5 GHz sharing

5 GHz history and ITS/DSRC slides for the 5 GHz discussion

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Abstract

- Taxonomy, band plans and channelization
- U-NII World Band
- TDWR in 5600-5650 MHz
- Look at 5850-5925 MHz channels

U-NII World Band, U-NII-2C

- **FCC 06-96, DFS testing of representative radar characteristics (bin 1) KDB 905462**
  - https://apps.fcc.gov/kdb/GetAttachment.html?id=PIDuzGyOggplxY%2F09X8mgA%3D%3D
- **FCC TDWR Interference Enforcement**
  - http://www.fcc.gov/encyclopedia/weather-radar-interference-enforcement
  - http://transition.fcc.gov/Daily_Releases/Daily_Business/2013/db0315/DA-13-295A1.pdf

DOC in 2013

- **NTIA Report to US Congress**
  - http://www.ntia.doc.gov/report/2013/evaluation-5350-5470-mhz-and-5850-5925-mhz-bands
    - The report concludes that further analysis will be required to determine whether and how the identified risk factors can be mitigated through, for example, the promulgation of new safeguards in addition to the FCC's existing requirements. Accordingly, NTIA, in collaboration with the federal and industry stakeholders and the FCC, will conduct quantitative analysis of potential mitigation requirements in connection with regulatory proceedings
- **DOC Feb 19 letter to FCC on 5 GHz (footnotes 3-8)**
  - https://mentor.ieee.org/802.18/dcn/13/18-13-0021-00-0000-ntia-letter-to-fcc-on-5-ghz-nprm.pdf

Following slides are from IEEE 802

- **March 18, 2013 5 GHz Tutorial**
- **https://mentor.ieee.org/802.11/dcn/13/11-13-0282-03-0000-802-5-ghz-tutorial.pptx**

802 5 GHz Tutorial

Date: 2013-03-12

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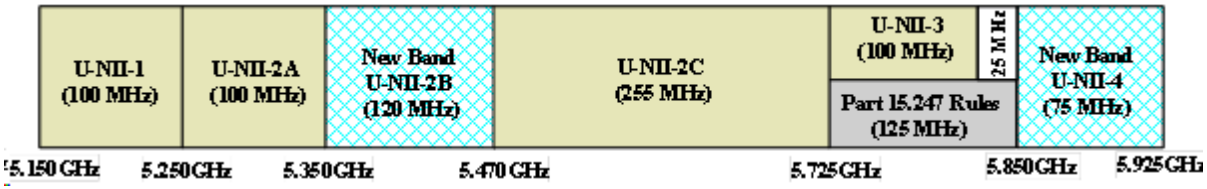
Current FCC Policy Initiatives

- **TV Band Auctions (Docket 12-268)**
- **3.5 GHz Commercial Operations (Docket 12-354)**
  - FCC 3.5 GHz Workshop
    - http://www.fcc.gov/events/35-ghz-workshop
      - Timemark 134:20-138:40 Three Big Ideas
- **Next Generation Unlicensed, Revision of Part 15 to Permit Unlicensed National Information Infrastructure Devices in the 5 GHz Band (Docket 13-49)**
  - Apple 1995 National Information Infrastructure proposal
    - http://www.warpspeed.com/lovette1.html

US 5 GHz TAXONOMY



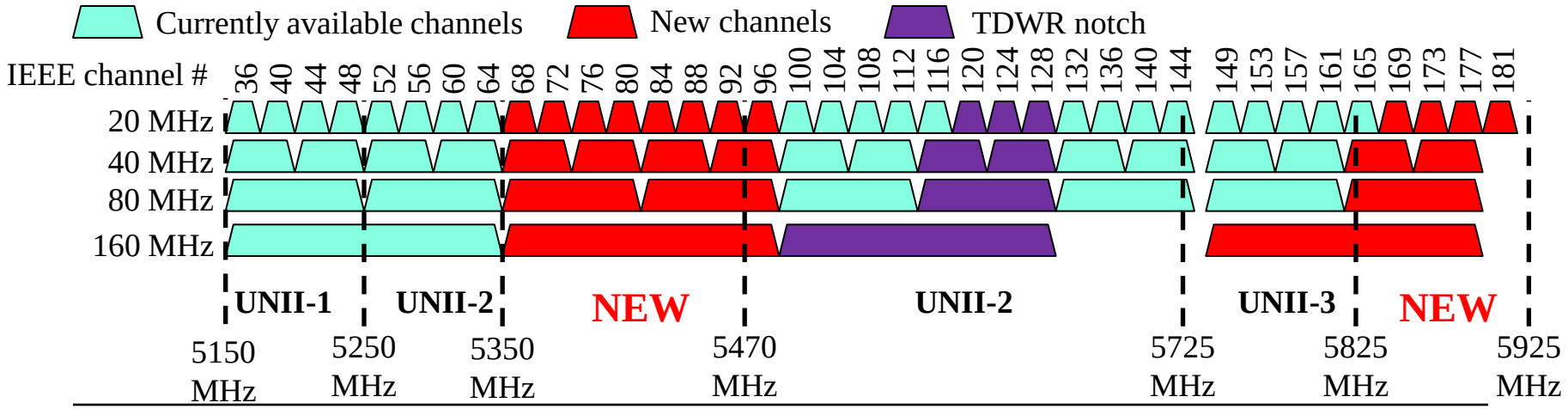
- http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-13-22A1.pdf (plain)
- **https://mentor.ieee.org/802.18/dcn/13/18-13-0017-01-0000-fcc-5-ghz-unii-rules-revision-nprm.docm** (highlights)

- **U-NII-1 = 5150-5250**
- **U-NII-2A = 5250-5350**
- **U-NII-2B = 5350-5470 NEW**
- **U-NII-2C = 5470-5725**
- **U-NII-3 = 5725-5825 (NEW Proposal to extend to 5850)**
- **U-NII-4 = 5850-5925 (NEW)**

Band plan with new spectrum

Importance of Additional Spectrum

- **Wide bandwidth channels desired to support high throughput requirements**
- **At the same time, large number non-overlapping channels desired to support high QoS requirements**
  - To avoid co-channel interference
- **Current UNII spectrum allows only**
  - **Five** 80 MHz channels
  - **One** 160 MHz channel
- **Additional unlicensed use of 5.35-5.47 GHz and 5.85-5.925 GHz would allow**
  - **Nine** 80 MHz channels
  - **Four** 160 MHz channels



Canadian 5 GHz situation

- **SMSE-012-12 Framework for the Use of Certain Non-broadcasting Applications in the Television Broadcasting Bands Below 698 MHz**
  - http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10497.html
- To a great degree will align with US Part 15 rules, in addition to preserving existing Remote Rural Broadband Systems RSS-196
  - http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09831.html

EU 5 GHz bands and rules evolved

- **EN 301 893 v1.5.1 (2008-12) added 40 MHz occupied bandwidths while protecting other services**
  - Changes to permit 802.11n operation
- **EN 301 893 v1.6.1 (2011-12) added wider occupied bandwidths while protecting other services**
  - Changes to permit 802.11ac operation
- **EN 301 893 v1.7.1 (2012-06) added politeness requirements in technology neutral form**
  - Listen Before Talk with listening proportional to transmit power, higher power requires more silence than lower power
- **EN 300 440, 5.725-5.875 GHz band, ERC 70-03 Short Range Device rules permit transmissions up to 25 mW**

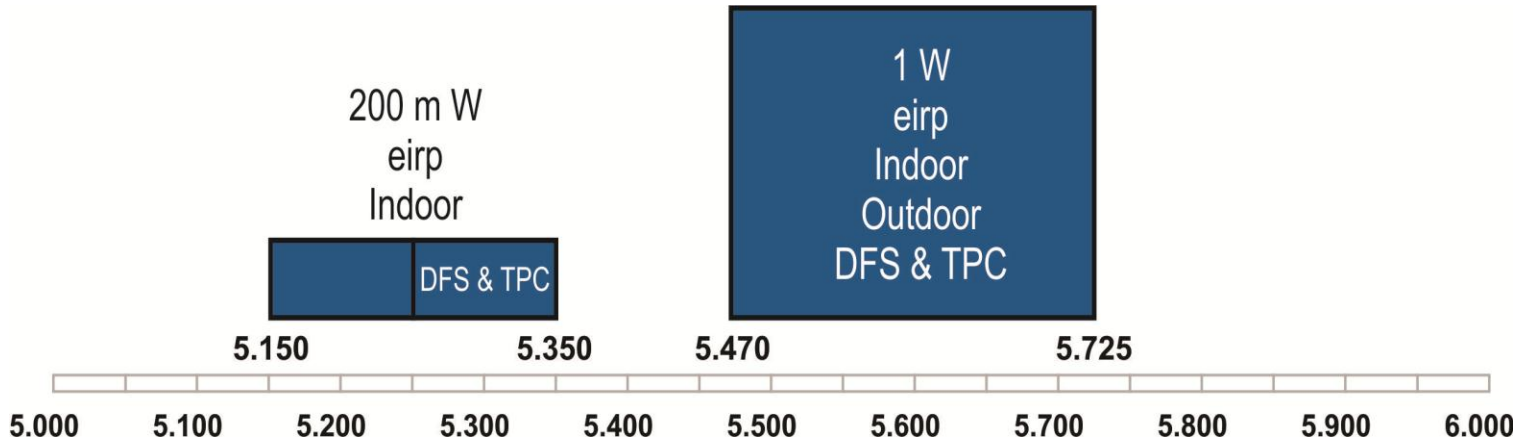
EU-27 situation

- **EC Radio Spectrum Policy Programme and spectrum sharing**
  - http://blogs.ec.europa.eu/neelie-kroes/spectrum-sharing/
  - http://blogs.ec.europa.eu/neelie-kroes/european-council-ict-single-market/
  - http://www.digitaltveurope.net/39292/kroes-gets-go-ahead-to-set-out-stall-for-telecoms-single-market/
- **Study "Impact of traffic offloading and related technological trends on the demand for wireless broadband spectrum“ SMART 2012/0015 awarded**
- **Plum consulting 5 GHz report to EC**
- https://communities.cisco.com/servlet/JiveServlet/downloadBody/32446-102-2-58832/Plum%20Jan2013%20Future%20proofing%20Wi-Fi.pdf.pdf

Mika Kasslin, Nokia

5 GHz in Europe today

- **Ever since 2005 there has been 455 MHz of spectrum in the 5 GHz for RLAN**
  - Additionally, 150 MHz of spectrum from 5.725 MHz onwards can be used as per SRD rules
- **RLANs share this band with others with means of TPC and DFS**



Sharing with other primary services

- **The 5 GHz band is used also by other primary services, such as radars**
- **Two sharing mechanisms are required**
  - Transmit Power Control (TPC)
  - Dynamic Frequency Selection (DFS)
- **TPC is a mechanism to ensure a mitigation factor of at least 3 dB on the aggregate power from a large number of devices**
  - Devices are allowed to operate without TPC but for them mean e.i.r.p limits for RF output power and power density are lower

Sharing with DFS

- **DFS is employed to**
  - detect interference from radar systems (radar detection) and to avoid co-channel operation with these systems
  - provide on aggregate a near-uniform loading of the spectrum
- **DFS builds upon concept of master and slave mode devices**
  - Master mode device uses a Radar Interference Detection function and controls the transmissions of RLAN devices operating in slave mode
    - A master mode device may rely on another device to implement the Radar Interference Detection function
  - Slave mode device transmissions are under control of a master mode device

Different phases of DFS

- **Channel Availability Check**
  - A device checks channels for the presence of radar signals in order to identify *Available Channels*
  - This shall be performed during a continuous period in time for at least ***60 s***
- **In-Service Monitoring**
  - Each *Operating Channel* is monitored for the presence of radar signals
- **Channel Shutdown**
  - Once a radar signal has been detected during the In-Service Monitoring on an *Operating Channel*, the master device and all associated slave devices stop transmissions within ***10 s***
- **Non-Occupancy Period**
  - RLAN device shall not make any transmissions for ***30 m*** on a channel after a radar signal was detected on that channel

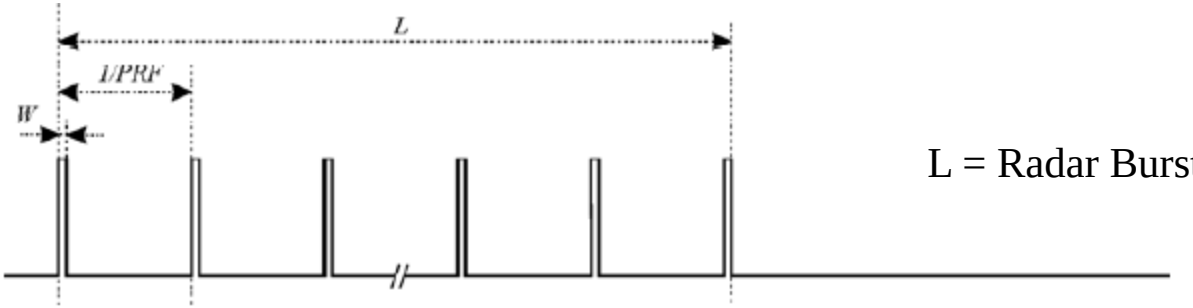
DFS requirement values

Parameter	Value
Channel Availability Check Time	60 s (see note 1)
Minimum Off-Channel CAC Time	6 minutes (see note 2)
Maximum Off-Channel CAC Time	4 hours (see note 2)
Channel Move Time	10 s
Channel Closing Transmission Time	1 s
Non-Occupancy Period	30 minutes
NOTE 1: For channels whose nominal bandwidth falls completely or partly within the band 5 600 MHz to 5 650 MHz, the *Channel Availability Check Time* shall be 10 minutes. NOTE 2: For channels whose nominal bandwidth falls completely or partly within the band 5 600 MHz to 5 650 MHz, the *Off-Channel CAC Time* shall be within the range 1 to 24 hours.	

e.i.r.p. Spectral Density dBm/MHz	Value (see notes 1 and 2)
10	-62 dBm

Radar test signals

Radar test signal # (see notes 1 to 3)	Pulse width W [µs]		Pulse repetition frequency PRF (PPS)		Number of different PRFs	Pulses per burst for each PRF (PPB) (see note 5)
	Min	Max	Min	Max		
1	0,5	5	200	1 000	1	10 (see note 6)
2	0,5	15	200	1 600	1	15 (see note 6)
3	0,5	15	2 300	4 000	1	25
4	20	30	2 000	4 000	1	20
5	0,5	2	300	400	2/3	10 (see note 6)
6	0,5	2	400	1 200	2/3	15 (see note 6)



L = Radar Burst Length

Figure D.1: General structure of a single burst/constant PRF based radar test signal

Radar test signals (cont'd)

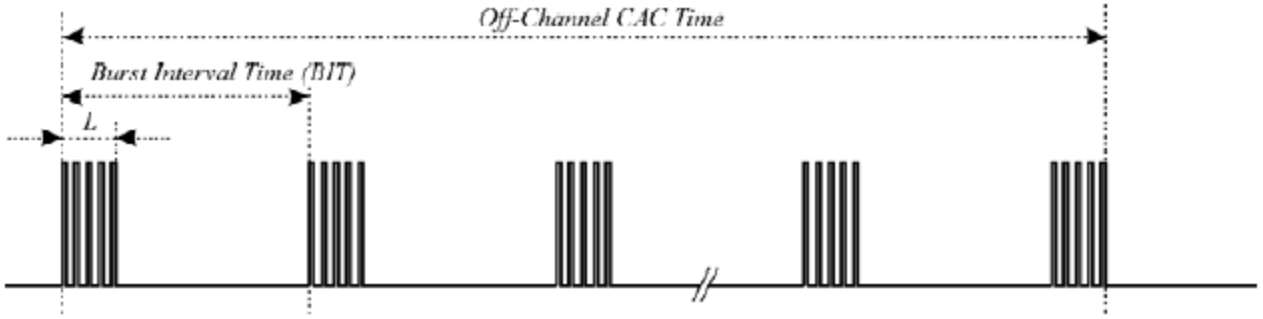


Figure D.2: General structure of a multiple burst/constant PRF based radar test signal

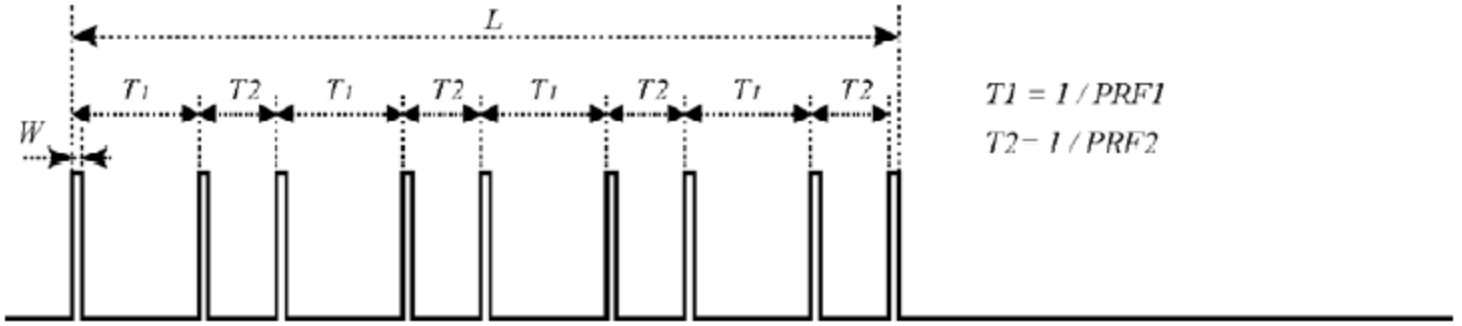


Figure D.3: General structure of a single burst/single pulse based staggered PRF radar test signal

Dedicated Short Range Communication (DSRC) Tutorial and Implications for Spectrum Sharing

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March 18, 2013

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Mission

- **Vehicle communication to/from proximate device**
  - Vehicle to Vehicle (V2V)
  - Vehicle to/from roadside Infrastructure (V2I)
- **Applications:**
  - Collision Avoidance
  - Road Hazard Safety
  - Mobility
  - Environment
  - Commerce
  - Entertainment
  - ?

Sometimes called "hard" and "soft" safety, respectively

V2V collision avoidance is driving deployment

V2V Safety

- **32,367 traffic fatalities in US – 2011**
- **Accidents have other huge costs:**
  - Injuries: 387000 in US in 2011
  - Property damage
  - Lost productivity
  - Health care and emergency services

  } AAA estimates aggregate cost of accidents $300B in 2011
- **V2V communication can "reduce, mitigate, or prevent 81% of light-vehicle crashes by unimpaired drivers" – US DOT**

Joint US DOT – OEM research

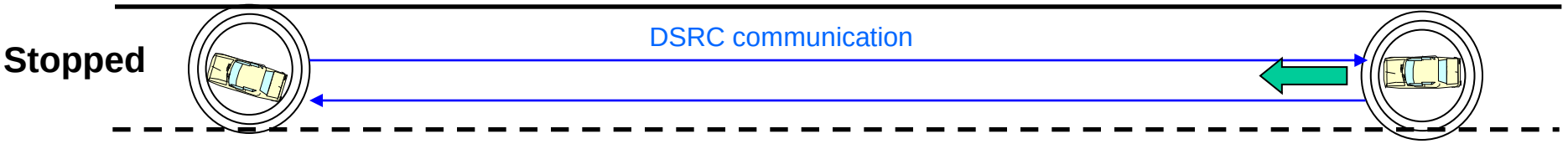
- **Vehicle Safety Communication (2003-05)**
- **EEBL (2005-06)**
- **VSC-Applications (2007-2009)**
- **V2V-Interoperability (2010-2014)**
- **V2V-Security Communication (2010-2013)**
- **Safety Pilot Driver Clinics (2010-2012)**
- **Safety Pilot Model Deployment (2011-2013)**

Note: my affiliation is Toyota. I do not represent VSC3

How does it work? (high level)

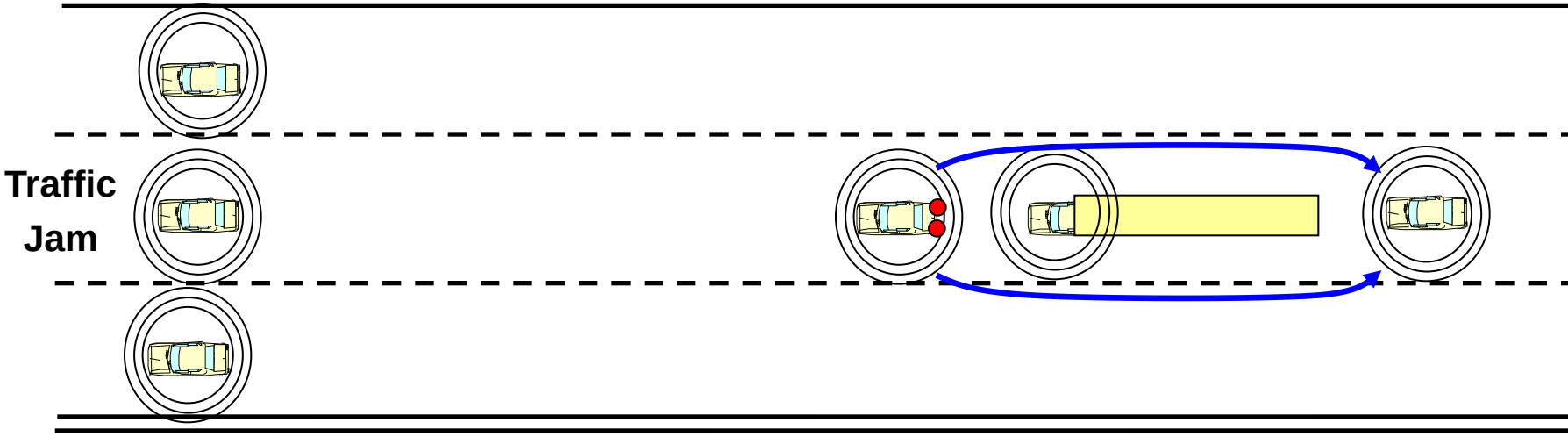
- Each vehicle broadcasts its core state information in a "Basic Safety Message" (BSM) nominally 10 times/sec.
- BSM is sent 360 degrees using IEEE 802.11p technology (more later)
- Receivers build model of each neighbor's trajectory, assess threat to host vehicle, warn driver or take control if threat becomes acute.
- Example application:

Forward Collision Warning (FCW)



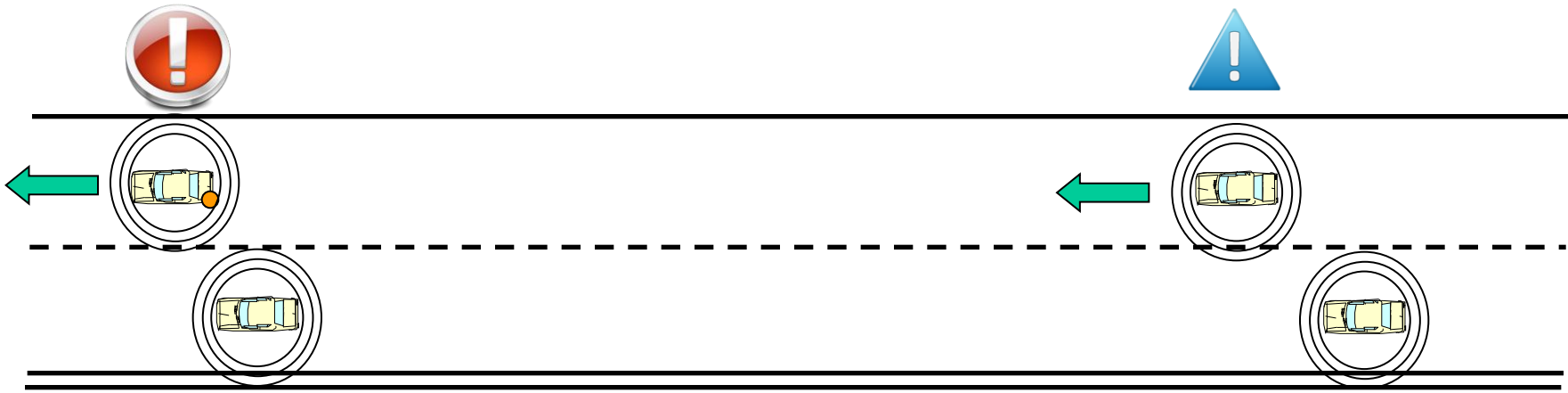
If driver of approaching car does not stop, warning issued within car

Emergency Electronic Brake Lights (EEBL)



High deceleration by car approaching jam. Trailing car Informed via DSRC within 100 msec.

Blind Spot Warning (BSW)

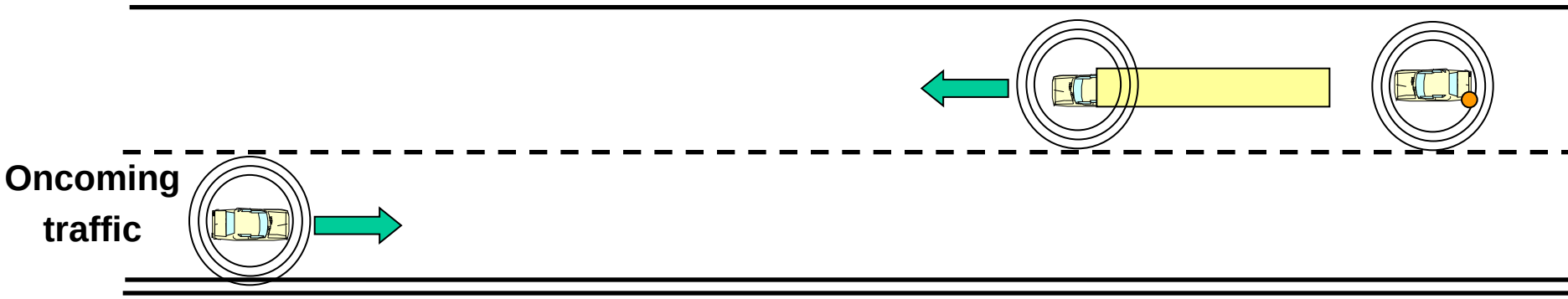


Driver receives warning when showing intent to change lanes

Normal driving – advisory indicator of car in blind spot

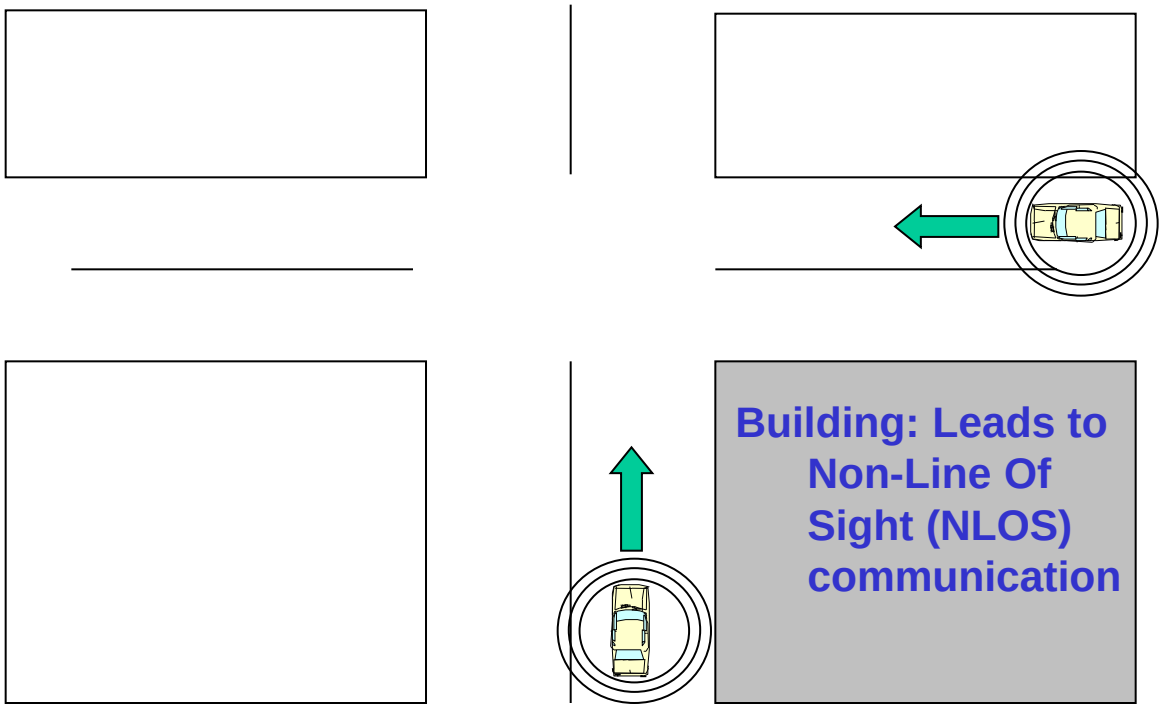
Note: Specific timing, format, or decision logic for advisories and warnings will likely vary for each car manufacturer

Do Not Pass Warning (DNPW)



When showing intent to move to oncoming lane, driver receives warning if not safe to pass.

Intersection Collision Warning (ICA)

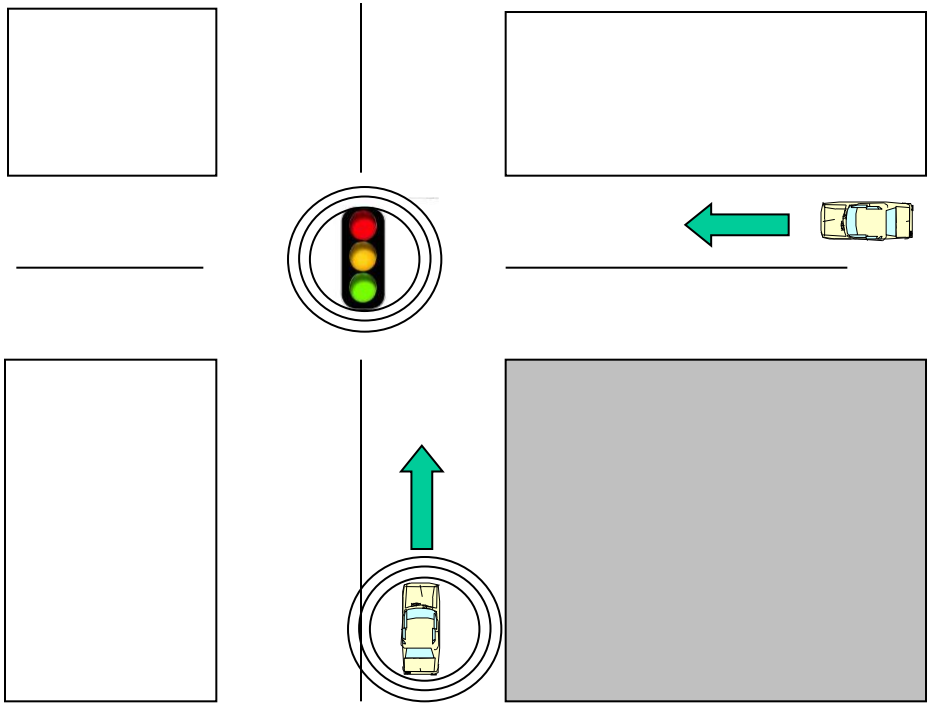


If intersecting trajectories are indicated, driver is warned.

Cooperative Intersection Collision Avoidance System (CICAS)

Two messages sent by signal:

- ***MAP (intersection topology) – changes slowly***
- ***Signal Phase and Timing (SPaT) – highly dynamic***

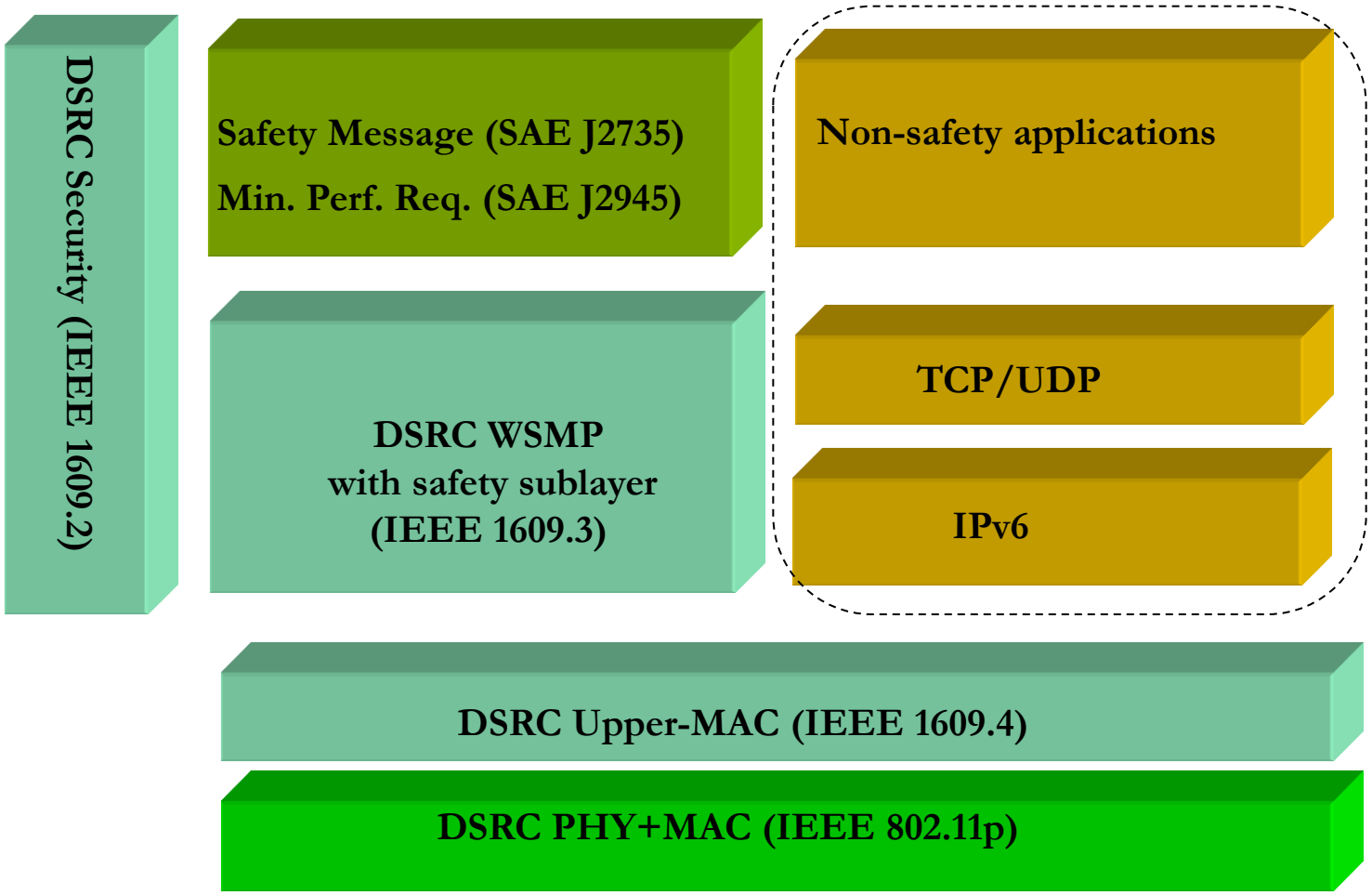


Car receives MAP and SPaT. Warning to driver if violation likely. Can avoid collision even if other car not equipped.

Future of DSRC

- **National Highway Transportation Safety Administration (NHTSA) regulates vehicles in US**
- **NHTSA is evaluating efficacy of DSRC-based collision avoidance systems**
- **NHTSA will announce later in 2013 whether they plan to begin a process to require DSRC devices in new cars**
  - Will make similar evaluation in 2014 with regard to heavy trucks
- **Several suppliers of aftermarket devices are also exploring this market**

How does it work? (details)

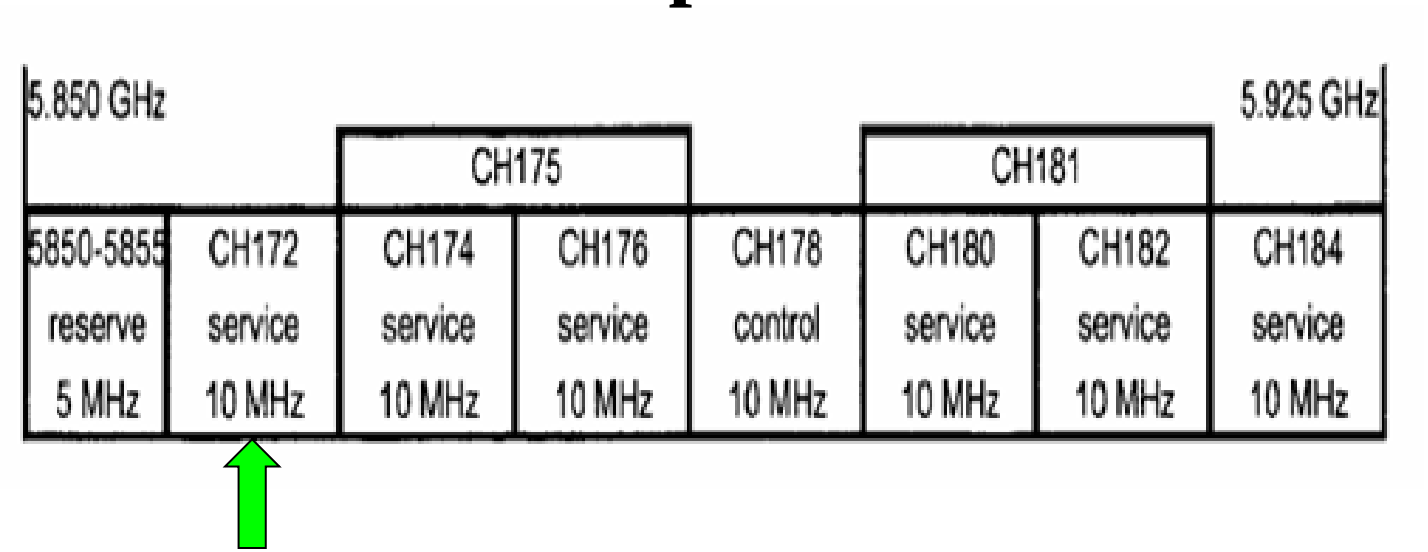


See: J. Kenney, "DSRC Standards in the United States", Proc. IEEE, July 2011, Vol. 99, No. 7, pp. 1162-1182

IEEE 802.11p-2010

- **Incorporated in IEEE 802.11-2012**
- **PHY**
  - OFDM (Clause 18)
  - Class C transmit mask for V2V safety (Table D-5)
  - Optional enhanced channel rejection (Table 18-15)
- **MAC**
  - Communicating outside the context of a BSS (dot11OCBActivated = true) – see e.g. Clause 10-20
  - No authentication or association at MAC sublayer
  - BSSID field holds wildcard value 0xFFFFFF

DSRC Spectrum

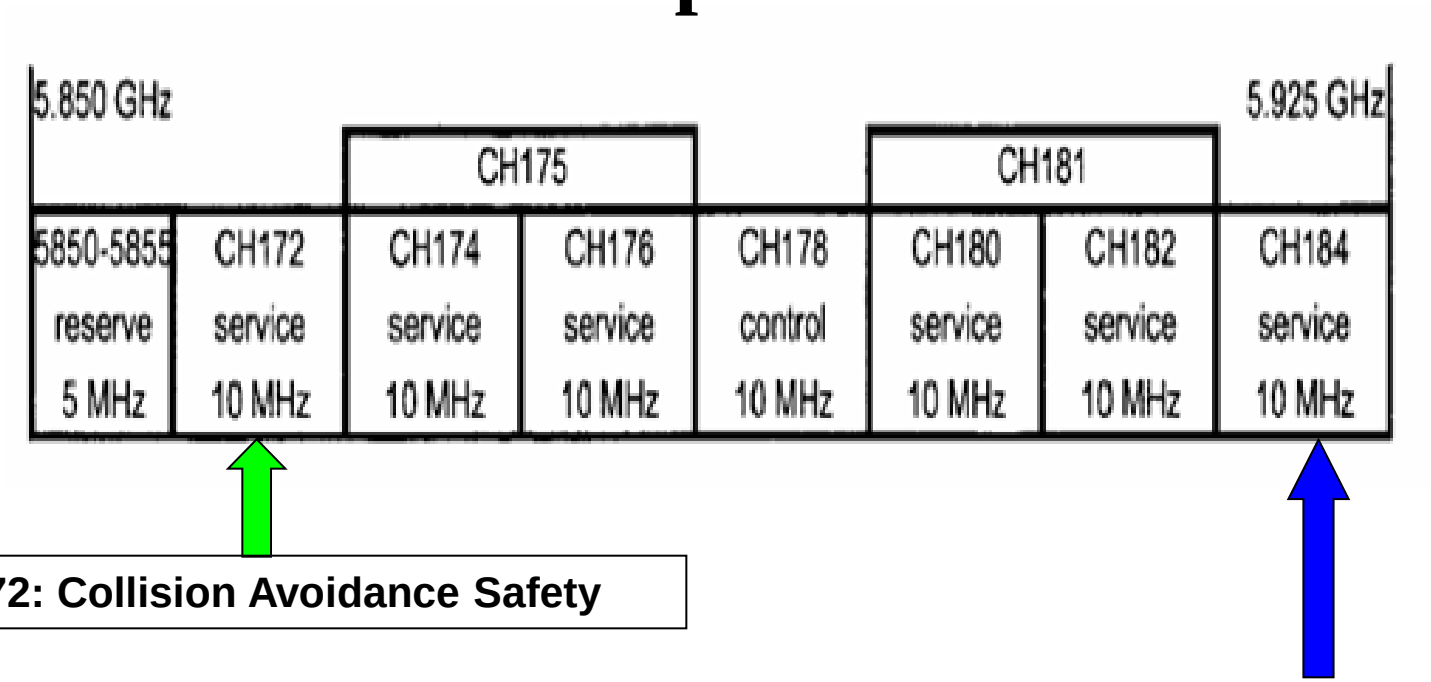


Ch. 172:

- **FCC designated "exclusively for vehicle-to-vehicle safety communications for accident avoidance and mitigation, and safety of life and property applications"**
- **Extensive industry research, testing, and field trials of safety applications using Ch. 172**
- **Will host 3 message types:**
  - **Basic Safety Message (V2V)**
  - **MAP Message (I2V)**
  - **Signal Phase and Timing Message (I2V)**
- **Nominal transmit power 20 dBm with 0 dBi antenna**

Peter Ecclesine (Cisco Systems)

DSRC Spectrum

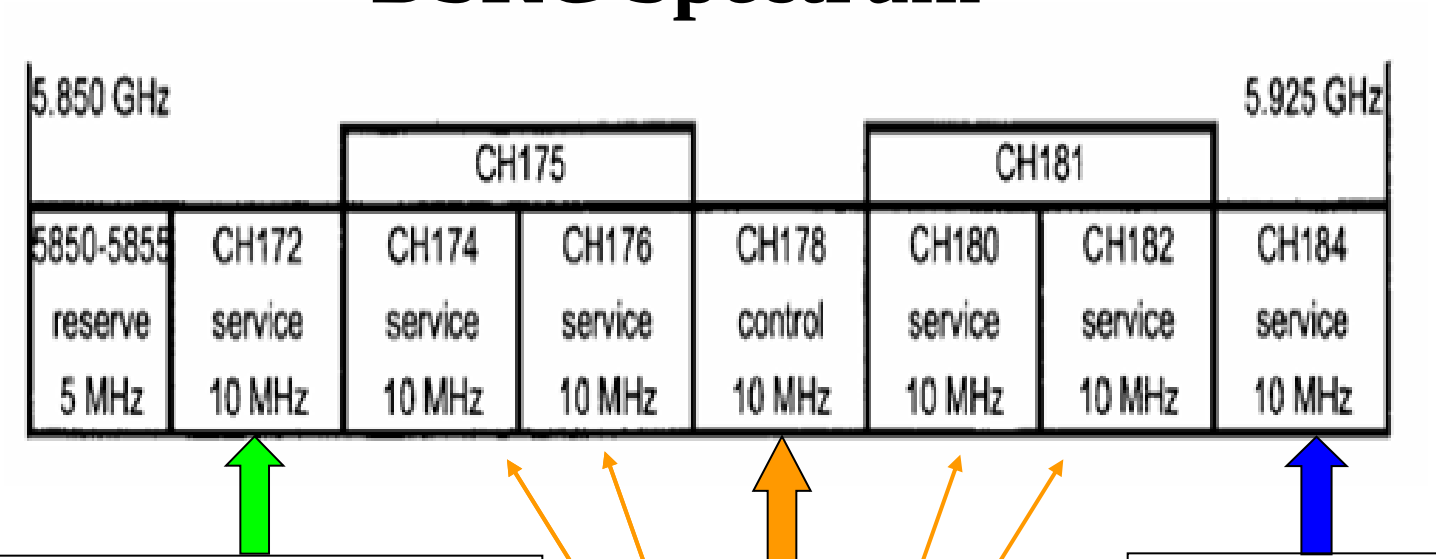


Ch. 172: Collision Avoidance Safety

Ch. 184:

- **FCC designated "exclusively for high-power, longer-distance communications to be used for public safety applications involving safety of life and property, including road intersection collision mitigation"**
- **Road authorities and public agencies primarily responsible for usage**
- **Max. power 40 dBm**

DSRC Spectrum



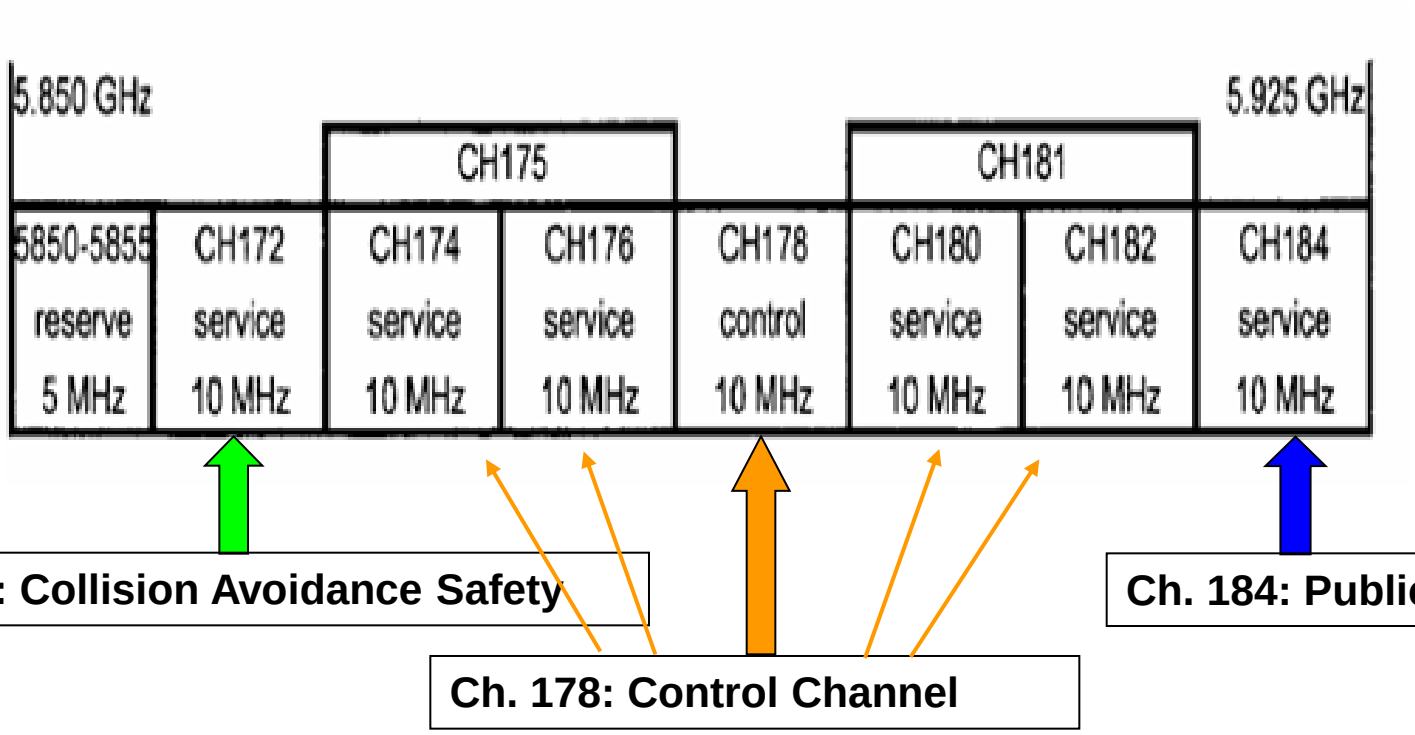
Ch. 172: Collision Avoidance Safety

Ch. 184: Public Safety

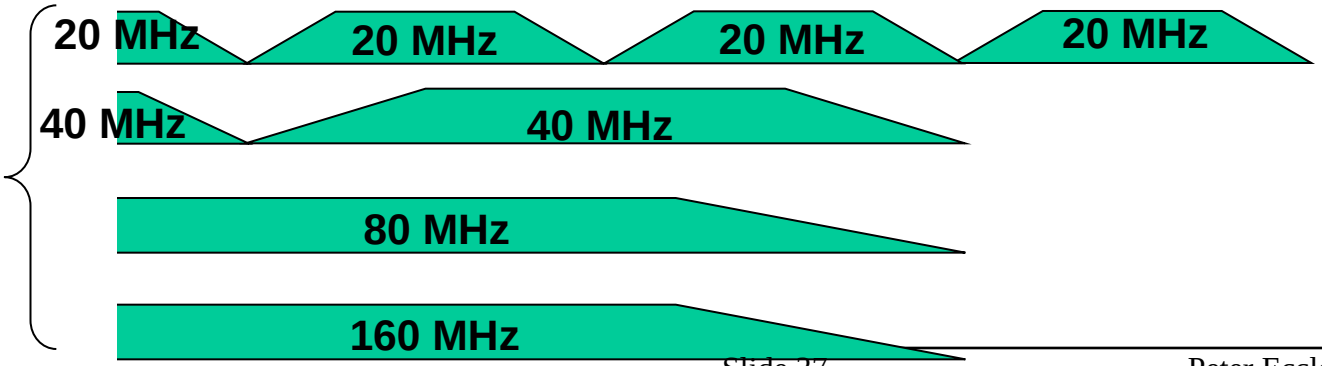
Ch. 178:

- **Control Channel**
- **WAVE Service Advertisements are broadcast here, indicating how to access services on other "Service Channels"**

DSRC and 802.11ac



From NTIA report



Some detection challenges

- Master – Client
- Asymmetric power, asymmetric channel
- Detection levels
- Detection latency when RLAN operating
- 10 MHz channels

Conclusions – DSRC Tutorial

- **DSRC holds the promise of:**
  - Saving lives and reducing property loss
  - Improving transportation efficiency
  - Improving the environment
  - Opening a new frontier for innovation
- **Will be used wherever vehicles go**
  - EU and Japan also planning implementations
- **Designed to operate solo**
  - E.g. adaptive congestion control based on channel load
- **Sharing presents significant challenges**

Pending Actions