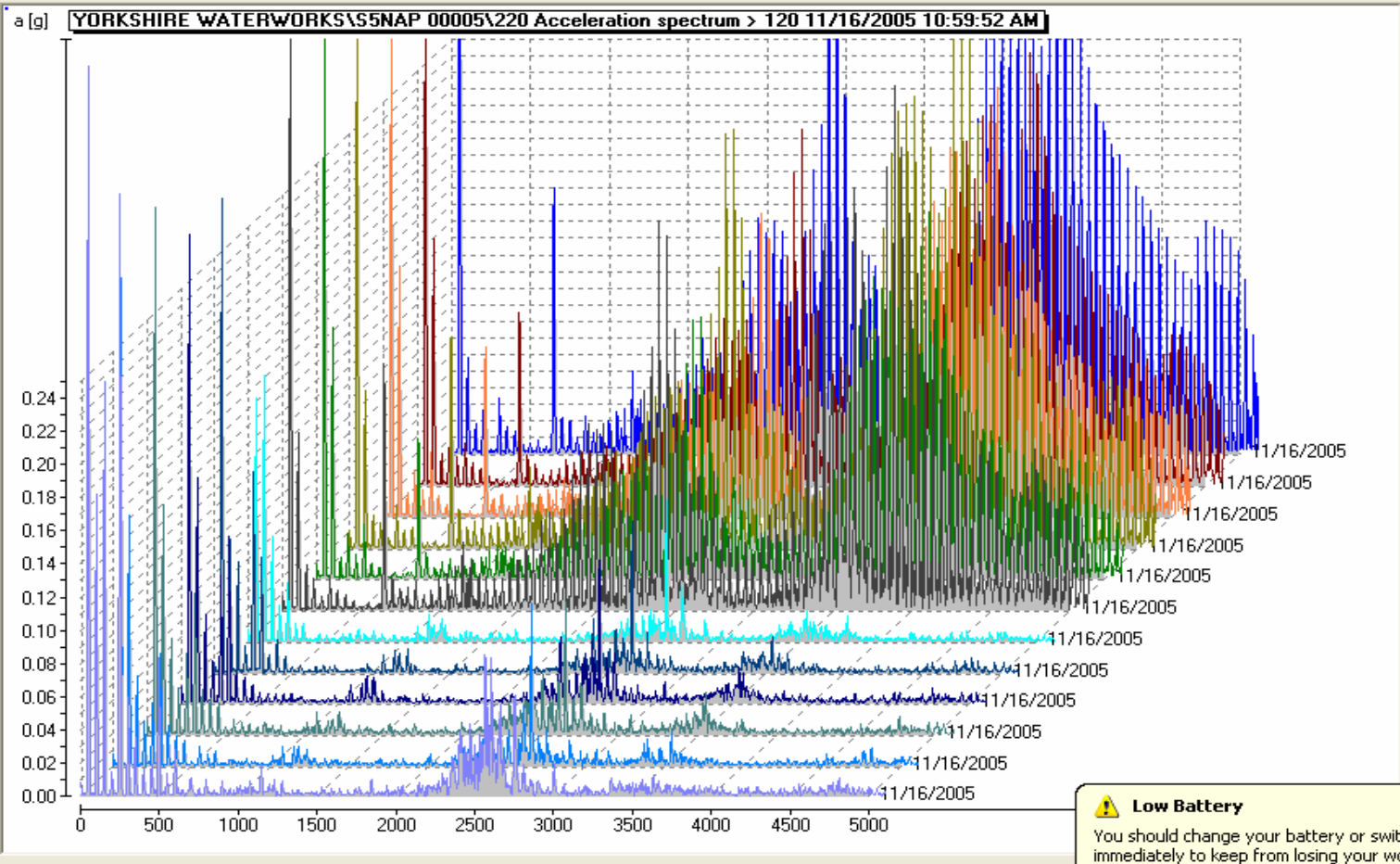
Sensor IO Module

Power Management Module



Sensors -
Accelerometer &
Temperature
(Behind Generator In Base)

Perpetuum PMG7
Power Generator

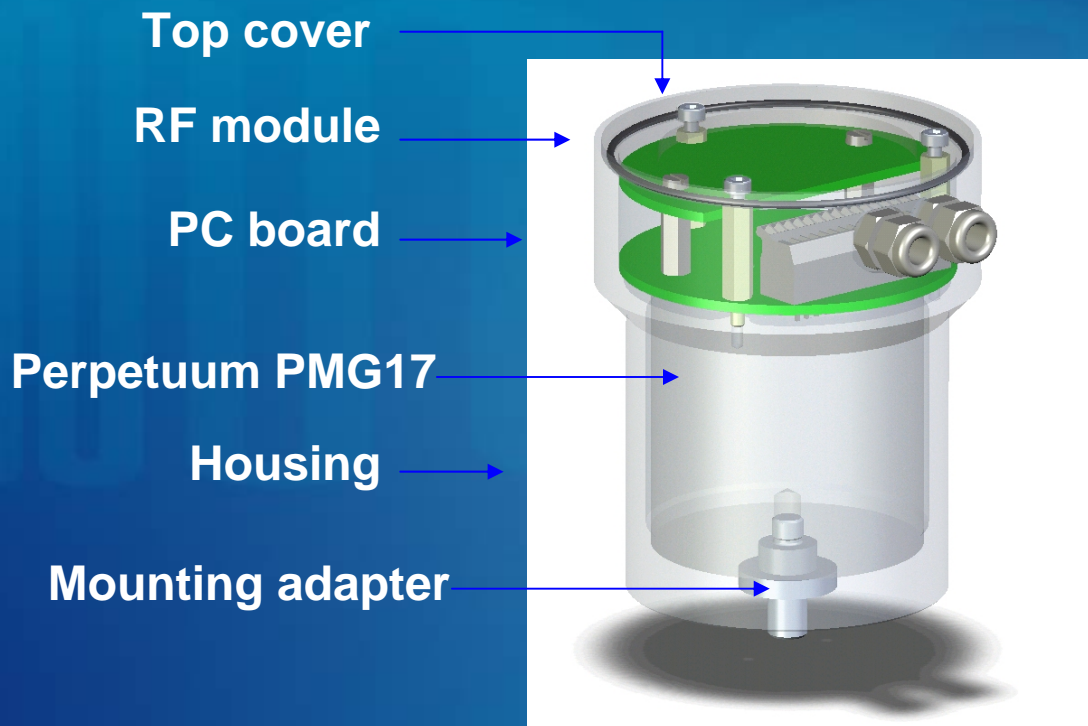


Cursor	Date	Alarm
	11/16/2005 1:59:45 PM	
	11/16/2005 1:49:37 PM	
	11/16/2005 1:39:28 PM	
	11/16/2005 1:29:20 PM	
	11/16/2005 1:19:11 PM	
	11/16/2005 1:09:03 PM	
	11/16/2005 12:58:53 P	
	11/16/2005 12:48:44 P	
	11/16/2005 12:38:36 P	
	11/16/2005 12:23:36 P	
	11/16/2005 12:08:27 P	
	11/16/2005 10:53:52 A	

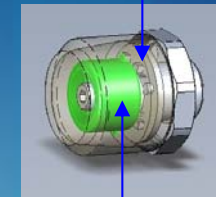
Low Battery
You should change your battery or switch to outlet power immediately to keep from losing your work.

Pruftechnik VIBNODE *RFA*

- Launched at Hanover Fair April 2007
- 2 Accelerometers per generator
- Nanotron Radio



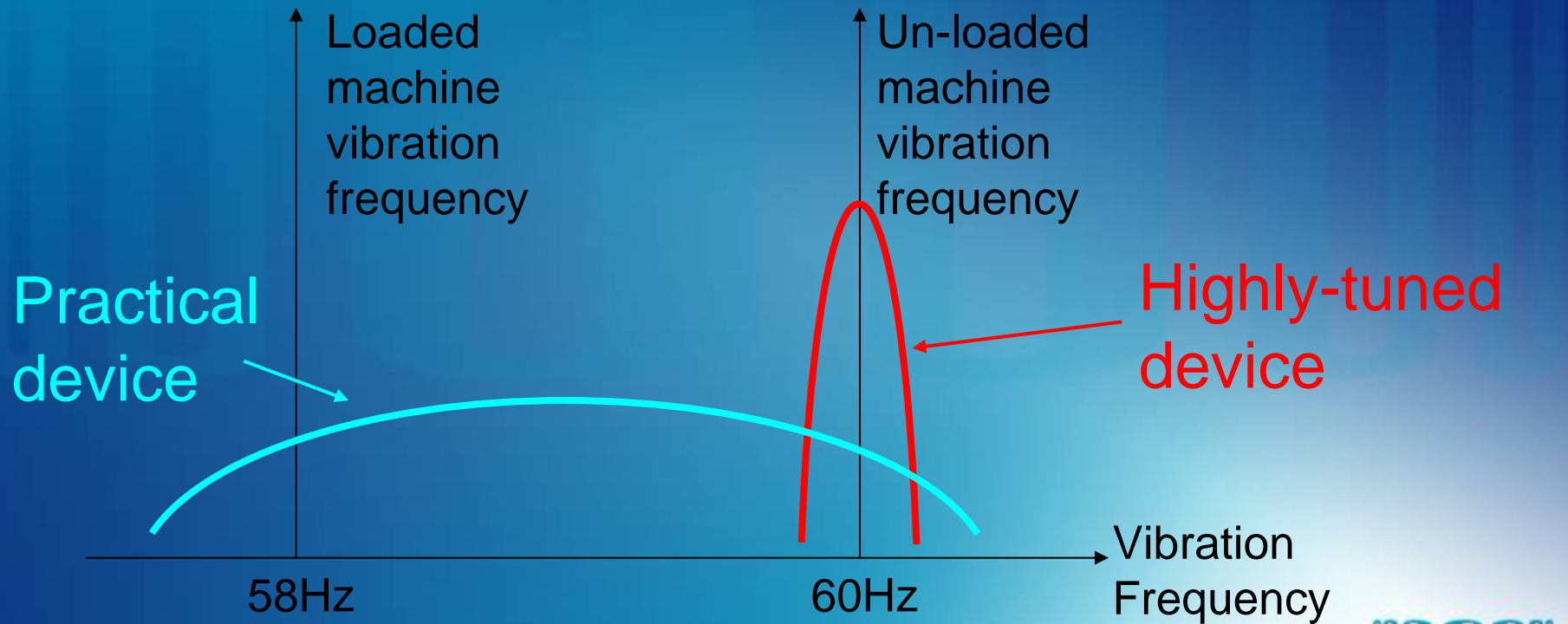
Temperature probe



Accelerometer

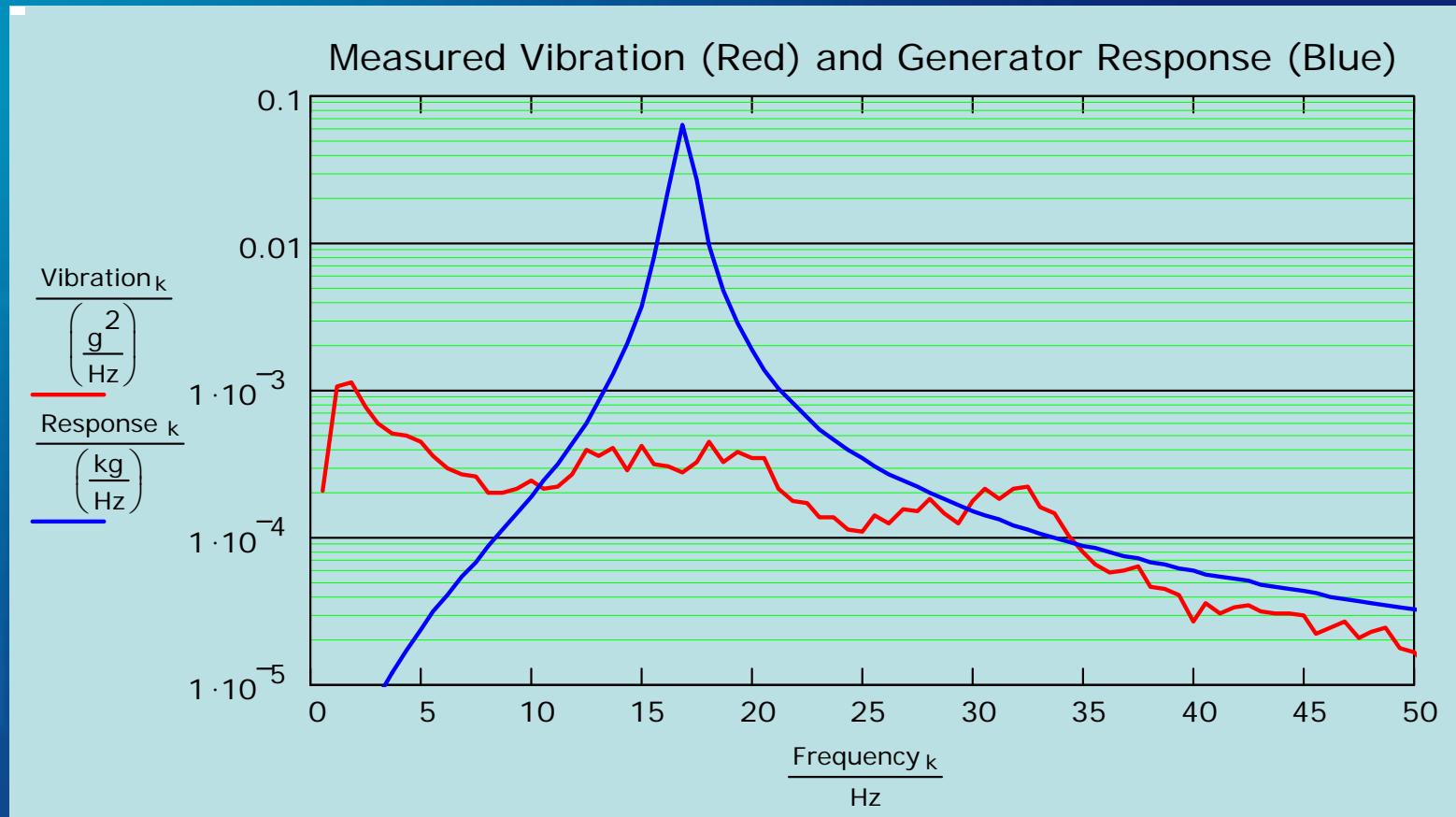
Practical Bandwidth and Stability

- Generator must cope with variations in:
 - Machine vibration frequency
 - Environmental temperature
- Narrow-band “hero” devices are of no practical use.



perpetuum

Vehicular Applications



- Measured vibration of saloon car body
- Power averaged over urban driving including stops: **3mW**

Future Trends in Energy Harvesting

- Battery technology will improve but is not everlasting source
- Solar, Vibration and Thermoelectric most likely options for W.S.N.'s
- Vibration will provide main power source in Industrial and Transportation sensing
- Energy Harvesting is key to unleashing demand for benefits of wireless

Conclusion - Energy Harvesting

- It can be done and it is being done
- Many wild claims out there
- Many laboratory devices
- Ask – where is it working and with what energy source?
- Success comes from realistic selection of proven device