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Spectrum Management & Regulatory Issues

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Note: These are preliminary notes, intended only for distribution among the participants. Beware of misprints!

Purpose

- to review regulations that specify how radio systems of any kind should (or should not) be used in all countries
- to complement my earlier talks on radio links, interference, and coexistence

Main topics for discussion

- What is spectrum management?
- What are the Radio Regulations?
- Who created them and how?
- What are new trends?

Note: We shall review basic topics and only touch on more advanced issues.
(To cover any of the many topics in detail, much more time would be needed.)

Radio = development

- It is widely accepted that the uses made of radio will contribute significantly to the economic growth and improvement of the living standard in the next few decades
- How these uses are regulated has thus profound impact on the society
  - security, prosperity, culture, education, propaganda, …

What is the spectrum?

- Our understanding of the spectrum has been changing:
  - *Mathematical concept?*
  - *Measurable physical quantity?*
  - *Common (public) resource?*
    - with satellite orbits included later
  - *Marketed commodity?*

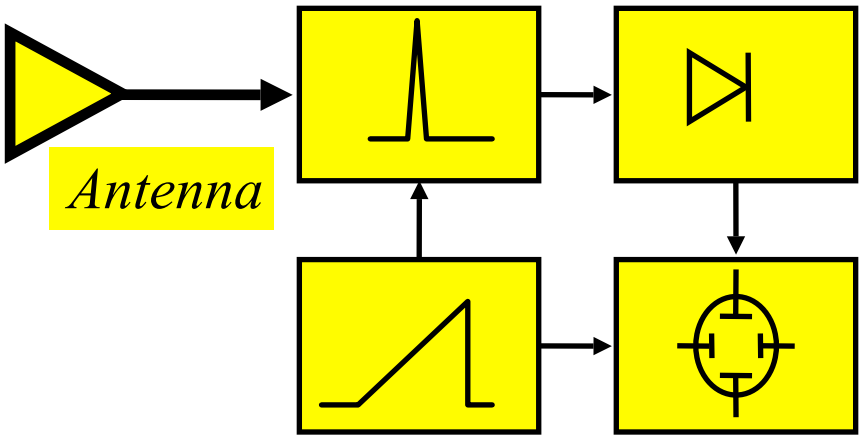
Spectrum = math. concept?

- 1822: An abstract concept of no practical value, only later accepted as mathematical tool
  - 1822: Concept of spectrum (J-B Fourier, 1768-1830)

$$S(\omega) = \int_{-\infty}^{\infty} f(t) e^{-j\omega t} dt$$

- 1873: Theoretical possibility of EM waves (J-C Maxwell, 1831-1879)

Spectrum = measurable quantity?



- A physical object
  - 1888: Hertz experiments
- Radio waves can transport energy and information at distance with no wires
  - 1895: Marconi and Popov experiments & *applications*
- Now: Spectrum analyzers

Spectrum = common resource?

- A natural freely accessible public resource: everybody can profit from its exploitation
  - 1901: First transatlantic wireless transmission
- Time of plenty
  - Competition - Unrestricted growth - technological progress - boom of civilian radio

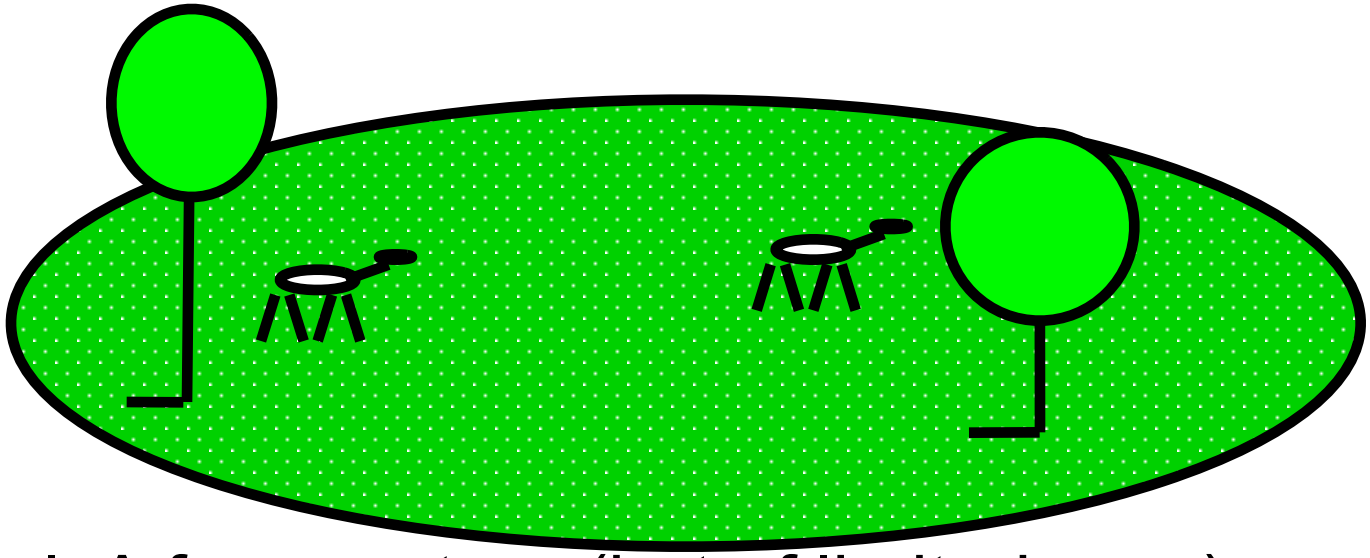
Commons: major problems

- Interconnection and tariff problems due to free (unregulated) competition
    - 1912: Titanic disaster, London Conference
- Radio interference problems due to competition ('power race') and primitive technology
    - » spectrum scarcity/ congestion, chaos
    - 1903/ 1906: Berlin Radiotelegraph Conference (27 States) contained a provision that radio services be organized to avoid interference between stations

Spectrum = scarce resource?

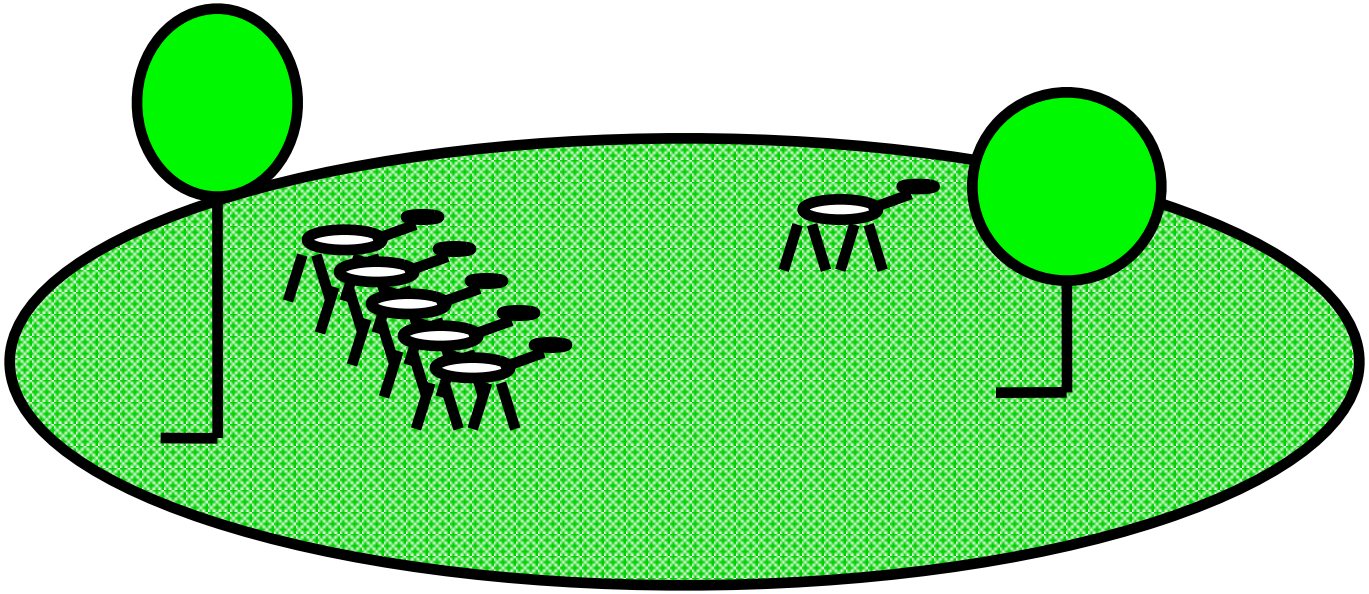
- 1925 “...no more spectrum available…”
  - » declares a US Secretary of Commerce
- In 1910, the US Navy petitioned to shut down ~4000 amateur radio stations because of RFI to ~1000 governmental & commercial stations.
  - The US Radio Act of 1912 solved this interference problem by relegating the amateurs to the “useless wavelengths of 200 meters and shorter” and by limiting their power to 1kW.
    - » Source: DD Hoolihan1, N Carter: A General History of the Evolution of the Discipline of EMC; EMC Zurich 2005

How do commons work?



- Model: A free pasture (but of limited area), open to any herdsman with cattle; no regulations
- Aim of each herdsman: to maximize his ***individual*** gain (which comes from selling cattle)

Time of plenty..



Following his best interest, each herdsman adds 1 animal more, and more… The number of cattle increases, and the wealth of the men follows …

Limit to growth

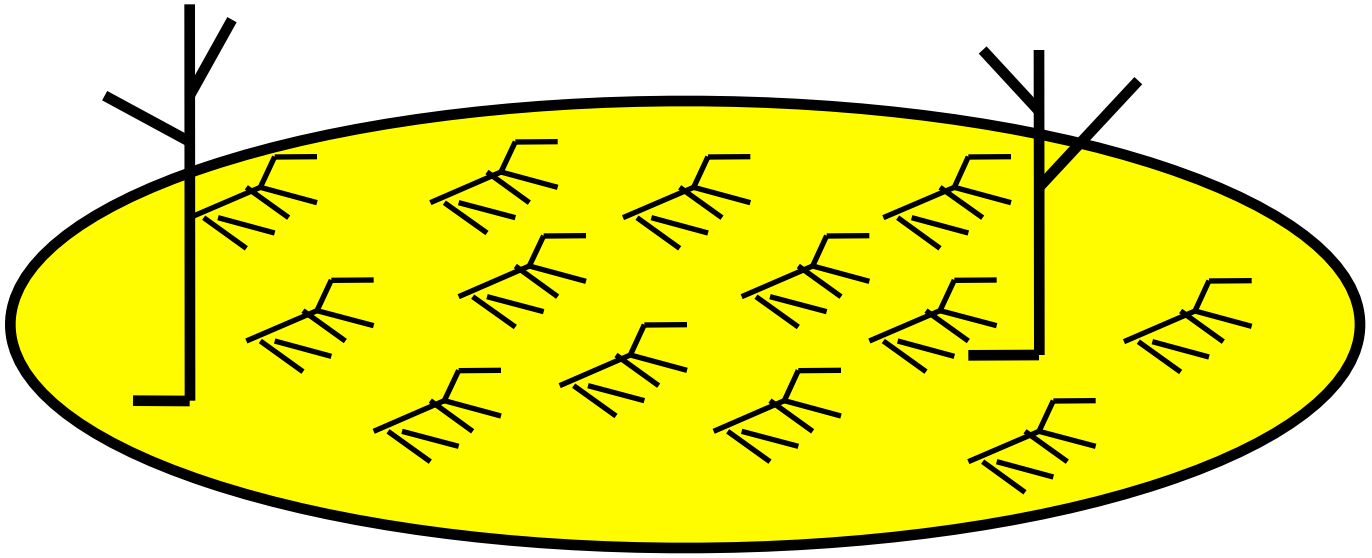
- How long such a growth can continue?
  - Until the pasture saturation, when the capacity limit is reached – and overgrazing begins
- At that point, a herdsman considers the pros and cons of adding 1 more animal:
  - Pros = 1 (the full gain from selling goes to me!)
  - Cons < 1 (the overgrazing effect is shared among all)
  - Conclusion: better to add one more animal!
- Each and every herdsman comes to such a conclusion!

Impasse

- Seeking individual gain, no one is caring of others and of commons, as it requires some self-sacrifice
- Nobody is motivated to limit his herd to avoid overgrazing or to invest in possible improvements

Tragedy of commons

- "...*Ruin is the destination toward all men rush, each pursuing his own best interest, in a society that believes in the freedom of the commons*..." [Hardin]



Commons: history

- Farmland
- Pasture areas
- Forest areas
- Hunting areas
- Fishing areas
- GSO?
- RF spectrum?
- Deforestation
- Desertification
- Water pollution
- Air pollution
- Ground-contamination
- Climate warming

Possible solutions

- Regulation
  - *Administrative* allocation
  - Allocation by lottery
  - Allocation according to criteria:
    - Merits/ needs: “Beauty contest”
    - Seniority: “First-come, first-served”
- Regulation by the “*invisible hand of the market*” = wealth criterion
  - Demand, supply, price

Is any ‘best’ way?

- Society is not uniform - consists of various groups, each group with its own traditions, beliefs, hierarchies of values, needs, goals, interests, etc.
- The goals and hierarchies of values of different groups may be mutually inconsistent and partially in conflict
- What is good for ones may be not good for the others

International spectr. management

- Very early, all interested parties come to the conclusion that collaboration is necessary to solve interconnection (tariffs) and mutual interference problems
- These are best managed by an intergovernmental treaty (regulations)
  - A similar treaty regulating wired telecommunications existed since 1865

- To facilitate negotiations, the International Radio Consultative Committee (CCIR) was created in 1927 within the ITU
  - Goal: to arrive at common understanding of a number of technical, regulatory and operational questions
- The CCIR proposed administrative spectrum management via the concept of radio services and spectrum allocation
  - 1927: the 1st Radio Services definition and 1st International Frequency Allocation Table (10 kHz - 60 MHz)

- 1932: International Telecommunication Union (ITU) treaty of 1865 extended to cover radiocommunications
  - to avoid/ solve conflicts and to coordinate regulatory, standardization, and tariff activities among the member countries
  - 1949: The ITU became the United Nations' Specialized Agency for Telecommunications

Source: ITU News 1/90

ITU / UIT

International Telecommunication Union

Place des Nations,
CH-1211 Geneva 20

http://www.itu.int

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How does the ITU system work?

Plenipotentiary Conference

Council

World Conference on International Telecommunications

ITU Policy Forum

General Secretariat

Development Sector (ITU-D)

Telecommunication Standardization Sector (ITU-T)

Radiocommunication Sector (ITU-R): Member Countries and Sector Members

RADIOCOMMUNICATION CONFERENCES
RADIO REGULATIONS BOARD

Radiocommunication Assembly & Study Groups

Radiocommunication Bureau

Plenipotentiary Conference (Kyoto 1994)

Source: ITU Newsletter 10/94

ITU spectrum management

- *Based on collaboration, mutual trust, goodwill (negotiations, no enforcement)*
  - *Sovereignty doctrine*
  - *Common heritage doctrine (free access) on the international forum*
  - *Common benefit doctrine (consensus)*

- *Equitable access doctrine*
- *Seniority doctrine (First-come, first-served)*
- *Static allocation (~40 services)*
- *Hierarchy of services (primary, secondary)*
- *Special needs of developing countries doctrine*

- 1947: To implement the seniority principle, the ITU PP decided all radio stations that need an international recognition must be recorded in the '***Master International Frequency Register*** *(MIFR)*' under the supervision of independent (elected) ***International Frequency Registration Board*** (IFRB)

MIFR (status 2004)

- 1 265 000 terrestrial frequency assignments
- 325 000 assignments related to 1 400 satellite networks
- 4 260 assignments related to satellite earth stations

» Source: Radio Spectrum Management for a converging world, ITU 2004, p. 15

IFRB - RRB

The RRB members "*shall serve, not as representing their respective Member States nor a region, but as* ***custodians of an international public trust***" 1994: CCIR and IFRB Secretariat integrated into ITU Radiocommunication Sector; IFRB transformed into Radio Regulations Board (RRB) [ITU constitution, 1999];

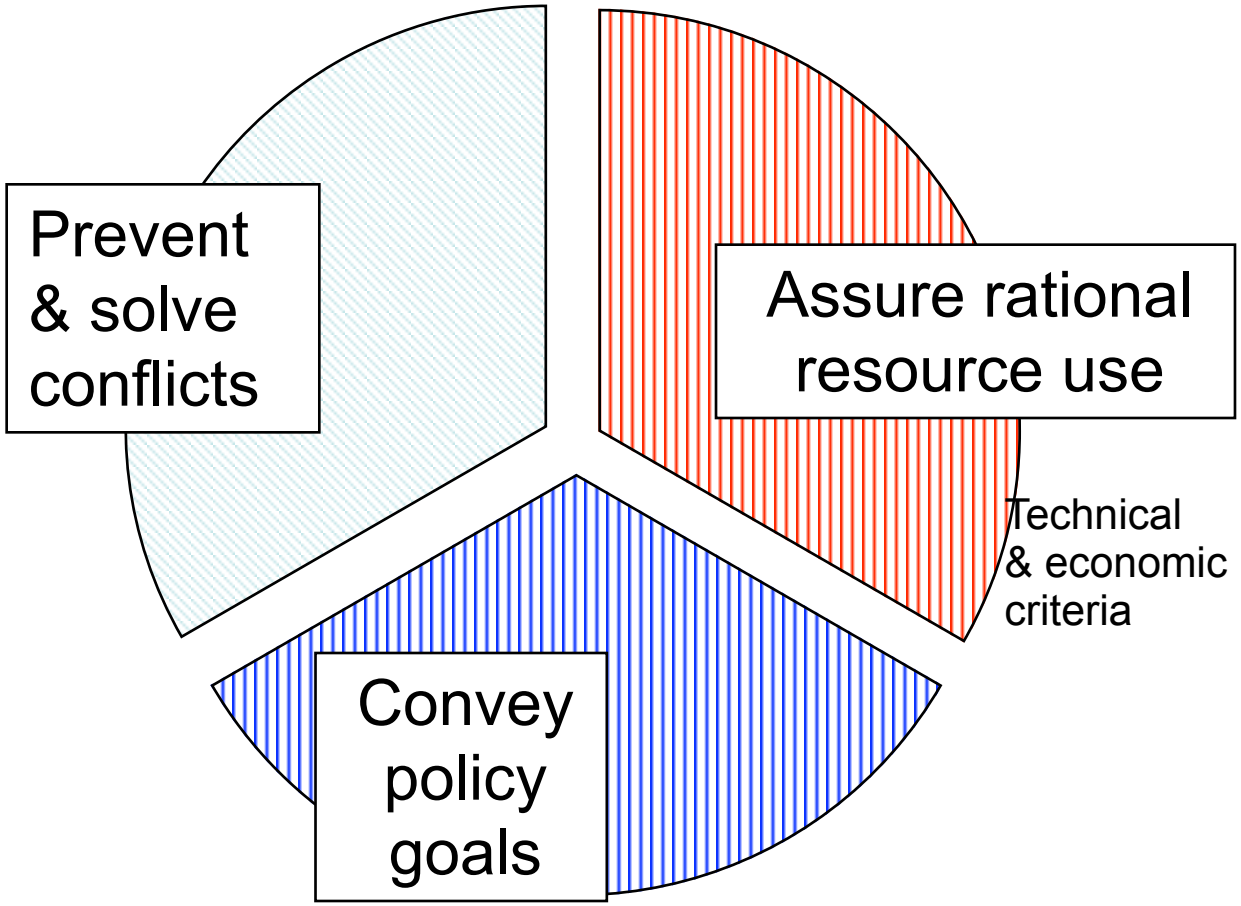
Photo: 1998 RRB members

- Internationally harmonized uses of the spectrum uses (through regulations and standards) assure
  - Interoperability of systems
  - Avoidance of mutual interference
  - Large international markets for equipment and services
  - Lower costs (equipment and services)

What are Radio Regulations?

- An International Treaty that defines how radio waves and satellite orbits should (or should not) be used and managed
  - A mixture of legal and technical provisions, existing since 1947, updated regularly every 2yrs or so at WRCs
  - Ratified by, and legally binding in, all countries (~190 in total)
  - Published in 4 Volumes of >1000 pages

What are the stated RR objectives?



What is the RR contents?

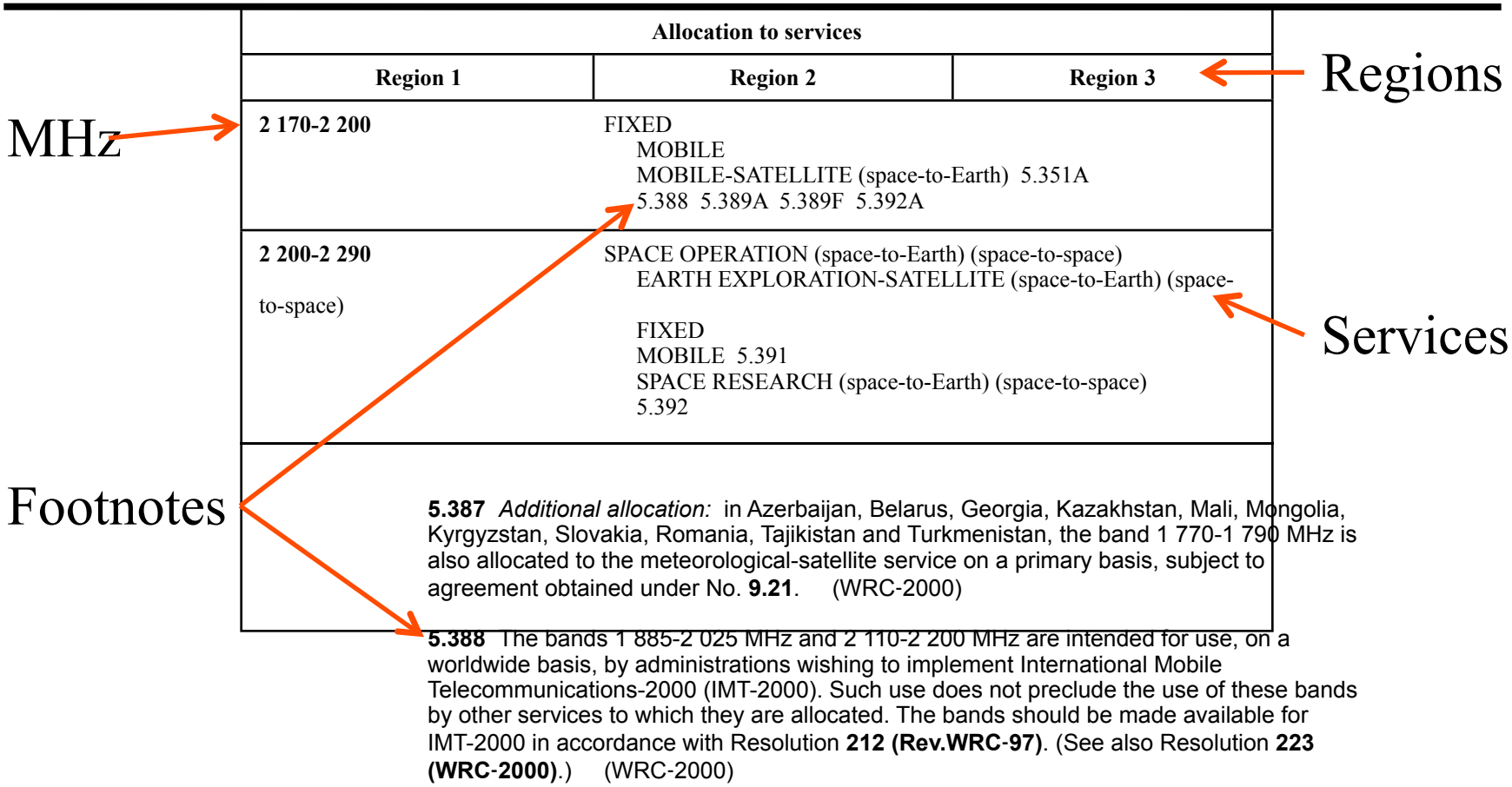
- Principles and provisions, rules, technical characteristics, formulas, data, maps, and plans dealing with international aspects of the use and management of RF spectrum/ orbit resources and the operation of radio services of all kinds
  - » Frequency Allocation Table
  - » Frequency Plans' databases
  - » Master International Frequency Register databases
  - » What to do in case of harmful interference

RRS04

"All [radio] stations…must be established and operated in such a manner as not to cause harmful interference to the radio services…of other [ITU] Members…which operate in accordance with the provisions of these regulations."

» **[RRS04 and No.197 of the ITU Constitution]**

RR Regions


MHz
Regions
Services
Footnotes
Allocation to services
Region 1
Region 2
Region 3
2 170-2 200
FIXED
MOBILE
MOBILE-SATELLITE (space-to-Earth) 5.351A
5.388 5.389A 5.389F 5.392A
2 200-2 290
to-space)
SPACE OPERATION (space-to-Earth) (space-to-space)
EARTH EXPLORATION-SATELLITE (space-to-Earth) (space-
FIXED
MOBILE 5.391
SPACE RESEARCH (space-to-Earth) (space-to-space)
5.392
5.387 Additional allocation: in Azerbaijan, Belarus, Georgia, Kazakhstan, Mali, Mongolia, Kyrgyzstan, Slovakia, Romania, Tajikistan and Turkmenistan, the band 1 770-1 790 MHz is also allocated to the meteorological-satellite service on a primary basis, subject to agreement obtained under No. 9.21. (WRC-2000)
5.388 The bands 1 885-2 025 MHz and 2 110-2 200 MHz are intended for use, on a worldwide basis, by administrations wishing to implement International Mobile Telecommunications-2000 (IMT-2000). Such use does not preclude the use of these bands by other services to which they are allocated. The bands should be made available for IMT-2000 in accordance with Resolution 212 (Rev.WRC-97). (See also Resolution 223 (WRC-2000).) (WRC-2000)

RR sample

- ICTP - The Abdus Salam International Centre for Theoretical Physics **ICTP Lecture Notes Series Volume XVI** (ISBN 92-95003-23-3) - *February 2003*
- *R. Struzak:* **Introduction to International Radio Regulations**
  - Download from ICTP: Pages 1 – 72 (Lecture Notes): PDF; pages 73 – 233 (RR Frequency Allocation Table): PDF;
    All Volume XVI: Ins016.tar.gz

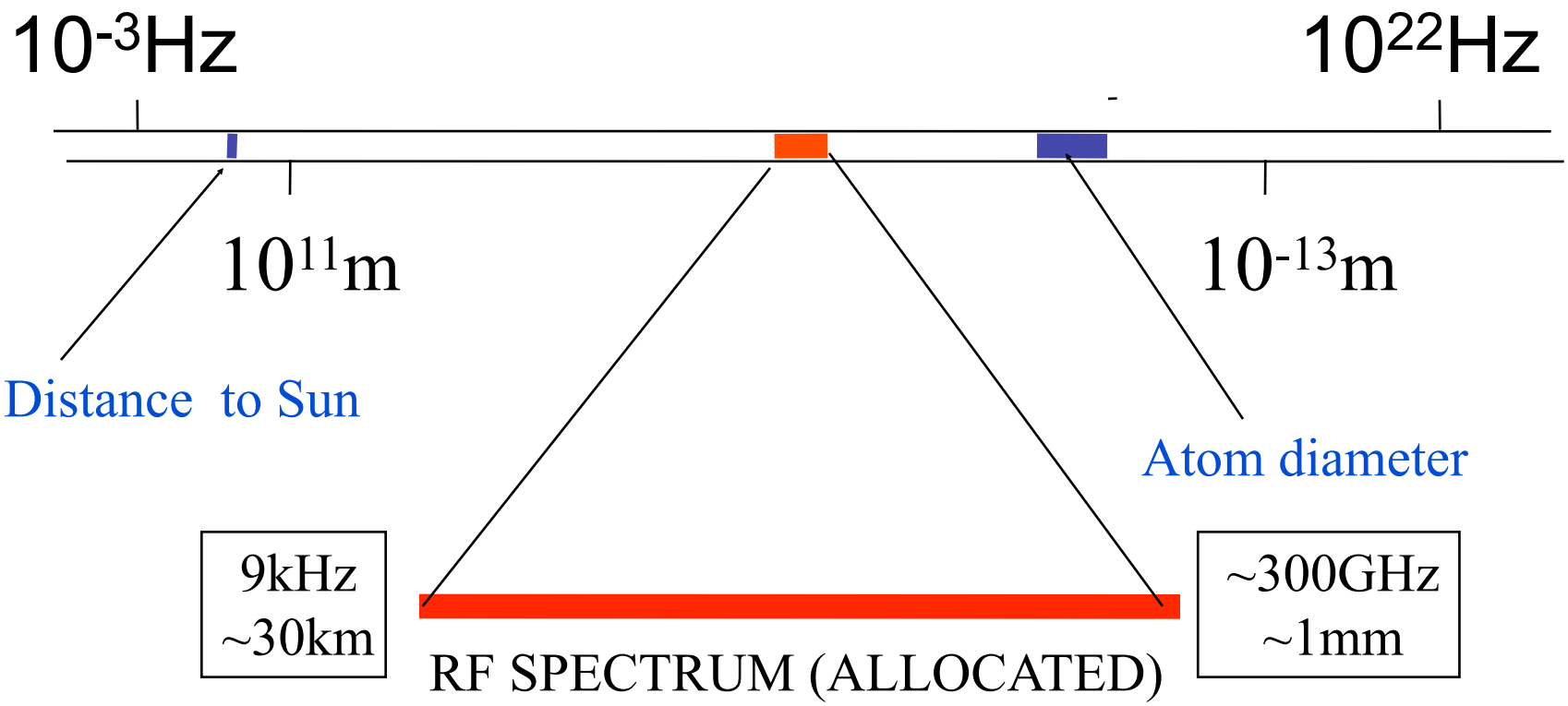
How are RR created?

National proposals (needs & practices)

Common studies in ITU-R Study Groups
& Radiocommunication Assemblies
& Conference Preparatory Meetings
& consensus-seeking
negotiations at
ITU Radiocommunication
Conferences

Radio Regulations & ITU-R Recommendations

What part of spectrum is regulated?



‘Spectrum commons’ - ISM bands

- ‘ISM’, or ‘free-radiation’ frequency bands
- Allocated originally for exclusive non-telecommunication applications (industrial, scientific, domestic and medical)

6.765 - 6.795	MHz
13.553 - 13.567	MHz
26.957 - 27.283	MHz
40.66 - 40.70	MHz
433.05 - 434.79*	MHz
902* - 928*	MHz
2.4 - 2.5	GHz
5.725 - 5.875	GHz
24 - 24.25	GHz
61 - 61.5	GHz

- Some ISM bands are now used also for radiocommunications (e.g. WiFi, Bluetooth)
- Radiocommunication systems must accept any interference in the ISM bands
- Many countries set nationally additional regulations (e.g. limited power radiated and other technical characteristics)

National spectrum management

- Example: the FCC (USA)
  - Created in 1934 as an independent government agency, responsible to Congress, to regulate national (non-governmental) communications by radio, television, wire, satellite and cable, and to represent USA (with the NTIA and Department of State) at international forums (including ITU)
  - Directed by 5 Commissioners appointed by the President (for 5-year terms) and confirmed by the Senate
  - Working in a fully transparent way with wide public consultations
    - » Only three Commissioners may be members of the same political party. None of them can have a financial interest in any Commission-related business
    - » FCC documents available at http://www.fcc.gov/

National RR

- Each country has the sovereign right to regulate its telecommunication and to interpret the international RR
- National spectrum management must follow the ITU RR

Licensing

- Licensing is an orderly way to manage who, when, where and how can use the spectrum/ orbit resource
- Governments define the rules and conditions of the frequency use
- Details that are not explicitly included in the ITU treaties may differ from country to country (also “footnotes”)

- Individual licenses specify portions of the spectrum resource assigned to specific users by governments
- Independently
  - governments may require a formal certification that a given radio equipment comply with specific technical standards
  - additional license may be required to offer telecom services

- Licensing implies QoS guaranteed via standards, regulations, etc. as referred to in the license, and via clear legal responsibility for interference
- This implies also governmental monitoring (are all license conditions fulfilled?)
- This implies also enforcing mechanism (punishment)

License-exempt equipment

- Some equipment may get the generic license under specific conditions (e.g. RF Identification ‘RFID’ tags, or WiFi)
- Such an equipment (known as ‘certified’) is allowed to operate without an individual license

ITU system weakness

- The ITU RR consider the spectrum/ orbit resources as a common heritage shared freely by the whole of humanity
- It is so since the times when the radio and space activities were the governments' monopoly

- No mechanism to enforce the regulations
- No mechanism to know the real spectrum uses
  - The MIFR reflects declarations and not factual data
- No mechanism to encourage spectrum economy/ conservation
  - The MIFR records contain ‘dead wood’
- Result: apparent scarcity of spectrum/ orbit resources

Changing environment

- With privatization, government monopolies are disappearing and the role of non-governmental entities is growing
    - At the same time, the availability of spectrum/ orbit resources is diminishing
- There are opinions that the present management system needs to be modified to follow these changes

New concepts

- Neo-liberal economists believe that market mechanism is better than the present ‘administrative’ spectrum management
- Portions of spectrum/ orbit resources are to be treated as private property, e.g. land
- Some (limited) amount of the spectrum reserved for public and governmental services

Spectrum market

- The owner has exclusive and transferable rights to aggregate, divide, buy, sell, lease, and to determine the usage of the spectrum resources at will
- With clear property rights, responsibilities are also clear:
  - Coordination of the uses made of the resource, monitoring, and solving conflicts/ interference
  - Many of governmental spectrum management activities replaced by court proceedings

- Standards set by industry with no (or minimal) government involvement
- International negotiations at the World Trade Organization (WTO) and not at ITU
- At the beginning, the spectrum may be auctioned to generate revenue for the government

- Proponents of spectrum market focus on similarities between the spectrum and real estate
- However, the similarity is limited because
  - The boundary of the spectrum/orbit resource owned are difficult (if possible) to determine with a precision
  - The interference potential and responsibilities are difficult to determine, which may generate an excessive number of costly legal disputes

- The free market proponents believe that maximizing the owner's profit coincide with maximizing public good
- Not everybody shares that view, as sometimes it may be the opposite
    - Maximizing auction revenues may not always be in the national interest, as the auction participants are trying to maximize their profits rather than serve the public good
    - Bidding on a license that would give the winner a monopoly, would be not in the public interest [Peha]
    - Universal access could not be assured

Spectrum market history

- 1989 - New Zealand, 1993 - USA (FCC) spectrum auctions
  - NZ withdraw liberalization in 2005!
- European auctions of UMTS licenses in recent years: ~US $100 billion
  - That amount was used mostly as an electoral argument of the ruling party
  - These expenses must be covered by the users - high prices of telecom services
    - Some believe that they contributed to bankruptcy of a number of telecom companies and to the general crisis of 2000s
  - Unsolved apparent inconsistency between the private (nationally) and the public (internationally) spectrum

Rebirth of ‘commons’ concept

- In the ITU spectrum management ‘philosophy’, each country gets for free what it wants (spectrum reservation), if this does not harm other spectrum users
- But the process is static, very slow, and costly, as it involves a series of formal co-ordinations/ negotiations among governments (with private sector involved)

- Advanced technology could do similar co-ordinations and ‘negotiations’ automatically and dynamically, in a flash, via built-in algorithms and protocols
- That makes it possible to apply the “Commons” model with no property-rights, and no (individual) licensing, and no bureaucracy

License-exempt spectrum

- Access to the spectrum-orbit resource for specific equipment subject certain restrictions (e.g. to protect passive services)
  - open-access spectrum for low power (short range) devices
  - Spectrum commons (radio amateur bands, ISM, IEEE 802.11… bands)

- Users share frequencies and any device is allowed to transmit (the ‘Internet spirit’) following the agreed conditions (etiquette)
  - Limited to ISM unlicensed and amateur bands
  - No legal responsibility for interference, no rights for protection from interference,
- Maximize the number of users having access to spectrum resources
  - Examples: WiFi, WiMax, Bluetooth, etc.

Possible future

- Eventually, technology may remove the need for most functions now included in spectrum management also in other frequency bands
- Future radio systems may be able to automatically coordinate (automatically) among themselves the best use of spectrum/ orbit resources in real time (e.g. software-defined radio)

- Research work underway on the best algorithms (strategies) to be used by the equipment
  - E.g. based on Game Theory
- Different viewpoints (interests)
  - service-provider, regulator, individual user, community, society, …
  - various behaviors (including cheating)

- Example 1:
  - An emergency phone network shares the common spectrum resources enjoying the highest priority.
  - When operating, it has the exclusive access to spectrum automatically.
  - When it does not operate, the resource is open for other users.

- Example 2:
  - ‘Intelligent’ radio equipment explores automatically the local environment
  - Identifies the spectrum users/ owners, frequencies, protocols, etc.
  - Negotiates conditions and priorities

- Obtains authorization to transmit
- When authorized, starts and completes the processes of authentication, transmission, and monitoring (and payment transfer, if necessary)

Advanced technologies

- *Ultra-wideband (underlying) radio*
- *Multi-use software-defined radio*
- *Mesh networks*
- *Nanotechnology and quantum communications (that makes direct use of distinctively quantum-physical phenomena)*

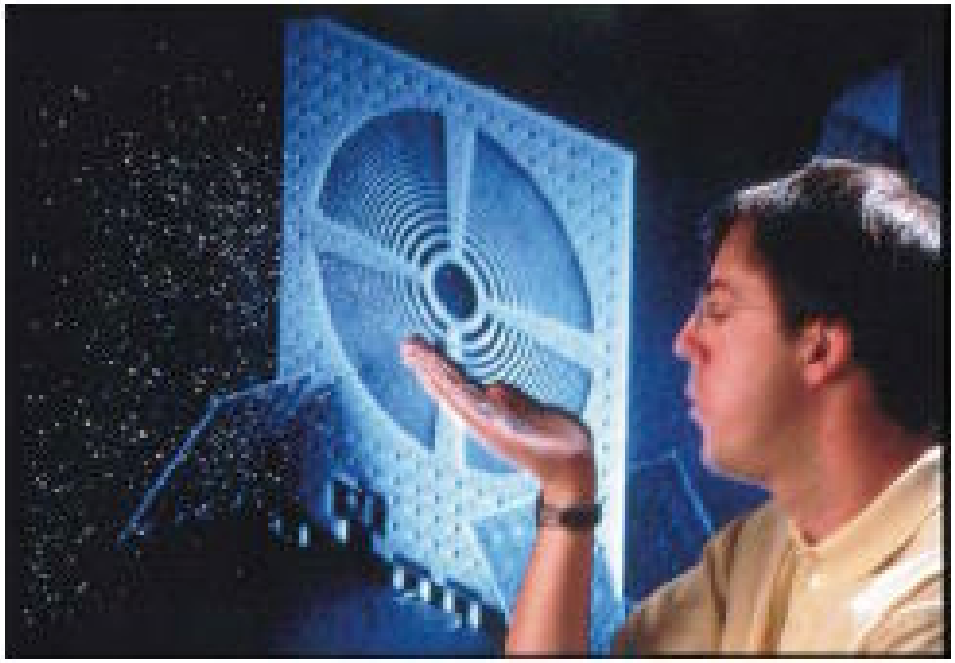
Ultra-wideband sharing…

- Ultra-wideband systems are able to share common frequency, time and service area with other systems in a compatible way
  - They use (underlying) signals of a very low power density, well below the sensitivity floor of the other systems so that their operation remains 'unnoticed' (except for radioastronomy and passive earth exploration services)
  - To transmit the required amount of information in such conditions, they must use a very wide frequency bands

Nanotechnology

- *Nanotechnology* as a collective term refers to technological developments on the nanometer scale, usually 0.1-100nm.
- Quantum computing and communications exploit new quantum-effects such as the spin quantum state

Nanotechnology



"Artificial insects"
"Smart Dust Motes"
"Pico-satellites"
Tiny, autonomous radios combined with sensors

http://robotics.eecs.berkeley.edu/~pister/SmartDust/ (Last visited 16 Sept 2004)
Guizzo E: Flying away; IEEE Spectrum, Jan 2004, p32-33

When?

- New concepts and new technologies are now intensively developed
- However, in view of enormous investments in the “old” equipment, the “new” systems will not be very popular soon (unless a low price and viable business model justify the replacement)

What have we learned?

- What is, and how works, the international (and national) management of spectrum/ orbit resources
- What are the Radio Regulations, how are they created and updated, and why they should be followed by all those involved in wireless technologies
- What might be expected in future

Selected references

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Any questions?

Thank you for your attention

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