Introduction to AFC System Lab Testing

JOINT WEBINAR
WIRELESS INNOVATION FORUM AND WI-FI ALLIANCE

FEBRUARY 16, 2023

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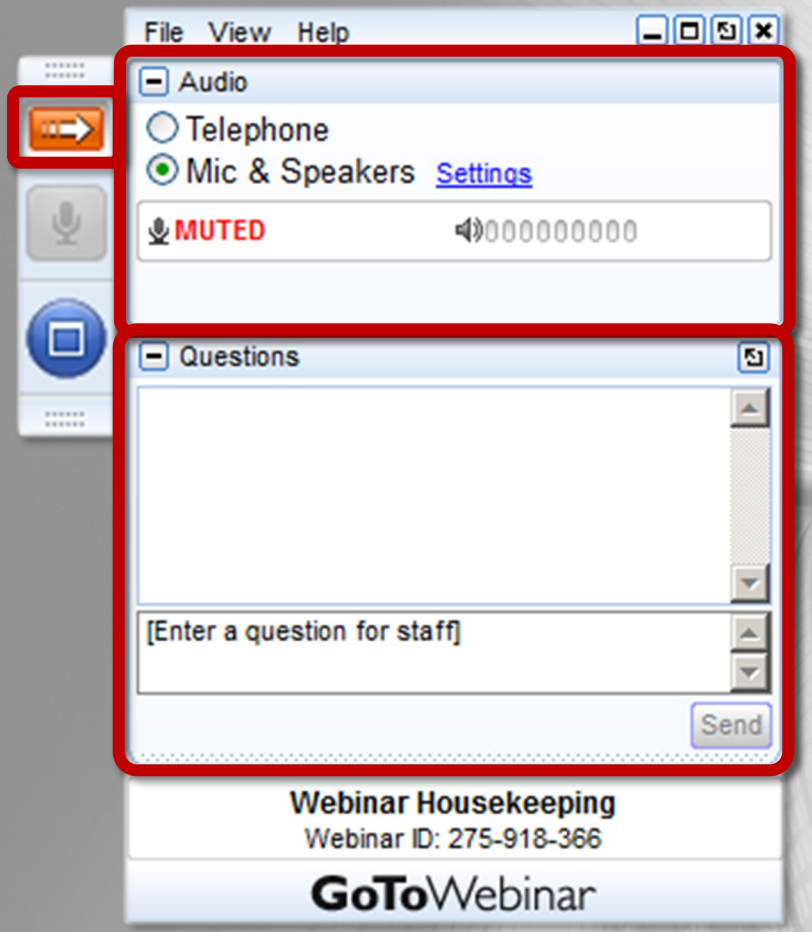
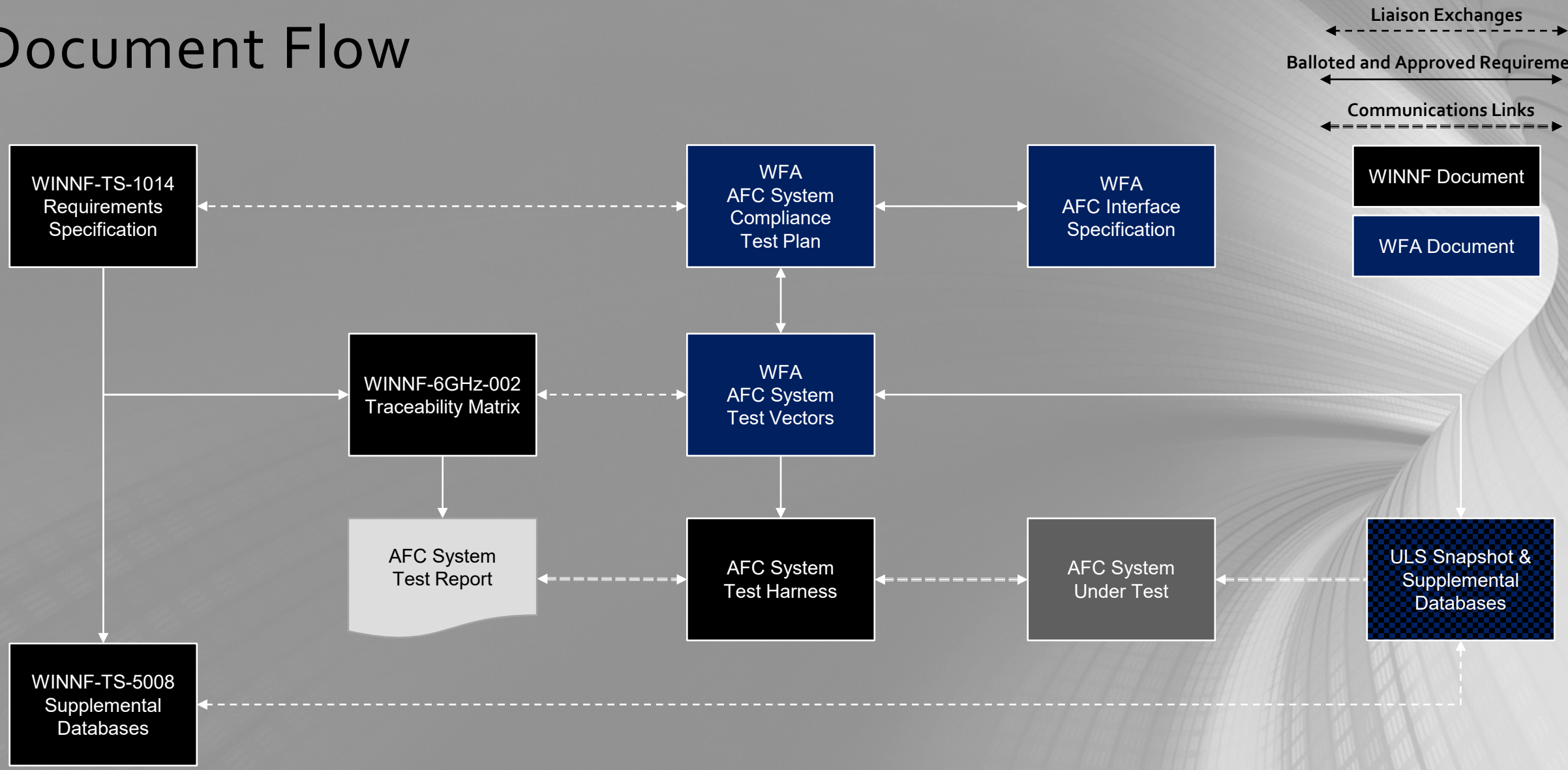


Opening Remarks

- Alex Roytblat
  - Vice President of Worldwide Regulatory Affairs, Wi-Fi Alliance

- Mark Gibson
  - Director of Business Development, Commscope
  - President and Chair, The Wireless Innovation Forum

Document Flow



Today's Speakers

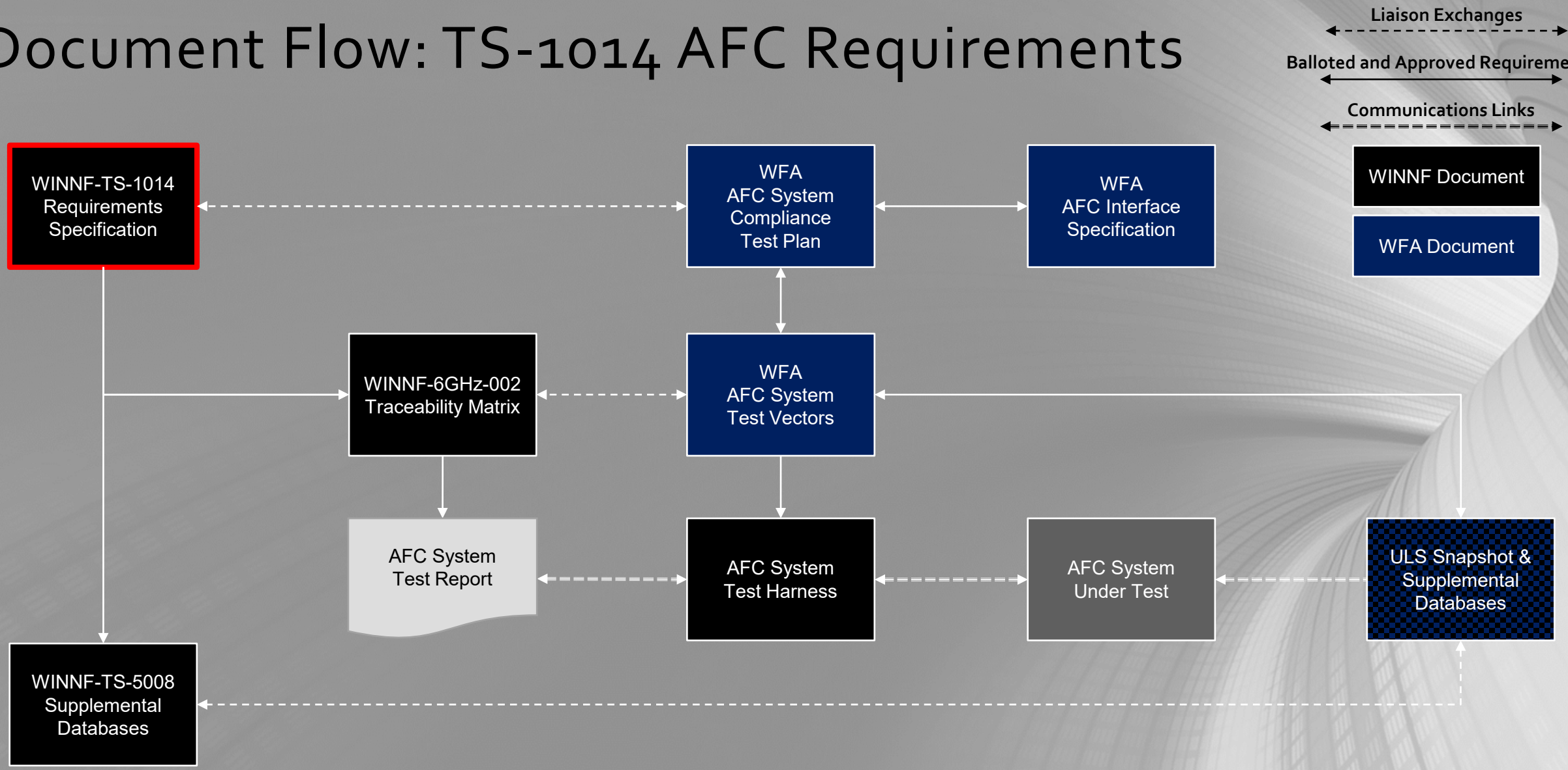
Intro to Requirements	Richard Bernhardt, WISPA
Overview of AFC Interface Specification	Thomas Derham, Broadcom
Overview of AFC System Under Test (SUT) Test Plan	Tevfik Yucek, Qualcomm
Overview of AFC System Under Test (SUT) Compliance Test Vectors and Responses	Stuart Strickland, Hewlett Packard Enterprise
Overview of the AFC System Requirements Traceability Matrix	Masoud Olfat, Federated Wireless
Introduction to the AFC System Test Harness	Andy Clegg, Google and Austin Egbert, Baylor University

Not Covered in this Webinar: Support for 5G NR-U and Other Air Interfaces

- WINNF-TS-4007-V1.0.0 WInnForum Extension to AFC System Under Test (SUT) Test Plan for the US 6 GHz Band
- WINNF-TS-3005-V1.1.1 Signaling Protocols and Procedures for 6 GHz Band; Extensions to AFC System - Standard Power Device Interface Technical Specification
- WINNF-TS-3007-V1.1.0 Signaling Protocols and Procedures for 6 GHz Band; AFC System - Standard Power Device Interface Technical Specification

- *Separate Training will be provided for these specifications at a later date*

Document Flow: TS-1014 AFC Requirements



Introduction to WInnForum TS-1014 AFC Functional Specifications

RICHARD BERNHARDT, SENIOR DIRECTOR, SPECTRUM AND INDUSTRY, WISPA & CHAIR, AFC FUNCTIONAL SPECIFICATIONS WORK GROUP WIRELESS INNOVATION FORUM

What the AFC System Functional Requirements Achieve

- Requirements for Registration of Standard Power Devices (SPDs) with AFC Systems.
- Requirements for Operation of AFC Systems in the 6 GHz Environment.
- Requirement for Protection of Incumbents from Harmful Interference.
- Requirements Needed for creation of Test and Certification Procedures for the Band Ecosystem.
- Create standards which comport to regulatory requirements provided by the FCC and the US Code of Federal Regulations.
- Create operating environment for industry and operators in the Band.

Participants: 196 individuals from 60 Organizations

- Members
  - Airspan
  - Amdocs
  - Aruba, an HPE Company
  - AT&T
  - Baylor University
  - C3Spectra
  - CableLabs
  - Cambium Networks
  - Charter Communications
  - Cisco Systems
  - Comcast
  - Commscope
  - Communications Research Centre Canada
  - CTIA
  - Ericsson
  - Fairspectrum
  - Federated Wireless
  - Google
  - Intel
  - NTIA/ITS
  - iPosi
  - L3Harris
  - Midco
  - MITRE Corp
  - Motorola Solutions
  - NCTA
  - NIST
  - Nokia
  - Optimum Semiconductor Technologies
  - Pathfinder Wireless
  - Qualcomm
  - RED Technologies
  - Redline Communications
  - Rohde & Schwarz
  - Samsung Networks
  - Sercomm
  - Shared Spectrum Company
  - Shure
  - SOLiD
  - Sony
  - Sporton International
  - T Mobile
  - Tarana Wirless
  - US Cellular
  - U of Colorado – Boulder
  - UWB Alliance
  - Verizon
  - WISPA
- Observers/Guests
  - APCO
  - Aviat
  - Broadcom
  - EPRI
  - Evergy
  - FWCC
  - Intel
  - ISED
  - National Grid
  - Southern Company
  - UTC
  - Vivint

AFC Systems – Functional Requirements – WInnForum Technical Specification-1014 with Appendices – An Introduction

- Requirements for AFC Systems as Mapped to 6 GHz Rules.
- **Scope of TS-1014**: The scope of this technical specification is to define the functional requirements for the AFC System, AFC System Operator, Standard Power Access Points, Fixed Client Devices and Proxies and to specify the necessary standards to enable test and certification procedures for a properly functioning environment in the 6 GHz band.
- The functional requirements specified in this specification are based on Federal Communications Commission (FCC) rules governing the use of 6 GHz band subject to the control of an AFC System, which are codified in Part 15 Subpart E of Title 47 the U.S. Code of Federal Regulations [n.1] adopted in the 2021.

Requirements Hierarchy

- R0-: Requirements directly from FCC rules
- R1-: Requirements derived from FCC rules or from the text of an applicable FCC order
- R2-: Requirements imposed by WInnForum to meet FCC rules
- R3-: Requirements imposed by WInnForum to meet industry needs.

- Only R0, R1, and R2 requirements addressed in this webinar

AFC System Requirements Anticipate:

- Standard Power Device (SPD) Registration Parameters
- SPD Geolocation Data
- Permissible Use of Domain Proxy (Network Device) as Intermediary for SPDs
- SPD Device Power and Emission Limitations
- SPD Security Requirements (as for the AFC System) – Assures Proper Use of FCC Approved AFC Systems
- SPD Interaction Requirements with AFC Systems

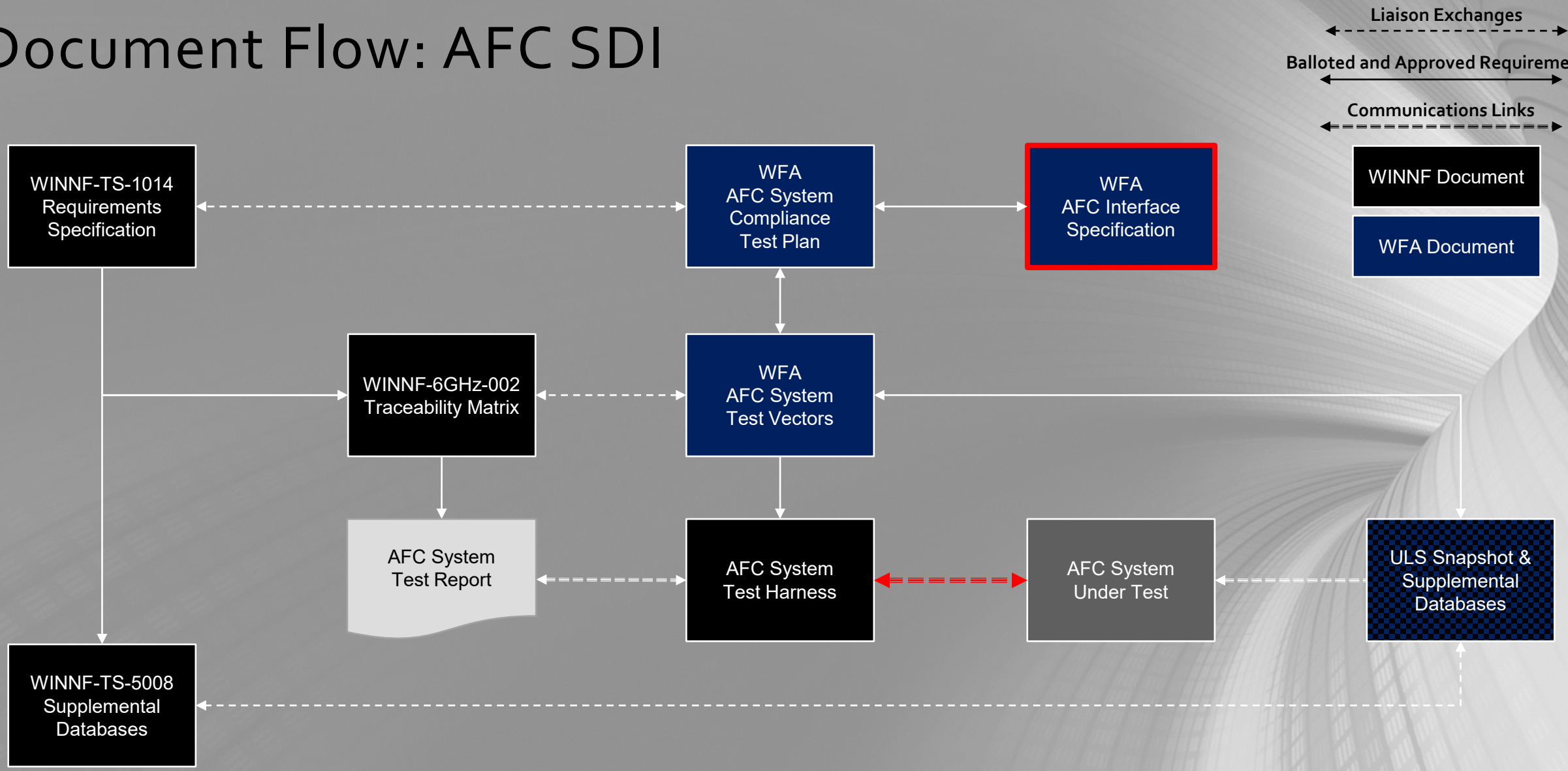
AFC System – Functional Requirements

- SPD Device Registration Information and Validation & AFC System Spectrum Inquiry
- AFC System Determination of Available Frequencies and Maximum Permissible Power as Communicated to the SPD Device Upon Registration and Request
- AFC System Storage of Information Requirements
- Enforcement of Instructions for Communications of the FCC
- Elements of AFC System Communications Security Requirements
- Role and Requirements of AFC Systems in Protecting FS Incumbents:
  - Interference Protection Criteria and Evaluation Points
  - Fixed Service (FS) Transceiver and Receiver Parameters (for Protection)
  - Propagation Models Requirements
  - Protection of Passive Sites
- Radio Astronomy Incumbent Protection Requirements
- International Border Protections

Annexes to TS-1014

- Annex A (Normative): 3GPP Specific Features (Optional)
- Annex B (Normative): IEEE 802.11ax Specific Features (Optional).
- Annex C (Normative): Reference Table for Fixed Service Receiver Parameters.
- Annex D (Informative): AFC System Operator Certification Procedure Information.
- Annex E (Informative): Data Interpolation Methods for Fixed Service Receiver Antenna and Passive Sites.
- Annex F (Informative): Revision History.

Document Flow: AFC SDI

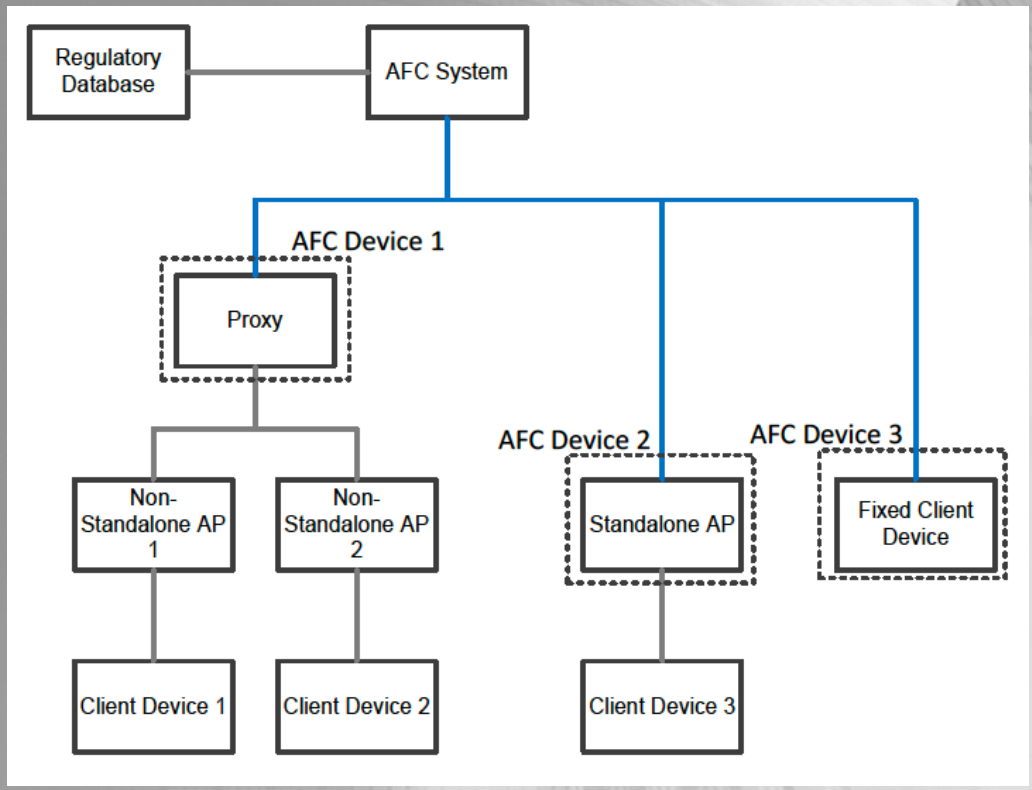


Overview of the AFC Interface Specification – Wi-Fi Alliance

THOMAS DERHAM, BROADCOM

Introduction

- AFC System to AFC Device Interface (SDI) specification
  - publicly available at https://www.wi-fi.org/file/afc-specification-and-test-plans
- Defines transport, signaling and behavioral requirements for the interface between an AFC System and AFC Devices
  - i.e. interfaces shown as blue lines in diagram
  - AFC Devices are:
    - Standalone APs
    - Proxy (representing Non-Standalone APs)
    - Fixed Client Devices



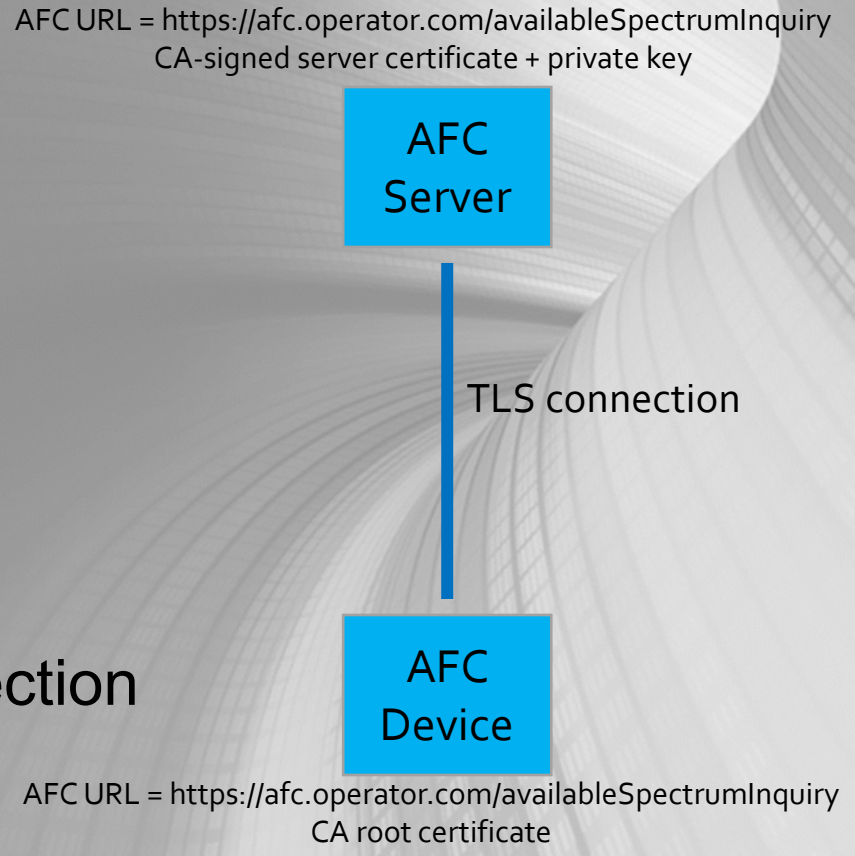
Transport

- HTTPS based API
  - AFC system (server) defined by a URL (e.g. https://afc.operator.com/availableSpectrumInquiry)
  - Request/response using HTTP POST
  - TLS (v1.2 or higher) security
- JSON message payloads
  - including fields that can be used for vendor extensions

Security

- TLS establishment includes Server Certificate Validation
  - Assumed AFC device is securely configured with trust basis
    - AFC server's URL
    - CA root certificate
  - The AFC Device validates the server certificate and does not connect if validation fails
    - strict match against hostname in AFC URL
    - validate certificate chain to configured CA root certificate
    - certificate revocation status (e.g. using OCSP stapling)
  - Protects against inadvertent connection to "rogue" AFC servers
- TLS ciphers ensure strong encryption and integrity protection

Example configuration



Request - overview

AvailableSpectrumInquiryRequest object

Fields	Presence	Descriptions
NAME: requestId DATA TYPE: string	R	Unique ID to identify an instance of an Available Spectrum Inquiry request. The value shall be unique within the request message. See example in Appendix A
NAME: deviceDescriptor DATA TYPE: object: DeviceDescriptor	R	This field contains the information of an AP or Fixed Client Device. (4.2.1.2)
NAME: location DATA TYPE: object: Location	R	This field describes the geographic area within which the AP or Fixed Client Device is located, including location uncertainty. (4.2.1.3)
NAME: inquiredFrequencyRange DATA TYPE: array of object: FrequencyRange	CR	This field contains one or more frequency ranges for which the AP or Fixed Client Device is requesting spectrum availability. One or both of inquiredFrequencyRange and inquiredChannels shall be present. If inquiredFrequencyRange is present, it indicates that the AFC System is to provide Available Spectrum information on the basis of frequency. (4.2.1.11)
NAME: inquiredChannels DATA TYPE: array of object: Channels	CR	This field contains one or more lists of channels for which the AP or Fixed Client Device is requesting spectrum availability. One or both of inquiredFrequencyRange and inquiredChannels shall be present. If inquiredChannels is present, it indicates that the AFC System is to provide Available Spectrum information on the basis of channels. (4.2.1.12)
NAME: minDesiredPower DATA TYPE: number	O	This field contains the minimum desired EIRP in units of dBm. This field is optionally present in a query by inquiredChannels; otherwise, it is absent. If a query by inquiredChannels is performed and this field is absent, the AFC System shall provide a response for all inquiredChannels which are available for use at any power. Otherwise, if the minDesiredPower is present, the AFC System shall provide all the inquired channels available for use at or above the defined minDesiredPower.
NAME: vendorExtensions DATA TYPE: array of object: VendorExtension	O	This field contains optional vendor extensions. (4.2.2.5)

DeviceDescriptor object

Fields	Presence	Descriptions
NAME: serialNumber DATA TYPE: string	R	This field contains the device serial number of an AP or Fixed Client Device. See example in Appendix A
NAME: certificationId DATA TYPE: array of object: CertificationId	R	This field represents the certification IDs of an AP or Fixed Client Device.
NAME: rulesetIds DATA TYPE: array of string	R	This field contains the identifiers of the regulatory rules supported by an AP or Fixed Client Device. Acceptable values are: • US_47_CFR_PART_15_SUBPART_E Allowed field values depend on the rules of each National Regulatory Authority.

- "Registration" parameters embedded within every request
- AP's (or Fixed Client's) geolocation and uncertainty
- Request for availability based on:
  - channels (list of OpClasses + Channel Numbers) and/or
  - frequency (frequency ranges)

Request – geolocation

Location object

Fields
NAME: ellipse DATA TYPE: object: Ellipse
NAME: linearPolygon DATA TYPE: object: LinearPolygon
NAME: radialPolygon DATA TYPE: object: RadialPolygon
NAME: elevation DATA TYPE: object: Elevation
NAME: indoorDeployment DATA TYPE: number

- 3 geometric alternatives to describe horizontal geolocation and uncertainty:
  - ellipse
  - linearPolygon
  - radialPolygon

Fields	Presence	Descriptions
NAME: center DATA TYPE: object: Point	R	This field represents the geographic coordinates of the center point of an ellipse within which the AP or Fixed Client Device is located.
NAME: majorAxis DATA TYPE: number	R	This field represents the length of the major semi axis of an ellipse within which the AP or Fixed Client Device is located. The value is a positive integer in meters.
NAME: minorAxis DATA TYPE: number	R	This field represents the length of the minor semi axis of an ellipse within which the AP or Fixed Client Device is located. The value is a positive integer in meters.
NAME: orientation DATA TYPE: number	R	This field represents the orientation of the majorAxis field in decimal degrees, measured clockwise from True North. The allowed range is from 0 to 180.

Ellipse object

lat / lon

uncertainty radius

- vertical geolocation (AGL or AMSL elevation) and uncertainty
- “indoor” flag (e.g. if AP is also LPI certified)

Response - overview

AvailableSpectrumInquiryResponse object

Fields
NAME: requestId DATA TYPE: string
NAME: rulesetId DATA TYPE: string
NAME: availableFrequencyInfo DATA TYPE: array of object: AvailableFrequencyInfo
NAME: availableChannelInfo DATA TYPE: array of object: AvailableChannelInfo
NAME: availabilityExpireTime DATA TYPE: string
NAME: response DATA TYPE: object: Response
NAME: vendorExtensions DATA TYPE: array of object: VendorExtension

AvailableFrequencyInfo object

Fields	Presence	Descriptions
NAME: frequencyRange DATA TYPE: object: FrequencyRange	R	This field contains a frequency range of the Available Spectrum information. (4.2.1.11)
NAME: maxPsd DATA TYPE: number	R	This field contains the maximum permissible EIRP available in any one MHz bin within the frequency range specified by the frequencyRange object. The limit is expressed as a power spectral density with units of dBm per MHz. See example in Appendix A

- PSD limits for each frequency (per-MHz)

AvailableChannelInfo object

Fields	Presence	Descriptions
NAME: globalOperatingClass DATA TYPE: number	R	This field is the global operating class used to define the channel center frequency indices and operating bandwidth. It may refer to the global operating class indices defined in Annex E of [5] or to another unique reference defined by the vendor.
NAME: channelCfi DATA TYPE: array of number	R	This field is the list of channel center frequency indices which are available for use.
NAME: maxEirp DATA TYPE: array of number	R	This field is the maximum permissible EIRP in units of dBm available for each of the channels specified in the channelCfi list, in the same order. In addition, in any portion of the channel, the conducted PSD plus the maximum antenna gain cannot exceed the maxEirp divided by the channel width defined by the globalOperatingClass.

- EIRP limits for each (bandwidth-specific) channel

- response code (success, error codes, ...)

Response – AP's channel/power selection

- A Standard Power AP or Fixed Client's channel and power selection algorithms must act in a manner that is compliant with its corresponding AFC response, i.e.
  - for channel-based response, use EIRP that does not exceed the specified EIRP limit for the corresponding bandwidth-dependent channel
  - for frequency-based response, transmit spectrum (including adjacent channels) does not exceed the specified PSD mask on any frequency
- Notes
  - If a channel/frequency is missing from the response, no power grant is provided for that channel/frequency
  - An AP or Fixed Client device might also be certified to operate under other modes (e.g. LPI) and so might use power limits in compliance with those other modes, instead of the AFC limits
  - An (IEEE 802.11) AP will also advertise the corresponding client power limits to STAs (TPE element)
  - More details in later segments...

Support for proxies

- Request/Response message structure supports multiple requests/responses
  - designed for a proxy that handles requests on behalf of multiple non-standalone APs
  - AFC system processes the requests as a batch, and provides a response for each request
- Each request corresponds to a different AFC device
  - with its own DeviceDescriptor (NRA, serial), its own geolocation, etc

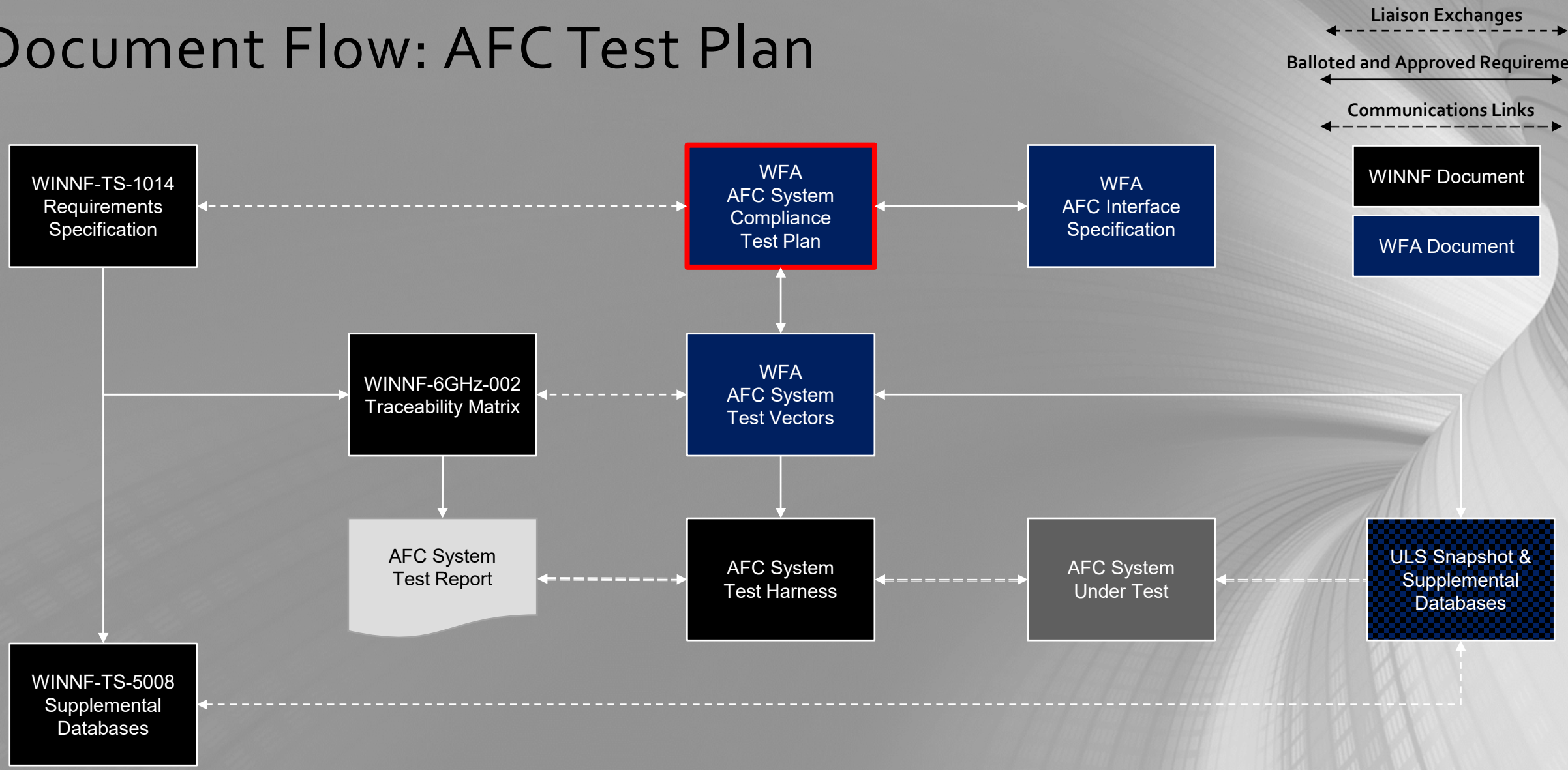
request message

Fields	Presence	Descriptions
NAME: version DATA TYPE: string	R	This field represents the Protocol Version, as defined in Section 4.1
NAME: availableSpectrumInquiryRequests DATA TYPE: array of object: AvailableSpectrumInquiryRequest	R	This field represents Available Spectrum Inquiry Request for one or more APs or Fixed Client Devices. (4.2.1.1)
NAME: vendorExtensions DATA TYPE: array of object: VendorExtension	O	This field contains optional vendor extensions. (4.2.2.5)

- array of one or more requests

- Security (TLS)
  - i.e. proxy performs server certificate validation
  - interfaces between proxy and non-standalone APs are not defined and assumed to be secure
    - AFC device “entity” consists of the proxy plus non-standalone AP(s)

Document Flow: AFC Test Plan

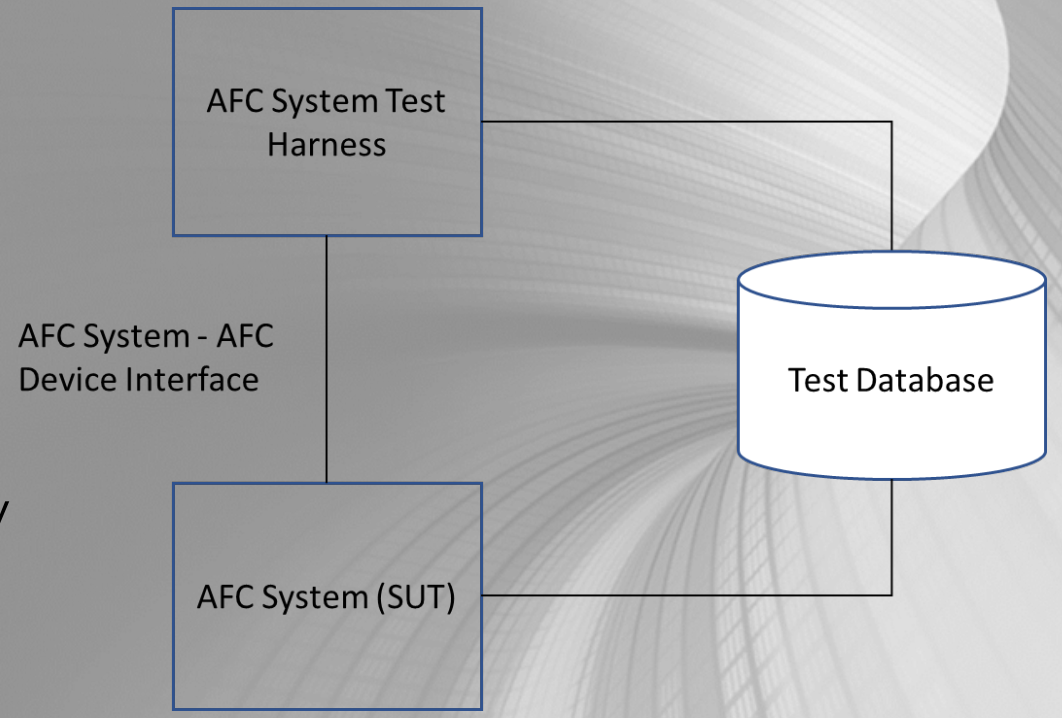


Overview of SUT Compliance Test Plan – Wi-Fi Alliance

TEVFIK YUCEK, QUALCOMM

Overview of Test Plan

- SUT Test Plan describes the test methodology and procedures used to test AFC system & provides test cases.
- For each test, steps to run the test and expected results are provided as well as purpose of the test.
- There are 5 Categories of tests:
  - AFCS.SRS: Successful Registration and Spectrum Availability
  - AFCS.URS: Unsuccessful Registration and Spectrum Availability
  - AFCS.FSP: Fixed Services Protection
  - AFCS.IBP: International Border Protection
  - AFCS.SIP: Special Incumbent Protection



Example Test: Radio Astronomy Protection

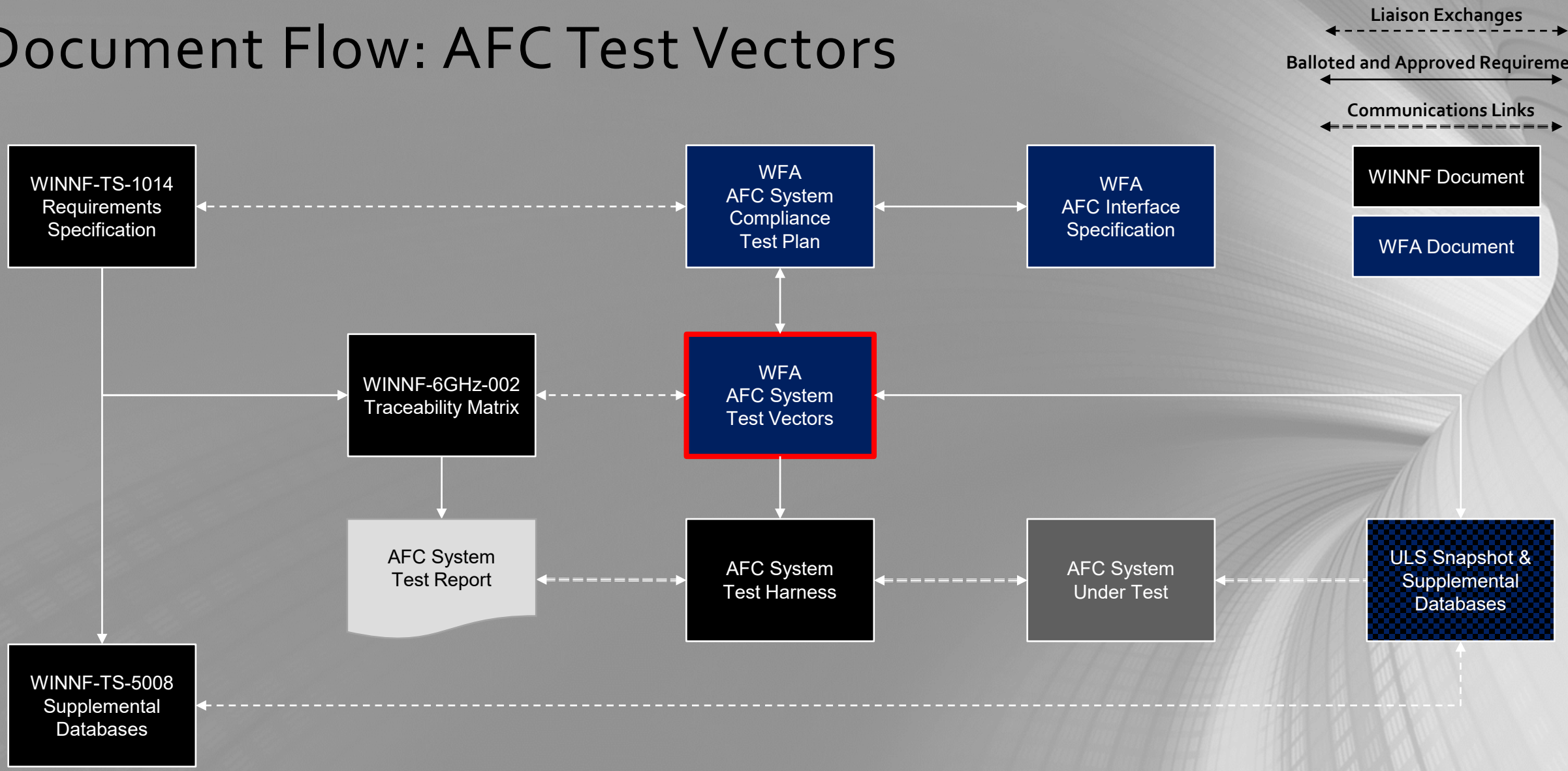
- Steps to execute the test and expected results for each test are provided:

Step	Description	Results	
1	The AFC System (SUT) is set to an initial pre-test state with a connection to AFC System Test Harness and Test Database	-	-
2	The AFC System Test Harness sends one or more Available Spectrum Inquiry Request (s) to the AFC System (SUT) that includes (1) an inquiredChannels list that include one or more channels that overlap the 6650-6675.2 MHz range; and/or (2) an inquiredFrequencyRange list that includes one or more frequencies in the range 6650-6675.2 MHz. The AFC Device is located within the specified distance d (km) of a radio observatory.	-	-
3	The AFC System (SUT) returns an Available Spectrum Inquiry Response including a response code value of 0 (SUCCESS)	Expected	Unexpected
4	The AFC System Test Harness compares the AvailableFrequencyInfo received from the AFC System (SUT) to the independently calculated AvailableFrequencyInfo value. The AFC System (SUT) Available Spectrum Inquiry Response shall not include channels or frequencies that overlap the 6650-6675 MHz range.	Expected	Unexpected

Data Sources and Parameters

- SUT Test plan includes specific data sources and parameter used to generate specific results.
- Some of these parameters not specified in the regulation and might vary from AFC system to AFC system. Specifying these values in the SUT test plan enables uniform results for testing purposes.
- Examples:
  - Location specific datasets, e.g., use of USGS Digital Elevation Models (DEMs)
  - Snapshot of incumbent dataset, e.g., a snapshot of ULS at a known date
  - Confidence levels for propagation models, e.g., confidence for ITM, antenna modeling

Document Flow: AFC Test Vectors



Overview of AFC System Test Vectors – Wi-Fi Alliance

STUART STRICKLAND, HEWLETT PACKARD ENTERPRISE

Overview of AFC System Test Vectors

- Structure and Coverage
- Inventory of Test Vector Requests
- Assumptions and Data Sources
- Methodology for Determining Expected Responses

Test Vector Structure and Coverage

- Each test vector is comprised of a pair of Available Spectrum Inquiry Requests and Responses based on the protocol defined in the AFC Interface Specification
- Test vectors have been defined for each of the test case specified in the AFC System Test Plan
- The AFC Interface Specification, AFC System Test Plan, and AFC System Test Vectors are publicly available here: https://www.wi-fi.org/file/afc-specification-and-test-plans
- In each case, parameters have been selected to ensure complete coverage across permutations of terrain morphologies, propagation models, incumbent antenna types and other characteristics relevant to assessing potential interference

Inventory of Test Vector Requests

Test Category	Test Vectors
Successful Registration	AFC.SRS.1 Successful registration and spectrum availability
Unsuccessful Registration	AFC.URS.1 – 7 test for AFC handling of requests with invalid FCC identifier, missing manufacturer's serial number, missing location, missing location uncertainty, missing elevation, missing vertical uncertainty, and requests from locations outside the United States
Fixed Services Protection	AFC.FSP.1 – 100 test for incumbent protection across permutations of: • Urban, suburban, and rural terrain morphologies • Indoor and outdoor RLAN deployments at high and low elevations • RLAN-to-FS distances requiring the use of free-space (< 30m), Irregular Terrain Model (ITM) (> 30m & < 1km), and WINNER II propagation models (> 1km) • Various NLCD land cover types • Single and double passive reflector and back-to-back antennas • Individual and aggregated requests
International Border Protection	AFC.IBP.1 – 4 test for protection of incumbents across the international border with Canada AFC.IBP.5 – 8 are planned to test for protection of incumbents across the international border with Mexico
Special Incumbent Protection	AFC.SIP.1 – 15 test for protection of identified radio astronomy observatories using prescribed algorithms AFC.SIP.16 tests for protection of a single radio astronomy observatory in Canada

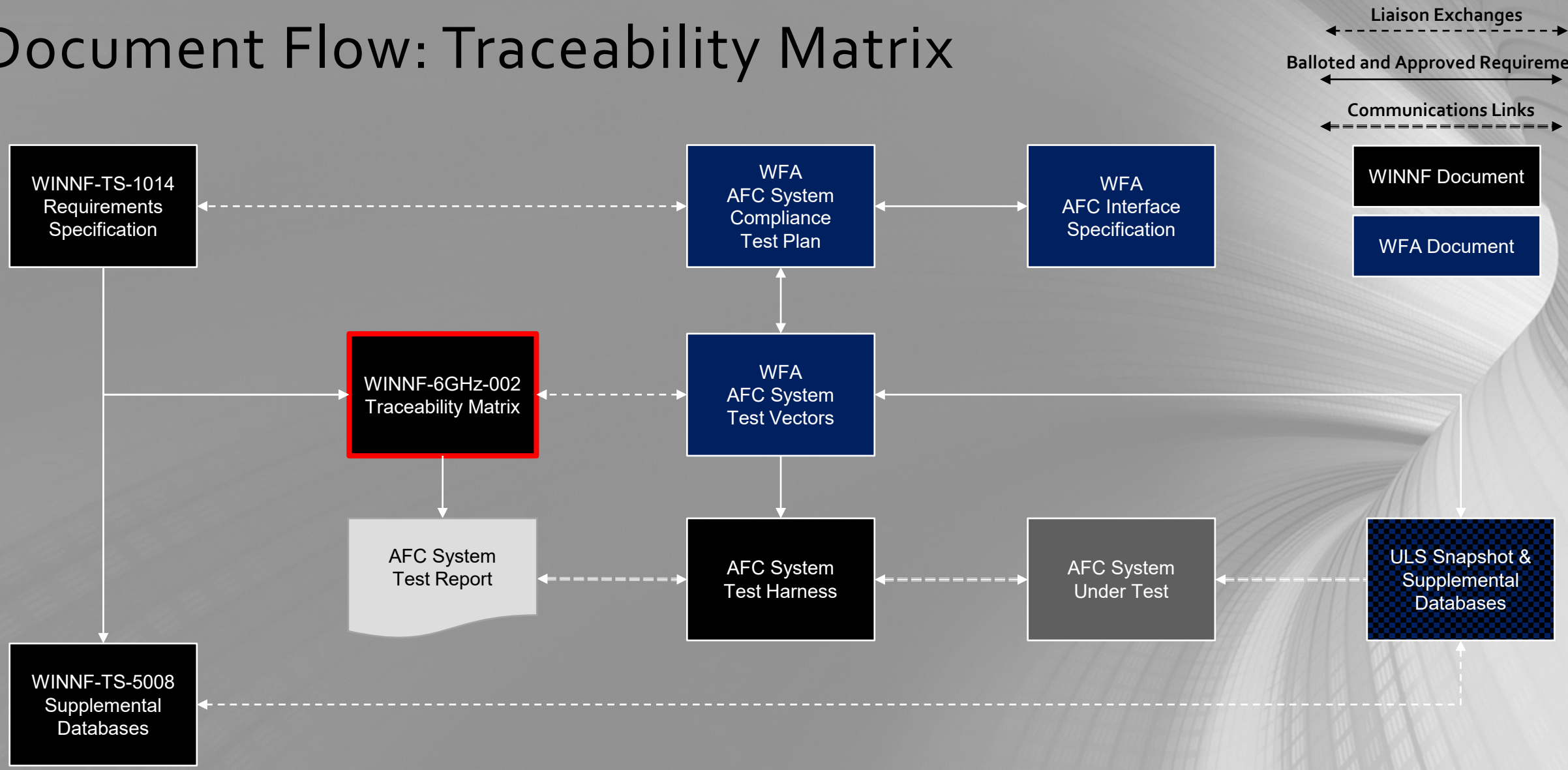
Test Vector Assumptions and Data Sources

- To ensure consistent assessment, expected responses have been generated based on clearly articulated assumptions and WFA-maintained snapshots and publicly available data sets
- Assumptions and essential parameters have been aligned between Wi-Fi Alliance and WInnForum and can be found in the WFA AFC System (SUT) Test Plan and WINNF TS-1014, respectively
- Static snapshots of essential data sets are available publicly at https://github.com/Wi-FiTestSuite/6GHz-AFC and include:
  - USGC 1 Arc-second Digital Elevation Models (2017)
  - Snapshot of National Land Cover Database 2019 (NLCD2019)
  - Snapshot of FCC Universal Licensing System (ULS) database of incumbents in the US
  - Snapshot of ISED database of incumbents in Canada

Methodology for Determining Expected Responses

- For each Spectrum Availability Request, the AFC System Test Vectors define a corresponding expected Spectrum Availability Response
- The expected responses contain the maximum transmit power, indexed by frequency and channel, consistent with regulatory requirements and the specified assumptions and data sets
- To determine values appropriate for each response, the WFA solicited input from prospective AFC System Operators
  - Contributors provided responses corresponding to each request and were asked to identify any departures in their calculations from the published assumptions and data sets
  - Where differences were observed, contributors worked offline to determine the sources of these differences and revise their contributions
  - Once all contributions converged to within a range of 2 dB, the contributors' results were averaged to arrive at a value for the expected responses
  - WFA recommends that results <= these values + 2 dB be considered expected

Document Flow: Traceability Matrix



AFC Traceability Matrix and SUT Testing Framework – WInnForum

MASOUD OLFAT, FEDERATED WIRELESS

Background

- According to FCC 6GHz R&O, prospective AFC Applicants have submitted their proposals describing how their systems would comply with all Commission AFC rules to OET
  - FCC subsequently received the public comments on these AFC system proposals.
  - AFC applicants are awaiting the conditional approval demonstrating their compliance with AFC requirements.
- Beyond conditional approval, the AFC systems will undergo a testing phase in a controlled environment (lab) followed by some type of demonstration projects (e.g., field testing), to be determined in future phases.
- WinnForum Test and Certification WG is tasked to collaborate with other SDO (e.g. WiFi Alliance) to develop an AFC certification framework to demonstrate that AFC Systems (SUT) can manage devices without causing harmful interference to fixed wireless services.
  - Develop the test and certification program
  - Develop the test software (Test Harness)
  - Define and propose procedures for lab selection
  - Develop proposals for demonstration project phase

AFC Traceability Matrix

- WinnF Traceability Matrix is composed of all Part 15 and TS-1014 requirements
- Every row contains one of the following requirements
  - Part 15 requirements not captured in TS-1014
  - R0 Requirement (Part 15 requirements directly from FCC rules captured in TS-1014)
  - R1 Requirement (Requirements derived from FCC rules or from the text of an applicable FCC order)
  - R2 Requirement (Requirements imposed by WInnForum to meet FCC rules)
- R3 Requirements (Requirements imposed by WInnForum to meet industry needs) not captured in the Traceability Matrix
- For each row Includes
  - The requirement, requirement ID, and related Part 15 rule
  - Tested Entity
  - Testing Method
  - Test Specification
  - Required Test vectors

AFC Traceability Matrix

FCC Part 15 Subpart E		Technical Specifications: WINNF-TS-1014-V1.2.0						TCWG Comment
Section	Rule	Requirement ID	Requirements	Tested Entity	Testing Method	Test Specification	Test Vectors	
§ 15.407(k)(5)	a standard power access point or fixed client device ceases operation at a location. For the purpose of this paragraph, a standard power access point or fixed client device is considered to have ceased operation when that device has not contacted the AFC system for more than three months to verify frequency availability information.	R1-AGR-04-b	The stored registration information shall be available for more than three months after the Standard Power Access Point or Fixed Client Devices last contacted with the AFC System.	AFC System	n/a	n/a	Attestation	Procedure
§ 15.407(k)(7)(ii)	The general purposes of AFC system include: Registering, authenticating, and authorizing standard power access point and fixed client device operations, individually or through a network element device representing multiple standard power access points from the same operating network.	R1-AGR-05	AFC Systems shall have the capability to deny spectrum access to a particular Standard Power Device upon requests by the Commission, in the event of harmful interference caused by a particular device or type of device. (R&O, Paragraph 83)	AFC System	Functional Test	WFA AFC SUT	AFCS.SRS.1, AFCS.URS.1,	Same treatement as Per R1-AGR-01 treatment
§ 15.407(k)(15)(vi)	Each AFC system operator designated by the Commission must: Establish and follow protocols to comply with enforcement instructions from the Commission, including discontinuance of standard power access point operations in designated geographic areas.	R1-AGR-06	Each AFC System Operator designated by the Commission must [shall] comply with enforcement instructions from the Commission, including discontinuance of Standard Power Access Point and Fixed Client Device operations in designated geographic areas. (15.407(k)(15)(vi))	AFC System	AFC System Operator Proposal & Functional Test		Attestation	Receiving FCC enforcement commands is considered as Attestation Similar to CBRS, we might need to define a procedure for FCC EB to communicate with AFC, including the format and content of this communication
§ 15.407(k)(4)	An AFC system must use the information supplied by standard power access points and fixed client devices during registration, as set forth in this section, to determine available frequencies and the maximum permissible power in each frequency range for a standard power access point at any given location. All such determinations and assignments must be made in a non-discriminatory manner, consistent with this part.	R2-AGR-03-b	Available Frequencies and the Maximum Permissible Power: b. The AFC System responding to the Standard Power Device using the method b in R2-DGR-02 shall identify the maximum allowed e.i.r.p for each specified Channel bandwidth.	AFC System	Functional Test	WFA AFC SUT	All the following Test Vectors AFCS.SRS AFCS.FSP AFCS.IBP AFCS.SIP	The result of this test (s) depends on whether AFC System may decides to support this mode of inquiries or not
§ 15.407(k)(4)	An AFC system must use the information supplied by standard power access points and fixed client devices during registration, as set forth in this section, to determine available frequencies and the maximum permissible power in each frequency range for a standard power access point at any given location. All such determinations and assignments must be made in a non-discriminatory manner, consistent with this part.	R2-AGR-04-a	Limits of Maximum Permissible Power determined by the AFC System a. Maximum PSD returned by the AFC System as per R2-AGR-03.a shall not exceed the maximum PSD limit specified in R0-DGR-07.a.	AFC System	Functional Test	WFA AFC SUT	All the following Test Vectors AFCS.SRS AFCS.FSP AFCS.IBP AFCS.SIP	For AFC SUTs supporting R2-AGR-03-a
§ 15.407(k)(4)	An AFC system must use the information supplied by standard power access points and fixed client devices during registration, as set forth in this section, to determine available frequencies and the maximum permissible power in each frequency range for a standard power access point at any given location. All such determinations and assignments must be made in a non-discriminatory manner, consistent with this part.	R2-AGR-04-b	Limits of Maximum Permissible Power determined by the AFC System: b. When calculating the maximum e.i.r.p of a queried Channel, the AFC System shall assume the Standard Power Device will operate on only the queried Channel over the frequency band of operation.	AFC System	Functional Test	WFA AFC SUT	All the following Test Vectors AFCS.SRS AFCS.FSP AFCS.IBP AFCS.SIP	For AFC SUTs supporting R2-AGR-03-b

Test Association to Requirements

- Testing not applicable (e.g., definitions, or Device Requirements, etc.)
- AFC Attestation (e.g., data retainment)
- Tested during Field Test
- Identify test vector (s) to determine the conformance

FCC Part 15 Subpart E		Technical Specifications: WINNF-TS-1014-V1.2.0						TCWG Comment
Section	Rule	Requirement ID	Requirements	Tested Entity	Testing Method	Test Specification	Test Vectors	
§ 15.407(k)(5)	a standard power access point or fixed client device ceases operation at a location. For the purpose of this paragraph, a standard power access point or fixed client device is considered to have ceased operation when that device has not contacted the AFC system for more than three months to verify frequency availability information.	R1-AGR-04-b	The stored registration information shall be available for more than three months after the Standard Power Access Point or Fixed Client Devices last contacted with the AFC System.	AFC System	n/a	n/a	Attestation	Procedure
§ 15.407(k)(7)(ii)	The general purposes of AFC system include: Registering, authenticating, and authorizing standard power access point and fixed client device operations, individually or through a network element device representing multiple standard power access points from the same operating network.	R1-AGR-05	AFC Systems shall have the capability to deny spectrum access to a particular Standard Power Device upon requests by the Commission, in the event of harmful interference caused by a particular device or type of device. (R&O, Paragraph 83)	AFC System	Functional Test	WFA AFC SUT	AFCS.SRS.1, AFCS.URS.1,	Same treatement as Per R1-AGR-01 treatment
§ 15.407(k)(15)(vi)	Each AFC system operator designated by the Commission must: Establish and follow protocols to comply with enforcement instructions from the Commission, including discontinuance of standard power access point operations in designated geographic areas.	R1-AGR-06	Each AFC System Operator designated by the Commission must [shall] comply with enforcement instructions from the Commission, including discontinuance of Standard Power Access Point and Fixed Client Device operations in designated geographic areas. (15.407(k)(15)(vi))	AFC System	AFC System Operator Proposal & Functional Test		Attestation	Receiving FCC enforcement commands is considered as Attestation Similar to CBRS, we might need to define a procedure for FCC EB to communicate with AFC, including the format and content of this communication

Security Testing for AFC SUT

- AFC SUT Security Aspects Tested in the Lab
  - SPD authentication by AFC SUT (Tested in the lab)
  - The use of Server Certificates by AFC SUT to allow SPDs authenticate AFC (Tested in the lab)
- AFC Security Aspects Not Tested but Included in the Lab Report (Attestation)
  - Server Certificate Authorities
    - Note: WInnForum compliance requires a "Trusted" Certificate Authority
  - Cipher suites used by AFC SUT
- SPD authentication by the AFC SUT as claimed by the AFC SUT
  - Using Client Certificates
  - Using Bearer Tokens
  - Using No SPD Authentication
    - If no SPD Authentication is used, this section of the test report will be left blank or otherwise treated

Security Testing for AFC SUT

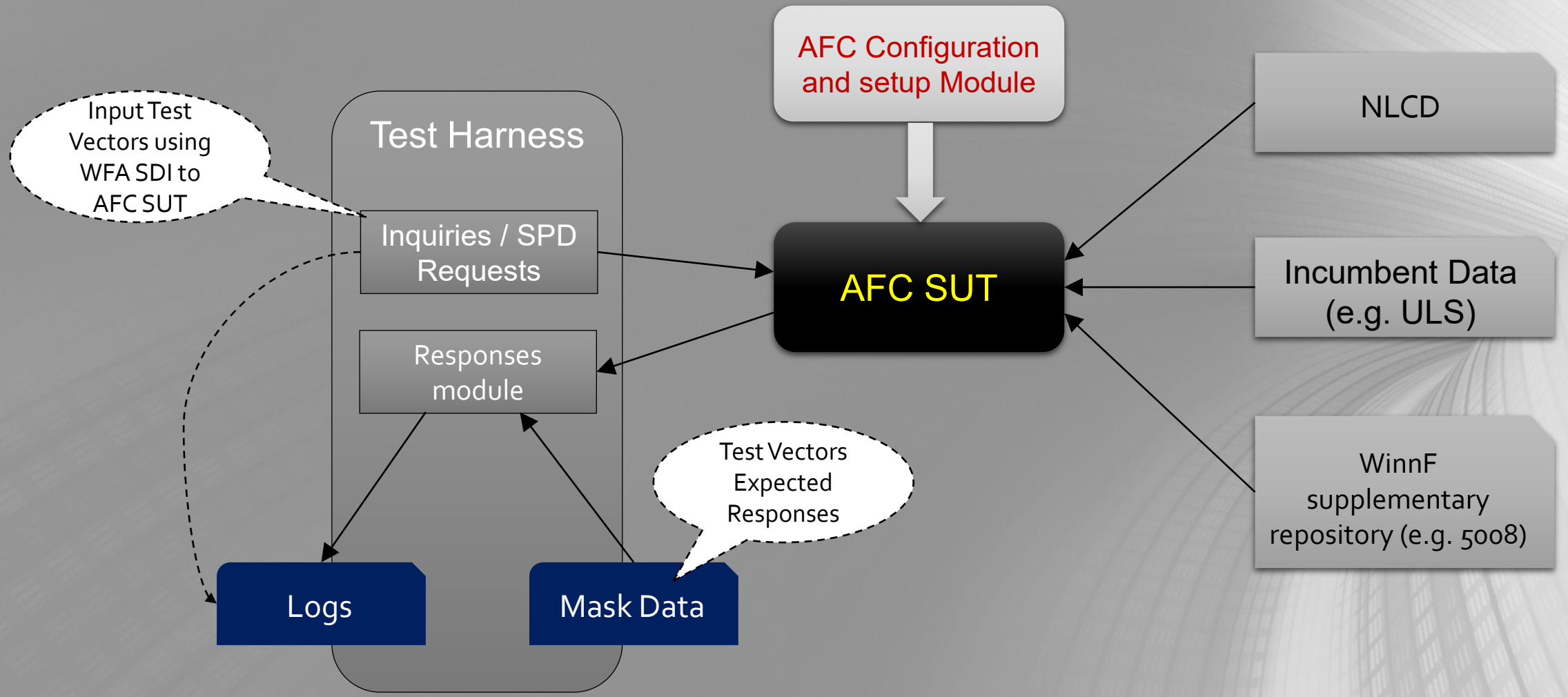
- SPD authentication by the AFC SUT
  - Test Harness uses two sets of test using any existing Test Vector
    - Positive Tests using valid credentials (Certificates or Tokens)
    - Negative Testing using invalid credentials (Certificates or Tokens)
  - Two modes of testing
    - Using two pre-determined configuration files containing valid and invalid credentials provided
    - Using a module to create online credentials

- Use of Server Certificates by AFC SUT to allow SPDs authenticate AFC (Tested in the lab)
  - The use of Server certificates are tested by Test Harness

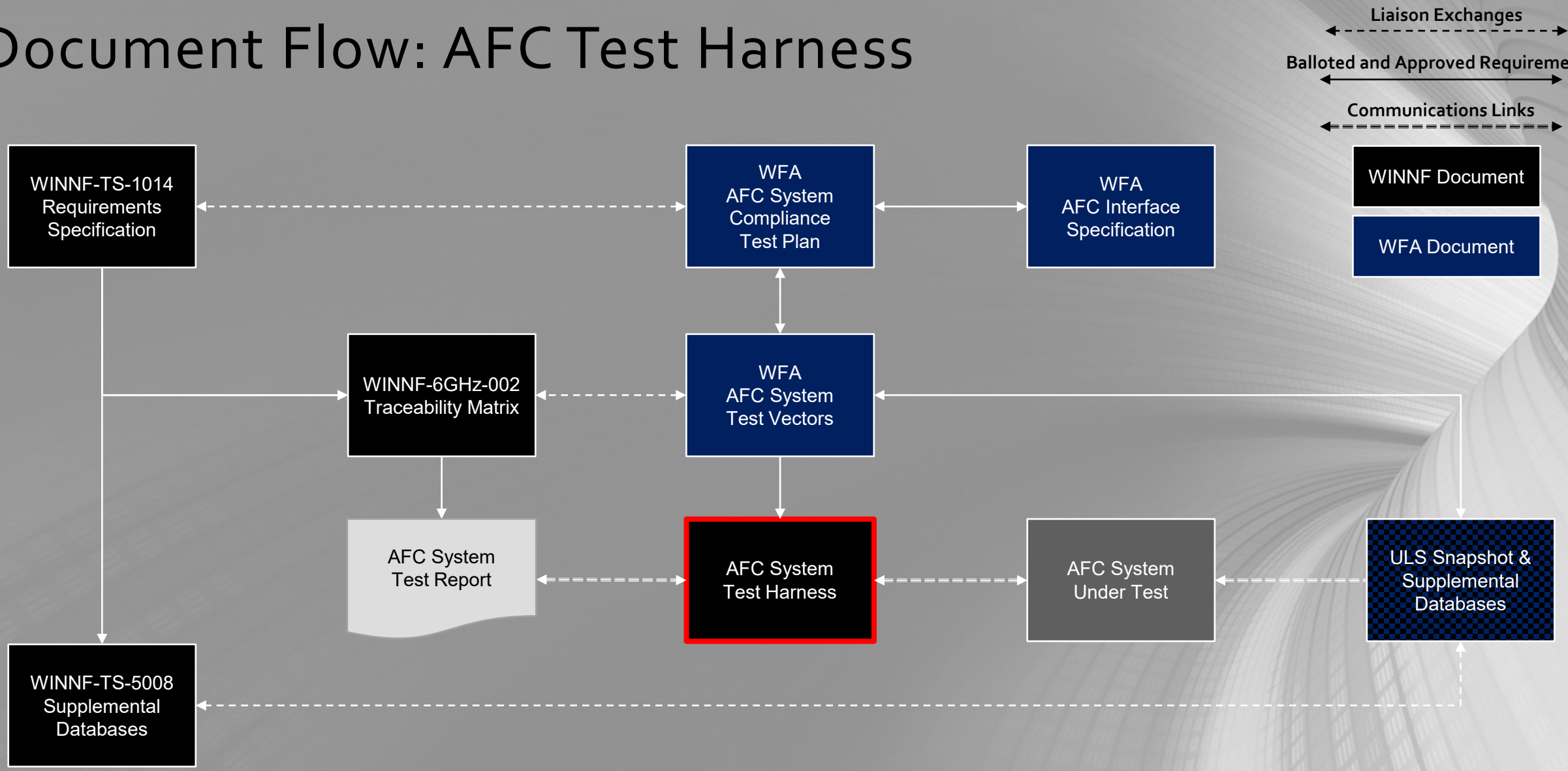
Security Testing for AFC SUT

FCC Part 15 Subpart E		Technical Specifications: WINNF-TS-1014-V1.2.0						TCWG Comment
Section	Rule	Requirement ID	Requirements	Tested Entity	Testing Method	Test Specification	Test Vectors	
§ 15.407(k)(13)	The AFC system must ensure that all communications and interactions between the AFC system and standard power access points and fixed client devices are accurate and secure and that unauthorized parties cannot access or alter the database, or the list of available frequencies and associated powers sent to a standard power access point.	R0-ASQ-01-a	The AFC System must [shall] ensure that all communications and interactions between the AFC System and Standard Power Devices are accurate and secure.	AFC System			Any Test Vector using valid and inlavild credentials by TH	AFC SUT Test harness uses the SPD authentication mechanism claimed by the AFC SUT in each TV (e.g. certificate, or token bearers) Use positive Security Testing with AFC SUT Test Harness using valid credentials (tokens or certificates). for a few TVs, invalid credentials (e.g., certificates, or tokens) are used by AFC SUT Test Harness. The expectation is that AFC does not provide any channel availability
§ 15.407(k)(13)	The AFC system must ensure that all communications and interactions between the AFC system and standard power access points and fixed client devices are accurate and secure and that unauthorized parties cannot access or alter the database, or the list of available frequencies and associated powers sent to a standard power access point.	R0-ASQ-01-b	The AFC System must [shall] ensure that unauthorized parties cannot access or alter the database, or alter the list of available frequencies and associated powers sent to a Standard Power Device.	AFC System			Any Test Vector using valid and inlavild credentials by TH	AFC SUT Test harness uses the SPD authentication mechanism claimed by the AFC SUT in each TV (e.g. certificate, or token bearers) Use positive Security Testing with AFC SUT Test Harness using valid credentials (tokens or certificates). for a few TVs, invalid credentials (e.g., certificates, or tokens) are used by AFC SUT Test Harness. The expectation is that AFC does not provide any channel availability
§ 15.407(k)(8)(i)	Standard power access points and fixed client devices: Must register with and be authorized by an AFC system prior to the standard power access point and fixed client device's initial service transmission, or after a standard power access point or fixed client device changes location, and must obtain a list of available frequencies and the maximum permissible power in each frequency range at the standard power access point and fixed client device's location.	R0-DGR-01-a	Standard Power Access Points and Fixed Client Devices must [shall] register with and be authorized by an AFC System prior to the Standard Power Access Point and Fixed Client Device's initial service transmission, or after a Standard Power Access Point or Fixed Client Device changes location. (15.407(k)(8)(i))	Standard Power Device	Functional Test	WFA AFC DUT	N/A	Device Requirement
§ 15.407(k)(8)(ii)	Standard power access points and fixed client devices: Must register with the AFC system by providing the following parameters: Geographic coordinates (latitude and longitude referenced to North American Datum 1983 (NAD 83)), antenna height above ground level, FCC identification number, and unique manufacturer's serial number. If any of these parameters change, the standard power access point or fixed client device must provide updated parameters to the AFC system. All information provided by the standard power access point and the fixed client device to the AFC system must be true, complete, correct, and made in good faith.	R0-DGR-01-b	Standard Power Access Points and Fixed Client Devices must [shall] register with the AFC System by providing the following parameters: geographic coordinates (latitude and longitude referenced to North American Datum 1983 (NAD 83)), antenna height above ground level, FCC identification number, and unique manufacturer's serial number. (15.407(k)(8)(ii))	Standard Power Device	Functional Test	WFA AFC DUT	AFCS.SRS.1, AFCS.URS.1, AFCS.URS.2, AFCS.URS.3, AFCS.URS.4, AFCS.URS.5, AFCS.URS.6,	

AFC Test and Certification Framework



Document Flow: AFC Test Harness



Introduction to the Test Harness

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Harness Overview

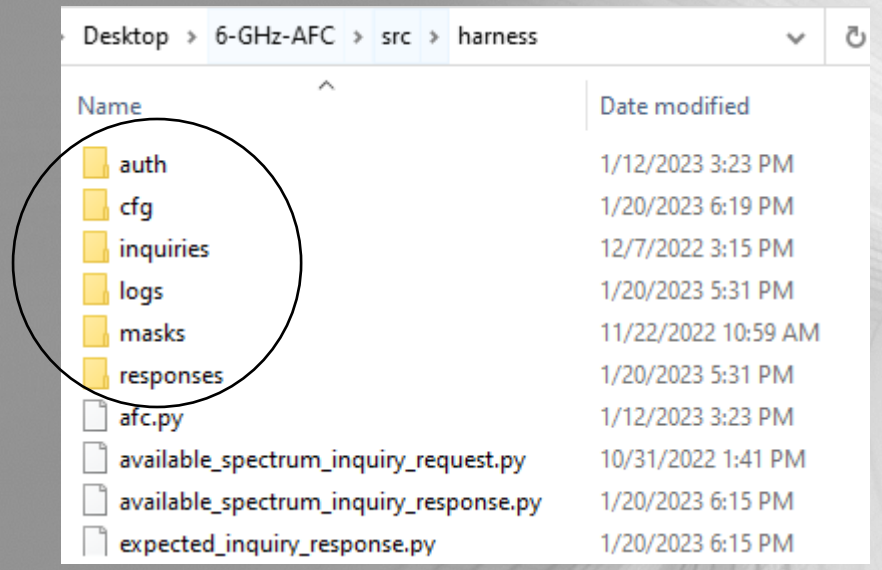
- Automates AFC test vector execution and evaluates whether response satisfies expected result criteria
- Available publicly on GitHub: https://github.com/Wireless-Innovation-Forum/6-GHz-AFC/tree/main/src/harness
- Harness repository also includes:
  - Test vector inquires
  - Test vector masks (expected responses) [Availability pending]
  - Template configuration and authentication files
  - SDI format, validation, and response comparison libraries
  - Test vector spreadsheet to JSON conversion script [Availability pending]
  - README and other documentation

Setup Instructions

- Harness requirements:
  - Python 3.10 (https://www.python.org/downloads/release/python-3109/)
    - Harness requires Python 3.10+ specific features (Versions <= 3.9 will not run)
  - Requests: HTTP for Humans (https://requests.readthedocs.io/en/latest/)
  - Tomli (https://github.com/hukkin/tomli)
- After installing Python, Requests and Tomli can be installed using pip:
  - Windows (if Python was added to path by installer): `python -m pip install requests tomli`
  - Windows (otherwise): `py -m pip install requests tomli`
  - Other platforms (pip on path): `pip install requests tomli`

Harness Configuration – Directory Overview

- `auth`
  - Support files for client authentication (certificates, bearer token implementations, etc.)
- `cfg`
  - Harness and AFC connection configuration files
- `inquiries`
  - Default location for test vector inquiries
- `logs`
  - Default location for harness log output
- `masks`
  - Default location for test vector expected responses
- `responses`
  - Default location for responses received from AFC SUT



Harness Configuration – Test Vector Files

- Test vector files (inquiries, masks) are grouped by name according to the following convention:
  - Inquiry: `{test_name}.json`
  - Mask: `{test_name}_mask.json`
- Each test name should be a unique identifier to avoid ambiguity in test results
- The included vector file names map to the WFA Test Case IDs:
  - Example: AFCS FSP 6 -> `AFCS.FSP.6.json` and `AFCS.FSP.6_mask.json`

Test Vector Files – Response Mask Definition

- The JSON format for response masks is adapted from the WFA SDI spec. Primary differences are outlined below:
  - Some field names have been changed, (e.g., "`availableChannelInfo`" to "`expectedAvailableChannelInfo`")
  - "`response`" field is replaced with a list of "`expectedResponseCodes`"
    - Permits multiple response codes to allow differences in AFC implementation (e.g., `GENERAL_FAILURE` and a more specific error code)
  - "`maxEirp`" and "`maxPsd`" fields are now `ExpectedPowerRange` objects, with the following fields:
    - `upperBound`: Maximum acceptable value (inclusive) [required]
    - `nominalValue`: The anchor point of the expected value [Default: None]
    - `lowerBound`: Minimum acceptable value (inclusive) [Default: -inf]
  - No "`availabliltyExpireTime`" is included in the mask

Harness Configuration – AFC Connection

- All harness configuration files follow the TOML standard (https://toml.io/en/) and contain full documentation for all configuration options as comments
- AFC connection configuration options are set in `cfg/afc.toml` by default
- Required fields:
  - `connection.base_url`: As defined in SDI standard (e.g., '`https://example.com/afc`')
  - `auth_info.type`: Type of client authentication (Options: '`none`', '`cert`', '`custom`')
- If no client authentication is required by the AFC SUT:
  - Set `auth_info.type` to '`none`'

Harness Configuration – AFC Connection

- If the AFC SUT requires the harness to present a client-side certificate:
  - Set `auth_info.type` to `'cert'`
  - Set `auth_info.options.client_cert` to the path to the client certificate
  - If the private key is not included in the certificate file, set `auth_info.options.client_key` to the path to the private key file
- If the AFC SUT requires the harness to perform some other authentication method (e.g., bearer token):
  - Set `auth_info.type` to `'custom'`
  - Set `auth_info.options.auth_module` and `auth_info.options.auth_class` to a python package and class implementing the custom authentication method according to the Requests library `AuthBase` interface
  - Pass any additional options required by the custom auth class via `auth_info.options.auth_config`
- An example implementation of a custom authentication method is included in `auth/custom_auth.py`

Harness Configuration – Test Selection

- By default, the harness runs tests from the list provided by `cfg/tests_to_run.py`
- If the first item in the list is `'all'`, the harness will run all tests (`*.json` files) found in the `inquiries` directory
- To run a specific subset of tests, modify the function to return a list with only those tests
  - Returned list can be generated programmatically or specified literally

Harness Configuration – Overriding Defaults

- Harness configuration options are available in `cfg/harness.toml`
- To specify a different default AFC connection config file:
  - Change `sut_config` to point to a different config file path
- To specify a different set of tests to run:
  - Change `tests.module` and `tests.list_func` to point to a different python module and function that returns the desired list of tests
- To have the harness look for tests in or log results to different directories:
  - Change the sub-fields (`inquiry_dir`, `response_dir`, `mask_dir`, `log_dir`) under the "`paths`" key

Executing the Tests

- To execute the test harness using the default configuration (`cfg/harness.toml`), execute:
  - `python ./test_main.py`
    - (Replace "`python`" with "`py`" if required by local python installation)
- To specify different config files at run-time (useful for maintaining multiple test configurations):
  - Use the following command-line options:
    - `--harness_cfg`: Specify the path to the overall harness configuration file
    - `--sut_cfg`: Specify the path to the AFC connection configuration file. This option overrides any `sut_cfg` provided by `harness_cfg`
  - Examples:
    - `python ./test_main.py --harness_cfg some/other/path/config.toml`
    - `python ./test_main.py --sut_cfg some/other/other/path/sut.toml`
    - `python ./test_main.py --harness_cfg some/other/path/config.toml --sut_cfg some/other/other/path/sut.toml`

Harness Output

- Harness output is provided in multiple ways:
  - On-going test status, final test result summary, validation warnings, and unexpected results are reported to standard output
  - Received JSON messages are logged to the `responses` folder as `{test_name}_response_{datetime}.json`
  - All log messages (including sent inquiries, received responses, and utilized response masks) are written on a per-test basis to the `logs` folder as `{test_name}_log_{datetime}.txt`
  - A full set of all log messages for all tests are written to the `logs` folder as `harness_main.log`
    - If the file already exists, it will be overwritten

Harness Output – Test Result

- Tests may end with one of three results:
  - EXPECTED: The received response satisfies the requirements specified in the response mask
  - UNEXPECTED: The received response has differed from the expected response in a meaningful fashion
  - SKIPPED: An error occurred in running the test, such that no determination of whether a result was expected or unexpected could be made automatically
- The number of tests obtaining each result is printed to standard output at the end of harness execution
- A list of which tests obtained which result is included in `harness_log.txt`

Harness Output – Log Format

- Complete log messages have the following form:
  - `{date_time} - {test_name} - {log_level}: message`
- Log levels include:
  - **DEBUG**: Notes currently performed action, logs ingested data (inquiries, responses, masks), or provides detailed information
  - **INFO**: Notes harness configuration and **EXPECTED** results and provides useful output to standard output
  - **WARNING**: May indicate a violation of the SDI specification or situation that may require manual interpretation; does not necessarily imply an issue with a test or result, though the root cause of a warning may lead to an **UNEXPECTED** result
  - **ERROR**: Indicates a condition that leads to an **UNEXPECTED** test result
  - **CRITICAL**: Indicates an error in executing the test, will result in a **SKIPPED** test
- All log levels are output to log files
- Levels of **INFO** and above are logged to standard output from code in `test_main.py`
- Levels of **WARNING** and above are logged to standard output from code in other modules

Live Demo

Support

- Issues with and questions regarding the test harness may be submitted to the GitHub repo issue tracker:
  - https://github.com/Wireless-Innovation-Forum/6-GHz-AFC/issues

Important Links

- Wi-Fi Alliance Specifications
  - https://www.wi-fi.org/file/afc-specification-and-test-plans
- WInnForum Specifications
  - https://6ghz.wirelessinnovation.org/baseline-standards
- AFC Test Harness
  - https://github.com/Wireless-Innovation-Forum/6-GHz-AFC
- Supplemental Databases
  - https://github.com/Wi-FiTestSuite/6GHz-AFC/tree/main/ULS_database
  - https://github.com/Wi-FiTestSuite/6GHz-AFC/tree/main/Supplemental_Document_Snapshot
  - https://github.com/Wi-FiTestSuite/6GHz-AFC/tree/main/3Dep
  - https://github.com/Wi-FiTestSuite/6GHz-AFC/tree/main/NLCD_data