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February 11, 2014

Via Electronic Filing

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, S.W., Room TW-A325
Washington, D.C. 20554

Re: ***Ex Parte:*** *Policies Regarding Mobile Spectrum Holdings*, WT Docket No. 12-269

Dear Ms. Dortch:

Sprint Corporation ("Sprint") respectfully submits the following proposal for a weighted spectrum screen in the above-captioned proceeding. In soliciting comment on necessary revisions to the Federal Communications Commission's current spectrum holdings policies, the Commission specifically requested input on whether it should distinguish among spectrum bands to reflect their varying impact on competition.[1] Along with a number of other commenters,[2] Sprint encouraged the Commission to adopt a weighting mechanism, revising the screen to incorporate significant variation in the utility of the wide range of frequency bands now available for mobile broadband networks.[3]

Pursuant to Section 1.1206 of the Commission's rules, this letter is being electronically filed with your office. Please let me know if you have any questions regarding this filing.

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[1] *Policies Regarding Mobile Spectrum Holdings*, Notice of Proposed Rulemaking, 27 FCC Rcd 11710, ¶¶ 36-39 (2012) ("*Spectrum Aggregation NPRM*").

[2] *See, e.g.*, Comments of Free Press, WT Docket No. 12-269, at 11 (Nov. 28, 2012) ("But today this simplistic method [of treating all spectrum bands equally] ignores the large differences in value and utility between bands like 700 MHz and BRS…If the Commission maintains a case-by-case evaluation approach, it has the flexibility and the duty to consider the difference in value between spectrum blocks, which is determined by wavelength, contiguous block size, block pairing, interference issues, market density, and market demographics.").

[3] Comments of Sprint Nextel Corporation, WT Docket No. 12-269, at 11-13 (Nov. 28, 2012); Reply Comments of Sprint Nextel Corporation, WT Docket No. 12-269, at 16-19 (Jan. 7, 2013).

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Respectfully submitted,

/s/ Lawrence R. Krevor
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Attachment

Sprint's Competition-Based Framework

For A Weighted Wireless Broadband Spectrum Screen

February 11, 2014

WT Docket No. 12-269

Sprint's Competition-Based Framework

For A Weighted Wireless Broadband Spectrum Screen

Executive Summary

In initiating a comprehensive review of its policies governing mobile spectrum holdings in September 2012, the Federal Communications Commission ("Commission") observed that in the decade since its last comprehensive review, wireless operators of all sizes, public interest groups and other interested parties have expressed concern that the Commission's spectrum screen needs revision. In particular, the Commission noted changes in technology, spectrum availability, and the marketplace that might affect firms' access to spectrum – and by extension on the competitive effects of any firm's acquisition of spectrum on the downstream market for mobile wireless services.

Spectrum represents a vital, irreplaceable input for the provision of mobile wireless services. To maintain robust competition in the market for these services, the Commission has sought to ensure, by applying its spectrum screen, that no firm's concentration of this input inhibits the ability of other firms to competitively respond to an attempted exercise of market power. Unfortunately, as a wide range of commenters have noted, the spectrum screen *has not* kept up with intervening changes since the Commission's last comprehensive review. Most notably, the screen's singular focus on bandwidth (the *amount* of commercial wireless spectrum, measured in raw megahertz, available for mobile wireless services by each provider) critically fails to reflect how firms actually acquire and deploy spectrum to provide mobile broadband services. While bandwidth continues to be a relevant consideration in an operator's decision to acquire particular spectrum, the single most important factor affecting the cost to deploy and operate spectrum in a particular band is its propagation.

The purpose of the screen is to analyze whether a particular spectrum acquisition undermines the ability of competing firms to swiftly and effectively enter the market or expand output in mobile

broadband services in response to another firm's attempt to exercise market power. The mere availability of *some* spectrum, irrespective of band, has little effect on the competitive response ability of such firms. The economics of deployment matter: the varying costs of deployment between bands directly affect the feasibility, timeliness, and effectiveness of a carrier's ability to compete.

In this filing, Sprint proposes a framework and methodology for replacing the current spectrum screen with a competition-based screen. This proposal responds to the Commission's ongoing proceeding to review the spectrum screen; the framework advanced herein does not supersede the calls by Sprint and a wide range of other commenters in the Commission's parallel Incentive Auction proceeding to adopt reasonable limits on the amount of 600 MHz spectrum an operator can acquire. Sprint's proposal incorporates weighting factors to account for known conditions that directly impact the competitive utility of different commercial broadband spectrum bands, thereby accounting for the fact that spectrum bands vary considerably in their competitive utility. Sprint's proposal would weight spectrum based on the cost to deploy and operate using that band, recognizing the reality that low-band spectrum is typically significantly more cost-effective to deploy than higher-frequency spectrum. This weighting is based on detailed engineering analysis and recognizes the varying utility of different bands across urban, suburban and rural environments. It also accounts for the existing spectrum holdings of a carrier planning to acquire additional spectrum in determining whether the proposed acquisition requires a more in-depth local market competitive analysis. Sprint also proposes ways to treat bands currently excluded from the screen, and offers a flexible and reliable methodology for adding future commercial broadband spectrum bands.

In summary, Sprint's competition-weighted spectrum screen proposal provides a robust framework for evaluating the impact of future spectrum acquisitions on competition and competitors' ability to respond, bringing the spectrum screen back to its original analytical mooring and public policy purpose.

Table of Contents

I. Introduction

Over one year ago the Commission released a Notice of Proposed Rulemaking to reexamine its policies regarding mobile spectrum holdings.[1] In the year since, over one hundred responsive filings have been submitted, including over a dozen economic and engineering studies examining the Commission's spectrum aggregation policies, both generally and in the context of the upcoming incentive auction. Sprint Corporation ("Sprint") has closely followed developments in this proceeding, thoroughly examining the record and evaluating the claims made by various parties – including operators, public interest organizations, advocacy groups, economic experts, and industry associations.

The weight of the record reveals broad consensus that the current spectrum screen is critically flawed; it also reveals overwhelming support for screen refinements that will more accurately evaluate the impact of a proposed spectrum acquisition on competition. While the Commission's overall spectrum holdings policies are broader than the spectrum screen alone, the screen represents a key tool with which the Commission performs its statutory obligations to promote wireless competition and prevent excessive concentration of licenses.[2] In formulating its spectrum holdings policies, the Commission has consistently focused on the ways that

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[1] *Policies Regarding Mobile Spectrum Holdings*, Notice of Proposed Rulemaking, 27 FCC Rcd 11710 (2012) ("*Spectrum Aggregation NPRM*").

[2] *See, e.g., 2000 Biennial Regulatory Review Spectrum Aggregation Limits for Commercial Mobile Radio Services*, Report and Order, 16 FCC Rcd 22668, ¶ 54 (2001) ("*Spectrum Cap Sunset Order*") ("The public policy objectives [of promoting pro-competitive ends] that we first articulated in 1994 with respect to review of CMRS spectrum acquisitions remain applicable today. Although we decide today that the spectrum cap rule is no longer necessary in the public interest, we must still achieve the objectives that the spectrum cap was intended to promote.")

spectrum – an essential, irreplaceable input in the provision of mobile wireless services – "affect[s] the structure, conduct, and performance" of competing providers.[3]

Historically, the Commission's spectrum screen analysis has concentrated on only a single facet of the spectrum holdings input: bandwidth, as expressed in raw megahertz. Over the past few years, however, significant changes in the wireless product market, consumers' needs and expectations, Commission spectrum allocation decisions and the wireless industry itself have radically undermined the soundness of the Commission's exclusive focus on bandwidth in evaluating spectrum inputs. The antitrust-based principle animating the Commission's spectrum aggregation inquiry remains valid; *i.e.*, ensuring that competing firms retain the ability to enter a market or expand output swiftly and effectively in response to one or more firms' attempt to exercise market power.[4] Nevertheless, focusing only on general spectrum availability as expressed by bandwidth no longer provides useful evidence on the state of the market and, specifically, the ability of firms to competitively respond to attempts to exercise market power.

Bandwidth represents only a single factor influencing the ability of a firm to effectively compete in the mobile wireless market. To accurately assess the level of competition within the mobile wireless marketplace (and the ability of firms to effectively respond to attempted

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[3] *See, e.g., Implementation of Section 6002(B) of the Omnibus Budget Reconciliation Act of 1993, Annual Report and Analysis of Competitive Market Conditions with Respect to Mobile Wireless including Commercial Mobile Services*, Notice of Inquiry, 24 FCC Rcd 11357, ¶ 24 (2009); *Wireless Telecommunications Bureau Seeks Comment on the State of Mobile Wireless Competition*, Public Notice, 25 FCC Rcd 8416, 8430 (2010); *Wireless Telecommunications Bureau Seeks Comment on the State of Mobile Wireless Competition*, Public Notice, 26 FCC Rcd 15595, 15607 (2011); *Wireless Telecommunications Bureau Seeks Comment on the State of Mobile Wireless Competition*, Public Notice, 28 FCC Rcd 7305, 7309 (2013).

[4] *See, e.g., Spectrum Cap Sunset Order* ¶ 39 (Explaining the adoption of antitrust principles in the Commission's evaluation of the impact of spectrum on the state of competition within CMRS markets); *Applications of AT&T Wireless Services, Inc. and Cingular Wireless Corporation For Consent to Transfer Control of Licenses and Authorizations*, Memorandum Opinion and Order, 19 FCC Rcd 21522, 21576 ¶¶ 134-137 (2004) ("*AT&T-Cingular Order*") (As explained by the Commission in its initial formulation -- and first utilization -- of the spectrum screen, the extent to which rival carriers have comparable service coverage and excess spectrum capacity (or ability to acquire additional spectrum) dictates whether a dominant firm can successfully exercise market power. Specifically, the "possibility of competitive response" is tied to the ability of competing firms to add *capacity*.)

exercises of market power), the Commission's screen must reflect the way in which industry participants actually evaluate, acquire and deploy spectrum in their networks. Counting raw megahertz fails to do so.

In other words, the Commission's spectrum screen can no longer be insensitive to the specific characteristics of different frequency bands available to operators to provide wireless broadband communications services. The spectrum screen must account for the propagation characteristics of different frequency bands and their effectiveness (*i.e.*, utility) in satisfying subscriber demand in varying network operating environments to be an accurate and useful tool for predicting the impacts of spectrum additions by one party on downstream mobile wireless competition. These factors directly and substantially affect the economics of using particular spectrum bands to provide mobile broadband services and therefore the competitive impact of proposed spectrum aggregation, whether by Commission auction or secondary market transaction.

II. History: The Commission Adopted Its Original Spectrum Cap to Make Spectrum Available for Competitive Voice Networks

The fact that the spectrum screen (and the spectrum cap before it) only considers raw bandwidth in assessing competition reflects the fact that the mobile wireless marketplace was far simpler during the early years of the wireless industry than it is today. The Commission's contemporary spectrum holdings policies trace their lineage to the Commission's efforts to promote competition between services that were viewed as substitutable and generally competitive.[5] The "three radio services" included in the Commission's original spectrum cap –

[5] As the Commission explained in devising an appropriate framework for analyzing competition in the emerging CMRS market in its original *Spectrum Cap Order*, this antitrust-inspired approach focused on products or services whose "reasonable interchangeability" enabled similar customer uses and needs. The relevant customer

cellular, Enhanced Specialized Mobile Radio (ESMR) and broadband Personal Communications Services ("PCS") – came to offer nearly identical voice services on a local basis.[6] While the *services* were based in distinct spectrum bands, they quickly became generally substitutable, particularly as the original cellular operators integrated PCS spectrum into their networks. The logical regulatory extension of the substitutability of these voice-centric services was to treat the spectrum underlying them as essentially indistinguishable for spectrum cap/competitive analysis purposes.[7]

Thus, the Commission's initial spectrum aggregation policy, manifested in the spectrum cap and the PCS-cellular cross-ownership rule,[8] ensured that incumbent cellular and ESMR

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uses and needs in this inquiry were "two-way voice communication" and paging. *Implementation of Sections 3(N) and 332 of the Communications Act Regulatory Treatment of Mobile Services,* 9 FCC Rcd 7988, ¶¶ 57-60 (1994) ("*Spectrum Cap Order*").

[6] *Implementation of Sections 3(N) and 332 of the Communications Act Regulatory Treatment of Mobile Services,* 9 FCC Rcd 7988, ¶¶ 261-261 (1994) ("*Spectrum Cap Order*").

[7] Notably, one of the only exceptions to this approach under the spectrum cap was the Commission's initial treatment of SMR spectrum used by ESMR operators. Though the Commission found the services overwhelmingly substitutable with existing cellular (and impending PCS) services, the Commission did note that the specific regulatory and licensing "encumbrances" of the SMR band significantly undermined the extent to which the spectrum could be deployed and operated in a competitive way as compared to cellular and PCS spectrum. These impediments to the "wide-area" licensing/deployment of SMR spectrum prompted the Commission to originally count no more than 10 megahertz of SMR spectrum in a market even though an operator could theoretically be licensed for more than double that amount. Similarly, as described below, a revised spectrum screen, that accurately assesses the competitive impact of a spectrum band by taking into account its propagation characteristics and its cost of deployment and operation in varying demand scenarios, must also take into account regulatory and legacy use encumbrances that distinguish similarly encumbered spectrum (such as the 2.5 GHz EBS and BRS bands) from unencumbered bands.

[8] The Commission's earliest policies were service-specific: In 1991 the Commission adopted what was in effect a cap on the amount of cellular spectrum a licensee could have in a cellular service area. Specifically, the cellular cross-ownership rule prohibited an entity with a controlling interest in one of the two cellular licenses in a geographic area from having more than a five percent direct or indirect ownership interest in the other licensee. This rule was eliminated for the more competitive Metropolitan Statistical Areas (MSAs) in 2001. With the introduction of the PCS band, the Commission established additional service-specific limitations on a carrier's attempt to aggregate PCS spectrum (prohibiting broadband PCS licensees from holding more than 40 megahertz in a given area), and broader cross-ownership limitations (prohibiting cellular licensees from holding more than 10 megahertz of PCS spectrum in their existing cellular service areas). These service-specific and cross-ownership limits related to the PCS band were eliminated in 1996, with implementation of a general 45 megahertz CMRS spectrum cap (adopted in 1994, covering cellular, PCS and SMR spectrum), though the cellular cross-interest rule remained in effect until 2004 for less competitive Rural Service Areas (RSAs).

operators could not stymie emergence of entirely new providers in the new PCS spectrum band.[9] With pro-competitive auction rules to promote new entrants and a large allocation of new spectrum for commercial wireless use (120 megahertz), the PCS band provided a bedrock for innovation and competition in voice services during the 1990s – a sharp contrast to the spotty coverage, large and unwieldy handsets, lackluster call quality and prohibitively expensive service that prevailed during the period when the cellular duopoly was the only commercial mobile competition in a market.[10]

The paradigm of relatively undifferentiated spectrum inputs for commercial wireless services has, however, been radically undermined over time. With the introduction of a wide range of new bands (AWS-1, WCS, 700 MHz, 2.5 GHz, AWS-4, and the G Block expansion to the PCS band), varying significantly in their suitability and utility for mobile broadband services, wireless carriers no longer view spectrum as an undifferentiated input. These new bands – and the timing of their introduction – present complex business decisions for carriers assembling a spectrum portfolio.[11] The consequence of these spectrum additions was magnified as the

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[9] *See Spectrum Cap Order*, ¶¶ 260-261 ("The effect of permitting unlimited aggregation of SMR and PCS spectrum could be an increase in the concentration of spectrum available for cellular-type services and a reduction in the number of potential providers, thus diminishing opportunity for more diverse ownership of mobile wireless spectrum… An entity controlling both SMR and PCS spectrum might use all their spectrum to take advantage of economies of scale and scope, which would be in the public interest. It is also possible, however, that they might seek to accumulate spectrum in order to limit entry by other providers and gain a headstart over their cellular competitors and other new entrants moving into PCS.").

[10] *See, e.g.* Jonathan E. Nuechterlein and Philip J. Weiser, Digital Crossroads at 268 (2007); Stephanie N. Mehta, "Cellular Evolution," Fortune, August 23, 2004. *Available at*: http://money.cnn.com/magazines/fortune/fortune_archive/2004/08/23/379399/index.htm

[11] One notable example of the ways in which introducing new bands – and the timing of their availability – can have important impacts for the ability of carriers to assemble competitive spectrum portfolios can be seen in the AWS-1 auction. With pent-up demand for additional capacity and "uncertainty over the potential 700 MHz band auctions," carriers like T-Mobile opted to actively participate in the auction of (and, upon winning, aggressively clear) the AWS-1 band, diverting capital resources away from participation in the subsequent 700 MHz auction. *See* Scott Fox and Jeffrey Walkenhorst, "Mobile Broadband in the Americas: Momentum Building in the AWS Band," Report Prepared for the GSM Association, at 15 (May 2009), *available at* http://www.gsma.com/spectrum/wp-content/uploads/2012/07/Spectrum-Momentum-Building-AWS-Band-English.pdf. (This view is corroborated by

relevant product market changed radically during the decade between the Commission's introduction of the spectrum screen and reappraisal of the product market in two major transactions in 2011 and 2012.

A. The Changing Product Market

The Commission's analysis of conditions within the spectrum input market has always served as a "partial proxy measure of competition" in the output market of mobile wireless communications services that it is "principally concerned" about.[12] This analytical framework undoubtedly reflected – and was in fact framed around – the relevant product market during this era: mobile voice services (with, from a spectrum holdings perspective, undifferentiated spectrum bands supporting voice service). Indeed, as recently as late-2008 the screen exclusively defined the relevant product market as "mobile telephony service." It was not until 2008's *Verizon-ALLTEL Order* that the Commission revised its product market definition to reflect a combined "mobile telephony/broadband services" market.[13] Moreover, as the Commission notes in the *Spectrum Aggregation NPRM*, it was not until the *AT&T-Qualcomm* (2011) and *Verizon Wireless-SpectrumCo* (2012) transactions that the Commission "recognized the growing importance of mobile broadband services and focused its analysis to an increasing degree on mobile broadband services."[14]

Kathleen Ham, Vice President, Federal Regulatory, T-Mobile. *See* Donny Jackson, "T-Mobile exec gives carrier's perspective on D Block debate," Urgent Communications (June 10, 2010), *available at* http://urgentcomm.com/policy-amp-law/t-mobile-exec-gives-carriers-perspective-d-block-debate)

12 *Spectrum Cap Order*, ¶ 27.

13 *Applications of Cellco Partnership D/B/A Verizon Wireless and Atlantic Holdings LLC for Consent to Transfer Control of Licenses, Authorizations, and Spectrum Manager and De Facto Transfer Leasing Agreements*, Memorandum Opinion and Order and Declaratory Ruling, 23 FCC Rcd 17444, ¶¶ 45-46 (2008) ("*Verizon-ALLTEL Order*").

14 *Spectrum Aggregation NPRM*, at ¶ 24.

The timing of the Commission's redefinition of the relevant product market is noteworthy when considering the underlying spectrum inputs used to support these services. By 2008, mobile wireless *telephony* had reached a level of penetration and consumer dependence that it effectively competed with – and often entirely replaced – wireline voice services. For example, in 2001, the Commission observed that "mobile telephony services have begun to compete with wireline services" – noting a recent survey indicating that three percent of mobile wireless subscribers rely on wireless "as their only phone."[15] By 2008, the Centers for Disease Control estimated that roughly 15% of adults lived in households with only wireless telephone service. By mid-2012, however, that figure had risen to 34% and continues to grow, as illustrated in Figure 1 below.[16] According to Commission estimates, the number of wireline connections dropped by over 52 million lines from 2008 to 2012.[17]

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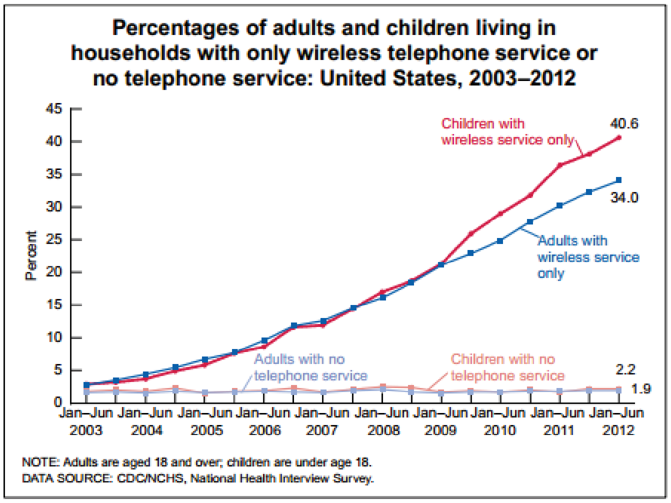
[15] *Spectrum Cap Order*, ¶ 36.

[16] Stephen J. Blumberg, Ph.D. & Julian V. Luke, "Wireless Substitution: Early Release of Estimates from the National Health Interview Survey, January-June 2012," Centers for Disease Control (rel. Dec. 2012), *available at* http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201212.pdf

[17] *Compare Local Telephone Competition: Status as of June 30, 2008*, Report, Wireline Competition Bureau (July 2009) (total lines: 154M) *and Local Telephone Competition: Status as of June 30, 2012*, Report, Wireline Competition Bureau (June 2013) (total lines: 101M).

Figure 1



Another notable aspect of the Commission's 2008 redefinition of the wireless product market is the extent to which it coincides with the introduction and rapid adoption of smartphones and mobile broadband devices. Representative of the time, the first generation iPhone lacked 3G capability in its U.S. release in the summer of 2007 (with a broadband-capable iPhone introduced in mid-2008). Since that time, however, broadband-capable smartphones have revolutionized the mobile wireless industry. A mere 10% of mobile subscribers had smartphones in 2008; by 2013, at least 64 percent of mobile subscribers were smartphone users.[18] The range of broadband-enabled applications and services supported by smartphone and mobile broadband devices such as tablets means that the majority of mobile wireless traffic now occurs indoors.[19] As AT&T CEO Randall Stephenson has said, "The iPhone mobilized the

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[18] *See, e.g.*, Chris Quick, "With Smartphone Adoption on the Rise, Opportunity for Marketers is Calling, The Nielsen Company, (Sept. 15, 2009), *available at* http://www.nielsen.com/us/en/newswire/2009/with-smartphone-adoption-on-the-rise-opportunity-for-marketers-is-calling.html (depicting 2008 smartphone penetration); "Smartphone Switch: Three-Fourth of Recent Acquirers Chose Smartphones," The Nielsen Company, (Sept. 17, 2013), *available at* http://www.nielsen.com/us/en/newswire/2013/smartphone-switch--three-fourths-of-recent-acquirers-chose-smart.html (presenting 2013 figures).

[19] *See, e.g.*, "Femtocells- A Natural Solution for Offload," Femtoforum (rel. June 2010), *available at* http://www.4gamericas.org/documents/016+Femtocells+Natural+Solution+for+Offload%5B1%5D.pdf (citing an estimate that 55% of mobile wireless usage occurs in the home and 26% occurs in the office); "Cisco Service

Internet."[20] With this mobilization of Internet capabilities, mobile service offerings changed dramatically, reflecting shifting consumer expectations and demands.

Stated differently, the spectrum cap and spectrum screen reflected regulatory concerns developed when wireless service was predominately an itinerant *voice* communications service connecting people as they moved *between* locations. Reflective of the way mobile voice services were utilized during the 1980s and early 1990s, devices were frequently referred to as "car phones."[21] Today, however, wireless services are increasingly data-intensive and are expected to work everywhere: in the car, at home, in the office, in the field or deep within the Empire State Building.[22] The reliance on wireless for ubiquitous Internet broadband connectivity cannot be understated; as the Commission has noted, feature phones and smartphones serve as the primary means of internet access for many underserved communities.[23] This remarkable shift in

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Provider Wi-Fi," Cisco, (2012), *available at* http://www.cisco.com/en/US/solutions/collateral/ns341/ns524/ns673/solution_overview_c22-642482.pdf (claiming that "close to 80 percent" of mobile data usage occurs indoors).

[20] Randall Stephenson, "Squawk Box," CNBC (Jan. 13, 2014), *available at* http://video.cnbc.com/gallery/?video=3000233539

[21] Elif Sinanoglu, "You Make the Call with Cellular Phone Plans," Money Magazine, Oct. 26, 1995, *available at* http://articles.chicagotribune.com/1995-10-26/business/9510260012_1_cell-phone-monthly-service-charges ("If you plan to use a portable phone only in your car, as many safety-conscious buyers apparently do, consider getting a car phone (also known as a mobile phone) instead.")

[22] This increasing focus on broadband – and radical change in the way voice services are provisioned – is typified by the shift of all four nationwide carriers to plans offering unlimited voice and messaging. Whereas previously operators had vigorously competed with plans offering varying, metered levels of voice minutes and messages per month, voice and text services (while important to ubiquitous mobile wireless offerings) today represent only a small part of the total mobile wireless plan a consumer purchases. *See* Thomas Gryta, "AT&T's Plan Revamp Signals the End of Voice Minutes," Digits – Wall Street Journal (Oct. 25, 2013), *available at* http://blogs.wsj.com/digits/2013/10/25/atts-new-phone-plans-signal-the-end-of-voice-minutes/

[23] National Broadband Plan, Recommendation 9.6 (2010) ("Although home broadband adoption (of wireline or fixed wireless technology) is lower for African Americans and Hispanics, these groups are relatively heavier users of mobile Internet. Although African Americans and Hispanics are as likely as other demographic groups to own a cell phone (85% do), they are more likely to have ever accessed the Internet on a mobile handheld device."; *See also* Kathryn Zickuhr & Aaron Smith, "Digital Differences" Pew Internet (April 13, 2012), *available at* http://www.pewinternet.org/Reports/2012/Digital-differences/Main-Report/The-power-of-mobile.aspx (indicating

consumers' use of and expectations for wireless communications capabilities has radically changed the way operators build their networks, including their choice of spectrum bands over which to offer service in a particular location or environment. As a result, the operational attributes of a carrier's spectrum portfolio have profound competitive consequences in an era of near-ubiquitous mobile broadband connectivity and must be integrated into the Commission's spectrum aggregation/spectrum screen competitive analysis.

B. The Spectrum Screen Does Not Reflect the Evolving Wireless Product Market or Wide Range of Commercial Mobile Spectrum Allocations

As a consequence of the expanded product market described above, a wireless carrier's ability to provide the applications and services its subscribers expect depends not on the mere *quantity* of spectrum it controls, but also on the mix of spectrum bands it can access. As the Commission has acknowledged in each of its last three *Wireless Competition Reports* (as well as the instant NPRM), a licensee's "*particular mix of spectrum holdings may affect its ability to provide efficient mobile wireless service*."[24] Most notably, "Given the superior propagation characteristics of spectrum under 1 GHz, particularly for providing coverage in rural areas and inside buildings, providers whose spectrum assets include spectrum below 1 GHz may possess

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that the percentage of Black/Hispanic smartphone users "who go online mostly using their cell phone" is 38% -- 19% higher than for Whites).

[24] *Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, Annual Report and Analysis of Competitive Market Conditions with Respect to Mobile Wireless, including Commercial Mobile Services*, WT Docket No. 11-186, Sixteenth Report, at ¶ 127 (2013) ("*Sixteenth Report*"); *See also Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, Annual Report and Analysis of Competitive Market Conditions with Respect to Commercial Mobile Services*, Fifteenth Report, 26 FCC Rcd 9664, 9837 ¶ 297 (2011) ("*Fifteenth Report*"); *Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, Annual Report and Analysis of Competitive Market Conditions with Respect to Commercial Mobile Services*, Fourteenth Report, 25 FCC Rcd 11407, 11573 ¶ 273 (2010) ("*Fourteenth Report*") (emphasis added).

certain competitive advantages for providing robust coverage when compared to licensees whose portfolio is exclusively comprised of higher frequency spectrum."[25]

These statements indicate that while the Commission has developed a more sophisticated understanding of why carriers seek to acquire, deploy and operate spectrum in different bands, it has not yet incorporated that understanding into the spectrum screen.[26] The Commission's recognition of a more nuanced product market (composed of combined services with different operational requirements) should lead the Commission to acknowledge the ways in which the wireless broadband input market – and specifically the spectrum input market – has become more complex and differentiated to support those services.

III. A Carrier's "Particular Mix" of Spectrum Holdings Directly Influences Its Competitive Positioning and Must Be Incorporated in a Revised Spectrum Screen

A carrier's "particular mix" of spectrum has a direct and substantial effect on its costs to deploy and operate a network – which in turn critically influences its ability to "swiftly and efficiently" provide a new service or expand service in response to a competitor's attempted exercise of market power. As carriers have assembled portfolios of spectrum in distinct band combinations, with an embedded base of devices and network equipment supporting those specific combinations, the mere availability of spectrum in *some* band is not – in and of itself – determinative of a carrier's ability to respond competitively. The distinct propagation

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[25] *Sixteenth Report*, ¶ 135.

[26] In a number of recent transactions the Commission has stipulated that it will "examine more closely" acquisitions of spectrum below 1 GHz given the "competitive effects" of sub-1 GHz spectrum. *See Applications of AT&T Inc., Cellco Partnership D/B/A Verizon Wireless, Grain Spectrum, LLC, and Grain Spectrum II, LLC For Consent to Assign and Lease AWS-1 and Lower 700 MHz Licenses*, Memorandum Opinion and Order, WT Docket No. 13-26, at ¶ 36 (rel. Sept. 3, 2013); *See also Applications of AT&T Inc. and Atlantic Tele-Network, Inc. for Consent to Transfer Control and Assign Licenses and Authorizations*, Memorandum Opinion and Order, WT Docket N0. 13-54 (rel. Sept. 20, 2013); *Application of AT&T Inc. and Qualcomm Inc.*, Order, 26 FCC Rcd 17589, 17608-11 ¶¶ 46-51 (2011). As described below, for the very reasons the Commission cites for 'closer examination,' the competitive differences inherent in spectrum below 1 GHz should be reflected in a revised screen.

characteristics of spectrum bands significantly affect the non-price rivalry between carriers, most prominently seen in the differences in coverage and in-building penetration facilitated by low-band spectrum.[27] The effectiveness of a particular band for enabling such a competitive response – or for foreclosing a competitive response – can only be evaluated in reference to the critical characteristics affecting the cost to deploy and operate a particular band: most notably propagation, but also any distinct regulatory encumbrances, interference risks and the availability of equipment and devices.

Thus, one of the most notable misconceptions about spectrum underlying the current outmoded spectrum screen is the implicit supposition that, as an undifferentiated input, available spectrum is simply something carriers 'plug in' to their networks and utilize. While this view might have effectively reflected industry dynamics for the initial "greenfield" wireless network deployments some 20 years ago, utilizing new spectrum in today's technically diverse and geographically large networks requires extensive planning and cost analysis. The actual cost to deploy and operate a particular band – and even the timeliness of doing so, which can vary by band – directly affects the competitive ability of a carrier in the downstream market. The availability and cost of equipment is another key factor impacting the cost to deploy and operate using a particular band.

To be sure, some of the cost involves planning and development. If the spectrum involved is an entirely new allocation, its use will first require standardization by a telecommunications standards body such as the Third Generation Partnership Project (3GPP), the international standards body that develops technical specifications for bands utilizing advanced

[27] For purposes of discussion in this document, we consider low-band spectrum to include commercial wireless bands on frequencies below 1 GHz, mid-band spectrum to include commercial wireless bands on frequencies between 1 GHz and 2.2 GHz, and high-band spectrum to include commercial wireless bands on frequencies above 2.2 GHz.

broadband radio access technologies like LTE.[28] This standards process can be time-consuming and is vulnerable to strategic behavior by carriers and manufacturers seeking to take advantage of the process. To some extent, these considerations can be captured in the Commission's determination of whether a particular spectrum band is "suitable and available" for mobile broadband use (prerequisites for inclusion in the spectrum screen).[29] As the Commission indicates, however, the current screen does not take into account "economic or technical justifications that would warrant modifying the criteria we use to determine the suitability and availability of spectrum" – for instance, "factors such as channel size, potential interference issues, or conditions that may develop after the allocation and licensing of spectrum (such as technological developments that affect the timely deployment of services)."[30]

Standards-setting aside, the ability to cost-effectively deploy service using a particular band is driven in large part by the spectrum bands a carrier already has. The decision to deploy service on a new band must confront the economic reality that a carrier already has deployed extensive cell sites and a base of consumer devices supporting its existing mix of bands. The cost and time of adding new hardware to each cell site, developing devices to support a new band, adding new transmission sites if today's tower deployment doesn't provide adequate coverage with the new frequency band, and seeding the customer base with new devices all

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[28] The creation – and growing importance – of 3GPP represents another way in which the mobile wireless industry today bears little resemblance to that of 2003. At that time, 3GPP focused predominantly on the development of a harmonized 3G standard (GSM) – a policy which the Commission explicitly disavowed in permitting the utilization of competing and incompatible 3G standards. (*See AT&T-Cingular Order*, ¶ 64: "Under the Commission's policy of affording carriers flexibility with regard to the choice of technological standards (unlike the policy in Europe and other areas), the deployment of competing second-generation ('2G') and next-generation network technologies has emerged as an important dimension of non-price rivalry among U.S. mobile telephony carriers.") Today, however, as carriers uniformly converge on LTE for their 4G (and beyond) technologies, 3GPP has garnered a more prominent role in the industry.

[29] *Spectrum Aggregation NPRM*, ¶ 26.

[30] *Id.* at ¶ 128.

affect the overall cost of any spectrum band's deployment and utilization – potentially prohibitively so. Even if these costs are manageable, carriers – especially smaller carriers – must still confront the fact that the decision to support an additional band within a smartphone or mobile broadband device is in large part driven by device manufacturers, which increasingly try to limit the variability of bands included in devices to minimize cost.[31] Further, carriers have an economic and engineering interest in minimizing the number of bands they must use nationwide to provide service. As former FCC Chief Technologist and Assistant Director of the White House Office of Science and Technology Policy (OSTP) Jon Peha notes, reducing the number of bands "reduces the frequency of handovers and the corresponding performance cost. Thus, carriers will seek to acquire spectrum in the same frequency nationwide."[32]

In its filing in the instant proceeding, the Department of Justice articulates much of the complexity – and the regulatory necessity – of accurately identifying the competitive import of carriers acquiring additional spectrum in different spectrum bands. DOJ notes that the competitive utility and effectiveness of any band depends on multiple factors, each profoundly influential in the market for spectrum inputs, such as:

- the availability of network equipment and consumer devices for the band (*i.e.*, both the network infrastructure and device ecosystems)

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[31] *See* Kevin Fitchard, "Making a T-Mobile iPhone is harder than it sounds," GigaOm (Jan. 16, 2012), *available at* http://gigaom.com/2012/01/16/making-a-t-mobile-iphone-is-harder-than-it-sounds/ ("Vendors like Apple simply can't slap a new antenna into a handset and start shipping. There's about a $1 cost per device when adding a new band, which isn't small in the low-margin world of handsets… 'It boils down to a simple business decision,' Matsumori said. 'Will these guys give me enough volume to justify the expense?'" Fitchard also notes that "Apple insists on doing a single SKU whenever possible" and that the "fragmentation of LTE into dozens of bands across the world and within the U.S. will create a big dilemma for handset vendors who will be forced to pick and choose which LTE bands they can feasibly support in a single device. The biggest impact of those choices will be felt by the smaller carriers who don't have the clout of Verizon to get devices made for their LTE networks.")

[32] Professor Jon M. Peha, Carnegie Mellon University, "Cellular Competition and the Weighted Spectrum Screen," *2013 Telecommunications Policy Research Conference*, at 9 (September 2013), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2241276.

- the presence of band classes that add weight and cost to consumer devices
- the degree of a band's international harmonization
- interference risk
- unique, unusual or atypical regulatory obligations
- propagation differences.[33]

As explained above, the underlying purpose of the spectrum screen has been to prompt the Commission to consider intervening in markets where a transaction leaves an operator's competitors insufficient accessible spectrum to effectively and swiftly respond to market power. By focusing only on raw megahertz of bandwidth, however, it can completely miss the mark.[34] By contrast, a screen that takes into account propagation and other competitive factors would make explicit the social and competitive costs of undue spectrum concentration in certain spectrum bands. This would enable the Commission to more effectively assess the competitive impact of proposed spectrum aggregation transactions and better assure a competitive distribution of spectrum resources.

[33] *Ex Parte* Submission of the United States Department of Justice, WT Docket No. 12-269, at 13 (filed April 11, 2013).

[34] Though the screen should be sensitive to market forces that could obviate the need for regulatory intervention, the Commission should not presume that the current screen (or cosmetic changes to it) facilitates pro-competitive outcomes. In fact, precisely the opposite is true: by treating each megahertz as indistinguishable for competitive purposes regardless of band, the existing screen has arguably incentivized dominant firms to pursue further concentration of low-band spectrum – particularly given the NPRM's proposal that any holdings running afoul of a revised spectrum holdings policy would be 'grandfathered.' *Spectrum Aggregation NPRM,* at ¶ 36. This fundamentally forecloses rival carriers from assembling their own necessary mix of spectrum bands.

IV. A Screen That Weights Spectrum According to its Effectiveness and Utility For Wireless Broadband Will Accurately Identify the Competitive Impact of Proposed Spectrum Aggregation

Sprint respectfully submits that the least intrusive regulatory approach to updating the effectiveness and accuracy of the Commission's spectrum screen is to develop spectrum weights that reflect the varying competitive impact of different bands. A spectrum screen that makes explicit the competitive consequences of carriers' spectrum aggregation decisions will promote competition and the public interest.[35] In this way, the Commission can provide a predictable and minimally intrusive policy framework that permits carriers to acquire additional spectrum *in a way that facilitates procompetitive outcomes and promotes the public interest*. By making the social cost of concentration of competitively-impactful spectrum an explicit and consequential aspect of the proposed acquisition, a weighted screen would in effect ensure operators are fully internalizing the negative externalities of their business decisions. This attention to social cost – in essence, the negative externalities of particular economic behavior, such as excessive concentration of competitively-critical low-band spectrum – comports well with the Commission's public interest responsibilities.

[35] In a large sense this framework mirrors a classic Pigouvian response to market failure. Specifically, the social cost of accumulation of competitive impactful low-band spectrum is not accurately captured in the price operators pay to acquire these licenses (either in monetary terms or in their regulatory treatment) – particularly when, by treating all bands as commensurable, an operator can accumulate ever more low-band spectrum while divesting less competitively-impactful higher-frequency spectrum to come under the screen. The negative externality of this market failure – shaped predominantly by a spectrum screen that fails to recognize the distinct competitive impact of different bands – is reduced competition (with associated effects in less innovation, higher prices, and reduced consumer choice). Rather than imposing a financial tax on operators to account for this uncovered social cost, however, a weighting system would instead make operators account for this social cost by assigning greater weights to competitively-impactful spectrum bands. In effect, this represents a classic "nudge" within a "choice architecture" – that is altering behavior "in a predictable way without forbidding any options or significantly changing their economic incentives." Richard H. Thaler & Cass R. Sunstein, *Nudge: Improving Decision About Health, Wealth and Happiness*, at 6 (2008). A weighted screen would thus permit carriers to acquire additional low-band spectrum, but it would alert them in advance that their acquisition decisions have important competitive consequences – and continued concentration of competitively-impactful low-band spectrum may as a consequence limit the amount of mid- and high-frequency spectrum they can acquire.

A properly weighted spectrum screen would fundamentally recognize that a competitive downstream market for mobile wireless services encourages firms to have a mix of differentiated low-, mid-, and high-band spectrum inputs. As a consequence, should a carrier with significant low-band spectrum wish to acquire additional licenses, the Commission's review of the effect of that acquisition would acknowledge the significant competitive advantages that carrier already enjoys based on its existing holdings of low-band spectrum. Because any new low-band allocations (for instance, the 600 MHz band) would be weighted to reflect their greater competitive utility, carriers with considerable amounts of sub-1 GHz spectrum would be disincentivized, if not prevented, from acquiring additional low-band spectrum simply to *foreclose* rival carriers from that critical input. In other words, because a carrier with extensive low-band holdings would be forced to consider divesting relatively commensurable amounts of its existing low-band spectrum (or correspondingly *larger* amounts of its higher-frequency holdings – potentially depriving it of maintaining a competitive mix of bands), the cost of acquiring new low-band spectrum would more closely reflect its utility and not exogenous factors, such as its foreclosure value.[36]

To the extent that carriers with considerable low-band resources pursued additional spectrum, the relatively greater weights attributed to their low-band licenses would prompt them

[36] As the Department of Justice explained in the context of its filing in the instant proceeding, incumbents with a concentration of low-band spectrum licenses will assign a supra-competitive value (a "foreclosure value") to spectrum over and above its "use value." This "private value" – which "does not reflect the consumer value" – is, effectively, an additional social cost borne by consumers (in the form of reduced competition, with associated costs of reduced innovation and higher prices). *Ex Parte* Submission of the United States Department of Justice, WT Docket No. 12-269, at 10-11 (filed April 11, 2013). By permitting such incumbents to acquire additional competitively impactful low band spectrum *only at the cost* of relinquishing an equal value of existing low-band spectrum (injecting an equal amount of low-band spectrum in the market for competitors) or relatively *larger* amounts of higher-frequency spectrum (potentially uneconomical given carriers' need for a mix of spectrum bands to effectively provide service) carriers with substantial portfolios of low-band spectrum would be unlikely to assess a particular low-band spectrum acquisition by reference to its "value of keeping spectrum out of competitors' hands" – such an acquisition, whether from divesting an equal amount of low-band spectrum or proportionately higher amount of higher-frequency spectrum, would in effect result in putting the same or (for bands with less utility) *more* spectrum in competitors hands.

to weigh divestiture of some of their existing low-band or mid-band licenses in order to expand their portfolios. This result would mean not only that carriers will have fully internalized the competitive costs of aggregating competitively impactful low-band spectrum, but also could produce pro-competitive outcomes through divestitures or transactions that enable all interested firms to obtain a competitive mix of differentiated spectrum inputs to sustain long-term effective competition.[37]

A. *Propagation is the Most Important Factor in Assigning Spectrum Weights to Assess Competitive Impact*

In the attached Appendix, Dr. Kostas Liopiros – founder and principal of the Sun Fire Group, with over 30 years of experience in broadband wireless and spectrum issues – demonstrates that the propagation characteristics of a particular band serve as the most significant factor affecting the cost to deploy and operate that spectrum in a wireless network and thus its competitive utility. Notably, these characteristics include the attenuation of radio signals as they travel through space, which determines the maximum range and coverage of a cell site, and the ability of radio signals to penetrate objects such as exterior walls, which determines coverage inside buildings. Because coverage and building penetration decrease with increasing

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[37] Objections to such revisions on the basis of arguments that future spectrum needs might change, altering the competitive utility of particular bands, adduce precisely the rationale for *adopting* a weighting approach: the problem with the current screen is that it *has not* kept up with market dynamics, thereby reducing substantially its ability to diagnose competitive harms from concentration in the spectrum input market. While a weighting system involves a novel, more refined approach to the screen, in no way does that render it inflexible to future changes. Indeed, to the extent a revised screen is explicitly focused on more fluid dynamics that impact the cost to deploy and operate particular bands (and thus that impact the competitive ability of firms), the Commission can adjust the weights to reflect any future changes. Further, the law does not require the Commission to achieve absolute perfection in formulating such rules and policies, especially in circumstances such as this where a spectrum screen is simply an instrument for identifying spectrum transactions requiring closer competitive inquiry. *See, e.g.*, *Vonage Holdings Corp. v. FCC*, 489 F.3d 1232, 1242 (D.C. Cir. 2007) (noting that "[p]erfection, however, is not what the law requires" when the Commission formulates a rule); *WorldCom, Inc. v. FCC*, 238 F.3d 449, 462 (D.C. Cir. 2001) ("The relevant question is whether the agency's numbers are within a 'zone of reasonableness,' not whether its numbers are precisely right.") (citation and internal quotation marks omitted); *see also Cablevision Systems Corp. v. FCC*, 649 F.3d 695, 717 (D.C. Cir. 2011) ("We generally defer to an agency's decision to proceed on the basis of imperfect scientific information, rather than to invest the resources to conduct the perfect study.") (citation and internal quotation marks omitted).

frequency, spectrum below 1 GHz has advantages in providing service over a wide-area, including inside buildings, at considerably lower cost than higher frequency spectrum – an important factor in designing networks to provide ubiquitous or near-ubiquitous coverage over the large land mass of the United States. The propagation characteristics of higher-frequency spectrum also offer certain competitive advantages in specific circumstances. The greater attenuation of these signals permits greater frequency re-use, allowing more cell-splitting in very dense urban areas producing greater capacity for more customers in a small area.

Contrary to some assertions,[38] the relative advantages between lower and higher frequency bands are not equivalent. As the Commission has acknowledged, carriers need a *mix* of low and high frequency bands to effectively and economically deploy broadband service across large (and variable) geographic areas. The consequences of *not having* such a mix are not symmetrical as between a carrier with significant high-frequency spectrum but little or no low-frequency spectrum, and a carrier with significant low-frequency spectrum but little or no high-frequency spectrum. For example, one of the advantages associated with the propagation characteristics of higher-frequency bands (notably, greater frequency reuse ability in dense urban areas, potentially providing greater capacity) can be accomplished with lower-frequency spectrum through conventional techniques such as reduced power and antenna downtilt. By contrast, the advantages associated with low-band spectrum – effective wide-area coverage and in-building penetration – cannot be replicated by an operator in higher band spectrum without the

[38] *See* Declaration of William H. Stone, Executive Director of Network Strategy, Verizon, at ¶¶ 7-13, *attached to* Reply Comments of Verizon Wireless, WT Docket No. 12-269 (January 7, 2013); Michael L. Katz, Philip A. Haile, Mark A. Israel, and Andreas V. Lerner, "Comment on the Submission of the U.S. Department of Justice Regarding Auction Participation Restrictions" (June 13, 2013) ("KHIL DOJ Comment") and Michael L. Katz, Philip A. Haile, Mark A. Israel, and Andreas V. Lerner, "Comments on Appropriate Spectrum Aggregation Policy with Application to the Upcoming 600 Auction" (June 13, 2013) ("KHIL Supplemental Reply"), *attached to* Letter from David L. Lawson, Sidley Austin LLP, Counsel to AT&T, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 12-268, WT Docket No. 12-269 (filed June 13, 2013).

devotion of significantly higher capital resources. Thus, as former FCC Chief Economist Jonathan Baker has observed, the "cost penalty for providing service without using a mix of spectrum frequencies is likely to be particularly high for providers with limited use of low-frequency spectrum."[39]

As Professor Peha notes, the lower cost to acquire higher-frequency spectrum does not make up for the enormous investments and disproportionately higher operating costs necessary to replicate the coverage of low-band spectrum. An operator with a portfolio of spectrum disproportionately comprised of higher-frequency spectrum must either "spend much more deploying and operating its infrastructure" (passing these costs on to customers in the form of "significantly higher prices" – and thus reducing the carrier's competitiveness) or "it can provide service that covers highways and population centers but that is not ubiquitous which means significantly 'lower quality.'"[40]

This latter point – that to replicate the service of carriers with low-band spectrum competing firms with predominantly (or only) higher-frequency spectrum will either incur enormous costs that are passed on to consumers or constrain their output – is the very crux of the antitrust principle underlying the existence of a spectrum screen. To the extent that competing firms are foreclosed from access to competitively impactful low-band spectrum, they must either raise prices or limit output – two clear examples of an *inability* to effectively counteract an attempted exercise of market power.

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[39] Jonathan B. Baker, "Further Comments on Spectrum Auction Rules That Foster Mobile Wireless Competition," at 3, *attached to* Letter from Howard J. Symons, Mintz Levin, Counsel to T-Mobile US, Inc., to Marlene H Dortch, Secretary, FCC, GN Docket No. 12-268, WT Docket No. 12-269 (filed Aug. 2, 2013).

[40] Jon M. Peha, "Bringing Weight to the Spectrum Screen: A Response to AT&T," WT Docket No. 12-269, at 4 (filed March 31, 2013).

B. Sprint's Proposed Spectrum Weights for a Revised Spectrum Screen

As described in the Appendix, Dr. Liopiros derives spectrum weights for each band in the spectrum screen based on their propagation characteristics and the corresponding costs to deploy in three typical wireless broadband network environments: low population density rural areas, medium population density suburban areas, and high population density urban areas. Dr. Liopiros describes how the propagation attenuation of each band varies as a result of physical and demand factors in each environment. Table 1, below, sets forth the relative cost to deploy spectrum for each environment and each band. Table 1 also provides the resulting relative spectrum weights Dr. Liopiros derived for each of the commercial mobile spectrum bands currently included in the spectrum screen for each of the three environments. The spectrum weight in a band and environment is the inverse of the cost to deploy in that same band and environment (*i.e.*, the higher the cost to deploy in a band and environment, the lower the competitive value or utility of that band).[41]

[41] The Commission has proposed to adjust the existing spectrum screen by removing the 700 MHz D block, which has been reallocated for public safety use, and to reduce the amount of 800 MHz ESMR spectrum within the screen to 14 megahertz. See *Spectrum Aggregation NPRM*, at ¶ 29. Table 1 assumes these changes will be made.

Table 1

Relative Costs and Spectrum Weights*						
Band	Relative Costs			Spectrum Weights		
	Rural	Suburban	Urban	Rural	Suburban	Urban
Lower 700 MHz	0.72	0.78	0.89	1.39	1.28	1.12
Upper 700 MHz	0.88	0.91	0.96	1.14	1.10	1.05
800 MHz (ESMR and Cellular)	1.00	1.00	1.00	1.00	1.00	1.00
AWS-1	4.33	2.97	1.69	0.23	0.34	0.59
PCS	5.11	3.36	1.79	0.20	0.30	0.56
WCS	7.69	4.55	2.07	0.13	0.22	0.48
BRS	10.15	5.59	2.29	0.10	0.18	0.44
*Relative costs refers to the costs to deploy and operate a wireless network in one frequency band as compared to the costs to deploy and operate a wireless network in the 800 MHz Band (ESMR and Cellular).						

Applying the spectrum weights to modify the total megahertz available in each band for commercial wireless network use (and to the spectrum holdings of carriers proposing to acquire additional spectrum) produces a far more meaningful and accurate assessment of the real world competitive consequences of a proposed aggregation than the Commission's current spectrum screen.[42] These proposed weights account for the band-dependent factors that determine the impact of a carrier obtaining additional spectrum on wireless competition; *i.e.*, on whether competing firms retain the ability to enter a market or expand output swiftly and effectively in response to one or more firms' attempt to exercise market power.

Table 1 is based on commonly used, real world propagation models, as described in the Appendix, which can vary based on environment. Dr. Liopiros' analysis indicates that, for example, in an urban environment a wireless operator using 2.5 GHz BRS spectrum would have

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[42] Sprint proposes continuing to use the one-third benchmark for determining whether additional competitive analysis is necessary. Consequently, if the proposed aggregation would exceed one-third of the total available spectrum, as calculated using the Table 1 spectrum weights, the Commission would conduct a more in-depth competitive analysis just as it does today in cases when the screen is exceeded.

to deploy approximately two and one-half times the number of base stations as would an operator deploying Lower 700 MHz spectrum to achieve comparable indoor coverage. This reflects the relatively improved utility of higher band spectrum in high-density environments, although still requiring more capital and operating expenditures to achieve comparable coverage to an urban low-band deployment. In rural environments, however, a 2.5 GHz operator would have to deploy up to 15 times the number of sites a Lower 700 MHz operator would need to achieve comparable coverage, highlighting the substantially higher utility of low-band spectrum in rural environments.

While the disparity in deployment costs between 2.5 GHz and the Lower 700 MHz band in an urban environment may be somewhat offset by the greater reuse potential of 2.5 GHz spectrum to create additional capacity, a carrier attempting to provide nationwide or near-nationwide coverage without low-band spectrum will forever suffer a cost disadvantage in both initial deployment costs and ongoing operating costs in relation to a carrier with a robust low-band portfolio. Using the spectrum weights in Table 1 would assure that the spectrum screen identifies transactions in which a carrier's acquisition of spectrum in a particular band – whether by Commission auction or in the secondary market – would result in anticompetitive concentration by highlighting the impact of proposed spectrum aggregation on competitors and their ability to respond to an attempted exercise of market power.

With the proposed weighted spectrum screen, the competitive value or utility of a spectrum band for competitive analysis purposes is simply the product of the spectrum weight and the bandwidth. Table 2 provides the revised spectrum screen inputs by applying an average spectrum weight, reflecting the approximate distribution of rural, suburban, and urban population in the country, to the raw spectrum totals in each band.[43]

Table 2

Averaged Weighted Spectrum Screen*			
Band	**Current Screen**	**Average Weight**	**Averaged Screen**
Lower 700 MHz	48.0 MHz	1.28	61.4 MHz
Upper 700 MHz	22.0 MHz	1.10	24.2 MHz
800 MHz ESMR	14.0 MHz	1.00	14.0 MHz
800 MHz Cellular	50.0 MHz	1.00	50.0 MHz
AWS-1	90.0 MHz	0.35	31.5 MHz
PCS	130.0 MHz	0.31	40.3 MHz
WCS	20.0 MHz	0.23	4.6 MHz
BRS	55.5 MHz	0.20	11.1 MHz
Total	429.5 MHz		237.1 MHz
Total Low-band	134.0 MHz		149.6 MHz
One-third total	143.2 MHz		79.0 MHz
*For purposes of this analysis, we have included two changes to the screen that the Commission has proposed: dropping the inclusion of the 700 MHz D Block and reducing the amount of 800 MHz ESMR spectrum from 26.5 megahertz to 14 megahertz.			

These average screen weights can be used to evaluate whether a proposed transaction would exceed the one-third screen trigger at the local level. For example, consider a hypothetical wireless licensee determining whether it could purchase 12 megahertz of Lower 700 MHz spectrum in a particular county. The hypothetical licensee currently holds 25 megahertz of 800 MHz cellular, 10 megahertz of AWS-1, and 30 megahertz of PCS spectrum. The following table shows the relevant calculations, which indicate that the proposed transaction would not trigger the spectrum screen.

[43] See Appendix for further discussion on the calculations used to approximate population distributions. Most markets (which are typically analyzed at the county level) are likely to contain portions that are rural, suburban, and urban. Using an averaged approach would avoid unnecessary complexity, including potentially divergent screen thresholds in markets encompassed within a single EA, REAG, or BTA.

Table 3

Spectrum Screen Calculations									Weighted Total (Weighted Trigger= 78.8)
	700 MHz	Weighted 700 MHz	Cellular	Weighted Cellular	AWS-1	Weighted AWS-1	PCS	Weighted PCS	
County A Holdings	12 MHz	(1.28*12)= **15.4 MHz**	25 MHz	(1.00*25)= **25.0 MHz**	10 MHz	(.35*10)= **3.5 MHz**	30 MHz	(.31*30)= **9.3 MHz**	**53.2 MHz**

As a second example, consider another hypothetical wireless licensee deciding whether it could purchase 12 megahertz of Lower 700 MHz spectrum in a particular county. The hypothetical licensee currently holds 50 megahertz of 800 MHz cellular, 20 megahertz of AWS-1, and 30 megahertz of PCS spectrum. The following table shows the relevant calculations, which indicates that the proposed spectrum screen trigger level would be exceeded, primarily because the licensee already holds a large amount of low-band spectrum, thereby requiring a more detailed competitive analysis for that geographic area.

Table 4

Spectrum Screen Calculations									Weighted Total (Weighted Trigger= 78.8)
	700 MHz	Weighted 700 MHz	Cellular	Weighted Cellular	AWS-1	Weighted AWS-1	PCS	Weighted PCS	
County B Holdings	12 MHz	(1.28*12)= **15.4 MHz**	50 MHz	(1.00*50)= **50.0 MHz**	20 MHz	(.35*20)= **7.0 MHz**	30 MHz	(.31*30)= **9.3 MHz**	**81.7 MHz**

Exceeding the screen might persuade the hypothetical licensee not to purchase the 700 MHz spectrum (effectively keeping that competitively-impactful low-band spectrum available to other operators), prompt the licensee to sell an equivalent amount of its significant cellular holdings (producing the same result) in order to consummate the transaction without greater regulatory scrutiny, or, if no greenfield higher-frequency spectrum is available, prompt the licensee to pursue mutually-beneficial transactions with another licensee in the area that has considerable higher-frequency spectrum, but a relative dearth of low-band spectrum. Even eschewing these options, the licensee could decide to proceed with the transaction, triggering the screen and prompting the more rigorous competitive analysis (in which the Commission might conclude that given other competitive factors in the area, the additional spectrum aggregation is permissible).

The current screen, as shown in the Table 5, would have not have been triggered by this transaction even though the licensee would hold almost half of the high utility low-band spectrum in the market. The proposed weighted approach, unlike the current screen, better identifies the true competitive impact of a proposed spectrum increase by assessing the utility of that increase in the context of the carrier's overall spectrum portfolio and the distribution of spectrum among its competitors.[44]

Table 5

Spectrum Screen Calculations (based on current screen)					Unweighted Total (Trigger =143.2)
	Unweighted 700 MHz	Unweighted Cellular	Unweighted AWS-1	Unweighted PCS	
County B Holdings	**12 MHz**	**50 MHz**	**20 MHz**	**30 MHz**	**112 MHz**

V. Inclusion of Additional Spectrum Bands

Sprint anticipates that the Commission's revision to its spectrum holdings policies will add a number of additional bands, or portions of bands, to its revised spectrum screen. In particular, the AWS-4 band (2000-2020/2180-2200 MHz) appears ripe for inclusion as it can be

44 Thus, using Sprint's proposed weighted screen does not prohibit any economic behavior by the licensee; it does, however, force the licensee to fully internalize the competitive costs of its proposed low-band spectrum transaction. That is, while the current screen would not have been triggered – allowing the carrier to impose on others a social cost associated with lessened competition – the weighted screen would make explicit the competitive significance of the proposed transaction, thereby prompting the carrier to fully internalize the competitive consequences of its behavior, as exemplified by the four hypothetical responses described above.

used to provide competitive broadband services as soon as equipment is available.[45]

Similarly, the Commission may consider including additional BRS spectrum under the screen. Currently, only 55.5 megahertz of BRS spectrum is included under the screen (2618-2673.5 MHz, which includes BRS channels BRS-2, E1, E2, E3, F1, F2, F3, H1, H2, and H3). The screen did not include BRS-1 (2496-2502 MHz), which is located at the lower end of the combined 2.5 GHz BRS/EBS band and is shared with Mobile Satellite Service (MSS) operations. It also does not include BRS channels F4 and E4 (2602-2614 MHz), since these channels are located in the mid-band portion of the 2.5 GHz BRS/EBS band and were often used for high power video distribution (and thus less usable for mobile broadband). Sprint continues to believe that BRS-1 should not be included under the spectrum screen, primarily because its usability is limited by Globalstar's existing MSS operations on the same channel. Nonetheless, Sprint does not object to adding BRS channels F4 and E4 to the screen since these channels are now more routinely available for mobile broadband use.

Similarly, the H-Block (1915-1920/1995-2000 MHz), AWS-3 (potentially 1695-1710 MHz and 1755-1780/2155-2180 MHz), and 600 MHz spectrum in the upcoming incentive auction should also be added to the screen once service rules have been finalized and auctions have been conducted. The framework set forth in the Appendix can be used to develop spectrum weights for each of these bands, and revised weighted spectrum screen numbers can be developed as each band is added.

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[45] Sprint recognizes, however, that DISH has been granted authority under its recent waiver to decide whether to use the 2000-2020 portion of the AWS-4 spectrum for either uplink or downlink. That flexibility is under DISH's control and thus provides no basis for not adding AWS-4 to the screen. *DISH Network Corporation Petition for Waiver of Sections 27.5(j) and 27.53(h)(2)(ii) of the Commission's Rules and Request for Extension of Time*, Memorandum Opinion and Order, DA 13-2409, WT Docket No. 13-225 (WTB rel. Dec. 20, 2013).

A. Consideration of 2.5 GHz Educational Broadband Service (EBS) Spectrum for Inclusion in the Spectrum Screen

The 2.5 GHz band appears to offer a large quantity of mostly-contiguous spectrum suitable for wireless broadband use. The usability of the EBS portion of the 2.5 GHz band is limited, however, by regulatory, propagation and legacy licensing realities that significantly complicate its utility for wireless broadband communications. For example, EBS channels are generally available for licensing only to educational entities, and commercial operators have to obtain a lease from the EBS licensee to use the spectrum. EBS channels are generally narrow in bandwidth (5.5 megahertz or 6 megahertz depending on the portion of the band), and several channels need to be aggregated in order to have sufficient spectrum to provide a typical 20 megahertz wide unpaired broadband channel. The Commission rules also require that an EBS licensee reserve at least five percent of the capacity of each EBS channel for the EBS licensee's educational use. Moreover, EBS licensed service areas are not based on geographic boundaries but instead on distance from a transmitter location. This results in comparatively small, irregularly shaped coverage areas and significant amounts of "white space" where many if not all of the EBS channel blocks are not licensed at all, thereby compromising a commercial lessee's ability to aggregate adjacent channels to create a 10 or 20 megahertz block for efficient, wide-area LTE use.

While developments within the BRS portion of the 2.5 GHz band warrant inclusion of additional BRS spectrum in the spectrum screen, ample public interest justification as well as Commission precedent exists for continuing to exclude EBS spectrum. For example, in its decision to include only 10 megahertz of SMR spectrum under the original spectrum cap, the Commission made a number of observations about the SMR band that distinguished it from the cellular and PCS bands. These differences, which impacted the ability and cost of SMR licensees to deploy and operate their systems, also impacted the extent to which SMR operators could "compete effectively with cellular and PCS."[46] Notably, the Commission observed that "regulatory obstacles" – including burdensome licensing procedures, difficulty assembling contiguous blocks, potentially conflicting adjacent operations that could result in interference, and complicated (and in some cases non-contiguous) service areas – distinguished the band from cellular and PCS spectrum.[47]

To the extent that regulatory or interference factors distinguish a particular band – *e.g.*, increasing the cost of deployment and operation or otherwise hampering its "suitability" or "availability" for mobile broadband – those factors should be included in the Commission's analysis of the impact of particular spectrum inputs on downstream competition (the very objective of the spectrum screen). These competition-impacting features could be used as additional quantitative corrective factors within a revised spectrum screen or in addition to the weighting framework. The Commission recently recognized this principle in determining that only 20 megahertz of the 30 megahertz-wide WCS allocation should count towards the spectrum screen, given the need for the major WCS licensee to use part of the WCS spectrum as guard bands to prevent interference between satellite radio and paired WCS spectrum on either side of the satellite radio DARS allocation.[48]

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46 *Spectrum Cap Order*, ¶ 95.

47 *Id.*, ¶¶ 270-275.

48 What the Commission did not do, however, is account for the propagation characteristics of the WCS 2.3 GHz spectrum, as it treated a megahertz of WCS spectrum as comparable to a megahertz of far more useful 700 MHz spectrum or 1.9 GHz PCS spectrum. *See Applications of AT&T Mobility Spectrum LLC, New Cingular Wireless PCS, LLC, Comcast Corporation, Horizon Wi-Com, LLC, NextWave Wireless, Inc., and San Diego Gas & Electric Company for Consent to Assign and Transfer Licenses*, Memorandum Opinion and Order, WT Docket No. 12-240, ¶ 31 (rel. Dec. 18, 2012). The weighted spectrum screen proposal contained herein would address that deficiency.

Sprint respectfully submits that advocates for including the 2.5 GHz EBS channels in the spectrum screen have failed to demonstrate that, given all of the competitive encumbrances discussed herein, EBS spectrum is "suitable and available" and should be counted in the screen. If, however, the Commission chooses to include EBS spectrum in a revised screen, it should take into account that these encumbrances affect the utility of EBS spectrum for competitive broadband use in ways that are not fully accounted for by the spectrum weighting methodology proposed herein. Accordingly, the following section discusses additional corrective factors that should apply to counting EBS channels for spectrum screen purposes in addition to the propagation and environmentally-derived weighting factors proposed for the 2.5 GHz band. These additional factors should be incorporated in the Commission's spectrum screen so that it more accurately identifies both the competitive response of incumbent 2.5 GHz spectrum licensees to incremental spectrum aggregation by a competitor, as well as the extent to which 2.5 GHz spectrum enables a licensee to compete with licensees of other commercial broadband spectrum bands.[49]

[49] Until very recently, the Lower 700 MHz A Block also served as a salient example of how various encumbrances associated with a particular spectrum license limited its competitive impact – distinguishing it even from spectrally-adjacent licenses. Though spectrally similar to the other blocks in the Lower 700 MHz (and Upper 700 MHz) Band and featuring paired 6 MHz allocations directly adjacent to the Lower 700 MHz B and C Blocks – the Lower 700 MHz A Block has starkly different utility as a competitive input. For one, the Lower A Block abuts a television broadcast allocation, which while frozen for new licensing, has been an operational obstacle for Lower A Block licensees. A considerably more insuperable obstacle, however, has been the introduction by 3GPP of E-UTRA Band 17, divorcing the A Block from its otherwise spectrally-similar B and C Block neighbors Yet under the spectrum screen a megahertz of A Block spectrum has been treated the same as a megahertz of B or C Block spectrum for competitive analysis purposes. The additional cost borne by Lower 700 MHz A Block licensees – and perhaps more importantly the critical delay in deploying a competitive service – illustrates how regulatory and interference factors can impact a band's competitive utility. A more nuanced screen that acknowledged these competitive differences might have included an adjustment factor for Lower 700 MHz A Block spectrum, giving it a lower weight than adjacent Lower 700 MHz B and C Block licenses. This adjustment factor could have been reduced – and eventually eliminated – in conjunction with the Commission's efforts to solve interoperability within the band. *See Promoting Interoperability in the 700 MHz Commercial Spectrum and Requests for Waiver and Extension of Lower 700 MHz Band Interim Construction Benchmark Deadlines*, WT Docket Nos. 12-69, 12-332, Report and Order and Order of Proposed Modification (rel. Oct. 29, 2013). In light of these developments, the proposed weighting criteria developed by Dr. Liopiros does not differentiate the Lower 700 MHz A Block from other spectrum within the Lower 700 MHz band.

B. Deriving a Spectrum Weight for the 2.5 GHz EBS Spectrum

If the Commission decides to add the 2.5 GHz EBS spectrum to its spectrum screen, it should adopt additional corrective factors that accurately adjust its competitive utility and value in relation to other broadband spectrum. In other words, the spectrum weight of this band should be calibrated to account for the unique encumbrances carrier-lessees face in deploying it.[50]

First, as Sprint has described previously, the EBS band is usually only licensed to educational entities, with availability for commercial services only on an excess-capacity, leased basis requiring eligible educational entities to retain *at least* five percent of the system's capacity for their educational mission. As the Commission noted in its *Fifteenth Report*, "the primary purpose of EBS is to further the educational mission of accredited public and private schools, colleges, and universities."[51] These leases are subject to periodic renegotiation rights that can significantly increase the cost of leased spectrum access. Lease obligations can also be subject to a wide range of special restrictions that are "designed to maintain the primary educational character of service provided."[52] Such encumbrances on the operational use and business continuity of EBS spectrum must also be factored into any weighting.

Second, the Commission needs to accurately assess (and exclude) the amount of unlicensed "white space" in any examined competitive market area. Specifically, because EBS

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[50] In addition, although the Commission reconfigured the 2.5 GHz band with the intent of making paired license assignments possible on either side of the mid-band segment, in practice its licensing regime makes pairing lower-band segment EBS channels with upper band segment BRS channels impractical because the coverage of geographically-licensed BRS stations typically does not match the site-licensed coverage of EBS stations. This regulatory and legacy licensing disconnect between BRS and EBS spectrum prevents upper-lower band pairing and requires unpaired, bi-directional transmission technology instead of the typical paired channels available in most other spectrum screen bands.

[51] *Id.* at ¶ 218 n.815. Some EBS licensees negotiate lease agreements that reserve a considerably greater percentage of spectrum capacity, retain one or more complete channels for their own educational use, or allow licensees to recapture their spectrum at any time during the lease term to meet those needs, which might warrant an even greater discount.

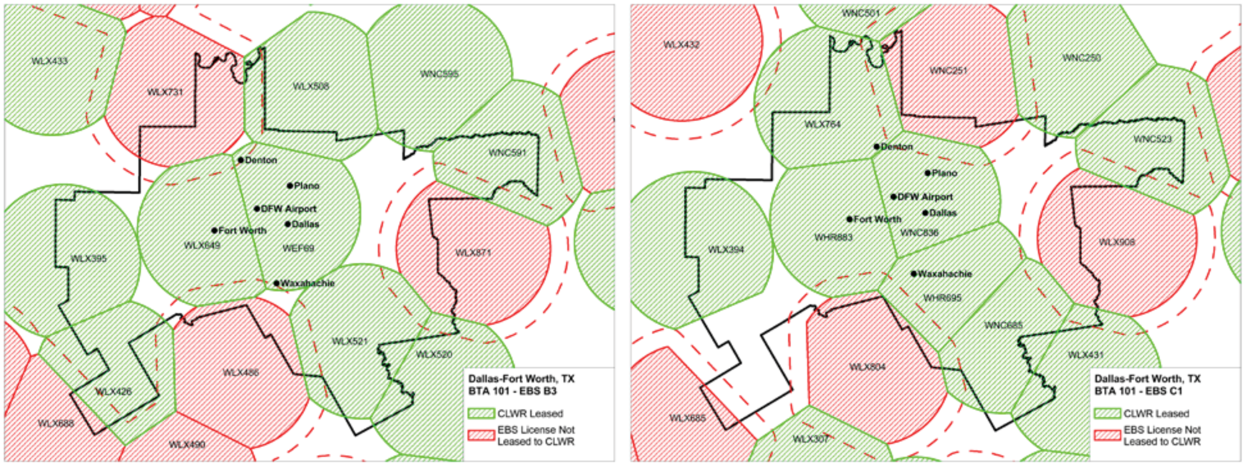
[52] *Fifteenth Report* ¶ 218 n.815.

is licensed using irregularly shaped licensing areas centered around transmitter locations that can vary by channel, significant portions of EBS white space exists within most markets. Unlicensed areas (*i.e.*, unassigned EBS "white spaces") are unusable for (and complicate) commercial deployment.[53] Unlike other commercial mobile bands, in which carriers can assemble geographically contiguous and predictable spectrum licenses to integrate in their networks, EBS spectrum presents complex (and at times insuperable) deployment obstacles to providing reliable, wide-area coverage.

For example, the following maps show the EBS leases that cover adjacent EBS channels B-3 and C-1 in the Dallas-Ft. Worth area. The black line shows the BTA licensing area that applies for BRS licenses in the area. The green areas represent the service areas covered by EBS leases held by Sprint (formerly Clearwire). Some EBS licenses (shown in red) are simply not available to Sprint under a lease and cannot be used. Other areas (shown in white) have no EBS license at all; this "white space" cannot be used. Under EBS rules, site placement is restricted near non-leased licenses in order to avoid interference (shown by dashed red lines).

[53] *Fifteenth Report* ¶ 281 n. 815; *Sprint Nextel Corporation and Clearwire Corporation; Applications for Consent to Transfer Control of Licenses, Leases, and Authorizations,* Memorandum Opinion and Order, 23 FCC Rcd 17570, ¶ 71 (2008) ("*Sprint Nextel-Clearwire Order*"); *Applications of Cellco Partnership d/b/a Verizon Wireless and Atlantis Holdings LLC for Consent to Transfer Control of Licenses, Authorizations, and Spectrum Manager and De Facto Transfer Leasing Arrangements and Petition for Declaratory Ruling*, Memorandum Opinion and Order and Declaratory Ruling, 23 FCC Rcd 17444, ¶ 67 (2008).

Figure 2



Thus, a commercial operator attempting to serve the entire Dallas-Ft. Worth BTA would be unable to use each EBS channel to supplement that coverage in large parts of the BTA due to the obstacle of unlicensed white space. Twelve EBS licenses overlap the BTA area on each channel, so a commercial operator might have to sign twelve leases just to use a single EBS channel over the non-white space areas in the BTA. Each of these EBS channels covers only 5.5 megahertz of bandwidth, however, and commercial operators will want to deploy, for example, a 20 megahertz unpaired channel to provide broadband service. Accordingly, a commercial operator intending to use EBS spectrum to provide broadband service would need to reach agreements with EBS licensees that hold licenses on four adjacent channels. This can be complicated because the size and location of EBS license geographic service areas on adjacent channels do not align, as shown on these maps.

Given the complexity involved in calculating white spaces (which would require a survey of each geographic area, with wide variability in the prevalence of white spaces between these areas) – and the effect the eventual figure would have on the numerator included in the screen in a specific geographic area, impacting all other carriers in their acquisitions – the Commission should consider adopting a uniform EBS white space discount nationwide to assure administrative practicability and regulatory certainty. Sprint has conducted a detailed, channel-by-channel study of EBS white space and has found that across all EBS channels, an average of approximately 16.5% of the population in the United States and Puerto Rico is located in EBS white space.[54] Thus, for purposes of administrative simplicity and regulatory certainty, Sprint respectfully submits that the Commission should discount the total amount of EBS spectrum that would be included under the screen by 16.5% and apply that factor across all market areas to prevent over-attributing EBS spectrum to a lessee (and the licensee) that would result from including EBS "white space" in a revised spectrum screen analysis.[55]

Third, as the preceding maps illustrate, EBS licenses and locations of licenses can vary on a channel-by-channel basis, requiring numerous leases to be obtained just to offer, for example, a 20 megahertz unpaired LTE channel. This requires additional refinements to the spectrum screen or to the subsequent competitive analysis when a transaction exceeds the screen trigger, to reflect the fact that EBS spectrum can only be effectively used for mobile broadband where it can be aggregated to larger channels. High frequency spectrum, and in particular EBS spectrum, is primarily useful for providing broadband capacity to consumers. However, EBS channels are licensed with just 5.5 megahertz or 6 megahertz bandwidth.

54 This study was conducted by overlaying 5.5 million census block locations containing population with existing EBS license contours. The amount of nationwide white space population varies on a channel-by-channel basis from 14.5% to 18.5%. The nationwide percentage of population in EBS white space is lower in the Top 100 Cellular Market Areas (6.8%), and actual population in EBS white spaces varies depending on the market and channel.

55 The amount of EBS white space could change when the Commission adopts a final decision in WT Docket No. 03-66.

Figure 3

Channel	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	G1	G2	G3
Denton	WNC582	WNC582	WHR882	WEF69	WEF69	WEF69	WLX764	WLX764	WNC990	WLX802	WLX802	WLX802	WHR830	WHR830	WHR830
Plano	WNC582	WNC582	WHR882	WEF69	WEF69	WEF69	WNC836	WNC836	WNC990	WND242	WND242	WND242	WHR830	WHR830	WHR830
DFW Airport	WNC582	WNC582	WHR882	WEF69	WEF69	WEF69	WNC836	WNC836	WNC990	WND242	WND242	WND242	WHR830	WHR830	WHR830
Dallas	WNC582	WNC582	WHR882	WEF69	WEF69	WEF69	WNC836	WNC836	WNC836	WND242	WND242	WND242	WHR830	WHR830	WHR830
Ft. Worth	WHR506	WHR506	WHR506	WLX649	WLX649	WLX649	WHR883	WHR883	WHR883	WHR881	WHR881	WHR881	WNC823	WNC823	WNC823
Waxahatchie	WNC582	WNC582	WHR882	WEF69	WEF69	WEF69	WHR695	WHR695	WHR695	KHS78	KHS78	KHS78	wHR830	wHR830	WHR830

Figure 3 depicts the difficulty of assembling the necessary leases to create unpaired 20 megahertz channels. The limited coverage of site-licensed EBS stations makes it necessary to negotiate leases with multiple adjacent or near-adjacent EBS on the same channel to assemble the desired wide-area or regional coverage necessary in many markets.[56] To assemble the 20 unpaired megahertz channels needed to provide the speeds and efficiency promised by competing networks, the above-described assembly process has to be repeated with licensees on adjacent EBS (and BRS) channel blocks. Ideally, EBS spectrum that cannot be aggregated into 20 megahertz-wide channels should be excluded from inclusion in the spectrum screen. As an alternative, the Commission could consider the availability of adjacent spectrum as a factor only when the screen trigger is exceeded.

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[56] See, for instance, the number of EBS C-1 Channels encompassed within the single BRS BTA of Dallas-Ft. Worth in Figure 2.

In summary, if the Commission includes EBS under the spectrum screen, Sprint submits that the following adjustments are warranted in the public interest to reflect the unique nature of the band.

Table 5

Potential EBS Spectrum Weight Calculation	
Items	**Amount of EBS Spectrum under Revised Screen**
Unweighted EBS (2502-2690 MHz)	**112.5 MHz**
5% reduction for capacity reserved for licensee use	-5.6 MHz **=106.9 MHz**
Adjustment for cost to deploy (spectrum weights adjusted by center frequency of 2596 MHz, rural 0.10, suburban 0.18, urban 0.44, average 0.20)	0.20 * 106.9 MHz **=21.4 MHz**
Adjustment for EBS white space	-3.5 MHz (16.5%*21.4 MHz) **=17.9 MHz**
Adjustment when 20 megahertz of adjacent spectrum is not available	Do not include under the screen an EBS channel that cannot be aggregated with adjacent EBS or BRS spectrum to create at least a 20 megahertz channel

VI. Analysis of Current Holdings for Four Nationwide Operators

Sprint has assessed how each of the four nationwide carriers' current spectrum holdings would fare if the Commission adopts Sprint's proposed weighted screen. For purposes of the study, Sprint assumed that the average weighted screen proposed in Table 2 (the Lower 700 MHz, Upper 700 MHz, 800 MHz ESMR, 800 MHz Cellular, AWS-1, PCS, WCS and 55.5 megahertz of the BRS band) would be modified by adding the AWS-4 band (40 megahertz bandwidth at an average weight of 0.28) and BRS E4 and F4 channels (12 megahertz bandwidth at an average weight of 0.20). We also included 106.9 megahertz of EBS spectrum (after subtracting the 5% capacity reserved for EBS licensee use) with an average weight of 0.20. This resulted in a total weighted screen of 272.1 megahertz and a screen trigger level of

90.7 megahertz. EBS white space MHz-POPs were excluded from the averaged holdings on a market-by-market basis, and EBS holdings in a market were not counted if a 20 megahertz channel could not be aggregated from adjacent EBS leased or BRS licensed channels. The following table shows the results of that analysis for the four nationwide commercial mobile operators:

Table 6

Weighted Screen	Sprint	AT&T	T-Mobile	Verizon
Threshold (MHz)	90.7	90.7	90.7	90.7
Exceeds Screen - Counties	0	298 (9.2%)	0	154 (4.8%)
Exceeds Screen – Population	0	85.3M(27.2%)	0	21.1 (6.7%)
Avg MHz	53	80.7	29.2	67
Avg MHz (Top 100 CMA)	56.8	86.1	33.1	68.3
Avg MHz (Top 10 CMA)	57.1	90.7	36.7	68.5

For comparison, the spectrum screen positions of the four nationwide carriers using the Commission's current screen are set forth below:

Table 7

Current Unweighted Screen	Sprint	AT&T	T-Mobile	Verizon
Threshold (MHz)	143.2	143.2	143.2	143.2
Exceeds Screen - Counties	0	333 (10.3%)	0	4 (0.1%)
Exceeds Screen – Population	0	44.9M (14.3%)	0	0.1M (0.0%)
Avg MHz	106	122.3	70.6	102.3
Avg MHz (Top 100 CMA)	108.3	126	77.3	104.9
Avg MHz (Top 10 CMA)	111	126.3	79.6	108.9

The results under Sprint's weighted spectrum screen proposal make sense because AT&T and Verizon collectively hold a nationwide average of approximately 75% of all spectrum below

1 GHz, which under the new weighted screen has the lowest cost to deploy and the highest utility weighting. At the same time, however, all four carriers would have room to add spectrum in the vast preponderance of markets, particularly through an auction (which would add to the overall spectrum available and would raise the one-third screen trigger level).

VII. Conclusion

The Commission's current spectrum policies (most notably its spectrum screen) have failed to keep pace with industry dynamics; the screen has failed, as a diagnostic tool, to fulfill its original purpose. Specifically, the Commission's spectrum aggregation policies – and in particular its spectrum screen – should ensure that firms can respond to attempted exercises of market power by dominant firms. A monolithic focus on raw bandwidth, to the exclusion of equally (if not more) important factors influencing the competitive impact of particular spectrum inputs, fails to accomplish this key public policy obligation.

As explained above and in the attached Appendix, the best way to rectify the disconnect between the screen and the industry it is intended to evaluate is to ensure that the screen is attuned to the critical differences in the spectrum inputs which impact downstream competition. As the Commission has increasingly acknowledged, competition in this downstream market can only be sustained if carriers have a mix of bands to economically and efficiently provide service. By adopting a weighted-screen, the Commission can restore its spectrum aggregation policies to their public policy mooring: promoting competition and preventing undue concentration of essential inputs by examining how a particular acquisition – and a carrier's particular holdings – has the potential to undermine the ability of competing firms to acquire the necessary mix of spectrum bands they need to compete.

Appendix

Formulation of a Weighted Spectrum Screen

Dr. Kostas Liopiros

FORMULATION OF A WEIGHTED SPECTRUM SCREEN

Dr. Kostas Liopiros[1]

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1. INTRODUCTION

The Commission's well-established policies assess competition based on the ability of a wireless operator to expand output or enter a market in response to competitive pressure. The usability or utility of different spectrum in expanding output or provisioning new service varies by frequency band, operating environment, and by available bandwidth within the frequency band. Relative, utility-based spectrum weights can be formulated to reflect these differences and can be used in a revised Commission spectrum screen.

The "spectrum screen" is the foremost tool of the Commission's case-by-case evaluation of the competitive impact of an acquisition of spectrum by transaction or auction.[2] The screen is a threshold test to identify local markets where an entity may hold an undue concentration of

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[1] Dr. Liopiros is founder and principal of the Sun Fire Group, a technology-based management consulting firm in Alexandria, VA. He consults on a wide range of issues in the Information and Communications Technology (ICT) and the Defense and Aerospace sectors, dealing with the intersections and interactions among strategy, technology, and business. He has advised clients in industry, government and the financial sector on the policy, technology, regulatory and business issues involving spectrum management, frequency planning and licensing and represented them before the FCC, NTIA, NOAA and NASA. He previously served as Director for Command, Control and Communications Policy -- advisor to the Secretary of Defense -- where he provided policy oversight on defense spectrum management and was responsible for the development of national policies on the civil availability of the Global Positioning System, continuity of government and the protection of domestic telecommunications. He holds a Ph.D. in electrical engineering (systems and information science) from Princeton University.

[2] See *Policies Regarding Mobile Spectrum Holdings*, Notice of Proposed Rulemaking, Federal Communications Commission, WT Docket No. 12-269 (rel. Sept. 28, 2012) ("*NPRM*").

spectrum *suitable and available* for the provision of mobile telephony/broadband services.[3] In a local market where the threshold is exceeded, the Commission's spectrum holdings policies instruct a more detailed examination to determine whether a spectrum acquisition would result in "an increased likelihood or ability" for anticompetitive behavior. If the threshold is not exceeded, the presumption is that the acquisition in question is not anti-competitive and further examination would not be warranted.

A well-designed spectrum screen should minimize the occurrence of false negatives, when a potentially anti-competitive spectrum acquisition is allowed to proceed without further scrutiny. False negatives result in an undue concentration of spectrum that could potentially limit competition. The screen should also limit the number of false positives, when a pro-competitive spectrum acquisition is subjected to unnecessary scrutiny.[4] False positives can impose significant costs if they deter carriers from acquiring spectrum that could potentially enhance competition. It may be more important, however, to minimize false negatives since the harm from false negatives (i.e., permitting an anti-competitive transaction to be approved) would be difficult to correct after the fact.

The current screen considers only the total amount of bandwidth in a carrier's spectrum holdings.

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[3] A two-part screen is used to evaluate spectrum acquisitions. A "market screen" focuses on changes in market concentration as a result of the acquisition. The "spectrum screen" focuses on changes in spectrum concentration and is used to identify local markets where an entity would hold more than approximately one-third of the total pool of spectrum *suitable and available* for the provision of mobile telephony/broadband services. The one-third threshold envisions at least three competitors having access to equivalent amounts of suitable spectrum in a local market. See *NPRM* ¶¶ 8, 17 n. 28, 29.

[4] Threshold tests typically involve a tradeoff between the acceptable level of false positives (Type I errors) and the acceptable level of false negatives (Type II errors). There is an inverse relationship between the number of false positives and the number of false negatives. While a threshold value can be varied to make the test more restrictive or more sensitive, decreasing false positives tends to increase false negatives and decreasing false negatives tends to increase false positives.

Relying on bandwidth alone can produce a distorted measure of the competitive value of a carrier's spectrum portfolio, which could lead to the false conclusion that an acquisition is not anti-competitive, i.e. a false negative. For the spectrum screen to work, it must be able to estimate the competitiveness of a carrier's spectrum holdings before and after a spectrum acquisition.

2. COMPETITIVE VALUE

The competitiveness of one block of spectrum over another is determined by the extent to which it can facilitate lower costs for the deployment and operation of a wireless network over the same service area. This depends on three principal factors. One factor is the bandwidth of the spectrum block. More bandwidth allows a carrier to build out its infrastructure at a lower cost.[5] An equally important factor is the relative cost to deploy and operate a wireless network with the spectrum, *i.e.*, the relative cost of using the bandwidth. If the cost to deploy and operate a wireless network over the service area with one block of spectrum is greater than with another block of spectrum, then the first block of spectrum is inherently less competitive. A third factor is the proportionate amount of the service area's population that is covered by the spectrum band.[6] A spectrum block that does not cover the entire population of an area is inherently less

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[5] Additional spectrum is substitutable up to a point with capital expenditures to build new cell sites and increase network density. The FCC developed an "indifference curve" that illustrates tradeoffs between the amount of additional spectrum and additional investment in network infrastructure. The curve shows the financial benefits of deploying additional spectrum over capital investment in infrastructure. Federal Communications Commission, *Mobile Broadband: The Benefits of Additional Spectrum* (October 2010) at 7 and 21.

[6] The competitive value of a spectrum band can also be affected by several other factors. One factor is the availability and cost of equipment that can work in the band. Delays in obtaining equipment and increased costs of network infrastructure and handsets reduce the competitive value of the band, while increasing risk and uncertainty. Another factor is the fragmentation of the band and whether there is sufficient adjacent spectrum available to create wide channel bandwidths for mobile broadband. A third factor is the extent to which the potential of interference may limit the geographic and spectral

competitive than one that does. Thus, the competitiveness of a spectrum band is considered to be directly proportional to the bandwidth BW and population coverage P and inversely proportional to the relative cost C. We define the competitive value of a spectrum block, *CV*, as:

$$CV = \frac{BW \times P}{C} = W \times BW \times P \tag{2.1}$$

where the spectrum weight *W* is the reciprocal of the relative cost[7]

$$W = \frac{1}{C} \tag{2.2}$$

3. PROPAGATION ENVIRONMENT

Wireless carriers provide mobile wireless services using a portfolio of spectrum bands at different frequencies.[8] Because of differences in propagation characteristics, the different bands in a carrier's spectrum portfolio contribute to wireless service in different ways. These differences determine the relative cost to deploy and operate a wireless network.[9] Since the path

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availability of the band. These factors can change more rapidly over time than the three principal factors considered above. Therefore, they are best addressed in the case-by-case review of a spectrum acquisition.

[7] Since C and P are dimensionless quantities, CV is expressed in terms of an overall weighted bandwidth, e.g. in MHz.

[8] Typically, wireless operators choose to have a mix of low, medium, and high-band spectrum in order to optimize coverage, capacity, and quality of the user experience.

[9] The Commission and the Department of Justice (DOJ) have recognized that differences in propagation in different frequency bands affect the utility of how a particular band is best used in providing mobile broadband services. See *Sixteenth Annual Mobile Wireless Competition Report*, FCC, WT Docket No. 11-186 (rel: March 21, 2013) ¶¶ 119-127, and *Fifteenth Annual Mobile Wireless Competition Report*, FCC, WT Docket No. 10-133 (rel: March 21, 2013) ¶¶ 289-297. Also United States of America et al. v. Verizon Communications Inc. and ALLTEL Corporation, Competitive Impact Statement, Case No. 08-cv-1878, at 5-6 (filed Oct. 30, 2008), *available at* http://www.justice.gov/atr/cases/f238900/238947.pdf.

loss varies not only with frequency but also the density of the environment, the relative cost will differ with frequency and density.

Low-band spectrum, below 1 GHz, provides superior range and building penetration compared to high-band spectrum, located significantly above 1 GHz. Low-band spectrum can provide more affordable coverage in a variety of propagation environments, from low-density rural environments to high-density urban environments. This provides a significant competitive advantage in a low-density environment, where a high-band network would require more base stations to cover the same geographic area. The additional base stations required to achieve an equivalent coverage with a high-band network result in a greater cost to deploy and operate a wireless network.[10] Thus the relative competitive value of low-band spectrum in low-density areas is greater than high-band spectrum.

Low-band networks also have a competitive edge in higher-density urban areas. Small urban cells at a lower frequency can also provide better building penetration and coverage inside buildings than the same size cell operating at a higher frequency.[11] The lower path loss and increased penetration at lower frequencies offers the potential for increased coverage per base

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[10] The poorer economics of deploying a high-band network in a low-density rural environment make it unlikely that a wireless operator would build out its network entirely with high frequency spectrum. For example, T-Mobile USA, Inc. had (until a recently-announced, currently pending transaction) no low-band spectrum. Its wireless network has been deployed with high-band spectrum – 1900 MHz PCS and 1700/2100 MHz AWS-1 bands – and is limited to more densely populated urban and suburban areas. A comparison of the coverage maps of T-Mobile with AT&T Mobility or Verizon Wireless graphically reveals the benefits of low-band spectrum.

[11] See, for example, *Application of AT&T Inc. and Qualcomm Incorporated For Consent To Assign Licenses and Authorizations*, Order, Federal Communications Commission, WT Docket No. 11-18 (rel: December 22, 2011) (‘*AT&T/Qualcomm Order”)* ¶ 49. See also *Consultation on assessment of future mobile competition and proposals for the award of 800 MHz and 2.6 GHz spectrum and related issues*, Ofcom, Annexes 7-13 (22 March 2011) 6-9.

station.[12] As mobile data usage increases, maintaining in-building coverage becomes increasingly important. The signal strength received inside of a building due to a cell site transmitter exterior to the building should be sufficiently high to maintain quality of service (QoS). In high-density urban environments, a high-band network would require smaller cells (and therefore more base stations) to compensate for the greater penetration loss at higher frequencies. The additional base stations required to achieve an equivalent building penetration results in a greater cost to deploy and operate a wireless network. Thus the relative value of low-band spectrum remains greater in urban areas.[13]

The range and penetration benefits of low-band spectrum translate to a significant competitive advantage due to the lower overall cost of providing wireless services across a variety of propagation environments. Carriers that are spectrum disadvantaged (i.e. with insufficient amounts of low-band spectrum in their portfolio) would be forced to spend considerably more on infrastructure and operations in order to provide equivalent coverage and building penetration.

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12 For example, AT&T Mobility is using an overlay of 850 MHz cellular spectrum to improve its 3G network in large cities, providing enhanced in-building coverage over its 1900 MHz PCS spectrum. See http://www.zdnet.com/blog/mobile-gadgeteer/at-and-t-solving-coverage-issues-with-850-overlay-and-new-cell-sites/3849.

13 In-building coverage can also be improved through the use of femtocells and picocells that can be installed indoors or in areas immediately adjacent to buildings. Distributed antenna systems (DAS) can also be used to distribute wireless signals within a building. While many wireless operators are actively deploying these transmitters, the sheer number of housing units, commercial buildings and industrial facilities dictates that the vast majority of indoor locations will continue to be served by outdoor "macro" transmitters. For example, AT&T intends to deploy 40,000 small cells by 2015. See http://www.att.com/Common/about_us/pdf/small_cell.pdf. However, U.S. Census Bureau studies indicate that in 2012 there were over 132 million housing units in the U.S. See http://quickfacts.census.gov/qfd/states/00000.html. The U. S. Department of Energy also estimates that in 2003 there were nearly 4.9 million commercial buildings in the U.S. See *Commercial Buildings Energy Consumption Study (CBECS)*, 2003 CBECS Survey Data, U.S. Energy Information Administration (2006). Further, the extensive operating costs necessary to sustain dense deployments of small cells and DAS (electricity, site leases, backhaul) are often prohibitively high and reinforce the importance of the outdoor macro cellular network for providing in-building service.

4. RELATIVE COST

The relative cost to deploy and operate a wireless network varies with differences in propagation in different frequency bands. The metric used to provide a comparison of the cost is the number of base stations required to meet the coverage and penetration requirements in different propagation environments.[14] The cost to deploy and operate a wireless network is roughly *proportional* to the number of base stations in the network. Therefore, the relative cost to deploy and operate one network to another is the ratio of the number of base stations in each network *all other things being equal*. For any given area, the number of base stations is inversely proportional to the cell area of a base station, which is proportional to the radius squared. Thus, the relative cost of two spectrum blocks with frequencies f_1 and f_2 is given by the ratio of the respective cell radii squared:

$$\frac{C_2}{C_1} = \left(\frac{r_1}{r_2}\right)^2 \qquad (4.1)$$

The minimum number of base stations required to cover a given geographical area is a function of the maximum achievable range of a base station – the maximum distance from cell tower to mobile device at which the signal to interference plus noise ratio (SINR) is adequate for the provision of mobile broadband and telephony services at a desired quality-of-service (QoS) level. The maximum achievable range is determined by the path loss (or path attenuation), which varies with frequency and density of the environment.[15] Thus relative costs and weights

[14] Since the access portion of the network, *i.e.*, the base station infrastructure and backhaul network, is generally the dominant factor in the total end-to-end network investment, a comparison of the number of base stations provides a good measure of the relative costs to deploy and operate different networks over the same or comparable areas.

[15] The path loss or path attenuation refers generally to the sum of all losses experienced by a radio

can be estimated as a function of frequency using propagation models for rural, suburban and urban environments.

4.1 Rural and Suburban Environments

Empirical models for estimating path loss (i.e. propagation or path loss models) do not fully cover the range of frequencies used for commercial mobile broadband, which range currently from 700 MHz through 2.7 GHz.[16] Calculation of relative costs and spectrum weights involves ratios of frequencies and cell radii over a range of frequencies and propagation environments, which is better accomplished with a theoretical area-to-area model.

Theoretical and measurement-based propagation models indicate that average received signal power decreases logarithmically with distance and with frequency, in both outdoor and indoor radio channels. Thus the difference in average large scale path loss ΔPL (dBs) at distances r_1 and r_2 and frequencies f_1 and f_2 can be expressed by using a path loss exponent n and a frequency

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wave as it propagates through space, excluding the effects of antenna gain and fast-fading due to multi-path propagation.

[16] Although different empirical models may be patched together to cover the full frequency range, there is a discontinuity in frequency dependence where one model transitions to the other. The commonly used Okumura-Hata model is valid for frequencies from 150 MHz to 1.5 GHz and is most appropriate for urbanized areas where the distance is relatively short (i.e. less than 30 km). The COST 231-Hata model is valid from 1500 to 2000 MHz and for distances from 1 to 20 km and was developed specifically for urban and suburban macro cells. (Its applicability to rural areas has not been clearly established). The frequency dependence of these two models changes rather sharply at 1,500 MHz from $26.16\log_{10}(f)$ to $33.9\log_{10}(f)$ respectively. Extension of the COST 231-Hata model beyond 2000 MHz involves another frequency-scaling factor of $26\log_{10}(f/2)$ (frequency specified in GHz). See Masaharu Hata, *Empirical formula for propagation loss in land mobile radio services*, IEEE Transactions on Vehicular Technology, vol. VT-29, No. 3 (August 1980), pp. 317–325 and COST 231 Final Report, *Digital Mobile Radio Towards Future Generation Systems*, Chapter 4, p. 135. See also *Radio Propagation Characteristics at 700 and 2,500 MHz Pertaining to Macrocellular Coverage*, Communications Research Centre Canada, Ottawa (April 2011) at 4-5.

loss exponent β:[17]

$$\Delta PL = 10log\left(\left(\frac{r_2}{r_1}\right)^n\left(\frac{f_2}{f_1}\right)^\beta\right) \tag{4.2}$$

Equation (4.2) is consistent with the commonly used Lee path loss model.[18] A range of values for n and β has been determined from empirical measurements in different propagation environments.[19]

If the path losses at two frequencies are equal, i.e. $\Delta PL=0$, equation (4.2) can be used to quantify the relationship between cell size and frequency and therefore relative cost and frequency:[20]

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17 See T. Rappaport, *Wireless Communications Principles and Practice*, IEEE Press (1996) pp.102-103 and T. S. Chu and L. J. Greenstein, *A Quantification of Link Budget Differences Between the Cellular and PCS bands*, IEEE Transactions on Vehicular Technologies, vol. 48, no. 1 (January 1999) ("*Link Budget Differences*") p.61.

18 One of the commonly used propagation models is the Lee model, which is characterized by simplicity and good prediction accuracy. The model was developed as a result of large data collection campaign performed throughout the 1980s in the northeastern United States. The model was developed initially for propagation in and around 900 MHz. Recently, extensive data collection and propagation model validations have demonstrated the model's applicability for frequencies up to and beyond 2 GHz. William C. Y. Lee, *Mobile Communication Design Fundamentals*, 2nd ed., Wiley, New York, 1993, pp. 59-67. See also William C. Y. Lee, *Mobile Cellular Telecommunications Analog and Digital Systems*, 2nd ed., McGraw Hill, New York, 1989, Chapter 4.

19 The values of the frequency loss exponent β and the path loss exponent n are determined experimentally from large quantities of measured data collected in different propagation environments. In rural environments β and n are approximately 2.0, which is equivalent to free space loss, since signals propagating over rural environments are subjected to very little diffraction. The path loss exponent n is greater in suburban and urban areas due to interference from reflections from the ground. The frequency loss exponent β is greater in suburban and urban areas due to the greater diffraction losses at higher frequencies. In suburban areas n is estimated to range from 3 to 5 and β is estimated to be approximately 2.6. In urban areas n can range from 2.7 to 3.5.

20 This assumes that the two bands use the same air interface and similar base station infrastructures (e.g. tower height and antenna size) and the same transmit powers.

$$\frac{C_2}{C_1} = \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{f_2}{f_1}\right)^{\frac{2\beta}{n}} \tag{4.3}$$

In a low-density rural environment, we use *n=β=2* and the relative cost is given by:

$$\left(\frac{C_2}{C_1}\right)_r = \left(\frac{f_2}{f_1}\right)^2 \tag{4.4}$$

Thus for a low-density rural propagation environment, the relative cost, i.e. the ratio of the maximum cell coverage, is approximately equal to the square of the frequencies.[21]

In a medium-density suburban propagation environment, we use *n=3.5 and β=2.6* and the relative cost is given by:[22]

$$\left(\frac{C_2}{C_1}\right)_s = \left(\frac{f_2}{f_1}\right)^{\left(\frac{5.2}{3.5}\right)} \tag{4.5}$$

Thus, in a medium-density suburban environment, a carrier must deploy more and smaller cells than would be required in a low-density rural environment due to greater propagation losses, which limit the maximum achievable cell range.

4.2 Urban Environment

In a high-density urban propagation environment, lower path loss and reduced building

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[21] As an example, in rural areas approximately five 1.9 GHz PCS cell sites are needed to provide comparable coverage to a single 800 MHz cell site, and the relative cost between these bands is approximately 5:1.

[22] Studies have determined that *n* can range from 3 to 5 in suburban areas and from 2.7 to 3.5 in urban areas. We use a different propagation model for urban areas that is penetration driven and more appropriate for denser urban environments. With *n* = 3.5, the suburban model would also be applicable to less dense urban environments.

penetration losses mean that low-band networks can provide superior indoor coverage. The difference in building penetration capability among spectrum bands translates into a requirement for more intensive deployment of higher frequency (mid-band and high-band) urban cell sites to maintain an equivalent indoor coverage as a low-band network.[23] The smaller radius allows the higher frequency cell to illuminate the exterior wall with more power to overcome the additional penetration loses due to frequency.[24]

The path loss advantage at low-band frequencies is considered to be for the most part, the result of lower free-space loss and reduced building diffraction (i.e. shadowing) loss.[25] Thus, in a dense urban environment with smaller cells sized to meet capacity requirements and with a direct line-of-sight path between base station and the exterior wall of a building, the difference in path loss for an urban cell outdoors and the same cell received inside a building can be modeled as the sum of the free space loss and the building penetration loss:

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23 The argument is often made, incorrectly, that in an urban environment all cells would be the same size, independent of network or frequency, in order to meet capacity requirements. If cells were the same size, then a low-band network would still have an advantage due to the superior building penetration and indoor coverage for lower frequencies. Generally speaking, this penetration differential among spectrum bands translates into a requirement for a more intensive deployment of higher-frequency (mid-band or higher-band) cells sites to maintain an equivalent indoor coverage to that provided by low band spectrum, while maintaining the increased capacity required in an urban environment.

24 Penetration of buildings by radio waves is dependent on the type of building construction and height within the building as well as frequency. For residential buildings, which are typically constructed from non-metallic building materials such as wood, cinder block, brick veneer and glass, penetration loss has been found to be relatively low and to increase with frequency. Penetration is also dependent on the presence, size and orientation of windows, which can act as apertures at certain wavelengths.

25 See *Measurement of In-building Signal Coverage and Building Penetration Loss in Downtown Ottawa at 700, 2500 and 4900 MHz*, Communications Research Centre Canada, Ottawa (October 2011) at v.

$$\Delta PL = 20log\left(\frac{r_2}{r_1}\right) + \Delta\alpha(f) \quad (4.6)$$

where *Δα(f)* is the difference in building penetration loss as a function of frequency and r_1 is the cell radius to the exterior wall and r_2 is the reduced cell radius (to compensate for building attenuation). By setting *ΔPL* = 0, the relative cost is given by:

$$\frac{C_2}{C_1} = 10^{\left(\frac{-\Delta\alpha(f)}{10}\right)} \quad (4.7)$$

A closed form solution can be derived using compiled estimates of residential building penetration loss values at a range of frequencies. Building penetration measurements from NTIA and various research groups show that the difference in attenuation as a function of frequency can be approximated by:[26]

$$\Delta\alpha(f) = 7.15log\left(\frac{f_1}{f_2}\right) \quad (4.8)$$

Substituting the above into equation (4.7), the relative cost can be expressed as:

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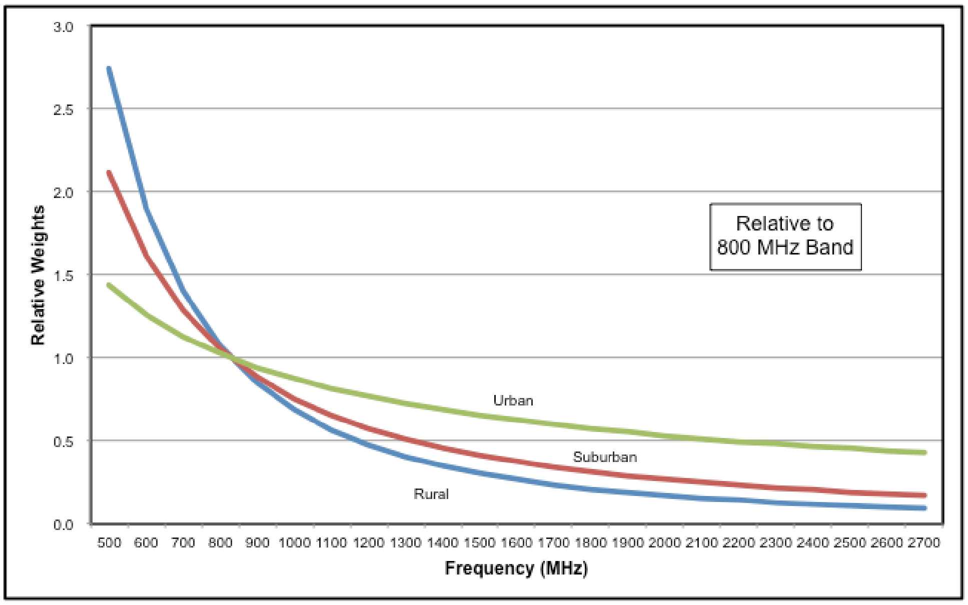
[26] The building penetration loss (attenuation) (dBs) can be approximated by $\alpha(f) = -15.8 + 7.15\log(f)$. The data shows that residential building penetration losses are estimated to be about 4 dB greater at the highest frequency commercial mobile band (2.5 GHz) than at the lowest frequency commercial mobile band (lower 700 MHz) – leading to decreased indoor coverage at the higher frequency. *See Comparison of Radio Propagation Characteristics at 700 and 2,500 MHz Pertaining to Macrocellular Coverage* at 4, Communications Research Centre Canada, Ottawa (April 2011). Also A. Davidson and C. Hill, *Measurement of building penetration into medium buildings at 900 and 1500 MHz*, IEEE Transactions on Vehicular Technology, vol. 46, no. 1, pp. 161–168 (February 1997); P.I. Wells, *The attenuation of UHF radio signals by houses*, IEEE Transactions on Vehicular Technology, vol. 26, no. 4 (1977); and U.S. Department of Commerce, NTIA Report 95-32.5, *Building penetration measurements from low-height base stations at 912, 1920, and 5990 MHz* (September 1995).

$$\left(\frac{C_2}{C_1}\right)_u = \left(\frac{f_2}{f_1}\right)^{\left(\frac{7.15}{10}\right)} \quad (4.9)$$

5. SPECTRUM WEIGHTS

Spectrum weights are the inverse of relative costs. Using the equations developed above (equations 4.4, 4.5 and 4.9), relative costs and associated spectrum weights can be derived for rural, suburban and urban environments. Curves of spectrum weights over a range of frequencies useful for mobile broadband are shown in the figure below.



The curves are calculated relative to the 800 MHz band, home to cellular and ESMR radio services.[27] The three curves have a common weight of 1 for the 800 MHz band and diverge at lower and higher frequencies due to the different effects of propagation at different frequencies.

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27 While 800 MHz ESMR and 800 MHz Cellular bands fall under separate FCC rule services, they are immediately adjacent to each other and have been combined by the 3GPP into a single global Band Class 26, The cost to deploy in these bands, from a propagation perspective, is virtually identical and, therefore, these bands are treated herein as a single band.

The increase in the curves at lower frequencies, *i.e.*, for the 700 MHz bands and a future 600 MHz band, illustrates the benefits of lower frequencies for mobile broadband across all environments.

The spectrum bands included in the Commission's current spectrum screen and that are useable for commercial mobile broadband are listed in the table below.[28]

Spectrum Bands Included in the Screen		
Band	**Uplink (MHz)**	**Downlink (MHz)**
Lower 700 MHz	698-716	716-746
Upper 700 MHz	776-787	746-757
800 MHz (ESMR and Cellular)	817-849	862-894
AWS-1	1710-1755	2110-2155
PCS	1850-1915	1930-1995
WCS	2305-2315	2350-2360
BRS*	2618-2690	2618-2690
* Unpaired spectrum – Uplink and downlink bands are the same		

Since the SINR ratio is generally lower on the uplink than the downlink, the relative costs are determined by the uplink link budget.[29] Therefore the frequency at the mid-point of the uplink band was used to calculate the relative costs and associated spectrum weight for each spectrum

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28 The 700 MHz D block, which has been reallocated by Congress for public safety, is not included. Because of the intervening public safety band, the commercial part of the 700 MHz band is shown as two separate bands, the Lower 700 MHz band and the Upper 700 MHz band. Instead of the total 26.5 MHz of SMR spectrum, only the contiguous 14 MHz ESMR band, which is more suitable for mobile broadband services, is included. See *AT&T/Qualcomm Order* ¶¶ 42, n. 126.

29 Since mobile devices have to be small and lightweight to be mobile, battery and antenna size will be limited. This limits the available transmit power and antenna gain. Nomadic devices, such as laptops and tablets, will often have greater antenna gains and transmit powers, especially if they have access to external power. Devices for fixed applications will have even greater antenna gain and transit powers.

band relative to the 800 MHz band (ESMR and Cellular).[30]

Relative Costs and Spectrum Weights						
Band	**Relative Cost***			**Spectrum Weight**		
	Rural	**Suburban**	**Urban**	**Rural**	**Suburban**	**Urban**
Lower 700 MHz	0.72	0.78	0.89	1.39	1.28	1.12
Upper 700 MHz	0.88	0.91	0.96	1.14	1.10	1.05
800 MHz (ESMR and Cellular)	1.00	1.00	1.00	1.00	1.00	1.00
AWS-1	4.33	2.97	1.69	0.23	0.34	0.59
PCS	5.11	3.36	1.79	0.20	0.30	0.56
WCS	7.69	4.55	2.07	0.13	0.22	0.48
BRS	10.15	5.59	2.29	0.10	0.18	0.44
*Relative cost refers to the cost to deploy and operate a wireless network in one frequency band compared to the cost to deploy and operate a wireless network in the 800 MHz Band (ESMR and Cellular).						

Although relative costs are calculated relative to the 800 MHz band, the ratio of relative costs can be used to determine the relative cost of two networks in different bands. The ratio of relative costs also shows how many more cell sites are required to achieve equivalent area coverage on different frequencies. For example, the ratio of relative costs between the BRS and PCS bands in rural areas is approximately 2, *i.e.*, about twice as many BRS cell sites would be required to provide the equivalent coverage of a PCS network.

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[30] Although the data presented in this and other tables are generally shown to three significant figures, the precise values were calculated in a spreadsheet model and may vary. However, all values given for spectrum weights in this and other tables are rounded off to two significant figures after the decimal point. This rounded off value is used in all calculations involving spectrum weights. This convention facilitates using the values given in the tables of this report to carry out calculations instead of relying on a spreadsheet. It also facilitates the Commission using weights in a weighted screen rather using a formula. Although rounding off intermediate values may introduce some error, in this case (i.e. calculating weighted spectrum), any error introduced is minimal (i.e. less than 1 percent).

6. WEIGHTED SPECTRUM SCREEN

The following table compares the overall amount of weighted spectrum, in each environment, to the current screen. The weighted bandwidth for rural, suburban and urban environments can be obtained by multiplying the bandwidth in each spectrum band by the appropriate spectrum weight in the table above.

Weighted Spectrum Screen				
Spectrum Band	**Current Screen**	**Rural (Low-density)**	**Suburban (Medium-density)**	**Urban (High-density)**
Lower 700 MHz	48.0 MHz	66.7 MHz	61.4 MHz	53.8 MHz
Upper 700 MHz	22.0 MHz	25.1 MHz	24.2 MHz	23.1 MHz
800 MHz ESMR	14.0 MHz	14.0 MHz	14.0 MHz	14.0 MHz
800 MHz Cellular	50.0 MHz	50.0 MHz	50.0 MHz	50.0 MHz
AWS-1	90.0 MHz	20.7 MHz	30.6 MHz	53.1 MHz
PCS	130.0 MHz	26.0 MHz	39.0 MHz	72.8 MHz
WCS	20.0 MHz	2.6 MHz	4.4 MHz	9.6 MHz
BRS	55.5 MHz	5.6 MHz	10.0 MHz	24.4 MHz
Total	429.5 MHz	210.7 MHz	233.6 MHz	300.8 MHz
Total Low-band	134.0 MHz	155.8 MHz	149.6 MHz	140.9 MHz
One-third total	143.2 MHz	70.2 MHz	77.9 MHz	100.3 MHz

With the current screen, the total low-band spectrum is less than the one-third threshold (i.e. one-third of the total spectrum). Thus, the current screen would potentially allow one carrier to acquire 100 percent, or 134 MHz, of the available low-band spectrum.[31] With the weighted screen, the total amount of low-band spectrum exceeds the one-third threshold in each of the environments. Thus weighting spectrum would improve the screen's capability to prevent an excess concentration of low-band spectrum by any one competitor.

7. APPLICATION

The weighted screen could be applied using the most appropriate set of weights for the local market. If the local market is classified as suburban, then the suburban weights could be used to weight a carrier's spectrum holdings. If the market is classified as urban, then the urban weights could be used. While this approach supports the notion that the competitive value of a spectrum band varies by environment, it would be very time-consuming and difficult to carry out a spectrum screen analysis such that each competitive market is broken down into urban, suburban, and rural areas. A more efficacious approach would be to adopt averaged spectrum weights that reflect the average relative cost over a market area of interest.

The Commission uses the Cellular Market Area (CMA) as the local geographic market in which to apply the screen.[32] CMAs comprise Metropolitan Statistical Areas (MSAs) and Rural Service Areas (RSAs), which in turn are aggregations of counties and county-equivalents.[33] In general,

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31 The result is that the largest cellular carriers in the U.S. hold the majority of the higher utility low-band spectrum. AT&T Mobility and Verizon Wireless control nearly 75% percent of low-band spectrum – on a nationwide population-weighted MHz basis. See *Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services*, Sixteenth Report, Federal Communications Commission, WT Docket No. 11-186 (rel. March 21, 2013) p. 18.

32 *NPRM* ¶ 30 n.95.

33 The U.S. Office of Management and Budget (OMB) defines an MSA as a contiguous geographic area with a relatively high population density at its core and close economic ties throughout the area. An MSA includes not only an urban core but also satellite cities plus intervening rural areas that are socio-

geographic entities such as MSAs, RSAs and counties are non-homogeneous mixes of rural, suburban and urban environments. The variety of population densities throughout MSAs, RSAs and counties complicates the direct application of a value-weighted screen.

Given the proportional population in urban, suburban and rural areas, P_r, P_s and P_u, an average spectrum weight W can be calculated over an arbitrary area such as a county or CMA:

$$W = P_r W_r + P_s W_s + P_u W_u \tag{7.1}$$

Although the terms urban, suburban and rural are useful for describing characteristics of propagation in various geographic areas, there is no consensus as to their definitions. The Census Bureau, for example, focuses on characterizing urban territory and defines rural by default as being outside of urban territory (i.e. not urban). There is no clear census definition of suburban territory, which often seems to be lumped into the urban and rural categories[34] For the application of a weighted spectrum screen, it is useful to classify rural/suburban/urban areas on the basis of a range of population densities (pops/mi^2).

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economically connected to the urban core city. The MSA classification includes about 84 percent of the U.S. population. See *Update of Statistical Area Definitions and Guidance on Their Uses*, OMB Bulletin No. 09-01, November 20, 2008. An RSA is simply an area that is left over after an MSA is defined. There are 306 MSAs and 428 RSAs in the U.S. for a total of 734 CMAs.

[34] The Census Bureau considers two categories of urban areas. An "urbanized area" consists of an urban area of 50,000 or more people; an "urban cluster" consists of an urban area of less than 50,000 people. Urbanized areas or urban clusters consist of core census block groups that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile. This very general definition includes what are typically considered suburban areas. The Census Bureau defines rural areas as all territory outside of Census Bureau defined urbanized areas and urban clusters. The term suburban population is sometimes used to refer to the population living in metropolitan areas, outside central cities. However, using this definition includes a nontrivial portion of county land area that is predominantly rural. See *Demography Trends in the 20th Century*, Frank Hobbs and Nicole Stoops, U.S. Census Bureau (November 2002) p. 38.

CMAs are an aggregation of counties, which are aggregations of census tracts, the largest geographic size category for which the Census Bureau compiles data.[35] Census 2010 data on census tracts is used to estimate population densities in rural/suburban/urban environments. By selecting appropriate delimiters for rural-suburban and suburban-urban, ranges of population density can be estimated for rural/suburban/urban environments.[36] These ranges are shown below.

Rural/Suburban/Urban Densities		
Environment	**Density (pops/mi^2)**	**Population**
Rural	≤ 100	14.0%
Suburban	100 < and < 10,000	75.5%
Urban	≥ 10,000	10.5%

The rural delimiter is based upon the Commission's "baseline" definition of rural as a county with a population density of 100 persons or fewer per square mile.[37] From the census tract data, we see that 14.0 percent of the U.S. population resides in census tracts with a population density

[35] The U.S. Census Bureau collects and compiles census data in several geographic size categories. Census blocks are the smallest entity – there are about 8.2 million blocks in the U.S. including Puerto Rico as of the 2010 Census. (However, about 2.7 million have zero population). Census block groups are the next level above census blocks. Census block groups generally contain between 600 and 3000 inhabitants and are made up of about 40 census blocks on average. There are about 220,000 census block groups in the U.S. including Puerto Rico as of the 2010 Census. Census tracts are the largest size and contain between 1,200 and 8,000 inhabitants and average about 4,000 inhabitants. They are made up of on average about four block groups. There are about 74,000 census tracts in the U.S. including Puerto Rico as of the 2010 Census. Several tracts commonly exist within a county.

[36] The 2010 census tract data includes population and area in square meters (m^2), which was used to calculate population density in square miles (pop/mi^2). Census tracts were rank ordered by decreasing density and the cumulative population was calculated for each tract. The 2010 census tract data is available at http://www.census.gov/geo/maps-data/data/relationship.html.

[37] See *Facilitating the Provision of Spectrum-Based Services to Rural Areas and Promoting Opportunities for Rural Telephone Companies To Provide Spectrum-Based Services*, Report and Order, Federal Communications Commission, WT Docket Nos. 02-381, 01-14, and 03-202 (2004) ¶¶ 11-12.

of 100 people per square mile or less.[38] For the urban delimiter, we choose a density at 10,000 people per square mile or more – at least 100 X that of a rural environment. From the census tract data, we see that 10.5 percent of the U.S. population resides in census tracts with a population density of 10,000 people per square mile or greater.

Given the proportionate population in urban, suburban and rural areas in the table above, an average spectrum weight can be calculated using equation (7.1) and the rural, suburban and urban spectrum weights determined in the previous table ("Relative Costs and Spectrum Weights"). The average weighted bandwidth is obtained by multiplying the bandwidth in each spectrum band by the average spectrum weight in the table below.

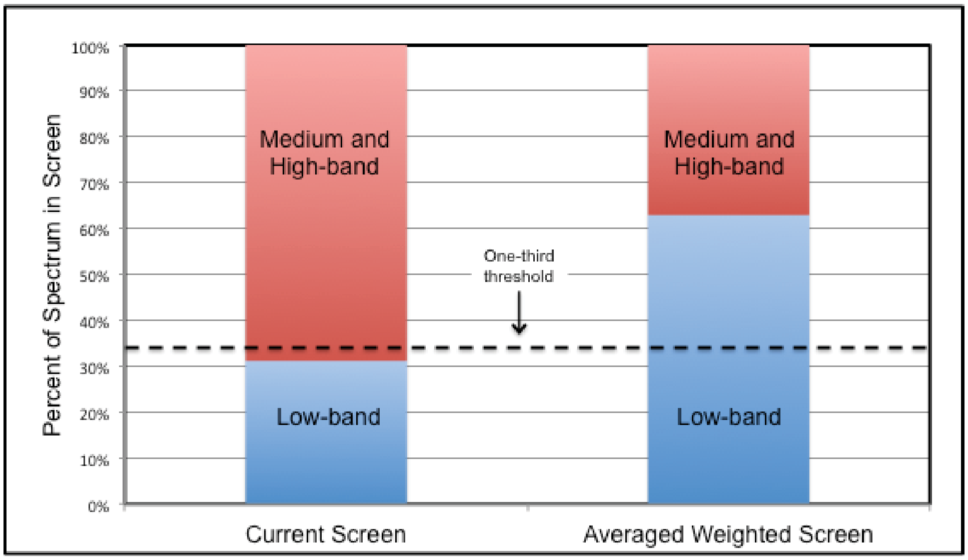
Averaged Weighted Spectrum Screen			
Band	**Current Screen**	**Average Weight**	**Averaged Screen**
Lower 700 MHz	48.0 MHz	1.28	61.4 MHz
Upper 700 MHz	22.0 MHz	1.10	24.2 MHz
800 MHz ESMR	14.0 MHz	1.00	14.0 MHz
800 MHz Cellular	50.0 MHz	1.00	50.0 MHz
AWS-1	90.0 MHz	0.35	31.5 MHz
PCS	130.0 MHz	0.31	40.3 MHz
WCS	20.0 MHz	0.23	4.6 MHz
BRS	55.5 MHz	0.20	11.1 MHz
Total	429.5 MHz		237.1 MHz
Total Low-band	134.0 MHz		149.6 MHz
One-third total	143.2 MHz		79.0 MHz

The averaged weights are similar to those derived above for a suburban environment (which

[38] By the Commission's classification, approximately 59 million people or 19 percent of the U.S. population live in rural counties. *Id*. Many of these counties, however, may contain census tracts with a greater density. Since the census tract data is finer-grained geographically than county data, the proportion of population with density less than 100 people per square mile or less would be less.

comprises the majority of the population) and the performance of the averaged screen is similar. Whereas, with the one-third threshold, the current screen would potentially allow one carrier to control 100 percent of the available low-band spectrum, the averaged screen would limit concentration of low-band spectrum to about 63 percent of the weighted low-band spectrum.

The corrective effect of an averaged weighted screen is illustrated in the chart below.



8. INCLUSION OF ADDITIONAL SPECTRUM BANDS

The spectrum bands included in the screen each have nationwide standard contiguous licensing areas that are licensed exclusively to one carrier (i.e. no sharing). It would be relatively straightforward to use the above framework to determine the appropriate spectrum weights that should be used when adding new bands with standard licensing areas, such as AWS-4, H-Block, AWS-3, and eventually 600 MHz, to the screen.

Several parties have suggested that the 2.5 GHz Educational Broadband Service (EBS) band be included in the screen as well. The EBS band, however, unlike the spectrum bands currently included in the screen, is licensed by non-contiguous license areas, which result in a fragmented availability and extensive white spaces that vary from area-to area.[39] The fragmented ownership and non-contiguous nature of EBS spectrum and other limitations exogenous to propagation impact the cost and feasibility of deployment of a network using EBS spectrum – thus impacting its cost to deploy and competitive value. As a consequence, assigning a relative spectrum weight to this band based solely on propagation would fail to reflect the significant encumbrances that impact the band's utility, relative cost and competitive value. Further, the extensiveness and complexity of the non-contiguous areas and white spaces mean that a given EBS channel is not "available" across a market area of interest, as are other bands included in the spectrum screen. These differences argue in favor of continued exclusion of the EBS band from the screen – potentially with examination of EBS holdings on a case-by-case basis should further competitive scrutiny be warranted.

Should the Commission decide to include the EBS band within a weighted screen, the competitive value of the band should reflect the unique limitations imposed on its utility.[40] The amount of bandwidth available in a market area should be adjusted with a five percent discount to account for the educational reserve – the minimum capacity EBS lessors must reserve for educational use.[41] The population coverage, *i.e.*, the percent of population covered, should take

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[39] EBS spectrum was originally licensed by non-contiguous geographic service areas (GSAs), with a 35-mile radius protected service area around the center coordinates of a transmitter site. The 35-mile radius was a maximum license area, which was frequently reduced – due to overlap with adjoining co-channel licensees – to prevent interference. These GSAs were eventually converted to fixed geographic area licenses and the boundaries were frozen. Areas between these odd-shaped GSAs have not yet been licensed, and are referred to as "white space."

[40] Recall that competitive value CV is defined as $= \frac{BW \times P}{C}$.

[41] EBS licensees are required to retain a reserve (the educational reserve) of *at least* five percent of capacity to further their educational mission. This is a minimum requirement and some licensees

into account the limited coverage of the EBS license area, as there is often unlicensed EBS white space within any market.[42] However, the fragmented ownership of EBS licenses means that the population coverage must be computed for each market on a channel-by-channel basis for each of the 20 EBS channels.[43] Thus the competitive value and thus the EBS spectrum weights will vary from area-to-area.

This last complication is due solely to the presence of white spaces. Although the Commission could develop a method to comprehensively calculate the extent of EBS white spaces in each examined market, the available EBS spectrum would vary from market-to-market, complicating the application of the screen to this spectrum.

9. SUMMARY AND CONCLUSIONS

Wireless carriers provide mobile broadband services using a portfolio of spectrum bands at different frequencies. Because of differences in propagation characteristics, different bands in a carrier's spectrum portfolio contribute to wireless service in different ways. These differences determine the relative cost to deploy and operate a wireless network.

The competitiveness of one block of spectrum over another is determined by the extent to which it can facilitate lower costs for the deployment and operation of a wireless network. While

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negotiate lease agreements that reserve a considerably greater percentage of spectrum capacity to meet their educational needs.

[42] Unlike the Broadcast TV white spaces, the EBS white spaces are unusable for commercial services.

[43] Different channel blocks within a market area can have different owners and the corresponding GSAs may have different center coordinates. The GSA of one or more channels may be contained wholly within the market area or might intersect the boundaries of the market area. Thus calculations of population covered may differ with the particular channel.

bandwidth is a key factor, differences in propagation characteristics, *i.e.* coverage and penetration, in different frequency bands determine the economics and relative cost to deploy and operate a wireless network.

For example, the superior range and penetration capabilities of low-band spectrum translate to a significant competitive advantage due to the lower overall cost of providing wireless services across a variety of propagation environments – rural, suburban and urban. Carriers that are spectrum disadvantaged (i.e. with insufficient amounts of low-band spectrum in their portfolio) would be forced to spend considerably more on infrastructure and operations in order to provide equivalent coverage and penetration.

These significant competitive differences are not captured by the current spectrum screen, which would potentially allow unlimited concentration of low-band spectrum. The competitive differences among spectrum bands can be captured by assigning weights to each spectrum band that reflect the relative cost of deploying and operating a wireless network at that frequency. The product of the weight assigned to a band and the bandwidth of the band is a measure of the competitive value of a spectrum band. The competitive value of a carrier's spectrum portfolio is the sum of each band's competitive value.

A weighted spectrum screen is easy to implement and would enhance the Commission's capability to measure the competitiveness of a carrier's spectrum holdings. By weighting low-band spectrum proportionately more than mid-band or high-band spectrum, a weighted spectrum screen would help reverse the current trend towards an excessive concentration of low-band spectrum.