TRANSENSE TECHNOLOGIES

Future Propulsion Conference 2022

Sharing Version

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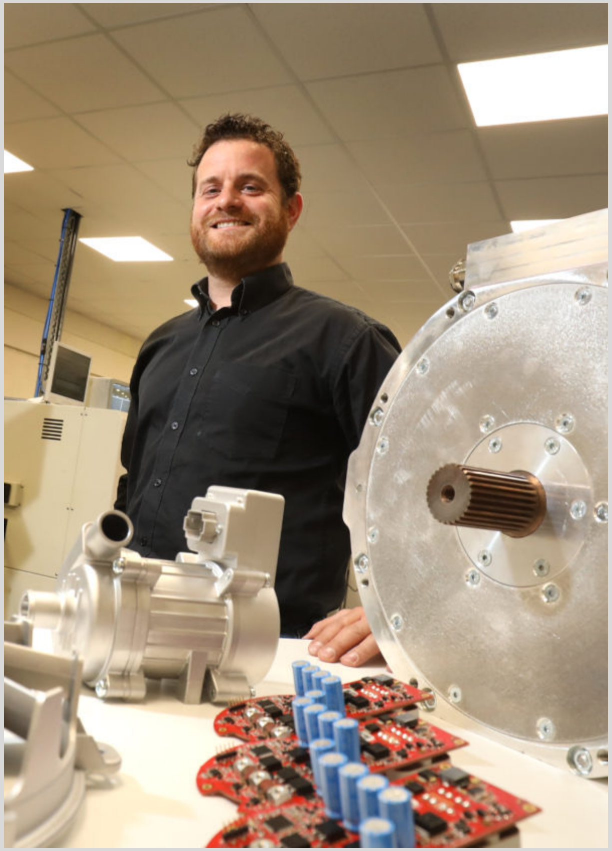
transense technologies plc

Ryan Maughan - Background

- Founded AVID Technology in 2004
- Developed powertrain components and systems solutions for electric and hybrid vehicles
- Sold non-contact rotary position sensor and drive by wire controls business to major German T1 in 2012
- Span out battery systems business, Hyperdrive in 2012
- Acquired EVO axial flux motor technology IP and business from GKN in 2018
- Exited AVID Technology to Turntide 2021
- Working as a Strategic Advisor to Transense Technologies since Jan ‘21
- Developing other new projects in motors, drives and battery systems



The Motor Development Cycle

- Motor torque is proportional to B field current in line with the motor torque constant K_t
- Motor properties and loss mechanisms affect the relationship and current control
- In order to calculate motor output torque we characterise motor over a range of operating points and create look up parameter tables and control variables
- Current is measured by hall effect sensors in the motor controller (Inverter) and this forms a control loop inside the inverter
- Dynamic nature of loss mechanisms, signal filtering required on current sensors and manufacturing tolerances motor control is complex and has to accommodate all of these parameters
- **What if there was a better way to characterise and control electric motors?**

Dyno Image Courtesy Marposs EDC

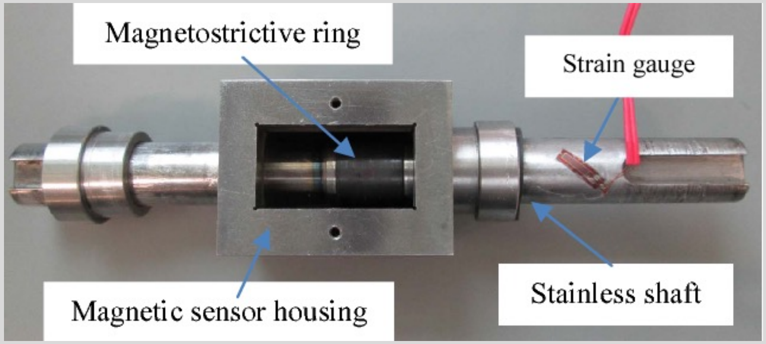
Alternative Sensor Technology

Why do we not fit torque sensors into every electric motor today?

Factors to consider:

- Cost
- Technology
- Position of sensor and electronics
- Size & mass
- Wireless
- Response rate
- Position of sensor
- Durability
- Shaft material
- Calibration durability

Magnetostrictive



Strain Gauge

SAW TECHNOLOGY

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SAW technology can provide real time measurement of:

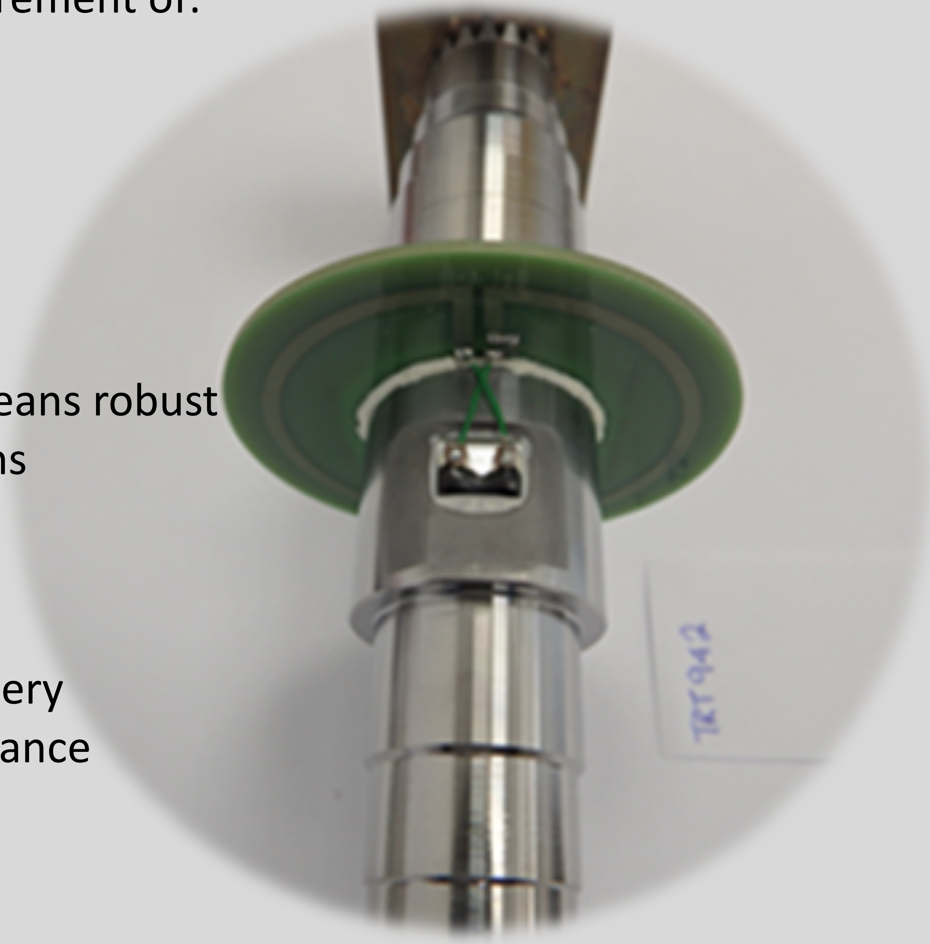
- Torque
- Temperature
- Pressure
- Strain

No active electronics on the rotating shaft, means robust low mass, wireless, battery-less sensor systems

Used to enable:

- Closed loop control of motors and machinery
- Real-time monitoring of machine performance
- Load and condition monitoring

A real time dynamometer in every motor!



COMPANY

Strategy and Vision:

Develop and supply robust and reliable wireless sensor technology and systems utilising patented SAW technology that measures torque, temperature, pressure and strain to improve efficiency, reliability and safety in critical propulsion and drive systems

Key Facts:

Founded 1991

Listed on AIM 1999

>£30m invested in technology

>50 granted patents

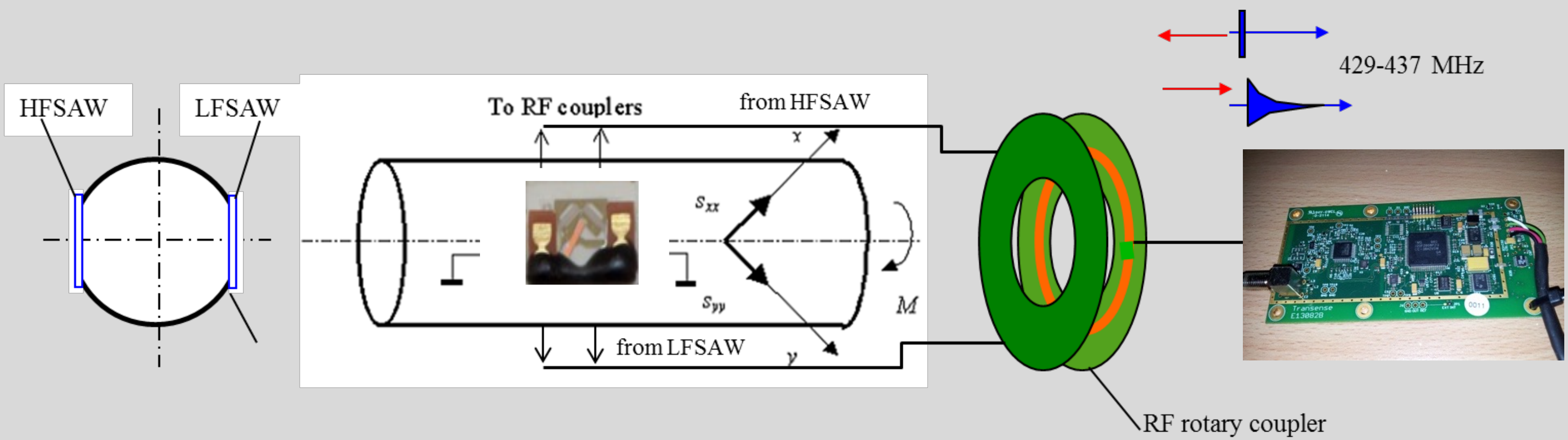
2015 – EMERSON – **Licence for Sensing HV Switch Temperature**

2016 – GE – **TMS Licence for Vertical Lift Propulsion**

2020 – BRIDGESTONE – **Licence for Off Highway Tyre Monitoring**

2021 – McLaren APPLIED – **TMS Joint Collaborative Agreement**

TECHNOLOGY



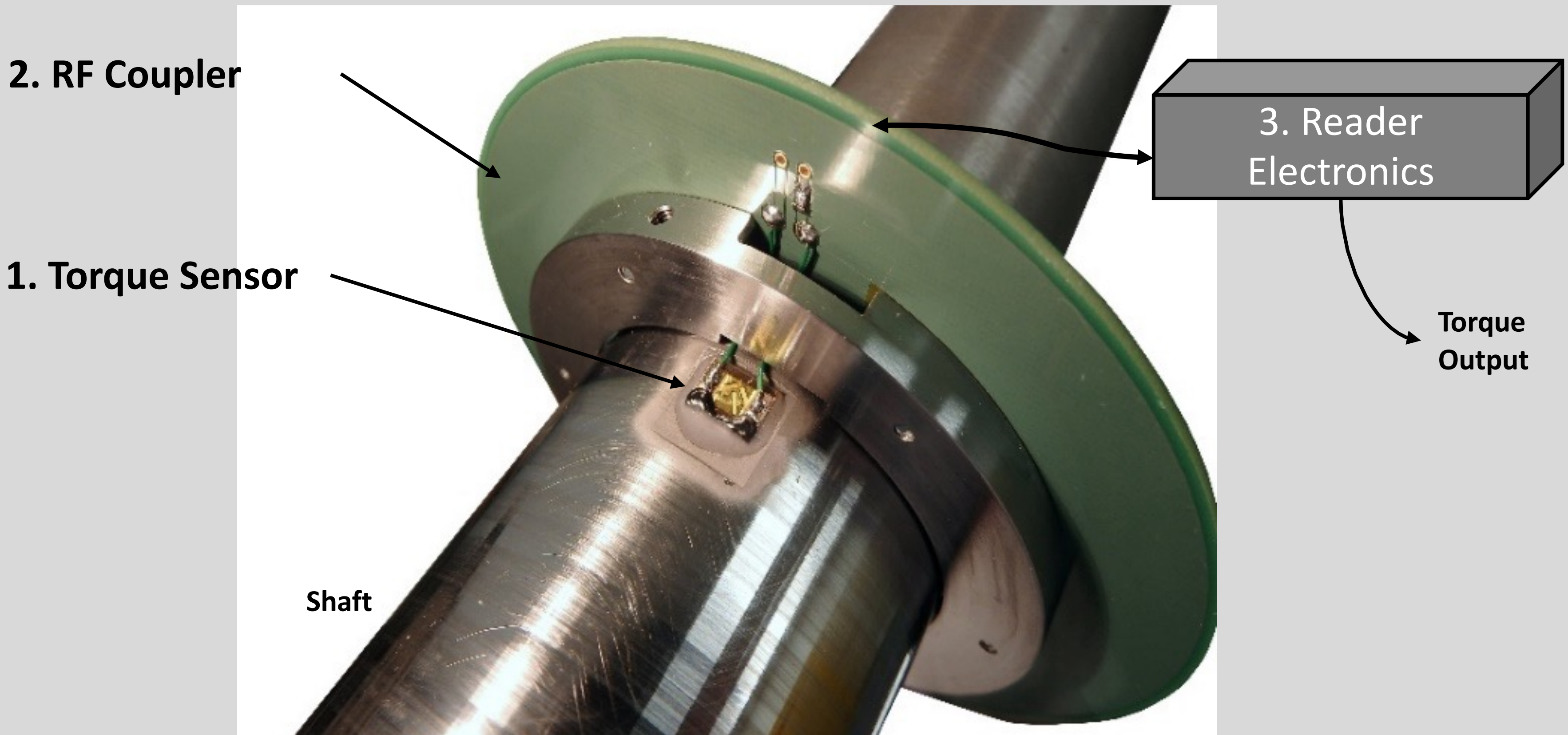
Torque M applied to the shaft changes the two SAW resonant frequencies in the opposite directions since they are strained differently.

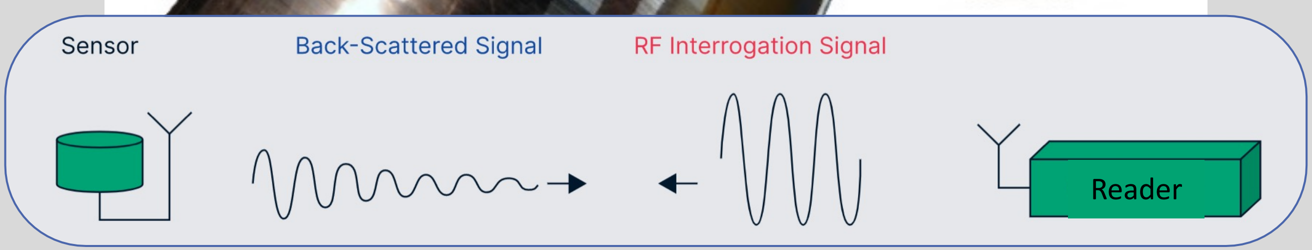
Using two SAW sensing elements and differential measurement allows compensation of axial forces and bending moments.

Main parameters of the reader:

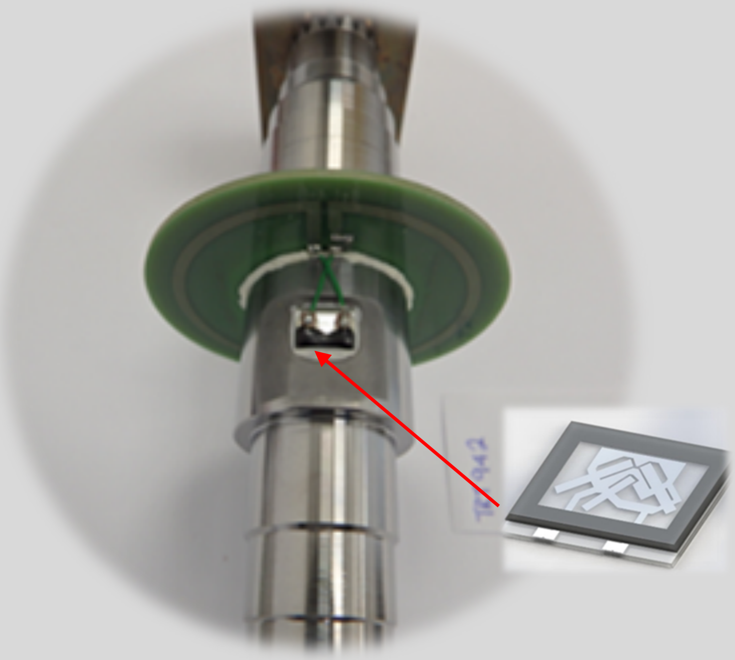
Frequency range:	420…440 MHz,
Frequency switching time:	<100 µs,
Output power:	0.5…10 mW,
Rx sensitivity:	-88 dBm
	@ SNR = 17 dB and BW_{rx}=1.75 MHz
Rx/Tx isolation:	>100 dB,
Random errors:	$\sigma_F \approx$ 100…600 Hz,
Systematic errors:	ΔF < 1 kHz,
Frequency measurement time:	150…366 µs

TMS COMPONENTS





MARKETS - Automotive



Typical EPAS sensor specification:

- Torque measurement range: ± 10 Nm
- Torque resolution (3σ) < 0.03 Nm
- Overload capability (die-shaft bond): ± (100…300) Nm
- Torque measurement combined error*: < ± 0.1 Nm
- Hysteresis < 0.06 Nm
- Torque reading update rate: 2 kHz
- Temperature range: -40° C - +125°C
- Dynamic torque: > 5 Nm/ms

Typical EDU sensor specification:

- Torque measurement max: 1000 Nm
- Torque resolution (3σ) < 1 Nm
- Torque measurement combined error*: < 1%FS
- Overload: 3 kNm,
- Torque reading update rate: 3.3 kHz
- Temperature range: up to 150°C
- Speed of rotation 12000 rpm

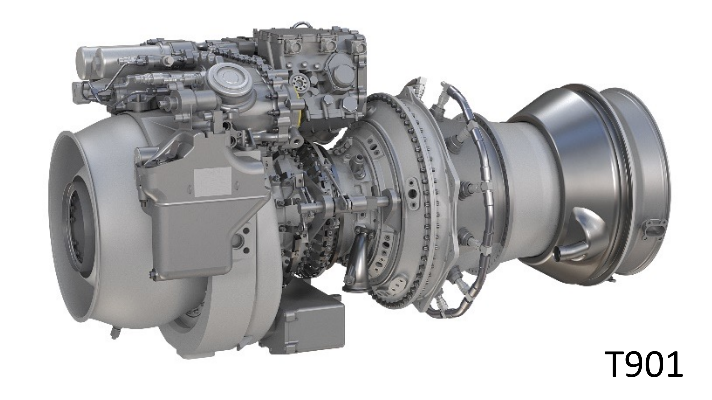
MARKETS - Motorsport

Typical INDY CAR sensor specification:

▪ Torque measurement max:	1000 Nm
▪ Torque resolution (3σ)	< 1 Nm
▪ Torque measurement combined error*:	< 1%FS
▪ Overload:	3 kNm,
▪ Torque reading update rate:	3.3 kHz
▪ Temperature range:	up to 150° C
▪ Speed of rotation	12000 rpm

MARKETS - Aerospace

- Improved Turbine Engine Program (ITEP) by US Army to replace T700 Gas Turbine with T901
- Transense technology is built into **every** T901 engine to provide real time torque monitoring for control and safety functionality
- The T901 turboshaft engine has **50% more** power, **25% better** specific fuel consumption while reducing life cycle costs to last **20% longer**
- **Strong demand for control and safety from new electric propulsion aerospace applications**



T901

CAPABILITIES
Torque Measurement System (TMS)

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- **Wireless**
- **Battery-less**
- **Non-Contact**
- **Small size and mass**
- **Not susceptible to magnetic forces**
- **Suitable for high volumes production**
- **Torque measurement capability**:
  - 0 to +/- 50KNm+
  - Option for bending compensation
  - Update frequency up to 6.67KHz
  - Accuracy <+/1% FSD
- **Suitable for wide range of Shaft types**
  - Steel, Aluminum, alloys
  - Ø20 ~ 250mm+
  - Hollow or solid
  - Any cross section

- **Environmental operating limits**
  - -40 to > +125^{o}C
  - Immersion in oil/oil mist is OK
  - Protected from water/moisture/debris
  - High shock/vibration tolerance
- **Connectivity and power supply**
  - Low voltage ~1W power supply
  - Dedicated CANBUS/Analogue or wireless output
- **Calibration requirements**
  - Torque & temperature (+/- 1% FSD)
  - Torque only (+/- 5% FSD)
- **Sensor Operating strain range**
  - Preferred range +/-350 µstrain
  - Max measurement +/-480 µstrain
  - Safe operating limit 1200 µstrain
  - Shaft design/adaptors used to mange strain range vs torque range

SUMMARY

- Robust and reliable embedded torque, temperature, pressure and strain measurement
- Small, wireless, batteryless, non-contact
- Possible to fit a real time Dynamometer to every electric motor!
- Improving system efficiency, reliability and safety integrity
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