**Before the**
**Federal Communications Commission**
**Washington, D.C. 20554**

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| M2Z NETWORKS, INC. | ) | |
| | ) | |
| Application for License and Authority to Provide National Broadband Radio Service In the 2155-2175 MHz Band | ) | WT Docket No. 07-16 |
| | ) | |
| Petition for Forbearance Under 47 U.S.C. § 160(c) Concerning Application of Sections 1.945(b) and (c) Of the Commission's Rules and Other Regulatory and Statutory Provisions | ) | WT Docket No. 07-30 |
| | ) | |

**Comments of Marcus Spectrum Solutions**

Marcus Spectrum Solutions is pleased to file these comments in the above proceedings. The attached report discusses our views of TDD as a technology to address today's spectrum issues.

/S/

Michael J. Marcus, Sc.D., F-IEEE
Director
Marcus Spectrum Solutions
55, rue Molitor
F-75016 Paris France

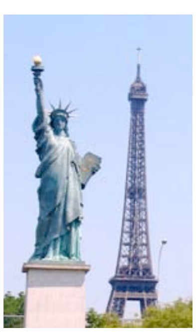
mjmarcus@alum.mit.edu
www.marcus-spectrum.edu
+1-301-229-7714

# TDD for Today

Michael J. Marcus, Sc.D., F-IEEE
Director
Marcus Spectrum Solutions
Paris France

mjmarcus@alum.mit.edu
www.marcus-spectrum.com

**March 2, 2007**



Marcus Spectrum Solutions
acknowledges the support of
M2Z Networks, Inc.
for this study.

# OVERVIEW

In an application currently pending before the Federal Communications ("FCC"), M2Z Networks, Inc. ("M2Z") is seeking a license to operate a nationwide wireless broadband network.[1] M2Z states that the proposed network would use Time Division Duplex ("TDD") technology to operate on the single, unpaired 2155-2175 MHz spectrum block. After describing TDD technology and comparing it to alternative radio communications technologies, this document highlights the FCC's previous discussions of TDD technology and the need to affirmatively provide for TDD-based services to ensure technology-neutral spectrum management.

Marcus Spectrum Solutions is an independent consulting firm presently based in Paris France. Its director, Dr. Michael J. Marcus, held various senior spectrum policy positions at the FCC from 1979 to 2004, when he retired as Associate Chief for Technology, Office of Engineering and Technology. He proposed, initiated and directed the rulemakings that dealt with unlicensed spread spectrum and commercial use of frequencies above 60 GHz.[2] The unlicensed spread spectrum proceeding directly resulted in Wi-Fi, Bluetooth, and many other systems in the three ISM bands. In 2006 he was a Special Advisor to Mrs. Viviane Reding, European Commissioner for Information Society and Media. He has a doctorate in electrical engineering from MIT and was elected a Fellow of the Institute of Electrical and Electronics Engineers "for leadership in the development of spectrum management policies." He is Editor for Spectrum Policy and Regulatory Issues for *IEEE Wireless Communications* and has been active in the Engineering and Technology Practice Committee of the Federal Communications Bar Association.

---

[1] *See* Application [of M2Z Networks, Inc.] for License and Authority to Provide a National Broadband Radio Service in the 2155-2175 MHz Band (filed May 5, 2006).
[2] *See* http://www.marcus-spectrum.com/SSHistory.htm.

## TDD Basics

Most contemporary uses of radio communications, including mobile voice, video, and data, are intrinsically two-way applications.[3] TDD is a technology that establishes two-way communication by using a radio channel alternatively in two different directions. A separate technology, Frequency Division Duplex ("FDD"), uses a pair of channels for two-way communications: one in each direction.

Conceptually, any orthogonal[4] multiplex system (timing, frequency, antenna polarization, CDMA coding, etc.), not just TDD and FDD, can be used to separate the two transmission directions at the user terminal. If two signals are perfectly orthogonal, they can be completely separated from each other at a receiver with no mutual interaction. Because systems must have enough orthogonality to ensure that the receiver is not overloaded by the collocated transmitter, in practice the only possible approaches for 2-way communications are to separate transmissions by either time (TDD) or frequency (FDD)[5]. FDD systems were simple to implement with traditional analog technologies, whereas TDD systems did not really become practical until digital systems matured. Analog 2-way systems, such as voice telephony, were also generally symmetrical in traffic flows which is basically the nature of FDD. Thus, TDD systems came of age later in an environment where FDD was already the commonly used two-way spectrum technology and much of the regulatory framework was based on FDD.

As shown in Figure 1, the fundamental difference between FDD and TDD is that FDD uses two distinct and separated[6] frequencies for the two directions of information flow. These directions are often referred to as "downlink" from base stations to users and "uplink" from users to base stations.

[3] Traditional radio and television broadcasting are examples of one-way applications.

[4] Systems are said to be orthogonal if the signals appear to overlap but can be separated by some technical means such as selection by frequency or time.

[5] CDMA cellular systems actually use FDD to separate the two directions of traffic at a base station and CDMA to separate the individual data streams within a given direction of flow.

[6] In the frequency region of interest, full duplex separations of 155 MHz and 400 MHz have been used by the FCC. Greater separation simplifies equipment design but complicates efficient frequency allocation.

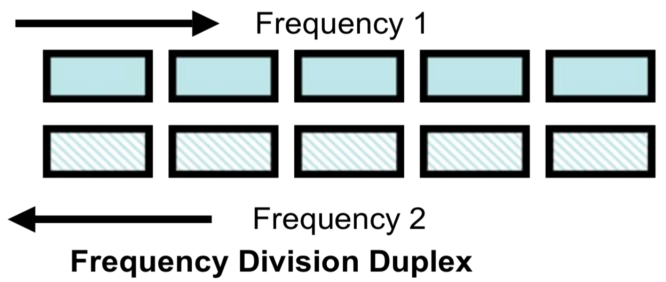



**Figure 1a: FDD**

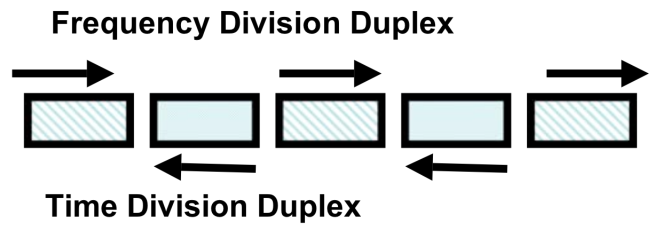



**Figure 1b: TDD**

TDD systems minimize the capacity loss experienced by FDD systems. In FDD systems, equal capacities are generally dedicated to the uplink and downlink directions, meaning that some capacity is wasted where the uplink and downlink traffic flows are not symmetrical unlike voice which is mostly symmetrical. By contrast, TDD systems avoid the wasted capacity by using the same frequency in both directions for two-way communications. Only a small fraction of the transmission time cannot be used between link reversals due to the practical problem of synchronizing all users.

TDD systems also allow for greater spectrum flexibility than FDD systems because they can accommodate unpaired spectrum blocks, such as the 2155-2175 MHz block identified in the M2Z Application. Because there are no prespecified frequency pairs, TDD systems naturally adapt to asymmetries in the traffic flows between the uplink and downlink directions, as is common in many communications applications today. TDD systems, therefore, can optimize the use of unpaired spectrum that would otherwise be orphaned in the spectrum management system.[7]

Finally, new advances in radio technology give the TDD network designer an impressive arsenal of tools that can be used to limit interference to systems in adjacent bands to a level specified by the regulator. The applicable advances include adaptive/”smart” antennas, fast automatic transmitter power control, and tight time synchronization using GPS signals as a time standard.

[7] Practically, FDD systems not only require paired spectrum blocks, but also require some separation between the channel pairs (typically greater than 1% of the center frequency). Most commercial radio communications systems in the United States use FDD to implement two-way communications.

## FCC INTEREST IN TDD

The FCC has repeatedly acknowledged TDD as a technology capable of providing two-way radio communications through the use of individual spectrum blocks. In the Public Notices announcing an unprecedented pair of OET tutorials on December 3, 2001[8] and July 9, 2003,[9] the FCC explained TDD technology and its possible significance:

> Technological advances in the field of digital communications and the widespread use of Internet networking protocols in recent years have led to the emergence of new digital multimedia applications and devices. While user applications have traditionally been circuit switched and focused on voice, these new applications are predominately packet-switched and centered on data. A significant characteristic of these applications is the asymmetry of traffic flow both to and from the user. Therefore, efficient use of systems resources may suggest utilizing a duplexed approach that supports the asymmetric nature of this form of traffic, such as TDD.[10]

> Technological advances continue to occur in the field of digital communications and one of the hottest areas of activity is in the standardization and deployment of both fixed and mobile broadband wireless access systems. Unlike the legacy cellular and PCS systems that have traditionally been circuit switched and focused on voice, these new systems can be optimized for the transmission of packet-switched data, which are characterized by asymmetric traffic flows both to and from the user. Increasingly, TDD is becoming increasingly popular for new broadband wireless access systems, including LAN systems like 802.11, and advanced broadband wireless access systems for mobile and fixed applications like those developed by members of the TDD Coalition and those being standardized in 3GPP and IEEE 802.[11]

The FCC took steps to accommodate TDD systems in the 700 MHz band by allowing spectrum users to operate in unpaired bands.[12] It also adopted power limits based on usage rather than frequency, which enables base and mobile transmitters on both the upper and lower bands and permits TDD-based technologies to operate in any of the bands.[13] In addition, the FCC adopted 6 MHz block sizes in the Lower 700 MHz Band in part because commenters stated that a 6 MHz block would be useful for TDD operations.[14]

---

[8] *Time Division Duplex (TDD) Technology: Applications, Benefits, and Opportunities*, Public Notice, DA 01-2754 (rel. Nov. 27, 2001) ("*November 2001 Public Notice*").

[9] *Tutorial on the Time Division Duplex (TDD) Systems (Second Part),* Pubic Notice, DA 03-1992 (rel. Jun. 17, 2003) ("*June 2003 Public Notice*").

[10] *November 2001 Public Notice*.

[11] *June 2003 Public Notice*.

[12] *In the Matter of Services Rules for the 746-764 and 776-794 MHz Bands, and Revisions to Part 27 of the Commission's Rules*, Memorandum Opinion and Order and Further Notice of Proposed Rulemaking, WT Docket No. 99-168, 15 FCC Rcd 20845 ¶ 10 (2000).

[13] *Id.* ¶¶ 7-10.

[14] *In the Matter of Reallocation and Service Rules for the 698-746 MHz Spectrum Band (Television Channels 52-59)*, Report and Order, GN Docket No. 01-74, 17 FCC Rcd 1022 ¶ 80 (2002).

More recently in the Broadband Radio Service ("BRS") Report and Order,[15] the FCC agreed with the "overwhelming majority of Commenters" who argued for technology-neutral rules, given that equipment manufacturers develop both TDD and FDD systems.[16] It declined to mandate any particular technology in the band, stating that "[a]llowing the band to be technology neutral is consistent with [its] goal to make the spectrum as flexible as possible as it permits licensees and the marketplace to determine which technologies should be utilized."[17] The FCC also rejected arguments that having both FDD and TDD systems on the same frequencies would increase the risk of co-channel interference, noting that incumbent operators in the band were already authorized to deploy the technologies of their choice.[18] The FCC also subjected both FDD and TDD systems to the same out-of-band-emissions limits.[19]

In the *AWS-1 Service Rules Order*, the FCC restated its commitment to "allowing new and innovative technologies to develop," including TDD.[20] The FCC also stated that it would "make every effort to provide spectrum opportunities for TDD systems in future allocation and spectrum proceedings," and that its "commitment to finding additional spectrum for TDD is supported by [its] decisions to allocate unpaired spectrum in the 1670-1675 MHz band and the lower 700 MHz band."[21]

As shown above, the FCC has been engaged in recent years in exploring the possible benefits of TDD, and has endeavored to facilitate TDD in the spirit of technology neutrality. To ensure that its rules and policies are truly technology-neutral, however, the FCC still has work to do. The FCC should take advantage of opportunities to promote TDD technologies, as exemplified by the M2Z Application. Although it has offered large amounts of paired cellular, PCS, AWS and 700 MHz spectrum,[22] it has only made a minimal amount of spectrum available for users interested in unpaired/single blocks, suggesting that its spectrum allocations have favored FDD over TDD.

In the *AWS-1 Service Rules Order*, the FCC stated that "one possible way" TDD technology could be encouraged is by "creating spectrum blocks that are unpaired but

---

[15] *In the Matter of Amendment of Parts 1, 21, 73, 74 and 101 of the Commission's Rules to Facilitate the Provision of Fixed and Mobile Broadband Access, Educational and Other Advanced Services in the 2150-2162 and 2500-2690 MHz Bands, et al.*, Report and Order and Further Notice of Proposed Rulemaking, WT Docket No. 03-66, et al., 19 FCC Rcd 14165 (2004).
[16] *Id.* ¶ 132.
[17] *Id.*
[18] *Id.* ¶ 133.
[19] *See* 47 C.F.R. § 27.53.
[20] *Service Rules for Advanced Wireless Services in the 1.7 GHz and 2.1 GHz Bands*, Report and Order, WT Docket No. 02-353, 18 FCC Rcd 25162 ¶ 46 (2003) (*AWS-1 Service Rules Order*).
[21] *Id.*
[22] *See, e.g.*, 47 C.F.R. §§ 22.905, 24.229, 27.5.

appropriately spaced so that they are also suitable for paired use."[23] In the conclusion of the *AWS-1 Service Rules Order*, however, *the* Commission explicitly ruled out TDD for the band under immediate consideration saying,

> "While we determine that it is best not to permit base and mobile stations to operate in the same AWS bands -- which effectively prevents TDD systems from operating in those bands -- we continue to believe that one of our primary goals in managing the spectrum is to facilitate the development of new and different technologies, including TDD. … We will also make every effort to provide spectrum opportunities for TDD systems in allocation and spectrum decisions affecting other bands, such as in the AWS Allocation proceeding[24]

Thus, while the FCC had concerns about TDD sharing with FDD in the *same band*, it continued to encourage development of TDD technology and promised future "efforts" to provide of TDD in subsequent proceedings.

---

[23] *AWS-1 Service Rules Order* ¶ 46 n.102.
[24] *Id.* ¶ 111

## TDD AND LICENSE SIZE ISSUES

Because the spectrum available to a TDD system may not be adequate for a single base station to serve the entire population around it, TDD systems rely on cellular technology for frequency reuse[25] and to increase network capacity. TDD systems also generally use immediately adjacent cells to cover urban corridors (e.g., the Boston-Washington corridor) or large urban areas. Single isolated cells only make sense in places with small, isolated population groupings.

In areas where there are multiple adjacent cells, TDD systems employ time synchronization between the cells and time slot duration parameters. If adjacent cells are synchronized and have common time slot sizes, they can control near/far problems that might otherwise arise from users located in one cell that are close to the boundary of another cell, or from a base station that is affected by strong signals from an adjacent cell when it is listening for weak signals from its own subscribers. Both of these problems can be avoided with synchronization, and synchronization is only possible with some common TDD parameters.[26]

As a result of these factors, TDD systems must either be extremely closely coordinated – more so than is the practice with many FDD communications systems – or a licensee must have control over a large geographic area to minimize interference issues with adjoining cell sites that have different operators. It is normal today for cellular operators to coordinate with each other regarding frequency assignments and cell site locations near the boundary of their service areas. But the coordination necessary to control TDD-TDD interference at system boundaries must be more detailed, involving both microsecond synchronization of system timing, common block durations, and agreements regarding what blocks are appropriate for each system at a given time. Such intersystem coordination is a challenge and would be problematic without a high level of coordination.

An aspect of the TDD coordination issue arose a few years ago regarding the 1670-1675 MHz and 2385-2390 MHz bands in the Government Transfer Bands proceeding (WT Docket 02-8). The two bands were both unpaired. In the case of the 1670-1675 MHz band, the proceeding record indicated a very strong interest in using TDD in the band. Although the FCC, keeping with its general policy of technology neutrality, did not restrict the 1670-1675 MHz and 2385-2390 MHz bands to TDD (or

---

[25] Early commercial 2-way radio systems only used a radio frequency once in each metropolitan area so the number of channels determined capacity. By contrast, cellular systems achieve <u>frequency reuse</u> by using frequencies multiple times in an area at different nonadjacent cell sites.

[26] Not all of the design details of adjacent cells have to be common to achieve such synchronization. For example, the data formats in the bit stream or voice encoding system could be different. The key issue is the size of each block in each direction.

FDD), it did decide that both bands should have nationwide single licensees, making it easier for TDD systems to flourish. The Report and Order explained:

> For the 1670-1675 MHz band, we are adopting a single nationwide license as proposed in the *Service Rules Notice*. We believe that nationwide licensing provides licensees flexibility to develop and provide new services ubiquitously across the entire band, as currently proposed by ArrayComm, AeroAstro, and InsideTrax. These commenters all agree that a single, five megahertz nationwide license for this band would be the most appropriate licensing approach, given the particular type of wireless services each commenter proposes to provide. While NTCA and RTG oppose a nationwide licensing approach for this band, suggesting instead smaller geographic area licensing throughout the government transfer bands, we believe that nationwide licensing in the 1670-1675 MHz band serves the public interest by promoting flexibility and efficient spectrum markets and facilitates the deployment of ubiquitous, innovative communications services to the public. We also believe nationwide licensing in this band will provide economies of scale for those seeking to offer new technology. In this connection, we have on more than one occasion noted that nationwide assignments are more likely to stimulate investment in new technologies and can provide a critical means of achieving greater spectrum efficiency and promoting research and development.[27]

[27] *In the Matter of Amendments to Parts 1, 2, 27 and 90 of the Commission's Rules to License Services in the 216-220 MHz, 1390-1395 MHz, 1427-1429 MHz, 1429-1432 MHz, 1432-1435 MHz, 1670-1675 MHz, and 2385-2390 MHz Government Transfer Bands*, Report and Order, WT Docket No. 02-8, 17 FCC Rcd 9980 ¶ 21 (2002).

## LIMITATIONS OF FDD

Even if one wanted to use only FDD for 2-way communications, practical considerations make this difficult, if not impossible. For example, there are other spectrum-based services that do not require paired spectrum, such as broadcasting and radar/radiolocation. It is thus inevitable that "orphaned" bands – i.e., bands that are not paired and cannot be paired with other bands for use by FDD systems – will appear. Figure 2, for example, shows the current FCC allocations and plans for the spectrum near 2 GHz. Four pairs of bands have been paired for FDD use, but spectrum that cannot be paired with other spectrum remains. In particular, the 2155-2175 MHz band that has been requested by M2Z fits this category. Using this band in a TDD mode could make the band economically productive in a short amount of time.

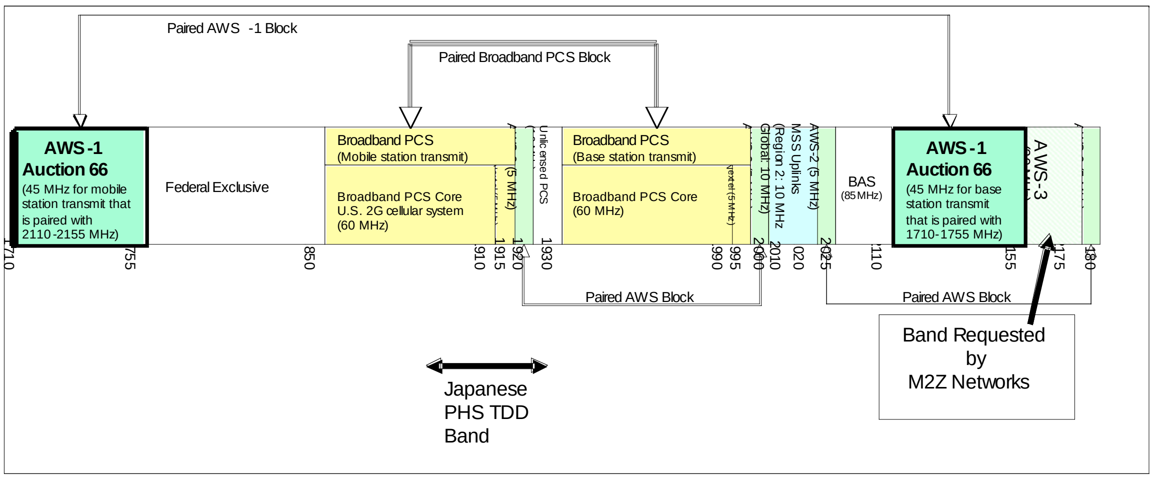



**Figure 2: Current and Proposed US Allocations for 1710-2180 MHz (Base diagram from FCC/OET)**

Using FDD systems for wireless broadband services, like those proposed by M2Z, is also inefficient. Many current broadband uses have asymmetrical data rates. For example, Internet access has low net data rates from the browser to the Internet Service Provider ("ISP") but much higher data rates in the other direction. Inevitably, one of the FDD pairs ends up being underutilized. Although one could try to resize the FDD pairs to compensate for this phenomenon, this is a speculative exercise as there is no agreement regarding what the appropriate ratio for uplink/downlink rates will be in the future as new applications evolve. Indeed, even today, different users may have vastly different uplink/downlink ratios. Thus, asymmetrical FDD pairing would promote spectral inefficiency. TDD systems, on the other hand, can adapt efficiently to such changing ratios by just changing the relative time used in each direction.

TDD has been used for commercial services outside the United States. For example, the Japanese-developed PHS cellular service[28] now has more than 100,000,000

[28] *See PHS Guidebook*, *available at* http://www.phsmou.or.jp/resources/phsguidebook.aspx.

users worldwide.[29] It operates in the 1884-1919 MHz band that comprises part of the bands shown in Figure 2. In Australia, ArrayComm's TDD-based iBurst mobile broadband access technology has been deployed by Personal Broadband Australia ("PBA").[30] As explained above, the lack of TDD spectrum in the United States is primarily the result of historical accident and technological availability.

---

[29] "*PHS MoU Group announced breakthrough of 100,000,000 PHS users worldwide*," November 9, 2006, *available at* http://www.phsmou.or.jp/news/en/745.aspx.

[30] "*PBBA iBurst Mobile Wireless Broadband Network, Australia*," mobilecomms-technology.com, *available at* http://www.mobilecomms-technology.com/projects/i-burst/; *see also* Kurt Mackie, "*PBBA Completes ArrayComm iBurst Trial*," Broadband Wireless Online (Oct. 13, 2003), *available at* *http://www.shorecliffcommunications.com/magazine/news.asp?news=2604*.

## ADJACENT BAND ISSUES

The same basic factors that make unpaired spectrum inevitable also lead to the inevitable boundary between TDD and FDD systems. Because real receivers have only a finite capacity to reject strong signals in the neighboring band, "near/far problems" can arise in which a receiver tuned to a weak signal is overwhelmed by a strong adjacent band signal from a closely located TDD system in the adjacent band. Of course, the problem is actually reciprocal, with TDD receivers near FDD transmitters experiencing the same problem.

The simplest approach to addressing near/far issues is to establish a guard band or "no man's land" between the TDD and FDD systems. Indeed, with traditional FDD technology there is really no other option. With today's increasing demands for spectrum, however, such guard bands are wasteful and should be used only as a last resort.

Fortunately, just as advances in technology ultimately made TDD systems practical, they have also created new options for solving the adjacent band problems. It appears that network designers now have enough technical options available to reduce adjacent band problems to an acceptable level. These options include: automatic power control, inter-network synchronization, inter-network frequency coordination, cross-polarization, smart antennas, antenna siting, and intra-system handoffs. Given the current regulatory trend towards technology neutrality and technical flexibility, these solutions need not be explicitly selected by the spectrum regulator. Rather, the problem could be addressed by requiring constructive coordination between TDD licensees and their adjacent band neighbors and by setting an overall interference goal that must be met as a result of such negotiations.

In a simple model of spectrum use, universal use of FDD would avoid near/far problems, as base stations would always be separated in frequency from mobiles, so one would never have the problem of mobiles operating too close to base stations transmitting on nearby frequencies. However, this avoidance of near/far problems is impractical in the real world for a variety of reasons:

- Radio bands with a given characteristic are finite in size, so there generally have to be some boundaries between FDD blocks in opposite directions that raise near/far issues even if TDD is not used unless other services are placed between the FDD pairs.
- There are a variety of radio services that must be placed in a given band, and these services usually have widely differing technical characteristics. Some are one-way broadcast systems, some radiolocation/radar, some FDD, some TDD, etc. Thus, there will always be interservice boundaries and interference questions that arise from them.[31] Although guard bands are one possible solution to these

[31] Perhaps the most memorable of these problems occurred in the early 1980s when the FCC's Broadcast Bureau granted an operating license to WVEU-TV on channel 69 to

problems, they are a wasteful solution since the resulting spectrum is essentially lying fallow.

Thus, the type of boundary problems that occur between TDD and FDD systems are related to the boundary problems that occur within a band when the edge of the downlink block is located near the edge of the uplink block, and are also related to the problems that occur when two different services are operating in adjacent blocks. The most difficult challenge in spectrum engineering generally relates to the "boundary condition" problems between different blocks of adjoining spectrum with different characteristics. Fortunately, modern communications technology gives system designers new tools that were not available even a few years ago to address these issues. As indicated in ITU-R Report M.2045, there are a variety of options available to address such concerns.

As mentioned above, there was significant discussion in the comments in the Government Transfer Bands proceeding about the possible use of TDD in the 1670-1675 MHz band.[32] Although the FCC's decision was neutral as to the TDD-FDD choice, the FCC chose not to impose any unusual, anti-TDD restrictions regarding adjacent band protection, stating:

> In determining whether we should adopt specific out-of-band emission limits, and/or emission masks to protect services operating adjacent to the 1670-1675 MHz band, we must be sensitive to balance the needs of adjacent-band operations with our goals to promote the development of viable services in the 1670-1675 MHz band pursuant to our overall spectrum management objectives. Because we believe that this balance is properly achieved through an approach that is neither technology specific nor too stringent or too flexible, we are adopting the standard 43 + 10log(P) limit on out-of-band emissions for equipment in the 1670-1675 MHz band. We believe this standard strikes the proper balance between protecting adjacent-band operations and allowing for viable service in the 1670-1675 MHz band.[33]
>
> *   *   *
>
> With regard to the 1670-1675 MHz band, we are adopting a 2000 watt EIRP maximum for base equipment and a 4 watt EIRP maximum for mobile equipment, as proposed by ArrayComm. We believe that these values seem to strike the proper balance between allowing flexible use of the band while limiting RF to safe levels. These limits will enable a licensee to deliver a wide-area broadband data service.[34]

---

transmit on the roof of Atlanta's Peachtree Plaza Hotel at a power of 5 MW only a few feet away from land mobile repeaters whose input receivers were tuned to the former TV channel 70. *See Broad. Corp. of Ga. (WVEU-TV) Atlanta, Ga.*, Memorandum Opinion and Order, 96 F.C.C.2d 901 (1984).

[32] *See*, *e.g.*, Comments of ArrayComm, WT Docket 02-8.

[33] In the Matter of Amendments to Parts 1, 2, 27 and 90 of the Commission's Rules to License Services in the 216-220 MHz, 1390-1395 MHz, 1427-1429 MHz, 1429-1432 MHz, 1432-1435 MHz, 1670-1675 MHz, and 2385-2390 MHz Government Transfer Bands, Report and Order, WT Docket No. 02-8, 17 FCC Rcd 9980 ¶ 123 (2002).

[34] *Id.* ¶ 135.

## SUMMARY

Advances in technology have made TDD a viable option for making constructive use of unpaired spectrum that is of little utility for FDD systems. Similar advances in technology have also created options that can be used to solve boundary condition problems between TDD systems and adjacent band users if the affected parties are willing and able to coordinate their operations. With these technological advances in mind, the FCC should encourage the deployment of TDD systems, such as the one proposed by M2Z.