

Metamaterials In RF industry

frecn|sys

Frequency Components and Systems



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Core business : Harsh environment and RF-ID, Tag

Sensors wireless and battery less



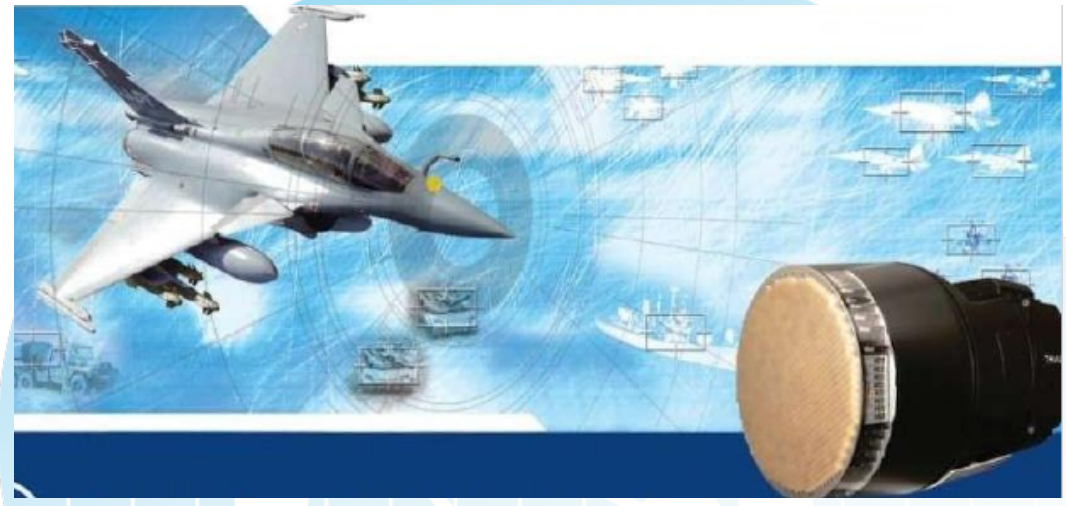
Pipeline, Alaska
Temperatures $< -50^{\circ}\text{C}$,
Humidity, Condensation,
remoteness



Turbines
Temperatures $> 500^{\circ}\text{C}$,
Rotation speed (3000 rpm),
Magnetic fields

Core business : Filters et sources (signal processing et metrology)

Defense



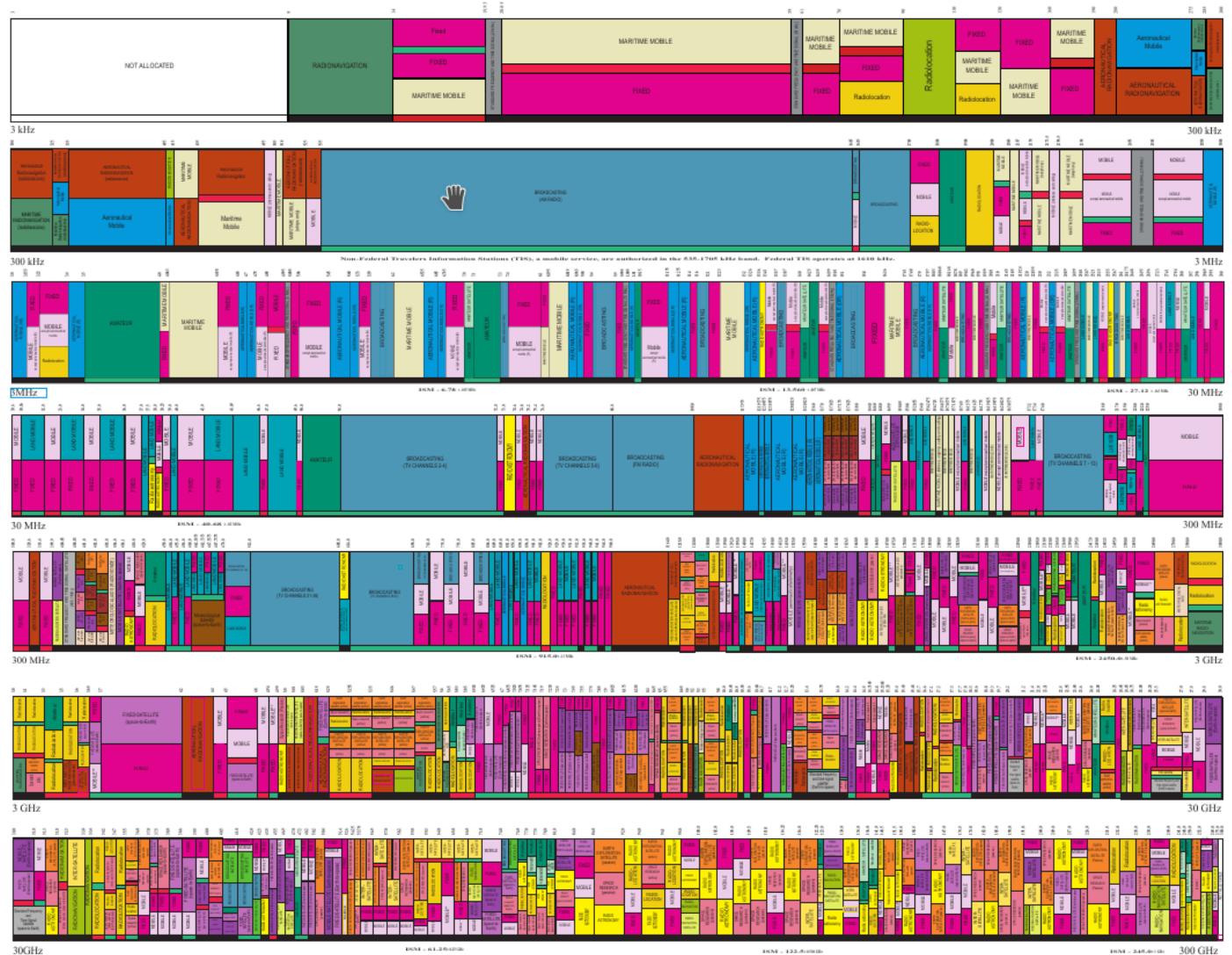
Spatial



Telecom



UNITED STATES FREQUENCY ALLOCATIONS THE RADIO SPECTRUM



RADIO SERVICES COLOR LEGEND

- | | | |
|--|---|---|
| ■ AERONAUTICAL MOBILE | ■ HYPER-SATELLITE | ■ RADIO ASTRONOMY |
| ■ AERONAUTICAL MOBILE SATELLITE | ■ LAND MOBILE | ■ RADIO TERMINATION SATELLITE |
| ■ AERONAUTICAL RADIONAVIGATION | ■ LAND MOBILE SATELLITE | ■ RADIONAVIGATION |
| ■ SATELLITE | ■ MARITIME MOBILE | ■ RADIONAVIGATION SATELLITE |
| ■ SATELLITE SATELLITE | ■ MARITIME MOBILE SATELLITE | ■ RADIONAVIGATION |
| ■ BROADCASTING | ■ MARITIME RADIONAVIGATION | ■ RADIONAVIGATION SATELLITE |
| ■ BROADCASTING SATELLITE | ■ METEOROLOGICAL | ■ SPACE OPERATION |
| ■ EARTH EXPLORATION SATELLITE | ■ METEOROLOGICAL SATELLITE | ■ SPACE RESEARCH |
| ■ FIXED | ■ MOBILE | ■ STANDARD FREQUENCY AND TIME SIGNAL |
| ■ FIXED SATELLITE | ■ MOBILE SATELLITE | ■ STANDARD FREQUENCY AND TIME SIGNAL SATELLITE |

- ### ACTIVITY CODE
- | | |
|---|---|
| ■ GOVERNMENT EXCLUSIVE | ■ GOVERNMENT/NON-GOVERNMENT SHARED |
| ■ NON-GOVERNMENT EXCLUSIVE | |

ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	Fixed	Capital Letter
Secondary	Mobile	Not Capital with lower case letters

This data is a preliminary draft and may not reflect the final allocations. It is provided for informational purposes only. For more information, please contact the Office of Spectrum Management, National Telecommunications and Information Administration, U.S. Department of Commerce, Washington, DC 20540.

U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management
August 2011



Target for RF industry

Filters

100GHz - 3THz
radioastronomy.

20GHz - 100GHz
satellite for ground
exploration,
radiolocation,
military target.

100MHz-10GHz
Military and tactic
Communication.

800MHz-2GHz
GSM,WIFI,
bluetooth, LoRa

Sources

315kHz,
405kHz,1,215G
Hz,1.5GHz
GPS

20GHz-100GHz
GSO

4GHz-25GHz
Military andd
civil Radar

RFID/wireless applications

medical implant
9kHz 15kHz,
13MHz, 6MHz,
26MHz, 40MHz

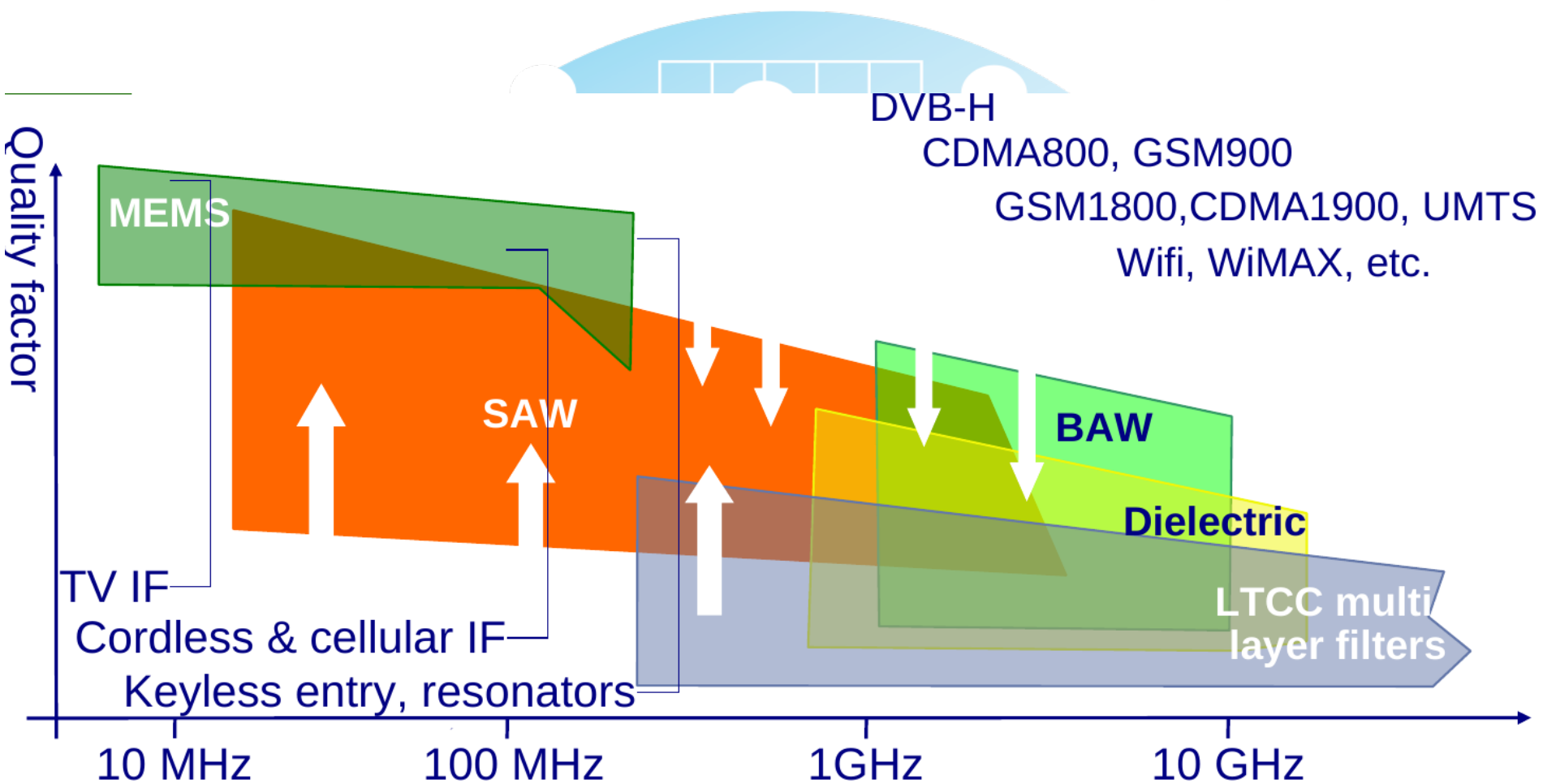
Passive and
active sensors
433MHz

identification
2.45GHz,
5.7GHz, 24GHz,
59.3GHz



Electronic Communications Committee (ECC)
within the European Conference of Postal and
Telecommunications Administrations (CEPT)



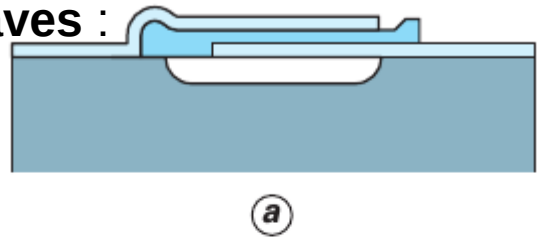


RF360-TDK-EPCOS

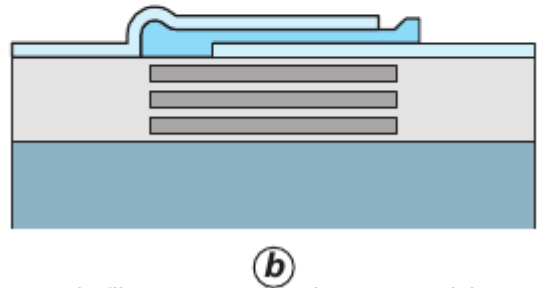


Elastic waves Devices in RF industry

BAW :
Bulk acoustic waves :
 FBAR

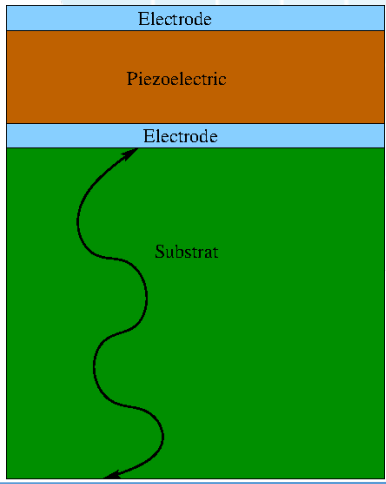


SMR



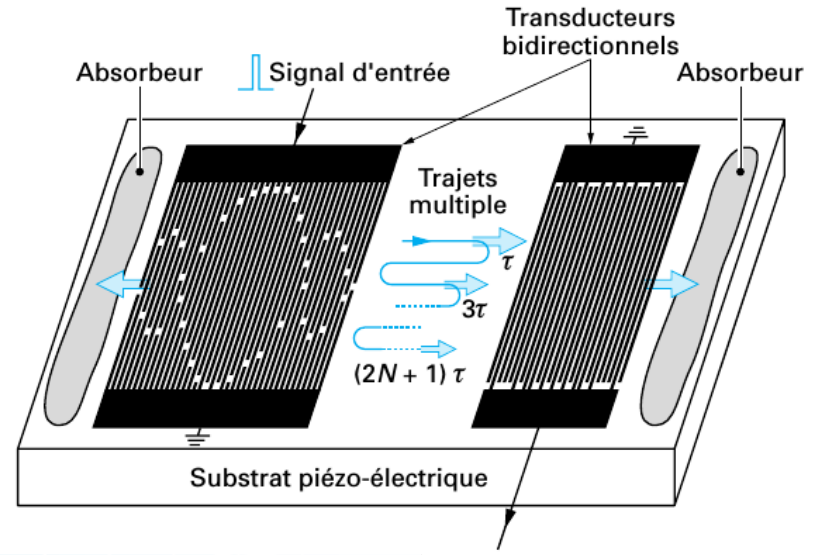
Composants acoustiques utilisés pour le filtrage, S. Ballandras, W. Steichen

HBAR



QF : 10^{14}
 (world record)

SAW: Surface Acoustic Waves



Filtres à ondes de surface, P. Defranould, P. Wright

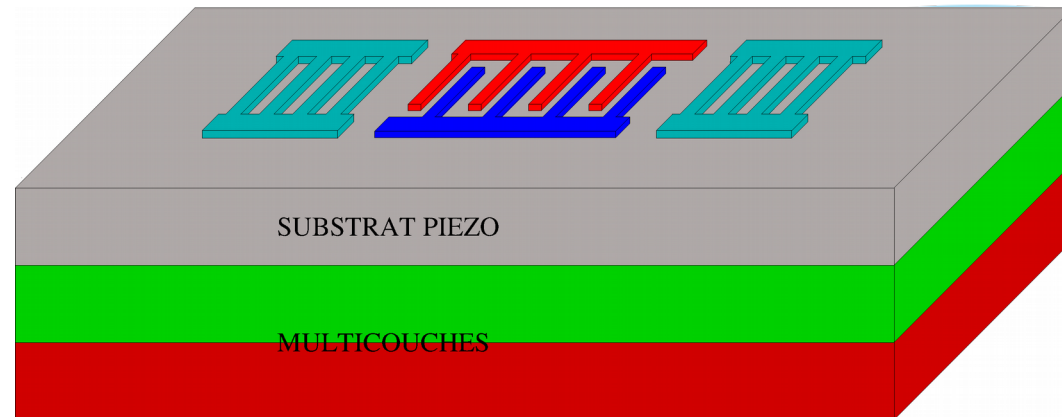
Technology frech|sys



Material	Application	Coupling factor (max)	Thermal sensitivity	Remarks
<u>LiNbO₃</u>	SAW, BAW, AcoustoOptics	45 %	-90 ppm/K	Ferroelectric & pyroelectric, high industrial reliability, T _c >1200°C
<u>LiTaO₃</u>	SAW, BAW	22 %	-36 ppm/K	Id., 525 < T _c < 700°C
<u>KnbO₃</u>	SAW, AcoustoOptics	55 %	< 1ppm/K	Huge coupling, no provider of wafers, T _c ~430°C
<u>LiB₄O₇</u>	SAW	3.5 %	-300ppb/K ²	Water Solubility → dry process
<u>Langasite</u>	SAW, BAW	0.4 %	-70 ppb/K ²	High operating temp. (~1000°C)
<u>Quartz</u>	SAW, BAW, vibrating structures	0.25 %	-40 ppb/K ² -60 ppb/K ²	The most used piezoelectric material, the less coupled, very high industrial reliability
<u>AlN</u>	FBAR	7.5 %	-20 ppm/K	Mainly used in FBAR industry
<u>ZnO</u>	FBAR, Lamb	9 %	-50 ppm/K	Alternative to AlN, more coupled but smaller mode velocity
<u>PZT</u>	Transducers	50%	> 50 ppm/K	The king-material for acoustic imaging

Attention : temperature compensation in filter but sensors sensitivity





Resonators:

- sensor
- Source
- Filter

Patent :Dispositif de capteur à ondes élastiques de surface à réponse électrique stable (EP #15198414)

Resonators size : from 1mm² to 50 mm²



Delay line, Tag :

- sensor
- User ID

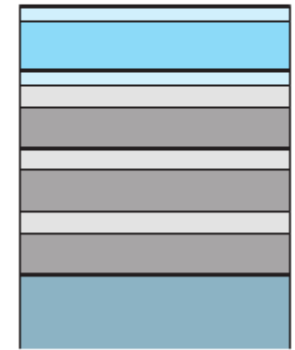
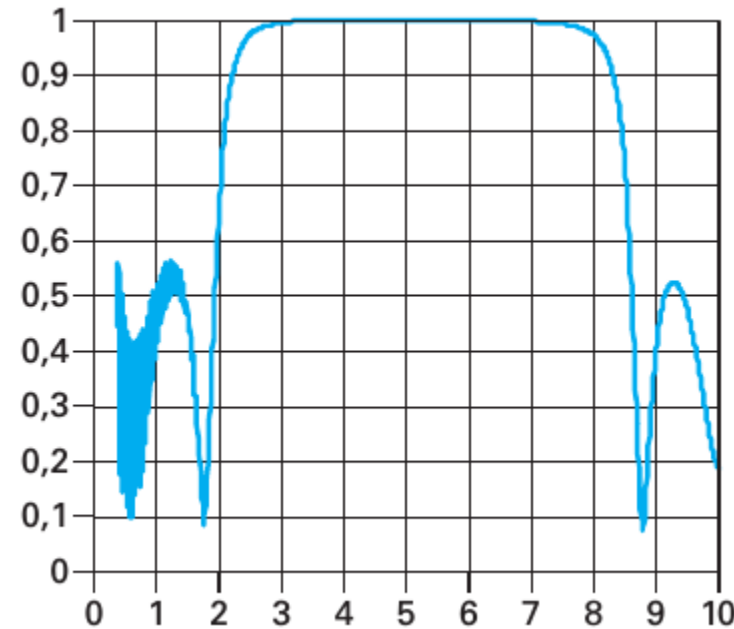
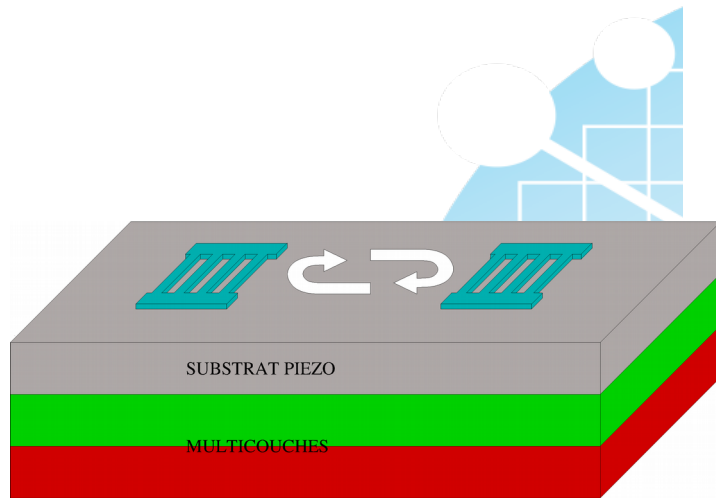
Patent :« SAW-Tag » temperature sensor able to operate up to 1000°C with identification capability (EC Patent application #11 50476)

Delay line size typically less than 1mm width and 4mm long

Usally made by metallic deposition, mirrors can be process by etching



SAW devices : Bandgaps, parameters



APPLICATIONS : mirror cavity ou confinement

ALTERNATIVES : Phase celerity to confine wave ($V_{fr} > V_g$) (LOVE waves, bus effects)

Parameters for SAW

Layer thickness (spectral position, reflexion, devices length)

Metal ratio (spectral position, reflexion, devices length)

Wave celerity (spectral position)

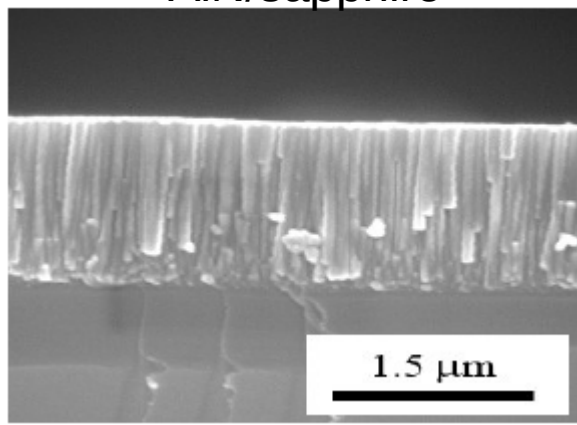
Electromechanical coupling (band width)



SAW devices : Bandgaps : technology

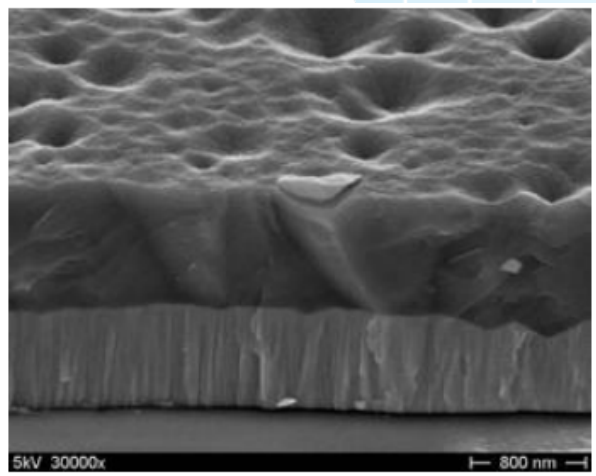
Thin Layer deposition

AlN/sapphire



Courtesy of IJL Nancy

ZnO/Si



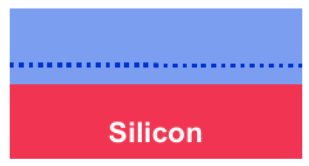
<http://www.helmholtz-berlin.de/forschung/enma/si-pv>

SMART-CUT SOI - POI

1) ion implantation



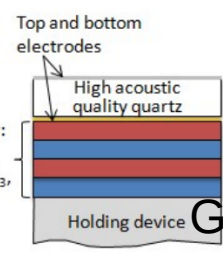
2) Wafer Bonding



3) Splitting



4) Polishing

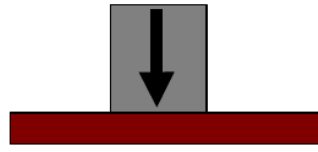


Gold/gold bonding

Cleaning and preparation



Surface compression



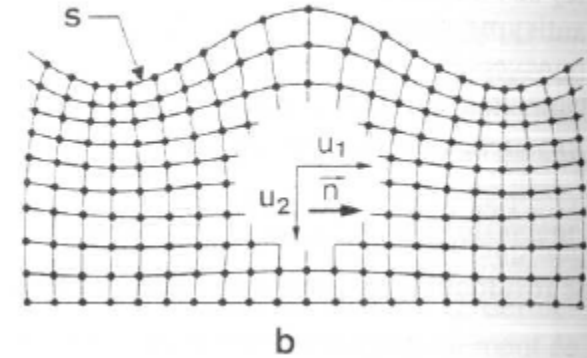
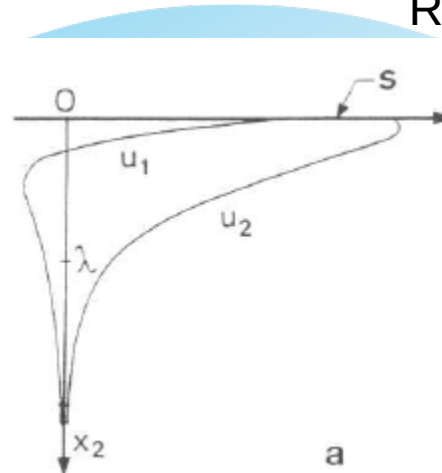
Strengthening the prebonding



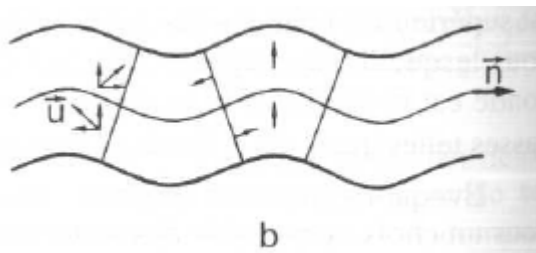
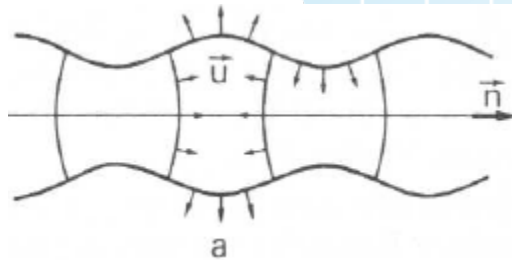
SAW applications: main waves

- Rayleigh waves: filters and resonators
- Transversal waves : IF band TV and satellites (love, lamb)
- Leaky wave high coupling for wide band but high losses

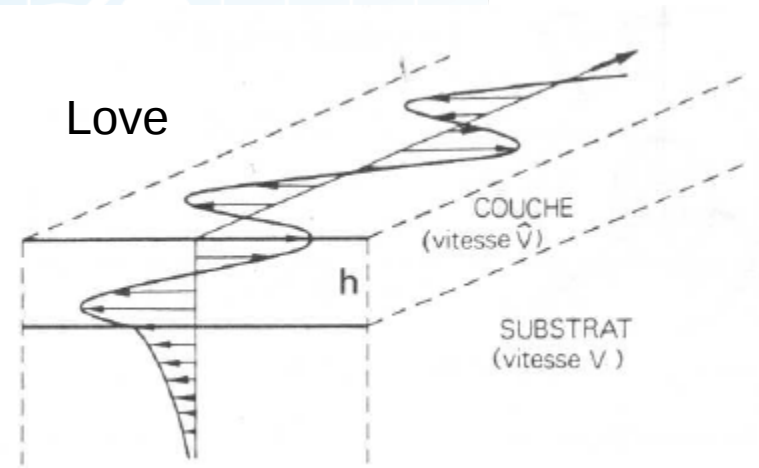
Rayleigh



Lamb



Love

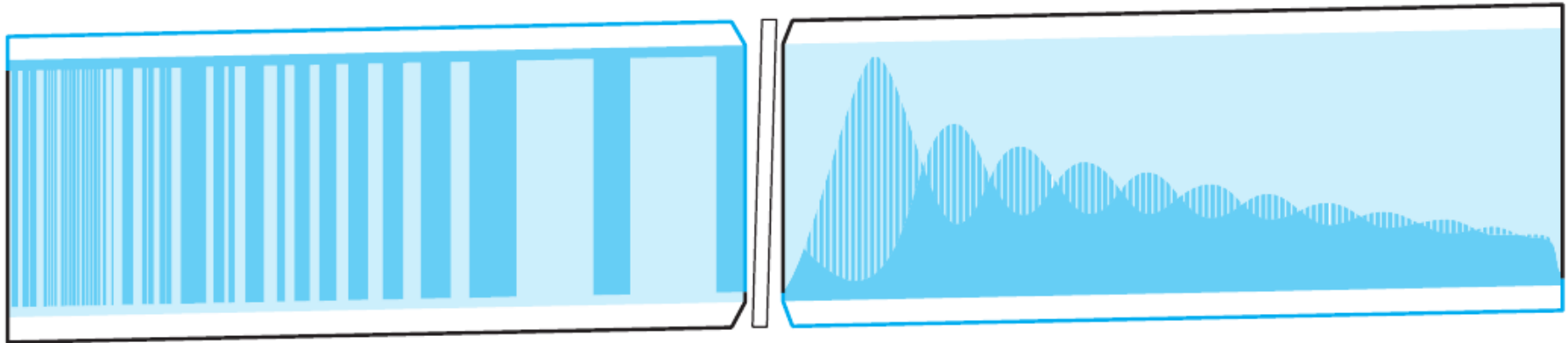


Royer Dieulesaint

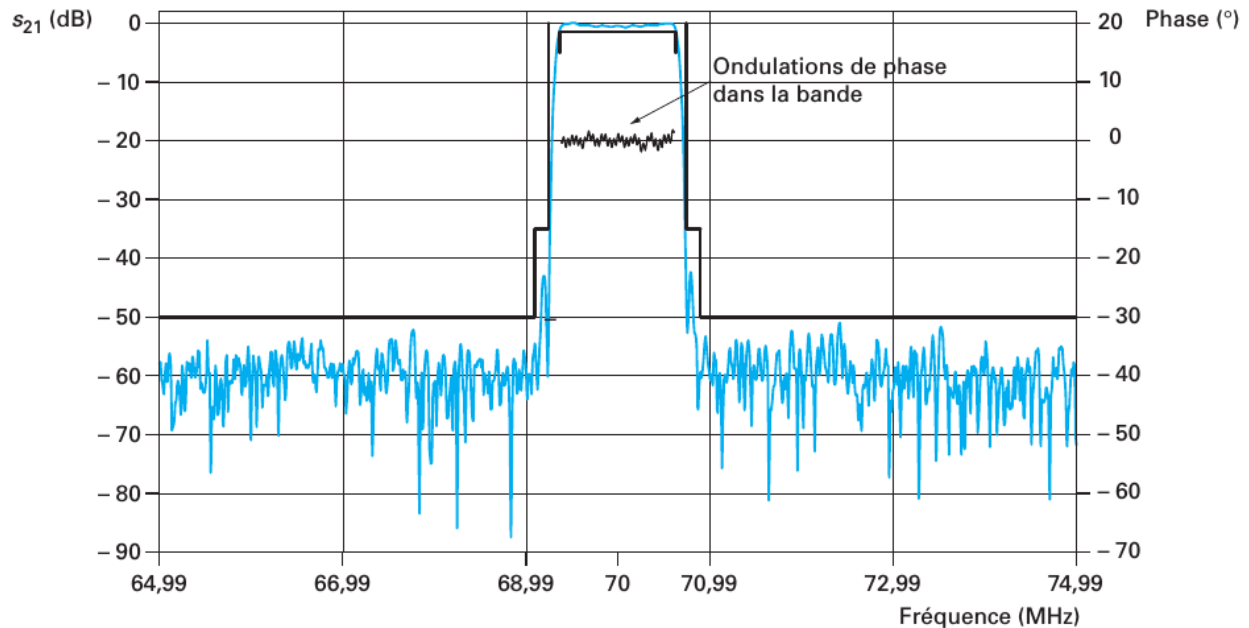


Saw application: architecture in RF industry

- Classic filters : sources balancing



Wide devices
But wide
application

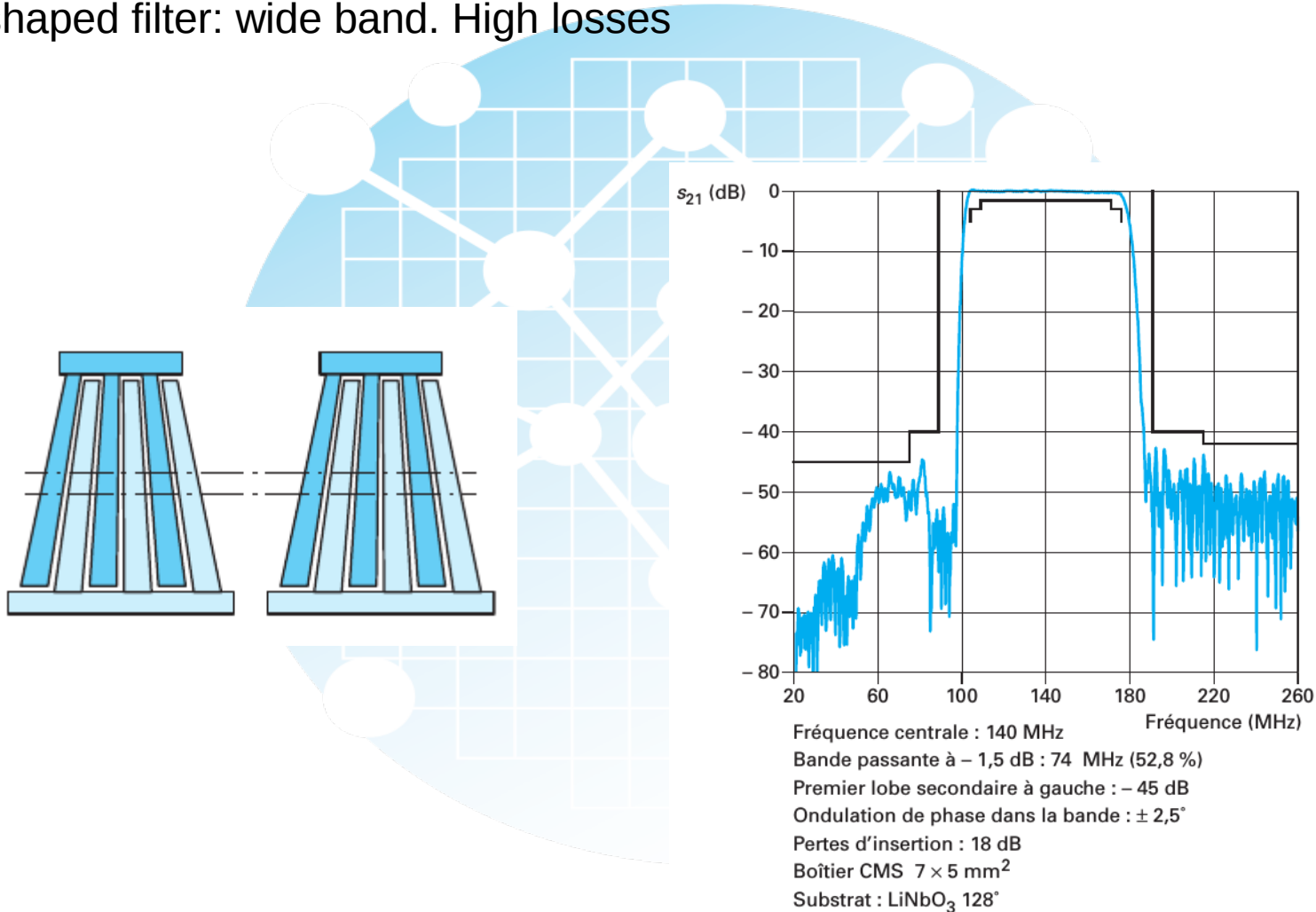


Source TEMEX



Saw application: architecture in RF industry

- fanshaped filter: wide band. High losses

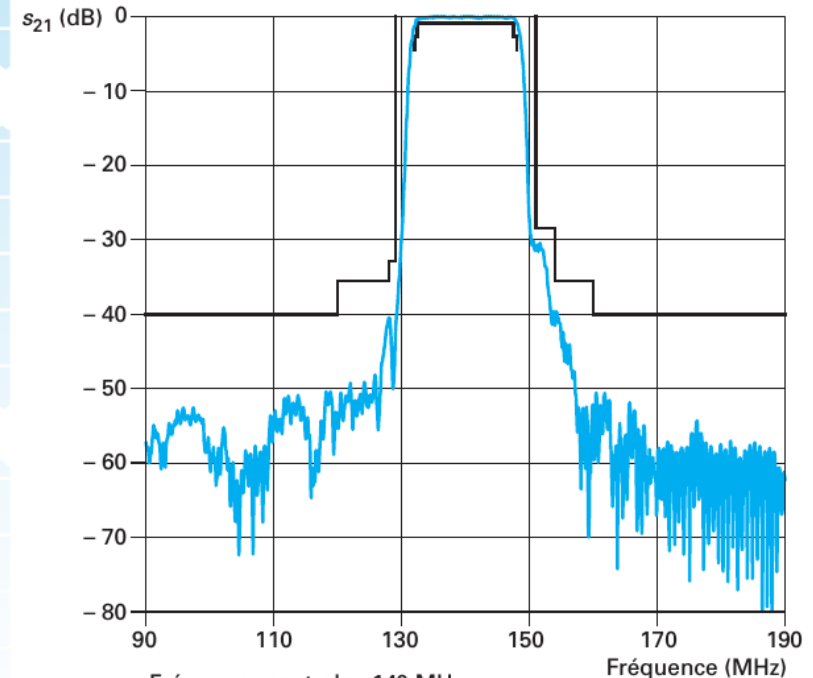
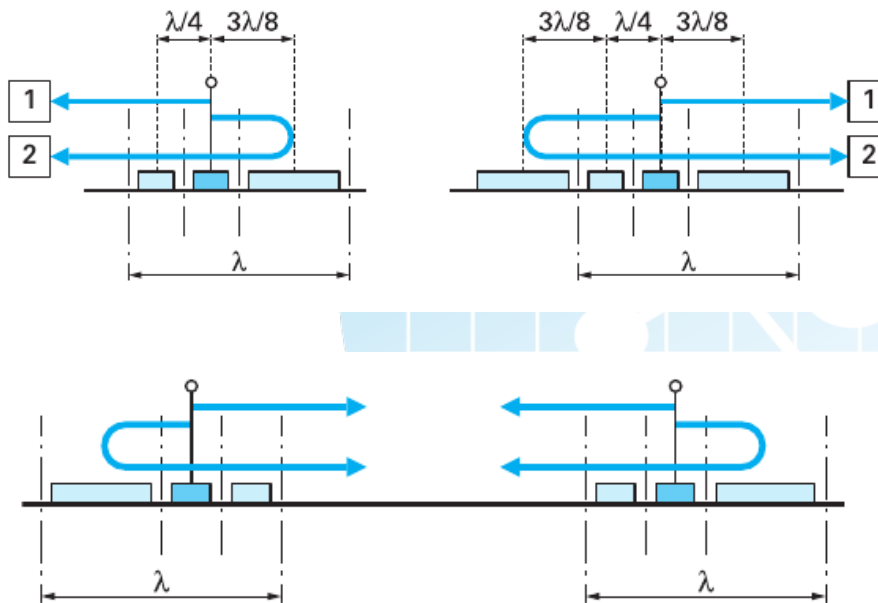


Source TEMEX



Saw application: architecture in RF industry

- Les filtres DART (distributed Acoustic Reflection Transducer): Improve insertion losses. Used with fanshapped.



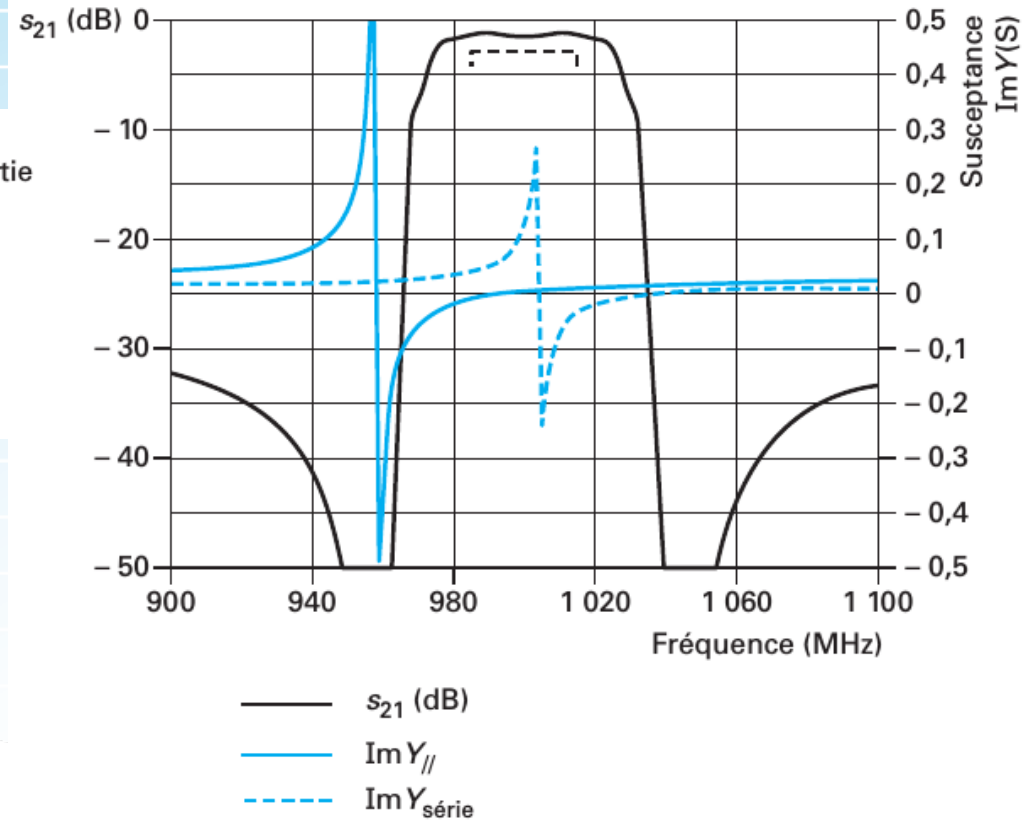
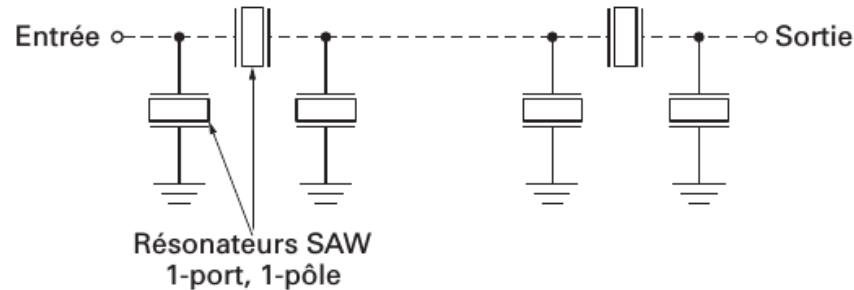
Fréquence centrale : 140 MHz
 Bande de transition (-3 à -32 dB) : 1,6 MHz (1,1 %)
 Bande passante : 15,8 MHz (11,3 %)
 Premier lobe secondaire à gauche : -45 dB
 Ondulation de phase dans la bande : $\pm 3^\circ$
 Pertes d'insertion : 7 dB
 Boîtier CMS $13,3 \times 6,5 \text{ mm}^2$
 Substrat : LiNbO_3 YZ

Source TEMEX



Saw application: architecture in RF industry

- Electrical coupling, ladder sample: sharp edge band, high power resist, poor remote rejections, low insertion losses, bulky devices

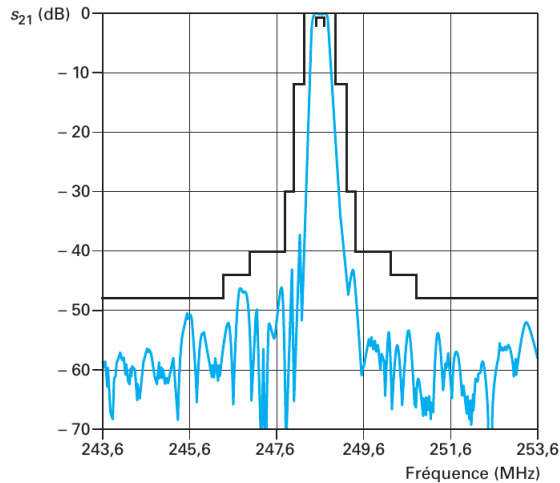
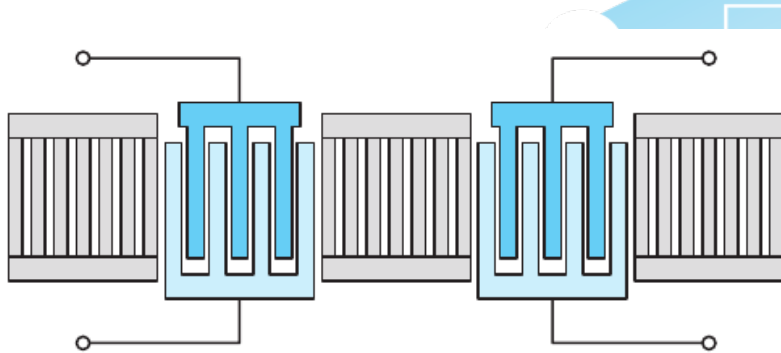


Source TEMEX



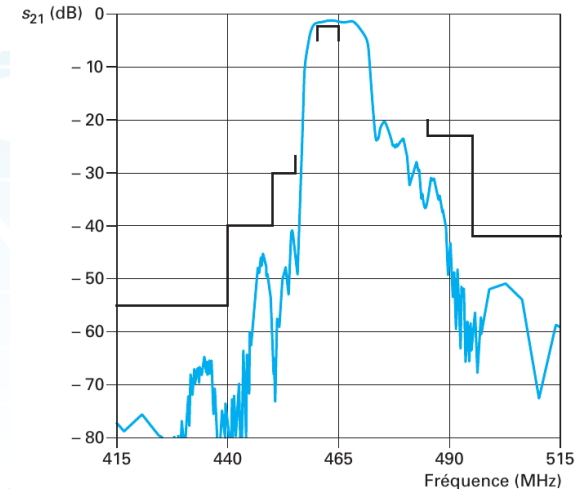
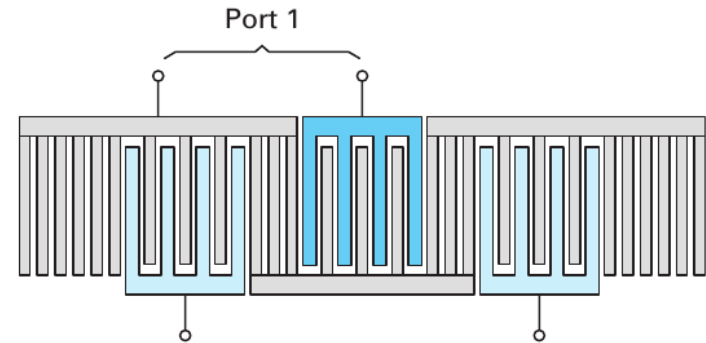
Saw application: architecture in RF industry

- Acoustic coupling: low insertion losses (cascade), high remote rejection



Fréquence centrale : 248,6 MHz
 Bande passante à - 0,5 dB : 0,32 MHz (0,129 %)
 Premier lobe secondaire à gauche : - 38 dB
 Variation de temps de groupe dans une bande de 200 kHz : 500 ns
 Pertes d'insertion : 4,7 dB
 Boîtier CMS 13,3 x 6,5 mm²
 Substrat : quartz

Narrow band LCRF



Fréquence centrale : 462,5 MHz
 Bande passante à - 1 dB : 10 MHz (2,1 %)
 Pertes d'insertion : 1,3 dB
 Boîtier CMS 3 x 3 mm²
 Substrat : LiTaO₃

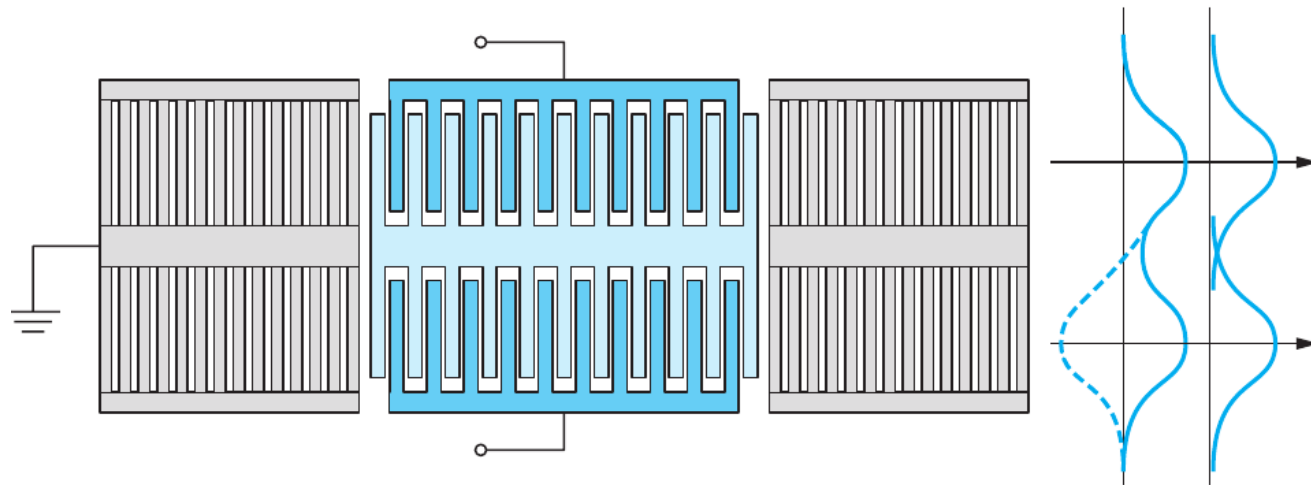
Wide band DMS

Source TEMEX



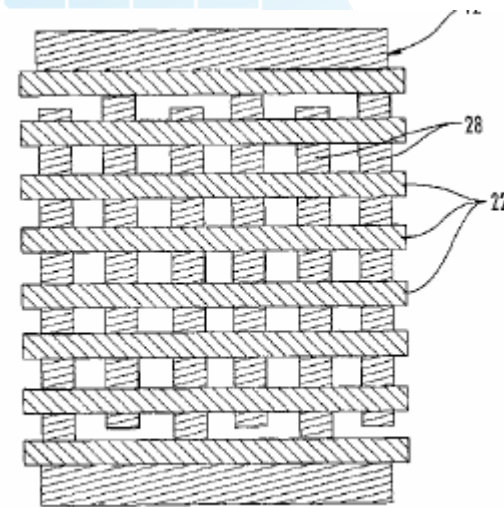
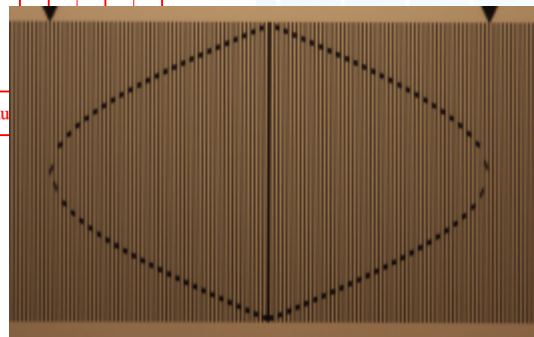
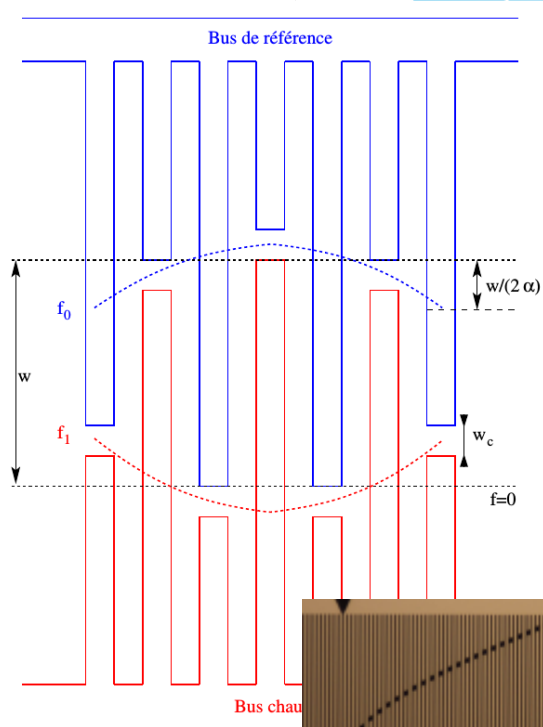
Saw application: architecture in RF industry

- Transversal coupling, TCRF: low insertion losses (cascade), high remote rejections, very narrow band



Saw application: architecture in RF industry

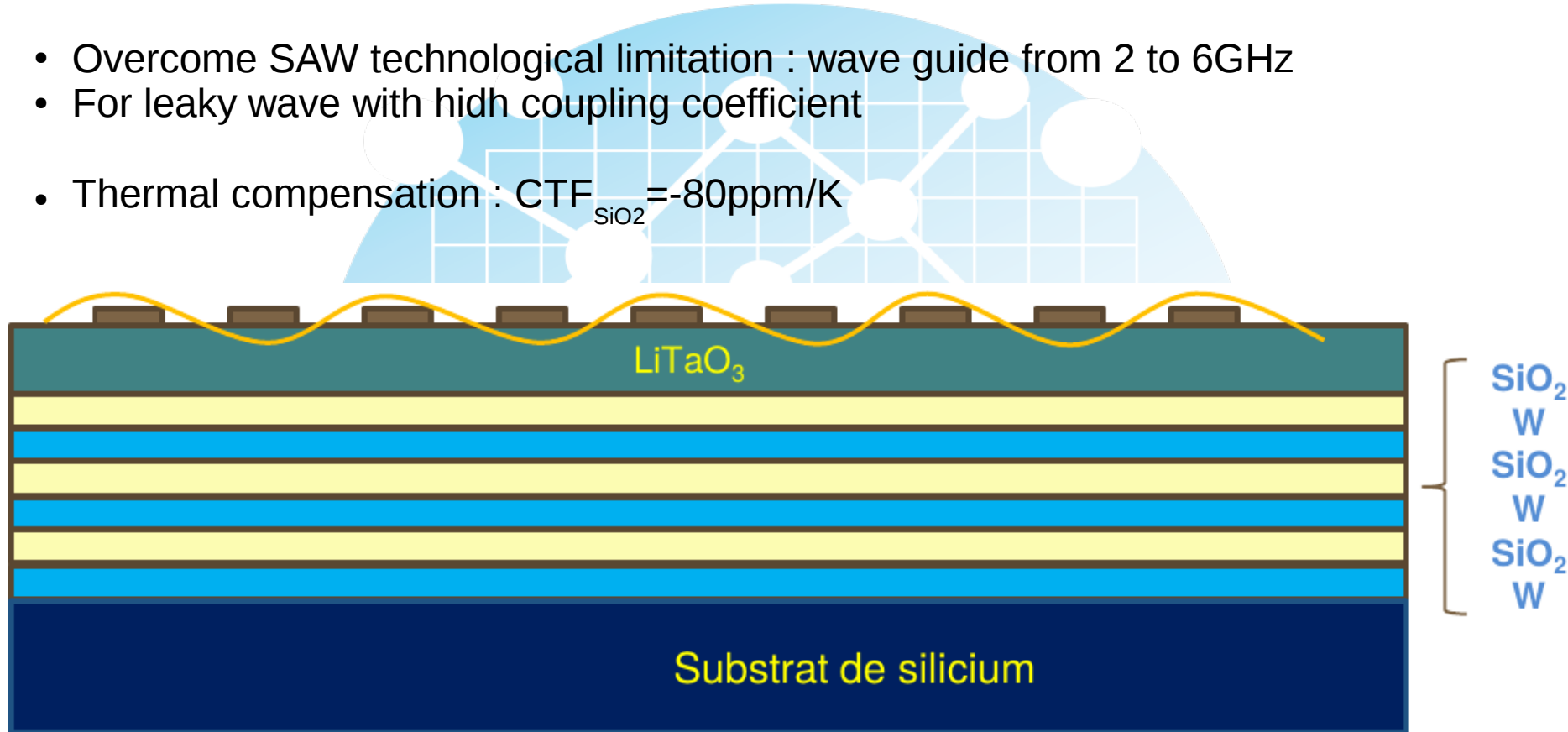
- Elimination of transversal modes. out of TCRF, transversal modes are spurious :
 - Apodization
 - Cross networks



Patent US 7,939,987 B1



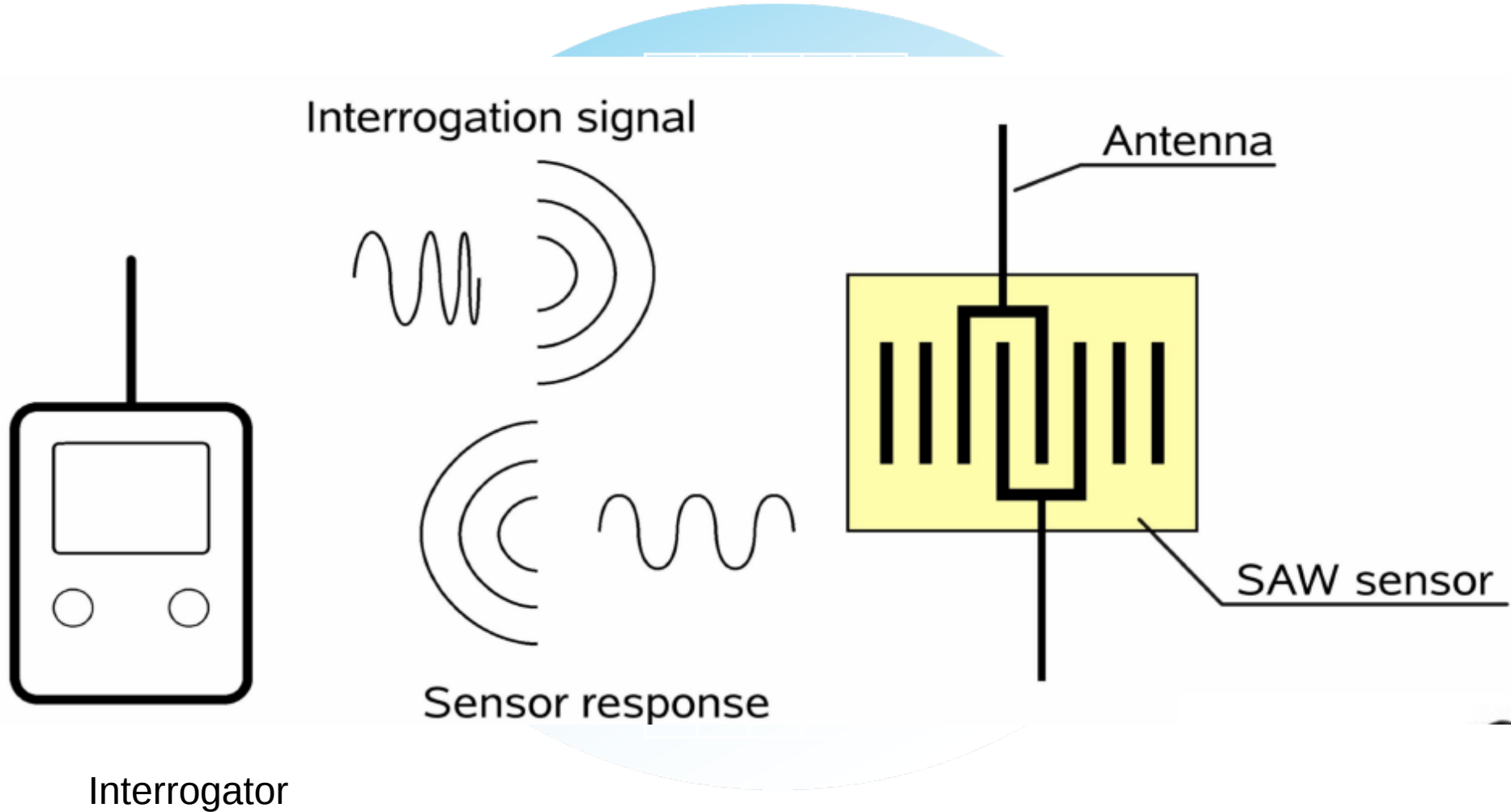
- Overcome SAW technological limitation : wave guide from 2 to 6GHz
- For leaky wave with high coupling coefficient
- Thermal compensation : $CTF_{SiO_2} = -80\text{ppm/K}$



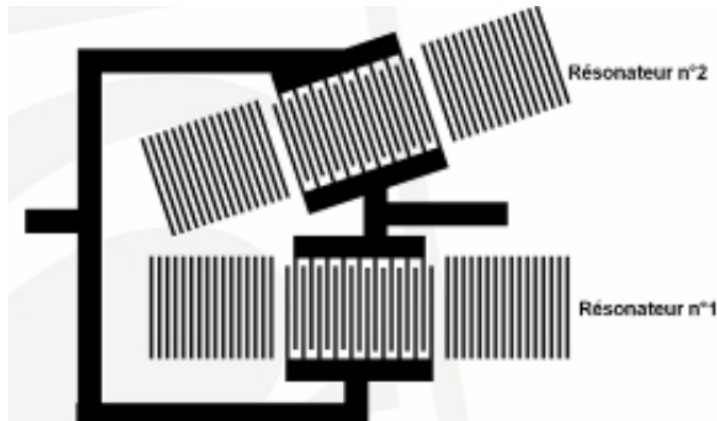
patent FEMTO-ST : Abdelkrim Khelif, Application Murata, SOITEC US8138856 (B2), 2012-03-20,

SOI - POI

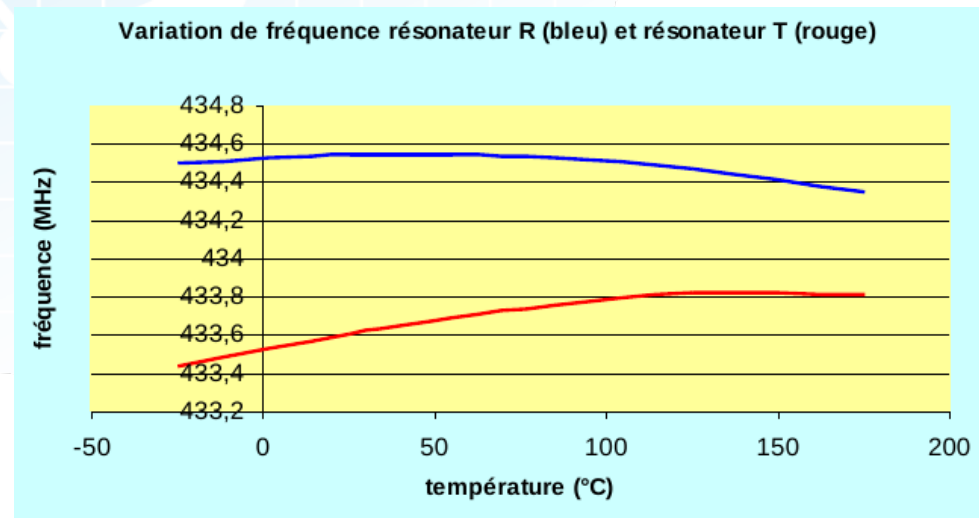
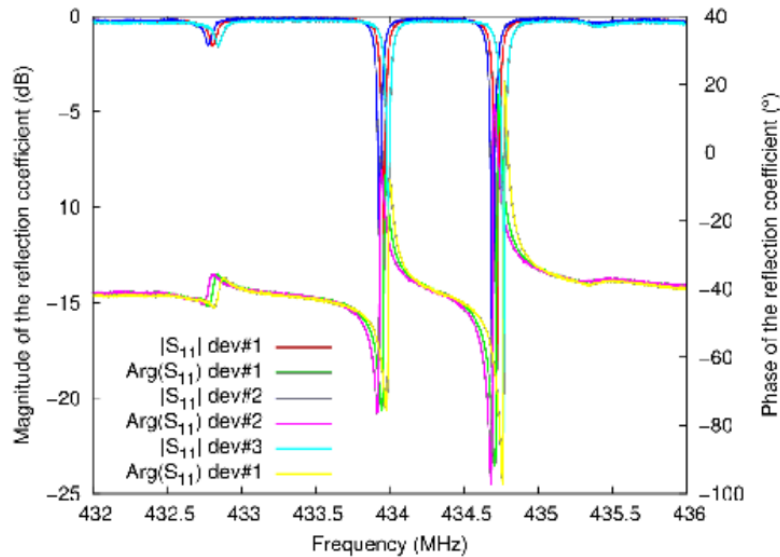
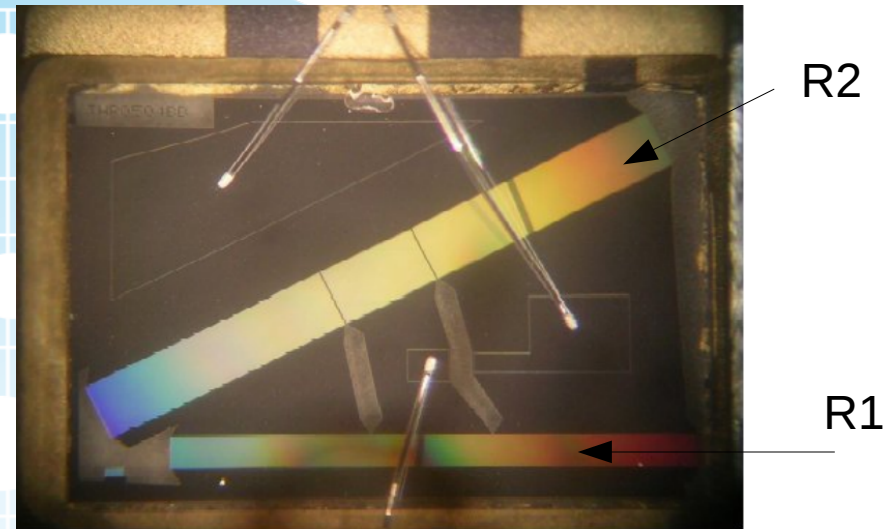




SAW applications: temperature sensor on quartz @433MHz



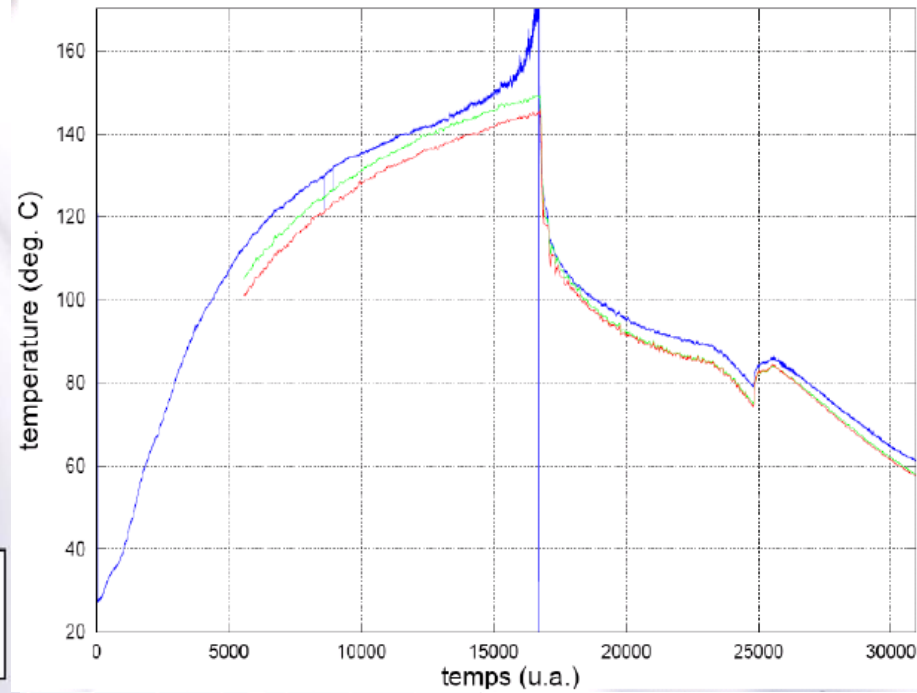
Device Size 3x3mm²



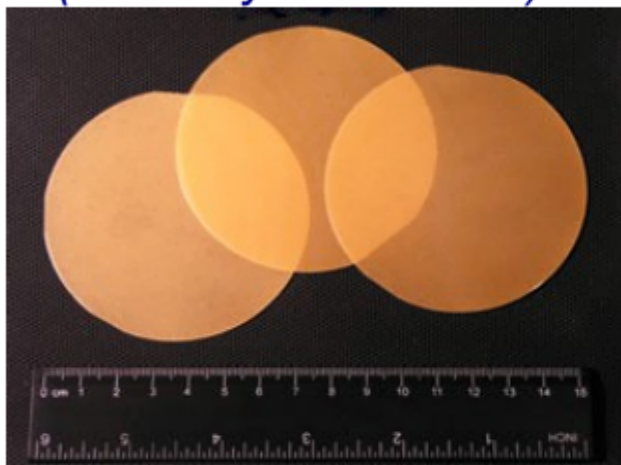
SAW applications: sensor temperature on quartz @433MHz



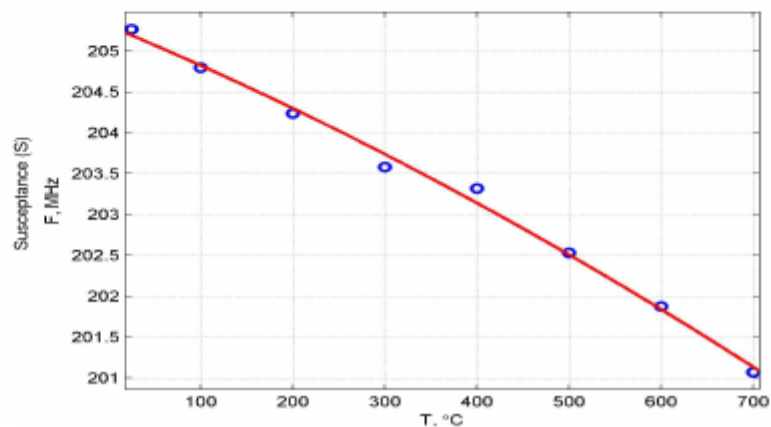
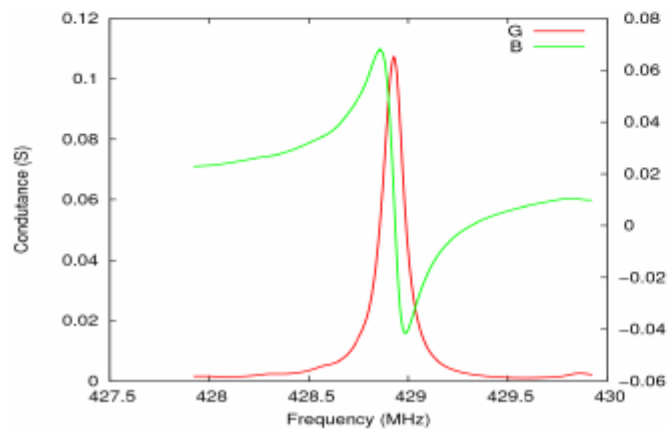
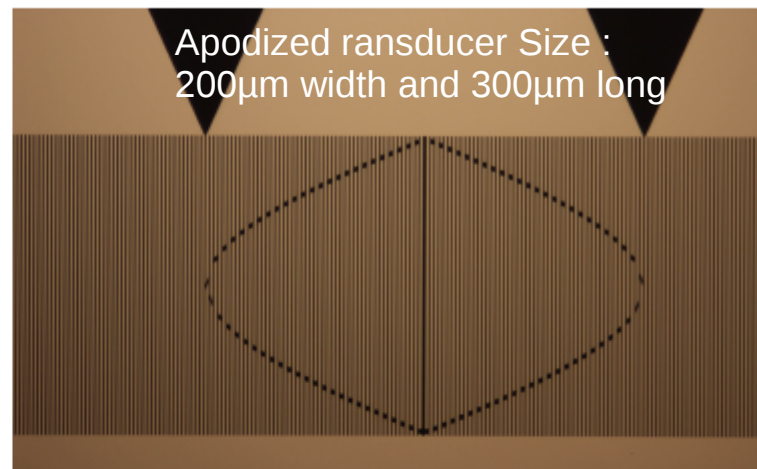
Antenna of the reader inside the tank



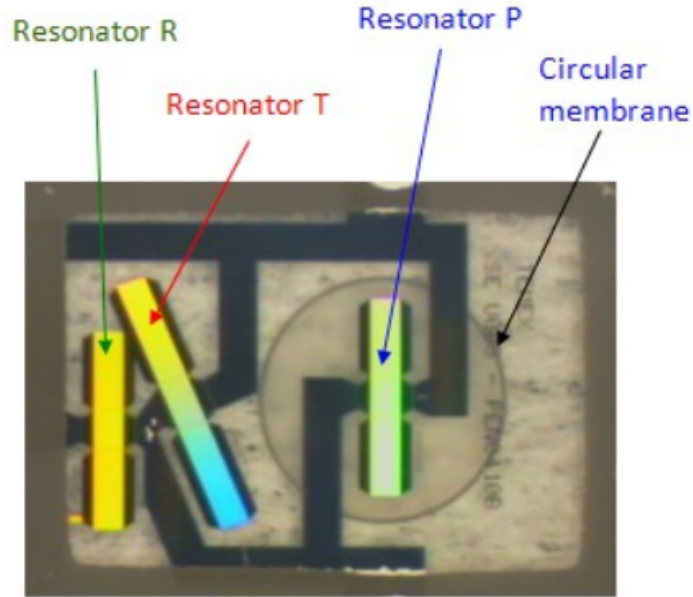
Langasite – LGS wafers (courtesy of FOMOS)



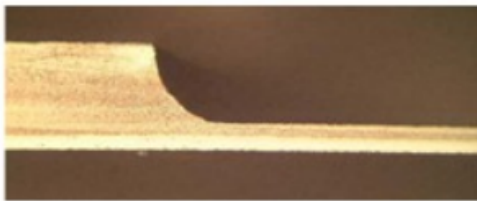
SAW resonator built using NIL @ DTI



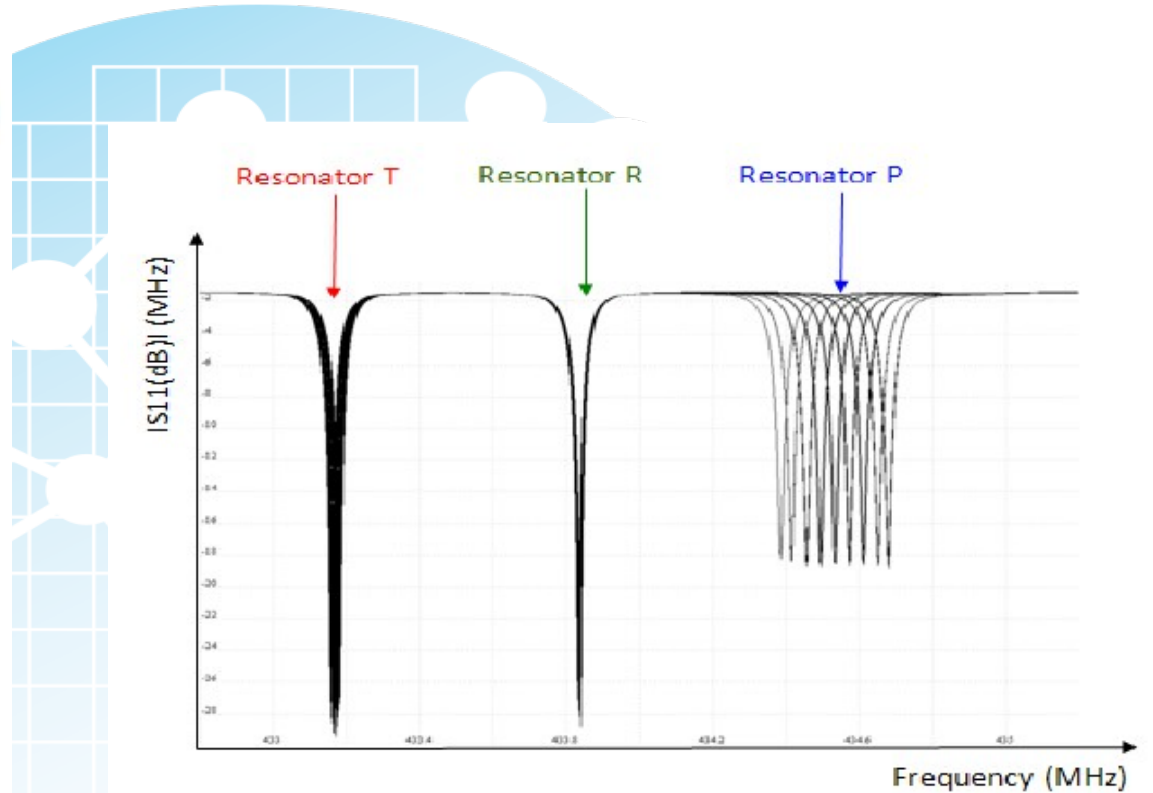
SAW applications : pressure and temperature sensor on quartz@433MHz



(a) SAW pressure and temperature sensor 0 – 10 bars ($8 \times 4 \text{mm}^2$)



(b) Cross section of the micro-machined circular membrane

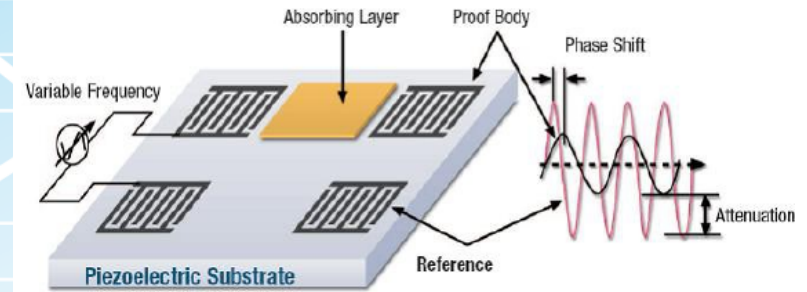


(c) S11 modulus variation for the SAW pressure and temperature sensor when overpressure varies from 0 to 5 bars

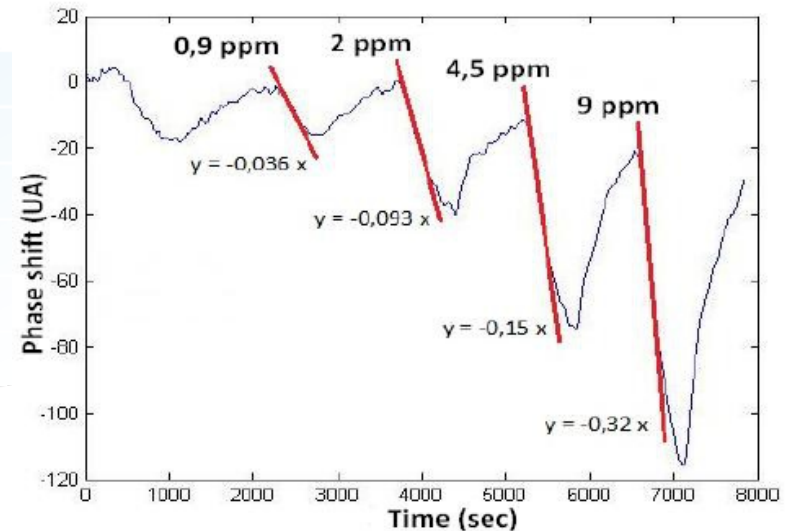
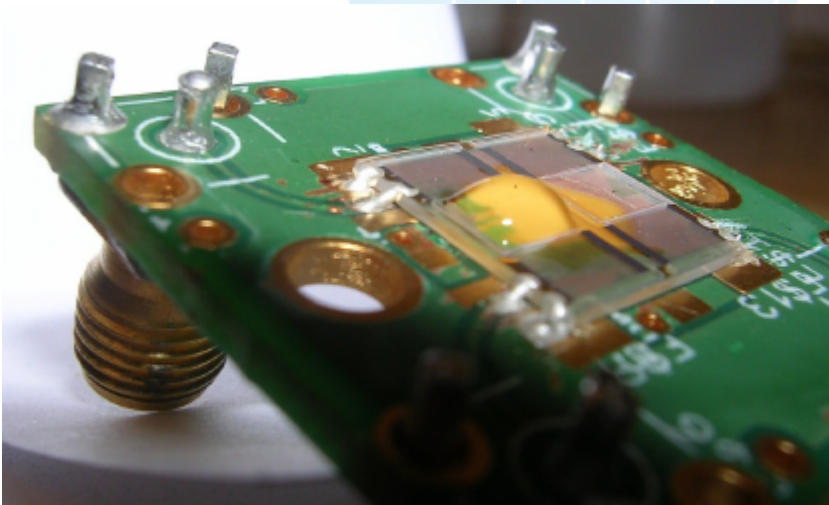
Exemple d'onde love pour la détection de CO utilisant les corolles de cobalt

Operating principle :

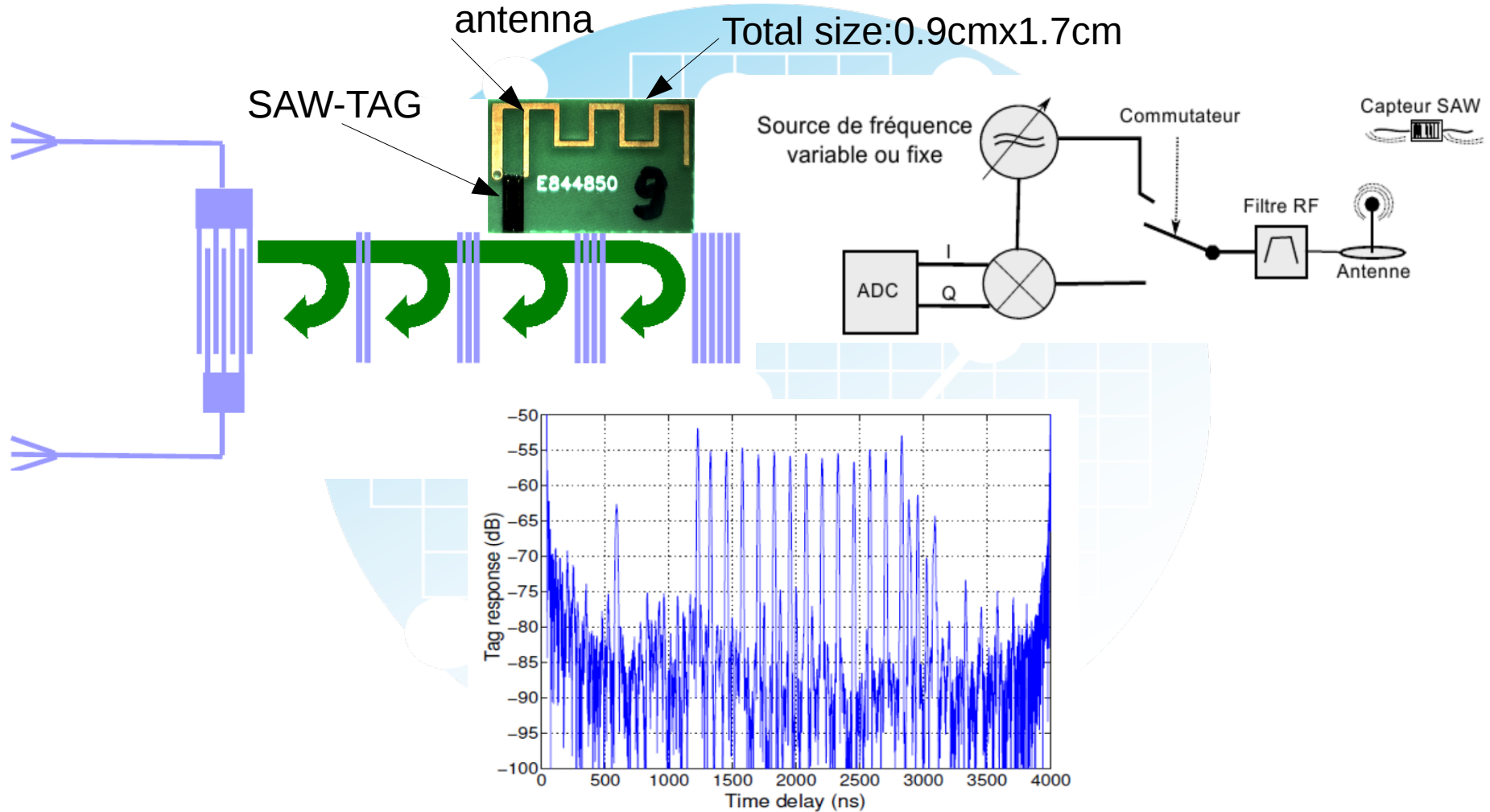
- 2 delay lines
 - reference
 - functionalized
- Adsorption particule on surface
- Celerity variation
- Phase variation
- Attenuation



Lab on chip

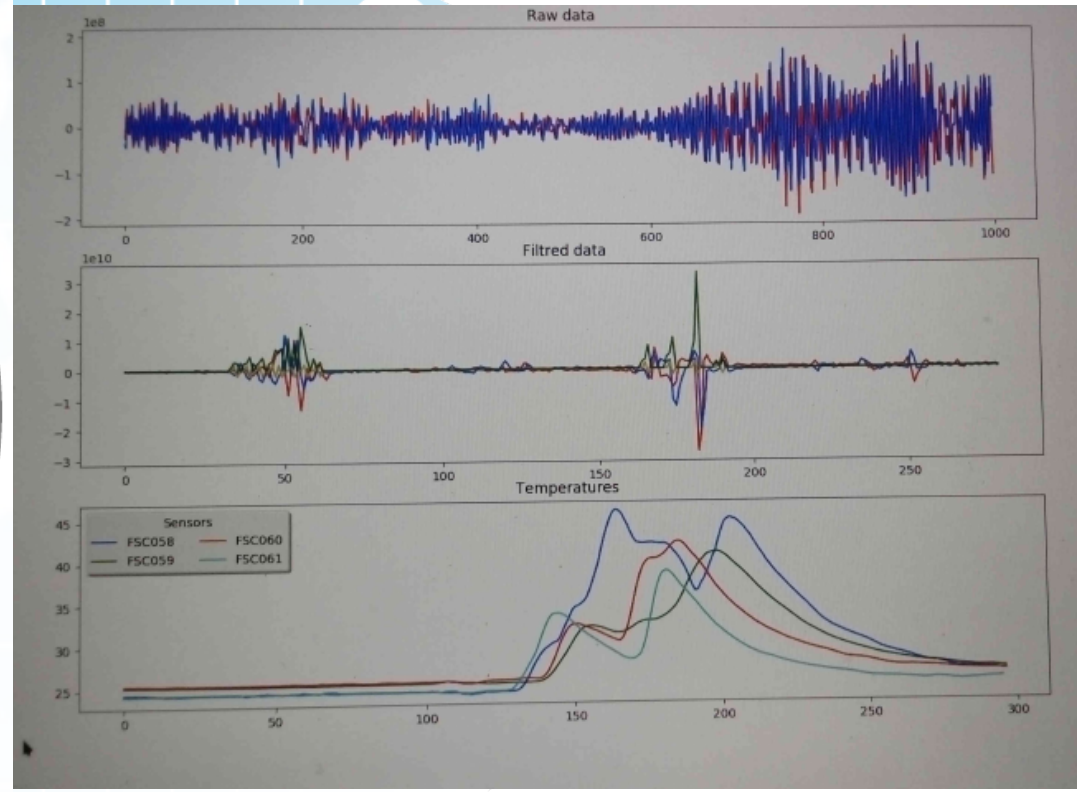
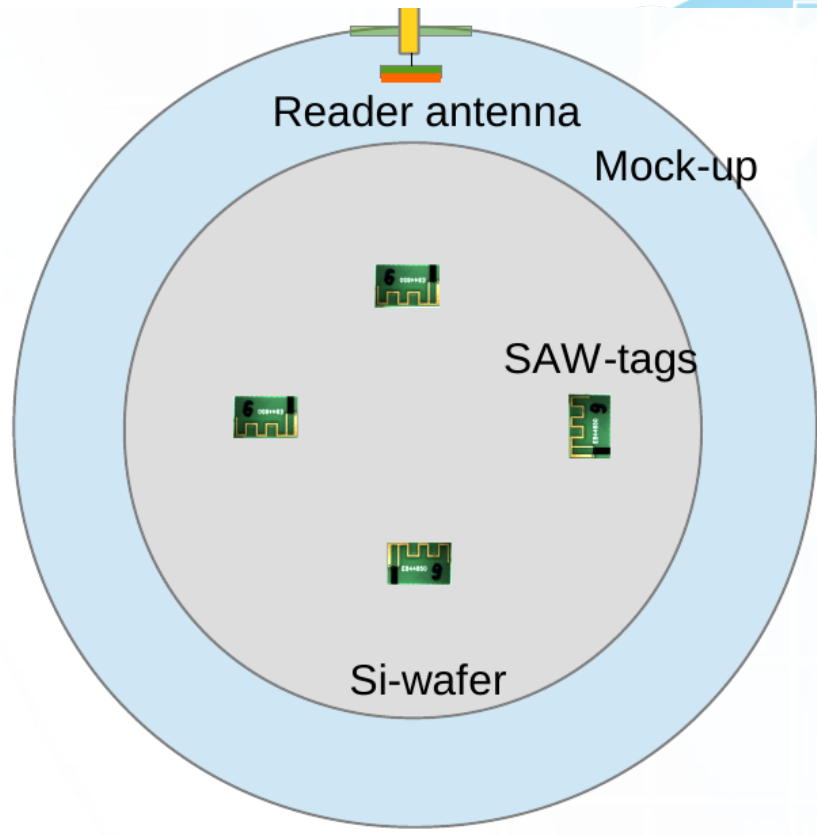


SAW applications : temperature sensors on LiNbO3@2.45GHz



Patent : « SAW-Tag » temperature sensor able to operate up to 1000°C with identification capability
(EC Patent application #11 50476)

SAW applications : temperature sensors on LiNbO3@2.45GHz



Applications	Production process management (traceability)	<ul style="list-style-type: none"> Containers identification Cold traceability Military or civil logistic 	Containing identifications (management : palettes...)	Identification et traceability (clothes, drugs...)	Identifications : trees, Construction equipment...
Technology	Passive RFID or battery assisted	Active RFID	RFID passif or battery assisted	Passive RFID	Passive RFID or battery assisted
Frequencies	125kHz 13.56MHz	2,45GHz	125kHz, 13,26MHz, 2.45GHz	13,56MHz	125kHz, 13,26MHz, 2.45GHz



Applications	Électronic Toll	Urban toll vehicule tax	Fleet positionning	Parking management	Access control (entry or exit)
Technology	Active RFID (en france) Passive RFID (au canada par exemple)	RFID actif or Passive RFID	Active RFID	Passive RFID or battery assisted	Passive RFID or battery assisted or active RFID
Frequencies	2,45GHz, 5,8GHz	2,45GHz, 5,8GHz	2.45GHz	13,56MHz, 2,45GHz	125kHz, 13,26MHz, 2.45GHz



Applications	ID card	Electronic purse (money)	Transport ticket	Risky area positioning (resue or fire men, montain,...)	Access control, schedule management
Technology	Passive RFID	Active RFID	Passive RFID	Active RFID, progress in passive	Passive RFID
Frequencies	13.56MHz	13,56MHz	13,26MHz	2,45GHz	125kHz, 13,26MHz, 2.45GHz



Applications	Pets identification	Farm animals identification	Competition or pleasure animals identification	Laboratory animals management
Technology	Passive RFID	Passive RFID	Passive RFID	Passive RFID
Frequencies	134,2kHz	125kHz, 134,2MHz	134,2kHz	125kHz, 134,2kHz

