SDR and Cognitive Radio Challenges and Possibilities

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content

- Software Defined Radio (SDR)
- Cognitive Radio (CR)
- ETSI Standardization, and others
- Applications, as White Space

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SDR definition ..

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.

- Definition used by FCC, ITU-R, ETSI ….
- Unfortunately, **quite meaningless** as almost all modern radio then can be said to be SDR.

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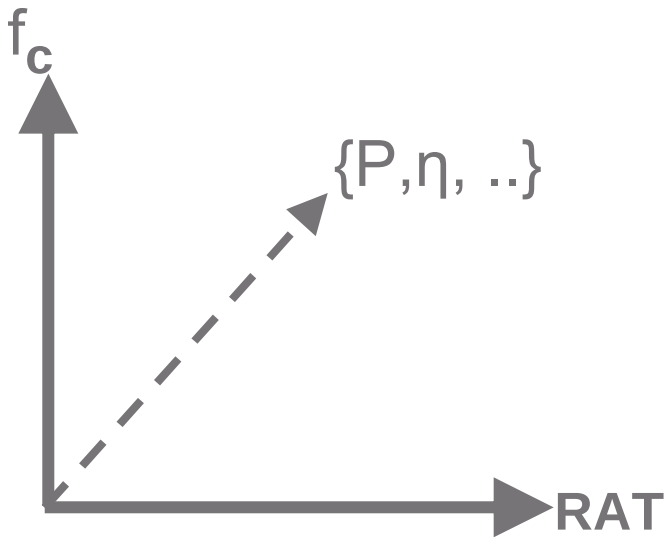
What is then SDR?

- Flexibility in various dimensions:
  - Radio Access Technology
  - Frequency
  - Output power / efficiency
  - “Services” (bearer)
  - …..
- Pooling & sharing concept; components have more than one use
- Close to implementation technology, i.e. how requirements are met!



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SDR – essential parts

- **Radio (or rf)** part is wavelength dependent. Component dimensions (size) determines behavior.
- **Signal processing** is real-time source- and channel coding / decoding. ***Simple,*** but the RT aspect does not leave any room for extravagancies!
- **Control,** managing work flow of the node. Admin of resources. With SDR, resource demands increases dramatically, as well as the possible combinations of various resources. Still, it is just a matter of more and complex sw ….
  RRM will be dramatically extended!

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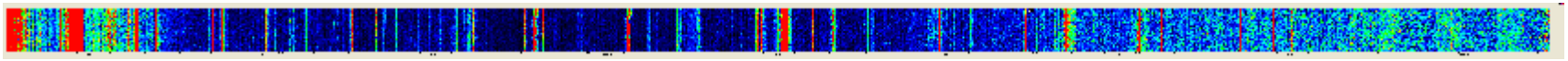
Developing SDR …

- It is straight forward to develop SDR-based equipment
- To make it cost effective is difficult
- In particular, frequency agility is really difficult
- In Mobile communications radio requirements (spectrum mask, linearity ..) are very high – added requirements, as SDR, are expensive.



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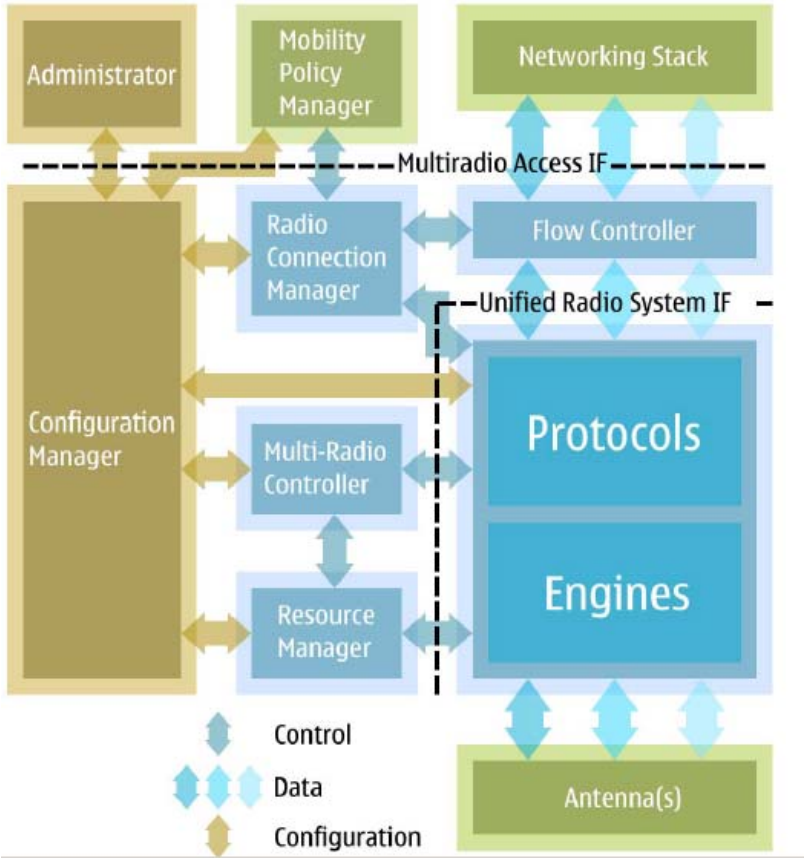
SDR standardization?

- Standardization of SDR has, up to now, not really taken off, as SDR is about ***implementation technology*** (which, principally, shouldn't be standardized)
- For specific sectors, as ***Public Safety and Defense***, there has been ***customer demand*** on SDR, usually to achieve extended interoperability. Still, in spite of intensive funding, no real results in these sectors.

SDR in cellular standardization 1

- A study in ETSI has focused SDR on terminals (~phones)
- Multi-radio concept is introduced (still SDR)
- Purpose is to open up possibilities for extended functionality, and to improve the supply chain!



ETSI World Class Standards

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SDR in cellular standardization 2

- In 3GPP work is ongoing in order to harmonize some rf parameters of GSM, WCDMA and LTE. Usually called ***MSR***
- This includes a relaxation of some GSM rf parameters, currently there are two stages (in ACLR, where WCDMA ACLR ~ -50 dB) :
  - 10 dB less
  - 20 dB less
- When this work is finalized it is possible to use the same MultiCarrier Power Amplifier for GSM, WCDMA and LTE.
- Work is driven by Ericsson. Purpose is to further improve possibilities in the cellular industry!
- Note: Multi Standard Radio, but f_c is the same!

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Frequency agile SDR ?

- Cellular systems have very sharp spectrum masks
- Filters in cellular are very special (~12 poles) and expensive.
- Filters, by nature, is selecting the wanted signal, and discriminates the un-wanted signals.
- To make these filters flexible … possible, but expensive.
- However, with time, also filters will be flexible.
- For low output power (< 1 W, “phones”) it is possible to use BAW filters.

What is ….

White Space

Frequency band *unused in time or space.*

Digital Dividend

The "leftover" frequencies resulting from the change of TV broadcasting from ***analog to "digital****".*

Cognitive Radio

A (set of) ***technology*** *(-ies) used to make radio self-adjusting, as … "aware of its environment and act upon it". Can be used for utilizing White Space.*

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CRS definition (ITU-R proposal)

Cognitive Radio System is a radio system, which has the following capabilities:

- to obtain the knowledge of radio operational environment and established policies and to monitor usage patterns and users' needs;
- to dynamically and autonomously adjust its operational parameters and protocols according to this knowledge in order to achieve predefined objectives, e.g. more efficient utilization of spectrum, and
- to learn from the results of its actions in order to further improve its performance
- **~ Aware of its radio environment, and act upon it.**

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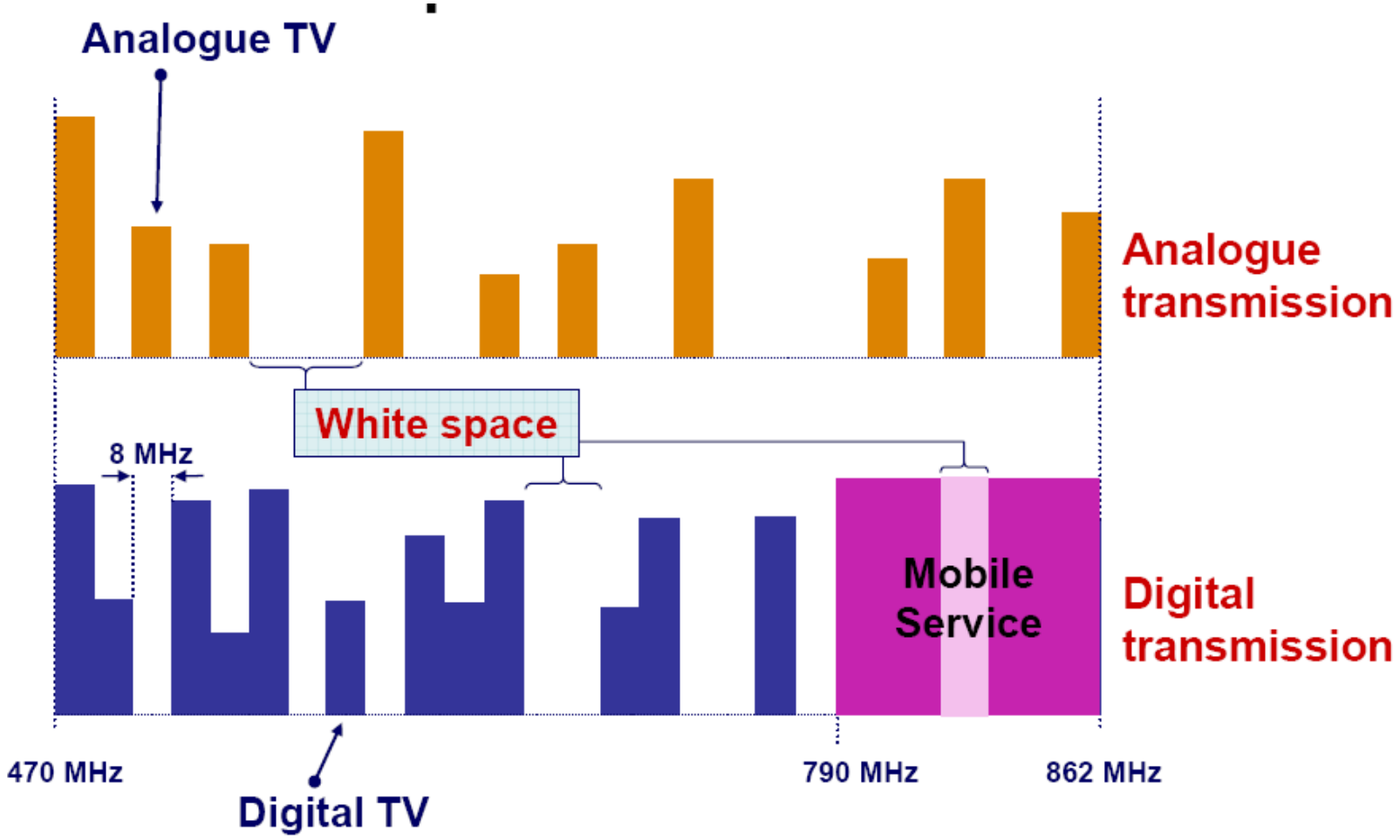
White Space in Europe, 472 – 862 MHz



Source: A Kholod, CEPT 1:st conf on CR, 2009

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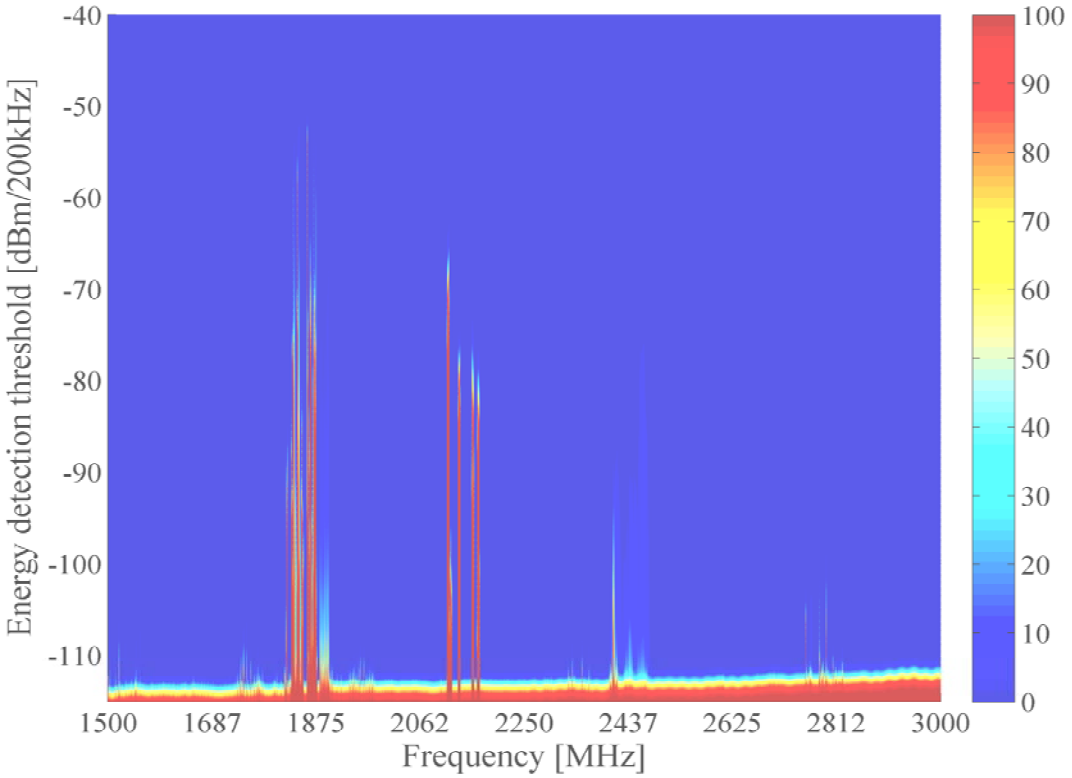
More White Space ...



However: most trafic channels will be ”underused” (empty slots)

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White space, digital dividend in US

- FCC announced in fall 2008 the rules for using White Space in the UHF TV-band (470-862 MHz).
- Some equipment have to protected, as wireless microphones etc (generally PMSE)
- Certainly the primary user, TV broadcast, has first priority.
- ➔ Rules for using “white space” in the TV-bands.

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”White Space” availability in USA

(UHF-band)

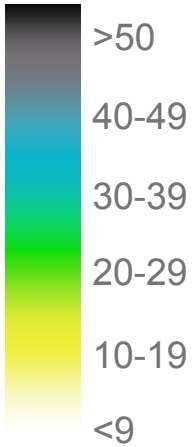
Number of available channels

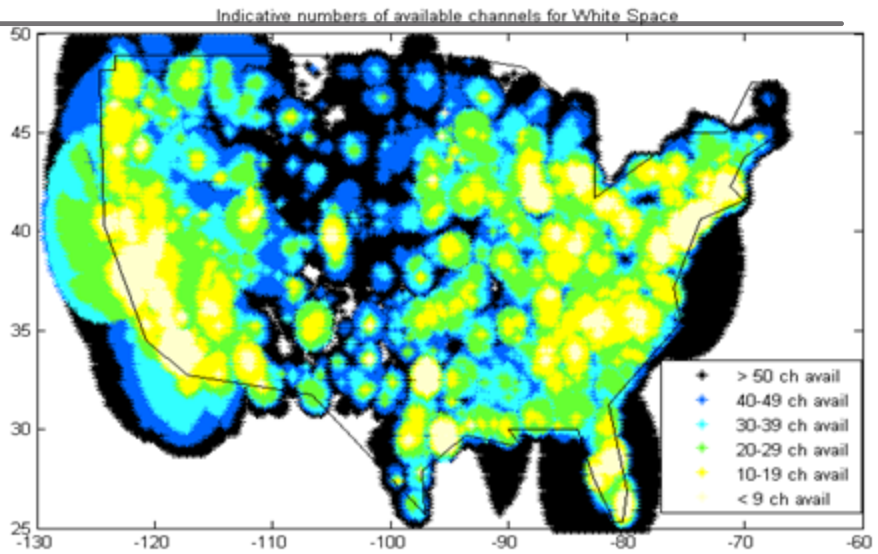
UHF band; 1 channel = 6 MHz

Data from FCC on TV licenses and TV transmitter contours

FCC WS rules; Protection channels removed

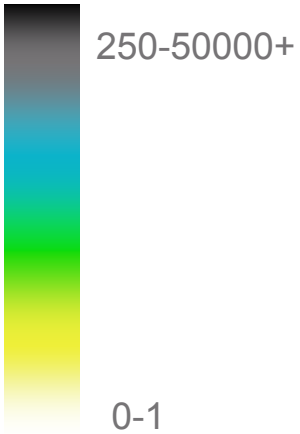
In some areas slightly fewer channels available due to neighboring countries, protection of other incumbent services (e.g PMSE) and cable TV head ends

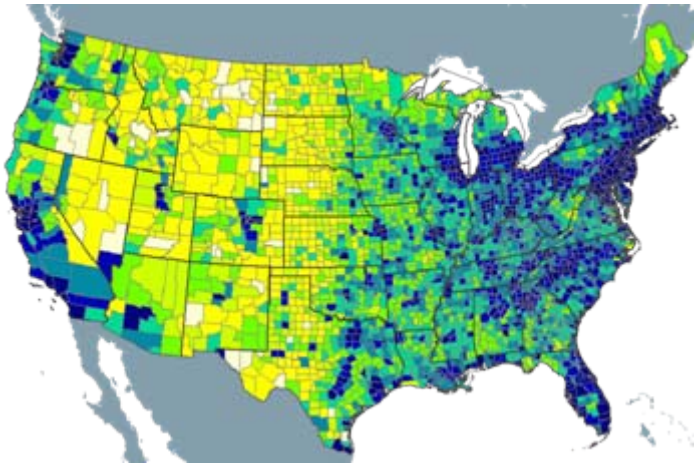




U.S. population density

(persons per square mile)





”White Space” mostly in rural areas – not where most people are...

WS Available channels in US

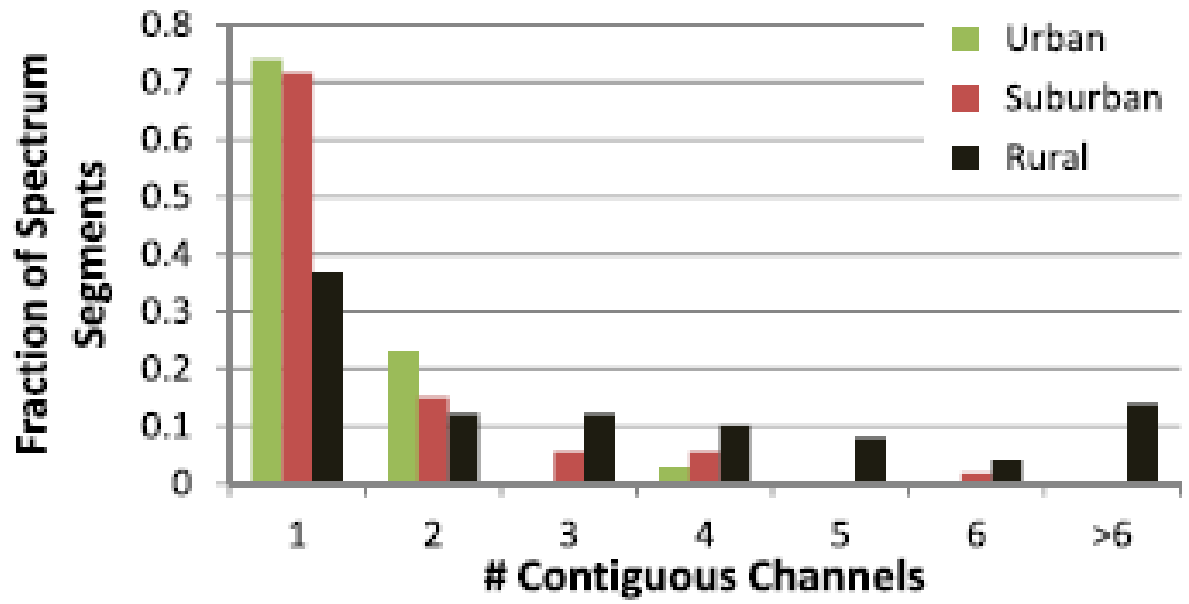


Figure 2: Expected spectrum fragmentation after the US DTV transition in June 2009. Rural and suburban regions exhibit a much lower degree of fragmentation and more contiguous spectrum than urban areas.

Source: Microsoft

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Applications

- There is a huge interest to use the White Space 470-790 MHz
- One initiative is called White-fi ....
- Microsoft has started a project called KNOWS

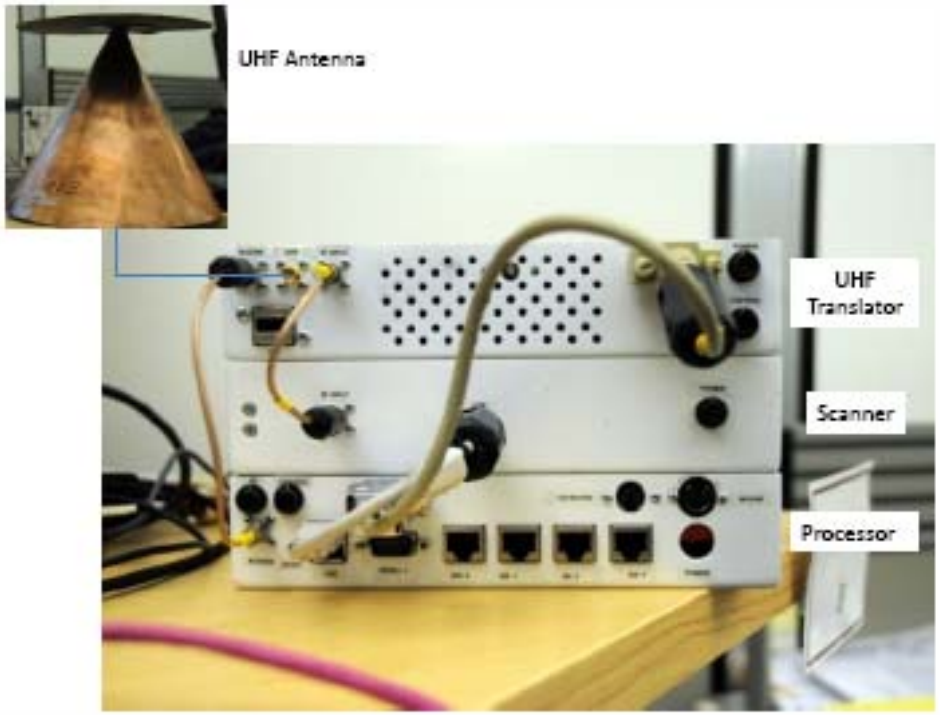

Figure 3: Photograph of the KNOWS hardware prototype.

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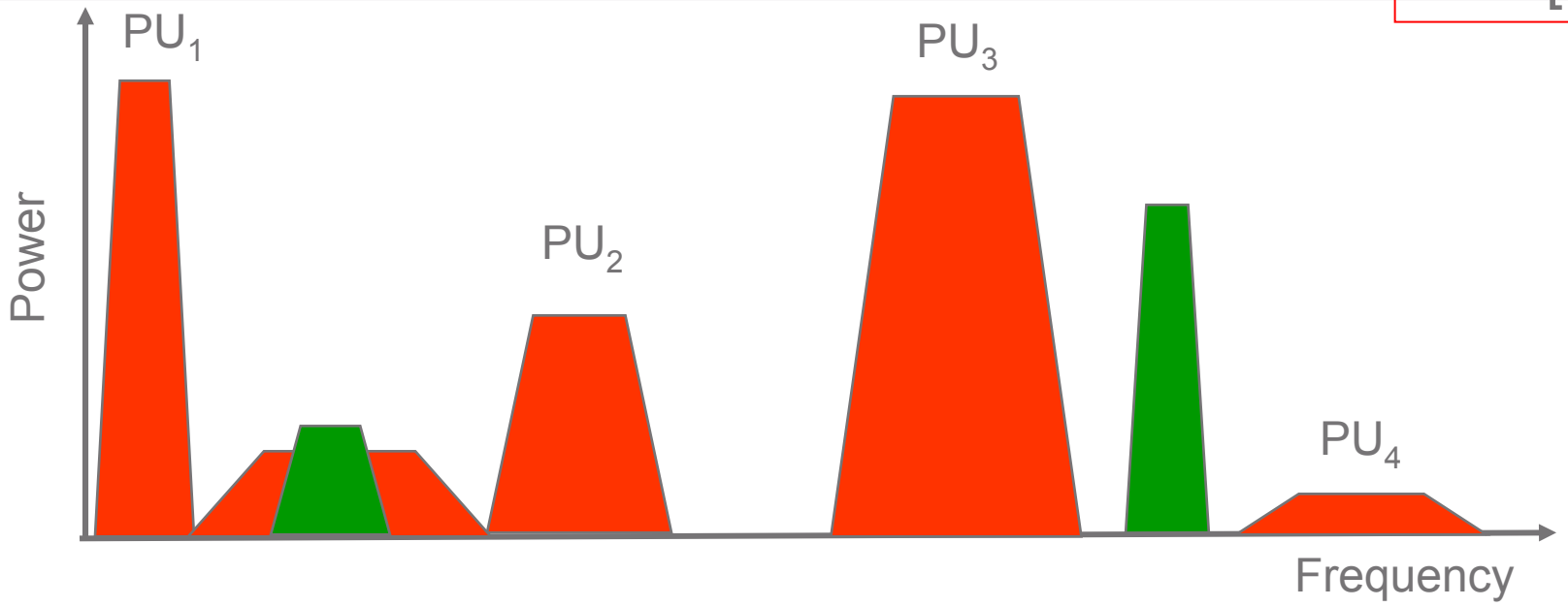
Opportunistic Use

Ref: [3]



- **Sense** the spectral environment over a wide bandwidth
- **Transmit** in “White Space”
- **Detect** if primary user appears
- **Move** to new white space
- **Adapt** bandwidth and power levels to meet requirements

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Cognitive Radio

- CR is often mentioned as the technology to access unused frequency bands.
- It will take a long time to develop the full-fledged CR due to high complexity and difficult requirements (as frequency agility in rf parts)
- => higher costs
- => Lower performance, at least initially
- Primary user will get increased interference
- The use of CR will increase interference.
- Early CR might be used

CR research needed!

- How much can we realistically expect to increase spectrum utilization?
- Detection, sensing and/or databases:
  technically, market
- Interference handling
  (conditions for primary and secondary use)
- Spectrum trading:
  technically, market

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EU FP6/7 projects E2R and E3

- E2R:
  End-to-end re-configurability
- E3:
  End-to-end-efficiency
- Started with a focus on SDR
- Has moved on to CR

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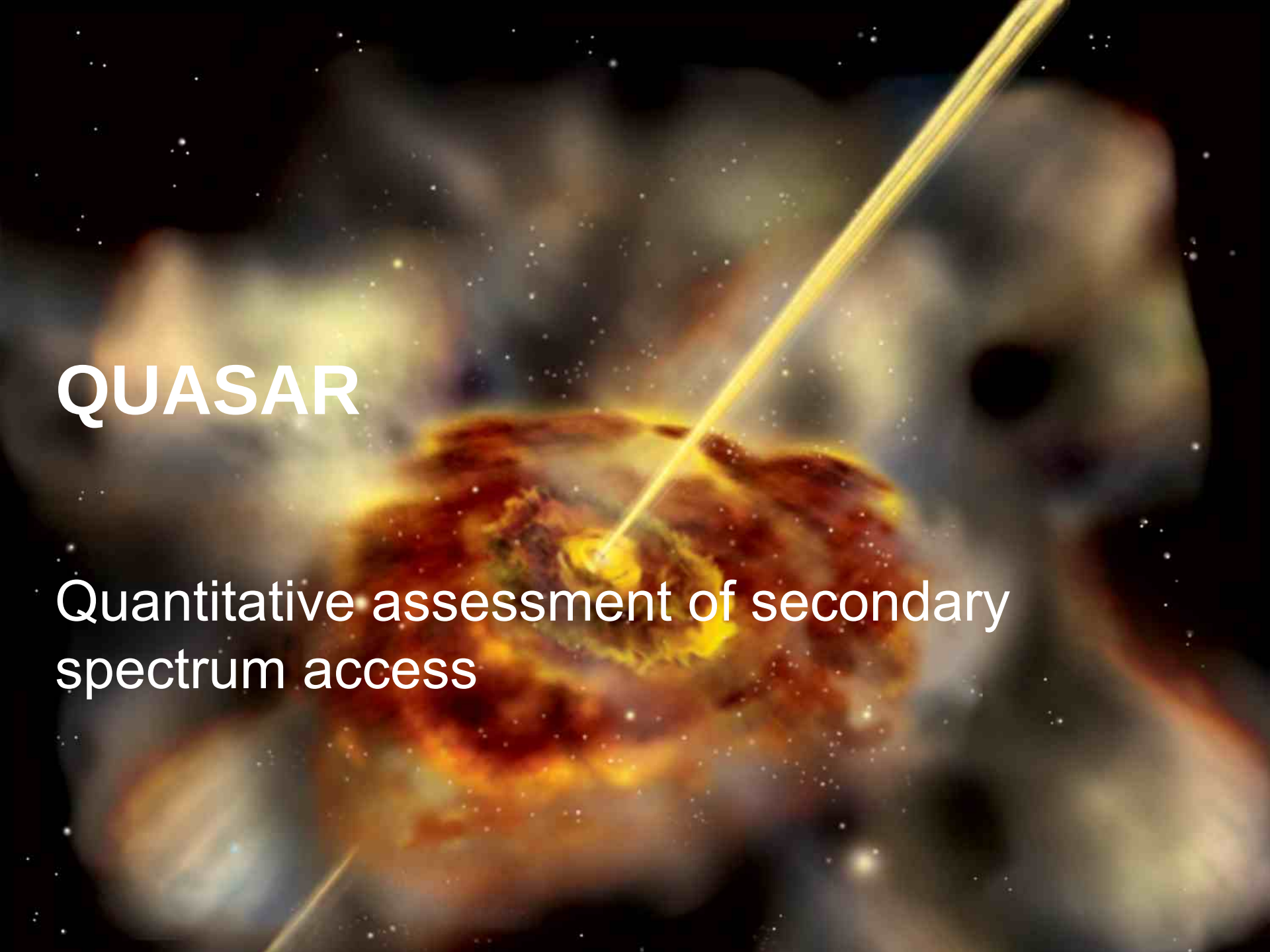
QUASAR
Quantitative assessment of secondary spectrum access

Standardization!

- CR requires a set of common rules, i.e. standards
- Although it will take many years until complete CR is marketed, it is time to consider standards now.

- Reconfigurable Radio Systems (RRS) in ETSI responsible for SDR and CR.

- IEEE has activities in various 802.x and SCC 41.

- SDR & CR Standardization have to be horizontal, across already established radio systems as GSM, WCDMA, LTE, TETRA, …. And possibly future radio systems as well

- CR standardization likely to impose requirements on SDR
  ➔ standardization of SDR!

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ETSI RRS

- Started spring 2008
- First phase was to investigate what, where & how SDR & CR should be standardized
- September 2009 these results were reported to the ETSI Board, bundled with a request to up-grade the mandate to actual standardization
- A number of Technical Reports have been created
  - SDR Reference Architecture for Mobile Device
  - Radio Base Station (RBS) Software Defined Radio (SDR) status, implementations and costs aspects, including future possibilities
  - Functional Architecture for the management and control of Reconfigurable Radio Systems
  - Cognitive Pilot Channel
  - User requirements for Public Safety
  - **Summary of Feasibility Studies and Potential Standardization Topics**

ETSI RRS organization

- RRS itself, Plenary 4x /year

- WG1, System Aspects
- WG2, Equipment Architecture
- WG3, Functional Architecture and CPC
- WG4, Public Safety
- (internet, phone, sometimes F2F)

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ReGulation?

- FCC has issued ”rules” for the use of White Space in the UHF TV-band
- OFCOM/UK seems to folllow, public consultation ongoing
- CEPT has started SE43 (report spring 2010), and
- ECC CG CR .... (report soon)
- EC RSPG CR .... Consultation period just now, end in Jan/Feb 2010.

- Unusual that regulators are the first on stage!
- Political pressure!
- However, too little is actually known today!

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Summary, SDR

- SDR-based products are being standardized and developed.
- Frequency flexibility ***is*** difficult, due to the wavelength dependence of analog radio parts.
- Ericsson is a technology leader in the field, eg driving standardization (ETSI, 3GPP).

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Summary, CR

- **FCC White Space rules yield low value spectrum**
- **Full-fledged Cognitive Radio will take many years**
- **Further studies and research are necessary**
- **White Space is NOT the future spectrum management approach**
  - Still need dedicated globally/regionally harmonized spectrum
  - White Space should not block additional dedicated spectrum
- **Increased complexity and frequency requirements ➔ costs increase, performance decrease.**
- **Interference can be a problem!**
- **Standardization has started (ETSI, IEEE)**

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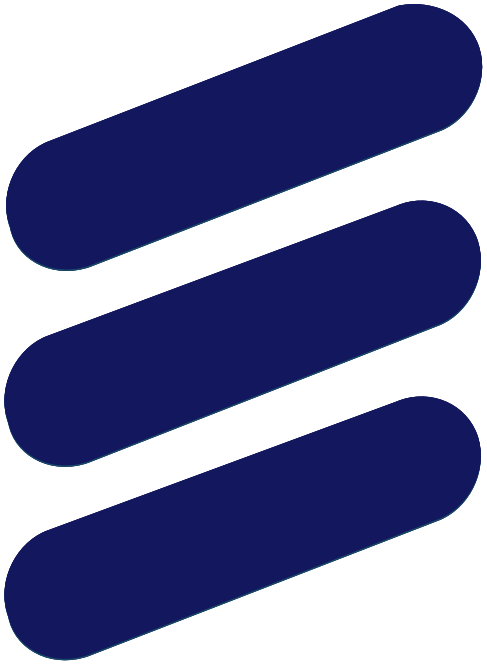

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