

# SDR and Cognitive Radio Challenges and Possibilities



*Dr Peter Olanders,  
Ericsson*

*Chairman , ETSI Reconfigurable Radio Systems (RRS)*

# content

---

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

# SDR definition ..

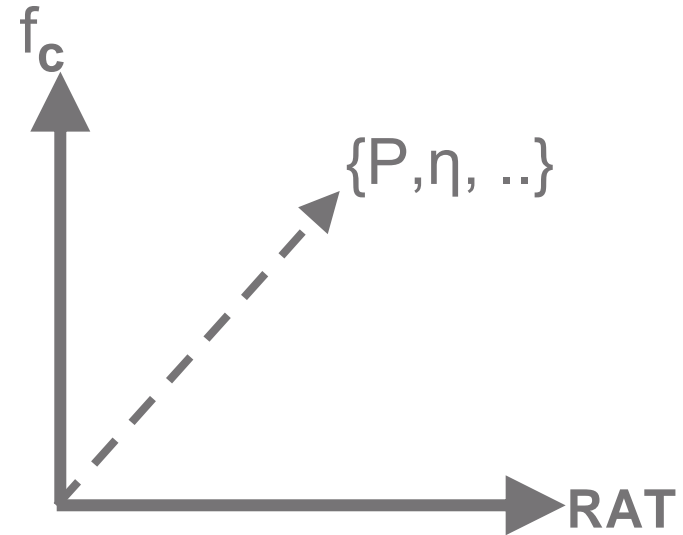
---

*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.

# 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!



# SDR – essential parts

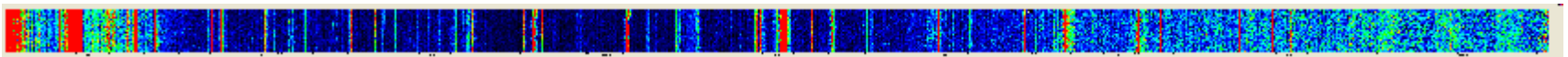
---

- › **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!

# 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.



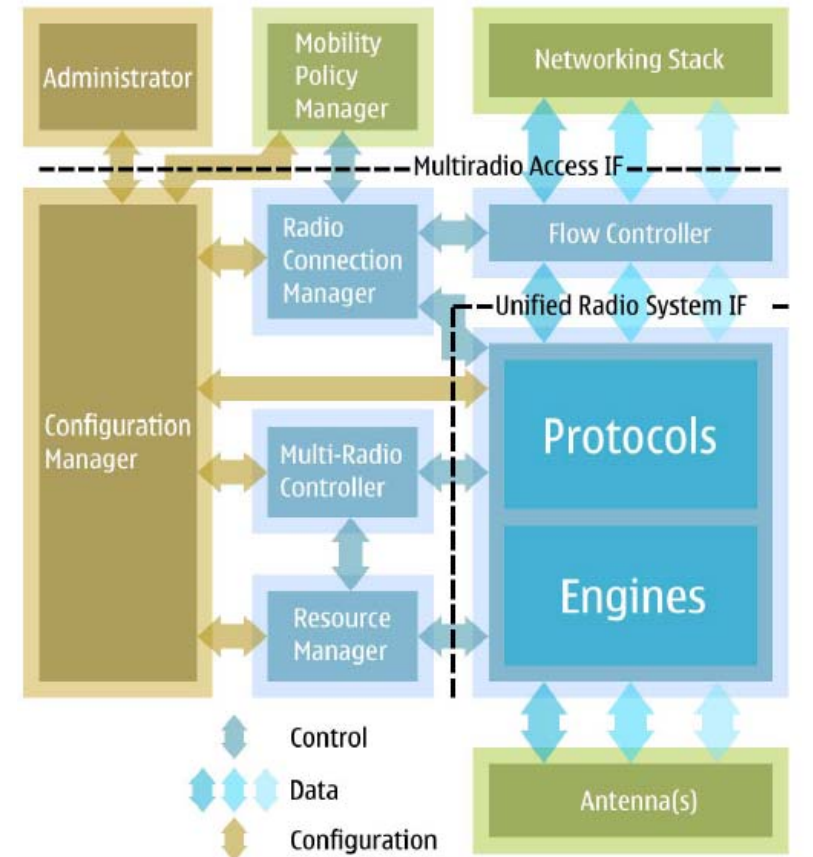
# SDR standardization?

---

- › 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!



# 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!



# 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.*

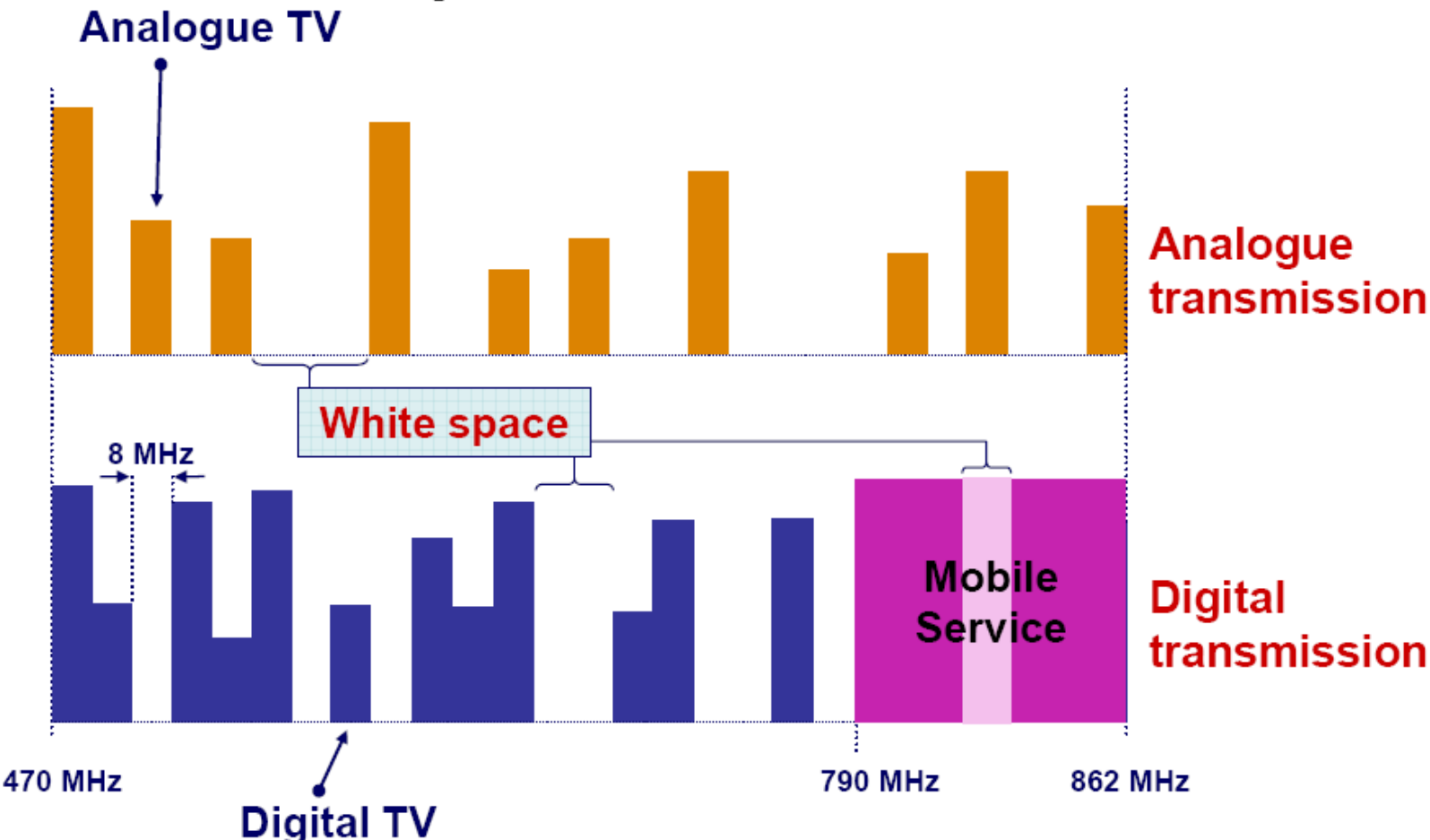
# CRS definition (ITU-R proposal)

---

**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.**

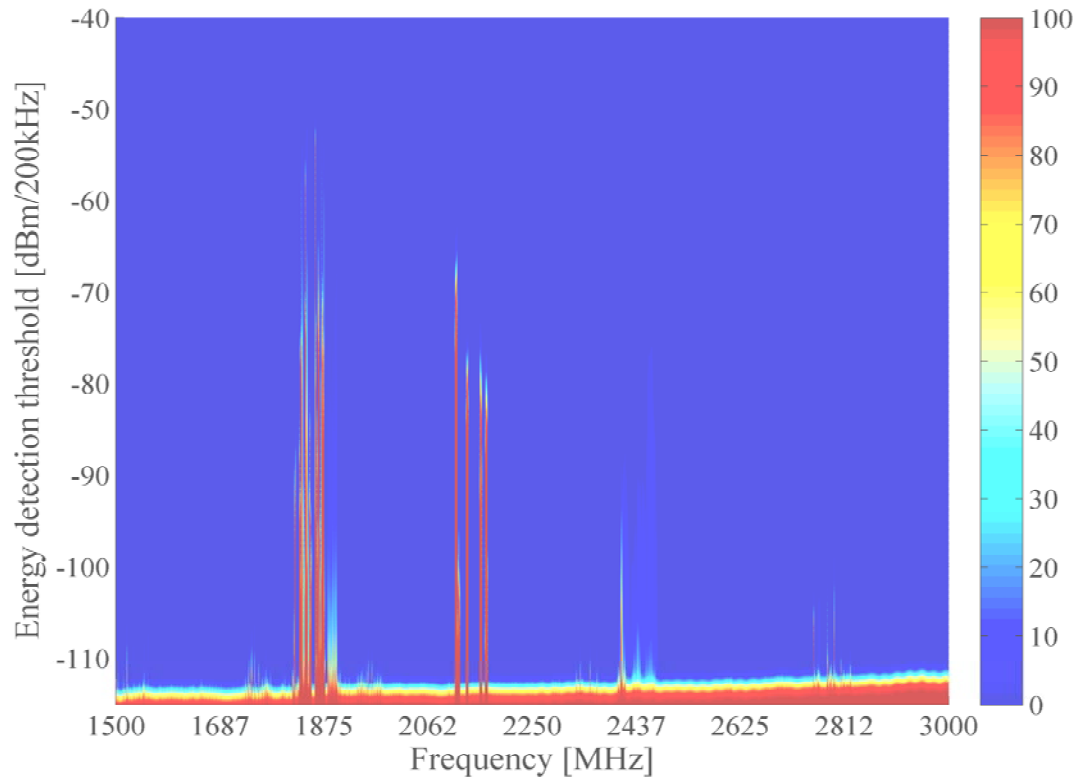
# White Space in Europe, 472 – 862 MHz



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



# More White Space ...



However: most traffic channels will be "underused" (empty slots)

# 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.

# "White Space" availability in USA

(UHF-band)

## Number of available channels

UHF band; 1 channel = 6 MHz

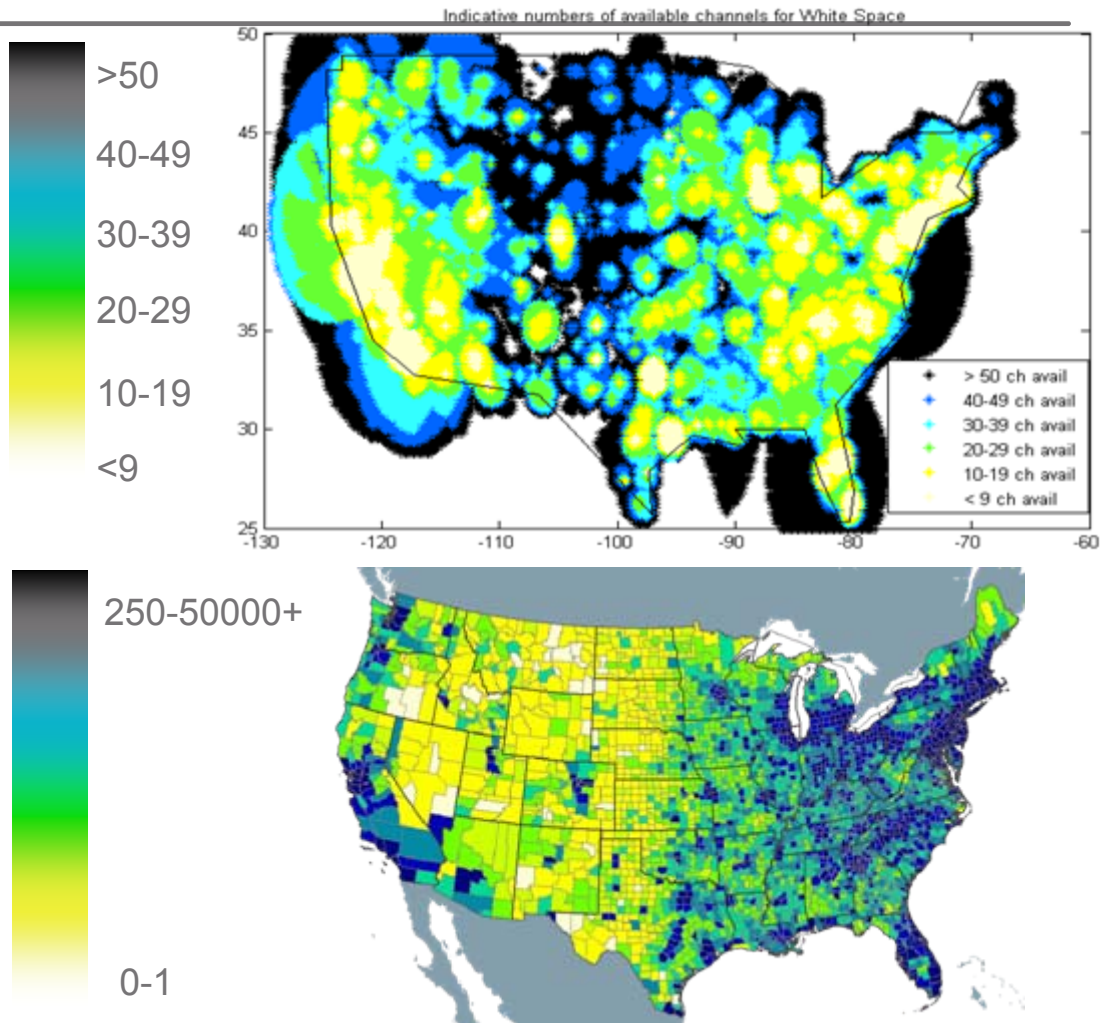
Data from FCC on TV licenses and TV transmitter contours

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

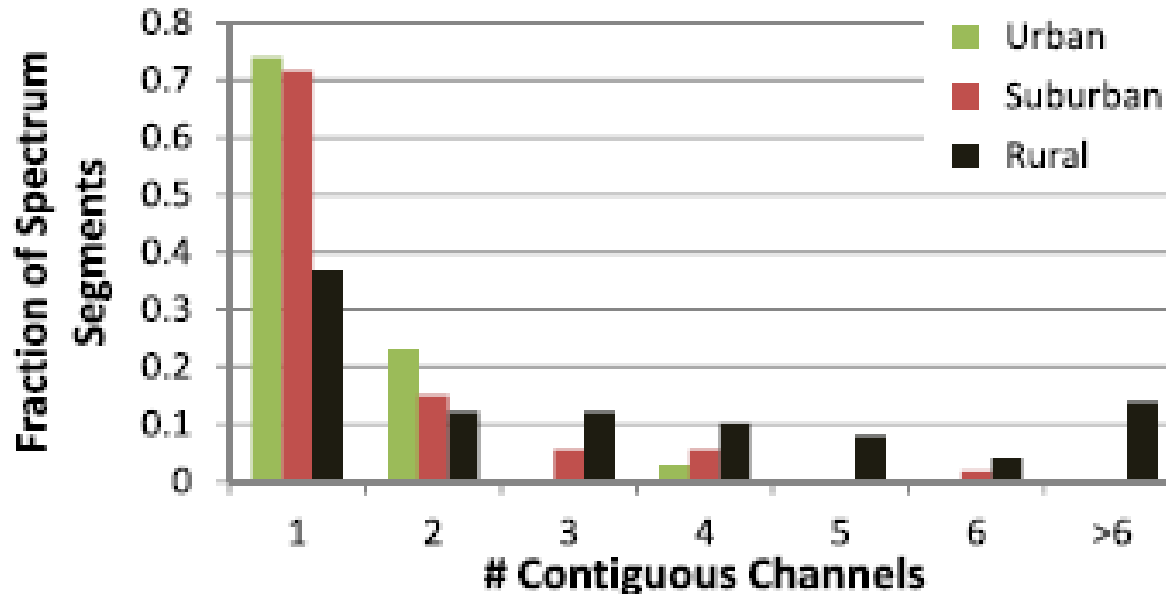
## U.S. population density

(persons per square mile)



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

# WS Available channels in US

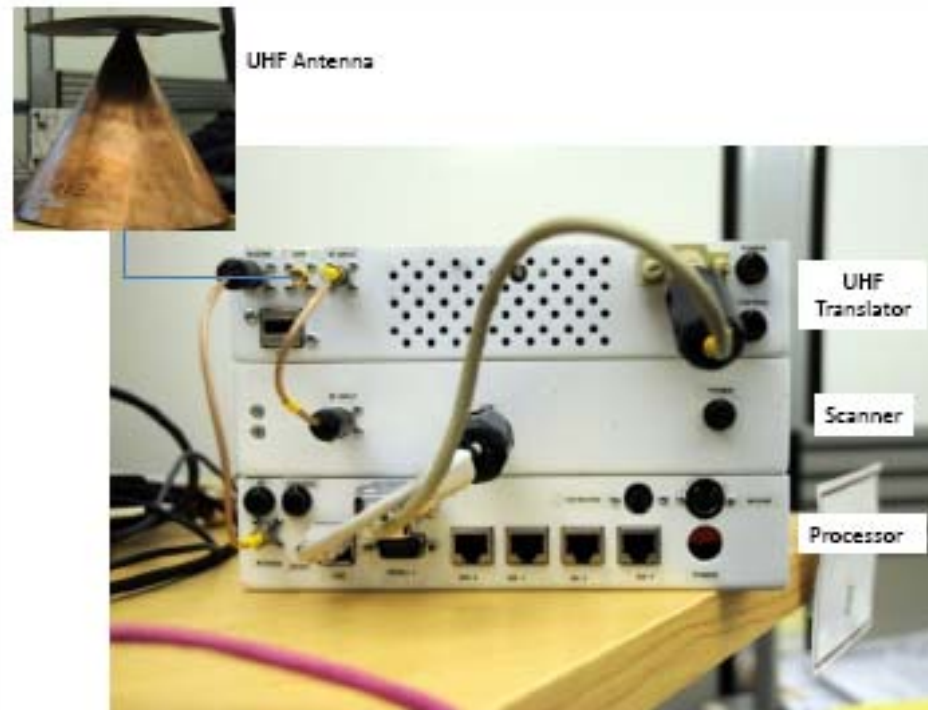


**Figure 2: Expected spectrum fragmentation after the US DTV transition in June 2009. Rural and suburban regions exhibit a much lower degree of fragmentation and more contiguous spectrum than urban areas.**

Source: Microsoft

# Applications

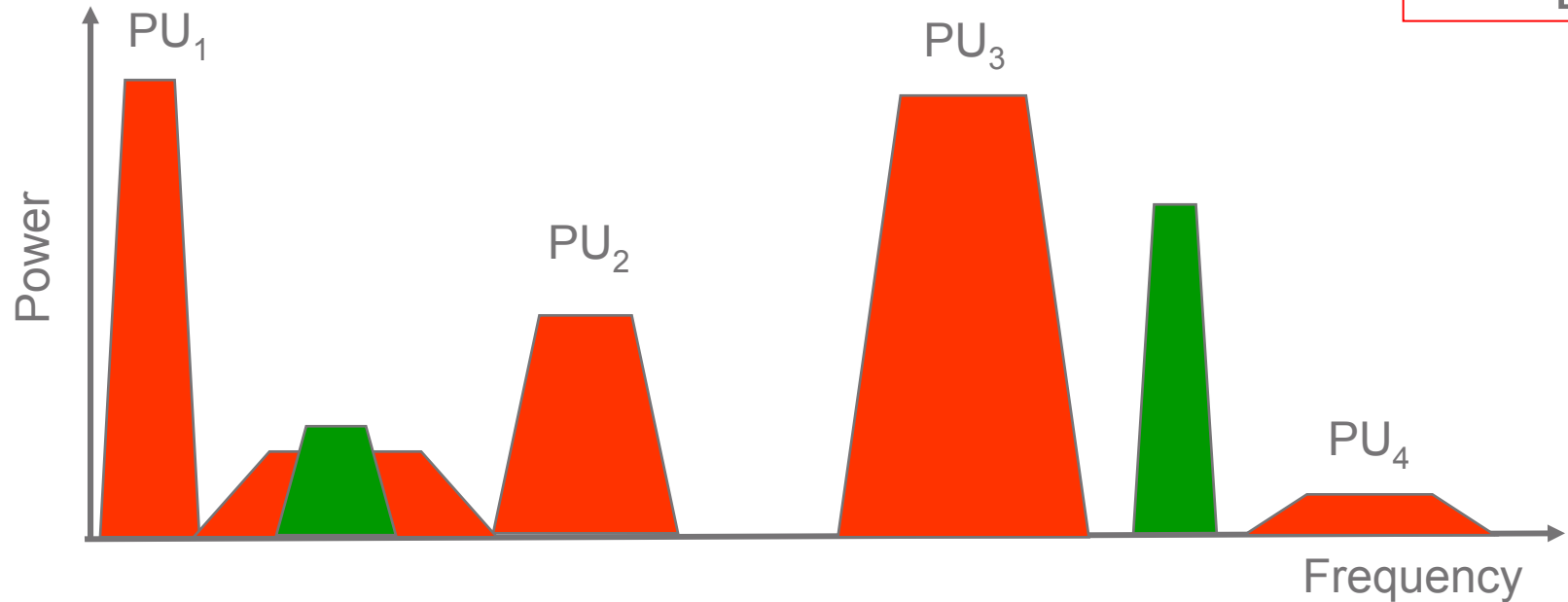
- › There is a huge interest to use the White Space 470-790 MHz
- › One initiative is called White-fi ....
- › Microsoft has started a project called KNOWS



**Figure 3: Photograph of the KNOWS hardware prototype.**

# 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

# 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

# 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





# 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!

# 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 )

# ReGulation?

---

- › FCC has issued "rules" for the use of White Space in the UHF TV-band
  - › OFCOM/UK seems to follow, 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!

# Summary, SDR

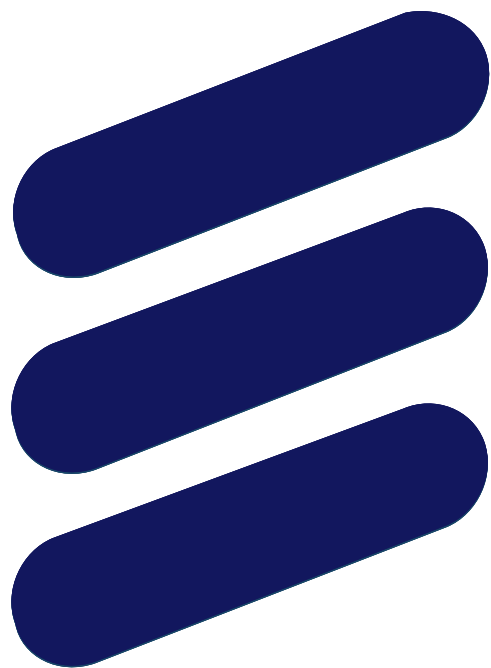
---

- › 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).

# 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)**



**ERICSSON**