Center for Convergence and Emerging Network Technologies

SPECTRUM CONSUMPTION MODEL BUILDER: A SOFTWARE TOOL TO ENHANCE SPECTRUM SHARING

Carlos E. Caicedo Bastidas

Associate Professor

Director - Center for Convergence and Emerging Network Technologies (CCENT)

School of Information Studies

Syracuse University

ccaicedo@syr.edu

Arnav Mohan

Student – Masters in Electrical Engineering

College of Engineering and Computer Science

Syracuse University

armohan@syr.edu

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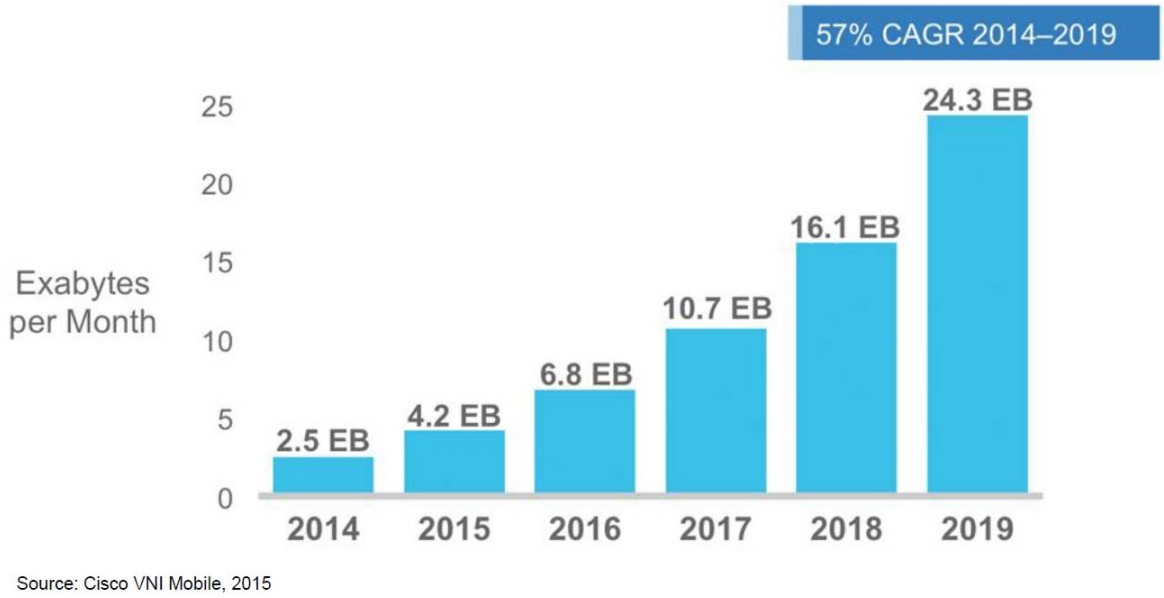
Modernizing Spectrum Management

- New spectrum management mechanisms
  - Spectrum sharing
  - Policy based mechanisms
  - Market mechanisms
  - ….
- New technologies
  - Dynamic Spectrum Access (DSA)
  - SDR / CR
  - Small cells



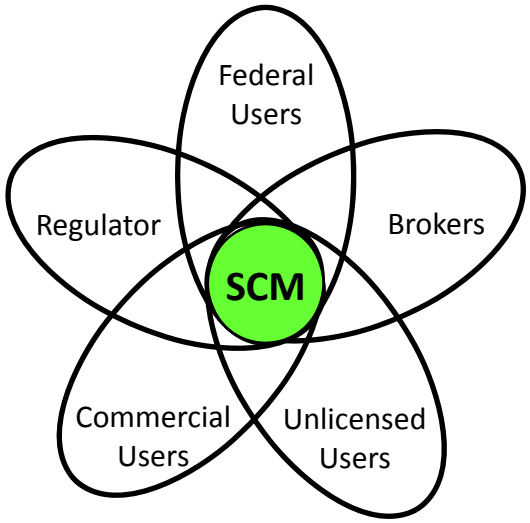
Source: Cisco VNI Mobile, 2015

USA – Regulatory/Policy initiatives

- 2012 PCAST Report
  (Realizing the Full Potential of Government–held Spectrum to Spur Economic Growth) [1]
  - Focus (initially) on sharing of federal spectrum with commercial users
  - Motivates the use of spectrum sharing, spectrum markets and new technical architectures
- 2013 presidential memorandum on Wireless Innovation
- 2013 and 2014: FCC NOI and NPRMs related to the use and implementation of spectrum sharing mechanisms
- April 2015: FCC Report and Order and Second NPRM
  - Rules for Commercial Operations in the 3550- 3700 MHz Band
  - Citizens Broadband Radio Service (CBRS)

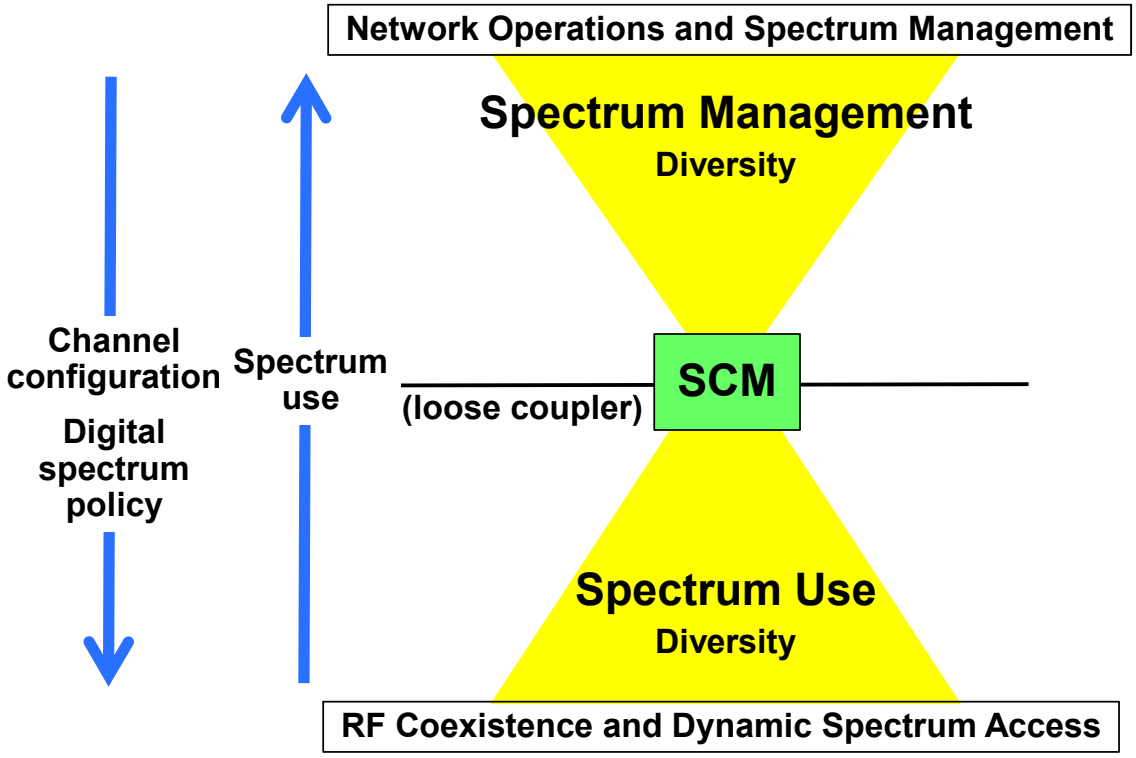
Motivation for SCMs

- Dynamically sharing spectrum requires defining the boundaries of spectrum use
- Defining boundaries of spectrum use requires
  - Defining how systems emit EM radiation
  - Defining what is interference to a system
  - Defining how these qualities of systems are different in time and space
  - Identifying behaviors that allow sharing
- **A common means to define spectrum use would enhance spectrum sharing interactions across a diverse set of entities**
  - SCMs are being standardized in IEEE 1900.5.2



Spectrum Consumption Models as a Loose Coupler [3, 5]

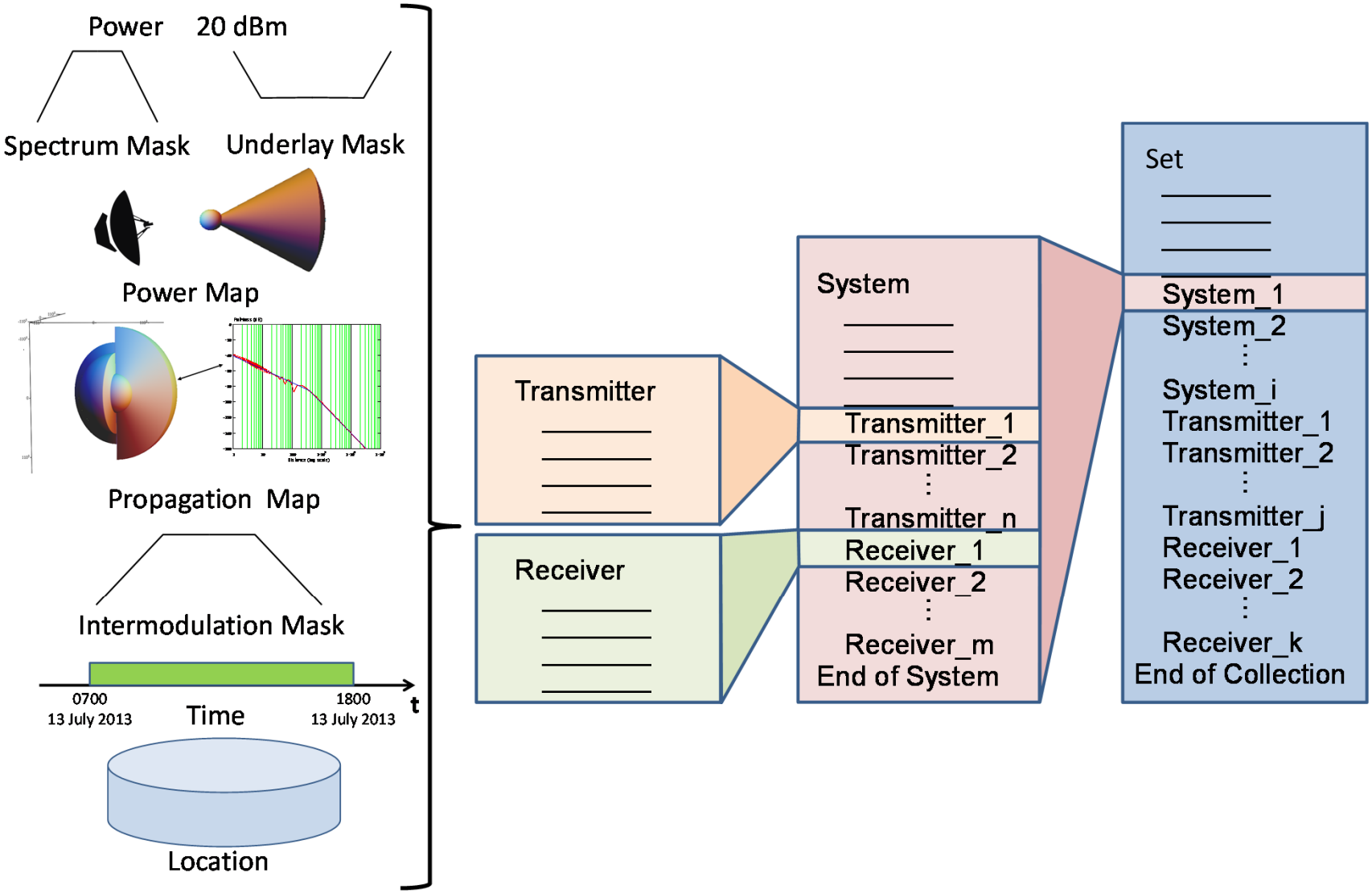
- SCMs capture the minimal amount of data for SM across diverse systems and uses (of spectrum)
- Captures the intent of users and the judgment of spectrum managers



Spectrum Consumption Modeling Objectives

- Provide means to capture all the relevant parameters and phenomena that affect spectrum consumption
- Provide means to compute compatibility between any two models without dependence on external databases of environmental or system data
- Support methods for computing compatibility that are tractable and definitive

Combining Constructs into Models



SCM Constructs

- Total power
- Spectrum mask
- Underlay mask
- Power map
- Propagation map
- Intermodulation masks
- Platform
- Location
- Schedule
- Minimum power spectral flux density
- Protocol or policy

Captures the spectral content of the signal and the unique characteristics of spread spectrum systems

Captures a definition of interference

Can capture antenna effects

Can capture environmental effects

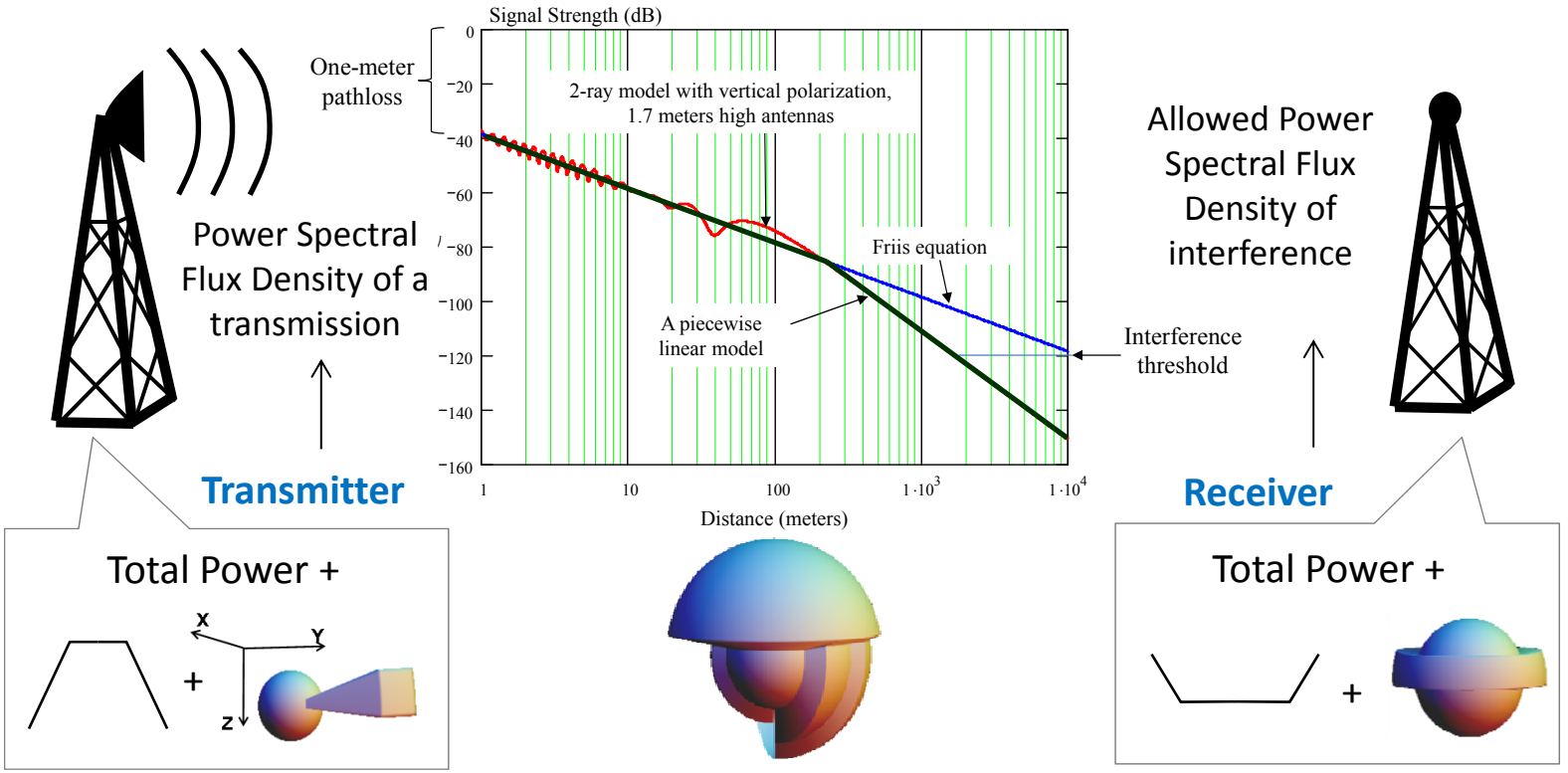
Captures susceptibility to intermodulation

Enable greater resolution in spectrum management

Can capture behaviors that enable compatible reuse

Most constructs have probability data elements to declare confidence in parts that are variable or are uncertain

Compatibility Computations[5, 6]

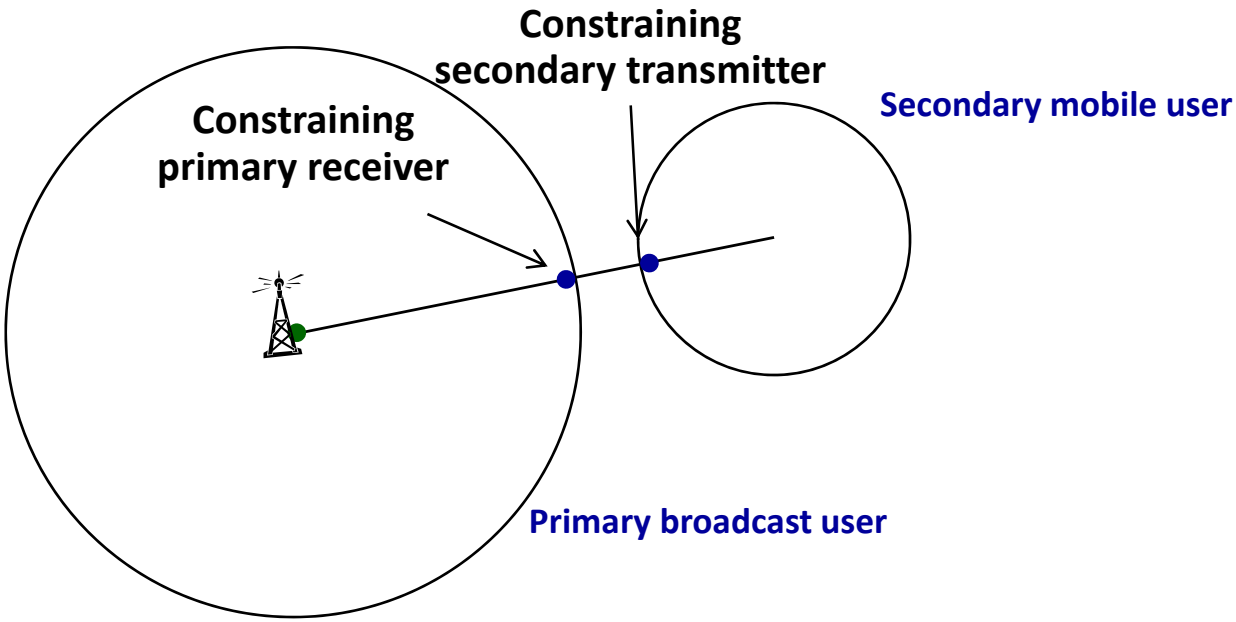


- Constructs are a means to specify the factors that determine a link budget in all directions
- Modelers build SCMs to identify the power spectral flux density of transmissions and allowed interference

SCMs are built to protect not to predict!

General Process for Computing Compatibility

- Determine if uses will overlap in time and spectrum
- Determine the constraining points (the point of primary operation and the point of secondary operation that most restrict the secondary user)
- Compute the allowed transmit power of the secondary



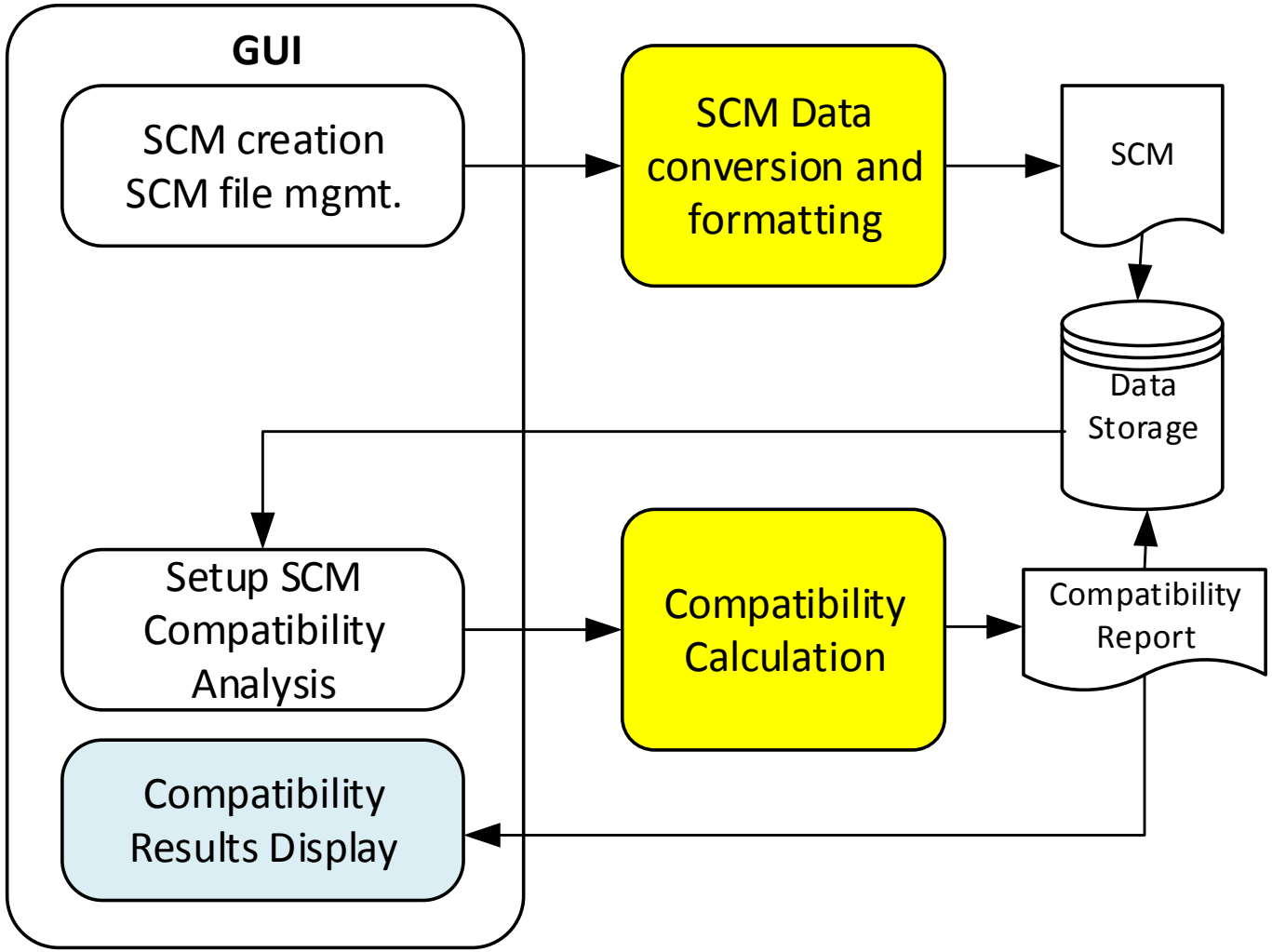
IEEE P1900.5.2

- Data Model for SCMs
  - Data types for the fundamental data elements required within each construct
  - Transmitter, receiver, and system data types
  - Data types for sets of transmitters, receivers, and system models
- Explanations & Definitions
  - What each construct captures
  - How constructs work collectively to represent use boundaries
  - Methods and algorithms for computing compatibility between uses
- 1900.5.2 WG has completed the draft standard document.

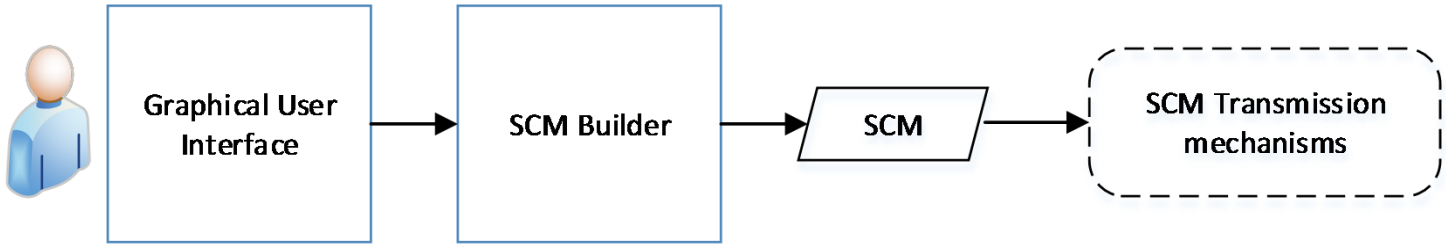
SCM Builder and Analysis Tool (Objectives)

- Software tool for elaborating/defining SCM models in conformance with the 1900.5.2 standard.
- Incorporates algorithms to compute the compatibility between SCMs
  - Several single Tx to single Rx receiver cases covered
  - Evolve to more complex scenarios
- Identify limitations in the use of SCMs
- Provide feedback and suggest improvements to the IEEE 1900.5.2 standard elaboration efforts

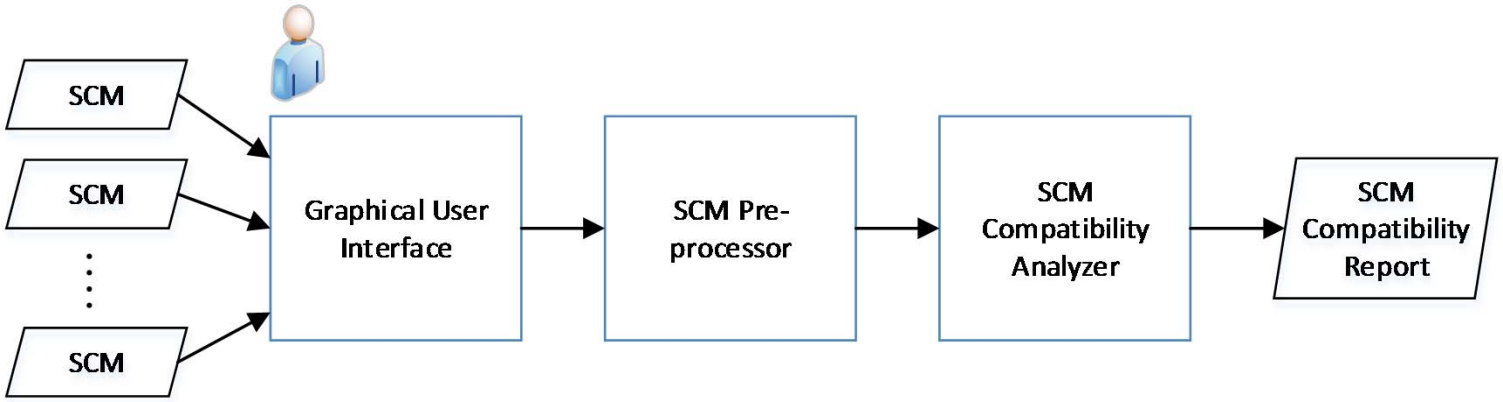
SCM Builder and Analysis Tool (Architecture)



SCM Builder and Analysis Tool (Use scenarios)

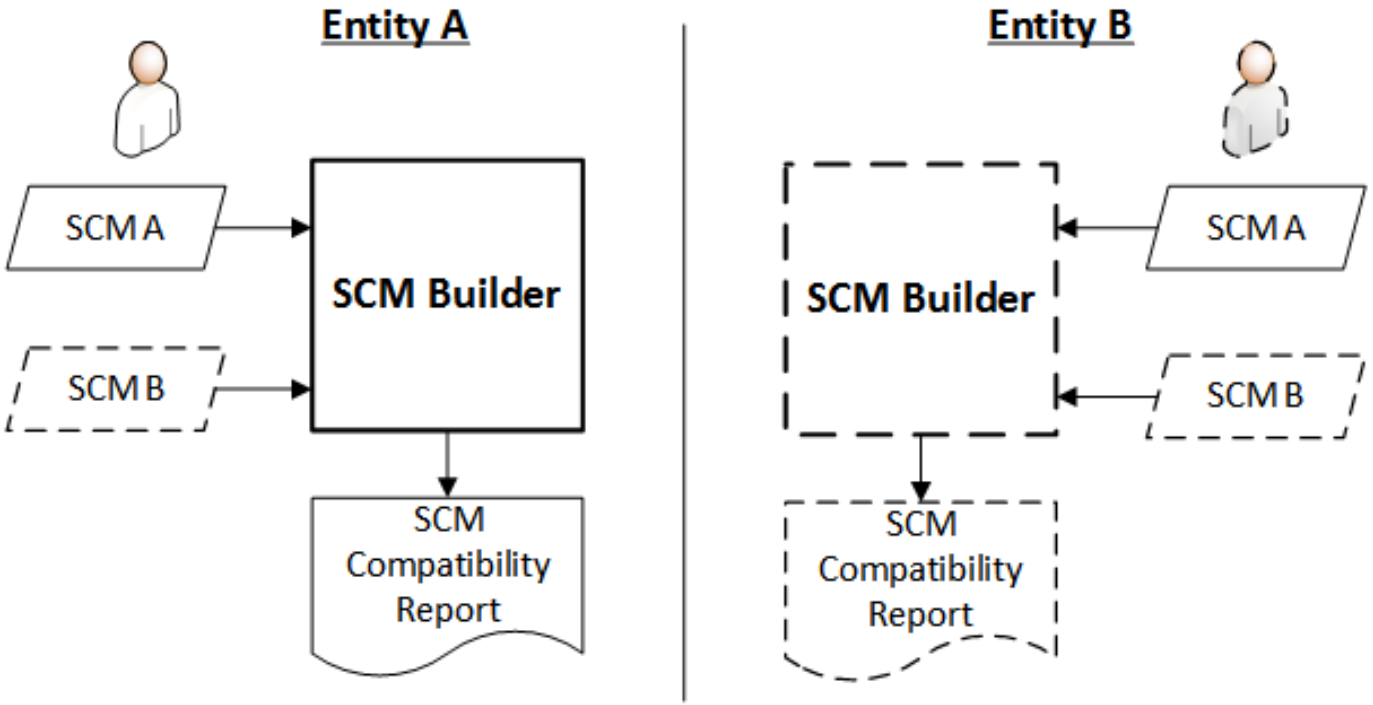


(a)

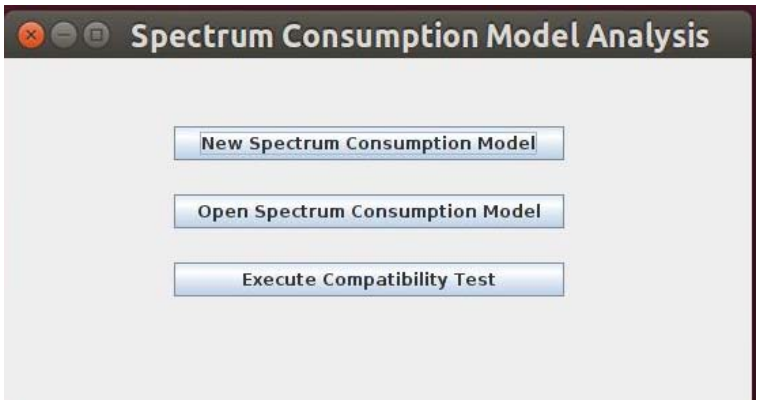


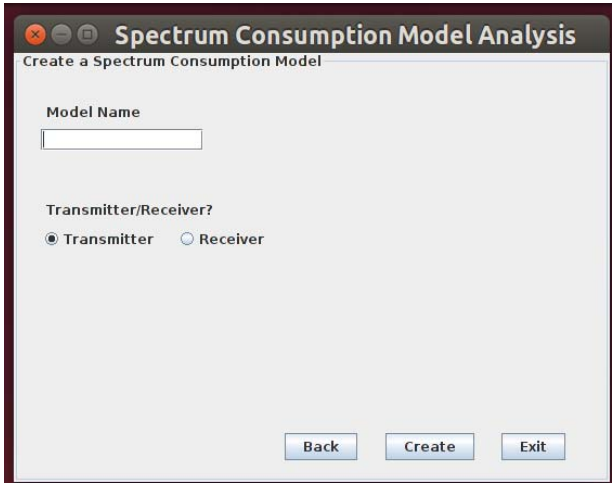
(b)

SCM Builder and Analysis Tool (Use scenarios)

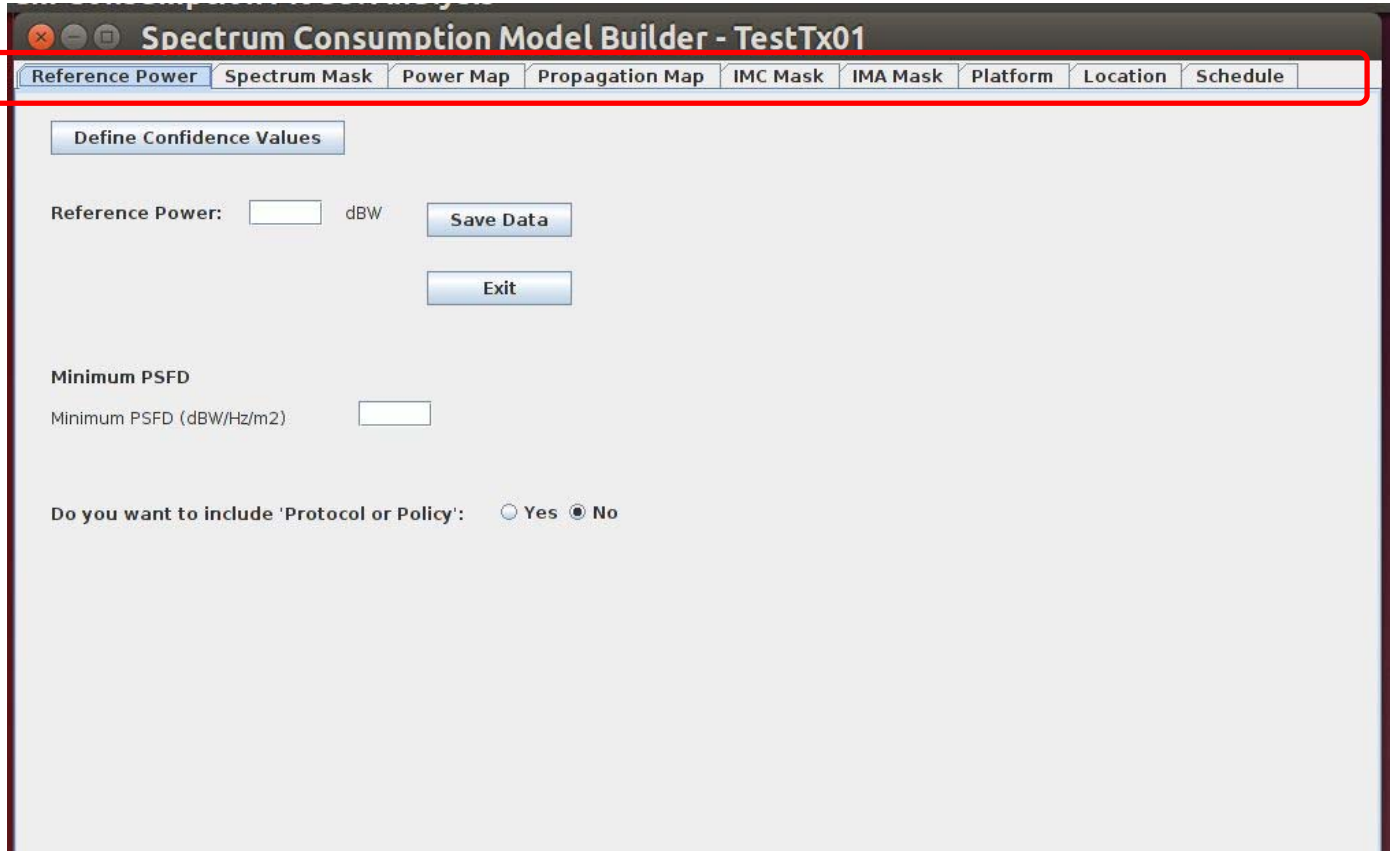


(c)





Tabs to input information for a Tx Model



Spectrum Consumption Model Builder - Tx_Tot

Reference Power | Spectrum Mask | Power Map | Propagation Map | IMC Mask | IMA Mask | Platform | Location | Schedule

Define Confidence Values

This is a frequency hopping system ◉ No ○ Yes

Specify frequency hopping characteristics via a: ○ Center frequency list ○ Band list

○ Use relative frequency values

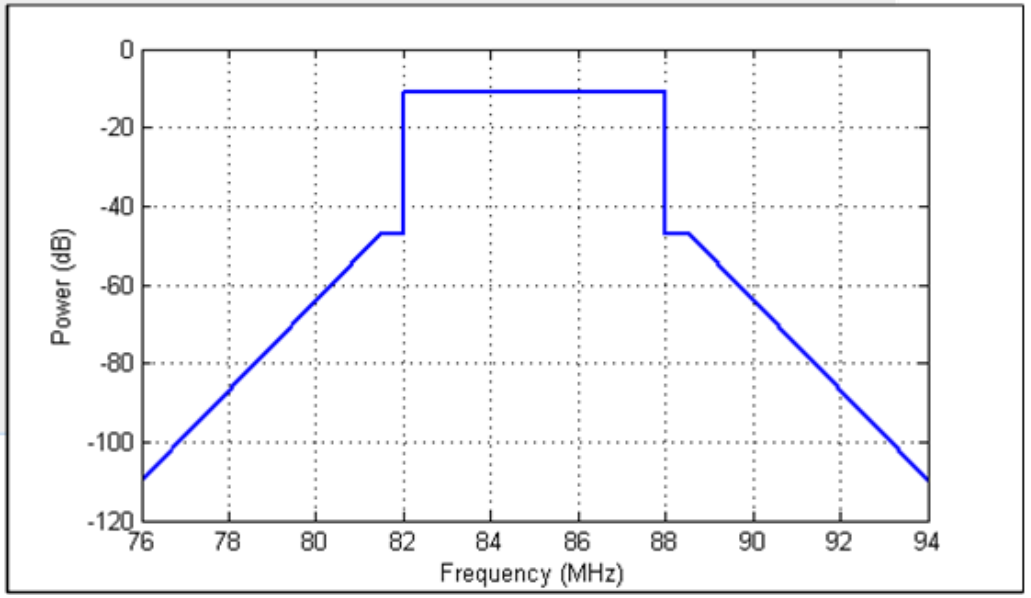
Resolution Bandwidth (Mhz) 0.001

Center Frequency (MHz) 0

#	Frequency (MHz)	Power (dB)
1	76	-110
2	81.5	-47
3	82	-47
4	82	-11
5	88	-11

Add Row | Exit

Remove Row | Save Data



Spectrum Consumption Model Builder - Tx_Tot

Reference Power | Spectrum Mask | Power Map | Propagation Map | IMC Mask | IMA Mask | Platform | Location | Schedule

Define Confidence Values

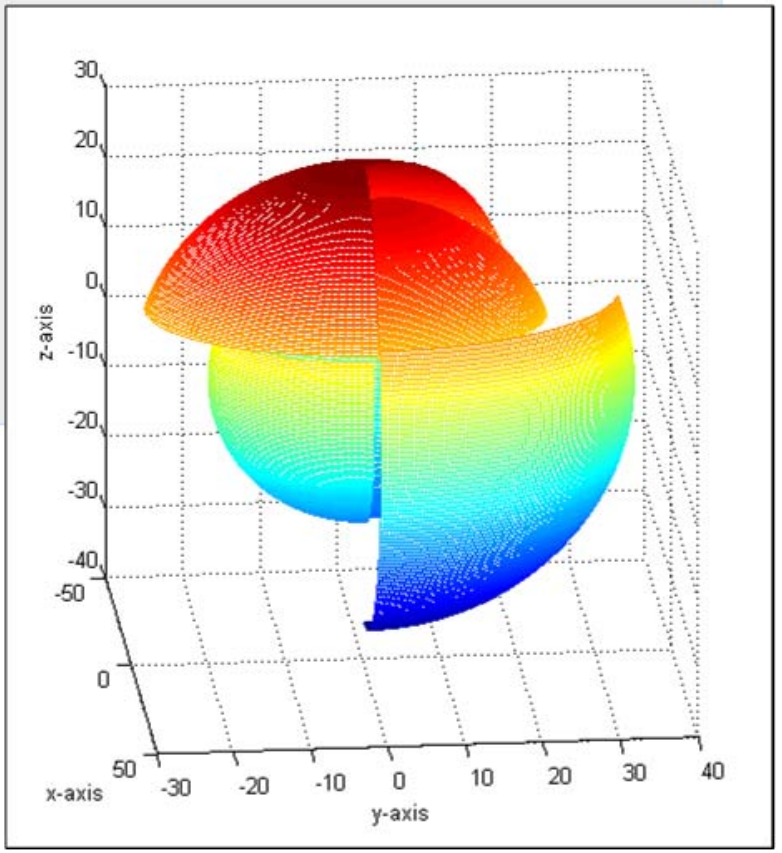
Orientation (•) Surface ( ) Relative to platform ( ) Towards reference point

Location Index (optional) [ ] Do you want to define a scanning region? ( ) Yes (•) No

Gain Map

#	Elevation Angle	Azimuth Angle	Gain (dB)
1	0	0	-35
2		80	-20
3	110	0	-25
4		135	-30

Add Row | Save Data | Remove Row | Exit



Spectrum Consumption Model Builder - Tx_Tot

Reference Power | Spectrum Mask | Power Map | Propagation Map | IMC Mask | IMA Mask | Platform | Location | Schedule

Define Confidence Values

Location Index (Optional)

Associate model with a specific distant height ○ Yes ◉ No

Propagation Map

Add new map | Previous | Next

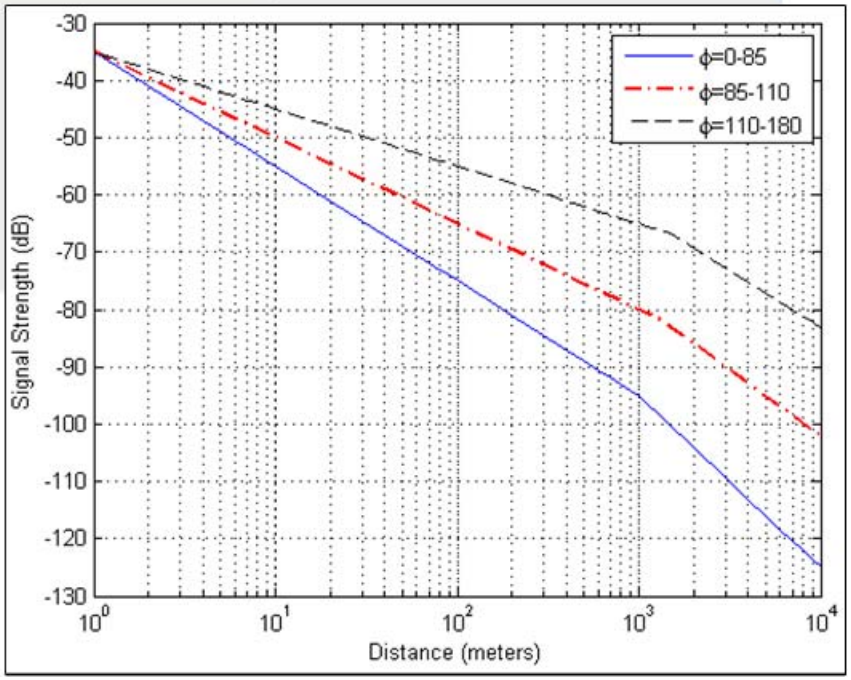
#	Elevation Angle	Azimuth Angle	n1	BreakPoint (m)	n2
1	0	0	2	1000	3
2	85	0	1.5	1300	2.3
3	110	0	1	1500	2

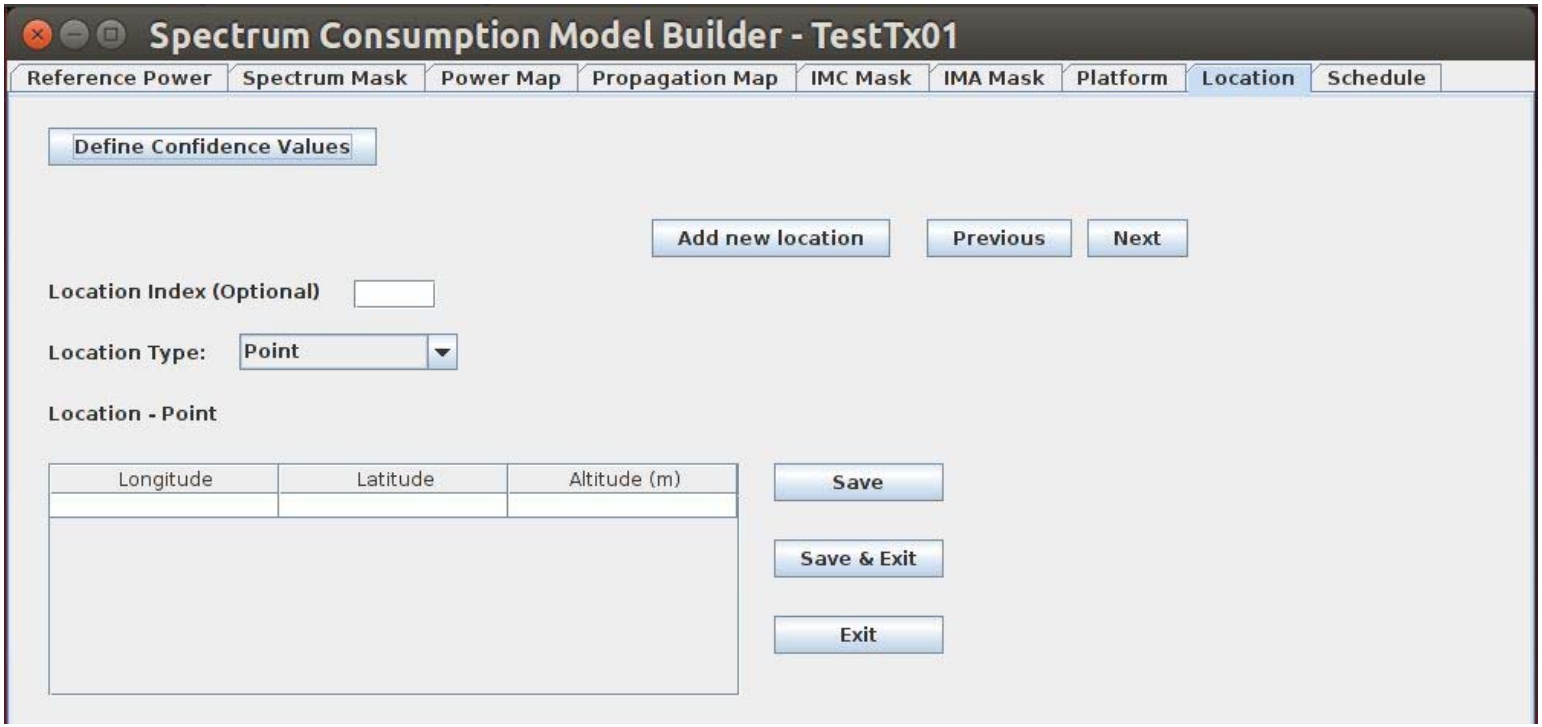
Add Row

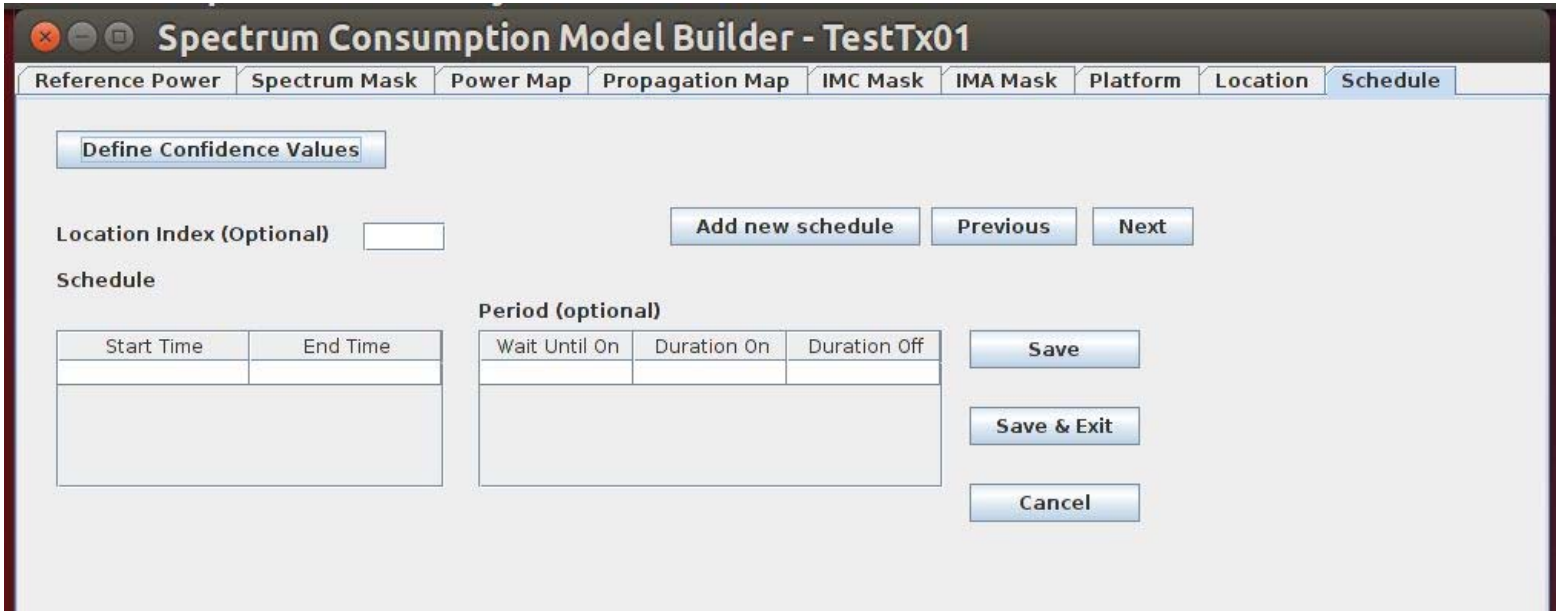
Delete Row

Save Values

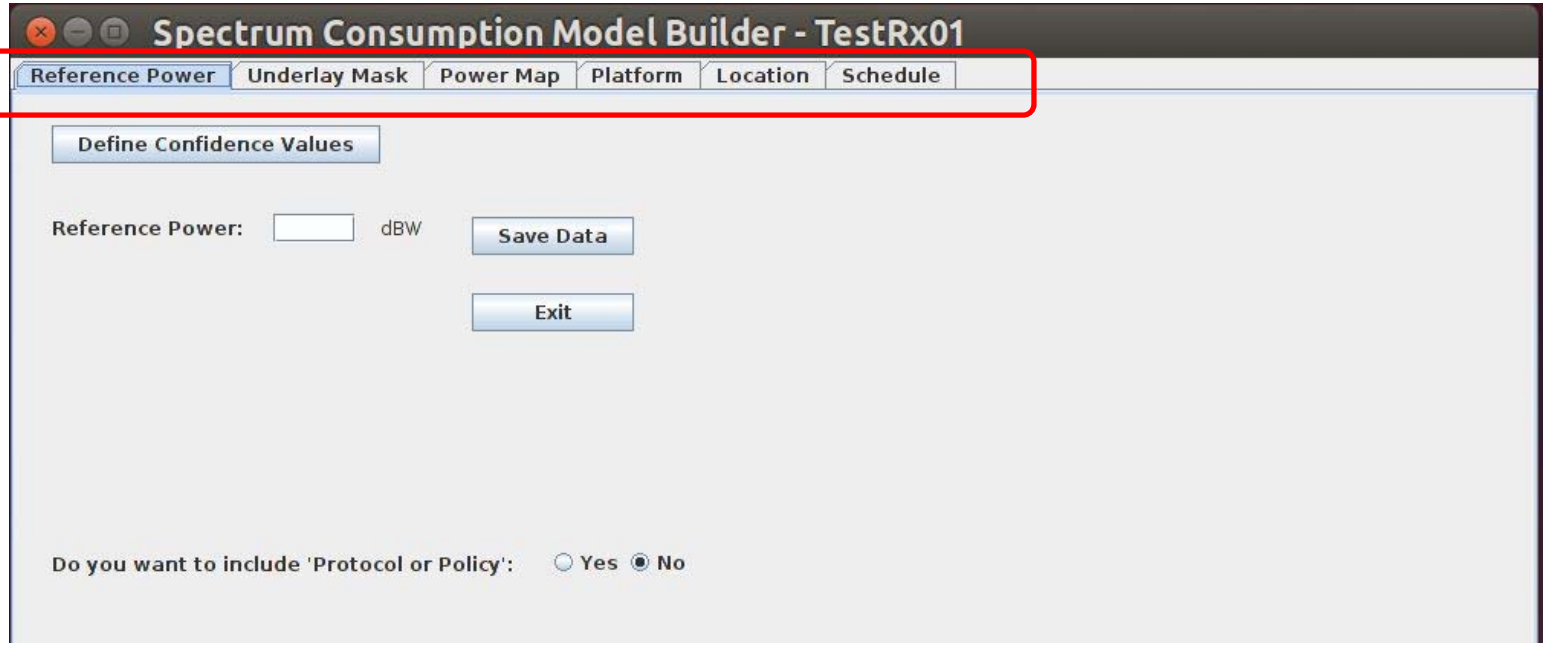
Save & Exit




Spectrum Consumption Model Builder - TestTx01
Reference Power
Spectrum Mask
Power Map
Propagation Map
IMC Mask
IMA Mask
Platform
Location
Schedule
Define Confidence Values
Add new location
Previous
Next
Location Index (Optional)
Location Type:
Point
Location - Point
Longitude
Latitude
Altitude (m)
Save
Save & Exit
Exit


Spectrum Consumption Model Builder - TestTx01
Reference Power
Spectrum Mask
Power Map
Propagation Map
IMC Mask
IMA Mask
Platform
Location
Schedule
Define Confidence Values
Location Index (Optional)
Add new schedule
Previous
Next
Schedule
Period (optional)
Start Time
End Time
Wait Until On
Duration On
Duration Off
Save
Save & Exit
Cancel

Tabs to input information for a Rx Model



Spectrum Consumption Model Builder - Rx_Tot

Reference Power | Underlay Mask | Power Map | Platform | Location | Schedule

Define Confidence Values

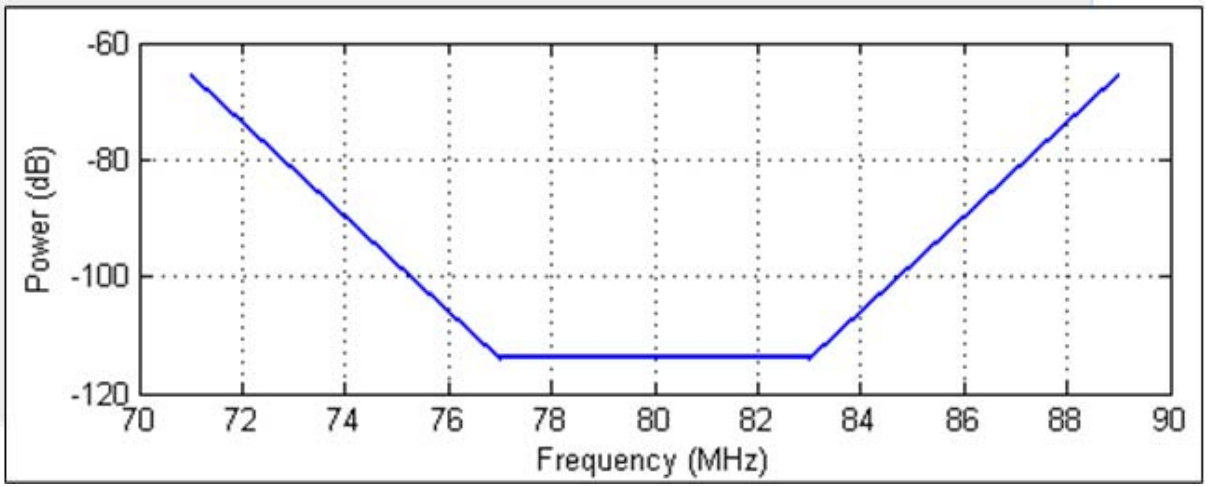
This is a rated underlay mask ◉ No ○ Yes

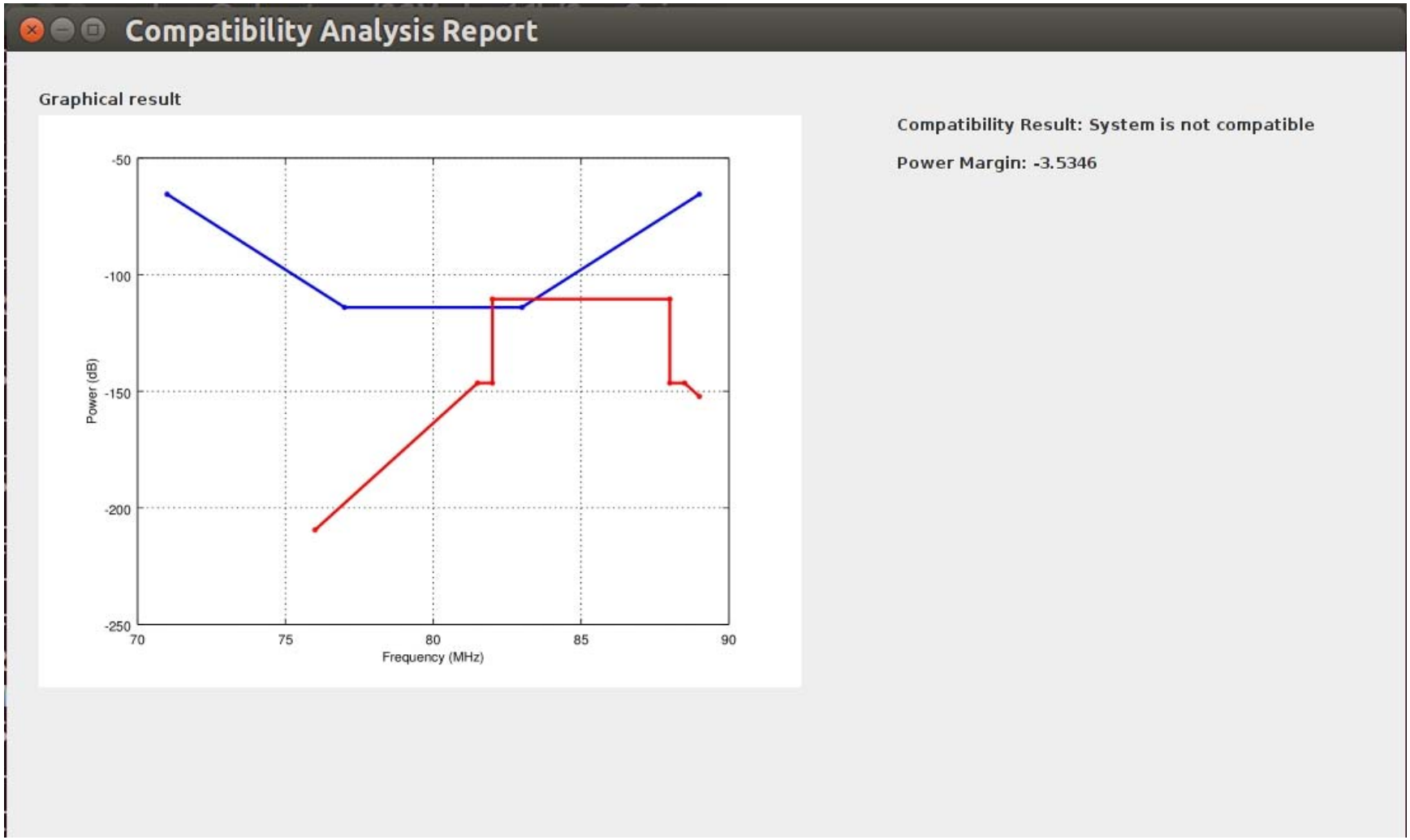
Power Margin method to use: ◉ Total Power ○ Max. Power Density

Resolution Bandwidth (Mhz) 0.01

#	Frequency (MHz)	Power (dB)
1	71	-65.5
2	77	-114
3	83	-114
4	89	-65.5

Add Row | Save Data | Remove Row | Exit

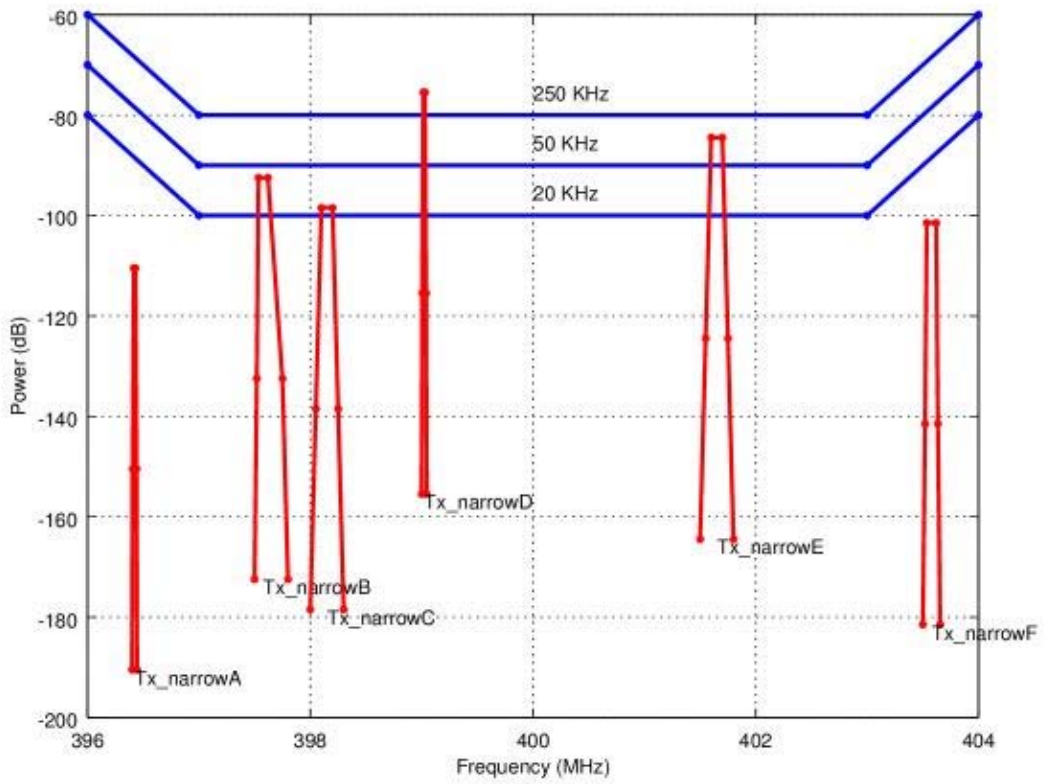




Compatibility calculation example. Shown is a receiver's underlay mask (Blue) and a transmitter's adjusted spectrum mask (red)

Compatibility Analysis Report

Graphical result



Not Compatible

Tx_narrowD

Compatible with all

Compatible with specific masks

Tx_narrowA with [0.25, 30.0, 0.05, 20.0]
Tx_narrowB with [0.25, 30.0]
Tx_narrowC with [0.25, 30.0]
Tx_narrowE with [0.25, 30.0]

Compatibility calculation example. Multiple interferers vs. a bandwidth rated underlay mask ([BW Rating (MHz), Power Adjust (dB)]={[0.25, 30], [0.05, 20], [0.02, 10]})

SCM Builder tool - Future perspectives

- Incorporate XML based SCM schema into tool
  - Has suffered delays
  - Its development was not part of the original scope of the project/tool
- Enhance compatibility calculations
- Release of version 1.0 summer 2016
  - Open source
  - Create and manage a development group/community around the tool
    - Enhance and promote the use of SCMs in spectrum management (e.g. SAS interactions)

Conclusions

- Spectrum sharing concepts are moving forward towards becoming the norm in modern spectrum management
  - Supported by regulatory/policy decisions
  - Supported by new standards
  - Supported by technology (small cells)
- Spectrum consumption modeling
  - Is a supporting framework for current spectrum management initiatives
    - Specifying spectrum use in a national SAS
  - Is being standardized by the IEEE Dynamic Spectrum Access Networks Standards Committee (DySPAN-SC) in project P1900.5.2
    - Non-proprietary
    - Vendor independent
- Spectrum sharing will drive the need for innovations in RF spectrum management
  - Communicating spectrum use
  - Enforcement/monitoring of spectrum use
  - …

References

[1] PCAST, “Report to the president: Realizing the full potential of government-held spectrum to spur economic growth”, available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast spectrum report final july 20 2012.pdf”, 2012.

[2] FCC, “FCC 14-49 further notice of proposed rulemaking. in the matter of amendment of the commission’s rules with regard to commercial operations in the 3550-3650 MHz band.” Federal Communications Commission, Washington, D.C., GN Docket No.12-354, 2014.

[3] J. A. Stine and S. Schmitz, “Model-Based Spectrum Management, Part 1: Modeling and Computation Manual, version 2.0,” MITRE Technical Paper, 2014.

[4] C. Caicedo, J. Stine, “Spectrum Markets and Sharing Via Spectrum Consumption Models”, Research Conference on Communication, Information and Internet Policy – TPRC, September, 2013

[5] J. Stine and C. Caicedo Bastidas, “Service Level Agreements with Spectrum Consumption Models”, IEEE Symposium on Dynamic Spectrum Access Networks (DYSPAN 2014)

[6] FCC, “FCC 15-47 Report and Order and Second further notice of proposed rulemaking: In the matter of amendment of the commission’s rules with regard to commercial operations in the 3550-3650 MHz band.”, Washington, D.C., GN Docket No.12-354, 2015.

[7] J. Stine, C. Caicedo, “Enabling Spectrum Sharing via Spectrum Consumption Models”, IEEE Journal of Selected Areas in Communications (JSAC), Vol 33, No. 4, 2015

Thank you !

- Contact info:
  - Carlos Caicedo ccaicedo@syr.edu