Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Service Rules for Advanced Wireless Services in the 2155-2175 MHz Band	)	WT Docket No. 07-195
	)	

To the Commission

COMMENTS OF M2Z NETWORKS, INC.

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EXECUTIVE SUMMARY

The Commission has an opportunity to act decisively in this proceeding, in order to use the AWS-3 spectrum to foster the development of a new national broadband network that allows all Americans to participate in the broadband era. The 2155-2175 MHz band that is the subject of the Commission's Notice of Proposed Rulemaking ("NPRM") has great potential. However, spectrum is simply raw material. What will truly unlock the potential of this band is Commission action to establish flexible technical rules that foster a new nationwide broadband service which, when combined with innovative public interest commitments, will revolutionize the broadband market for the benefit of American consumers.

With broadband services continuing to be out of reach for so many Americans, M2Z believes the time is ripe for the Commission to put in place a set of service rules for this band that will make a major difference in the lives of millions of people disconnected from broadband in our country. To do so, the Commission's decisions in this proceeding should promote four fundamental goals established by the Communications Act and the Commission's rules and policies: (1) enable the widespread availability of affordable broadband services; (2) ease regulatory obstacles to innovation in order to encourage the efficient and intensive use of electromagnetic spectrum; (3) enhance the competitive landscape for broadband in the United States and (4) protect all licensees from harmful interference.

In an effort to facilitate the achievement of these goals, M2Z has attached to these Comments a set of proposed Advanced Broadband Radio Service ("ABRS") rules that will ensure that the entire 2155-2175 MHz band is put to its highest and best use. The proposed ABRS rules would lead to the grant of a single, exclusive nationwide 20 MHz license and would obligate the 2155-2175 MHz band licensee to comply with strict incumbent relocation obligations. The proposed rules establish these and other licensee obligations in order to

promote the highest and best use of the band, and thereby generate an extensive number of public interest and consumer benefits, including:

- the provision of free, nationwide, "always on" wireless broadband service;
- network access open to all compatible devices and applications;
- the implementation of technology solutions that protect children from potentially harmful online materials;
- the provision of secondary broadband services to public safety entities, free of subscriber or service fees;
- rapid construction of the network, spurred by stringent performance requirements;
- competitive entry and rapid deployment of service, due to eligibility requirements; and
- the provision of wholesale services.

The technical aspects of the rules proposed by M2Z are closely aligned with the rules that the Commission adopted for the 2.5 GHz and 700 MHz bands, which, by design, provide licensees with the flexibility to implement those technical solutions that are most appropriate to their broadband networks while protecting other licensees from harmful interference. The same type of result can and should be the outcome of this proceeding, because the goals of permitting licensees to enjoy technical flexibility and requiring such licensees to protect others from harmful interference are not mutually exclusive aims.

Unfortunately, many of the spectrum use proposals and proposed rules discussed in the NPRM run counter to the above-stated policy goals. For example, the asymmetric pairing option presented under the downlink-only approach described in the NPRM would put the Commission in the position of playing a "reverse Robin Hood" role, taking spectrum access opportunities away from potential new entrants and giving them to "spectrum rich" incumbents. It is hard to imagine how the Commission's competition goals could be furthered by the adoption of such a proposal. The structured uplink/downlink proposal would mark the unceremonious return of

command and control spectrum regulation, needlessly sacrificing the principles of operator flexibility, spectrum use efficiency, and technological innovation in exchange for illusory interference management benefits. Finally, designating this particular band for unlicensed use would deliver fewer benefits to consumers, imperil the successful relocation of incumbents in the band, and depart from more than a decade's worth of the Commission's AWS spectrum allocation and spectrum policy decisions just as their benefits are on the verge of being realized.

M2Z's proposed service rules provide a better way. If the Commission avoids mandating a particular technological approach and requires the ultimate AWS-3 licensee to be bound by comprehensive public interest commitments, this spectrum band would be primed for deployment of an innovative, nationwide, free and family-friendly wireless broadband network. The proposed ABRS rules attached hereto would ensure that the licensee in the 2155-2175 band has every incentive to build its network and provide service, operating not simply in that licensee's own pecuniary interest but in the public interest. Moving forward in this manner would answer the call of Congress, the Commission, and the American people for an affordable, accessible, and widely available broadband network open to the millions of Americans who are still without affordable broadband service.[1]

This Commission has already shown courageous leadership by committing to a deadline for putting the 2155-2175 MHz band to its highest and best use in the coming year. Now it must finish the job by rapidly promulgating service rules for this band that create a free, nationwide, family-friendly wireless broadband network in the public interest.

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[1] *See, e.g.*, *In the Matter of High-Cost Universal Service Support, Federal-State Joint Board on Universal Service*, WC Docket No. 05-337, CC Docket No. 96-45, Recommended Decision, FCC 07J-4, ¶ 61 (rel. Nov. 20, 2007) ("*Joint Board Recommended Decision*") (noting that "[t]he state commissioners on the Joint Board all have personal experience with consoling irate telephone customers who find themselves unable to buy broadband Internet service at home or at their place of employment" and concluding that "ubiquitous broadband access will improve the lives of millions of Americans, particularly in the coming years when Internet communications are expected to become an even more essential communications tool in daily life").

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COMMENTS OF M2Z NETWORKS, INC.

M2Z Networks, Inc. ("M2Z") hereby respectfully submits these Comments in response to the Federal Communications Commission (the "Commission") Notice of Proposed Rulemaking ("NPRM")[2] in the above-captioned docket. In the NPRM, the Commission "seek[s] comment on service rules for licensed fixed and mobile services, including Advanced Wireless Services (AWS), in the 2155-2175 MHz band (AWS-3)."[3] M2Z proposes that the Commission take this opportunity to establish service rules that are focused on consumer benefits rather than benefits to a particular type of licensee or pre-existing business model. The Commission can take a leadership role by adopting rules that would allow the 2155-2175 MHz licensee to make a profound impact on the availability and the affordability of broadband service in the United States, for the benefit of all consumers, through the provision of a free and family-friendly nationwide wireless broadband network.

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[2] *Service Rules for Advanced Wireless Services in the 2155-2175 MHz Band*, WT Docket No. 07-195, Notice of Proposed Rulemaking, FCC 07-164 (rel. Sept. 19, 2007) ("NPRM").

[3] *Id.* ¶ 1.

I. INTRODUCTION AND SUMMARY

As amply demonstrated in the voluminous record developed in response to M2Z's application (the "Application")[4] for a license to use the same band under consideration here, the Commission has an historic opportunity to establish service rules for putting this long under-utilized spectrum to its highest and best use. To that end, M2Z herein proposes rules[5] that will protect adjacent band licensees as well as incumbent in-band licensees that will soon vacate the AWS-3 band. Moreover, M2Z's proposed Advanced Broadband Radio Service ("ABRS") rules would promote widespread consumer benefits by establishing a variety of public service obligations that any 2155-2175 MHz licensee must meet. When fulfilled by the eventual licensee, these obligations would engender: (1) a free, nationwide and "always on" wireless broadband service; (2) network access open to all compatible devices and applications; (3) technology solutions that protect children from potentially harmful online materials; (4) the provision of secondary broadband services to public safety entities at no recurring cost to such entities; (5) rapid network construction, spurred by stringent performance requirements; (6) the establishment of licensee eligibility requirements that promote competition and the deployment of services; and (7) the provision of wholesale services. To ensure that the licensee has the proper incentives actually to provide service rather than engage in speculation or hoarding, M2Z proposes strict performance or buildout requirements with interim benchmarks, coupled with a five-year spectrum holding period. These steps should ensure that this public resource will be put to use quickly to serve consumers across the nation.

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[4] *See* M2Z Networks, Inc., Application for License and Authority to Provide National Broadband Radio Service in the 2155-2175 MHz Band, WT Docket No. 07-16 (filed May 5, 2006, and amended Sept. 1, 2006).

[5] *See* Appendix A, attached hereto.

The proposed ABRS rules are designed to satisfy the Commission's primary directive to promote the public interest through the spectrum management and licensing process. The rules will: (1) enable the widespread availability of affordable broadband services;[6] (2) ease regulatory obstacles to innovation in order to encourage the efficient and intensive use of electromagnetic spectrum;[7] (3) enhance the competitive landscape for broadband in the United States;[8] and (4) protect all licensees (*i.e.*, both incumbent licensees in the band and licensees in adjacent bands) from harmful interference. In stark contrast, certain other proposals discussed in the NPRM would not fulfill – and, indeed, would run counter to the Commission's fulfillment of – multiple statutory mandates of the Communications Act. Should the Commission proceed with the contemplated rulemaking,[9] its best option to obtain for the American people the same type of public interest benefits promised in the M2Z Application would be the rapid adoption of the

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[6] *See* Telecommunications Act of 1996, Sec. 706, Pub. L. No. 104-104, 110 Stat. 153 (1996), *codified at* 47 U.S.C. § 157 nt.; *see also Deployment of Wireline Services Offering Advanced Telecommunications Capability*, Memorandum Opinion and Order and Notice of Proposed Rulemaking, 13 FCC Rcd 24012, ¶¶ 69, 76 (1998) ("*Wireline Broadband Deployment Order*") (noting that Section 706 "directs the Commission to use the authority granted in other provisions, including the forbearance authority under section 10(a), to encourage the deployment of advanced services" and to "further Congress' objective of opening all telecommunications markets to competition") (emphasis added); FCC 2006 – 2011 Strategic Plan at 5, available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-261434A1.pdf ("Strategic Plan"). The Commission has incorporated the goals of Section 706 in its Strategic Plan. The Strategic Plan identifies several specific objectives necessary to meet the Commission's broadband goal. It states that the Commission shall: (1) promote the availability of broadband to all Americans; (2) define broadband in a technologically neutral fashion that includes any platform capable of transmitting high-bandwidth intensive services, applications, and content; (3) ensure harmonized regulatory treatment of competing broadband services; (4) encourage and facilitate an environment that stimulates investment and innovation in broadband technologies and services; and (5) continue to monitor the deployment of advanced telecommunications capability in order to provide ongoing national and international policy leadership and consumer education in the emerging broadband area. *Id.* at 5-6.

[7] *See* 47 U.S.C. § 309(j)(3)(D); *see also* Strategic Plan at 3, 8.

[8] *See* supra note 6.

[9] The Commission dismissed without prejudice the M2Z Application, and denied M2Z's related Petition for Forbearance, in an order released on August 31, 2007. *See Applications for License and Authority to Operate in the 2155-2175 MHz Band, Petitions for Forbearance Under 47 U.S.C. § 160*, WT Docket Nos. 07-16 & 07-30, Order, FCC 07-161 (rel. Aug. 31, 2007) (the "Order"). M2Z timely appealed the Order by filing on September 11, 2007, a Notice of Appeal in the United States Court of Appeals for the District of Columbia Circuit. The case was docketed by the court and assigned No. 07-1360, and filings in the docket have already begun. In the Notice of Appeal, M2Z asked the court to hold unlawful and set aside the Order, and also to compel the Commission to grant M2Z the license unlawfully withheld under the terms of that Order.

principles, proposals, and specific service rules described below. M2Z respectfully submits as well that the Commission should reject proposals in the NPRM that would hinder or prevent achievement of the Commission's stated aim "to allow for the most effective and efficient use of the spectrum in this [2155-2175 MHz] band, while also encouraging development of robust wireless broadband services."[10]

II. THE COMMISSION'S FIRST TASK IS TO DETERMINE THE HIGHEST AND BEST USE OF THE 2155-2175 MHZ BAND

A. The Commission is Obligated to Encourage the Deployment of Affordable Broadband and Advanced Telecommunications Capability to <u>All</u> Americans

As the Commission itself has recognized, Section 706 of the Telecommunications Act of 1996 "directs the Commission to encourage broadband deployment by utilizing 'measures that promote competition . . . or other regulating methods that remove barriers to infrastructure investment'"[11] and commands the Commission to "encourage the deployment on a reasonable and timely basis of advanced telecommunications capability to <u>all</u> Americans."[12] Because Section 706 charges the Commission to adopt regulatory policies that encourage broadband deployment on these terms, the Commission should use the utmost care to fashion service rules that will encourage the highest and best utilization of the 2155-2175 MHz band: that is, use of

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[10] NPRM ¶ 2.

[11] *Implementation of Section 621(a)(1) of the Cable Communications Policy Act of 1984 as amended by the Cable Television Consumer Protection and Competition Act of 1992*, Report and Order and Further Notice of Proposed Rulemaking, 22 FCC Rcd 5101, ¶ 62 (2007) (citing 47 U.S.C. § 157 nt.) ("*Local Cable Franchising First Report and Order*"). This order noted the Commission's obligation under Section 706 and found that "a provider's ability to offer video service and to deploy broadband networks are linked intrinsically, and the federal goals of enhanced cable competition and rapid broadband deployment are interrelated." *Id.* The Commission thus concluded that "if the franchising process were allowed to slow competition in the video service market, that would decrease broadband infrastructure investment, which would not only affect video but other broadband services as well." *Id.*; *see also Wireline Broadband Deployment Order* ¶ 69, 76.

[12] 47 U.S.C. § 157 nt., sec. (a) (emphasis added). The term "advanced telecommunications capability is defined as "high-speed, switched, broadband telecommunications capability that enables users to originate and receive high-quality voice, data, graphics, and video telecommunications using any technology." *Id.* sec. (c)(1).

the spectrum to provide a new broadband service that would be available to the vast majority of the nation, as quickly as possible, and on the most reasonable and affordable terms possible.

As the Court of Appeals for the District of Columbia has held, the Commission can "consider the goals of Section 706" when formulating policy under the Act.[13] Furthermore, other Communications Act provisions, as well as various Commission decisions and policies designed to implement these statutory mandates, naturally support and ally with the directives of Section 706. For example, at the very outset of the Communications Act, Section 1 obligates the Commission to ensure that "all the people of the United States" have access to "wire and radio communication service with adequate facilities at reasonable charges."[14] In light of present technology and present-day marketplace realities, Section 1 requires the Commission to work diligently to ensure that all Americans have access to affordable broadband capability if they are to have anything approaching "adequate facilities" needed to take full advantage of today's economic, educational, civic, and social opportunities.[15] Unlike other options discussed in the NPRM, M2Z's proposal makes it possible for the Commission to achieve this goal.

The Commission's Strategic Plan for 2006-2011 confirms its commitment that "[a]ll Americans should have <u>affordable</u> access to robust and reliable broadband products and services."[16] The plan also stipulates that the Commission's "[r]egulatory policies must promote technological neutrality, competition, investment, and innovation to ensure that broadband

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[13] *See, e.g.*, *Local Cable Franchising First Report and Order* ¶ 4 (citing *USTA v. FCC*, 359 F.3d 554, 579-80 (D.C. Cir. 2004)).

[14] 47 U.S.C. § 151.

[15] *See Joint Board Recommended Decision* ¶ 61; *see also id.* ¶ 58 (finding that "broadband Internet services are essential to education, public health, and public safety" but that "[i]n all of these applications, classical dial-up Internet access is marginally useful, and is often inadequate").

[16] Strategic Plan at 5 (emphasis added).

service providers have sufficient incentive to develop and offer such products and services."[17] The Commission identified in the plan several specific steps it will take to achieve its broadband development goals, including its intention to "encourage and facilitate an environment that stimulates investment and innovation in broadband technologies and services."[18] For these reasons, any service rules adopted for the 2155-2175 MHz band should have as their core purpose the aim of increasing the number of affordable broadband choices available to all Americans.

B. The Commission Should Promulgate Regulations that Encourage Innovative Service Offerings for Consumers as well as Efficient and Intensive Use of Spectrum

Section 706 and Section 1 do not stand alone, of course, in directing the Commission to promote aggressively the deployment of new services throughout the nation. The Commission also is required under other statutory provisions to promote "the development and rapid deployment of new technologies, products, and services for the benefit of the public . . . without administrative or judicial delays."[19] This language, contained in Section 309(j)(3)(A), bolsters and expands upon the Commission's mandate under Section 7 "to encourage the provision of new technologies and services to the public."[20]

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[17] *Id.*

[18] *See id.*

[19] 47 U.S.C. § 309(j)(3)(A). Section 309(j)(3) directs the Commission to consider six specific public interest factors when establishing competitive bidding processes, including any such competitive bidding mechanism that the Commission may use to assign licenses for the 2155-2175 MHz band. Moreover, Commission precedent dictates that these same factors apply when the Commission considers the public interest benefits of assigning licenses pursuant to other mechanisms as well. *See Implementation of Sections 309(j) and 337 of the Communications Act of 1934 as Amended*, Report and Order and Further Notice of Proposed Rulemaking, 15 FCC Rcd 22709, ¶ 21 (2000).

[20] 47 U.S.C. § 157(a). M2Z notes that the Commission's Order dismissing M2Z's Application without prejudice erroneously concluded that M2Z's proposed free, family-friendly, nationwide broadband service is not a "new technology or service" within the meaning of 47 U.S.C. § 157(b). *See* Order ¶ 13. To the contrary, the service proposed by M2Z in its Application would be "new" because no one in the market offers a service like it, and would be innovative because of its use of spectrally efficient and innovative technologies.

The Commission could best encourage innovation and the rapid deployment of new services in the 2155-2175 MHz band – and also avoid the type of administrative delays that left the 2155-2175 MHz band under-utilized for the better part of fifteen years[21] – by adopting service rules that would reduce technological and legal encumbrances to efficient and intensive use of the spectrum. The mandates of Section 309(j)(3) are quite clear: the statute requires the Commission, in the design of competitive bidding processes and other license assignment mechanisms, to "include safeguards to protect the public interest in the use of the spectrum and . . . promote the purposes specified in [Section 1] of this Act."[22] Among the objectives that the Commission must promote are the aforementioned rapid deployment of new technologies, as well as "efficient and intensive use of the electromagnetic spectrum."[23] Adoption of service rules such as those proposed in these Comments, and earlier proposed in the original M2Z Application, would promote this goal of efficient and intensive use of the 2155-2175 MHz band.

Finally, with respect to efficient and intensive use of spectrum, the Commission has a duty under Section 303 of the Communications Act to adopt such regulations as it deems necessary to prevent harmful interference between radio stations <u>and</u> to encourage more effective use of radio spectrum in the public interest.[24] By adopting service rules such as those outlined in Part III of these Comments, and by allowing for the use of spectrally efficient, modern engineering approaches to ameliorate harmful interference as described in further detail in Parts IV and V below, the Commission can fulfill these various statutory mandates.

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[21] As M2Z has noted previously, the Commission first identified a segment of the spectrum in question in this proceeding as a candidate for reallocation during its 1992 Emerging Technologies proceeding. *See Redevelopment of Spectrum to Encourage Innovation in the Use of New Telecommunications Technologies*, Notice of Proposed Rule Making, 7 FCC Rcd 1542 (1992).

[22] 47 U.S.C. § 309(j)(3).

[23] *Id.* § 309(j)(3)(D). A service using spectrally efficient time division duplex ("TDD") technology, such as the service proposed in M2Z's Application, would satisfy this directive in Section 309(j)(3)(D).

[24] *See id.* § 303(f)-(g).

C. The Commission Should Encourage New Entry that Will Stimulate the Economy, Expand Consumer Choice, and Promote Affordable Services

The requirement that the Commission to promote new entry by way of the service rules it adopts for the 2155-2175 MHz band are just as clear as the requirements described above for new services, technologies, and investment in broadband infrastructure. The Communications Act requires the Commission to promote competitive entry and to prevent "excessive concentration of licenses" in the hands of any one entity or group of incumbent licensees. Section 309(j)(3)(B) requires the Commission to fulfill through its licensing processes the objective of "promoting economic opportunity and competition and ensuring that new and innovative technologies are readily accessible to the American people by avoiding excessive concentration of licenses and by disseminating licenses among a wide variety of applicants."[25]

Careful reading of this statutory provision reveals the importance that the Communications Act places on the broad dissemination of licenses to a wide variety of prospective licensees, including small businesses, companies that typically serve rural areas, businesses that are "owned by members of minority groups and women,"[26] and other entities likely to be new entrants in the market to provide broadband and other communications services. Section 309(j)(3)(B) indicates that Congress viewed avoidance of excessive concentration of licenses not just as a valuable aim in and of itself, but as a means to achieve other vital public policy goals such as promoting economic opportunity and competition and thereby ensuring that new and innovative technologies are accessible to all Americans. Therefore, while the Commission has stated that its duty under the Communications Act "is to protect efficient

[25] *Id.* § 309(j)(3)(B).

[26] *Id.* Section 309(j)(4)(D) also directs the Commission to "ensure that small businesses, rural telephone companies, and businesses owned by members of minority groups and women are given the opportunity to participate in the provision of spectrum-based services," and to consider concrete steps for reaching these goals such as the use of tax certificates and bidding preferences. *Id.* § 309(j)(4)(D).

competition, not competitors,"[27] the Act does require the Commission to promote dissemination of licenses among potential new entrants as a means of obtaining the benefits that competition delivers.

III. THE COMMISSION SHOULD ESTABLISH A BAND PLAN AND SERVICE RULES THAT PROMOTE THE AVAILABILITY OF A FREE BROADBAND SERVICE WHILE ENCOURAGING NEW INNOVATIONS AND INNOVATORS

A. Consumers Would Reap Considerable Benefits if the Commission Were to Permit Exclusive, Nationwide Use of the Entire 20 Megahertz Block

In the NPRM, the Commission seeks comment on the appropriate band plan for the AWS-3 band.[28] In particular, the NPRM requests comment on the appropriate license block sizes, the use of geographic area licensing, and the specific geographic area for each license.[29] The Commission also seeks comment on whether it should abandon the current allocation for the 2155-2175 MHz band in favor of an unlicensed regime or a non-exclusive licensing approach.[30] As discussed below, the Commission should adopt a single, 20 MHz nationwide license for the unpaired 2155-2175 MHz band and provide for exclusive use of the band. Doing so would hasten the deployment of broadband services, promote innovation, and promote new entry and increased competition as well.

20 MHz Block Size. As the Commission recently stated in the *700 MHz Second Report and Order*, spectrum blocks that are 20 MHz or larger "enable a broader range of broadband services (including Internet access at faster speeds), accommodate future higher data rates, and

[27] *AT&T Inc. and BellSouth Corporation, Application for Transfer of Control*, Memorandum Opinion and Order, 22 FCC Rcd 5662, ¶ 195 (2007).

[28] *See* NPRM ¶ 24 *et seq.*

[29] *See id.* ¶¶ 24-38.

[30] *See id.* ¶ 95.

provide operators with additional capacity and, importantly, flexibility."[31] Moreover, adopting a 20 MHz block size would be consistent with prior license sizes adopted in the AWS bands.[32] In addition, the Commission recently adopted a 22 MHz block in the Upper 700 MHz Band, noting that it would "promote more innovative and efficient broadband deployment" and "stimulate[ ] new entry."[33] To further those same goals, the Commission should adopt a 20 MHz block for the AWS-3 band. Finally, assigning the spectrum in one 20 MHz block would make it more likely that the licensee of the block – if it is a new broadband market entrant – would have a sufficient amount of spectrum to compete effectively against incumbent broadband providers nationally and in various local markets. Assuming M2Z's technical proposals are adopted, 20 MHz would ensure a sufficient amount of spectrum for the licensee to provide a robust broadband service that could be viewed as a real substitute for – rather than a mere complement to – existing wireline broadband offerings.

Geographic Area Licensing. The Commission also should assign the AWS-3 band using geographic area licensing, as proposed in the NPRM.[34] Geographic area licensing would maximize flexibility and promote the rapid deployment of new technologies, permit economies of scale, and reduce the transaction costs associated with site-by-site licensing.[35] Adopting

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[31] *Service Rules for the 698-746, 747-762 and 777-792 MHz Bands*, Second Report and Order, 22 FCC Rcd 15289, ¶ 69 (2007) ("*700 MHz Second Report and Order*") (citing *Service Rules for Advanced Wireless Services in the 1.7 and 2.1 GHz Bands*, Order on Reconsideration, 20 FCC Rcd 14058, ¶ 15 (2003) ("*AWS-1 Order on Reconsideration*")); *see also Service Rules for Advanced Wireless Services in the 1.7 and 2.1 GHz Bands*, Report and Order, 18 FCC Rcd 25162, ¶ 44 (2003) ("*AWS-1 Report and Order*").

[32] For example, in the AWS-1 band plan, the Commission auctioned three of the five spectrum blocks (accounting for two-thirds of the total available spectrum) in 20-megahertz blocks. *AWS-1 Order on Reconsideration* ¶¶ 15, 19-20.

[33] *700 MHz Second Report and Order* ¶ 69.

[34] NPRM ¶ 31.

[35] *Id.* ¶ 32.

geographic area licensing for the AWS-3 band also would be consistent with the approach adopted for the AWS-1 bands.[36]

Nationwide Geographic Area. To ensure that the benefits of a free wireless broadband service are made available to as many Americans as possible, the Commission should adopt a nationwide geographic license area for the 20 MHz AWS-3 band license. As discussed above, Section 706 requires the Commission to encourage the deployment of advanced telecommunications capability on a reasonable and timely basis to all Americans, and the Commission's Strategic Plan commits to meeting that goal. A nationwide 20 MHz license, combined with aggressive performance requirements, would meet these objectives.

Creating a single nationwide license also would greatly simplify interference mitigation and reduce the likelihood of harmful interference to adjacent bands. With a single AWS-3 licensee, coordination with adjacent band operators to limit harmful interference would be significantly simplified and such an approach would provide the necessary level of protection that the Commission seeks.

A nationwide license also would encourage new entrants to apply for the license (or bid on the license, if the Commission adopts a competitive bidding framework). If the Commission instead adopts smaller geographic areas, new entrants interested in providing a nationwide service would face an "aggregation risk" or "exposure risk" due to the risk that they could obtain only a portion of the nationwide footprint they desire. In the 700 MHz proceeding, the Commission found that the use of large geographic service areas reduces transaction costs and

[36] *See AWS-1 Report and Order* ¶ 30. For these reasons, the Commission should reject the coordinated-use licensing scheme previously proposed by NextWave.

can facilitate new entry into the marketplace.[37] Its findings in the 700 MHz band are just as relevant here, where the Commission also has the opportunity to promote new entry.

Unpaired Use. Unpaired spectrum at 2155-2175 MHz is ideal for the deployment of broadband services using time division duplex ("TDD") technology, and a licensee with exclusive use of the band could use TDD to facilitate broadband quality and faster data rates. TDD technology makes an unpaired spectrum allocation a viable method for promoting new entry into the broadband services market. Furthermore, by adopting service rules requiring the use of this spectrum to deploy wireless broadband as well as technical rules that allow for the use of TDD technologies, the Commission would be fulfilling its desires both to increase broadband availability and to identify a potential home for TDD.[38]

Technical Flexibility. To ensure the benefits to be obtained from deployment of advanced technologies that would use the 2155-2175 MHz band most efficiently, the Commission should adopt service rules that provide the highest degree of technical flexibility for the AWS-3 licensee. To that end, M2Z proposes ABRS service rules that would give the licensee the same freedom to deploy new services and technology that the Commission grants licensees in other services, subject, as such other licensees are, to limitations setting generally applicable emission thresholds and limits on harmful interference to other spectrum users. The interference impact of ABRS on neighboring licensees should be no greater than the impact of more traditional technologies; therefore, the AWS-3 licensee need not and should not be subject to unreasonable and unprecedented interference mitigation requirements. As explained in greater detail below, the Commission should adopt service rules based on its longstanding principles of

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[37] *See 700 MHz Second Report and Order* ¶¶ 74, 81.

[38] *AWS-1 Report and Order* ¶ 46 (stating that the Commission would "make every effort to provide spectrum for TDD systems in future allocation and spectrum proceedings").

technical flexibility, in order both to enable the provision of new services and to protect existing licensees from harmful interference.

Unlicensed Regime. The Commission seeks comment on the benefits and costs of establishing an unlicensed regime for the AWS-3 band, either in lieu of a licensed regime or as a complement to a licensed regime.[39] Establishing an unlicensed regime, however, would depart from more than a decade's worth of AWS spectrum allocation decisions, just at the point when the long-anticipated public interest benefits of those prior allocation decisions would be realized.[40]

Furthermore, establishing an unlicensed regime would represent an unwarranted departure from prior Commission precedent regarding the relocation of incumbent licensees, as the Commission has long recognized that relocation costs are best borne by permanent licensees.[41] In the *AWS Ninth Report and Order*, the Commission required users of the 2155-2175 MHz band to relocate line-of-sight incumbent Broadband Radio Service ("BRS") systems and incompatible Fixed Service ("FS") operations according to a definite timetable.[42] Although an AWS-3 band licensee would have an economic incentive to relocate incumbents quickly and smoothly, unlicensed users would not have such an incentive. While the Commission has previously established procedures for clearing spectrum designated for unlicensed use, those

[39] *See* NPRM ¶ 95.

[40] *See id.* ¶ 7.

[41] *See id.* ¶¶ 72-77.

[42] *See Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, Including Third Generation Wireless Systems*, Ninth Report and Order and Order, 21 FCC Rcd 4473, ¶¶ 16-54 (2006) ("*AWS 9th R&O*") (BRS interference and relocation standards); *id.* ¶¶ 55-63 (FS relocation rules).

procedures relied on imposing an assessment on the manufacturers of the equipment designed to operate in the unlicensed band, and they proved to be wholly ineffective.[43]

The amount of contiguous spectrum that is available in the AWS-3 band is also too small to warrant an unlicensed designation. The Commission has generally favored designating larger blocks when setting aside spectrum for unlicensed use. In the 5 GHz U-NII proceeding, for example, the Commission designated a total of 255 MHz of contiguous spectrum in the 5 GHz band for unlicensed use.[44] In the 2.4 GHz ISM band, the Commission designated 83 MHz of contiguous spectrum for unlicensed use.[45] Where the Commission has designated a smaller amount of contiguous spectrum for unlicensed use, such as with UPCS, the designation was not very useful and, in the case of asynchronous UPCS, the Commission ended up reallocating the band.[46]

Even if an unlicensed regime could overcome the technical and other challenges of operating in the AWS-3 band, designating the band for unlicensed use would fail to guarantee the delivery of a free, high-quality, and ubiquitous nationwide broadband service, along with the associated benefits to consumer welfare that would come with such a service. There is no

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[43] Indeed, the only precedent for "unlicensed" relocation is the unlicensed PCS ("UPCS") band at 1910-1930 MHz, where UTAM, Inc. was designated as the frequency coordinator to handle this activity. Under the provisions of the original Section 15.307 of the Commission's rules, manufacturers of unlicensed equipment for use in the UPCS band had to pay $20 per unit to UTAM, Inc. to finance licensed user relocation. *See* http://www.utam.org/ClearingFees.html. However, the Commission's own Spectrum Policy Task Force documented the failure of this policy as indicated by the small number of equipment authorization filings that were made in the band. *See* Report of the Unlicensed Devices and Experimental Licenses Working Group, Spectrum Policy Task Force, at p. 10-11. Any "UTAM-like" mechanism established to handle relocation at 2155-2175 MHz would face a daunting dilemma regarding the proper regime for funding incumbent relocation: the fees imposed on manufacturers would need to be low enough to encourage use while high enough to fund the relocations.

[44] *See Revision of Parts 2 and 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, Report and Order, 18 FCC Rcd 24484 (2003).

[45] *See* 47 C.F.R. § 2.106.

[46] *See Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, including Third Generation Wireless Systems*, Sixth Report and Order, Third Memorandum Opinion and Order, and Fifth Memorandum Opinion and Order, 19 FCC Rcd 20720, ¶ 41 (2004).

evidence that unlicensed use would result in the same level of public interest benefits that a licensed, free, nationwide broadband network would engender, meaning that such a decision would run contrary to the Commission's obligation to promote access by all Americans to advanced services.[47]

B. Establishing Additional Licensee Qualifications and Service Rules Would Ensure the Delivery of Meaningful Broadband Services to Consumers

In the NPRM, the Commission seeks comment on the appropriate regulatory framework for the AWS-3 band.[48] In particular, the NPRM requests comment on the particular service rules that should govern the AWS-3 band, as well as whether any specific licensee qualifications or eligibility restrictions should apply.[49]

During the pendency of M2Z's Application, hundreds of parties filed comments in support of M2Z's vision for the 2155-2175 MHz band. These commenters noted and lauded the wide-ranging public interest benefits that a free, nationwide family-friendly broadband service would generate, including (1) bolstering the competitiveness of small and independent businesses,[50] (2) creating a more competitive broadband marketplace,[51] (3) increasing diversity

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[47] *See* 47 U.S.C. § 157 nt. (setting forth Section 706 of the Telecommunications Act of 1996).

[48] *See* NPRM ¶¶ 92-94.

[49] *See id.* ¶¶ 101-103.

[50] *See, e.g.*, Comments of the California Association for Local Economic Development, WT Docket No. 07-16, at 2-3 (submitted Feb. 14, 2007) (noting that widespread governmental interest in deploying broadband stems from recognition that broadband access fosters economic development and that M2Z's innovative proposal will help government expand broadband access using private funds); Amicus Curiae Comments of the Minority Media and Telecommunications Council, WT Docket No. 07-16, at 10-11 (submitted Mar. 2, 2007) ("MMTC Comments") (noting that the Internet is crucial to the success of all small and independent businesses, which account for over 99% of all companies, and asserting that "a free, nationwide broadband Internet access service would extend the potential of e-commerce to all businesses"); Comments of The Electronic Retailing Association, WT Docket Nos. 07-16 and 07-30, at 1-2 (submitted Feb. 26, 2007) ("ERA Comments") (noting that connection to the Internet makes available to online entrepreneurs the ability to market directly to the end-consumer in an affordable and direct way through e-mail, websites, and advertising); Comments of MAN-n-BAG, WT Docket Nos. 07-16 and 07-30, at 1 (submitted Mar.16, 2007) (highlighting the importance of online distribution channels for small business operators).

[51] *See, e.g.*, Comments of The Center for Digital Future, WT Docket No. 07-16, at 2 (submitted Feb. 27, 2007) ("Center for Digital Future Comments") (explaining the importance of market competition by highlighting the price drop for DSL service and an associated increase in broadband adoption); Comments of FiberTower Corporation,

in the management and ownership of communications outlets,[52] (4) enhancing educational opportunities,[53] (5) bridging the digital divide,[54] (6) supplementing and enhancing public safety

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WT Docket No. 07-16, at 2 (submitted Mar. 2, 2007) ("FiberTower Comments") ("Consumers win because they ultimately enjoy all the benefits of enhanced competition including greater choice and lower prices."); ERA Comments at 2 (noting that only 35% of small businesses currently have websites and only 57% use the Internet for business related activities, which "further exemplifies the need for affordable, reliable solutions to the significant, and often times, insurmountable, cost of broadband connectivity"); MMTC Comments at 10-11 (asserting that readily available broadband access is essential for small and independent businesses to remain successful in an increasingly electronic world); Comments of The Latino Coalition, WT Docket Nos. 07-16 and 07-30, at 1 (submitted Mar. 22, 2007) ("Latino Coalition Comments") (explaining that most Americans only have two choices for broadband: cable and DSL, which are still cost prohibitive to many Americans).

[52] *See, e.g.*, MMTC Comments at 2, 4 (noting that ("[w]ith one of the most diverse ownership and management teams of any communications business," M2Z is "a model of diversity for other communications businesses to follow").

[53] *See, e.g.*, Comments of Educause, WT Docket No. 07-16, at 1 (submitted Feb. 28, 2007) ("Ubiquitous broadband Internet access would empower teachers and promote student success by taking the educational experience beyond the walls of the classroom."); Comments of the National PTA, WT Docket No. 07-16, at 2 (submitted Mar. 1, 2007) (asserting that M2Z's proposal is as an "innovative and equitable way to ensure that broadband is an educational resource available to all Americans – parents, children and educators"); Comments of the Higher Education Wireless Access Consortium, WT Docket No. 07-16, at 1 (submitted Feb. 28, 2007) (supporting M2Z's proposal because M2Z will help bridge the gap of wireless connectivity in the classrooms of those schools with fewer resources); Comments of the League for Innovation in the Community College, WT Docket No. 07-16, at 1 (submitted Feb. 28, 2007) (reporting that while computer and Internet access has increased, there still remains a substantial information divide with "communities that do not have adequate access to the Internet and technology-based training, resources, and services"); Comments of the College Parents of America, WT Docket No. 07-16, at 1 (submitted Feb. 28, 2007) (indicating that with the cost of college rising, free broadband service would provide great financial relief to struggling parents and would allow more students to participate in distance learning programs).

[54] *See, e.g.*, Comments of the Association of Community Organizations for Reform Now, WT Docket No. 07-16, at 1-2 (submitted Feb. 2, 2007) ("ACORN Comments") (stating that current Internet providers are more interested in the bottom line through service to wealthier Americans with high monthly subscription rates, while M2Z will solve the problems of broadband availability and affordability); Comments of One Economy Corporation, WT Docket No. 07-16, at 2 (submitted Mar. 1, 2007) ("One Economy Comments") ("[T]his type of market innovation will further One Economy's mission, benefit an underserved portion of our country, and serve the public interest."); Latino Coalition Comments at 2 (submitted Mar. 22, 2007) (citing National Center for Education Statistics showing that only 44% of Hispanic children use the Internet at school, compared to 59% of all students, and arguing that "M2Z Networks offers a legitimate opportunity to shrink the digital divide and provide real opportunities for the Latino community to take advantage of the incredible educational and economic development opportunities available on the Internet and to develop skills and compete for jobs in the information economy").

communications,[55] (7) promoting spectral efficiency,[56] and (8) protecting children from potentially harmful online materials,[57] among many others.

These Comments underscore why M2Z's ABRS proposal for the 2155-2175 MHz band represents the highest and best use of the spectrum. To maximize the potential benefits of the 2155-2175 MHz band, therefore, the AWS-3 licensee should be subject to the proposed ABRS service rules, which articulate the enforceable public interest requirements described below. Furthermore, the Commission should promote competition and new entry by enacting meaningful performance or buildout requirements and limiting eligibility for the AWS-3 band to entities that: (1) hold less than 20 MHz of spectrum in at least 50% of the counties of the United States; and (2) have not failed to meet performance requirements for any licenses that they currently hold. These proposed services rules are discussed in greater detail below and set forth in Appendix A.

Each of these proposed requirements is designed to respond to a particular market failure. Although the Commission only required minimal public interest commitments from neighboring AWS-1 licenses, "[o]ne of the most significant advantages of the administrative process is its

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[55] *See, e.g.*, Comments of the National Troopers Coalition, WT Docket No. 07-16, at 1 (submitted Feb. 6, 2007) ("M2Z's proposed network will provide another layer of redundancy to bolster existing and planned public safety-operated networks and help law enforcement stay operational in disasters.").

[56] Comments of Alion Science & Technology, WT Docket Nos. 07-16 and 07-30, at 2 (submitted Mar. 2, 2007) (concluding, after review of M2Z's proposal, that "M2Z's proposed network will use the most spectrally efficient technologies that are currently available for commercial radio systems").

[57] *See, e.g.*, Comments of Most Reverend Paul S. Loverde, WT Docket No. 07-16, at 2 (submitted Mar. 2, 2007) (emphasizing the importance of advancements like M2Z's network level filter to protect families from Internet pornography); Comments of United Families International, WT Docket Nos. 07-16 and 07-30, at 1-2 (submitted Mar. 16, 2007) (supporting access to "clean" wireless broadband for American families); Comments of Internet Keep Safe Coalition, WT Docket No. 07-16, at 2 (submitted Mar. 1, 2007) (expressing approval of M2Z's network-level filtering of indecent and pornographic material); Comments of Enough is Enough, WT Docket Nos. 07-16 and 07-30, at 1 (submitted Mar. 13, 2007) ("By making a commitment to use highly effective network based filtering, M2Z has found an innovative balance between spurring the rapid adoption of high speed internet service and protecting children and families from on line pornography and sexual predators.").

ability to adapt to new circumstances in a flexible manner."[58] The records developed in response to M2Z's Application[59] and the 700 MHz service rules proceeding,[60] among other proceedings, make clear that wireless incumbents are failing to deploy broadband services on a timetable that comports with the goals of Congress and the Commission. Moreover, those incumbents have a track record of limiting consumer use of the Internet through device and application restrictions.[61] In addition, public safety users have a critical need for interoperable broadband services. Even though the Commission adopted a plan in the 700 MHz proceeding to cause the deployment of a shared broadband network intended to meet public safety's needs, that network is still years away from serving the public safety community, and the costs to public safety of using the network – which could be very high – have not yet been determined.

As the Commission stated in the *700 MHz Second Report and Order*, "[w]hile the Commission strives to apply a consistent regulatory framework to like services," it is not obligated to "treat all spectrum-based services identically."[62] The Commission has applied different spectrum regulatory models under different market conditions, and has adopted policies to encourage new entrants and new competitive services.[63] Thus, as the Commission recognized, "in certain instances, it may be necessary to vary the regulation of spectrum use to achieve certain critical public interest objectives."[64] For these reasons, the Commission should adopt the service rules enumerated below.

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[58] *FCC v. National Citizens Committee*, 436 U.S. 775, 811 (1978).

[59] *See* WT Docket No. 07-16.

[60] *See* WT Docket No. 06-150.

[61] *See 700 MHz Second Report and Order* ¶ 190.

[62] *Id.* ¶ 202.

[63] *See id.*

[64] *Id.* In the *700 MHz Second Report and Order*, the Commission cited for this point its decisions in *Wireless Operations in the 3650-3700 MHz Band*, Memorandum Opinion and Order, 22 FCC Rcd 10421 (2007) ("*3650 MHz*

1. *Free, Nationwide Broadband Service*

The Commission should require, consistent with its public policy goals, that any licensee of the 2155-2175 MHz band provide a robust level of broadband service throughout the United States, free of subscriber and service charges. Because there is no presently available, ubiquitous wireless broadband service that can serve as a substitute for cable or DSL, such a service requirement is necessary to increase the availability of broadband service to all Americans without regard to geographic and demographic factors. Free broadband service will give consumers greater choice at lower prices.[65] It will allow unserved and under-served communities and populations, such as the rural, Latino, and small business communities, as well as low-income individuals and families throughout America, to have access to affordable broadband connectivity, thus bridging the digital divide.[66] A free service requirement also would increase broadband penetration, not only by accelerating the deployment of such services to the areas and people mentioned above, but also by spurring incumbents to expand their broadband networks and offer Internet services at lower prices.[67]

Facilitating use of the AWS-3 band to provide free, ubiquitous, nationwide broadband services would yield billions of dollars in economic benefits. According to Drs. Rosston and Wallsten, whose analyses were submitted with M2Z's Application,[68] universal access to

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Reconsideration Order"); *Unlicensed Operation in the TV Broadcast Bands*, First Report and Order, 21 FCC Rcd 12266 (2006); and the Spectrum Policy Task Force Report, ET Docket No. 02-135 (rel. Nov. 1, 2002). The special requirements adopted for the Upper 700 MHz D Block, relating to its operation under a Public/Private Partnership, amply demonstrate the Commission's willingness to craft market-based regulations that are nonetheless designed to meet identified needs.

[65] *See, e.g.*, Center for Digital Future Comments at 2; FiberTower Comments at 2; ERA Comments at 2; MMTC Comments at 10-11; Latino Coalition Comments at 1.

[66] *See, e.g.*, ACORN Comments at 1-2; One Economy Comments at 2; Latino Coalition Comments at 2.

[67] M2Z notes that several entities, including NetfreeUS and Open Range, have also offered to provide free broadband services in the AWS-3 band. As indicated above, M2Z respectfully suggests that the provision of free broadband service be required of the AWS-3 licensee.

[68] *See* M2Z Application, App. 5, at 1.

broadband ultimately could lead to total benefits of about $500 billion,[69] as well as reduced federal and state spending on universal service programs with a projected annual savings of $8.4 - $20 billion.[70] Similarly, the Commission's former Chief Economist, Dr. Simon Wilkie, and Dr. Kostas Liopiros also determined that free universal broad service would result in billions of dollars in economic benefits for consumers.[71] These benefits include lower prices for broadband service, free access for public safety entities, avoided new universal service broadband subsidies and other related savings.[72]

The societal benefits to consumers of a free nationwide broadband network are notable and could rival the benefits of broadcast TV. Like the initial grants of commercial broadcasting licenses under the Act, permitting exclusive, nationwide, and unpaired use of the entire 20 MHz block would facilitate the development of a free, advertising-supported wide-area communications service that would generate significant public value.[73] Just as the licensing of commercial broadcasting has contributed to the wider dissemination of public affairs and news programming, service rules establishing exclusive, nationwide, and unpaired use of the AWS-3 band also would result in a better-informed citizenry by making it easier for the majority of

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[69] *See id.* at 8.

[70] *Id.* at 20, 24.

[71] *See* Simon Wilkie, "The Consumer Welfare Impact of M2Z Networks Inc.'s Wireless Broadband Proposal," WT Docket No. 07-16, at 3, 8 (filed Mar. 2, 2007) (Wilkie, "Consumer Welfare Impact"); Kostas Liopiros, "The Value of Public Interest Commitments and the Cost of Delay to American Consumers," WT Docket No. 07-16, at i-ii (filed Mar. 19, 2007) ("Liopiros"). Like Dr. Wilkie, Dr. Liopiros took a cautious approach in estimating these benefits, yet Dr. Liopiros estimated the total benefit at a higher level due in part to inclusion of public safety agency benefits. *See* Liopiros at i-ii.

[72] *See* Wilkie, "Consumer Welfare Impact," at 3, 8; Liopiros at i-ii.

[73] *See, e.g.*, M2Z Application at 2.

Americans to gain access to a vast amount of information via eminently affordable broadband connections.[74]

2. *Open Platforms for Devices and Applications*

Consumers should have a myriad of choices when selecting wireless devices and applications. In the *700 MHz Second Report and Order*, the Commission adopted an open platform requirement for the Upper 700 MHz C Block to ensure that consumers could use the devices and access the applications of their choosing.[75] Even though many commenters argued in that proceeding that market forces would ensure sufficient device options for consumers, the Commission found that "there is evidence that wireless service providers nevertheless block or degrade consumer-chosen hardware and applications without an appropriate justification."[76] The Commission should continue to address device- and application-blocking problems by requiring the AWS-3 licensee to provide an open platform on its network.

3. *Family-Friendly Service*

A network-level filtering technology is necessary to protect children and families from harmful content that otherwise may be freely available on the Internet.[77] Although today's children are often competent users of the Internet, they do not have the maturity, experience, or knowledge to identify, much less avoid, the risks inherent in the global communications

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[74] *See, e.g.*, *Carriage of Digital Television Broadcast Signals: Amendments to Part 76 of the Commission's Rules*, Second Report and Order and First Order on Reconsideration, 20 FCC Rcd 4516, ¶ 14 (2005) (discussing the value of "preserving the benefits of free, over-the-air local broadcast television for viewers[ ] and [thereby] promoting the widespread dissemination of information from a multiplicity of sources").

[75] *See 700 MHz Second Report and Order* ¶ 195.

[76] *See id.* ¶ 200. M2Z committed to offering an open platform and providing wholesale services under its Application.

[77] *See, e.g.*, Comments of Most Reverend Paul S. Loverde at 2; Comments of United Families International at 1-2; Comments of Internet Keep Safe Coalition at 2; Comments of Enough is Enough at 1.

medium.[78] Even the most well-intentioned child can now accidentally stumble into inappropriate content on the Internet by typing in the wrong web address or search terms. Unlike the situation with broadcast television, however, no robust legal or business framework exists to protect children from harmful materials found on the Internet.[79] The Commission has an opportunity to address this problem by establishing rules that require the use of state-of-the-art, network-level content filters and other enhancements designed to assist parents in protecting their children.[80]

Providing filtering technology with free, ubiquitous service is both a responsible and efficient use of the spectrum. With such filtering in place, parents would be able to have more confidence in their ability to protect their children from inappropriate Internet content and activities, which should ensure expanded use of the Internet as an educationally valuable medium.

4. *Public Safety Use*

The Commission should require that a 2155-2175 MHz licensee provide public safety officials with broadband network access to basic service that is free of recurring charges, and the licensee should not be allowed to impose a limit on the type and number of AWS-3 compatible

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[78] For example, certain sexual content, including violent portrayals of sex and depictions of unorthodox sexual activity, may influence a child's developing attitudes towards sex and relationships. *See* Janis Wolak & David Finkelhor, "Unwanted and Wanted Exposure to Online Pornography in a National Sample of Youth Internet Users," Pediatrics, Vol. 119 No. 2, 247 (February 2007) (stating that "unwanted exposure [to pornography] could have a greater impact on some youth than voluntary encounters with pornography," and "some youth may be psychologically and developmentally unprepared for unwanted exposure, and online images may be more graphic and extreme than pornography available from other sources") (internal references omitted). Researchers have speculated that the negative impact of indecent images on children could be profound and lasting. *See id.* (stating that "[t]he high rate of exposure to online pornography among youth Internet users merits more attention," and that "[r]esearchers in the field of sexual development do not know whether there are important "primacy effects" related to early exposure of youth to pornography or what the effects of such exposures might be on anxieties, normative standards, or patterns of arousal in some youth") (internal references omitted).

[79] *See, e.g.*, 18 U.S.C. § 1464 (prohibiting the utterance of "any obscene, indecent or profane language by means of radio communication"); 47 C.F.R. § 73.3999 (prohibiting broadcast radio and television stations from airing obscene material, and limiting the time of day in which indecent material may be aired); *Infinity Broadcasting Corporation of Pennsylvania*, 2 FCC Rcd 2705 (1987) (defining indecent speech and citing *Pacifica Foundation*, 56 FCC 2d 94, 98 (1975), *aff'd sub nom. FCC v. Pacifica Foundation*, 438 U.S. 726 (1978) (upholding an indecency determination by the Commission against a First Amendment challenge)).

[80] Indeed, Section 230 of the Communications Act, 47 U.S.C. § 230, provides the Commission with adequate authority in this area.

devices that any particular public safety agency can attach to the licensee's network. In this way, public safety entities would be able to take advantage of a wide range of broadband applications that are not currently available on a wide-area public safety network, including data transmission and retrieval, data analysis, and some video applications. Such access would add a needed layer of redundancy to existing and planned public safety networks (including the proposed 700 MHz D Block shared network) and add a cheaper alternative for public safety access to broadband capabilities. If the Commission were to adopt a nationwide license for the band, it could also address further the interoperability challenges faced during September 11th and Hurricane Katrina and provide a secondary broadband IP network for the public safety community without using public funds.[81]

Under M2Z's proposed rules, any federal, state, county, or municipal public safety organization willing to utilize the ABRS will be able to do so for free, without any limit as to the nature and number of devices it may attach to the network.[82] The equipment that public safety officers might use to communicate such a network could also be capable of operating over local area networks, potentially enabling the use of extremely data-rich applications.[83]

5. *Meaningful Performance Requirements*

To ensure that an AWS-3 licensee builds and deploys a new, competitive broadband network as rapidly as possible, and consistent with the Commission's obligations under the Act to promote rapid deployment and avoid excessive concentration of licenses,[84] the Commission should adopt meaningful performance requirements. In the NPRM, the Commission seeks

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[81] *See Ex Parte* Filing by the Association of Public-Safety Communications Officials-International, International Association of Chiefs of Police, and International Association of Fire Chiefs, WT Docket Nos. 07-16 and 07-30 (submitted Aug. 30, 2007).

[82] M2Z Application at 25.

[83] *Id.*, Appendix 4, at 4.

[84] *See* Part II, *supra*.

comment on whether it should adopt the "substantial service" standard applied to the AWS-1 and other bands, or whether it should adopt specific construction benchmarks. M2Z believes that the Commission should require licensees to construct sufficient base stations to cover (a) 33% of the U.S population within three years of the license grant; (b) 66% of the U.S population within five years of the license grant; and (c) 95% of the U.S population within ten years of the license grant.[85]

6. *Licensee Eligibility Restrictions and License Holding Period*

Stringent construction benchmarks would help to ensure that the spectrum will be put to use quickly, but adopting performance requirements alone will not alter the incentives of a carrier that may be motivated to warehouse spectrum in order to limit, delay, or prevent new competitive entry.[86] As explained by Dr. Wilkie in an economic analysis submitted in dockets 07-16 and 07-30, incumbent wireless carriers have a troubling track record relating to the warehousing of spectrum.[87] While acquiring spectrum without any intent to put it to good use

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[85] The construction benchmarks proposed by M2Z are similarly aggressive to those recently adopted for the Upper 700 MHz C block. *See, e.g.*, *700 MHz Second Report and Order* ¶¶ 162-164. However, the Commission should adopt the benchmarks proposed herein or other benchmarks that are more appropriate for the AWS-3 band rather than those set forth in the *700 MHz Second Report and Order*.

[86] *See* Simon Wilkie, "Spectrum Auctions Are Not a Panacea: Theory And Evidence Of Anti-Competitive and Rentseeking Behavior in FCC Rulemakings and Auction Designs," WT Docket Nos. 07-16 & 07-30, at 13-19, 39 (filed Mar. 26, 2007) (Wilkie, "Spectrum Auctions"); *see also Ex Parte* Comments of the *Ad Hoc* Public Interest Spectrum Coalition, WT Docket No. 06-150, Attachment B (submitted Apr. 3, 2007) ("PISC Comments"); Letter from Harold Feld, Senior Vice President, Media Access Project, to Marlene Dortch, Secretary, Federal Communications Commission, WT Docket No. 06-150 (submitted Apr. 19, 2007) (submitting affidavit and study prepared by Dr. Gregory Rose) (hereinafter, "Rose Study"). The PISC comments in the 700 MHz proceeding cited and included as an exhibit an earlier study prepared for the Center for American Progress by Dr. Rose and Mark Lloyd, entitled "The Failure of FCC Spectrum Auctions," which similarly concluded that the Commission's spectrum auctions had been a "failure" and "subject to collusion and manipulation by big business." PISC Comments, Attachment B, at 1. Rose and Lloyd generally found that a small number of bidders tend to acquire the majority of spectrum auctioned by the Commission. *See id.* at 7. In his subsequent affidavit and study submitted later in April 2007, Dr. Rose concluded that incumbent spectrum licensees and providers of wireline broadband service used bid signaling and other tactics to exclude potential new entrants from the AWS-1 auction. *See* Rose Study at 1, 8-10.

[87] *See* Wilkie, "Spectrum Auctions," at 20 (citing *In the Matter of Promoting Efficient use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, Comments of 37 Concerned Economists, WT Docket No. 00-230, at 6 (submitted Feb. 7, 2001)).

might seem like an irrational economic choice, Dr. Wilkie explains that incumbent carriers may in fact have the incentive and ability to deter entry by new service providers, using methods designed to raise potential competitors' costs.[88]

For this reason, the Commission would not be able to satisfy the mandate in Section 309(j)(3)(B)[89] to avoid excessive concentration of licenses and disseminate licenses among a wide variety of applicants if it allowed incumbent spectrum licensees to acquire AWS-3 spectrum. Opening an auction for this spectrum to incumbents also would ignore the poor track record that incumbent wireless carriers have in terms of deploying fixed and portable wireless broadband services that serve as substitutes for – rather than mere complements to – the existing offerings of duopolistic wireline broadband service providers.[90] The Commission should therefore restrict eligibility to hold a license in the AWS-3 band to only those entities that: (1) hold less than 20 MHz of spectrum in at least 50% of the counties of the United States; and (2) have not failed to meet "substantial service" performance requirements for any licenses that they currently hold. Moreover, the 2155-2175 MHz licensee should be subject to a "holding period" of at least five years, in which no secondary market transactions in the license are permitted.[91] Thus, the AWS-3 licensee will have every incentive to build out its network.

Real world examples of apparent spectrum warehousing are numerous. For instance, licensees in the 2.3 GHz Wireless Communications Service ("WCS"), including AT&T, BellSouth, NextWave, Verizon, and others, have consistently failed to construct their networks

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[88] *See* Wilkie, "Spectrum Auctions," at 15-17.

[89] *See* 47 U.S.C. § 309(j)(3)(B).

[90] *See* Wilkie, "Consumer Welfare Impact," at 7-8.

[91] The Commission already imposes similar holding requirements to meet other public policy goals. *See, e.g.*, 47 C.F.R. § 1.2111 (describing the unjust enrichment provisions applicable to designated entities).

and meet applicable buildout requirements for licenses they acquired at auction in 1997.[92] The WCS band can be used to offer wireless broadband services, including services provided utilizing WiMAX technology, that would compete directly against cable modem and DSL services offered by incumbent local exchange carriers and cable operators that hold these licensees.[93] Perhaps not surprisingly, the wireline incumbents and affiliates that control many of the extant WCS licenses spent money to acquire these licenses at auction and in the secondary markets, but have done nothing to develop a service that might compete against wireline broadband offerings. Instead, after more than nine years of delay and finger pointing, these companies received a three-year extension of their buildout obligations.[94]

Another service in which licenses were acquired at auction before the turn of the century, but remain unused today is the Local Multipoint Distribution System ("LMDS") service. In 1998, the Commission auctioned two blocks amounting to 1300 MHz of spectrum for private commercial service utilizing LMDS in the 28, 29 and 31 GHz bands.[95] In assigning the licenses, the Commission expected licensees to provide fixed broadband services that would compete directly against DSL, cable modem and other fixed broadband access technologies. Incumbent LECs acquired licenses in this service, yet to date have done little with the spectrum.[96]

Spectrum warehousing also seems to be an issue in the Multichannel Video Distribution and Data Service ("MVDDS"). For example, EchoStar, owns 49.9 percent of South.com, a company that acquired 37 spectrum licenses in the 12.2-12.7 GHz band in auctions held in 2004

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[92] *See* Wilkie, "Spectrum Auctions," at 22-23 (citing *In the Matter of Consolidated Request of the WCS Coalition For Limited Waiver of Construction Deadline for 132 WCS Licenses*, Order, 21 FCC Rcd 14134, ¶ 13 (2006) ("*WCS Waiver Order*")).

[93] *See* Wilkie, "Spectrum Auctions," at 22.

[94] *See WCS Waiver Order* ¶ 13 (2006).

[95] *See* Wilkie, "Spectrum Auctions," at 25.

[96] *See id.*

and 2005, but has yet to construct facilities or offer services using those authorizations.[97] Finally, in the 2.1 GHz and 2.5 GHz bands currently allocated to the Educational Broadband Service ("EBS") and BRS, AT&T and BellSouth agreed as one of their merger commitments to divest all of the spectrum that BellSouth controlled, but put to little use, in the 2.5 GHz band.[98]

In light of the history of apparent spectrum warehousing by incumbents, spectrum policy experts have for years called upon the Commission to streamline processes available to new entrants in need of spectrum use rights.[99] If the Commission were to auction the 2155-2175 MHz band without an appropriate licensee eligibility restriction, there is a significant chance that large incumbent wireless and broadband providers would try to obtain the spectrum rights primarily to keep new entrants out of the market.

The wireless industry has seen significant consolidation and aggregation since the Commission removed the spectrum cap for Commercial Mobile Radio Services ("CMRS").[100] As incumbent wireless carriers continue to grow, and their incentives and ability to warehouse spectrum and prevent competition increase, it becomes ever more important for the Commission to prevent such anticompetitive behavior.

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[97] *See id.* at 23-24 (citing *In the Matter of Consolidated Request of the WCS Coalition For Limited Waiver of Construction Deadline for 132 WCS Licenses*, Order, 21 FCC Rcd 14134, ¶ 13 (2006)).

[98] *See id.* at 24.

[99] *See id.* at 25-28.

[100] *See, e.g.*, *2000 Biennial Regulatory Review Spectrum Aggregation Limits For Commercial Mobile Radio Services*, Report and Order, 16 FCC Rcd 22668 (2001) ("*2000 Biennial Review*"); *Nextel Communications, Inc. and Sprint Corporation for Consent to Transfer Control of Licenses and Authorizations*, Memorandum Opinion and Order, 20 FCC Rcd 13967 (2005); *Assignment of License Authorization Applications, Transfer of Control of Licensee Applications, De Facto Transfer Lease Applications and Spectrum Manager Lease Action Notifications*, Public Notice, Report No. 2086 (Wireless Telecom. Bur. rel. Mar. 2, 2005) (granting license transfer application of NextWave Telecom Inc. and Cellco Partnership d/b/a Verizon Wireless); *Applications for Consent to the Assignment of Licenses from NextWave Personal Communications, Inc., and NextWave Power Partners, Inc., to Subsidiaries of Cingular Wireless LLC*, Memorandum Opinion and Order, 19 FCC Rcd 2570 (2004); *Applications of AT&T Wireless Services, Inc., Transferor, and Cingular Wireless, Corp., Transferee*, Memorandum Opinion and Order, 19 FCC Rcd 21522 (2004); *Applications of Northcoast Communications, LLC and Cellco Partnership d/b/a Verizon Wireless For Consent to Assignment of Licenses*, Memorandum Opinion and Order, 18 FCC Rcd 6490 (2003).

The 2155-2175 MHz band presents an excellent opportunity for the Commission to fulfill its mandates under Section 309(j) by encouraging a new entrant to compete in the market for wireless broadband services. In the absence, however, of carefully structured rules and qualifications to protect against spectrum warehousing by incumbent operators, an auction could yield suboptimal results. When the Commission removed the spectrum cap in favor of a case-by-case analysis, it noted that it could still "shape the initial distribution of licenses" through specific rules.[101] Adopting licensee eligibility restrictions and a holding period for this band would ensure that the licensee has the incentive to build and deploy a new, competitive network.

7. *Wholesale Services*

The Commission also should require the AWS-3 licensee to provide wholesale access to its network on any additional tiers of services beyond the basic service, and to do so on reasonable and nondiscriminatory terms and conditions. In this way, the Commission could facilitate the development of a vibrant, competitive wholesale market. A meaningful wholesale requirement also would promote the deployment of wireless broadband services.

C. If the Commission Decides to Auction the Spectrum, Its Auction Rules Should Match the Commission's Priorities Under the Communications Act

The NPRM seeks comment on several auction-related issues that would be raised if the Commission were to decide that it is in the public interest to assign the AWS-3 band via competitive bidding. These issues set forth for comment include the appropriate auction format, the possibility of package bidding, and the timing of any auction.[102] As explained in numerous M2Z filings in its license application proceeding, the Commission is not required to auction the

[101] *See 2000 Biennial Review* ¶ 52.

[102] NPRM ¶¶ 39-48.

2155-2175 MHz spectrum.[103] If, however, it decides to auction the AWS-3 band, the Commission should utilize a simultaneous multiple round ("SMR") ascending format auction, as it has done in many prior auctions (including the AWS-1 auction). The SMR format has worked well in the past, and many potential bidders are familiar with those auction procedures.[104]

M2Z believes that the Commission should schedule and begin any auction for the AWS-3 band as soon as possible, in order to ensure the rapid deployment of services to the public consistent with Section 309(j)(3)(A). The Commission issued a Notice of Proposed Rulemaking in 2001 asking, among other things, whether 2110-2170 MHz would be suitable for third generation ("3G") services.[105] Six years later, and although a number of large incumbent wireless operators supported speedy reallocation of the 2155-2175 MHz band for advanced wireless services,[106] the band remains devoid of permanent occupants and mature, consumer-based services, to the detriment of American consumers. Therefore, the Commission should ensure that its service rules and auction procedures facilitate and require an aggressive timeline for network and service deployment, so that innovative advanced wireless services may be provided to the public without further delay.

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[103] *See, e.g.*, M2Z Consolidated Opposition, WT Docket No. 07-16, at 31-60 (filed Mar. 26, 2007). M2Z's proposal also provided for an alternate payment method so that the Commission could recover for the public of a portion of the value of the public spectrum resource. *See, e.g.*, M2Z Application at 26.

[104] The Commission also should adopt the basic SMR format without a package bidding option. As discussed above, the AWS-3 band should be assigned via a single, nationwide license, which eliminates the need for package bidding.

[105] *Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, Including Third Generation Wireless Systems, Petition for Rulemaking of the Cellular Telecommunications Industry Association Concerning Implementation of WRC-2000: Review of Spectrum and Regulatory Requirements for IMT-2000*, Notice of Proposed Rulemaking and Order, 16 FCC Rcd 596, ¶¶ 50-57 (2001) ("*Implementation of WRC-2000 Order*").

[106] Petition for Rule Making of the Cellular Telecommunications Industry Ass'n Concerning Implementation of WRC-2000: Review of Spectrum and Regulatory Requirements for IMT -2000 (July 12, 2000) (CTIA Petition); Petition for Rule Making of the Cellular Telecommunications Industry Ass'n Concerning Implementation of WRC-2000, RM-9920 (2000) (Comments of Qualcomm Inc.); Review of Spectrum and Regulatory Requirements for IMT-2000, RM-9920 (2000) (Comments of AT&T Wireless Services, Inc.); Review of Spectrum and Regulatory Requirements for IMT-2000, RM-9920 (2000) (Comments of Verizon Wireless).

The Commission should refrain from adopting the other auction-related proposals detailed in the NPRM. For example, the Commission seeks comment on the possibility of relying on an auction-based mechanism for selecting among a limited number of band plan options, in which bidders would bid simultaneously on an assortment of licenses from different band plans.[107] Under this format, the band plan that received the highest aggregate bid value (by totaling the bids for each of the licenses offered under that band plan) would be adopted by the Commission.[108] This proposal is both inefficient and impractical. As the Commission suggests in the NPRM, an auction in which only some of the licenses offered would actually be sold complicates bidding strategies, creates opportunities for bidders to distort prices, and increases the risk of bid signaling.[109] In addition, selecting the band plan as part of the auction process creates an additional bidding problem: because the same bid determines both the winner of the license and the particular band plan adopted, bidders may feel "forced" to bid on a license that is part of a less-desirable (to the bidder) band plan in order to obtain the license, even though that individual bidder may have been willing to bid more for a license offered under a different band plan.

The Commission apparently acknowledges the challenges associated with simultaneously selecting the winning band plan and winning licensee because it also seeks comment on the potential use of a "two-stage" auction.[110] Under this approach, the Commission would first use an auction to determine the band plan, and then determine the winning licensee in a second auction (considered the second "stage"). However, a two-stage auction approach raises too

[107] NPRM ¶ 42.

[108] *Id.*

[109] *See id.* ¶ 43.

[110] *Id.* ¶ 45.

many questions and is not feasible. For example, the Commission fails to identify the "currency" that would be used for bidding in the first auction. Bidders may be hesitant to pay money to the Commission in return for adopting a preferred band plan, given that such bids would not ensure that the bidder would actually obtain a license in the second stage of the auction. Moreover, it is unclear whether the second stage would be open only to bidders that placed bids (or otherwise signaled their preferences) on the winning band plan or whether a larger group of potential bidders would be eligible to participate in the second stage. Additionally, an auction-based mechanism for selecting among a limited number of band plan options would be completely unnecessary if the Commission, as M2Z proposes, were to adopt a single, nationwide license for the 2155-2175 MHz band and provide service rules flexible enough for the licensee to provide uplink, downlink, or a combination of uplink and downlink operations in the band.

Finally, the Commission should reject the proposal to utilize an auction approach to determine the appropriate performance requirements for the AWS-3 band.[111] Such an approach would be subject to the same feasibility concerns as those mentioned above for the two-stage auction approach. In addition, combining bid values with performance commitments (*e.g.*, using a "scoring auction") would effectively tilt the auction in favor of incumbent providers that have already constructed networks. "Scoring" applicants would also effectively add a "beauty contest" component to the auction. If the Commission adopts service rules and auction rules that lead to the acceptance of mutually exclusive applications, Section 309(j)(1) requires that it auction the spectrum.

[111] *Id.* ¶ 47.

IV. THE COMMISSION SHOULD NOT MANDATE A SPECIFIC TECHNOLOGICAL APPROACH FOR USE IN THE 2155-2175 MHZ BAND BUT SHOULD PROMOTE TECHNICAL FLEXIBILITY TO ENSURE THE HIGHEST AND BEST USE

There are several objectives that the Commission must consider when evaluating a technological approach for the AWS-3 band. The NPRM proposes three technological approaches that might be used in the band, but each of these approaches should be evaluated in terms of whether it (1) enables a new, nationwide broadband entrant (2) provides for technical and operator service flexibility, and (3) optimizes the efficiency with which the spectrum can be used. Of the three approaches, the uplink/downlink approach best meets these objectives. By contrast, the other approaches suggested in the NPRM would limit a licensee's choice of technology, operations, and services, and therefore would be inconsistent with the Commission's technological neutrality principles. M2Z supports rules for the AWS-3 band that would permit the maximum amount of flexibility regarding licensee operations and services under a technologically neutral regime with interference constraints. By contrast, M2Z sees no justification for mandating a particular technological or operational approach. The Commission should permit an AWS-3 band licensee the technical flexibility to conduct any combination of uplink and/or downlink operations in the band, as long as that licensee protects other licensees from harmful interference using the measures outlined in greater detail below.

A. There Is No Rational Policy or Technical Justification for a Downlink-Only Model

The Commission seeks comment on a "downlink-only" approach for the AWS-3 band, which would limit use of the band to base transmissions only.[112] Such an approach would enable licensees to use the band (either alone or in combination with other downlink bands) for

[112] *See id.* ¶ 21.

downlink-only, broadcast-type operations, such as video streaming.[113] This approach also might enable an existing licensee of paired spectrum to combine the 2155-2175 MHz band with the downlink block of that licensee's existing spectrum in order to provide greater capacity for downstream transmissions.[114]

A downlink-only approach would not be technologically neutral, as it would favor broadcast-like and FDD technologies to the exclusion of TDD technology.[115] The lack of technical flexibility over the long term would limit the ability of a licensee to deploy new technology and services. The Commission should reject this downlink-only approach as unnecessarily restrictive because it would unnecessarily limit any eventual licensee's choice of technology[116] and could prevent service providers from adopting the technology that would permit the highest and best use of the band. This approach also greatly reduces the band's utility for promoting new entry.

The NPRM notes that by allowing existing licensees to combine AWS-3 spectrum with spectrum in other bands, a downlink-only approach could make available to current licensees additional spectrum for broadcast operations; or this approach could make available to current licensees of paired spectrum additional spectrum to utilize asymmetric pairing, in order to provide greater spectrum capacity for downstream transmissions.[117] Of course, new entrants do not have existing spectrum holdings, and would be excluded by such a regime. By making spectrum attractive to and feasible for use *only* by incumbents, the downlink-only approach

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[113] *See id.*

[114] *See id.*

[115] *See id.* (suggesting that such an approach facilitating "asymmetric pairing could promote . . . wireless services that use FDD technology").

[116] In other unpaired spectrum bands, the Commission has not directed the choice of technology. For example, unpaired spectrum blocks in the Lower 700 MHz band, the 1.4 GHz band, the WCS band, and the BRS band are all technologically neutral.

[117] *See* NPRM ¶ 21.

would fail to prevent an "excessive concentration of licenses" and promote economic opportunity and competition.[118] The Commission should not "freeze out" new entrants and turn over the AWS-3 band to incumbent spectrum licensees, particularly given these incumbent licensees' poor track record in deploying wireless broadband services.[119]

Finally, asymmetric pairing under the downlink-only approach would not promote efficient use of the AWS-3 band. Because the spectrum allocation between uplink and downlink is fixed, FDD systems are most efficient for fixed or static traffic asymmetries (meaning specific downlink-to-uplink ratios, or "DL/UL ratios") but operate much less efficiently when the asymmetry in traffic patterns change. Said another way, asymmetric pairing would not promote long-term efficient use of the spectrum band. TDD systems, on the other hand, can be configured to accommodate differing DL/UL ratios.[120] Moreover, advanced TDD technologies, coupled with the use of adaptive antenna systems ("AAS"), can achieve significantly greater spectral efficiencies – thereby making possible greater throughput than is achievable with legacy FDD technologies, which cannot take full advantage of AAS technologies.[121] Thus, by excluding the use of advanced technologies, the downlink-only approach would fail to promote the "efficient . . . use of the electromagnetic spectrum" required by the Act.[122]

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[118] *See* 47 U.S.C. § 309(j)(3)(B).

[119] *See* Part III.B.5, *supra*.

[120] TDD systems, within limits, can allow a service provider to define the percentage of capacity dedicated to the downlink by allocating the available time slots in each direction.

[121] Current legacy 3G FDD technologies, such as CDMA 2000 and W-CDMA are limited in their ability to utilize AAS technology to improve system performance in both the downstream and upstream directions. Significant gains in and spectral efficiency and overall system capacity can be achieved with AAS technologies, which can be more easily implemented in TDD systems that operate both directions at one frequency and therefore have channel reciprocity – rather than with FDD systems, which must use different frequencies for the downstream and upstream directions.

[122] *See* 47 U.S.C. § 309(j)(3)(D).

While the NPRM contends that the advantage of a downlink-only approach is that it "would greatly simplify the treatment of interference issues in this band,"[123] simplicity for its own sake cannot trump the public interest, which is not necessarily served best by the adoption of the simplest set of rules. This is particularly true when a downlink-only approach is not necessary to protect adjacent licensees, yet would eliminate new entry, stifle innovation, and promote inefficient spectrum utilization.

B. Structured Uplink/Downlink Use Would Sacrifice Spectral Efficiency and Operator Flexibility While Providing Negligible Interference Protection to Other Licensees

The Commission also seeks comment on a "structured uplink/downlink approach" that would allow utilization of the AWS-3 spectrum for mobile-plus-base transmit operations as well as downlink-only operations, each in specified parts of the band. Specifically, the Commission notes that the upper and lower five megahertz blocks of the band at 2155-2160 and 2170-2175 MHz could be designated for fixed or base transmit-only operations, such as "fixed wireless access," backhaul, or one-way (downstream) video services. The ten megahertz of spectrum in the center of the band could be used for TDD or Half-duplex Frequency Division Duplex ("HFDD") based mobile services.[124]

Like the downlink-only approach, the structured uplink/downlink approach is a poor compromise driven primarily by concerns about potential harmful interference to the adjacent AWS-1 and AWS-2 bands and to the nearby Mobile Satellite Service ("MSS") bands from transmissions in the AWS-3 band. However, this approach also would be unnecessarily restrictive and preclude the use of advanced technologies in fifty percent of the band. Because of these deficiencies, the Commission should reject this proposal.

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[123] NPRM ¶ 21.

[124] *See id.* ¶¶ 19-20.

Further, if a structured uplink/downlink approach were adopted, it would lead to less efficient use of the spectrum due to the operational limitations (*i.e.* fixed or base transmit-only operations) imposed on the outer sub-bands. An AWS-3 band licensee should instead be permitted the technical flexibility to offer any combination of uplink and/or downlink services in the band as long as it sufficiently protects other licensees from harmful interference.

C. The Uplink/Downlink Approach Provides Technical Flexibility That Would Allow an AWS-3 Licensee to Deploy Efficient Services while Meeting Standard Interference Protection Goals

The NPRM also seeks comment on an uplink/downlink approach for the 2155-2175 MHz band.[125] The uplink/downlink proposal would allow both mobile and base station operations and allow the licensee the flexibility to determine which technology to deploy.[126] The NPRM requests comment on the potential for interference between AWS-3 and AWS-1 licensees under this approach.[127] M2Z notes that these issues are identical to those related to both BRS licensees and future Upper 700 MHz licensees in terms of the need to address the potential for harmful interference between FDD and TDD systems, and the Commission has adopted flexible technical rules in those situations as described more fully below. This flexible uplink/downlink approach encompasses the other approaches put forward in the NPRM, meaning that under this approach an AWS-3 licensee, if it so desired, would be free to divide its AWS-3 spectrum into smaller blocks and use some or all of it in an asymmetrical FDD pairing while using the remainder for TDD.[128]

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[125] *See id.* ¶¶ 14-18.

[126] *See id.*.¶¶ 11, 15.

[127] *See id.* ¶¶ 15-16.

[128] *See id.* ¶ 18.

The Commission has determined recently the appropriate technical rules to meet its interference-protection goals for both the Upper 700 MHz and BRS/EBS bands, and in each case these technical rules are neutral with respect to technology.[129] M2Z has previously proposed technical rules similar to those that the Commission already adopted for BRS/EBS, and these technical rules are included in the proposed ABRS service rules set forth in Appendix A to these Comments. M2Z's proposed ABRS service rules would take full advantage of the flexibility afforded by the uplink/downlink approach, in that they would allow for every use of the band proposed in the NPRM.

This flexible uplink/downlink approach would permit the use of advanced technologies that increase spectral efficiency and improve interference avoidance. Under this approach the Commission "would require only that licensees comply with the interference protection requirements that we adopt."[130] Such technical flexibility would enable deployments resulting in the highest and best use of the 2155-2175 MHz spectrum. The Commission should adopt this approach over the others discussed in the NPRM.

Technical flexibility would afford the licensee the ability to deploy advanced TDD technology that could include orthogonal frequency division multiple access ("OFDMA")[131] and AAS. Without the flexibility to deploy a TDD system, a licensee could not take full advantage of AAS technology, which can produce significant improvements in spectral efficiency.[132] The

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[129] *See* Part V.A, *infra*.

[130] NPRM ¶ 18.

[131] Orthogonal Frequency Division Multiple Access is the multi-user version of the OFDM digital multi-carrier modulation scheme used in wireless networks. OFDM divides a frequency channel into as many as 2,048 subcarriers (or tones) and then groups together several of these subcarriers into a communications channel which carries user data.

[132] *See* ArrayComm, "Navigating the Harsh Realities of Broadband Wireless Network Economics," at Exh. 9 (2004), *available at* http://www.arraycomm.com/docs/ArrayCommonMBWAecons.pdf (indicating that spectral efficiency improves five times when AAS is employed with a baseline 802.16d or 802.16e system).

flexibility afforded by the uplink/downlink approach would enable a new entrant to compete with the current service providers by exploiting the advanced technologies that are available to a green-field deployment. The Commission therefore should adopt technical rules based on the uplink/downlink approach that allow for mitigation of harmful interference but that do not preclude the introduction of new services and innovative new technologies.

V. THE COMMISSION AND INTERNATIONAL REGULATORS HAVE ADOPTED TECHNICAL FLEXIBILITY OVER COMMAND AND CONTROL FOR BROADBAND DATA SERVICES

Advances in technology and increases in the demand for wireless services, among other things, have led the Commission to adopt a flexible framework for managing spectrum. Ensuring technical flexibility in the AWS-3 band requires regulations that impose on the licensee generally applicable emission limits and limits on harmful interference to other licensees, but that allow the licensee to determine the technical and operational parameters that are most appropriate for its service.

In many cases, technical flexibility has proven to be a key enabling factor in realizing the full potential of new wireless services deployed in various spectrum bands. With service rules that provide for technical flexibility, a licensee has the incentive to deploy innovative, efficient, and low-cost technologies to provide its service, subject to limitations setting the acceptable level of interference, acceptable power limits, and other general regulations.

The relationship between interference goals and technical rules is clear. Prior to establishing any technical rules, the Commission makes certain determinations regarding the rights and responsibilities of existing and potential new licensees. After that, it is a relatively straightforward process to define specific technical rules that will enable the provision of new service, protect existing licensees, and allow for technical flexibility over the long term. Whatever service is deployed, the licensee should only be held to limiting any serious

degradation in an adjacent licensee's service with respect to the deployment technology. This is in contrast to a physically impossible zero interference expectation.

Although highly specific and complex technical rules might prevent some degree of interference, such rigid rules will necessarily limit technology choices for the deployment of new services. Should the Commission decide to depart from technical flexibility and instead impose artificial rules, such a decision would lead to a distortion in investment and innovation and therefore could result in underutilization of the spectrum resource. Flexible technical rules, however, allow spectrum users to strike the appropriate balance between provision of new service and protection of existing users.

A. There is Significant Commission Precedent Supporting Technical Flexibility

Technical flexibility was first applied to the 800 MHz cellular service in 1987, when the Commission declined even to seek comment on – let alone mandate – a specific second generation ("2G") standard.[133] The Commission also applied this approach successfully to the Personal Communications Service ("PCS"), which also implemented 2G cellular radiotelephone system technology. The Commission gave PCS licensees the technical flexibility to use alternative cellular technologies in order to provide fixed and/or mobile services, while holding licensees responsible for preventing harmful interference to other licensees.[134] The impact of technical flexibility in the PCS rules was immense. In the twelve years since the PCS A and B

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[133] *See Amendment of Parts 2 and 22 of the Commission's Rules to Permit Liberalization of Technology and Auxiliary Service Offerings in the Domestic Public Cellular Radio Telecommunications Service*, Notice of Proposed Rulemaking, 2 FCC Rcd 6244 (1987).

[134] As the Commission's former PCS rules stated: "Licensees of cellular systems may use alternative cellular technologies and/or provide fixed services on a co-primary basis with their mobile offerings, including personal communications services (as defined in Part 24 of this chapter) on the spectrum within their assigned channel block. . . . Licensees must perform or obtain an engineering analysis to ensure that interference to the service of other cellular systems will not result from the implementation of co-primary fixed services or alternative cellular technologies." *See* 47 C.F.R. § 22.901(d) (1996).

block auctions, the wireless industry has experienced unprecedented growth, with increased competition and commensurate reductions in price that have benefited all consumers.[135]

The Commission subsequently has adopted technical flexibility in other spectrum bands, relying on interference protections based on out-of-band emission ("OOBE") criteria and frequency coordination procedures.[136] Licensees in these bands are thus permitted to provide any combination of services, consistent with their regulatory status and interference protection requirements.

1. *The AWS-1 Technical Rules Are an Instructive Example for AWS-3*

In the AWS-1 proceeding, the Commission afforded licensees the flexibility to engage in any network operations and provide any fixed or mobile services consistent with the allocation for the spectrum, following the Commission's general trend towards flexible use and flexible technical rules that commenced with the PCS rules.[137] The Commission found that permitting licensees to use the AWS-1 spectrum for any fixed or mobile use would not result in harmful interference among spectrum users. In adopting flexible technical rules, the Commission stated that "the flexible use we are permitting will itself provide licensees the ability to adjust their operations to minimize any interference that might occur."[138]

The Commission licensed the AWS-1 band under Part 27 of the Commissions' rules

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[135] *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 Commercial Mobile Services*, Tenth Report, 20 FCC Rcd 15908, ¶ 154 (2005) ("[T]here is ample evidence of a sharp decline in mobile telephone prices in the period since the launch of PCS service. One analyst estimated that the average per-minute cost of wireless calling plunged over 65 percent in the past four years alone.").

[136] For example, the Commission has implemented flexible use and flexible technical rules in the Lower 700 MHz band, 1.4 GHz band, 1670-1675 MHz band, WCS, and BRS, to name a few.

[137] *See AWS-1 Report and Order* ¶ 14 ("Our experience with licensing the Personal Communications Services (PCS) supports the conclusion that flexibility spurs investment and service innovations. In the PCS bands, flexibility has encouraged industry investment, promoted competition, and fostered technology innovations. We believe . . . that flexibility 'will promote investment in different technologies.'") (Citation omitted).

[138] *Id.* ¶ 15.

rather than Part 24, which had been adopted for broadband and narrowband PCS. While both Part 27 and Part 24 provide substantial flexibility, Part 27 rules provide a broader and more flexible regulatory framework and have been applied to different services in multiple spectrum bands (*e.g.*, the upper and lower 700 MHz bands and the 2.3 GHz band since its inception).[139]

In the AWS-1 rules, co-channel interference between AWS licensees in adjacent geographical regions is limited by adopting interference limits at the boundary – a measure also found to be effective in the deployment of PCS.[140] Adjacent channel interference between AWS licensees is limited by the use of OOBE limits, and the Commission adopted the same limits for AWS transmitters as those used for broadband PCS.[141] The AWS-1 rules also provide the flexibility for licensees operating in adjoining areas to agree to alternative signal limits at the licensees' common borders. Thus, the rules provide for a default interference level only in the absence of a specific agreement between licensees.[142] Finally, although the Commission's rules facilitated FDD operations in the paired spectrum available in the AWS-1 band, that decision was a reasonable one in light of the licenses available in that auction. In AWS-3, the Commission should adhere to its technical flexibility principles in order to facilitate possible TDD operations in the unpaired, contiguous 20 MHz block of spectrum available at 2155-2175 MHz. The Commission should not, however, stand its technical flexibility principles on their head by going out its way to facilitate FDD operations in this unpaired AWS-3 band.

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[139] *See id.* ¶ 19.

[140] *See id.* ¶¶ 89-90.

[141] *See id.* ¶¶ 91-92.

[142] *See id.* ¶ 89.

2. *The BRS Technical Rules Already Address FDD and TDD Coexistence*

The Commission also adopted an approach providing for technical flexibility in the context of allowing TDD and FDD coexistence in the same band in its BRS rulemaking.[143] In that proceeding, the Commission noted that the previous Multipoint Distribution Service/Instructional Television Fixed Service ("MDS/ITFS") rules for the band already permitted licensees to choose between and use either TDD or FDD technology.[144] The Commission concluded in this respect "that the band should be technology neutral," finding that such an approach "is consistent with our goal to make the spectrum as flexible as possible as it permits licensees and the marketplace to determine which technologies should be utilized."[145]

Notably, the only technology-related restrictions imposed in the BRS rulemaking were those that the Commission imposed on FDD operators, who were restricted as to which of the two BRS bands could be used for uplink operations and which could be used for downlink operations. The Commission gave TDD operators *more* flexibility, with TDD operations allowed in both bands.[146] Establishing similarly flexible technical rules for the AWS-3 band would allow potential licensees to develop network implementation plans and deploy technologies that best meet their business goals, while also encouraging use of the most advanced, efficient, and cost-effective technology available, subject only to Commission rules

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[143] *See Amendment of Parts 1, 21, 73, 74 and 101 of the Commission's Rules to Facilitate the Provision of Fixed and Mobile Broadband Access, Educational and Other Advanced Services in the 2150-2162 and 2500-2690 MHz Bands*, Report and Order and Further Notice Of Proposed Rulemaking, 19 FCC Rcd 14165 (2004) ("*2004 BRS/EBS Report and Order*"). The record in this rulemaking contains data on the spacing purportedly necessary (in terms of MHz) between TDD and FDD systems in order to avoid inter-system interference, but nothing in the record indicates that this specific frequency spacing represents a fundamental physical limit for adjacent TDD and FDD systems.

[144] *Id.* ¶ 133.

[145] *Id.* ¶ 132.

[146] *Id.* ¶ 134.

setting acceptable limits of inter-system interference and facilitating coordination between licensees to mitigate any harmful interference.

3. *The Upper 700 MHz Technical Rules Adhere to Technical Flexibility Despite Heightened Interference Protections Accorded to Public Safety*

Recently the Commission has addressed the complex task of developing the band plan and technical rules for highly sought-after spectrum in the Upper 700 MHz band.[147] In that proceeding, the Commission faced the challenge of adopting technical rules that would address interference concerns of both the commercial sector as well as those of public safety, with especially stringent interference protections required because many public safety narrowband deployments are designed to operate in noise-limited environments.

The Commission ultimately adopted rules that allow for technical flexibility (*e.g.*, TDD and FDD operation in both the C and D blocks) while placing the burden of protecting the public safety systems on the commercial spectrum holders.[148] Although eventual commercial licensees must ensure that the operational environment is optimized for adjacent public safety uses, the Commission did not abandon its technical flexibility principles in order to achieve the goal of interference protection.

B. Progressive Regulators in Other Countries Also Have Followed and Advanced This Trend Toward the Adoption of Technical Flexibility

This Commission is not alone in its trend toward technical flexibility and flexible spectrum use, as regulators in other nations have also adopted rules that encourage technical flexibility – chiefly by specifying emission limits in particular spectrum bands.

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[147] *See 700 MHz Second Report and Order*, *supra* note 31.

[148] *See* 47 U.S.C. § 27.53(h) ("When an emission outside of the authorized bandwidth causes harmful interference, the Commission may, at its discretion, require greater attenuation than specified in this section.").

In the United Kingdom, Ofcom[149] is currently addressing the service, technical, and auction rules for the 2500-2690 MHz band due to that agency's interest in wider deployment of TDD technologies. In addressing the technical rules for the band, Ofcom has used modern engineering techniques and statistical analyses to better understand the overall interference impact of TDD/FDD coexistence, departing from previous worst case, noise-limited scenarios for harmful interference.[150] Its proposed band plan provides for both TDD and FDD sub-bands, with a specific mechanism to increase the number of TDD sub-bands if licensees require more spectrum. Likewise, in New Zealand, the government recently adopted band plans in both the 2.3 GHz and 2.5 GHz bands that provide for technical neutrality, once again permitting both TDD and FDD operations.[151] The New Zealand plan establishes two 20 MHz blocks at 2500-2540 MHz and two at 2620-2660 MHz that have technical rules allowing for the coexistence of TDD and FDD operations, with a single set of technical requirements to cover both TDD and FDD services.

C. Industry Also Supports Technical Flexibility Approaches Rather Than Command and Control

The Commission should adopt technologically neutral approaches to interference mitigation as wireless carriers adopt newer, more advanced systems based on OFDMA, TDD, and AAS. These newer systems must coexist with existing technology (*e.g.*, FDD) and new

[149] Ofcom is the independent regulator and competition authority for the UK communications industries, with responsibilities across television, radio, telecommunications and wireless communications services.

[150] *See* Mason, 2500-2690 MHz, 2010-2025 MHz and 2290-2302 MHz Spectrum Awards – Engineering Study (Phase 2), November 2006, *available at* http://www.ofcom.org.uk/consult/condocs/2ghzawards/masonresearch.pdf; Ofcom, 2010-2025 MHz, 2290-2302 MHz, and 2500-2690 MHz Spectrum Awards, Technical Study, Adjacent and In-Band Compatibility Assessment for 2500-2690 MHz, December 2006, *available at* http://www.ofcom.org.uk/consult/condocs/2ghzawards/technicalassessment/assessment.pdf; Ofcom, Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz, August 2007, *available at* http://www.ofcom.org.uk/consult/condocs/2ghzdiscuss/main.pdf.

[151] Radio Frequency Auction No. 9, Ministry of Economic Development, 2 November 2007, ISBN 978-0-478-31610-0, *available at* http://data.rsm.govt.nz/auctions/auction23-25-ghz/auction-catalogue.pdf.

licensees, and must protect incumbents from harmful interference by causing no more interference to legacy systems than other new licensees might cause.

The WiMAX Forum[152] advocates the idea of flexible spectrum policy that relies on a combination of technological solutions and deployment policies to mitigate harmful interference. A recent report published by the WiMAX Forum concludes that "a new approach," rather than rigid technical rules, may be necessary to allow for more flexible spectrum usage polices, with the relaxation of default rules when operators on adjacent channels "can agree to cooperate and find mutually acceptable deployment policies."[153] The WiMAX Forum report concludes that although this approach may complicate matters in some respects, it "may enable otherwise 'unusable' spectrum to be utilised, which would be a win-win situation for regulators and operators alike."[154]

As demonstrated throughout this Part V, the Commission and other communications regulatory bodies have in the past adopted flexible use and technically flexible approaches of the type proposed by M2Z, favoring operator coordination and technological solutions for interference issues over rigid technical rules. Moreover, there are a multitude of engineering measures and devices that the eventual AWS-3 licensee could employ to improve the isolation between transmitters and receivers and thereby mitigate the potential for harmful interference, including: improved analog RF filters, to reduce power radiated to the adjacent channel; improved analog and digital filters on the receive side; the use of AAS active interference

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[152] The WiMAX Forum® is an industry-led, not-for-profit organization formed to certify and promote the compatibility and interoperability of broadband wireless products based upon the harmonized IEEE 802.16/ETSI HiperMAN standard.

[153] WiMAX Forum, "Service Recommendations to Support Technology Neutral Allocations, FDD/TDD Coexistence," at 43-44 (Apr. 10, 2007) ("WiMax Forum) (attached hereto as Appendix B), *available at* http://www.wimaxforum.org/technology/downloads/Service_Recs_Tech_Neutrality_-_FDD-TDD_Coexistence.pdf.

[154] *Id.*

cancellation; and cooperation and coordination between operators on issues such as base station placement. Given the vast array of technological approaches available to mitigate harmful interference,[155] and the real promise of greater spectral efficiency, the Commission should adopt technical rules that facilitate the use of these reasonable mechanisms before resorting to prescriptive command and control techniques to manage spectrum.

CONCLUSION

For the foregoing reasons, M2Z respectfully submits that the Commission should adopt the proposed ABRS services rules outlined in these Comments and attached hereto as Exhibit A. The Commission also should adopt flexible spectrum use policies and flexible technical rules in order to allow the eventual licensee the freedom to make intensive use of the band, while nonetheless protecting incumbents from harmful interference in accordance with the rules adopted by the Commission for other services and spectrum bands. The Commission should not adopt any of the overly restrictive band plan and technical rules proposals set forth in the NPRM. Moreover, the Commission should reject suggestions to allocate the spectrum for unlicensed use, and should reject as well the infeasible alternative auction proposals set forth in the NPRM in the event the Commission decides to assign licenses via competitive bidding.

At the very least, the Commission should ensure that the 2155-2175 MHz band is put to its highest and best use, which, as demonstrated in these Comments and in the record generated by M2Z's Application, would facilitate the entry into the marketplace of a true nationwide wireless broadband competitor rather than a mere mobile complement to entrenched wireline broadband offerings. To that end, M2Z respectfully submits that the Commission should adopt

[155] There are a variety of techniques that can be used to mitigate harmful interference, including coordination of base station siting, adaptive antennas, power control, receiver and transmitter enhancements such as improved filtering, and antenna polarization.

service rules incorporating the enforceable, public interest obligations proposed in the ABRS rules outlined herein. By adopting such service rules, the Commission could finally unlock the potential of this long under-utilized band and fulfill its statutory mandate to promote the deployment of advanced services, competition, and new entry. Furthermore, the Commission's action to adopt such service rules for the AWS-3 licensee would create tremendous consumer benefits by promoting the deployment of a family-friendly, nationwide broadband service, free of subscriber and service charges, that could be made available rapidly to the vast majority of Americans.

Respectfully submitted,

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LIST OF APPENDICES

Appendix A	**Proposed Service Rules for Advanced Broadband Radio Service in the 2155-2175 MHz Band**
Appendix B	**WiMAX Forum, "Service Recommendations to Support Technology Neutral Allocations, FDD/TDD Coexistence" (Apr. 10, 2007)**

APPENDIX A

Comments of M2Z Networks, Inc.

Proposed Service Rules for Advanced Broadband Radio Service in the 2155-2175 MHz Band

SERVICE RULES FOR ADVANCED BROADBAND RADIO SERVICE IN THE 2155-2175 MHZ BAND

License and operation in the 2155-2175 MHz band shall be conditioned on the following requirements:

1. Service Name and Definition

The Licensee of the 2155-2175 MHz band shall provide Advanced Broadband Radio Service ("ABRS"). ABRS is a radio service provided under a single nationwide license on 20 MHz of spectrum in the 2155-2175 MHz band for the provision of fixed and portable broadband data services, without charge to end-users, on a network engineered to provide data rates of at least 384 kbps downstream and 128 kbps upstream.

2. Frequencies of Operation

The Licensee shall provide ABRS in the 2155-2175 MHz band on a primary basis.

3. Service Areas

The Service Area for ABRS in the 2155-2175 MHz band shall be nationwide. The nationwide service area consists of the fifty states, the District of Columbia, American Samoa, Guam, Northern Mariana Islands, Puerto Rico and the United States Virgin Islands.

4. License Period

Initial authorization and renewal terms for the ABRS license shall be fifteen (15) years from the date of initial issuance or renewal.

5. Construction requirements; Criteria for comparative renewal proceedings.

The Licensee shall commence the ABRS by constructing sufficient base stations to cover:

(a) 33% of the U.S population within three years of the license grant;
(b) 66% of the U.S population within five years of the license grant; and
(c) 95% of the U.S population within ten years of the license grant.

6. Power limits

The following power limits shall apply to the 2155-2175 MHz bands:

(a) *Main, booster and base stations.*

(i) The maximum EIRP of a main, booster or base station shall not exceed 33 dBW + 10log(X/Y) dBW, where X is the actual channel width in MHz and Y is 6 MHz.

(ii) If a main or booster station sectorizes or otherwise uses one or more transmitting antennas with a non-omnidirectional horizontal plane radiation pattern, the maximum EIRP in dBW in a given direction shall be determined by the following formula: EIRP = 33 dBW + 10 log(X/Y) dBW + 10 log(360/beamwidth) dBW, where X is the actual channel width in MHz, Y is 6 MHz, and beamwidth is the total horizontal plane beamwidth of the individual transmitting antenna for the station or any sector measured at the half-power points.

(b) *User stations.* All user stations are limited to 2.0 watts transmitter output power.

7. Emission limits

For operations in the 2155-2175 MHz band, the power of any emissions outside the ABRS Licensee's frequency bands of operation shall be attenuated below the transmitter power (P) measured in watts.

(a) *For fixed and temporary fixed digital stations.* The attenuation for fixed and temporary fixed digital stations shall be not less than 43 + 10 log (P) dB, unless a documented harmful interference complaint is received from an adjacent channel licensee. Provided that the complaint cannot be mutually resolved between the parties, both licensees of existing and new systems shall reduce their out-of-band emissions by at least 67 + 10 log (P) dB measured at 3 MHz from their channel's edges.

(b*) For user stations*. The attenuation factor for user stations shall be not less than 43 + 10 log (P) dB at the channel edge and 55 + 10 log (P) dB at 3 MHz from the channel edges.

8. Relocation of Incumbents

(a) *Relocation of fixed microwave service licensees.* Incumbent fixed microwave service licensees in the 2160-2175 MHz band shall be relocated pursuant to the procedures established by the Commission in the Ninth Report and Order on Advanced Wireless Services. *See Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, including Third Generation Wireless Systems*, Ninth Report and Order, FCC 06-45, ¶¶ 55-63 (Rel. Apr. 21, 2006) ("*AWS 9th R&O*").

(b) *Relocation of fixed BRS licensees.* Incumbent BRS licensees in the 2150-2162 MHz band shall be relocated pursuant to the procedures established by the Commission in the Ninth Report and Order on Advanced Wireless Services. *See AWS 9th R&O* ¶¶ 11-63.

9. Protection of Incumbents

(a) *Protection of Part 101 operations*. Prior to initiating operations from any base or fixed station, the ABRS Licensee must coordinate its frequency usage with co-channel and adjacent channel incumbent Part 101 fixed-point-to-point microwave licensees operating in the 2110-2155 MHz band. Coordination shall be conducted in accordance with the provisions of Section 24.237 of this chapter.

(b) *Protection of Part 21 operations.* Prior to initiating operations from any base or fixed station, the ABRS Licensee must coordinate its frequency usage with co-channel and adjacent channel incumbent Part 21 BRS licensees operating in the 2150-2162 MHz band. In the event that the ABRS Licensee and BRS licensees cannot reach agreement in coordinating their facilities, either licensee may seek the assistance of the Commission, and the Commission may then, at its discretion, impose requirements on either or both parties.

10. Public Interest and Other Obligations of Licensee

(a) *Basic service*. The ABRS Licensee shall make available Advanced Broadband Radio Service at engineered data rates of at least 384 kbps download and 128 kbps upload speeds free of airtime or service charges. The ABRS Licensee may condition service provision on the use of customer premises equipment that is certified by the ABRS Licensee to operate in the band according to its specifications and other relevant Commission regulations.

(b) *Service to Public Safety Entities*. The ABRS Licensee shall serve any public safety organization in the U.S. willing to utilize ABRS, without limit to the type and number of 2155-2175 MHz customer devices, and without service charges, provided that the ABRS Licensee has constructed its network and makes service generally available in the public safety agency's service area. The ABRS Licensee shall provide any public safety entity that registers with service of up to 384 kbps download and 128 kbps upload speeds. Such service may be conditioned on the use of a gateway device certified by the ABRS Licensee to operate in the band according to its specifications and other relevant Commission regulations.

(c) *Content Filtering Capabilities*. The ABRS Licensee shall include, with its Advanced Broadband Radio Service, automatic, default blocking of access to content it deems harmful to minors. Such default blocking shall be based on technology and processes readily available in the marketplace. The ABRS Licensee may disable this blocking capability for Advanced Broadband Radio Service or "Premium Service" customers who provide M2Z with appropriate proof that they are of the age of majority. *See, e.g.,* 47 C.F.R. § 64.201. The ABRS Licensee shall be permitted to disconnect any end user from its service for any violation of its service agreement, this condition, or the Commission's regulations.

(d) *Wireless Broadband Service.* The ABRS Licensee will be regulated as a provider of wireless broadband service.

(e) *Wholesale.* To the extent the ABRS Licensee provides additional tiers of services beyond the basic service, such services shall be made available on a wholesale basis on reasonable and nondiscriminatory terms and conditions.

(f) *Open Platform.* The ABRS Licensee shall provide a basic service package on a wireless network that permits open access to affiliated and unaffiliated consumer devices by providing, publicly and royalty-free, published technical standards for developing and deploying subscriber equipment that can operate on the network.

(g) *Holding Period and Partitioning and Disaggregating.* The ABRS Licensee shall be prohibited from engaging in secondary market transactions, including transactions involving the partitioning or disaggregation of 2155-2175 MHz spectrum, for a period of five years from the date of the license grant.

11. Eligibility Restrictions

The ABRS Licensee shall at the time of initial licensing (a) hold less than 20 MHz of spectrum in at least 50% of the counties of the United States; and (a) have not failed to meet "substantial service" performance requirements for any other Commission licenses that it may hold.

APPENDIX B

Comments of M2Z Networks, Inc.

WiMAX Forum White Paper of April 10, 2007
"Service Recommendations to Support Technology Neutral Allocations: FDD/TDD Coexistence"

Service Recommendations to Support Technology Neutral Allocations

FDD/TDD Coexistence

10 April 2007

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Executive Summary

Technology-neutral licensing of broadband wireless technologies such as WiMAX™ technology has the potential to facilitate technology growth and to enable market mechanisms to drive the adoption of spectrally efficient and economically efficient radio technologies. However, since different operators in adjacent bands might choose to use differing technologies, the coexistence of technologies is a fundamental concern; when transmitters and receivers are operating simultaneously in adjacent spectrum and in close proximity, the transmitters may cause significant interference to the receiving systems. One special case in which the interference paths are not mutual is the coexistence of frequency division duplex (FDD) systems, which operate in paired spectrum, with time division duplex (TDD) systems.

In Figure A, we show a typical band structure with FDD uplink (UL) and downlink (DL) at either end of the band, sandwiching an unpaired band assigned to TDD systems. The green and blue paths on the diagram indicate wanted UL and DL signal paths, respectively. The yellow paths indicate mobile station to base station interference in the FDD uplink band; base station to mobile station interference in the FDD downlink band; and interference in both directions in the TDD band. These forms of interference are relatively benign, as good separation can usually be maintained. Nevertheless, so-called 'dead zones' may be created around the base stations of the interfering network. Various mitigation techniques exist, however, such as the collocation of base station sites. More serious are the base station to base station and mobile station to mobile station interference paths.

In the case of TDD systems these interference paths may be removed by synchronising uplink and downlink transmissions in adjacent channels, furthermore, the interference is mutual (as indicated by the double headed orange arrows). Thus resolving any interference issues will typically benefit both operators and so there is an incentive for operators to cooperate.

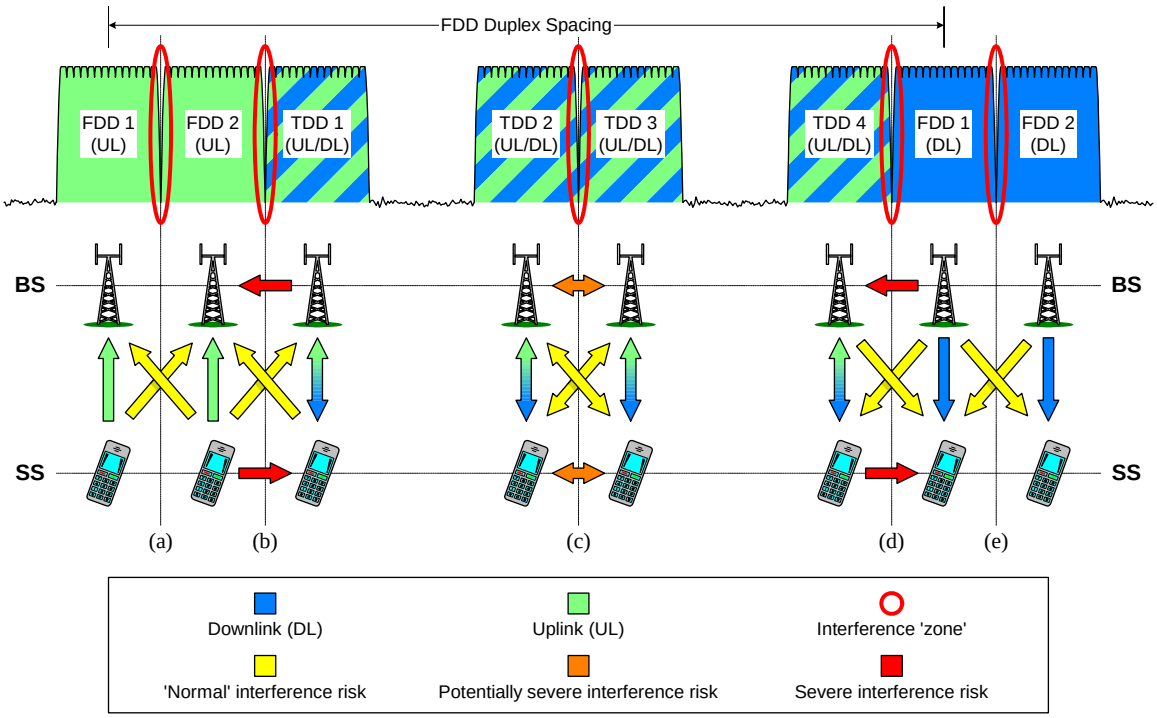

Figure A The sources of adjacent channel interference for the various FDD/TDD coexistence scenarios.

The most serious interference paths are between FDD and TDD systems and *vice versa* (shown in red), in which the interference is unidirectional, i.e. the operator of the interfering network has no incentive to help resolve interference issues experienced by the victim network. For FDD uplink adjacent to a TDD channel, the FDD base station suffers interference from the TDD base station, whereas the TDD mobile, as well as the base station suffers interference from the FDD mobile station. Similarly, for FDD downlink adjacent to a TDD channel, the TDD base station and the TDD mobile station suffer interference from the FDD base station, whereas the FDD mobile station suffers interference from TDD base stations and mobile stations. Since base stations tend to have high transmit powers, sensitive receivers with high gain antennas and are frequently in line-of-sight, interference between them can be very serious. Simply collocating base stations to alleviate base-to-mobile interference will exacerbate base station-to-base station interference so other solutions need to be found to enable efficient use of spectrum.

In bands such as the 3.4-3.8 GHz band, technology-neutral paired allocations are made, and should a paired allocation be used for TDD, the corresponding channels in the lower and upper bands have the same licencees in the adjacent channels. In this case, FDD and TDD operators do have an incentive to cooperate to resolve interference as, for example, if there is significant FDD base station-to-TDD base station interference one band there is likely to be significant TDD base station-to-FDD base station interference in the other band.

There are technology factors that can affect coexistence that arise in the transmitter, e.g. out-of-band and spurious emission levels, linearity and filtering, while further factors exist in the victim receiver, e.g. selectivity and blocking. Since the interference is a function of both, achievable receiver performance should be considered when setting transmitter performance specifications. Other considerations that affect the consequences of interference include antenna discrimination (including the use of so-called 'smart', i.e. adaptive, antennas) and active interference cancellation techniques.

Deployment strategies can also affect coexistence and mitigation techniques include the use of physical separation, site features for shielding and cooperation and coordination between operators.

Regulation should specify appropriate limits for transmit powers and out-of-band emissions.

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List of Abbreviations

AAS	Adaptive antenna systems
ACLR	Adjacent channel leakage ratio
ACIR	Adjacent channel interference ratio
ACP	Adjacent channel protection
ACS	Adjacent channel selectivity
BS	Base station
BRS	Broadband radio services
CFR	Code of Federal Regulations
DECT	Digitally enhanced cordless telecommunications
DL	Downlink
DSP	Digital signal processing
EBS	Educational broadband services
FCC	Federal Communications Commission
FDD	Frequency division duplex
GMSK	Gaussian minimum shift keying
HFDD	Half frequency division duplex
IMP	Intermodulation product
LOS	Line-of-sight
MAC	Medium access control
OFDM	Orthogonal frequency division multiplexing
OOBE	Out-of-band emissions
PA	Power amplifier
PAPR	Peak-to-average power ratio
PHY	Physical layer
RF	Radio frequency

SIR	Signal-to-interference ratio
SS	Subscriber station
TDD	Time division duplex
TDMA	Time division multiple access
UL	Uplink
UNII	Unlicensed national information infrastructure

1 Introduction

With the onset of new broadband wireless technologies such as WiMAX™ technology, technology neutral assignments are increasingly being considered (and indeed required) to facilitate technology growth and deployment. Regulators across the globe are recognising the importance of technology neutrality. However, they are faced with new questions regarding the ability of technologies with different characteristics to coexist in shared frequency bands.

One of the main considerations to promote coexistence is to address the needs of differing duplex methods, namely, time division duplex (TDD) or frequency division duplex (FDD). Unchecked, operating systems with differing duplex methods in close proximity to one another may cause unacceptable levels of inter-system interference, when the base stations and terminals have very different characteristics.

Various interference mitigation techniques are available that may be used to allow a mixture of FDD and TDD systems to coexist. This document describes these techniques (primarily in the context of WiMAX technology) and discusses how technology neutral deployments may be realised successfully in the future. It is important to note that the contents of this document are only intended to provide a guideline since geo-regulatory and spectrum variations mean that each usage scenario is likely to be different and unique both in terms of equipment and deployment.

In Section 2 we introduce WiMAX systems and describe the duplex methods that represent one of the key factors distinguishing the various 'flavours' of the technology. Then we consider the main coexistence scenarios and the factors relevant to the performance in each scenario. The need for FDD and TDD systems to coexist in adjacent spectral bands is not a new requirement, and neither is it specific to WiMAX technology. Section 3 summarises the main findings of a literature search into the subject. In Section 4 we discuss regulatory matters that may need to be considered if FDD and TDD variants of WiMAX technology are deployed into a common band. Finally, in Section 5 the main findings are concluded.

2 WiMAX Technology and the Coexistence of FDD/TDD Systems

We begin by introducing WiMAX technology and then consider the various coexistence scenarios that may be envisaged, with a view to identifying the various interference 'paths' that may result. We conclude this section by considering the factors that may affect performance in the coexistence scenarios identified.

2.1 WiMAX Technology Overview

WiMAX is an emerging standards-based broadband wireless technology that defines the physical (PHY) and medium access control (MAC) layers. The standards upon which WiMAX technology is based are the IEEE 802.16 standards, which are large, complex standards with many possible configurations and non-mandatory options. This means that differing equipment that is 802.16-compliant is not necessarily compatible. WiMAX technology addresses this problem by defining 'system' profiles that define allowed modes of operation and specifying mandatory options. These options are then specified to greater detail, e.g. specifying frequency, duplex method, etc, in the form of 'certification' profiles. Thus equipment conforming to a particular certification profile should be interoperable, regardless of vendor.

Currently two system profiles are defined. 'Fixed WiMAX™' is based on the IEEE 802.16-2004 standard and is intended primarily for the implementation of fixed, high bandwidth wireless links with low transceiver complexity. 'Mobile WiMAX™' is based on the 802.16e-2005 amendment to the 802.16-2004 standard and is designed to support mobile applications, with improved robustness in a mobile, time varying radio channel. In the future, a third system profile, 'evolutionary' WiMAX is likely to be defined. Fixed WiMAX currently has both FDD and TDD certification profiles. Certification profiles for Mobile WiMAX are currently only defined for TDD modes of operation.

The characteristics of WiMAX technology make it an ideal contender for a number of 'modern' applications. These include 'last mile' broadband connections, broadband hotspots, cellular backhaul and high-speed enterprise connectivity for business.

2.2 Duplex Methods

In the majority of point-to-point wireless communication applications, full duplex operation is required, i.e. the flow of data needs to be bi-directional. (There are of course some point-to-point and point-to-multipoint applications when only unidirectional, simplex operation is required, e.g. radio and TV broadcast). Therefore, most radio technologies require a method to support the transfer of data in both directions. There are three main duplex methods used in digital wireless systems, namely time division duplex (TDD), frequency division duplex (FDD) and half frequency division duplex (HFDD). These duplex methods are illustrated in Figure 1 and discussed in the following sections.

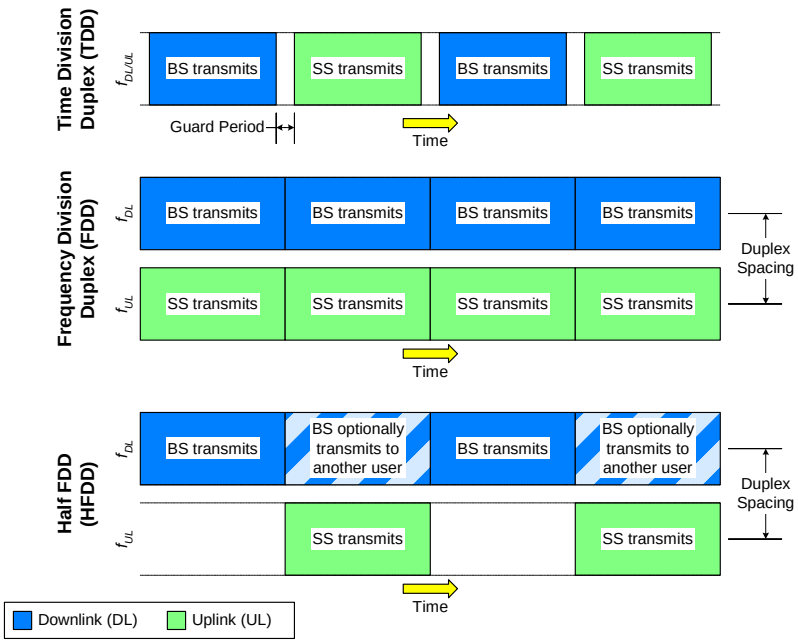

Figure 1 The three main types of duplex technology used in wireless systems, time division duplex (top), frequency division duplex (middle) and half frequency division duplex (bottom), which is a special form of FDD.

The selection of a duplex method is based on technology and regulatory considerations that are beyond the scope of this document. However it is sufficient to say that the arguments to use FDD in preference to TDD and *vice versa* are similar to those of existing cellular mobile radio technologies.

2.2.1 Time Division Duplex

TDD, shown in Figure 1 (top), is a technique whereby information is transmitted and received using a common frequency band but at different times. Thus by reusing a single frequency band for both uplink (UL) and downlink (DL) transmissions, TDD operation typically only requires a single band of frequencies. This means that TDD systems can be deployed in paired and unpaired spectrum. Note that this ability to operate in unpaired spectrum means that TDD is favoured by unlicensed radio products, eg, the unlicensed national information infrastructure (UNII) bands in the USA, digitally enhanced cordless telecommunications (DECT) equipment and WiFi. Nevertheless, FDD and TDD systems are used in licensed and unlicensed spectrum.

TDD has the potential to offer improved spectral efficiency over FDD in applications where the data bandwidth required on the UL and DL is asymmetrical and time variant. In a basic TDD system the proportion of time allocated to the UL and DL transmissions is fixed. However, in more advanced TDD systems, it is possible to adapt the timing of the physical layer to share the available bandwidth between the UL and DL dynamically. This ability to adapt the characteristics of the physical layer to the traffic requirements of the user can be used to increase capacity and/or improve perceived data throughput. This concept is not without complications, however. Using a dynamic rather than fixed timing structure does come at the expense of increased system complexity. Moreover, there are advantages to a fixed timing structure because, as will be discussed in greater detail later on, a fixed timing structure permits different systems to be synchronised to mitigate against adjacent channel interference issues. Note that WiMAX systems support adaptive transmission timing for TDD transmissions.

In a point-to-multipoint TDD system the subscriber stations[1] (SSs) will typically adjust their transmit timing so that the signals arriving at the base station (BS) are aligned with the BS's timing structure. Despite this, however, it is necessary to

[1] Other widely recognised terms for subscriber station are mobile station (MS), user equipment (UE) and customer premises equipment (CPE), depending on the application.

introduce 'guard' periods between UL and DL transmissions to prevent collisions and to allow the transceiver equipment to switch from transmit to receive mode and *vice versa*. Note that abrupt changes in output power can result in significant wideband emissions. Therefore, TDD transmitters typically have to ramp their output power up and down in a controlled manner. These ramp up and ramp down periods are part of the switching time and must be taken into account when deciding the duration of the guard periods. Another factor that has to be taken into account when considering TDD operation is round trip delay time. Radio waves propagate approximately 300 m every microsecond. Thus as the separation between the BS and SS increases, the minimum time allowed between transmit and receive packets increases also. This potentially affects the size of the guard periods and/or imposes a maximum link distance. Note that round trip delay issues are typically mitigated to a certain extent in time division multiple access (TDMA) systems by interleaving transmissions to/from the various users.

Increasing the size of the guard periods allows the timing requirements (i.e. switching time and timing adjust capabilities) of the transceiver equipment to be relaxed. However, no useful data can be transmitted during the guard periods so increasing the size of the guard periods reduces the spectral efficiency of a system.

2.2.2 Frequency Division Duplex

FDD, shown in Figure 1 (middle), is a technique whereby information is transmitted and received using different frequency bands. The separation between the UL and DL frequencies is referred to as the 'duplex spacing'. Generally, but not always, for any given frequency plan the duplex separation is fixed leading to an ordered arrangement of paired channels in two sub-bands.

Typically FDD sub-bands are identified explicitly for UL and DL transmissions, with the DL typically assigned to the higher frequency band in most existing cellular radio systems. FDD systems require the use of paired spectrum. To this end, spectrum licenses are generally granted in pairs. The duplex spacing, i.e. the separation between UL and DL frequency bands is typically several tens of MHz. This minimum separation functions as a guard band to prevent UL/DL interference. Most cellular

systems employ FDD and spectrum is commonly licensed for FDD operation, eg, 3.5 GHz in Europe, 1.9 GHz in North America and 2 GHz in Japan.

FDD is less well suited to operation in unlicensed spectrum than TDD. With a TDD system it is only necessary to find a single band of unused spectrum. With FDD two bands are required. Clearly it is easier to find a single band than two! If the duplex spacing could be adjusted dynamically then the task of finding available spectrum might be easier. However, the consequence of a variable duplex spacing is an increase in the complexity of the terminals and filtering requirements together with the need for signalling the appropriate spacing. Furthermore, the duplexing filter is fixed at the time of manufacture, although there has been research into switchable and tuneable filters.

Whereas TDD systems have the potential to adapt their transmission timing to offer asymmetrical data links (and hence improve spectral efficiency when symmetrical data links are not required) there is no such option in an FDD system. In an FDD system the frequency bands and hence useable bandwidth are predefined separately for the DL and UL. Whilst traditional wireless applications such as voice services are well suited to symmetrical data links, newer applications such as web browsing and video on demand often require more bandwidth on the DL. Recent FDD technologies, eg, third generation technologies tend to have significantly greater downlink efficiencies compared with their uplink efficiencies, in part because throughput needs to be greater on the downlink, and the same bandwidth is available. Therefore, TDD systems are more suited for asymmetrical data traffic, which can improve spectrum efficiency for data services.

2.2.3 Half Frequency Division Duplex

HFDD, shown in Figure 1 (bottom), is a special case of FDD. In FDD BS equipment a special filter or ‘duplexer’ is used to allow the BS to transmit and receive on different frequencies simultaneously without significant power from the transmitter leaking into the receive path and ‘blocking’ the receiver.

High-performance duplexers are often quite bulky, expensive and are optimised for operation with predefined frequency bands. Considering the ever present requirements to minimise cost and weight in high-volume, entry-level mobile handsets, having to integrate a duplexer into SS equipment is not desirable. HFDD addresses this issue by operating a TDD-style transmit and receive timing structure. Thus the timing can be arranged such that the SS never has to simultaneously transmit and receive, which means that the duplexer can be replaced by a simple low-cost radio frequency (RF) switch.

HFDD basically represents a limitation imposed by the SS on the timing of the DL and UL transmissions. BS equipment would generally use a duplexer and support full FDD (to only transmit half the time on two frequency bands would be very inefficient and would not normally be done). Thus the BS can support two SSs using HFDD by transmitting to SS A whilst receiving from SS B.

Examples of successful technologies that use HFDD include GSM and TETRA.

2.2.4 WiMAX Profiles and Defined Duplex Methods

WiMAX certification profiles based on the IEEE 802.16 family of standards are in development to support TDD, FDD and HFDD modes of operation. The choice of duplex method mainly affects the RF channel bandwidth and frame length required. In WiMAX systems, the implementation of the duplex method is handled at the physical layer (PHY).

Currently, Fixed WiMAX profiles exist for both TDD and FDD modes of operation. The certification profiles for Mobile WiMAX, which is based on 802.16e, will predominately specify the TDD duplex method.

2.3 Flexible Usage Regulations Benefits and Challenges

Traditionally, licensed (and indeed some unlicensed) spectrum has been allocated via strict command and control methods, i.e. spectrum access has been controlled by a central regulatory body. Typically, as well as deciding who may operate in any given frequency band, the regulator has also dictated which radio technologies may

be used and for what purpose. Globally, there is an ever increasing desire to move away from command and control methods towards spectrum trading, i.e. where the regulator takes a back seat and allows operators to trade spectrum freely between themselves, and spectrum liberalisation, i.e. where restrictions on technology and service type are relaxed. Both concepts aim to promote more efficient spectrum utilisation; first by placing financial value on spectral resources and then by allowing operators to deploy more spectrally efficient technologies in order to reduce their spectral needs. The potential benefits of spectrum trading and liberalisation are clear. However these concepts, specifically allowing different radio technologies to operate in adjacent spectrum, also bring significant challenges.

Of particular concern is the ability of FDD and TDD systems, e.g. different WiMAX variants, to coexist. Opening spectrum access to allow these systems to coexist has been difficult to realise, especially in some regions where the many potential national and licence boundaries have lead to a perception that TDD operation can bring coordination problems. There is growing interest in TDD operation, which has led to a number of studies that have looked at the challenges and solutions in considerable detail (these are discussed later in Section 3). A key aspect of these studies has been the realisation that no matter what techniques are employed, it is impossible to guarantee there will never be any interference challenges but that there are many considerations and measures that can be applied to manage and mitigate the problems in any given deployment scenario.

With the understanding that interference mitigation techniques are available, regulations are becoming more flexible and mixed TDD and FDD operation is widely anticipated. In some cases this can be seen with separate frequency blocks identified for TDD and FDD systems. However there are other examples where paired frequency blocks have been identified without any assumption made regarding the duplex method that should be deployed. Furthermore, there are examples of complete flexibility whereby even the FDD duplex spacing remains unspecified in the regulatory frequency plans. In the latter two examples, technology neutral measures like block edge emission masks are proposed to control the amount of interference into adjacent frequency blocks. These represent a

compromise between a tolerable and manageable level of potential interference against the extra constraints and requirements on the in-block equipment operating near the block edge. Allocating contiguous blocks to operators minimises the numbers of block edges, and allows greater flexibility in filtering and mitigation, e.g. imposing internal guardbands and therefore contiguous allocations are recommended.

Finally there are examples where regulation has mandated specific guard frequencies between blocks. This approach can reduce technological neutrality and is less flexible in accounting for the specifics of equipment characteristics and deployment scenarios. Moreover, enforcing mandatory guard bands implies reduced spectrum utilisation as guard bands may prohibit the deployment of solutions that are compatible with the technologies deployed on either side. Whilst such solutions are likely to be sub-optimal in terms of outright spectral efficiency, there are clearly advantages in allowing some traffic to be carried in the 'guard frequency' bands.

As an example of how guard frequency bands may be utilised consider a frequency band in which operators want to deploy both TDD and FDD variants of WiMAX technology. Mixing TDD and FDD systems is quite a challenging coexistence scenario. A 'safe' approach would be to rule that one or more channels be left unused between the TDD and FDD systems in order to ensure that there are no serious interference issues. Thus these channels can not be used to carry any traffic which implies poor overall spectrum efficiency. A more effective solution would be to deploy a FDD WiMAX system in these guard channels and configure both UL and DL for HFDD operation (typically HFDD is only used on the UL as described in Section 2.2.3) and synchronise the timing to that of the TDD system. Thus from the perspective of the TDD network the HFDD system appears as another TDD system with synchronised timing to prevent blocking during the receive phase. From the perspective of the FDD network the HFDD system appears as a FDD system so again blocking problems are avoided. At first glance configuring a FDD network to use HFDD on both the UL and DL would appear inefficient, which is correct because the spectrum is at most 50% utilised. However, achieving 50% utilisation is clearly

much better than 0% utilisation which is the case when all operation in the guard bands is prohibited.

2.4 Coexistence Scenarios

As discussed in Section 2.2, wireless radio technologies can use different methods to implement full duplex communications. When similar systems are deployed by different and competing operators in close proximity there are various system planning challenges that have to be addressed. When systems operating different duplex methods are deployed additional challenges may be introduced.

The network planner has a wide ranging 'toolbox' of techniques that may be used to help mitigate inter-technology and inter-network interference problems. These are discussed in greater detail in later sections of this report. First, however, it is necessary to identify the coexistence scenarios that might be encountered if TDD and FDD variants of WiMAX technology (and indeed any other wireless technology) are deployed in adjacent frequency bands. Figure 2 shows the five adjacent channel coexistence scenarios that would be possible if TDD and FDD variants of WiMAX systems were deployed within a single frequency band. UL and DL transmissions are identified by the green and blue arrows, respectively. Fundamentally, interference problems may occur if equipment on one frequency is trying to receive whilst nearby equipment on an adjacent frequency is transmitting. In each scenario there are four paths to be considered, namely, BS-to-BS, BS-to-SS, SS-to-BS and SS-to-SS. The potential interference paths are identified with the yellow, orange and red arrows, where the colour represents the potential risk/severity of interference related issues. Each scenario is discussed in greater depth in the following sections.

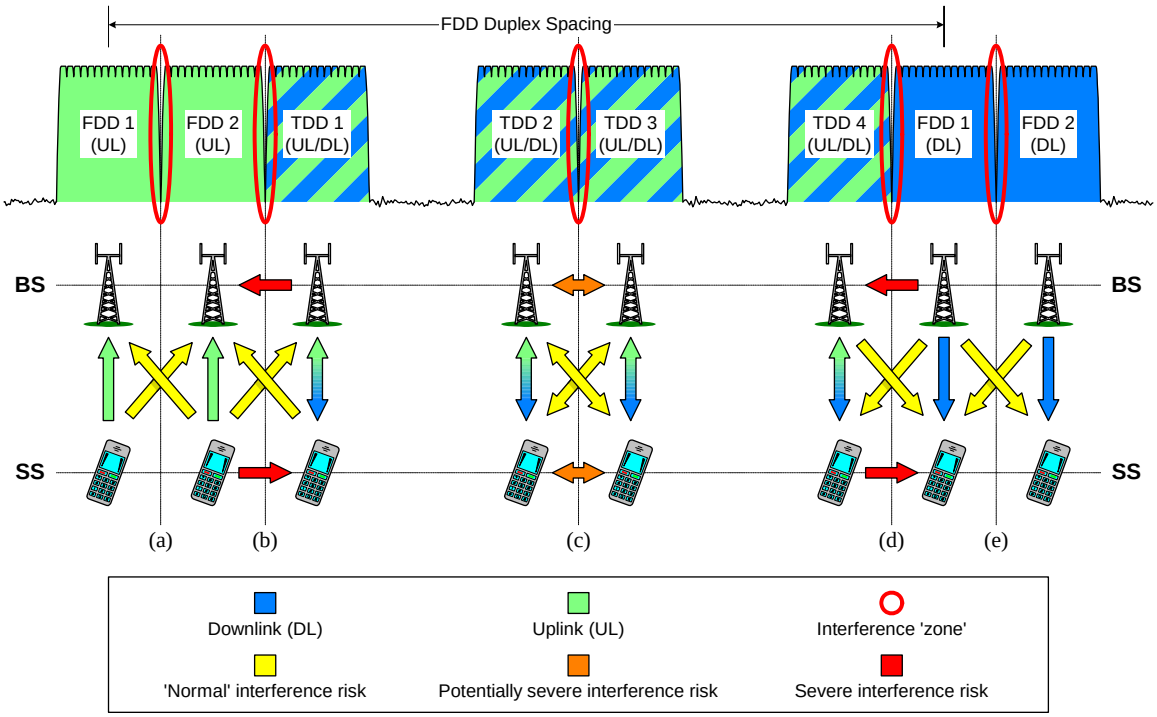

Figure 2 The sources of adjacent channel interference for the various FDD/TDD coexistence scenarios.

2.4.1 FDD-FDD

The first coexistence scenario is FDD-FDD. There will typically be two interference 'zones'. These are between adjacent UL frequencies (as shown in Figure 2 (a)) and between adjacent DL frequencies (as shown in Figure 2 (e)). Note that for the purposes of this discussion we will assume that there is always a sufficient guard band between UL and DL frequencies so that interaction between the two is negligible. This assumption is typically valid in multi-licensee scenarios, in which the DL and UL frequencies tend to grouped and ordered consistently.

As stated above, adjacent channel interference problems may occur if equipment on one frequency is trying to receive whilst nearby equipment on an adjacent frequency is transmitting. Therefore for the FDD-FDD coexistence scenario the primary interference paths are SS-to-BS on the UL and BS-to-SS on the DL; BS-to-BS and SS-to-SS interference will not generally be significant.

A scenario in which BS-to-SS interference on the DL can become problematic is shown in Figure 3 (top). Here, two adjacent channel BSs are positioned to cover a

particular region. The BSs are operated by competing operators and are positioned independently. When operating close to their BS, SSs from Network A receive with very good signal-to-interference ratio (SIR). However, as SSs from Network A move towards Network B's BS, adjacent channel interference levels rise significantly as the signal level from BS A drops and the adjacent channel interference power from BS B increases.

The problems observed in the above scenario can be alleviated by encouraging operators to collocate BS equipment at shared locations. This is shown for our example in Figure 3 (bottom). Now both BSs are 'looking' in the same direction and adjacent channel interference levels are bilaterally more uniform across the entire coverage region, which should lead to more deterministic, reliable coverage for *both* operators.

A similar scenario to the above example can occur on the UL; a SS that is transmitting at a high power to communicate with a distant BS can cause significant adjacent channel interference if in the vicinity of an adjacent channel BS. Again, this so-called 'near/far' problem is improved when BSs are collocated.

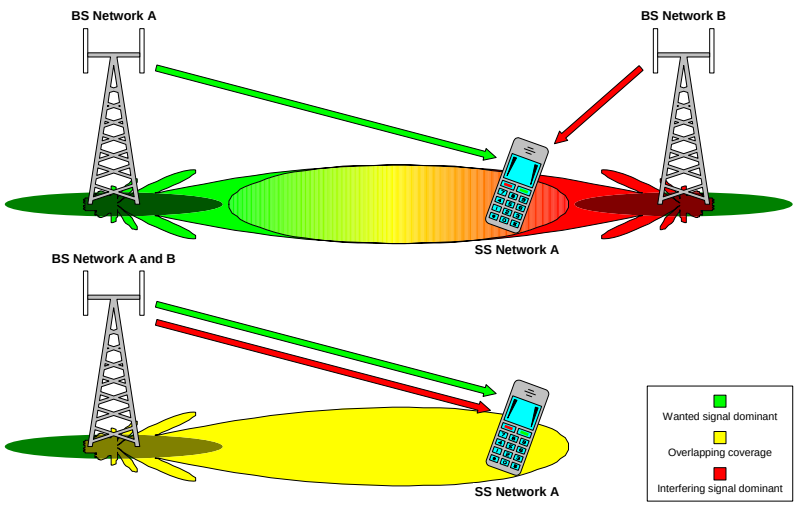

Figure 3 Collocating BSs to mitigate adjacent-channel interference.

A final note on the FDD-FDD coexistence scenario is that if a consistent DL/UL plan is not in place, i.e. the UL and DL frequencies are not grouped together and

separated from each other or arbitrary duplex spacings are adopted, then frequency discrimination between UL and DL transmissions can no longer be ensured, particularly if an UL channel were adjacent to a DL channel, and the interference scenario tends towards that of the FDD-TDD scenario, discussed in the following section.

2.4.2 FDD-TDD

The second coexistence scenario is FDD-TDD. Again there are two interference 'zones', i.e. a TDD system operating in the band adjacent to the UL (as shown in Figure 2 (b)) and a TDD system operating in the band adjacent to the DL (as shown in Figure 2 (d)). The most obvious difference between this and the previous scenario is that frequency discrimination cannot be relied upon to isolate the UL and DL. This scenario includes the same interference paths found in the FDD-FDD scenario *plus* potentially crippling BS-to-BS and SS-to-SS interference paths between the systems. These paths are identified in Figure 2.

SS-to-SS problems are caused when one SS is transmitting in the close proximity of another receiving in the adjacent channel. When the TDD system operates in a channel adjacent to the FDD UL, the TDD SS suffers interference from the FDD SS, but not necessarily *vice versa*, while if the TDD system operates in a channel adjacent to the FDD DL, the FDD SS suffers interference from the TDD SS, but not necessarily *vice versa.* In general, if the SSs are operated close enough to one another there is nothing that can be done to mitigate this problem. However, we note that affected SSs will generally be mobile so a) the problem will only continue whilst the SSs are close together and b) the number of users affected by the problem is minimal. Furthermore, the severity of the problem is a function of the transmit power of the SSs and the level of cochannel interference received. Therefore we will not consider this interference path further in this section.

BS-to-BS interference affects the FDD system on the UL and TDD systems adjacent to the FDD DL band. Again this is caused when one BS transmits whilst the other receives on the adjacent channel. Unlike the SS-to-SS case, BS-to-BS interference is more deterministic (i.e. it will typically be a problem or it won't), as BSs are active

continuously and they do not generally move. However, BS-to-BS interference potentially affects all cell users and will typically be more serious than SS-to-SS interference.

In the previous scenario we noted that collocation of BS equipment may be used to mitigate against the main source of adjacent channel interference issues in the FDD-FDD scenario. This approach is still applicable when considering BS-to-SS and SS-to-BS interference issues, in the FDD-TDD case. However, without additional measures, simply collocating BS equipment could make BS-to-BS problems worse due to the close proximity (and hence low isolation) of the antenna systems. Solutions that may be applied include the use of higher performance analogue transmit/receive filters (although this can only achieve so much when considering systems operating very close together in frequency because the filters still have to pass the wanted signals without significant distortion or attenuation). Another solution is to use available structures (either man-made or natural) and intelligent antenna selection and positioning to minimise the coupling between the various antenna systems. Examples include using directional antennas with vertical separation and using a building's structure to shield one antenna from the other. These mitigation approaches and others will be described in Section 2.5.

2.4.3 TDD-TDD

The final coexistence scenario is TDD-TDD, shown in Figure 2 (c). The TDD-TDD scenario is very similar to that of the FDD-TDD scenario and solutions for the latter are also applicable to the former. There is, however, an additional interference mitigation method that can be applied in the TDD-TDD scenario to virtually eliminate BS-to-BS and SS-to-SS interference issues.

As discussed in Section 2.2.1, TDD systems alternate between transmit and receive modes. Moreover, as mentioned previously, interference problems exist when one entity is trying to receive whilst another transmits. Therefore, if the transmit and receive timing of adjacent channel TDD systems could be synchronised, eg, to GPS, with the same frame structure, the most significant interference paths can be eliminated. This is shown in Figure 4, using BS-to-BS interference as an example.

With unsynchronised BSs (as shown in Figure 4 (top)) transmissions from one BS can desensitise the receive path of another. Synchronising the timing of the transmit and receive windows (as shown in Figure 4 (middle)) eliminates this problem. Note that, however, this only works if all systems use a common transmit/receive timing structure; if the timing is adapted to the bandwidth requirements then it becomes virtually impossible to avoid contention (as shown in Figure 4 (bottom)).

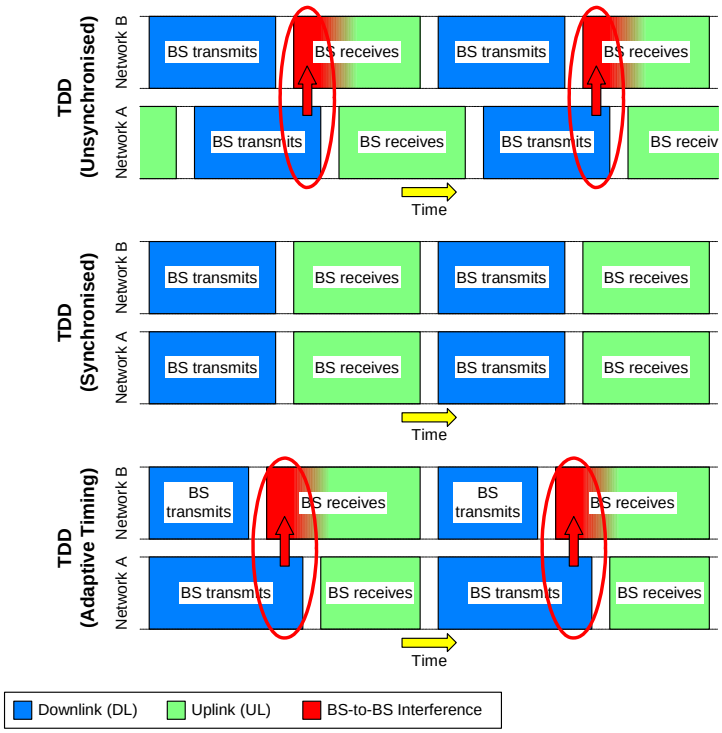

Figure 4 Synchronising TDD systems to mitigate BS-to-BS (and SS-to-SS) interference (top and middle). The scope for synchronising systems with adaptive timing is limited (bottom).

2.5 Factors Affecting Coexistence

In the previous sections we have used our knowledge of the various duplex methods (described in Section 2.2) to consider the potential interference paths in the main coexistence scenarios. Thus the paths of interest have been identified. However, in order to be able to evaluate possible mitigation techniques, we need to understand which factors may affect the ability of two systems to coexist in adjacent frequency bands. These factors can be split into so-called 'technology' factors, i.e. factors related to the radio equipment itself and 'deployment' factors, i.e. factors related to

the wide-area planning and deployment of equipment. We consider each of these in turn in the following sections.

2.5.1 Technology Factors

There are a number of factors related to the radio equipment that may affect performance in a coexistence scenario. The key factors are as follows:

- *Transmitter out of band and spurious emission levels*

  The first source of adjacent channel interference is out-of-band emissions (OOBE) and spurious signals generated by the transmitter. Ideally, 100% of the power output by the transmitter will be contained 'in band'. However, in reality this is not practical due to the limitations of realisable filters and the non-ideal characteristics, e.g. nonlinearities, of components used in the construction of the transmitter. OOBE generally refers to power measured over a predefined bandwidth whereas spurious emissions refer to the power of persistent unwanted spectral components.

  OOBE and out-of-band spurious emissions from a transmitter operating on one network may represent in band interference to a receiver operating on another network. Even with an 'ideal' receive filter a receiver cannot suppress this kind of interference. An example is shown in Figure 5. In Figure 5 (top), a signal is transmitted with significant OOBE. At the receiver some of the power from the transmitted signal passes through the receiver filter, as shown in Figure 5 (middle). This power will reduce the SIR for wanted signals and hence reduce the sensitivity of the receiver.

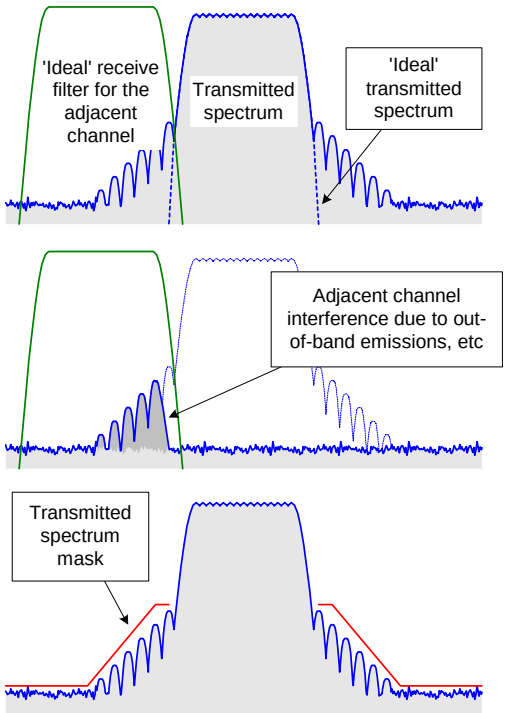

Figure 5 Interference caused by out-of-band emissions (top and middle) and the use of spectral masks for transmitter conformance (bottom).

To keep problems related to OOBE and spurious emissions to manageable levels, most radio standards impose strict spectral masks for the transmitter, as shown in Figure 5 (bottom). By ensuring that all equipment conforms to these masks, network planners can assume worst case scenarios when analysing the possible impact of interferers operating in adjacent channels. It is possible that more stringent transmission masks may be imposed on equipment that will be operated 'next to' unlike equipment.

As an example, OOBE for a typical FDD or TDD transmitter may be, say, -30 dBc in the first adjacent channel and -50 dBc in the second adjacent channel [1]. Adding a relatively low cost, band pass cavity filter may improve these figures by 15 and 40 dB, respectively. Thus a transmitter with even basic filtering should be able to suppress OOBE below -45 dBc in the first adjacent channel and -90 dBc in the second adjacent channel.

A typical measure of OOBE and spurious emissions is adjacent channel leakage ratio (ACLR), which is measures OOBE in the adjacent channel with respect to the power of the 'main', i.e. wanted, signal.

- *Transmitter linearity*

As stated above, one factor that may contribute to OOBE is the filter characteristics achievable with practical filters (especially when considering filters in SSs). Another significant contributor is system nonlinearities and power amplifier (PA) nonlinearity in particular.

Minimising power consumption is often a key requirement in any wireless transmitter and the PA is often one of the most power-hungry elements in a transmitter. Although highly efficient, nonlinear PAs may be used with constant-envelope modulation schemes such as Gaussian minimum shift keying (GMSK), linear modulation schemes such as orthogonal frequency division multiplexing (OFDM) require the use of less-efficient, linear PAs. Even 'linear' PAs will exhibit nonlinear behaviour if driven hard enough. Therefore it is typically necessary to 'back off' the output power of a linear PA to keep any nonlinearities to acceptable levels, which further reduces PA efficiency. Some of these problems may be mitigated by linearization techniques that may be used to improve the efficiency, but even these have limitations, as will be described later. Therefore a compromise must be struck to trade power consumption against nonlinearity and the resulting OOBE.

A simple example showing the potential effects of a nonlinear transmit path is shown in Figure 6. Figure 6 (top) shows the spectrum of an 'ideal' 2048-carrier OFDM signal; no significant out-of-band power is present. In Figure 6 (bottom) then same signal is augmented with a third-order component to represent the behaviour of a PA with a nonlinear characteristic. The resulting third-order intermodulation products (IMPs) have resulted in significant OOBE, which may represent significant interference power to users operating in the adjacent channels.

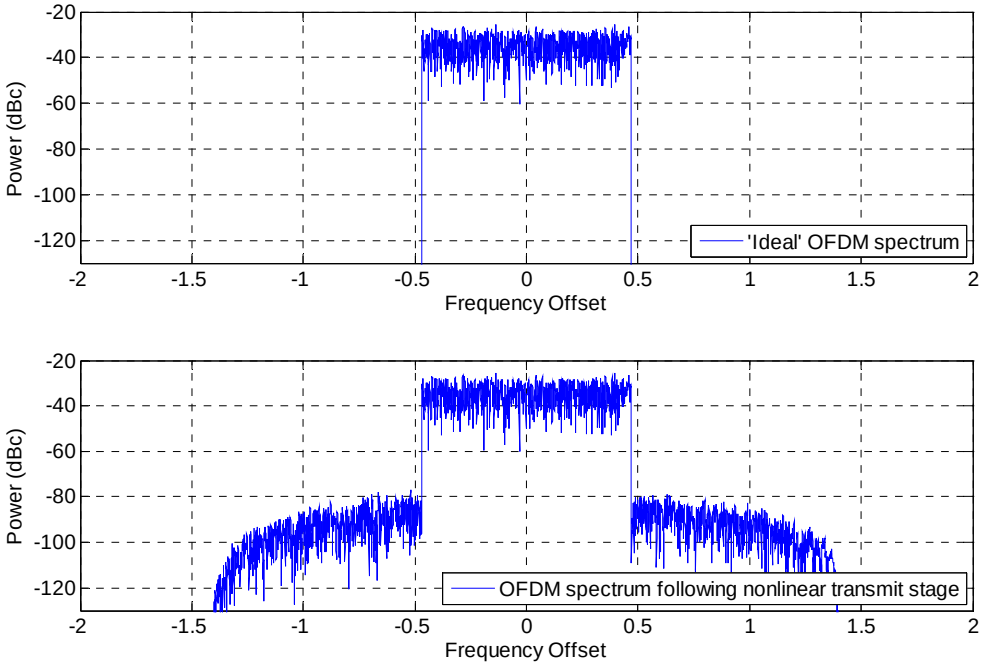

Figure 6 The effects of transmitter nonlinearity when applied to a linear modulation scheme such as OFDM.

Figure 6 shows why good transmitter linearity is essential when using linear modulation schemes such as OFDM. We have also explained why simply using overrated linear PAs backed off to ensure good linear characteristics is typically unacceptable due to very poor efficiency. There are, however, several digital techniques that can be used to 'linearise' PAs, which allow them to be operated well beyond levels that would otherwise be acceptable.

These techniques can be generally be grouped into two categories. The first includes techniques that attempt to compensate for nonlinearities in the PA. These typically use concepts such as pre-distortion or feed-forward correction (or a combination thereof). The second includes techniques that use novel methods of driving inherently nonlinear amplifiers in such a way as to generate the desired waveforms at the output. One example of this kind of technique is polar modulation.

Pre-distortion works by modifying the signal entering the PA such that, when combined with the nonlinear characteristics of the PA, unwanted nonlinear products at the output signal are heavily attenuated. Performance is increased in adaptive systems in which the model used to control the pre-distortion is continually updated by monitoring the output of the PA, eg, through the use of a directional coupler. The performance of pre-distortion systems is heavily dependent on the accuracy of the PA model and the ability of this model to predict how the PA will respond to any given input. However, as an example, Kim and Konstantinou [2] have demonstrated 11 to 13 dB ACLR improvements when using predistortion techniques to pre-distort UMTS carriers. As more advanced models and techniques are developed, even greater improvements may be realised.

Feed-forward correction uses a high-quality, lower powered 'error' amplifier in parallel with the main PA to add a suitable correction signal to the output of the main PA and cancel out any nonlinear effects. As an example, this technique may be used to improve the linearity of a Class-C amplifier by between 20 and 30 dB [3].

Polar modulation splits the wanted signal into phase and amplitude components. The phase information is used to drive a voltage-controlled oscillator (VCO) which in turn drives a very efficient, nonlinear amplifier. The output of this amplifier is then modulated by using the amplitude information to control the envelope, e.g. by adjusting the biasing applied to the output stage. As with the pre-distortion technique, performance can be improved by using feedback from the output to 'close the loop'. Polar modulation has been successfully demonstrated for narrowband systems such as EDGE, which uses an 8-PSK modulation scheme in a 200 kHz channel, and commercial solutions exist, e.g. RF Micro Devices' POLARIS™ 2 TOTAL RADIO™ solution [4]. However, an issue with this technique is that the bandwidth of the control signals and in particular the phase signal tends to be very great, eg, consider the phase change required when crossing zero. This issue may

mean that techniques such as polar modulation are less well suited to use in wideband systems such as UMTS and WiMAX.

The complexity of the linearization techniques available varies greatly, with concomitant variations in performance. In particular, some of the simpler techniques/implementations that may be applied to great effect in narrowband systems are less effective when used with wideband systems because wideband amplifiers tend to exhibit temporal and frequency-selective nonlinearities. PA linearization is a complex topic and a more in-depth discussion is outside the scope of this report. However, further information is widely available; one suggested source of information is Kenington [3].

- *Receiver selectivity*

Moving to consider the performance of the receiver, the equivalent of OOBE is receiver selectivity. Ideally, the receive filter will pass the wanted band exclusively. However, as with the transmit filter, this is not generally possible and suppression of out-of-band signals will be finite. The selectivity of a receiver refers to its ability to suppress out-of-band signals.

An example is shown in Figure 7. In Figure 7 (top), the output from an 'ideal' transmitter is received in the adjacent channel. Ideally the receive filter would reject virtually all of this signal. However, a practical filter implementation cannot match the adjacent channel rejection of the ideal filter so some of the power from the adjacent channel interferer reaches the demodulator, as shown in Figure 7 (bottom). This power will reduce the SIR for wanted signals and hence reduce the sensitivity of the receiver.

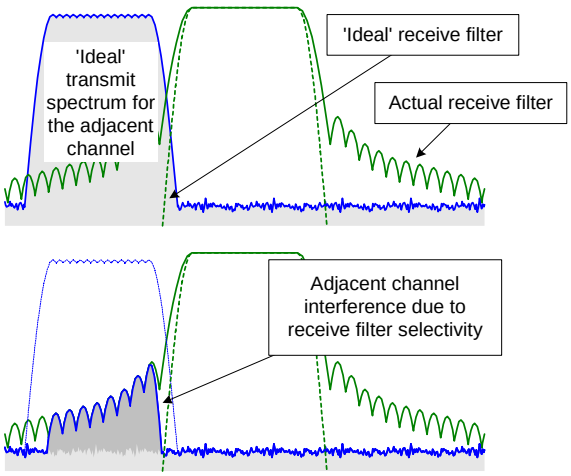

Figure 7 Interference through non-ideal receiver selectivity.

Generally receiver selectivity can be improved by increasing the complexity of the baseband channel filters and, to a lesser degree, using higher-order analogue filters at the RF input. However, both of these options typically involve greater cost and, in the case of the implementation of the baseband filters, potentially higher power consumption. Nevertheless, operators operating equipment in bands adjacent to third-party equipment, especially when different technologies are involved, may require greater selectivity and may consider the associated costs acceptable.

A typical measure of receiver selectivity is adjacent channel selectivity (ACS), which is essentially the attenuation offered to an adjacent channel signal by the receiver.

- *Receiver blocking performance*

Receiver selectivity refers to a receiver's ability to reject adjacent channel signals. As stated above, power from adjacent channel signals reaching the demodulator will reduce SIR and hence sensitivity. Sensitivity is typically limited by the performance of the channel filter, which is generally implemented at baseband. Although the range of frequencies allowed to enter the RF front end is normally restricted by the use of an analogue RF bandpass filter, this filter will typically pass a relatively wide range of

frequencies. Normally this is satisfactory as the RF front end will handle any adjacent channel signals with ease. However, in extreme circumstances, e.g. when collocated with transmitter equipment operating within the bandwidth of the RF filter, strong adjacent channel signals can 'block' the input to the receiver from receiving the wanted signal. Blocking can occur if the interfering signal forces the receiver to reduce its gain; reducing gain will degrade the sensitivity. If the gain is not reduced and the RF front end enters compression, the resulting intermodulation products can manifest themselves as significant in-band interference power and the wanted signal will become heavily distorted.

Thus, blocking performance is generally limited by the dynamic range of the RF analogue front end. Blocking performance can therefore be improved by two means. First effort can be expended to increase the dynamic range of the receiver by improving the 1-dB compression point. However this can only be done to a limited extent and typically increases power consumption of the amplification stages. The other approach is to improve the RF filtering, i.e. prevent the out-of-band signals entering the receiver in the first place. Drawbacks of this approach is the increased size, complexity and cost of the filters and, by virtue of the fact that the filter is optimised for the wanted frequency, the potential loss of flexibility in terms of reconfiguring the receiver for operation on different frequencies, e.g. in response to frequency plan updates.

- *Net filter discrimination*

We have discussed transmitter performance in terms of OOBE and receiver performance in terms of receiver selectivity. In practice, of course, the observed performance will be a combination of the two, i.e. SIR will be reduced by OOBE from the transmitter falling within the passband of the receive filter and also by power in the adjacent channel 'leaking' through the stopband of the receiver filter. A measure of this combined performance is net filter discrimination (NFD). Essentially this is an estimate of the power

entering the demodulator (i.e. after the receive filter) of a typical signal in an adjacent channel normalised to the power of an equivalent co-channel, i.e. wanted, signal. The general process is shown in Figure 8.

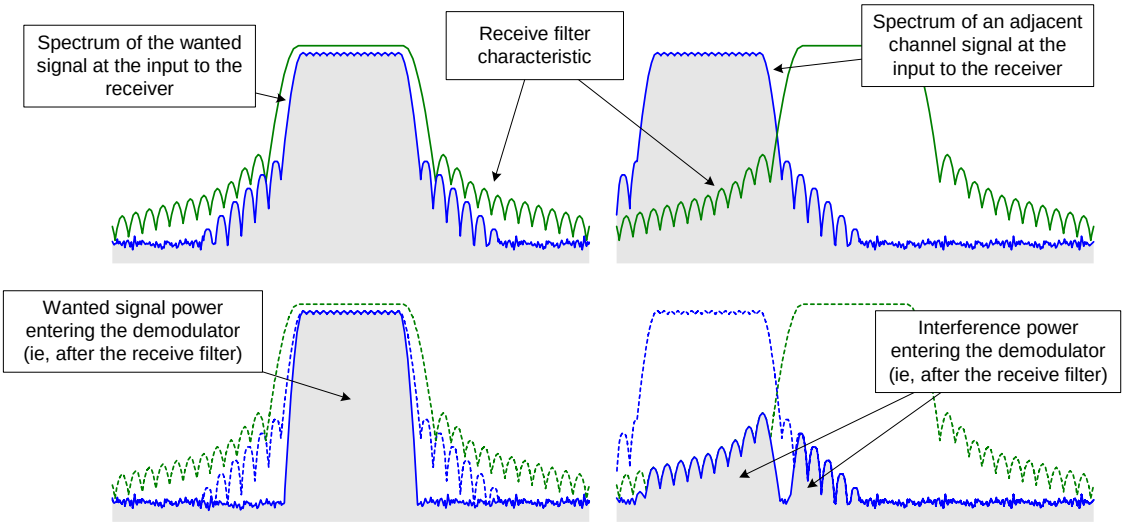

Figure 8 Net filter discrimination is the ratio of power in the wanted signal (top left) reaching the demodulator (bottom left) to that of an equivalent signal in the adjacent channel (top right) reaching the demodulator (bottom right).

Worst-case scenario NFD values can be estimated using the transmission mask to represent the spectrum of the interfering signal. However, more realistic and less pessimistic figures can be obtained by characterising 'typical' transmitter equipment.

- *Antenna discrimination (BS-to-BS interference)*

When collocating BS equipment, careful positioning of the antennas can make a great difference to the levels of isolation that can be achieved between the different systems. All antennas have a non-isotropic radiation pattern that can be characterised for any given frequency. More specifically, most antennas have nulls in their radiation pattern, i.e. directions in which negligible gain is observed with respect to the maximum forward gain. If the multiple antennas systems are simply mounted next to each other with no regard to the characteristics of each antenna, significant coupling between the antennas

may occur. However, by carefully positioning the different antennas such that the nulls are aligned significant levels of isolation between the antennas can often be achieved.

The potential to increase inter-system isolation through antenna discrimination will typically be greater when considering point-to-point data links that use highly directional antennas. In this scenario, the antennas will typically have relatively high forward gain and narrow beamwidth and, whilst sidelobes will exist, the power in the sidelobes will be much reduced compared to the main beam (e.g. 30 dB attenuation [1]) and there will generally be numerous nulls that can be exploited. Note that using a more directional antenna with a narrower beamwidth may also help reduce coupling caused by RF energy reflecting off of nearby buildings and other objects. Although directional antennas may be preferable, even sector antennas with 120° horizontal beamwidths typically have relatively narrow vertical beamwidths. Therefore vertical separation of antennas can often be used to good effect to help achieve good isolation between systems, even with cellular sector antennas.

As a final note, when considering collocated BS systems, simply increasing the separation between the respective antenna systems can have a considerable effect on inter-system isolation. For example, 3 m (10') separation corresponds to a free-space loss of 50 dB at 2.5 GHz.

- *Antenna discrimination (BS-to-SS/SS-to-BS interference)*

Antenna discrimination is also applicable to mitigating BS-to-SS and SS-to-BS interference.

When considering fixed point-to-point wireless links the use of highly directional antennas should be considered. The benefits are twofold. Firstly, as directivity is increased, i.e. as beamwidth is reduced, the gain of an antenna generally increases. Thus, the same effective isotropic radiated power (EIRP) can be achieved with considerably reduced transmit power, which lowers power consumption and either enables a PA with lower power

rating to be used (which reduces cost) or allows the PA to be backed off further which will improve linearity and help reduce OOBE.

For example, if a 7 dBi antenna is replaced by a 17 dBi antenna the output of the PA can be reduced by 10 dB to maintain a constant EIRP. Reducing the output of the PA by 10 dB will reduce out-of-band third-order IMPs generated by the PA by 30 dB. Thus, radiated OOBE due to nonlinear effects in the PA would undergo a 20 dB net reduction in the direction of the main beam. Even greater reductions would be observed outside of the main beam of the antenna.

The second benefit of using directional antennas is that RF power is directed to/received from the intended transceiver only, which helps minimise interference (both co-channel and adjacent channel) caused to and received from other users. Thus SIR can be maximised.

Note that there are numerous advantages to maximising SIR. This is especially true when considering the latest advanced radio technologies, which are able to adapt the modulation method and channel coding to take advantage of improved SIR. Thus, by improving SIR, higher-order modulation and/or lower-rate channel coding schemes can be selected, which permits higher data rates to be sustained or, through freeing up radio resources, allows more users to be supported. Even in radio technologies that do not support adaptive modulation and/or channel coding, increasing SIR generally will enable greater frequency reuse, which implies better spectral efficiency.

For fixed point-to-multipoint or mobile applications the use of directional antennas is less practical. For the former the BS needs to direct power in multiple directions simultaneously and to construct an antenna to achieve this is impractical. To use a separate antenna for each user (assuming that there are more than one or two users) is similarly impractical. (Note that generally the SS will still benefit from a directional antenna, however.) For the latter the users are, by definition, moving so a fixed beam pattern is of little use. A solution to both scenarios is the use of adaptive, smart antennas. These

come in various guises but the more advanced use beamforming techniques to a) focus gain, i.e. power, along the bearings of interest and b) direct nulls at known sources/recipients of interference. Thus, smart antennas have the potential to bring some of the benefits offered by fixed, directional antenna to applications involving multiple and/or moving targets and help maximise SIR.

- *Antenna polarisation*

Taking the concept of antenna discrimination a stage further, we note that the electromagnetic output from an antenna can often be polarised in a number of different ways; the polarisation of some antennas is a feature of the design; other antennas, e.g. multi-fed patch antennas can actually produce different polarisations depending on how they are fed. For maximum coupling between antennas, both transmit and receive antenna should have matched polarisations. Conversely, if the polarisation is different, i.e. 'cross polarised' then some loss is experienced. This feature may be used to improve antenna isolation where multiple antennas are collocated. Thus, one approach might be to configure FDD systems to use one form of polarisation and TDD systems another. If cross polarisation is used, 10 to 15 dB of isolation may be achieved [1].

Note that although linear polarisation may be used effectively in line-of-sight (LOS) point-to-point radio links, less discriminative antennas are often required for use in cellular networks that a) need to communicate with arbitrarily orientated SSs and b) operate in multi-path environments that may have a randomising effect on the polarisation of the received signal. Nevertheless, whilst antenna polarisation may not be beneficial when considering BS-to-SS and SS-to-BS communications, there may be gains when considering BS-to-BS interference in TDD-TDD and FDD-TDD coexistence scenarios.

- *Active interference cancellation techniques*

  The preceding factors are essentially all hardware related (ignoring the fact that channel filtering is typically performed in the digital domain at baseband). There may also be some scope for digital signal processing (DSP) techniques to be used to improve operation in the presence of strong interfering signals. In simple terms, if the effect of the interfering signal can be modelled then, by subtracting the interfering signal from the received signal the SIR can be improved for the wanted signal.

  Such approaches are typically computationally intensive and may also require highly accurate characterisation of the signal path, accurate estimation of the interfering signal, and large dynamic range in the analogue signal path. Nevertheless, this is an area that, if used with other mitigation techniques may be used to improve performance in the high interference environments.

2.5.2 Deployment Factors

In addition to the technology factors listed above, the following deployment factors may also affect performance in a coexistence scenario:

- *BS location*

  The relative location of the BS equipment in coexistence scenarios can have a significant impact on the ability for the various systems to coexist. Considering BS-to-SS interference, then there may be considerable advantages to collocating BS equipment as this ensures consistent SIR levels across the coverage region, as shown in the example of Figure 3. In harmonised FDD-FDD and synchronised TDD-TDD coexistence scenarios BS-to-BS interference is not typically a major issue because the case in which a receiver has to operate on a frequency adjacent to an operating transmitter is avoided. However in FDD-TDD and unsynchronised TDD-TDD scenarios this is not the case. Here collocating BS equipment may lead to crippling inter-system interference, with the transmitter of one system blocking the receiver of another.

Therefore, when considering FDD-TDD and unsynchronised TDD-TDD systems a compromise needs to be found that achieves an acceptable trade off between BS-to-SS and BS-to-BS interference.

If collocation is a requirement, various mitigation steps may be taken. One option is to improve the roll-off and rejection offered by the RF filters. However the gains that may be achieved through this approach will diminish as the separation between the frequencies of operation is reduced. Other approaches include using antenna discrimination and careful siting of the antennas to maximise inter-system isolation and, if possible, use the mounting structure to shield one antenna from another.

If the BS equipment is not to be collocated then suitable man-made and/or geographical features may be exploited to shield one BS from another. The key point here is that the BS should not be arranged so that they 'fire' at one another or are positioned as in Figure 3 (top) which may lead to significant interference problems resulting from the near/far effect.

- *SS location*

When considering fixed wireless links the SS may be treated in a similar manner to BSs as it is a stationary transceiver, often using a fixed antenna with moderate directivity. Therefore, care should be taken to maximise isolation with other nearby systems by carefully choosing and siting the antenna and, if necessary, augmenting the RF filtering. In the case of mobile SSs, then, by definition it is impossible to control their locations relative to one another. Furthermore, a low gain, omnidirectional antenna is typically required for ease of use, which means that techniques such as antenna discrimination are impractical.

- *Use of site features for shielding*

As discussed above, site 'features' be they man-made or natural may be used to great effect to improve isolation between one system and another by using

them to shield one antenna from another. The level of isolation that may be achieved will vary from site to site and will be dependent on the characteristics of the 'shielding materials' and reflections from nearby objects. The use of site features for shielding is applicable to both BSs and 'fixed' SSs.

- *Frequency planning*

  Where techniques such as the exploitation of site features and antenna discrimination are not available or are unable to provide sufficient isolation then the use of high performance RF filters may be necessary. Practical filters can only achieve finite roll-off rates. Moreover, if the passband of the filter is too heavily constrained then phase distortion, which causes delay variations, may have a significant impact on signal integrity. Therefore the analogue filter may impose practical limits on the separation required between active frequency bands. This in turn means that careful assignment of the available channels to the BS sites may be required to not only keep co-channel interference levels to acceptable levels but also ensure that there is always sufficient frequency separation between carriers used by different systems at each site with collocated BSs. Note that the ability of operators to achieve this may depend on the relevant operators agreeing to cooperate and to work out procedures to share the data needed to enable the coordination of frequency assignment plans.

- *Inter-operator cooperation and coordination*

  If multiple operators are to be allowed to operate different radio systems in adjacent spectrum in the same geographic location then cooperation and coordination between operators is likely to be essential. If operators choose to operate behind closed doors and deploy and operate their equipment independently problems may be inevitable. In particular, new equipment deployed by one operator may adversely affect the service already established by another.

In the TDD-TDD scenario encouraging inter-operator coordination is probably not too difficult because interference issues, if they occur, are likely to be bilateral, i.e. if Network A suffers interference from Network B then in all likelihood Network B will also suffer interference from Network A. The FDD-FDD scenario is similar although, as discussed previously, there is less scope for problems in an FDD-FDD scenario.

Problems are most likely to occur in the FDD-TDD scenario in which the most severe forms of interference are unilateral, i.e. BS-to-BS interference affects the FDD system when a TDD system is deployed adjacent to the FDD UL and affects the TDD system if deployed next to the FDD DL. Therefore some additional incentive and/or making inter-operator cooperation a condition of spectrum access may be necessary.

Inter-operator cooperation and coordination may achieve the following goals:

- *TDD synchronisation* – A massive reduction in the potential for inter-system interference in a TDD-TDD coexistence scenario can be achieved by synchronising the transmissions from the relevant systems. Thus the scenario in which one BS transmits whilst in the close proximity of a BS trying to receive is avoided. As mentioned in Section 2.4.3, TDD synchronisation is only practical when all systems implement a common, fixed timing structure.

  There may also be situations in which there is some gain to be had by synchronising TDD systems to HFDD systems, e.g. if HFDD systems were deployed to utilise 'guard' channels inserted between adjacent TDD and FDD systems.

- *Frequency plan coordination* – The characteristics of practical RF filters mean that the closer nearby systems are in frequency to one another, the harder it is to achieve the necessary inter-system isolation. Operators with multi-channel licenses could carefully engineer their frequency assignments to try and mitigate adjacent and co-channel

interference. When considering 'band-edge' channels, neighbouring operators may be able to optimise their networks by sharing and coordinating their frequency plans. Whilst the release of network configuration data is unlikely to be well received by operators, doing so may allow each to make more efficient use of their allocated spectrum. If cooperation and mutual consent cannot be reached, then guard channels will be mandatory with a consequent loss in spectral efficiency.

- *BS and antenna location coordination* – In a similar way that consensual frequency planning may facilitate greater overall spectrum utilisation, cooperation and coordination when planning the siting of BS and antenna equipment may also be beneficial to the operators concerned.

3 Studies to Date

As part of this work, a review of some of the many studies into the coexistence of FDD and TDD systems that have been completed to date was performed. The abstracts from the documents found as a result of a literature search are reproduced in Appendix A and the main findings of the review are presented in the remainder of this section. Note that this review was restricted to literature published in the public domain.

The studies identified that investigate the co-existence of TDD and FDD systems primarily involve the scenario in which different systems operate in the same area but on adjacent channels. Most of these studies are simulation based and present their results in terms of the capacity loss or outage probability as a means of measuring and analysing the impact of co-existing systems. Note that the majority of these studies (and hence their conclusions) are specifically concerned with the performance of UMTS systems. Given that systems using CDMA technology are inherently interference limited and, as a result, include mechanisms such as power control to dynamically adjust to 'ambient' interference levels, the findings of these studies may not be directly applicable to systems that are typically noise limited, i.e.

are not designed to simultaneously share spectrum with other users eg, some OFDM systems.

Four interference paths are identified and considered; interference experienced from base station to base station (i.e. BS-to-BS), interference from mobile station to mobile station (i.e. SS-to-SS), interference from mobile station to base station (i.e. SS-to-BS) and the interference from base station to mobile station (i.e. BS-to-SS). (These concur with the interference paths that were identified in Section 2.4.) In general, BS-to-BS interference is believed to be the main and most damaging interference path [5][6][7]. SS-to-SS interaction is also identified as a potentially severe source of interference, specifically if the two SSs are geographically or spectrally too close to each other [7][8][9][20]. One study identifies SS-to-SS interference as the main interference path [10]. This result is due to the ACS and ACLR values assumed for the SS and BS; the adjacent channel interference ratio (ACIR), effectively a measure of net filter discrimination, for the BS-to-BS path was calculated to be 12 dB greater than that for the SS-to-SS path.

According to [5], system performance is dependent on the frequency offset between the interfering BSs, ACIR and the BS and SS transmit power. Moreover, it finds that if the performance of one system is affected the performance of the other system is affected as well, which leads to the conclusion that system performance depends on the loading of *both* FDD and TDD systems. Therefore, in order to optimise the performance of both systems, some cooperation and compromise is required between the system operators.

Earlier work addressing SS-to-SS and SS-to-BS interference [8][11][12][13][14][15] suggests that with a 5 MHz carrier spacing, TDD/FDD co-existence is feasible based on the ACLR/ACS requirement thereof and that no additional guard bands are required. Reference [16] concurs that the C/I requirement can be met with high probability in most realistic scenarios. A number of studies conclude that there is adequate power available in the UMTS TDD system to handle interference from UMTS FDD, so there is negligible impact on the TDD system's capacity due to a FDD system in the adjacent channel, however, minor capacity loss is experienced by

the FDD UL if the TDD BS is located too close to the FDD BS [10][16][17][18]. Reference [9] concludes that co-existence can be supported provided that ACIR is better than 70 dB and BS separation is greater than 200 to 300 m. Moreover, since there is no duplex filter available to isolate the transmit and receive frequencies in TDD systems, the TDD transceiver requires a higher ACIR than that in the FDD system.

More recent work on sharing using OFDMA modulation was done in CEPT SE19 which performed coexistence studies in [19] and [20], those studies were between BWA systems operating in the 3.5 GHz band. The studies analyse the interference situation which occurs between WiMAX FDD and TDD or between unsynchronized TDD systems in terms of the amount of guard band.

It should be noted that the 3GPP UMTS specification makes no guarantee that the co-siting of TDD and FDD systems in the core bands is feasible [6]. Moreover, whilst the ACLR and adjacent channel protection (ACP) specifications of the TDD BS are adequate to combat interference when co-siting, the ACS and blocking performance of the FDD BS is not, so additional filtering is required, which is reported to be technically and economically viable.

A more comprehensive study has been addressed in [7], covering a range of scenarios to investigate the separation distance required for TDD/FDD coexistence, the ACIR required for 3.84 Mchip/s TDD/FDD coexistence and the separation distance required for TD-SCDMA/FDD coexistence. It concludes that a potential problem is when BS transmitters are geographically and spectrally close to sensitive SS receivers, regardless of the duplex method. Large separation distances and additional isolation are required in several scenarios to combat interference (while some other scenarios do not have such requirements). Moreover, it finds that the separation distance can be traded-off against coverage and increased SS transmitter power in the victim system. Finally, [7] concludes that the collocation of BSs will become prevalent in future systems. However, when considering existing WCDMA specifications, even 5 and 10 MHz guard bands are not sufficient to overcome the potential interference issues.

Solutions to combat the BS-to-BS interference have been proposed in [1][7][21][22]. These include additional RF filtering, careful site placement, antenna separation, antenna polarization, adaptive (i.e. smart) antenna arrays, power control and radio link adaptation. The application of smart antennas in TD-SCDMA systems is investigated in [23] and finds that they can be used not only to suppress the interference from TDD systems to FDD systems, but also protects the TDD system from FDD interference. The impact of adjacent channel interference on capacity and the ability to compensate this by dynamically increasing BS power is been studied in [24]. Finally, the use of TDD frequency reuse to minimize the interference from TDD systems to FDD systems is addressed in [25].

4 Regulatory Considerations

Regulators have an obligation to take all reasonable steps to ensure that the equipment operated by one spectrum user does not cause unacceptable interference to equipment operated by another. This is especially true when licences are awarded through beauty contests and auction processes in which considerable sums of money can be exchanged for the right to operate in a particular part of the RF spectrum. When such substantial financial commitments are made on the part of the licence winners it is reasonable that they expect some form of guarantee from the regulator regarding the interference levels that may be experienced. Some compromise is needed, however. Political drivers for competition and liberalisation in service provision often provide pressure for a number of licences to be awarded within any given area (regional or national); where these licence areas overlap, competing operators can find themselves operating in close proximity to each other.

Traditionally, where spectrum usage has be governed rigidly and the technology and service types have been predefined, the interaction between adjacent systems has been relatively predictable, which has enabled the regulators to make informed decisions regarding guard bands and maximum radiated power levels. However, with the advent of spectrum liberalisation, the relationships are far less predictable and the permutations far more numerous. This means that a new approach may need to be adopted when planning future spectrum releases and for more generic

and more flexible usage polices to be adopted in preference to rigid, inflexible channel allocations. Moreover, there may be arguments for a means by which the 'default' rules can be relaxed when operators operating in adjacent channels can agree to cooperate and find mutually acceptable deployment policies. Whilst this complicates matters, such an approach may enable otherwise 'unusable' spectrum to be utilised, which would be a win-win situation for regulators and operators alike.

A significant contributor to interference between coexisting wireless systems are the emissions from devices operating outside the band of frequencies designated for operation, i.e. OOBE. However, even 'in band' power will affect coexistence for the reasons discussed previously, e.g. receiver selectivity, receiver blocking, etc. Furthermore, we note that OOBE is inherently linked to transmit power, typically with both first- and third-order components, e.g. filter performance and PA linearity, respectively. In other words, limiting transmit power will have a limiting effect on OOBE also.

The traditional approach to dealing with these problems has been to define maximum transmitter powers and to identify guard frequency bands between operator blocks, which relies on frequency discrimination to provide some of the isolation required between nearby systems. However in certain scenarios a rigid fixed guard band can limit flexibility and prohibit schemes that might make use of otherwise unusable spectrum. Furthermore, these methods tend to be technology specific. Therefore alternative, less technology specific methods are required.

4.1 Transmitter Power

For any given radio technology, maximum transmit powers are normally given for the various classes of equipment defined. These limits, which are necessary to facilitate spectrum reuse and to limit adjacent channel interference levels at the receiver, take into account factors such as signal bandwidth, modulation and multiple access methods and are inherently technology specific. When considering technology neutral bands, technology specific limits are not appropriate. Therefore, a clear, unambiguous method of limiting transmitter power is required.

An example of how maximum transmitter power may be defined in a technology neutral manner is given in the Code of Federal Regulations (CFR) 47CFR27.50(h) [26], developed by the US Federal Communications Commission (FCC). Here, the EIRP for BSs operating either broadband radio services (BRS) or educational broadband services (EBS) in the 2150 to 2162 and 2496 to 2690 MHz bands must not exceed

$$\text{EIRP} = 33 + 10\cdot\log_{10}(X / Y) + 10\cdot\log_{10}(360° / \textit{beamwidth})\ \text{dBW}, \qquad (1)$$

where X represents the channel width, in MHz and Y is either 6.0 MHz if in the middle band segment or 5.5 MHz if in the upper or lower band segments. *beamwidth* represents the horizontal 3 dB beamwidth, in degrees, of the transmitting antenna. Note that for omnidirectional antennas, the *beamwidth* is 360°, i.e. the last term is equal to zero.

The inclusion of X in Equation 1 means that this equation effectively defines a maximum power spectral density, with an adjustment for antenna beamwidth. This is underlined by the 'small print' of the ruling that states that this maximum EIRP assumes a uniform power spectral density. If power spectral density is not uniform, the ruling states that the power in any 100 kHz bandwidth must not exceed that of a uniform transmission with an equivalent EIRP. Thus, if Equation 1 returned a maximum EIRP of 33 dBW (2 kW) in 6 MHz, the maximum power allowed in any 100 kHz within the 6 MHz would be 15 dBW (33.3 W). This corresponds to a power spectral density of 25 dBW/MHz.

For mobile stations EIRP is limited to 3 dBW (2 W) irrespective of signal bandwidth. For other SSs, transmit power, i.e. exclusive of antenna gain, is limited to 3 dBW (2 W). This effectively allows directional antennas to be used in SS installations to achieve EIRPs greater than 2 W.

4.2 Out-of-Band Emissions

Specifying maximum EIRP in a technology neutral manner is not too complex a task. Specifying OOBE limits, however, is potentially much more difficult. Traditionally OOBE limits can be calculated knowing not only the characteristics of the transmitted

signal but also those of the receiver, i.e. what interference levels can be tolerated before signal degradation becomes unacceptable. As stated previously, a traditional approach has been to pre-define suitable guard bands. In a technology neutral environment, however, the characteristics of the radio technology are not known. Moreover, if the permitted systems operate different channel bandwidths, the concept of fixed guard bands becomes impractical.

Rather than defining the guard bands explicitly, a means is required by which suitable guard bands, the width of which is appropriate for the technology deployed, can be derived. One approach is to define OOBE constraints either in the form of a block edge mask or a general signal mask. Thus, whereas guard bands rigidly prohibit access to selected frequency bands, a mask-based approach takes the performance of the radio equipment into consideration and/or may allow the use of equipment at lower transmit powers, i.e. shorter ranges. Together, better spectrum utilisation may be realised.

The use of a block edge mask is recommended by the Electronic Communication Committee (ECC), part of the European Conference of Postal and Telecommunications Administrations (CEPT), in Recommendation (04)05 [27]. This mask, reproduced in Figure 9, defines the power that may be radiated into spectrum adjacent to a licencee's assigned 'block' in absolute terms. Note that, however, the required roll-off is proportional to the width of the assigned block. Thus the mask is completely technology neutral; it makes no assumption regarding duplex methodology or even channel bandwidth.

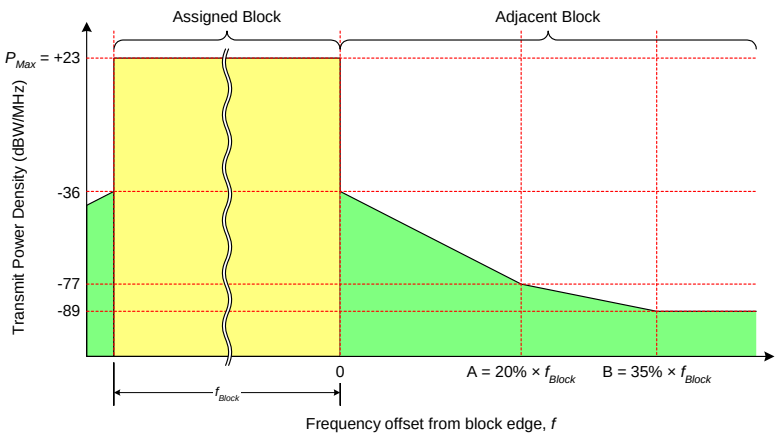

Figure 9 BS block edge spectral density mask defined in ECC Recommendation (04)05.

This mask clearly defines what power may be emitted outside the block of spectrum assigned to a particular operator. Armed with knowledge of the characteristics of its transmitter equipment, an operator may conform to the mask in a number of different ways. These include:

- Implement a self-imposed guard band within the assigned block so that OOBE remain below the mask.
- Configure transmitters operating close to the block edge to transmit at a lower power, thereby reducing OOBE (and range).
- Reduce OOBE by specifying equipment with improved RF performance, eg, improved PA linearity, for transmitters operating close to the block edge.
- Fit additional RF filtering to transmitters operating close to the block edge to suppress OOBE to acceptable levels.

Finally, it should be noted that Recommendation (04)05 further states that if operators of adjacent frequency blocks agree to cooperate then the levels shown in Figure 9 may be exceeded by mutual consent. In practice this means that operators may alleviate potential interference issues near the block boundary by coordinating their frequency plans.

The ECC is not the only organisation to propose the use of block edge masks, the FCC has also considered the use of block edge mask requirements to control the potential emissions from different wireless systems and technologies operating on adjacent channels [28]. Recognising the need to maximise spectral efficiency whilst protecting operators from interference, the FCC has adopted a so-called 'dual mask' approach for BRS and EBS equipment, which is shown in Figure 10.

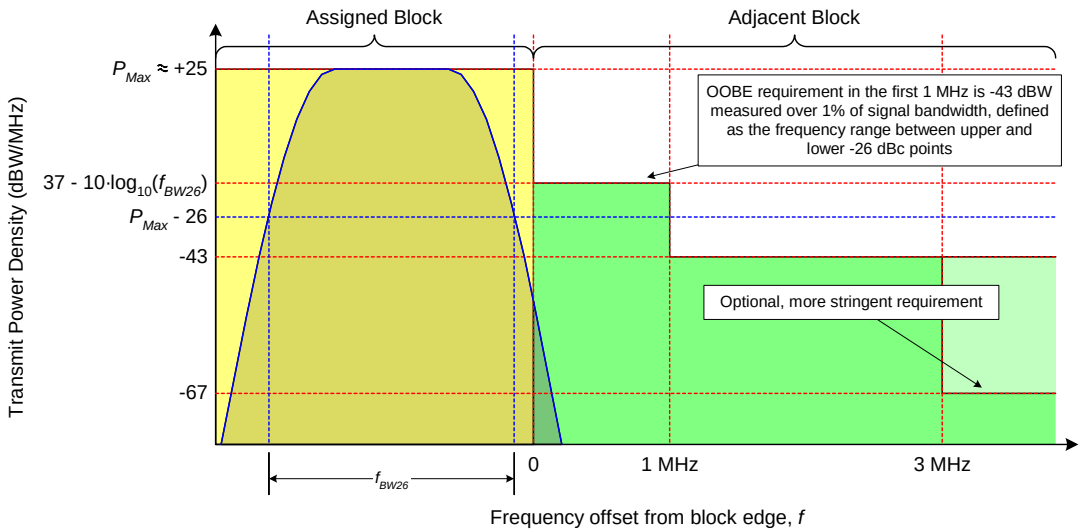

Figure 10 Interpretation of the FCC dual mask specification for BRS and EBS equipment.

The 'default' requirement is that OOBE measured from the band edge must be attenuated by no less than 43 + 10·$\log_{10}$ (P) dB at the band edge, where P is the transmitter power in W. This equates to a level of −43 dBW (−13 dBm). In the first 1 MHz adjacent to the assigned block, a measurement bandwidth equal to 1% of the emission bandwidth[2] is specified. Thus, for example, if the transmitted signal has a 5 MHz emission bandwidth, the equivalent power spectral density is −30 dBW/MHz (0 dBm/MHz). Beyond the first 1 MHz, a 1 MHz measurement bandwidth should be used, so the OOBE requirement translates into a maximum power spectral density of

[2] The emission bandwidth is defined as "the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, outside of which all emissions are attenuated at least 26 dB below the transmitter power".

−43 dBW/MHz (−13 dBm/MHz). This is intended to be a relatively relaxed requirement, designed to promote high spectrum utilisation.

In certain circumstances, the −43 dBW limit may not be sufficient and unacceptable interference may be caused users operating in the adjacent block. In the first instance, operators will be encouraged to reach a mutually acceptable solution, eg, through the coordination of frequency plans, upgrading of transmitter equipment, etc. However, if such a solution cannot be found then, on submission of a documented interference complaint, both parties will be required to instead adhere to stricter OOBE attenuation requirements.

Assuming that the affected equipment are separated by 1.5 km or more, the optional OOBE requirement is that OOBE integrated over a 1 MHz measurement bandwidth are attenuated by no less than $67 + 10 \cdot \log_{10}(P)$ dB when measured 3 MHz from the channel edge. This corresponds to a power spectral density of −67 dBW/MHz (−37 dBm/MHz), i.e. an additional 24 dB attenuation. If site separation is less than 1.5 km then even greater attenuation is required. These stricter levels are designed to limit any desensitisation of uncoordinated equipment operating in the adjacent channel to 1 dB[3] [29]; a 1 dB desensitisation is considered to be an acceptable compromise between enabling high spectral utilisation and protecting operators in adjacent bands. In practice, the 1 dB desensitisation limit is achieved by ensuring that the interference power spectral density at the input to the receiver is 6 dB below the noise floor of the receiver.

In essence, this dual mask approach is designed to encourage operators to cooperate in return for a relaxed OOBE requirement. However, for cases where this fails, there is a documented 'fall back' plan. As with the ECC recommendation, the FCC has also included provision to allow operators to replace the FCC OOBE limits

[3] Note that the FCC does not specify an antenna gain or a noise figure, both of which are required to determine the actual noise rise. Higher gains or lower noise figures will case the desensitisation to be increased.

with less stringent limits that are mutually acceptable to the parties affected. Thus there are in fact *three* levels of OOBE control!

The concept of a block edge mask should permit the regulator to take a back seat, stepping in only to resolve disputes. A possible alternative to the use of block edge masks would be to extend the concept of 'guard band managers', currently employed in the US to control access to selected bands in the range 746 to 794 MHz [30]. Here, from the point of view of the regulator, the guard band manager is the licensee. The guard band manager then effectively subleases its spectrum to the network operators. Thus, it is the guard band manager who is responsible for the coordination of the spectrum users (both in terms of frequency and space), the enforcer of guard bands and the resolver of spectral disputes.

4.3 Smart Antennas

In any cellular system, one of the challenges for the operator is to provide the subscriber with consistent performance across the coverage area. Typically this requires the use of a multiple BSs, with a frequency reuse ranging from one, i.e. a single-frequency network, eg, WCDMA, to, say, seven. One technique that has traditionally been used by network planners to optimise coverage and/or capacity is cell sectorisation. Sectorisation effectively involves the process of splitting cells with omnidirectional coverage into a number (typically three) of smaller cells or 'sectors'. Sectorisation is essentially a cost effective method of 'cell splitting', a proven method of improving network performance. However, sectorisation can only deliver finite gains and these gains diminish as more sectors are added to a site [31].

Sector antennas generally have relatively rigid characteristics; perhaps with the exception of optional features such as electronic down-tilt, the beam pattern is fixed. Smart antenna systems introduce the concept of beam agility and represent an evolutionary step in BS implementation. With this capability, smart antennas can 'track' users and, by dynamically adapting the composite beam pattern, realise significant SIR gains that, in turn, can be used to improve coverage and/or capacity and reduce interference caused to and received from other networks operating in the vicinity. WiMAX technology supports adaptive antenna systems (AAS).

In their simplest form, smart antennas may consist of a number of fixed-beam antennas. Thus, users can be tracked by switching from one antenna to another. Ultimately, however, smart antenna systems may use multi-element antenna arrays together with advanced beamforming techniques to simultaneously track both users and interferers alike. Thus, by focusing gain on cell's users whilst simultaneously steering 'nulls' at sources/potential recipients of interference SIR can be maximised.

Smart antennas would appear to have the potential to offer significant spectral efficiency and/or throughput gains, with benefits for regulators and operators alike. For example, they focus the 'wanted' signal to where it is required, which will certainly reduce adjacent channel interference due to leakage at the receive filter, i.e. poor receiver selectivity of receivers using the adjacent spectrum.

Therefore, smart antennas are a good idea and regulators should encourage their adoption. However, there are some points that smart antennas (including adaptive beamforming smart antennas) raise that the regulator should consider.

The in-band power and OOBE will vary in time as the antenna weights change to direct power to different users. Typically, beamforming is performed at baseband by applying complex weights (i.e. amplitude and phase) to the waveforms sent to and received from the various antenna elements. When the individual signals are combined (at baseband in the receive case and in the radio channel in the transmit case) beam patterns are realised. In a linear system the relationship between the element weights and corresponding beam pattern is straightforward, and one would expect the beam pattern of the OOBE to be similar to that of the inband signal. In practice, however, BS transmitters are not perfectly linear and nonlinearities in the PA, cause the amplitudes and phases of the OOBE to be different to those of the wanted signal. Phase and gain differences between filters in the elements may also have similar effects. The consequence is that for a single beam, beam shape of the OOBE will differ from that of the in-band signal. As a result, nulls in the wanted signal beam may contain OOBE power, and it may not be practical to attempt to steer the OOBE power and the inband power away from potential interference victims.

However OOBE power in other directions may be lower relative to the in-band power.

Relative to single antenna systems, smart antennas reduce in-band power transmitted in unwanted directions and have the potential to reduce OOBE.

4.4 Coexistence between Systems in Different Geographic Regions

So far in this report we have considered the coexistence of different technologies in adjacent spectrum but in the same geographic region. There is of course also an equivalent range of coexistence scenarios for co-channel operation but in *different* geographic regions. A situation in which these scenarios might exist is along international borders, for example.

When considering mitigation of co-channel interference between dissimilar systems some of the factors and techniques identified previously are no longer applicable. For example, OOBE become insignificant because the interference will be predominantly from 'in-band' emissions. Also filtering techniques and ACLR and ACS performance will be of little significance for similar reasons. Some of the listed techniques will still be of use, however. Directional or smart antennas, antenna polarisation and inter-operator coordination and cooperation may all be beneficial. Moreover, when considering cross-boundary interference, cooperation between regulators may also be required in order to promote operator interaction and coordination.

Fundamentally, however, interference between TDD and FDD systems operating on the same frequency can only be controlled by ensuring that there is sufficient separation between equipment so that the emissions from one system are sufficiently attenuated at the input to the other that desensitisation remains below acceptable levels. In a worst case scenario in which a both the interferer and recipient have directional antennas pointed at one another, several hundred km may be required for natural path loss mechanisms to reduce the signal power to a level where receiver desensitisation is limited to 1 dB (in the order of 200 dB attenuation

may be required). Using directional antennas, etc, simply provide means of reducing the separation distances required.

5 Conclusions

Regulators worldwide are adopting the concepts of spectrum trading and spectrum liberalisation as a means of promoting and encouraging more efficient utilisation of RF spectrum. This shift from rigid and prescriptive command and control management techniques to more flexible approaches embracing the use of market mechanisms to manage spectrum access has many potential benefits for both the regulators and for the spectrum users. However, the introduction of technology neutral spectrum allocations is not without its challenges. One particular issue is the ability of systems using different duplex methodologies, namely, FDD and TDD, to coexist in adjacent frequency bands. This is an essential requirement if true spectrum liberalisation is to be realised.

Four possible interference paths have been identified. These are BS-to-BS, BS-to-SS, SS-to-BS and SS-to-SS. In this report these paths were considered in the context of the three main coexistence scenarios, namely, FDD-FDD, FDD-TDD and TDD-TDD. The FDD-FDD scenario is present in the majority of existing cellular networks and is thus well understood. The coexistence of TDD-TDD systems is also understood albeit to a slightly lesser extent. To date, however, there is little practical experience of the FDD-TDD scenario.

Discussion of the four potential interference paths in the case of the FDD-TDD coexistence scenario concluded that BS-to-SS and SS-to-BS interference is likely to be similar to that experienced in the FDD-FDD and TDD-TDD scenarios. However, it was concluded that there is a high risk of BS-to-BS interference and SS-to-SS interference. Moreover, this interference risk is unilateral. This is summarised in Table 1. Finally, considering the overall impact of inter-system interference, it was concluded that BS-to-BS interference will generally be more critical than SS-to-SS interference because SS-to-SS interference will typically only affect a small number of users and, in the case of mobile users at least, will be temporary. It was also noted that there will generally be less scope to mitigate interference issues at the SS

because a) cost, weight, power and size requirements may prohibit the implementation of some of the more effective mitigation techniques and b) SSs will typically be free to roam very close to one another.

Interference Path	TDD Adjacent to FDD DL	TDD Adjacent to FDD UL
FDD BS to TDD BS	High risk	No risk
TDD BS to FDD BS	No risk	High risk
FDD SS to TDD SS	No risk	High risk
TDD SS to FDD SS	High risk	No risk

Table 1 Most severe interference paths in the FDD-TDD coexistence scenario.

Previous studies on this subject that have been completed to date generally concur with the assertion that BS-to-BS interference is the most critical interference path. Moreover, a number draw the attention to the fact that TDD systems have generally been designed to coexist with adjacent channel users and therefore already mandate adequate (or at least improved) filtering requirements. This is not necessarily the case for FDD systems where frequency discrimination afforded by the duplex spacing generally relaxes the filtering requirements greatly. Therefore, in a coexistence scenario, the TDD system may typically be more resilient to interference from the FDD system than the FDD system is to the TDD system.

Various mitigation techniques may be used to improve inter-system isolation. These include:

- *Improving transmitter ACLR performance* – Through reduction of OOBE and the use of higher-performance analogue RF filters the amount of power allowed to radiate in the adjacent channel may be reduced. OOBE may be reduced by using higher-order pulse-shaping filters at baseband and by improving PA linearity, perhaps through the use of linearization techniques.

- *Improving receiver ACS and blocking performance* – Equivalent improvements may be possible in the receiver by improving the performance

of the analogue and digital filters and through improvements to the dynamic range of the analogue front end.

- *Antenna discrimination* – In fixed point-to-point applications, simple directional antennas may be used to great effect to focus power in the direction of the intended target whilst simultaneously rejecting interference power caused to and received from other users. Moreover, when collocating BS equipment, exploitation of nulls in the antenna's radiation pattern and maximising antenna separation will help maximise system isolation. In point-to-multipoint and mobile applications the use of fixed directional antennas may not be suitable. Smart (switched beam and phased array) antennas have the potential to bring some of the benefits of directional antennas to these applications..

- *Antenna polarisation* – One suggested method of improving system isolation is to use different antenna polarisation on each system. This is probably most applicable to fixed, line-of-sight links and as a mitigation technique when collocating BS equipment as polarisation information may typically be lost in a multipath environment.

- *Active interference cancellation techniques* – It is possible that future radio systems may use active interference cancellation techniques. Such techniques are likely to be computationally intensive which may limit their application.

- *BS/SS location* – Careful coordination of site placement and BS placement in particular may prove to be a very effective, low cost mitigation technique. For example, existing site features may be exploited to shield one system from another. Further coordination to minimise direct line-of-sight signal paths from one BS to another and to minimise problems from the near/far scenario will also help prevent unacceptable interference issues.

- *Inter-operator cooperation and coordination* – Key to the successful implementation of many of the above techniques and other techniques such as synchronisation of TDD and HFDD systems is the cooperation and

coordination of operators. As shown in Table 1, the main interference paths in FDD/TDD coexistence scenarios are unilateral. Essentially, therefore, the situation may be created in which one operate has to compromise the deployment of their network in order to aid the deployment of a competitor's network. Such a scenario may result in reluctance on the part of the interfering network to cooperate openly. Therefore, regulators may need to be able to implement effective incentives to encourage full cooperation. This may be in the form of unilateral penalties in situations were it can be clearly demonstrated that one party is deliberately being uncooperative, eg, a development of the FCC's dual mask system.

In addition to the identification of these mitigation techniques, the following recommendations are made:

- Depending upon the deployment scenarios and the use of mitigation techniques, the size of the guard band required to successfully deploy TDD and FDD systems in adjacent spectral allocations is difficult to determine without unduly constraining one or both of the systems. Therefore it is recommended that the implementation of guard bands should be left to agreement between the operators and their regulators. Block edge masks are an effective alternative to mandatory guard bands; the operator is then free to choose how best to meet the mask requirements, the implementation of guard bands being just one such solution.

- Even without mandatory guard bands, block edge masks are likely to impose some form of restriction on the use of the spectrum at each end of an operator's assigned block. Therefore, the percentage of each operator's allocated spectrum subject to restrictions is dependent on the size of the frequency block allocations.

  For instance, if a block consists of just one or two channels, then 100% of the stations will be required to meet the block-edge mask. This may prevent optimal network deployment, which may have a negative effect on overall spectral efficiency. If instead each block consists of five channels, only 40%

of the stations will be subject to the block edge mask; stations using the central three channels can be deployed freely, potentially improving spectrum utilisation. Clearly improving spectral efficiency benefits both operators and regulators alike. Therefore it is recommended that reasonably large contiguous block sizes are considered wherever possible.

- As is the case with the findings of the ECC [27] and the FCC regulations for the BRS and EBS bands [28], operators should be given the option of replacing the default block edge masks with mutually acceptable OOBE limits. Thus, if other interference mitigation techniques, eg, the use of careful site placement and antenna orientation, are sufficient to prevent significant inter-system interference, then, through the consent of the affected operators, removal of the mask requirements may allow better spectrum efficiency to be achieved. This should not be prohibited and the provision for it in the findings of the ECC and FCC is welcomed.

- Finally we recommend that regulators assume the responsibility of encouraging or mandating that the operators of adjacent frequency blocks cooperate and coordinate their network planning. Coordinating tasks such as frequency planning and site placement are effective methods of minimising inter-system interference. If this is successful, the number of inter-operator disputes that require intervention by the regulator should be reduced.

  The bilateral gains that may be achieved by coordinating TDD networks will hopefully provide a suitable incentive for inter-operator cooperation. However, when considering TDD-FDD coexistence scenarios BS-to-BS interference tends to be unidirectional. (If all assignments, including those used by TDD systems are paired, then one half of the pair is affected by interference in one direction while the other is affected in the reverse direction and so there is an incentive to cooperate to maximise the use of spectrum.) Therefore extra incentives and/or encouragement may be required in order to gain the cooperation of the operator of the interfering network. Considering the FCC's dual mask system, maybe one option would be to only enforce the

stricter OOBE requirements on the equipment of the uncooperative party (as defined the stricter mask, if invoked, is a bilateral requirement).

Finally, as stated previously, smart antennas would appear to have the potential to help mitigate interference issues in both point-to-multipoint and mobile applications.

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Appendix A Abstracts from Results of Literature Search

This appendix reproduces the abstracts from some of the documents found as a result of a literature search of studies that have been completed to date into the coexistence of FDD and TDD systems. Where an abstract is not available, a brief description of the document is provided:

Author(s): Rémi Chayer (TDD Coalition)

Title: Tutorial on TDD Systems – Part 3: Spectrum Allocation and Coexistence Issues

Source: Presentation delivered to FCC Office of Engineering and Technology, 3 December 2001

Comment: This presentation provides a general guide for FDD-TDD co-existence in terms of recommended practice, TDD-FDD collocation, general rules and practice, mitigation techniques and efficient spectrum allocations.

Author(s): Lee, T., L., Faure, C., Grandblaise, D.

Title: Impact of FDD/TDD Co-Existence on Overall UMTS System Performance

Source: Vehicular Technology Conference 2001 (VTC 2001 Spring) IEEE VTS 53rd, vol 4, pp 2655–2659, May 2001

Abstract: Interference and compatibility issues relating to coexistence of two duplexing modes in UMTS, FDD and TDD, are highlighted in this paper. Performance degradation due to co-existence is quantified by comparing with single system scenarios. It has been found that system performance depends on the loading of both FDD and TDD. Co-existence can be optimised when some compromise is observed. This optimal compromise has been derived in this paper, giving the maximum

loading in one system when loading of another is known. BS↔BS interference scenario is found to be most damaging and therefore, the distance between BSs of the two systems should be maximised.

Author(s): Wilkinson, T., Howard, P.

Title: The Practical Realities of UTRA TDD and FDD Co-Existence and their Impact on the Future Spectrum

Source: Personal, Indoor Personal, Indoor and Mobile Radio Communications, 2004, PIMRC 2004, 15th IEEE International Symposium, vol 1, pp 22–26, September 2004

Abstract: This paper presents some of the first published results of real UTRA TDD and FDD equipment performance in respect of co-siting. The relevant 3GPP specifications are examined in detail to see whether they guarantee co-existence and if not whether they are exceeded in practice. In conclusion, the paper shows that the necessary performance to facilitate co-existence, co-siting and indeed antenna sharing has already been achieved in practice. These results not only have implications on the coexistence discussions for new spectrum allocations for 3G, such as the IMT-2000 extension band, but also on new standards for these.

Author(s): ITU

Title: Coexistence between IMT-2000 Time Division Duplex and Frequency Division Duplex Terrestrial Radio Interface Technologies around 2600 MHz Operating in Adjacent Bands and in the same Geographical Area

Source: REPORT ITU-R M.2030, 2003

Comment: In this Report the coexistence between IMT-2000 time division duplex (TDD) and frequency division duplex (FDD) radio interfaces are

investigated. The interference properties between IMT-2000 CDMA Direct Spread (also called WCDMA or UTRA FDD) and IMT-2000 CDMA TTD (also called UTRA TDD) with its two modes high chip rate (HCR, 3.84 Mchip/s) TDD and low chip rate (LCR, 1.28 Mchip/s) TDD are studied for a large number of scenarios. Specifically, the BS-BS interference for both proximity and co-location scenarios are studied in the main part of the report, as well as the MS-BS, BS-MS and MS-MS scenarios are studied for proximity scenarios.

Author(s): Siemens

Title: Simulation Results on FDD/TDD Co-Existence Including Real Receive Filter and C/I Based Power Control

Source: TSGR4#6(99) 419, July 1999

Comment: This report is a follow on study of an earlier discussion of 3GPP on using an ideal receive filter and carrier-based power control for FDD/TDD co-existence on the 1920 MHz frequency border. This report provides new results including the impact of 'real' receive filters, C/I-based power control and it also proposes ACLR/ACS requirements for the UE and BS based on the simulation results.

Author(s): Qingyu, M., Wenbo, W., Dacheng, Y., Daqing, W.

Title: An Investigation of Interference between UTRA-TDD and FDD System

Source: Communication Technology Proceedings, 2000, WCC - ICCT 2000 International Conference on Communication Technology, vol 1, pp 339–346, August 2000

Abstract: Interference between the UTRA-TDD and FDD system is investigated. There are some specific interference modes in the TDD mode because

the uplink and the downlink use the same frequency band in the TDD mode. The UTRA-TDD and the UTRA-FDD have severe adjacent channel interference if they use the adjacent carrier. Some simulations are done to study the interference. Impacts of four different interference instances were considered in the simulation. The impact on the UTRA-FDD uplink capacity is evaluated. Some interesting results are given from the simulations. The TDD and FDD base station can not be co-located if they use the adjacent frequency band between which the value of ACIR is below about 70 dB. The TDD and FDD cells can use the same frequency in some scenarios, which will increase the capacity, and utilize the underused UTRA-FDD uplink resources.

Author(s): Qingyu, M., Wenbo, W., Dacheng, Y.

Title: The Coexistence of UTRA-TDD and FDD System in the Adjacent Channel

Source: Global Telecommunications Conference, 2001, GLOBECOM 2001, vol 6, pp 3714–3718, November, 2001

Abstract: The coexistence of UTRA-TDD and FDD system in the adjacent channel is investigated in this paper. Different interference cases between the UTRA-TDD and FDD system are given. The UTRA-TDD and the UTRA-FDD have some adjacent channel interference if they use the adjacent carrier. Some simulations are done to study the interference and the Coexistence of UTRA-TDD and FDD system in the adjacent channel for the hierarchical cellular structure and the different ACIR value of BS-BS, MS-MS and BS-MS are taken into account.

Author(s): Siemens

Title: TDD/FDD Co-Existence - Summary of Results

Source: 3GPP TSG RAN WG4#3 Tdoc 96/99, March 1999

Comment: This report continues earlier investigations that were made to identify the ACP requirement for FDD/TDD coexistence on the assumption that 5 MHz carrier spacing is used and gives a more complete set of results based on extensive simulations.

Author(s): Siemens

Title: Interference of FDD MS (macro) to TDD (micro)

Source: TSG RAN WG4#7 Tdoc 568/99, September 1999

Comment: The co-existence of a macro cellular FDD and a micro cellular TDD system is investigated. The simulations cover the interference caused by a macro FDD MS towards both TDD MS and FDD MS and determines the ACLR/ACS requirements for the TDD modes in the HCS scenario.

Author(s): Siemens

Title: Co-Siting of TDD/FDD and TDD/TDD Base Stations

Source: TSG RAN WG4#3, TSGR4#3(99)145, March 1999

Comment: This is a follow on study of the previous work by Siemens submitted for 3GPP. The co-siting of base station is included in this report and the requirements for co-siting FDD/TDD systems are identified. Furthermore, filter solutions to fulfil the requirements are presented.

Author(s): Siemens

Title: Summary of Results on TDD/FDD and TDD/TDD Co-Existence

Source: TSGR4#8(99) TDoc 653, October 1999

Comment: This report collates and summarises the results of the numerous FDD/TDD co-existence simulations conducted by Siemens.

Author(s): Siemens

Title: TDD/FDD Co-Existence Investigation

Source: 3GPP TSG RAN WG4#2 TDoc 53/99, February 1999

Comment: This report summarises the results of extensive simulations performed to determine the probability of coupling losses in different environments, eg, macro, micro, pico.

Author(s): 3GPP

Title: Universal Mobile Telecommunications System (UMTS); Radio Frequency (RF) System Scenarios (3GPP TR 25.942 version 6.4.0 Release 6)

Source: 3GPP TR 25.942, March 2005

Comment: This document discusses system scenarios for UTRA operation primarily with respect to the radio transmission and reception and provides a comprehensive study of FDD/TDD co-existence. The scenarios are studied to define RF parameters and to evaluate corresponding carrier spacing values for various configurations.

Author(s): ITU

Title: Characteristics of Terrestrial IMT-2000 Systems for Frequency Sharing/Interference Analyses

Source: REPORT ITU-R M.2039, 2004

Comment: This report provides the baseline characteristic of terrestrial IMT-2000 systems for use in frequency sharing and interference analysis studies involving IMT-2000 systems and between IMT-2000 systems and other systems.

Author(s): Nokia

Title: Simulation Results on TDD Local Area BS and FDD Wide Area BS Coexistence

Source: 3GPP TSG RAN W4#14, TSGR4#14(00)0966, Tdoc R4-000966, 2000

Comment: This report studies the interaction between UTRA TDD indoor and UTRA FDD macro systems and thus investigates the possibility of UTRA TDD – UTRA FDD coexistence.

Author(s): Motorola

Title: MWA Systems to FWA/NWA Systems Coexistence Analysis in the 3.5 GHz Band

Source: 36th meeting of PT SE19, SE19(06)54, 5 September 2006

Comment: This report presents simulation results for the scenarios of a Mobile Wireless Access (MWA) system interfering a Fixed Wireless Access (FWA)/Nomadic Wireless Access (NWA) system adjacent in frequency in 3.5 GHz band.

Author(s): Motorola, UK Broadband, Clearwire Denmark, WiMAX Telecom Europe

Title: Inter-System MWA MS to MWA MS Coexistence Analysis in 3.5 GHz band for Unsynchronized TDD Systems or TDD Adjacent to FDD Systems

Source: 37th meeting of PT SE19, SE19(06)54, 17 November 2006

Comment: This report studies MS-MS (SS-SS) interference using a statistical model based on certain hotspot definitions. The statistical MS-MS interference simulation considers the high user density areas (hotspots) instead of assuming uniform user distribution throughout the whole sector. It models the MS-MS interference problem in a more balanced manner than deterministic worst case analysis and statistical analysis using uniform distribution. In particular, this methodology effectively captures the two major intrinsic aspects of the MS-MS interference: i.) the event that two mobiles come close to each other occurs with certain probability and mostly happens in high user density areas, ii.) the power control scheme can scale down the Tx power of the interfering MS depending on its location relative to the base station. The report concludes that MS-MS interference is likely to be the critical scenario for deciding the guard band between a TDD MWA operator and FDD MWA operator.

Author(s): ITU

Title: Mitigating Techniques to Address Coexistence between IMT-2000 Time Division Duplex and Frequency Division Duplex Radio Interface Technologies within the Frequency Range 2500-2690 MHz Operating in Adjacent Bands and in the Same Geographical Area

Source: REPORT ITU-R M.2045, 2005

Comment: This Report considers techniques to improve compatibility between IMT-2000 TDD and FDD radio interface technologies operating in adjacent

frequency bands and in the same geographic area. This report considers techniques, within specified classifications, to mitigate this interference and hence improve coexistence between TDD and FDD mobile networks in adjacent frequency bands and in the same geographic area. In so doing, this report describes the degree of improvement each techniques offers.

Author(s): Siemens

Title: Escape Mechanisms for the Case of FDD/TDD Co-Existence and TDD/TDD Co-Existence

Source: 3GPP RAN WG4#9, TSGW4#9(99)943, December 1999

Comment: This report discusses the co-existence of FDD/TDD in the case of non-coordinated, multiple operators and provides the escape mechanisms for coexistence.

Author(s): Peng, M., Huang, B., Wang, W.

Title: Investigation of TDD and FDD CDMA Coexistence in the Macro Environment Employing Smart Antenna Techniques

Source: Communications, 2004 and the 5th International Symposium on Multi-Dimensional Mobile Communications Proceedings, vol 1, pp 43–47, August 2004

Abstract: This paper investigates the impact of adjacent channel interference between TDD and FDD CDMA operators operating in macro environment. In the TDD-CDMA system, the smart antenna technique is employed and the performance is investigated and compared with the omni-directional antenna. Evaluation of TDD/FDD CDMA system coexistence is studied based on a static simulator. Intersystem

interference impacts the capacity under various ACIRs (adjacent channel Interference ratios), the base station location offsets, and the cell radiuses are studied. Furthermore, the differences in impacting the capacity loss between the omni-directional and smart antennas are compared and analyzed. Results and conclusions are shown, which are useful for future CDMA cellular planning and frequency license allocation in 2 GHz.

Author(s): Haas, H., McLaughlin, S., Povey, G.

Title: Capacity-Coverage Analysis of TDD and FDD Mode in UMTS at 1920 MHz

Source: Communications, IEE Proceedings, vol 1, no 1, pp 51–57, February 2002

Abstract: In the Universal Mobile Telephony System (UMTS) the frequency division duplex (FDD) and time division duplex (TDD) modes have adjacent carriers at 1920 MHz. This creates adjacent channel interference (ACI) between the two different air interfaces. Since different duplexing modes are used, the implications for each system are different, with respect to capacity and coverage: these implications are investigated. The separation distance of the TDD and FDD base station and the load in each system are varied and a symmetrical speech service in both systems is considered, with non-ideal power control assumed. It is found that for an FDD cell radius of 1000 m, a TDD cell radius of 50 m and 10% maximal tolerable outage, the effects of ACI on capacity can be compensated by dynamically increasing the required power at each BS, without affecting the coverage.

Author(s): IEEE 802.16 Broadband Wireless Access Working Group

Title: Adjacent Frequency Block TDD/FDD Coexistence Scenarios for BWA

Source: 802.16cc-00/03

Comment: Same area-adjacent frequency block system coordination will be a requirement for coexistence of BWA systems. Adjacent carrier interference mitigation may require frequency guard bands, polarization discrimination and substitution of sector frequency assignments. This report examines one example of the coordination issues that need to be considered. A TDD system is selected as the interference source and an FDD system is specified to be the victim. Interference simulation estimates indicate that the reserve carrier assignments that can be made available with some TDD frequency re-use plans are very effective as a coexistence resolution technique.

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