Before the
Federal Communications Commission
Washington, DC 20054

In the Matter of	)	
	)	
Promoting Interoperability in the 700 MHz Commercial Spectrum	)	WT Docket No. 12-69
	)	
Interoperability of Mobile User Equipment Across Paired Commercial Spectrum Blocks in the 700 MHz Band	)	RM-11592 (Terminated)

COMMENTS OF AT&T SERVICES INC.

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TABLE OF CONTENTS

INTRODUCTION AND SUMMARY 1

I. A BAND 12 MANDATE WOULD GENERATE NO BENEFITS. 10

A. The A Block Licensees Can Obtain Affordable Band 12 LTE Devices Today. 10

B. A Band 12 Mandate Will Not Create New Roaming Options, As The A Block Licensees Already Have Numerous And Increasing Roaming Options. 16

II. AN INTEROPERABILITY MANDATE WOULD BE COSTLY AND COUNTERPRODUCTIVE. 19

A. Reversing 3GPP Standards Years After The Fact Would Inflict Enormous Public Interest Harms. 21

B. A Band 12 Mandate Creates A Real Likelihood That AT&T LTE Services Will Suffer Substantially Increased Interference And That The Quality Of Its LTE Services Will Be Adversely Impacted. 27

1. Fundamental Principles Of Engineering And Physics Strongly Indicate That A Band 12 Mandate Would Subject AT&T To Substantially Increased Interference From Both Channel 51 and Block E Interference. 28

2. The Potential Harms To Consumers And AT&T From Interference Would Be Substantial. 32

C. The Vulcan Testing Is Unreliable And Can Be Given No Weight 35

III. ALTHOUGH THE COMMISSION HAS BROAD JURISDICTION TO EVALUATE SPECTRUM-RELATED INTERFERENCE CLAIMS AND TO FASHION APPROPRIATE REMEDIES THAT PROMOTE COMPETITION, INTEROPERABILITY AND THE EFFICIENT USE OF SPECTRUM, THERE IS NO BASIS TO IMPOSE THE SPECIFIC BAND 12 MANDATE THE A BLOCK LICENSEES SEEK HERE. 37

A. A Band 12 Mandate Would Be An Unlawful Retroactive License Modification. 38

B. No Provision Of The Act Permits This Retroactive Modification Of The B And C Block Licenses. 40

IV. THE COMMISSION SHOULD TAKE PROACTIVE STEPS TO ELIMINATE THE INTERFERENCE FROM CHANNEL 51 AND THE E BLOCK. 43

CONCLUSION.....50

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COMMENTS OF AT&T SERVICES INC.

AT&T Services Inc. ("AT&T") submits the following comments in response to the Commission's Notice of Proposed Rulemaking in WT Docket No. 12-69, issued on March 21, 2012.[1]

INTRODUCTION AND SUMMARY

As the Commission's *Notice* recognizes, industry-led efforts to establish and advance mobile wireless technical standards are far "preferable" to rigid regulatory mandates.[2] To that end, the Commission has long maintained a hands-off, flexible use policy that permits all industry participants, through international standards-setting bodies and their collective best engineering judgments, to devise the technical standards on which carriers, device and network equipment manufacturers, chipset makers, and software developers worldwide rely. This sound policy has brought enormous consumer benefits. Broadband investment and innovation have flourished because of the certainty provided by a stable standards-setting process and because of

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[1] Notice of Proposed Rulemaking, *Promoting Interoperability in the 700 MHz Commercial Spectrum; Interoperability of Mobile User Equipment Across Paired Commercial Spectrum Blocks in the 700 MHz Band*, WT Docket No. 12-69 (Mar. 21, 2012) ("*Notice*").

[2] *See Notice* ¶ 49.

the flexibility each carrier enjoys within those technical boundaries to obtain devices that best suit its network, spectrum holdings, and customers' needs.

Of course, standards-setting processes must work within constraints imposed by the Commission's spectrum allocations, and the Lower 700 MHz band plan created unique challenges for the 3GPP standards-setting body. The Lower 700 MHz is bounded on both sides by spectrum that is or can be used for interfering high-power broadcasts: DTV Channel 51 (adjacent to the Lower 700 MHz A Block transmit frequencies) and the unpaired E Block (adjacent to the A Block receive frequencies). The response to these technical challenges illustrates the merit of the Commission's hands-off policy: in an effort to promote spectral efficiency and protect as many consumers as possible from as much potential interference as possible, 3GPP established two standards, Band 12 (which covers the A, B, and C Blocks) and Band 17 (which covers the B and C Blocks and thus allows carriers operating only in those blocks to filter out interference from the high power transmissions adjacent to the A Block).

Relying upon these standards, the industry has invested heavily over the past few years to develop network infrastructure, chipsets, software and other components to support a wide array of innovative multi-band LTE devices. With devices that operate not only in Bands 12 and 17, but also in various combinations of the many other LTE and non-LTE band classes, these standards-driven industry efforts have produced a robust, dynamic – and highly interoperable – multi-band device ecosystem that allows each operator to tailor its handset portfolio to its own spectrum holdings and those of its desired roaming partners. And with multiple, competing LTE networks already in operation, still more under construction, and millions of LTE devices –

many of them Band 17 devices – already in consumers' hands, U.S. LTE deployment is the envy of the world, boasting nearly 90 percent of *global* LTE subscribers by the third quarter of 2011.[3]

Now, however, certain Lower 700 MHz licensees – who voiced no objection during the standards-setting process – ask the Commission, years after the fact, to mandate that all Lower 700 MHz licensees use Band 12. Such an unprecedented countermanding of the standards-setting body would undermine the integrity and predictability of the standards-setting process, retard broadband investment and deployment, threaten the reliability of existing LTE services, expose millions of consumers to additional interference risk, and *yield none of the "interoperability" benefits upon which the proposed regulatory mandate is falsely premised.*

Proponents of regulation say that it is needed to promote two goals, but neither claim is correct. *First*, they claim that unless the Commission requires AT&T to switch to Band 12, device manufacturers will lack sufficient scale to create affordable Band 12 devices. This claim rests on a fundamental misunderstanding of wireless handset design. A manufacturer does not start from scratch each time it introduces a device with a new radio protocol. Rather, in the real world, wireless technologies always support multiple radio protocols and band classes, so manufacturers typically develop device platforms that can be configured to support any number of different protocols depending upon customer needs. Manufacturers thus can – and already do – readily create Band 12 *variants* of LTE devices first introduced for other band classes. As one A Block licensee has noted, the "[c]omponents that are required" to change a Band 17 device, for example, into a Band 12 device "are all < $1 and, in quantity, *have no cost impact*."[4] Indeed, the

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[3] *See* U.S./Canada No. 1 in LTE Connections with 87% Global Market Share, 4G Americas (Dec. 7, 2011), *available at* http://www.4gamericas.org/index.cfm?Fuseaction=pressreleasedisplay&pressreleaseid=3378.

[4] *See, e.g.*, Letter from Michele C. Farquhar (Vulcan) to Marlene Dortch (FCC), WT Docket No. 11-18, dated December 12, 2011, Attachment at 9 (emphasis added).

market has already refuted the A Block licensees' claim that they need regulation to obtain Band 12 devices: US Cellular has announced that it is introducing a variety of Band 12 LTE devices this year, and it already sells a Band 12 smartphone, tablet, modem, and WiFi hotspot.[5]

Moreover, it is erroneous to believe that regulation would eliminate the need even for this routine, "no cost" customization. The A Block licensees could not use the same devices as AT&T even if the Commission imposed the Band 12 mandate they seek. AT&T operates GSM-based networks, and therefore its LTE devices are designed to "fall back" to GSM-based service for all voice service and for data service outside AT&T's LTE coverage areas. The A Block licensees are CDMA carriers and thus need devices that fall back to CDMA. Consequently, even if AT&T purchased only Band 12 devices, A Block licensees would still have to work with manufacturers to obtain CDMA variants of those devices, which would require a substantial redesign. It should thus be no surprise that US Cellular's current LTE device offerings appear to be variants of *Verizon* Band 13 devices designed with CDMA fall back.

In short, a Band 12 regulatory mandate would do nothing to improve the device prospects of A Block licensees that already enjoy the benefits of the robust device ecosystem and scale economies made possible by the industry-leading LTE investments of AT&T and Verizon.

Second, the A Block licensees claim that a Band 12 mandate is necessary to give them nationwide roaming opportunities, but this claim rests on the false premise that they are limited to Band 12 roaming partners. In fact, with broad availability of multi-band LTE devices, every operator has many LTE roaming options. AT&T's LTE devices, for example, have both Band 17 (700 MHz) and Band 4 (AWS) LTE radios; future offerings will add Band 2 (Cellular) and Band 5 (PCS) LTE radios. AT&T, Verizon, Sprint, T-Mobile, Clearwire, Leap, and MetroPCS

[5] *See* http://www.uscellular.com/4G/index.html (June 1, 2012).

are all deploying LTE networks, and A Block licensees with no LTE device base have maximum flexibility to plan their device portfolios to support roaming on any of those networks. And given their need to fall back to CDMA, it is doubtful that AT&T would be at the top of any A Block licensee's roaming partner list. Of course, A Block licensees can roam on each other's Band 12 LTE networks as well – the geographic coverage of 700 MHz A Block licenses is, after all, equally as broad as the coverage of B and C Block licenses.

Moreover, standards-driven industry development is paving the way for even greater roaming flexibility and efficiency. Chipset makers will soon offer integrated chipsets that allow device manufacturers to combine two LTE band classes (*e.g.*, Bands 12 and 17) in a single radio port. Devices embedded with these chipsets could operate on an A Block licensee's Band 12 network while in-region and on Band 17 networks while roaming, increasing the roaming options available to A Block licensees. The reality is that A Block licensees are just as well positioned as other operators to implement whatever roaming strategies best meet their needs, and a regulatory mandate would do nothing to expand their roaming partner options.

With literally nothing on the benefit side of the scale, *any* risk of harm should doom the unprecedented regulatory intervention the A Block licensees propose. But, in fact, a decision overriding technical standards years after they have been implemented would do extraordinary damage. The *Notice* focuses narrowly on predicting interference impacts of a Band 12 mandate on Band 17 carriers and their customers, but the relevant harms extend well beyond the consequences of second-guessing the particular technical standards at issue here. The regularity of the industry-led standards-setting process is absolutely critical to broadband deployment because the establishment of a new standard sets into motion years of collaborative development work by carriers, manufacturers, and other innovators throughout the wireless ecosystem. If the

Commission were to signal that it may intervene years after the fact and nullify a long-established standard, then a cloud of uncertainty will hang over every new standard, retarding innovation and investment at all levels of the industry.

Even if the Commission could responsibly ignore these broader impacts, the case against a Band 12 mandate is overwhelming. Here, a reality check is in order. The network, equipment and software that would be necessary for AT&T simultaneously to support both Band 12 and Band 17 devices *does not exist today and will not be available for years*. AT&T's Band 17 device base (handsets, tablets, and embedded devices) is approaching two million units and is expected to grow many times over in just the next twelve to eighteen months as additional Band 17 devices that are already in the development pipeline will become available. These Band 17 devices include not only smartphones, tablets and laptop cards, but modules that can be hard-wired into routers, set-top boxes, automobiles and other machines distributed by third parties. As the Commission itself recognizes, any mandated transition could only occur under circumstances in which AT&T would be able to continue to support this large existing base of Band 17 devices.[6] Although it cannot be known today, before the relevant technical standards have even been finalized, precisely how long such a forced transition would take, or the full extent of the cost, complexities, and potential marketplace disruptions that would be involved, it would be a mistake in the first order to assume, as the *Notice* does, that the proposed mandate could be implemented in two years.

Myriad other harms would flow from upending industry standards years after they were finalized. AT&T's network planning, investment and coordinating work with device, equipment and chipset manufacturers has been based on Band 17. Critical assumptions in AT&T's business

[6] *Notice* ¶ 50.

plans driving decisions ranging from base station deployment, to service offerings and performance expectations, to spectrum deployment, to work on carrier aggregation and other technology advances, are predicated on Band 17 and its characteristics. Although impossible to quantify, requiring AT&T to change course midstream and support a different band class would necessarily cause delay, uncertainty, and the risk of service-impacting disruptions. Other key industry actors that have contributed to Band 17 progress would be similarly impacted. As handset manufacturers, chipset makers, and industry trade associations all warned when the Commission previously sought comment on the A Block licensees' proposal, adopting the proposal would inevitably strand investment, delay innovation, and raise costs.

And then there is the matter of harmful interference. The science is indisputable. As Professor Reed and Dr. Tripathi explain, fundamental engineering and physics principles establish that the interference from high-powered Channel 51 and E Block transmissions is quite real. Band 12 provides almost no separation from these high-powered transmissions, and the greater separation Band 17 provides necessarily means a greater ability for mobile devices to filter them out. The more interference allowed through the filter, the worse the signal quality experienced by the mobile device. And worse signal quality means reduced performance – lower throughput, a higher risk of blocked or dropped connections and less overall spectrum capacity to serve customers. These are the facts.[7]

The A Block licensees are left to speculate about the *extent* of the increased interference, where and how it might materialize and what investments AT&T might make to mitigate the harm. The *Notice* treats these as questions that can be answered in the abstract, but the

[7] Jeffrey H. Reed and Nishith D. Tripathi, "Impact of Channel 51 and E Block Interference on Band 12 and Band 17 User Equipment Receivers," at 9-16, attached hereto as Exhibit A ("Reed-Tripathi Report").

LightSquared debacle dramatically illustrates the dangers of plowing ahead with a regulatory mandate based on predictions that legitimate interference concerns will not be realized or hopes that mitigation solutions will be discovered. The full extent of the harmful interference that AT&T and its customers would suffer from a Band 12 mandate could not be known until *after* AT&T made the switch and *after* E Block licensees deploy services over that spectrum – although the IWPC Mobile RF Filter Group has already said that it would be "almost impossible" to filter out E Block transmissions from a Band 12 device.[8]

And the price of incorrectly guessing would be extraordinarily high – potentially reducing the service quality experienced by tens of millions of consumers and significantly reducing spectral capacity at a time when there is urgent need for additional capacity. AT&T could never fully stop this interference; even after incurring enormous costs, it could only hope to mitigate the worst effects. At a minimum, AT&T would be forced to deploy additional cell sites in areas experiencing the greatest interference, but even if the harms from interference required only a small percentage increase in the number of cell sites nationwide, such mitigation costs could easily exceed $1 billion. The problem is exacerbated by the fact that suitable locations for new cell sties are rare and necessary approvals can take years to obtain. Even after incurring these costs, because of the nature of interference from Channel 51 and the E Block, the mitigation efforts would not be wholly effective and AT&T customers would be worse off.[9] AT&T paid a premium at auction to obtain Lower B Block spectrum that is far better insulated from high-power broadcasts, and saddling AT&T after the fact with an inferior interference profile would be a regulatory bait and switch of the worst sort. Equally important, there is no

[8] IWPC Mobile RF Filter Group Presentation at 20 (available at http://www.iwpc.org/ResearchLibrary.aspx?ArchiveID=175&Display=doc.)

[9] Declaration of David R. Wolter, ¶¶ 48 & 51, attached hereto as Exhibit B ("Wolter Decl.").

justification for singling out AT&T and forcing its customers to suffer inferior service and increased costs merely to pay for an illusory benefit to its A Block competitors.

In addition to the fact that the proposed Band 12 mandate would be abysmal public policy, the Commission could not adopt it. To do so would force AT&T and its customers to incur the risks of harmful interference that AT&T paid to avoid. As the D.C. Circuit has held, "an agency cannot, in fairness, radically change the terms of an auction after the fact."[10] Nor could the requirement be justified by any of the hodgepodge of statutory provisions cited in the *Notice*. Those provisions authorize the Commission to impose conditions on licenses *prior* to auctions and to adopt regulations to *reduce* interference. None authorizes rules that would deprive carriers of billions of dollars of investment by retroactively changing auction terms and subjecting them to increased harmful interference in order to benefit competitors who knowingly assumed these risks.

At the end of the day, the A Block carriers' request for an interoperability mandate is really a misdirected expression of frustration at a very different and far more fundamental problem that should be the Commission's real focus. Because of the exclusion zones around Channel 51 broadcast towers (as well as the ever-present possibility of harmful E Block transmissions), large swaths of A Block spectrum are seriously impaired. The Commission should focus on the one area where it is well-positioned to deliver a win-win solution: it should eliminate these sources of interference. By taking proactive steps to eliminate the interference from adjacent high power uses, the Commission can increase the utility of *all* Lower 700 MHz spectrum and remove the only real impediment to broader LTE deployment by A Block licensees.

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[10] *U.S. Airwaves, Inc.* v. *FCC*, 232 F.3d 227, 235 (D.C. Cir. 2000).

Congress has authorized Channel 51 licensees to participate in reverse auctions that could eliminate these sources of harmful interference in the long run, but there are a variety of steps the Commission can take now to provide Channel 51 licensees with incentives voluntarily to relocate or cease their broadcasts during the period leading up to reverse auctions. The Commission also has ample authority to ensure that the now fallow E Block spectrum cannot be used for services that would cause significant harm in other Lower 700 MHz blocks. Strong Commission leadership in these areas will bring immense benefits: increased spectrum capacity, accelerated broadband investment, improved LTE service quality and an environment that provides the industry with even greater flexibility to balance interoperability and other needs.

I. A BAND 12 MANDATE WOULD GENERATE NO BENEFITS.

The Commission seeks comment on possible benefits of a regulatory mandate that would require AT&T to provide LTE services using only Band 12 wireless devices.[11] There are none. The A Block licensees assert that such a mandate is necessary to provide the economies of scale to support the availability of Band 12 devices and to provide them with roaming opportunities.[12] In fact, the mandate they seek would be completely pointless, because it would not provide either of these benefits – or any other benefit that is not already available to them.

A. The A Block Licensees Can Obtain Affordable Band 12 LTE Devices Today.

The A Block licensees argue that device manufacturers will not make Band 12 devices because the only potential buyers are A Block licensees in the United States, and that the Commission should therefore prohibit the future use of Band 17 and force all Lower 700 MHz

[11] *Notice* ¶¶ 21, 24, 29, 40-42, 52-54; *see also id.* ¶ 50 ("those licensees deploying LTE in the Lower 700 MHz band would no longer be allowed to offer mobile units operating on Band 17").

[12] *Notice* ¶¶ 21, 27.

licensees – especially AT&T – to use Band 12 devices to ensure that manufacturers will make devices for all providers. This argument fails at every level.

First, device manufacturers are making Band 12 devices today without a regulatory mandate. U.S. Cellular, an A Block carrier, now offers the Samsung Galaxy S Aviator (a Band 12 LTE Android smartphone), the Samsung Galaxy Tab 10.1 (an LTE tablet),[13] and a mobile hotspot device (Samsung SCH-LC11), and it has announced that these three devices are just the first of many to be released this year.[14] Since the Band 12 standard was finalized last year, A Block licensees that are pressing ahead with the deployment of their LTE networks are obviously able to obtain a variety of Band 12 devices to offer in conjunction with the rollout of their networks.

Contrary to the mandate proponents' claims,[15] Band 12-only devices share economies of scale with Band 13 and Band 17 devices.[16] Device manufacturers do not have to design Band 12

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[13] U.S. Cellular Web Site, http://www.uscellular.com/4G/index.html (visited May 21, 2012) ("Out network is growing to bring you faster speeds, and so is our portfolio of devices. We are currently working with manufacturers to deliver the best 4G LTE capable devices, and we're pleased to introduce our first 4G LTE tablet, the Samsung Galaxy Tab™ 10.1, our first 4G LTE Smartphone, the Samsung Galaxy S® Aviator™, and our first 4G LTE mobile hotspot, the Samsung SCH-LC11.").

[14] *See, e.g.*, Presentation by U.S. Cellular and TDS, Raymond James 33rd Annual Institutional Investors Conference, at Slide 10 (March 7, 2012), available at http://phx.corporate-ir.net/phoenix.zhtml?c=106793&p=irol-presentations; Phil Goldstein, *U.S. Cellular: We'll Wait for an LTE iPhone*, Fierce Wireless, December 5, 2011, available at http://www.fiercewireless.com/story/us-cellular-well-wait-lte-iphone/2011-12-05#ixzz1rvljAs00 ("U.S. Cellular will likely wait until Apple unveils an LTE-capable iPhone before considering whether to sell it, according to TDS CEO Ted Carlson. . . . He said that U.S. Cellular's top priority is launching LTE, *lining up companies to provide LTE devices* and then migrating customers to the service . . . " (emphasis added)) (May 14, 2012).

[15] *See Notice* ¶ 12 (mandate proponents "contend that unless Verizon Wireless and AT&T are required to support Band Class 12 in their devices, Lower A Block licensees will not be able to obtain devices with competitive economies of scale").

[16] Declaration of Michael Prise, ¶¶ 15-17, attached hereto as Exhibit C ("Prise Decl.").

devices from scratch.[17] Rather, manufacturers routinely work with different carriers to develop variants of the same phone during the early planning stages of development.[18] And manufacturers have a strong incentive to modify devices developed for other bands to function on Band 12. Once the device manufacturers have invested the resources to design a LTE phone for a non-Band 12 carrier, the incremental cost to create a variant for Band 12 is negligible.[19] A manufacturer has every incentive to incur those minimal costs to gain the potentially substantial revenues from selling Band 12 devices to the growing number of LTE subscribers that will be served by A Block licensees.

Manufacturers can create a Band 12 variant of a Band 17 device simply by installing a different filter and radio, and by making modest changes to the operating software – changes that represent only about a dollar of the cost of a device (and which largely merely replace one component for a different like-kind component).[20] Indeed, one of the principal mandate proponents, Vulcan, has conceded that a manufacturer can create a Band 12 variant of a Band 17 phone "simply [by] broaden[ing] the duplexer to Lower A, B and C Blocks," and even if a new filter and power amplifier modules are required, "similar [bill of materials] component prices are all less than $1 and, in quantity, have no cost impact" because these changes merely reflect switching like-kind components.[21]

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[17] *Id.* ¶ 15.

[18] *Id.* ¶¶ 15-16.

[19] *Id.* ¶ 15.

[20] *Id.*

[21] Letter from Michele C. Farquahar (Vulcan) to Marlene H. Dortch (FCC), WT Docket Nos. 06-150, 11-18, RM-11592 (Dec. 5, 2011), Attachment at 22; *see also, e.g.*, Letter from Michele C. Farquahar (Vulcan) to Marlene H. Dortch (FCC), WT Docket No. 11-18 (December 12, 2011), Attachment at 9 ("Components that are required" to change a Band 17 device into a Band 12 device "are all < $1 and, in quantity, *have no cost impact*" (emphasis added)). In addition, as Qualcomm has explained in the Commission's Interoperability Workshop, manufacturers like

U.S. Cellular's new Samsung devices are perfect examples of these principles at work. U.S. Cellular's tablet, handset and mobile hotspot are variations of Verizon's Band 13 Samsung Galaxy Tab 10.1, Samsung Droid Charge, and Samsung SCH-LC11, respectively.[22] Samsung did not have to incur all of the costs to design these devices for U.S. Cellular from scratch. Verizon, AT&T and other LTE carriers have already created a large market and ecosystem for 700 MHz LTE devices, and A Block carriers can take advantage of those economies of scale by working with manufacturers to obtain Band 12 variants of devices that are already under development. Indeed, because of the existing, robust supply of 700 MHz LTE devices from which U.S. Cellular could order variants, U.S. Cellular was able to offer an LTE smartphone very quickly after it launched its LTE service.[23] By contrast, it took AT&T *three months* to introduce its first smartphone after initially rolling out its first data-only devices.[24] Moreover, U.S. Cellular is obviously obtaining these devices at "competitive economies of scale,"[25] because it is offering the devices at aggressively competitive prices.[26]

Qualcomm routinely makes chipsets specially for small carriers. *See* Statements by Michael Chard, Business Development, Qualcomm CDMA Technologies, FCC Interoperability Workshop, 159 minutes and 45 seconds (April 26, 2011), *available at* http://www.fcc.gov/events/700-mhz-interoperability-workshop.

[22] Prise Decl. ¶ 18.

[23] Press Release, Samsung Galaxy Tab™ 10.1 Available On U.S. Cellular Online And In Stores Today (March 22, 2010); Press Release, U.S. Cellular Launches First 4G Smartphone: Samsung Galaxy S Aviator (April 5, 2012). All of these press releases are available at http://www.uscellular.com/about/press-room/2012/index.html.

[24] Prise Decl. ¶ 19. *See also* Press Release, *First LTE/HSAP+ Devices Arrive in AT&T Stores Aug. 21* (Aug. 16, 2011), *available at* http://www.att.com/gen/press-room?pid=20671&cdvn=news&newsarticleid=32431; Press Release, *First LTE Smartphones for AT&T Customers Available Nationwide Nov. 6* (Oct. 31, 2011), *available at* http://www.att.com/gen/press-room?pid=21882&cdvn=news&newsarticleid=33192.

[25] *Cf. Notice* ¶ 12.

[26] *See supra* note 24.

But the A Block licensees' theory is fatally flawed for another, independent reason: even if the Commission forced AT&T to use only Band 12 devices in the future, the A Block licensees would almost certainly be unable to use AT&T's devices.[27] AT&T's LTE devices are hybrid devices that fall back to a GSM network when LTE service is unavailable.[28] The A Block licensees, by contrast, are primarily CDMA carriers and thus would need devices that fall back to a CDMA network.[29] Moreover, LTE is currently a data-only service and therefore the A Block licensees must have a CDMA radio in their devices to provide voice service within their regions.[30] But the differences run even deeper: AT&T's GSM/UMTS/LTE devices can switch between the LTE and GSM/UMTS radios as needed to provide simultaneous voice and data service, whereas CDMA/LTE technology uses a completely different radio architecture requiring *two* different radios that operate concurrently to provide simultaneous data and voice services.[31]

Accordingly, even if the Commission forced AT&T to use Band 12, the A Block licensees would still have to work with manufacturers (as they do today) to design their own versions of Band 12 devices.[32] Indeed, designing a multi-radio CDMA variant of an AT&T LTE/UMTS Band 17 device would typically pose far greater engineering and design challenges, and would be a significantly costlier change, than simply changing a device from one band to another band, as "converting" a GSM-based device to CDMA would require a substantial and fundamental redesign of the device.[33] Thus, it is not surprising that, as noted, U.S. Cellular's

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[27] Prise Decl. ¶¶ 20-25.

[28] *Id.* ¶ 21.

[29] *Id.* ¶ 22.

[30] *Id.* ¶¶ 22-23.

[31] *Id.* ¶ 24.

[32] *Id.* ¶ 25.

[33] *Id.*

first three LTE devices appear to be variants of Verizon Band 13 devices that already incorporate the necessary CDMA radios and radio architecture, rather than variants of AT&T LTE/UMTS Band 17 devices.[34]

Now that the Band 12 standards have been finalized, there is nothing to stop any A Block licensee from working with manufacturers to obtain Band 12 variants of devices that have come to market or are currently in the planning stages of development, and it is clear that major A Block licensees are in fact doing so. In retrospect, it should not be surprising that multiple Band 12 device options are just now coming to market. As Vulcan and others have candidly admitted in other proceedings, it is the interference from Channel 51 (and potential interference from the E Block) – not a lack of availability of handsets – that is deterring A Block licensees' deployment of LTE networks, which in turn has prevented many A Block licensees (most notably, Verizon) from pursuing Band 12 devices.[35] Large swathes of A Block spectrum are within very large, Commission-designated exclusion zones around Channel 51 broadcast towers,[36] and a number of A Block licensees have yet even to announce plans to deploy LTE networks using that spectrum.

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[34] *Id*.

[35] *See, e.g.*, Comments of Vulcan Wireless LLC and the Rural Telecommunications Group, Inc.. RM-11626, at 4-5 (April 27, 2011) (full power Channel 51 television have the potential to "interfere with nearby A Block base station receivers," but "Class A and LPTV stations operating on Channel 51 *also* pose serious interference risks to nearby A Block base stations because of their high power levels (relative to A Block transmitters), proximity to more densely populated areas, and the fact that they are generally deployed low to the ground . . ."; "[i]n some cases, the interference effects from the far greater number of 125 Class A and LPTV stations can be more damaging than from full power stations"); Letter from Kathleen Grillo, Verizon, to Rick Kaplan, FCC, WT Docket No. 12-4, dated May 22, 2012 (Verizon has "communicated with equipment vendors about procuring both devices and network equipment that will operate on the Lower 700 MHz A and B blocks," but "deploying service on some of the Lower A Block licenses is complicated by FCC rules that require A Block licensees to avoid interference to adjacent full power TV Channel 51 operations and that set exclusion zones").

[36] *See* Letter from Tamara Preiss, Verizon, to Marlene H. Dortch, FCC, WT Docket No. 06-150, RM-11592, dated Sept. 1, 2011 (providing examples of limitations in the ability to provide LTE services using 700 MHz A Block because of Channel 51 exclusion zones).

This does not mean that A Block spectrum cannot be used to provide LTE service. To the contrary, it is a potential source of valuable spectrum to alleviate growing capacity constraints, particularly in a multi-frequency network deployment. But the current limitations on the use of that spectrum underscores that, as explained in Section IV below, the Commission should focus on eliminating the sources of A Block interference, rather than imposing regulation that will have no impact on the underlying problem.

One fact, however, is indisputable: now that some A Block licensees have begun to deploy their LTE networks, those carriers have been able to obtain affordable LTE handsets. Because A Block licensees that ask for Band 12 devices are clearly obtaining them without a Band 12 mandate, the mandate proponents' central premise is incorrect.

B. A Band 12 Mandate Will Not Create New Roaming Options, As The A Block Licensees Already Have Numerous And Increasing Roaming Options.

The A Block licensees' suggestion that a Band 12 mandate is necessary to ensure roaming opportunities is also false.[37] The A Block licensees' fundamental premise is, again, simply wrong: there is nothing unique about Band 17 and no carrier (other than Verizon) has nationwide coverage over a single band. Thus, any carrier that wants to offer broad, facilities-based service will need to use multiple LTE bands, and there are numerous available options. For example, AT&T currently plans to offer LTE over four different Bands: 2, 4, 5 and 17.[38] Numerous carriers have announced or are in the process of deploying LTE networks over Band

[37] *See Notice* ¶¶ 27-28.

[38] Prise Decl. ¶ 26.

4, including Sprint, T-Mobile, MetroPCS and Leap.[39] And Qualcomm has just announced that it will be supporting Clearwire's LTE deployment in Band 41.[40]

Multi-band handsets are the norm in the industry. For example, in addition to ports used for GSM/UMTS services and international roaming, AT&T handsets have both a Band 17 port (700 MHz) and a Band 4 port (AWS), which allows AT&T to offer LTE service (including roaming on another carrier's network) on either band.[41] Other carriers likewise have obtained dual-LTE band handsets.[42] Manufacturers are now in the process of developing handsets with four LTE radio ports.[43]

Given the availability of multi-band handsets, every LTE carrier has numerous roaming options. For example, Verizon recently revealed that it has offered an LTE roaming agreement to MetroPCS, even though Verizon offers LTE using Band 13 (700 MHz) and MetroPCS uses Band 4 (AWS).[44] Indeed, given that Verizon has nationwide coverage over Band 13 and that multiple carriers are providing LTE over Band 4, it is far from clear that A Block licensees will even want to roam on Band 17. In this regard, the A Block licensees have maximum flexibility when it comes to roaming. As they have generally not even begun deploying LTE networks,

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[39] *Id.* ¶ 27.

[40] *See, e.g.*, http://www.qualcomm.com/media/releases/2012/05/08/clearwire-expands-lte-choices-north-america (announcing that Qualcomm chipsets will support Clearwire's Band 41 LTE deployment with multi-band devices: "By adding support for the B41 band to our LTE chipsets, in combination with providing support for other LTE bands, Qualcomm is enabling OEMs to design cost-competitive devices and offer them in multiple geographies") (May 16, 2012).

[41] Prise Decl. ¶ 26.

[42] Prise Decl. ¶¶ 26-28; *see also, e.g.*, http://www.htc.com/us/smartphones (May 16, 2012); http://www.samsung.com/us/mobile/cell-phones/SCH-R930DSAUSC-specs (May 16, 2012).

[43] Prise Decl. ¶ 26.

[44] Letter from John T. Scott, III, Verizon, to Marlene L. Dortch, FCC, WT Docket No. 12-4, at 3 (filed May 17, 2012).

they have the ability to pick a second (and third and fourth) port frequency that maximizes their ability to roam on a carrier or carriers of their choice.[45]

But even with respect to AT&T's Lower 700 MHz spectrum, technological innovation and the standards-setting process will give the A Block carriers multiple additional avenues for roaming on that spectrum long before an interoperability mandate could. At the handset level, Qualcomm is developing a chipset that would allow a carrier to combine Band 12 and Band 17 in a single handset using only one radio port.[46] There is nothing to stop A Block licensees from negotiating with manufacturers to design handsets using such chipsets, which would operate on Band 12 in-region but could roam on Band 17 networks.[47] Indeed, the obvious purpose behind Qualcomm's investment in these chipsets is to have them included in LTE handsets.

In addition, innovation at the network level may eventually give the A Block licensees yet another way of obtaining roaming on Band 17 networks. The 3GPP standards-setting process is currently developing a new standard that would allow a 700 MHz LTE network to transmit and receive simultaneously over Bands 12 and Band 17.[48] Of course, years of development, testing and deployment of new network equipment and handsets will be required after the new standard is completed before industry participants could take advantage of these new capabilities.[49] But the reality is that most A Block licensees have not yet even begun to

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[45] Of course, the A Block licensees should also be able to enter into roaming arrangements with each other using Band 12. The Commission has authorized national coverage for A Block spectrum and it has obligated licensees to build out that spectrum in the near future, and the prospect of roaming on other A Block providers would be dramatically enhanced if the Commission takes the steps advocated in Section IV to eliminate the sources of interference plaguing the A Block.

[46] Prise Decl. ¶ 28.

[47] *Id.*

[48] Wolter Decl. ¶ 16.

[49] Wolter Decl. ¶¶ 16-39.

build out LTE networks and obviously have no immediate roaming needs. More fundamentally, the existence of these industry-led interoperability efforts further underscores the lack of any justification for a regulatory mandate.

In the end, the proposed Band 12 mandate is not necessary to advance any pro-competitive goal, and the arguments to the contrary by those favoring such a mandate do not withstand even the slightest scrutiny. To be sure, A Block licensees face interference challenges, which, until addressed, will impair the utility of A Block spectrum, but the answer is not needlessly to expose other spectrum to this interference. Rather, as discussed below, the Commission should address those obstacles head on by ensuring that E Block transmissions do not cause harmful interference and devising equitable measures that will clear Channel 51 broadcasts as soon as possible.

II. AN INTEROPERABILITY MANDATE WOULD BE COSTLY AND COUNTERPRODUCTIVE.

The Commission also seeks comment on the costs of a Band 12 mandate. The Commission asks, in particular, whether a Band 12 mandate would subject AT&T to increased risk of interference.[50] The answer is indisputably yes. Basic principles of physics and engineering establish that AT&T would be subject to greater interference if AT&T were forced to use Band 12 devices, and there is a very substantial risk that the increased interference levels would significantly degrade the quality of AT&T's LTE services, harming consumers and forcing AT&T to expend substantial resources to partially mitigate such disruptions. It may be difficult at this time to quantify that impact with precision, but the Commission cannot possibly determine that increased interference would not, in fact, result.

[50] *Notice* ¶ 30.

But the public harms from the mandate would not be limited to the increased risks of interference that would result. The threat of harmful interference may have been the only relevant question at the time the 3GPP standard setting body created Band 17, but not so today. The Band 17 standard was adopted years ago. Since then, an entire infrastructure has been established in reliance on this standard. Wireless carriers, equipment manufacturers, software companies and chipset makers have made multibillion investments that resulted in today's state-of-the-art Band 17 LTE network, devices, and services, and ongoing investments to enhance Band 17 products and services are occurring today. During this period, millions of end user consumers have purchased Band 17 devices, and numerous manufacturers have incorporated Band 17 LTE into consumer and other products ranging from iPads to routers to commercial machines. Even if the Commission could, with an unattainable combination of hindsight and foresight, be *certain* that a Band 12 mandate would result in only minimal interference issues for AT&T and its customers, the imposition of this mandate would destroy reliance interests of participants throughout the wireless ecosystem. The Commission's proposal to delay the effective date of any mandate by two years could ameliorate only a portion of the resulting harms. Given these harms – and the lack of any public interest benefits from a Band 12 mandate – it would be patently arbitrary to adopt the A Block carriers' proposed mandate.[51]

[51] Handset manufacturers, chipset makers and industry groups have likewise warned that the A Block licensees' proposal would harm innovation and increase costs. *See, e.g.*, Letter from Steve B. Sharkey, *et. al.* to Marlene H. Dortch, RM-11592 (Feb. 8, 2010) ("Motorola 2/8/10 Letter"); Comments of Qualcomm Incorporated, RM-11592 (March 31, 2010) ("Qualcomm 3/31/10 Comments"); Letter from Alan K Tse to Marlene H. Dortch, RM-11592 (July 11, 2010) ("LG 7/11/2010 Letter"); Comments of the Consumer Electronics Association, RM-11592 (March 31, 2010) ("CEA Comments"); Reply Comments of Telecommunications Industry Association, RM-11592 (April 30, 2010) ("TIA 4/30/10 Comments").

A. Reversing 3GPP Standards Years After The Fact Would Inflict Enormous Public Interest Harms.

The proposed Band 12 mandate would produce profound harms even if it did not cause harmful interference for AT&T's customers. First, the proposed mandate, in which the Commission would outlaw an industry standard years after it was adopted, would severely and irreparably undermine the predictability of a standard-setting process that is directly responsible for wireless innovation and investment. Second, the mandate proposed here would be especially unreasonable because it is not even technologically feasible today – and will not be for years – without stranding millions of Band 17 customers. It makes no sense to force AT&T to completely change standards at great cost and complexity when such a transition could not possibly be accomplished until years later, when the supposed "benefits" of such a mandate are even more clearly nonexistent.

First, any Commission action to force network operators to abandon established standards years after they have been implemented – no matter how well-intentioned – would have a profoundly negative impact on the standard-setting process and wireless innovation. The predictability and reliability of the standards-setting process is the foundation on which the entire wireless ecosystem rests.[52] The Commission historically has not second-guessed the standards-setting process, and has allowed the industry to use its best engineering judgment in establishing standards. The wireless ecosystem – carriers, device manufacturers, and all other innovators in the ecosystem – rely on those standards to design base stations, antennas, radios, chipsets, software, and much else. These standards inform what devices can be made, how they will

[52] *See, e.g.*, Wolter Decl. ¶¶ 7-12; Prise Decl. ¶¶ 5-14.

operate with other networks, what basic network architecture is deployed, and what services are delivered.[53]

For example, once Band 17 was finalized, AT&T developed device specifications that had to be met by handset manufacturers and that were designed to ensure that handsets would operate efficiently on Band 17 and support the types of services AT&T intended to offer over Band 17. Handset and chipset manufacturers in turn undertook research and development to produce devices that satisfied AT&T's device specifications.[54]

Similarly, equipment manufacturers typically do not begin designing equipment until the relevant 3GPP standards are finalized because those standards determine the frequencies at which the equipment must transmit and receive data, the form in which that data must be transmitted and received and other critical digital processing functionality.[55] Industry participants have been developing Band 17 equipment and devices for years now, and the industry continues to work to develop and upgrade the networks, equipment, devices and software used to provide Band 17 compliant LTE services.[56]

The interoperability mandate proposed here – which would force the entire industry to abandon Band 17 – would strand investments across the industry and thus severely undermine the entire standards-setting process. All of AT&T's business planning has been based on Band 17.[57] AT&T's base of Band 17 devices (handsets, tablets, and embedded devices) is now

[53] Wolter Decl. ¶¶ 7-8; Prise Decl. ¶¶ 5-14.

[54] Wolter Decl. ¶¶ 10; Prise Decl. ¶¶ 5-14.

[55] Wolter Decl. ¶ 10; Prise Decl. ¶¶ 5-14.

[56] Wolter Decl. ¶ 14; Prise Decl. ¶¶ 5-14.

[57] Wolter Decl. ¶ 13; Prise Decl. ¶¶ 5-14.

approaching two million units, and the number grows by thousands each day. And AT&T has already committed to purchase very large volumes of additional Band 17 devices.[58]

The wireless industry is investing heavily today in upgraded network and innovation, but the reliability and predictability of 3GPP standards is the indispensible linchpin of all of those efforts. Any attempt by the Commission to legislate Band 17 out of existence at this late date would have profoundly adverse effects for wireless investment and innovation throughout the wireless ecosystem. This process will be irreparably impaired if the Commission establishes a precedent under which it may, on an ad hoc basis, countermand 3GPP standards by second-guessing the 3GPP's engineering judgments years after a standard has been implemented in the marketplace. If such a precedent were established, no standard could be considered established or reliable. That in turn would reduce incentives to invest the vast sums necessary to develop wireless infrastructure equipment, wireless devices, and wireless services. Industry participants will be inhibited from making these investments if they can be stranded by after-the-fact regulatory fiat.

Second, an attempt to force carriers to switch from Band 17 to Band 12 would be particularly unreasonable because such a switch is not even technically feasible today. The reason is that there are no standards that would permit an LTE network today to simultaneously communicate with Band 12 and Band 17 devices.[59] Rather, current networks can communicate with devices in only one of those bands. Thus, if AT&T were to flash cut to Band 12 today, AT&T would strand millions of Band 17 devices that it has already provided (and the millions more that it has committed to or are in the product development pipeline).[60] A flash cut by

[58] Wolter Decl. ¶ 13; Prise Decl. ¶¶ 5-14.

[59] Wolter Decl. ¶ 15; Prise Decl. ¶¶ 5-14.

[60] Wolter Decl. ¶ 15.

AT&T would also strand the wireless modules integrated into countless machines, automobiles, burglar alarms, and other consumer products that are provided by third parties, but depend on AT&T's Band 17 LTE services.[61]

As the Commission itself recognizes, a mandate that would strand millions of current and future Band 17 customers is not a viable option.[62] The public interest clearly requires AT&T to continue to support this embedded base of devices. But it is not knowable today when a switch to Band 12 could be implemented or the full extent of the costs and complexities that may be involved in such an unprecedented mid-course change. 3GPP is currently working on a new standard that would, in theory, allow AT&T's network simultaneously to communicate in Band 12 and Band 17, but that release is still under development.[63] Contrary to the Commission's suggestion, however, it would take significantly longer than two years after the new standard is finalized to implement such a change.[64]

The issuance of a standard is merely the start of a multi-year process of implementation. Initially, AT&T may have to develop carrier-specific specifications, after which manufacturers would likely need another two years to develop the necessary software to implement those specifications.[65] In the case of a potential Band 12/Band 17 standard, manufacturers have

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[61] *Id.*

[62] *Notice* ¶ 50. The proposed Band 12 mandate could also have adverse effects on international roaming. Across the world many carriers have adopted Band 17 devices so that their customers can roam inside the United States. For example, every iPad sold around the world is a Band 17, but not Band 12, device.

[63] Wolter Decl. ¶ 16.

[64] The Commission has suggested that it could adopt a transition period of "no longer than two years" to allow AT&T to achieve the network upgrades required to serve the many millions of legacy Band 17 devices. *Notice* ¶ 50.

[65] Wolter Decl. ¶¶ 21-25.

informed AT&T that they cannot provide any reasonable guidance on how long it will take to develop such software until after the standard is finalized.[66]

Equally important, if the Commission set a deadline, AT&T would have to try to prioritize the implementation of this mandate with all of its vendors. Such prioritization would come at a cost: manufacturers and the many specialized independent contractors with whom they work have limited resources, and therefore a Commission deadline could force the Band 12 mandate to the head of the queue over other important standards-based features that would, among other things, increase throughput speeds, improve spectral efficiency through expanded support for heterogeneous networks, and provide voice over LTE.[67] Forcing AT&T and its equipment vendors to prioritize features that offer little or no value to AT&T's customers – and, indeed, features that actually harm its customers by subjecting them to a greater risk of interference – while delaying features that AT&T has determined will bring the greatest value to its customers could only harm AT&T's competitive position. Although the adverse impacts on customer retention and attraction – and resulting in harm to AT&T's goodwill – are obviously difficult to quantify, they are nonetheless real and substantial.[68] AT&T should not be the only carrier in the industry forced to postpone improvements to its LTE network merely to provide a dubious benefit to its A Block competitors.

Once manufacturers develop the necessary software and equipment to support a new Band 12/Band 17 standard, it could take another full year for AT&T to perform lab and field tests, install the software, and progressively implement the changes throughout its nationwide

[66] *Id.* ¶ 25.

[67] *Id.* ¶ 36.

[68] *Id.* ¶ 37.

network.[69] In addition, AT&T must test all of its legacy Band 17 devices to make sure they will work properly in the modified network environment.[70] Although the new standard is intended to be "backwards"-compatible with legacy Band 17 devices, there is nevertheless a real risk that some devices will not work without some additional modifications and adjustments.[71] Even if only a small percentage of such devices did not work, the cost to AT&T in lost goodwill with customers could be enormous. In an ordinary deployment, AT&T would have ample opportunity to work with manufacturers to manage any problems, but a rigid, Commission-imposed deadline could force all parties to pursue costlier and/or inferior fixes, all of which would threaten quality of service.[72] Deployment would be further complicated by the fact that AT&T would be simultaneously implementing software changes from different vendors both in traditional macro cell sites and in smaller DAS and microcells, and AT&T must ensure that each aspect of the network is interoperable with the others.[73]

In short, even if everything were to run as smoothly as possible, it could be three years before the mandate that the A Block licensees seek could be implemented. But this would be an extremely complex process with many potential "fail points" that could further delay final implementation – for example, not all vendors may be able to accelerate their development work, not all Band 17 devices may be compatible with the new software, and so on.[74] Accordingly, any Commission attempt to force AT&T and the industry to accomplish such a transition on a fixed and rigid timeline would run a severe risk of stranding millions of legacy Band 17 devices.

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[69] *Id.* ¶¶ 28-32.

[70] *Id.* ¶ 31.

[71] *Id.*

[72] *Id.*

[73] *Id.* ¶ 30.

[74] *Id.* ¶¶ 34-39.

The notion that the Commission should force AT&T to embark on such a complex and potentially quite costly switch to Band 12 when such a change could not reasonably be accomplished well into the future if not later is absurd. Manufacturers are *already* producing Band 12 devices, and it is likely that they will provide A Block licensees with a robust and varied portfolio of Band 12 devices long before AT&T could change its own nationwide and already-deployed network and devices to Band 12. These realities simply underscore again the radical lack of fit between the claimed "benefits" of a mandate (which, as explained above, are nil) and the costs of a "solution" that would involve substantial and needless network investments, potential customer disruptions, degradation of service quality, and which could only be implemented long after the "problem" has solved itself.

B. A Band 12 Mandate Creates A Real Likelihood That AT&T LTE Services Will Suffer Substantially Increased Interference And That The Quality Of Its LTE Services Will Be Adversely Impacted.

The question posed by the *Notice* is flawed for a second, fundamental reason. The *Notice* indicates that the determination of the public interest harms from a Band 12 mandate will turn on "measurements and quantitative analyses regarding the magnitude and extent of the interference risk from adjacent Channel 51 and Lower Block E transmissions for Band Class 12 devices operating in the Lower B and C Blocks."[75] But there is no "real world" experiment that can demonstrate the actual extent to which AT&T would suffer increased interference from Channel 51 and the E Block if it were required to use Band 12 devices. That question could be answered only *after* AT&T launched Band 12 service and *after* E Block holders begin to fully utilize that spectrum.

[75] *Notice* ¶ 40.

The relevant question, thus, is whether the proposed mandate creates a real risk of such interference and the answer to that question is certainly yes. No one seriously disputes that AT&T devices utilizing Band 12 would be subject to greater interference than AT&T devices utilizing Band 17. As a matter of basic principles of physics and engineering, Band 17 devices have a much greater ability to filter out interference caused by Channel 51 intermodulation and high-powered E Block transmissions.[76] This is true even to the extent that AT&T would provide Band 12 devices that utilize only Lower 700 MHz Spectrum Blocks B and C.[77]

The only dispute has been the *extent* of such interference and the impact that such interference would have on carriers and customers. It is easy for mandate proponents to speculate that such interference may not have a significant impact on the quality of AT&T's broadband wireless services. But, again, first principles suggest that there is a significant potential for interference, both from Channel 51 and E Block transmissions.[78] The Commission should exercise great caution in assessing these risks.[79]

1. Fundamental Principles Of Engineering And Physics Strongly Indicate That A Band 12 Mandate Would Subject AT&T To Substantially Increased Interference From Both Channel 51 and Block E Interference.

Channel 51 Interference. Channel 51 is a high-powered broadcast television station that operates in the 692-698 MHz frequency range with "operations at power levels of up to 1000 kW."[80] It is directly adjacent to the send (base station receive) frequency for Band 12 (699-716 MHz) mobile devices and it is separated by 6 MHz from the send (base station receive)

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[76] Reed-Tripathi Report at 9-16.

[77] *Id*. at 12, 14-16.

[78] *See infra* Part A.

[79] *See infra* Part B.

[80] *Notice* ¶ 7.

frequency for Band 17 (704-716 MHz) mobile devices. Mobile devices operating in Band 12 and Band 17 typically operate in the 1 kW range, *i.e.*, at far less power than Channel 51.

As a matter of textbook physics and engineering principles, Band 12 devices are subject to substantially more interference from high-powered Channel 51 broadcasts than Band 17 devices.[81] This means that, compared to Band 17 devices, Band 12 devices subject to Channel 51 interference may achieve significantly slower data throughput and more network connection errors.[82]

As explained in the *Notice*, the technical name for the interference caused by Channel 51 at issue here is power amplifier "reverse intermodulation interference"[83] Reverse intermodulation interference occurs, among other circumstances, where an outside transmission (in this case, Channel 51 transmissions) interacts with transmissions from a wireless device (*e.g.*, a handset or data card), creating a third transmission (referred to as an "intermodulaton product") in the same frequency used by the wireless device to *receive* transmissions.[84] This intermodulation product interferes with the wireless device's ability to receive transmissions from the base station, resulting in packet errors, slower throughput speeds, and even lost connections.[85] The reverse intermodulation relevant here is the combination of Channel 51 transmissions with the "uplink" transmissions created by devices operating in the B and/or C Blocks to create intermodulation products centered in the A and/or B Block "receive" frequencies for the mobile device.

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[81] Reed-Tripathi Report at 9-16.

[82] *Id.* at 11-13.

[83] *Notice* ¶ 32.

[84] *See* Reed-Tripathi Report at 9-11.

[85] *See id.* at 11-12.

The existence of reverse intermodulation interference to Band 12 and Band 17 from Channel 51 transmissions is not speculation. As explained in greater detail by Professor Reed and Dr. Tripathi, it is a mathematical fact of the physics of wireless transmissions and interactions.[86] Indeed, the existence of reverse intermodulation interference from Channel 51 has been acknowledged in technical presentations by Motorola, Ericsson, and AT&T in 3GPP standards proceedings,[87] and by proponents of interoperability, such as Vulcan Wireless and Wireless Strategies.[88]

It is also a fact of wireless engineering that Band 12 mobile devices are more susceptible to reverse intermodulation interference from Channel 51 broadcasts than are Band 17 devices.[89] The reverse intermodulation created by Channel 51 emissions fall within the A Block receive frequencies used by Band 12 devices, but that are filtered by Band 17 devices.[90] Thus, the question is not whether Band 12 mobile devices will be subject to more reverse intermodulation interference than Band 17 mobile devices, but how much more.

Interference From E Block Transmissions. The Lower 700 MHz frequency allocation includes an unpaired E Block in the frequency range 722-728 MHz. AT&T holds five E Block licenses. The rest of the E block licenses are held by other entities, primarily Dish Network. E

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[86] *See id.* (explaining and setting forth the mathematical physics of reverse intermodulation).

[87] *See* Letter from Michele C. Farquhar (Vulcan) to Marlene H. Dortch (FCC), WT docket No. 11-18, RM-11592 (Dec. 14, 2011) (attaching 3GPP presentation by Motorola, Ericsson, and AT&T).

[88] *See, e.g.*, Doug Hyslop, Wireless Strategy, Presentation at FCC Interoperability Workshop (April 26, 2011); Letter from Michele C. Farquahar (Vulcan) to Marlene H. Dortch (FCC), WT Docket Nos. 06-150, 11-18, RM-11592 (Dec. 5, 2011).

[89] Reed-Tripathi Report at 11-12.

[90] *Id*.

Block licensees (other than AT&T) are authorized to transmit at 50 kW, about 50-100 times more power than an ordinary broadband mobile wireless transmission.[91]

In the records of the Commission proceedings related to these issues, all participants have agreed that E Block transmissions are virtually certain to cause substantial interference to mobile devices operating in Band 12, and far less interference to devices operating in Band 17.[92] Band 17, with 6 MHz of separation from the E Block, was created to allow the filter in a mobile wireless device to provide sufficient attenuation of the E Block interference. Consequently, Band 12 devices are far more susceptible to interference from E block than are Band 17 devices, resulting in potentially much slower performance for Band 12 devices and networks.[93]

As the *Notice* points out, because Band 12 devices are subject to so much more interference from E Block transmissions than Band 12 devices, the 3GPP had to adopt lower "receiver blocking" standards for Band 12 devices that are below those used for Band 17 devices. "Receiver blocking requirements address a receiver's ability to receive at least 95% of the maximum throughput at its assigned channel in the presence of an unwanted interfering signal falling into the devices receive band or into the first adjacent 15 megahertz. . . . Unlike Band Class 17, 3GPP determined that Band Class 12 cannot achieve the typical minimum

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[91] *Notice* ¶ 7.

[92] *See, e.g.*, Letter from MetroPCS Communications, Inc., Sprint Nextel Corporation, T-Mobile USA, Inc., the Rural Telecommunications Group, Inc., the Rural Cellular Association, United States Cellular Corporation, Cellular South, Xanadoo Company, Access Spectrum, LLC, and Triad 700, LLC to Marlene H. Dortch (FCC), WT Docket No. 06-150; PS Docket No. 06-229; GN Docket No. 09-51; RM Docket, No. 11592 (May 10, 2010), attaching White Paper by Wireless Strategy admitting that E Block interference will be greater for Band 12 devices, and explaining that providers could try to mitigate this problem by adding cell sites.

[93] Reed-Tripathi Report at 13-16.

specification for blocking interference from the Lower 700 MHz E Block, so this requirement was omitted from the Band 12 technical specification."[94]

2. The Potential Harms To Consumers And AT&T From Interference Would Be Substantial.

The proposed mandate assumes that the interference issues from Channel 51 and the E Block either "are not a reasonable obstacle to interoperability or can be mitigated by industry efforts and/or Commission action."[95] If the interference concerns have not in fact been addressed – and the Commission's experience with Lightsquared illustrates the dangers in concluding too early or eagerly that interference will not present a problem – a forced change to Band 12 will harm millions of AT&T customers and require AT&T to incur substantial additional costs to mitigate the harms. AT&T's network was designed and deployed based on the assumption that it would be able to use Band 17 and thus largely avoid interference from Channel 51 and the E Block. A Band 12 mandate in these circumstances would introduce interference from these sources to AT&T's LTE network, which, in effect, would at a minimum require AT&T to re-design, retrofit, and re-optimize the LTE network it has already built, resulting in substantial cost to AT&T and significant customer disruption, and it would be impossible for AT&T to fully combat such interference even after incurring these mitigation costs. Even if the interference concerns required AT&T to increase its number of cell sites nationwide by only a small percentage, such mitigation costs could quickly exceed one billion dollars.[96] There is no justification for singling out AT&T and forcing its customers to suffer

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[94] *Notice* ¶ 10 n.22.

[95] *Notice* ¶ 50.

[96] Wolter Decl. ¶ 51.

greater harms from interference, merely in a misguided attempt to give a leg up to some of AT&T's competitors.

For example, Band 12 would expose AT&T's customers to intermodulation from Channel 51 broadcasts, which could result in poor reception, dropped calls, and slower speeds for data services.[97] To combat the problem, AT&T would be forced to deploy multiple additional cell sites in the neighborhoods around each such Channel 51 broadcast tower that would not otherwise be necessary (and re-optimize the network).[98] This would increase the cost of AT&T's LTE deployment and divert resources from other important projects, including the construction of cell sites and other infrastructure where they are most needed to address AT&T's growing capacity constraints. And, of course, resources aside, it is not necessarily the case that AT&T would even be able to find suitable locations where it could place the additional cell sites needed effectively to address Channel 51 interference. It is very difficult to find new locations for cell sites. Even where AT&T could find a suitable cell site location, it often takes years to obtain the permits necessary to deploy a new site.[99]

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[97] Reed-Tripathi Report at 9-13.

[98] Wolter Decl. ¶¶ 45-47; Reed-Tripathi Report at 16-18. In this regard, a Band 12 mandate at this late date would be particularly harmful to AT&T. Because of the ability to use Band 17, AT&T has been able to deploy its network without accounting for Channel 51 broadcast towers. Thus, AT&T has customers located in areas potentially subject to substantial Channel 51 interference. In contrast, A Block licensees understood the impact Channel 51 could have on their service from the start and could make deployment decisions accordingly.

[99] AT&T has previously explained in great detail the many significant barriers to building new cell sites, and AT&T incorporates those pleadings by reference. *See, e.g.*, Comments of AT&T, Acceleration of Broadband Deployment: Expanding the Reach and Reducing the Cost of Broadband Deployment by Improving Policies Regarding Public Rights of Way and Wireless Facilities Siting, WC Docket No. 11-59 (July 18, 2011); Reply Declaration of William Hogg, *Applications of AT&T Inc. & Deutsche Telekom AG for Consent to Assign or Transfer Control of Licenses and Authorizations*, WT Docket No. 11-65, at 26-30 (June 10, 2011); *see also* Wolter Decl. ¶ 46.

Interference from out of band emissions from the E Block would potentially be even more destabilizing, because the forced use of Band 12 devices would expose AT&T's customers to powerful E Block transmissions that are immediately adjacent to Band 12. Although few licensees are conducting any operations on the E Block today, those licensees have the *right* to begin 50 kilowatt broadcasts at any time (and the party that holds the vast majority of those licensees, the Dish Network, is in fact testing such operations).[100] Further, E Block licensees (in contrast to Channel 51 licensees) can deploy multiple transmitters throughout a city.[101] Until now, AT&T has not factored the possibility of high-powered E Block broadcasts into its network planning, because Band 17 devices more effectively filter out such interference. However, if the Commission were to mandate the use of Band 12 devices, and E Block licensees begin broadcast operations, AT&T would face severe difficulties in trying to mitigate those interference concerns.[102] AT&T would have to deploy many more cell sites (and engage in complex re-optimization of the entire network) to combat the powerful interference problems that would be caused by out of band emissions from the E Block, and in many instances such measures could only marginally reduce the consumer harms rather than eliminate them altogether.[103] Service quality would suffer and, moreover, the significant costs to address potential E Block interference concerns would by itself outweigh any benefits from an interoperability mandate.

In addition, singling out AT&T and forcing its customers to accept reduced service quality and increased costs would unreasonably distort competition. The potential costs of addressing this interference is enormous. For example, if Dish Network (or an assignee) were to

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[100] Manifest Wireless, 700 MHz Performance Status Report (Jan. 13, 2012).

[101] Wolter Decl. ¶

[102] *Id.* ¶¶ 49-51.

[103] *Id.* ¶ 49; Reed-Tripathi Report at 16-18.

deploy just 1000 high power transmitters in AT&T's service areas and AT&T were forced to deploy three base stations to mitigate interference from each E Block transmitter, the costs of deploying those base stations would likely exceed $1 billion and AT&T would also incur tens of millions of dollars of additional operating costs per year.[104]

Wireless providers are competing intensely today to deploy state-of-the-art LTE networks and to offer innovative new services, but forcing AT&T to prioritize a misguided interoperability mandate over other LTE service quality improvements, while subjecting AT&T to increased interference and massive mitigation costs, would retard competition, undermine AT&T's competitive position, and destroy AT&T's goodwill with its customers. There is no sound policy justification for extending the harms and costs of interference to other providers and crippling AT&T's ability to compete with other LTE providers, especially given that the interoperability mandate the A Block providers seek would provide no public interest or pro-competitive benefit whatsoever.

C. The Vulcan Testing Is Unreliable And Can Be Given No Weight

In November, 2011, Vulcan Wireless ("Vulcan") submitted what purported to be a study of the impact of interference from Channel 51 and E block transmissions on Band 12 and Band 17 devices. This original submission was comprised of only high-level summaries with no documentation that would allow third parties to reproduce the purported results.[105] As explained by Prof. Reed and Dr. Tripathi, even these summaries raised significant questions about the validity of the procedures and assumptions used in the test. Vulcan only very recently submitted the underlying 76 page report on which its original submission was based, which shows that it was conducted by Wireless Strategies. Although there has not been sufficient time fully to

[104] Wolter Decl. ¶ 51.

[105] *See* Reed-Tripathi Report at 19-23.

evaluate this report, as explained by Prof. Reed and Dr. Tripathi, it is quite clear that the procedures and conclusions are flawed in numerous respects.[106]

Most fundamentally, Wireless Strategies never tested a Band 12 device. Consequently, the Wireless Strategies report cannot (and does not) purport to evaluate how an actual Band 12 device performs in the presence of E block and Channel 51 interference.[107] Wireless Strategies also focuses on the wrong questions. It focuses on whether interference will cause a device to not work at all or fall below *minimum* 3GPP standards. The relevant question, however, is the relative *performance* of Band 17 and Band 12 devices in the presence of Channel 51 and E block interference.[108] As explained by Prof. Reed and Dr. Tripathi, Band 12 devices are less able to attenuate interference from these sources and will thus experience greater degradation of service in terms of throughput and the ability to establish reliable connections to the network.[109] Thus, the interference concern here is not only that the interference from Channel 51 and the E block will cause a Band 12 device to stop functioning or to function below minimum 3GPP standards, but that the performance of Band 12 devices will be substantially below that of Band 17 devices.[110]

Professor Reed and Dr. Tripathi also explain that the Wireless Strategies analysis has numerous technical flaws. For example, among others, it incorrectly assumes that Channel 51 intermodulation would be a problem only where AT&T is operating in both the B and C blocks; it focuses on off-center transmissions that understate the actual impact of Channel 51

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[106] *See id.*

[107] *See id.*

[108] *See id.*

[109] *See id.*

[110] *See id.*

interference; and it is based on an insufficient sample of field measurements that were, in any event, too far away from transmitters to provide relevant information.[111]

III. ALTHOUGH THE COMMISSION HAS BROAD JURISDICTION TO EVALUATE SPECTRUM-RELATED INTERFERENCE CLAIMS AND TO FASHION APPROPRIATE REMEDIES THAT PROMOTE COMPETITION, INTEROPERABILITY AND THE EFFICIENT USE OF SPECTRUM, THERE IS NO BASIS TO IMPOSE THE SPECIFIC BAND 12 MANDATE THE A BLOCK LICENSEES SEEK HERE.

AT&T does not dispute the Commission's jurisdiction to evaluate the potential for interference to Lower 700 MHz wireless devices from adjacent high power broadcasts, the harms that would be caused by that interference, ways that such harm might be mitigated, and the potential interoperability and other benefits of a lawful solution. AT&T encourages the Commission to do just that. The Commission should promptly rule, consistent with the wireless engineering facts, that the interference threat to Band 12 devices is real and substantial and will continue so long as high power Channel 51 and E Block transmissions remain possible. And the Commission should quickly take the lawful regulatory steps outlined below to relocate Channel 51 broadcasts and to ensure that E Block licensees do not initiate harmful transmissions – the only remedy that can simultaneously solve the interference problem and promote legitimate interoperability goals.

The Commission could not, in contrast, impose the specific Band 12 mandate proposed by the A Block licensees. Requiring B/C Block licensees to use Band 12 would be flatly contrary to the terms under which the Commission auctioned the 700 MHz spectrum and an unlawful retroactive modification of the B Block licenses. Moreover, the Band 12 mandate is not permitted by any of the statutory provisions that are listed in the *Notice.*

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[111] *See id.*

A. A Band 12 Mandate Would Be An Unlawful Retroactive License Modification.

As the D.C. Circuit has cautioned, "we start from the intuitive premise that an agency cannot, in fairness, radically change the terms of an auction after the fact."[112] Section 309(j) established a system of auctions that is fundamentally different from the prior regime in which licenses were distributed essentially free of charge through comparative hearings or lotteries. Congress expressly required the Commission to ensure, "in the scheduling of any competitive bidding under this subsection, an adequate period is allowed . . . after issuance of bidding rules, to ensure that interested parties have a sufficient time to develop business plans, assess market conditions, and evaluate the availability of equipment for the relevant services." 47 U.S.C. § 309(j)(3)(E) (emphasis added). This reflects Congressional understanding that an auction must occur on the basis of clear expectations concerning the "equipment for the relevant services" that are not subject to material change by the Commission at the behest of disgruntled auction participants that regret their own competitive bidding choices. Having auctioned off the B Block licensees under rules that allow the winning bidders to use devices that take advantage of the characteristics of this spectrum, the Commission cannot now prohibit B Block licensees from providing such devices and require them instead to use devices that will be subject to greater interference (including the very same interference risks that are faced by A Block licensees).[113]

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[112] *U.S. Airwaves, Inc.* v. *FCC*, 232 F.3d 227, 235 (D.C. Cir. 2000). The proposed "interoperability" requirement is an example of what courts call "secondary retroactivity." Although the proposed rule would apply only to future use of handsets, it would alter the expectations on which past actions were taken. Secondary retroactivity is reversible error unless an agency rule is reasonable "both in substance *and* in being made retroactive." *U.S. Airwaves*, 232 F.3d at 233 (emphasis added); *see Celtronix Telemetry, Inc.* v. *FCC*, 272 F.3d 585, 589 (D.C. Cir. 2001).

[113] Courts of appeals have upheld new rules that are at odds with the terms of prior auctions only in narrow circumstances not present here. *See, e.g., Celtronix Telemetry, Inc.*, 272 F.3d. at 589-90 (upholding new rule and rejecting retroactivity challenge because there was no suggestion

These principles apply with special force here. The 700 MHz band plan, and the characteristics of each of the different blocks within the band, were well understood in advance by all bidders. The Commission spent years formulating a band plan that it described as offering varying qualities of 700 MHz spectrum, including "premium" Lower B Block spectrum that is far better insulated from high-power broadcast sources than the Lower A Block spectrum. The Commission repeatedly emphasized the interference issues that would face A Block licensees. For example, as early as 2002, the Commission expressly pointed out that it expected "bidders for this [A Block] spectrum" to "take into account" these interference issues to "develop their business plans, services, and facilities accordingly."[114]

Because of the significant interference concerns, Lower A Block licenses were purchased for far lower prices.[115] Equally important, all bids were made against the backdrop of the Commission's settled "flexible use" policies that allow winning bidders to design their networks, services, and device offerings in whatever ways they believe will best serve their customers.[116] Thus, B (and C) Block licensees have deployed networks and developed and marketed services and handsets that take advantage of the characteristics of that B and C Block spectrum, for which

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"that rule change would inflict material injuries on any set of licensees" or that prior rules "would have induced reliance, either in the form of higher bids by licensees at the bidding stage . . . or of any different conduct thereafter"); *Mobile Relay Associates* v. *FCC*, 457 F.3d 1, 10 (D.C. Cir. 2006) (rejecting retroactivity challenge because Commission adopted remedial actions that eliminated almost all harm); *U.S. Airwaves*, 232 F.3d at 235 (rejecting retroactivity challenge because new rule was not inconsistent with the rules that governed the prior auction).

[114] Report and Order, *Reallocation and Service Rules for the 698-746 MHz Spectrum Band* (*Television Channels 52-59)*, 17 FCC Rcd 1022, ¶ 23 (2002).

[115] In Auction 73, A block licenses sold for an average of $1.13 per MHz POP, compared to an average of $2.65 per MHz POP paid for B block spectrum. *See* Blair Levin *et al.*, Stifel Nicolaus, *Special Focus: The Wireless World After 700 MHz*, at 2, 4, Washington Telecom, Media & Tech Insider (Mar. 28, 2008).

[116] *Lower 700 MHz Second Report Order* ¶ 94; Report and Order, *Service Rules for the 698-746, 747-762 and 777-792 MHz Bands*, 17 FCC Rcd. 2153, ¶¶ 1, 13-15, 124-125 (2007).

they paid billions of dollars. Because the successful B Block bidders were promised, and paid for, spectrum that avoids much of the A Block's interference issues, the Commission cannot now degrade the B Block licenses, and deprive those bidders of the benefits of the Commission's flexible use policies. That is particularly so because the Commission and Courts have repeatedly held that the Communications Act is designed to foster *competition*, not to help individual "*competitors*" at the expense of others.[117]

B. No Provision Of The Act Permits This Retroactive Modification Of The B And C Block Licenses.

Even if the proposed Band 12 mandate did not violate Section 309, no provision of the Communications Act permits the Commission to promulgate such a requirement.[118] The *Notice* cites provisions of the Communications Act that are nothing more than broad statements of the Act's purposes, such as Section 301's statement that it is the purpose of the Act to "maintain control of the United States over all channels of radio communication" and to provide for the "use of such channels" by persons who receive licenses granted by the Commission.[119] Courts

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[117] *In re Applications of Craig O. McCaw, Transferor, and American Tel. & Tel. Co., Transferee*, 10 FCC Rcd. 11786, ¶ 9 (1995) ("[T]he Communications Act requires [the Commission] to focus on competition that benefits the public interest, not on equalizing competition among competitors"); *SBC* v. *FCC*, 56 F.3d 1484, 1491 (D.C. Cir. 1995) ("[t]he Commission is not at liberty . . . to subordinate the public interest to the interest of equalizing competition among competitors") (internal quotations omitted); *Applications of Motorola, Inc. for Consent to Assign 800 MHz Licenses to Nextel Commc'ns, Inc.*, 10 FCC Rcd. 7783, ¶ 20 n.58 (public interest requires promoting competition, not "equalizing competition among competitors"); *United States* v. *W. Elec. Co.*, 969 F.2d 1231, 1243 (D.C. Cir. 1992).

[118] *Michigan* v. *EPA*, 268 F.3d 1075, 1081 (D.C. Cir. 2001) (a federal agency has "only those authorities conferred upon it by Congress").

[119] *Notice* ¶ 58 n.151.

have repeatedly held that general statements of purpose or the Commission's subject matter jurisdiction are not delegations of authority to adopt specific regulations.[120]

The *Notice* also suggests that Sections 304, 307 and 309 grant the Commission authority to "condition [its] licensing actions" on operational requirements that do not "contradict any basic parameters" of the Commission's authority and to adopt other "requirements" that the Commission deem[s] consistent with the public interest, convenience, and necessity."[121] The Commission also notes that it required interoperable customer equipment in the 1982 decision that adopted rules to govern the initial licensing of cellular radio service on two different blocks of 800 MHz spectrum.[122] These provisions establish at most that the Commission is authorized to impose such conditions *before* new licenses are granted (and to interpret and enforce requirements that are consistent with the terms of previously granted licenses).

The other provisions cited in the *Notice* are also irrelevant. Sections 302(a) and 303(e) & (f) give the Commission authority to adopt regulations to *reduce* the risk of harmful interference; the "interoperability requirement" at issue here would *produce* interference in the B and C Blocks. Section 316 provides authority to "modify" licenses, but it is well settled that to

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[120] *Comcast Corp.* v. *FCC*, 600 F.3d 642, 652-54 (D.C. Cir. 2010); *see Motion Picture Ass'n of Am., Inc.* v. *FCC*, 309 F.3d 796, 806 (D.C. Cir. 2002). The *Notice* suggests that the Commission has authority to adopt the proposed interoperability requirement because it would advance the goals set forth in Section 1 and Section 302 of the Act. *See Notice* ¶¶ 56, 58 & nn.147, 155. In *Comcast*, the D.C. Circuit rejected indistinguishable claims on the ground the Commission has previously acknowledged that section 1 is a statement of policy that itself "delegate[s] no regulatory authority," and the same is plainly true of Section 1302. *Comcast*, 600 F.3d at 652; *see also id.* at 654 ("[p]olicy statements . . . are not delegations of regulatory authority").

[121] *Notice* ¶ 58.

[122] *Notice* ¶ 59 & n. 159, *citing* Report & Order, *Inquiry Into the Use of the Bands 825-845 MHz and 870-890 MHz for Cellular Communications Systems; and Amendment of Parts 2 and 22 of the Commission's Rules Relative to Cellular Communications Systems*, CC Docket No. 79–318, 86 FCC 2d 469, 482 (1981).

"modify" means to change carriers' obligations "moderately or in minor fashion,"[123] and the D.C. Circuit has assumed that the Commission's modification authority under Section 316 does not include the power to "fundamental[ly] change" the nature of the service that a licensee is authorized to provide.[124] Section 303(r) provides authority to "[m]ake such rules and regulations and prescribe such restrictions and conditions . . . as may be necessary to carry out the provisions of the Act,"[125] but the D.C. Circuit has held that Section 303(r) is not an independent grant of authority and the Commission cannot adopt rules under that section "if the agency does not *otherwise* have the authority to promulgate the regulation at issue."[126] The A Block licensees' invocation of Section 706 is equally baseless, for the Commission and the D.C. Circuit have held that it is not a grant of regulatory authority.[127]

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[123] *MCI Telecommunications, Inc.* v. *AT&T Corp.*, 512 U.S. 218, 225 (1994); *see also id.* (finding that the word "modify" has "a connotation of increment or limitation").

[124] *Cmty. Television, Inc.* v. *FCC*, 216 F.3d 1133, 1141 (D.C. Cir. 2000).

[125] 47 U.S.C. § 303(r). *See Notice* ¶¶ 56, 58 & n. 153.

[126] *Motion Picture Ass'n of Am., Inc.*, 309 F.3d at 806 (emphasis added); *see also id.* ("[t]he FCC must act pursuant to *delegated authority* before any 'public interest' inquiry is made under § 303(r)") (emphasis in original).

[127] *Comcast Corp.*, 600 F.3d at 658-59 (*citing* Commission decisions). The A Block licensees have also argued that the Commission should find the current contractual arrangements between wireless providers and equipment providers unlawful under Sections 201(b) and Section 202(a), but these provisions apply only to "common carrier" services, not to the negotiated contracts between carriers and equipment providers at issue here. *See, e.g.*, Report and Order, *Inquiry Into the Use of the Bands 825-845 MHz and 870-890 MHz for Cellular Commc'ns Sys.; and Amendment of Parts 2 and 22 of the Comm'n's Rules Relative to Cellular Commc'ns Sys*, 86 F.C.C.2d 469, ¶¶ 58-61 (1981). Equally unavailing is the A Block licensees' suggestion that Section 254(b)(3) of the Act, which "sets forth universal service principles," permits the Commission to impose the proposed interoperability requirement. Section 254(b)(3) sets forth a universal service "principle" and does not permit the Commission to radically change the terms of an auction after the fact and require carriers to provide customers with telecommunications equipment that will degrade the carriers' service in order to benefit competitors.

Finally, there is no merit to the A Block licensees' argument that Section 4(i)[128] and the Commission's "ancillary" jurisdiction under Title I would authorize the adoption of the proposed interoperability requirement.[129] Ancillary jurisdiction exists only if (1) the services at issue fall within the Commission's general grant of authority under Title I and (2) the regulation is "reasonably ancillary to the Commission's effective performance of its statutorily mandated responsibilities."[130] Here, the second requirement is not met. For the reasons stated, the proposed interoperability requirement is not related to any specific grant of authority to the Commission and, indeed, is inconsistent with Section 309(j).

IV. THE COMMISSION SHOULD TAKE PROACTIVE STEPS TO ELIMINATE THE INTERFERENCE FROM CHANNEL 51 AND THE E BLOCK.

In this proceeding, the Commission should focus on adopting measures to eliminate the very real interference associated with the Lower 700 MHz spectrum allocation. If the Commission does so, it will enable broader and more effective deployment of broadband services within *all* Lower 700 MHz blocks, which in turn will facilitate the deployment of next-generation broadband wireless services throughout the country.

Equally important, however, elimination of the interference concerns will also create the conditions that will allow the industry to work voluntarily toward more interoperable solutions. To its credit, the Commission correctly and repeatedly recognizes in the *Notice* that a heavy-handed "interoperability" mandate is not desirable. As the Commission notes, "an industry solution to the question of interoperability in the Lower 700 MHz band would be preferable

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[128] 47 U.S.C. § 154(i) provides: "The Commission may perform any and all acts, make such rules and regulations, and issue such orders, not inconsistent with this chapter, as may be necessary in the execution of its functions."

[129] *Notice* ¶ 56 & n.142.

[130] *American Library Ass'n* v. FCC, 406 F.3d 689, 691-92 (D.C. Cir. 2005).

because such a solution allows the market greater flexibility in responding to evolving consumer needs and dynamic and fast-paced technological developments."[131] Interference and other technical concerns aside, all industry participants have a natural incentive to work for more interoperability throughout the 700 MHz band. Interoperability that can be achieved without service degradation could potentially increase the amount of spectrum available to each carrier and further simplify roaming arrangements. If the Commission eliminates the need to manage legitimate interference issues, it will create an environment that provides industry-led standards-setting bodies with much greater freedom to promote interoperable solutions.

Accordingly, the Commission should focus in this proceeding on measures that will facilitate the relocation or cessation of Channel 51 broadcasts and rules that will ensure that E Block transmissions do not cause harmful interference. With respect to Channel 51 broadcasts, the Commission should work with the industry to fashion regulatory measures that will appropriately balance the interests of wireless providers and broadcasters while achieving the clearing of Channel 51 broadcasts as soon as possible, and prior to the upcoming incentive auctions. AT&T suggests some possible regulatory measures here, but welcomes further suggestions from across the industry and stands willing to work with the Commission and others to design the best possible solutions. With respect to E Block transmissions, the Commission should expeditiously adopt rules or conditions imposing on all E Block licensees the same interference-reducing limits that currently apply to AT&T's D and E Block holdings.

Channel 51. The Commission should eliminate the interference from Channel 51 television broadcasts altogether. The Commission has established broad exclusion zones within

[131] *Notice* ¶ 49.

which A Block licensees are prohibited from operating.[132] These exclusion zones preclude the use of A Block spectrum in portions of many major cities. Indeed, the Channel 51 exclusion zones are so extensive that in some cases A Block licensees contend that it is practically impossible for them to meet their build-out requirements.[133] Although the Commission and the industry have been aware of the limitations on this spectrum since before the 700 MHz auction, there has been no concerted attempt to relocate Channel 51 broadcasts to clear the way for valuable LTE deployments in the four years since the auction.

These concerns require an expeditious solution. Congress recently provided a solution that, assuming broad participation by Channel 51 broadcasters, can ensure that at least some of the interference concerns are eliminated in the *long run.* Section 6403 of the Middle Class Tax Relief and Job Creation Act of 2012 authorizes the Commission to conduct an incentive auction of broadcast television spectrum, which will allow that spectrum to be repurposed for wireless services and will thus eliminate the harmful interference from full-power television broadcasts.[134]

However, it will be years before the Commission can complete the process of auctioning and clearing this spectrum. In the meantime, Channel 51 broadcasts will cause substantial interference during a critical period in the deployment and development of LTE services in the Lower 700 MHz bands. Accordingly, there is a pressing need for the Commission to fashion targeted, interim solutions that will encourage Channel 51 licensees to cease or relocate their

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[132] *See* Memorandum Opinion and Order, *Reallocation and Service Rules for the 698-746 MHz Spectrum Band (Television Channels 52-59)*, 17 FCC Rcd. 1022, ¶ 16 (2002); 47 C.F.R. § 27.60.

[133] *See* Letter from Tamara Preiss, Verizon, to Marlene H. Dortch, FCC, WT Docket No. 06-150, RM-11592, dated Sept. 1, 2011.

[134] Title VI, Subtitle D, of the "Middle Class Tax Relief and Job Creation Act of 2012" ("Spectrum Act").

broadcasts in the period leading up to the auctions and that will also preserve the broadcasters' statutory rights to participate in and benefit from the auctions and to exercise must carry rights.

Such measures could take a number of forms, and indeed, Channel 51 broadcasters could be given a variety of options. The Channel 51 licensee could choose to cease broadcasting or move its broadcasts to another channel under a temporary, provisional license that it would hold for the period of the interim plan (*i.e.*, until the auction process is completed). The Channel 51 licensee could also be given the option to channel share with another channel on a different frequency. The Commission would ensure under each of these options that the licensee could still place its Channel 51 spectrum in the auction. The Commission could also permit a Channel 51 licensee that wished to exercise its rights early to sell (or lease) its licenses in a market transaction to another party, including a wireless carrier or other third parties, which would cease to operate the station under the terms of these interim rules (and would be permitted to participate in and benefit from the auction).[135]

The Commission has broad discretion under Title III to adopt flexible regulatory schemes such as this to reduce harmful interference.[136] Indeed, such temporary relocations are the bread and butter of the Commission's tools for managing the spectrum, as Section 303(f) authorizes the

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[135] The interim actions contemplated by this plan to eliminate existing interference would not preclude participants from participating in the reverse auction. Under Section 6403(a), any "broadcast television licensee" that has "broadcast television spectrum usage rights" is eligible to participate in the reverse auction. The Spectrum Act does not define the term "usage rights," and the Commission could reasonably hold that the licensee in this scheme retains "broadcast television spectrum usage rights" in Channel 51 within the meaning of the statute that can be relinquished in the reverse auction.

[136] *See* 47 U.S.C. § 303(b) (Commission may "[p]rescribe the nature of the service to be rendered by each class of licensed stations and each station within each class"); 47 U.S.C. § 316(a)(1) ("any station license . . . may be modified by the Commission either for a limited time or for the duration of the term thereof, if in the judgment of the Commission such action will promote the public interest, convenience, and necessity, or the provisions of this Act . . . will be more fully complied with").

Commission to "[m]ake such regulations not inconsistent with law as it may deem necessary to prevent interference between stations and to carry out the provisions of this Act," including "changes in the frequencies . . . of any station" that are made with "the consent of the station licensee."[137] Courts have given the Commission even greater deference when fashioning *interim* rules and mechanisms to address special situations on a temporary basis, even where the Commission addressed industry-wide problems with complex interim regulatory schemes that were much more far-reaching than the targeted interim plan contemplated here.[138]

To be sure, the Commission's rules impose a number of specific duties on those who hold a broadcast television station license.[139] But the Commission has ample grounds to waive such requirements to facilitate the types of interim rules contemplated here. The Commission may waive its rules if "good cause" is shown,[140] and it is well-settled that a waiver is appropriate if "special circumstances warrant a deviation from the general rule and the deviation will serve the public interest."[141] The Commission could easily find that such "special circumstances" exist here: this spectrum is earmarked for a Congressionally-mandated auction that will shift the spectrum away from broadcasting entirely to other uses, and the public interest requires the

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[137] 47 U.S.C. § 303(f).

[138] *See, e.g.*, *Texas Office of Public Utility Counsel* v. *FCC*, 265 F.3d 313, 325 (5th Cir. 2001) (upholding the CALLS Plan even though the Commission did not conduct a full forward-looking cost study in part on the ground that the court gives "special deference to transitional rules"); *Alenco Communications, Inc. v. FCC*, 201 F.3d 608, 616 (5th Cir. 2000) ("our review here is especially deferential, because the provisions under review are merely transitional").

[139] *See, e.g.*, 47 C.F.R. §§ 73.614 (setting minimum and maximum power limits), 73.682 (setting transmission standards for broadcast television signals), 73.1740(a)(2) (setting minimum operating schedule for television stations), 73.671 (requiring educational and informational programming for children).

[140] 47 C.F.R. § 1.3.

[141] *Northeast Cellular Tel. Co., L.P.* v. *FCC*, 897 F.2d 1164, 1166 (D.C. Cir. 1990); *WAIT Radio* v. *FCC*, 418 F.2d 1153, 1159 (D.C. Cir. 1970).

licensee to cease broadcasting on Channel 51 earlier than otherwise contemplated in order to eliminate harmful interference with important and widely used services in the adjacent Lower 700 MHz band. Given that there will likely be no broadcasting at all in this spectrum after the auctions, a temporary waiver of the broadcasting-related requirements for these licenses pending the completion of the auctions would be well within the Commission's authority.

As noted, to speed the clearing of harmful Channel 51 broadcasts, the Commission could also give those licensees the option to sell their license to a wireless carrier or other third party now, and permit the carrier both to cease television broadcasting pending the spectrum auction and to auction the spectrum itself. If it adopts the sort of interim rules contemplated here, the Commission will have already made the public interest findings required under 47 U.S.C. § 310(d) – *i.e.*, there is a need for an interim regime that eliminates the interference from Channel 51 broadcasts pending the auction. Permitting the transfer of Channel 51 licenses to other entities would directly accomplish that overriding public interest objective; indeed, the transfer of such licenses would likely speed the public interest benefits of reducing interference from Channel 51 broadcasts, given that such carriers would cease broadcasts immediately without the need to arrange for the relocation and marketplace transition of the television broadcasts to another channel.[142]

[142] Pursuant to the interim scheme described above, the Commission could temporarily waive for good cause shown the ordinary regulatory requirements imposed on a television broadcast licensee and would permit the carrier simply to hold the license and voluntarily decline to exercise its "usage rights" pending the auction. There would be no public interest basis for insisting that the new licensee operate a broadcast station during the period of the interim plan, because this spectrum would be destined for auction and repurposing to wireless services in all events, and the sale would facilitate the cessation of broadcasts that would otherwise cause harmful interference during a critical period of the development of LTE services in the 700 MHz bands. Also, the new licensee would still hold the post-auction "broadcast television spectrum usage rights" of the original licensee, which would allow the new licensee to place the Channel 51 spectrum in the reverse auction and capture the benefit of the incentive auction.

E Block. The Commission should also adopt rules to eliminate the possibility of debilitating interference from E Block transmissions. As a result of the AT&T/Qualcomm transaction, the E Block licenses in five cities (and all of the D Block licenses) are held by AT&T subject to conditions that ensure that they will be operated according to the same power limits that apply to other mobile wireless services in the Lower 700 MHz band. Almost all of the remaining E Block licenses are held by a single entity – an affiliate of the Dish Network. As noted above, although Dish is currently conducting almost no operations in its E Block spectrum, it is testing certain high-powered broadcast services.[143]

Many Lower 700 MHz band carriers, including both AT&T and US Cellular, have argued that the Commission should impose conditions on Dish's operation of its E Block spectrum similar to the ones imposed on AT&T in the *Qualcomm* proceeding, and it should do so expeditiously in this proceeding.[144] Bringing uniformity to the Lower 700 MHz Block will eliminate interference from E Block that can degrade LTE service, and thereby further the public interest by creating regulatory certainty as to how that spectrum can be used, enhance the value of all of the spectrum in that block, and ultimately facilitate the deployment of next-generation broadband wireless services. The Commission has the authority under the Act to modify licenses to accomplish these goals.[145] Section 303(f) gives the Commission express authority to change the "frequency" and "power" of a licensee without the licensee's "consent" when, as here, such a change is necessary to "prevent interference" and will "promote the public

[143] Manifest Wireless, 700 MHz Performance Status Report (Jan. 13, 2012).

[144] *See, e.g.*, Letter from Joan Marsh, AT&T, to Marlene Dortch, FCC, IB Docket No. 11-149, dated February 17, 2012.

[145] 47 U.S.C. § 303(f).

convenience or interest." Further, because Dish is not now operating on the E Block, the proposed condition on its licenses would not "inflict material injuries on any set of licensees."[146]

CONCLUSION

For the foregoing reasons, the Commission should not adopt an interoperability mandate but should instead expeditiously establish mechanisms to eliminate harmful interference from adjacent broadcasts.

Respectfully submitted,

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[146] *Celtronix Telemetry, Inc.*, 272 F.3d. at 589-90. In addition, to the extent that Dish may claim reliance interests, there are mechanisms that can ameliorate any adverse effects on Dish. *Mobile Relay Associates v. FCC*, 457 F.3d 1, 10 (D.C. Cir. 2006).

EXHIBIT A

IMPACT OF CHANNEL 51 AND E BLOCK INTERFERENCE ON BAND 12 AND BAND 17 USER EQUIPMENT RECEIVERS

BY

JEFFREY H. REED AND NISHITH D. TRIPATHI

Impact of Channel 51 and E block Interference on Band 12 and Band 17 User Equipment Receivers

Jeffrey H. Reed and Nishith D. Tripathi

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EXECUTIVE SUMMARY

The Federal Communications Commission ("FCC") seeks comment on the impact of high-powered Channel 51 and E block broadcasts on Long Term Evolution ("LTE") mobile wireless devices operating in Band 12 and Band 17 of the Lower 700 MHz frequency range.[1] In this paper, we explain that, as matter of fundamental physics and electrical engineering principles, mobile devices configured with Band 12 (which are capable of operating on the Lower 700 MHz A, B and C Blocks) are more susceptible to interference from Channel 51 and the E block broadcasts than mobile devices configured with Band 17 (which are capable of operating on only the B and C Blocks). And, because Band 12 devices are more susceptible to such interference, Band 12 devices and networks are more likely to experience reduced performance compared to Band 17 devices and networks. We note that Band 17 was created by the Third Generation Partnership Project ("3GPP") – the international standards body responsible for developing LTE technical standards – for the express purpose of developing a Band that is less susceptible to interference from Channel 51 and the E block than Band 12.

These interference issues arise because the frequency ranges of the Lower 700 MHz spectrum are very close to the frequency ranges used by the high-powered Channel 51 and E block broadcasts. For Band 12, the mobile station to the base station ("uplink") and the base station to the mobile station ("downlink") frequencies are located immediately adjacent to the frequencies used by the high-powered Channel 51 broadcasts and the E block, respectively. Unlike Band 12, Band 17 has 6 MHz separation from both Channel 51 and E block broadcasts. It is this additional 6 MHz of separation for Band 17 that, in multiple respects, provides Band 17 mobile devices with more insulation from interference compared to Band 12 mobile devices.

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[1] Notice of Proposed Rulemaking, *Promoting Interoperability in the 700 MHz Commercial Spectrum; Interoperability of Mobile User Equipment Across Paired Commercial Spectrum Blocks in the 700 MHz Band*, WT Docket No. 12-69 (Mar. 21, 2012) ("*Public Notice*").

To understand why, it is important to understand the two different types of interference caused by these two sources of high-powered transmissions.

For Channel 51, the potential interference is the result of "reverse intermodulation." As noted, Channel 51 is a high powered broadcast that is located adjacent to the uplink frequencies used by Band 12. Channel 51 signals therefore enter Band 12 (and, to a much lesser extent, Band 17) devices and interact with devices' uplink transmissions. This interaction results in reverse intermodulation, which creates new signals called "intermodulation products." The frequency ranges in which the intermodulation products fall can be readily calculated using standard wireless engineering formulae. Here, centers of some of the intermodulation products fall largely within the lower end of the frequencies used by Band 12 devices to receive downlink signals (*i.e.*, the A block) but outside the radio frequency ("RF") operating range of Band 17 devices. As a result, Band 12 devices will be more susceptible to interference from these intermodulation products than Band 17 devices.

For E block broadcasts, the potential interference is caused by adjacent channel interference ("ACI"). E block transmissions occur in frequency ranges immediately adjacent to the Band 12 downlink frequencies. Although all Band 12 and 17 mobile devices have receive filters designed to attenuate signals outside the desired frequency range, no filter can fully attenuate signals that are relatively close to the "passband" frequency. Rather, radio filters experience "roll-off," which means that signals immediately adjacent to the passband are less attenuated than signals further from the passband frequency. The FCC has authorized high-powered transmissions in the E block, and because the E block frequency range is immediately adjacent to the lower passband frequency used in Band 12 devices,[2] significant power from E block signals will pass through a Band 12 device's receive Radio Frequency ("RF") filter and cause interference. By contrast, the frequency range used by Band 17 devices have 6 MHz of separation from E block signals, and, therefore, the RF filters in Band 17 devices are better able to attenuate E block signals resulting in less interference.

To the extent that Band 12 devices experience more interference than Band 17 devices, Band 12 devices and networks will experience reduced performance and efficiency compared to Band 17 devices and networks. One of the most important factors governing mobile device and network performance is the signal-to-interference ratio ("SIR"). As interference levels rise relative to the "desired" signal, the SIR decreases. Lower SIRs result in lost packets and other problems that adversely affect device and network performance. For example, lower SIRs result in more data packets getting corrupted, and when the device records a corrupt data

[2] There is only 1 MHz separation between the E block and Band 12.

packet, the base station typically retransmits that data packet, which uses up network resources that could otherwise have been used to send new data packets to that device or others served by the base station, and slows throughput as the device awaits the resent packet. Similarly, decreased SIRs mean that mobile devices will more often fail to receive resource allocation messages from base stations, which means that the mobile devices could completely miss data packets sent by the base station. The base station would have to resend the data packets and the resource allocation messages in such cases, using up additional network resources. In addition, when mobile devices send data packets to the base station, lower downlink SIRs will cause the mobile device to more frequently fail to receive the needed confirmations from the base station indicating that the uplink packets were received, resulting in the devices resending the data packets to the base station, which again utilizes additional network resources and slows uplink data throughput. Lastly, given the very close proximity of E block interference to Band 12, there is a significant risk that the E block interference will cause "overloading" in mobile devices using Band 12, which means that the device will no longer operate.

For these reasons, the interference caused by Channel 51 and E block transmissions will have a greater adverse impact on the performance of Band 12 devices and networks than on Band 17 devices and networks. However, the precise amount by which the performance of a Band 12 network will be below that of an otherwise identical Band 17 network cannot be known without comprehensive real world experience. Depending on numerous factors – such as the level of data activity in the cell site, the device's distance from the LTE base station and from the interfering high power broadcast source, the resource-intensiveness of the device user's application (*e.g.*, high definition video streaming), the device circuitry design, the susceptibility of the device user's application to latency and data errors (*e.g.,* voice over LTE) and topography – the impact of Channel 51 and E block interference on Band 12 devices relative to Band 17 devices could be very substantial at some places and times, while in others it might be relatively low.

But real world testing that can fully account for these factors is not yet feasible. Among other things, high power E block transmissions have not yet commenced (and the potential architecture of E block networks is not yet even determined) and commercial Band 12 LTE networks have only begun to be deployed (and those currently deployed networks do not, in any event, have the spectrum characteristics that create the Channel 51 intermodulation interference threat). Given these realities and the fact that LTE itself is a very new technology, it is our opinion that the FCC should exercise great caution and should critically and thoroughly evaluate the claims that lab or field testing "proves" that increased interference in the real world will be tolerable.

The FCC should likewise carefully analyze claims that such interference concerns can be easily mitigated. We have reviewed submissions by parties arguing that interference from Channel 51 and the E block can be adequately addressed by adding base stations and changing network parameters. As an initial matter, the extent to which these techniques will mitigate interference is not at all clear, and we cannot know how well such techniques will work until E block and Band 12 networks actually have been widely deployed. In addition, these mitigation techniques often will be impractical to implement. For example, base stations would have to be added at specific locations. It is likely, however, that suitable locations for new base stations may not be available in many of these locations, and even where these locations are available, it can take years to bring a new cell site online.

We have also reviewed submissions by owners of A block spectrum that purport to have evaluated interference from Channel 51 and the E block and demonstrated that devices configured for Band 12 devices are not subject to any more interference than devices configured for Band 17. Our review of these analyses confirms that they are flawed in numerous respects. Most fundamentally, they never examine the performance of a Band 12 device under any conditions, let alone in the presence of Channel 51 or E block interference. Moreover, these analyses purport to test only whether devices will operate above minimum 3GPP standards in the presence of interference. But even if that were true, it is not the relevant question. The relevant question is the extent to which Channel 51 and E block interference will cause greater interference – and hence slower throughput – for Band 12 devices compared to Band 17 devices. In all events, as we discuss further below, the analyses contain numerous analytical errors.

The rest of this paper is organized as follows. In Section I, we provide an overview of the types of interference at issue here and the impacts of such interference on device and network performance. In Section II, we explain the nature of Channel 51 and E block interference in the Lower 700 MHz spectrum in more detail and discuss why Band 12 devices are more susceptible to such interference than Band 17 devices. In Section III, we explain why it would be difficult to mitigate interference from Channel 51 and E block broadcasts. Finally, in Section IV we discuss the fundamental flaws in the interference testing proffered by those purporting to have conducted "real world" tests, and why those tests provide no useful information for ascertaining the extent to which interference will degrade the performance of devices configured for Band 12 compared to those configured for Band 17.

1. OVERVIEW OF MOBILE DEVICE PERFORMANCE AND INTERFERENCE

In this section we explain how increased interference degrades the performance of mobile devices and causes networks to operate less efficiently. We also identify the two sources of

interference that raise significant concerns for Band 12 networks and devices, but far less so for Band 17 networks and devices.

1.1. Increased Interference Degrades Network And Device Performance

Mobile broadband devices use a transceiver (a combined transmitter and receiver) to send and receive transmissions. For reception, analog radio signals enter the antenna. The transceiver then, among other things, filters unwanted signals, amplifies the remaining signals, converts them to a digital format, and decodes those digital signals so that they can be converted to voice, text, pictures, video, or whatever final product is intended. For transmissions, the transceiver encodes the data from the handset (*e.g.,* voice, text, pictures, and video) using the scheme associated with the relevant wireless technology (*e.g.*, LTE), converts it into an analog signal, amplifies the analog signal, and transmits the signal through the antenna to the base station.

One of the most important factors affecting the performance of a network and a device – that is, the efficiency and speed at which devices can receive and send transmissions – is the strength of the desired signal relative to interfering signals. Wireless engineers refer to this critical factor as the signal-to-interference ratio ("SIR"). The greater the SIR, the better the device will perform, for the reasons discussed further below.

There are many potential sources of interference, and modern networks and devices have hardware and software designed to mitigate such interference. One of the principal mechanisms used to protect against interference is the RF filter. RF filters are placed in wireless transceivers and are designed to attenuate unwanted signals and thus reduce interference. These filters have significant limitations.

First, no filter can block all transmissions emanating from immediately adjacent frequencies. All filters experience "roll off," which means that a filter designed to block transmissions below a particular frequency (the edge of the passband) will actually achieve a gradually decreasing attenuation for frequencies closer to the passband. In other words, the filter cannot fully attenuate the transmissions directly adjacent to the passband and those transmissions will enter the device at a relatively high level. This type of interference is referred to as adjacent channel interference ("ACI"). The higher the power of the adjacent transmissions, the higher the power of the ACI. Thus, high-powered broadcasts in an immediately adjacent frequency range can significantly degrade SIR. At the same time, the impact of ACI on the SIR is much lower for frequency ranges that are further separated from the band where high powered broadcasts occur.

Second, filters can only attenuate signals in unwanted frequencies. Unwanted signals occupying the same frequency used by the "desired" signal cannot be attenuated without also

attenuating the desired signal. This type of interference is often created by interactions between the mobile device transmission and the transmission from an adjacent high-powered broadcast station through "reverse intermodulation." For example, a high power broadcast signal may enter the power amplifier of the mobile device from the output port of the power amplifier and interact with the mobile device's transmit signal, creating reverse intermodulation distortion ("IMD"). Such IMD can cause interference to the mobile device's receiver when it is in the passband of the device's RF filter. The closer the frequencies of the broadcast signal and the mobile device's transmit signal and the higher the power levels of the broadcast signal and the mobile device's transmit signal, the higher the likelihood of the interference degrading the performance of the mobile device. We discuss this type of interference in more detail in Section 2.

In environments where the SIR is low due to high ACI, intermodulation products, or other sources of interference that cannot be adequately mitigated by the radio frequency filters, the performance of the network and the device are significantly reduced. The impact of decreased SIR on mobile broadband networks is very well understood. That is why the international standards and specifications for LTE developed by the 3GPP include SIR specifications of at least 33 dB[3], which means that to meet the 3GPP minimum performance specifications the strength of the desired signal must be at least 2000 times the strength of the adjacent channel interference at the receiver. The impact of interference can be magnified when the network protocols that handle errors kick in due to interference. As explained immediately below, this causes a loss of capacity, increased latency, and lower data rates in a trade-off made by the network to insure that the data received is correct. With extremely high interference power, the circuitry of the device may also be permanently damaged.

The most direct impact of reduced SIR in the band used by devices to receive data packets from base stations is a reduction in throughput. When the downlink resources[4] allocated to a mobile device are corrupted by interference, the packet carried by these resources will be received in error at the mobile device. As a result, the base station, called the "eNodeB" in LTE networks, will usually retransmit the packet. Because the base station now needs to use resources to retransmit the packet, it cannot use those resources to send a new packet for another purpose, which means that the network is operating less efficiently. Moreover, the throughput at the

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[3] The value of 33 dB is specified as the adjacent channel selectivity in relation to the adjacent channel interference (see [7]).

[4] The mobile device is allocated radio resources called Physical Resource Blocks (PRBs) in LTE. One PRB consists of twelve narrowband channels called subcarriers. In a 10 MHz bandwidth, a total of 600 subcarriers exist, corresponding to 50 PRBs.

device is reduced because it is now waiting for the base station to resend packets. From the customer's point of view, the device is operating more slowly, *e.g.,* increased time required (more latency) to download a web page or email and poor quality of video streaming.

For Voice over LTE ("VoLTE"), the voice quality may also suffer due to such interference. Voice services cannot tolerate long delays. While the LTE air interface is efficient, it has limited opportunities for retransmitting a "lost" speech frame due to the delay constraint. Hence, when interference corrupts one or more speech frames, the effective speech frame error rate ("FER") or block error rate will increase and the voice quality perceived by subscribers may be poor.[5]

A decreased downlink SIR also reduces downlink *and uplink* throughput due to missed downlink and uplink resource allocation messages and missed positive acknowledgements for the uplink transmissions. The LTE eNodeB uses downlink control channels called physical downlink control channels ("PDCCHs") to convey the downlink and uplink resource allocations to a cell where the mobile device operates. When strong interference corrupts these PDCCHs, the mobile device will not know that it has been allocated downlink and/or uplink resources for reception and/or transmission of its data. In such a case, when the eNodeB transmits packets on the allocated downlink resources, the mobile device will not be looking for those packets. The mobile device will thus miss those downlink packets, and the eNodeB will need to retransmit those packets, reducing the achievable downlink throughput. Similarly, the mobile device will not transmit a packet on the allocated uplink resources. These uplink resources will remain unutilized, reducing the user throughput and cell throughput in the uplink. Not only is the user who is the victim of this interference impacted, but the whole network is impacted because more resources have to be allocated to the user experiencing interference to help overcome the interference, which leaves fewer resources for other users in the network.

The uplink throughput may also be adversely affected due to the positive acknowledgments sent by the eNodeB but missed by the mobile device. When the eNodeB correctly retrieves an uplink packet from a device, it sends a positive acknowledgment to the device using a channel called Physical HARQ[6] Indicator Channel (PHICH). The device can then send a new packet with new information in the uplink. However, strong downlink interference can corrupt the PHICH received at the device, leading to a missed (potentially) positive acknowledgment sent by the

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[5] For real-time voice service, the 3GPP standard for LTE calls for a minimum 1% error rate for Quality of Service Class Indicator (*i.e.*, QCI=1).

[6] HARQ stands for Hybrid Automatic Repeat reQuest.

eNodeB. The device will then unnecessarily retransmit the old uplink packet information, reducing the achievable uplink throughput and increasing delay.

1.2. The Sources Of Interference For Band 12 Devices.

In 2009, the FCC auctioned frequency blocks in the 700 MHz range for mobile broadband use. The auctioned 700 MHz frequency blocks were unusual in that they included certain frequency blocks (namely, the Lower A blocks) that were located directly adjacent to frequencies used by high-powered television stations (Channel 51) and high-powered video transmission services (E block). As was widely recognized, the proximity of mobile broadband frequencies to these high-powered television and video broadcast frequencies creates significant potential interference issues [19].

First, transmissions from mobile devices can interfere with the set top boxes used to receive Channel 51 television broadcasts. Second, Channel 51 and E block broadcasts cause interference within the frequency ranges used by base stations to receive transmissions from mobile devices. Third, the high-powered transmissions from Channel 51 and the E block cause interference in the frequency ranges used by mobile devices to receive transmissions from the base station. To address the first interference issue, the FCC adopted exclusion zones that prohibit mobile devices from operating within a certain distance from the legacy television/video broadcast sites. The FCC has not addressed the latter two sources of interference.

The Third Generation Partnership Project ("3GPP") – the international standard setting body for LTE in this lower 700 MHz spectrum range – recognized these significant interference concerns and sought to address them by adopting standards and specifications for two different "Bands" in the lower 700 MHz frequencies. Initially, the 3GPP defined Band 12 only, which includes lower 700 MHz A, B, and C blocks. Because Band 12 includes the A block, it is directly adjacent to Channel 51 and the E block and is thus subject to significant interference from those broadcasts. Hence, the 3GPP later defined Band 17, which includes only the lower 700 MHz B and C blocks. There is thus 6 MHz of separation between Band 17 and Channel 51 and the E block. Figure 1 illustrates the Bands adopted by the 3GPP and their proximity to the adjacent high powered broadcasts.

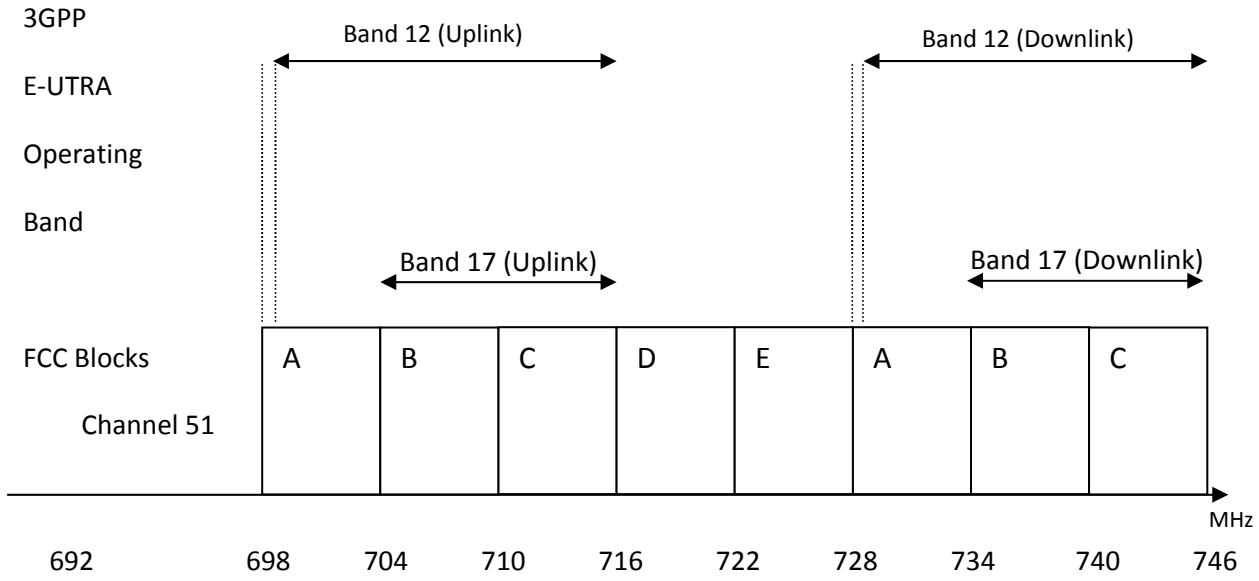

Figure 1. FCC and 3GPP Band Plans in the Lower 700 MHz Spectrum

2. THE RELATIVE SUSCEPTIBILITY OF BAND 12 AND 17 DEVICES TO CHANNEL 51 AND E BLOCK INTERFERENCE.

The *Public Notice* asks whether there is a significant risk of additional interference from Channel 51 and the E block if wireless carriers are required to use Band 12 devices, rather than Band 17 devices. The short answer, based on the physics of electromagnetic transmissions, is yes.

2.1. Reverse Intermodulation Interference Caused By Channel 51 Interference

As shown in Figure 1, Channel 51 frequencies (692-698 MHz) are located adjacent to Band 12 and Band 17 uplink transmissions (699-716 MHz for Band 12[7] and 704-716 MHz for Band 17). Consequently, the very high power Channel 51 broadcasts – as much as 1 megawatt – will interact with the Band 12 and Band 17 uplink transmissions to produce "reverse intermodulation" and create new signals called "intermodulation products" (explained above in Section 1). When B and/or C block spectrum is used for uplink transmissions, these intermodulation products will occur in the A block downlink frequencies and to a lesser degree

[7] The original Band 12 lower bound was at 698 MHz, but 3GPP later adopted a 1 MHz guard band between the lower bound of Band 12 and Channel 51 in an attempt to provide at least some minimal ability for Band 12 users to attenuate Channel 51 transmissions.

in the B-Block downlink frequencies. As a result, Band 12 devices, which do not filter the A block, are subject to greater interference from Channel 51 than Band 17 devices, which do filter the A block.

Reverse intermodulation is well understood. To occur, it requires two relatively strong signals in nearby frequency ranges and nonlinearities in the transmitter (typically the power amplifier). Here, the two strong signals of interest are (1) the Channel 51 broadcast and (2) the B block and C block uplink transmissions used by the mobile device.

We begin by explaining the power amplifier's role in a mobile broadband device and how it results in nonlinearities in the transmitter. The transmit power amplifier is used to amplify the transmission signals from the handset so that they can be received reliably by the base station. The base station effectively determines the amount of power that the power amplifier in the handset is asked to apply to a transmission through the uplink power control mechanism.[8] Higher power levels are requested when, among other reasons, the base station determines that radio noise and interference levels are high, the application or service (such as video) requires higher throughput, and/or there is a relatively long distance between the base station and the device. Thus, for example, a device may be requested to transmit at very high power levels when it is near the cell edge or, alternatively, when the device located in the middle of the cell and needs to send packets at high data rates.

Power amplifiers in mobile devices are designed to support maximum power specifications. These maximum power specifications reflect a trade off of many factors. Higher maximum power specifications mean, among other things, that the power amplifier may be more expensive, that it may be larger, that it will require greater power from the battery, and that it will generate greater heat. These issues can affect device form factors, battery life, handset costs, and other important aspects of the device. The power amplifiers used in mobile devices reflect these tradeoffs.[9]

It is not uncommon for the base station to instruct the device to transmit at levels that may exceed the maximum specifications of the device's power amplifier. Power amplifiers used in handsets are designed to exceed maximum transmit power specifications under certain circumstances. When the base station's uplink power control commands effectively request a device to transmit at a power level that exceed the power amplifier's maximum power

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[8] The goal of the power control mechanism is to meet a certain error rate while minimizing the transmit power, and hence minimizing potential interference to other users of radio spectrum.

[9] 3GPP specifications for LTE define "Power Class 3" for a mobile devices, which corresponds to the maximum transmit power of 200 mW or 23 dBm.

specifications, the power amplifier may transmit at power levels that exceed its maximum specification. When this occurs, the power amplifier is operating in a "non-linear" fashion.[10]

Another mode in which handsets implement non-linear amplification is through the use of pre-distortion. A common and inexpensive way to get more efficiency at lower cost out of a power amplifier is to run it in the non-linear mode but pre-distort the signal before it goes into the power amplifier such that the pre-distortion and amplifier distortion cancel each other to give the appearance of a linear amplified signal. However, the power amplifier is still non-linear and produces reverse intermodulation distortion.

When the transmission from the device passes through a power amplifier that is operating in non-linear mode, harmonics are created. Harmonics are additional transmissions that occur at specific frequency intervals from the frequency of the original transmission. The reverse intermodulation problem at issue here occurs when the harmonics caused by a power amplifier operating in a non-linear fashion mix with the adjacent high-powered Channel 51 broadcasts to create "third order intermodulation products." The frequency ranges in which third order intermodulation products occur are well known. The mathematical formula for identifying the frequencies of the third order intermodulation products is ($mf_1 \pm nf_2$), where m and n are integers, f_1 is the center frequency of the first signal and f_2 is the center frequency of the second signal. The "order" of the intermodulation product is the sum (m+n). For example, a "third order" intermodulation product will occur when m=1 and n=2, or when m=2 and n=1.

It is easy to see how Channel 51 interacts with uplink transmissions from a mobile device using B block or C block – in particular, transmissions from C block uplink frequencies – to create unwanted transmissions in the device's downlink frequency range. For example, uplink C block transmissions from the mobile device occur in the 710-716 MHz frequency range, with a center frequency of 713 MHz. The center frequency for Channel 51 (692-698 MHz) is 695 MHz. Accordingly, when these transmissions interact in the Band 12 or 17 mobile device's non-linear range of the power amplifier, they will produce a third order intermodulation product centered at 731 MHz (m=1, n=2, f_1=695, and f_2=713), which is the center frequency for the block A downlink frequency.

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[10] When a power amplifier is requested to transmit at a level up to the maximum transmit power, it can fully comply with such request. The power amplifier is said to operate in the linear region. However, if the power amplifier with the maximum rating of 200 mW is asked to transmit at 220 mW, it may be able to really transmit only 210 mW. The power amplifier is then said to be operating in the nonlinear region.

Table A summarizes the various Channel 51-related third-order intermodulation distortion ("IMD") products when a device is operating in B Block only, C Block only, and combined B and C Blocks. The center carrier frequency for Channel 51 is f_x=695 MHz, which is the center of Channel 51 spectrum that ranges from 692 MHz to 698 MHz. The center carrier frequencies for the LTE transmission scenarios are f_y= 707, 713, and 710 MHz when the device is operating in B Block only (uplink: 704-710 MHz), C Block only (uplink: 710-716 MHz), and combined B and C Blocks (uplink: 704-716 MHz), respectively. The bandwidth of the third order IMD products can be computed using well accepted engineering guidelines.[11]

Table A. Channel 51 Related 3rd Order Intermodulation Product for UEs Operating in B & C Blocks

Case	Location of Center Carrier Frequency for (f_x-2f_y)	Implication for Center Carrier Frequency for (f_x-2f_y)	Frequency Range of the 3rd Order IMD (Assumption: LTE Signal Bandwidths of 5 MHz or 10 MHz)
(I) Device Operating on Block B Only	719 MHz	Outside Band 12 and Outside Band 17	711 MHz to 727 MHz
(II) Device Operating on Block C Only	731 MHz	Inside Band 12 but Outside Band 17	723 MHz to 739 MHz
(III) Device Operating on Combined Blocks B & C	725 MHz	Inside Band 12 but Outside Band 17	712 MHz to 738 MHz

Although some of these intermodulation products will fall within both Band 12 and Band 17 downlink frequencies, it will cause the greater interference, and hence result in a lower SIR, in Band 12 devices. The greatest difference in SIRs for Band 12 and Band 17 devices will occur in Case II shown in the Table A, where the center frequency of the intermodulation product falls squarely within Band A. The bandpass filters used in Band 12 devices do not filter transmission in the A block, and thus will not be able to filter the energy from the intermodulation product that falls within the A block. By contrast, Band 17 bandpass filters do filter A block frequencies, which means that Band 17 bandpass filters are able to significantly attenuate the energy

[11] This bandwidth is the sum of the Channel 51 bandwidth (*e.g.*, 6 MHz) and two times the LTE signal bandwidth (*e.g.*, 2*5 MHz). The bandwidth of the third order IMD product is 16 MHz when the LTE channel bandwidth of 5 MHz is assumed for B Block only and C Block only operations. The bandwidth of the third order IMD product is 26 MHz when the LTE channel bandwidth of 10 MHz is assumed for combined B and C Block operations.

created by the intermodulation product. Band 12 devices will be subject to greater interference in Case I and III (shown in Table A) as well. The intermodulation product in these cases is still centered within (or immediately adjacent to) Band 12, which means that the Band 12 passband filters will not be able to attenuate as much of the energy from the intermodulation products.

In addition, the power level of the interfering third order intermodulation products created by Channel 51 will be greater for Band 12 devices than for Band 17 devices, because the power level of the Channel 51 transmission will be greater when it enters a Band 12 device. Because Band 12 devices are immediately adjacent to the Channel 51 broadcast frequencies, whereas Band 17 devices have 6 MHz separation, the power level of the Channel 51 broadcasts entering the Band 12 device will be greater, creating higher powered intermodulation products, which in turn create greater interference in the device's receive frequencies.

Moreover, the relative level of the interference from intermodulation products could increase significantly as the mobile device moves towards a Channel 51 transmitter (where the Channel 51 power levels are high) and away from cellular base stations (requiring the mobile device to transmit at higher power) because, as noted, as both the Channel 51 signal and the mobile device's transmit signal become stronger, the third order intermodulation product becomes substantially stronger.

It is important to again emphasize, however, that whether reverse intermodulation will occur (and the extent to which it occurs) does not depend solely on the relative location of the device to the Channel 51 transmitter and the base station. Rather, as noted, the extent to which the power amplifier operates in the nonlinear region – one of the prerequisites for reverse intermodulation – also depends on noise and interference levels and how the device is being used. For example, if the device is being used for services, such as video, that require high throughput levels, the device could be asked by the base station as part of an uplink power control mechanism to transmit at higher levels thus increasing the extent to which the power amplifier will be operating in a non-linear fashion. Given that the availability of LTE is expected to increase the use of services like video that require high throughput levels, the incidence of reverse intermodulation could increase significantly beyond the classic examples of the device being geographically near the cell edge.

2.2. Adjacent Channel Interference Caused By E block Transmissions.

The E block is licensed for high powered broadcasts – up to 50 kW – for video services. We understand that most of the E block spectrum is held by subsidiaries of Dish/Echostar. Dish/Echostar has not yet deployed any service using its E block spectrum.

It is well understood that high-powered E block transmissions will cause interference and hence decrease SIRs for Band 12 devices, and less so for Band 17 devices. As shown in Figure 1, E block spectrum will transmit in the frequency 722-728 MHz, which is immediately adjacent to the downlink A block spectrum (729-734 MHz) used by Band 12, and separated by 6 MHz from the B and C blocks used by Band 17. As discussed in Section 1.1, above, passband filters necessarily experience roll off, which means that they have limited ability to attenuate transmissions immediately adjacent to the passband frequencies. Because there is only a 1 MHz buffer between the lower passband frequency of the Band 12 RF filter and the E block transmissions, the Band 12 RF filter has limited ability to attenuate the E block transmissions. By contrast, the lower passband frequency for the Band 17 filter has 6 MHz of separation from the E block transmissions and thus is much more effective at attenuating E block transmissions.

The relative E block interference levels experienced by Band 12 devices and Band 17 devices are shown in Figure 2. The top portion of the figure shows the impact of E block interference on blocks B and C when using a Band 12 device and the lower portion of the figure shows the impact of E block interference on blocks B and C when using a Band 17 device. Note that the interference level caused by E block signals spilling over to blocks B and C (the green line) using a Band 17 device is much lower than the interference level caused by E block interference with a Band 12 device (blue line). This is typical of filter characteristics: the farther away from the band that transmits the energy, the more effective the filter will be in attenuating energy.

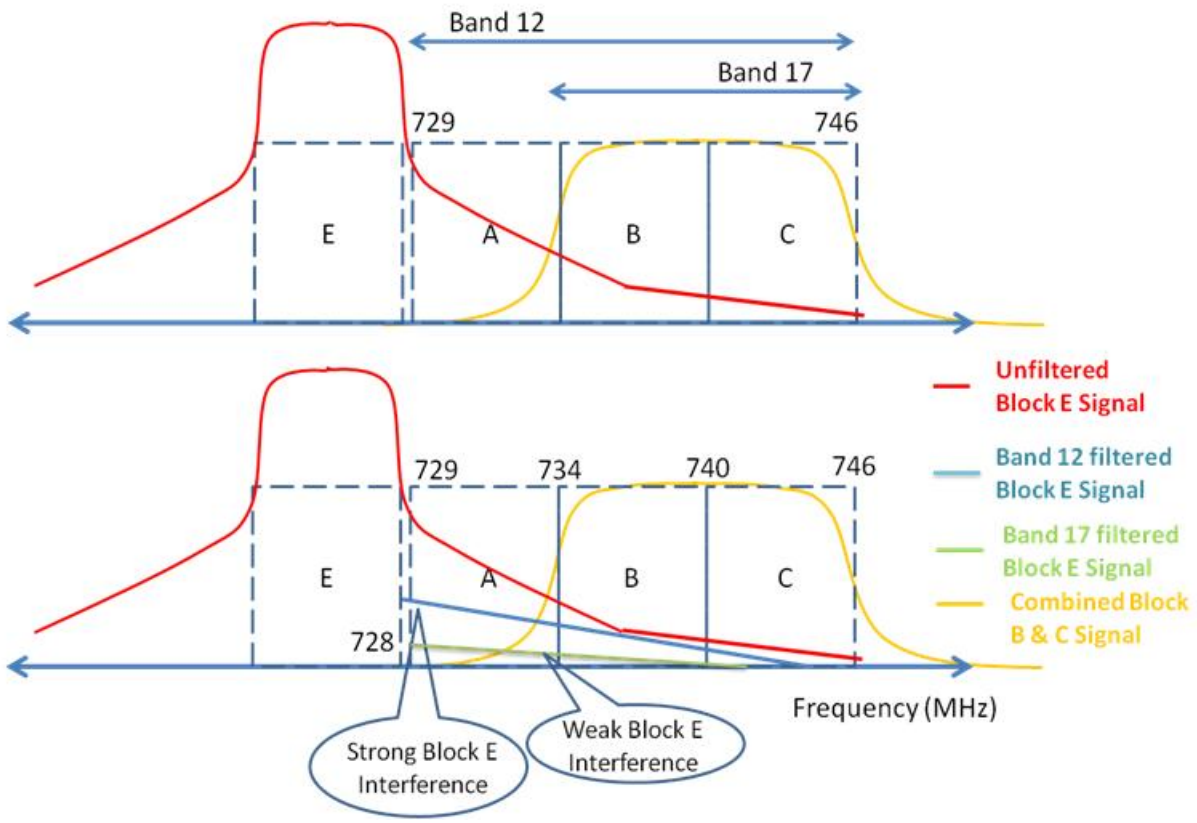

Figure 2. Impact of E Block interference on Band 17 and Band 12 UEs Operating on Blocks B & C

Because Band 12 devices are more susceptible to interference from E block compared to Band 17 devices, Band 12 devices will have lower SIRs than Band 17 devices, resulting in slower throughput and less efficient use of network resources.

Moreover, in some areas, particularly nearby E block transmitters where interference will be greatest, the ACI experienced by Band 12 devices may be so high as to result in receiver "overloading." Overloading occurs when the total signal strength at the receiver – *i.e.,* the sum of ACI and the desired signal – increases the temperature of the device to such an extent that it causes damage to the devices' electronic circuits. Overloading can significantly impair the device's functionality and may even render it inoperable. The total signal strength that causes overloading varies from device to device, and depends on the ability of various components in the device's receiver (*e.g.*, the low noise amplifier and filter) to withstand signal levels and associated rise in device temperature. It is not at all unlikely that receiver overloading will occur in Band 12 devices operating nearby high powered E block transmissions. As explained above, the mere 1 MHz separation between the E block and Band 12 means that a Band 12 filter will have limited ability to attenuate the high powered E-Block signal, resulting in strong E

block signals affecting the device's receiver components. By contrast, Band 17 devices are far less likely to experience overloading due to their much greater (6 MHz) separation from the E block.

3. INABILITY OF MITIGATION TECHNIQUES TO ADDRESS CHANNEL 51 And The E BLOCK INTERFERENCE

We have reviewed submissions by parties suggesting that interference from Channel 51 and the E block can be adequately mitigated by adding base stations, network optimization, restrictions on channel bandwidths, and base station scheduler modifications [16]. We note at the outset that such claims are not and cannot be supported by any real world testing. Neither E block networks nor Band 12 devices have even been widely deployed, making it impossible to know today the extent to which such mitigation techniques are practical or useful.

For example, adding LTE base stations (eNodeBs) would certainly increase the LTE signal levels and lead to increased SIRs to counteract high Channel 51 and E block interference levels. But no one can say with any certainty how many base stations would have to be added or the extent to which such additions would mitigate the interference.

Moreover, there are numerous practical impediments to this approach. Base stations would need to be added all around the Channel 51 transmitter and E block transmitters. RF network planning and design, which is a non-trivial matter, would need to be done for each newly added LTE cell site and modified for existing LTE cell sites. RF design modification is an iterative process. Implementation of the modified RF design would consume significant engineering and non-engineering human resources, and would delay the ability to deploy such interference mitigation measures.

After the initial RF design that reflects interference caused by Channel 51 and E block is done, it would be necessary to determine whether the new cell site locations recommended by the RF design process could actually be used to deploy eNodeBs. In general, the places where new cell sites could be of help will have very specific locations. Given the very specific locations where cell sites would be needed, in many instances a suitable location for a new cell site will not be available. And, even where new cell sites are available, we understand that it can take years to make a new cell site operational due to factors such as requirements for zoning approvals, leaving the interference from Channel 51 and E block unaddressed for a significant period of time.[12]

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[12] *See, e.g.,* Comments of AT&T, Acceleration of Broadband Deployment: Expanding the Reach and Reducing the Cost of Broadband Deployment by Improving Policies Regarding Public Rights

There are especially unique impediments to trying to mitigate interference from E block transmissions. As an E Block network is deployed, Band 12 carriers will constantly face new sources of interference as each new E block transmitter tower is added. Moreover, E block transmitters can be expected to be placed with much higher density compared to Channel 51 transmitters, reducing the potential for mitigating interference generated by E block towers. Moreover, to the extent that E block signals are at or near levels that cause receiver overloading, adding additional eNodeBs would only *increase* the potential for receiver overloading because the total signal strength would be higher after the addition of eNodeBs.

Placing Channel 51 and E block constraints on the RF design would further restrict the degrees of freedom to tune the network to achieve optimal LTE performance. Network optimization is a critical component in the lifecycle of a cellular technology. Network optimization leads to enhanced network performance and user experience, as well as lower cost. Example mechanisms to optimize the RF performance include changes in antenna related parameters (*e.g.*, tilt, azimuth, beamwidth, and antenna height), changes in configuration parameters (e.g., Physical Cell Identities), and operational parameters (*e.g.*, handover and power control parameters). RF optimization is already limited by LTE constraints such as the amount of intra-LTE interference. Modifying antenna parameters, as some have suggested, to overcome non-LTE interference such as Channel 51 and E block interference would most certainly degrade the LTE network performance in numerous cell sites and not just the first tier of LTE cell sites surrounding Channel 51 and E block transmitters. For example, when the LTE antenna azimuth is changed to focus more energy toward the area with strong Channel 51 and E block interference, it may create coverage holes in the existing LTE network, reducing the network throughput and user throughput in multiple cell sites. Network optimization alone would be severely inadequate to solve Channel 51 and E block interference and is not a viable solution.

It has also been suggested that Channel 51 and E block interference can be mitigated by modifying the eNodeB scheduler. The scheduler is a proprietary algorithm that is quite complex and is an important product differentiator for the eNodeB vendors. The scheduler allocates downlink and uplink radio resources to the users in a cell. The scheduler considers numerous inputs (*e.g.*, amount of user data in the buffer and promised Quality of service ("QoS")) to make such resource allocation decisions. If the scheduler is customized for each site

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of Way and Wireless Facilities Siting, WC Docket No. 11-59 (July 18, 2011); Reply Declaration of William Hogg, *Applications of AT&T Inc. & Deutsche Telekom AG for Consent to Assign or Transfer Control of Licenses and Authorizations*, WT Docket No. 11-65, at 26-30 (June 10, 2011). As explained in the accompanying declaration of David Wolters, the need for multiple new base stations would also require significant additional expenditures both in the form of capital expenditures and operating expenditures.

(expensive) such that certain portions of the spectrum that experiences Channel 51 and/or E block interference are not allocated to users, it could avoid some interference. However, the network performance and user experience would be adversely affected, due to fewer radio resources being available. For example, if only 5 Physical Resource Blocks ("PRBs") (corresponding to 0.9 MHz spectrum) are unused to avoid Channel 51 and/or E block interference, the network throughput is reduced by nearly 10% in the case of a 10 MHz channel.[13]

The impact of Channel 51 and E block interference on the LTE network performance may be magnified further when the interference affects the downlink control channels (*i.e.*, PDCCHs as mentioned earlier in Section 2). The PDCCHs allocate downlink and uplink resources and if the interference affects the PDCCHs, the devices could miss the resource allocation messages, leading to lower throughput in the downlink and the uplink. If a certain part of the spectrum is not used by the scheduler for the PDCCHs to avoid the interference, fewer PDCCHs would be available to convey resource allocations to users, reducing the number of users that can be simultaneously supported during a given time interval.[14]

Finally, it is conceivable that Channel 51 intermodulation (but not E block interference) could be ameliorated, but not eliminated, by reducing instances in which mobile device amplifiers produce non-linear output. This would likely result in higher cost and/or lower quality consumer devices for the consumers. As explained above, the reason why mobile amplifiers are operating in the non-linear range is because power input must be increased to maintain acceptable signal strength or because high data rates are necessary. Constraining amplifiers from non-linear operation in these circumstances might mitigate intermodulation concerns, but could result in degraded device performance. Installing higher power amplifiers could also reduce intermodulation effects, but at a higher cost for the device. And more importantly, higher power amplifiers would dissipate more heat and potentially increase the size of mobile devices.[15]

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[13] Furthermore, channel extraction of OFDM (Orthogonal Frequency Division Multiplexing) subcarriers is done with an FFT (Fast Fourier Transform), and FFT alone is not a very good filter; if interference corrupts a subcarrier, its impact may be experienced by the surrounding subcarriers.

[14] This time interval is referred to as a subframe in LTE. The subframe is 1 ms long. The users are typically allocated resources per subframe.

[15] It is also the case that the more that a device is "tailored" to address unique intermodulation issues caused by Block B and C "uplink" transmissions, the less these devices could serve as a

4. MEASURING THE IMPACT OF CHANNEL 51 AND E BLOCK INTERFERENCE

For the reasons set forth above, as a matter of basic physics and engineering, Band 12 devices will be more susceptible to interference from Channel 51 and E block broadcasts than Band 17 devices. All else being equal, this greater interference will cause Band 12 networks and mobile devices to operate less efficiently and at slower throughput than Band 17 networks and mobile devices.

What we cannot say with certainty – and what no one can legitimately say with certainty at this time – is the precise amount by which Band 12 networks will operate less efficiently and experience slower data throughput compared to Band 17 networks, or the precise geographic areas where that will occur. The precise amount by which Channel 51 and/or E block transmissions will impose greater performance reductions for Band 12 devices than for Band 17 devices depends on numerous factors that cannot be known or measured today.

For example, to measure the difference in performance of Band 12 and Band 17 mobile devices in the presence of interference from Channel 51 and E block broadcasts on an apples-to-apples basis requires a network and mobile devices capable of supporting both Band 12 and Band 17 mobile devices, so that the *only factor* affecting performance is the choice of the band. But there is no deployed network that supports both Band 17 and Band 12, and Band 12 LTE devices have just begun to appear.

Further, the impact of E block transmissions on Band 12 and 17 networks would be impossible to measure today in any real world application, because the E Block licensees have not yet deployed such networks. Without knowing the locations of E block base stations, the height of the transmitters, the tilts of the antennae, and myriad other factors, it is not possible to accurately predict the extent to which (or where) E block transmissions will interfere with Band 12 networks and mobile devices.

Another problem with attempting to predict the interference caused by Channel 51 and the E block with precision is that mobile networks are dynamic, not static. For example, operators of an E block network likely will be constantly adding E block transmitters, optimizing antenna tilts, optimizing power, and making the many other day-to-day changes to the network to maximize its performance. In response, Band 12 carriers would be forced to invest resources to continually re-optimize their networks. As a result of these constant actions and reactions, the radio environment will constantly be changing.

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platform for carriers using A block— which we understand to be the principal justification for the Band 12 mandate in the first instance.

The impact of interference also depends on usage patterns that affect network loads. The impact of interference – which reduces network resources – will be greater where there is higher demand for network resources. Moreover, the impact of interference will be greater where customers are using relatively high-throughput applications, such as video streaming, or low-latency applications, such as VoLTE.[16]

For all of these reasons, any testing that purports to have reached definitive conclusions as to the actual impact of the Channel 51 and E block interference on Band 12 and 17 devices must be analyzed thoroughly and critically.

The only purported analysis of the impact of interference from Channel 51 and E block transmissions on Band 12 and Band 17 devices in this proceeding that we are aware of was submitted to the FCC by a company called Vulcan Wireless ("Vulcan") [15]. Vulcan's original submission was comprised of high-level summaries of its "tests" with no documentation that would allow third parties to reproduce the purported results. And even the summaries raised significant questions about the validity of the procedures and assumptions used in the test.

Vulcan only recently submitted the underlying report on which its original submission was based, which shows that it was conducted by Wireless Strategies. We have not yet had sufficient time to thoroughly review this supplemental submission, but our initial review confirms that the analysis is flawed in numerous respects.

Most notably, the Wireless Strategies analysis confirms that no Band 12 devices were used in the analysis. This is a critical flaw. The central scientific hypothesis here is that Band 12 devices will be subject to greater interference than Band 17 devices. It is impossible to test this hypothesis without using both a Band 12 and Band 17 device.

Instead, to analyze Channel 51 interference, Wireless Strategies merely purports to test whether a Band 17 device would work if it were subject to interference within its filter's passband ranges, and assumes that if it does, then so too would a Band 12 devices when faced with Channel 51 interference that creates interference within a Band 12 device's passband frequencies. This is a significant assumption. But even if it were true, Wireless Strategies' analysis focuses on the wrong question. The relevant question is whether Channel 51 interference will cause the performance of Band 12 devices and networks to fall below those of Band 17 devices and networks, all else being equal, not whether a device will work at all. As we

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[16] The impact of interference will also depend on the transceiver design. New transceivers are coming out all the time and they may have different characteristics in the way they react to Channel 51 and E block interference.

explain above, the increased interference from channel 51 is highly likely to cause Band 12 devices to operate at lower throughput levels compared to Band 17 devices.

The Channel 51 analysis is also flawed because it appears designed to understate the extent to which the intermodulation interference will be greater for Band 12 devices compared to Band 17 devices. As we explained above, using the center frequency for Channel 51 transmissions and the center frequency for block C transmissions, produces the center carrier frequency of the intermodulation products in the block A receive frequency for the device (*i.e.*, 731 MHz), which is filtered well by Band 17 devices but not by Band 12 devices. The Wireless Strategies analysis, instead focused on an intermodulation product produced by an off-center Channel 51 broadcast that results in the center carrier frequency of the intermodulation products that falls within the B block (*i.e.*, 735 MHz), which is not filtered as well by either Band 12 or by Band 17 devices, thus creating the false impression that this interference generally affects both Band 12 and Band 17 equally.

In this regard, Wireless Strategies also incorrectly asserts ([16] at 6) that "[f]or such IM interference to impact the device's receive frequencies, the device must transmit at maximum power near the upper portion of the Lower C Block while simultaneously receiving in the lowest portion of the Lower B Block," and thus concludes that Channel 51 interference will only affect a hypothetical AT&T Band 12 network in Channel 51 markets where AT&T has both B and C block spectrum (so that AT&T can both transmit on C and receive on B). That is not accurate. As we explained in Sections 1 and 2, Band 12 will be more susceptible to interference from reverse intermodulation everywhere that AT&T devices transmit using the C block (or combined B & C blocks). It is the interaction between C block transmissions and Channel 51 that causes centers of the intermodulation products to fall within or very near the RF passband frequency ranges used by Band 12 devices, but outside the RF passband frequency ranges used by Band 17 devices, resulting in greater interference for Band 12 devices relative to band 17 devices. As we explained in Sections 1 and 2, Band 12 devices use RF filters that are substantially less able to attenuate third order intermodulation products produced from interactions between Channel 51 transmissions and C block transmissions, whereas Band 17 devices can significantly attenuate such transmissions. Accordingly, Band 12 devices are more susceptible to interference than a Band 17 device.

Similarly, Wireless Strategies asserts that a Band 12 device using C block to transmit and receive would not be subject to IMD, because the IMD product would fall only in the A and B block receive frequencies. Although it is true that the bandwidth of the intermodulation product intersects with the A and B receive frequencies and not with the C receive frequencies, it is not true that this IMD product will not cause interference for a Band 12 device receiving in the C block. The signals do not suddenly drop like a pulse function to minimal power outside the

bandwidth; their power levels gradually decrease. Hence, strong IMD will have a high power level when it hits the baseband filter of the C block, causing significant interference. By contrast, a Band 17 device would be less subject to such IMD because the Band 17 device would be able to attenuate the IMD to a larger extent compared to a Band 12 device due to the increased amount of RF filtering and would experience less interference.

The Channel 51 field testing presented by Wireless Strategies is also flawed. These field tests purport to measure Channel 51 and base station signal levels in different areas near one Channel 51 receiver. Obviously, even assuming these measurements are accurate, a sample size of one is not sufficient to draw conclusions about the environments nearby the numerous other Channel 51 receivers. Furthermore, the distances where the measurements were made were relatively far from the Channel 51 transmitters. More locations closer to the Channel 51 transmitters should have been selected for measurements. Moreover, it is important to note that Wireless Strategies' field measurements failed to include in-building measurements where the difference between cellular base station and Channel 51 transmissions may be significantly higher, especially on higher floors.

The analysis of E block is also fundamentally flawed. Here, again, Wireless Strategies does not analyze the relative performance of Band 12 and 17 devices in the presence of E block transmissions. Instead, Wireless Strategies purports to have used lab tests to show that a Band 17 device will continue to operate above 3GPP minimum specifications in the presence of high powered transmissions from the immediately adjacent frequency bands (the A block). From this they conclude that a Band 12 device would also operate above minimum 3GPP specification in the presence of high powered transmission from immediately adjacent frequency bands (the E block).

But, again, whether a device might still work when faced with the additional interference is not the relevant question. The issue here is the relative impact of E block transmission on Band 12 and Band 17 performance. This difference depends on the relative effectiveness of RF filtering of E block transmission for devices configured for the two Bands. As we explained above, the RF filter in a Band 17 device is able to attenuate the interfering signal by a larger amount compared to the RF filter in a Band 12 device due to (i) larger separation between the interfering signal and the left edge of the passband of the RF filter and (ii) the practical RF filter limitations such as roll-off. Hence, the E-Block interference reaching the baseband is weaker for a Band 17 device and stronger for a Band 12 device. The Wireless Strategies analysis, which by its own terms removes the impact of the RF filters, fails to account for these critical factors.

Wireless Strategies also purports to have measured real-world E block transmission levels based on a now defunct E block video system, and based on these measurements purports to draw conclusions about the power levels that could be expected from future E block networks.

The main problem here, is that the now defunct E block system used in Wireless Strategies' test contained a relatively small number of E block transmitters, and it is likely that any future deployments would use many more transmitters. It is a common phenomenon of physics that more densely situated transmitters with a given transmit power level (*e.g.,* 50 kW) cause more interference than sparsely situated transmitters with the same transmit power level. Just as a matter of common sense, an LTE device is much more likely to be closer to a transmitter in case of densely situated transmitters and hence is much more likely to experience a higher degree of interference.[17]

[17] Wireless Strategies recognized this flaw in the test it presented and responded incorrectly that "[a] larger number of towers would improve coverage in weak signal areas, but would not add to the strong signal in the near vicinity of a broadcast tower. From this perspective, the number of towers in the city is immaterial." But the Vulcan submissions show that E block transmissions near E block transmitters would cause significant interference for Band 12 devices. And the laws of RF propagation dictate that more fixed transmit power level transmitters in a given area would enhance the signal level distribution. Greater consistency of increased E block energy levels would thus increase the likelihood of interference caused to LTE devices.

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CURRICULUM VITAE

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Vitae

Section I: Experience & Education

Current Position:

Director of Wireless at Virginia Tech (Wireless@VT), 2005-present
Professor of the Bradley Department of Electrical and Computer Engineering, June 2002- Present
Interim Director, The Ted and Karyn Hume Center for National Security and Technolgy, January 2010 – May 2011
CEO and Co-Founder, Power Fingerprinting, Inc. 2011-Present
CTO and Co-Founder, Cognitive Radio Technology, 2007-present
Willis G. Worcester Professor, Bradley Dept. of Electrical and Computer Engineering, 2005-present

Professional Interest:

Research and teaching in signal processing and communication systems

Specific Research Interests	Specific Teaching Interests
Software Radios	Software Radios
Smart Antennas	Digital and Analog Communications
Interference Rejection	Discrete Time and Digital Signal Processing
Wireless Networks	Cellular and Personal Communications
Cognitive Radio	DSP-based Communication System Design
Location Technology	Adaptive Filtering

Education:

Ph.D.
Electrical and Computer Engineering, December 1987, University of California, Davis
Awarded American Electronics Fellowship for Faculty Development
Major: Statistical Signal Processing; Minor: Control Systems and Statistics
Dissertation: *Interference Rejection Using Time-Dependent Adaptive Filters*
Attended part-time at University of Santa Clara, September 1980 through June 1983

M.S.
Electrical and Computer Engineering, June 1980, University of California, Davis
M.S. Project Topic: An EEG Data Acquisition and Analysis System

B.S.
Electrical and Computer Engineering, March 1979, University of California, Davis

Employment:

Professor, Virginia Tech, April 2001-present
Director, MPRG 200-2002
Associate Professor, Virginia Tech, 1997-2001
President and co-founder, Power Fingerprinting, 2011 - present
CTO and co-founder, Cognitive Radio Technologies**,** 2007-present
Co-founder, Dot Mobile, Inc., March 2000-2001
Consultant, Reed Engineering (Self-Employed), 1987-present
Assistant Professor, Virginia Tech, 1992-1997
Research Engineer, University of California, Davis, 1992
Lecturer, University of California, Davis, 1988-1992
Associate Instructor, University of California, Davis, 1985-1987
Teaching Assistant, University of California, Davis, 1984-1985
Member of Technical Staff, Signal Science, Inc., Santa Clara, CA and Hanover, MD, 1980-1985

Professional Affiliations:

Member of **Tau Beta Pi Honor Society**
Member of **Phi Kappa Phi Honor Society**
Member of AFCEA
Fellow of the IEEE

Professional Awards:

Vehicular Technology Society Distinguished Lecturer 2011
Named Willis G. Worcester Professor of ECE, summer 2005, Fall 2010
Industry Achievement Award, SDR Forum 2004
Institute of Electrical and Electronics Engineers Fellow, Dec. 2004
Virginia Tech College of Engineering Outstanding Researcher Award, 2001

Section II: Funded Research
(Principal Investigator or Co-Principal Investigator)

Enhanced Security Monitoring and Intrusion Detection Using Power Fingerprinting and SDR and CR Wireless Systems, Power Fingerprinting Inc., $50,236.00 7/1/2012 – 12/31/2012

Rural Virginia Testbed Planning, CAER, $169,999.00, 1/1/2012 – 9/30/2012

Wireless Assessment of the Gigapark Sites in the Mid Atlantic Broadband Footprint, Mid-Atlantic Broadband. $54,419.00, 7/1/2011 – 9/1/2011

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EndedUpdated to OSSIE Core Framework to Enhance Compatibility with Open CPI, Mercury Federal Systems, $39,998, 7/1/2011 – 12/31/2011

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SDR Technology Development Support, Maryland Reocurement Office, 9/30/10 – 9/29/2010 $1,562.300 (expected duration 5 years at $5M)

Mobile Cognitive Radio Testbed, ICTAS, 7/1/10 – 6/30/11 $213,566 (co-PI)

Experimental Develoment Capability for Software Defined Radio with Agile Hardware, ONR, 1/27/2010 – 1/26/2011 $277,718 (co-PI)

Collaborative Research: Enhancing Access to the Radio Spectrum (EARS) Workshop, NSF 4/15/2010 – 03/31/2011 $21,860.00 (co-PI)

Recommendations for Transitioning Silvus MNM FPGA Core IP, DARPA (Silvus Technologies) 2/18/2010 – 2/17/2011, $39,970.00 (co-PI)

NSWC-TO13-Wireless Distributed Computing: Concept to Reality, Naval Secure Warfare (DARPA) Center 8/16/10 – 8/15/2011 - $498.798.0

Investigating the Relationship of OSSIE to Higher Layers, NSF 8/1/2009 – 2/28/10 $76,040

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IC CAE: Emerging Tehcnologies IC CAE, Howard University 9/23/2009 – 9/22/2011 $2.5M

REU Supplement to award #0520418 Nets: Oriwub:An Open Systems Approach for Rapid Proto-typing Waveforms for Software Defined Radio, NSF $41,800

Nets Prowin: An Open Systems Approach for Rapid Prototyping Waveforms for Software Defined Radio, National Science Foundation, 8/1/08 – 7/31/09 $12,000 (asking for additional REU funding)

Enhancements to OSSIE: (Open Source SCA Implementation: Embedded), Science Applications International Corporation, 4/1/07 – 90/07 $75,000

Collaborative Research: CT-T TRIESTE: A Trusted Radio Infrastructure For Enforcing Spectrum Etiquettes, NSF, 10/01/07 – 9/30/10, $150.000 (Reed Co-PI)

Development Design of a Cognitive Engine and Anyalysis of WRAN Cognitive Radio Algorithms, ETRI, 7/01/07 – 12/31/07 $119,999

An Integrated Tool for SCA Waveform Development, Testing, and Debugging and A Tool for Automated Estimation of DSP Resource Statistics for Waveform Components, US-Army-CERDEC Office, 6/12/07 – 6/11/08, $326,125

Software Defined Radio Waveform and Device Development and Component Deployment Using OSSIE, DOD, 7/19/07 – 7/18/10, $975,639 ($184,744 awarded to this point)

Reasoning and Learning in Adapative Wireless Networks, BBN Technologies, 10/1/07 – 12/31/10, $913,196 (co-PI)

US/Ireland International Workshop on Next Generation Open Architectures for Software-Defined Radio, NSF, 9/15/07 – 8/31/08, $35,963

VT-CogNet: Virginia Tech Cognitive Radio Network, ICTAS, 1/1/08 – 6/30/09,$160,170 (Reed, Bose PIs)

Trade Study Of Implementation of SDR: Fundamental Limitations and Future Prospects (DARPA SEED), US Army Aviation & Missile Command, 9/11/07 – 6/30/08 (Reed PI) $115,364

Distributed Computing for Collaborative Software Radio, Office of Naval Research, 02/05/07 - 02/04/10, $533,722 ($108,728 awarded first year)

A Panel of Commercial GSM Experts For Supporting JIEDDO Operations, JIEDDO, 12/18/06 - 2/28/07 $38,275

Cognitive Radio Test-bed, Virginia Space Grant Consortium, 08/16/06 - 08/15/07 $5,000

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A Low-Cost All-Band/All-Mode Radio for Public Safety, National Department of Justice (Dept. of Justice), 10/01/05 - 09/30/08 $399,816 (Reed Co-PI)

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Interference, Propagation, and Antenna Placement Issues for XM Radio, GM, 3/26/01 - 9/25/02 $583,527

AOL Fellowship in Wireless Home Networking Technologies, AOL, 01/01/01 - 05/15/03 $84,583

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Motorola University Partnership in Research: Overloaded Array Processing, Motorola, 09/01/00 - 08/31/02 $84,944

Multiuser Detection for Overloaded Antenna Arrays, Raytheon, 05/00 - 05/02 $1,126,194

An Investigation of Base Station Diversity For Cellular Applications - Phase II, Metawave, 02/29/00 - 02/28/01 $104,000

Broadband Channel-Adaptive Radio Modem for NGI Network Extension and Access, Hughes Research Laboratory, 10/01/99 - 11/30/01 $81,412

Research Into Signal Recovery Algorithms in Support of Spectral Spatial Interference Cancellation System (SSICS) – Phase II Research Effort, Raytheon Company, 02/01/00 - 05/15/01 $149,756

Navy Collaborative Integrated Information Technology Initiative (NAVCIITI), Office of Naval Research, 04/00 - 06/04 $9,651,087 (Reed portion $534,089)

Research into Spatial Signal Recovery Algorithms in Support of Spectral Spatial Interference Cancellation System - Phase I (SSICS), Raytheon Company, 080/2/99 - 01/10/00 $97,857

Low Power and Robust Communications Using Hand-Held Smart Antennas for Receiving and Transmitting, Texas Instruments, 07/01/98 - 06/30/00 $331,993

An Investigation of Base Station Diversity for Cellular Applications, Metawave Communications, 03/01/99 - 02/28/01 $179,706

International Wireless Communication Research Program, Virginia Tech Research and Graduate Studies' SEED Program, 01/01/99 to 06/30/00 $7,500

Navy Collaborative Integrated Information Technology Initiative (NAVCIITI), Office of Naval Research, 11/14/98 - 09/30/00 $2,700,000.

Enhancing the Capacity of IMT-2000 Through Turbo Coding and Smart Antennas, LGIC, 10/01/98 - 09/30/99 $122,904

Low Power and Robust Communications Using Hand-Held Smart Antennas for Receiving and Transmitting, Texas Instruments, 07/01/98 - 06/30/99 $132,000

Techniques for Evaluating Location Technologies, Comcast, 05/01/98 - 12/31/98 $112,154

Development of Tools for CDMA Cellular Network Planning, Innovative Global Solutions (IGS), 04/01/98 - 01/31/99 $42,889

Configurable and Robust Wireless Communications Nodes, DARPA, 07/01/97 - 12/30/00 $2,015,431

Support of Telelink System Test, Global-Net, Inc., 09/25/96 - 09/24/97 $50,000

Sprint RFI and Evaluation, Sprint Spectrum L. P., 09/26/96 - 12/31/96 $31,158

Rural MayDay/800 Call-in System Feasibility, I-95 Corridor Coalition/ Virginia Department of Transportation, 02/01/96 - 01/31/97 $299,176 (MPRG share $157,988)

A Study of Reconfigurable Receivers for Cellular and PCS, Texas Instruments, 08/25/95 - 08/25/96 $35,000

CDMA/FM Evaluation Effort, Comdial Corporation/Sigtek, 08/28/95 - 12/31/95 $25,000 (plus $7,500 CWT match)

Measured DECT System Performance in Actual Radio Channels, National Semiconductor, 10/01/94 - 2/15/96 $35,024

Investigation of BMP Impacts on Nonpoint Source Pollution Using System Analysis Procedures, Virginia Water Resource Center/U.S. Dept. of Interior, 04/01/95 - 04/30/96 $9,963

Development and Implementation Of Interference Rejection Techniques for Cellular Communications, SAIC, Center for Wireless Telecommunications (CWT), $50,000 (SAIC, 03/22/95 to 12/31/95) $25,000 (CWT, 07/01/95 to 06/31/96)

Expanded Testing of a High Capacity Adaptive Wireless Receiver, ARPA/AASERT, 08/01/95 - 07/31/98 $125,522

Co-Channel Interference Rejection for FM Mobile Phone Systems, Motorola, 01/16/95 - 09/15/9, $33,000

Curriculum Innovation for Simulation and Design of Wireless Communications Systems, National Science Foundation, 08/16/95 - 07/31/98 $289,291

A High Capacity Wireless Receiver Implemented with A Reconfigurable Computer Architecture, ARPA/WAMIS, 09/94 - 08/30/97, $1,727,230 ($533,250 for the first year, $586,750 second year)

Development of a Low Power High Data Rate Spread-Spectrum Modem**,** Grayson Electronics, Virginia's Center for Innovative Technology (CIT), Center for Wireless Telecommunications (CWT), $29,833 (Grayson, 03/01/94 - 11/30/94), $13,204 (CIT, 03/01/94 - 10/31/94) and $16,000 (CWT matching funds, 04/01/94 - 06/30/95)

Rejection of Interference in AMPS Cellular Communication, ARGO Systems, VA's Center for Innovative Technology (CIT), $25,000 (ARGO Systems, 12/10/93 - 05/10/94) and $12,500 (CIT, 04/01/94 - 07/31/94)

Capacity and Interference Resistance of Spread-Spectrum Automatic Vehicle Monitoring Systems in the 902-928 MHz Band, Southwestern Bell Mobile Systems, 10/01/93 - 08/15/94 $70,007

University Road Connection - A Smart Highway, Virginia Dept. of Transportation, 07/01/94 - 11/01/94 $19,523.79

Development of a Spread Spectrum Transceiver for the DECT System, National Semiconductor, 07/01/94 - 06/30/95 $30,000

Investigation of a Dynamic Range Enhancer for an Electro-optic Interface, Southwestern Bell Technology Resources, Inc., 08/01/93 - 06/01/94 $45,000

IVHS Research Center of Excellence, Federal Highway Administration (FHWA), 1993 - 1998, $1 million/year for 5 years (MPRG total approximately $390,000 over performance period, $330,000 received in 93-94, 94-95, 95-96, 96-97 contract years)

Center for Wireless Communications, Center for Innovative Technology, 09/01/93 - 08/31/98, $300,000 for first year. (Anticipated total funding approximately $1,490,835 plus an additional $357,551 of cost sharing by Virginia Tech)

The Performance and Feasibility of Time-Dependent and Non-Linear Adaptive Filters for Rejecting High-Power Co-Located Co-Channel Interference, US Navy via Systems Research Center, 05/15/93 - 09/01/93, Amount: 1/2 summer session support (value approximately $3,750)

Evaluation of an NTP-Based Protocol for Paging and Advanced Data Services, MobileComm, 07/01/93 - 09/30/93 $39,986

Grants & Gifts:

Ted and Karyn Hume center for National Security and Technology Endowment Fund January 2010, $5,000,000 (Note that most of this money goes for student fellowships, with $200k provided for center support.)
Total Amount - $5,209.010.00

Intel – Jan. 2010, gift for unrestricted research $50,000.00

Tektronix, reconditioned real time spectrum analyzer and two portable analyzers, ~ $130,000

Tektronix - Dec. 2009, reconditioned Arbitrary Function Generator, 100 Mhz, 2 Channel $5,110.00

Wireless@VT Industrial Affiliates Membership 2006-2009:
Affiliate Funding for the year 2009 – 2010 for Dr. Jeffrey H. Reed is $66,960.
Affiliate Funding for the year 2008 - 2009 for Dr. Jeffrey H. Reed is $40,534

Intel Coporation:: 2009 to support the research in "Cognitive Radio for Minimizing Power Consumption" $44,000

Tektronix, 12/2005, cash gift $20,000

Texas Instruments, 08/2005, cash gift $27,519

Tektronix, 07/2005, cash gift $20,000

Texas Instruments. 12/2004, cash gift $99,000

Tektronix, spring 2004, cash gift $20,000

CISCO Systems, 08/2003 and 02/2005, cash gift $176,000

Mercury Computer Systems, Inc., 2003, cash gift $50,000

Analog Devices, 2001-2002, cash gift $37,500

HRL, *Smart Antenna Research,* 2000, cash gift $40,000

Rockwell, Flexible Communications Using Reconfigurable Computing, 1998, $25,000 cash gift

Investigation of CDMA, donation from ITT, 1996, cash gift $100,000

MPRG Industrial Affiliates Membership 1993-2006: Grant total split between the five MPRG faculty (total paid $4,866,500 and an additional $110,000 committed to date). Services provided to sponsors include advanced copies of thesis and dissertations, informal consulting, and special opportunities to employ students.

Intel, 10/2007, $40,000, Support research in "Cognitive Radio for Minimizing Power Consumption," 5/2008, $44,000

Texas Instruments, Evaluation Module Kit, 01/2007, $995

Tektronix, Arbitrary Waveform Generator, 02/2007, $138,000.

Xilinx, Inc., Xilinx System Generator, ChipScope Pro, Xilinx Real-PCI interface, AccelDSP Synthesis Tool with AccelWare DSP IP Toolkits, VLYNQ Interface LogiCORE, ISE Foundation, University Option Embedded Development Kit, 01/2007, $39,615

Tektronix, equipment, $114,000

Texas Instruments, 06/2006, $49,500

Mercury Systems, AdapDEV 1280 Chassis with 900 MHz processor, 08/2003

Spectrum Signal Processing, Inc., Hardware necessary to implement a true software defined radio, 08/2002, $62,329

Grayson Wireless, Cellular test and measurement system, 08/2002, $66,312

Signia-IDT (formerly BAE), RF Front-end valve, 2002, ~$6,000

Altera*,* MAX + Plus II Fixed Node Subscription (FPGA board), $2,000

Texas Instruments, Evaluation Module incl. Code Composer Studio, 06/2001, $19,960

Texas Instruments, ADC-Converter, 03/2001, $99

Analog Devices, Evaluation Boards (5), Visual DSP software (2), In-Circuit Emulators (2), $3,790

Wireless Valley Communications, 2 copies SitePlanner w/LanFielder $49,980, 1 copy SiteSpy on SMT $995, 2005, $50,975

Analog Devices, receiver, processor, and receiver chip set, $645

Texas Instruments, boards, 2001, $2,495

HRL, 2000, Diversity Antenna, $200

Altera, development package, 2000, $995

Altera, (2) MAX+ PLUS II Fixed Node Subscription for PC, (1) design lab package, (1) Micro-Chip; $4,765

Motorola, 56311EVM computer board with DSP and 56311 on it, software, documentation, tutorial, and input/output capabilities, 12/2000, $2000

Texas Instruments, Evaluation software and manuals, 1998, $2,500

Texas Instruments, Evaluation Software, 1997, $1,000

Altera, Development Tools for Programming Configurable Logic Devices, $350

Texas Instruments, DSP Development Systems and Software, 1997, $11,475

Texas Instruments, DSP Hardware and Software, 1997, $27,500

Analog Devices, DSP Development Boards, 1996, $3,200

Altera, Software Materials, 1996, $5,000

SIGTEK, Spread Spectrum Receivers, 1995, $10,000

Section III. Teaching & Advising

Classes Taught:

Graduate Courses

Cellular and Personal Communications (ECE6644)
Software Radios: A Modern Approach to Radio Engineering (ECE5674)
Digital Signal Processing (ECE5624)
Cellular (ECE 5664)

Undergraduate Courses

Implementation of Communication Systems (ECE4654)
Signal Processing (ECE4624)
Communication Systems (ECE3604)

Courses Developed:

Major Revision of ECE course 5664 Cellular Radio and Personal Communications to focus on systems level description and design considerations of cellular standards this will take two more years to complete and result in a textbook.
Implementation of Communication Systems (ECE 4654)
Developed Class in Software Radio (ECE 5664)

Advising: Completed Ph.D. Dissertations:

Yash Vasavada, "An Iterative Confidence Passing Approach for Parameter Estimation and Its Applications to MIMO Systems," May, 2012

Hazem Shatila, "Adaptive Radio Resource Management in Cognitive Radio Communications Using Fuzzy Logic," April 2012

Ashwin Amanna, "Statistical Experimental Design Framework for Cognitive Radio," March 19, 2012

Carlos Aguayo Gonzales, “Power Fingerprinting for Integrity Assessment of Embedded Systems,” December 5, 2011

Xueato Chen, “Resource Allocation for Wireless Distributed Computing Networks,” (Co-Advised with Dr. Tamal Bose) completed May 2012

An He, “ Power Consumption Optimization – A Cognitive Radio Approach,” February 2011

Joseph Gaeddert, “Facilitating Wireless Communications through Intelligent Resource Management on Software-Defined Radios in Dynamic Spectrum Environments,” January 2011

Lizdabel Moarles Tirando, “An Approach to Using Cognitive in Wireless Networks,” December 2009

Kyou Woong Kim, “Exploiting cyclostationarity for radio environmental awareness in cognitive radios,” May 2008

Youping Zhao, “Enabling cognitive radios through radio environment maps,” May 2007

Rekha Menon, “Interference avoidance based underlay techniques for dynamic spectrum sharing,” April 2007 (co-advised with Dr. Michael Buehrer)

Jong-Han Kim, “On the impact of MIMO implementations on cellular networks: An analytical approach from a system perspective,” March 2007

Ramesh Chembil Palat, “Performance analysis of cooperative communications for wireless networks,” December 2006

Jody Neel, “Analysis and design of cognitive radio networks and distributed radio resource management algorithms,” September 2006

Chris Anderson, “A software defined ultra wideband transceiver testbed for communications, ranging, or imaging.” September 2006

James Hicks, “Novel approaches to overloaded array processing,” August 2003

Raqibul Mostafa, **“**Feasibility of smart antennas for the small wireless terminals,” April 2003

William Newhall, “Radio channel measurements and modeling for smart antenna array systems using a software radio receiver,” April 2003

Pablo Max Robert, “Reduction in coexistent WLAN interference through statistical traffic management,” April 2003

Tom Biedka, “Analysis and development of blind adaptive beamforming algorithms,” August 2001

Srikathyayani Srikanteswara, “Design and implementation of a soft radio architecture for reconfigurable platforms,” July 2001

Rich Ertel, “Antenna array systems: Propagation and performance,” July 1999

Nitin Mangalvedhe, “Development and analysis of adaptive interference rejection techniques for direct sequence code division multiple access systems,” July 1999

Nishith Tripathi, “Generic handoff algorithms using fuzzy logic and neural networks,” November 1997

Paul Petrus, “Novel adaptive array algorithms and their impact on cellular system capacity,” April 1997

Jeff Laster, “Robust GMSK demodulation using demodulator diversity and BER estimation,” January 1997

Rong He, “AMPS co-channel interference rejection techniques and their impact on system capacity, August 1996

Completed M.S. Theses:

Scott Meuleners, “Design and Implmentation of a Distributed TDOA-Based Geolocation System using OSSIE and Low Cost USRP Boards,” May 2012

Thomas Cooper, “ Integration of Open-Source Networks,” May, 2012

Shawn Hymel, “Massively Parallel Hidden Markov Models for Wireless Applications,” December 5, 2011

Peter Sahmel, “Eigenspace Approach to Specific Emitter Identification of Orthogonal Frequency Division Multiplexing Signals,” Nov. 2011

Hermie Mendoza, “Distributed Localization for Wireless Distributed Networks in Indoor Environments,” June, 28, 2011

Soumava Bera, “Design and Implementation of a MAC Protocol for Wireless Distributed Computing,” June 11

Hermie Mendoza, “Distributed Localization for Wireless Distributed Networks in Indoor Environments,” May 2011

Matthew Price , “Automatic Modulation Classification Using Grey Relational Analysis,,” April 2011

Ben Hilburn, “Component-Based Design and Service-Oriented Architectures in Software-Defined Radio,” April 2011

Sabares S. Moola, “Rapid Prototyping of Software Defined Radios using Model Based Design for FPGAs,” on July 22, 2010
Nikhil Challa, “ Approaches for Optimizing Software Defined Radio Performance,” on January 31, 2011

Ishtiaq Rouf, “Statistical Analysis of Wireless Communication Systems Using Hidden Markov Models,” July 2009

Matthew Carrick, “Logical representation of FPGA’s & FPGA circuits within the SCA,” July 2009

Patrick Farrell, “Digital hardware designing decisions & trade-offs for software radio systems,” May 2009

Philip Balister, “A software defined radio implemented using the OSSIE core framework deployed on a TI OMAP processor.” December 2008

Jacob DePriest, “A practical approach to rapid prototyping of SCA waveforms,” April 2006

Srinivasan Vasudevan, ”A simulation for analyzing the throughput of IEEE 802.11b wireless LAN systems,” January 2005

Brian Donlan, “Ultra-wideband narrowband interference cancellation and channel modeling for communications,” January 2005

Anil Hebbar, “Empirical approach for rate selection in MIMO OFDM,” December 2004

Seshagiri Krishnamoorthy, “Interference measurements and throughput analysis for 2.4 GHz wireless devices in hospital environments,” April 2003

Yasir Ahmed, “A model-based approach to demodulation of co-channel MSK signals,” December 2002

Ramesh Chembil Palat, “VT-Star – Design and implementation of a test bed for differential space-time block coding and MIMO channel measurements,” October 2002

Jody Neel, “Simulation of an implementation and evaluation of the layered radio architecture,” December 2002

Bing-Leung (Patrick) Cheung, “Simulation of adaptive algorithms for OFDM and adaptive vector OFDM systems,” August 2002

Shakheela H. Marikar, “Resource management in 3G systems employing smart antennas, January 2002

M. Soni, “Computing engine for reconfigurable software radio,” Oct. 2001

Christian Rieser, “Channel sounder for LMDS,” May 2001 (co-advisor)

James Hicks, “Overloaded array processing with spatially reduced search joint detection,” May 2000

Zhong Hu, “Evaluation of joint AOA and DOA estimation algorithms using the antenna array systems,” May 1999

Kim Phillips, “Probability density function estimation for minimum bit error rate equalization,” May 1999

Pablo (Max) Robert, “Simulation tool and metric for evaluating wireless digital video systems,” May 1999

Steven F. Swanchara, “An FPGA-based multiuser receiver employing parallel interference cancellation,” July 1998

Don Breslin, “Adaptive antenna arrays applied to position location,” August 1997

Steve Nicoloso, “Investigation of carrier recovery techniques for PSK modulated signals in CDMA and multipath mobile environments,” May 1997

Brian Fox, “Analysis and dynamic range enhancement of the analog-to-digital interface in multimode radio receivers,” February 1997

Nena Zecevic, “Interference rejection techniques for the mobile unit direct-sequence CDMA receiver, August 1996

Kevin Saldanha, “Performance evaluation of DECT in different radio environments,” August 1996

Milap Majmundar, “Adaptive single-user receivers for direct sequence CDMA systems,” February 1996

Yash Vasavada, “Performance evaluation of a frequency modulated spread spectrum system,” February 1996

Scott Elson, “Simulation and performance analysis of CDPD,” January 1996

Matthew Welborn, “Co-channel interference rejection using model-based demodulator,” January 1996

Francis Dominique, “Design and development of a frequency hopper based on the detection system for the 902-928 MHz ISM band,” December 1995

Nitin Mangalvedhe, “An Eigenstructure technique for direct sequence spread spectrum synchronization,” April 1995

Paul Petrus, “Blind adaptive arrays for mobile communications,” December 1994

Sihano (Raymond) Zheng, “Channel modeling and interference rejection for CDMA automatic vehicle monitoring systems,” November 1994

Fu-Sheng (Frank) Cheng, “A new approach to dynamic range enhancement,” September 1994

Volker Aue, “Optimum linear single user detection in direct-sequence spread-spectrum multiple access systems,” March 1994

Current Ph. D Students:

Eyosias Iman – Ph.D expected completion date December 2013

Dinesh Datla – Ph.D expected completion date July 2012

Karim Said – Ph.D expected completion date May

Abid Ullah – Ph.D expected completion date December 2013

Shravan Garlapati – Ph.D expected completion date May 2013

Matthew Vondall – Ph. D (Co-Advised with Amir Zaghoul) expected completion date Spring, 2013

Stephen Dudley – Ph.D expected completion date May 2014

Matthew Carrick – Ph.D. expected completion date May 2015

Current M.S. Students:

Karim Said - M.S expected completion date June 2012

Thomas Tsou – M.S. expected completion date June 2012

Michael Benonis – M.S. expected completion date December 2012

Sumedha Mohan – M.S. expected completion date May 2013

Section IV. Publications List

Books Authored or Co-Authored:

1. J. H. Reed, ed., An Introduction to Ultrawideband Communications Systems, Prentice Hall, March 2005, ISBN: 0-13-148103-7.

2. J. H. Reed, Software Radio: A Modern Approach to Radio Design, Prentice Hall, May 2002, ISBN: 0-13-081158-0.

3. N. D. Tripathi, J. H. Reed, and H. F. VanLandingham, Radio Resource Management in Cellular Systems, Kluwer Academic Publishers, Spring 2001.

Books & Proceedings Edited:

1. W. H. Tranter, B. D. Woerner, J. H. Reed, T. S. Rappaport, and P. M. Robert, Wireless Personal Communications – Bluetooth and Other Technologies, Kluwer Academic Publishers, 2000.

2. W. H. Tranter, B. D. Woerner, T. S. Rappaport, and J. H. Reed, Wireless Personal Communications – Channel Modeling and Systems Engineering, Kluwer Academic Publishers, 1999s.

3. W. H. Tranter, T. S. Rappaport, B. D. Woerner, and J. H. Reed, eds., Wireless Personal Communications: Emerging Technologies for Enhanced Communications, Kluwer Press, 1998.

4. T. S. Rappaport, B. D. Woerner, J. H. Reed, and W. H. Tranter, eds., Wireless Personal Communications: Improving Capacity, Services, and Reliability, Kluwer Press, 1997.

5. J. H. Reed, B. D. Woerner, and T. S. Rappaport, eds., Wireless Personal Communications: Advances in Coverage and Capacity, Kluwer Press, 1997.

6. T. S. Rappaport, B. D. Woerner, and J. H. Reed, eds., Wireless Personal Communications: The Evolution of PCS, Kluwer Press, 1996.

7. B. D. Woerner, T. S. Rappaport, and J. H. Reed, eds., Wireless Personal Communications: Research Developments, Kluwer Press, 1995.

8. T. S. Rappaport, B. D. Woerner, and J. H. Reed, editors, Wireless Personal Communications: Trends and Challenges, Kluwer Press, 1994.

Book Contributions:

1. H. I. Volos, D. Datla, X. Chen, A. He, A. Amanna, T. R. Newman, S.M. Shajedul Hasan, J. H. Reed, and T. Bose, "Green Communications: Realizing Environmentally Friendly, Cost Effective, and Energy Efficient Wireless Systems," in Energy-Aware Systems and Networking for Sustainable Initiatives, IGI Global, June 2012

2. A. He, A. Amanna, X. Chen, D. Datla, J. Gaeddert, S.M. Hasan, H. Volos, “Sustainable Green Computing: Practices, Methodologies and Technologies,” edited by Dr. Wen-Chen Hu and Dr. Naima Kaabouch, University of North Dakota, USA IGI Global, 2012

3. “Technical Challenges in Applying Network Neutrality Regulations to Wireless Systems,” “Net Neutrality: Contributions to the Debate,” Nishith D. Tripathi and Jeffrey H. Reed, Edited by Jorge Perez Martinez, 2011

4. “The Radio Environment Map”, (Book Chapter) Cognitive Radio Technology, Dr. Bruce Fette, ed., Y. Zhao, S. Mao, J. Neel, and J.H. Reed2nd edition, 2 April 2009

5. J. Neel. J. Reed, A. MacKenzie, Cognitive Radio Network Performance Analysis in Cognitive Radio Technology, B. Fette, ed., Elsevier, 2nd edition, 2 April 2009.

6. Y. Zhao, S. Mao, J. Neel, and J. H. Reed, “The Radio Environment Map” (Book Chapter) in Cognitive Radio Technology, B. Fette, ed., 2nd ed., Elsevier, April 2009.

7. J. Neel. J. Reed, and A. MacKenzie, “Cognitive Radio Network Performance Analysis” (Book Chapter) in Cognitive Radio Technology, B. Fette, ed., 2nd ed., Elsevier Inc., April 2009.

8. Y. Zhao, B. Le, and J. H. Reed, “Network Support: The Radio Environment Map” (Book Chapter) in *Cognitive Radio Technology*, by B. Fette, Elesvier Inc., pp. 337-363, August 2006, ISBN: 978-0-7506-7952-7.

9. J. O. Neel, J. H. Reed, and A. B. MacKenzie, “Cognitive Radio Performance Analysis” (Book Chapter) in *Cognitive Radio Technology*, by B. Fette, Elesvier Inc., pp. 501-579, August 2006, ISBN: 978-0-7506-7952-7.

10. B. M. Donlan, R. M. Buehrer, and J. H. Reed, “Ultra-wideband Wireless Systems,” in the *Encyclopedia of RF and Microwave Engineering*, pp. 5411-5423, Spring 2005, ISBN: 0-471-27053-9.

11. N. D. Tripathi, J. H. Reed, and H. F. VanLandingham, “Application of a Neurofuzzy System to Handoffs in Cellular Communications” (Book Chapter) in *Neuro-Fuzzy and Fuzzy-Neural Applications in Telecommunications (Signals and Communication Technology)*, by P. Stavroulakis, Springer Publishing, May 2004, ISBN: 3540407596.

12. J. H. Reed and C. J. Rieser, “Software Radio: Technical, Business and Market Implications,” in *World Market Series Business Briefing Wireless Technology 2001,* WMRC *PLC – World Markets Research Centre*, pp. 146-150, October 2000, ISBN 1-903140-36-1.

13. P. Petrus and J. H. Reed, “Co-channel Interference in Wireless Communication Systems,” in *Encyclopedia of Electrical and Electronics Engineering*, John Wiley & Sons, Inc., February 1999 (invited paper).

14. N. R. Mangalvedhe and J. H. Reed, “Analysis of an Eigenstructure Technique for DSSS Synchronization,” in *Wireless Personal Communications: The Evolution of PCS*, Kluwer Press, 1996 (also appears in *Virginia Tech’s Sixth Annual Symposium on Wireless Personal Communications*, June 1996), pp. 201-214.

15. J. D. Laster and J. H. Reed, “A Survey of Adaptive Single Channel Interference Rejection Techniques for Wireless Communications,” in *Wireless Personal Communications: Research Developments*, Kluwer Press, 1995 (also appears in *Virginia Tech’s Fourth Annual Symposium on Wireless Personal Communications*, June 1994), pp.29-54.

16. I. Howitt, J. H. Reed, V. Vemuri, and T. C. Hsia, “Recent Developments In Applying Neural Nets to Equalization And Interference Rejection,” in *Wireless Personal Communications: Trends and Challenges*, Kluwer Press, 1994 (also appears in *Virginia Tech's Third Symposium on Wireless Personal Communications*, June 1993), pp.49-58.

Papers in Refereed Journals:

1. Reed, J. H.; Bernhard, J. T.; Park, J.-M. "Spectrum Access Technologies: The Past, the Present, and the Future," Proceedings of the IEEE , vol.100, no. Special Centennial Issue, pp.1676-1684, May 2012, (invited paper)

2. Ashwin E Amanna, Daniel Ali, Manik Gadhiok, Matthew Price and Jeffrey H Reed, “Cognitive radio engine parametric optimization utilizing Taguchi analysis,” EURASIP Journal on Wireless Communications and Networking 2012, 2012:5

3. Xuetao Chen, Tamal Bose, S.M. Hasan and Jeffrey H. Reed, “Efficient detection of primary users in cognitive radio networks,” Journal International Journal of

Communication Networks and Distributed Systems, Publisher Interscience Enterprises Ltd, Issue Volume 8, Number 3–4/2012, Pages 267-285.

4. Shatila, H., Khedr, M. and Reed, J. H., Opportunistic channel allocation decision making in cognitive radio communications. Int. J. Commun. Syst.. April 2012. DOI: 10.1002/dac.2350

5. Datla, D.; Chen, X.; Tsou, T.; Raghunandan, S.; Hasan, S.M.S.; Reed, J.H.; Dietrich, C.B.; Bose, T.; Fette, B.; Kim, J.; , "Wireless distributed computing: a survey of research challenges," Communications Magazine, IEEE , vol.50, no.1, pp.144-152, January 2012

6. T. Yang, W. Davis, W. Stutzman, J. Nealy, D. Dietrich, S.M. Hasan, J.H. Reed, "Antenna Design Strategy and Demonstration for Software-Defined Radio (SDR)," Analog Integrated Circuits and Signal Processing: Volume 69, Issue 2 (2011), Page 161-171 (update paper from SDR'10 conference)

7. Harpreet S. Dhillon, Jeong-O Jeong, Dinesh Datla, Michael Benonis, R. Michael Buehrer and Jeffrey H. Reed, "A sub-space method to detect multiple wireless microphone signals in TV band white space," Analog Integrated Circuits and Signal Processing, Springer Netherlands, December 2011, Volume 69, Issue 2, pp. 297-306. (update paper from SDR'10 conference)

8. Carlos R. Aguayo González and Jeffrey H. Reed, "Power fingerprinting in SDR integrity assessment for security and regulatory compliance," Analog Integrated Circuits and Signal Processing, Volume 69, Numbers 2-3 (2011), 307-327. (update paper from SDR'10 conference)

9. Dinesh Datla, Haris I. Volos, S. M. Hasan, Jeffrey H. Reed and Tamal Bose, "Task allocation and scheduling in wireless distributed computing networks," Analog Integrated Circuits and Signal Processing , Volume 69, Numbers 2-3 (2011), 341-353. (update paper from SDR'10 conference)

10. Amanna, K. Thamvichai, M. Carrick, AT. Bose, J. Reed, "Grey Systems Theory Applications to Wireless Communications," Analog Integrated Circuits and Signal Processing: Volum 69, Issue 2 (2011), Page 259 (update paper from SDR'10 conference)

11. An He, Ashwin Amanna, Thomas Tsou, Xuetao Chen, Dinesh Datla, Joseph Gaeddert, Timothy R Newman, Shajedul Hasan, Haris I Volos, Jeffery H Reed, Tamal Bose, "Green Communications: A Call for Power Efficient Wireless Systems," Journal of Communications, Vol 6, No 4 (2011), 340-351, Jul 2011

12. A. He, A. Amanna, T. Tsou, X. Chen. D. Datla, J. Gaeddert, T. Newman, S.M. Hasan, H. Volos, J.H. Reed, T. Bose, "Green Communications: A New Paradigm for Power Efficient Wireless Systems," Journal of Communications Special Issue on Practical Physical Layer Techniques for 4G Systems & Beyond, Vol 6, No. 5. July 2011.

13. D.Datla, H.I. Volos, S.M. Hasan, Jeffrey H. Reed and Tamal Bose, "Wireless Distributed Computing in Cognitive Radio Networks, Ad-Hoc Network (Elsevier," available online April 15, 2011. (Print copy to be issued)

14. T. Newman, S.M. Hasan, D.Depoy, T. Bose, J.H.Reed, "Designing and Deploying a Building-Wide Cognitive Radio Network Testbed," *IEEE Communications Magazine,* September 2010

15. A. He, S. Srikantesware, K.K. Bae, T.R. Newman, W. Tranter, M. Verhelst, J. Reed, "Power Consumption Minimization for MIMO Systems- A Cognitive Radio Approach," IEEE JSAC September 2010.

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2. C. Dietrich, E. Wolfe, G. Vanhoy, C. Evans, "Cognitive Radio Testing Using Psychometric Approaches," Wireless Innovation Conference and Product Exposition (SDR'11-WinnCom) November 29-December 2, 2011 in Washington, DCC. Dietrich and J.H. Reed, "OSSIE SCA-based Open Source SDR," 2011 IEEE MTT Society's International Microwave Symposium, June 5-10, Baltimore, MD

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4. Yaeyoung Yang, William A. Davis, Warren L. Stuzman, S.M. Hasan, Randall Nealy, Carl B. Dietrich and Jeffrey H. Reed; "Antenna Design Strategy and Demonstration for Software-Defined Radio", SDR'10 November 30th – December 3rd, Washington DC

5. D.Datla, S.M. Hasan, T. Bose, J. Reed, "Computational Accuracy of Distributed Signal Processing in Wireless networks," SDR'10 Novermber 30th – December 3rd, Washington, DC

6. H, Gaeddertm H, Reedm "Resource Managementwith Real-Time Complexity Monitoring in Software-Defined Radios", SDR'10 Novermber 30th – December 3rd, Washington, DC

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99. R. He and J. H. Reed, "Spectral correlation of AMPS signals and its application to interference rejection," *IEEE Military Commun. Conf. (MILCOM)*, October 1994, pp. 1007–1011 (Invited paper.)

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Papers, Talks, & Lectures Presented at Professional Meetings:

1. Mid Atlantic Broadband Corp. “Initiatives in Wireless Communications, April 2011

2. 66th Annual Meeting of the ORAU Council of Sponsoring Institutions, “The Hume Center”, Oak Ridge TN, March 2011

3. Under invitation OSTP, “Testbed & Technology Platforms,” White House Conference Center, Truman Room, Washington, DC January, 2011

4. Speaker, Oak Ridge National Laboratory Board of Governors, Oak Ridge, TN May 2010, “The Hume Center for National Security and Technology”

5. Keynote Presentation, “The Future of Cognitive Radio,” Univ of Texas and Austin Technology Incubator. A group of faculty and VCs.

6. Invited Presentation, "The Second Wave of Wireless: A New Wave of Disruptive Technology," Atlantic Council (DC think-tank) to help inform international decision makers, Oct. 2010.

7. Cognitive Wireless Networking (CoRoNet), Keynote Speaker, Chicago, Illinois, September 20, 2010

8. The Ted & Karyn Hume Center Inauguration Reception and Board Meeting, Arlington, VA August 18, 2010.

9. NSF EARS Workshop, "Workshop on Enhancing Access To The Radio Spectrum', August 2010, Arlington, VA

10. Invited talk, "Cognitive Radio Research at VT," ISART, NTIA, July 2010.

11. DoD Technical Exchange Meeting at the Finnish Embassy under the aegis of the Secretary of Defense, Washington D.C. May 2010

12. Speaker, Oak Ridge National Laboratory Board of the Governors, May 2010

13. JASON, an independent group of scientists which advises the United States Governement on matters of science and technology - San Diego, CA May 2010

14. Dr. Jeffrey Reed and Dr. Nishith Tripathi, *Wireless Net Neutrality Regulation: A Response to Afflerbach and DeHaven, March 2010*, submittedd to the FCC.

15. Jeffrey H. Reed & Nishith D. Tripathi, *The Application of Network Neutrality Regulations to Wireless Systems: A Mission Infeasible,* submitted to the FCC, Jan. 2010

16. Note the two reports above are *responses to the FCC Notice of Proposed Rule Making on Network Neutrality (a highly controversial subject that poses a major threat to the US wireless industry)*

17. "The Nexus of Security and Technological Leadership, Deemed Export Rule Recommendations and Zero-based Methods to Identify Technologies that Require Deemed Export Control', Submitted to the Security of Commerce by the Emerging Technologies and Research Advisory Committee, A Federal Advisory Committee Appointed by the Secretary of Commerce To examine EARS Regulations. 2009.
    Note current EARS regulations currently represent a major challenge to US industry and academia for engaging international personnel in research and this committee addressed this challenge.

18. Institute for Defense and Government Analysis Conference – Security Issues in Cognitive Radio, 2010.

19. Army Research Lab Seminar, Sept. 2009

20. Lectured VT-MENA in Alexandria, Egypt Nov. 2009

21. Technical seminar at Cairo University, Nov. 2009

22. Presented to NTIA, the telecom regulatory authority in Egypt, Nov. 2009

23. Korean US Communications Technology Symposium, July 2009

24. Finnish Embassy – US Military Collaboration with Finnish Government, March 10-11, 2008

25. Institute for Defense and Government Analysis Conference -- VT's Cognitive Radio and Security Research, March 2009

26. J. H. Reed, IEEE presentation to the IEEE San Diego Section, April 7, 2009 San Diego, CA.

27. J. H. Reed, "Distributed computing in collaborative software radio," presented to the Office of Naval Research, May 1, 2007.

28. J.H. Reed, Keynote Speaker at the *Communications Technology Program Review, Planning Assessment Meeting*, "Distributed computing for collaborative software defined radio," Naval Research Laboratory, May 2007.

29. J. H. Reed, "Issues in cognitive wireless networks," talk presented at the *Intel Research Forum Seminar Series*, Portland, OR, March 28, 2007.

30. J. H. Reed, "Issues in cognitive wireless networks," talk presented at NIST, March 2, 2007.

31. J. H. Reed, "Understanding the issues in software defined cognitive radios," seminar presented at the University of Pennsylvania, October 16, 2006.

32. J. H. Reed, "Issues in cognitive wireless networks," talk presented at the *IEEE Workshop Networking Technologies Software Defined Radio (SDR) Networks*, (held in conjunction with *SECON*), Reston, VA, September 25, 2006.

33. J. H. Reed, "Applications of Markov modeling to cognitive radio," presented at the *SASDCRT Conf.*, Naval Post Graduate School, Monterey, CA, September 12-13, 2006.

34. J. H. Reed, "Understanding the issues in software defined cognitive radios," seminar presented at Clemson University, SC, July 21, 2006.

35. J. H. Reed, "Understanding the issues in software defined cognitive radios," seminar presented at Kyung Hee University, Korea, June 12, 2006.

36. J. H. Reed, "Open architecture bridging the gap in emergency communications," guest speaker at the *International Wireless Communications Expo – IWCE Conf. Tektronix Symposium,* Las Vegas, NV, May 19, 2006.

37. J. H. Reed, "An introduction to cognitive radio and some research trends in cognitive radios," talk presented at *ETRI Cognitive Radio Workshop*, Seoul, Korea, April 2006.

38. J. H. Reed, S. Srikanteswara, and J. A. Neel, "Design choices for software radios," DVD tutorial. Available: http://sdrforum.org/store.html

39. Presentation titled "Software radio: The key for enabling 4G wireless networks," at the *International Forum - 4th Generation Mobile Commun.*, Centre for Telecommunications Research, May 2003.

40. J. H. Reed, “Key challenges in the design on software radios,” workshop presented at *IDGA Software Radio Conf.*, Alexandria, Va., February 23, 2004.

41. J. H. Reed, “Issues in software radios,” presented at Microsoft, Seattle, WA, March 3, 2003.

42. J. H. Reed, “Wireless convergence paradox,” presented at *Samsung Telecom Forum*, Seoul, Korea, March 16-23, 2003.

43. W. H. Tranter, J. H. Reed, D. S. Ha, D. McKinstry, R. M. Buehrer, and J. Hicks, “High capacity communications using overloaded array,” presented at *COMMTEC*, Chantilly, VA, September 16-20, 2002.

44. R. M. Buehrer and J. H. Reed, “Robust ad-hoc, short-range wireless networks for tracking and monitoring devices,” presented to the Marine Corp., April 2002.

45. J. H. Reed, “Overloaded array processing with spatially reduced search joint detection,” presented at the Dresden University of Technology, September 24, 2001.

46. J. H. Reed, Invited lecture series to several Korean companies, compliments of Samsung Advanced Institute of Technologies. The list of companies included: Samsung, LGIC, and ETRI. Spring 2000.

47. J. H. Reed, “The future of wireless,” invited talk, Atlantic City, NJ, November 15, 1999.

48. J. H. Reed, “Software radios,” *Motorola Futures Forum*, invited talk to corporate strategists, Pheonix, AZ, November 8, 1999.

49. P. Robert and J. H. Reed, “Digital video transmissions in a wireless system,” *9th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1997. (Poster session.)

50. M. Hosemann and J. H. Reed, “Synchronization techniques for spread spectrum signals,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

51. S. Srikanteswara and J. H. Reed, “Development of a software radio architecture using reconfigurable computing,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

52. J. Hicks, P. Roy, J. Tilki, L. Beex, J. H. Reed, and W. Farley, “Simulation tool for speech recognition over wireless,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

53. R. Ertel and J. H. Reed, “Optimum SINR antenna array performance analysis,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

54. R. Banerjee, B. D. Woerner and J. H. Reed, “Case studies in software radios,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

55. P. M. Robert, A. M. Darwish, and J. H. Reed, “Fast bit error generation for the simulation of MPEG-2 transmissions in wireless systems,” *IEEE Wireless Commun. Networking Conf.*, September 21-24, 1999. (Invited paper; proceedings on CD Rom.)

56. J. H. Reed and S. Srikanteswara, “Software radio architecture for a reconfigurable computing platform,” *IEEE Commun. Theory Workshop*, Aptos, CA, May 23-26, 1999.

57. R. Ertel , Z. Hu and J. H. Reed, “Antenna array vector channel modeling and data collection system,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

58. P. M. Robert and J. H. Reed, “Digital video transmissions in a wireless system,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

59. S. Swanchara, S. Srikanteswara, P. Athanas, and J. H. Reed, “Implementation of a multiuser receiver on a recongifugurable computing platform,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

60. Maheshware, et al., “Reconfigurable software radio,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

61. K. Phillips and J. H. Reed, “PDF estimation,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

62. N. Mangalvedhe and J. H. Reed, “Performane of reduced complexity algorithms in adaptive CDMA receivers,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

63. R. Mostafa and J. H. Reed, “Study of smart antenna as an interference rejection technique for the handset,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

64. N. Mangalvedhe and J. H. Reed, “Adapative receivers for multi-rate DS-CDMA systems,” *8th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1998. (Poster session.)

65. J. H. Reed and B. D. Woerner, "Analog to digital conversion and digital signal synthesis for software radios," half-day tutorial presented at the *IEEE 9th International Symposium Personal, Indoor, Mobile Radio Commun.*, Boston, MA, September 13-16, 1998. (Invited tutorial.)

66. J. H. Reed, “The software radio: Modern radio engineering,” Dresden University of Technology Guest Lecture, Dresden, Germany, November 25, 1997.

67. J. H. Reed, “Adaptive antenna arrays,” Dresden University of Technology Guest Lecture, Dresden, Germany, November 26, 1997.

68. J. H. Reed, “Overview of fundamental wireless systems in today’s telecommunications technology,” *46th Annual International Wire Cable Symposium*, Philadelphia, PA, November 17-20, 1997. (Invited tutorial.)

69. J. H. Reed and R. D. James, “Position location: Overview and business opportunities,” *Wireless Opportunities Workshop*, Roanoke, VA, October 22-23, 1997.

70. R. Ertel and J. H. Reed, “Geometrically based spatial channel models,” *7th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1997. (Poster session.)

71. A. Hannan and J. H. Reed, “GloMo radio API (application program interface,” *7th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1997. (Poster session.)

72. S. Swanchara, J. H. Reed, and P. Athanas, “Design and implementation of the GloMo multiuser receiver on a reconfigurable computing platform,” *7th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1997. (Poster session.)

73. N. D. Tripathi, J. H. Reed, and H. VanLandingham, “High performance handoff algorithms using fuzzy logic and neural networks,” *7th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1997. (Poster session.)

74. D. Breslin and J. H. Reed, “Multi-sensor testbed hardware development at the mobile and portable radio resesarch group,” *7th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1997. (Poster session.)

75. N. Mangalvedhe and J. H. Reed, “Blind CDMA interference rejection in multipath channels,” *7th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1997. (Poster session.)

76. K. Phillips, J. Laster, and J. H. Reed “Adaptive signal processing by bit error rate (BER) estimation,” *7th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1997. (Poster session.)

77. T. S. Rappaport, J. H. Reed, and T. E. Biedka, “Position location & E-911: Techniques for wireless systems,” *IEEE International Conf. Universal Pers. Commun.*, Cambridge, MA, October 1, 1996. (Invited tutorial.)

78. N. Tripathi and J. H. Reed, “DSP implementation of communications systems: An NSF sponsored curriculum development initiative,” *6th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1996. (Poster session.)

79. B. Fox, G. Aliftiras, I. Howitt, J. H. Reed, and B. D. Woerner, “Flexible hardware architectures for multimode wireless handsets,” *Sixth 6th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1996. (Poster session.)

80. P. Petrus and J. H. Reed, “Geometrically based statistical single bounce macrocell channel model for mobile environments,” *6th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1996. (Poster session; also in *IEEE Smart Antennas: Adaptive Arrays, Algorithms, & Wireless Position Location*, 1998, pp. 483-487.)

81. GloMo team, “GloMo adaptive antenna array research,” *6th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1996. (Poster session.)

82. GloMo team, “GloMo mobile yser research,” *6th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1996. (Poster session.)

83. J. D. Laster and J. H. Reed, “Improved GMSK demodulation using non-coherent receiver diversity,” *Sixth 6th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1996. (Poster session.)

84. K. Khan, J. H. Reed,and I Howitt, “Interference mitigation in AMPS/NAMPS and CMP using artificial neural networks,” *6th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1996. (Poster session.)

85. N. Tripathi, J. H. Reed, and H. VanLandingham, “Neural net & fuzzy logic approaches to handoffs in cellular systems,” *6th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1996. (Poster session.)

86. K. Saldanha and J. H. Reed, “Performance evaluation of an AMPS digital base station with automatic gain control,” *6th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1996. (Poster session.)

87. R. He and J. H. Reed, “System capacity improvement by ysing DSP interference rejection techniques,” *6th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1996. (Poster session.)

88. B. D. Woerner, T. S. Rappaport, and J. H. Reed, “Improved spectral efficiency for CDMA systems,” *Wireless Technology Conf. Exposition Proceedings*, Stamford, CT, September 1995.

89. P. Petrus and J. H. Reed, “New blind multichannel filtering techniques,” *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

90. N. Zecevic and J. H. Reed, “Comparative study of adaptive CDMA interference rejection techniques,” *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

91. M. Majmundar and J. H. Reed, “Interference rejection for IS-54,” *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

92. D. Bailey and J. H. Reed, “MPRG: Signal processing and communications laboratory,” *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

93. R. He and J. H. Reed, “Co-channel interference for AMPS and NAMPS signals,” *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

94. N. Mangalvedhe and J. H. Reed, “An Eigenstructure technique for soft synchronization of DSSS signals,” *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

95. M. Welborn and J. H. Reed, “Interference rejection using model-based spectral estimation,” *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

96. A. Amanna, R. James, and J. H. Reed, “Communications on the smart road,” *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

97. F. Dominique and J. H. Reed, “Development of a frequency hopping system for the 902-928 MHz ISM band,” *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

98. S. Elson and J. H. Reed, “Modeling CDPD,” *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.).

99. P. Petrus, F. Dominique, and J. H. Reed, "Spectral redundancy exploitation in narrowband interference rejection for a PN-BPSK system," *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

100. F. Cheng and J. H. Reed, "Dynamic range enhancement techniques for RF and fiber optic interface," *5th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1995. (Poster session.)

101. P. Petrus and J. H. Reed, " Blind adaptive arrays for mobile communications," *4th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1994. (Poster session.)

102. R. He and J. H. Reed, "Spectral correlation of AMPS signals with applications to interference Rrejection," *4th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1994. (Poster session.)

103. R. Zheng and J. H. Reed, "System modeling and interference rejection for spread spectrum CDMA automatic vehicle monitoring systems," *4th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1994. (Poster session.)

104. N. Mangalvedhe and J. H. Reed, "An eigenstructure technique for soft spread spectrum synchronization," *4th Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1994. (Poster session.)

105. R. Holley and J. H. Reed, "Time-dependent filters For CDMA interference rejection," *3rd Annual Symposium Wireless Pers. Commun.*, Virginia Tech, June 1993. (Poster session.)

Technical Reports:

1. Y. Zhao, "Enabling cognitive radios through radio environment maps," MPRG-TR-07- Ph.D. dissertation, May 2007.

2. R. Menon and J. H. Reed, "Interference avoidance based underlay techniques for dynamic spectrum sharing," MPRG-TR-07-, Ph.D. dissertation, April 2007.

3. J.-H. Kim and J. H. Reed, "On the impact of MIMO implementations on cellular networks: An analytical Aapproach from a system perspective," MPRG-TR-07-, Ph.D. dissertation, March 2007.

4. R. Chembil Palat and J. H. Reed, "Performance analysis of cooperative communications for wireless networks," MPRG-TR-06-, Ph.D. dissertation, December 2006.

5. J. O. Neel and J. H. Reed, "Analysis and design of cognitive radio networks and distributed radio resources management in algorithms," MPRG-TR-06-14, Ph.D. Dissertation, September 2006.

6. C. R. Anderson and J. H. Reed, "A software defined ultra wideband transceiver testbed for communications, ranging, and imaging," MPRG-TR-06-13, Ph.D. dissertation, September 2006.

7. C. R. Anderson, S. Venkatesh, D. Agarwal, R. Michael Buehrer, P. Athanas, and J. H. Reed, "Time interleaved sampling of impulse ultra wideband signals: Design challenges, analysis, and results," MPRG-TR-06-12, technical report, August 2006.

8. J.-H. Kim and J. H. Reed, "Efficacy of transmit smart antenna at mobile station in cellular networks," MPRG-TR-06-09, Ph.D. preliminary, May 2006.

9. J. A. DePriest and J. H. Reed, "A practical approach to rapid prototyping of SCA waveforms," MPRG-TR-06-06, M.S. thesis, April 2006.

10. B. M. Donlan, R. M. Buehrer, and J. H. Reed, "Ultra-wideband narrowband interference cancellation and channel modeling for communications," MPRG-TR-05-02, M.S. thesis, January 2005.

11. S. Vasudevan and J. H. Reed, "A simulator for analyzing the throughput of IEEE 802.11b wireless LAN systems," MPRG-TR-05-01, M.S. thesis, January 2005.

12. A. M. Hebbar and J. H. Reed, "Empirical approach for rate selection in MIMO OFDM," MPRG-TR-04-11, M.S. thesis, December 2004.

13. C. R. Anderson, A. M. Orndorff, R. M. Buehrer, and J. H. Reed, "An introduction and overview of an impulse-radio ultrawideband communication system design," MPRG_TR-04-07, technical report, May 2004.

14. J. Hicks and J. H. Reed, "Novel approaches to overloaded array processing," MPRG-TR-03-19, Ph.D. dissertation, August 2003.

15. R. Mostafa and J. H. Reed, "Feasibility of smart antennas for the small wireless terminals," MPRG-TR-03-12, Ph.D. dissertation, April 2003.

16. S. Krishnamoorthya and J. H. Reed, "Interference measurements and throughput analysis for 2.4 GHz wireless devices in hospital environments," MPRG-TR-03-10, M.S. thesis, April 2003.

17. P. M. Robert and J. H. Reed, "Reduction in coexistent WLAN interference through statistical traffic management, MPRG-TR-03-09, Ph.D. dissertation, April 2003.

18. W. G. Newhall and J. H. Reed, "Radio channel measurements and modeling for smart antenna array systems using a software radio receiver," MPRG-TR-03-08, Ph.D. dissertation, April 2003.

19. Y. Ahmed and J. H. Reed, "A model-based approach to demodulation of co-channel MSK signals," MPRG-TR-02-24, M.S. thesis, December 2002.

20. R. Chembil Palat and J. H. Reed, "VT-STAR design and implementation of a test bed space-time block coding and MOMI channel measurements," MPRG-TR-02-19, M.S. thesis, October 2002.

21. W. Newhall and J. H. Reed, "Radio channel measurements, modeling, and characterization for antenna array Ssystems," MPRG-TR-02-16, Ph.D. preliminary, August 2002.

22. B.-L. Cheung and J. H. Reed, "Simulation of adaptive array algorithms for OFDM and adaptive vector OFDM systems," MPRG-TR-02-15, M.S. thesis, September 2002.

23. R. Mostafa, R. Gozali, W. Newhall, I. Akbar, J. H. Reed, B. D. Woerner, and W. H. Tranter, “Navy collaborative integrated information technology initiative,” report #19, MPRG-TR-02-13, technical report, April 2002.

24. R. Mostafa, R. Gozali, W. Newhall, I. Akbar, J. H. Reed, B. D. Woerner, and W. H. Tranter, “Navy collaborative integrated information technology initiative,” report # 17, MPRG-TR-02-05, technical report, January 2002.

25. S. Marikar, L. DaSilva, and J. H. Reed, “Resource management in 3G systems employing smart antennas,” MPRG-TR-02-04, M.S. thesis, January 2002.

26. P. M. Robert and J. H. Reed, “Reduction in coexistent WLAN interference through statistical traffic management,” MPRG-TR-02-01, Ph.D. preliminary, August 2001.

27. R. Mostafa, R. Gozali, W. Newhall, I. Akbar, J. H. Reed, B. D. Woerner, and W. H. Tranter, “Navy collaborative integrated information technology initiative,” report # 16, MPRG-TR-01-17, technical report, October 2001.

28. M. Soni, P. Athanas, and J. H. Reed, “Computing engine for reconfigurable software radio,” MPRG-TR-01-15, M.S. thesis, October 2001.

29. T. E. Biedka and J. H. Reed, “Analysis and development of blind adaptive beamforming algorithms,” MPRG-TR-01-14, Ph.D. dissertation, August 2001.

30. R. Gozali, R. Mostafa, P. M. Robert, R. Chembil Palat, W. Newhall, B. D. Woerner, and J. H. Reed, “Design process of the VT-STAR multiple-input multiple-output (MIMO) test bed,” MPRG-TR-01-12, technical report. August 2001.

31. R. Mostafa, R. Gozali, W. Newhall, I. Akbar, J. H. Reed, B. D. Woerner, and W. H. Tranter, “Navy collaborative integrated information technology initiative,” report # 15, MPRG-TR-01-11, technical report, July 2001.

32. S. Srikanteswara and J. H. Reed, “Design and implementation of a soft radio architecture for reconfigurable platforms,” MPRG-TR-01-10, Ph.D. dissertation, July 2001.

33. R. Mostafa and J. H. Reed, “Feasibility of transmit smart antenna at the handset,” MPRG-TR-01-07, Ph,D. preliminary, December 2000.

34. J. Hicks and J. H. Reed, “Overloaded array processing with spatially reduced search joint detection,” MPRG-TR-00-08, M.S. thesis, May 2000.

35. T. Biedka and J. H. Reed, “A general framework for the analysis and development of blind adaptive algorithms,” MPRG-TR-OO-O5, Ph.D. preliminary, April 2000.

36. S. Srikanteswara and J. H. Reed, “Design and implementation of a soft radio architecture for reconfigurable platforms,” MPRG-TR-00-02, Ph.D. preliminary, November 1999.

37. R. B. Ertel and J. H. Reed, "Antenna array systems: Propagation and performance,” Ph.D. dissertation, July 1999.

38. N. R. Mangalvedhe and J. H. Reed, “Development and analysis of adaptive interference rejection techniques for direct sequence code division multiple access systems,” Ph.D. dissertation, July 1999.

39. K. Phillips and J. H. Reed, “Probability density function estimation for minimum bit error rate equalization,” MPRG-TR-99-04, M.S. thesis, May 1999.

40. Z. Hu and J. H. Reed, “Evaluation of joint AOA and DOA estimation algorithms using the antenna array systems,” MPRG-TR-99-02, M.S. thesis, December 1998.

41. R. B. Ertel and J. H. Reed, "Antenna array systems: Propagation and performance," MPRG-TR-98-12, Ph.D. preliminary, December 1998.

42. N. R. Mangalvedhe and J. H. Reed, "Development and analysis of adaptive interference rejection techniques for direct sequence code division multiple access systems," MPRG-TR-98-13, Ph.D. preliminary, December 1998.

43. P. M. Robert and J. H. Reed, "Simulation tool and metric for evaluating wireless digital video systems," MPRG-TR-98-11, M.S. thesis, September 1998.

44. S. F. Swanchara and J. H. Reed, “An FPGA-based multiuser receiver employing parallel interference cancellation,” MPRG-TR-98-06, M.S. thesis, July 1998.

45. N. Tripathi and J. H. Reed, “Generic handoff algorithms using fuzzy logic and neural networks,” Ph.D. dissertation, MPRG-TR-97-18, November 1997.

46. D. Breslin and J. H. Reed, “Adaptive antenna arrays applied to position location,” MPRG-TR-97-14, M.S. thesis, August 1997.

47. S. Nicoloso and J. H. Reed, “Investigation of carrier recovery techniques for PSK modulated signals in CDMA and multipath mobile environments,” MPRG-TR-97-11, M.S. Thesis, May 1997.

48. N. Tripathi, J. H. Reed, and H. VanLandingham, “An adaptive direction biased fuzzy handoff algorithm with unified handoff candidate selection criterion,” MPRG-TR-97-08, April 1997.

49. N. Tripathi, J. H. Reed, and H. VanLandingham, “An adaptive algorithm using neural encoded fuzzy logic system,” MPRG-TR-97-07, April 1997.

50. N. Tripathi, J. H. Reed, and H. VanLandingham, “A new class of fuzzy logic based adaptive handoff algorithms for enhanced cellular system performance,” MPRG-TR-97-06, April 1997.

51. B. Fox and J. H. Reed, “Analysis and dynamic range enhancement of the analog-to-digital interface in multimode radio receivers,” MPRG-TR-97-02, February 1997.

52. A. Alexander, S. Panchapakesan, D. Breslin, J. H. Reed, T. Pratt, and B. D. Woerner, “The feasibility of performing TDOA based position location on existing cellular infrastructures,” MPRG-TR-96-37, December 20, 1996.

53. N. Tripathi and J. H. Reed, “Handoffs in cellular systems: A tutorial,” MPRG-TR-96-35, November 1996.

54. N. Zecevic and J. H. Reed, “Interference rejection techniques for the mobile unit direct-sequence CDMA receiver,” MPRG-TR-96-27, August 1996.

55. K. J. Saldanha and J. H. Reed, “Performance evaluation of DECT in different radio environments,” MPRG -TR-96-28, August 1996.

56. R. He and J. H. Reed, “AMPS co-channel interference rejection techniques and their impact on system capacity,” MPRG-TR-96-25, July 1996.

57. N. Zecevic and J. H. Reed, “Techniques and adaptation algorithms for direct sequence spread spectrum capacity,” MPRG-TR-96-27, July 1996.

58. M. K. Khan, J. H. Reed, and I. Howitt, “Interference mitigation in AMPS/NAMPS and GSM using artificial neural networks,” MPRG-TR-96-24, June 1996.

59. J. H. Reed, T. S. Rappaport, and B. D. Woerner, “What you should know before returning to school,” *RF Design*, pp. 67-69, March 1996.

60. T. Biedka and J. H. Reed, “Direction finding methods for CDMA mobile wireless systems,” MPRG-TR-96-20, June 1996.

61. Y. M. Vasavada and J. H. Reed, “Performance evaluation of a frequency modulated spread-spectrum system,” MPRG-TR-96-13, February 1996.

62. M. V. Majmundar and J. H. Reed, “Adaptive single-user receivers for direct sequence CDMA systems,” MPRG-TR-96-12, January 1996.

63. R. He and J. H. Reed, “Co-channel interference rejection techniques for AMPS signals using spectral correlation characteristics,” MPRG-TR-96-11, January 1996.

64. J. S. Elson and J. H. Reed, “Simulation and performance analysis of cellular digital packet data,” MPRG-TR-96-08, February 1996.

65. J. D. Laster and J. H. Reed, “Improved GMSK demodulation emphasizing single channel interference rejection techniques,” MPRG-TR-96-05, February 1996.

66. M. Welborn and J. H. Reed, “Co-channel interference rejection using model-based demodulator” MPRG-TR-96-04, January 1996.

67. F. Dominique and J. H. Reed, “Design and development of a frequency hopper based on the DECT system for the 902-928 MHz ISM band,” MPRG-TR-96-02, January 1996.

68. P. Athanas, I. Howitt, T. S. Rappaport, J. H. Reed, and B. D. Woerner, “A high capacity adaptive wireless receiver implemented with a reconfigurable computer architecture,” MPRG-TR-18, November 1995.

69. N. Mangalvedhe and J. H. Reed, “An eigenstructure technique for direct sequence spread spectrum synchronization,” MPRG-TR-95-04, April 1995.

70. Y. M. Kim, N. Mangalvedhe, B. D. Woerner, and J. H. Reed, “Development of a low power high data rate spread-spectrum modem,” MPRG-PPR-95-01, February 1995.

71. Y. M. Kim, N. R. Mangalvedhe, B. D. Woerner, and J. H. Reed, “Development of a low power high data rate spread-spectrum modem,” MPRG-PPR-95-02, June 1995.

72. P. Petrus and J. H. Reed, “Blind adaptive antenna arrays for mobile communications,” MPRG-TR-95-01, December 1994.

73. S. Yao and J. H. Reed, “Differential detection of GMSK signals,” MPRG-TR-94-27, October 1994.

74. R. Zheng, J. Tsai, R. Cameron, L. Beisgen, B. D. Woerner, and J. H. Reed, “Capacity and interference resistance of spread-spectrum automatic vehicle monitoring systems in the 902-928 MHz ISM Band,” MPRG-TR-94-26, final report to Southwestern Bell Mobile Systems, October 1994.

75. F.-S. Cheng and J. H. Reed, “A new approach to dynamic range enhancement,” MPRG-TR-94-25, October 1994.

76. R. S. Zheng and J. H. Reed, “Channel modeling and interference rejection for CDMA automatic vehicle monitoring systems,” MPRG-TR-94-21, November 1994.

77. R. He and J. H. Reed, “AMPS interference rejection: Blind time-dependent adaptive filtering - Volume I,” final report to ARGO Systems Inc., MPRG-TR-94-19, July 1994.

78. T. H. Qazi and J. H. Reed, “Model-based demodulation of FM signals - Volume II,” MPRG-TR-94-17, final report to ARGO Systems, August 1994.

79. M. Subramanian and J. H. Reed, “Noncoherent spread-spectrum communication systems,” MPRG-TR-94-14, August 1994.

80. F. Cheng, A. Kelkar, I. Jacobs, and J. H. Reed, “Performance evaluation for the dynamic range enhancement technique (DRET),” MPRG-TR-94-10, final report to Southwestern Bell Technology Resources, September 1994.

81. V. Aue and J. H. Reed, “Optimum linear single user detection in direct-sequence spread-spectrum multiple access systems,” MPRG-TR-94-03, March 1994.

82. R. Holley and J. H. Reed, “Time dependent adaptive filters for interference cancellation in CDMA systems,” MPRG-TR-93-15, September 1993.

Other Papers & Reports:

1. P. M. Robert and J. H. Reed, “Va. Tech finds soft radio’s missing link,” *EE Times*, August 2004.

2. J. H. Reed, T. C. Hsia, and H. Etemad, “Differential demodulation of BPSK using time dependent adaptive filtering,” final report to California MICRO Program, 1992.

3. J. H. Reed, “Adaptive filters and their application to interference rejection,” *Defense Electronics*, pp. 85-86 and 89-90, May 1989.

4. W. Gardner, B. G. Agee, W. A. Brown, C. K. Chen, J. H. Reed, and R. S. Roberts, “A comparison of Fourier transformation and model fitting methods of spectral analysis,” Signal and Image Processing Lab Report No. SIPL-86-4, Department of Electrical and Computer

Engineering, University of California, Davis, 1986. (Also in *Statistical Spectral Analysis — A Non Probabilistic Theory*, Prentice-Hall.)

Selected Corporate Report Topics:

* A DSP-Based Receiver for the New North American Digital Cellular Standard
* Spread Spectrum Detection Techniques
* Cyclic Spectral Analysis of Modulated Signals
* Projection of Future High-Volume Digital Communication Systems
* A High Speed Digital Filter for Sample Rate Conversion
* A Least-Squares System Identification Method
* Cyclic Adaptive Filtering for Interference Rejection
* Implementation Issues of Adaptive Interference Rejection Techniques
* Investigation of Modern Spectral Analysis Techniques
* The Performance of Time-Dependent Adaptive Filtering of Real Data
* A Maximum-Likelihood Estimator for Tracking and Detecting Frequency Hopping Signals
* Digital Signal Processing Algorithms for Squelch Control
* A Low-Cost Whitening Filter for Jammer Applications
* Time-Dependent Single Channel and Multi-Channel Interference Rejection Algorithms

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Section V. Public Service/Outreach

Industrial Affiliate/Outside Agency Contacts:

Companies and Government Agencies visited in 2009 - 2012 to promote Wireless@ VT and the Hume Center:

Apple Computer	Nokia
Booz Allan Hamilton	IDA
DARPA	Motorola
Army Research Lab	NSA
ZETA	MA-COMM
SAIC	Intel
DRT	NSF
Laboratory of Telecommunications Science	FCC
John Hopkins Applied Physics Lab	FBI
NRO	Samsung
NSA	Aerospace Corporation
CRT	CIA
Defense Spectrum Office	US Army
NIST	Thales Communications

NRL
Northrup Grumman
ISI
RINCOM
CERDEC
Award Solution
ONR
Applied Signal Technologies
DSO
GE
MBC
LTS
Textronix
ONR
SPAWAR
ATT
Ventura Solutions
Syracuse Research Corp
SPAWAR
I-APRA
L-3
DRS
CAER
Lockheed Martin

Funding Agency Reviewer:

NSF
University of California, MICRO
Kansas 2000
Qtar Science Foundation
ARO
Canadian Foundation for Innovation

Sponsored Visiting Researchers:

Ahmed Darwish from Cairo University, June-September 1999
Yeongjee Chung from Korea, January-August 1999
Shinichi Miyamoto from Kobe, Japan, April 2001-March 2002
Young-Soo Kim from Seoul, Korea, February 2002-February 2003
Friedrich Jondral from Karlsruhe, Germany, April-June 2004
Francisco Portelinha from Brazil, October 2004-February 2006
Seuck Ho Won from Korea, February 2005-January 2006
Duk Kyu Park from Seoul South Korea, January 2007-February 2008
Marojevic Vuk from Spain, September 2007-January 2008
Francisco Martins Portelinha from Brazil, February 2008-March 2008
Jeong Ho Kim from South Korea, July 2008 – February 2010
Stefan Werner Nagel from Germany, August 2009 - October 2009
Arthur Herzog from Darmstadt, Germany April 2010 – June 2010

Conference Organization & Technical Reviewing:

Editorial Board Member for the Proceedings of the IEEE
Organizing Committee for Globecom 2010
Technical Program Committee for IEEE Dyspan 2009/2010
Technical Program Committee for Globecomm 2009
Technical Program Committee for VTC 2009
Technical Program Committee for COMCAS 2009 (and session chair)
Associate Editor for Proceedings of the IEEE, Issue on Cognitive Radio, April & May 2009
Associate Editor for IEEE Journal on Select Area of Communications, Issue on Cognitive Radio
Technical Program Committee for IEEE Conference on Communications

Technical Program Committee for CrownCom
Reviewer

IEEE Transactions on Antennas and Propagation
IEEE Transactions on Wireless Communications
IEEE Transactions on Communications
IEEE Transactions on Signal Processing
IEEE Transactions on Aerospace and Electronics Systems
IEEE Transactions on Selected Areas of Communications
IEEE Signal Processing Letters
IEEE Communications Magazine
IEEE Communications Letters
International Journal of Electronics

Session Chair for the SDR Forum 2007, Denver, CO, November 5 – 9, 2007
Advisory Board, *IEEE International Conf. Ultrawideband (ICU)*, September 2005.
Moderator for the paper session "Ultrawideband Design Approaches," at the *Communications Design Conf.*, March - April 2004.
Moderator for the panel, "UWB Panel on Communication Systems Design," at the *Communications System Design Conf.*, October 2003.
Chair of session titled, "Mobile Computing and Software Defined Radios," at the *International Conf. Engineering Reconfigurable Systems Algorithms (ERSA)*, June 2003.
Co-technical program chairman for the *SDR Forum Conf.*, November 2002.
General Chair for the *UWBST Conf.*, November 2003.
Technical program chairman for the *SDR Forum/MPRG Workshop Smart Antennas*, June 2003.

Federal & State:

President's Council of Advisors in Science and Technology working group on transitioning federal spectrum for commercial use and economic growth, 2011-2012

Army Research Office Board of Visitors, 2012- present

Idaho National Labs Advisory Board, 2012 - present

IEEE Fellows Evaluation Committee for Computer Science, 2012

National Science Foundation workshop co-organizer, *Enhancing Access to the Radio Spectrum*, August, 2010. Goal was to develop a major research program to support spectrum research for the National Broadband Plan. Participants include Secretary of Commerce, a Commissioner of the FCC, interim head of NSF, multiple NSF Division Directors, Whitehouse and Capitol Hill staffers.

US Dept. of Commerce Committee on EARS Regulations 2008-2009. A Federal Advisory Committee Appointed by the Secretary of Commerce To examine EARS Regulations. 2009. *Note current EARS regulations currently represent a major challenge to US industry and academia for engaging international personnel in research and this committee addressed this challenge.* 2007.

Co-Leader for the SDR Forum and Object Management Group of Smart Antenna API standardization efforts 2008-2009

Co-Leader for NSF workshop on SDR held in Ireland on May 12 – 16, 2008.

Virginia Broadband Task Force (headed by now Senator Warner and US CTO Anish Chopra) to examine steps for bridging the digital divide.

DARPA panel member to identify and create new programs for DARPA to support NSA. This activity is expected to result in $60M – $80M in new DARPA programs. 2007

Workshop help DARPA define a new program in bio-mimesis, the imitation of living organisms through electronics and mechanics.

Assisted the Army Research Office in developing their five year research plan forcommunications.

University Professional Service Current & Past:

Distinguished Lecturer for the IEEE Vehicular Technology
Director Wireless @ Virginia Tech
Interim Director, Ted and Karyn Hume Center
Participation within the Center for Wireless Telecommunications (CWT)
Department Computing Committee
Faculty Advisor to the Honor System
Faculty Advisory Committee, Information Technology for VT
EE Graduate Administrative Committee (Grad AdCom)
Communications Area Committee
US Student Recruitment Strategy Task Force
Course supervisor of ECPE 5674 and ECPE 4654
ECE Department Head Search Committee
ECE Executive Committee
ECE Resource Committee
Deputy Director, MPRG
ECE Recruiting Committee

Section VI. Industrial Experience

Industrial Employment:

Power Fingerpring, Inc. President and Co-Founder, 2011-Present
Cognitive Radio Technology, LLC. CTO and co-founder, 2007- Present
Co-founded Dot Mobile, Inc. March 2000-2001
(Company specializes in mobile data applications including wireless-internet based applications.)

Past Clients

ACM Systems	Grass Valley Group
Analog Devices	BRTRC
DIGCOM	E-Systems
F&S	General Dynamics

Gray Cary	Harris Broadband
Honeywell	HRL
IWT	Jones Day
NORCOMM	SAIC
Labarge	IDA
SRC	Weil
Samsung	MITRE
Shafer	SCA Technica
IIT	Navsys
US Navy	Tantivy
Arnold Porter	Sidley Austin

Founded Reed Engineering, March 1986 – Present
(Company performs consulting, expert witnessing and training in wireless communications and signal processing.)

Member, Technical Staff Signal Science, Inc., Santa Clara, CA, 1980-1985
Areas of Specialization:
- Spread spectrum detection
- Foreign technology analysis
- Computer systems administration

Past and Current Advisory Board Positions:

TechContinuum
Samsung Telecommunications
Spyrock
Totus Lighting
Airbee
FAWNA
Wayve Tech

Selected past industry projects:

- Technical Evaluation of AT&T and T-Mobile Merger
- Comments on FCC NPR making
- Expert Witness Wireless Email
- Software Architecture for Radios
- Company acquisition evaluation
- Expert witness in wireless location systems (multiple times)
- Evaluation of a wireless high-speed internet access system
- Evaluation of wireless/signal processing companies for acquisition
- Tutorials on software radio issues
- Tutorials on trends in wireless communications
- Adaptive interference rejection techniques
- Spread spectrum signal detection
- Expert witness for wireless power sources
- Study Panelist for NSA/DARPA programs via Schafer Corp.
- Advising on Trends in Communications: SAIC

- Provide Survey of Low Power Communications Trends: Mitre Corporation

CURRICULUM VITAE

NISHITH D. TRIPATHI

Nishith D. Tripathi, Ph. D.
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AREAS OF EXPERTISE

LTE (E-UTRAN and EPC), LTE-Advanced, WiMAX, 1xEV-DO (Rev. 0 and Rev. A), UMTS R99, HSDPA, HSUPA, HSPA+, CDMA2000 1xRTT, IS-95, CDMA, OFDM, OFDMA, Advanced Antenna Technologies, IP-related Technologies, IMS

PUBLICATIONS

- Author of an upcoming **book** (with Jeffrey H. Reed), "Cellular Communications: A Comprehensive and Practical Guide," ***Accepted for Publication by IEEE/Wiley***, 2012. (**Book Contents**: Introduction to Cellular Communications, Elements of a Digital Communication System, Radio Propagation, IP Fundamentals, GSM, GPRS, EDGE, IS-95, CDMA2000 1xRTT, R99 UMTS/WCDMA, 1xEV-DO Rev. 0, HSDPA, 1xEV-DO Rev. A, HSUPA, HSPA+, IMS, Emerging 4G Technologies)
- Author of a **book** (with Jeffrey H. Reed and Hugh F. VanLandingham), "Radio Resource Management in Cellular Systems," Kluwer Academic Publishers, 2001.
- Contributor (With Jeffrey H. Reed) to the article, "Technical Challenges in Applying Network Neutrality Regulations to Wireless Systems," in the book titled "Net Neutrality: Contributions to the Debate," Edited by Jorge Perez Martinez, 2011.
- Author of one chapter in the book, "Neuro-Fuzzy and Fuzzy-Neural Applications in Telecommunications," Editor- Peter Stavroulakis, Springer, April 2004.

EXPERIENCE

AWARD SOLUTIONS *March '04 to Present*

Principal Consultant

- Successfully launched a new program to ensure and develop SME (Subject Matter Expert) expertise in the areas of LTE RAN and Ethernet-based Backhaul. Developed processes and plans to facilitate SME certification. Devised expertise development plans, on-line tests, and defense tests. Directed the oral defense meetings for the final stage of SME certification.
- Managed and led SMEs for following course development projects: LTE Bootcamp-Phase II (**Topics**: End-to-end Data Sessions in LTE-EPC, PCC: QoS and Charging Architecture for LTE, Voice over LTE (VoLTE) using IMS, Voice services using CSFB and SRVCC, LTE and eHRPD Interworking, LTE and GSM/UMTS interworking, and LTE-Advanced), and LTE Radio Network Planning and Design.
- Mentored SMEs to prepare them to teach technologies such as LTE, WiMAX, OFDM, and Advanced Antennas.
- Developed courses on LTE-Advanced and TD-LTE.
- Developed two sessions, TD-LTE and Self Organizing Network (SON), as part of LTE Bootcamp- Phase II for an infrastructure vendor.
- Enhanced the LTE Radio Network Planning and Design course to reflect configurations of commercial deployments using LTE log-files and to adhere to customer-specific RF design guidelines.
- Continued to teach a variety of LTE and HSPA+ courses (e.g., VoIP, IMS, and IPv6 for LTE and HSPA+ Signaling) at new and existing clients.
- Delivered several web-based sessions of LTE Bootcamp- Phase II.

Lead SME

- Taught *first-time offerings* of courses at various clients to acquire new training business.
- Managed and guided SMEs for timely and quality-controlled completion of following course development projects: LTE/1xEV-DO Interworking, EPC Overview, HSPA+

Overview, Fundamentals of RF Engineering, IP Convergence Overview, and Advanced Antenna Techniques.

- Devised and implemented strategies to maximize the quality of project deliverables and to accelerate the completion of the deliverables.

SME- Course Development

- Developed an in-depth LTE Bootcamp Series for an infrastructure vendor (**Topics**: EPS Network Architecture, OFDMA/SC-FDMA, Radio Channels, System Acquisition & Call Setup, DL & UL Traffic Operations, Handover, and Antenna Techniques).
- Developed numerous instructor-led and web-based training courses by working in a team environment (**Examples**: Interworking of LTE with 1xEV-DO & 1xRTT, LTE Air Interface, WiMAX Essentials, WiMAX Network Planning, UMB, 1xEV-DO, HSUPA, Multiple Antenna Techniques, and IP Convergence).
- **Example Course Contents**: Network architecture, air interface features, DL & UL data transmission, call setup, handover/handoff, resource management, and interworking.
- Designed outlines for several new courses.

Senior Consultant- Training

- Taught *in-person* and *web-based* (via WebEx and LiveMeeting) courses at major chip-set manufacturers, infrastructure & device vendors, service operators, and test-tool vendors.
- Delivered an in-depth LTE bootcamp multiple times for a major LTE infrastructure vendor.
- **Area Expertise**: LTE Radio Network Planning & Design (including Certification), Interworking of LTE with (1xEV-DO, 1xRTT, UMTS, and GERAN), LTE Protocols & Signaling, LTE Air Interface, WiMAX Networks and Signaling, 1xEV-DO Optimization, 1xEV-DO Rev. 0 and Rev. A, IP Fundamentals, HSDPA/HSUPA/HSPA+, UMTS R4/R5 Core Networks, UMTS Network Planning and Design
- Strived to make the training experience full of *relevant* knowledge and to maximize the value of training to students.

VIRGINIA TECH *January'10 to Present*

Adjunct Professor

- Co-taught the cellular communications class.
- Developed and presented the lecture material.
- Designed and graded quizzes.

HUAWEI TECHNOLOGIES *October '01 to March '04*

Product Manager and Senior Systems Engineer

- Worked with engineers to resolve numerous **field trial issues** for **CDMA2000** systems.
- Defined test procedures for various features to evaluate performance of the CDMA2000 product.
- Designed advanced RL MAC and Power Control algorithms for a 1xEV-DO System.
- Designed various high-performance radio resource management (RRM) algorithms for the **CDMA2000** base station and base station controller. Major designed features include adaptive forward link and reverse link call admission control algorithms, dynamic F-SCH rate and burst duration assignment algorithms, R-SCH rate assignment algorithm, F-SCH burst extension and termination mechanisms, schedulers, forward link and reverse link overload detection and control algorithms, SCH soft handoff algorithm, F-SCH power control parameter assignment mechanism, adaptive radio configuration assignment algorithm, load balancing algorithm, and cell-breathing algorithm.
- Worked on the design of an RRM simulator to evaluate the performance of call admission control, load control, and scheduling algorithms for a **CDMA2000** system.
- Designed system level and network level simulators to evaluate the capacity gain of the smart antenna-based **UMTS** systems employing multiple beams.

- Reviewed **UMTS** RRM design and proposed enhancements related to call admission control, cell breathing, load balancing, soft capacity control, potential user control, and AMR control.
- Educated engineers through presentations to facilitate development of the **1xEV-DO** product.
- Led a team of engineers to define a comprehensive **simulation tool-set** consisting of link level simulator, system level simulator, and network level simulator to evaluate performance of CDMA systems including **IS-95**, **IS-2000**, **1xEV-DO**, **1xEV-DV**, and **UMTS**.
- Managed a group of engineers, prepared project plans, and established efficient processes to meet the requirements of the **CDMA2000** BSC product line.

NORTEL NETWORKS *September '97 to September '01*

Senior Engineer

Radio Resource Management, July '99 to Sept. '01

- Developed a comprehensive RRM simulator that models data traffic and major features of the MAC layer and physical layer. Analyzed various aspects of the RRM for several test cases. The performance results such as capacity and throughput were used in educating the service providers on the RRM for IS-2000 systems.
- Proposed a generic call admission control algorithm and filed a patent with the U.S. Patent Office.

Management of Supplemental Channels, June '00 to Sept. '01

- Designed and analyzed supplemental channel management for enhanced data performance and filed a patent with the U.S. Patent Office.

Data Traffic Modeling, Jan. '99 to Sept. '01

- Prepared a common framework for data traffic models for analysis of systems carrying data (e.g., 1xRTT and UMTS). Types of analysis include RF capacity, end-to-end performance, and provisioning. The data models for telnet, WWW, ftp, e-mail, FAX, and WAP services are considered.

Multi-Carrier Traffic Allocation, June '99 to Sept. '01

- Provided MCTA capacity improvements (compared to non-MCTA systems) that proved to be identical to the ones observed during the field-testing. Developed a method to estimate the MCTA capacity using the field data. This method was used in estimating MCTA capacity gains by RF engineering teams.

SmartRate and Related Vocoder Designs (e.g., SMV), June '99 to Sept. '01

- Provided estimates of SmartRate capacity improvements that were found to be close to the observed capacity gains in the field tests.

CDMA Based Fixed Wireless Access Systems, Sept. '97 to Dec. '98

- **Capacity Estimates**. Determined the system capacity for a variety of configurations using an IS-95 based simulator. These configurations include different rates such as 9.6 kbps and 13 kbps, different deployment scenarios such as 2-tier embedded sector and border sector, and different diversity techniques such as switch antenna diversity and phase sweeping transmit diversity. These capacity estimates were used for various project bids. The simulator utilizes propagation channel models extracted from the actual field measurements.
- **Handoff and Power Control Algorithms**. Analyzed existing handoff and power control mechanisms for fixed wireless systems and proposed new approaches.
- **Bridge between the Simulator and a Deployed System**. Developed a procedure to estimate the loading level for the simulator so that the capacity estimate from the simulator is close to the achieved capacity in real systems.
- **Switch Antenna Diversity Schemes**. Proposed three algorithms to exploit mobile switch antenna diversity. These schemes provide a low-cost solution that significantly enhances RF capacity.
- **Combined Overhead Power and Handoff Management**. Proposed a method of combined management of overhead channel power and handoff to improve capacity.

Educator

- Made presentations on topics such as data modeling, fixed wireless systems, and AI tools.
- Taught "Introduction to Wireless" class at Nortel.
- Prepared tutorials on the standards such as 1xRTT, 1xEV-DO, and UMTS.

VIRGINIA TECH *January '93 to August '97*

Research/Teaching Assistant, Mobile & Portable Radio Research Group (MPRG), Electrical Engineering

- Developed adaptive intelligent handoff algorithms to preserve and enhance the capacity and the Quality of Service of cellular systems.
- Helped *develop* and *teach* a new wireless communications course **(DSP Implementation of Communication Systems**) as part of an **NSF** sponsored curriculum innovations program. Implemented different subsystems of a communication system (e.g., a digital transmitter, a carrier recovery system, a code synchronizer, and a symbol timing recovery system) using the **Texas Instruments** TMS320C30 DSP development system.
- Refined the class material for undergraduate and graduate signal processing classes.
- Investigated different aspects involved in dual-mode adaptive reconfigurable receivers as part of a project sponsored by **Texas Instruments**.

PATENTS/DRAFTS (AUTHOR/CO-AUTHOR)

- Enhanced Power Control Algorithms for CDMA-Based Fixed Wireless Systems, Patent Number 6,587,442, Filed Date: October 28, 1999.
- Method and apparatus for managing a CDMA supplemental channel, Patent Number 6,862,268, Filed Date: December 29, 2000.
- Dynamic Power Partitioning Based Radio Resource Management Algorithm, Patent Disclosure No.: 11942RR, Filed Date: August 23, 2000.
- Switch Antenna Diversity Techniques at the Terminal to Enhance Capacity of CDMA Systems, Patent Disclosure No. RR2544, Filed Date: June 19, 1998.
- Adaptive Radio Configuration Assignment for a CDMA System, October 2003.
- Multi-carrier Load Balancing for Mixed Voice and Data Services, October 2003.
- Methodology for Hierarchical and Selective Overload Control on Forward and Reverse Links in a CDMA System, October 2003.
- A New Predictive Multi-user Scheduling Scheme for CDMA Systems, November 2003.
- A New Method for Solving ACK Compression Problem by Generating TCK ACKs based on RLP ACKs on the Reverse Link, October 2003.

ACTIVITIES

Member of **IEEE**. Reviewed research papers for the *IEEE Transactions on Vehicular Technology*, *IEE Electronics Letters* and the *IEEE Control Systems Magazine*.

EDUCATION

VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY **Blacksburg, VA**
Ph.D., Wireless Communications, August 1997, Overall GPA: 3.8/4.0
Dissertation: Generic adaptive handoff algorithms using fuzzy logic and neural networks

M.S., Electrical Engineering, November 1994, Overall GPA: 3.8/4.0

GUJARAT UNIVERSITY **Ahmedabad, India**
B.S., Electrical Engineering, September 1992
Graduated among the top 2% of the class.

EXHIBIT B

DECLARATION OF DAVID R. WOLTER

Before the
Federal Communications Commission
Washington, DC 20054

In the Matter of	**)**	
	)	
Promoting Interoperability in the	**)**	**WT Docket No. 12-69**
700 MHz Commercial Spectrum	**)**	
	)	
Interoperability of Mobile User	**)**	**RM-11592 (Terminated)**
Equipment Across Paired Commercial	**)**	
Spectrum Blocks in the 700 MHz Band	**)**	

DECLARATION OF DAVID R. WOLTER

TABLE OF CONTENTS

I. QUALIFICATIONS AND BACKGROUND 1

II. PURPOSE AND SUMMARY.....2

III. STABLE 3GPP STANDARDS ARE HIGHLY IMPORTANT TO THE DEVELOPMENT OF WIRELESS NETWORKS AND SERVICES.....3

IV. BARRIERS TO AT&T ADOPTING BAND 12. 7

V. INTERFERENCE FROM CHANNEL 51 AND THE E-BLOCK AND THE SUBSTANTIAL COSTS ASSOCIATED WITH ATTEMPTING TO MITIGATE THAT INTERFERENCE. 17

Before the
Federal Communications Commission
Washington, DC 20054

In the Matter of	)	
	)	
Promoting Interoperability in the 700 MHz Commercial Spectrum	)	**WT Docket No. 12-69**
	)	
Interoperability of Mobile User Equipment Across Paired Commercial Spectrum Blocks in the 700 MHz Band	)	**RM-11592 (Terminated)**

DECLARATION OF DAVID R. WOLTER

I. QUALIFICATIONS AND BACKGROUND

1. My name is David R. Wolter. I am an Executive Director for Radio Technology in the Radio Access and Devices organization in AT&T. My team's responsibilities include evaluation of radio technology performance, evolution, and standards support for cellular and Wi-Fi technologies. Prior to becoming Executive Director, I was Lead Member of the Technical Staff working in the radio technology arena at SBC Communications, Inc. ("SBC") and later AT&T Labs, Inc., where I focused on wireless system performance. Prior to joining SBC in 1991, I was a Unit Chief in the Avionics Technology division of McDonnell Aircraft Corporation (now Boeing), where I was responsible for advanced tactical communication, navigation and identification systems development and analysis for advanced aircraft designs.

2. I hold Bachelor of Science and Master of Science degrees in Electrical Engineering from Washington University in St. Louis. I am a member of the Institute of Electrical and Electronics Engineers and serve as AT&T's representative on the Industry Advisory Board for the Wireless Networking and Communications Group at the University of Texas at Austin.

II. PURPOSE AND SUMMARY.

3. The purpose of this declaration is threefold. First, I explain that the development and deployment of mobile broadband services requires coordination among a wide array of industry participants. Durable and reliable standards adopted by an industry-driven international standards development organization – the Third Generation Project Partnership ("3GPP") – facilitates such coordination and thus drives substantial investment in innovative and evolving mobile broadband technologies.

4. Second, I address the proposal in the *Public Notice*[1] issued by the Federal Communication Commission ("FCC") that would prohibit AT&T from using the 3GPP standards and specification for LTE Band 17 and require AT&T to transition to Band 12 in two years. I explain that there is no existing standard that would allow AT&T to make such a transition without stranding millions of customers that use Band 17 LTE devices. I further explain that the network features that theoretically would allow a carrier to simultaneously support 3GPP Band 12 and Band 17 devices are contained in 3GPP standards and specifications that are still in the development phase, and that even after those new 3GPP standards and specifications are adopted, it could take far longer than two years to implement them.

5. 3GPP approval of a new feature, particularly one that alters network/device signaling protocols, triggers a lengthy collaborative process that includes the development of carrier-specific performance specifications based on the new 3GPP standard, the creation and testing of compliant software, chipsets and equipment, carrier lab and field testing, and then gradual roll out of the new technology on a market-by-market basis to ensure scalability. Even a

[1] Notice of Proposed Rulemaking, *Promoting Interoperability in the 700 MHz Commercial Spectrum; Interoperability of Mobile User Equipment Across Paired Commercial Spectrum Blocks in the 700 MHz Band*, WT Docket No. 12-69 (Mar. 21, 2012) ("*Public Notice*").

best case scenario would likely require more than two years and that assumes that (i) vendors would put development of this new technology at the front of the development line, displacing and delaying other pressing LTE development projects that can improve network performance and the customer experience; (ii) the new products pass testing without the need for significant additional work, and (iii) the new technology is backwards compatible with existing devices. Problems at any of these fail points could substantially extend the time for deployment.

6. Third, I explain that forcing AT&T to use 3GPP Band 12 standards and specifications rather than Band 17 would subject AT&T and its customers to additional and unavoidable interference that could adversely affect device and network performance. This additional interference could not be fully mitigated, and in some cases could not be mitigated at all. And the mitigation efforts needed to reduce such interference, where possible, would be very costly, potentially more than a billion dollars for AT&T alone. Thus, unless and until interfering Channel 51 and E block transmissions are eliminated, a Band 12 mandate would harm consumers and AT&T.

III. STABLE 3GPP STANDARDS ARE HIGHLY IMPORTANT TO THE DEVELOPMENT OF WIRELESS NETWORKS AND SERVICES.

7. Mobile broadband services require coordination among numerous industry participants. Network operators, chipset manufacturers, infrastructure and device manufacturers, and software developers all contribute to the seamless wireless broadband services that customers currently enjoy. Because of the interdependent nature of the wireless marketplace, the products and services of the various industry participants operating in different layers of the wireless ecosystem must be coordinated to be of value.

8. Such coordination would not be possible without established and durable specifications and standards. They provide the “ground rules” from which the wide range of

industry participants within the wireless ecosystem can work, and the confidence that the equipment, devices, and software they develop will be compatible with mobile broadband networks based on those same standards.

9. To develop these critical standards for LTE and previous generations of wireless services, the industry established 3GPP, which is comprised mainly of engineers from industry participants representing all sectors of the industry, including both domestic and foreign-based companies.[2] When new spectrum becomes available for LTE deployment, the 3GPP, among other things, studies the spectrum and seeks to develop standards, specifications and test requirements to enable mobile broadband services that can support that spectrum. Standards set by the 3GPP are developed on a consensus-driven, engineering basis and govern not just wireless standards in the United States, but internationally.

10. For these reasons, new standards and specifications adopted by the 3GPP typically spark enormous investment and activity throughout all levels of the wireless ecosystem. Network operators begin engineering networks that comply with the new standards, which includes, among many other things, specifying equipment, obtaining and adding new cell sites, optimizing existing cell sites, preparing deployment plans and guidelines, and writing software that complies with the new 3GPP protocols. They also establish device specifications that must be met by suppliers that are based on the 3GPP standards, acquire appropriate test equipment, and set up certification test processes and environments. Equipment manufacturers begin

[2] 3GPP processes are fully transparent and open to all, and the published lists of participants at 3GPP meetings confirm the wide participation and the breadth of the expertise and input provided. *See, e.g.*, http://webapp.etsi.org/3gppmembership/Results.asp?Member=ALL_PARTNERS&SortMember=Name&DirMember=ASC&SortPartner=Name&DirPartner=ASC&SortMarket=Name&DirMarket=ASC&SortObserver=Name&DirObserver=ASC&SortGuest=Name&DirGuest=ASC&Name=&search=Search; http://webapp.etsi.org/3GPPRegistration/fViewPart.asp?mid=29002.

developing network equipment that complies with the standards, such as base stations, with their baseband processing, antennae, transceivers, and filters. Device manufacturers and their component suppliers begin designing compliant devices. Chipset manufacturers begin designing compliant chipsets and radios for use in the new devices. Test equipment manufacturers develop new test equipment, or they develop upgrades for existing equipment to support the diverse requirements off the new specifications. In addition, software developers begin writing software to control the interactions between the new networks, equipment, and devices. These entities all begin working together to design and test these new components and software and contract with one another for the purchase and sale of these new products.

11. In addition to sparking substantial investment in developing the physical networks, components, and software, the network operators begin designing service plans and pricing for the new service. The ultimate characteristics of broadband services are to a significant degree tied to the 3GPP standards upon which they are based. Thus, service plans and pricing are based on reliability, speed and other performance measures set forth in (or derived from) the 3GPP standards. These business plans play a significant role in determining the level of investment in any new 3GPP standard and the timing of deployments. Marketing plans are also developed based on the quality and the performance of the services enabled by the 3GPP standard.

12. Just as the 3GPP standards are initially established on the basis of consensus, the 3GPP standards are generally altered or changed only by consensus of 3GPP members. This approach provides the needed certainty that investments based upon 3GPP standards and specifications will not be undercut by unexpected changes and allows both domestic and

international roaming. This certainty facilitates the broad scale investment, development, and deployment of innovative mobile broadband services throughout the wireless ecosystem.

13. AT&T has invested heavily in Band 17. The first Band 17 3GPP standards and specifications were finalized in September, 2008. Since 2008, AT&T has based its planning and deployments on the Band 17 standards and specifications. From a physical network perspective, AT&T has, among many other things, relied upon the Band 17 specifications to add base stations, optimize existing base stations, and run extensive testing (both in the field and in the lab). AT&T has negotiated numerous contracts for Band 17 compliant equipment and devices, and worked with its suppliers to optimize that equipment to the Band 17 specifications. AT&T's LTE network covered more than 74 million "POPs" at the end of 2011. AT&T plans to more than double its LTE POPs coverage by year end 2012 and to largely complete its LTE build, covering 80 percent of total U.S. POPs, by year end 2013.

14. Innovation based on the Band 17 standards continues to occur. AT&T is constantly working with infrastructure vendors, device manufacturers and chipset makers to design, develop, test and deploy innovative mobile services for its customers. The typical time for the deployment of a new device from the time the carrier and manufacturer agree to specifications and enter into a contract to actual deployment of the new device ranges from about 12 to 24 months. Today, AT&T and its device partners have numerous Band 17 devices in the pipeline at various stages of readiness. Furthermore, AT&T is constantly planning and allocating resources to upgrade and improve its Band 17 compliant network to enhance capacity, speed and reliability, including the addition of cell sites, implementing advanced radio and antenna techniques, and acquiring additional spectrum.

IV. BARRIERS TO AT&T ADOPTING BAND 12.

15. I understand that some entities have proposed that the FCC "should immediately mandate interoperability in the lower 700 MHz band."[3] That is, these parties contend that the FCC should immediately require AT&T to support the Band 12 3GPP specifications rather than the Band 17 specifications that AT&T has relied upon since 2008 to build out its LTE network. This proposal is not technologically feasible today without stranding the Band 17 devices AT&T currently has in service. There is no standard and no equipment available today that would allow AT&T – or any carrier – to simultaneously support both Band 17 and Band 12 devices. Current 3GPP standards allow a carrier to support either Band 17 or Band 12 devices, but not both. Thus, if AT&T were required to implement a Band 12 mandate immediately, the necessary network changes would render *all* Band 17 devices inoperable.[4]

16. I also understand that the Commission has asked whether such a mandate that was delayed for two years would eliminate the risk to consumers.[5] The answer is no. The 3GPP "feature" standard that would theoretically facilitate simultaneous network support of Bands 12 and 17 is still being developed. There is no fixed release date, but I understand that it may be incorporated in the 3GPP's next broad release ("Release 11") of standards and specifications for

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[3] *See, e.g.*, Letter from Steven K. Berry (RCA) to Marlene H. Dortch (FCC), WT Docket No. 11-186 (May 24, 2012).

[4] The practical impediments of replacing Band 17 devices are even greater for devices sold by third parties with embedded modules that enable them to use AT&T's Band 17 LTE network. AT&T has long worked with third parties on such devices for its 2G and 3G networks as well. These modules can be embedded in a broad range of products, including, for example, automobiles, e-readers, and GPS devices. Because these services are offered by third parties (and in fact, end users may not even know that the services use AT&T's network), AT&T may have no relationship with the actual users of the Band 17 devices.

[5] *Public Notice* ¶ 50.

LTE services.[6] Specifically, I understand that Release 11 will likely include standards and specifications for support of multiple Frequency Band Indicators ("multiple FBIs"), that in turn would permit a network to service both Band 17 and Band 12 devices. In theory, implementing this feature of Release 11 could permit a Band 17 carrier to serve new, Release 11-compliant Band 12 devices while still serving legacy Band 17 customers. But even in the rosiest scenario, an inflexible regulatory mandate that took effect in two years could cause substantial harm.

17. Foremost, these standards and specifications are still being developed. Although there are draft standards and specifications for this feature, they are subject to change, and it is not at all uncommon for significant changes in draft standards and specifications to occur before the final release. Indeed, I understand potential changes to the multiple FBI standards and specifications are being considered at this very time. The industry cannot begin to implement these standards and specifications – or have confidence that implementation will be complete by any fixed date – until they have been finalized.

18. And even if standards and specifications for a Release 11 feature that permits a network to support both Band 12 and Band 17 devices were ready today, there are many time-consuming steps that would have to be completed before it could be fully deployed.

19. Before this new technology could be deployed in AT&T's network, AT&T would need to i) design any necessary carrier-specific performance specifications based on this feature of Release 11; ii) work with equipment vendors to develop the necessary software to implement this feature of Release 11; iii) work with device manufacturers to obtain Release 11-compliant

[6] I understand that 3GPP may also provide the standards supporting this feature as a Technical Enhancement or Improvement ("TEI") to Release 10. But even if it does so, because the TEI would come in such close proximity Release 11, the industry would effectively consider these features as part of the Release 11 development cycle. Thus, for ease of reference, I will refer to the relevant feature that would allow wireless networks to support Bands 12 and 17 simultaneously as part of Release 11.

devices; iv) lab and field test the upgraded network equipment and devices to ensure compatibility; (v) fully regression test legacy band 17 devices to ensure they work with the new release; and, (vi) roll out this Release 11 feature throughout AT&T's network.

20. Although it is impossible to predict with certainty before the standard is even released, because of the complexities in each of these steps, I believe it could take three years for AT&T to properly implement this capability into its network. And it could take longer depending on several variables, including, for example, the speed at which vendors can allocate resources to this project (typically vendor resources are fully occupied with multiple projects and it can take significant time before they can allocate resources to a new one), and the extent to which initial production units require modification after lab and field testing.

21. *Carrier-specific performance standards.* 3GPP standards are not typically self-executing. They need to be supplemented by carrier-specific specifications. For example, they require a network operator to develop and set performance standards specific to their network before vendors can fully develop the equipment, software and devices for that carrier based on the 3GPP standard. Until the final 3GPP Release 11 standards and specifications that permit networks to support both Band 12 and Band 17 devices are complete, it is not possible to determine precisely how long it would take to develop carrier-specific standards for this feature. However, the feature at issue here raises several uniquely complex issues – including issues related to signaling, mobility management, and operational support systems – and depending on the complexity of the standard and the level of specificity in the standard, I expect that it could take several months or more for AT&T to develop carrier-specific standards and specifications for this new feature.

22. *Software development.* To implement the multiple FBI feature of Release 11 with the associated carrier-specific requirements, AT&T would have to work with vendors to develop the necessary software. Development of this software would be a significant undertaking. AT&T would require software that allows its existing network equipment to simultaneously broadcast in Bands 12 and 17, and thus simultaneously manage two 3GPP Bands. Implementing the Release 11 feature permitting a network to support both Band 12 and Band 17 would most certainly require new, highly specialized software for controlling AT&T's base stations, and likely also impacting AT&T's mobility management equipment. Special software would also be required for AT&T operational support systems that are responsible for maintaining and provisioning the information necessary for operation of the wireless network, including, for example, the configuration, frequenc(ies) and power level of each base station.

23. The process is further complicated by the fact that AT&T would need to upgrade *all* of its base stations (and, likely, its mobility management equipment and operational support systems) if its network is to be able to communicate with both Band 12 and Band 17 devices. AT&T's base station and mobility management equipment, however, is provided by several different companies. Thus, given the customization required, AT&T would need to obtain software updates from multiple vendors.

24. The potential issues may very well multiply as a result of AT&T's ongoing deployment of small cell technology (*e.g.*, distributed antenna systems, small-cell systems and other forms of heterogeneous networks). Such technology can improve network performance, but achieving full integration between small cells and macro cells is extremely complex and difficult. Although it is impossible to know at this time the extent to which the multiple FBI feature of Release 11 would impact layer management and hand off between small and macro

cells, this is an issue that will require careful attention and examination by equipment manufacturers.

25. Implementation of a new feature derived from a 3GPP standard of this complexity, and, for AT&T, the need to obtain finished products from multiple vendors, could mean a two year cycle between the manufacturers beginning development work and the delivery of the finished products. Underscoring this point, AT&T's network suppliers have informed AT&T that they cannot provide any reasonable guidance on how long it will take them to complete the necessary development work until after Release 11 is finalized and analyzed.

26. *Device development.* In the event that AT&T is required to provide service in Band 12 as opposed to Band 17, AT&T would need more than new software for the network; it would also need a complete inventory of new devices. The forthcoming 3GPP standard is designed to be backwards compatible with legacy devices from a single 3GPP Band, *i.e.*, the devices designed to support the same 3GPP Band as the "primary" signal from the network. Because AT&T has millions of Band 17 devices in the field, its network would necessarily have to broadcast a Band 17 signal as the primary signal. Thus, only Band 12 devices that have been developed in compliance with the forthcoming Release 11 standards would be able to transmit and receive over a formerly Band 17-only network that has been upgraded to simultaneously support Band 17 and Band 12.

27. To be sure, AT&T expects that device manufacturers will work to implement the new release and, given the competitive nature of the marketplace, a broad array of Release 11-compliant Band 12 devices will be produced. But there is good reason to be concerned that such devices will not be available on the rigid timetable contemplated by the *Public Notice*. I understand that the development of a new device line usually takes in the neighborhood of 18 to

24 months. It is reasonable to expect this development to be at the high end (or even longer) given that these devices would need to work in a new environment with potentially new and more complex signaling requirements.

28. *Lab and field testing.* Development and delivery of the necessary software and equipment is by no means the end of the process. Extensive testing must be conducted to ensure that the software will work as intended, and will not adversely affect the performance of AT&T's network. This is a critical step. AT&T cannot deploy a national software upgrade unless it is absolutely sure that it will support the millions of devices currently using AT&T's network and that it will continue to manage spectrum at peak efficiency. Accordingly, comprehensive and careful testing – and addressing any issues raised during testing – is an absolute pre-requisite to the deployment of new features in AT&T's network. There are several steps to this testing.

29. Testing is first performed by the developers and device manufacturers to ensure that their products work as intended in isolation as well as conducting some level of interoperability testing with the equipment from other vendors. AT&T then conducts its own testing to ensure that the individual pieces of upgraded equipment work properly with the other equipment in AT&T's network (including other pieces of upgraded equipment). This requires not only lab testing, but field testing as well – *i.e.*, trial deployment in limited test areas. Such real world trials are an essential step prior to full implementation across AT&T's LTE network because no amount of lab testing can fully address real world conditions.

30. Particularly careful testing would be required in these circumstances for two independent reasons. First, as noted, in addition to standard macrocell operation the deployment of small cell technology presents unique issues in achieving stable and reliable handoffs between the small and macro-cells. It would be necessary to ensure not only that the multiple FBI feature

of Release 11 does not impact these hand offs, but that it would function effectively in an environment where the small and macro cell equipment may be manufactured by different vendors. In other words, it is not enough for each type of equipment to function properly in isolation, but also in the real world environment in which all of the types of equipment must interoperate effectively.

31. Second, the multiple FBI feature of Release 11 requires changes that could potentially render AT&T's customers' existing Band 17 handsets inoperable. Because Release 11 has not been finalized and no testing has been done (or could be done) to confirm the extent to which it will be compatible with Release 10 or earlier Band 17 devices, it is not clear that all of the legacy Band 17 devices used by AT&T's customers would even be compatible with the multiple FBI feature of Release 11. Although, as noted, the new standard is intended to be "backwards" compatible with devices operating in the primary signaling band, there is a real risk that a substantial number of devices would not work in a Release 11 environment without some additional modifications and adjustments. Rigorous testing would be necessary to see how the wide variety of pre-Release 11 Band 17 devices would function after full implementation of the Release 11 features that permit a network to support both Band 12 and Band 17 devices to ensure that customers do not lose service entirely (or suffer loss of functionality). Even if only a small percentage of AT&T's legacy Band 17 devices proved to be incompatible with the new feature, that would be an unacceptable level of customer harm and would require further delays to address the relevant network and/or device issues. If some of the incompatible devices were machine-to-machine devices sold by third parties, the difficulties would be compounded even further.

32. Adequate lab testing of upgraded network equipment and/or devices typically takes at least three months and field testing typically takes another three months. Again, I would expect implementation of Release 11 features permitting a network to support both Band 12 and Band 17 devices to require testing of at least this length given the inherent complexities in implementing such novel and complex systems and the need to be absolutely certain that customers' existing devices will continue to function. And although difficult to quantify, rigorous testing entails significant cost, including devoting skilled personnel that could be performing other network management and development tasks.

33. *Network deployment*. Finally, after the completion of testing, the actual upgrades must be made to the network. Even software-only upgrades cannot be made as nationwide "flash cuts." Rather, even after a new feature release has been successfully field tested in a test market or two, there is still the question of scalability. Software upgrades, particularly upgrades that implement complex new features are thus rolled out gradually to ensure that the software remains stable in a broad scale deployment. Moreover, AT&T engineering professionals have responsibility for maintaining and operating AT&T's existing wireless network, expanding that network, and implementing the many other improvements and adjustments to that network. Given these competing demands, in my experience it would likely take at least an additional six months after the end of testing before there could be full deployment of the multiple FBI feature in AT&T's network. Again, as with testing, proper network deployment of a complex upgrade will entail significant direct and opportunity costs.

34. In addition, there are myriad "break points" to implementing multiple FBI that could cause substantial delays.

35. Foremost, there can be no guarantee that equipment manufacturers will be prepared to begin implementing the Multiple FBI CRs immediately upon its finalization by 3GPP. Equipment manufacturers and software developers must manage limited resources, competing demands for their equipment, feature priorities, and other products, and can only focus on a limited number of projects at any given time. The equipment and software needed to support the multiple FBI feature is highly specialized and will require substantial involvement of highly experienced engineers and programmers who may not be immediately available. In fact, it is highly likely that the engineers and programmers that would be needed to implement the multiple FBI Release 11 feature are currently working on other projects – including projects to implement important features of Release 10, and even earlier releases – that are at various levels of development. In the event that any of the several vendors upon which AT&T depends to obtain the necessary Release 11 equipment fails to commence the necessary development upon finalization of that release, the delivery of a multiple FBI feature could be considerably delayed.

36. Moreover, it is important to recognize that even if vendors chose to prioritize development of the multiple FBI feature, that could come at a cost in terms of delays to other projects to which the vendors would otherwise have given priority. In fact, LTE equipment vendors are currently working on myriad high priority projects that will significantly improve LTE service quality, LTE spectral efficiency and network performance. Examples of such features include higher throughput services, improved support for heterogeneous networks, and Voice-over-LTE ("VoLTE") services. Prioritizing the multiple FBI feature of Release 11 thus may come at a significant opportunity cost.

37. It is also important to recognize that the items that AT&T has currently asked equipment vendors to prioritize are those that AT&T has determined will likely bring the greatest

value to its customers and thus improve AT&T's competitive position in the marketplace. Forcing AT&T and its equipment vendors to prioritize features that offer little or no value to AT&T's customers – and, indeed, features that actually harm customers by subjecting them to a greater risk of interference – while delaying features that would improve AT&T's offerings could only harm AT&T's competitive position. Although the adverse impacts on customer retention and attraction are obviously difficult to quantify, they are nonetheless real and substantial. This is particularly significant given that the burdens of the proposed Band 12 mandate would fall almost entirely on AT&T; key competitors, including Verizon, would largely be exempt.

38. In any event, because of the nature of implementing Release 11 there is also a real risk that major delays could occur. The time frames that I discussed above include delays associated with the normal adjustments that have to be made after testing reveals a problem. But as noted, although the multiple FBI feature is intended to be backwards-compatible for existing Band 17 devices, there is a real risk that interoperability issues may be observed in a subset of legacy Band 17 devices. If this turns out to be the case, AT&T would have to work with the device manufacturer to see if the issue can be addressed through a software update – a time consuming process requiring a software development and testing process that can be quite extensive. And only certain changes can be made by software updates. Some problems may require that the subscriber exchange devices – which is obviously an expensive and time consuming process.

39. Finally, until the specification is finalized and analyzed, it is impossible to state with any certainty whether my assumption that the multiple FBI feature will require only software upgrades and not new network equipment will be borne out.

V. INTERFERENCE FROM CHANNEL 51 AND THE E-BLOCK AND THE SUBSTANTIAL COSTS ASSOCIATED WITH ATTEMPTING TO MITIGATE THAT INTERFERENCE.

40. As explained in the accompanying declaration of Professor Reed and Dr. Tripathi, forcing AT&T to use Band 12 would subject AT&T's customers to additional interference from high-powered Channel 51 and E block television and video broadcasts that could adversely affect the performance of AT&T's network and devices. It would not be possible to completely mitigate such interference, and in some areas AT&T might not be able to mitigate it at all, leaving AT&T and its customers much worse off. Moreover, the main technique for mitigating interference would be to add base stations and re-optimize existing ones, and those are complex and expensive processes. Base stations are very costly to build and operate. If interference mitigation required AT&T to increase the number of its base stations by only one to two percent, that would represent hundreds of millions or even billions of dollars in incremental capital investment and hundreds of millions of dollars more in incremental annual operating costs.

41. Moreover, to the extent mitigation was ineffective or delayed and AT&T's network and device performance suffered, AT&T would incur competitive harm as its customers experience reduced performance with devices operating on AT&T's network. This would both negatively impact AT&T's goodwill as well as weaken its ability to compete with AT&T's many rivals that do not use Band 12 and will not be subject to these interference issues.

42. As explained in the accompanying declaration of Professor Reed and Dr. Tripathi, forcing AT&T to use Band 12 would subject AT&T to additional interference from the high-powered broadcasts in Channel 51 and the E block that are directly adjacent to the Band 12 frequencies. It was this additional interference that led the 3GPP to create Band 17. Because the Lower 700 MHz B block has greater separation from these sources of interference than the A

block, Band 17 devices are much more effective at attenuating interference from these sources than Band 12 devices.[7]

43. As Professors Reed and Dr. Tripathi explain in their declaration, such interference could have a significant adverse impact on the quality of the LTE services that AT&T's customers would receive using Band 12 compliant devices. Interference from Channel 51 and E block transmissions can substantially slow download transmission speeds and increase the likelihood of service interruptions. Indeed, it is possible that the interference may interrupt service altogether.

44. Although it is impossible to know at this time the full extent to which AT&T would suffer from Channel 51 and E block interference, there is indisputably a substantial risk of interference from these sources should the Commission mandate that AT&T use Band 12 rather than Band 17.

45. As Professor Reed and Dr. Tripathi correctly point out, the interference to Band 12 devices from Channel 51 and E block cannot be addressed at the device level. Rather, AT&T would need to make changes to its network to try to mitigate such interference. With regard to Channel 51 interference, the most direct way of addressing this issue would be for AT&T to increase the level and quality of AT&T's LTE signal to customers (and thus increase the signal to interference ratio seen by Band 12 devices). That in turn would require building new base stations in very specific locations around Channel 51 broadcast towers. There are, however, numerous Channel 51 broadcast towers spread throughout AT&T's service areas. Thus, for each of these locations, AT&T would need to search for locations for additional Band 12 cell towers (or locations where AT&T could collocate on an existing tower), conduct engineering studies of

[7] *See, e.g.*, Ericsson Submission, TG-RAN Working Group 4 (Radio) meeting AH-Band 12, Chicago, September 29-30, 2010.

the locations, negotiate with the landlords, have proceedings before local zoning boards, erect (and then maintain) the cell towers and re-optimize the surrounding base stations, among other things. For each new base station, this process takes anywhere from several months to several years and, in any event, is an expensive undertaking requiring the devotion of significant internal resources and capital.

46. In many instances there may not be a suitable location for a new cell tower in the specified area. Even where there is a suitable location, local zoning or resistance by landlords may make it impossible for AT&T to put a cell tower in the requisite location. Thus, in some areas, AT&T may not be able to address the Channel 51 interference at all.

47. Moreover, deploying a substantial number of new base stations can *create* other problems. Although doing so will increase signal strength in some areas, it can have the consequence of creating interference and coverage issues in other areas.

48. Even in areas where the increased interference could by mitigated by adding base stations, the potential costs of doing so would be very substantial. Deployment of additional base stations requires substantial capital expenditures and operating costs. Depending on the geographic scope of the interference, numerous new base stations could be required to boost signal to interference ratios to necessary levels. Deployment of additional base stations also requires additional backhaul to connect those base stations with the network.[8] Overall, it typically costs about a half million dollars for AT&T to deploy an LTE base station (and

[8] I also understand that some proponents of the Band 12 mandate have suggested that any Channel 51 interference issues can be mitigated by modifying the eNodeB scheduler. The suggestion is that the scheduler would not allocate the resource blocks that are experiencing interference. Even if such a complex change could be implemented to address intermodulation interference, it would cause harm comparable to the problem it is attempting to address. In effect, such a change would eliminate a portion of the spectrum available to AT&T's customers. This, in turn, lowers the data transmission speed available to AT&T's subscribers in the affected area in the same way that the interference would.

sometimes more, particularly in dense urban areas). Annual operating costs for each new base station are also very substantial.

49. As explained by Professor Reed and Dr. Tripathi, it is not at all clear that there is any solution to interference from E block transmissions. Because E block transmissions are located immediately adjacent to A block mobile "receive" frequencies and because E block licensees have the right to transmit signals that are approximately 100 times the strength of AT&T's LTE signals, there is a real risk of overload (or blocking) interference that prevents Band 12 devices from receiving LTE transmissions over an area around the E block transmitter. But even where overloading does not occur, as explained by Professor Reed and Dr. Tripathi, interference from E block transmissions will increase interference levels for Band 12 devices compared to Band 17 devices, which in turn results in lower Band 12 device and network performance compared to Band 17.[9]

50. Further, E block networks have not yet been deployed, and there is no limitation on where, when or how many transmitters may be deployed. Consequently, although it is broadly accepted that the deployment of such networks will produce significant adjacent channel interference to Band 12 networks, it is not clear the extent to which mitigation of such interference is feasible, or what the costs of any mitigation would be. For this reason, there may be many areas in which AT&T's legacy Band 17 devices currently operate but where Band 12 devices cannot operate or will operate only with substantially degraded performance. In addition, these transmitters could be deployed at any time on an ongoing basis such that this

[9] *See* Ericsson, ST-Ericsson, Band 12 coexistence and possible changes to TS 36.101, TSG RAN Working Group 4 (Radio) Meeting AH-Band 12 Chicago, USA, (Sep. 29-30) (describing testing confirming the significant interference from E band transmission on Band 12 devices).

interference mitigation issue would be an ongoing problem with continuing degradation to the performance of AT&T's networks.

51. At a minimum, deployment of additional base stations to boost AT&T's signal strength would be costly both in terms of the base station deployment itself as well as the need to engage in network reoptimization in connection with such deployment. For example, even if Dish Network deployed only 1,000 E block transmitters in AT&T's service area and AT&T added only three base stations for each of those E block transmitters to mitigate interference, total mitigation costs would quickly run over a billion dollars.

52. In short, requiring AT&T to provide LTE service using Band 12 would subject AT&T to additional interference from Channel 51 and E block transmissions that could adversely affect the performance of AT&T's network and devices. AT&T may not be able to mitigate all such interference. Consequently, customers would be subject to potentially significantly degraded service, which in turn could cause significant competitive harm to AT&T and loss of goodwill. Moreover, to the extent AT&T can partially mitigate such interference by adding new base stations and optimizing its network, doing so would be extremely expensive.

VERIFICATION PAGE

I hereby swear under penalty of perjury that the foregoing is true and correct.

/s/ David R. Wolter
David R. Wolter

Dated: May 31st, 2012

EXHIBIT C

DECLARATION OF MICHAEL PRISE

Before the
Federal Communications Commission
Washington, DC 20054

In the Matter of	**)**	
	)	
Promoting Interoperability in the	**)**	**WT Docket No. 12-69**
700 MHz Commercial Spectrum	**)**	
	)	
Interoperability of Mobile User	**)**	**RM-11592 (Terminated)**
Equipment Across Paired Commercial	**)**	
Spectrum Blocks in the 700 MHz Band	**)**	

DECLARATION OF MICHAEL PRISE

TABLE OF CONTENTS

I. QUALIFICATIONS AND BACKGROUND 1

II. PURPOSE OF DECLARATION 1

III. THE DEVELOPMENT OF NEW DEVICE PLATFORMS. 3

IV. THE DEVICE PLATFORMS DEVELOPED FOR AT&T'S AND VERIZON'S 700 MHz NETWORKS CAN BE INEXPENSIVELY MODIFIED TO CREATE "VARIANTS" FOR USE ON OTHER 700 MHz NETWORKS. 7

V. EVEN IF AT&T USED BAND 12, MOST OTHER BAND 12 PROVIDERS COULD NOT USE OFF-THE-SHELF AT&T DEVICES. 9

VI. ELIMINATION OF BAND 17 IS NOT NECESSARY TO CREATE ROAMING OPPORTUNITIES FOR BAND 12 PROVIDERS. 11

Before the
Federal Communications Commission
Washington, DC 20054

In the Matter of	)	
	)	
Promoting Interoperability in the 700 MHz Commercial Spectrum	)	**WT Docket No. 12-69**
	)	
Interoperability of Mobile User Equipment Across Paired Commercial Spectrum Blocks in the 700 MHz Band	)	**RM-11592 (Terminated)**

DECLARATION OF MICHAEL PRISE

I. QUALIFICATIONS AND BACKGROUND

1. My name is Michael Prise. My title is Distinguished Member of Technical Staff in the Subscriber Product Engineering group at AT&T Labs. I am responsible for overall coordination of the Device Requirements at AT&T. These are the technical requirements which are delivered to all wireless device and chipset manufacturers. I have served in a similar role since 1995 with McCaw Cellular, AT&T Wireless and Cingular Wireless. Between 1985 and 1995 I was a research engineer (1992-1995 a Distinguished Member of Technical Staff) in the Communication Research Division at AT&T Bell Labs, working on modem design of cordless phones. I received my B.Sc. in Physics from University of Aberdeen (1980) and Ph.d in Physics from Heriot-Watt University (1983), both in Scotland.

II. PURPOSE OF DECLARATION

2. The purpose of this declaration is to address three topics. *First*, as explained in detail below, when a provider wishes to obtain a device for use on its network, the provider can work with a manufacturer to develop an entirely new device, or the provider can work with the manufacturer to obtain a "variant" of an existing or already planned device. Whereas developing

a new device from scratch is expensive and time consuming, developing a variant of an existing or already planned handset can be quite inexpensive. Changing one of the bands, for example, consists essentially of replacing two or three parts, which cost less than one dollar, with similar parts that also cost less than one dollar. Thus, when a Band 12 provider seeks access to a variant of a device that was originally developed primarily for AT&T or Verizon, the Band 12 provider can obtain that device at low cost and in much less time.

3. *Second*, even if AT&T were required to use only Band 12 devices, it still would be exceedingly rare that another Band 12 provider could use any AT&T Band 12 devices "off-the-shelf." Rather, the other Band 12 provider still would need a variant of AT&T's device. This is so because LTE devices must operate on "fall back" legacy networks to ensure maximum coverage. AT&T is one of the few LTE operators in the U.S. that uses a GSM/UMTS technology as a fall back network. Most other LTE providers use CDMA technology as a fall back network. In addition, CDMA providers typically use a dual simultaneous radio (*i.e.*, they use two radios when simultaneously providing LTE data service and CDMA voice service) whereas AT&T uses a single simultaneous radio (*i.e.*, the handset switches to the UMTS radio for a voice call and supports data on the UMTS radio during the voice call, then switches back to LTE after the voice call is completed). Accordingly, even providers that use the same 700 MHz LTE spectrum and the same Band as AT&T would still have to obtain a variant of AT&T's device by replacing the GSM/UMTS chipsets and firmware with CDMA chipsets and firmware, which would include the quite different radio architecture underlying the use of dual simultaneous radios. This may explain why U.S. Cellular is using Band 12 devices that appear to be variants of Verizon devices rather than variants of AT&T handsets. Unlike AT&T,

Verizon also uses CDMA technology for its fall back network and dual simultaneous radio for voice in LTE devices.

4. *Third*, Band 12 providers do not need be able to roam on a hypothetical AT&T Band 12 network to ensure that they have access to a vast array of roaming opportunities. There are numerous providers in the United States that are deploying LTE networks, including Verizon, Sprint, T-Mobile, Leap, MetroPCS, and Clearwire, and they are using or deploying a number of LTE bands on which Band 12 providers could roam, including, Band 4 (AWS), Band 2 (Cellular), Band 5 (PCS), Band 41 (Clearwire), and Band 13 (700 MHz). A Block providers could also roam on each other's LTE networks using Band 12. It is the norm in the industry for providers to have multi-band handsets that permit roaming in one or more bands.

III. THE DEVELOPMENT OF NEW DEVICE PLATFORMS.

5. To facilitate coordination for LTE services (and previously for 3G services), the industry established the 3GPP standards-setting body, which is comprised mainly of engineers from industry participants, including, among many others, representatives of Qualcomm, Motorola, Ericsson, Alcatel-Lucent, U.S. Cellular, Vulcan Wireless, C Spire Wireless, AT&T, Verizon, Sprint, Deutsche Telecom, Samsung, HTC, LG, Nokia, and Apple. When new spectrum becomes available for LTE deployment, the 3GPP, among other things, studies the spectrum, reviews industry input and develops standards and specifications designed to support the many-faceted needs of the mobile communications industry. This, in turns, helps speed products to market and improves the quality of mobile broadband services that can be offered with that spectrum.

6. The standards and specifications developed by 3GPP are critical to the efficient development and deployment of LTE services. They provide the blueprint from which the many and varied participants in the wireless ecosystem can work. By following this blueprint,

manufacturers and developers can be assured that their products will operate with the networks deployed to those standards, and with other equipment, devices and software developed to those standards.

7. Among other things, the 3GPP standards and specifications include the protocols used by devices to communicate with the network. These protocols are designed, among other things, to maximize the efficient use of spectrum. Efficient protocols are required to provide devices and networks that support low latency, high data throughput speeds, reliable connections, and various other characteristics that provide substantial benefits to customers in real-world applications. Device manufacturers can be assured that by following the specifications for these protocols in the 3GPP standards, their devices should work with networks using the same standards and operate at the specified performance levels.

8. For these reasons, when the Federal Communications Commission ("FCC") announces the availability of new spectrum for mobile broadband services, members of the 3GPP initiate the process of developing the standards and specifications for the deployment of that spectrum. Once the 3GPP issues standards, the wireless industry undertakes enormous investments in reliance on those standards. Network owners that intend to deploy networks based on those standards publish the standards and specifications (which reflect those adopted by 3GPP) for equipment, devices, and software that they will need for their networks. In addition, network operators begin building a network that meets the new 3GPP standards. At the same time, the rest of the industry develops 3GPP-compliant network equipment, devices, software, and the numerous other components needed to deploy a wireless network based on those standards.

9. As to devices, the initial development of devices that incorporate new radio requirements involves substantial investment and typically takes 18-24 months from conception to deployment. Both network operators and manufacturers invest significant resources in designing the device and working with chipset manufacturers and others to obtain the necessary components for the device. The network operator and manufacturer also work closely together to test the new device in a wide range of real-world scenarios, to fine-tune the device, and ultimately deploy it.

10. In the case of the 700 MHz spectrum auctioned by the FCC in 2008, the 3GPP ultimately adopted four "Band Classes" or "Bands." Each Band represents a set of specifications and standards for a range of frequencies within the 700 MHz spectrum range allocated by the FCC for mobile broadband use. Band 13 is comprised of the upper 700 MHz C block. Band 14 is comprised of the upper 700 MHz D block spectrum and the Public Safety Broadband Allocation (763-768 MHz, 793-798 MHz). Band 17 covers the lower 700 MHz B and C blocks, and Band 12 covers the lower 700 MHz A, B, and C blocks.

11. Band 12 is subject to significant potential interference from adjacent high powered broadcasts (Channel 51 and the E block). To account for this interference, the 3GPP created Band 17, which, by contrast, is not subject to the same interference concerns as Band 12 because Band 17 frequencies have significant separation from the high powered broadcasts from Channel 51 and the E block. Consequently, AT&T (which holds mainly Lower B Block and C Block spectrum) chose to deploy its 700 MHz spectrum using the 3GPP Band 17 standards and specifications. Band 17 specifications were finalized in the fall of 2008 (shortly after the 700 MHz auction), and once that decision was made, AT&T began investing significant time and effort in reliance on 3GPP's adoption of Band 17 standards. AT&T issued device requirements

for its Band 17 network in December 2008, and began coordinating with device manufacturers and others to develop devices that would be compliant with the Band 17 standards and specifications. Over the next two and a half years, AT&T worked closely with device manufacturers to design, develop, test and fine-tune these devices.

12. In mid-2011 – three years after the adoption of the Band 17 specifications – AT&T began selling the first Band 17 mobile devices, which were data-only USB modems. In October, 2011, AT&T began selling its first Band 17 smart phone. Today, AT&T offers a wide range of Band 17 devices from virtually all of the major device manufacturers, including Nokia, Samsung, LG, Apple, RIM, Pantech, and HTC, and there are close to two million Band 17 devices deployed in AT&T's network. AT&T expects that number to grow rapidly as AT&T continues to expand its Band 17 LTE footprint and as consumers continue to adopt AT&T's LTE services. In addition, since it generally takes from 12 to 24 months to develop a new device from scratch, many more devices for AT&T's network are currently in the pipeline, and AT&T has already committed to purchase some of these devices.

13. It is also important to recognize that AT&T works with third parties that want to use AT&T's Band 17 LTE network with their own products. These are referred to as "non-stock items" because they are products that use AT&T's Band 17 LTE network, but are sold by third parties, not AT&T. To develop these products, AT&T works with third parties to develop "modules" that can be embedded in a third party's product and used to communicate with AT&T's Band 17 LTE network. For example, automobile manufactures will soon be embedding Band 17 LTE modules in cars to provide drivers with emergency services and other Internet-related data services, such as weather and traffic information, email service, texting service, social media services, and music streaming. There are already 15 devices containing these

modules that have been approved for use, and several of these devices are coming on-line now. In addition, there are about 20 more devices for which approval is pending, and as many as 50 more devices are forecasted for review over the next year or so.

14. Based on press reports and competitive analysis, Verizon has also developed and deployed many mobile broadband devices from many different manufacturers for use on its 700 MHz Band 13 LTE network.

IV. THE DEVICE PLATFORMS DEVELOPED FOR AT&T'S AND VERIZON'S 700 MHz NETWORKS CAN BE INEXPENSIVELY MODIFIED TO CREATE "VARIANTS" FOR USE ON OTHER 700 MHz NETWORKS.

15. The significant investments AT&T and Verizon have made in the development and deployment of 700 MHz LTE devices has produced a wide variety of devices that work on Band 13 (Verizon) and Band 17 (AT&T). When a network operator that uses 700 MHz Band 12 wants to purchase one of these devices for use on its network, the device manufacturer does not have to develop that device all over again from scratch. Rather, the device manufacturer will offer a "variant" of that device to the Band 12 provider. That is, the manufacturer offers to modify the existing device – also called the device "platform" – to operate on the Bands used by that provider. The costs involved in producing such variants are trivial. The development of such variants would involve only the replacement of a few components, such as a radio, filter, or duplexer, each of which costs less than one dollar, with a different radio, filter, and/or duplexer, each of which also costs less than one dollar. I understand that one of the A Block licensees in the proceeding has conceded that modifying a Band 17 device to work with Band 12 requires only the replacement of very inexpensive components that comprise an extremely small fraction of the overall cost of the device. *See, e.g.*, Vulcan 12/12/11 *Ex Parte*, WT Docket No. 11-18, Attachment at 9.

16. Device manufacturers have long used this approach. For example, Research in Motion has frequently issued the same model Blackberry for different carriers, with multiple variants designed to work on a different networks in different bands. There are numerous other examples of manufacturers selling variants of the same device to different providers, with the only difference being in the internal radio components. HTC's website, for instance, displays numerous identical handsets, being offered on several different networks, including Sprint, AT&T, T-Mobile, Verizon, Cincinnati Bell, MetroPCS, and Virgin.

17. The large investments by AT&T and Verizon in the early development and deployment of LTE networks have created a device ecosystem in which virtually all of the major handset manufacturers now have a 700 MHz LTE device platform that can be modified at very low cost to work with the spectrum and Band plans of just about any provider, including Band 12 providers. This means that providers that are only now deploying 700 MHz LTE services using Band 12 are benefiting greatly from the very significant investments that AT&T and Verizon have already made to develop and deploy a wide range of 700 MHz LTE device platforms.

18. For example, U.S. Cellular launched its Band 12 LTE network in March of this year and immediately offered an LTE tablet (Samsung Galaxy Tab 10.1) for use on the network, followed about two weeks later by an LTE handset (Samsung Galaxy S Aviator), which in turn was quickly followed by a mobile hotspot device (Samsung SCH-LC11). U.S. Cellular has announced that it will introduce additional LTE devices later this year.

19. The speed at which U.S. Cellular has been deploying these devices stands in stark contrast to AT&T's and Verizon's initial deployments, which were limited to wireless USB modems and similar data-only devices followed months later by handsets. U.S. Cellular has been able to release devices for its network so quickly because these devices are all variants of

device platforms originally developed for an LTE/CDMA network provider, such as Verizon Wireless. U.S. Cellular's tablet, handset and mobile hotspot are variants of Verizon's Samsung Galaxy Tab 10.1, Samsung Droid Charge, and Samsung SCH-LC11, respectively. The cost effectiveness of using these variants is evidenced by the fact that, for example, Verizon initially offered the Droid Charge at a price of $299, with a 2-year contract,[1] whereas U.S. Cellular initially offered the Galaxy S Aviator for only $99, with a two year contract.[2]

V. EVEN IF AT&T USED BAND 12, MOST OTHER BAND 12 PROVIDERS COULD NOT USE OFF-THE-SHELF AT&T DEVICES.

20. Even if AT&T were required to switch to Band 12 devices, those same devices could not be used "off-the-shelf" by other Band 12 providers any more than Band 17 devices could be used off the shelf. Rather, other Band 12 providers would still have to obtain variants of any (hypothetical) AT&T Band 12 devices – variants that would be much more expensive to create than the ones these providers can already easily obtain.

21. Mobile devices must contain radio equipment that is compatible with other wireless technologies in addition to the LTE bands. Although AT&T is rapidly deploying LTE service, in areas where AT&T does not have LTE service, AT&T's LTE devices must be backwards compatible with AT&T's previous generation GSM/UMTS networks to ensure that AT&T's customers have the broadest possible network coverage. Moreover, because under current standards, LTE is a "data only" service, AT&T equips its devices with GSM/UMTS capabilities for voice traffic. Accordingly, any LTE device deployed by AT&T – whether it operates on Band 17 or Band 12 – must also have radio equipment and software capable of using AT&T's GSM/UMTS networks (which support AT&T's HSPA+, 3G and 2G services).

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[1] http://news.verizonwireless.com/news/2011/04/pr2011-04-20.html.

[2] http://androidcommunity.com/us-cellular-begins-selling-the-lte-equipped-samsung-galaxy-s-aviator-20120405/.

22. By contrast, most providers using Band 12 have legacy networks that use CDMA technology. These providers need CDMA radios in their handsets to ensure that their customers have coverage in areas where LTE service has not been deployed. Consequently, even if AT&T were to deploy Band 12 devices, the A Block carriers could not use off-the-shelf AT&T Band 12 devices, because the AT&T devices would not have the CDMA radios that Band 12 providers would need to offer fall-back data services.

23. Moreover, even if Band 12 providers were willing to forgo a fall-back network outside of LTE service areas, they would still need CDMA fallback capability in order to provide voice services. As noted, LTE technology currently does not support voice services and a hypothetical AT&T Band 12 device, like its actual Band 17 devices, would use GSM/UMTS radios for voice service. This would make an AT&T Band 12 device of almost no value to most other Band 12 providers; indeed, such devices would not even function as phones on an A Block provider's network unless they included CDMA fallback.

24. There is another important difference between LTE/UMTS/GSM networks and LTE/CDMA: CDMA providers are using what is known as the simultaneous dual radio approach to provide simultaneous voice on CDMA and data on LTE. Whereas AT&T's GSM/UMTS/LTE devices can switch between the LTE and GSM/UMTS radios as needed to provide simultaneous voice and data service over a single radio, CDMA/LTE technology requires *two* different radios that operate concurrently to provide simultaneous data and voice services. In other words, the CDMA providers are using a substantially different radio architecture in their handsets – differences that extend well beyond the mere use of different radios and filters. For this reason, any attempt to convert a platform with GSM/UMTS fall-back

to a CDMA fall-back would involve complex and costly changes to the architecture of the device.

25. The incompatibility between AT&T's legacy GSM/UMTS networks and those of most Band 12 carriers may explain why the first Band 12 devices appear to be variants of Verizon's Band 13 devices, and not variants of AT&T's Band 17 devices. Like the A Block carriers, Verizon's legacy network uses CMDA technology. Accordingly, for the reasons explained above, the existing CDMA radios and software in Verizon's handsets could thus be used with minimal modification in the handsets by Band 12 providers, and the Band 13 radios could be made Band 12 compatible at minimal cost by changing the device's filter and software. By contrast, converting an AT&T device to be useful for Band 12 providers would also require replacing all of the GSM/UMTS radios with CDMA radios and redesigning the circuitry for simultaneous dual radio operation, which would be a far more complex and expensive set of modifications. There is simply no reason why most A Block carriers would want to use an AT&T device when Verizon's devices can be so easily, and likely less expensively, adapted for their needs.

VI. ELIMINATION OF BAND 17 IS NOT NECESSARY TO CREATE ROAMING OPPORTUNITIES FOR BAND 12 PROVIDERS.

26. A mandate requiring AT&T to use Band 12 – effectively eliminating Band 17 – is not necessary to ensure a large number of roaming opportunities for Band 12 providers. There are numerous LTE bands on which Band 12 providers could roam, including for example, Band 4 (AWS), Band 2 (PCS), Band 5 (Cellular), and Band 13 (700 MHz). It is the norm in the industry for providers to have multi-band handsets that permit roaming in one or more of these bands. AT&T's current LTE devices, for example, have both Band 17 (700 MHz) and Band 4

(AWS) LTE radios, and its future handset offerings will have Band 2 and Band 5 LTE radios as well.

27. AT&T, Verizon, Sprint, T-Mobile, Clearwire, Leap, and MetroPCS are all deploying LTE networks, and because the Band 12 providers have no LTE handset base, they have maximum flexibility today to plan their device portfolios to support roaming on any of those networks. In addition, given their need to fall back to CDMA, AT&T would probably not be their preferred partner for roaming. Band 12 providers also could roam on each other's LTE networks.

28. Moreover, the number of roaming options available to Band 12 providers will expand further in the near future. Qualcomm has publicly stated that it is developing a chipset that would allow a carrier to combine Band 12 and Band 17 in a single handset using only one radio port. There is nothing to stop Band 12 providers from negotiating with manufacturers to design handsets using such chipsets, which would operate on Band 12 in-region but could roam on Band 17 networks.

VERIFICATION PAGE

I hereby swear under penalty of perjury that the foregoing is true and correct.

/s/ Michael Prise_____
Michael Prise

Dated: May 31st, 2012