SIXTH FRAMEWORK PROGRAMME
PRIORITY [4]
AERONAUTICS AND SPACE

SPECIFIC TARGETED RESEARCH PROJECT

Deliverable D2.1.:

Title: State of the art of the smart Seat development

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1. Introduction

1.1. Smart materials

1.1.1. Definition:

Smart fabrics and interactive textiles (SFITs) can be defined as textile or garment-based marketable products incorporating textiles, fabrics or fibres which, in their pre-converted or post-converted state, facilitate or enhance any of the following interactions with their environment or their user:

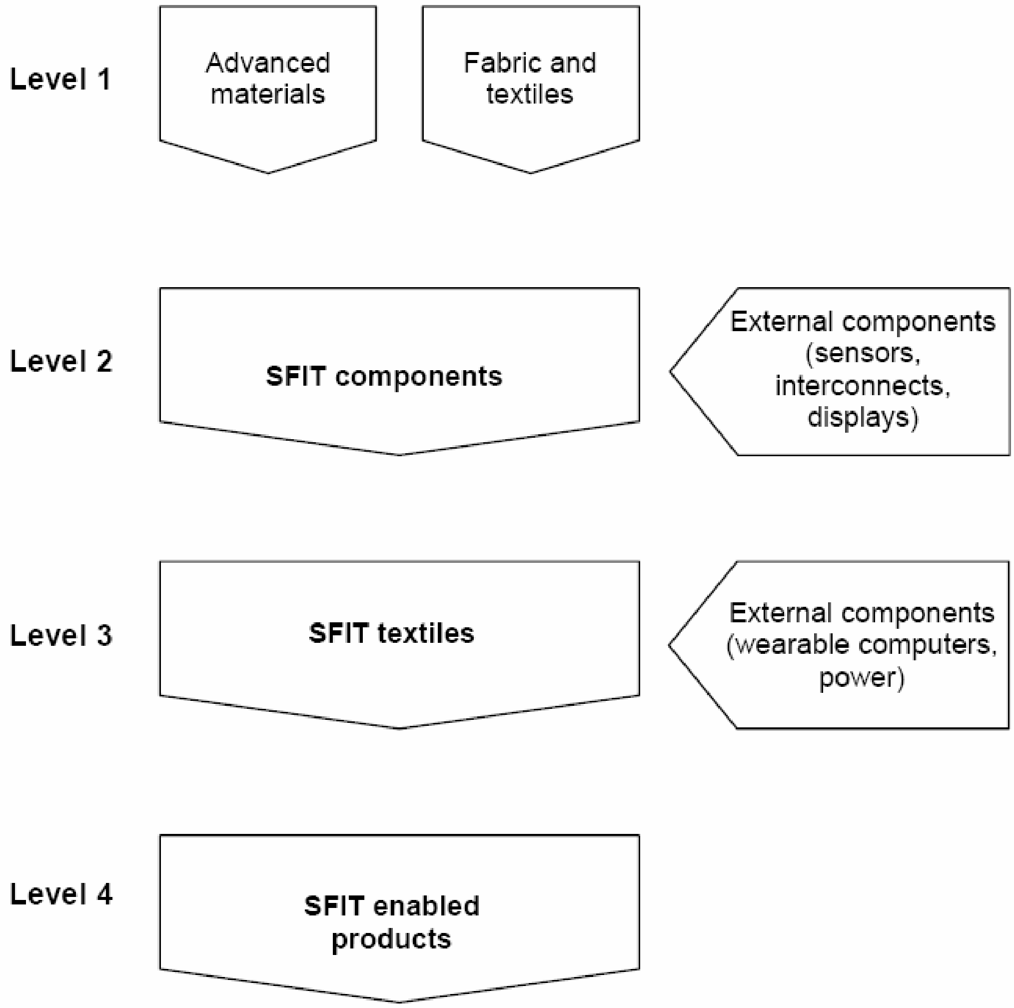
- the conduction, transfer or distribution of electrical current, light energy, thermal energy, or molecular or particulate matter, either through the material or across the membrane, for the purposes of:
    - transmitting signal commands;
    - moving sensory or other data; or
    - transferring heat or matter between two or more points on the product (as in the case of a garment);
- a material phase change, either through an external signal command from the user, or an internal or environmental stimulus, such as a change in temperature, humidity, pH, porosity, conductivity, or permeability;
- the provision of shielding and protection from electromagnetic (EM) and/or radio frequency (RF) interference; and
- The provision of protection against biological, chemical, or other threats to the integrity of the protected being or item utilising the SFIT material.

Suppliers to the market for smart fabrics and interactive textiles (SFITs) occupy a variety of levels. The relationship between these is illustrated in Figure 1.

- **Level 1: SFIT advanced materials.** These materials are used to treat or create the fibres, threads, and yarns which form the carrier of the interactive technology.
- **Level 2: SFIT components.** Components include fabric components such as fibres, filaments, threads, yarns and films as well as externally applied components such as sensors, batteries, touch pads and a variety of electronic devices.
- **Level 3: SFITs.** This is the level where components are brought together into the matrix which will make up the resulting fabric, film or other form that will constitute the platform for the solution.

- **Level 4: SFIT enabled products.** These are the final, marketable products which will be sold to the end user.

Figure 1
Supply chain – flow of materials, value creation for SIFT (smart fabric and interactive textile) enabled products



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1.1.2. Summary:

➢ **Metals**

The first stage in the conversion of inert materials into the “building blocks” of interactive technology is often the treatment of natural and synthetic fibres with a range of metals, metal salts, alloys, inks and dyes.

Metallising enables materials to:

- transmit signals;
- generate heat through electrical means; and
- Provide hazard protection.

Examples of important metallised fibres and yarns include the following.

- **Conductive stainless steel yarns.** These are used extensively for electrically conductive textiles. They can be worked with, and can be sewn into fabrics. They are efficient conductors, relatively strong, and biologically inert.

- **Metal clad aramid fibres (MCAFs).** One example of a metal clad aramid fibre (MCAF) is DuPont’s Aracon. MCAFs normally comprise a Kevlar aramid core coated with silver, nickel, copper, gold or tin. These fibres are able to withstand repeated temperature fluctuations, have good flexibility, and are resistant to the effects of radiation.

  These characteristics make MCAFs the preferred choice for aerospace applications. They are also likely to be chosen for many areas requiring conductive fabrics, including electronic circuitry. Silver has the added advantage that it inhibits the growth of bacteria.

- **Non-conductive fibres coated with metal or metal salts** such as copper sulphide. The use of metallic salts is limited by their low conductivity and their inability to withstand repeated laundering. However, the use of a silver coating has the advantage of controlling bacterial growth on a material, as well as conducting electrical current through a garment.

➢ **Conductive polymers**

An alternative to the use of metals is the use of polymers such as polyaniline and polypyrrole as the conductive element. These have proved successful in a number of textile applications.

An example of conductive polymer technology is Panion, a polyaniline-based fibre developed by Santa Fe Science and Technology Inc.

Panion is an all-plastic textile fibre which combines conductivity similar to that of metal with the versatility of a polymer. The manufacturer claims that Panion has metal-like conductivity but with "the mechanical properties and weight of nylon".

Two parallel developments are in shape-memory alloys and smart polymer gels.

- Shape-memory alloys offer a variety of physical properties at different temperatures.

- Smart polymer or polyelectrolyte gels have the ability to expand and contract with changes in temperature, pH or the flow of electric current.

➢ **Nanotechnology**

The next phase of research in smart fabrics and interactive textiles (SFITs) is the implementation of nanotechnology. Nanotechnology can be defined as "research and technology development at the atomic, molecular or macromolecular levels (in the 1-100 nanometer range) aimed at creating and using materials which have novel properties and functions".

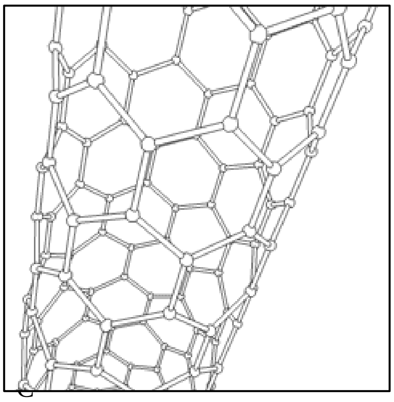
Research into, and the development of, advanced materials which provide flexible, conductive, washable, temperature resistant, phase change properties are currently under way.

Penetration of the market by nanotechnology-based products is expected to occur at the end of the current decade. Physically, nanotechnology products are likely to be incorporated in the spaces which exist between the fibres from which apparel and durable goods are formed.

- **Carbon nanotubes**

Carbon fibre is well established as an electric heating element. Carbon nanotubes are also being developed as conducting materials for use in textiles.

Carbon nanotubes provide strength, flexibility and inherent conductivity. However, their success will depend on their ability to remain effective under practical conditions of use.



C
arbon nanotube

Carbon nanotubes are expected to provide a conductive matrix in woven textiles. This matrix will be useful for:

- power generation and storage;
- providing electromagnetic shielding; and
- Acting as radio antennae.

A promising start has been made by introducing carbon nanotubes into fabrics for apparel and durable goods. Used in this way, carbon nanotubes make such fabrics electrically conductive without losing strength and flexibility.

1.2. Sensors

1.3. Hardware and transmission protocols

The hardware and transmission protocols must take in consideration several levels of integration:

1. The smart seat sensors integration
2. The smart seat integration with the cabin/aircraft services
3. The communication with the devices of the user, as part of the in-flight entertainment.

The data rates and power involved change in each level from slow rates and low power, to a high rate and medium power. The data rates involved in the SEAT project allow the use of wired and wireless solutions.

In a wired environment, each seat receives a high speed data port to support the in-flight multimedia and office services, this wire can also transport the slow rate data involved in the seat sensing and control without disrupt the performance. The wired environment fits well with data and power integration but has a high cost in weight, space and maintenance (example maintenance of the user connectors).

Smart seat sensors integration could use the wireless sensor network technologies, in this approach a set of smart seats or sensors communicate with a slow rate router node. The router node is the responsible to communicate the sensors with the cabin/aircraft services. Other high rate router nodes could provide in-flight entertainment services connecting the devices of the users with the cabin/aircraft servers. This is a more innovative approach that could be a more expensive cost of fabrication, that will be compensate in the reliability and maintenance of the system. A wireless approach is a more open system to the current new wireless emergent technologies. The main handicap is the security; the system must avoid the interferences with the cabin/aircraft instrumentation.

2. Types and Functionalities

2.1. Textile materials

2.1.1. Conductive fibres / filaments

These are those textile materials that are combined with metals (normally stainless steel, nickel, copper or silver) or conductive polymers, either during the spinning and weaving processes themselves or during the fabric finishing process when the conductive treatment is applied, to offer various properties without affecting the comfort of the final article in use.

With the appearance of conductive textile materials, an infant industry of collaboration between textile companies and companies in the electronics sector has grown up to use the properties of these conductive materials to integrate multiple electronic devices directly into textile and clothing products, using shared resources that increase mobility, comfort, functionality and convenience, while offering the items greater added value.

There are a wide variety of conductive fibres on the market, all with different characteristics that make them appropriate for specific applications, depending on the main characteristic to be given to the fabric. There are various types:

- Cut fibre conductive yarn:

  These are filaments in which the metal content consists of between 5% and 20% of cut fibres closely mixed with other kinds of fibres, either natural (cotton) or synthetic (Polyester, Polyamide, etc.). This configuration is stronger than continuous filament and its manufacturing process makes it cheaper than the latter.

  The metal fibres used to make this kind of conductive yarn are mainly stainless steel, copper and silver, with the conductivity varying with the conductive material used.

Metal	Electrical conductivity relative to copper (σ_r)
Copper	1
Silver	1.06
Aluminium	0.63
Iron	0.17
Steel	0.02

Relative conductivity of different metals relative to copper

- Continuous filament conductive yarn:

  These are yarns of different textile materials (cotton, Polyester, Polyamide, etc.) where the core of the yarn is a continuous metal filament, which, in the same way as cut fibre yarn, can be of silver, stainless steel or nickel.

  In this case the conductivity is much greater, as the conductive material is continuous and does not depend on the contact between metal fibres. The manufacturing process to obtain these fibres is more complex, making them more expensive than cut fibre yarn.

- Conductive polymers:

The last decade has seen the development of conductive polymer materials that, due to their conjugated double bond structure and the addition of doping material, allow electrons to travel along polymer chains carrying electrical energy.

There are many different conductive polymers and doping elements that offer a very wide range of conductivities.

Polymer	**Doping substance**	**Approx. conductivity (S/cm)**
Polyacetylene	I, Br, Li, Na, AsF	10000
Polypyrrole	BF, ClO, tosylate	500-7500
Polythiophene	BF, ClO, tosylate, FeCl	1000
Poly(3-alkylthiophene)	BF, ClO, FeCl	1000-10000
Polyphenylene sulphide	AsF	500
Polyphenylenevinylene	AsF	10000
Poly(p-phenylene vinylene)	AsF	2700
Polyphenylene	AsF, Li, K	1000
Poliisotianafteno	BF, ClO	50
Polyfuran	BF, ClO	100
Polyaniline	HCl	200

Conductivity of different polymers

These materials are gradually taking over from the traditional use of conductive metal yarn, due to their versatility and the ease with which they can be mixed with other polymers, as well as offering the possibility of obtaining conductive materials with almost “tailor-made” characteristics in the future.

- Conductive finishes:

One way to obtain conductive materials is to use finishes and coatings with this characteristic, such as:

  - Coating with conductive polymers: coating the textile substrate with a conductive polymer: polyaniline, polypyrrole.
  - Fibre filling or loading: filling fibres with other textile fibres that possess carbon or metal salts.
  - Carbonising: processing the textile in a furnace at 1000ºC.

- Conductive dyes: this technique consists of adding carbon, copper, silver, nickel or gold to the colouring, which can then be applied to fibres and fabrics to obtain conductive substrates. These conductive circuits are integrated in the textile to be designed.

The biggest drawback of these conductive finishes is their lack of durability in certain cases, as they are merely deposited on the substrate and, if not anchored firmly, can disappear over time due to washing, rubbing, environmental conditions, etc.

There are myriad textile applications of conductive fibres, as the conduction of electrical energy can be made use of in many ways, depending on the characteristic the fabric is to be provided with:

- Energy transport:

  These fibres, as they contain metal elements (nickel, copper, silver and steel) are able to carry energy along the yarn and connect different parts or different elements integrated in the core of the fabric.

  This property allows 100% textile items with an integrated electric energy supply circuit to connect power sources to actuators, sensors or any elements that requires electricity to work.

  The use of conductive fibres for energy transport is becoming ever more popular for two main reasons. The first is the reduction in costs due to improved manufacturing systems and increased demand, while the second lies in the textile finish of these kinds of fibres, as they are integrated in the article. Neither should we forget the inherent functionality of a fabric through which electric current can flow.

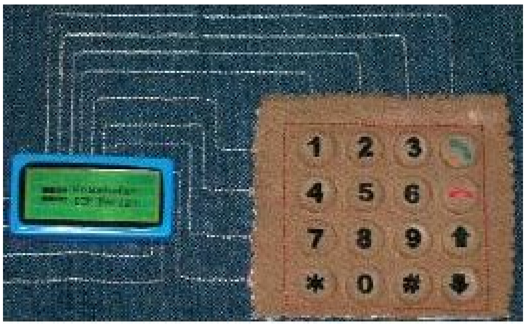
  They are used to connect all kinds of sensors that are integrated in the textile and which need energy supply to work, such as pressure and temperature sensors, or any connections with external apparatus.

- Signal transport:

  These fibres can also transmit electrical signals from sensors that can be interpreted to determine such properties as temperature, pressure, conductivity, etc.

  Conductive fibres can be woven to create an electric circuit that allows the interconnection of different parts, resulting in electrical systems designed to control electronic devices.

  In this field, control applications have been developed for such portable items as MP3 players, mobile phones, etc., and textile keyboards have even been made for displays and controlling laptops and PDAs.



Textile numerical control system connected to a data visualisation display.

- Electrostatic charge dissipators:

  Another property associated with the electrical conductivity of the fibres is their ability to eliminate the residual static electricity that fabrics acquire through rubbing. This means that the static electricity generated in the fabric can escape and not build up.

  The protective clothing textile sector has been using these conductive fibres for several years to prevent the appearance of static electricity and eliminate the possible fire risk of sparks.

  Health is another field of major importance, where the elimination of static electricity prevents dust from adhering to clothing, thus increasing hygiene and asepsis in health care centres.

  The most recent application is the use of conductive fibres in bed linen and underwear, as certain studies carried out by Japanese scientists show that eliminating static electricity has a destressing effect on those who are in contact with the anti-static fabric.

- Electromagnetic wave attenuators:

  Another inherent property of high-density metals such as nickel, steel or silver is their ability to absorb and reflect electromagnetic radiation.

  This means that fabrics made using metal fibres can also attenuate electromagnetic radiation and be used as to block electromagnetic energy emissions.

- Thermal comfort control:

  This field covers those textile articles using conductive textiles within their structure to allow them to generate heat and control the thermal comfort of the fabric. The main property that allows heat to be supplied is the resistivity of the fibres to the forced passage of an electrical current, which leads to the dissipation of heat energy as a result of the “Joule effect”.

  The first yarns and those most used to obtain heat for the thermal comfort of textile items are those containing either cut fibre or continuous filament stainless steel in varying percentages.

  Other types of fibre with the same effect have appeared in recent years:

- A conductive mesh with PAN is being developed for use in wetsuits, climbing boots and gloves.
- Folded carbon fibres are used with any basic polymer.
- Conductive polymer yarn with high elasticity is used for knitwear inside gloves using tailor-made technologies.

The problems lie with the short useful life and excessive weight of the power source, usually batteries, although technology is progressing towards very small, light batteries with ever-longer life.

- Sensors:

  The final example of the integration of conductive fibres in textile items is to create sensors with their help. Sensors monitoring temperature, pressure, conductivity, electric pulse detection, etc. can all be made.

  Measurement of such properties is normally determined by the variation in conductivity experienced by the conductive fibre in relation with the property to be analysed. These parameters have a linear relationship (in most cases) with conductivity, meaning that a mathematical equation can be used to transform the signal into a quantitative value.

2.1.2. Active polymers

Active polymers are those polymers able to react in a controlled way to external stimuli. Certain of the polymers commonly known as active or intelligent are listed below, classified according to the type of stimulus or behaviour.

- Electroactive polymers:

  In the last decade we have seen the development of a new group of polymers that respond to external electrical stimuli by significantly changing shape or size. These materials are known as electroactive polymers (EAPs). Their most attractive feature is that they work in a very similar way to human muscles, particularly regarding their resilience and ability to induce pronounced deformation. This has led to EAP materials to be also known as “Artificial Muscles”.

  Initial experiences in the application of EAPs to textiles have taken two clearly defined routes:

  - EAP-coated fabrics, obtained by depositing the material on the fabric in accordance with a predetermined geometry.
  - Fabrics with EAP-based yarn, fabrics made using yarn based on these materials.

Interest in the applications of these materials to textiles has shown an exponential increase in the last two years, something seen in the statistics relating to articles, documents and references dealing with the subject. These experiences show that the conductive polymer group is the most used to manufacture actuator fibres and yarns. Their main advantages lie in the low voltages used to actuate them and their easy integration in the textile and fabrics, as well as mechanical properties that do not differ from the standard "textile character".

Generally speaking, EAPs are able to induce stresses twice as great as electroactive ceramics (EACs), with much faster response times, lower densities and improved recovery from deformation when compared with SMAs (Shape Memory Allows).

Classification of Electroactive Polymers

Electroactive polymers	
Electronic	Ferroelectric polymers
	Dielectric polymers
	Elastomers with electrostrictive implants
	Electrostrictive paper
	Elastic Electro-Visco elastomers
	Liquid Crystal Elastomer (LCE) materials
Ionic	Ionic Polymer Gel (IPG)
	Ionomeric Polymer-Metal Composites (IPMC)
	Conductive Polymers (CP)
	Carbon Nanotubes (CNT)
	Electrorheological Fluids (ERF)

Classification of EAP's by activation mechanism.

Electroactive polymers		
Electronic activation	Piezoelectric	Polyvinylidene fluoride
		Polyvinylidene trifluoroethylene
		Polyhydroxybutyrate
		Crystalline polymers liquid
	Electrostrictive	Dielectric elastomers
		Polyvinylidene fluoride
		Polyvinylidene trifluoroethylene copolymers
		Polyvinylidene hexafluoropropylene copolymers
	Electrostatic	Dielectric elastomers (silicon or acrylic rubbers)
Ionic activation	Electromechanical	Carbon nanotubes (CNT)
		Conductive polymers (Polypyrrole, Polyaniline)
		Polyelectrolytic gels (PAN)
		Polymer-Metal composites (IPMC)

- Photoactive Polymers:

  These materials act by emitting light when subject to external stimulus.

  - *Electroluminescent:* they emit bright light in different colours when powered by electrical impulses, as when they are stimulated electronically, e.g. with AC current. While they emit light, they do no produce heat, an important property if the aim is to obtain cold light.
  - *Fluorescent:* they return the light with greater intensity. The fluorescent pigments produce visible or invisible light as the result of the incidence of short wavelength light (X-rays, UV rays, etc.). They are white or pale in daylight, but irradiate a bright fluorescent colour when exposed to UV radiation, with the effect disappearing as soon as the excitation source is removed.
  - *Phosphorescent:* they store energy and emit after the initial light source is removed.

  They are already being applied to signing and safety systems. In the case of electroluminescent polymers, they emit cold light and are arranged as films (flat lamps) that are combined with plastic articles using such techniques as IMD (In Mould Decoration) to create 3D items that emit their own light.

- Chromoactive polymers: (Thermochromic, Photochromic, Piezochromic)

  These materials change colour when subject to changes in temperature, light or pressure.

  - *Thermochromic:* they change colour temporarily according to temperature. The colour change occurs within a predetermined temperature range.
  - *Electrochromic:* they change their absorption spectrum and, normally, colour when their oxidation status is altered by the application of an external voltage change.
  - *Photochromic:* these change colour temporarily when subjected to changes in the strength of light. When sunlight or UV radiation is applied, the molecular structure of the material changes and a colour appears. This colour disappears when the light source is removed.

  Thermochromic polymers are already being used for temperature control labels (cold chain), household goods (microwave containers, saucepans, handles, etc.), and toys (cars that reveal a picture when rubbed).

2.1.3. Shape memory materials.

These materials are defined as those able to "remember" their shape and able to return to said shape even after deformation. This shape memory effect can be triggered by either thermal or magnetic changes.

The shape memory effect can be described as the ability of a material to change shape when subject to an external stimulus.

The term shape memory materials covers four different types, depending on their nature, material or the external stimulus they respond to. These four types are:

- Shape Memory Alloys (SMAs).
- Shape Memory Ceramics (SMCs).
- Shape Memory Polymers (SMPs).
- Ferromagnetic Shape Memory Alloys (FSMAs).

With metal alloys, the shape memory effect is based on the transition produced between two solid phases, one at low temperature or martensitic and the other at high temperature or austenitic.

The material deforms in the martensitic phase and recovers its original dimensions as a result of being heated above a critical transition temperature.

Shape memory polymers are polymeric materials able to remember their original shape. This effect is related to the combination of the structure and morphology of the polymer, together with process and programming technology. This means that the material must be trained to remember a specific shape.

The first step is to process the polymer to record its shape permanently and the polymer is then deformed, thus fixing the temporary shape.

The shape memory mechanism in polymers can be triggered by temperature, light and chemical reactions.

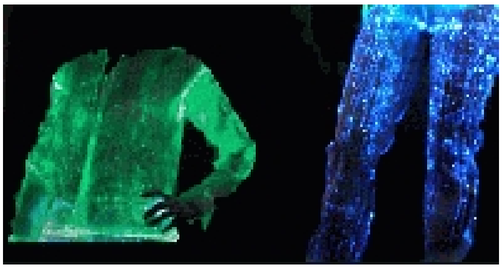
Finally, we should be mention the appearance of a new class of materials that undergo the shape memory effect with the application of different magnetic fields and show significant elongation (approximately 6%).

Here the behaviour is similar to that of shape memory alloys (SMAs), but the stimulus they respond to is the magnetic field applied instead of temperature. These materials are known as Ferromagnetic Shape Memory Alloys (FSMAs) or Magnetoelastic Metals

2.1.4. Optic fibre.

This is a guideway or conduit for waves in the shape of a filament, normally glass (polysilicon) although they can be made from plastic materials, able to transport optical power in the form of light, normally emitted by laser or LED technology.

Each filament consists of a central core or plastic or glass (silicon oxide and germanium) with a high refractive index, covered by a layer of a similar material with a slightly lesser refractive index. When light strikes a surface that limits with a lesser refractive index, most is reflected. The greater the difference in refractive indices, the greater the angle of incidence, this being referred to as total internal reflection. Thus, light reflects off the walls at very shallow angles within an optical fibre, so that it practically travels straight along the centre. This allows the luminous signals to travel long distances without loss.



Fibre optic fabric

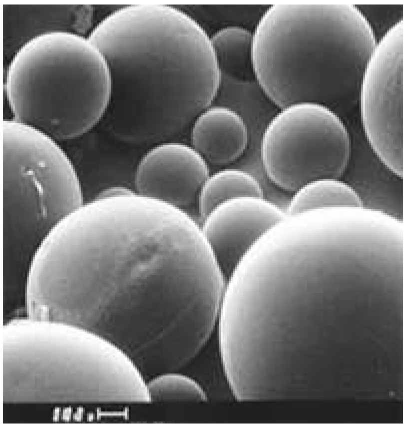
2.1.5. Micro and nanoencapsulation.

Microencapsulation is a technique with significant implantation in many fields, including pharmaceutics and foodstuffs, and is starting to be used in the textile sector. Its comprehensive implementation in the future will offer new opportunities for obtaining innovative fabrics with many functional possibilities.

Microencapsulated products have a significant number of potential uses in the textile sector, allowing us to obtain highly functional fabrics with undreamt of characteristics. These characteristics are based on the nature of the agents contained in the core of the microcapsules, which can contain:

- Perfumes. Therapeutic and cosmetic products (moisturisers, air fresheners, tonics).
- Bactericides, mosquito repellents, acaricides.
- Combinations of ingredients (perfume + bactericide).
- Pigments whose colour changes with temperature (photo and thermochromism).
- Fire Resistant agents.
- UV radiation protection agents.

With certain applications, the microencapsulated agents can be released in a progressive and controlled fashion to achieve the emission of aromas or cosmetics, something that can be obtained by the nature of the polymer.



Microcapsules

2.1.6. PCM (phase change) materials for climate adaptation.

Special mention should be made of PCM materials (phase change materials), with excellent prospects for development of the textile sector, as the microcapsules are able to store the heat emitted by the body and release it according to the external temperature thanks to their ability to change from solid to liquid phases and vice-versa.

Microcapsules work very simply, as it can be seen that when the body temperature is higher than the PCM transition temperature, this liquefies inside the capsule absorbing excess heat, meaning that the body feels cooler. The opposite is true when the body temperature falls below the transition point and the PCM solidifies and gives off heat, causing the body to feel warmer.

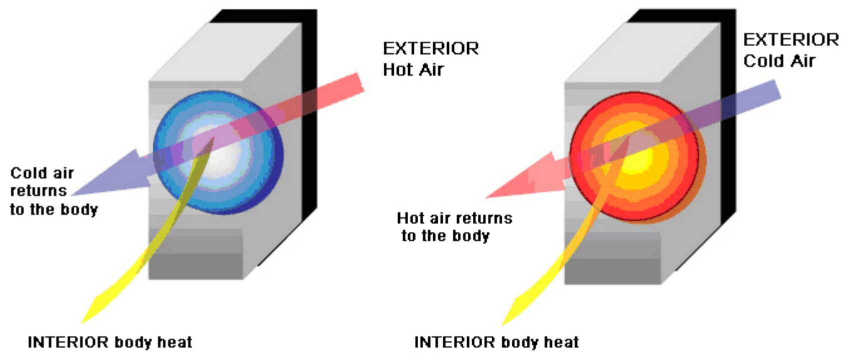


Figure 4. Ambient temperatue > fusion of PCM

Figure 5. Ambient temperature < fusion of PCM

The enormous possibilities arising from the application of microcapsules in the textile field have led to the appearance of the term "intelligent textiles" as a result of the properties they can offer. This technique can be used to achieve cutting-edge properties of all kinds: therapeutics, cosmetics functions, perfume release, protection and many other functions, always depending on the encapsulated agent and in the absence of external changes. However, it is essential to bear in mind all applicable legislation and regulations concerning the emission of toxic substances, as fabrics treated in this way are in direct contact with the skin.

2.2. Sensors

2.2.1. Temperature

2.2.2. Humidity

2.2.3. Pressure

2.2.4. Physiologic

2.3. Hardware and transmission protocols

There are many possibilities to communicate the hardware and the applications involved in the SEAT project. One approximation in the analysis is to consider the connection, wired cable or radiofrequency spectra.

For each one of these we have many physical layers, modulations and protocols promoted by industrial consortiums and international organisations. We must maintain two points of view in the communication revision: the services for the user and the SEAT integration on the aircraft.

- If we must interact with the devices of the passenger, we must consider the current market tendencies in order to anticipate possible communication channels and applications.
- If we want to integrate the smart seat in the aircraft cabin and services we must consider the industrial tendencies in the control technologies.

2.3.1. Wired

User devices use commercial serial interfaces as:

- Legacy serial
  RS422/232/485
- USB
- FireWire (IEEE 1394)
- Ethernet 10/100/1000BASE-X

The wiring buses are a well stabilised technology where the USB is the most popular. We could imagine the smart seat as a smart device connected as a USB device, but we must consider the current tendency to replace wired connections by faster and reliable wireless communications.

In order to integrate the smart seat as part of the aircraft we must consider aircraft buses:

- MIL-STD-1553

- MIL-STD-1760
- ARINC-664
- ARINC-429
- CAN Bus

The Controller Area Network (CAN) bus was developed by Bosch GmbH for use in road vehicles. It is currently gaining wider acceptance in the avionics industry. It uses a differential 2 wire interface running over shielded twisted pair cable, at a maximum speed of 1Mbps.

MIL-STD-1553 is a serial data bus standard used for integration of military avionics and weapon systems. It has been in use since 1973, and is widely used by all branches of the U.S. military and NATO. The standard has two variations, 1553A and 1553B. The 1553B standard increases compatibility between designs by different manufacturers by enabling them to be electrically interchangeable.

MIL-STD-1760 implements an enhanced MIL-STD-1553 digital interface for the transfer of digital messages to a remote terminal. The enhancements include additional error detection in the form of a checksum. A checksum is mandatory on critical control messages and provisional on the remainder of the messages. Implementing this level of error detection ensures a higher degree of error free data.

The Avionics Full Duplex Switched Ethernet standard, known as AFDX or ARINC 664, defines a reliable real-time environment for the use of Ethernet networks for the communication of avionics data. AFDX is widely becoming adopted within the avionics industry as the successor to ARINC 429 point-to-point communications.

ARINC 429 defines the air transport industry's standards for the transfer of digital data between avionics system elements; it is the most common standard, as every modern aircraft of Airbus or Boeing uses this protocol. It provides the basic description of the functions and the supporting physical and electrical interfaces for the digital information transfer system. This protocol works either with 12.5 kHz to 14.5 kHz or 100 kHz and 32 bits of data length. ARINC 429 is a two-wire data bus, the connection wires are twisted pairs. The specification defines the electrical and data characteristics and protocols. ARINC 429 uses a unidirectional data bus standard (Tx and Rx are on separate ports) known as the Mark 33 Digital Information Transfer System (DITS). No more than 20 receivers can be connected to a single bus (wire pair) and no less than one receiver, though there will normally be more. Using the low speed mode of operation tolerances of 10% apply, whereas only 5% tolerances apply to the high speed operation mode.

Final system integration must have in consideration the ARINC series. The Standard ARINC Categories are:

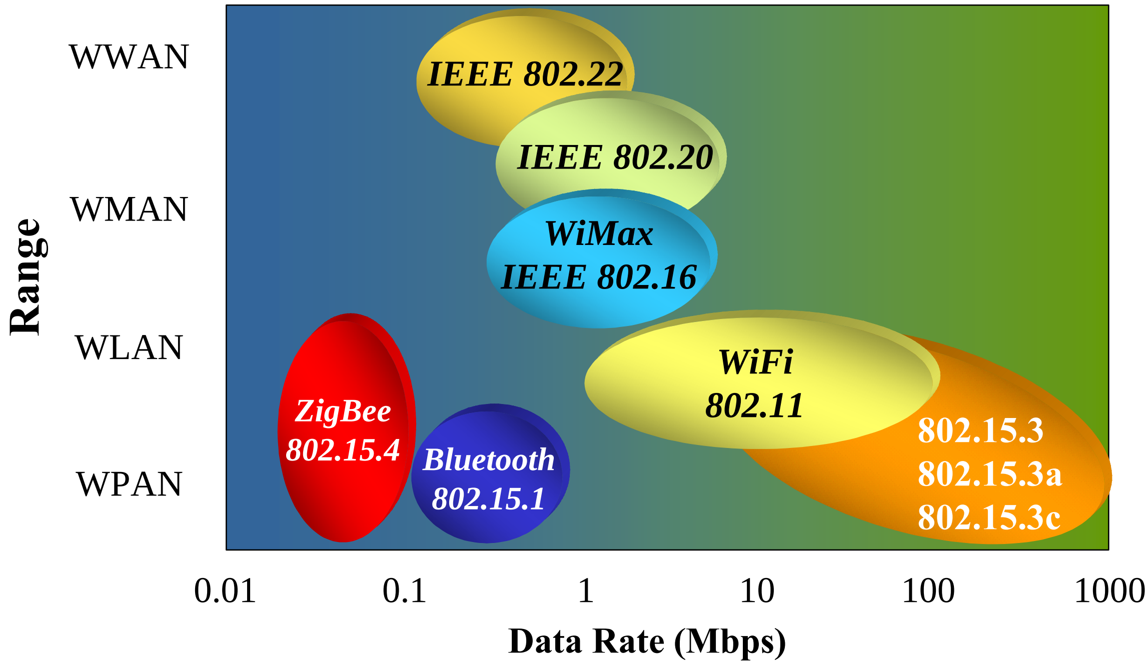
- 400 Series:
  guidelines for installation, wiring, data buses, databases

- 500 Series:
  Analog avionics equipment
- 600 Series:
  design foundation for equipment specified per the ARINC 700 Series
- 700 Series:
  digital systems and equipment installed on aircraft of digital avionics systems. Among the topics covered by Specifications are data link protocols
- 800 Series:
  enabling technologies supporting the networked aircraft environment. Among the topics covered in this series is fibre optics used in high-speed data buses
- 900 Series:
  avionics systems in an integrated modular and/or networked architecture

A smart SEAT wired integration could be based on an Ethernet connection reusing part of the user link used to implement the in-flight entertainment services or could use an ARINC digital standard (ARINC 664) as part of the cabin element. Wiring has a weight, space and maintenance cost that could be very important in the new aircraft, so the possibility to use a wireless solution could be a competitor advantage in a near future.

2.3.2. Wireless

Not long ago, 3G and Wi-Fi were the only major broadband wireless technologies implemented or planned by telecom operators and service providers around the globe. However in the near term, the telecom world will be surrounded by a multitude of new broadband wireless technologies such as WiMAX (802.16 2004 / 802.16e), Ultra Wide Band (UWB), ZigBee, and 4G. Some of those new broadband wireless technologies are now crucial for service providers, enabling them to provide high speed connections, in addition to value added services such as VoIP, mobile TV, video on demand (VOD), video telephony and mobile gaming.



Wireless is one of the markets with a higher growth and where the industry has a higher interest. As at other important development moments, the commercial and technical interests are not always in concordance. Proprietary solutions could suppose a short time to market but have the risk of the market acceptance. Standard solutions have less risk but it is hard to obtain a consensus. This dilemma is the origin of the conflict to fix the IEEE 802.15.3 High Rate WPAN; two industrial consortiums are in conflict to impose their "proprietary" solution as the standard; the MultiBand OFDM supported by the Alliance (MBOA) and the WiMedia Alliance and the Direct sequence-UWB (DS-UWB), supported by the UWB Forum.

Sometimes the proprietary success makes the standard unnecessary because the proprietary becomes the standard; this is the case of the USB. Some other times the standard takes the proprietary as a base for the standard; this is the case of the Bluetooth that is now the IEEE 802.15.1 standard. Finally, sometimes the companies select a market sector and orient the product to this sector. Examples of wireless proprietary solutions are:

- WirelessUSB from Cypress
- ADIismLINK protocol.

But the use of a standard provides:

- Product interoperability
- Vendor independence
- Increased product innovation as a result of industry standardization
- A common platform is more cost effective than creating a new proprietary solution from scratch every time

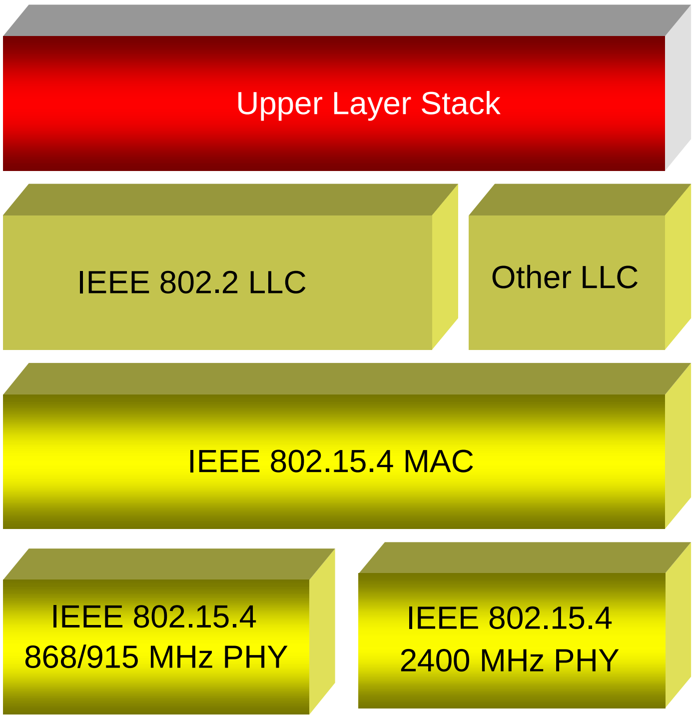
These are very important features for an industrial project as SEAT, and it is for these reasons that the use of standards is highly recommended. Examples of successful wireless standards are:

- WLAN IEEE802.11a,b,g

- WPAN Low Rate. IEEE 802.15.4

2.3.2.1 IEEE 802.15.4 and ZigBee

Recently, IEEE approved a standard for medium access layer (MAC) and physical layer (PHY) for low-rate wireless personal area networks (LR-WPAN IEEE 802.15.4). IEEE 802.14.5 is a multi-optional communication MAC and PHY layer with a medium-size set of primitives that can support a large variety of higher layer protocols as IEEE802.2 LLC.

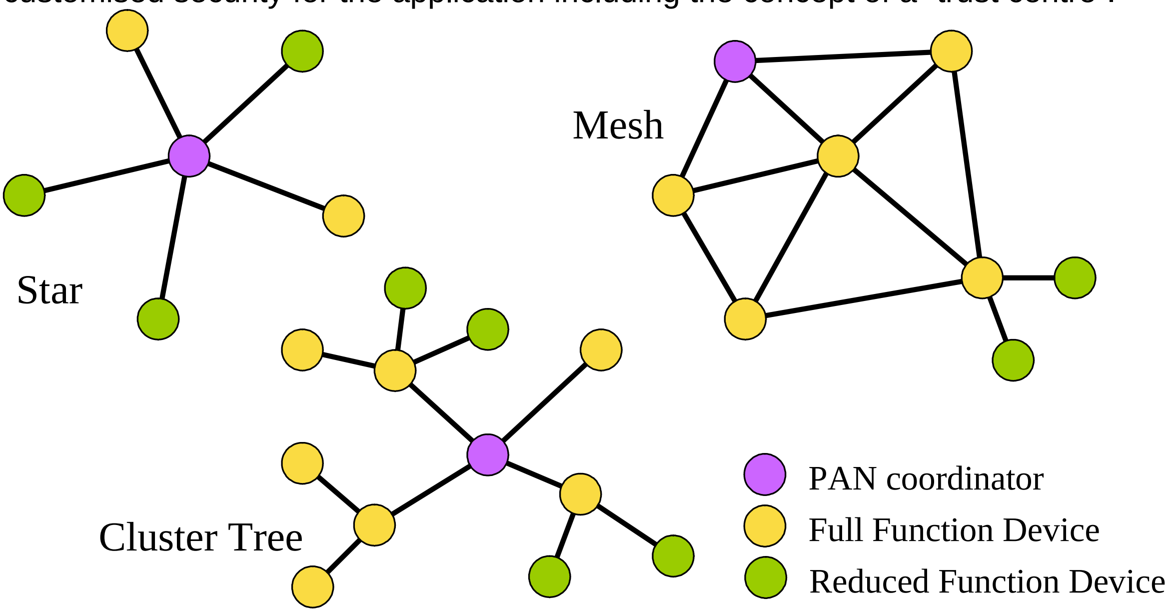


Complemented with the ZigBee networking and application layer, which is proposed by ZigBee Alliance, it is a synonym for a standard platform for the development of sensor network applications. It allows for large networks (large number of devices and large coverage area) that can form autonomously and that will operate very reliably for years without any operator intervention. Other important advantages are the low power allowing very long battery life (years off of a AA cell), the very low infrastructure cost (low device & setup costs) and the very low complexity and small size.

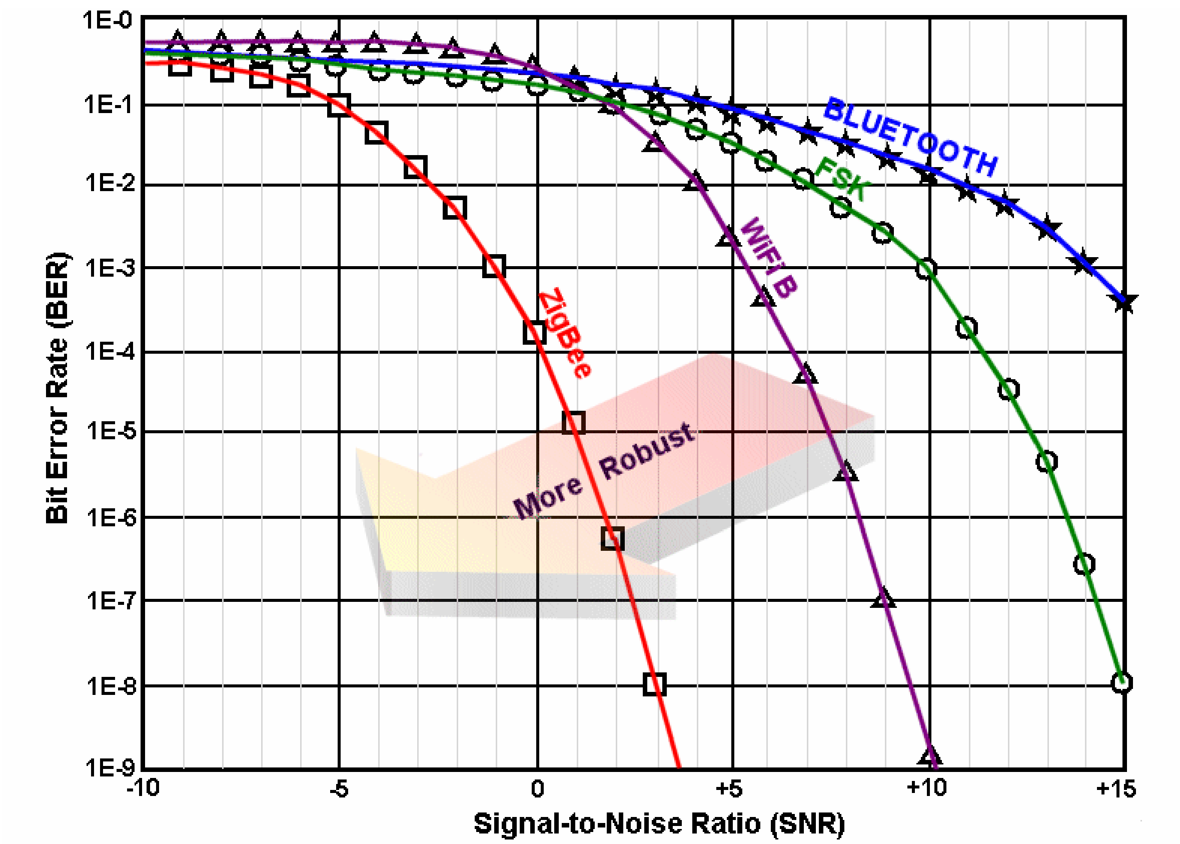
IEEE 802.15.4 includes clustering capability and distinguishes between simple sensor nodes with reduced processing capability and power, called reduced functionality devices (RFD), and more advanced sensor nodes or specialized router/gateway nodes with extended storage, processing and communication functionality, called full functionality devices (FFD).

IEEE 802.15.4 and ZigBee Network Topologies are important building blocks for a standard sensor network communication stack. ZigBee supports Mesh and tree networking protocol that provides redundant paths with automatic retries and acknowledgements and IEEE 802.15.4 provides high intrinsic interference tolerance, multiple channels, frequency agility and robust modulation. ZigBee broadcast delivery scheme ensures reliable broadcasts across the network.

Security and privacy are other important features on a shared media. ZigBee utilises high level encryption (AES 128-bit encryption), authentication and customised security for the application including the concept of a “trust centre”.



Basic Radio Characteristics ZigBee technology relies upon IEEE 802.15.4, which has excellent performance in low SNR environments



IEEE 802.15.4 provides several PHY Layers and Data Rates. In the case of the SEAT up to 15 channels of 250kbps could be integrated to communicate with the aircraft services.

Frequency Band	License Required?	Geographic Region	Data Rate	Channel Number(s)
868.3 MHz	No	Europe	20kbps	0
902-928 MHz	No	Americas	40kbps	1-10
2405-2480 MHz	No	Worldwide	250kbps	11-26

IEEE 802.15.4 and ZigBee Network Topologies are a cost effective solution to interconnect the SEAT instruments with the aircraft/cabin services reducing the cabling requirements and maintenance.

2.3.3. SDR

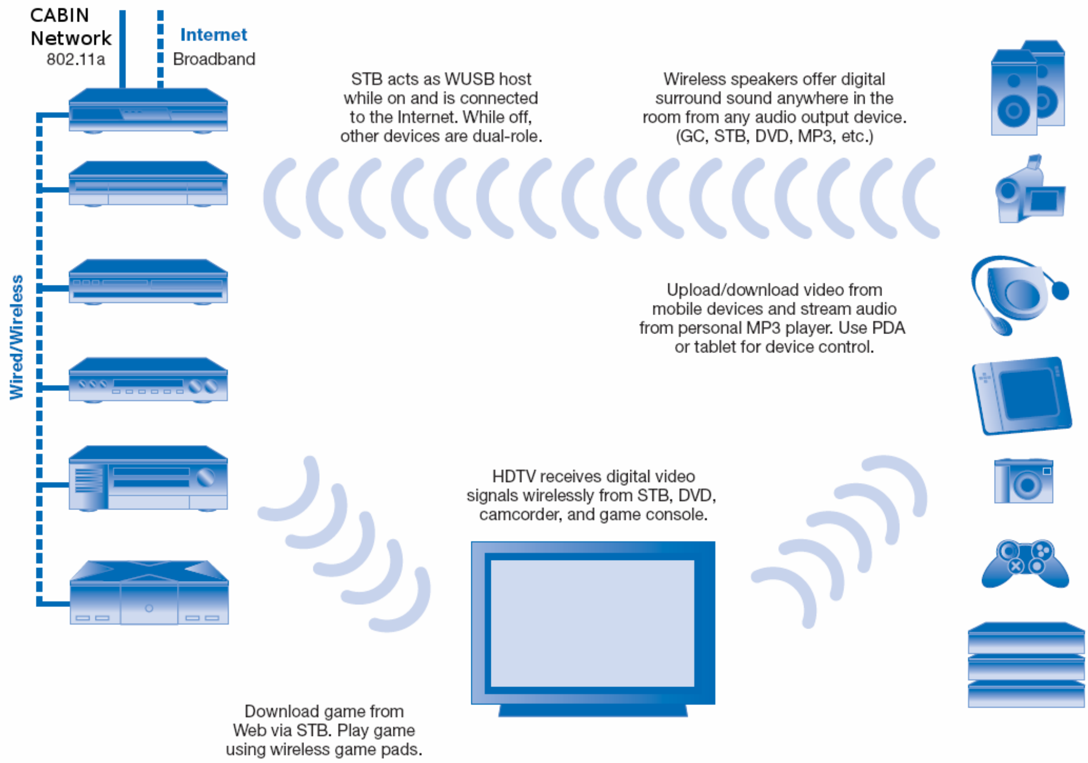
RF spectrum is a limited resource following international and local regulations. Wireless standards and proprietary solutions use the industrial, scientific and medical (ISM) radio bands that were originally reserved internationally for non-commercial use of RF electromagnetic fields for industrial, scientific and medical purposes. ISM frequencies have also been open to license free communication applications.

The main ISM bands for license free communication applications are:

- 868 MHZ band.
- 900 MHz band.
- 1.8 GHz Band.
- 2.4 GHz band. IEEE802.11b,g
- 5.8 GHz band. IEEE802.11a

This limitation on the radiofrequency spectrum produces an overlapping of the communications. A Software-Defined Radio (SDR) is a technological approach to implement a simple radio modem that can tune any frequency and receive any modulation according with the possible ISM communications protocols. SDR performs significant amounts of signal processing but this technology could become the dominant technology in radio communications, the current IEE802,11a,b,g routers as an example of this integration of several RF interfaces and modulations in single system. One example of this approach is the Radio Free Intel, which embodies the concept of a smart radio that can reprogram and reconfigure itself based on available spectrum, the desired application and the device at hand. Configurations would include an 802.11 radio for communicating with a WLAN hotspot, a Bluetooth Technology radio for communication with a cell phone, or a UWB radio for participation in a WPAN. , and WiMAX in wireless wide area networks (WWAN).

SEAT wireless services must include this approach to be capable of providing services to the different ISM protocols of the passengers devices.



3. Industrial applications.

3.1. Smart textiles

3.1.1. Conductive fibres / filaments.

As we have seen in this report, conductive yarns have applications in many of the so-called intelligent textiles and some of the most relevant developments are shown below:

- A special kind of net curtain is being developed with metal fibre yarns possessing electrostatic properties that avoid the accumulation of dust caused by static electricity.
  The net also acts as a barrier to electromagnetic radiation, as the metal fibres absorb and reflect most of the waves striking the fabric.

- Closely linked to this project is the development of prototype bed linen using conductive fibres that eliminate the negative charge of the fabric and offer consumers a destressing effect.

- Another prototype being developed involves self-heating clothing. This is obtained by inserting conductive yarns that are heated by the Joule Effect with the application of an electric current, thus making the wearer feel warmer.

- In addition, a Spanish university is testing a textile pressure sensor that detects the pressure exerted on an area of the fabric by the variation in the conductivity undergone by the filament as a result of its elongation. The project is aimed at obtaining a 100% textile touch screen.

- Philips has developed a fabric that lights up using LEDs and conductive fibres to supply energy. The fabric can create countless drawings and messages. All the elements are integrated in the garment without diminishing the properties of the textile article.

- Finally, it should be mentioned that several companies have launched a prototype vest that can measure the electrical impulses of the heart, send the data to a PC and print out an E.C.G., thus monitoring the patient 24/7.


Left: E.C.G. measurement vest from Smartex.

Centre: Luminescent pillow developed by Philips

3.1.2. Active polymers.

The NANOEFFECT "Nanocomposites with High Colouration Efficiency for Electrochromic Smart Plastic Devices" Project led by the Fraunhofer-Institut Silicatforschung (ISC) is developing flexible, 100% plastic electrochromic devices that are able to change colour when an electric current is applied to them. The main result of the project will be a new nanohybrid material with high chromatic efficiency, integrated in plastic devices with excellent behaviour as regards price, durability and colour range. The end uses of new devices that are able to change colour by the action of an electric current will include electrochromic glasses and other applications in the textile and automotive sectors.

3.1.3. Shape memory materials.

For clothing applications, the desirable temperatures for the shape memory effect to be triggered will be near body temperature.

Polyurethane films have been made which can be incorporated between adjacent layers of clothing. When the temperature of the outer layer of clothing has fallen sufficiently, the polyurethane film responds so that the air gap between the layers of clothing becomes broader. This broadening is achieved if, on cooling, the film develops an out-of-plane deformation, which must be strong enough to resist the weight of the clothing and the forces induced by the movements of the wearer. The deformation must be capable of reversal if the outer layer of clothing subsequently becomes warmer.

Grado Zero Espace has used shape memory metals as a fabric for the manufacturing of a shirt with long sleeves. The fabric could be programmed so that the sleeves shorten as room temperature becomes hotter. The fabric can rolled up, pleated and creased, then returned automatically to its former shape by applying heat to the material.

Another application consists in a seat assembly includes a seat fabric, wherein at least a portion of the seat fabric comprises a yarn comprising a shape memory polymer adapted to undergo a change in a modulus of elasticity at a thermal transition temperature; a support material upon which the seat fabric is disposed; and a controller in operative communication with the shape memory polymer, wherein the controller is operable to selectively apply a thermal activation signal to the shape memory polymer to effect a change in the modulus of elasticity of the shape memory polymer, wherein the change in the modulus of elasticity of the shape memory polymer results in a change in a stiffness and/or flexibility of the seat fabric.

3.1.4. Optic fibre.

France Telecom developed a display made of optical fibres woven into a fabric. The pixel number was just 64 and the fibre diameter 0.5 mm due to the mechanical limitations of the optical fibres. Textile displays also can be realized with conductive fibres covered with a fine layer of an electroluminescent material.

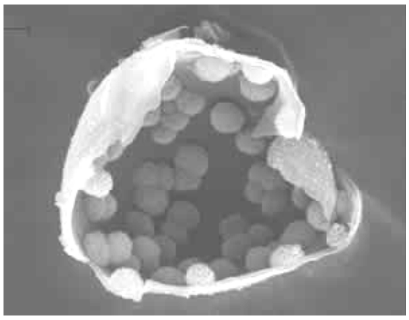
3.1.5. Micro and nanoencapsulation

Germany-based Cognis, a leading speciality chemicals company, is working at the forefront of developments in cosmeto-textiles using microencapsulation. The company combines its strengths in cosmetics and textiles to produce innovative treatments under the banner "active textiles", which are aimed at meeting the market for ever-more intelligent garments. The range of active textile treatments produced by Cognis includes one which provides the wearer with a cooling effect and another which is designed to moisturise the skin. One textile treatment even claims to revitalise tired and heavy legs. The active ingredients microencapsulated in these textile treatments are released with natural body movements and the effect persists through several washes.

Cognis has seen above-average growth in its markets, partly as a result of capitalising on two broad trends: wellness; and environmental sustainability and performance. By focusing its product development and expertise on these trends, the company plans to increase market penetration of new and speciality products which are more profitable and which drive sales.

3.1.6. PCMs (phase change materials).

Under this project encapsulated PCMs for use in pilot uniform are being developed in collaboration with DEBEL, Bangalore. The indigenously developed PCM capsules which are about a few microns in diameter maintain temperature around 30 ^{o}C and store almost twice as much heat per unit weight than encapsulated materials available abroad. Project aims at solving some of the fundamental technological challenges associated with development of PCMs such as core to wall ratio, stability, and efficiency.



Fibre with encapsulated

3.2. Sensors

3.2.1. Temperature

3.2.2. Humidity

3.2.3. Pressure

3.2.4. Physiologic

4. Legal framework

4.1. Textile requirements

4.2. Electronic requeriments

4.2.1. Sensors

4.2.2. Hardware

5. References:

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Textile numerical control system connected to a data visualisation display

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- Fibre optic fabric: http://www.luminex.it/pagine/photo2.html#

E.C.G. measurement vest from Smartex.

Luminescent pillow developed by Philips

- http://www.smartex.it/smartex.htm (products\wealthy)
- http://www.research.philips.com/newscenter/pictures/downloads/ldm-lighting_09-0_h.jpg

Shape memory material

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6. Bibliography