Introduction to telemetry

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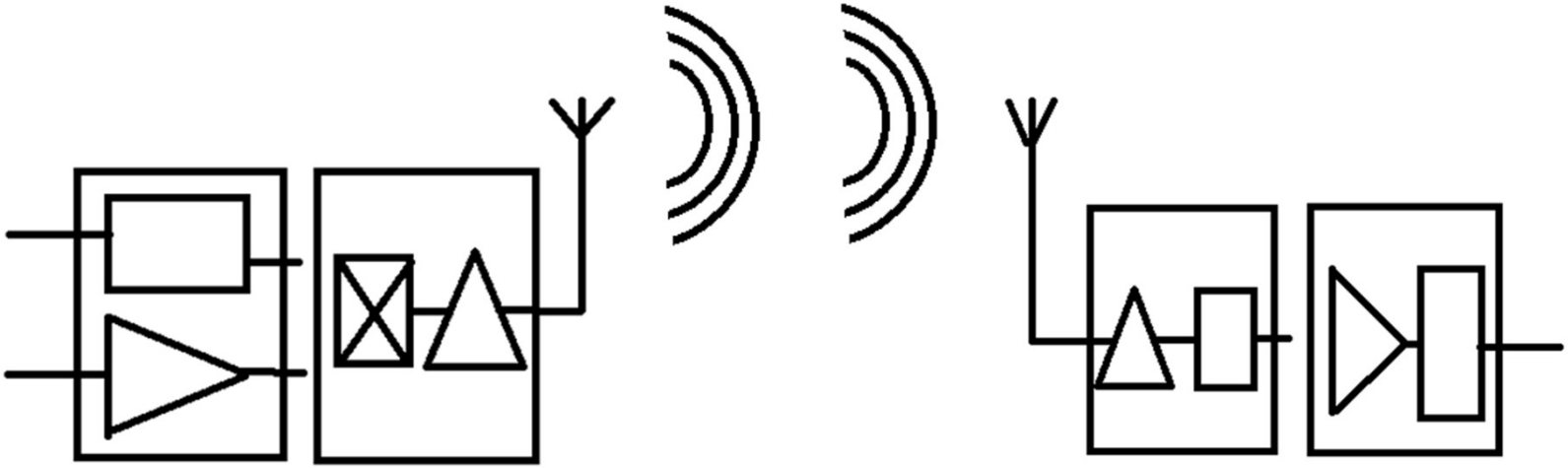
Giacintec
Mesure, Télémesure, Equipement

Telemetry is the mean of reading measurements remotely.

In this large notion we are only discussing of what we know pretty well, the part transmitting measurements wireless. From these technologies, our expertise is focusing on industrial systems using radio transmissions.

Following discussion is concentrating on what we know the best, the efficient radio transmissions for rotating machines.

What is including a telemetry system



Conditionning and amplification

Modulation Coding and Transmission

Reception Demodulation Decoding

Scaling Filtration

Transmitter

Receiver

The information to be transmitted is converted in electromagnetic wave train that will be propagated in space.

So a pulse succession
Or a sinusoidal signal

And what are transmitting these wave trains ?
- An amplitude modulation or
- A frequency modulation

Analog modulation using a sinusoidal carrier
U1 to be transmitted, auxiliary signal or carrier is
$Up(t)=Up \cos \omega pt=Up \cos 2\pi fpt$

For the antenna Upt modified by voltage U1(t) so U2(t)
U2 is not sinusoidal $U2(t)=U2(t)\cos [\varphi 2(t)]$

U1 act on U2(t) amplitude modulation
On f frequency modulation
And on φ phase modulation

From these bases telemetry concept can be built knowing direct carrier modulation means possible disturbances, measurement signal may be bothered. For this reason, measurement signal will be shaped and protected before transmission.

Out of conditioning and before transmission there is a phase of formatting the signal.

One has to remember that two main technics are available :

- Digital
- Analogical

In both cases an error or spurious signal out of conditioning will be at receiver output, either hidden in digital message or displayed in analogical output.

Different coding and transmissions

Different technologies

- Bluetooth, WiFi, ZigBee, proprietary
- Modems RS 232 etc …
- Pseudo PCM
- PAM
- PDM
- PCM
- FM
- FM / FM

Bluetooth, WiFi and so on … are designed for point to point or proprietary networks.

RS is send after measurements through, for instance, above listed means.

Pseudo PCM are coding using cheap clocks compared to underneath systems.

PAM, PDM and PCM are efficient digital means but expensive.

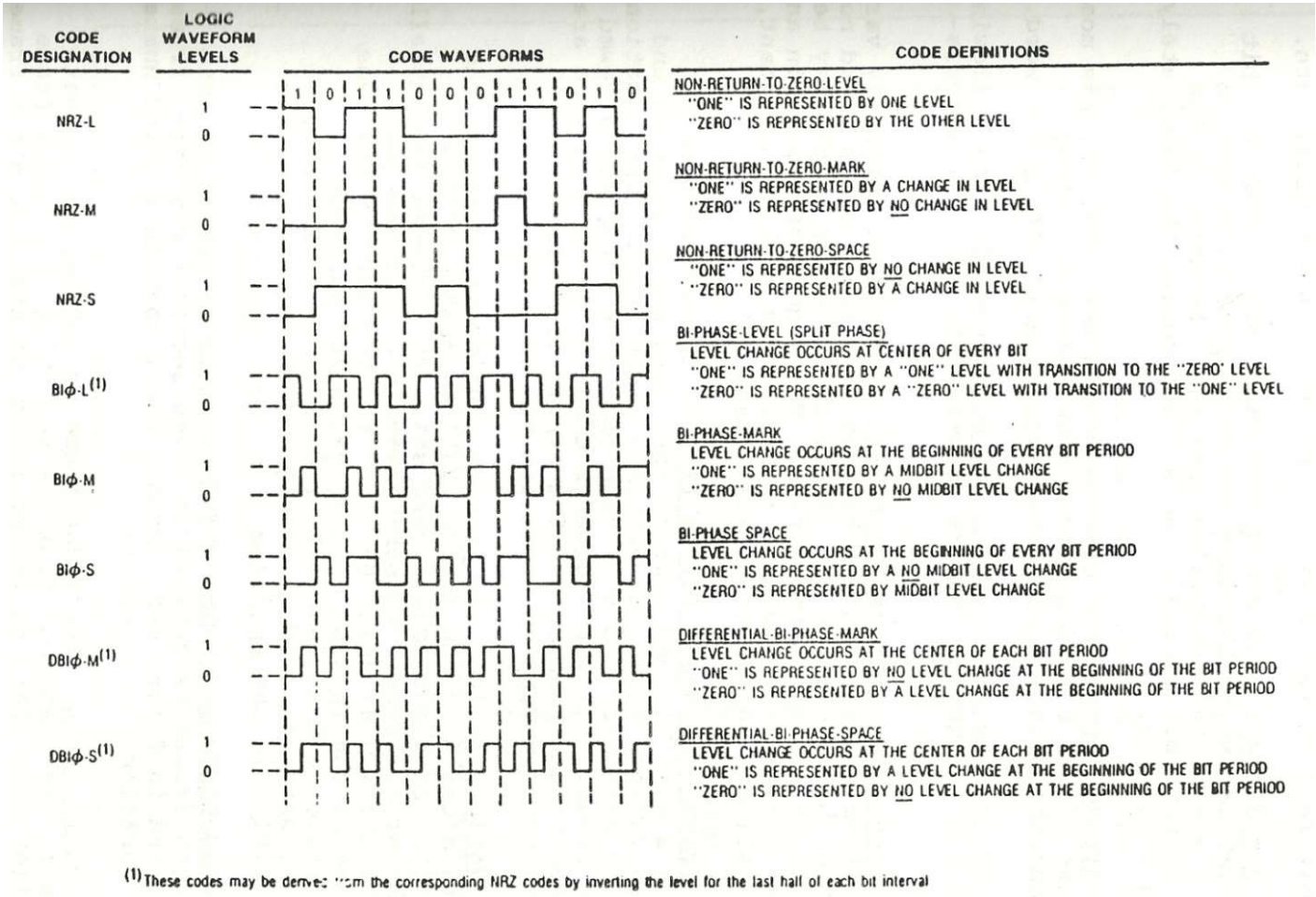
PDM : Pulse Duration Modulation
PAM : Pulse Amplitude Modulation
PCM : Pulse Code Modulation

The first one is currently used for simple coding helping PDM clocks developments.
PAM still exist but is not frequently used.

PCM is in use for mil and spatial telemetries were a large number of channels and large bandwidth are needed.

PCM is expensive and particularly because clocks used are complex.

Example of PCM encoding



Frequency modulation :

Carrier amplitude is constant, U1(t) modify carrier frequency

Fz(t)= fp+ Δ f(t) >> Δf(t))= U2(t)

U3(t) = Up cos [$2\pi V$]

μz(t) = Up cos [$2\pi fpt + 2\pi V\int$ Uz(t) dt]

Si U1(t) = U1 Cos ω1t

U2(t) = Up cos [$2\pi fpt + 2\pi$V.U1/ω1. sin ω t]

Uz(t) = Up cos [$2\pi \boldsymbol{fpt}$+ Δf/f1 sin ω1 t]

Small volume transmitter includes :

- Conditioner (s)
- Gain adjust soldering pins
- Sub carrier (s)
- Transmitter

Receiver catch the signal, filters sub carrier (s)

And convert into analogical output.

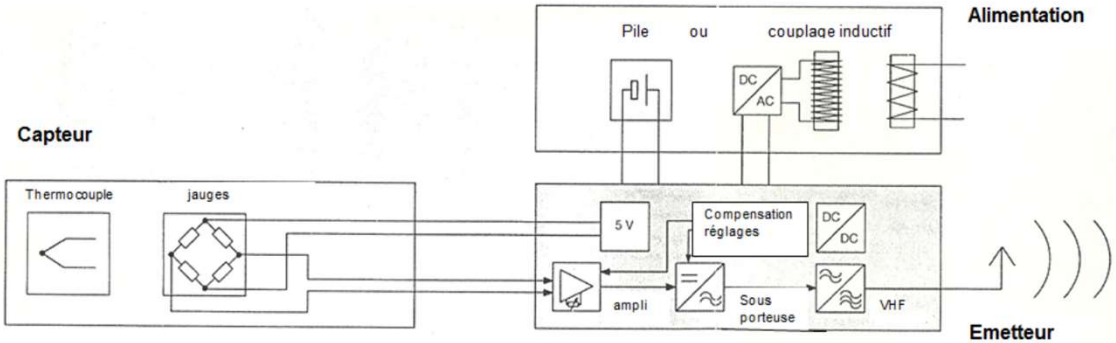
Direct FM modulation : this use a direct modulation of the carrier with measurement signal and this is not reliable, as for direct AM modulation.

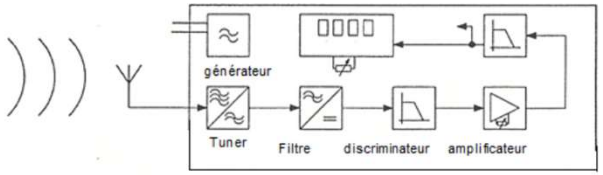
Double modulation and particularly FM / FM help designing efficient analogical systems.

Even if we are familiar to digital transmission, as a lot of systems exists we concentrate on analogical FM/FM telemetry.

Single channel FM /FM

- Powered with batteries
- Or inductive loop
- Conditioned sensors
- Converted into frequency
- Then frequency modulate carrier
- Tuner receive the carrier
- Pass band filter recover sub carrier
- That is converted into voltage
- Then filtered or not and adjusted for Voltage output

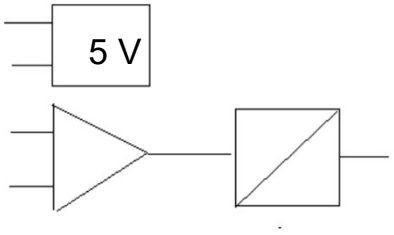




FM carrier

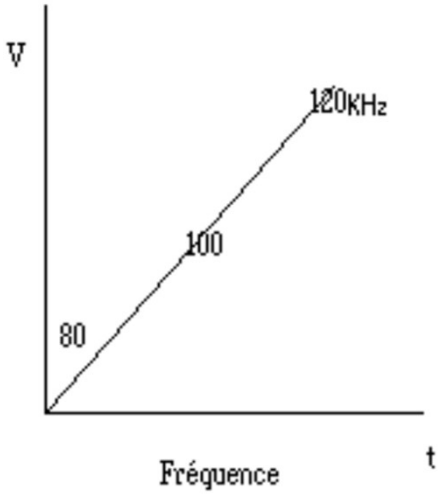
- Frequency carrier has been chosen in range 150 to 300 MHz extended P band, non directional.
- Power of 5 mW allows transmission over 10 meters but is low enough not to generate perturbations in surrounding area and being prohibited.
- This carrier allows to set 8 simultaneous channels on a single band.
- It is, beside this, possible to use several frequency bands carriers in same area
- Measurements are in phase one with the other and carriers as well allowing several transmitters in same location.
- Extended P band can be used legally without any problem as long as power remains below 5 mW

Measurements at transmitter side



Differential amplifier

Subcarrier



Transmitter can supply power to the sensor if needed (5V). Differential amplifier handle signal out of sensor with gain adjustment and or cold junction compensation for thermocouples. Voltage is then converted into subcarrier frequency that will modulate the carrier frequency. For instance a 0.000 V will be translated as 100 KHz, minus full range, 80 KHz and positive full range120 KHz.

Thinking of a full range 0 to 100 °C, 1 °C will be 1,2 KHz as zéro = 100 KHz and full range = 120 KHz.
Thinking of another sensor with zero at 101,2 KHz and nothing can be done to recover the real zero, new zero will then virtually be of 1,2 KHz.
If it is possible to adjust at sensor end the offset will be eliminated, otherwise zero value will be set at new value.

For the purist true zero is a frequency value, for measurement operator, cheating will mean zero is not really the sensor truth.

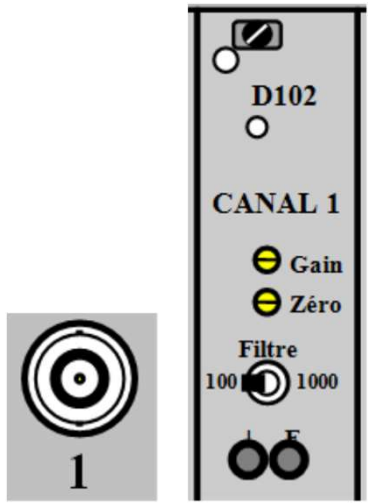
Same way for the gain where the transmitter will be dependant of gain adjust via external resistor and may, despite its excellent accuracy may show a small difference.

On receiver side the frequency may be picked up through F jack at bottom right and Voltage value on BNC connector at backside.

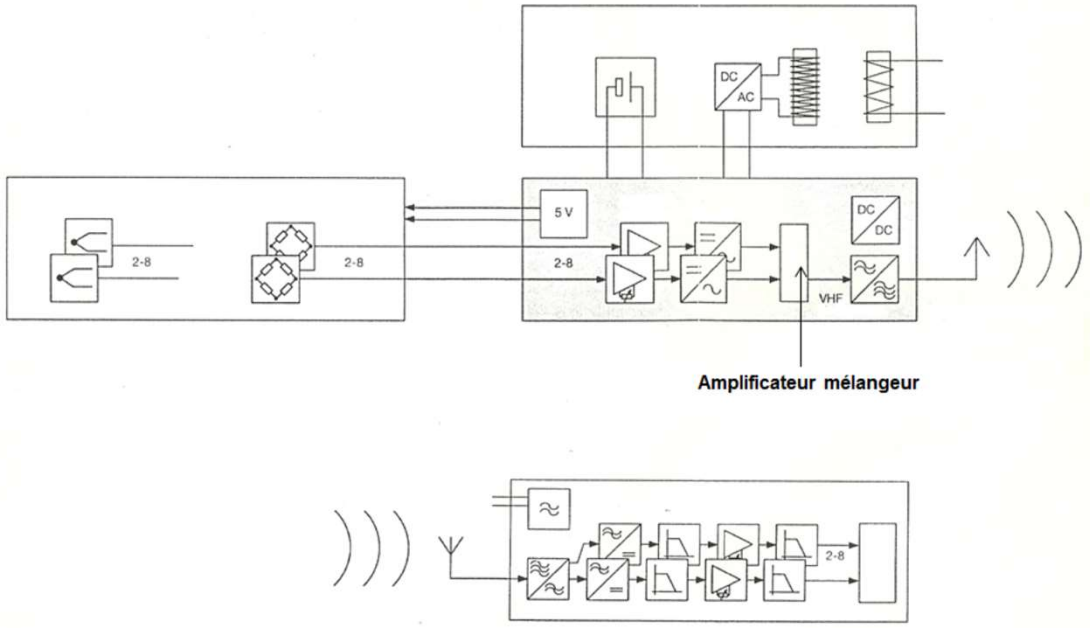
BNC output can be adjust at 1,2 KHz representing 50 mV on a 5 V range, Potentiometer named zero will reset the output so 0,000 mV will be the reading. For the gain that may not be 120 KHz gain potentiometer will modify of few mV the KHz offset.

A real mechanical calibration will ease adjustments of zero and full scale and print the motion determining linearity and hysteresis.

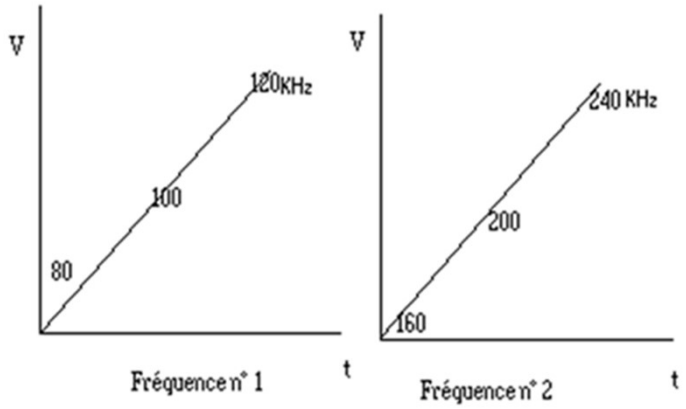
At the opposite of sensors wired physically, no adjustment can be done on transmitter side from receiver side.



Multichannel system : Each measuring channel has its own conditioner and its own Voltage to frequency conversion. Each sub carrier frequency dedicated to a measurement channel will use a different frequency band. Such a way, mixing the different frequencies will achieve a frequency multiplex and the multiplex will be transmitter on the carrier.



For instance for two strain gages bridges channels, if both are exactly balanced to 0 V on each channel, Channel 1 zero Volt will give 100 KHz and channel 2 : 200 KHz, Both frequencies mixed will modulate the carrier at 200 MHz.
Both channels will be transmitted simultaneously.



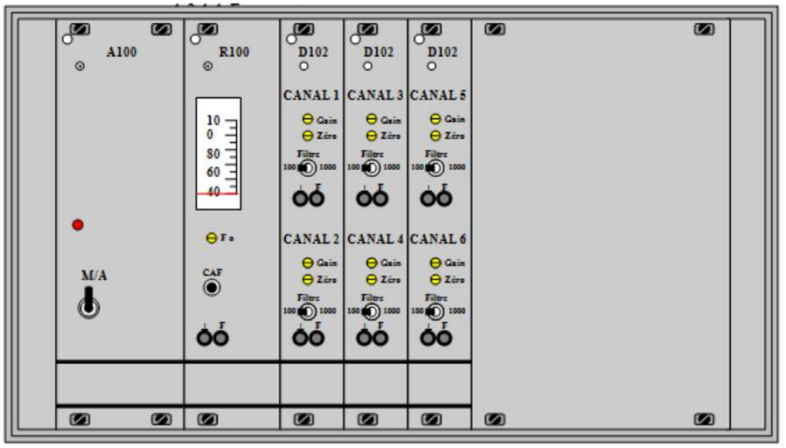
2 sous porteuses transmises simultanément

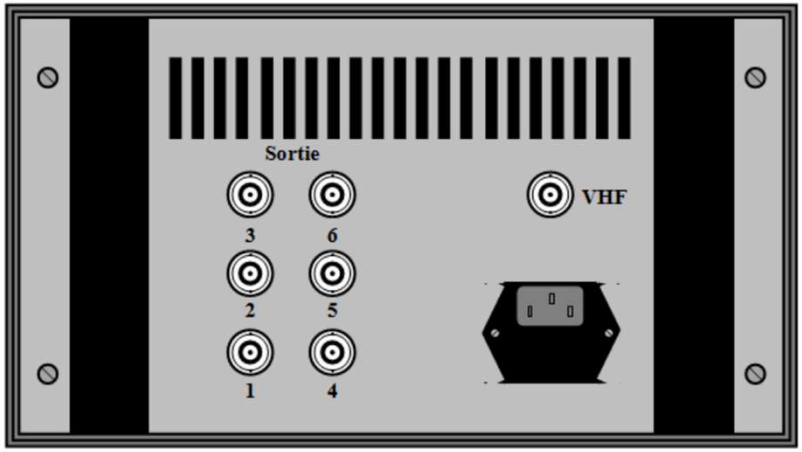
This allows large bandwidth per channel DC to 10 KHz or DCX to1 KHz for 8 channels Without Phase difference in between channels.
Another point is there is no phase difference in between measurements from several transmitters.

Here we can see front and back view of a 6 channel receiver.

Left module is used for power supply next one is the FM tuner and the 3 left are 2 discriminators modules each.

On back side we can see VHF receiving antenna input and the 6 BNC connectors for each channel Voltage output.





Environment

Temperature : - 40 °C to + 125 °C for the transmitter

Humidity : 90 % RH

Shocks and acceleration :

- Shocks 25 000 g and over
- Centrifugal acceleration 25 000 g to 100 000 g

- Submarine operation with specific housing
- ATEX 

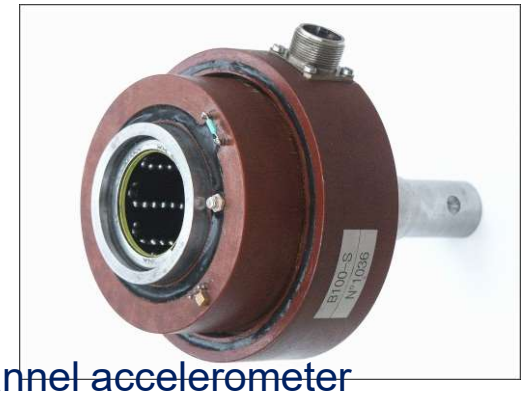
with protection housing

Classical and miniature systems

6 channel temperature

Ribbon transmitter

2 channels strain gages



1 channel accelerometer

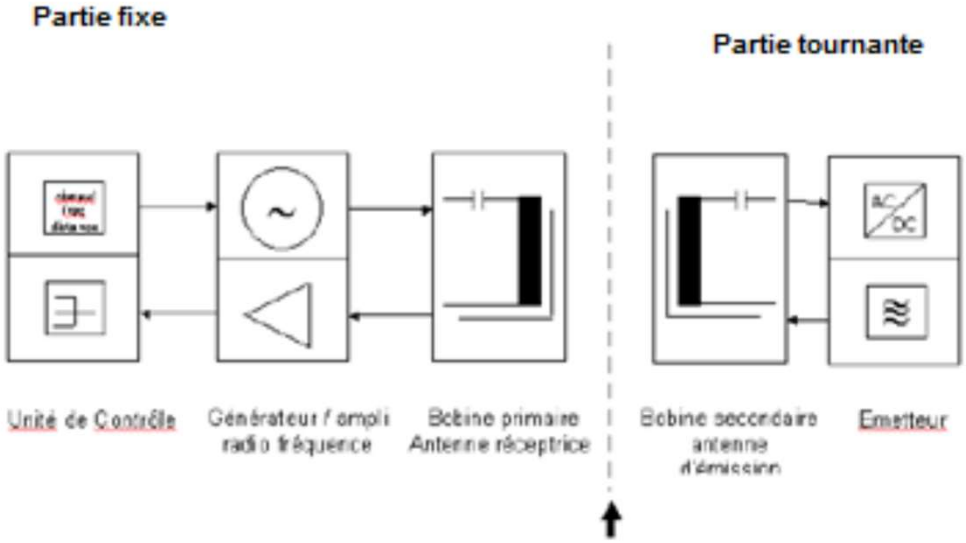
Classical single channel

Power supply

- Battery
- Or induction

Lithium 9 Volt

Inductive power supply is a power transformer withair gap instead of metal.

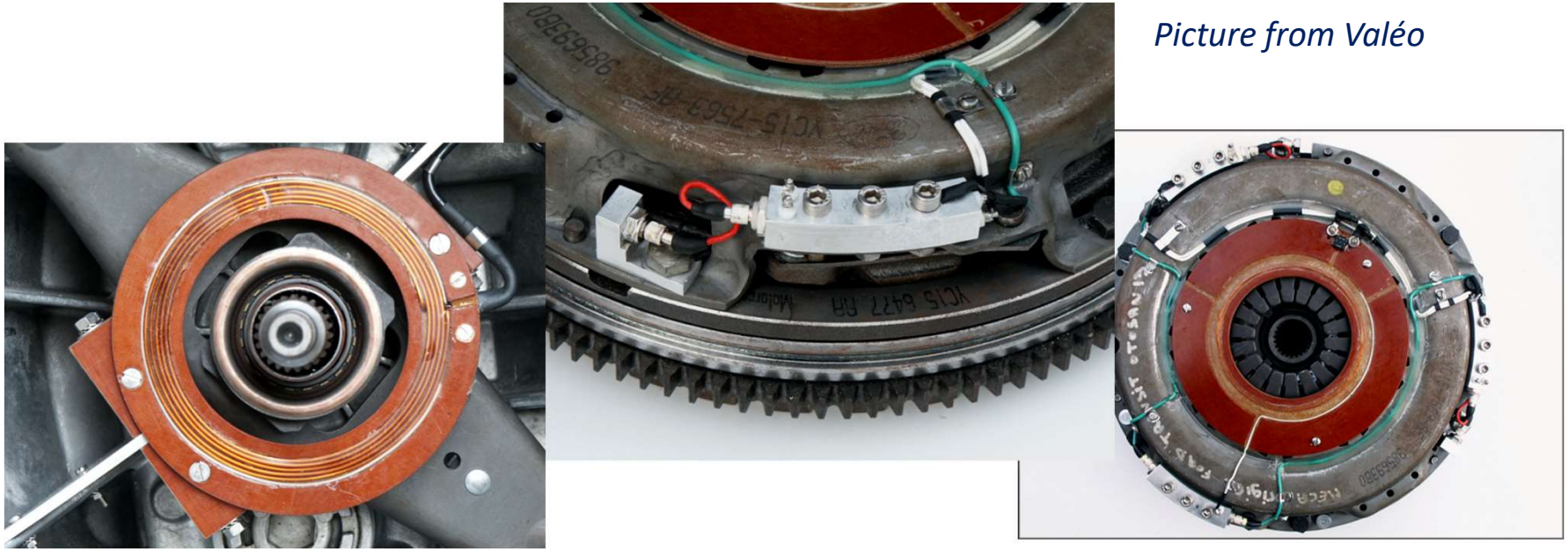


Applications :

The picture shows two transmitters single channel for plastic extruding machines screws. Behind the crown in their envelope, the two inductive secondary coils may be seen. The flat part has primary coil and receiving antenna.

Picture from Clextral system

Acceleration measurements on a clutch bell, picture on the middle shows the transmitter, on the right the complete rotating system and on left the primary inductive coil.
The system uses two piezoelectric accelerometers for tengentials dynamic acceleration measurements.

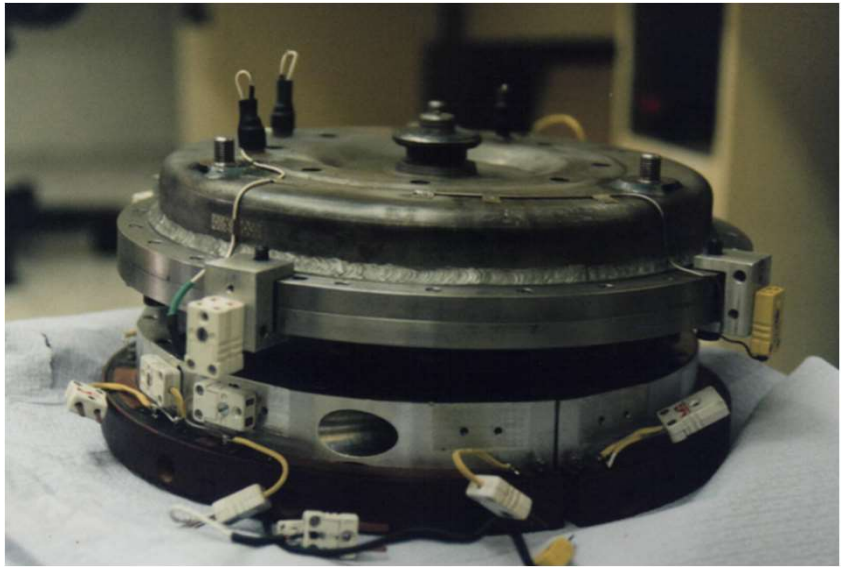


Picture from Valéo

On the right another clutsc bell with 6 temperature measurements and two pressures. Afterword a blade speed measurement behind the the bell has been added. For quick connections, plugs have been installed. The entire system is powered via inductive loop.

Below, part of a gear box.
3 strain sensors.

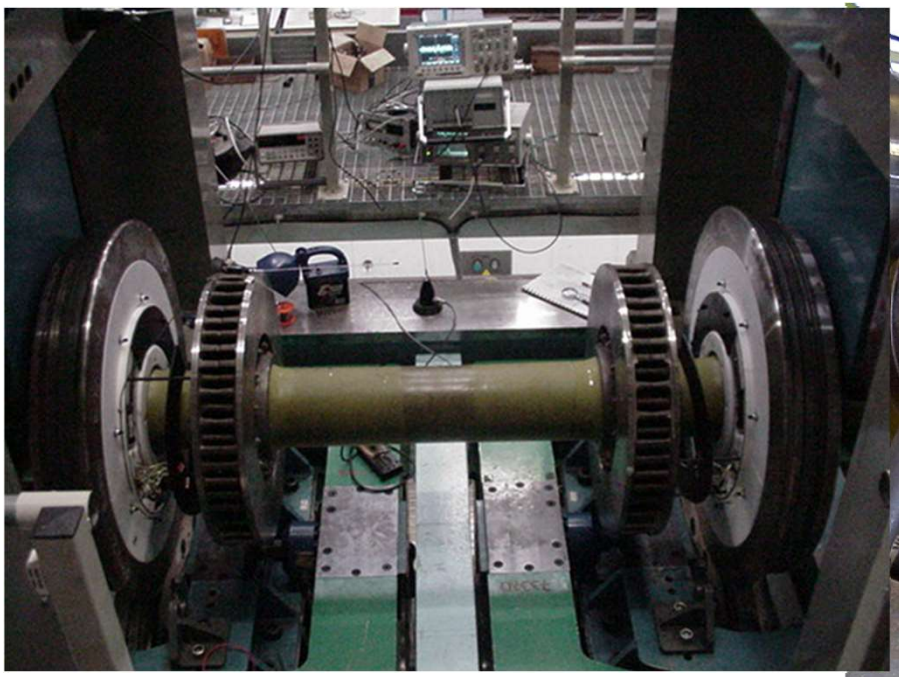
Pictures :
- *G.M.*
- *Valéo*



On the right torque measurements on railroad fatigue rig.

On the left, 6 copmponent strain balance on each side of the axle. A gauche, 6 voies de mesures de déformations de part et d'autre de l'essieux

Picture J.L. Rouvet at SNCF



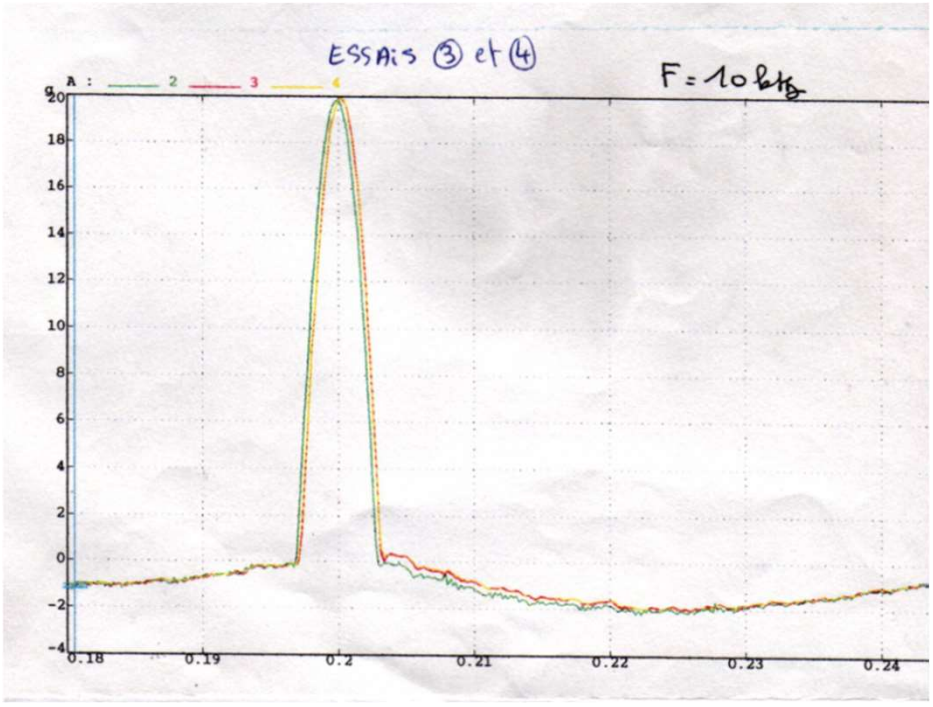
Temperature measurements on a small alternator. Transmitter was installed on a mechanical part for cooling and uses a Teflon spacer to decouple temperature of the rotor above 125°C from transmitter.

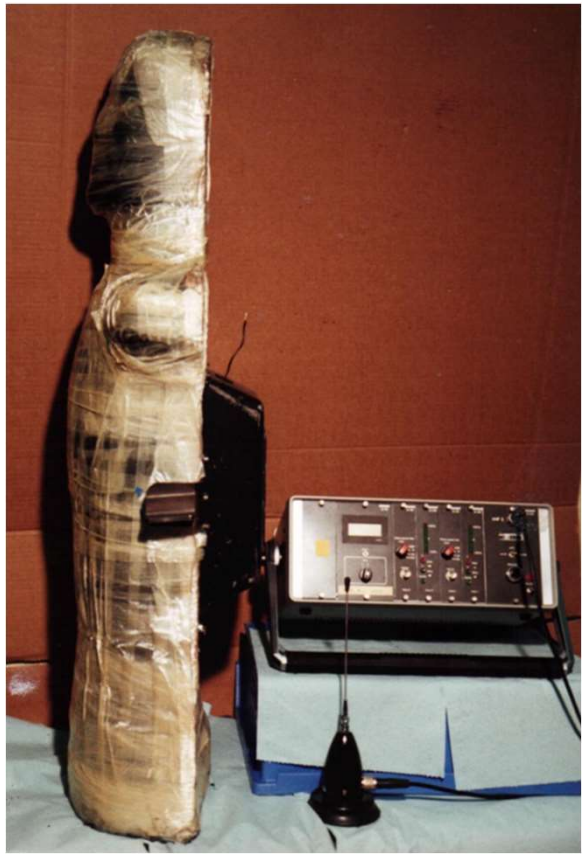
System is powered by inductive power supply.

Picture in our lab

Impact body block telemetry. The entire system has been calibrated on shacker. Black housing contains batteries.

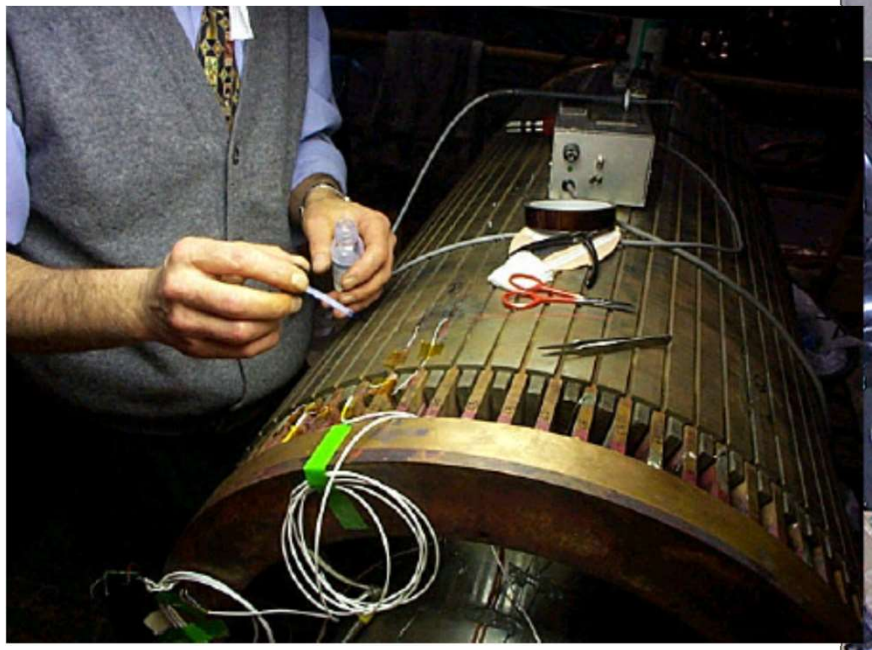
Picture ZF

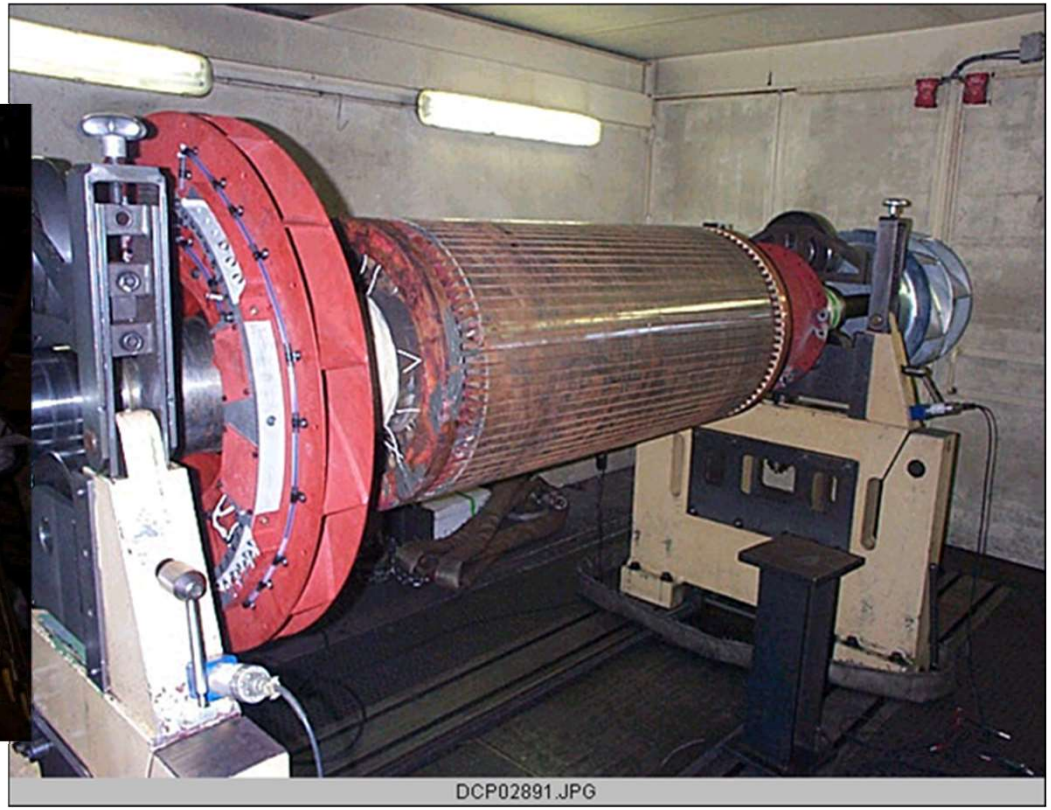




Multichannel strain and temperature measurements on an alternator. Sensors are directly implemented on alternator copper bars.

Picture Alstom

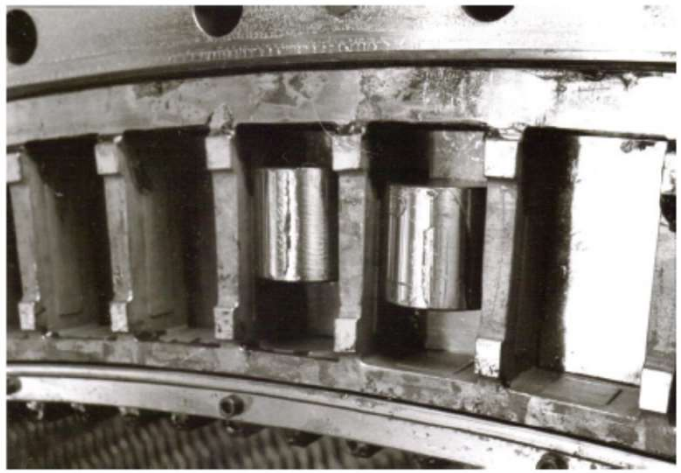




Micro miniature telemetry system for a steam turbine.
Transmitter is connected to Matroc's dynamic strain gages.
Power supply is achieved via batteries installed in same volume than the transmitter.
Several transmitter have been installed and measurements are in phase one with the others.

Application : Load measurements inside the rolls of a large tunneler ball bearing.

Ball bearing was 8 meters diameter and the target was to verify if the ball bearing was over loaded while drilling.



Picture J.L. Rouvet at R.K.S

Acceleration and temperature measurement on a catenary pylon for RATP. The target was top measure mechanical traction on the cable along with temperature. Beside this one telemetry channel was used to measure cable length coming back from the ground.

This specific application needed a transmission distance of 30 meters to connect the transmitting assembly to mobile ground receiving station.

Picture RATP

Picture Dynae

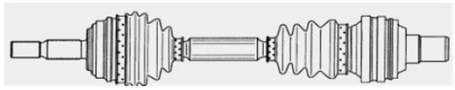
Torque measurement on a concrete crusher.
One can understand the telemetry is installed quickly on site for diagnostic purposes.

Several systems are used around the world for diagnostic purposes on machines.

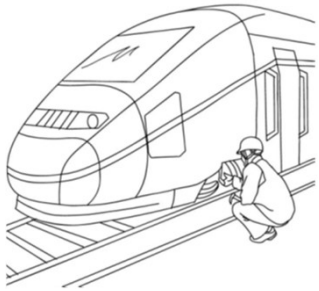
Each part of the system is small ant fit into a portable case with all equipment to install stain gages and thermocouples.

Applications

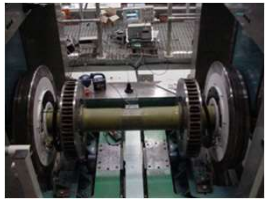
Automotive



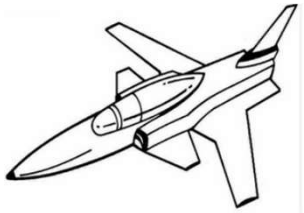
Torque measurements and others



Railroad



Test rigs, fatigue measurements
motors and others
Six composants sensors



Aeronautics

Turbines : strength, blades
vibrations and others

Marine

Motors
Torque, motor steering, clutches, gear boxes, connecting rods and others

End