Introduction to Software Defined Radio (SDR) - A Hands-on Course

Class 1: Intro to SDR

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Presented by:

This Week's Agenda

9/25 Intro to SDR

9/26 RF and Radio Basics

9/27 Exploring SDR with the RTL-SDR, Part 1

9/28 Exploring SDR with the RTL-SDR, Part 2

9/29 Commercial SDR Designs

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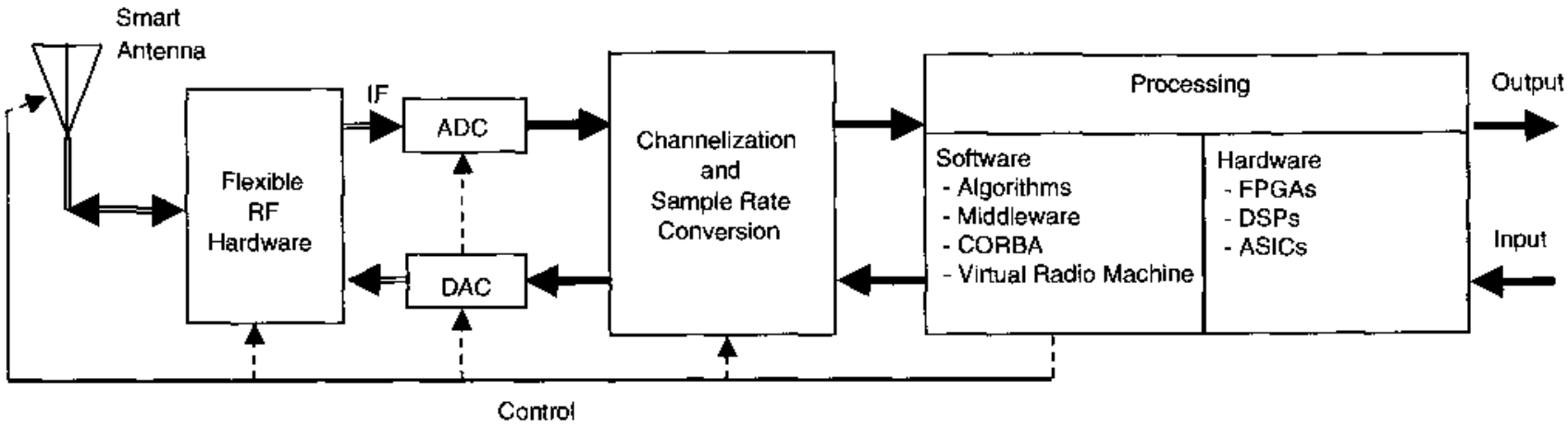
Just Imagine…

- A radio transmitter and receiver that can operate on a wide range of bands and with a wide variety of modulation / demodulation methods – all defined and variable on the fly
- Completely self-tuning and self-correcting for oscillator accuracy
- Easily controlled remotely or even autonomously by a computer

Enter Software Defined Radio (SDR)



What are the drivers of SDR?

- Need for SDR
- Technologies that facilitate SDR
- What's on the horizon?

The Problem

- Myriad standards exist for terrestrial communications
- Cell phone communication standards change every few years
- Satellite ground station would like to listen to multiple spacecraft, some launched in the 1970s
- Spectrum space is a precious resource
  - Each frequency is “owned”
  - How do we deal with new technologies like ultra wide band (UWB)?

First-responder communications failures

The Homeland Security Act required the establishment of the Technical Advisory Board for First Responder Interoperability

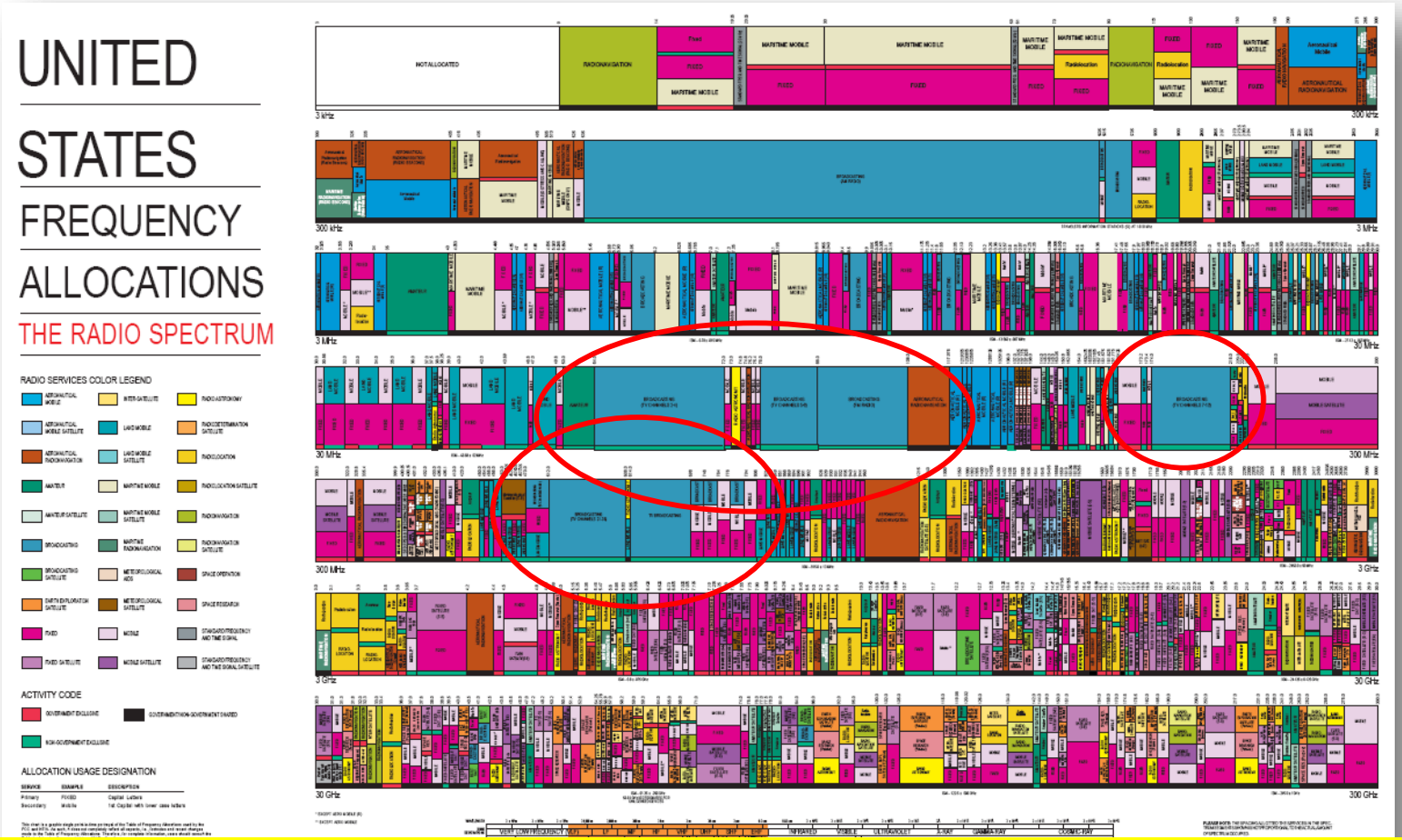
Relentless March of Cell Phone Technology

- SDR can facilitate upgrade paths

New mobile services

- In the US, 700-MHz spectrum band came up for auction from the Federal Communications Commission in 2008
- Bidders included cell operators…and Google

Spectrum space as a scarce resource

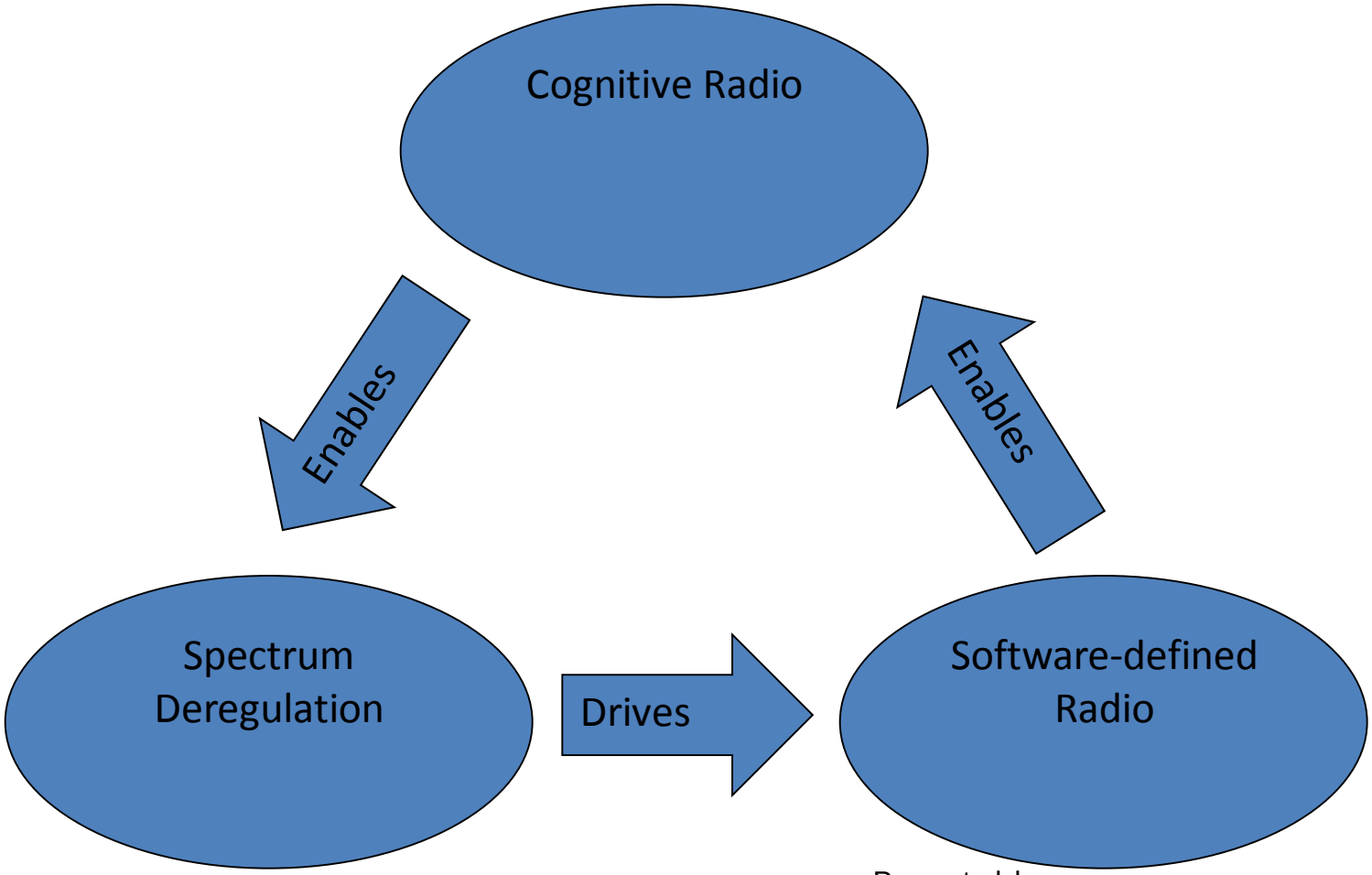


Question 1 – what are the circled blue blocks above and why are they important?

Cognitive Radio

- CR is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones.
- Makes maximum use of otherwise wasted spectrum

Evolution of Cognitive Radio



Definitions for Cognitive Radio

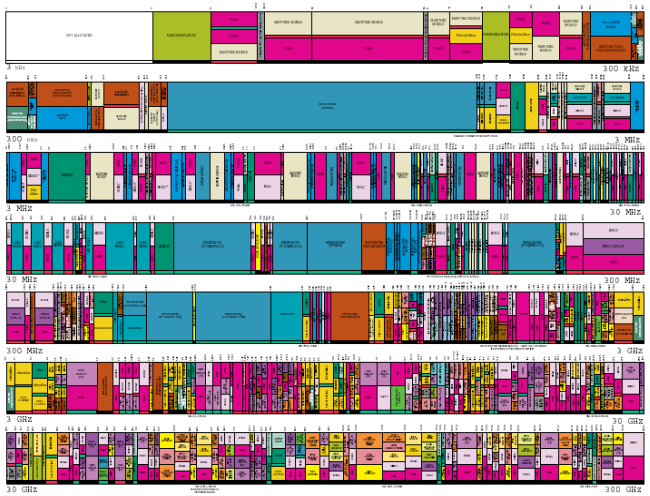
- Full Cognitive Radio: every possible radio parameter is taken into account to make spectrum decision
- Spectrum Sensing Cognitive Radio: only radio frequency (RF) spectrum is observed and used in decision making
- Licensed Band Cognitive Radio: device is capable of using licensed spectrum in addition to unassigned spectrum
- Unassigned Band Cognitive Radio: device is only allowed to use unassigned and/or license exempt spectrum

DARPA's XG

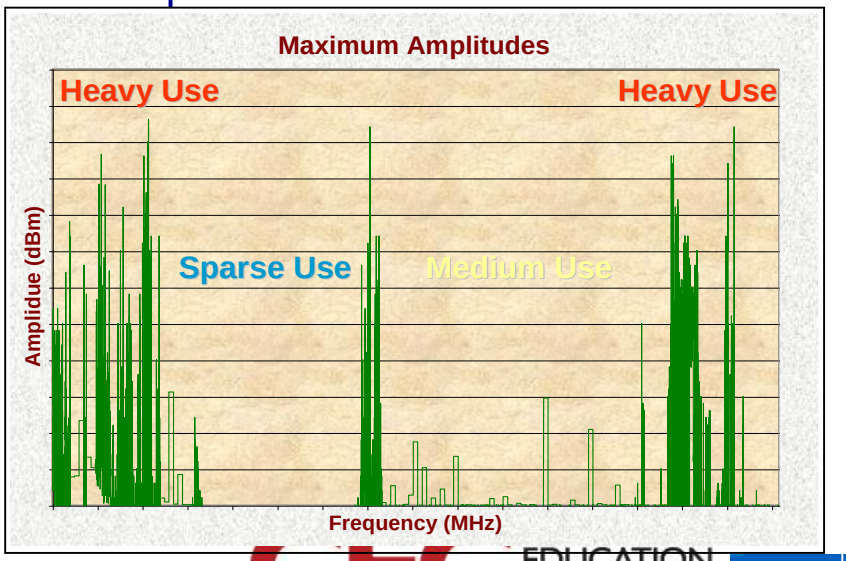
NeXt Generation Program

DARPA XG Program

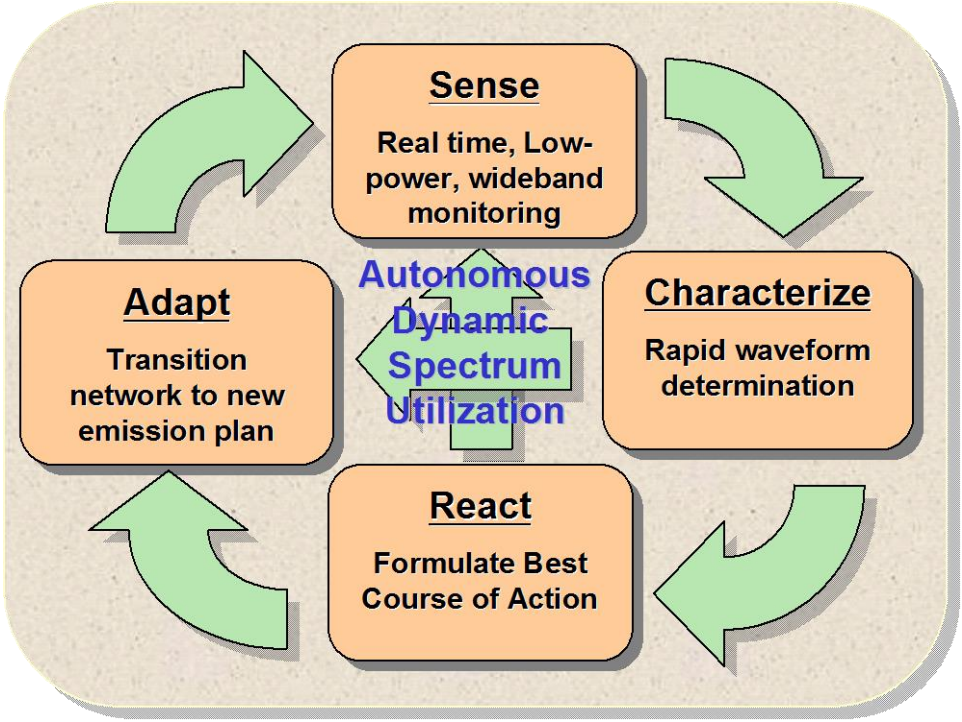
All Spectrum May Be Assigned, But…



…Most Spectrum Is Unused!



XG is Developing the *Technology* and *System Concepts* to Dynamically Access Available Spectrum



Goal: Demonstrate Factor of 10 Increase in Spectrum Access

Increasing number of wireless standards

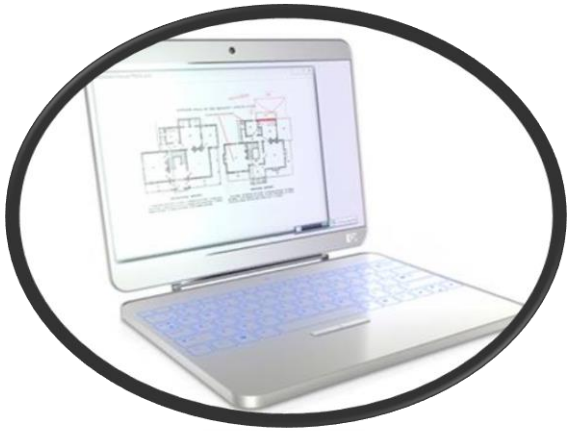
Bluetooth®

ZigBee™

IEEE 802.15.4

6LoWPAN
IPv6-based Low-power Wireless Personal Area Networks

LoRa™



abg WiFi n DRAFT CERTIFIED®

WIRELESS CERTIFIED USB™

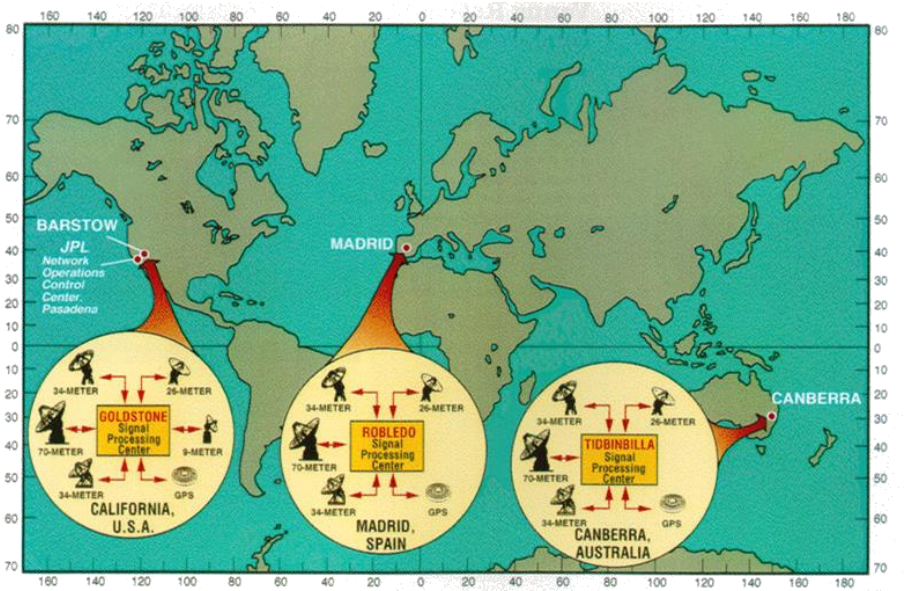
wimax

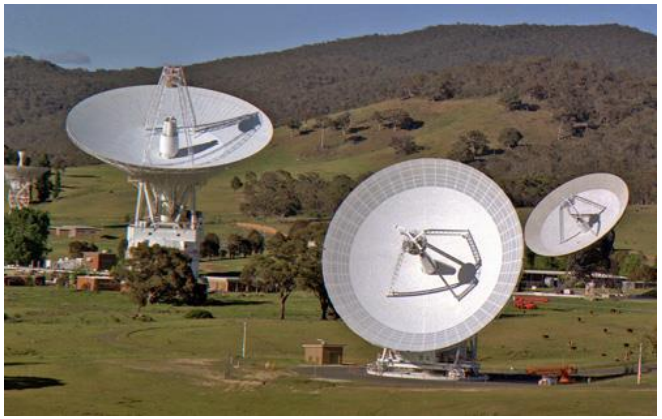
HDTV HIGH-DEFINITION TELEVISION

GPS, Cell Phone

- SDR will allow IT devices include more and more radio devices

Deep Space Communications





The Solution?

- Software Defined Radio
  - Flexible radio systems that allow communication standards to migrate
  - Flexible methods for reconfiguring a radio in software
  - Flexible, intelligent systems that communicate via different protocols at different times

Software-Defined Radio

SDR Forum

Radios that provide software control of a variety of modulation techniques, wide-band or narrow-band operation, communications security functions such as hopping, and waveform requirements of current and evolving standards over a broad frequency range.

www.sdrforum.org

Software Radio Classification

1/3

- Tier 0: Hardware Radio (HR)
  - No changes to system can by done by software

- Tier 1: Software-Controlled Radio (SCR)
  - Control functionality implemented in software, but change of attributes such as modulation and frequency band *cannot* be done without changing hardware

Software Radio Classification

2/3

- Tier 2: Software-Defined Radio (SDR)
  - Capable of covering substantial frequency range and of executing software to provide variety of modulation techniques, wide-band or narrow-band operation, communications security functions and meet waveform performance requirements of relevant legacy systems
  - Capable of storing large number of waveforms or air interfaces, and of adding new ones by software download
  - System software should be capable of applying new or replacement modules for added functionality or bug fixes without reloading entire set of software
  - Separate antenna system followed by some wideband filtering, amplification, and down conversion prior to receive A/D-conversion
  - The transmission chain provides reverse function of D/A-conversion, analog up-conversion, filtering and amplification

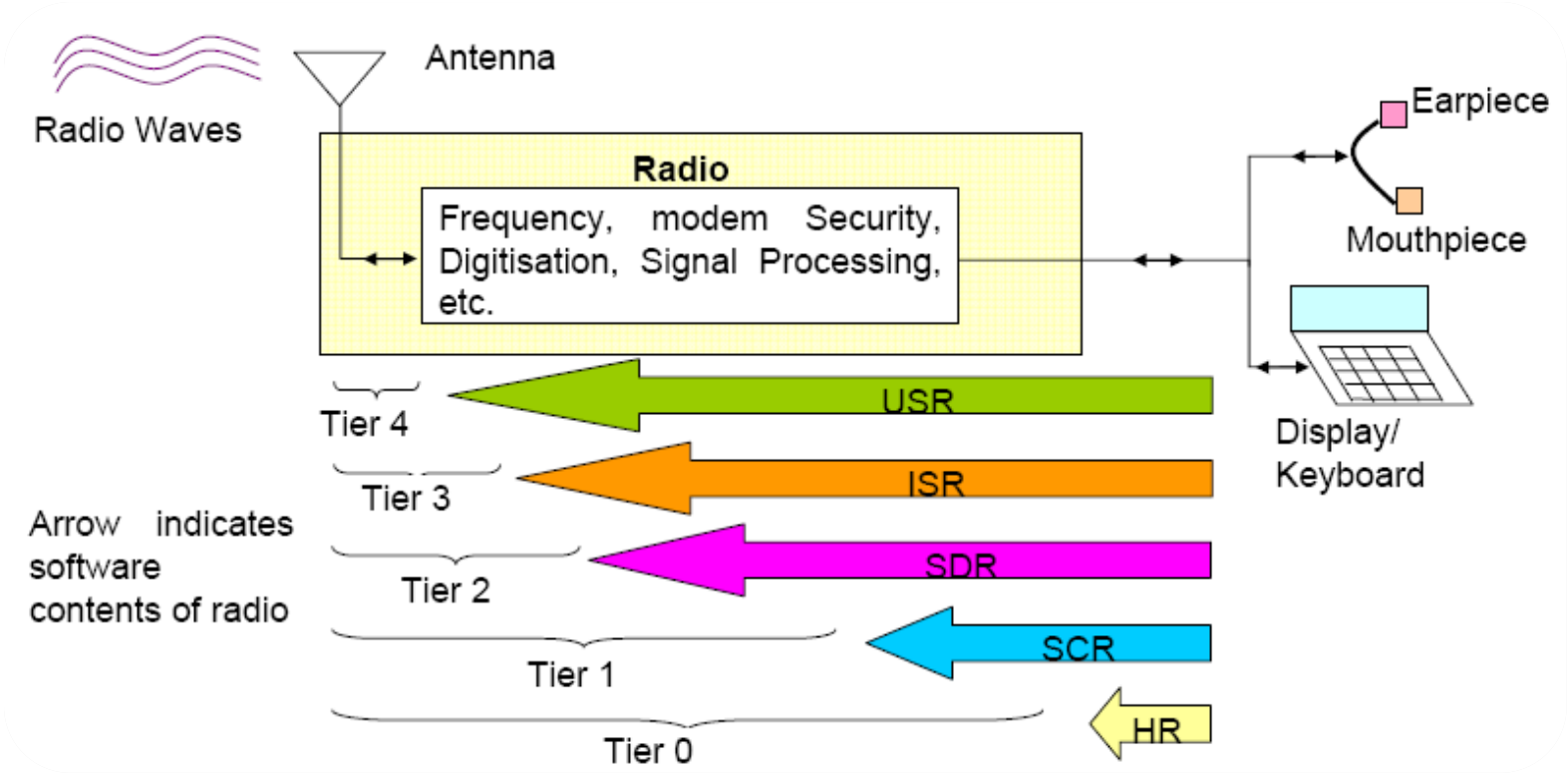
Software Radio Classification

3/3

- Tier 3: Ideal Software Radio (ISR)
  - All of capabilities of software defined radio, but eliminates analog amplification and heterodyne mixing prior to A/D-conversion and after D/A conversion
- Tier 4: Ultimate Software Radio (USR)
  - Ideal software radio in a chip, requires no external antenna and has no restrictions on operating frequency
  - Can perform a wide range of adaptive services for user
  - Intended for comparison purposes rather than implementation

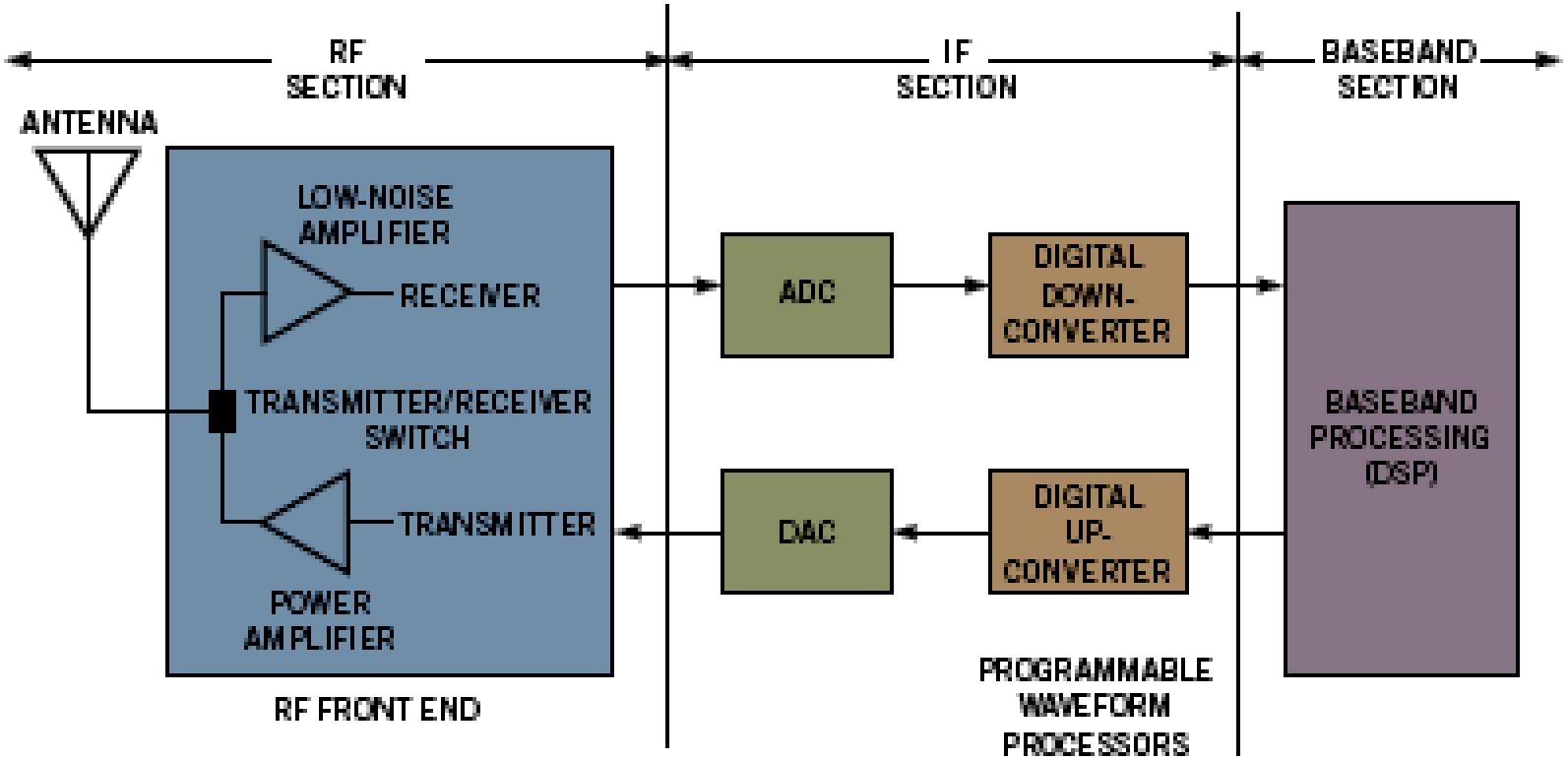
Question 2 – Are you or have you been an amateur radio operator?
(CQ CQ de WD4CHW…)

Future: Shift from Tier 0 to 4

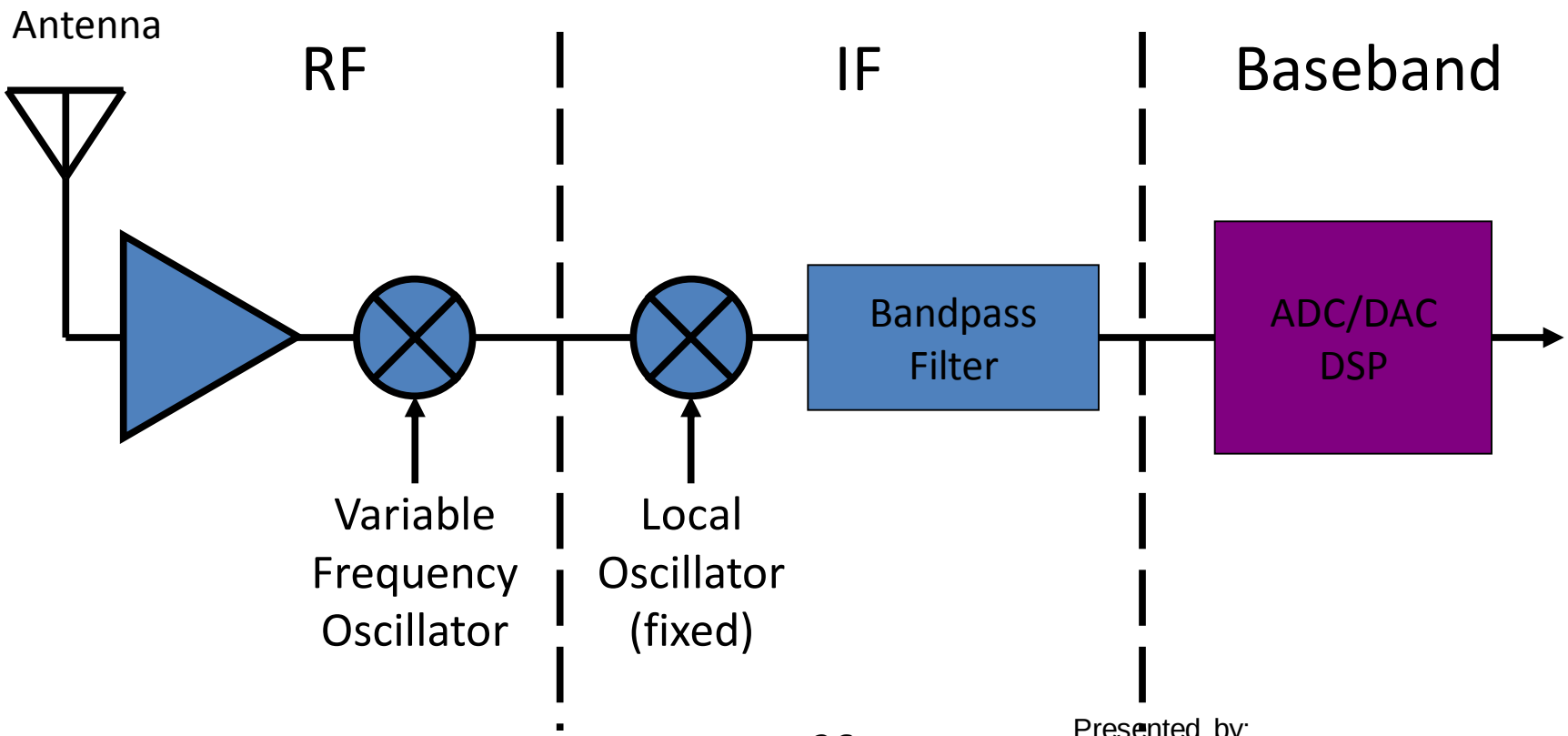


Anil Shukla, QinetiQ

SDR Architecture



Block Diagram
Software Defined Radio



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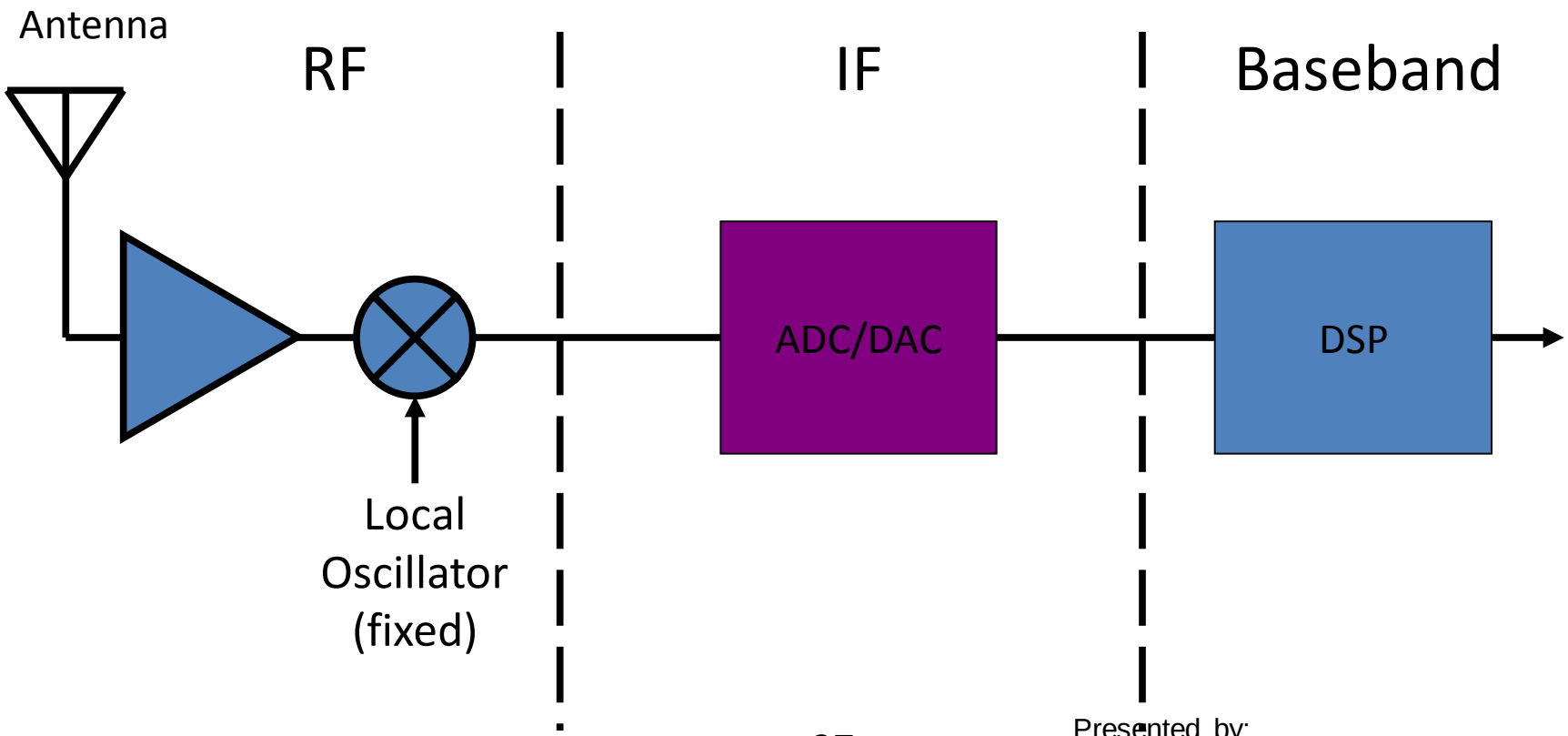

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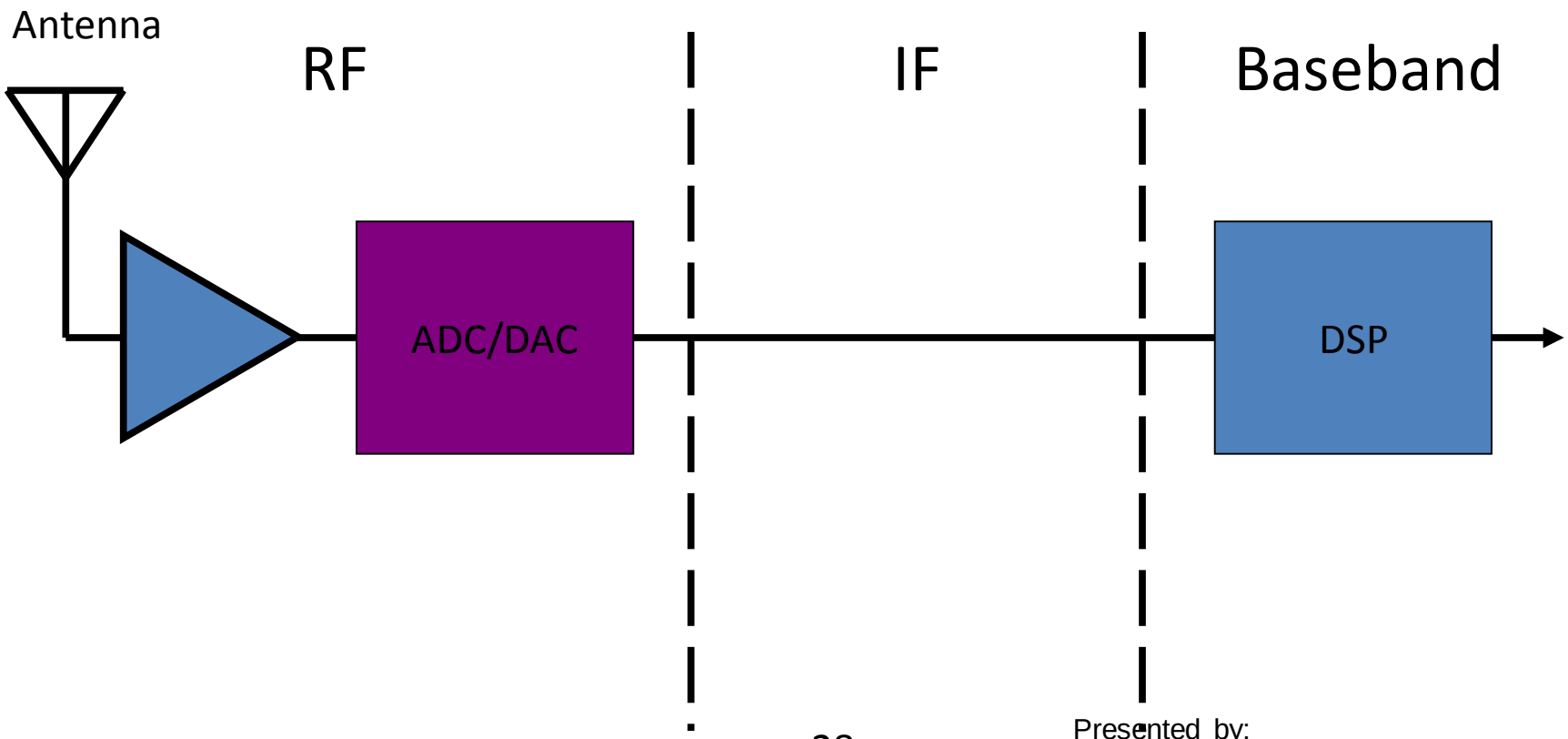


Advantages of SDR

- Ease of design
  - Reduces design-cycle time, quicker iterations
- Ease of manufacture
  - Digital hardware reduces costs associated with manufacturing and testing radios
- Multimode operation
  - SR can change modes by loading appropriate software into memory
- Use of advanced signal processing techniques
  - Allows implementation of new receiver structures and signal processing techniques
- Fewer discrete components
  - Digital processors can implement functions such as synchronization, demodulation, error correction, decryption, etc.
- Flexibility to incorporate additional functionality
  - Can be modified in the field to correct problems and to upgrade

Benefits of SDR

- Flexible/reconfigurable
  - Reprogrammable units and infrastructure
- Reduced obsolescence
  - Multiband/multimode
- Ubiquitous connectivity
  - Different standards can co-exist
- Enhances/facilitates experimentation
- Brings analog and digital worlds together
  - Full convergence of digital networks and radio science
  - Networkable
  - Simultaneous voice, data, and video

Technologies that will facilitate SDR systems of the future

- Antennas
- Waveforms
- Analog-to-Digital Converters (ADCs, DACs)
- Digital Signal Processing
- Amplifiers
- Batteries
- Cognition, behaviors
- Design tools

Technologies that enable SDR

- Antennas
  - Receive antennas are easier to achieve wide-band performance than transmit ones
  - New fractal & plasma antennas expected in 5–10 years that will be smaller and wideband
- Waveforms
  - Management and selection of multiple waveforms
  - Cancellation carriers and pulse shaping are relatively new techniques (research papers 5 years)

Technologies that enable SDR

- Analog-to-digital converters
  - ADC sampling speed has tripled every 6–8 years
  - If ADC development continues then by the year 2010, ~500 MHz of bandwidth could be digitized instantaneously
- Digital signal processing/FPGAs
  - Number of transistors doubles every 18 months
  - When will this pace slow down? Some indicate this pace is only sustainable until 2010
  - More specific purpose DSPs and FPGAs

Technologies that enable SDR

- Batteries
  - More and more power needed (need to focus on more efficient use of power)
  - Fuel cell development, another 5–10 years until viable for handhelds
- Terrain databases
  - Interference prediction, environment awareness 5 years away
- Cognitive science
  - A key aspect will be to understand how multiple CRs work with each other

Design tools

- Tools facilitate rapid design iterations
- Systems tools to help evaluate trade-offs
- Much more on this Friday!

SDR issues

- Wideband radio circuits (Rx): high requirements
- High requirements on A/D converter (16 bits, 300 Ms/s)
- Wideband PA (Tx): linearity, bandwidth, efficiency
- Higher initial costs

Military Applications of SDR

- Enable and improve efficiency of joint operations (cooperation between separate troops)
  - National and international operations
- Enable and improve efficiency of interoperability (connections between different systems)
- Implement new features and systems without need to procure new equipment
- Reduce number of radios
  - US armed forces has 25–30 radio families in use
  - Number of radios is ~750,000
- Provide flexible services
  - e.g., adaptive and/or covert waveforms

JTRS

Joint Tactical Radio System

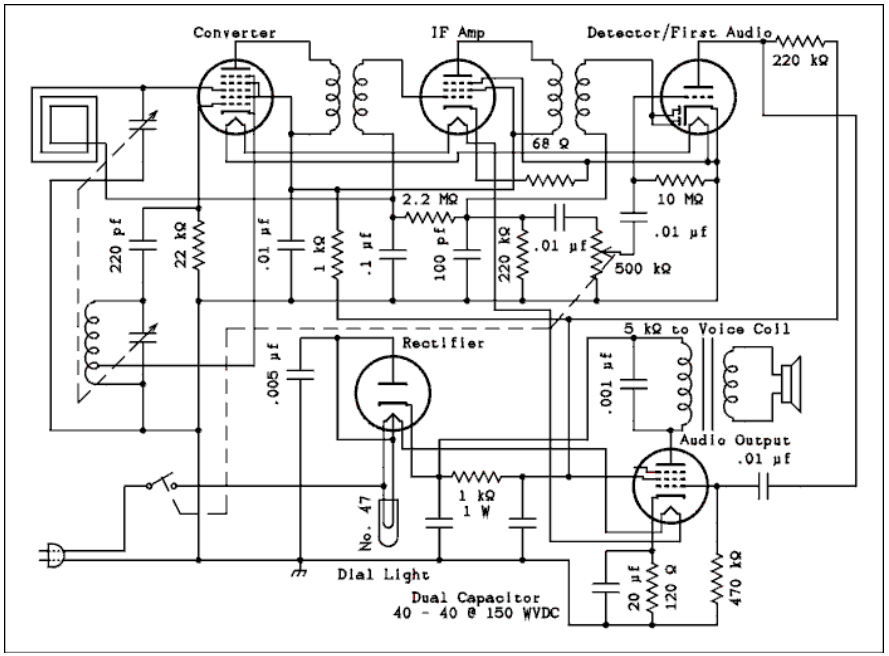
- US military software radio program
- Multi-billion dollar program
- Family of common radios and waveforms built around standard open architecture
- New radios of US armed forces must fulfill JTRS requirements
- Radios must be based on Software Communications Architecture (SCA)
  - SCA establishes implementation-independent framework with baseline requirements for development of software-configurable radios

Commercial applications of SDR

- Role of software radio in commercial applications is not yet clear
- Some possible applications
  - Next generation multimedia satellites
    - Only (economical) way to introduce new services or systems to orbiting satellites
  - Implementation of 4G-terminals
    - Same terminal or base station can operate in several different systems
  - Reconfigurable multi-standard terminal for heterogeneous networks
    - Development and introduction of new kind of features and applications to users

Tomorrow

- We will take a step back and look at the basics of RF and radio design (particularly receivers)



Our Radio

- More on this Wednesday and Thursday!

Question 3 – Will you be doing the hands-on portion of this week's class?

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Please stick around as I answer your questions!

- Please give me a moment to scroll back through the chat window to find your questions
- I will stay on chat as long as it takes to answer!
- I am available to answer simple questions or to consult (or offer in-house training for your company)
  c.j.lord@ieee.org
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  http://www.linkedin.com/in/charleslord
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