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
	)	
Service Rules for Advanced Wireless Services in the 1915-1920 MHz, 1995-2000 MHz, 2020-2025 MHz, and 2175-2180 MHz Bands	)	WT Docket No. 04-356

REPLY COMMENTS OF M2Z NETWORKS, INC.

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REPLY COMMENTS OF M2Z NETWORKS, INC.

M2Z Networks, Inc. ("M2Z") respectfully submits this reply to comments filed in response to the Federal Communications Commission ("Commission") Further Notice of Proposed Rulemaking ("*Further Notice*")[1] in the above-captioned dockets. The *Further Notice* sought comment on the Commission's proposal to combine the 2155-2175 MHz band with the 2175-2180 MHz band in a reconfigured AWS-3 band, and additionally sought comment on various application, licensing, operating, and technical rules for the 2155-2180 MHz band.[2] M2Z timely filed comments supporting the majority of the Commission's proposals in the *Further Notice*, while suggesting revisions to certain proposed service rules.[3]

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[1] *See Service Rules for Advanced Wireless Services in the 2155-2175 MHz Band; Service Rules for Advanced Wireless Services in the 1915-1920 MHz, 1995-2000 MHz, 2020-2025 MHz, and 2175-2180 MHz Bands*, WT Docket Nos. 07-195 & 04-356, Further Notice of Proposed Rulemaking, FCC 08-158 (rel. June 20, 2008).

[2] *Id.* ¶ 3.

[3] *See* Comments of M2Z Networks, Inc., WT Docket Nos. 07-195 & 04-356 (filed July 25, 2008) ("M2Z Further Notice Comments"). (For the sake of brevity and ease of reference, all citations in this reply to comments filed in response to the *Further Notice* and in the above-captioned dockets will be described as the submitting party's "Further Notice Comments.") M2Z suggested modifying the proposed definition of a user of the free service required of the eventual AWS-3 licensee, and also suggested that the Commission reassess engineered data rate requirements at the end of the license term. M2Z also proposed mobile device power limits in line with Commission precedent, meaning an out-of-band emission ("OOBE") limit of 43 + 10 log(P) and a 33 dBm mobile power limit, and suggested that the Commission limit AWS-3 auction eligibility to new entrants. *See id.* at 1-2.

INTRODUCTION AND SUMMARY

Some parties filing comments in response to the *Further Notice*, rather than supplying new information for the record as requested, merely have repeated the same discredited legal and technical arguments previously attempted in earlier rounds of comments or prior *ex parte* submissions to the Commission. Accordingly, in these reply comments, M2Z once again corrects the erroneous statements and meritless legal and technical arguments of the opponents of a free, wireless broadband service, including the incumbent wireless carriers, their trade association allies, and their equipment vendors. M2Z focuses particularly herein on refuting unsound arguments about the Commission's lack of authority to adopt the proposed AWS-3 service rules and rebutting alarmist claims regarding the potential for harmful interference.

The detailed technical appendices that follow this reply,[4] and the attached affidavit from experienced filter designer Dr. Hector J. de los Santos concerning the practicality of designing proper AWS-1 filters, address previously aired technical concerns and new test results introduced into the already voluminous record. As the technical appendices illustrate, the test results submitted by other parties in response to the *Further Notice* add nothing to the record, as they serve merely to confirm what M2Z has made clear all along: static, deterministic, unrealistic analyses will show that mutual interference between AWS-1 and AWS-3 users can and will occur on occasion, but the likelihood of harmful interference when properly analyzed according to universally accepted, modern, statistical engineering methods is exceptionally low and, in fact, is no more than what is routinely experienced by CMRS licensees.[5] Far from

[4] *See* Technical Appendices 1-8, attached as exhibits hereto.

[5] *See infra* Part II and Technical Appendix 1 attached hereto; *see also* Reply Comments of Sprint Nextel Corporation, WT Docket No. 07-195, at 18 (filed Jan. 14, 2008) ("Sprint Nextel Reply Comments").

suggesting a need for further testing, the recently introduced data merely confirm conclusions regarding compatibility set forth previously by M2Z in this proceeding.

Other parties' comments in response to the *Further Notice* only demonstrate, once again, that there has been fully sufficient testing and analysis already performed and documented in the record for the Commission to follow its longstanding precedents and adopt neutral, flexible service and technical rules for the AWS-3 band. The Commission should not heed calls for unnecessary additional testing and delay in this proceeding, and should instead move expeditiously to adopt AWS-3 service rules that would advance the clear public interest benefits to be realized from the service proposed in the *Further Notice*. Indeed, the Commission should uphold its commitment to the public, made in the initial notice of proposed rulemaking in this proceeding, "to issu[e] an order adopting rules in this proceeding within nine months following the publication of this Notice in the Federal Register"[6] – a date that will come and go later this week on August 14, 2008. At the least, the Commission should not fail to issue service rules by September 5, 2008, *i.e.*, within twelve months of initiating this proceeding pursuant to the adoption of the *Initial Notice* last year.[7] Every day of delay postpones the benefits of free broadband that the public could be enjoying.

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[6] *Service Rules for Advanced Wireless Services in the 2155-2175 MHz Band*, WT Docket No. 07-195, Notice of Proposed Rulemaking, 22 FCC Rcd 17035 (2007) ("*Initial Notice*"). The *Initial Notice* was published in the Federal Register on November 14, 2007. *See* 72 Fed. Reg. 64013 (Nov. 14, 2007).

[7] *See Initial Notice* ¶ 14 (noting that the Commission's commitment to issue AWS-3 service rules in a timely fashion was "intended to facilitate the introduction of new and innovative wireless broadband services to American consumers as soon as possible") (emphasis added); *see also* 47 U.S.C. § 157(b) ("If the Commission initiates its own proceeding for a new technology or service, such proceeding shall be completed within 12 months after it is initiated.").

I. The Legal and Policy Objections Raised in Other Parties' Comments Are Not Supported by the Record in this Proceeding, and the Commission Should Not Deviate From Its Proposed Course of Action in the *Further Notice*.

M2Z's Further Notice Comments supported the potential creation of a single, contiguous 25 megahertz block in the 2155-2180 MHz band, while making clear that the public interest conditions and free service requirements proposed in the *Further Notice* could be fulfilled in a 20 megahertz block of usable spectrum pursuant to neutral service and technical rules of the type advocated by M2Z.[8] M2Z also reaffirmed its continued support for the majority of the Commission's proposed service rules in the *Further Notice*, which generally called for the adoption of competitively and technologically neutral service rules accompanied by important public interest requirements to be placed on the eventual AWS-3 licensee.[9] Despite its support for the bulk of the proposed rules, M2Z did suggest some rule modifications to allow for the facilitation of new entry, more certainty for the eventual AWS-3 licensee, and closer adherence to the Commission's technical precedents governing a licensee's service offering.[10]

As explained in our Further Notice Comments, the record in this proceeding does not support the meritless claims of parties that seek to delay the introduction of robust, competitive wireless broadband offerings in the AWS-3 band. These parties advocate the adoption of non-

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[8] *See* M2Z Further Notice Comments at 2, 5.

[9] *See id.* at 2-3. M2Z explained its support for AWS-3 service rules as set forth in the *Further Notice* that would (1) permit downlink and uplink transmissions in the band; (2) create a single nationwide license for the band; (3) require the licensee to provide free, two-way broadband Internet access service generally consistent with the Commission's data rate and network capacity proposals; (4) require the licensee to provide for open devices and open applications with respect to its premium service and open devices with respect to its free service; (5) set the initial license and renewal terms at ten years; (6) establish network coverage requirements calling for aggressive buildout; (7) allow spectrum disaggregation, partitioning, and leasing; (8) resolve mutually exclusive license applications via competitive bidding; and (9) set in-band power and out-of-band emissions ("OOBE") limits for AWS-3 base and fixed downlink stations.

[10] *See id.* at 3 (proposing a more equitable method of counting free service users and a more predictable process for reassessing or adjusting minimum engineered network data rates; eligibility restrictions to ensure that the AWS-3 auction would facilitate new market entry; and adherence to precedent with regard to AWS-3 mobile device OOBE and in-band power limits).

neutral, overly burdensome, and unorthodox zero tolerance interference protections, and their mistaken technical claims are dealt with in Part II, as well as in M2Z's technical appendices that follow. These opponents of free wireless broadband also raise a host of arguments regarding alleged substantive or procedural flaws in this proceeding, coupling those assertions with unsupported claims regarding the Commission's supposed lack of authority to adopt the service rules proposed in the *Further Notice*. We briefly respond to these legal and policy assertions in the remainder of this Part I before turning to the technical issues discussed in greater detail in Part II and the technical appendices that follow.

A. Alleged Deficiencies in the Commission's Authority, or in its Substantive and Procedural Actions in this Proceeding, Are Easily Answered and of No Avail to Opponents of Free Wireless Broadband in AWS-3.

Some parties submitting comments in response to the *Further Notice* reiterated arguments already addressed in the record regarding the Commission's alleged lack of authority to adopt a so-called "rate regulation" requiring free wireless broadband service in the AWS-3 band.[11] Other parties dwelled on the supposedly impermissible retroactive nature of the proposed AWS-3 service rules,[12] or on the supposed unconstitutional taking that would occur if the Commission were to adopt neutral technical rules for the AWS-3 band.[13] None of these arguments presents any impediment to the Commission's adoption of the service rules proposed in the *Further Notice*.

Responding to M2Z's explanation of the Commission's authority to require the AWS-3 band licensee to provide free, two-way broadband Internet service pursuant to the Commission's

[11] *See* MetroPCS Further Notice Comments at 26-33.

[12] *See, e.g.*, AT&T Further Notice Comments at 35-37; CTIA Further Notice Comments at 34; T-Mobile Further Notice Comments at 36-38.

[13] *See, e.g.*, AT&T Further Notice Comments at 36 n.79; MetroPCS Further Notice Comments at 20-21.

plenary authority under Title III to regulate radio communications,[14] MetroPCS attempts to find a distinction between free over the air broadcast and free wireless broadband service.[15] MetroPCS argues that the Commission may require free digital television broadcasting based on its general Title III authority and not pursuant to any explicit statutory command, but only because free television is one of the Commission's "more historically-based general goals."[16] On the other hand, according to MetroPCS, the Commission may not require free wireless broadband service of the eventual AWS-3 licensee because "[o]ver-the-air broadcasting services have always been free," whereas "wireless broadband Internet services are not inherently free services."[17] MetroPCS's attempt to define the Commission's statutory authority by reference to unspoken "historically-based goals" and the "inherent[ ]" classifications of certain services cannot withstand scrutiny. Either the Commission has the authority under Title III to require licensees to provide free service or it does not, and no extra-statutory historical goals should change the answer to that question. The record shows that the Commission does have such authority pursuant to Title III, and that such authority is sufficient to allow the Commission to mandate both free digital television and free wireless broadband. The fact remains that the Commission has relied previously on nothing other than its Title I and Title III mandates to regulate spectrum use in the public interest in this manner – determining of its own accord to require licensees to use at least a portion of their licensed spectrum for the provision of free

[14] Letter from Uzoma Onyeije to Marlene H. Dortch, WT Docket Nos. 07-195 and 04-356, at 1 (filed July 1, 2008) ("M2Z July 1 *Ex Parte*").

[15] *See* MetroPCS Further Notice Comments at 27 n.87 (citing M2Z July 1 *Ex Parte* at 4).

[16] MetroPCS Further Notice Comments at 30.

[17] *Id.* at 31. MetroPCS also chides M2Z for failing to cite Commission precedent that is on point, yet MetroPCS seeks support for its statutory analysis of the Communications Act in cases about the Securities and Exchange Commission and the Americans with Disabilities Act. *See id.* at 29, 31-32.

service, and specifically citing the public interest benefits of widely accessible service and greater competition as justification for such action.[18]

AT&T argues against the Commission's proposed rules by claiming that provisions for a free broadband service would necessarily be arbitrary and capricious because "[t]he APA requires that the record demonstrate the existence of an actual problem in need of a regulatory solution" before the Commission can adopt such a solution.[19] AT&T suggests that "no record of any specific problem exists" with respect to the proposed free service requirement, ignoring the extensively documented problem of unserved and under-served populations and geographic areas in the United States. If AT&T were correct, the Commission would be required to provide in each set of service rules a reasoned explanation for its "rejection" of all possible alternative service rules. Yet since 2005 the Commission has made available via auction or band restructuring the equivalent of more than 632 megahertz of spectrum for wireless broadband services, and none of those prior assignments and allocations made any reservation for a free wireless broadband service or provided a reasoned basis for the Commission's rejection of such an alternative.[20]

AT&T also argues that the free service requirement and other service rules proposed in the *Further Notice* would violate Section 309(j)(3) of the Communications Act by impermissibly casting aside the auction mechanism "expressly chosen" by Congress.[21] But the service rules in

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[18] *Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service*, Fifth Report and Order, 12 FCC Rcd 12809, ¶ 5 (1997). It is also worth noting that the Commission had no difficulty imposing this free service requirement on broadcasters, which by definition are not common carriers. *See* 47 U.S.C. § 153(10).

[19] AT&T Further Notice Comments at 40.

[20] *See* M2Z Further Notice Comments at 7.

[21] *See* AT&T Further Notice Comments at 42.

the *Further Notice* clearly and unambiguously propose resolving mutually exclusive applications via auction, and as presently drafted call for open eligibility in any such auction.[22]

AT&T then argues that the Commission should strip away its proposed public interest service requirements in order to obtain a greater monetary return on the AWS-3 spectrum at auction.[23] As M2Z demonstrated during the course of its license proceeding, however, the Commission is forbidden from taking auction revenues into account when making public interest determinations about spectrum allocations and assignments.[24] Prioritizing revenue considerations also would violate the Communications Act's several mandates requiring the Commission to allocate and assign spectrum in the public interest, and to do so in order to fill a wide array of goals in addition to recovery of a portion of the value of the public spectrum. These goals include the objectives of facilitating "the development and rapid deployment of new technologies, products, and services for the benefit of the public, including those residing in rural areas, without administrative or judicial delays" and "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."[25]

AT&T's last argument in this vein is its claim that the Commission's adoption of license conditions proposed in the *Further Notice* would "unjustly enrich[ ] the winning bidder whose

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[22] *See Further Notice* ¶ 3.

[23] *See* AT&T Further Notice Comments at 42.

[24] *See* M2Z Consolidated Opposition, WT Docket Nos. 07-16 & 07-30, at 64 (citing 47 U.S.C. § 309(j)(7)(A) ("In making a decision . . .to assign a band of frequencies to a use for which licenses or permits will be issued . . .the Commission may not base a finding of public interest, convenience, and necessity on the expectation of Federal revenues from the use of a system of competitive bidding under this subsection.")).

[25] *See* 47 U.S.C. § 309(j)(3)(A), (B); *see also id.* § 151 (creating the Commission "to make available . . . to all the people of the United States. . . a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges"); *id.* § 157(a) (making it "the policy of the United States to encourage the provision of new technologies and services to the public").

unique business plan is embraced by the agency."[26] If AT&T's argument on this point has any merit, it would seem fair to ask AT&T why "restrictive service rules" such as the downlink-only approach it advocates for AWS-3 would not likewise unjustly enrich the incumbent licensees that would stand to gain the most from such an outcome. Furthermore, the service rules proposed in the *Further Notice* are markedly different in many material respects from M2Z's business plan as set forth in its earlier application, dismissed by the Commission last year.

MetroPCS and AT&T join together to repeat the argument, already addressed in the record, that the proposed service rules permitting TDD operations in the AWS-3 band would effect an unconstitutional taking of incumbent licensee property.[27] It is well established, however, that no AWS-1 licensee holds any property interest whatsoever in its licensed spectrum. As M2Z has explained previously, "courts have held that under the Communications Act, licensees have no property rights in radio licenses"[28] and recognized "that the Commission has the authority to alter the terms of an existing license by rulemaking."[29] The Communications Act makes clear that the Commission licenses radio channels "to provide for the use of such channels, <u>but not the ownership thereof</u>" by licensees.[30] Thus, as the Court of Appeals for the District of Columbia Circuit held just two years ago in *Mobile Relay Associates v. FCC*,

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[26] *See* AT&T Further Notice Comments at 42-43.

[27] *See, e.g.*, AT&T Further Notice Comments at 36 n.79; MetroPCS Further Notice Comments at 21 (describing a potential unconstitutional taking based on the claim that "[t]he interference from AWS-3 operations may be so harmful as to render a portion of the AWS-1 spectrum unusable").

[28] *Improving Public Safety Communications in the 800 MHz Band*, Second Memorandum Opinion and Order, 22 FCC Rcd 10467, ¶ 16 (2007) (citing *Ashbacker Radio Corp. v. FCC*, 326 U.S. 327, 331 (1945) ("No licensee obtains any vested interest in any frequency."); *FCC v. National Citizens Committee for Broadcasting*, 436 U.S 775, 805-06 n.25 (1978)).

[29] *Id.* (citing *United States v. Storer Broadcasting*, 351 U.S. 192, 205 (1956); *Committee for Effective Cellular Rules v. FCC*, 53 F3d 1309, 1319-20 (D.C. Cir. 1995)). M2Z, of course, does not view the Commission's latest proposal as involving the alteration of any existing licenses, and AT&T and MetroPCS provide no precedent justifying such an interpretation.

[30] 47 U.S.C. § 301 (emphasis added).

Commission licenses "confer the right to use the spectrum for a duration expressly limited by statute subject to the Commission's considerable regulatory power and authority. This right does not constitute a property interest protected by the Fifth Amendment."[31]

Finally, AT&T, T-Mobile, and CTIA together reiterate the argument that the adoption of the service rules proposed in the *Further Notice* would constitute retroactive rulemaking.[32] But, as already established in the record, Commission action to authorize a new radio service is neither "primarily" nor "secondarily retroactive," as the *Mobile Relay* court confirmed. "Retroactive rules 'alter[ ] the past legal consequences of past actions.'"[33] Agency rules that may alter future consequences of a party's actions or that may change business expectations are not retroactive, and "[t]o conclude otherwise would hamstring not only the FCC in its spectrum management, but also any agency whose decision affects the financial expectations of regulated entities."[34] As discussed below, permitting mobile transmissions in the AWS-3 band would not upset the prior expectations of incumbent licensees – but even if it did, this would not make the new rules impermissibly retroactive on a primary or secondary basis. Any rule change that may affect a regulated entity's investment made in reliance on prior regulations need only be reasonable and not arbitrary and capricious to be upheld.[35] The Commission's decision to facilitate new wireless broadband services in the AWS-3 band pursuant to a carefully reasoned decision in this lengthy proceeding surely would meet those standards.[36]

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[31] *Mobile Relay Associates v. FCC*, 457 F.3d 1, 12 (D.C. Cir. 2006) (emphasis added).

[32] *See, e.g.*, AT&T Further Notice Comments at 35-37; CTIA Further Notice Comments at 34; T-Mobile Further Notice Comments at 36-38.

[33] *Mobile Relay Associates v. FCC*, 457 F.3d at 11 (quoting *Bowen v. Georgetown Univ. Hospital*, 488 U.S. 204, 219 (Scalia, J., concurring) (emphasis in original)).

[34] *Id.*

[35] *See id.*

[36] *See DIRECTV v. FCC*, 110 F.3d 816, 826 (D.C. Cir. 1997) ("A change in policy is not arbitrary or capricious merely because it alters the current state of affairs. The Commission 'is entitled to reconsider and revise its views as

B. Parties Have Been On Notice That The Commission Could Authorize TDD Operations in the AWS-3 Band for at Least the Past Five Years, and the Commission Can Readily Dismiss Claims of Inadequate Notice and Asymmetrical Interference

T-Mobile and other parties argue again in their comments that the Commission provided inadequate notice (chiefly, it is claimed, to AWS-1 licensees that were, formerly, AWS-1 auction bidders) of the potential for two-way services in the AWS-3 band.[37] As the Bureau's order extending the time for comments in response to the *Further Notice* made clear, however, "parties have had notice of the possibility that TDD operations would be permitted in the AWS-3 band since at least the issuance of the AWS-3 Notice of Proposed Rulemaking in WT Docket No. 07-195 nearly one year ago – and nothing proposed in the [*Further Notice*] alters that basic proposal."[38]

More importantly, however, as is already documented in the record, the Commission put potential AWS-1 bidders on notice of the potential for TDD operations in the AWS-3 band more than five years ago, some <u>three years before the AWS-1 auction</u>. The Commission indicated in 2003 that it would "make every effort to provide spectrum opportunities for TDD systems in future allocation and spectrum proceedings, such as in the *AWS Allocation* proceeding"[39] that led to the current AWS-3 proceeding. T-Mobile continually mischaracterizes another passage from the same 2003 order to claim, incorrectly, that the Commission placed a higher burden of proof

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to the public interest and the means needed to protect that interest,' *Black Citizens for a Fair Media v. FCC*, 719 F2d 407, 411 (D.C. Cir. 1983), if it gives a reasoned explanation for the revision.").

[37] *See, e.g.*, T-Mobile Further Notice Comments at 33; *see also* AT&T Further Notice Comments at 2; CTIA Further Notice Comments at 30-33..

[38] *Service Rules for Advanced Wireless Services in the 2155-2175 MHz Band; Service Rules for Advanced Wireless Services in the 1915-1920 MHz, 1995-2000 MHz, 2020-2025 MHz, and 2175-2180 MHz Bands*, WT Docket Nos. 07-195 & 04-356, Order, DA 08-1614, ¶ 4 (rel. July 8, 2008).

[39] *Service Rules for Advanced Wireless Services in the 1.7 and 2.1 GHz Bands*, Report and Order, 18 FCC Rcd 25162, ¶ 46 (2003) ("*AWS-1 Report and Order*").

on proponents of allowing TDD operations in AWS-3.[40] T-Mobile's argument distorts the language in the 2003 order to argue erroneously that the decision not to authorize TDD operations within the AWS-1 band, where Federal Government operations were present, somehow applied to the AWS-3 band as well, though it plainly did not.[41]

Moreover, CTIA has argued that interference between the AWS-1 and AWS-3 bands would be in some manner "asymmetrical" and "received by AWS-1" alone.[42] In other words, AWS-1 is characterized as the unilateral victim of interference from AWS-3 on the basis of the negligible possibility of AWS-3 handsets interfering with AWS-1 handsets. As discussed in the technical appendices attached to these reply comments, the most pressing interference issue involves AWS-1 base station interference with AWS-3 base stations.[43] In cases where either AWS-3 or AWS-1 operations are the victim of some potential interference, however, the licensees can cooperate to mitigate the interference. Nevertheless, as further detailed in the appendices, there is no support for CTIA's claim regarding asymmetrical interference – just as there is no support for other claims suggesting that the negligible probability of mobile-to-mobile interference <u>from</u> AWS-3 to AWS-1 would be somehow unique or especially unmanageable, or that the AWS-3 licensee should bear special burdens above and beyond the Commission's

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[40] *See* T-Mobile Further Notice Comments at 34. As it has on other occasions, T-Mobile relies improperly on language from the same paragraph in the 2003 order that promises to seek spectrum opportunities for TDD in future AWS allocation. The language that T-Mobile distorts does indicate that TDD proponents would need to "conclusively demonstrate that portions of <u>this spectrum</u> could be used for such transmissions without causing interference to Federal government users or other licensees" before TDD could be authorized in AWS-1. *AWS-1 Report and Order* ¶ 46 (emphasis added). The reference to "this spectrum" clearly denotes AWS-1 spectrum, not the future AWS-3 spectrum allocation.

[41] See M2Z Further Notice Comments at 14 n.39. In the AWS-1 proceeding, the Commission expressed explicit concern for federal government operations when it declined to authorize TDD operations in that band. Not only have government operations never existed in AWS-3, but such operations were never present in the portion of the AWS-1 spectrum that is germane to the proceeding.

[42] *See* Letter of Christopher Guttman-McCabe to Marlene H. Dortch, WT Docket Nos. 07-195 & 04-356, at 9 (June 5, 2008).

[43] *See* Technical Appendix 3 hereto.

typical technical rules prescribing a new licensee's harmful interference mitigation responsibilities.

T-Mobile also argues that "M2Z enjoys no presumption under [Section 7 of the Act], given the Commission's prior rejection of its section 7 claims."[44] In making such claims, T-Mobile fails to appreciate that the contours of the service proposed in M2Z's initial application are different in several material aspects from the service rules proposed in the *Further Notice*. In any event, Section 7 makes clear that "[a]ny person or party (other than the Commission) who opposes a new technology or service proposed to be permitted under this chapter shall have the burden to demonstrate that such proposal is inconsistent with the public interest."[45] Section 7 also makes clear that the Commission has a duty to complete within twelve months any proceeding that it initiates for a new technology or service.[46] Therefore, additional testing is not only unnecessary (as demonstrated in Part II of these reply comments), but the concomitant delay would cause the Commission to violate Section 7's mandate for the new service proposed by the Commission in the *Initial Notice*.[47]

C. The Commission Should Reject Lately Filed Alternative Band Plan Proposals and Unnecessary Entry Barriers That Would Increase Delay but Decrease Efficiency if Adopted.

Several parties, including some that are relatively new to this proceeding, have argued that the Commission should adopt an AWS-3 band plan and service rules that either create smaller and differently structured spectrum blocks or that mandate smaller geographic license

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[44] *See* T-Mobile Further Notice Comments at 31 n. 97 (citing *Applications for License and Authority to Operate in the 2155-2175 MHz Band; Petitions for Forbearance Under 47 U.S.C. § 160*, Order, 22 FCC Rcd 16563 (2007)).

[45] 47 U.S.C. § 157(a).

[46] *See id.* § 157(b).

[47] *See, e.g.*, *Initial Notice* ¶ 4 (indicating that the Commission's commitment to adopt service rules by August 14, 2008 was "intended to facilitate the introduction of new and innovative wireless broadband services to American consumers as soon as possible") (emphasis added).

sizes.[48] The Commission has recognized, however, that contiguous spectrum blocks that amount to at least 20 megahertz of usable spectrum and nationwide licenses are important elements for facilitating the entry of a new nationwide competitor and the provision of robust wireless broadband offerings.[49] As M2Z demonstrated in our Further Notice Comments, nationwide licensing in the AWS-3 band would help to simplify interference mitigation and incumbent relocation issues.[50] Moreover, Commission consideration of alternative band plans[51] now would lead to further delay in the issuance of service rules and the ultimate deployment of service. The adoption of any such alternative band plan would also decrease spectral efficiency and significantly diminish (or even eliminate) the AWS-3 licensee's ability to offer a free, wireless broadband service using part of its authorized spectrum.[52]

II. The Commission Should Reject Technical Objections to Its Proposed AWS-3 Service Rules, as Those Objections Rely Only on Static Analyses and Improper Assumptions About the Likelihood, Severity, and Impacts of Harmful Interference.

In addition to their unfounded legal and policy arguments, parties opposed to the Commission's proposed AWS-3 service rules rely on technical arguments that are inconsistent

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[48] *See, e.g.*, ITTA Further Notice Comments at 2; NTCH Further Notice Comments at 2-3; RICA Further Notice Comments at 4-5; RTG Further Notice Comments at 9; TCA Further Notice Comments at 2.

[49] *See Service Rules for the 698-746, 747-762 and 777-792 MHz Bands*, Second Report and Order, 22 FCC Rcd 15289, ¶ 69 (2007) (noting that 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 provide operators with additional capacity and, importantly, flexibility"); *see also AWS-1 Report and Order* ¶ 44 (2003); *Service Rules for Advanced Wireless Services in the 1915-1920 MHz, 1995-2000 MHz, 2020-2025 MHz and 2175-2180 MHz Bands; Service Rules for Advanced Wireless Services in the 1.7 GHz and 2.1 GHz Bands*, Notice of Proposed Rulemaking, 19 FCC Rcd 19263, ¶ 29 (2004) (noting that "licensing the spectrum at issue in [that] proceeding on a nationwide basis . . . might provide the opportunity for a variety of advanced wireless services to be implemented . . . through the entry of a new nationwide competitor").

[50] *See* M2Z Further Notice Comments at 7.

[51] *See, e.g.*, ICO Comments at 10-13.

[52] *See* Technical Appendix 5 hereto. M2Z notes as well that adoption of various MetroPCS proposals, such as the establishment of a high reserve price in the AWS-3 auction and a requirement for unwarranted performance bonds or other security instruments, also would be likely to increase delay and decrease overall efficiency in the AWS-3 license assignment process. *See* MetroPCS Further Notice Comments at 48-53. The Commission's standard auction procedures would provide sufficient protections for the public interest without unduly burdening any potential new entrant.

with state-of-the-art interference management and mitigation techniques, and that also are not supported by the record in this proceeding. The proceeding record – bolstered by a series of statistical analyses that have been completed by national and international regulatory agencies and standards-setting organizations – demonstrates that while interference between AWS-1 and AWS-3 handsets in operation could occur, the likelihood of such events is very low.[53] Field studies on equipment comparable to what will be deployed by AWS-1 licensees, as well as statistical analyses conducted using modern, probabilistic methodologies, show conclusively that the parties opposed to the Commission's proposed AWS-3 service rules overstate both the potential for and the severity of harmful interference between adjacent TDD and FDD operations.

M2Z briefly restates in these reply comments the core principles regarding interference analysis already developed and included in the record of this proceeding. We also submit the technical appendices that follow these reply comments in order to address at greater length the arguments (and errors therein) of commenters claiming incorrectly that the Commission's proposal would result in various types of "widespread and essentially unmanageable" interference problems.[54] The reply comments and the Technical Appendices also respond to mistaken claims of superior efficiency for alternative band plans. Finally, we refute a collection of other commenters' assertions maintaining that adoption of the proposed service rules in the Further Notice would require unprecedented, additional, and redundant testing; unprecedented technical rules and unusually burdensome interference mitigation responsibilities for the AWS-3 licensee; or the use by AWS-1 licensees of commercially impracticable filters – a point refuted

[53] *See* Technical Appendix 1 hereto.
[54] T-Mobile Further Notice Comments at 15.

in the attached affidavit from experienced filter designer Dr. Hector J. de los Santos. As shown herein, none of these claims is true.

A. Although Some Commenters Rely on Static, Unrealistic Models, Modern Statistical Analyses Demonstrate Conclusively the Low Likelihood and Impact of Interference Under the Commission's AWS-3 Proposal.

Some commenters have continued to object to the Commission's proposed service rules for the AWS-3 band on the basis of mobile-to-mobile interference described by them as "widespread and essentially unmanageable,"[55] "frequent,"[56] "so harmful as to render a portion of the AWS-1 spectrum unusable,"[57] or able potentially to "prevent AWS-1 licensees from making use of at least the AWS-1 F-Block, and possibly the D and E Blocks as well."[58] These claims are simply untrue. While these assertions attempt to convey a sense of pervasive interference, they are based on static, deterministic analyses and tests conducted under unrealistic conditions. Incumbent wireless carriers and licensees are especially eager to have the Commission buy into these worst-case scenarios, based on antique testing methods. Only one commenter, Motorola,[59] offers any statistical analysis; in Technical Appendix 1, we address Motorola's critique of our statistical analysis and explain why the Commission still may confidently rely on the conclusion that handset interference will be as rare in the AWS-1/AWS-3 scenario as it is in the CMRS environment today.

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[55] *Id.*

[56] AT&T Further Notice Comments at 19.

[57] MetroPCS Further Notice Comments at 21.

[58] U.S. Cellular Further Notice Comments at 3.

[59] *See, e.g.*, Motorola Further Notice Comments at 8. While adopting the proper statistical analysis approach, Motorola expressed concerns about the validity of Monte Carlo analyses in high-user density areas, such as hot spots, stadiums, mass transit stations, and other such hubs. *See id.* at 9. Nevertheless, statistical analyses conducted by Ofcom have indeed taken the hot spot phenomenon into account, and by analyzing the aggregate interference such have conclusively demonstrated that TDD and FDD coexistence in adjacent bands is manageable. *See* Technical Appendix 1 hereto.

The incumbent licensees and their allies, instead of offering a proper statistical analysis, base their alarmist claims of pervasive and disruptive harmful interference on their own analyses, or on the "Laboratory Test Report" submitted with T-Mobile's comments. Yet, by relying only on unrealistic scenarios and conditions, these deterministic analyses and studies demonstrate only that interference could possibly happen. What they do not offer is any evidence of the likelihood that such interference would be noticed by the AWS-1 handset user, or the likelihood that it would be harmful in any way to the population of such users.[60]

In sorting out these interference claims, the Commission should remain focused on fulfilling its statutory mandate to "allocate electromagnetic spectrum so as to provide flexibility of use" so long such use would not result in "harmful interference among users."[61] M2Z has never denied that some interference would occur, as it would with all spectrum uses and allocations, due to adjacent channel operations; but the question before the Commission concerns the likelihood of such occurrences and whether such interference would be harmful – not whether it is possible that some interference could occur under an unrealistic scenario. As the record in this proceeding has shown, and as described more fully in Technical Appendix 1 to these reply comments, independent tests and statistical analyses of FDD/TDD compatibility and coexistence have shown that mobile-to-mobile interference under the Commission's AWS-3 proposal would be rare and that it would not be "harmful" according to the Commission's longstanding definition of "harmful interference."

The Commission defines "harmful interference" in relevant part as "[i]nterference which . . . seriously degrades, obstructs, or repeatedly interrupts a radiocommunication

[60] *See generally* Technical Appendix 1 hereto (explaining in greater detail the underlying assumptions of deterministic analyses).
[61] 47 U.S.C. § 303(y); *id.* § 303(y)(2)(C).

service."[62] Field tests and statistical analyses performed on analogous user equipment and spectrum bands by the United Kingdom's Office of Communications ("Ofcom"), and of the type performed by the International Telecommunication Union ("ITU"), the Institute of Electrical and Electronics Engineers ("IEEE"), 3rd Generation Partnership Project ("3GPP"), and other national and international regulatory agencies and standards organizations, confirm that harmful interference, as properly defined and understood, would not occur under the Commission's AWS-3 service rules proposed in the *Further Notice* and as modified according to M2Z's suggestions in our initial Further Notice Comments.[63] In fact, these widely accepted testing and analysis methods confirm that the impact of the interference for adjacent channel TDD and FDD operations would be below typical Commission thresholds for harmful interference, meaning, for example, below the typical amount of interference that would be expected and experienced within a typical FDD system (such as those currently deployed by AWS-1 incumbent carriers) among the carriers' own users.[64]

The Commission should embrace the statistical analyses used and endorsed by these other regulatory and standards bodies. Such methods also are widely used in the communications industry (and, indeed, have been endorsed by Motorola in this proceeding), and

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[62] 47 C.F.R. § 2.1(c).

[63] *See* Technical Appendix 1 for further analysis and details of Ofcom's seminal study, "On the Impact of Interference from TDD Terminal Stations to FDD Terminal Stations in the 2.6 GHz Band" (April 21, 2008), *available at* http://www.ofcom.org.uk/consult/condocs/2ghzregsnotice/tech.pdf. The Ofcom report included results from a field study performed by ERA Technology, "Measurements of UTRA FDD User Equipment Characteristics in the 2.1 GHz Band," (April 2008), *available at* http://www.ofcom.org.uk/consult/condocs/ 2ghzregsnotice/era.pdf. This report and the accompanying study demonstrated that FDD and TDD operations in adjacent bands are compatible, due to the very low likelihood of any harmful interference or noticeable degradation of service, and the remote chance consequently of any blocking or OOBE harmful interference of the types complained of by opponents of the Commission's AWS-3 proposal.

[64] *See id.*

they have previously been used by the Commission as well.[65] The Commission should not accept T-Mobile's implicit invitation to take a step backwards by relying on deterministic modeling, and should instead follow T-Mobile's own suggestion to Ofcom when the company called upon that agency to use Monte Carlo statistical simulations in order to resolve an interference question.[66]

Finally, the Commission should not accept T-Mobile's characterization of its test results as "realistic" and "typical."[67] That claim is belied by T-Mobile's Laboratory Test Report itself, which indicates that the values and conditions used in the study are heavily weighted toward unrealistic scenarios and statistically aberrant samples.[68] Incumbent licensees frequently suggest testing not in typical or realistic settings, but rather explicitly call for testing under "marginal radio conditions."[69] The Commission should not make harmful interference determinations and establish technical rules based on marginal assumptions, especially where such regulatory choices would result in inflexible service rules that would unjustifiably hamper or altogether preclude TDD operations in the AWS-3 band.[70]

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[65] *See, e.g.*, *Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range*, Memorandum, Opinion and Order and Second Report and Order, 17 FCC Rcd 9614, ¶ 71 (2002); *see also State of New York Request for Waiver of Section 90.545 of the Commission's Rules to Implement a 700 MHz Public Safety System in Specified Counties in the Greater New York City Metropolitan Area*, Order, 22 FCC Rcd 22195, ¶ 21 (2007) ("Regarding mobile interference, we concur . . . that statistical modeling is the most appropriate method to analyze the random nature of mobile-into-fixed interference.").

[66] *See* T-Mobile comments to Ofcom Digital Dividend Review consultation at 6 (filed Mar. 20, 2007), *available at* http://www.ofcom.org.uk/consult/condocs/ddr/responses/st/TMobile.pdf.

[67] *See, e.g.*, T-Mobile Further Notice Comments at 12-13.

[68] *See id.*, Laboratory Test Report at 13.

[69] *See* Letter from Michael Lazarus, Esq., Paul, Hastings, Janofsky & Walker LLP, to Marlene H. Dortch, WT Docket No. 07-195, at 4 (filed July 30, 2008).

[70] *See, e.g.*, *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, First Report and Order, 17 FCC Rcd 7435, ¶ 159 (2002) ("[W]e do not believe it is appropriate to use such a close separation distance as the basis for controlling harmful interference. Any interference at close distances can be easily remedied by moving the devices a short distance apart.").

B. Additional Testing Is Unnecessary Because It Would Add No New Information to the Record, and Would Serve Only to Further Delay the Implementation of the Commission's Proposed AWS-3 Service Rules.

Although some commenters suggest the need for still more testing,[71] the Commission should not heed these calls for further delay in the issuance of AWS-3 service rules and ultimate assignment of the license. The extensive testing by international regulatory and standards bodies, cited above and described in greater detail in Technical Appendix 1 below, has shown that adjacent channel FDD and TDD operations are compatible. Furthermore, the interference complaints lodged by incumbent licensees in this proceeding are well understood, and further testing would be extremely unlikely to shed any new light on these issues.[72] Moreover, new information about specific handset design and performance could be more readily obtained if AWS-1 mobile device manufacturers would merely provide more details about the devices and filters they are designing for use in the AWS-1 band, so that such information could be compared against recent test results commissioned by Ofcom to study these very same issues in closely analogous bands and operating environments.[73]

In the end, commenters advocating additional testing have not made any credible arguments as to what such testing would add, either to the record compiled in this proceeding or to the information already available from other independent sources. The only thing that additional testing is certain to achieve is additional delay benefiting parties opposed to the Commission's AWS-3 service rules, who will place more mobile user devices with the type of defective filters described below into the marketplace, and secure delay in the ultimate deployment of truly competitive wireless broadband service. Whatever technical challenges

[71] *See, e.g.*, T-Mobile Further Notice Comments at 4; U.S. Cellular Further Notice Comments at 1; MetroPCS Further Notice Comments at 8; Qualcomm Further Notice Comments at 2; CTIA Further Notice Comments at 30.
[72] *See* Technical Appendix 2 hereto.
[73] *See id.*

exist as a result of the defective filters, remedying the problem only becomes more complex with additional delay.

C. Parties Opposing the Commission's Proposed AWS-3 Service Rules Suggest the Adoption of Overly Restrictive and Unprecedented Technical Rules; Such Rules Are Unnecessary Given the Level of Expected Interference and the Mitigation Techniques Available.

Various commenters opposed to the service rules proposed in the *Further Notice* call for overly restrictive mobile device power limits and inordinately large guard bands to resolve blocking (or receiver overload) interference concerns,[74] and seek overly restrictive out-of-band emissions ("OOBE") limits as well.[75] The record in this proceeding does not support the adoption of such unprecedented measures, and the Commission should instead adopt the AWS-3 technical rules proposed in the *Further Notice*, subject to certain revisions suggested by M2Z in our Further Notice Comments.[76]

It is now clear that AWS-1 handsets beginning to appear in the market and currently in the pipeline for deployment are susceptible to blocking interference because of the design choices made for those devices – *i.e.*, the decision to use less robust direct conversion architecture, coupled with the almost unfathomable decision to employ in AWS-1 devices filters that allow for the reception of virtually unattenuated signals from the entire AWS-3 band.[77] The solution to blocking concerns is not, however, the widely varying – and wildly over-protective –

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[74] *See, e.g.*, Motorola Further Notice Comments at 5-6; AT&T Further Notice Comments at 16, 22; T-Mobile Further Notice Comments at 14; Ericsson Further Notice Comments at 4, 6; U.S. Cellular Further Notice Comments at 4; MetroPCS Further Notice Comments at 10; SpectrumCo Further Notice Comments at 5.

[75] *See e.g.*, Motorola Further Notice Comments at 7; AT&T Further Notice Comments at 17; Ericsson Further Notice Comments at 3, 5; MetroPCS Further Notice Comments at 13; SpectrumCo Further Notice Comments at 5; U.S. Cellular Further Notice Comments at 6; Nokia Further Notice Comments at 4.

[76] *See supra* note 10. M2Z called upon the Commission to adopt the standard 43 + 10 log(P) mobile OOBE limit for AWS-3 mobiles, rather than the 60 + 10 log (P) limit proposed in the *Further Notice*, and suggested a mobile power limit of 33 dBm for AWS-3 mobiles rather than the inapposite 23 dBm/MHz EIRP power spectral density limit proposed by the Commission initially. *See* M2Z Further Notice Comments at 10-12.

[77] *See* Technical Appendix 3 hereto for additional detail.

measures suggested by various parties opposed to the Commission's proposal, which ranged from requests for transmission power spectral density limits of 0 dBm/MHz to eliminate *all possibility* of interference,[78] to proposals for a 10 MHz guard band with power limited to 23 dBm EIRP above 2168 MHz,[79] to even a 13 MHz guard band.[80]

Unsurprisingly, these suggestions tend to come from parties advocating the use of static, deterministic, and unrealistic interference analysis. Statistical analyses and tests conducted for Ofcom showed significantly better performance with respect to blocking, however, and fully support the adoption of the 33 dBm mobile power limit advocated by M2Z.[81] Furthermore, an independent analysis prepared by filter expert Dr. Hector J. de los Santos (and submitted as part of Technical Appendix 7 following these reply comments) confirms that it is both commercially practical and technically feasible to employ filters actually designed for the Commission's AWS band plan, rather than for use across the entire 2110-2170 MHz band.

With respect to OOBE limits, parties opposed to the Commission's proposed AWS-3 service rules are once again all over the map. Motorola and MetroPCS propose a limit of -60 dBm/MHz; T-Mobile proposes -66 dBm/MHz; SpectrumCo proposes -73 dBm/MHz; and AT&T proposes -75 dBm/MHz.[82] These commenters tend to rely once again on static, non-statistical methodology to derive these values, but they do not arrive at consistent conclusions from their analyses; and even Motorola – the single commenter that is opposed to the Commission's AWS-3 proposal and that relied on some statistical analysis – proposed overly conservative OOBE

[78] *See* MetroPCS Further Notice Comments at 10.

[79] Motorola Further Notice Comments at 6.

[80] AT&T Further Notice Comments at 16.

[81] *See* Technical Appendix 3 (reporting results of a study conducted for Ofcom that showed a low potential for blocking, even in hot spot and high user-density situations).

[82] *See* Motorola Further Notice Comments at 7; MetroPCS Further Notice Comments at 13; T-Mobile Further Notice Comments at 13; SpectrumCo Further Notice Comments at 5; AT&T Further Notice Comments at 17.

limits based on its assumptions that were not proved out by Ofcom's studies. Meanwhile, although Ericsson indicates that an AWS-1 handset has a noise floor of -103 dBm,[83] T-Mobile's study included tests of some handsets at -105 dBm.[84] This means that T-Mobile likely tested units below the noise floor, where no reliable reception of the desired signal could be expected, and thus where supposed "harmful interference" from adjacent bands would not be an issue. In the end, based on tests in which a three meter separation between devices was employed, all of the parties opposing the Commission's proposed service rules suggest OOBE limits that would result in a signal at least 5.5 dB below the noise floor, *i.e.* below the level at which the handset can detect a signal. Even with a one meter separation, only the -60 dBm/MHz proposed by Motorola and MetroPCS would result in a signal at the noise floor.[85] This is unprecedented. As indicated in Part II.A above, the opponents of the Commission's proposal unjustifiably call for the elimination of all possible interference, but the Commission should concern itself only with balancing the need for protection against harmful interference against the benefits of fostering new service in the AWS-3 band. That balance weighs heavily in favor of adopting the *Further Notice* proposal, subject to refinements suggested previously by M2Z.

M2Z also notes with interest that none of the parties opposing the Commission's AWS-3 proposal mentioned base-to-base interference issues in their analyses, perhaps because the study commissioned for Ofcom and a separate ITU analysis both suggest that base-to-base interference to AWS-3 stations is just as problematic as, or more problematic than, mobile interference to AWS-1 devices.[86] In any event, whatever the level of interference that would affect both AWS-

[83] Ericsson Further Notice Comments at 5.
[84] T-Mobile Further Notice Comments, Laboratory Test Results at 18.
[85] *See* Technical Appendix 3.
[86] *See id.*

1 and AWS-3 licensees in adjacent bands, modern statistical analyses and previously conducted tests confirm that the Commission's standard 43 + 10 log(P) mobile OOBE limit would be sufficient to protect AWS-1 users from OOBE-based interference.[87]

Finally, M2Z notes that the technical aspects of the AWS-3 service rules proposed by M2Z (in our suggested revision to the *Further Notice* proposal) are closely aligned with rules that the Commission adopted for the 700 MHz bands. AT&T and T-Mobile argue against reliance on the 700 MHz rules as precedent for AWS-3, asserting that the Commission explicitly decided to allow flexible use, including TDD, in the 700 MHz bands, but that it failed to do so explicitly for the Commission's AWS allocation.[88] AT&T's and T-Mobile's arguments in this regard depend in part on their alleged lack of notice regarding the potential for TDD operations in the AWS-3 band – a claim that is not supported by the record in this proceeding or the Commission's pronouncements on this topic.[89] Yet another reason to dismiss arguments regarding the inapplicability of 700 MHz precedents, however, is the fact that the M2Z's proposal for a standard 43 + 10 log(P) OOBE limit[90] on AWS-3 mobile devices would in fact afford the same level of protections to AWS-1 licensees as the Commission gave to public safety users in the 700 MHz band. AT&T and T-Mobile made identical mathematical errors when converting the OOBE limits adopted for the 700 MHz bands,[91] and thus failed to realize that

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[87] M2Z further notes that concerns about spurious emission interference, chiefly raised in Nokia's comments, *see* Nokia Further Notice Comments at 4, are – ironically enough – spurious concerns. The Commission's definition of spurious emissions expressly excludes out-of-band emissions. *See* 47 C.F.R. § 2.1(c). There is no evidence in the record of this proceeding suggesting that spurious emissions are a concern here, and Nokia provides no such evidence in its comments.

[88] *See, e.g.*, T-Mobile Further Notice Comments at 19-22; AT&T Further Notice Comments at 28-34.

[89] *See supra* note 39 and accompanying text.

[90] The 43 + 10 log(P) limit is based upon a 1 MHz bandwidth, which is equivalent to the 65 + 10 log (P) limit with a 6.25 kHz bandwidth for the 700 MHz mobile transmissions. *See* Technical Appendix 6 hereto.

[91] *See* AT&T Further Notice Comments at 29; T-Mobile Further Notice Comments at 21. *See generally* Technical Appendix 6 hereto.

M2Z's proposal results in the same level of protection afforded to public safety mobiles by the Commission's 700 MHz decisions.

D. The Commission Should Afford the Same Level of Protection to MSS Licensees That It Will Afford to AWS-1 Licensees, and Should Not Revise the AWS-3 Band Plan for the Sake of MSS Licensees or in Pursuit of Illusory Efficiency Gains.

A few parties submitting comments in response to the *Further Notice* call for consideration of newly proposed band plan alternatives,[92] suggesting in essence that special consideration should be given to interference concerns for Mobile Satellite Service ("MSS") satellites and base stations. As explained in Part I above, consideration of alternative band plans now would only add delay to an already lengthy proceeding, and would unnecessarily re-visit issues already considered by the Commission in the *Initial Notice* in AWS-3 service rules docket.

Calls for special consideration of MSS uses are unwarranted from a technical standpoint as well.[93] ICO, TerreStar, and MetroPCS offered up in their comments very different proposals for these special rules.[94] Yet, the statistical analysis methodology for predicting harmful interference applies with equal force to AWS-1 and MSS licensees, and there is no reason to provide additional protections to MSS users beyond those justified by such analyses. MSS receivers may have greater sensitivity,[95] but MSS user-density typically will be much lower due to the paucity of users in urban areas, as well as the low user densities and geographic distances involved in rural areas. In other words, "hot spots" of MSS users are unlikely to occur in cities

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[92] *See, e.g.*, MetroPCS Further Notice Comments at 11-12; ICO Further Notice Comments at 10-13; *see also* TerreStar Further Notice Comments at 3 n.3 (supporting ICO band plan).

[93] *See* Technical Appendix 4 hereto.

[94] *See, e.g.*, TerreStar Further Notice Comments at 2-3 (suggesting a base emission limit of 32 dBW/5 MHz, the exclusion of mobile and portable operations from the 2175-2180 MHz, and an OOBE limit of 70 + 10 Log (P) at 2180 MHz); ICO Further Notice Comments, Exhibit A, at 4 (proposing an OOBE limit of 90 + 10 Log (P) at 2180 MHz as well as a guard band of 10 megahertz).

[95] *See, e.g.*, ICO Further Notice Comments at 6.

because there are so few MSS users there, and are unlikely to occur in rural areas because the users, though potentially more numerous than in cities, are more spread out. These factors combine to reduce even further the likelihood of MSS use that is simultaneous, spectrally proximate, and geographically proximate to an AWS-3 mobile device, making the probability of harmful interference remote.[96]

The alternative band plans proposed by ICO and MetroPCS, and by others suggesting instead that AWS-3 be reserved for downlink-only FDD operations,[97] do not adequately consider the trade-off in spectrum efficiency that would be lost under these alternatives. The Commission should analyze such alternative proposals on neutral grounds, comparing the amount of guard band spectrum and the number of spectral boundaries created by these plans to such considerations under the band plan proposed in the *Further Notice*. Even more importantly, the Commission should not ignore the fact that TDD operations are inherently more efficient than FDD,[98] a legacy duplex architecture that does not allow for the same efficient and intensive uses of spectrum made by possible by Adaptive Antenna Systems, Spatial Diversity Multiple Access, and other solutions optimized for use on TDD platforms.[99] In this light, M2Z compared the amount of usable capacity and spectrum made available under the AWS-2 and AWS-3 band plan proposals in the *Further Notice* with the capacity and spectrum available under ICO's recent proposal. Based on those calculations, which are reported and illustrated in Technical Appendix

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[96] *See* Technical Appendix 4 hereto. Even in higher user-density urban environments, MSS users would rely on operations using Ancillary Terrestrial Component ("ATC") transmissions, once again suggesting adoption of the same technical rules to govern AWS-3 relationships to both AWS-1 and MSS licensees.

[97] *See, e.g.*, Ericsson Further Notice Comments at 10.

[98] *See* Reply Comments of the TDD Coalition, WT Docket No. 02-353, at 17 (filed Mar. 14, 2003) ("TDD-based 3G implementations both transmit and receive within the same frequency band, thereby offering a higher spectral efficiency (i.e., more bits transmitted per hertz of bandwidth) for an equal amount of spectrum than FDD implementations.").

[99] *See, e.g.*, ArrayComm Further Notice Comments at 2-3; *see also* Technical Appendix 5 hereto.

5, it is apparent that trading in 56 Mbps in capacity in 35 MHz of spectrum (under the Commission's current plan) for an alternative that delivers only 44 Mbps of capacity in 40 MHz of spectrum is no way to maximize spectral efficiency.

CONCLUSION

For the foregoing reasons, M2Z respectfully submits that the Commission should move expeditiously to adopt the service rules proposed in the *Further Notice*, subject to the modifications suggested in M2Z's initial Further Notice Comments. The Commission can readily reject the legal and policy objections raised by parties opposed to the AWS-3 service rules proposal set forth in the *Further Notice*, as these objections merely restate prior arguments that are not supported by the record. On the same grounds, the Commission can likewise reject calls for reliance on outdated testing models and for further testing, as well as incumbent licensee claims to special and unprecedented protection from interference due to TDD operations in the AWS-3 band. The Commission should adopt flexible, competitively and technologically neutral service rules in AWS-3, thereby speeding the long overdue deployment of a competitive and eminently affordable wireless broadband alternative in this spectrum band.

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August 11, 2008

Technical Appendices to Further Notice Reply Comments of M2Z Networks, Inc.

WT Docket Nos. 07-195 & 04-356

August 11, 2008

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Appendix 1: Statistical Methods are the Proper Mode of Interference Analysis and Demonstrate that Harmful Interference is Highly Unlikely

1. Overview

- Statistical analyses for determining the technical rules for wireless coexistence are broadly accepted by regulatory agencies and standards communities such as 3GPP, ITU, IEEE, and Ofcom. Unrealistic analyses such as those that the AWS-1 incumbents urge upon the Commission are not acceptable.
- There is longstanding domestic and international precedent for protecting against "harmful interference" as opposed to the impractical goal of protecting against all interference.
- A reasonable way to set the "harmful interference" threshold is to make it comparable to the outages that occur naturally in today's CMRS systems, which is about 2% or greater.
- The combined body of results from work by Ofcom, ITU and 3GPP conclusively demonstrates that the coexistence of TDD and FDD in adjacent bands is manageable, and may actually support relaxation of provisions proposed in the Further Notice.

2. Claims of Severe, Widespread, Unmanageable, Harmful Interference are Premised on a Limited Single-Situation, Deterministic Analysis Approach, Not a Statistical Assessment, Which is the Proper Method of Analysis

Some commenters have objected to the Commission's proposed technical rules, arguing that such rules would allow for unacceptable levels of mobile-to-mobile interference. These claims are conveyed in terms such as "widespread and essentially unmanageable"[1] or "frequent mobile-to-mobile interference,"[2] that would be "so harmful as to render a portion of the AWS-1 spectrum unusable,"[3] or that "could prevent AWS-1 licensees from making use of at least the AWS-1 F-Block, and possibly the D and E Blocks as well."[4] These assertions attempt to convey a sense of pervasive interference; that is to say, interference is everywhere you look. These assertions are also all based on static, deterministic analyses and tests conducted under unrealistic conditions. With the exception of Motorola, none of the parties claiming overwhelming mobile-to-mobile interference points to any statistical analysis. Rather, they base these claims on their own (or most often T-Mobile's) test results and analysis. These deterministic analyses rely on scenarios and conditions that show only that interference *could possibly* happen, not how likely it is to be noticed by the handset user, nor whether it would be in any way harmful to the user community.

[1] T-Mobile Further Notice Comments at 15.
[2] AT&T Further Notice Comments at 19.
[3] MetroPCS Further Notice Comments at 21.
[4] U.S. Cellular Further Notice Comments at 3.

3. Statistical Analysis has Become the Accepted Method for Analyzing and Predicting Interference, Despite the Assertions of Incumbent Commenters and Their Vendors

The central question is not whether it is conceivable that interference could occur under an unrealistic scenario, but rather how often and how likely is it that "harmful interference" will occur. The likelihood is often expressed in terms of a capacity loss calculated based on the probability of exceeding certain interference levels.[5] As shown below, this is a key threshold for harmful interference, with threshold values in the range of 2% to 5%. In other words, even in the current operating environment, with actual handsets in use, there is a certain amount of interference that is tolerated and not meaningfully noticed by the handset user. Industry standards, and the actions of national and international regulatory agencies and engineering publications, all recognize that a statistical approach should be used to measure the likelihood of harmful interference.[6]

Despite the widespread acceptance of statistical methods for predicting harmful interference, some commenters urge the Commission not to respect and adopt this industry practice,[7] even though the Commission has relied upon this form of analysis in the past. MetroPCS even questions whether it is lawful for the Commission to consider interference as a statistical issue.[8] These negative views of statistical or "Monte Carlo" analysis ignore the simple facts that such statistical analysis is widely used in the communications industry in setting voluntary standards for interference control, and that it has previously been used by the Commission. Indeed, basing interference protection policy upon infrequent, unrealistic events would require a change in the Commission's long standing practice of preventing harmful interference as that term is defined in § 2.1 of the Commission's rules.[9]

Even if the Commission were to consider backtracking, in order to disavow its reliance on statistical analysis and to reevaluate the Commission's authority to rely upon such

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[5] *See* 3rd Generation Partnership Project, "Technical Specification Group Radio Access Networks; Radio Frequency (RF) system scenarios (Release 7)," 3GPP TR 25.942 V7.0.0, at 46 (Mar. 23, 2007) ("3GPP RF Scenarios").

[6] *See* ITU-R SM.2028, "Monte Carlo simulation methodology for the use in sharing and compatibility studies between different radio services or systems" ("ITU Monte Carlo Methodology"); Ofcom (UK), "On the Impact of Interference from TDD Terminal Stations to FDD Terminal Stations in the 2.6 GHz Band" (April 21, 2008) ("Ofcom April 2008 Study"), *available at* http://www.ofcom.org.uk/consult/condocs/2ghzregsnotice/tech.pdf; *see also* Motorola Further Notice Comments; 3GPP RF Scenarios. For the purpose of these Technical Appendices, here, statistical analysis of interference is basically the same as "Monte Carlo" analysis, and the various parties have used the terms interchangeably.

[7] *See, e.g.*, U.S. Cellular Further Notice Comments at 5 ("Any interference generated by AWS-3 devices that interfere with an AWS-1 device cannot be avoided simply because it is probabilistic in nature.").

[8] MetroPCS Further Notice Comments at 9 ("[T]he Commission must consider whether the 'Monte Carlo' approach advocated by M2Z is a lawful approach to address interference concerns, in light of the Commission's obligation under Section 303(f) of the Communications Act to '. . . [m]ake such regulations not inconsistent with law as it may deem necessary to prevent interference.'" MetroPCS added the emphasis to its quotation from Section 303(f).

[9] *See* 47 C.F.R. § 2.1(c) (defining "Harmful Interference" as "Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [the ITU] Radio Regulations").

methods, the Commission should conclude that the Communications Act provides it with broad authority to control interference. While § 303(f) of the Act does not specifically refer to "harmful" interference" it gives the Commission broad latitude to control interference "as it may deem necessary."[10] Nothing in the statute requires the Commission to eliminate all possibilities of all interference, contrary to what MetroPCS implies. MetroPCS's analysis also neglects to mention the language of § 303(y)(2)(C), which specifically gives the Commission authority "to allocate electromagnetic spectrum so as to provide flexibility of use" if it finds that "such use would not result in harmful interference among users."[11]

While T-Mobile has been silent in its recent comments in this proceeding on the applicability of statistical treatment of interference, its comments to the Commission's UK counterpart, Ofcom, tell a different story. In comments submitted to Ofcom, T-Mobile has advocated the "urgent" use of Monte Carlo modeling to resolve a UHF interference question then under consideration.[12]

Simply put, the Commission is under no obligation to prevent all interference that could occur under all circumstances, including unrealistic scenarios. If that were required, as some commenters advocate, the whole concept of unlicensed devices certified under Part 15 of the Commission's Rules would be impossible. It is well documented that both intentional emitters (such as cordless telephones) and unintentional emitters (such as personal computers) will cause interference to devices operating on licensed spectrum if they are close enough to such devices. Indeed, the 800 MHz cell phones offered by several of the carriers in this proceeding will interfere with television reception if held close enough to a TV receiver. Adherence to a policy of no allowable interference would both increase the cost of equipment significantly, as well as prevent many new communications services from being introduced. For this reason, both the ITU and the Commission have for decades based spectrum policy decisions on preventing harmful interference.

While most of the incumbent AWS-1 licensees commenting in the proceeding, as well as their vendors, dispute the use of statistical techniques, Motorola diverges from the group in stating that it "has a long history and unique understanding of statistical Monte Carlo simulations as applied to inter-system interference analysis. In fact, Motorola was among the first to support the use of statistical Monte Carlo technique for complex radio compatibility analysis when the commonly used technique was worst case deterministic."[13] Motorola goes on to state that it "has continued its own internal efforts to refine the initial Monte Carlo methodology in order to be able to design new systems

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[10] 47 U.S.C. § 303(f).
[11] *Id.* § 303(y)(2)(C) (emphasis added).
[12] *See* T-Mobile comments to Ofcom Digital Dividend Review consultation at 6 (filed Mar. 20, 2007), *available at* http://www.ofcom.org.uk/consult/condocs/ddr/responses/st/TMobile.pdf ("The issue of introducing mobile uplinks [in the UHF band] needs to be clarified by further tests and *the use of Monte Carlo simulations* as a matter of urgency.") (emphasis added).
[13] Motorola Further Notice Comments at 8.

(e.g., W-CDMA, OFDMA), define specifications in 3GPP and other standards bodies, help define spectrum usage and regulatory rules and deploy new radio systems."[14]

Indeed, Motorola provides seven published references to its development of Monte Carlo techniques and their application to spectrum management.[15] While Motorola questions the specific analysis and assumptions submitted by M2Z, Motorola clearly both supports the concept of using the statistical approach for decision-making in this proceeding and acknowledges its use of such methods in the past.[16]

4. The Commission and its Counterparts Around the World Have Relied on Statistical Analysis, as Have Standards Setting Bodies

The Commission's Multichannel Video and Data Distribution Service ("MVDDS") decision in 2002 is a good example of its previous use of statistical methods. In allowing MVDDS to share the 12 GHz band with incumbent Broadcast Satellite Service ("BSS") operations, the Commission limited any incremental interference owing to the new service to 10% of naturally occurring outages, concluding that this increment did not constitute harmful interference in that particular instance.[17] The Commission did not target zero interference possibility as the proper benchmark. That approach was exactly the statistical approach that many of the parties now say is unlawful and without precedent.

The Commission is in good company in relying upon statistical analysis for predicting harmful interference. A recent proposal by the European spectrum regulator CEPT used the very same SEAMCAT model, which M2Z also has relied upon in this proceeding, to justify a proposal[18] for band sharing in spectrum in the 1.5 GHz region that is similar to the AWS-3 band in terms of its propagation characteristics. The FCC's UK counterpart, Ofcom, frequently uses Monte Carlo techniques in evaluating interference in its policy deliberations. A good example is a recent report on FDD/TDD interference in a situation almost identical to that under consideration here, although in a slightly higher band.[19]

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[14] *Id.*
[15] *Id.* nn.14-16.
[16] See infra at 8-9.
[17] *See Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range*, Memorandum, Opinion and Order and Second Report and Order, 17 FCC Rcd 9614, ¶ 71 (2002) ("*MVDDS Second Report and Order*").
[18] Electronic Communications Committee (ECC) within the European Conference of Postal and Telecommunications Administrations (CEPT), Draft ECC Report on Compatibility Studies Between Professional Wireless Microphone Systems (PWMS) and Other Services/Systems in the L Band, DRAFT ECC REPORT 121, at page 18 (2008), *available at* www.ero.dk/367C8D90-8C23-4A16-8B8D-349C5B086E5D?frames=no&.
[19] *See* Ofcom April 2008 Study. Other Ofcom studies on other spectrum interference issues using Monte Carlo techniques include "Low-power concurrent use in the spectrum bands 1781.7 – 1785 MHz paired with 1876.7 – 1880 MHz" (July 28, 2006), *available at* http://www.ofcom.org.uk/consult/condocs/1781/lowpower/concurrent.pdf; "Are Future EMC Emissions a Threat to Radio Services?" (2006), *available at* http://www.ofcom.org.uk/research/technology/research/speclib/permit/7-9.pdf; and "Assessment of Interference from Digital Set-top Boxes to

As indicated above, Ofcom used statistical simulations to determine appropriate protections to prevent harmful interference. Ofcom demonstrated, for a W-CDMA deployment, that without a TDD mobile transmitting "there is a 5% probability that the FDD downlink throughput drops below 205 kbits/s over the cell area."[20] Ofcom then concluded that TDD operation under its rules would create "a 5% probability that the throughput would drop below 180 kbits/s over the cell area."[21] Thus, a 12.1% drop in throughput at the 5% probability level was used in that case as the threshold for harmful interference.

The International Telecommunications Union ("ITU") also has endorsed the use of Monte Carlo simulations methodology for compatibility studies since 2001.[22] The ITU also employs the use of SEAMCAT, which mirrors the approach taken by Motorola in its Further Notice Comments and by Alion Science and Technology Corporation ("Alion") in a study commissioned by M2Z.[23] The ITU has used this methodology in a study to understand the impact of TDD/FDD coexistence. In that study, the ITU used a statistical model to identify capacity loss in FDD systems due to adjacent TDD operations, and concluded, "[t]he adjacent channel interference from 802.16 TDD to standard CDMA-DS downlink is negligible for all scenarios. No additional isolation from 802.16 TDD base station to CDMA-DS mobile station and from 802.16 TDD subscriber station to CDMA-DS mobile station is required."[24]

In the more general technical work by contributors to organizations such as the IEEE, Monte Carlo techniques are frequently used to study interference in a variety of contexts.[25] More importantly, the IEEE Standards organization has recently published a standard for best practices in coexistence analysis, wherein the use of statistical methods is endorsed and described.[26]

COSPAS/SARSAT Receivers," (August 2006), *available at* http://www.ofcom.org.uk/research/technology/ctc/era05-07/2006-0410.pdf.

[20] *See* Ofcom April 2008 Study at 13.

[21] *See* id. at 14.

[22] *See* ITU Monte Carlo Methodology, *supra* note 6.

[23] *See* Letter from Uzoma C. Onyeije, M2Z, to Ms. Marlene H. Dortch, WT Docket Nos. 07-195 & 04-356 (filed June 3, 2008) ("M2Z June 3 *Ex Parte*"). This filing included as an attachment Alion's study entitled "Analysis of AWS-3 to AWS-1 Mobile to Mobile Interference Effects" (hereinafter, "Alion Analysis").

[24] *See* ITU-R M.2113, "Report on sharing studies in the 2500-2690 MHz band between IMT-2000 and fixed broadband wireless access systems including nomadic applications in the same geographical area" (2007).

[25] A sampling of technical papers published in peer reviewed journals dealing with Monte Carlo analysis and interference include: Verdone, R., "Outage probability analysis for short-range communication systems at 60 GHz in ATT urban environments," *IEEE Transactions on Vehicular Technology*, Vol. 46 , No. 4, at 1027 (Nov. 1997); Corazza, G.E., De Maio, G., Vatalaro, F., "CDMA cellular systems performance with fading, shadowing, and imperfect power control," *IEEE Transactions on Vehicular Technology*, Vol. 47, No. 2, at 450 (May 1998); Kai-Kit Wong, Cheng, R.S.-K., Letaief, K.B., Murch, R.D, "Adaptive antennas at the mobile and base stations in an OFDM/TDMA system," *IEEE Transactions on Communications*, Vol.49 , No. 1, at195 (Jan. 2001).

[26] *See* discussion of selection of the analysis approach, tools, and techniques, IEEE 1900.2, "IEEE Recommended Practice for the Analysis of In-Band and Adjacent Band Interference and Coexistence Between Radio Systems," at 36.

The IEEE also addresses the statistical nature of interference events in the recently published standard for coexistence analysis, describing the use of statistics and probabilities associated with terms like "widespread interference" and "harmful interference criteria."[27] It is clear from a reading of the IEEE standard that singular proofs of the mere possibility of interference (i.e., "conceivable interference") are inadequate to conclusively demonstrate anything other than the absence of interference. When addressing complex, multiple user scenarios such as the instant case, the statistical methods and definitions for interference thresholds should apply.

The equipment standard groups, such as the 3GPP, use statistical simulation to perform coexistence studies. The 3GPP group has set the equipment standards for W-CDMA (UTRA /UMTS) that is being deployed and tested by T-Mobile, and is developing the standards for LTE (E-UTRA/UMTS) which is considered to be the next generation (4G) technology. In their 2007 report, 3GPP simulates scenarios in the FDD/TDD coexistence studies.[28]

As the discussion above makes clear, the ITU, IEEE, Ofcom, Motorola, and the cellular community's own standards group, 3GPP, all use statistical methods to evaluate coexistence and the likelihood of harmful interference.

5. Harmful Interference Metrics Must Comport with the Commission's Policies

The Commission wisely has not pursued the impossible goal of trying to prevent all interference to licensed services, but rather has focused on preventing "harmful interference." The Commission has a longstanding strategic goal of preventing such harmful interference. For example, every FCC Strategic Plan since the FY2003-2008 plan has included language about preventing harmful interference, not language about preventing all interference.[29]

The Commission uses the same definition of harmful interference as the ITU Radio Regulations, and this language has not changed in decades. The full text of this definition, as it appears in the Commission's rules, defines "harmful interference" as:

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[27] *See id.* (discussion of harmful interference criteria).

[28] *See* 3GPP RF Scenarios, at Chapter 5.

[29] The FY2003-2008 plan included as a spectrum-related objective to "[v]igorously protect against harmful interference." *See* Federal Communications Commission Strategic Plan FY 2003-2008 at 7, *available at* http://www.fcc.gov/omd/strategicplan/strategicplan2003-2008.pdf. The FY 2006-2011 and draft FY 2009-2014 plans also include similar specific objectives, stating that "[t]he Commission shall develop and implement policies that delineate the rights and responsibilities of both licensed and unlicensed spectrum users, particularly with respect to harmful interference." *See* Federal Communications Commission Strategic Plan FY 2006-2011 at 10, *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-261434A1.pdf; Federal Communications Commission Strategic Plan FY 2008-2014, at 11, *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-283196A1.pdf. This commitment to preventing harmful interference predates the August 2006 commencement of Auction 66 for AWS-1 licenses, and thus should not have been a surprise to the bidders.

> Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radio-communication service operating in accordance with [the ITU] Radio regulations.[30]

Parts of this definition apply only to safety-related services such as aeronautical and maritime service; the part relevant to the instant matter is

> Interference which . . . seriously degrades, obstructs, or repeatedly interrupts a radio-communication service operating in accordance with [the ITU] Radio regulations.

In the Commission's Spectrum Policy Task Force deliberations some consideration was given to the idea of seeking a more explicit definition of harmful interference, but the Task Force eventually declined to propose one because of a lack of consensus among the commenters about whether and how the existing language could be improved upon.[31] However, various case-specific decisions on types of interference that were <u>not</u> harmful have been made over the years. For example, interference from a personal computer to a TV receiver was deemed not harmful if the separation distance was less than 10m[32] and interference from an MVDDS system to a BSS (DBS) receiver was considered not harmful if it increased expected, naturally occurring rain-related outages by no more than 10%.[33]

Harmful interference metrics are related in important ways to the statistical analysis of interference probability. Statistical analysis measures the probability that the interference will occur, while the harmful interference concept expresses regulators' judgment that certain types of interference scenarios evaluated by statistical analysis are *de minimis* and need not be prohibited by regulation. Thus, the analysis performed by Ofcom and the 3GPP group uses specific values for determining the threshold above which interference may be deemed harmful. Ofcom uses a 12% reduction of capacity at a 5% probability as the threshold. 3GPP uses 2% probability of interference as the threshold value. A recent Chinese paper on TDD/FDD coexistence, prepared as part of ITU-R SG 8F deliberations, considered a capacity loss due to intersystem interaction of less than 5% as reasonable.[34] In all cases, the harmful interference and probability measurements were never pegged at zero.

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[30] 47 C.F.R. § 2.1(c).

[31] *See* Report of the Interference Protection Working Group, Spectrum Policy Task Force (Nov. 2002), *available at* http://www.fcc.gov/sptf/files/IPWGFinalReport.pdf.

[32] *See Amendment of Part 15 to redefine and clarify the rules governing restricted radiation devices and low power communication devices*, Report and Order, 79 FCC 2d 28, ¶ 53 (1979).

[33] *See MVDDS Second Report and Order* ¶ 71.

[34] Zhou Meng; Tu Guofang; Liang Shuangchun, "Interference Analysis between Macro WCDMA and Macro WIMAX Coexisted in Adjacent Frequency Band," International Conference on Wireless Communications, Networking and Mobile Computing, *WiCom 2007*, at 910 (2007).

6. Weaknesses of the Incumbent Commenters' Approaches and the Inferences Drawn from Those Approaches

The question before the Commission in this Further Notice is whether to deny market entry in the AWS-3 band to TDD operators, who would provide service using advanced technologies that provide significant spectrum efficiency and flexibility advantages, and whether to base such denial on the mere possibility of interference, without considering how often this interference may actually occur. Because the social costs of denying entry to such innovative new services on such an unrealistic basis would be enormous, the Commission should hold the incumbent licensees claiming potential harm to a standard based on realistic, rather than an unrealistic, likelihood of interference.

T-Mobile urges the Commission to rely on T-Mobile's own analyses and tests, which employ non-standard, non-statistical methods and, unsurprisingly, predict widespread interference. Some other commenters also rely on the T-Mobile results.[35] Since T-Mobile's results exemplify the category of non-standard, non-statistical testing, this Appendix challenges the applicability of T-Mobile's tests and analyses in order to illustrate the weaknesses of the entire family of non-statistical, worst-case assessments being offered in opposition to the service rules proposed in the Further Notice.

T-Mobile provided an Interference "Laboratory Test Report" with its comments to the Further Notice. The test results in T-Mobile's report are based on a limited selection of test scenarios, applying a static coupling model with a one-meter separation between handsets. The results and conclusions derived from this report are inappropriate for the following reasons:

- While a one-meter (or less) separation between active, in-use handsets <u>could</u> occur, the analysis provides no evidence of how often it would occur.
- The served signal levels tested (-105 dBm, -100 dBm, and -90 dBm) are not "high likelihood" or "typical signal strengths" that will be received by AWS-1 mobile devices, despite T-Mobile's claim that these are typical conditions.[36]
- The analysis does not account for the time dimension; *i.e.*, the chances that there will be a coincidence of events where two nearby users are: i) both operating at the same time; ii) both operating on adjacent channels; and iii) the AWS-3 user is transmitting a packet; iv) the AWS-1 user is receiving a packet; and v) the AWS-3 user is operating at the full authorized power.

Motorola's comments indicate that it advocates the use of statistical analysis methods, but Motorola disagrees with M2Z's previous SEAMCAT analysis results, stating:

> The assumption of a standard statistical distribution of the users about the cell leads to optimistic results by making the chance of AWS-1 and AWS-3 mobiles coming close to each other unreasonably low. Mobile users tend to aggregate at high-user density areas such as a coffee shop, sports stadium, metro station or

[35] *See, e.g.*, U.S. Cellular Further Notice Comments at 3.
[36] *See, e.g.*, T-Mobile Further Notice Comments at 18.

> other transportation hubs. Modeling of these hotspots of cellular usage will portray a more accurate representation of the interference environment. These concerns were also raised by 3GPP and WiMAX Forum.[37]

The independent statistical analysis submitted by M2Z in June did not address extreme hotspot scenarios. Yet, Motorola's analysis, even while criticizing the absence of hotspot analysis in M2Z's results, simultaneously undermines the reasonableness of T-Mobile's artificial one-meter static separation test.[38] Clearly, basing conclusions and recommended actions on a single value, such as a one-meter separation distance used by T-Mobile, is inadequate. In the Ultrawideband ("UWB") rulemaking, various parties representing PCS interests sought to limit permitted, unlicensed UWB emission strength so that such emissions would not cause interference to PCS mobiles at distance of 1 meter or less. The Commission rejected this request, indicating that "[W]e do not believe it is appropriate to use such a close separation distance as the basis for controlling harmful interference. Any interference at close distances can be easily remedied by moving the devices a short distance apart."[39]

Ofcom did include a hotspot analysis in its study, which (contrary to Motorola's claims) demonstrates the compatibility of adjacent TDD and FDD operations. The Ofcom analysis applied a statistical approach (5000 snapshot Monte Carlo) to a "hot spot" defined as follows: UMTS users located at random distances from the base station within a 1 km cell amidst a 25 meter radius filled with TDD users at an average density of 1 device per square meter. TDD devices were placed using a uniform random distribution, so that the distances within the hot spot radius and the distance from the UMTS base station varied with each snapshot in the Monte Carlo simulation.[40] The Ofcom simulation also took into account the aggregate interference power of the multiple interferers within the hot spot. This simulation thus addresses the concerns expressed by Motorola and quoted above, and it conclusively demonstrated to Ofcom that TDD and FDD coexistence in adjacent bands is easily manageable.

In addition to measuring user distributions, the Ofcom approach relied on measured data to observe user equipment behaviors in a statistically meaningful manner. Ofcom commissioned a measurement program studying five different UMTS mobile devices. The measurements conducted by ERA Technology on Ofcom's behalf examined:

- Spectrum emission mask and adjacent channel leakage ration ("ACLR")
- Receiver adjacent channel selectivity ("ACS")
- Receiver blocking performance
- Receiver inter-modulation characteristics.

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[37] Motorola Further Notice Comments at 9.

[38] The preliminary analysis done in the Alion Analysis addressed high average user density scenarios, and included approximately three times the density of AWS-3 users as AWS-1 users. The intent was to simulate relatively high user equipment ("UE") populations for both systems, and not underestimate the potential market for either system. Alion assumed actively operating user densities of 36 UE/km^2 and 125 UE/km^2 for AWS-1 and AWS-3, respectively.

[39] UWB First Report and Order ¶ 159.

[40] Ofcom April 2008 Study at 11.

The results of these measurements conclusively demonstrated that the expected user equipment performance was often much better than specified by outdated standards. For example, a blocking threshold of -10 dBm was found to be justified in a statistical analysis because that is what the performance of real devices is likely to be, according to this study.[41]

The impact of interference on user equipment ("UE") is directly related to the served signal enjoyed by the UE at the moment of interference. The lower the served signal to the handset, the more sensitive the UE is to disruption. T-Mobile used served signal levels of -105 dBm, -100 dBm and -90 dBm in its analysis, derived from drive tests in a vehicle equipped to make served signal measurements. There is no way to assess whether these signal measurements are reasonably typical. Nor its there any way to assess the reasonableness of any other parameters of the drive test because T-Mobile's Laboratory Test Report does not indicate the cell size, terrain type, or drive test distance criteria that were used. Nevertheless, the out-of-band emissions ("OOBE") limits recommended by T-Mobile are based on the lowest of these served signal levels; *i.e.*, -105 dBm.[42] This reliance on worst-case conditions alone should make the Commission reluctant to give credence to T-Mobile's report.

Even though no information is presented upon which typicality could be assessed, T-Mobile's comments represent these served signal levels as "realistic" and "typical."[43] However, the key point to consider is that T-Mobile picked the lowest of these three atypically low numbers from the distribution, and then they used that number as a basis for recommending AWS-3 OOBE limits to the Commission. Supporting the view that these signal values are not typical, MetroPCS, in a recent *ex parte*, refers to its own recommended testing at these values as "marginal radio conditions,"[44] which is more in line with the characterization of such conditions put forward by M2Z, Ofcom, and multiple IEEE analyses.

In contrast to the T-Mobile analysis, the Ofcom April 2008 analysis represents a sound approach. In that analysis, Ofcom derived distance separations between the base station and the mobile device in each Monte Carlo snapshot, as described above. It then calculated the served signal for that snapshot using a method based on the extended (urban) Hata model, assuming that the base station will transmit the minimum power needed to sustain a good quality link, up to a maximum of 61 dBm, EIRP.[45] The aggregate interference from TDD mobiles was then calculated using the same propagation model, and the interference state was determined by comparing interference

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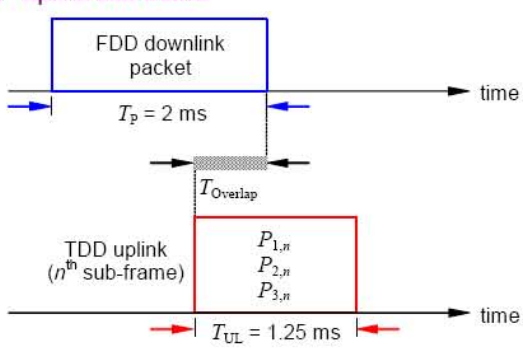
[41] *See* ERA Technology, "Measurements of UTRA FDD User Equipment Characteristics in the 2.1 GHz Band," at 3-4 (April 2008) ("ERA Technology Report"), *available at* http://www.ofcom.org.uk/consult/condocs/2ghzregsnotice/era.pdf.
[42] *See* T-Mobile Further Notice Comments, Laboratory Test Report at 5, 21.
[43] *See, e.g.*, T-Mobile Further Notice Comments at 12-13.
[44] *See* Letter from Michael Lazarus, Esq., Paul, Hastings, Janofsky & Walker LLP, to Marlene H. Dortch, WT Docket No. 07-195, at 4 (filed July 30, 2008).
[45] *See* Ofcom April 2008 Study at 11, 29.

to thresholds based on the served signal and blocking threshold data.[46] The result of multiple iterations of this Monte Carlo process is a credible analysis based on the full range of served signal statistics found in an operational setting.

The Commission should also note that the assertions by M2Z's opponents of frequent and widespread interference are based on analysis that does not consider the effects of time coincidence. For example, T-Mobile does not consider the probability of two users (who happened to find themselves side-by-side) simultaneously using the first adjacent channels relative to one another – which was the situation T-Mobile tested, as if it always would happen just that way. The Alion Analysis's SEAMCAT study submitted by M2Z also failed to take into account certain effects of limited time coincidence, such as packet collisions. In that respect, our own analysis may have been too pessimistic. The more realistic statistical methods applied by Ofcom take into account the effects of user duty cycles, channel occupancy, and the time domain aspects of packet transmission overlap. The excerpt below illustrates the depth and value of this approach.[47] The analysis offered by Ofcom uses such time-dependent events to compute the aggregate interference power from multiple interference sources for each Monte Carlo snapshot.

A1.65 Figure 14 illustrates a scenario where a FDD downlink packet of duration $T_P = 2\,\text{ms}$ (as in UTRA-FDD HSDPA) partially collides with the nth TDD uplink sub-frame of duration $T_{UL} = 1.25\,\text{ms}$ (as in WiMAX) containing transmissions from $K = 3$ TDD terminal stations. The *effective* in-block EIRPs of these terminals stations are $P_{k,n}$ for k = 1, 2, 3, where $P_{k,n} = \alpha_{k,n} P_k$ (see Equation 7).

Figure 14: Example of collision between a FDD downlink packet and TDD packets in the nth uplink sub-frame.



[46] A blocking threshold of -10 dBm was derived based on testing of five UMTS handsets by ERA Technology. The testing indicated significantly better performance than predicted by older standards. *See* ERA Technology Report at 4.
[47] *See* Ofcom April 2008 Study at 31-32.

7. Errors Evident in T-Mobile's Proposed Analysis Methods

In addition to the above reasons for questioning the validity of the static, single-scenario approach, M2Z offers below some specific corrections to the values used by T-Mobile:

- The coupling loss of 40 dB used in the analysis at one meter separation was underestimated.[48] This comment is based on previous analysis by Motorola submitted in response to the initial NPRM in the AWS-3 service rules proceeding, where Motorola applied a total coupling loss of 45 dB. [49]
- T-Mobile's report incorrectly applies the conversion of the power spectral density ("PSD") to formulas equivalent to the FCC OOBE limit format. For example, -66 dBm/MHz is actually equivalent to 90 + 10 log (P), where P is the power of the device emissions in the band in watts.[50] This conversion applies to the estimated 4.1 MHz actual bandwidth that WiMAX devices would likely use in a 5 MHz channelized band. Thus, when T-mobile insists on a 96 – 10 log (P) OOBE limit,[51] it really means 90 + 10 log (P).

As a final observation, we acknowledge Motorola's effort and approach in using statistical methods for the computation found in its analysis. Motorola provided insufficient detail to understand what input parameters, assumptions about distributions, and computational methods were actually used, and thus we may still disagree with some of Motorola's results. However, Motorola is correct that this is the type of approach that should be applied. We also note that Motorola concludes from its "initial" Monte Carlo analysis that, "if evaluated using the Monte Carlo simulation with uniform user distribution, no interference would be predicted because the hotspot areas that would occur in practice are not modeled, while consideration of hotspots can increase the probability to approximately 38 percent that the AWS-3 mobile service would degrade AWS-1 spectrum efficiency by 5 percent."[52] This conclusion was drawn for an analysis with <u>no guard band</u>. Thus, even if Motorola is correct, which is impossible to judge given the limited nature of its submission, the worst case scenario would mean a 5% reduction in spectrum efficiency in AWS-1 in exchange for a nearly 100 % gain in efficiency in the band next door by allowing TDD. This is well within the capacity thresholds deemed acceptable by Ofcom and 3GPP, and would represent a reasonable judgment by the Commission in executing its statutory mandate.

8. Conclusion

Longstanding practice and current trends in the mobile industry, as adopted by standards-setting bodies and regulators with TDD/FDD adjacent operation experience, embrace the use of statistical methods in analyzing coexistence. This is clearly the correct approach

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[48] *See* T-Mobile Further Notice Comments, Laboratory Test Report at 10.
[49] *See* Comments of Motorola, Inc., WT Docket No. 07-195, at 4 (filed Dec. 14, 2007).
[50] *See* T-Mobile Further Notice Comments, Laboratory Test Report, at 21, Table 1; *see also* 47 C.F.R. § 27.53 (defining the value "P" as "transmitter power (P) within the licensed band(s) of operation, measured in watts").
[51] *See* T-Mobile Further Notice Comments at page 13.
[52] Motorola Further Notice Comments at 10.

for the Commission to use in evaluating AWS-3/AWS-1 interference issues. The Commission should reject the invitation of other commenters to take a step backwards in time, as well as a step backwards in terms of the quality of interference analysis, and to revert to outdated methods based on faulty premises. The chief faulty premise urged by opponents of the Commission's proposal in the *Further Notice* is the proposition that technical rules for spectrum bands should be based solely on worst-case scenarios for familiar FDD technology, unless a conclusive demonstration can be made that interference cannot conceivably happen, ever. The Commission should embrace instead the type of analysis provided by Ofcom, which sets the standard for conclusively demonstrating the possibility of compatibility and coexistence for adjacent FDD and TDD operations.

Appendix 2: Heeding Calls for Additional Testing Would Yield No New Information and Merely Would Delay Resolution of the Further Notice

Overview

Testing can be helpful to decision-making when such testing is thoughtfully designed to achieve specific objectives and focuses on technical phenomena that are neither well understood nor readily susceptible to mathematical modeling. That would not be the case in this instance.

- The points of contention in this proceeding relate to issues – such as out-of-band emissions and receiver blocking/desensitization – that are well understood at this point.
- Extensive testing and studies by international bodies have already been conducted on the issue of FDD/TDD co-existence, and no further testing is necessary.
- No one has presented a credible argument as to what additional testing will achieve or what its goals would be.
- Further testing would only result in delay in licensing and deployment in the AWS-3 band, while more AWS-1 handsets were deployed, exacerbating the problem claimed by the incumbents.

Some commenters have suggested that additional testing should be performed to evaluate the suspected interference claims raised by parties in this proceeding.[53] While additional testing may seem like a good precautionary measure with little downside, that is not the case here.

First, additional testing is not necessary because it would be redundant. Extensive testing has already been done on the issue of FDD/TDD coexistence and has demonstrated that the two technological platforms can be successfully operated in adjacent bands with appropriate protections. Further, there are actual deployments which provide further proof that TDD and FDD can coexist – including one deployment in the Czech Republic by T-Mobile, one the most outspoken critics of the Commission's AWS-3 proposal.[54]

The extensive testing already reported in the record, both by independent entities and other regulators, places the current situation in stark contrast with other situations in which the Commission has sanctioned testing to resolve technical issues.

For example, Congress directed the Commission to conduct testing for the MVDDS rulemaking.[55] The MVDDS proceeding involved sharing of the same band between

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[53] *See* MetroPCS Further Notice Comments at 8; Nokia Further Notice Comments at 4; OPASTCO & WCA Further Notice Comments at 2; Qualcomm Further Notice Comments at 2; U.S. Cellular Further Notice Comments at 3; CTIA Further Notice Comments at 30.

[54] *See* Letter from Uzoma Onyeije to Ms. Marlene H. Dortch, WT Docket Nos. 07-195, 04-356, 07-16 & 07-30, at 1 (filed July 28, 2008) ("M2Z July 28 *Ex Parte*").

[55] *See MVDDS Second Report and Order* ¶ 13.

incumbent BSS licensees and a new Fixed Point-to-Multipoint service. The interference protection issue between co-frequency users focused on the ability of consumer grade (*i.e.* residential) DBS antennas to reject signals arriving from a direction very different than that of the satellite from which they were intended to receive signals. This necessitated detailed data on the characteristics of antennas receiving signals from a very different direction than the intended direction of pointing – information that was just not available at the time for such consumer antennas. Thus, testing made sense.

By contrast, the technical issues in contention in this proceeding are already well understood and have been studied extensively within the technical community. Testing of currently available AWS-1 equipment will yield little information that could not already be predicted from the facts already known, including the fact that such equipment was apparently designed intentionally to cover the 2110-2170 MHz band, even though none of the AWS-1 licensees hold any authorization to use AWS spectrum between 2155 and 2170 MHz, and even though both the ITU and the FCC allocations for this band allow Mobile or Fixed Service use.[56] In fact, the AWS-1 equipment appears to have a passband even beyond 2170 MHz (up to 2180 MHz), based upon observation of the literature of commercial filters now available.[57] Of course, any remaining issues as to the frequency response of current designs could be settled quickly if the manufacturers would simply provide the characteristics of the filters that are actually being used in present production of their AWS-1 handsets, or at least provide their model numbers. The Commission even could encourage knowledgeable parties to supply this information in the record. However, no further testing is necessary to understand the characteristics of such equipment.

Second, the advocates of additional testing have not specified what the objectives of another new testing regime would be. One of the likely issues of interest could be to characterize the RF performance of various handsets. Of course, that test already has been performed by ERA Technology, in a recently concluded test conducted in April 2008 for Ofcom.[58] Based on four parameters – (1) spectrum emission mask and adjacent channel leakage ratio (ACLR); (2) receiver adjacent channel selectivity (ACS); (3) receiver blocking performance; and (4) receiver inter-modulation characteristics, ERA characterized the performance of five UMTS handsets made by different manufacturers for the 2.1 GHz band. As the report points out, "[a]ll measurements were undertaken in accordance with the test methods defined in ETSI performance standard TS 134 121-1 v8.0.0 (2007-10)."[59] In summary, the performance of the handsets based on these four parameters shows that, on average, all tested devices perform better than the ETSI minimum requirement. There is no reason to believe that new or additional testing will result in different conclusions. Even if new test results differed slightly, every category tested by ERA performed far better than that required by the relevant standards document.

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[56] *See* 47 C.F.R. § 2.106 note 5.388.
[57] See, for example, literature for the EPCOS Model B7835.
[58] *See* ERA Technology Report.
[59] *Id.* at 44.

Third, commenters advocating additional testing have not presented any credible arguments as to what additional testing would reveal beyond what is already well known from various standards and the testing that led up to those standards. Parties suggesting additional testing have not provided any indication as to what unanswered questions they hope to answer or what hypotheses they are looking to prove.

Thus, it seems clear from these open-ended calls for testing that the only thing to be accomplished would be further delay in the licensing and deployment of the AWS-3 spectrum. Such delay would allow more time for existing and ill-conceived AWS-1 handsets and terminal equipment to populate the marketplace, thus exacerbating any problem that arises in part from the poor design of current AWS-1 handset models. Existing equipment with a passband filter that encompasses the entire 2110-2170 MHz band (and perhaps an even higher end to that range) is more susceptible to harmful interference than would be equipment with a filter roll-off starting at the upper end of the AWS-1 band (*i.e.*, 2155 MHz). Remedying this problem only would become more complex if there were additional delays in starting the process.

In sum, if additional sources of information are required because TDD equipment is not yet available for the AWS-3 band, the Commission can look to the experience of operators and test results from other bands. For example, the 2500-2690 MHz band could serve as an appropriate proxy, as it nears auction in the United Kingdom. Ofcom has recently published the rules[60] for an auction in this band that will allow for both FDD and TDD operation, with appropriate protections so that they can coexist. Ofcom also produced a report[61] in which it addressed the impact of adjacent-channel interference from TDD terminal stations to FDD terminal stations in the band. The Ofcom report, which should be reviewed by the Commission, provides a thorough and objective analysis of the same interference issues that are involved in this proceeding, the likelihood that harmful interference would occur in AWS-3, and the necessary mechanisms to resolve such issues. In this case, as in every other case in the wireless arena, some interference is a possibility but harmful interference can be prevented with appropriate measures.

[60] *See* Ofcom, "Award of available spectrum: 2500-2690 MHz, 2010-2025 MHz" (April 4, 2008) ("Ofcom 2500-2690 MHz Award").
[61] *See* Ofcom April 2008 Study.

Appendix 3: Protection of AWS-1 Services

Overview

- The international community has determined that, where TDD and FDD systems operate in adjacent bands, base-to-base interference is the more egregious interference scenario when compared to mobile-to-mobile interference. Both are readily manageable with proper coordination.
- Spurious emissions are not of concern with the AWS-3 band plan.
- Currently available equipment provides sufficient blocking protection as high as -10 dBm.
- Statistical analysis conducted by Ofcom and the ITU supports evidence submitted by M2Z (and recommended by ArrayComm) indicating that the mobile-to-mobile OOBE interference potential would be manageable using -13 dBm/MHz to -19 dBm/MHz limits.

Potential interference among the AWS-1, AWS-3, and MSS bands comes in three forms: spurious emissions, blocking via adjacent channel emissions, and out-of-band emissions. It is important to note in analyzing these potential sources of interference that, as indicated above in Technical Appendix 1, standards bodies and international regulatory bodies use for harmful interference a threshold value no lower than 2%. In other words, interference that may occur below this threshold is not considered harmful.

1. Spurious Emissions are Not a Concern Here

The Commission defines spurious emissions in § 2.1 of its rules as "emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, <u>but exclude out-of-band emissions</u>."[62]

There is nothing in the record of this proceeding suggesting that *any* spurious emissions, as properly defined, would occur, or that the general out-of-band emission limits would not adequately protect existing licensees from spurious emissions. Therefore, the issue of spurious emissions in this proceeding is a "red herring" that has its origin in some parties' apparent misunderstanding of the terminology.[63]

Thus , the Commission should give no weight to Nokia's statement that spurious emissions from AWS-3 transmitters may present "more serious interference concerns."[64] Nokia does not provide or even hint at any data supporting this claim. M2Z has investigated the possibility of spurious emissions with potential equipment vendors and confirmed that this should not be of any concern in this proceeding. Even T-Mobile

[62] 47 C.F.R. § 2.1(c) (emphasis added).
[63] *See, e.g.*, AT&T Further Notice Comments at 3, 20.
[64] Nokia Further Notice Comments at 4.

agrees in its Laboratory Test Report[65] that spurious emissions will have negligible effects.

2. Blocking is Remedied Through Proper Equipment Selection

Blocking occurs when the absolute values of the received adjacent-channel signals are beyond a certain threshold. Blocking is also referred to as receiver overload, saturation, or blanketing.[66]

Blocking is controlled in traditional receiver designs by a combination of filtering the receiver input to minimize undesired signals from adjacent bands (particularly strong signals), and receiver selectivity that further eliminates all signals but the specific one to which the receiver is tuned. As shown below, the AWS-1 mobile units in the supply pipeline have serious blocking susceptibility due to two design factors that have a synergistic negative effect: 1) These mobiles have initial filters that allow the receiver to get power from outside the AWS-1 band, indeed from the whole AWS-3 band, *virtually unattenuated*[67] and 2) the direct conversion architecture of these receivers eliminates the physical intermediate frequency ("IF") filter used in most receivers since Maj. Armstrong's invention of the superheterodyne receiver in the 1930s, and replaces it with a digital filter. While digital filters have many advantages with respect to selectivity, they have significantly dynamic range limitations when used in consumer equipment where component cost is a key issue. The negative synergy of these two design decisions is a key factor in making the "pipeline" AWS-1 mobile units susceptible to blocking.

Incumbent AWS-1 service providers and vendors propose widely varying emission rules to protect against blocking. MetroPCS suggests a transmission power spectral density limit of 0 dBm/MHz to eliminate *all possibility* of interference,[68] while SpectrumCo would eliminate transmission below 2170 and limit the 2170-2180 band to 20 dBm EIRP.[69] Motorola suggests that a 10 MHz guard band would be necessary and that power be limited to 23 dBm EIRP above 2168 MHz.[70] T-Mobile suggests that there must be "at least 12.5 to 13 MHz of guard band."[71] AT&T argues that a 13 MHz guard band would be necessary to protect against blocking.[72] Ericsson asserts that an AWS-3

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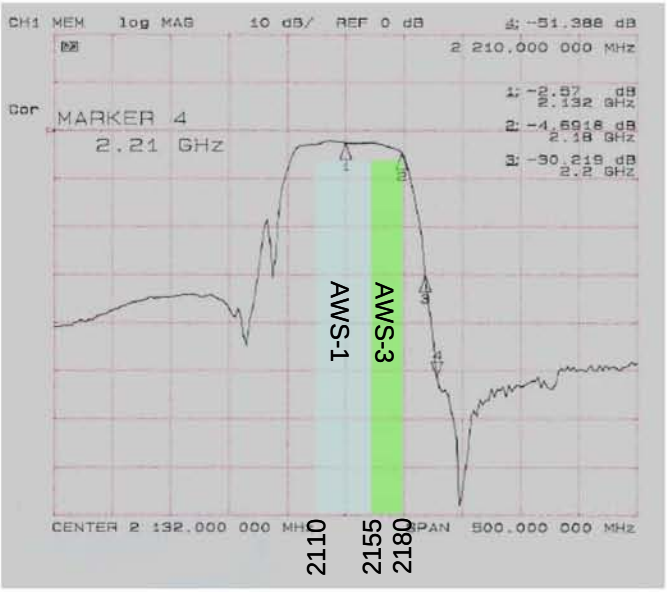
[65] *See* T-Mobile Further Notice Comments, Laboratory Test Report at 7 ("In the particular case of AWS-3 interference to AWS-1 it is anticipated that spurious emissions will have negligible effects for the reasons noted above; therefore the analysis concentrates on the other two effects.").
[66] *See* 47 CFR §§ 73.14, 73.310.
[67] All practical filters let in <u>some</u> power from adjacent bands, but this is not the reason why the pipeline AWS-1 units pass the <u>whole</u> AWS-1 band. The only explanation is a major misunderstanding of the Commission's longstanding deregulatory approach to CMRS spectrum and a baseless expectation that the European band plan might be implemented in the United States.
[68] MetroPCS Further Notice Comments at 10.
[69] SpectrumCo Further Notice Comments at 5.
[70] Motorola Further Notice Comments at 6.
[71] T-Mobile Further Notice Comments at 12. It is unfortunate that T-Mobile did not supply test information for its TDD deployment in the Czech Republic that is at 1910-1915 MHz and is only 5 megahertz away from the O2 FDD deployment at 1920-1940 MHz. *See* M2Z July 28 *Ex Parte* at 1.
[72] AT&T Further Notice Comments at 16.

mobile radiating a 25 MHz wide signal at 37 dBm would produce a -5 dBm signal at the antenna at 1 m[73] and thus induce blocking.

In response to these scattered suggestions, M2Z notes initially that blocking results from a combination of the output power within the adjacent channel and the design of the receiver filter on the AWS-1 handset. Recent measurements by an M2Z consultant on an AWS-1 mobile purchased in the U.S. from a U.S. AWS-1 licensee[74] indicate that some AWS-1 handsets have a filter manufactured by a common cellular filter provider with filter roll-offs up to and beyond 2180 MHz. This is consistent with specifications for commercially available AWS-1 filters,[75] calling into question AT&T's claim that it did not know that such filters existed.[76] (As shown in Technical Appendix 7 below, filters with much better attenuation could be designed, produced, and implemented if licensees



Receive Pass Band from Handset Operating in F-Block

were to request them.)

Second, blocking within the context of the AWS-3 proceeding is not a function of power spectral density, but of the total power that is seen by the receiver. Power spectral density limits are used to provide protection against receiver-generated intermodulation distortion. Receiver-generated intermodulation interference has been an issue in the FCC/FAA interaction over possible upper-end FM broadcast station interference to the Instrument Landing System, in the Nextel/public safety 800 MHz interference dispute, and, more recently, in the PCS H block dispute. However, there is nothing in the record of this proceeding indicating that receiver-generated intermodulation is an issue with respect to AWS-3 possibly impacting AWS-1. Thus, the issue of limiting in-band AWS-

[73] Ericsson Further Notice Comments at 6.
[74] *See* Letter from Uzoma Onyeije to Ms. Marlene H. Dortch, WT Docket Nos. 07-195, 04-356, 07-16 & 07-30, Overview of Technical Issues at 11 (filed July 2, 2008) ("M2Z July 2 OET/WTB *Ex Parte*").
[75] *E.g.*, EPCOS Models B7645 and B7835.
[76] AT&T Further Notice Comments at 25 n.53; *see also* M2Z July 2 OET/WTB *Ex Parte*, Overview at 11.

3 emissions in terms of power spectral density (dBm/MHz), raised in the Further Notice, appears to be an unintended carryover from PCS H block deliberations, without any place in the AWS-3 discussion.[77] Blocking interference is caused by the total in-band power that passes the receiver filter of the mobile device in the adjacent band, and any regulation addressing blocking should be stated in terms of total in-band power, not power spectral density.

Third, the proposed emission limits are based on static, unrealistic analysis methods that have been departed from or dismissed previously by the Commission, the ITU, cellular communications standards groups (*e.g.*, 3GPP), the academic and R&D communities, and other regulators within the international communities (*e.g.*, Ofcom).[78] As will be discussed below, testing of 3G equipment and extensive statistical analysis indicates that more robust emission values are permissible than those proposed by the AWS-1 vendors.

Specifically, with respect to the mobile-to-mobile blocking potential, Ofcom concluded after testing 3G mobile station equipment (*i.e.*, handsets) that the performance of such equipment with respect to blocking was significantly better than expected. In fact, this study demonstrated adequate performance with adjacent-channel interferer power of up to -10 dBm or greater.[79] Ofcom concluded that the potential for blocking was very low, even for hot-spot situations.[80] An analysis of component level capabilities yielded similar results.[81] M2Z expects, due to the international nature of the telecommunication vendor community, that similar performance would be available for operations in the AWS-1 band in the U.S.

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[77] *See* M2Z Further Notice Comments at 11-12. Power spectral density can be the appropriate framework for regulation of out-of-band emissions, but that is an issue that is not in dispute.

[78] *See* Technical Appendix 1, *supra*.

[79] *See* Ofcom 2500-2690 MHz Award, paragraph 5.84 ("3GPP TS 25.101 specifies that a UTRA-FDD terminal station receiver should be able to apply a linear ACS of 33 dB to a 1st adjacent-channel interferer received at a power level of up to 25 dBm. Measurements commissioned by Ofcom suggest that commercially available UTRA-FDD user equipment in the 2.1 GHz band perform much better than this, and can apply an ACS of 33 dB when subjected to a 1st adjacent-channel interferer power of up to -10 dBm or greater, i.e. 15 dB better than the 3GPP minimum requirements.").

[80] *See* Ofcom 2500-2690 MHz Award, paragraph 5.97 ("As can be seen, while the aggregate interferer power exceeds −25 dBm with a probability of around 10%, it does not exceed the −10 dBm saturation threshold of commercially available 3G user equipment. This implies that the probability of blocking is very low, even in hot-spot situations, and is likely to be even less of a problem than was indicated in the Discussion Document.").

[81] A review of existing cellular and PCS technology for individual components (LNAs, Mixers, downconverters, filters) was conducted by an outside consultant. The IP3 and P1dB performance for a sample of individual components and cascaded assemblies of those radio components was provided to M2Z. The results show a cascaded (LNAs, mixers) IP3 performance for a PCS chip will range from -9.3 dBm to +7.1 dBm, depending on the gain settings. Similarly, cascaded 1 dB gain compression values of -13.5 dBm or better are expected, depending on gain settings. Individual components' performance is much better, as would be expected. For example, P1dB levels for LNAs in this frequency range are above 0 dBm. The components analyzed are used in existing PCS technologies, thus these performance figures apply to the generation of technology preceding AWS. Based on the results of this independent review by Dr. Rezin, it seems reasonable to use the value of -10 dBm for a UMTS blocking threshold applied by Ofcom and derived from testing in the ERA report.

Thus, if a -10 dBm adjacent channel signal level is tolerable, then with 2 dB of body loss, even the 1.2 meter standoff supports a 33 dBm emission level for AWS-3 mobiles.[82]

3. Out-of-Band Emissions ("OOBE")

Out-of-Band emissions ("OOBE") are emissions by an adjacent channel emitter that are co-channel with the band of the receiver. The Commission's OOBE definition is "Emission on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions."[83]

Incumbent AWS-1 service providers and vendors suggest a widely varying set of proposed OOBE emission rules. Motorola and MetroPCS propose -60 dBm/MHz; T-Mobile proposes -66 dBm/MHz; SpectrumCo proposes -73 dBm/MHz; and AT&T proposes -75 dBm/MHz.[84] These respondents use a static, non-statistical analysis methodology to derive these values.

M2Z notes that there is a 15 dB spread in the values advocated among these commenters. It is also worth noting that Ericsson indicates that an AWS-1 handset has a noise floor of -103 dBm,[85] yet T-Mobile tested some handsets at -105 dBm.[86] For a 3-meter standoff, all of these commenters propose values that would have a signal at least 5.5 dB below the noise floor. Even at 1-meter standoff, only the -60 dBm/MHz level that Motorola and MetroPCS propose would be at the noise floor, and all the remaining proposals would be down to 6 dB below the noise floor.

Conversely, ArrayComm suggests that the 700 MHz rules of -3 dBm/MHz are sufficient.[87]

None of the commenters calling for exceptionally stringent OOBE limits discuss the technical challenges for solving base-to-base interference issues, which should play a central role in any interference analysis. Ofcom certainly did not ignore the base-to-base issue: "The potential for base-to-base interference plays a central role in the definition of technical conditions for spectrum use at the frequency boundaries which separate paired (FDD) and unpaired (TDD) spectrum."[88] In fact, Ofcom's decision to use a restricted block between FDD and TDD services was intended to protect the TDD base stations from OOBE from the FDD base stations.[89] T-Mobile claims that "mobile-to-mobile

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[82] 33 dBm – 2 dB – 41 dB = -10 dBm adjacent channel power at the antenna. This still assumes that the antennas are co-aligned, which will be very rare at a 1 m, high-density configuration.
[83] *See* 47 C.F.R. § 2.1(c).
[84] Motorola Further Notice Comments at 7; MetroPCS Further Notice Comments at 13; T-Mobile Further Notice Comments at 13; SpectrumCo Further Notice Comments at 5; AT&T Further Notice Comments at 17.
[85] Ericsson Further Notice Comments at 5.
[86] T-Mobile Further Notice Comments, Laboratory Test Results at 18.
[87] *See* ArrayComm Further Notice Comments at 6.
[88] *See* Ofcom 2500-2690 Award, paragraph 5.20.
[89] *See id.*, paragraph 5.42 ("As a result, a 5 MHz 'restricted' block will be mandated at every frequency boundary which separates a paired (FDD) block from an unpaired (TDD) block in the 2.6 GHz band. Base station transmissions in these restricted blocks will still be permitted, but at a significantly reduced EIRP.").

interference is more severe than other forms of interference, including base-to-base interference, and cannot be easily mitigated."[90] Yet regulatory bodies and standards organizations agree with Ofcom's assessment instead of T-Mobile's, with the ITU coming to the same conclusion that Ofcom reached.[91]

[90] T-Mobile Further Notice Comments at 17.
[91] See ITU-R M.2113 at 55 ("Due to the existence of LOS between base stations, the worst adjacent channel interference is experienced between the base stations of these two systems.").

OOBE values are imposed in order to limit the amount of potential interference to a level below the threshold for harmful interference. Ofcom has indicated that for mobile-to-mobile interference, an OOBE mask provided by the SE42 BEM[92] is sufficient to protect

Table 6: SE42 BEM for terminal stations.

Frequency	Maximum mean EIRP for out-of-block emissions
From 2470 MHz to offset of –6 MHz from lower block edge	–19 dBm/MHz
Offsets of –6.0 to –5.0 MHz from lower block edge	–13 dBm/MHz
Offsets of –5.0 to –1.0 MHz lower block edge	–10 dBm/MHz
Offsets of –1.0 to 0.0 MHz lower block edge	–15 dBm/30kHz
Offsets of 0.0 to +1.0 MHz upper block edge	–15 dBm/30MHz
Offsets of +1.0 to +5.0 MHz upper block edge	–10 dBm/MHz
Offsets of +5.0 to +6.0 MHz upper block edge	–13 dBm/MHz
Offset of +6.0 MHz from upper block edge to 2720 MHz	–19 dBm/MHz

against harmful interference. To translate these values for use in the 2155-2180 MHz band, it is necessary to address the fact that Ofcom's final configuration has the TDD operation 5 MHz away from the FDD operations due to the base-to-base interference concerns. Thus, the offsets of 5 MHz from block edge are the appropriate values. Ofcom selected an OOBE level of -19 dBm/MHz for its band plan. As indicated in Technical Appendix 1, this figure addresses the potential for interference and keeps the level of interference below the 12% capacity loss threshold for 5% of time used to identify harmful interference. Several other organizations have reached similar conclusions and used similar methods to accomplish the goal of limiting harmful interference, including the Commission in its 2500-2690 BRS/EBS rules.[93]

Ofcom also addressed the OOBE requirements for base-to-base interference. Its conclusion was:

> an edge-to-edge frequency separation of 5 MHz is required at frequency boundaries which separate paired (FDD) and unpaired (TDD) blocks, or at those which separate licensees of unpaired (TDD) spectrum, in order to allow technologically viable mitigation of *base-to-base* interference via transmit and receive filtering.

Ofcom used this offset to reach an OOBE value of -45 dBm/MHz EIRP to protect base station receivers and 4 dBm/MHz to protect mobile station receivers. That is, the

[92] *See* Ofcom April 2008 Study; CEPT Report 19, Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS at Annex IV (Rev. Mar. 17, 2008), *available at* http://www.erodocdb.dk/doks/filedownload.aspx?fileid=3451&fileurl=http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP019.PDF.

deployment can utilize filters and appropriate spatial technique to provide more protection for base station receivers that are within line-of-sight of the base station.

4. Additional Analysis

The results presented in this section rely heavily on the April 2008 study conducted by Ofcom and a similar analysis completed in 2007 by the ITU. The ITU report concluded that:

> The adjacent channel interference from 802.16 TDD to enhanced CDMA-DS downlink is negligible for all scenarios. No additional isolation from 802.16 base station to CDMA-DS mobile station and from 802.16 subscriber station to CDMA-DS mobile station is required.[94]

Therefore, the ITU concurs with the use of statistical techniques and reached a similar conclusion to Ofcom's.

5. Conclusion

The technical rules to enable TDD/FDD coexistence have been studied thoroughly by the international regulatory community, which has determined that base-to-base interference often may be a more egregious interference scenario than mobile-to-mobile interference. The record in this proceeding indicates that spurious emissions are not of concern with respect to the AWS-3 band plan and that in-band AWS-3 mobile power levels of 33 dBm provide sufficient blocking protection. Finally, the statistical analyses conducted by Ofcom and the ITU affirm the evidence provided by M2Z (and supported by ArrayComm) indicating that the mobile-to-mobile OOBE interference potential can be appropriately managed using OOBE limits of -13 dBm/MHz to -19 dBm/MHz.

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[93] *See* ITU-R Report M.2113 at 55; 47 C.F.R. § 27.53(*l*).
[94] See ITU-R M.2113 at 55.

Appendix 4: Protection of MSS Services

Overview

The same rules that are used to protect AWS-1 should apply to the MSS bands:

- Currently available equipment provides sufficient blocking protection at levels as high as -10 dBm.
- Statistical analysis done by Ofcom supports the evidence provided by M2Z (and supported by ArrayComm) that the mobile-to-mobile OOBE interference potential can be appropriately managed using -13 dBm/MHz to -19 dBm/MHz limits.

MSS consists of the satellite downlink and the ancillary terrestrial component ("ATC") downlink. The ATC downlink is used primarily to enable MSS to offer high-quality, mobile services to users inside buildings and in urban areas, in addition to providing MSS in rural areas.

The technical rules proposed by MSS providers TerreStar and ICO to protect their downlink operations in the 2180-2200 MHz band are quite different from one another. ICO proposes an OOBE level of -60 dBm/MHz at 2180 MHz, as well as a guard band of 10 MHz.[95] TerreStar proposes adopting a base emission limit of 32 dBW/5 MHz, excluding mobile and portable operations from the 2175-2180 MHz, and setting an OOBE level of 70 + 10 Log (P) at 2180 MHz.[96] MetroPCS also addresses MSS, suggesting in a proposed band plan that AWS-3 operation be limited to 2160-2180 MHz. MetroPCS indicates that if statistical analysis were appropriate, then the MSS band which is not as intensively used would be less likely to experience interference.[97]

The statistical analysis methodology described in Technical Appendix 1 also applies when analyzing the potential for MSS interference. MSS operations in low user-density areas such as rural areas will have a significantly reduced chance of simultaneously operating and being in close proximity to transmitting AWS-3 mobiles. Although MSS receivers may have greater sensitivity, MSS user density will be low. The probability of an interference event will be much lower even than for AWS-1 users, and the probability of harmful interference is remote.

MSS operations in high user-density areas such as urban areas will be conducted with ATC. Thus, the same operational scenarios should exist as have been presented for the protection of AWS-1 operations, but with fewer subscribers. The statistical analysis that Ofcom[98] and Alion[99] performed indicated that the most likely scenario for interference events will be in high user-density areas, though both analyses still concluded that the probability of an interference event is low.

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[95] *See* ICO Further Notice Comments at 8, 13.
[96] *See* TerreStar Further Notice Comments at 2-3.
[97] *See* MetroPCS Further Notice Comments at 12 n.32.
[98] *See* Ofcom 2500-2690 MHz Award.
[99] *See* Alion Analysis.

Appendix 5: Alternate Band Plans

Overview

- ICO and Wireless Strategies indicate that a 2 MHz offset is sufficient to protect cellular mobile reception from TDD mobile transmission.
- The highest spectral efficiency is achieved from use of TDD technology in unpaired bands.
- The band plan proposed in the Further Notice is the most efficient band plan overall.

1. Several alternate band plans have been suggested, but they do not adequately consider the trade-offs in terms of spectrum efficiency

Some commenters suggest alternative band plans, with proposals ranging from specifying guard bands to completely reallocating the H-Block, AWS-2, and AWS-3 spectrum bands.[100] Nearly all of these commenters advocate use of the AWS-3 band for downlink-only operation using an FDD technology in paired spectrum. For example, Ericsson suggests that "[a] more efficient and technically rational use of the AWS-3 band would be to allow for downlink-only transmissions in the band and asymmetric pairing with existing AWS-1 uplink spectrum."[101] Virtually all of these commenters use an argument based on improved spectrum efficiency to justify alternate band plans. An even more extreme example is MetroPCS's accusation that by adopting the Further Notice's proposed service rules "the Commission [would be] violating its statutory mandates: (a) to use spectrum efficiently, and (b) to seek to recover for the public a fair value for scarce spectrum. In effect, the Commission would be wasting potentially-valuable spectrum in order to achieve a result that is speculative at best."[102]

A detailed analysis of each alternative band plan is not possible within the scope of these appendices, but in evaluating each alternative the Commission should use a common yardstick in comparing them to the Further Notice proposal: that is, the Commission should evaluate whether spectrum efficiency is gained or lost as compared to the Further Notice proposal. Several respondents make this very point, while making broad statements that "[e]fficient use of spectrum resources should be a goal of spectrum management policy."[103]

The ICO band plan provides a good illustration of the type of preliminary considerations that must be addressed before seriously considering any such alternative band plan, as ICO's proposal contains many altered features: different guard bands, reallocation of several bands, and down-link only provisions. We rebut and clarify here the premises behind certain assertions developed in the ICO's alternative band plan submitted with its comments to the Commission on July 25, 2008.

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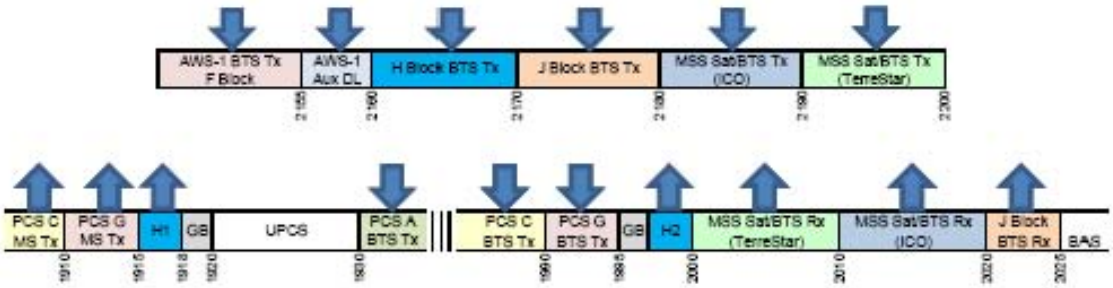
[100] *See* ICO Further Notice Comments at 10.
[101] *See* Ericsson Further Notice Comments at 10.
[102] *See* MetroPCS Further Notice Comments at 6.
[103] *See* Nokia Further Notice Comments at 3; *see also* MetroPCS Further Notice Comments at 6.

ICO suggests replacing 20 MHz of spectrum available for both TDD and other technologies with an asymmetric 10 MHz downlink and 6 MHz uplink FDD allocation.[104] The figure below illustrates the revised band structure advocated by ICO. The key features of this proposal are a reduction in the number of guard bands from four to two, a reduction in the size of the guard bands to 2 MHz, and overall reconfiguration of the band for paired spectrum based on current FDD technology.



2. The ICO Example: Claims of new 2 MHz guard bands and improved interference

Assuming for the moment that all other things are equal, reducing the number of transmitter-to-receiver boundaries (and the corresponding number of guard bands) from four to two would save some spectrum, as ICO suggests. However, not only the spectrum savings claims, but also claims about interference and required guard-band size, should be treated similarly when comparing the Further Notice band plan to the proposed alternative band plan. If the FCC agrees that the 2 MHz guard-bands advocated in the alternative band plan are adequate to protect UPCS and G-block PCS (primarily Nextel), then that may also be the case for preventing TDD WiMAX harmful interference to AWS-1. Data and analysis by Ofcom suggests that guard bands for TDD/FDD boundaries may indeed be relaxed, and certainly may be far less than the 10, 12, and 15 MHz boundaries that have been proposed by some AWS-1 licensees.

There should be no double standard in applying guard bands. If 2 MHz guard-bands are adequate to protect UPCS and G-block PCS (primarily Nextel), then they are sufficient for AWS-1.

3. The ICO Example: Doing a real comparison of spectrum efficiency

It is our contention that all other things are not equal when comparing the spectrum efficiency and capacity of FDD and TDD. This contention applies to all of the responses advocating downlink-only operations. We agree that spectral efficiency should be a key objective, but do not agree that FDD implementations under an alternative band plan

[104] *See* ICO Further Notice Comments at 10.

would offer superior efficiency. FDD is a proven legacy duplex architecture, but it does not enable some of the emerging, advanced technologies that have now themselves been proven to be practical, efficient, and effective. TDD, on the other hand, does readily allow for these innovative technologies.

Should M2Z obtain the AWS-3 license, we intend to use Adaptive Antenna Systems ("AAS"), which enable Spatial Diversity Multiple Access ("SDMA"). Vendors of such advanced antenna systems indicate that spectrum efficiency can be increased two-fold or more in some instances.[105] Additionally, link budget enhancement achieved from use of such advanced smart antenna technology can further increase efficiency by supporting higher-order modulations (see Ref 1). This AAS/SDMA technology is optimized for TDD.[106] Since the TDD transmitters and receivers use the same frequency, TDD provides for accurate, dynamic, rapid antenna weighting algorithms to maintain each link in a separate "spatial channel" on a packet-by packet basis, even for mobile deployments. FDD implementations do not achieve the same high levels of efficiency achieved in TDD implementations.

Other advanced technologies are uniquely enabled in an OFDMA TDD architecture as well. For example, TDD offers the ability to dynamically and adaptively manage the ratio of capacity dedicated to uplink vs. downlink traffic, providing an additional degree of freedom for optimizing the efficiency of the network through timeslot and sub-channel management. This flexibility improves the efficiency of spectrum use by a significant factor by making available the use of uplink and downlink capacity in exact proportion to the instantaneous demand.[107] Fixed allocations present in FDD operations do not offer the ability to implement advanced technologies that adaptively swap uplink capacity for downlink capacity, rendering the FDD operations less efficient for uses characterized by the fluctuating demand typical of AWS deployments.

Spectral efficiency should indeed be a key objective for the Commission. A real "apples-to-apples" comparison of spectrum efficiency must be a key consideration in evaluating alternate band plans, and on the basis of such comparisons it is clear that FDD does not offer superior efficiency.

To illustrate this point, we have recalculated the capacity table originally offered by ICO.[108] The table below recalculates the total capacity based on application of the same guard band sizes (2 MHz) for both the Further Notice and alternate band plans, and adds a conservative factor of 1.8 in additional efficiency for TDD operations utilizing the advanced technologies described above.

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[105] See ArrayComm data on practical implementations of AAS and SDMA, *available at* http://www.arraycomm.com/serve.php?page=practice.
[106] *See* ArrayComm Further Notice Comments at 2-3.
[107] *See id.* at 4.
[108] *See* ICO Further Notice Comments, Exhibit B, slide 8.

	Parameter	FNPRM Approach		Alternate FDD		
	Band	AWS-3	H-Block	New H Block	New J Block	Aux. Downlink
	Structure	TDD	FDD	FDD	FDD	Unpaired DL
	Total Spectrum (MHz)	25	10	20	15	5
Downlink Analysis	Guard Band (MHz)	4	0	0	0	0
	Usable Spectrum (MHz)	21	5	10	10	5
	Time Division Duplexing	67%	100%	100%	100%	100%
	bps/Hz	2.52	1.4	1.4	1.4	1.4
	Capacity (Mbps)	35.4564	7	14	14	7
	Total DL Capacity (Mbps)	42.4564		35		
Uplink Analysis	Guard Band (MHz)	4	0	4	0	0
	Usable Spectrum (MHz)	21	5	6	5	0
	Time Division Duplexing	33%	100%	100%	100%	100%
	bps/Hz	1.44	0.8	0.8	0.8	0.8
	Capacity (Mbps)	9.9792	4	4.8	4	0
	Total UL Capacity (Mbps)	13.9792		8.8		

This table reproduces the Performance Comparison offered in Slide 5 of Wireless Strategy's ex parte presentation of 3 July, entitled Affordable Family Friendly Broadband Alternate FDD Proposal, with the following modification in a Revised NPRM (RNPRM) Approach :
Applies both a spectrum efficiency increase by a factor of 1.8 and 2 MHz guardabnds.

In an "apples-to-apples" comparison, it makes no sense to exchange the Further Notice band plan that yields 56 Mbps of capacity in 35 MHz of spectrum for a new band plan that would deliver 44 Mbps of capacity in 40 MHz of spectrum – especially where the alternate plan essentially would prevent implementation of these and other advanced technologies optimized for TDD that could promise further improvements.

While ICO claims to recover perhaps 6 MHz out of a total 35 MHz (17%) in spectrum previously needed for guard bands, the inability under this FDD-centered proposal to employ advanced technologies may cost a factor of nearly 2 (perhaps more) in the capacity that would be yielded by the AWS-3 band if retained as unpaired spectrum. Supporting such advanced technologies is consistent with the Commission's "new technology" mandate in Section 7 and with Commission precedent supporting TDD.[109]

4. Conclusion

For the reasons discussed above, the Commission should reject any alternative band plan that advocates restriction to downlink-only use, which would make the band useful only to existing FDD licensees. While we applaud the effort to minimize guard-bands, we urge the Commission to evaluate the effect of any alternative band plan in a context that assesses the value of advanced radio technologies enabled by TDD. Thanks to the advances that accompany TDD technology, islands of unpaired spectrum can be equally as useful as, or even more useful than, traditional paired spectrum.

[109] *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*, Third Report and Order, 18 FCC Rcd 2223, ¶¶ 68-69 (2003); *see also Service Rules for Advanced Wireless Services in the 1.7 and 2.1 GHz Bands*, Report and Order, 18 FCC Rcd 25162, ¶ 46 (2003).

Appendix 6: 700 MHz Rules Should Serve as Precedent for the AWS-3 Technical Rules

Overview

- The Commission explicitly allowed paired, unpaired, FDD, and TDD services in the 700 MHz bands;
- A 43 + 10 log (P) OOBE rule for AWS-3 would provide the same protection as Upper-700 MHz C-Block is required to provide to Public Safety narrowband receivers; and
- Equipment standards for TDD services were not completely developed due to the marketplace. Incumbent FDD service providers obtained the 700 MHz licenses; and

M2Z has argued that the Commission should be guided by its own precedent in the 700 MHz proceeding in resolving the Further Notice. The technical aspects of the rules proposed by the Commission in the Further Notice are closely aligned with the rules that the Commission adopted for the 700 MHz bands, which, by design, provide licensees with the flexibility to implement technical solutions that are most appropriate to their broadband networks while protecting other licensees from harmful interference.

AT&T and T-Mobile argue that the 700 MHz rules are not a valid precedent for AWS-3 because the FCC explicitly provided for flexible uses, including TDD, in 700 MHz, but according to these commenters the Commission specified flexible use less explicitly with respect to AWS-3. Finally, these commenters claim that the Commission led the industry to believe that FDD was the *de facto* (but not explicit) standard for AWS-3.[110] In August 2005, however, the FCC released the AWS-1 service rules authorizing paired FDD service and explicitly assigning certain uplink and downlink blocks.[111] By contrast, in August 2007, the FCC adopted the 700 MHz service rules with much of the band authorized for flexible use, and containing both paired and unpaired blocks without explicit requirements for either the service to be provided or the uplink and downlink blocks.[112] Thus, the Commission has shown that it knows how to establish service rules authorizing either specific or flexible uses, when appropriate. AT&T and T-Mobile have not provided any evidence demonstrating that the Commission meant to preclude flexible use in the AWS-3 band on a *de facto* basis, but without expressly doing so.

Both AT&T and T-Mobile also argue that in the 700 MHz proceeding the Commission provided extra protections against interference to the Public Safety mobile receivers, and argue by analogy for additional protections here.[113] But if they wish to argue for the same level of protection, these incumbent licensees should at least understand that they

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[110] *See* AT&Y Further Notice Comments at 28-34; T-Mobile Further Notice Comments at 19-20.
[111] *See Service Rules for Advanced Wireless Services in the 1.7 GHz and 2.1 GHz Bands*, Order on Reconsideration, 20 FCC Rcd 14058 (2005).
[112] *Service Rules for the 698-746, 747-762 and 777-792 MHz Bands*, Second Report and Order, 22 FCC Rcd 15289, ¶ 69 (2007).
[113] AT&T Further Notice Comments at 29; T-Mobile Further Notice Comments at 20.

already would receive that level of protection under M2Z's proposal. 65 + 10 log (P) over 6.25 kHz is the 700 MHz C-Block mobile OOBE limit into Public Safety,[114] which is equivalent to 65 + 10 log (P) - log(1000 kHz/6.25 kHz) = 43 + 10 log (P) over 1 MHz. The protection is, in fact, higher than 43 + 10 log (P) over 100 kHz, which would be equivalent to 33 + 10 log (P) over 1 MHz. Both AT&T and T-Mobile make the identical mathematical error, thereby failing to realize that the M2Z's proposed OOBE limits would afford them the same protections afforded in the 700 MHz band.

AT&T and T-Mobile also make arguments that AWS-1 auction participants were not aware prior to the AWS-1 auction that the Commission might authorize TDD in AWS-3.[115] As explained in our reply comments, and in numerous earlier filings, this argument is utterly without merit.[116] Parties have had notice of the potential deployment of TDD in AWS-3 for at least five years, since the issuance of the Commission's 2003 AWS-1 service rules order.[117] More recently, the Commission affirmed that "parties have had notice of the possibility that TDD operations would be permitted in the AWS-3 band since at least the issuance of the AWS-3 Notice of Proposed Rulemaking in WT Docket No. 07-195 nearly one year ago."[118]

Additionally, T-Mobile and AT&T argue that there were no standards issued for TDD deployment in the 700 MHz bands, suggesting that despite explicit statements by the Commission that TDD was allowed in the bands, industry viewed FDD as the d*e facto* use of the band .[119] First of all, the equipment standards process was ongoing within the 3GPP, 3GPP2, and WiMAX organizations when the 700 MHz rules were being developed and the 700 MHz auction was being planned. The WiMAX forum was developing both TDD and HFDD technical standards.[120] 3GPP2 was developing UMB and 3GPP was primarily developing UTRA (UMTS) standards. The 3GPP2 and WiMAX significantly reduced their efforts after 1) most licenses were obtained by incumbent FDD

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[114] *See* 47 C.F.R. § CFR 27.50.
[115] *See* T-Mobile Further Notice Comments at 20; AT&T Further Notice Comments at 28.
[116] *See, e.g.*, M2Z Further Notice Comments at 14-15 and n.39.
[117] *See* M2Z Further Notice Comments at 14-15 and n.39; *see also* Letter from Uzoma Onyeije, M2Z, to Mr. Matthew Berry, General Counsel, Federal Communications Commission, WT Docket Nos. 07-195 & 04-356, at 2-3 (filed June 23, 2008); Letter from Uzoma C. Onyeije, M2Z, to Ms. Marlene H. Dortch, WT Docket Nos. 07-195 & 04-356, at 1-3 (filed June 5, 2008); Letter from Uzoma C. Onyeije, M2Z, to Ms. Marlene H. Dortch, WT Docket Nos. 07-195 & 04-356 (filed June 3, 2008) ("AWS- 2 AWS-3 Timeline").
[118] *See Service Rules for Advanced Wireless Services in the 2155-2175 MHz Band; Service Rules for Advanced Wireless Services in the 1915-1920 MHz, 1995-2000 MHz, 2020-2025 MHz, and 2175-2180 MHz Bands*, WT Docket Nos. 07-195 & 04-356, Order, DA 08-1614 (rel. July 8, 2008) (noting further that "parties have already been in the process of commenting and engaging in a meaningful dialogue about these issues in response to the AWS-3 NPRM.").
[119] *See* T-Mobile Further Notice Comments at 20; AT&T Further Notice Comments at 31.
[120] See WiMAX Forum® Position Paper for WiMAX Technology in the 700 MHz Band, *available at* http://www.wimaxforum.org/technology/downloads/wf_700mhz_messaging_white_paper_final.pdf, which documents TDD operator interest in the 700 MHz band in the United States.

service providers and 2) AT&T and Verizon indicated their decision to deploy LTE equipment.[121]

[121] *See* "Verizon confirms LTE 4G network trials with Vodafone; to share with AT&T," *available at* http://www.intomobile.com/2007/11/29/verizon-confirms-lte-4g-network-trials-with-vodafone-to-share-with-att.html.

Appendix 7: AWS-1 Receiver Filters

Overview

- Incumbent AWS-1 licenses now acknowledge that they opted to use in the U.S. receiver filters designed for use in the European market, where a different band plan applies.
- Economies of scale could be quickly realized in the production of receiver filters more appropriate for the U.S. market
- The U.S. had and has no obligation to conform its band plan to that adopted in other nations.

The AWS-1 licensees[122] generally admit that mobile models in the supply pipeline have receiver passbands that cover 2110-2170 MHz. Moreover, a review of commercially available filters and tests of AWS-1 handsets on sale in the U.S. indicates that while 2110-2170 MHz is the nominal coverage of the receiver bandpass, the actual coverage of the filters is really 2110-2180 MHz.[123] While the U.S. AWS-1 downlink band is 2110-2155 MHz, the European band does indeed go to 2170 MHz. Thus, it appears that the handsets in the supply pipeline for the U.S. have incorporated filters designed for the European market.

It has been difficult to secure reliable information from vendors who have supply relationships with incumbent licensees about how difficult it would be to produce filters that are better suited for the U.S.-licensed band. However, in order to illuminate the issue, M2Z submits the attached affidavit (See Appendix 9) from Dr. Hector de los Santos ("Affidavit"), an experienced filter designer. Dr. de los Santos avers on the basis of his experience that a filter matching the U.S. band plan can be designed and introduced into large scale production using presently available technologies.[124] As Dr. de los Santos makes clear, no such filters are presently available simply because they were not requested by the manufacturers and licensees, who apparently could not envision that the Commission might adopt technical service rules not in lock-step with CEPT despite numerous occasions on which the Commission has taken such steps.

Corroborating this view, while no filter manufacturer has been willing to state on the record that it can build such a filter – perhaps because of an unwillingness to contradict existing customers – several manufacturers have told M2Z off the record that such a filter could be designed and manufactured in a timely and expeditious manner.

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[122] *See* T-Mobile Further Notice Comments, Laboratory Test Report at 10.

[123] This is probably because those developing specifications for these mobile units expected the upper neighbor of the AWS-1 downlink band to be an MSS downlink that was not an interference threat. A review of sales literature for such filters shows no performance specification between 2170 MHz and 2205 MHz, which suggests that the handset manufacturers ordering such filters and their carrier customers did not pause to consider receiver filter performance in this frequency range that encompasses the entire AWS-3 band.

[124] Dr. de los Santos states that such filters could have "insertion loss lower than 10dB in the 2110-2155 MHz band, and a skirt steepness of 20dB over 5MHz in the 2150-2155 frequency range." Affidavit at 4-5.

Predictably, Nokia argues to the contrary that "[d]esigning U.S.-specific filters would be unique and consequently more expensive as they would not benefit from global economies of scale."[125] But with the U.S. population exceeding 300 million, the failure of economies of scale to materialize is implausible, and Nokia offers no support for its assertion.

Filters for these types of mobiles would cost less than $1 in production quantities. Absent any statements in the record to the contrary from mobile or filter manufacturers, and based on the Affidavit of Dr. de los Santos, we assume that any cost increase associated with the use of U.S. band plan filters would be negligible, considering the economies of scale possible for the U.S. market. If the manufacturers felt otherwise, the appropriate time to complain would have been much earlier in the AWS proceedings, when making the U.S. band plan parallel to the European band plan was still an option.

Nokia also implies that there would be long delays associated with building new user models with the new filters.[126] While two years might be a normal design cycle, it is notable that the strategic importance of a product such as the iPhone sparked several manufacturers[127] to introduce clones less than a year after the iPhone's introduction in order to compete with the new design.

Nokia's comments also imply that the U.S. had an obligation to conform its band plan to the one adopted by other nations.[128] Of course, this is not true. There are no such treaty obligations. The only applicable treaty obligation is stated in ITU allocation footnote 5.388 which states:

> The bands 1885-2025 MHz and 2110-2200 MHz are intended for use, on a worldwide basis, by administrations wishing to implement International Mobile Telecommunications-2000 (IMT-2000). Such use does not preclude the use of these bands by other services to which they are allocated.[129]

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[125] Nokia Further Notice Comments at 5.
[126] *See id.* at 3.
[127] *See, e.g.*, Walter S. Mossberg, "Samsung's Instinct Doesn't Ring True as an iPhone Clone," All Things Digital, June 12, 2008, *available at* http://ptech.allthingsd.com/20080612/samsungs-instinct-doesnt-ring-true-as-an-iphone-clone/.
[128] *See* Nokia Further Notice Comments at 2-3.
[129] 47 C.F.R. § 2.106 note 5.388. ITU and FCC allocations for 2155-2180 MHz are simply Fixed and Mobile – although there is an ITU allocation, but no corresponding U.S. allocation, for Mobile Satellite downlinks in 2120-2170 MHz.

Appendix 8: Cognitive Techniques

Overview

- Cognitive radio technology has been considered by the Commission in the past, and recent testing has shown that detector sensitivities adequate for AWS-3 mobiles to detect nearby AWS-1 mobiles are readily achievable.
- Most AWS-1 mobiles can and will switch to alternative bands in the rare instance in which they encounter an inadequate signal due to either poor AWS-1 coverage or interaction with a very close AWS-3 mobile that is transmitting. Some small carriers do not have coverage in other bands, but generally these carriers cover low population density areas where AWS-1 to AWS-3 close range interaction would not likely occur.

MetroPCS raises the issue of using cognitive radio techniques to minimize any residual threat of AWS-3 mobile to AWS-1 mobile interference.[130] Since this interference can only occur under specific circumstances that include close proximity of an AWS-3 mobile to a specific AWS-1 mobile that has a design vulnerability to adjacent channel interference, detection of the uplink signal of the AWS-1 mobile by the AWS-3 mobile seems straightforward. The Commission has already examined cognitive radio issues in both the Spectrum Policy Task Force setting[131] as well as its Cognitive Radio rulemaking.[132] The Commission has stated that cognitive radio is a promising technology for reducing interference, saying:

> "We recognize the importance of new cognitive radio technologies, which are increasingly being used in spectrum-based communication systems and are likely to become more and more prevalent over the next few years. These technologies hold tremendous promise in helping to facilitate more effective and efficient access to spectrum by opening opportunities for spectrum use in space, time, and frequency dimensions that until now have been unavailable. The ability of cognitive radio technologies to adapt a radio's use of spectrum to the real-time conditions of its operating environment offers regulators, licensees, and the public the potential for more flexible, efficient, and comprehensive use of available spectrum while <u>reducing the risk of harmful interference</u>."[133] (Emphasis added)

FCC Laboratory testing is now ongoing in ET Docket No. 04-186 to determine the sensitivity of signal detectors for DTV transmissions that might be used in cognitive "white space devices" in TV broadcast spectrum. This topic of TV white space is very controversial and complex. However, before the testing began, many doubted that practical detectors of DTV signals could operate at signal levels of -114 dBm or less. While the results of the FCC testing have not yet been published, the testing was open to

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[130] *See* MetroPCS Further Notice Comments at 20.
[131] *See generally* ET Docket No. 02-135.
[132] *See generally* ET Docket No. 03-108.
[133] *Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies*, Report and Order, 20 FCC Rcd 5486, ¶ 18 (2005).

the public and it is clear that at least two of the prototype models that were tested consistently and reliably detected signals at power levels less than -120 dBm.[134]

M2Z has previously indicated that AWS-1 mobiles experiencing interference would generally switch to alternative bands, as they do when they leave a coverage area. AT&T points out that some carriers, such as MTA Communications, Inc., only have coverage in one band and in a limited area.[135] M2Z acknowledges that there are a small number of carriers like MTA Communications, but such small carriers generally cover low-density areas (Alaska REAG-7 in the case of MTA) and in these areas, the likelihood of AWS-3 to AWS-1 mobile-to-mobile interference becomes vanishingly small. With proper engineering, the likelihood of this interference will be comparable to the likelihood of dropouts due to poor spatial coverage, which is inevitable and will not be noticeable.

[134] Detectors can always be much more sensitive than actual receivers, since an actual receiver must make thousands or millions of decisions a second on whether a zero or a one was sent. But the detector can take a long time, perhaps a second, to make a decision about whether or not a signal of a known structure is present. The ratio of the difference of decision times in the two cases is the "processing gain" sensitivity advantage that the detector can theoretically have over a normal receiver. *See* presentation given by Dr. John Betz of MITRE Corp. at FCC/OET Tutorial, February 12, 2003, which is available at http://www.fcc.gov/realaudio/presentations/2003/021203/featuredetection.pdf.

[135] AT&T Further Notice Comments at 21.

Appendix 9: Affidavit of Hector J. de los Santos, PhD Regarding Filter Technology

AFFIDAVIT OF HECTOR J. DE LOS SANTOS, Ph.D., F-IEEE

The undersigned affiant, Hector J. De Los Santos, hereby declares:

1. I am over the age of eighteen, suffer no legal disabilities and have personal knowledge of the facts set forth below.

2. I am sufficiently qualified to render an opinion regarding radio frequency ("RF") microelectromechanical (MEMS) filters. I hold a Ph.D. degree in electrical engineering from Purdue University. I was elected as a Fellow of the Institute of Electrical and Electronics Engineers "for contributions to radio frequency (RF) and microwave micro electromechanical systems (MEMS) devices and applications." Since 1993, I have been primarily working on issues relating to advanced device and circuit technologies for wireless communications. Specifically, I was employed at Hughes Space and Communications Company (HSC), Los Angeles, CA, for more than 10 years (1989-2000) where I served as Principal Investigator and Director of the Future Enabling Technologies IR&D Program. Under this program I pursued research in the area of RF MEMS Devices and Circuits. From 2000-2002, I was Principal Scientist at Coventor, Inc., Irvine, CA, where I led Coventor's intellectual property R&D effort, with activities including the conception, modeling, and design of novel RF MEMS devices. Since 2002 I am President and CTO of NanoMEMS Research, LLC, Irvine, CA, where I am engaged in RF MEMS and Nanotechnology R&D and consulting. I hold 16 US patents and have authored four books, including *Introduction to Microelectromechanical (MEM) Microwave Systems,* Norwood, MA: Artech House, (1999), *RF MEMS Circuit Design for Wireless Communications,* Norwood, MA: Artech House, 2001, and *Principles and Applications of NanoMEMS Physics*, Dordrecht: The Netherlands: Springer, 2005.

3. I have reviewed the technical literature to assess the feasibility of realizing a filter with an insertion loss lower than 10dB in the 2110-2155 MHz band, and a skirt steepness of 20dB over 5MHz in the 2150-2155 frequency range for use in mobile phone duplexers.

   Based on my review, I have concluded that there exist a number of design and manufacturing degrees of freedom (DOF) that are exploitable to engineer the filter characteristics of interest. The film bulk acoustic wave resonator (BAW)-based filter design feasibility issue is fully explained below.

BAW FILTER DESIGN FEASIBILITY EXPLAINED

4. Filter performance is fundamentally linked to the type of resonators it employs. In duplexers for mobile phones, these resonator technologies are implemented in two configurations, namely, the membrane-supported BAW, referred to as FBAR resonator, and the solidly-mounted BAW, referred to as SMR resonator[1]. These are piezoelectric resonators based on aluminum nitride (AlN) piezoelectric material[2]. The general configuration of these resonators is shown in Figure 1. [1]

[1] K.M. Lakin, et al, "Improved Bulk Wave Resonator Coupling Coefficient For Wide Bandwidth Filters," *IEEE 2001 Ultrasonics Symposium*, Paper 3E-5 October 9,2001.

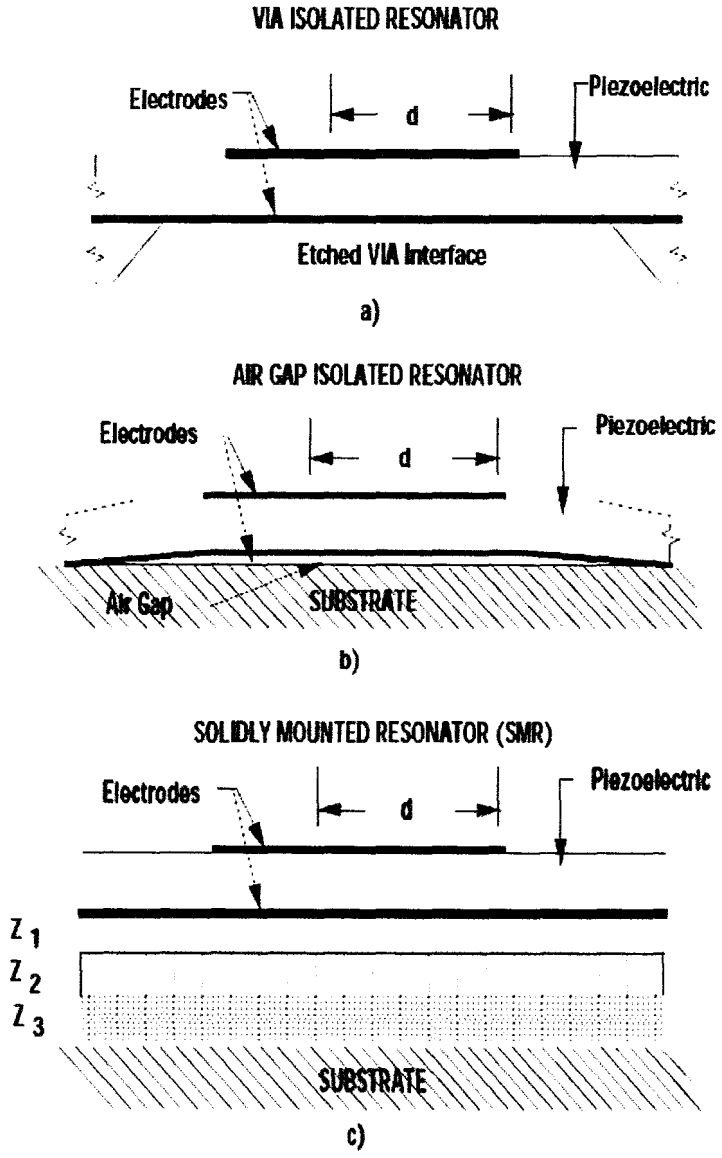
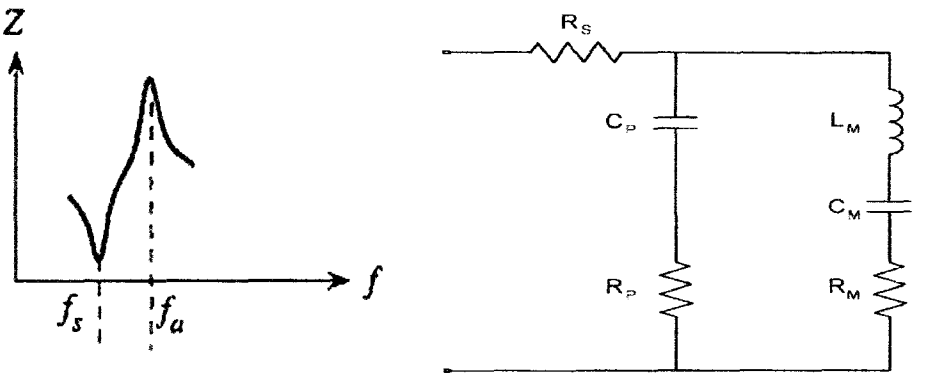


Figure 1. Thin film resonator configurations suitable for implementation with thin films[1]. a) Membrane formed by etching a VIA in the substrate. b) Air gap isolated resonator. c) Solidly Mounted Resonator (SMR) using a reflector array to isolate the resonator from the substrate. The first two are known as Film Bulk Acoustic Resonators , FBAR.

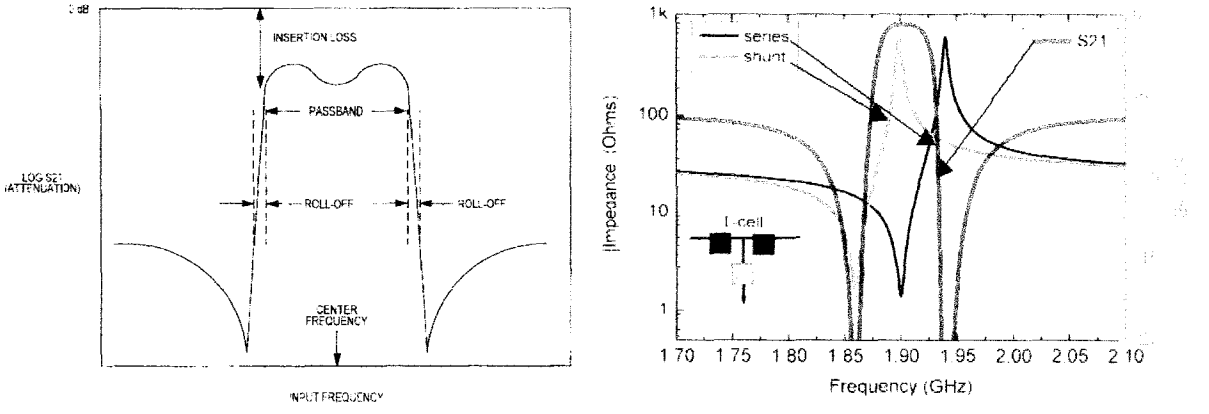
5. Whether SMR or FBAR, BAW resonator impedance versus frequency behavior is characterized by series and parallel resonance frequencies, fs and fa, respectively, at which their impedance is a minimum (Rs) and maximum (Ra), respectively, Figure 2, and by the quality factors Qs and Qa at each resonance. The difference between the resonance frequencies, fa and fs, captures the rapidity with which the impedance transitions between minimum and maximum values. This rapidity is related, in turn, to the effective acoustic coupling parameter, kt^2, given by $kt^2 = \phi/\tan(\phi)$ where $\phi = 1.571\, fs/fa$ [1]. Overall BAW resonator performance is characterized by its kt^2-Q product figure of merit, $FOM = kt^2 * Q$[1]. Notice that for a given resonator kt^2 is not a function of frequency.

Figure 2. (a) Impedance versus frequency behavior of BAW resonator. (b) Circuit model of BAW resonator



(a) (b)

6. BAW resonators, electrically connected in a ladder topology, determine the filter parameters, namely, its insertion loss, bandwidth, and roll-off (skirt selectivity), Figure 3(a), as follows. The shunt resonators are parallel resonant near the frequency where the series resonators are series resonant. Thus, see Fig. 3(b), the lower skirt is set by series resonance frequency of the shunt branches, and the upper skirt is set by parallel resonance frequency of series branches; this sets the filter bandwidth (BW). The pass band insertion loss is set by the resistance at series resonance of the resonators in the series branches. From the sketch in Fig. 3(b), it is apparent that the skirt will be steepest when the effective coupling kt^2 is smallest, and this would correspond to a narrower bandwidth filter. Indeed, a well known rule of thumb is that the filter BW in percent is half the value of kt^2, which is given in percent[2]. Thus, BAW resonators with FBARs with kt^2=4.2% would produce a filter with a 2.1% BW.



(a) (b)

Figure 3. (a) General filter characteristics. (b) Synthesis of filter characteristic using BAW resonators.

7. In general, the number of resonators (the number of sections in the ladder) determines the steepness of the skirt selectivity and to a certain extent filter bandwidth[1]. High kt^2*Q directly impacts the corners of the pass band filter response, in particular, the higher this product, the sharper the corners[1]. A design trade-off between kt^2 and Q can be made to optimize filter characteristics.[1,2]

OPTIMIZATION OF BAW FILTER CHARACTERISTICS

8. A number of techniques have been discovered to optimize the characteristics of BAW filters. These embody degrees of freedom (DOF) that could be exploitable to engineer the AWS-3 filter characteristics of interest[3]. For example, in duplexers, the effective coupling coefficients of FBARs in a transmit band-pass filter are fabricated to have a lower effective coupling coefficient than the FBARs of the receive band-pass filter of the same duplexer. This is achieved in various ways[3]:

1) The difference in the effective coupling coefficients may be effected by varying the thicknesses of the electrode layers;
2) The effective coupling coefficient of an acoustic resonator may be modified by varying the ratio of the thickness of the piezoelectric layer to the total thickness of the electrode layers;
3) The effective coupling coefficient may be reduced by forming a capacitor in parallel with at least some of the resonators of the Tx filter;
4) The effective coupling coefficients of individual resonators within a full duplexer are tailored, so that the roll-off at the opposite edges of the passband can be tailored;
5) Each of the shunt FBARs is coupled to ground through an external inductor. The inductors may be used to position the attenuation poles of the shunt bars, so that the pass band response exhibits the desired characteristics, such as steep roll-off at the outside edges of the response.

9. In general, the BAW resonator resistance is related to the FOM as follows[4]: $Ra \sim FOM \cdot Z_0$, and $Rs \sim Z_0 / FOM$, where Z_0 is the characteristic impedance. Thus, maximizing FOM results in a low Rs and a high Ra. But, since kt^2 should be small to attain narrow bandwidths and steep skirts, this implies that such a filter should exhibit lower insertion loss (lower Rs→higher Q) and negligible pass band ripple. Indeed, steep skirts go hand-in-hand

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[2] K.R. Lakin, "Thin Film Resonators and High Frequency Filters," Available: [Online] http://www.triquint.com/prodserv/tech_info/docs/white_papers/BAW_General_Reference.pdf

[3] R.C. Ruby, et al. "Controlled effective coupling coefficients for film bulk acoustic resonators, US Patent # 6472954.

[4] R. Ruby, "Review and Comparison of Bulk Acoustic Wave FBAR, SMR Technology," *2007 IEEE Ultrasonics Symposium*, pp. 1029-1040.

[5] "Some Comments on RF Filtering." A technical presentation by Avago Technologies to Verizon Wireless, 5 December 2007.

with narrower BW filters rather than with wide band filters[5]. Several materials are being explored as BAW electrodes to lower Rs, including, Molybdenum, Tungsten and Ruthenium, as these three materials are notable for both having a high acoustic impedance and a high electrical conductivity[4].

10. The acoustic coupling kt^2 may be controllably varied by changing the electrode composition and the piezoelectric thickness. [6] Figure 4 shows simulations of the effective kt^2 versus AlN thickness for molybdenum- and tungsten-electroded FBARs, indicating that kt^2 is reduced from ~7.5% to ~1% [6]. Using Lakin's rule of thumb[1], this would imply the feasibility of filters of 0.5% BW with extremely steep skirts [5].

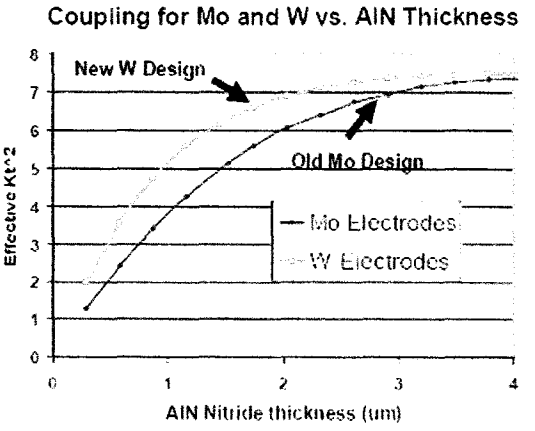

Figure 4. Simulated effective coupling of molybdenum vs. tungsten electroded FBARs as a function of piezoelectric AlN thickness. Two points are shown that were used for the old Mo and new W Tx filter designs.[6]

11. Monitoring of run-to-run variations in kt^2 obtained from production FBAR filters in the year 2000, Figure 5, indicates that indeed kt^2~2% is experimentally possible[7].

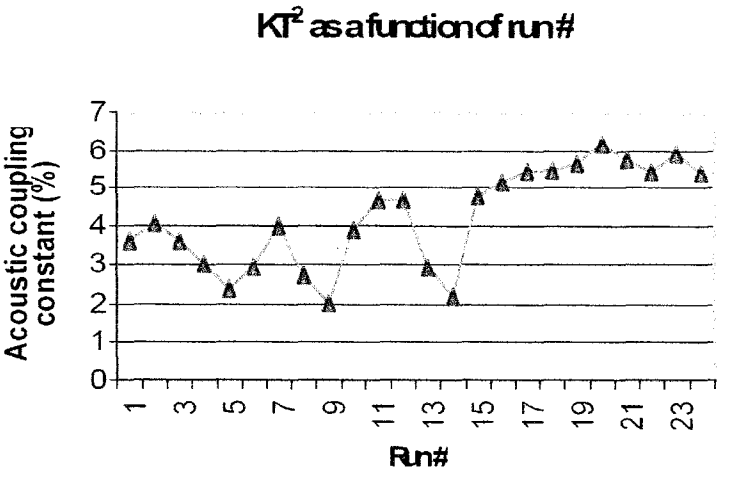

Figure 5. Plot of median kt^2 vs. lot run [7].

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[6] P. Bradley et al., "2X Size and Cost Reduction of Film Bulk Acoustic Resonator (FBAR) Chips with Tungsten Electrodes for PCS/GPS/800 MHz Multiplexers," *2007 Ultrasonics Symposium*, 28-31 Oct. 2007 Page(s):1144 – 1147.

[7] R. Ruby, "FBAR—From Technology to Production," Available:[Online]: http://www.usl.chiba-u.ac.jp/~ken/Symp2004/PDF/2C1.PDF

BAW FILTER TEMPERATURE COMPENSATION

12. BAW filter characteristics are temperature-sensitive[1]. Since the temperature coefficient of frequency (TCF) of AlN is -25 ppm per deg C, experimentally, the procedure to get compensation is to gradually increase the content of positive TC material and reduce the negative material while maintaining the same frequency [1]. Due to its positive TCF (+85ppm per deg C), silicon dioxide (SiO_2) is often used to temperature-compensate AlN. This technique of putting SiO_2 in the resonator structure, however, also has the effect of decreasing the effective piezoelectric coupling coefficient and decrease filter bandwidth [1]. A novel technique, involving the addition of a micromachined air-gap capacitor in series with an FBAR has achieved an overall TCF of only **+0.45 ppm per deg C** (between +85 deg C and +110 deg C) at 4.4 GHz[8].

13. In another recent study, dealing with the temperature compensation of SMR BAW resonators, it was determined that inserting and adjusting the thickness of SiO_2, on the top electrode and in the Bragg reflector, together with those of AlN and Mo, allows the thermal stability to be improved. This study indicated that reaching a **zero TCF of the parallel resonance frequency, fa,** is possible while keeping realistic layer thicknesses[9].

14. Based on the above results [8, 9], it is my expert opinion that there are sufficient DOF to engineer BAW resonators with zero, or very close to zero TCFs.

BAW FILTER MANUFACTURING YIELD

15. The successful manufacturing of commercially available BAW filters has been the result of overcoming many complex obstacles. For example, minimizing energy loss required: 1) Keeping ohmic series resistances of electrodes and interconnects below approx. 500mΩ/resonator; 2) Minimizing the vertical acoustic energy leakage through the Bragg reflector by choosing the proper materials and number of mirror-pairs; and 3) Optimizing the lateral acoustic energy trapping [10]. To achieve yields greater than 80%, it was necessary to conceive and implement a method of trimming, to correct run-to-run variations, and a method of localized wafer processing to address uniformity issues.

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[8] Wei Pang, Hongyu Yu,Hao Zhang, and Eun Sok Kim, "Temperature-Compensated Film Bulk Acoustic Resonator Above 2 GHz," *IEEE ELECTRON DEVICE LETTERS*, VOL. 26, NO. 6, JUNE 2005, pp. 369-371.

[9] Brice Ivira et al, "Modeling for Temperature Compensation and Temperature Characterizations of BAW Resonators at GHz Frequencies," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 55, no. 2, February 2008, pp. 421-430.

[10] Robert Aigner *et al.*, "Bulk-Acoustic-Wave Filters: Performance Optimization and Volume Manufacturing," *2003 IEEE MTT-S Digest*, pp. 2001-2004.

AWS-3 BAW FILTER DEVELOPMENT EXPECTATIONS

16. BAW filter technology has been in mass production for more than 5 years, with current shipping volumes into the millions per month[11]; in my expert opinion, this is evidence of the considerable technical experience and skill accumulated. The many DOF available for device optimization and the application of these highly experienced and skillful individuals to a dedicated effort, together with the latest advances in fabrication infrastructure, should minimize the development risks involved. These factors, among others, in expert my opinion, make it plausible that a filter with an insertion loss lower than 10dB in the 2110-2155 MHz band, and a skirt steepness of 20dB over 5MHz in the 2150-2155 frequency range for use in mobile phone duplexers could be developed. Given the maturity of the technology, it would be reasonable, in my expert opinion, to expect that the long term costs would be comparable to filters presently used.

I declare under the penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

This the 10th day of August, 2008.

Hector J. De Los Santos

Hector J. De Los Santos, Ph.D., F-IEEE
Kevin Kennedy & Associates, Inc
3405 Vincennes Road, Suite 320
Indianapolis, IN 46268

Sworn and subscribed before me this

the _____ day of _____, 200_.

_____
Notary Public

My Commission expires: _____

see attached

[11] "Avago Technologies Ships 200 Millionth FBAR Filter for Mobile Phones, Data Cards; Industry's Smallest FBAR Filters Now Ship at More Than 15 Million/Month," *Business Wire*, Dec. 22, 2005, Available: [Online]: http://findarticles.com/p/articles/mi_m0EIN/is_2005_Dec_22/ai_n15965674.

Jurat

State of California

County of Orange

Subscribed and sworn to (or affirmed) before me on this 18 day of August, 20 08 by Hector J De Los Santos,

proved to me on the basis of satisfactory evidence to be the person(s) who appeared before me.

Signature

(Notary seal)

SHERRY K. DIZEAJI
Commission # 1592486
Notary Public - California
Orange County
My Comm. Expires Jun 28, 2009

OPTIONAL INFORMATION

DESCRIPTION OF THE ATTACHED DOCUMENT

Affidavit of Hector J. De Los Santos
(Title or description of attached document)

PhD. F IEEE #01
(Title or description of attached document continued)

Number of Pages 7 Document Date 8/18/08

(Additional information)

INSTRUCTIONS FOR COMPLETING THIS FORM

The wording of all Jurats completed in California after January 1, 2008 must be in the form as set forth within this Jurat. There are no exceptions. If a Jurat to be completed does not follow this form, the notary must correct the verbiage by using a jurat stamp containing the correct wording or attaching a separate jurat form such as this one which does contain proper wording. In addition, the notary must require an oath or affirmation from the document signer regarding the truthfulness of the contents of the document. The document must be signed AFTER the oath or affirmation. If the document was previously signed, it must be re-signed in front of the notary public during the jurat process.

- State and County information must be the State and County where the document signer(s) personally appeared before the notary public.
- Date of notarization must be the date that the signer(s) personally appeared which must also be the same date the jurat process is completed.
- Print the name(s) of document signer(s) who personally appear at the time of notarization.
- Signature of the notary public must match the signature on file with the office of the county clerk.
- The notary seal impression must be clear and photographically reproducible. Impression must not cover text or lines. If seal impression smudges, re-seal if a sufficient area permits, otherwise complete a different jurat form.
  - Additional information is not required but could help to ensure this jurat is not misused or attached to a different document.
  - Indicate title or type of attached document, number of pages and date.
- Securely attach this document to the signed document