WSRD SSG Workshop V: Understanding the Spectrum Environment:
Data and Monitoring to Improve Spectrum Utilization
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Keynote Remarks

Thank you Rangam for the very kind introduction. And thank you and the other organizers of the workshop for giving me the opportunity to offer a few remarks on the topic of Interference Resolution and Enforcement within the overall subject matter of the workshop "*Using data and monitoring to improve spectrum utilization.*"

Before I jump into my formal remarks, I want to distinguish between (a) more passive, ideally long term spectrum monitoring aimed at measuring spectrum occupancy for the primary purpose of identifying under-utilized or inefficiently used spectrum and (b) more active, real-time spectrum and direction-finding measurements that are aimed primarily at detecting, identifying, and locating interference sources for mitigation and enforcement purposes. The focus of my remarks is on the latter, although there is clearly overlap that I will address later if there is time. I should also add the standard disclaimer that I am only speaking for myself here this morning.

When I sat down to sketch out these remarks, I decided that I would lay out a series of five hypotheses starting with ones that I think are widely believed to be true -- or at least ones I believe are true -- and moving on to ones that I feel are more controversial, or if not more controversial, ones that have received less policy attention.

My *first* hypothesis or premise is that the United States is experiencing explosive growth in wireless devices and systems that must successfully operate not only in increasingly close proximity to one another in the frequency, space and time dimensions but also to other electrical and electronic devices that unintentionally or incidentally emit (or are susceptible to) electromagnetic radiation. As we all understand, this increased densification is driven by such things as (a) the need for increased frequency reuse because of the challenges of increasing capacity by other means, (b) the need to reduce guard bands to free up valuable spectrum and (c) by taking advantage of the fact that systems are not always on the air 24X7 thus allowing dynamic temporal sharing. This increased densification of often disparate devices and systems increases the risk of disruptive and harmful interference.

So my first hypothesis or premise is that there is continuing rapid growth in demand for spectrum that is producing increasing densification which, in turn, increases the risk of disruptive and harmful interference.

My *second* hypothesis or premise is that the increased value of the radio spectrum resource will put additional pressure on the Federal Communications Commission, the National Telecommunications and Information Administration and other governmental agencies to appropriately protect the radio spectrum resource and, in particular, to more quickly and effectively resolve cases of interference when they do arise. The latter is especially true of services that are not only critical to the Nation's economic and social wellbeing, but to public safety, homeland security and national defense as well.

More specifically, in terms of the PCAST recommendations, the immediate prospect of increased sharing of spectrum between and among federal government and non-federal government controlled devices and systems creates new challenges in terms of the institutional relationships and processes that are used to detect, identify, locate, mitigate and report interference incidents. These challenges have been exacerbated by the wider availability of illegal devices capable of jamming or otherwise disrupting wireless systems that are part of the Nation's critical infrastructure.

Clearly, the value of dynamically shared spectrum to commercial entities depends upon the processes and resources spectrum managers have available (a) to reduce the number of incidents of harmful and disruptive interference and (b) to resolve them quickly when they do occur. Similarly, the willingness of federal government agencies to share larger amounts of spectrum in more dynamic ways depends upon their confidence that the applicable rules, regulations, contracts and Memoranda of Understanding regarding such sharing will be effectively enforced in a timely manner.

To summarize then, my second hypothesis is that the increased value of the radio spectrum resource will put additional pressure on government agencies -- principally the FCC and the NTIA -- to intensify their protection of the amazing natural resource -- the radio spectrum -- and, in particular, to make sure that they have the appropriate tools and processes for quickly and effectively resolving cases of interference when they do arise. To do otherwise, will undercut the very basis upon which the increased sharing called for in the PCAST report rests.

My third hypothesis or premise is that many of the technological changes being made in radio systems to capture increased spectral efficiencies and generate additional spectrum capacity present challenges for the traditional spectrum measurement and direction-finding systems used in interference resolution and enforcement. They present challenges to our ability to detect, identify, locate, mitigate, report and, when necessary, prosecute those responsible for causing harmful interference.

The changing environment for interference resolution and enforcement is illustrated by noting that, in the not too distant past, radio systems typically operated at high power, used high, fixed, outdoor antenna sites, utilized one or a relative handful of channels in bands not widely shared with other services, operated in the analog mode with a very limited number of modulation methods or waveforms, were licensed by the Commission (or authorized by NTIA in the case of government systems), and regularly transmitted unique identifying information (e.g., call letters) in the clear. Finally, end-user devices had very limited processing, storage and display capabilities and had no means of ascertaining their location.

Today, the situation is vastly different in nearly every respect. As I touched on before, to provide the capacity necessary to communicate successfully with millions of highly mobile devices and to provide indoor coverage, systems often transmit at low power and at low elevations from multiple sites rather than a handful of very high power/high elevation sites. They may utilize hundreds of channels assigned on a highly dynamic basis in multiple bands that may be shared with other services on an active basis. Increasingly, they operate in the digital mode using a myriad of complex waveforms that dynamically adapt to changing channel conditions. This dynamism is apt to make interference much more transient in nature.

Another trend is toward communications devices (and systems) that operate on an unlicensed, lightly licensed or licensed-by-rule basis where regular over-the-air identification for interference resolution and enforcement purposes is not a requirement. Furthermore, because of the increased demand for spectrum capacity, widely deployed nomadic and mobile systems are moving higher up in the radio spectrum -- e.g., above 3 GHz.

To summarize once again, my third hypothesis or premise is that these otherwise worthwhile technological developments present challenges for the traditional spectrum monitoring and direction-finding systems that are critical to interference resolution and enforcement.

While the technological developments I just described present spectrum measurement, direction finding and other enforcement related challenges, my fourth hypothesis or premise is that these same (and related) technological developments hold the promise of increasing the efficiency and efficacy of interference resolution and enforcement activities. For example, modern access points and end user devices often have increased processor power, much larger data storage capacity, more sophisticated display capabilities, connectivity to the internet and geo-location awareness. Following the lead laid out in the PCAST report, these increased capabilities are being harnessed by Spectrum Access Systems that facilitate increased dynamic spectrum sharing based upon the geo-location/database approach. These advanced SAS systems are able to determine the location and "health" of access points or end user devices. Using appropriate logic, devices that are not performing properly or are encroaching upon a protected geographic area can be identified and taken out of service remotely before they cause interference. Or, if harmful interference is detected, the system can, conceptually at least, remotely change the power of the individual access points, change the antenna radiation patterns (e.g., using beam steering), turn the access point off entirely, change channels within the band to avoid causing or receiving interference, and perform other diagnostic and interference mitigation actions.

These technological advances can also be combined with other advanced techniques that have been suggested as a way of improving interference resolution and enforcement activities. For example, the FCC is using crowd sourcing techniques to gather anonymous data from the smartphones of thousands of volunteers in order to assess broadband performance nationwide. Conceivably, at least, the FCC Speed Test, as the app is known, could be expanded on a voluntary basis to include utilizing the smartphone or similar device to detect and then store and report information on suspected interference incidents.

I believe it was John Chapin who came up with the idea of having the device continuously record a short period of I/Q information from the receiver in order to allow *ex post* or after the fact forensic analysis of the root causes of a particular incident. This would work in a similar way to how flight data recorders or "black boxes" are used to give investigators clues to the cause of accidents associated with commercial aircraft. On a larger scale, it might be possible to automatically classify and report on various types of interference -- for example, interference from a defective light fixture -- using processing-intensive after the fact analyses.

Another advanced technique that holds promise for increasing the efficiency and efficacy of interference resolution and enforcement activities is built on the notion of the big data paradigm. While I recognize that there is a certain degree of hype surrounding the notion, I am pretty convinced it has some applicability in this space.

What led me to this conclusion is what I have learned over the past several months -- including the time preparing for this workshop. What I learned is that there is a surprising -- at least to me -- amount of spectrum monitoring already being done by a host of organizations including the wireless carriers, tower companies, academic and private research institutions, specialized spectrum user groups, and government agencies such as the FCC, NTIA and the FAA all using a whole host of tools that can be applied to interference resolution and enforcement. These tools or platforms including (a) satellite systems, (b) airborne platforms (both manned and unmanned -- i.e., drones), (c) fixed observatories such as the ones operated by Dennis Roberson and his crew at IIT in Chicago, by Microsoft at numerous locations, and, to a limited extent, by the FCC, (d) transportable monitoring and direction finding equipment that can be left at a fixed location for a period of time, (e) mobile vans/SUVs like those operated by both government agencies such as the FCC, NTIA, the FAA and private entities, and (f) portable, handheld measurement and direction finding equipment of which there are lots of examples.

My sense is that much of this data is collected in silos and is not often shared even where it would be advantageous on a cost and/or performance basis to do so. That is where the big data notion of extracting insights from large and complex data sets comes in. Before moving ahead, I would like to make one more -- perhaps obvious -- observation. Namely, each of the monitoring platforms I identified has advantages and disadvantages in terms of their role and usefulness in interference resolution and enforcement. As someone who believes in the need for interference resolution and enforcement modernization based upon the premises I set forth earlier, I believe our role as system engineering and subject matter experts is to come up with recommendations on how these tools can be optimally combined in the future. Note that while I am focusing mostly on interference resolution and enforcement (and compliance), there may well be situations where there are significant economies of scale and scope in combining enforcement measurements with spectrum occupancy/efficiency measurements on a common platform.

To briefly summarize once again, my fourth hypothesis or premise is that many of the same technological developments that present challenges to traditional spectrum measurement, direction finding and other enforcement tasks also hold out great promise of increasing the efficiency and efficacy of interference resolution and enforcement activities especially when combined with notions such as crowd sourcing and the big data paradigm.

My fifth and final premise relates to consumer privacy and confidentiality. While I see great promise in some of the more advanced monitoring and related techniques I just described, great care must be taken in their design, deployment and use to ensure open and transparent processes that protect consumer privacy. While I am admittedly far from an expert in privacy, I have been favorably impressed by the Commission's wireless Speed Test apps that rely upon crowd sourcing and volunteers to gather anonymous measurement data from smartphones as I touched upon earlier. Of course there is a tradeoff between more dynamic/fine grained detection, identification and location of interference sources and consumer privacy -- a tradeoff that must be made with the utmost care.

While that concludes my prepared remarks, I would like to add a couple additional comments that occurred to me this morning while I was reviewing what I planned to say.

First, I perceive that there is a gap between the research community's efforts to study enforcement in the more challenging and dynamic wireless world we find ourselves in now and the people actually practicing interference resolution and enforcement in the field. I believe that a tighter coupling between the two groups would be highly beneficial and I am pleased that there are senior people from the Enforcement Bureau here with us today. One of the recent recommendations of the FCC's Technical Advisory Committee -- TAC -- was that the Commission takes steps to facilitate more contacts between academic and industry researchers interested in enforcement and the people actually responsible for modernizing the agency's enforcement equipment and processes.

Second, in my prepared remarks I seemed to focus on the government's role in interference resolution and enforcement. That was unintentional. We all know that most interference incidents are resolved voluntarily today without -- or with only minimum -- government involvement.

While government led enforcement must clearly be the ultimate backup in cases that, for example, involve deliberate interference or jamming, the private sector can also help by not only supplying equipment and services to the government's enforcement effort but also by engaging in self-regulation and in engaging in other volunteer activities that may lighten the compliance and enforcement load on the relevant agencies. I am looking forward to additional discussion of this important topic -- the role of the private sector -- in our interference resolution and enforcement breakout session this afternoon.

Thank you.