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December 16, 2011

Notice of *Ex Parte* Presentation

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
The Portals
445 Twelfth Street, S.W.
Washington, D.C. 20554

Re: WT Docket No. 11-18; WT Docket No. 06-150; GN Docket 09-51

Dear Ms. Dortch:

Sprint Nextel Corporation ("Sprint") supports a competitive wireless marketplace. As the Commission has noted in numerous proceedings, spectrum is an integral part of maintaining a robust, competitive environment.[1] Allowing new entrants to gain access and productively use the spectrum they have acquired is vital to ensuring continued competition in the provision of wireless services.

In this respect, commenters are right to urge the Commission to condition approval of the proposed transfer of Qualcomm's 700 MHz licenses to AT&T on interoperability among the Lower 700 MHz spectrum blocks.[2] By acquiring Qualcomm's licenses, AT&T would control a significant share of Lower 700 MHz spectrum.[3] Conditioning AT&T's proposed acquisition on interoperability among the Lower

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[1] *See, e.g.*, *Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993; Annual Report and Analysis of Competitive Market Conditions with Respect to Mobile Wireless, Including Commercial Mobile Services*, Fifteenth Report, WT Docket No. 10-133, ¶ 266 (2011)("Access to spectrum is a precondition to the provision of mobile wireless services. Ensuring that sufficient spectrum is available for incumbent licensees, as well as for entities that need spectrum to enter the market, is critical for promoting competition, investment and innovation.")

[2] *See*, *e.g.,* Petition to Deny, Cellular South, Inc., WT Docket No. 11-18 (March 11, 2011), *available at*: http://fjallfoss.fcc.gov/ecfs/document/view?id=7021034266; Petition to Deny, Free Press, Public Knowledge, Media Access Project, Consumers Union and the Open Technology Initiative of the New America Foundation, WT Docket No. 11-18, DA 11-252 (March 11, 2011), *available at*: http://fjallfoss.fcc.gov/ecfs/document/view?id=7021034143; Petition to Deny, Rural Cellular Association, WT Docket No. 11-18, DA 11-252 (March 11, 2011), *available at:* http://fjallfoss.fcc.gov/ecfs/document/view?id=7021034151; Petition to Deny, Rural Telecommunications Group, WT Docket No. 11-18 (March 11, 2011), *available at:* http://fjallfoss.fcc.gov/ecfs/document/view?id=7021034267; Reply Comments filed by Vulcan Wireless LLC, WT Docket No. 11-18 (March 28, 2011), *available at*: http://fjallfoss.fcc.gov/ecfs/document/view?id=7021235632; Notice of Ex Parte, Cavalier Wireless, WT Docket No. 11-18 (December 7, 2011), *available at*: http://fjallfoss.fcc.gov/ecfs/document/view?id=7021749960

[3] AT&T holds the Lower B Block, C Block, or both, in counties covering nearly 90% of the U.S. population.

700 MHz Blocks limits the risk that AT&T can use the expanded control it would acquire as a result of the Qualcomm spectrum acquisition in ways that competitively disadvantage licensees in the Lower 700 MHz A Block that AT&T does not directly control.

Moreover, conditioning approval of the transaction on Lower 700 MHz A Block interoperability promotes competition. While AT&T has periodically raised interference concerns in an attempt to thwart interoperability, these concerns are misguided and, in any case, not supported by the facts. As the attached technical studies prepared by Wireless Strategy amply demonstrate, Long Term Evolution ("LTE") incorporates techniques and interference management mechanisms designed to both limit and overcome precisely the type of interference issues that AT&T has raised in this proceeding and in other proceedings.[4]

Before allowing AT&T to acquire additional 700 MHz spectrum, the Commission should take steps to ensure that AT&T does not implement a restrictive and anticompetitive band class in an attempt to indirectly control what little Lower 700 MHz spectrum AT&T does not already directly own and control. Mandating interoperability in the Lower 700 MHz band would impose no extraordinary interference or cost-burden on AT&T while helping to mitigate AT&T's considerable market power, and thereby promote wireless competition and efficient use of available broadband spectrum.

Sincerely,

/s/ Lawrence R. Krevor

Lawrence R. Krevor,
Vice President, Government Affairs

Trey Hanbury,
Director, Government Affairs

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Attachments

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[4] Sprint has previously filed the attached white papers in other dockets (*see, e.g.*, Letter from Mark Stachiw, MetroPCS Communications, Inc., Lawrence Krevor, Sprint Nextel Corp., Thomas Sugrue, T-Mobile, USA, Inc., Michael Gottdenker, Access Spectrum, LLC, Marshal Pagon, Xanadoo Company, Caressa Bennet, Rural Telecommunications Group, Craig Viehweg, Trial 700, LCC, Grant Spellmeyer, United States Cellular Corp., Steven Berry, Rural Cellular Association, and Eric Graham, Cellular South, Inc., to Marlene Dortch, FCC Secretary, WT Docket No. 06-150 (May 10, 2010); Notice of Ex Parte Presentation, Sprint Nextel Corp., WT Docket No. 06-150; PS Docket No. 06-229; GN Docket No. 09-51 (December 15, 2010)). Sprint is filing the white papers in this docket so that the Commission has the benefit of a full and well-researched technical record of the 700 MHz interoperability issue in this proceeding.

Lower 700 MHz Interference Management

September 10, 2010

the business of wireless technology

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I. Introduction

In AT&T's ex parte response[1] to our first paper on the 700 MHz band[2], AT&T inaccurately portrays LTE system deployment techniques and interference management mechanisms. To correct the record, we respectfully submit "Lower 700 MHz Interference Management" to explain the interference mechanisms which may be encountered in the lower 700 MHz band. The analyses contained herein demonstrate how the 3GPP specifications, in combination with commonplace engineering techniques, are more than sufficient to eliminate the lower 700 MHz interference concerns while supporting the Band 12 filtering approach in the LTE devices.

To introduce the technical concepts, Section II provides an overview of the main interference mechanisms influencing device performance in wireless systems. We describe the typical circumstances under which interference may occur, and explain the standard industry approaches to mitigating or eliminating the interference.

In later sections, we explain the lower 700 MHz interference concerns raised by opponents of Band 12. Section III describes the interference mechanisms relevant to DTV Channel 51 reception, which is the block adjacent to the lower end of Band Class 12. Section IV describes the reverse power amplifier intermodulation issue first raised by Motorola within 3GPP. Section V describes the interference mechanisms and mitigation methods relevant in the device receive portion of the lower band, especially as related to the high-power lower D and E blocks. Throughout the paper, each 700 MHz interference case is stated, along with a technical explanation of the factors behind the interference, the practical deployment considerations related to each case, and if necessary, the common procedures employed by RF engineers in the system design process to eliminate inter-system interference.

It is worthwhile to note that base station filtering can and should be block-specific. In PCS and other spectrum bands, each base station is planned to operate in one block out of many possible blocks. The base station filtering is tailored for the block(s) of operation to provide better protection to/from neighboring systems. The major base station costs are in power amplifiers and other elements which can be scaled across a range of blocks; the filtering, as a separate base station component, is easily tailored for a particular block. Therefore, our discussion of Band 12 versus Band 17 only applies to the LTE devices. Fragmentation of device volume among sub-bands increases the number of unique products required by the marketplace, reducing scale, and is unnecessary from a technical point of view. Therefore, the device should be designed to support the full 3GPP band of operation.

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[1] Letter from AT&T to Marlene H. Dortch (FCC), WT Docket No. 06-150; PS Docket No. 06-229; GN Docket No. 09-51; RM Docket No. 11592 (dated June 3, 2010).

[2] Doug Hyslop & Chris Helzer, *Wireless Strategy 700 MHz Band Analysis* (May 6, 2010) ("*700 MHz Band Analysis*"), available in Coalition for 4G in America, Written Ex Parte Presentation, WT Docket No. 06-150; PS Docket No. 06-229; GN Docket No. 09-51; RM Docket No. 11592 (May 27, 2010).

As demonstrated herein, the 3GPP Band 12 device performance will meet or exceed 3GPP performance criteria in practical deployment conditions. The high power Channel 51 and lower D/E broadcast signals will not degrade lower B/C Band 12 device performance in a properly designed LTE system. The interference claims raised by opponents of Band 12 are easily managed through standard RF engineering practices.

II. Wireless Device Interference

In a cellular-like wireless system where thousands of cell sites are deployed, the wireless system specifications and deployment approach must carefully consider potential intra- and inter-system interference. Wireless devices encounter unique challenges because the devices are often mobile, and thus experience a wider range of RF environments relative to that of fixed base stations. Three interference mechanisms which may impact a wireless device are receiver blocking, out-of-band emissions (OOBE), and intermodulation. The causes, impacts, and mitigation measures for each mechanism are explained below.

Receiver Blocking

Receiver blocking, or overload, occurs when a sufficiently strong signal in a nearby channel appears at the receiver of a victim device when the desired signal is weak, as shown in Figure 1. When receiving a weak desired signal, the device increases its front-end gain to maximize signal reception. The additional amplification improves the device sensitivity, but the front end also amplifies the strong interfering signal. If the interfering signal is sufficiently strong, then receiver performance may degrade.

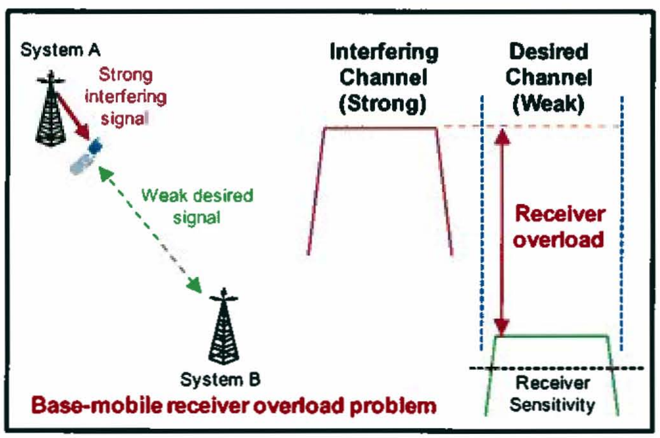

Figure 1: Base-to-Mobile Receiver Blocking Problem

The converse is also true – when the desired signal is strong, then the device front-end gain is reduced, and the device is less susceptible to nearby strong interfering signals. Receiver blocking can be successfully mitigated by providing a stronger desired signal in the vicinity of strong interfering signals.

Figure 2: Exemplary near-far receiver overload interference to a device

Figure 2 provides an illustration of how receiver blocking may impact a device operating near the edge of its serving base station's coverage range but close to the interfering base station. This is the classic near-far interference case where base stations may interfere with device reception, a base-to-mobile interference issue. Similarly, if a device transmit block is near a device receive block then a mobile-to-mobile receiver overload case may result. The approach to dealing with receiver blocking depends on whether the interference is mobile-to-mobile or base-to-mobile.

With mobile-to-mobile blocking interference, the separation distance between the victim and interfering devices is not easily controlled – two people each using a cellular phone may stand close together. Thus the coupling loss, or radio signal attenuation as a function of distance, between the two devices may be less than that between a base station and a device. The frequency separation and device filter performance are especially important in the mobile-to-mobile scenario. Frequencies close to the desired signal undergo less attenuation by the device filter. The amount of frequency separation required to adequately protect the device receiver depends on the device filter response curve and the receiver design, which dictates the receiver blocking level. The receiver blocking level defines the maximum interfering signal strength tolerable by the victim receiver when operating near the minimum receiver sensitivity.

With a base-to-mobile interference scenario as shown in Figure 2, additional mechanisms are available to effectively manage the interference. One such approach, described in the first Wireless Strategy white paper, is base station near-location, which is the practice of placing a base station of the victim system in the vicinity of the interfering system's base station. When the interfering base station is a high-site broadcast tower, only one or two locations per city must be considered. Near-location in this situation is straightforward - not impossible to implement as AT&T inaccurately claims[3]. The near-location approach simply requires the proper planning of one site, already in the operator's build plan for

[3] AT&T June 3 at 4.

coverage, to be deployed somewhat close to the offending base station such that a sufficiently strong desired signal is available in the vicinity of the interfering base station. Base station near-location to potential base-to-mobile interferers is a basic RF engineering technique widely used in the industry. Figure 3 illustrates how a stronger desired signal overcomes the receiver blocking problem.

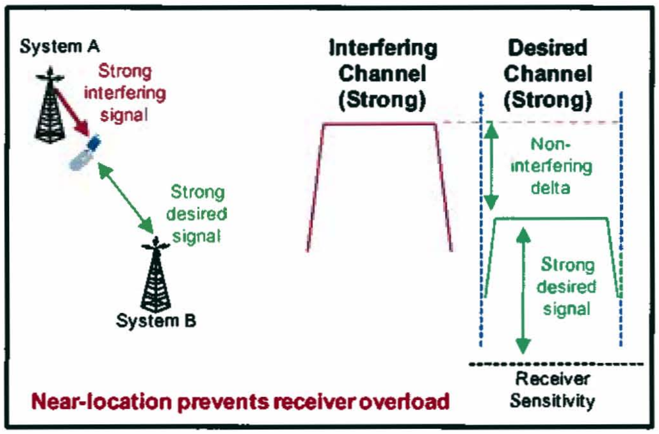

Figure 3: Near-location of Base Stations Prevents Device Overload

Figure 4 illustrates the system view of locating one base station closer to the interfering source, and eliminating the small circle of near-far interference. By providing a desired signal level which is sufficiently stronger than the minimum receiver sensitivity of the device, the interfering signal's impact to the receiver is eliminated.

Figure 4: Deployment of a desired site near the interferer eliminates the receiver blocking region

Out-of-band Emissions

The second interference mechanism which may impact device performance is out-of-band emissions. A wireless transmitter places most of the energy within the desired transmission bandwidth, but some of the energy is transmitted in the neighboring frequencies. These transmissions in nearby frequencies are unwanted and termed out-of-band emissions (OOBE). The OOBE levels generally decrease with frequency separation, and are further attenuated by transmitter filtering. Interference from OOBE is received directly within the desired channel and cannot be filtered out by the receiver, as shown in Figure 5. Therefore, the impact of OOBE to a device receiver is solely determined by the interfering transmitter filtering and power level, and does not depend on the receiving device's duplexer performance.

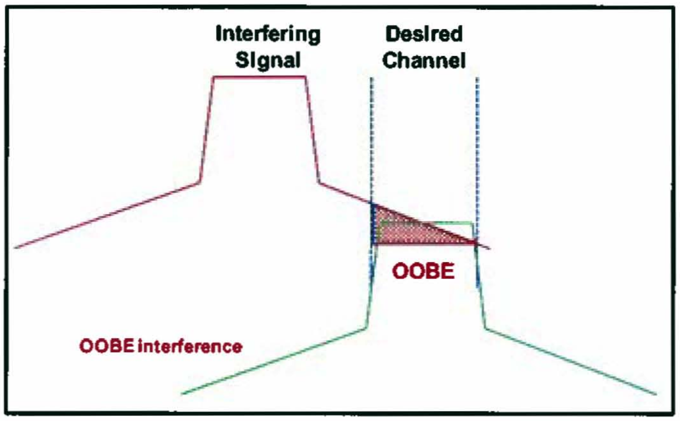

Figure 5: OOBE Interference Mechanism

To comply with regulatory guidelines for OOBE, the interfering transmitter must ensure the emissions level into the victim receiver's pass band is low. The FCC rules managing OOBE specify the conducted power level at the edge of the victim receive band, providing flexibility for the interferer to mitigate the interference through either transmit power reduction or more stringent transmit filtering. If regulatory conditions are met but interference remains a concern, physical separation can be an effective technique. Physical separation reduces OOBE by controlling the minimum coupling loss between the interferer and the victim. When the interference mechanism is base-to-mobile as with a broadcast tower interferer, the victim operator has the further option of base station placement to eliminate the impact of the OOBE. Increasing the desired signal strength within the area affected by OOBE effectively overcomes the interference, as shown in Figure 6.

Once again, the OOBE impact to a device receiver is independent of the duplexer filtering employed by the device. OOBE is a transmitter issue which must be handled by the mechanisms described above.

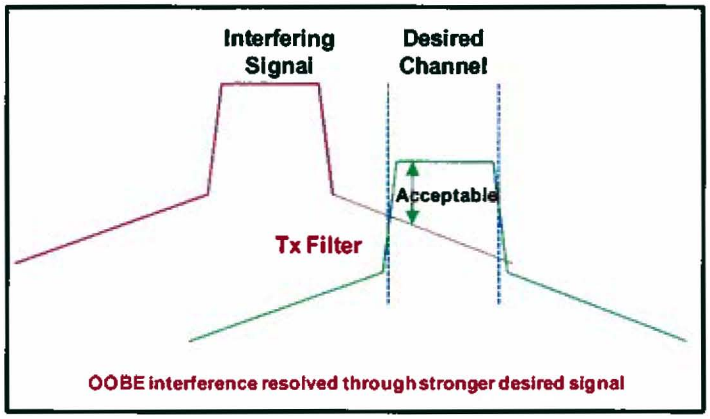

Figure 6: Management of OOBE Interference

Intermodulation Interference

Intermodulation interference occurs when two or more transmit signals mix and create products on new frequencies. For example, transmit frequencies x and y may mix and create the following third order intermodulation products: 2x+y, 2x-y, 2y+x, 2y-x. If the intermodulation products are of sufficient signal strength and fall on a desired receive frequency, then the resulting interference may disrupt communications.

Three main conditions must exist for intermodulation problems to occur:

1. Transmissions must exist on the right mix of frequencies to develop an intermodulation product on a receive frequency
2. The mixing signals must be of sufficient strength such that the resulting intermodulation products are strong enough to disrupt communications
3. A system non-linearity must exist, such as a component operating in a non-linear region, to produce the intermodulation product.

The mitigation approach followed for intermodulation problems depends on the nature of the intermodulation. Where practical, the frequencies mixing together may be isolated or filtered to reduce interaction. Power reductions of one or both signals will reduce the strength of the intermodulation product, decreasing the impact of any interference. Sources of system non-linearity may also be addressed, such as rust-covered metallic structures or wireless equipment components operating in a non-linear region.

III. Channel 51 Protection

The lower bound of the 3GPP Band 12 mobile transmit section is at 698 MHz, forming a border with the digital television channel 51 as shown in Figure 7. The lower A block interference situation relative to channel 51 was covered in the May 2010 Wireless Strategy paper[4]. As for the lower B and C mobile transmit blocks, the potential causes of interference from these blocks to channel 51 include receiver overload and OOBE.

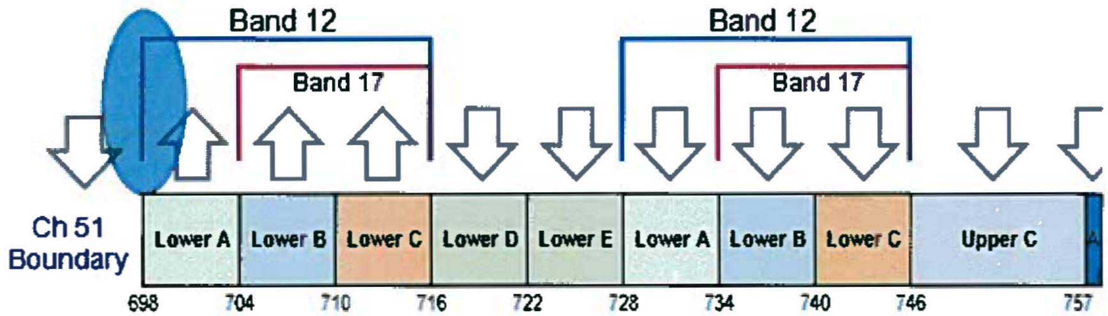

Figure 7: Lower 700 MHz Boundary with DTV Ch 51

We will first examine DTV receiver blocking. The potential for blocking a DTV receiver would require a lower B or C block device to be transmitting at high power near a DTV receiver tuned to Channel 51 and operating near its coverage reception limit. The FCC rules do not require a transmit power reduction within the B or C blocks when within the coverage contour of a DTV channel 51 station[5]. Moreover, the mechanism of receiver blocking depends on the device receiver filter, not the interfering transmitter filter. A tighter device transmitter filter, such as that offered by Band 17, does not reduce the lower B or C block in-band transmit power and therefore does not mitigate a receiver overload problem to channel 51 receivers. In terms of receiver blocking, there is no benefit from tightening the LTE device duplexer transmit filter more than band 12 because the LTE device transmitter filter plays no role in this interference mechanism.

Any Channel 51 receiver blocking concerns would be addressed by tightening the filter of the DTV receiver, or by reducing the transmit power of the device operating in the lower B or C blocks. These measures do not impact the lower 700 MHz device duplexer selection. A lower B or C block transmission passing through a Band 12 or Band 17 duplexer will deliver the same power, from a blocking perspective, to the channel 51 receiver.

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[4] Ib. at 8.

[5] 47CFR 27.60 (b) (2) (ii) (D) "(e.g., a base station may be operating within TV Channel 62 and the mobiles within TV Channel 67, in which case the TV channels 61, 62, 63, 66, 67, and 68 must be protected)." The regulations do not specify further protection to second-adjacent channel 64, for instance. Therefore, the lower B and C blocks, being the second- and third-adjacent channels to DTV Channel 51, are not required to mitigate transmit power within the Channel 51 service contour.

The second interference mechanism potentially impacting the Channel 51 receiver is OOBE. The FCC regulations for the OOBE levels applicable to the lower B and C blocks are for an attenuation of 43 + 10 log P in a 100 kHz bandwidth[6], which is equivalent to -3 dBm/MHz at 1 MHz separation from the transmit carrier. The 3GPP LTE specifications for both Band 12 and Band 17 are for 65 + 10 log P in a 6.25 kHz bandwidth, which translates to -13 dBm/MHz with 1 MHz or more carrier separation[7]. Thus, both Band 12 and Band 17 emission masks exceed the FCC rules for OOBE. As noted in the Wireless Strategy paper "700 MHz Upper Band Analysis"[8], the duplexer filter plays no role in meeting this tightened OOBE level. The LTE transmit chain complies without assistance from the duplexer.

No technical evidence has been submitted to the Commission demonstrating a need for more stringent guidelines to protect DTV receivers. Since the 3GPP LTE specifications require the transmit chain to perform better than the FCC OOBE rules, and the transmit filter plays no role in receiver blocking, there is no demonstrated need for the tighter Band 17 filter to protect channel 51 receivers from lower B and C block transmissions.

IV. Device Reverse PA Intermodulation

In Motorola's 3GPP submission discussing the need for a sub-band in the lower 700 MHz band[9], Motorola claimed that Band 12 devices, by virtue of their wider filter, could produce reverse power amplifier intermodulation if the device were to use lower B and C blocks near Channel 51 broadcast towers. The mechanism that Motorola suggests may occur is a strong Channel 51 transmission entering the device antenna, passing through the device duplexer with some attenuation, and mixing with a strong lower B or C block transmission in the device power amplifier. Any resulting intermodulation products would theoretically re-radiate out through the device duplexer, undergo attenuation by the transmit filter, and then cross over to the receiver, potentially causing interference if the receiver is tuned to the channel affected by the intermodulation product.

A brief examination of the intermodulation products relating to Channel 51 and the lower B and C blocks shows the frequencies where mixed products could occur. The relevant intermodulation mix is twice the higher frequency minus the lower frequency. For example, device transmissions in the lower B block mixing with channel 51 may theoretically produce intermodulation products from 710 to 728 MHz,

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[6] 47CFR 27.53.

[7] 3GPP TS 36.101 v9.3.0 (2010-03), Table 6.6.2.2.3-1: Additional requirements, signaled value NS-06, p. 36.

[8] Doug Hyslop & Chris Helzer, Wireless Strategy 700 MHz Upper Band Analysis, at 12, (July 19, 2010), available in the filing by Sprint Nextel Corporation, T-Mobile USA Inc., United States Cellular Corporation, Clearwire Corporation, the Rural Cellular Association, the Rural Telecommunications Group, Inc., Access Spectrum, LLC and Xanadoo Company, dated July 19, 2010.

[9] R4-081108 3GPP TSG RAN WG4 (Radio) Meeting #47, "TS36.101: Lower 700 MHz Band 15", agenda item 6.1.2, April 2008. The proposal was originally referred to as band 15 and later modified to become band 17.

depending on the number of LTE resource blocks in use within the lower B block. These frequencies do not fall within the Band 12 device receive passband. Indeed, the only Band 12 device transmit frequencies which may pose an intermodulation concern would be a lower C block device transmission mixing with channel 51, producing frequencies which could fall within the lower A and B device receive blocks, as shown in Figure 8.

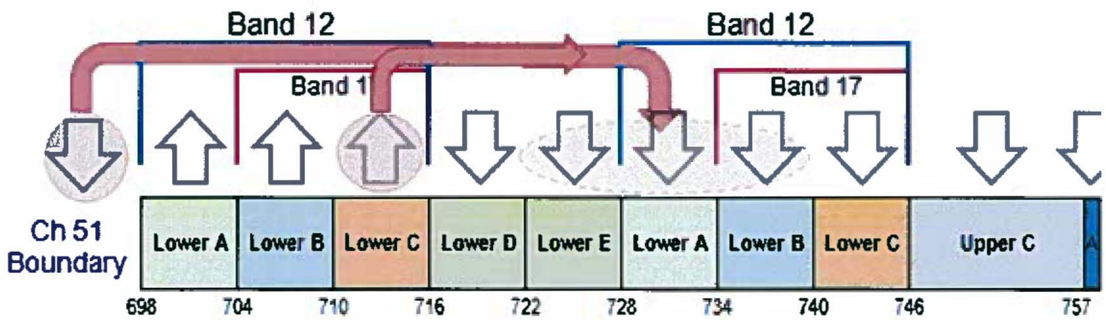

Figure 8: Reverse PA Intermodulation

For 5 MHz LTE systems, such a scenario would not cause self-interference, as the intermodulation products would never fall within the device receive block paired with the device transmission. For 10 MHz LTE systems, device transmissions within the C block could theoretically interfere with the same device receiving the lower B block frequencies, if the LTE scheduler were to make such an allocation, an unlikely event when the device is transmitting at high power. LTE uplink transmissions use fewer resource blocks, meaning less spectrum, when signal conditions are poor and device transmit power is high, in order to maximize coverage reception. Nevertheless, to ensure the 10 MHz uplink transmission case is protected, further analysis is provided to demonstrate that engineering practices may sufficiently manage this unlikely interference case.

As described in section II, in order for intermodulation to occur, a nonlinear element must be present, and the magnitudes of the mixing signals must be strong enough to cause interference to a receiver. While the Channel 51 transmission is strong near its broadcast tower, the lower C block device transmit signal level may be controlled by placing an LTE base station in proximity to the channel 51 tower. When the LTE device is near its serving base station, the device power control algorithm reduces the device transmit power significantly. In this situation, the interference-reduction benefits from device power control are two-fold. First, the lower LTE transmit power reduces the magnitude of any intermodulation products which may occur, lessening the likelihood of intermodulation interference. Second, as the device input power decreases, the device power amplifier operates in a highly stable linear region. Intermodulation typically occurs in nonlinear elements. Power amplifiers operating near the rated maximum power are close to the nonlinear region and are more likely to produce reverse intermodulation. Simply by designing the LTE system such that an LTE base station is somewhat near the channel 51 tower, the device transmit power is reduced to a considerably lower level and the amplifier operates in the linear region, mitigating the probability of intermodulation production.

This near-location practice reduces the probability and magnitude of any intermodulation products. Furthermore, near-location increases the desired downlink signal strength in the areas where the interference is strong, eliminating the impacts of any intermodulation products. For instance, if an intermodulation product is generated in the power amplifier, the interfering signal would traverse the duplexer and undergo the transmitter filter attenuation of 50 to 60 dB. Any remaining signal making its way to the receiver will not cause interference if the desired downlink signal is much stronger than this low-level intermodulation interferer. The proximity of the LTE base station would provide such a strong downlink signal, and avoid any intermodulation interference.

In order to prevent reverse PA intermodulation as related to channel 51, the level of protection required from device power control may be easily calculated, through comparison with a similar reverse PA intermodulation issue with the lower D and B blocks. Interestingly, the Band 12 opponents have not flagged the D/B issue as a situation requiring significant guard band or unusual filtering. Regardless, the analogous situation is as follows: Bands 12 and 17 share the same boundary at 716 MHz with the adjacent lower D block, licensed for high-power base station transmissions. The lower D block base station broadcast transmissions could mix with lower B block device transmissions through the same reverse PA intermodulation problem raised by Motorola for channel 51, creating intermodulation products ranging from 722 to 740 MHz, as shown in Figure 9. This issue is more severe than the channel 51 case because the intermodulation of the B and D channels creates products on the lower B block device receive frequency, causing self-interference for both the 5 and 10 MHz carrier sizes. In other words, *the paired B transmit block interferes with its own receive block.* In spite of this notable issue, AT&T does not plan to coordinate their LTE base station installations with the adjacent lower D block operators[10]. Therefore, the AT&T devices must be capable of adequate operation under any potential reverse PA intermodulation between the lower B and D channels, including cases where the LTE device is transmitting near its maximum power when close to a D block broadcast tower.

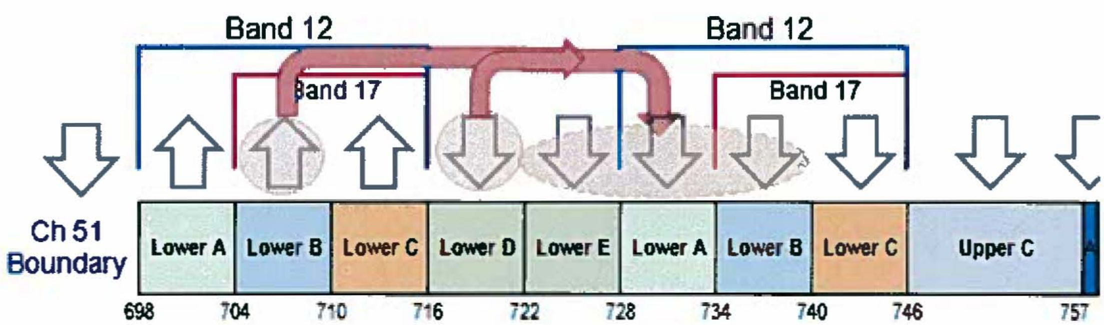

Figure 9: Lower B and D Block Reverse PA Intermodulation Self-Interference

Next, we will compare this notable potential for reverse PA intermodulation to the case proposed by Motorola involving channel 51. Since the device can handle the D/B block border successfully without coordination, then we simply need to determine any differences between this case and the channel 51 case. The only potential difference is the higher transmit power allowed for the channel 51 DTV

[10] AT&T June 3 at 6, "Coordinating base station placement… approaches a practical impossibility."

station of 1 MW versus the ERP for the D block of 50 kW, a 13 dB difference in power. Therefore, Motorola's reverse PA intermodulation concern involving channel 51 may be completely eliminated by ensuring that at least 13 dB of power control is applied when devices are in very close proximity to the Channel 51 tower. The device transmit power reduction lowers the power level of any intermodulation products, replicating the powers involved in the B/D boundary. From an RF system design perspective, this relatively small amount of power control can be achieved by installing one LTE B/C block base station within a few hundred meters of a channel 51 transmitter. Since there are few channel 51 transmitters nationwide, and a large number of LTE base stations deployed within a particular city, the RF system design may easily be modified to accommodate such a modest RF consideration as ensuring one of the sites is reasonably close to a DTV broadcast tower. This does not require a new site installation, but rather simply requires planning one of the to-be-deployed sites such that it is within a few hundred meters of the broadcast tower.

In summary, the channel 51 reverse PA intermodulation issue raised by Motorola within 3GPP will not create intermodulation products on the paired 6+6 MHz blocks within the lower 700 MHz band. Further indication that this reverse PA intermodulation issue is not a valid concern is evident by the lack of industry concern regarding the lower B and lower D blocks mixing through the same mechanism. Although the intermodulation products in this case would interfere with the same paired block (lower B), no unusual band classes are being pursued to use the lower C device transmit block as guard band to protect the lower B block reception. Indeed, in Motorola's 3GPP filing where the channel 51 reverse PA intermodulation issue is first raised, Motorola admits that "the magnitude of this problem is a function of the operator's deployment scenario."[11] In other words, in the unlikely event that an intermodulation problem with Channel 51 may exist, the operator may install one LTE base station within a few hundred meters of the channel 51 transmitter to eliminate the concern.

V. Lower 700 MHz Device Receive Blocks

The band 12 device receive blocks, from 728 to 746 MHz, are adjacent to the lower D and E high-power broadcast blocks as shown in figure 10. The lower D and E blocks are authorized to transmit at 50 kW ERP, 20 dB more power than a typical cellular-like base station ERP of 500 W. AT&T claims[12] that this higher power level may cause interference to the lower B and C device receive blocks. As demonstrated below, the higher power level of these blocks will not cause unusual interference conditions, if a minimal effort is made in proper RF system design.

[11] R4-081108 3GPP TSG RAN WG4 (Radio) Meeting #47, "TS36.101: Lower 700 MHz Band 15", agenda item 6.1.2, April 2008, p. 2.

[12] Ex parte by AT&T, WT Docket No. 06-150; PS Docket No. 06-229; GN Docket No. 09-51; RM Docket No. 11592 (dated May 28, 2010), p. 5.

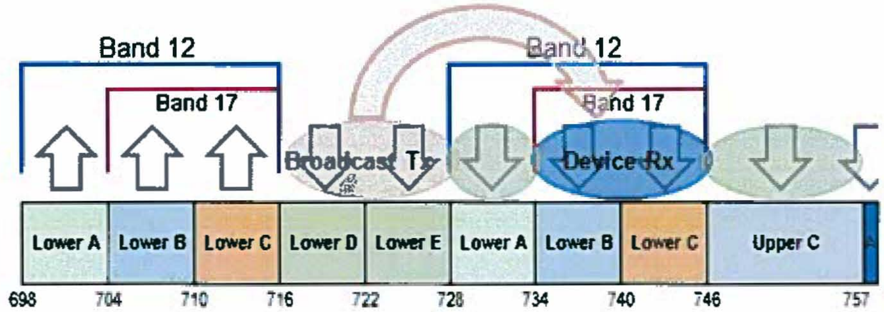

Figure 10: Band 12 Device Receive Blocks

We demonstrate below that the lower D block does not present a receiver overload concern to either Band 12 or Band 17 devices based on the frequency separation from the receive blocks and reasonable duplexer performance. Further, we note that the lower E block, newly auctioned in 2008 and not yet widely deployed, presents a receiver blocking situation not markedly different from the adjacent lower A block and upper C block base stations. The analysis demonstrates that device performance will fall well within 3GPP specifications by locating one lower B/C block LTE base station within 500 meters of a lower E block broadcast tower.

As shown in figure 11, for both the Band 12 (blue curve) and Band 17 (black curve) duplexer receive filters, the lower D block (716-722 MHz) is subject to more than 40 dB of attenuation. As calculated in Table 1, the interfering D block signal level at the device receiver would be at least 20 dB lower than the corresponding signal levels from an adjacent lower A Block or Upper C Block base station, regardless of the separation distance/coupling loss.

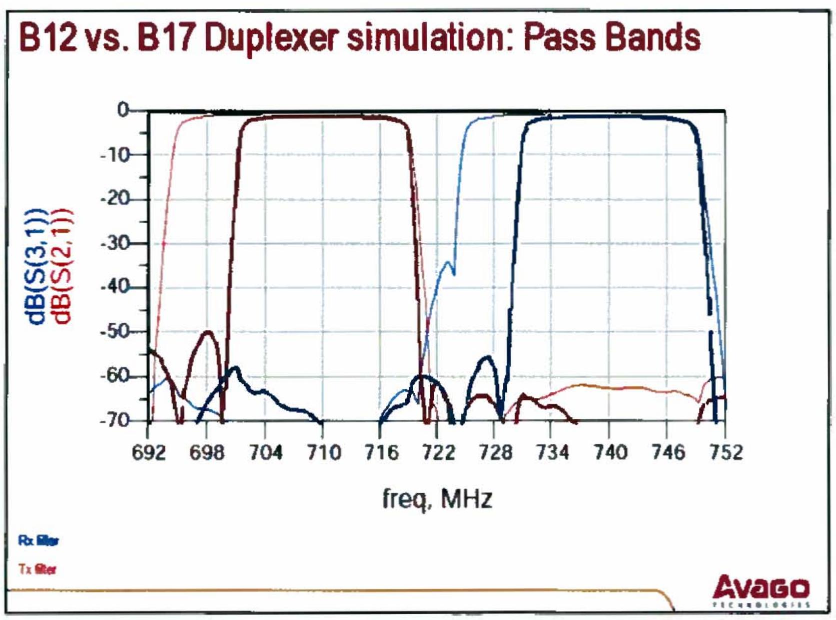

Figure 11: Band 12 vs. Band 17 Duplexer Simulation

	Lower D Block	Lower A Block	Upper C Block	Formula
Typical ERP (dBm)	77	57	57	a
Band 12 Duplexer Attenuation (dB)	> 40	0	0	b
Effective ERP to Band 12 Rcvr (dBm)	37	57	57	c = a - b

Table 1: Band 12 Filtering Eliminates Lower D Block Interference

Note that, due to manufacturing specifications and filter temperature tolerance, the Band 12 and Band 17 duplexer filters provide minimal attenuation to the Upper C base station transmissions (incursion above 746 MHz in figure 11). This boundary is shared by both band plans, and filtering performance for the two duplexers at 746 MHz is nearly identical. For similar reasons, the Band 17 duplexer does not provide attenuation to the lower A block base station transmissions. Therefore, the logic in Table 1 holds – the lower D block transmissions undergo significant attenuation by either Band 12 or Band 17 duplexers, and based on the less stringent Band 12 duplexer performance, the lower D block does not present a receiver blocking interference challenge.

The E block base station transmission will fall within the temperature variance of the Band 12 duplexer filter, as noted by the blue curve within 722-728 MHz in Figure 11. For this reason the E block warrants a closer examination of potential interference impacts. Recall the three potential interference mechanisms affecting devices: intermodulation, OOBE, and receiver blocking. The potential for intermodulation was addressed in section IV.

The potential impact of OOBE from the E block to the lower B and C device receive blocks would not depend on the B/C device duplexer. Recall that OOBE interference falls within the desired passband of the device receiver. This interference is in-band to the receiver, and is not affected by device receive filtering. Thus, the selection of a Band 12 versus a Band 17 duplexer has no impact on controlling OOBE interference from the lower E block.

The last remaining potential interference mechanism is receiver blocking, the mechanism which may occur if a nearby interfering signal is strong enough to disrupt reception of a weak desired signal. In terms of device receiver blocking, the relevant 3GPP LTE performance criteria is the in-band blocking specification[13]. The in-band blocking specification requires the device to provide >95% of the reference throughput when the desired signal level is -88 dBm (10 MHz bandwidth) and the interfering signal level is -56 dBm. In typical device blocking performance, the relationship between the desired and interfering signal strengths remains for stronger signal levels as well; i.e., for a stronger desired signal, the device will continue to meet the performance criteria in the presence of a similarly stronger interfering signal.

[13] 3GPP TS 36.101 v8.9.0 (2010-03) section 7.6.1.1.

The 3GPP standard does not attempt to solve all conceivable interference issues through device filtering and guard band alone – such an attempt would significantly reduce spectrum utilization. Instead, the standard defines the required minimum performance under defined environments likely to be seen in operating networks. Operators may use the performance requirements to develop deployment guidelines for managing interference among networks. Often, specific scenarios occur so infrequently that modest adjustments to site placement negate the interference, and permit greater flexibility in device filtering and design. The E block to lower B/C blocks is just such a situation.

The 3GPP in-band blocking specifications provide the guidelines needed to define a deployment strategy for the lower B/C block operator which will eliminate the potential for interference from the lower E block high-power transmission. First, the coverage range for the E block transmission may be calculated as shown in Table 2. The E block station parameters assume a 100 m tower with a 50 kW radiated power level, parameters which meet or exceed numerous MediaFLO site installations today. The radii for urban and suburban environments are calculated using the Okumura Hata model, a commonly used radiofrequency propagation model for spectrum bands below 1500 MHz. In-building penetration loss of 20 dB for urban and 10 dB for suburban are included as well, since wireless networks are designed for the weakest link, indoor coverage. On-street signal levels for both desired and interfering signals would be stronger than the limiting, indoor signal level. In an urban environment, the interfering signal level of -56 dBm may reach up to 500 m from the tower location, versus 3.1 km for a suburban environment.

Distance from Tower (m)	Propagation Model	Path Loss (dB)	Ant gain reduction (dB)	Building Loss (dB)	Interfering Signal at Device (dBm)
540	Hata Urban	108	-5	20	-56.2
3100	Hata Suburban	123	0	10	-55.8

Table 2: Lower E Block Propagation Distance

The second step in the process is to calculate the relative radius of the lower B/C base station transmission for -88 dBm, assuming a 30 m radiation center and a radiated power of 500 W, assumptions typical for cellular-like wireless deployments. The relevant calculations are provided in Table 3. In an urban environment, the lower B/C base station has twice the available range to reach the -88 dBm level compared to the E block interfering signal range for -56 dBm. This affords significant flexibility in the lower B/C base station placement relative to the E block tower. Similarly, in suburban environments, the lower B/C base station range advantage provides flexibility of several hundred meters relative to the E block tower location.

Distance from Base (m)	Propagation Model	Path Loss (dB)	Ant gain reduction (dB)	Building Loss (dB)	Desired Signal at Device (dBm)
1050	Hata Urban	125	0	20	-87.8
3500	Hata Suburban	134	0	10	-87.4

Table 3: Lower B/C Block Near-Location Distance to Prevent Blocking

The relationship between the E Block base station location and the range of possible lower B/C base station locations to eliminate interference is illustrated in Figure 12. The lower B/C base station is shown by the black tower, and the E block base station is illustrated in red.

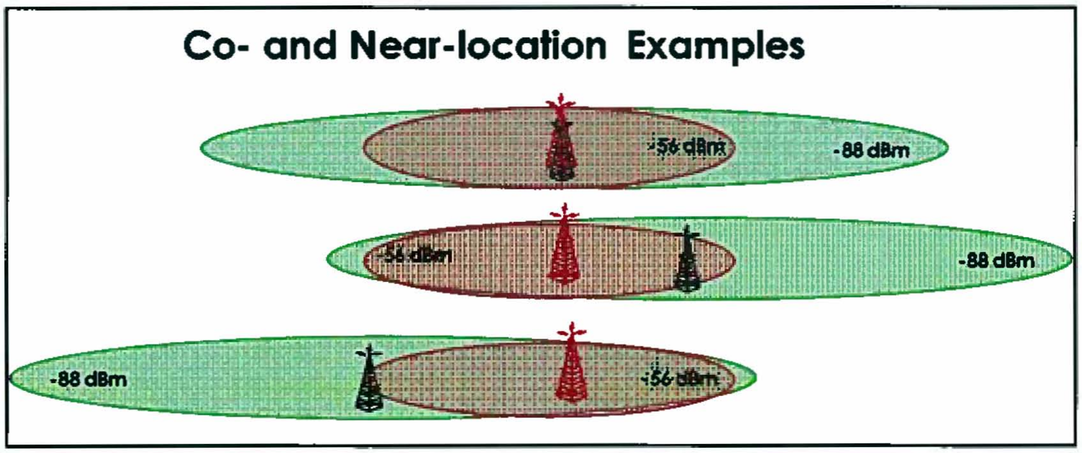

Figure 12: Lower B/C Base Station Deployment Flexibility in Preventing Device Blocking

Although the E block has an advantage of 20 dB in transmit power and a taller transmit height, the 3GPP minimum performance of the in-band blocking specification effectively overcomes these advantages. Near-locating one Lower B/C base station within 400-500 meters of an E block transmitter will ensure compliance with the reference signal conditions in the 3GPP standard. Note that the larger B/C radius allows flexibility in the location of the tower relative to the E block transmitter, greatly simplifying the deployment planning process for the lower B/C operator. The base station may be placed anywhere within several hundred meters of the E block transmitter, a simple planning assumption given the large number of towers required for an LTE wireless deployment.

The above analysis is confirmed through an Ericsson contribution to 3GPP in 2008[14], noting a less than 0.2% impact to the lower B block devices in system simulations when using the Band 12 duplexer. Indeed, Ericsson's conclusion after assessing the interference scenarios was that "Band 15

[14] R4-081356, "On the Introduction of Band 15", agenda item 6.1.2.2, TSG-RAN Working Group 4 (Radio) Meeting #47bis, Munich, Germany, June 16-20, 2008, p. 3. The Band 15 discussion in the first half of 2008 is the same band later adopted as Band 17.

should not be introduced considering the risk of market fragmentation."[15] (Band 15 was the term used for Band 17 in the first half of 2008.)

VI. Conclusions

As demonstrated above, the interference cases raised by opponents of Band 12 are not unusual and are easily eliminated through minimal RF planning such as takes place within any new technology deployment. The nature of broadcast system design is such that at most one or two towers per city are deployed, to reduce cost of deployment and operations. In the rare circumstances where base station near-location may be needed, the RF design impact is minimal. Locating one base station within 500 meters of a broadcast tower, when a typical city requires hundreds of LTE base stations for coverage and capacity, is a simple RF engineering step to include in the deployment planning process. The Band 12 duplexer employed in a system as described above will fully comply with the 3GPP performance criteria for the lower B and C blocks. There is no compelling interference reason for selecting a Band 17 duplexer which only covers a subset of the lower 700 MHz paired spectrum blocks.

[15] Ib. at 5.

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700 MHz Band Analysis

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wireless strategy

the business of wireless technology

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I. Introduction

The 700 MHz band has reached a crucial juncture requiring further regulatory guidance. The possibility of multiple operating bands for 700 MHz threatens wireless competition, consumer flexibility, and the affordability of public safety wireless broadband devices, and is a marked departure from precedent in the US wireless industry. From the early days of cellular through later deployments in the PCS and AWS bands, devices have supported all blocks within the designated band, affording economy of scale for large and small operators alike. In addition, the balkanization of 700 MHz threatens the National Broadband Plan recommendation that Public Safety have the benefit of the entire 700 MHz to roam and the benefit of the economies of scale from having all like devices include the Public Safety band. The direction taken by the two largest operators at 700 MHz reverses this openness in device design, inhibits the ability of small operators to reach the marketplace, and threatens the National Broadband Plan's mandate for a national interoperable public safety network.

Comments in the record cite interference concerns as the driving factor behind the 700 MHz band fragmentation.[1] The analyses in sections III and IV demonstrate that the interference concerns may be handled through typical network planning and coordination measures, and do not require unusual block-specific filtering by the devices. As shown in section V, Device Design, two operating bands may fully cover all paired commercial 700 MHz spectrum and the Public Safety Broadband (PSBB) block: band 12 for lower A, B, and C and a proposed new band for upper C, D, A, and PSBB. This approach would greatly simplify compliance with the recommendation of the National Broadband Plan encouraging public safety device support of all commercial paired blocks in the 700 MHz band,[2] reducing the required number of duplexers from four to two. To maximize the device ecosystem, all commercial 700 MHz broadband devices operating in paired spectrum should support both Band 12 and the newly proposed Upper Band. Commission action is necessary to provide the lower and upper A block licensees, the future upper D block licensees, and the public safety community with a competitive footing in terms of device cost and variety.

700 MHz Band Ownership

AT&T and Verizon Wireless emerged from Auction 73 with the largest holdings of 700 MHz spectrum and contributed nearly 82% of the total auction revenue.[3] Verizon Wireless owns the upper C Block within the continental United States, along with significant holdings in the lower A Block (147.9

[1] Motorola ex parte February 8, 2010; Comments of Verizon Wireless, March 31, 2010; Comments of Motorola, Inc., March 31, 2010; Comments of AT&T Inc., March 31, 2010, RM-11592.

[2] "The FCC should explore other ways to encourage the deployment of public safety devices that transmit across the entire broadband portion of the 700 MHz band (i.e., Band 12, Band 13, Band 14 and Band 17)." p. 316, *Connecting America: The National Broadband Plan*.

[3] DA 08-595, Report No. AUC-08-73-I (Auction 73), "Auction of 700 MHz Band Licenses Closes", Attachment D. Also http://www.wirelessstrategy.com/700auction.html

million POPs) and B Block (46.3 million POPs). Prior to the auction, AT&T had purchased much of the lower C Block from other license holders, and emerged from the auction with the winning bid for most of the lower B block licenses (175.8 million POPs). Both operators have announced plans to deploy 3GPP Long Term Evolution (LTE) technology in their respective blocks, with the first markets planned for launch in 2010 and 2011.

The remaining licenses in Auction 73 went to 99 bidders constituting a mix of smaller wireless operators and new entrants to wireless. Although bidding for the large markets was dominated by AT&T and Verizon Wireless, the licenses won by the 99 bidders were largely in the lower A block and covered a sizable portion of the country, promising to invigorate competition in the 700 MHz band.

Threat to Wireless Competition

An essential requirement to sustain competition by smaller operators is the availability of low-cost devices. Device costs are lowered through scale; a critical mass of device volume must be reached to achieve low price points and interest multiple device manufacturers in developing equipment for a given band. The initial band selections by AT&T and Verizon Wireless remove the benefit of scale from the lower and upper A block operators, the future D block operator(s), and PSBB operators. Based on the filtering selections of AT&T and Verizon Wireless, unique device designs must be developed for the lower and upper A blocks and for the D Block and PSBB (Band 14), significantly reducing commonality of device components and increasing costs.

Threat to Consumer Flexibility

Under the currently defined operating bands, 700 MHz devices built for AT&T will only work on systems deployed in the lower B and C blocks, and 700 MHz devices built for Verizon Wireless will only work on the upper C block. Consumers purchasing devices from these operators would be locked into their systems. If lower A block and upper A and D block competitors were running systems in the same geography, a consumer would need to purchase separate devices to work on either of their systems. Consumer flexibility will be significantly restricted unless action is taken to ensure that all commercial devices operating in paired spectrum are capable of supporting all paired broadband allocations at 700 MHz.

Threat to Affordability of Public Safety Devices

The fragmented band plans at 700 MHz pose similar scale issues to device development for the PSBB spectrum. Rather than leveraging the wide array of devices developed for the commercial upper C block, the public safety community must work with device manufacturers to tailor devices for Band 14. If public safety's network goals include multiple roaming options, coverage redundancy, and scalable capacity, then public safety devices should include support for the lower A, B, and C blocks as well as the upper C, A, D and PSBB blocks. The current 700 MHz operating bands would require a minimum of four transmitter-receiver chains, significantly increasing device complexity. Implementing four chains requires not only four duplexers, but also multiple components such as LNAs, mixers, and up-converters. Moreover, Qualcomm has stated [4] that their current chipset portfolio supports only two 3G/4G

[4] Comments of Qualcomm Incorporated, March 31, 2010, RM-11592.

transmitter-receiver chains below 1 GHz. The public safety device goal stated in the National Broadband Plan is not achievable using Qualcomm's current chipset and the current operating bands. The unique device design and the low volume of public safety devices sold annually will result in high unit costs as experienced in the trunked radio world today, a significant cost penalty relative to the commercial sector.

When the D Block is commercially auctioned, the commonality of Band 14 could provide some scale to the public safety community. However, the D block operator(s) will face a similar obstacle of developing devices for a new band while struggling to overcome the disadvantage of a three-year lag relative to AT&T and Verizon Wireless in deploying nationwide coverage[5].

Public safety's interests would be better served if all commercial 700 MHz broadband devices supported the PSBB block. Such an approach would provide the public safety community with lower-cost devices driven by the combined scale of the commercial, paired block operators, and deliver the added benefit of multiple roaming partners for the PSBB devices. During construction of the nationwide public safety system, the public safety community could make use of the commercial 700 MHz networks through roaming arrangements. And in the event of capacity or coverage issues within the PSBB system, the PSBB devices could readily roll over to the commercial bands.

Analyses provided herein demonstrate that such an approach is feasible and cost-effective. Accordingly, the Commission should require all devices sold in the commercial, paired 700 MHz blocks must support the operating bands of Band12 and the New Upper Band described below.

II. 700 MHz Devices

As the LTE standard evolved within 3GPP, four band plans for 700 MHz were introduced. Verizon Wireless has selected 3GPP Band 13, which covers the upper C block[6]. Verizon notes in the record their decision to hold in reserve their significant license ownership in the lower A block[7]. AT&T is targeting Band 17[8] for LTE devices, which covers the lower B and C blocks, but excludes the lower A block, where AT&T owns no spectrum.

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[5] The auction value of the upper D block would increase significantly through enforcement of a common banding approach with the upper C block.

[6] Bands 13 and 14 were included in Table 5.2-1 E-UTRA Frequency Bands, p. 10, 3GPP TS 36.101 v8.1.0 (2008-03).

[7] "Given that Verizon Wireless does not plan to deploy its Lower A Block spectrum in the near term, it makes no sense for it (or its 4G customers) to bear the burden of additional cost associated with including that band in its initial LTE devices…", p. 11, Comments of Verizon Wireless, RM-11592, March 31, 2010.

[8] Bands 12 and 17 were introduced in Table 5.5-1 E-UTRA Operating Bands, p. 14, 3GPP TS 36.101 v8.7.0 (2008-09).

The selection of operating bands by the two large incumbents has prompted a petition for rulemaking by lower A block owners, citing difficulties in obtaining devices. [9] The A Block licensees state that device manufacturers are focused on Bands 13 and 17 to the exclusion of the other spectrum blocks in the 700 MHz band.

Comments by manufacturers confirm the issue of a limited number of bands supported in devices developed for AT&T and Verizon Wireless.[10] Although currently available device chipsets support the entire 700 MHz band, in the case of Qualcomm's RTR8600 multi-mode chipset, the current number of 3G or 4G low-frequency bands which may be supported within a device is limited to two. [11] A low-frequency band is defined as a sub-1 GHz operating band such as 900 MHz, cellular, or 700 MHz. The device manufacturers select filters to support specific bands, and given this chipset limitation of low-frequency band paths, the device manufacturer must prioritize its 700 MHz support to the one or two bands of interest to the wireless operator. For their 700 MHz launch devices, AT&T and Verizon Wireless are targeting multi-mode and multi-band devices which may serve on 3G cellular systems in areas where 700 MHz coverage is not yet operational, leaving one low-frequency band for 700 MHz support. Without regulatory intervention, devices built for AT&T and Verizon Wireless will only support their individual spectrum holdings at 700 MHz; the remaining paired blocks will not be supported by the devices.

As a result, the licensees in Bands 12, 14, and the upper A block cannot leverage the mainstream, high-volume device ecosystems driven by AT&T and Verizon Wireless, imposing a significant cost penalty on both the smaller US wireless commercial operators and the public safety community.

III. Lower Band Analysis

The FCC band plan for the 700 MHz band is shown in Figure 1. The 3GPP-recommended device transmit and receive directions are indicated by the arrows above the blocks, with an "up" arrow denoting device transmit and a "down" arrow denoting device receive. The Band 12 and Band 17 boundaries are illustrated.

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[9] Comments of Cellular South Inc., September 30, 2009, GN Docket Nos. 09-157 and 09-51; Comments – NBP Public Notice #26, GN Docket Nos. 09-47, 09-51, 09-137; DA 10-278, *Wireless Telecommunications Bureau Seeks Comment on Petition for Rulemaking Regarding 700 MHz Band Mobile Equipment Design and Procurement Practices*, RM-11592.

[10] Motorola ex parte February 8, 2010, RM-11592.

[11] p. 5, Comments of Qualcomm Incorporated, March 31, 2010, RM-11592.

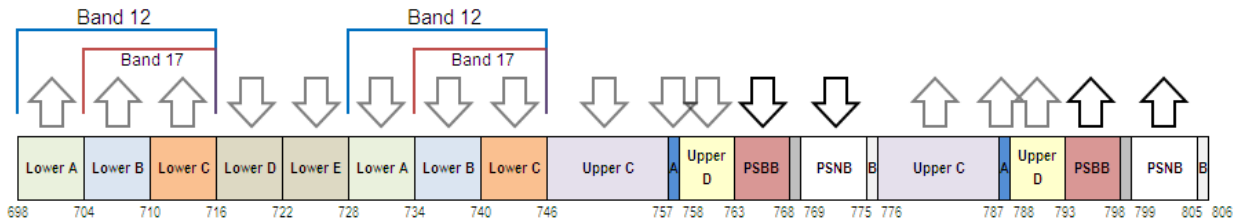

Figure 1: Lower 700 MHz Band with Bands 12 and 17

The black arrows above the Public Safety blocks indicate the direction mandated by the FCC. The blocks licensed in Auction 73 were allocated as "flexible use", meaning any block could be used for transmit or receive. The 3GPP recommended directions minimize the number of transitions between transmit and receive, which minimizes the interference boundaries and simplifies filter and device component design.

In the lower 700 MHz band, three 6 MHz blocks of spectrum from 728 to 746 MHz are paired with three similar blocks at 698 to 716 MHz, forming the lower A, B and C blocks. Two unpaired 6 MHz blocks, D and E, are located between the A, B and C blocks at 716-728 MHz. The lower D and E blocks are suitable for high-power broadcast applications, allocated with a maximum ERP of 50 kW. Qualcomm's MediaFLO technology is an example of a typical service which may be employed in the D and E blocks.

The lower band has three potential sources of interference which may impact device filter design: the lower A block boundary with DTV Channel 51 at 698 MHz; the lower C block boundary with the lower D block at 716 MHz; and the lower E block boundary with the lower A block at 728 MHz.

Lower A Block Boundary with DTV Channel 51 at 698 MHz

In the 700 MHz band, the FCC requires licensees to provide co-channel and adjacent-channel protection to the TV/DTV contours. With the completion of the digital TV transition, the last remaining DTV channel requiring protection is Channel 51, adjacent to the lower A block device transmit. Per section 27.60, the A block licensee must protect the broadcast contour of the DTV station by ensuring the adjacent channel desired signal-to-undesired signal (D/U) ratio is met[12]. This D/U ratio limits the radiated power within the A block near the service contour of the television station. The second and third adjacent blocks, B and C, are not required to observe a minimum separation distance from, or meet an adjacent channel D/U ratio to, the Channel 51 contour. [13] Instead, the FCC regulations applying to the A, B and C blocks are the maximum transmit power defined in 27.50 and the OOBE criteria of 43 + 10 log P applied to all commercial blocks at 700 MHz.

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[12] 47CFR 27.60 (a) (2) "The minimum D/U ratio for adjacent channel stations is 0 dB at the hypothetical Grade B contour (64 dBuV/m) (88.5 kilometers (55 miles)) of the TV station or -23 dB at the equivalent Grade B contour (41 dBuV/m) (88.5 kilometers (55 miles)) of the DTV station."

[13] 47CFR 27.60 (b) (2) (ii) (D) "(e.g., a base station may be operating within TV Channel 62 and the mobiles within TV Channel 67, in which case the TV channels 61, 62, 63, 66, 67, and 68 must be protected)." The regulations do not specify further protection to second-adjacent channel 64, for instance.

The FCC rules provide several approaches under which an A block licensee may meet the protection criteria to the DTV Channel 51 service contour:

- Maintain a minimum distance from the DTV station contour[14];
- Provide an engineering study demonstrating adherence to the D/U ratio;
- Obtain written concurrence from the TV/DTV station. [15]

The rules provide clear options for the A block licensee to protect the channel 51 contour without applying stringent filtering to the device front end. It would be illogical for A block licensees to sacrifice the majority of their spectrum as guard band when other means are available to control the interference, such as distance separation. Furthermore, since the lower B and C blocks are not adjacent to Channel 51, the adjacent channel D/U ratios do not apply to those blocks. The regulations imply that DTV receiver filtering is expected to handle strong transmit signals in the second adjacent channel, provided that the OOBE criteria of 43 + 10 log P is met. Additional guard band near 698 MHz is not required to protect channel 51 receivers.

The Channel 51 transmissions are high-power broadcast signals which may interfere with reception in the lower A, B, and C blocks. However, when applying the 3GPP recommended device transmit direction to 698-716 MHz, the interference becomes a base station-to-base station interference scenario. The device receive band has 30 MHz of separation from Channel 51, providing significant attenuation of the broadcast transmission. Therefore, the Channel 51 transmissions do not impact the device receive filter design.

The base station-to-base station interference scenario may be handled through traditional operator coordination measures such as base station location selection, antenna downtilt, sector orientation, and base station filtering. An example demonstrating the effectiveness of these network coordination techniques is the 3GPP approach at the 716 MHz boundary. The situation is nearly identical – a high-power broadcast signal (D block) is immediately adjacent to the cellular-style UE transmit block (C block), yet no guard band is required.

Given the device transmit direction within 698-716 MHz, the multiple approaches for A block licensees to protect the DTV station contour, and the parallel situation at 716 MHz, the boundary at 698 MHz does not require unusual filtering sacrificing the A block as guard band.

Lower D Block Boundary with Lower C Block at 716 MHz

At this boundary, device transmissions in the lower C block reside adjacent to the high-power broadcast transmissions in the lower D block. There are two interference scenarios at this boundary. The

[14] While network operators do not control mobile locations explicitly, the network coverage area where the device may transmit can be controlled such that the A block device will not operate in a geography where the DTV station contour D/U ratio would not be met.

[15] 47CFR 27.60 (a) (1) (i) – (iv).

first scenario is the D block impact to the C block, which is similar to the Channel 51-to-A block impact above where the D block may interfere with C block base station receive. This is a base-to-base interference scenario, handled through base station location, sector orientation, antenna downtilt, and base station filtering, and does not impact device filter design.

The second interference scenario involves the C block device transmission interfering with the D block device reception. This is a mobile-to-mobile interference case similar to the A block situation where the device transmit is adjacent to Channel 51 device receive.

These two interference scenarios are an inherent function of the 716 MHz boundary where transmit operations are adjacent-channel to receive operations. These scenarios remain identical regardless of whether Band 12 or Band 17 is adopted. No unusual filtering requirements are specified by 3GPP at the 716 MHz boundary.

Lower E Block Boundary with Lower A Block at 728 MHz

The final boundary in the lower band is at 728 MHz. Motorola states a concern that the high-power base station transmissions in the D and E blocks may interfere with the device reception in the lower A, B and C blocks[16]. To handle the interference, Motorola recommended using the A block as guard band[17].

Given the 3GPP recommendations for transmit direction, the entire range from 716 through 776 MHz is harmonized as base station downlink transmission. The out-of-band emissions applicable to the A, B and C blocks are identical throughout that spectrum range. The main regulatory difference for the lower D and E blocks is the higher permitted ERP of 50 kW. The interference mechanism which may result from this higher base station transmit power is device receiver overload. A device attempting to receive a low desired signal will increase its front-end gain to maximize its receiver sensitivity. If a strong signal is present in a nearby channel, the device front-end may be overloaded or de-sensitized by the strong signal. In the case of the 728 MHz boundary, the potential for receiver overload is a near-far interference problem. If an A, B or C block device closely approaches the D or E block transmitter, and the desired A, B or C block signal is weak, then interference may result. However, network operators may easily plan their base station deployment to eliminate this interference issue by placing A, B or C block base stations in the vicinity of the D and E block transmitters. The broadband devices will receive a strong desired signal in this area and lower the device front-end gain, improving blocking performance. This is a normal design situation, and a common industry practice. Co-location or near-location of base stations successfully avoids this interference mechanism by limiting the extremes of signal strengths between the two systems.

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[16] Motorola ex parte February 8, 2010, p. 8, RM-11592.

[17] 3GPP TSG RAN WG4 (Radio) Meeting #47, R4-081108, "TS36.101: Lower 700 MHz Band 15", Motorola contribution, p. 2 section 2c.

With a broadcast deployment strategy, the D and E block licensees are incented to install as few sites as possible to achieve their coverage targets. The near-far situation with respect to the lower A, B and C blocks is easily handled through near-location of base stations to the D and E block transmitters. No modifications to device filtering are required to protect device reception. Standard network coordination mechanisms are sufficient.

The review of the lower band boundaries demonstrates no need for filtering more stringent than operating band 12. Band class 17 is not required from an interference perspective. The US 700 MHz deployments in the lower band should be using UE Band Class 12.

IV. Upper Band Analysis

In the upper 700 MHz band, the blocks currently consist of a paired 11+11 MHz upper C block, two paired 1+1 MHz blocks (A and B), the upper D paired block (5+5 MHz), the PSBB paired block (5+5 MHz), the public safety narrowband spectrum (6+6 MHz), and 1+1 MHz of guard band between the PSBB and PSNB allocations. The Coalition for 4G in America has proposed that the Commission combine the upper A and D blocks and auction them as a combined block.[18] The operating bands applicable to the upper 700 MHz band are shown in figure 2.

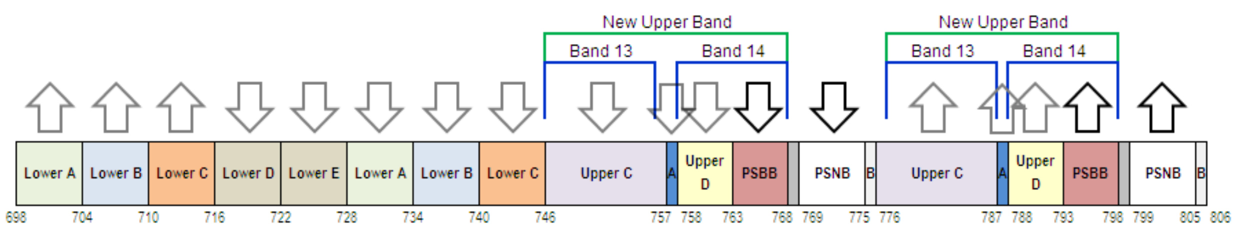

Figure 2: Upper 700 MHz Band and Bands 13, 14, and New Upper Band

Bands 13 and 14 are close to each other but separated per the 700 MHz band plan. However, the following analysis shows that a single band covering 13, 14, and the Upper A block, referred to as the New Upper Band in Figure 2, can meet OOBE requirements.

The interference scenario in the upper 700 MHz block consists of additional emissions protection for the public safety spectrum.

The FCC rules state that the public safety narrowband (PSNB) channels must be protected at their edge by a more stringent OOBE requirement than the commercial blocks. The commercial block OOBE requirement is for 43 + 10 log P with a 100 kHz measurement bandwidth. For simplicity, this

[18] Coalition for 4G in America ex partes, Jan. 6, 2010 and April 28, 2010, WT Docket No. 06-150.

translates to a power level of -3 dBm/MHz[19]. The tighter FCC requirements into the PSNB spectrum are 76 + 10 log P for base stations and 69 + 10 log P for mobiles and portables, with a measurement bandwidth of 6.25 kHz. Normalizing these levels to 1 MHz, the OOBE protection criteria becomes -17 dBm/MHz for mobiles[20] and -24 dBm/MHz for base stations.

The base station filtering may be tailored for an individual operator, employing tighter filtering than that of the entire band. Filtering is often block-specific at the base station to meet OOBE requirements to adjacent blocks. Therefore, since we are analyzing the feasibility of widening the block support for the UE, and the node B is under operator discretion, we will focus on the -17 dBm/MHz requirement for mobiles.

From the 3GPP specifications, the minimum required emissions mask for an LTE UE, normalized to 1 MHz measurement bandwidth, is -10 dBm/MHz as shown in Table 1 below. Other signaling options delivering OOBE levels of -13 dBm/MHz or better are also supported in the standard[21]. Therefore, the LTE UE will be within a few dB of the FCC protection criteria to the public safety block simply by complying with the 3GPP minimum specifications for transmitter performance. The level of filtering necessary to protect the PSNB spectrum is a modest 4 to 7 dB, depending on the signaling option selected.

Distance from Carrier Edge (MHz)	Relative Level (dBm)	Measurement Bandwidth (kHz)
1	-18	30
2	-10	1000
3	-10	1000

Table 1: LTE UE Emissions Mask (3GPP TS 36.101 v9.3.0)

As demonstrated above, the OOBE requirements into the public safety spectrum may be met with minimal filtering beyond the spectrum mask. The C block licensee would not be placed at a disadvantage if required to use the proposed New Upper Band.

[19] OOBE of 43 + 10 log P, with P in W, reduces to -43 dBW for the measurement bandwidth of interest, 100 kHz. Converting the measurement to dBm yields -13 dBm/100 kHz. For ready comparison to the 3GPP spectrum mask tables, the OOBE level is further adjusted for a 1 MHz measurement bandwidth, or -3 dBm/MHz.

[20] The increased protection from device emissions to public safety may be calculated as (69 + 10 log P) = -39 dBm/6.25 kHz. Converting the bandwidth to 1 MHz yields -17 dBm/MHz.

[21] P. 35 Table 6.6.2.2.1-1: Additional requirements, signaled value NS-03 improves the emissions mask to -13 dBm/MHz. 3GPP TS 36.101 v9.3.0 (2010-03).

V. Device Design

The recommendations in sections III and IV increase the amount of spectrum covered by the operating bands and reduce the spacing, or gap, between the transmit and receive passbands. The proposed Lower and Upper operating bands are shown in figure 3.

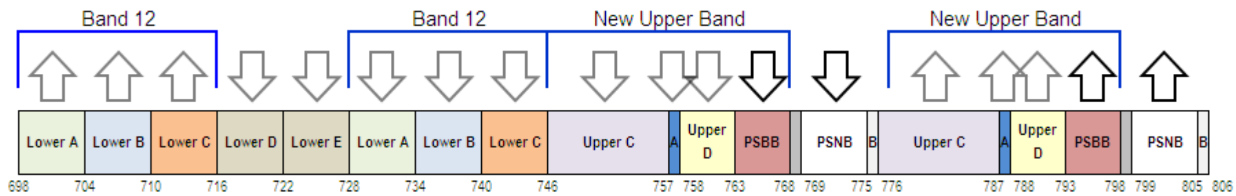

Figure 3: Upper and Lower 700 MHz Bands

The duplexer performance depends on the duplex gap and the size of the passbands. Too narrow of a spacing between the transmit and receive blocks may increase the insertion loss or reduce the isolation between passbands. The effectiveness of the duplexer design is approximated by the ratio of the duplex gap size to the passband size[22]. A comparison of the insertion loss, isolation, and duplexer ratio for Avago duplexers[23] for several 3GPP bands is provided in Table 2.

						Insertion Loss (dB)				Isolation (dB)			
						UE Rx Band		UE Tx Band		UE Rx Band		UE Tx Band	
Avago Part Number	Frequency Band	Frequency Range (Rx/Tx, MHz)	Passband (MHz)	Duplex Gap (MHz)	Ratio	Typical	Maximum	Typical	Maximum	Minimum	Typical	Minimum	Typical
ACMD-7602	Band I	1920-1980/2110-2170	60	130	2.17	1.1	2	1.1	1.6	53	61	41	52
ACMD-7409	Band II (US PCS)	1850-1910/1930-1990	60	20	0.33	1.5	3.5	1.1	3	52	56	43	48
ACMD-7403	Band II (US PCS)	1850-1910/1930-1990	60	20	0.33	1.3	3	1	2.1	52	59	40	49
ACMD-7606	Band VIII	880-915/925-960	35	10	0.29	2.2	3	2.2	2.7	45	55	44	56
N/A	Band XII	698-716/728-746	18	10	0.56	1.3	3	1.1	2.1	52	59	40	49
N/A	New Upper Band	746-768/777-798	22/21	9	0.43	1.3	3	1.1	2.1	52	59	40	49

Table 2: 700 MHz Band Duplexer Performance

The first four rows of Table 2 summarize the published specifications of Avago duplexers for 3GPP bands I, II and VIII. The Band I duplexer is for the 2100 MHz UMTS band. The large duplex gap provides exceptional performance in terms of low insertion loss[24] (1.1 dB typical) and isolation[25]. Band

[22] A steeper filter rolloff requires a higher order filter which is often more complex or more expensive. However, the "steepness" of rolloff is measured in relation to the pass band's width or filter's cutoff frequency, using metrics such as shape factor or dB/decade. For example, the shape factor is the ratio of the width of the transition region and pass band to the width of the pass band. The ratio used above is the shape factor minus one.

[23] Avago film bulk acoustic resonator (FBAR) duplexer specifications as downloaded from their web site at http://www.avagotech.com/pages/en/rf_for_mobile_wlan_mmw/fbar_filters/duplexers/umts_band_duplexer/

[24] Insertion loss quantifies the amount of signal attenuated as it passes through the filter. Higher insertion loss means more signal is attenuated by the filter, which reduces the coverage range.

[25] Isolation refers to the amount of attenuation from one passband to the other, an important metric for technologies requiring simultaneous transmit and receive in the same device, such as UMTS and FDD LTE. Isolation ensures that the device transmission does not interfere with reception.

II, the US PCS band, separates two 60 MHz passbands with a 20 MHz duplex gap. The ratio is less favorable than Band I, but the performance is still acceptable.[26] Band VIII is noteworthy as being a low-frequency band with a 10 MHz duplex gap. The passbands are narrower than the PCS band, but the ratio is less favorable, at 0.29 versus 0.33. The insertion loss for Band VIII is slightly less favorable than the 2100 MHz and PCS bands.

The last two rows in Table 2 provide the passband and duplex gap information for the 3GPP band 12 and New Upper Band duplexers. The shaded duplexer specifications are extrapolations from the performance of the other bands. The duplex gap to passband ratios are more favorable than the ratio for the PCS band, indicating that the performance of the proposed duplexers would exceed that of 3GPP Band VIII and be similar or better than the US PCS band.

In short, the duplex gaps for band 12 and the upper band proposal are well within the current state of the art for duplexer design. Sufficient isolation between transmit and receive will be achieved, and the filter insertion loss impact on coverage range will be comparable to other bands.

Verizon Wireless raised a device design concern that requiring a 700 MHz device to support all paired 700 MHz blocks automatically requires the device to support all air interface technologies:

> "For example, if a 700 A Block licensee chooses WiMAX, it would need devices that use WiMAX as the air interface. But under the Alliance's proposal, that device would also need to include the ability to use LTE on the A Block or C-Block spectrum."[27]

Verizon misconstrues the intent of the Alliance request, which was "to require that all mobile units for the 700 MHz band be capable of operating over all frequencies in the band[28]." A device may be capable of operating over all frequencies in a band without supporting all air interface technologies. For example, today AT&T sells devices which operate throughout the PCS band and support GSM and/or UMTS technologies. Verizon Wireless sells devices which operate throughout the PCS band and support CDMA 1x and 1xEVDO technologies. Neither operator's devices currently support the other's technologies, yet the devices are capable of operating over all frequencies in the band.

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[26] Although not reflected in the chart above, it is noteworthy that the FCC has assigned new licenses in the PCS G Block that reduce the duplexer gap to 15 MHz; moreover, the FCC has allocated, though not yet assigned, additional spectrum for mobile broadband use in the PCS H Block that would further reduce the available duplexer gap to 10 MHz. The incremental decrease in the PCS duplexer gap reflects technical improvements that have occurred since the PCS bands were first assigned.

[27] Comments of Verizon Wireless, March 31, 2010, RM-11592.

[28] *700 MHz Block A Good Faith Purchaser Alliance Petition for Rulemaking Regarding the Need for 700 MHz Mobile Equipment to be Capable of Operating on All Paired Commercial 700 MHz Frequency Blocks*, filed Sept. 29, 2009 (Petition), at iii, 12.

With this understanding, a 700 MHz device adhering to the petition's request is not required to support multiple air interface technologies. The device must simply provide the capability of operating over the paired frequency blocks in terms of the filtering supported.

VI. Upper A Block

Return of Upper A Block

The upper A block lies in the center of the newly proposed Upper Band filtering scheme. With 1+1 MHz, the bandwidth is insufficient to deploy an LTE carrier. As previously stated, the Coalition for 4G in America has proposed a return of the spectrum to the Commission, in exchange for compensation to the incumbent licensees [29]. This proposal should be granted, with the upper A spectrum combined with the upper D block to form a 6+6 MHz block for auction.

VII. Conclusions

Lower 700 MHz Band

Mandating paired spectrum device support for band 12 will increase competition in the 700 MHz band and improve the value and utilization of spectrum. As demonstrated above, an LTE band 12 duplexer is feasible with current duplexer technology and provides similar performance and interference protection as other bands. The interference mechanisms between lower D and lower C are the same as between Channel 51 and lower A; therefore, there is no reason to require 6 MHz of guard band on one boundary but not the other. Channel 51 must be protected as per the FCC rules, but the A block licensees have a variety of means to provide the protection other than through a device filtering approach that relegates the A block to guard band. To sustain competition, the A block licensees must gain access to device scale with the corresponding lower costs. Further, if public safety is to achieve roaming, priority access, and economies of scale, the lower A block must be included in device designs supported by the lower B and C licensees.

Upper 700 MHz Band

Mandating device support across the Upper Band paired commercial blocks and PSBB spectrum will benefit public safety and increase the value of D block spectrum. As demonstrated above, the new Upper Band filtering would support all regulations regarding OOBE and would not cause interference beyond the normal network coordination situations. For LTE deployments, the new Upper Band duplexer design is well within the current state of the art and the filtering requirements are consistent with other 3GPP standard operating bands. Requiring support of a common band for the Upper 700 MHz blocks will lower the cost of PSBB devices and simplify implementation of PSBB roaming onto the upper C and

[29] Coalition for 4G in America ex partes, Jan. 6, 2010 and April 28, 2010, WT Docket No. 06-150; Access Spectrum ex parte, March 5, 2010, WT Docket Nos. 96-86 and 06-150, and PS Docket 06-229.

D blocks. The new operating band would likely increase D Block auction revenues as the bidders will not have to factor a device premium into their business plan.

Commission Action Requested

The FCC should act to mandate commercial broadband device support across the band 12 paired blocks and the upper band commercial and PSBB blocks to increase competition, benefit public safety, maximize spectrum usage, and further the goals of the national broadband plan. Specifically, the Commission should consider the following recommendations:

- All commercial devices operating in 700 MHz paired spectrum should support the lower A, B and C blocks and the upper C, A, D and PSBB blocks;
- The upper A block should be returned to the Commission and combined with the upper D block for auction[30].

[30] Coalition for 4G in America ex parte, April 28, 2010, WT Docket No. 06-150, PS Docket No. 06-229, GN Docket No. 09-51.