Summary of the work on SDR and Cognitive Radio within ITU-R

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Related ITU-R documents

Software Defined Radios

- Question 230-2/8

  "Software Defined Radios"

- **Report ITU-R M.2117**

  "Software defined radio in the land mobile, amateur and amateur satellite services"

Cognitive Radio Systems

- Question 241-1/8 "Cognitive radio systems in the mobile service"

Question ITU-R 230-2/8 "*Software Defined Radios*" 2000-2003-2007

- What should the appropriate ITU-R definition for SDR be?
- What are the key technical characteristics that are associated with the design and application of SDR?
- What frequency band considerations are important to the application of SDR?
- What special interference considerations may be required in SDR applications?
- What are the operational implications of SDR to mobile radio systems?
- What technical considerations are necessary to insure conformance with ITU Recommendations and Radio Regulations?

Report ITU-R M.2117

“Software defined radio in the land mobile, amateur and amateur satellite services”

Definition

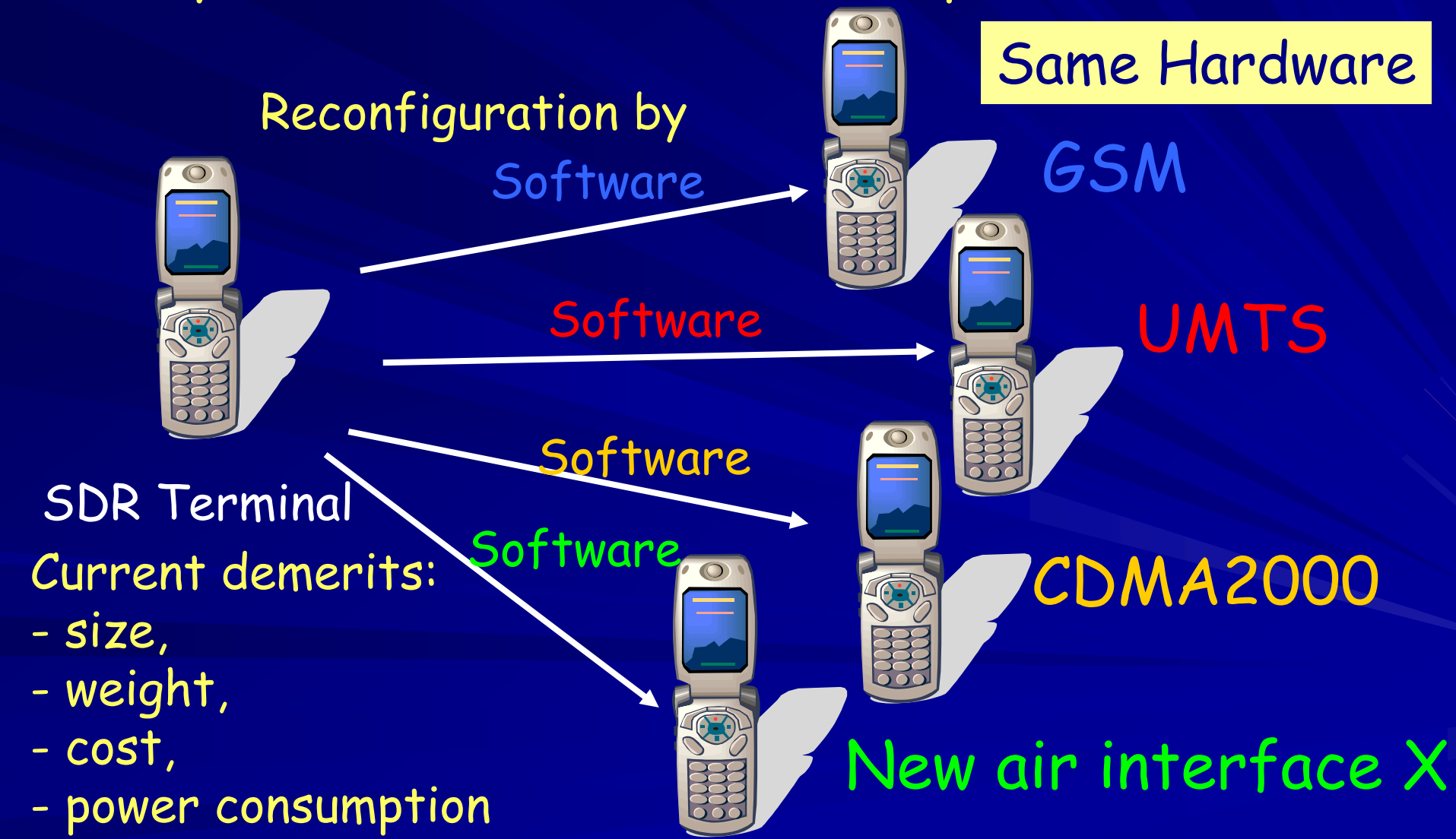
Software defined radio :

A radio in which the RF operating parameters including but not limited to frequency range, modulation type, or output power can be set or altered by software, and/or the technique by which this is achieved.

NOTE 1 – Excludes changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard.
NOTE 2 – SDR is an implementation technique applicable to many radio technologies and standards.
NOTE 3 – Within the mobile service, SDR techniques are applicable to both transmitters and receivers.

Functional Characteristics

Ability of a radio to emulate multiple air interfaces



Operational Characteristics (1)

- SDR can provide an effective means to bridge operational requirements involving multiple bands and protocols,
- However, standardized air interface and common software framework are required,
  - The standardized air interface protocols
    - Identify features, including encryption, authentication, scanning, priority, emergency, caller-ID, and
    - define how they will work,
  - Air interfaces can be exchanged from one radio platform to another one by using a common software platform.

Operational Characteristics (2)

- Interoperability can be achieved by;
  - bridging between multiple interfaces,
  - allowing a subscriber to enable his/her equipment to implement a specific service according to his/her requirements,
  - device reconfiguration by
    - over the air transmission;
    - infrared link;
    - download from a personal computer;
    - reconfiguration while in a battery charger;
    - factory authorized update at local kiosks; or
    - memory card insertion by a network operator

Operational Characteristics (3)

- Protection mechanisms:

  To avoid inappropriate transmission, while reconfiguring, SDR should be protected from;

  – reconfiguration by individuals with malicious intent and

  – inadvertent reconfiguration by authorized technicians ;

Operational Characteristics (4)

- Heterogeneous radios

  - multi-mode/ multi-band radios -

  The SDR flexibility allows operation with;

  – multiple radio interfaces with given available specifications and

  – multiple RF bands ;

- The selection of the air interfaces or RF bands can be done automatically, if the radio has

  –"policy-based" or "cognitive" capabilities.

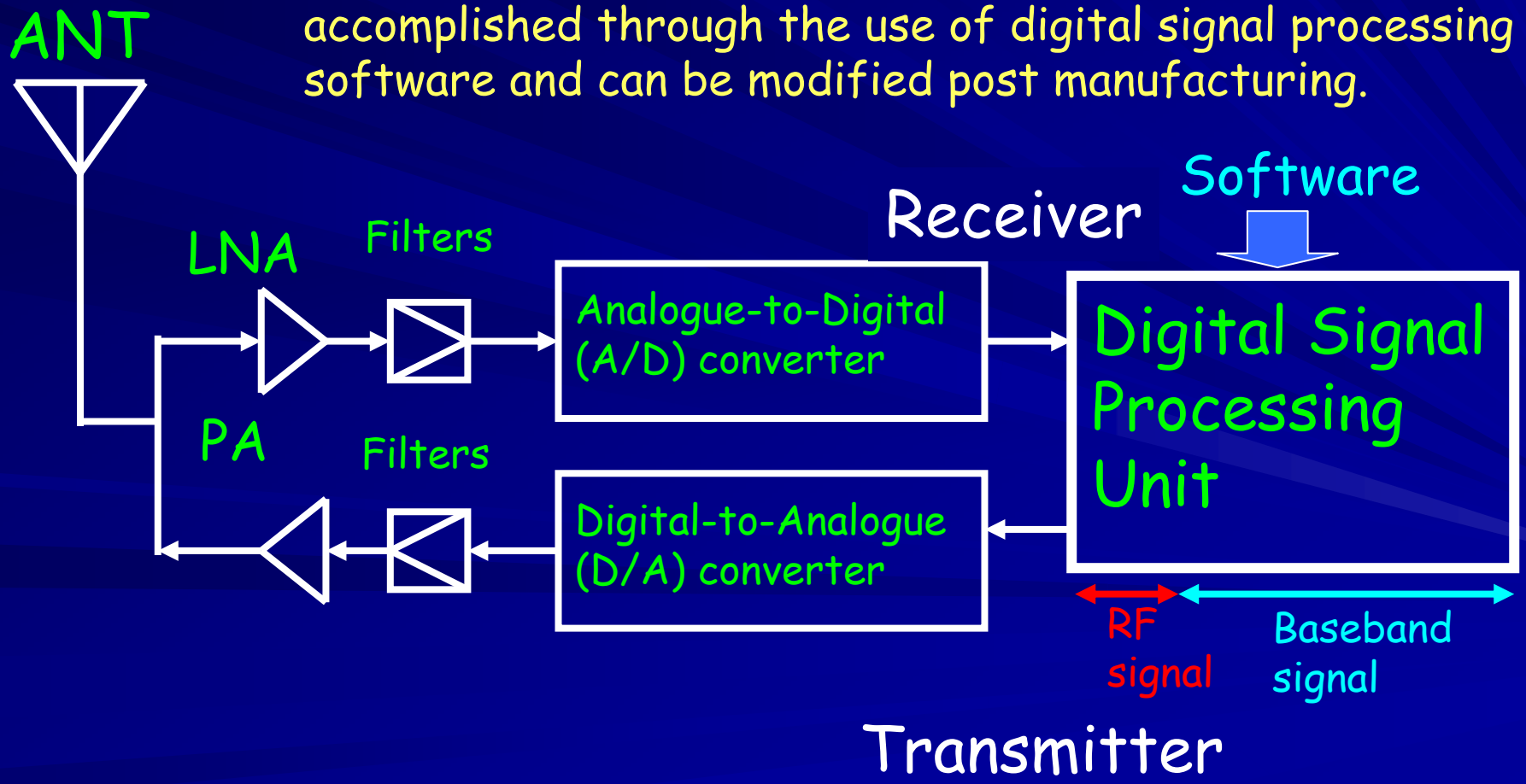
Operational Characteristics (4)

- Key items for the heterogeneous radios;
  - The air interface specifications are made public so that every radio vendor can implement and offer them on their radio, and
  - The software architecture(s), on which the air interfaces are built, allows air interface software developed by Company A to be used on a Company B's radio. – common platform -

Technical Characteristics (1)

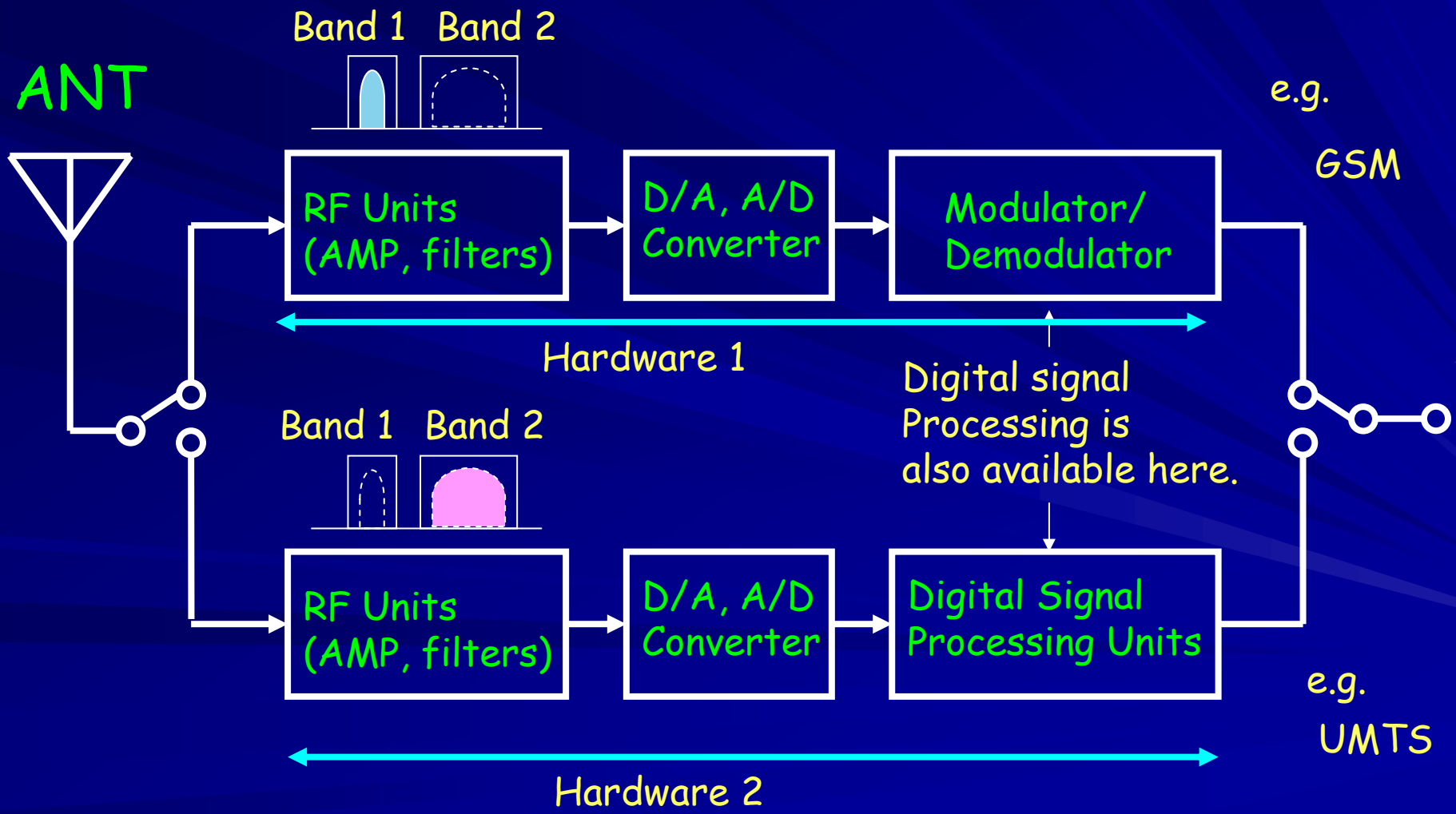
- Basic SDR transceiver structure

A radio is considered to be a Software Defined Radio if some or all of the baseband or RF signal processing is accomplished through the use of digital signal processing software and can be modified post manufacturing.



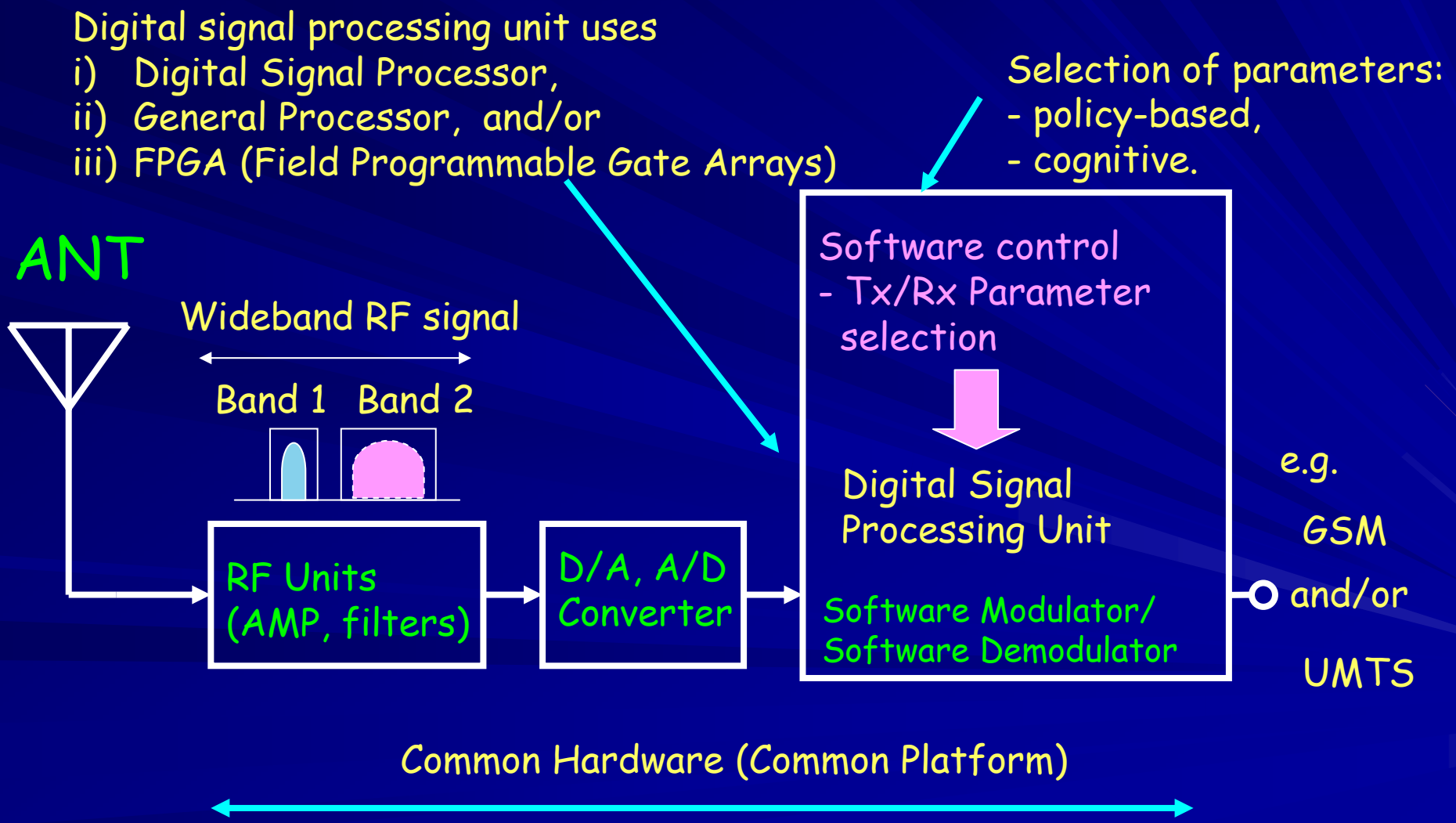
Technical Characteristics (2)

- Conventional multi-band/multi-mode TRX



Technical Characteristics (3)

- SDR based multi-band/multi-mode TRX



Software Download (1)

- Download of codes
  - Definition:

    it may be defined as the download of the complete executable code, parameters, standard description, etc. which implements a certain air-interface standard or serves as the update or replacement of some of its modules,
  - Usages:
    - upgrades of device capabilities.
    - purchase of support for a newer version of a standard or for an additional standard,
    - distribution of upgrades of original manufacturer software by operators,

Software Download (2)

- Download of air-interface parameters:
  - Definition:
    - It may be defined as the selection from pre-defined operational modes or the re-parameterization of functionality, relating, e.g. to
      - transmit frequency, power, modulation, burst structure, encoding, timing, certain aspects of the protocol, etc.,

      which can be described by parameters or templates.
  - This does not in general require the exchange of executable code,
- Security mechanisms:
  - mechanisms such as signed code (digital signature) are needed.

Security aspects (1)

- Rollback mechanism:
  - the terminal can switch back to a safe starting position after incomplete or faulty download of a new standard.
- Examples study items :
  - How to assure integrity of the software, and how to prevent malicious software (malware), e.g. Trojan horses and computer viruses from being installed by hackers.
  - How to protect private information,
  - How to authenticate the identity of individuals intending to install software,
  - How to identify the consistency between terminal and software, and
  - How to recover from a failure of installation.

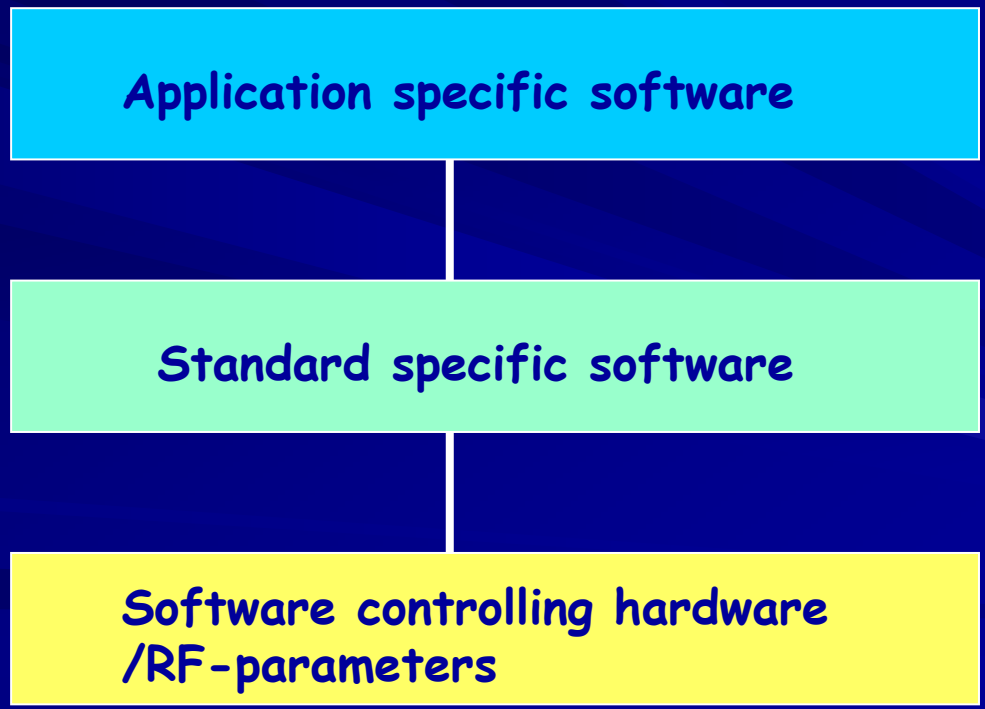
Security aspects (2)

- When a number of systems are installed in a terminal, there are study items regarding terminal addressing and user management:
  - Whether every system has different addresses for identification.
  - How to manage the address resource and how to avoid duplication of addresses and shortage of the address resource.
  - How operators gather information about the system which is installed on a terminal to use their services.

Note: output of ITU-T Study Group 17 on security aspects is relevant

Deployment consideration (1)

- Schematic of different types of software present in an SDR terminal or base station



Deployment consideration (2)

- A stepwise market evolution
  - 1st step: Vertical Model:
    - all hardware and software components are under responsibility of only one entity (e.g. via contracts or certification processes) which is responsible for the conformity and faultless functioning of both,
    - this well-defined responsibility ensures that the devices will operate within the given regulatory limits.

Deployment consideration (3)

- A stepwise market evolution

  2nd step: Horizontal Model:

  - many different independent companies will develop and offer SDR hardware and/or software components based on open interfaces.
  - mechanisms have to be elaborated to ensure that the hardware of company X is compliant with the software of company Y.
  - Before new software or hardware components are offered to the market, they have to pass through validation processes and have to perform test cycles successfully and the process can be by the involved industry players self-dependently.

Potential regulatory implications (1)

- Interference considerations (1) :
  - The ability of an SDR to dynamically modify its operating parameters is a key in managing interference;
  - however the potential for causing interference to other authorized radio services cannot be overlooked.
  - The primary concern of SDRs would be;
    - they are remotely programmable and
    - they have the hardware capability to transmit in critical frequency bands in which they are not authorized.

Potential regulatory implications (2)

- Interference considerations (2) :
  - The security for SDR software is a key factor in ensuring equipment operates within its allowable parameters to avoid the emission of harmful interference,
  - The main security issues include:
    - who has the authority to control the reconfiguration of the communications equipment;
    - protection of the reconfiguration signalling;
    - privacy of the reconfiguration information;
    - the correctness and availability of the information on which the reconfiguration is based; and
    - secure download of the software required for reconfiguration and issues related to the radio emission and associated conformance requirements of radio equipment.

Potential regulatory implications (3)

- Spectrum management (1) :
  - Current spectrum management techniques provide for designating specific frequency bands for each radio services. As more services are added, spectrum allocations will become more difficult,
  - There are portions of spectrum that are unused when considered on a time and geographical basis,
  - Studies have shown that the reuse of such spectrum can provide improvement in available capacity,
  - SDR using cognitive or policy-based control mechanisms is one approach for achieving better spectrum utilization, dynamic spectrum management, and flexible spectrum use.

Potential regulatory implications (4)

- Spectrum management (2) :
  - In sharing arrangements, it is important that a radio have the ability to have their operating parameters modifiable via software in the field. Equally important is the need to be able to change the policies that dictate the radio's behaviour.
  - SDR can assist to provide access to those bands already allocated to a particular service, as well as assisting in allocation of additional harmonized frequency bands for services.
  - While the operating frequency and other channel parameters (e.g. modulation type, error coding scheme and power) could be manually selected, this would be slow and mistakenly result in unacceptable interferences.

Potential regulatory implications (5)

- Spectrum management (3) :
  - Adaptive control mechanisms allowing dynamic spectrum access could be beneficial, such as policy-based and cognitive.
  - In those cases, the radio makes aware of its environment and automatically establish its operating parameters.
  - The selection is based on a number of rules-set to avoid interference.

Potential regulatory implications (6)

- Spectrum management (4) :
  - The input information to the control mechanism may include, for example:
    - Policies (regulatory, operational, user)
    - Sensor information
    - Available RF bands
    - Propagation data
    - Available protocols
    - Performance requirements
    - Information about the radio network infrastructure.

Potential regulatory implications (7)

- Spectrum management (5) :
  - Adaptive Control Mechanisms:
  - (a) Policy-based approach:
    - a deterministic mechanism is used whereby the selection process is repeated for every new situation
  - (b) Cognitive approach
    - the mechanism is closer to Artificial Intelligence (AI) whereby a learning mechanism is implemented and the selection is based on past experience, therefore speeding up the process.

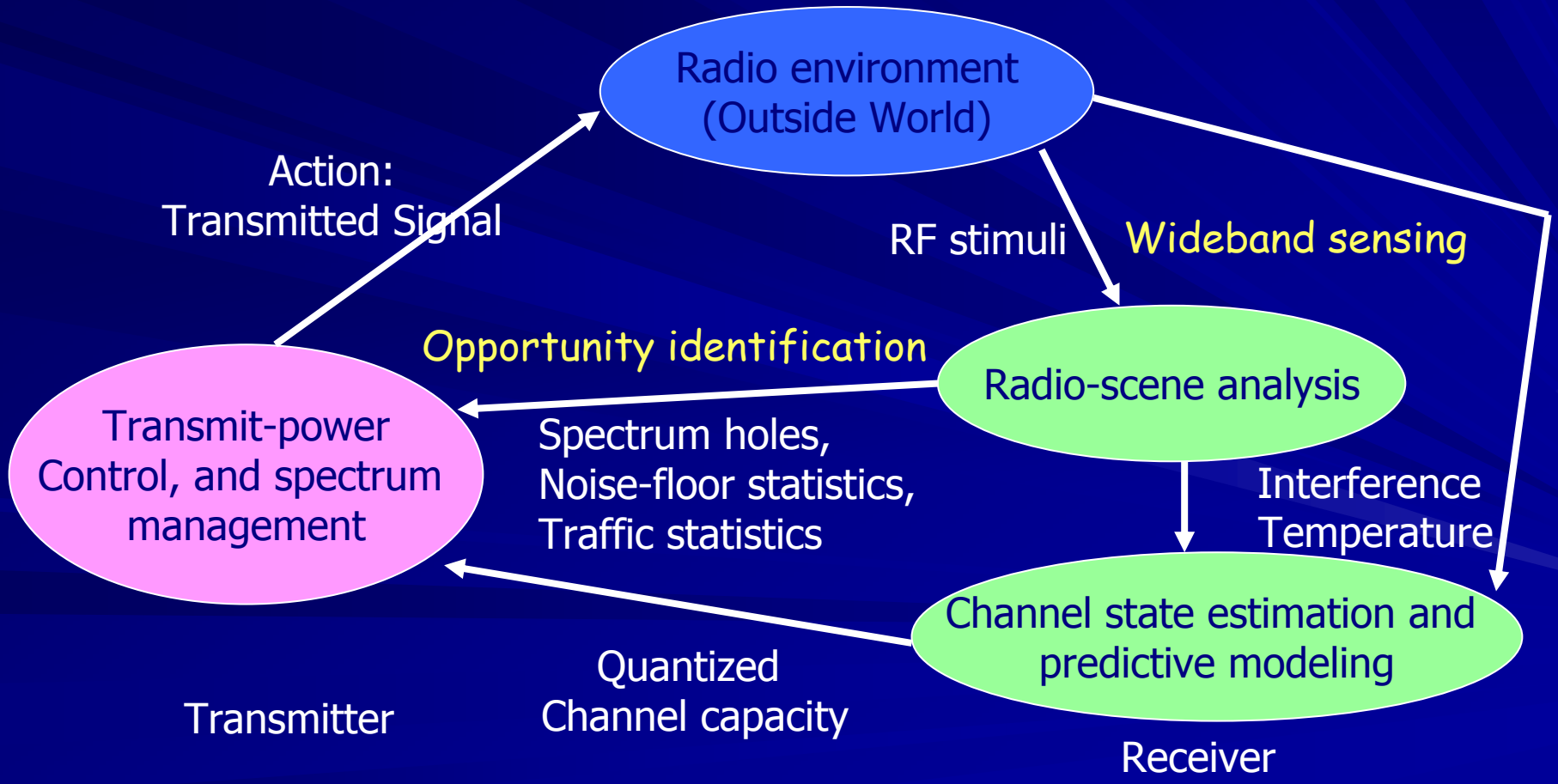
Cognitive Radio

- The term "cognitive" comes to the radio community via the AI and computer science realm.
  - Applying practical considerations to the AI definitions of cognitive, the characteristics of a cognitive-based control mechanism emerges:
    - maintains knowledge representation, automated reasoning, and machine learning capabilities in accordance with the Turing test;
    - automated reasoning can be purely rational (deterministic) or can be inconsistent with strict rationality when reasoning, problem solving, planning, and learning;
    - for practical implementations, the degree of inconsistent (non-deterministic) rationality must be limited by a deterministic bound such that it consistently obeys a set of rules or policies that govern its behaviour.
- The use of "cognitive" throughout the wireless communications community spans the spectrum of dynamic radio control capabilities.

Example of Cognitive Cycle

[1] S.Haykin: "Cognitive Radio: Brain-Empowered Wireless Communications,"IEEE JSAC, Vol.23, No.2

Two primary objectives in mind:
1) Highly reliable communications whenever and wherever needed,
2) Efficient utilization of the radio spectrum.



Cognitive Radio

[1] S.Haykin: "Cognitive Radio: Brain-Empowered Wireless Communications," IEEE JSAC, Vol.23, No.2

Cognitive Radio: [Note: No ITU-R definition so far.]
an intelligent wireless communication system that is aware of its surrounding environment (i.e. outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g. transmit-power, carrier-frequency, and modulation strategy) in real-time,
with two primary objectives in mind:
- Highly reliable communications whenever and wherever needed,
- Efficient utilization of the radio spectrum

Potential regulatory implications (8)

- Implications for certification and conformity
  - conventional certification regimes have been developed based on an *ex ante* determination that the operating parameters of the device are in accordance with local regulations. Such regimes have no mechanisms to deal with a fundamental capability attributed to SDRs – that such devices can change their operating parameters *ex post* of its certification or declaration of conformity.
  - Administrations have also recognized the conformity issues and have begun activities to examine and/or modify conformity regulations to enable SDR devices to be deployed.

Potential regulatory implications (8)

- Implications for certification and conformity
  - Certification and conformity issues:
    - Enabling such radios to be reconfigured in the field by establishing rules to allow for equipment identification, recertification or declaration of conformity of such terminals post deployment.
    - Conformance certification.
    - Software installation issues such as:
      - Installation rights
      - Installer certification
      - Media delivery
      - User and operator installation
      - Recovery from installation failure
      - Prevention of unauthorized software changes
      - Roaming and reconfiguration mechanisms
      - Installation procedures and mechanisms

Potential regulatory implications (9)

- Implications for circulation
  - For instance one administration may require a specific type approval for SDRs, requiring that the manufacturer take steps to ensure that only software that has been approved with a software defined radio can be loaded into such a radio. The software must not allow the user to operate the transmitter with frequencies, output power, modulation types or other parameters outside of those that were approved.
  - Administrations with other conformity regimes might require different procedures.

SDR Application to specific mobile systems

- IMT-2000 (1)

  SDR will have some impact on these sub-systems and on the interworking between them.

  - In particular the User Equipment (**Terminals**) and their network interface are most affected since the different standards have to be implemented into the terminal.
  - Implementation of the various IMT−2000 radio interface standards leads to different technical requirements in regard to the terminal capabilities e.g. storage capacities, computing power and power consumption.
  - The main target for introducing SDR technology into

SDR Application to specific mobile systems

- IMT-2000 (2)
  - The main target for introducing SDR technology into the base station and its controllers of a mobile radio access network (**RAN**) is to increase flexibility of radio access networks.
  - The use of SDR potentially enables the base station to be “reconfigured” which could include the change of functionality, for instance changing from one IMT−2000 radio access technology to another, as well as the partial modification or update of certain aspects of a radio access technology, such as the introduction of an optional capability or a new version.

SDR Application to specific mobile systems

- IMT-2000 (3)
  - Terminal reconfiguration favours worldwide roaming and interoperability, because, ideally, one single terminal might be reconfigured to employ any radio access technology and/or access differing frequency bands.
  - Likewise, it enables the separation of services offered to the user, and the technology used to provide them.
  - It also makes the correction of software errors easier and more effective, as the physical need for recalling defective terminals is substantially reduced or eliminated through software based changes.

SDR Application to specific mobile systems

- Wireless access systems (WAS) including RLAN
  - WAS devices can operate on a licensed or licence-exempt basis. In addition to widespread deployment for networking computers in companies and in private homes, many international carriers and service providers are offering service via “hot-spots”.
  - This has been termed “heterogeneous roaming” – staying connected to the same operators, but roaming between different air interfaces.
  - SDR will permit the manufacturer to develop a product once and then have it deployable globally, allowing jurisdictions to tailor to fit local needs.

SDR Application to specific mobile systems

- Public protection and disaster relief (PPDR)
  - A primary challenge which is often faced by the people and agencies responsible for public protection and disaster relief (PPDR) operations is the incompatibility of the communications equipment that they use.
  - By allowing the dynamic reconfiguration of radio operational characteristics, SDRs provide a communications mechanism through which:
    - individual agencies can function independently in normal operations, without interference from the equipment of other agencies; and
    - agencies can communicate when cooperation is necessary.

SDR Application to specific mobile systems

- Intelligent transport systems (ITS)
  - Various kinds of radio services are provided to vehicles at present. This includes, for example, broadcasting services such as FM radio, TV as well, ETC (electronic toll collection) services. VICS (vehicle information and communication service) are also provided in some regions.
  - SDRs, therefore, will be an essential component of future suites of in-vehicle technologies.

SDR Application to specific systems

- Amateur and amateur satellite systems
  - Typical 16-bit PC soundcards have a maximum sampling rate of 44 100 Hz, meaning that the maximum bandwidth signal that can be accommodated is 22 050 Hz.
  - Soundcards have been used as hardware platforms for development of audio-frequency modems for chat mode communications such as PSK31 and data transmission both narrow band and voice frequency bandwidths.
  - Nearly all amateur satellites now being designed have some SDR functions. These permit software to be uploaded from earth telecommand stations to alter parameters of the satellites.

Thank you
for your attention