Possible Use of MIMO/Massive MIMO Technology to Increase Spectrum Access by Controlling Interservice Interference

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Most wireless technology researchers view obtaining access to spectrum as a specialty for others who focus solely in spectrum policy. Thus, the researcher finds out from others what bands are available for their application. In many cases, the question of whether band *x* can be used for application *y* ultimately depends on whether this application in this band will cause interference to other users in either the same band or nearby bands. This type of problem is usually approached by developing power budgets for both the desired transmitter to desired receiver path as well as from the new band user transmitter to incumbent receiver path and checking what the desired-to-undesired-signal ratios are and whether they will result in harmful interference. Generally, the design of equipment for new spectrum uses has not been greatly influenced by the need to protect incumbent spectrum uses. Rather, spectrum regulators often base use decisions on traditional technology and whether such technology might result in interservice interference to incumbent systems.

In recent years, in the United States, there have been several contentious spectrum policy issues concerning possible interference to nearby bands or the same band where better control of the elevation profile of emissions could be part of a solution to allow more spectrum use and indeed might make the difference of enabling the new spectrum use or not. This paper explores how new uses of multiple-input multiple-output (MIMO), massive MIMO [1], and even ultra-massive MIMO [2] technologies might address such interservice sharing issues and thus facilitate use of new bands for wireless communications.

The current contentious spectrum policy issues mentioned above are:

- The "Ligado" issue of whether use of 1526–1536 MHz for a 5G-like system will cause interference to the GPS L1 signal in the nearby band of 1559-1591 MHz [3].
- The issue of whether 5G signals in 24.25-24.45 GHz and 24.75-25.25 GHz will cause interference to passive weather satellites in 23.6-24.0 GHz [4].
- The issue of possible interference from 5G use of 3.7–3.98 GHz to aircraft radar altimeters in 4.2–4.4 GHz [5].
- The issue of whether terrestrial communication use at low elevation angles of any of the 10 passive bands in 100–252 GHz would cause interference to passive satellites in these bands [6]. (While International Telecommunication Union, ITU, allocations now forbid any emissions in these bands, World Radiocommunications Conference (WRC)-19 Resolution 731 sets out a framework for such possible sharing [7].)

In all four of these cases, the fundamental issue of new wireless communications use of the band in question depends on finding a cost-effective and reliable way to prevent harmful interference from the new spectrum use to the incumbent spectrum use. The first three examples involve possible interference to nearby, but not adjacent, bands and *in theory* might be solved by improving the frequency selectivity of the incumbent users. But in practical communications systems, it is not always possible or practical to make such upgrades in incumbent systems in a timely way. Indeed, for the same theoretical reason that transmitters cannot be strictly band limited by a "brick wall filter," receiver selectivity also cannot be strictly band limited, and efforts to limit bandwidth sometimes introduce new complications.

MIMO and massive MIMO were introduced for several purposes and have many benefits, but reducing interference to other spectrum uses was not a primary goal for this technology. Both of these technologies use multiple antenna elements where the phase and often the amplitude of the radiated signal in each element is adjusted to maximize a desired goal, such as the signal-to-noise ratio at the intended receiver so to maximize the throughput at that receiver. An objective function relating the goal to antenna element phases and amplitudes is formed, and then an algorithm adjusts the phases and amplitudes to maximize the desired goal.

More complex objective functions could be used to both maximize a desired communication system goal and to control interference to other spectrum users by limiting the radiated power in directions that are problematic to interservice interference. This will require more degrees of freedom than traditional MIMO systems have, so they must either have an increased number antenna elements or be massive MIMO. In general, commercial telecommunications systems are omnidirectional in azimuthal coverage, but have limited required elevation angle ranges, generally near the horizontal plane. Attention is spent by designers on ensuring coverage of the desired service area, but much less attention is devoted to designing elevation angle profiles.

There is usually no incentive to a telecom operator to limit their elevation range to only what is necessary in bands where there are neither sharing problems with cochannel nor tight beamwidth regulation nor nearby band users entitled to protection. In these cases, without an incentive to limit elevation range of emitted power, the emissions in directions where they are not needed are what economists call an "externality" [8], meaning there is no economic incentive to minimize them even though they may be harmful to others.

In the Ligado case, the main potential for interference comes from high signal strengths in an anulus around the tower supporting the antenna. Such high signal strengths in such an area have no tangible benefit to the operation of the transmitter and results from antenna sidelobes at negative elevation angles that could be suppressed with MIMO technology. The other three cases all involve high positive elevation angle emissions from communications transmitters that could impact the other radio service involved. (The 100–252 GHz case was discussed in more detail in the previous column here, and the sharing potential results in part from the large atmospheric absorption loss at such frequencies for low elevation angle paths to satellites) [9].

Exploring this technical approach to facilitate spectrum sharing and resolving challenging nearby band interference issues require activity by both the technical community and the spectrum policy community because there is a "chicken or egg" issue here. Developers usually develop technology to use bands that have been established with allocations and technical rules. Spectrum policy authorities in individual countries and at ITU usually make allocations based on technology that is proven or at least well understood. The use of MIMO or massive MIMO to reduce emissions in directions where they might threaten other radio services while also enabling large data rates and reliable communications channels is not a topic that has been explored in the literature. However, it is this type of new approach to solve spectrum sharing problems that could enable a bold increase in the amount of spectrum that is available for wireless communications without adversely impacting incumbent users or forcing their relocation, which is not possible in the case of passive satellites since their input frequencies correspond to atom resonances. Use of MIMO-like technologies could alleviate these contentious spectrum issues, and thus should be of interest to both the wireless communications R&D and spectrum policy communities.

References

[1] A. Puglielli *et al.*, "Design of Energy- and Cost-Efficient Massive MIMO Arrays," *Proc. IEEE*, vol. 104, no. 3, Mar. 2016. DOI: 10.1109/JPROC.2015.2492539.
[2] F. Akyildiz and J. M. Jornet, "Realizing Ultra-Massive MIMO Communication in the (0.06–10) Terahertz band," *Nano Commun. Networks J.*, Elsevier, vol. 8, Mar. 2016, pp. 46–54.
[3] https://www.gps.gov/spectrum/ligado/; https://ligado.com/press/ligado-networks-statement-retain-gps-act/.
[4] M. J. Marcus, "5G/Weather Satellite 24 GHz Spectrum Disagreement: Anatomy of a Spectrum Policy Issue," *IEEE Wireless Commun.*, vol. 26, no. 4, Aug. 2019, pp. 2–3. DOI: 10.1109/MWC.2019.8809651.
[5] https://www.5gandaviation.com/; https://www.alpa.org/resources/aircraft-operations-radar-altimeter-interference-5G.
[6] https://csps.aerospace.org/sites/default/files/2021-08/BracingForImpact_0.pdf.
[7] ITU WRC-19, Resolution 731, 2019; https://www.itu.int/dms_pub/itu-r/oth/0C/0A/R0C0A00000F00149PDFE.pdf.
[8] T. K. Forde and L. E. Doyle, "Exclusivity, Externalities & Easements: Dynamic Spectrum Access and Coasean Bargaining," *2007 2nd IEEE Int'l. Symp. New Frontiers in Dynamic Spectrum Access Networks*, 2007, pp. 303–15; https://www.imf.org/external/pubs/ft/fandd/basics/external.htm. DOI: 10.1109/DYSPAN.2007.48.
[9] M. J. Marcus, "6G Spectrum Policy Issues Above 100 GHz," *IEEE Wireless Commun.*, vol. 28, no. 6, Dec. 2021, pp. 7–8. DOI: 10.1109/MWC.2021.9690484.

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