5 GHz DFS Technology Development and Deployment: Challenges Met and Lessons Learned

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DFS History: Introduction Beginning in 1996

- 5 GHz Unlicensed National Information Infrastructure (U-NII) band concept originated in late 1990s with industry proposals to FCC.
- In 1996 the FCC released an NPRM for U-NII devices.
- NPRM proposed to make available 350 MHz of spectrum at 5.2 GHz and 5.8 GHz.
- Proposed sharing criteria for incumbents and newly proposed 5 GHz systems to prevent interference.

DFS History
Initial FCC R&O and MO&O

- In January 1997 the FCC released an R&O on U-NII devices. This set the allowable band at 300 MHz from 5150-5350 MHz and 5725-5825 MHz.
  - There is no mention in this R&O of potential conflicts with radar systems or a need for detect & avoid Dynamic Frequency Selection (DFS) technology.

- In June 1998 the FCC released an MO&O that limited U-NII devices to 1 watt peak power with directional antennas up to 23 dBi gain.
  - There is still no mention in this MO&O of potential conflicts with radar systems or a need for DFS.

DFS History: WRC-03 & Recommendation M.1652

- WRC-03 had a proposal for a new allocation in the bands 5250-5350 and 5475-5725 MHz for a new mobile unlicensed service.

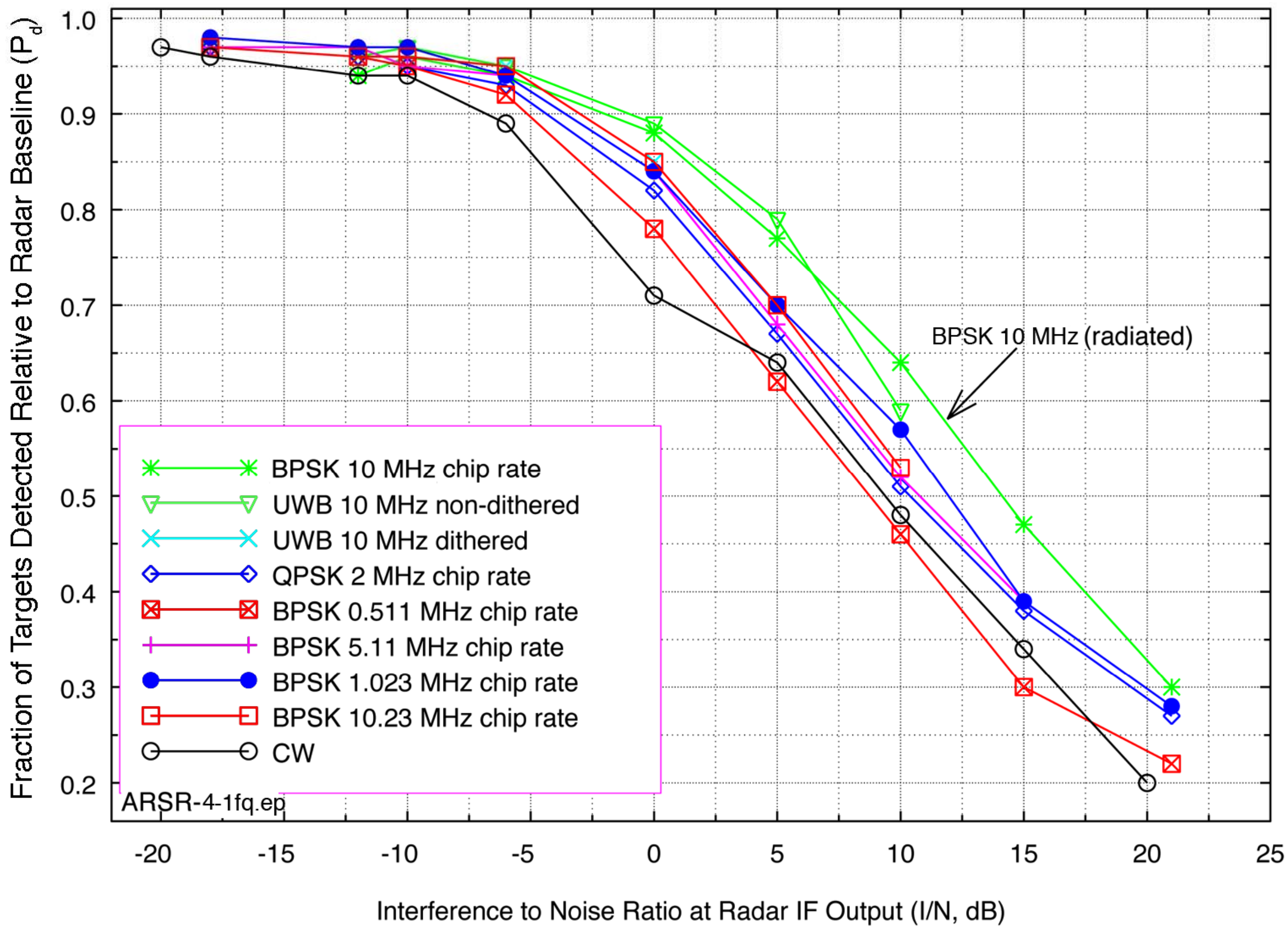
- The U.S. actively promoted this allocation under the condition that the new service *had to use DFS* to protect radar operations.

- The United States was successful in obtaining the new allocation under the DFS provision at the conclusion of WRC-03.

- A related new ITU-R Recommendation, M.1652, came out of WRC-03. It roughly outlined the guidelines, limits, and operating procedures for 5 GHz DFS-capable U-NII devices.

DFS History:
Basis of DFS Rules in M.1652

- Multi-year ITS and OSM fundamental research program into levels at which interference causes radars to lose targets.
  - Losses begin when interference levels are 6 dB *below* radars' own receiver noise.
  - Substantial losses occur when interference level = radar receiver noise level.



Features of ITU-R M.1652

- WRC-03: 5250-5350 MHz & 5470-5725 MHz bands allocated to mobile service co-primary with radiodetermination— Mobile devices to use DFS technology to protect radars from interference.

- WAS and RLAN operations must not cause interference to radar receivers.
  - DFS devices must detect & avoid local radar signals through constant monitoring while also sending & receiving data traffic.

- Provided some representative 5 GHz radar system characteristics.

- Set detection thresholds for radar signals.

- Set requirements for determining channel availability prior to data transmissions.

- Set speed requirements for vacating DFS channels when radar signals detected.

DFS History: First Implementation Steps in the U.S.

- After WRC-03, domestic rules for the Code of Federal Regulations (CFR) were begun; FCC initiated a rulemaking for 5 GHz U-NII devices.
- The process was quite involved, including NTIA, FCC, DoD, other Federal agencies and industry. Industry was represented by various Fortune 500 companies acting as one entity.
- In spring of 2004 three companies (Cisco, Motorola, and Atheros) had developed DFS-capable prototype U-NII devices that they submitted to NTIA for lab tests in Boulder.
- DFS performance of these devices was evaluated at ITS.

DFS History: Certification Requirements Developed

- ***Power-On Test:*** Verify that monitoring works and no emissions occur for 60 seconds after initial power-up of 5 GHz DFS U-NII device.

- ***Initial Detection Tests:*** Devices must detect a radar signal within the first six seconds and last six seconds of the initial channel check and not transmit.

- ***In-Service Monitoring Test:*** Must detect various synthesized radar waveforms representative of radar emissions in the 5 GHz bands.
  - The most comprehensive test for DFS U-NII devices; hundreds of trials required.
  - Operational radar waveforms are not exactly replicated.

- ***30-Minute Non-Occupancy Test:*** When a previously used DFS channel has been occupied by a radar signal, U-NII devices must be verified as not attempting to use it again for at least the next 30 minutes.

DFS History: Sharing Protocol Summary

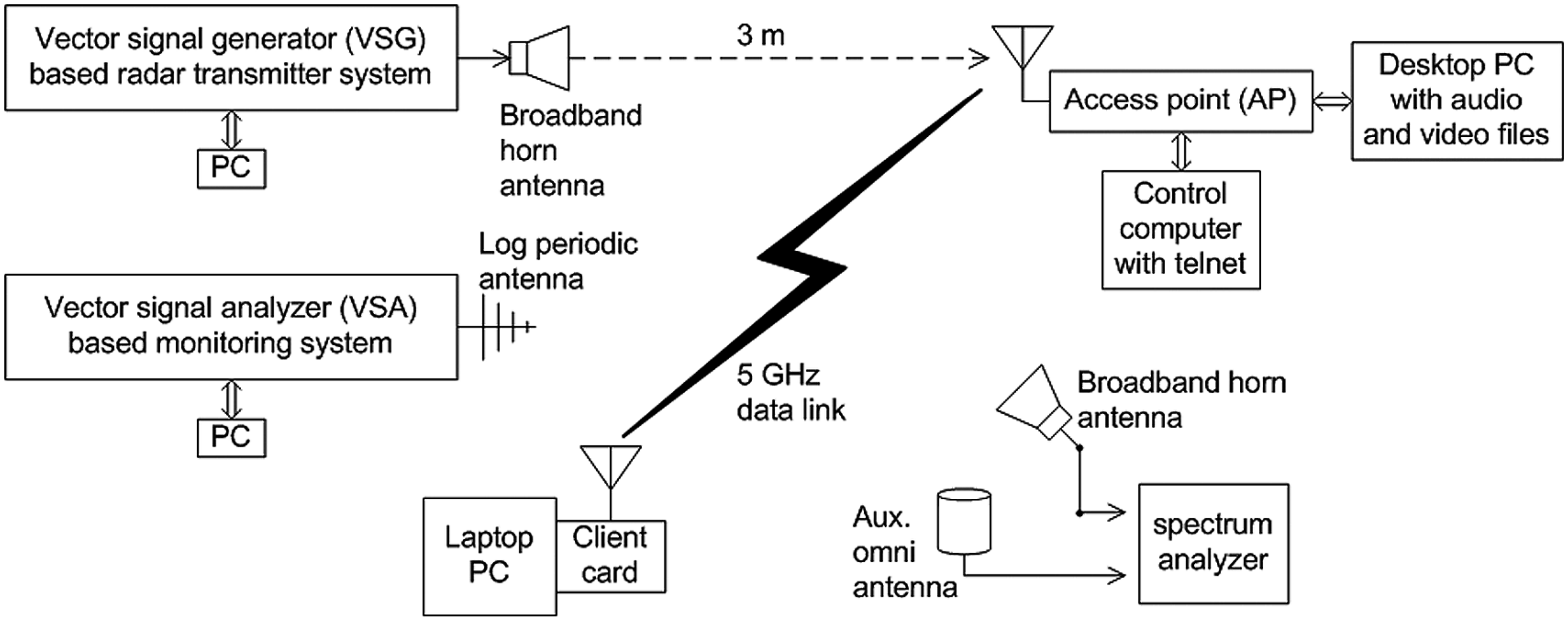
Parameter	DFS Requirement
Radar Signal Detection Threshold in DFS receivers	-62 or -64 dBm in 1 MHz bandwidth
Channel availability-check interval before any channel can be used	60 seconds
Channel non-occupancy period after radar detection	30 minutes
Maximum interval allowed for channel move after radar detection	10 seconds
Maximum intervals allowed for housekeeping transmissions during a channel move	200 ms + approx. 60 milliseconds over remaining 10 second period

DFS History:
DFS Compliance Testbed Finished

- Radar signal generator and synthesizer:
  - Produces bursts of un-modulated and chirped pulses in 5 GHz bands.
  - Variable and user selectable: frequency, # of pulses, pulse width, pri, and chirp bandwidth.
  - RF power control on pulses.
  - Uses Agilent Vector Signal Generator (VSG) and other test devices.
- Timing measurement system:
  - Monitors RF activity on U-NII channel.
  - Uses Agilent Vector Signal Analyzer (VSA) and E4440 spectrum analyzer for fine and coarse measurement of the RF emissions of the U-NII AP and client transmissions over 12 seconds.
  - Very accurate as shown on Slide 12.
- The two systems are synchronized so that a press of a button starts an in-service test and collects data for 12 or 24 seconds.

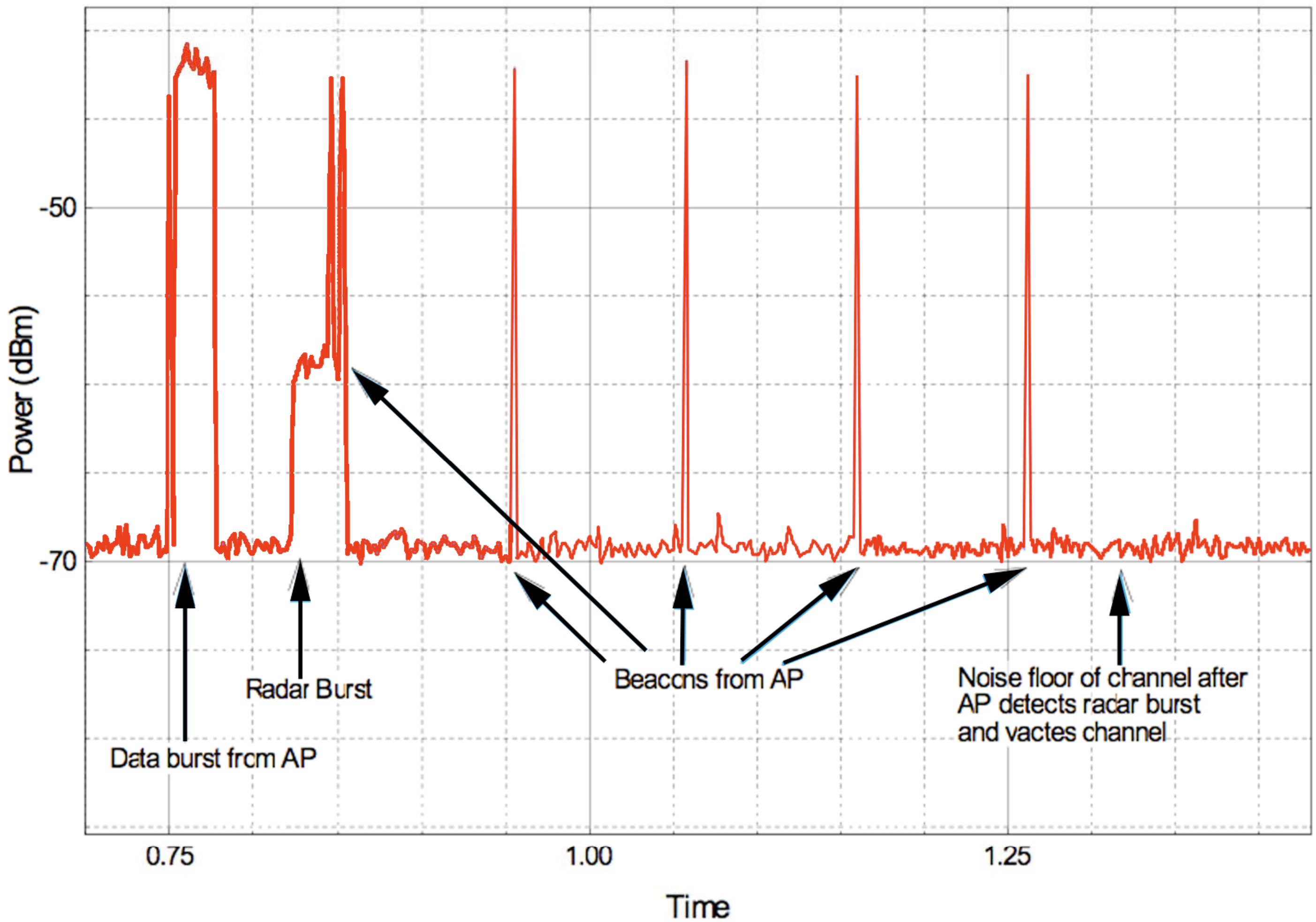
DFS History: Certification-Compliance Test System Transferred to FCC

- Certification hardware & software were transferred to FCC. Overall development effort required several engineer-years of effort; linear timeline was over a year.



- For in-service tests, MPEG file is streamed from one computer to another using a DFS access point (AP) and client to load the RF channel; APs have DFS functions built-in; clients do not.

DFS History:
Early NTIA-FCC-Army DFS Testing at the ITS Lab in Boulder



DFS History: Certification Testbed Development

- In 2005-06 bench tests with prototype DFS devices took place at ITS, followed by field tests at the McGregor Range, NM.

- *Thus testing began 9 years after the initial FCC NPRM for U-NII at 5 GHz, and 2 years after adoption of ITU-R Recommendation M.1652 which described DFS requirements.*

- The bench tests utilized a specially built laboratory radar transmitter that replicated radar waveforms defined in M.1652.

DFS History: Outcomes of Initial Testing

- Two rounds of testing completed:
  - Some difficulties with DFS detection of radar waveforms were encountered in the initial rounds of testing.
  - DFS device performance was better during a second round of testing
  - FCC and US Army participated in both rounds of testing
- Initial tests accomplished two goals:
  - Showed that DFS devices could actually detect radar waveforms as specified in M.1652.
  - Validated a test-and-measurement setup that could be used by the FCC and independent certification labs for actual certification of DFS devices.
- 2005-06: NTIA transferred DFS certification hardware design and associated custom-written software to the FCC's Columbia, MD laboratory for use in U-NII DFS-performance certification testing.

DFS History: Deployment Experience

- **July 2006:** DFS-capable U-NII devices available to consumers ≈ 3 years after WRC-03 and 10 years after initial FCC R&O.
  - A wide variety of DFS-capable 5 GHz U-NII devices were soon certified by FCC and independent labs, and marketed by several manufacturers.
  - NTIA later undertook random off-the-shelf spot-checks of commercially available products to verify their DFS performance.

- **2008:** NTIA and FCC found a certified product that was not detecting radar signals.
  - Post-certification changes to the device's firmware unintentionally disabled DFS.
  - Ongoing NTIA and FCC spot-checks have identified additional issues with certification identifications of some devices.

DFS Deployment Experience
(continued)

- **Early 2009:** FAA reported interference to 5 GHz microburst-warning weather radars — caused by DFS-capable 5 GHz U-NII transmitters.
  - Extensive NTIA, FAA and FCC studies, with help and cooperation of industry, identified some devices that passed DFS certification tests but do not adequately detect radar signals in the field.
  - Government and industry are working together to improve certification-testing parameters.
- Certification testing of new 5 GHz DFS-capable U-NII devices intended for outdoor use is suspended pending development of revised certification-testing parameters.

DFS Deployment Experience
(continued)

- **July 27, 2010:** FCC issues Memorandum, “Elimination of interference to Terminal Doppler Weather Radar (TDWR)” (Julius Knapp, OET and P. M. Ellison, Enforcement Div.) containing information about 5 GHz U-NII interference to TDWRs.
- The FCC Memo encourages wireless internet service providers (WISPs) to use WISPA on-line database developed by government and industry.
- Database (www.wispa.org) publicly lists all TDWR coordinates and frequencies.
  - WISPs are urged by FCC Memo to not operate closer than 30 MHz to TDWR frequencies if their transmitters are within 35 km of any TDWR.
  - Government may use WISPA database information to help locate interfering 5 GHz U-NIIs.

DFS History Summary: Challenges Met

- First technology for DFS successfully developed, now operational.
- 5 GHz spectrum now being shared with radars by many DFS-capable commercial U-NII products from many manufacturers.
- Close cooperation required between government & industry.
- Substantial effort required to determine interference protection criteria (IPCs) for incumbent service: radars.
- About 10 years from initial DFS concepts to marketed devices:
  - DFS protocols developed before any DFS-capable devices built;
  - Time to formulate DFS protocols as embodied in Recommendation M.1652;
  - Time to develop certification compliance-testing hardware and software;
  - Time to evaluate prototype DFS devices & provide feedback to industry.

Lessons for Development of Future Spectrum-Sharing Systems

- Timelines for converting spectrum-sharing concepts into marketed devices can be a decade — including time to:
  - Develop protection criteria for incumbents (in this case radars);
  - Develop engineering sharing models;
  - Develop sharing protocols and rules;
  - Develop compliance-certification hardware and software;
  - Perform initial test-and-evaluation of prototype devices.
- Government resources may be needed on an ongoing basis to perform spot-checks on marketed devices for compliance with spectrum-sharing rules in government spectrum bands.
- Attention must be devoted to ensuring field performance = performance during certification testing.

References

[1] FCC 96-193, ET Docket No. 96-102: Unlicensed NII/SUPERNet Operations in the 5 GHz Frequency Range.

[2] FCC 97-5, ET Docket no. 96-102: Unlicensed NII Devices in the 5 GHz Frequency Range.

[3] FCC 98-121, ET Docket no. 96-102: Unlicensed NII Devices in the 5 GHz Frequency Range. Copies of all FCC ET Docket documents are available at http://www.fcc.gov/oet/dockets/et96-102/.

[4] International Telecommunication Union Radio-Communication Sector (ITU-R), *Dynamic frequency selection (DFS) in wireless access systems including radio local area networks for the purpose of protecting the radiodetermination service in the 5 GHz band*, ITU-R Recommendation M.1652, June 2003.

[5] F. H. Sanders, R. Sole, B. Bedford, D. Franc and T. Pawlowitz, Effects of interference on radar receivers, NTIA Report TR-06-444, Sep. 2006. http://www.its.bldrdoc.gov/pub/ntia-rpt/06-444/